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NASA-VOF2D: A Computer Program for Incompressible Flows with Free Surfaces

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CONTENTS

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by

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ABSTRACT

We present the NASA-VOF2D two-dimensional, transient, free-surface hydrodynamics program. It has a variety of options that provide capabilities for a wide range of applications, and it is designed to be relatively easy to use. It is based on the fractional volume-of-fluid method and allows multiple free surfaces with surface tension and wall adhesion. It also has a partial cell treatment that allows curved boundaries and internal obstacles. This report includes a discussion of the numerical method, a code listing, and a selection of sample problems.

I. INTRODUCTION

The NASA-VOF2D program simulates incompressible flows with free surfaces using the volume-of-fluid (VOF) algorithm.[1-3] This technique is based on the use of donor-acceptor differencing[4] to track the free surface across an Eulerian grid. Similar procedures were developed contemporarily by other workers[5-9] to track material interfaces as well as free surfaces. A similar program has been written specifically for simulating the draining of spacecraft propellant tanks.[10] The NASA-VOF2D program contains several improvements over these codes, and these improvements will be described along with the governing equations, the numerical algorithm, a program description, several numerical solutions, and a program listing.

One of the chief weaknesses of the earlier VOF codes written for the tank draining problem is that obstacles and curved boundaries are created by blocking out the appropriate computational cells. This weakness means that curved boundaries are represented by discrete stair-step approximations. Our original plan was to improve upon this situation by letting curved boundaries be represented by a string of cell sides using the arbitrary mesh capability of a modified version of the ALE code CONCHAS-SPRAY.[11] The resulting technique would have resembled the LINC technique,[12] but with a rezoning capability. However, the occurrence of a strong parasitic node-coupling mode in tank-draining problems forced us to abandon this approach. It should be noted that this mode is much less severe when the code is run in the Lagrangian mode. It might therefore be possible to utilize such a code in the Lagrangian mode with infrequent, gross rezoning such as that proposed by Horak et al.,[13] Dukowicz,[14] and Ramshaw.[15] In particular, this would allow the code to put the free surface along a grid line, which in turn would allow the simple and accurate calculation of surface-tension and wall-adhesion forces. The main limitation would be difficulty in programming the logic needed to allow one region of fluid to join another region of fluid, such as we have in propellant reorientation calculations. However, the technique would be straightforward and accurate for the simple tank-draining solution presented in this report.

The development of a partial-cell treatment for SOLA-VOF type programs (for example, as described in Ref. 16) allowed us to return to this more robust methodology. The basic concept is to introduce the fraction of the cell volume open to fluid, the fraction of each cell face open to flow, and to use this information to modify the difference equations in the partial cells. A concept similar to this was used at least as early as the FLIC program.[17] Appendix A gives a justification for the partial obstacle treatment.

A number of other improvements have been made to the original SOLA-VOF program. These include fixes in the donor-acceptor differencing, a better algorithm for picking the fluid orientation flags, and an upgraded surface-tension calculation. In addition, we have added the option of solving the pressure equation by a conjugate residual method rather than successive over-relaxation (SOR) method.

The basic algorithm is based on the Navier-Stokes equations for an incompressible fluid. The continuity equation is

$$\nabla\cdot(\theta\,\underset{\sim}{u}) = \frac{1}{r}\,\frac{\partial(r\,\theta\,u)}{\partial x} + \frac{\partial(\theta\,v)}{\partial y} = 0 \quad , \tag{1}$$

where x and y are the coordinates, θ is the partial cell parameter defined in Appendix A, $\underset{\sim}{u}$ is the velocity vector, u and v are velocity components in the x- and y-directions respectively, and r is a factor that is unity in Cartesian coordinates or x in cylindrical coordinates. In cylindrical coordinates, y is the axial coordinate. The momentum equations are

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = g_x - \frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \xi \left(\frac{1}{x} \frac{\partial u}{\partial x} - \frac{u}{x^2}\right)\right] \tag{2}$$

and

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = g_y - \frac{1}{\rho} \frac{\partial p}{\partial y} + \nu \left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\xi}{x} \frac{\partial v}{\partial x}\right] \quad , \tag{3}$$

where p is the pressure, ρ is the density, g_x and g_y are the components of the external acceleration, ξ is a factor that is zero or unity in Cartesian or cylindrical coordinates respectively, and ν is the kinematic viscosity. These equations apply at every point inside the fluid.

The free surfaces are treated by introducing a function F(x,y,t) that is defined to be unity at any point occupied by fluid and zero elsewhere. When averaged over the cells of a computing mesh, the average value of F in a cell is equal to the fractional volume of the cell occupied by fluid. In particular, a unit value of F corresponds to a cell full of fluid, whereas a zero value indicates the cell contains no fluid. Cells with F values between zero and one are partially filled with fluid and are either intersected by a free surface or contain voids (bubbles) smaller than cell mesh dimensions. The F function is utilized to determine which cells contain a boundary and where the fluid is located in those cells. Additionally, the derivatives of F can be used to determine the mean local surface normal, and using also the cell F value, to construct a line cutting the cell that will approximate the interface. Sufficient information is then available to incorporate surface-tension and wall-adhesion forces into the calculation. Because F is a step function its derivatives must be computed in a special way, as described in the next section. The time dependence of F is governed by

$$\frac{\partial F}{\partial t} + u \frac{\partial F}{\partial x} + v \frac{\partial F}{\partial y} = 0 \quad . \tag{4}$$

This approach allows the fluid interface(s) to be represented in a simple and elegant way in the differential equation form. However, the flux of F through each cell face of our Eulerian grid will be required. Standard finite-difference techniques would lead to a smearing of F, and the interfaces would lose their definition. The fact that F is a step function allows us to use a form of donor-acceptor differencing that preserves the discontinuous nature of F.

The next section describes the numerical method in detail. The third section is a user's manual for the computer program, and the final section is a selection of applications of NASA-VOF2D. A program listing is given in Appendix B .

II. THE NUMERICAL METHOD

This section provides a detailed description of the numerical algorithm used in the NASA-VOF2D program. It is essentially an extended version of the SOLA-VOF method,[2] and our description of the numerical method draws heavily on the discussion in Ref. 2. The program is Eulerian and allows for an arbitrary number of segments of free surface with any reasonable shape. The complete Navier-Stokes equations in primitive variables for an incompressible fluid are solved by finite differences, with surface tension and wall adhesion included.

A typical computational grid is illustrated in Fig. 1. The Eulerian mesh comprises rectangular cells having variable sizes, δx_i for the i^{th} column and δy_j for the j^{th} row. There is a row of fictitious cells around the entire mesh.

Figure 2 shows the location of the velocity components, pressures, and F-values within each cell. The pressure $p_{i,j}$ and fractional volume of fluid $F_{i,j}$ are cell-centered quantities. The horizontal velocity component $u_{i+1/2,j}$ is defined on the right cell face, and the vertical velocity component $v_{i,j+1/2}$ is defined on the top of the cell. Also shown are the locations of the geometrical quantities AR, AT, and AC, arising from the partial-cell treatment, which are the fractions of the right cell face, top cell face, and cell volume open to flow. In cylindrical coordinates, these fractions are multiplied by the value of $2\pi x$ evaluated at the appropriate cell face or cell center.

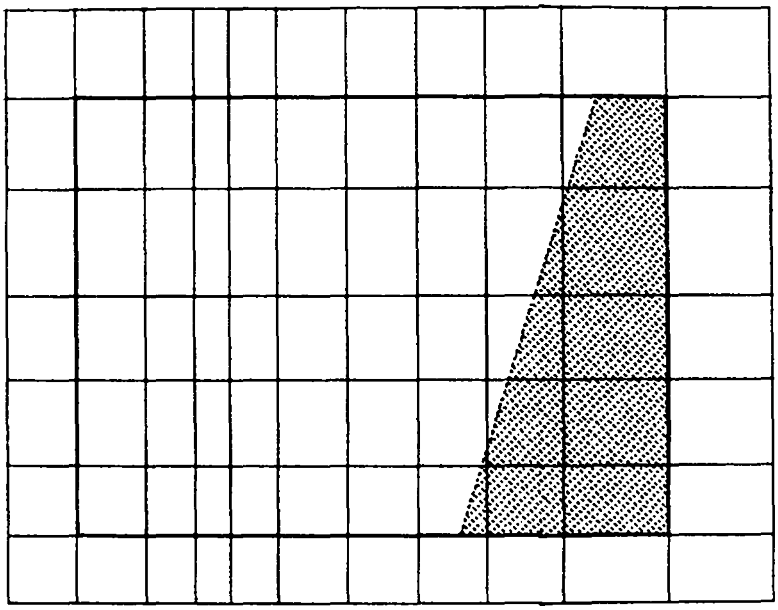

Fig. 1. A typical computational mesh with variable rectangular cells and an obstacle (indicated by the shaded area). The mesh is surrounded by a row of fictitious cells.

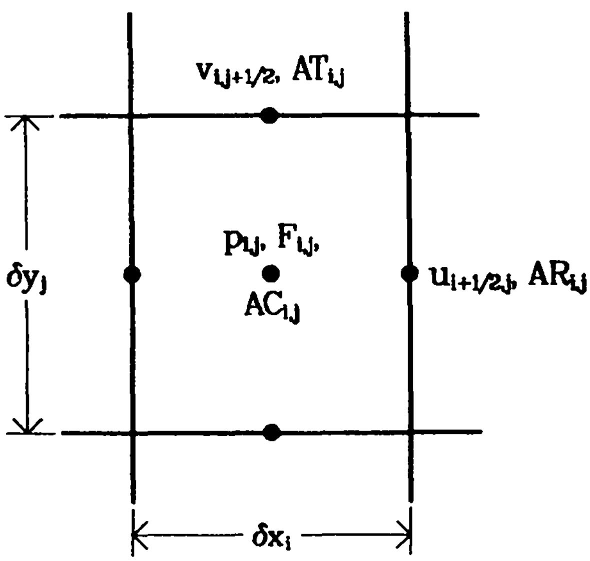

Fig. 2. Location of the variables in a typical mesh cell.

A free-surface or interface cell (i,j) is defined as a cell containing a nonzero value of F <u>and</u> having at least one neighboring cell $(i\pm1,j)$ or $(i,j\pm1)$ that contains a zero value of F. In a surface cell, we assume that the free surface can have only one orientation (mainly horizontal or mainly vertical), and for that orientation all the liquid is on one side or the other of the surface. That is, the liquid is mainly located adjacent to one of the four sides of the cell. Some surface orientations result in cells with nonzero values of F and no empty neighbors $(i\pm1,j)$ or $(i,j\pm1)$. These are treated as full cells. We keep track of the free-surface orientation with a cell flag array, NF(i,j), as shown in Table I.

The basic procedure for advancing the solution through one time step δt consists of three steps. First, from time n values, explicit approximations to the momentum Eqs. (2) and (3) are used to find provisional values of the new time velocities. Second, an iterative procedure is used to solve for advanced time pressure and velocity fields that satisfy Eq. (1) to within a convergence criterion (EPSI) at the new time.

Finally, the F-function is updated by solving explicitly Eq. (4), the new free-surface orientation in each surface cell is determined, and surface-tension forces are computed. Suitable boundary conditions must be imposed at all mesh, free-surface, or obstacle boundaries during each stage. Repetition of these three steps allows advancing the solution through an arbitrary interval of time. Details of these operations are presented in the paragraphs below.

The first task in solving a problem is to set up the computational mesh. Two kinds of information are required. First, the horizontal and vertical locations of cell faces $x_{i+1/2}$ and $y_{j+1/2}$ are specified. The cell centers (x_i,y_j) are defined as

$$x_i = 0.5\,(x_{i-1/2} + x_{i+1/2}) \qquad (5)$$

and

$$y_j = 0.5\,(y_{j-1/2} + y_{j+1/2}) \quad . \qquad (6)$$

Second, geometrical arrays $AR_{i+1/2,j}$, $AT_{i,j+1/2}$, and $AC_{i,j}$ must be defined if an obstacle is included in the mesh. These tasks are simplified by automatic mesh and obstacle generators included in the code.

TABLE I

DEFINITION OF NF ARRAY VALUES

Free surface does not bisect cell

NF = 0 fluid cell--no void cells adjacent

NF > 5 void cell--no fluid in cell

Free surface mainly vertical

NF = 1 surface cell--neighboring fluid cell to the left

NF = 2 surface cell--neighboring fluid cell to the right

Free surface mainly horizontal

NF = 3 surface cell--neighboring fluid cell on the bottom

NF = 4 surface cell--neighboring fluid cell on the top

Free-surface orientation indeterminate

NF = 5 surface cell--isolated, all adjacent cells are void

The next task is to select boundary conditions, to define the volume occupied by fluid, and to set the initial values of the velocity and pressures fields. Selecting boundary conditions is described in detail in the next section and is accomplished by setting four input boundary flags. The other tasks are problem dependent and must be implemented by the user unless the simple default setup routine is adequate. Finally, physical properties of the fluid, output requirements, and solution options must be furnished as input data.

The program is then ready to begin a cycle. The first step is to solve explicit difference equations for an estimate of the new time velocities. This calculation is done only if the cell face on which the velocity (u or v) is located is open to flow (that is, $AR_{i\pm1/2,j} > 0$ or $AT_{i,j\pm1/2} > 0$) and some fluid is adjacent to the appropriate boundary. Void/void and fluid/obstacle boundaries are skipped for efficiency. We begin by defining the gradients of the velocity components that are required for the finite-difference approximation for Eqs. (2) and (3). They are for the x-coordinate,

$$\left(\frac{\partial u}{\partial x}\right)_{i,j} = \frac{u_{i+1/2,j} - u_{i-1/2,j}}{x_{i+1/2} - x_{i-1/2}} \tag{7}$$

and

$$\left(\frac{\partial u}{\partial y}\right)_{i+1/2,j+1/2} = \frac{u_{i+1/2,j+1} - u_{i+1/2,j}}{y_{j+1} - y_j} \quad . \tag{8}$$

Similar equations with appropriate indices are used to calculate u-velocity derivatives at (i+1,j), (i+1/2,j-1/2) since second derivatives will be required. Once the velocity gradients are calculated, the viscous term in Eq. (2) is approximated by

$$\begin{aligned}
VISX_{i+1/2,j} = \nu \Bigg\{ & \left[\left(\frac{\partial u}{\partial x}\right)_{i+1,j} - \left(\frac{\partial u}{\partial x}\right)_{i,j}\right] / (x_{i+1} - x_i) \\
& + 2\left[\left(\frac{\partial u}{\partial y}\right)_{i+1/2,j+1/2} - \left(\frac{\partial u}{\partial y}\right)_{i+1/2,j-1/2}\right] / (y_{j+1} - y_{j-1}) \\
& + \frac{\xi}{x_{i+1/2}}\left[\delta x_{i+1}\left(\frac{\partial u}{\partial x}\right)_{i,j} + \delta x_i\left(\frac{\partial u}{\partial x}\right)_{i+1,j}\right] / (\delta x_i + \delta x_{i+1}) - \frac{\xi u_{i+1/2,j}}{x^2_{i+1/2}} \Bigg\} \quad .
\end{aligned} \tag{9}$$

In the preceding equations, factors such as $(\partial u/\partial x)_{i+1/2,j}$ are obtained by linear interpolation of cell-centered quantities.

We use similar difference equations for the viscous terms in Eq. (3). We define the velocity gradient components

$$\left(\frac{\partial v}{\partial y}\right)_{i,j} = \frac{v_{i,j+1/2} - v_{i,j-1/2}}{y_{j+1/2} - y_{j-1/2}} \tag{10}$$

and

$$\left(\frac{\partial v}{\partial x}\right)_{i+1/2,j+1/2} = \frac{v_{i+1,j+1/2} - v_{i,j+1/2}}{x_{i+1} - x_i} \quad . \tag{11}$$

The viscous term in Eq. (3) is then approximated by

$$\mathrm{VISY}_{i,j+1/2} = \nu \left\{ \left[\left(\frac{\partial v}{\partial y}\right)_{i,j+1} - \left(\frac{\partial v}{\partial y}\right)_{i,j} \right] / (y_{j+1} - y_j) \right.$$

$$+ 2\left[\left(\frac{\partial v}{\partial x}\right)_{i+1/2,j+1/2} - \left(\frac{\partial v}{\partial x}\right)_{i-1/2,j+1/2} \right] / (x_{i+1} - x_{i-1})$$

$$\left. + \frac{\xi}{2x_i} \left[\left(\frac{\partial v}{\partial x}\right)_{i+1/2,j+1/2} + \left(\frac{\partial v}{\partial x}\right)_{i-1/2,j+1/2} \right] \right\} , \qquad (12)$$

where the last term is a simple average of derivatives located at the cell corners.

We follow the procedure of Nichols, Hirt, and Hotchkiss[2] in approximating the convective terms. These terms are calculated explicitly at the same time as the viscous terms using the same velocity derivatives. Thus, we have

$$\left(u \frac{\partial u}{\partial x}\right)_{i+1/2,j} = \frac{u_{i+1/2,j}}{\delta x_\alpha} \left\{ \delta x_i \left(\frac{\partial u}{\partial x}\right)_{i+1,j} + \delta x_{i+1} \left(\frac{\partial u}{\partial x}\right)_{i,j} \right.$$

$$\left. + \alpha \, \mathrm{sgn}(u_{i+1/2,j}) \left[\delta x_{i+1} \left(\frac{\partial u}{\partial x}\right)_{i,j} - \delta x_i \left(\frac{\partial u}{\partial x}\right)_{i+1,j} \right] \right\} , \qquad (13)$$

where

$$\delta x_\alpha = \delta x_i + \delta x_{i+1} + \alpha \, \mathrm{sgn}(u_{i+1/2,j}) \, (\delta x_{i+1} - \delta x_i) \ . \qquad (14)$$

Here δx_i is the width of cell i, α is the donor-cell fraction, and sgn(u) means the sign of $u_{i+1/2,j}$; that is, the convective differencing is a linear combination of donor cell and centered differencing. When $\alpha = 0$, this formulation reduces to a second-order-accurate, centered-difference approximation. When $\alpha = 1$, the first order donor-cell form is recovered. This particular form is then at least first-order-accurate for any α between these limits. In order to obtain stability while maximizing accuracy, experience indicates that $0.25 < \alpha < 0.5$ may be utilized. In practice the initial runs of a problem are generally made with $\alpha = 1$. Subsequent runs are often made with reduced α. Similarly, the vertical convection of horizontal momentum is approximated by

$$\left(v \frac{\partial u}{\partial y}\right)_{i+1/2,j} = \frac{v_{i+1/2,j}}{\delta y_\alpha} \left\{(y_{j+1} - y_j) \left(\frac{\partial u}{\partial y}\right)_{i+1/2,j-1/2} \right.$$

$$+ (y_j - y_{j-1}) \left(\frac{\partial u}{\partial y}\right)_{i+1/2,j+1/2}$$

$$+ \alpha \,\mathrm{sgn}(v_{i+1/2,j}) \left[(y_{j+1} - y_j) \left(\frac{\partial u}{\partial y}\right)_{i+1/2,j-1/2}\right.$$

$$\left.\left. - (y_j - y_{j-1}) \left(\frac{\partial u}{\partial y}\right)_{i+1/2,j+1/2}\right]\right\} , \tag{15}$$

where

$$\delta y_\alpha = \Delta y_{j+1/2} + \Delta y_{j-1/2} + \alpha \,\mathrm{sgn}(v_{i+1/2,j})[\Delta y_{j+1/2} - \Delta y_{j-1/2}] , \tag{16}$$

$$\Delta y_{j+1/2} = y_{j+1} - y_j , \ \Delta y_{j-1/2} = y_j - y_{j-1} , \tag{16.1}$$

and where we use double linear interpolation to compute

$$v_{i+1/2,j} = \frac{\delta x_i (v_{i+1,j+1/2} + v_{i+1,j-1/2}) + \delta x_{i+1} (v_{i,j+1/2} + v_{i,j-1/2})}{2\ (\delta x_i + \delta x_{i+1})} . \tag{17}$$

Analogous difference equations are written for the convection of v.

The complete momentum equations are

$$u^{n+1}_{i+1/2,j} = u_{i+1/2,j} + \delta t \left[g_x - (p^{n+1}_{i+1,j} - p^{n+1}_{i,j})/(\rho(x_{i+1} - x_i)) \right.$$

$$\left. - \left(u \frac{\partial u}{\partial x}\right)_{i+1/2,j} - \left(v \frac{\partial u}{\partial y}\right)_{i+1/2,j} + VISX_{i+1/2,j} \right] \tag{18}$$

$$v^{n+1}_{i,j+1/2} = v_{i,j+1/2} + \delta t \Bigg[g_y - (p^{n+1}_{i,j+1} - p^{n+1}_{i,j})/(\rho(y_{j+1} - y_j))$$

$$- \left(u \frac{\partial v}{\partial x} \right)_{i,j+1/2} - \left(v \frac{\partial v}{\partial y} \right)_{i,j+1/2} + VISY_{i,j+1/2} \Bigg] , \quad (19)$$

where a superscript n+1 denotes an advanced time quantity. Variables without a superscript are taken at the old time level, n.

The velocities from Eqs. (18) and (19) will not satisfy the continuity Eq. (1), which is differenced as

$$\Bigg[\frac{u^{n+1}_{i+1/2,j} \, AR_{i+1/2,j} - u^{n+1}_{i-1/2,j} \, AR_{i-1/2,j}}{\delta x_i}$$

$$+ \frac{v^{n+1}_{i,j+1/2} \, AT_{i,j+1/2} - v^{n+1}_{i,j-1/2} \, AT_{i,j-1/2}}{\delta y_j} \Bigg] / AC_{i-1} = 0 \quad (20)$$

In this equation, fractional volumes open to flow are denoted by integral subscripts and fractional areas open to flow are denoted by half-integral subscripts, i.e., $\theta_{i,j}$ and $\theta_{i+1/2,j}$ respectively. Moreover, as currently used in the code

$$AR_{i+1/2,j} = \theta_{i+1/2,j} \quad ,$$

$$AT_{i,j+1/2} = \theta_{i,j+1/2} \quad ,$$

and

$$AC_{ij} = \theta_{i,j} \quad .$$

In order to satisfy Eq. (20) simultaneously throughout the mesh, the pressures and velocities must be adjusted in each computational cell occupied by fluid. The solution may be obtained by the following iterative process: Eqs. (18) and

(19) evaluated with time n quantities produce a provisional velocity field used as an estimate of the advanced time velocities. In cells that contain fluid, a pressure correction is calculated from

$$\delta p = -S/(\partial S/\partial p) \quad , \tag{21}$$

where S in each cell is the value of the left side of Eq. (20), the residual, evaluated with the most updated values of p, u, and v available. Equation (21) is derived by substituting the right sides of Eqs. (23) through (26) below into Eq. (20) and solving for δp. The quantity $\beta = \frac{1.0}{\partial S/\partial p}$ is

$$\beta = \frac{\rho\, AC_{i,j}}{2\delta t\,(\lambda_{i+1/2} + \lambda_{i-1/2} + \zeta_{j+1/2} + \zeta_{j-1/2})} \quad ,$$

where

$$\lambda_{i+1/2} = \frac{AR_{i+1/2,j}}{\delta x_i(\delta x_{i+1} + \delta x_i)} \quad ,$$

$$\lambda_{i-1/2} = \frac{AR_{i-1/2,j}}{\delta x_i(\delta x_i + \delta x_{i-1})} \quad ,$$

$$\zeta_{j+1/2} = \frac{AT_{i,j+1/2}}{\delta y_j(\delta y_{j+1} + \delta y_j)} \quad ,$$

and

$$\zeta_{j-1/2} = \frac{AT_{i,j-1/2}}{\delta y_j(\delta y_j + \delta y_{j-1})} \quad .$$

The ν^{th} iterate for the pressure is

$$p_{i,j}^{(\nu)} = p_{i,j}^{(\nu-1)} + \delta p \quad , \tag{22}$$

and the velocities for all four cell faces are updated with

$$u_{i+1/2,j}^{(\nu)} = u_{i+1/2,j}^{(\nu-1)} + \delta t \ \delta p/[\rho(x_{i+1} - x_i)] \quad , \tag{23}$$

$$u_{i-1/2,j}^{(\nu)} = u_{i-1/2,j}^{(\nu-1)} - \delta t \ \delta p/[\rho(x_i - x_{i-1})] \quad , \tag{24}$$

$$v_{i,j+1/2}^{(\nu)} = v_{i,j+1/2}^{(\nu-1)} + \delta t \ \delta p/[\rho(y_{j+1} - y_j)] \quad , \tag{25}$$

and

$$v_{i,j-1/2}^{(\nu)} = v_{i,j-1/2}^{(\nu-1)} - \delta t \ \delta p/[\rho(y_j - y_{j-1})] \quad . \tag{26}$$

This procedure is modified for cells containing a free surface. For these cells $[p_{i,j}]$ is obtained from linear interpolation (or extrapolation) between the surface pressure $[p_s]$, computed from surface-tension and wall-adhesion forces, and a neighboring pressure $[p_n]$ inside the fluid in a direction most nearly perpendicular to the free surface. Specifically,

$$p_{i,j} = [1 - \eta]p_n + \eta \ p_s \quad , \tag{27}$$

where $\eta = d_c/d$ is the ratio of the distance between the cell centers and the distance between the free surface and the center of the interpolation neighbor cell as shown in Fig. 3. A δp is obtained from the new p_n and the old $p_{i,j}$ and, as explained below, the new $p_{i,j}$ is obtained iteratively by under-relaxation.

The iteration is continued until all the S's are made sufficiently small such that the velocity field is within accuracy requirements; that is, the magnitude of S < EPSI, which is chosen to be approximately 10^{-3} times a typical absolute value of $\partial u/\partial x$ or $\partial v/\partial y$. The last iterated quantities of velocity and pressure are taken as the advanced time values.

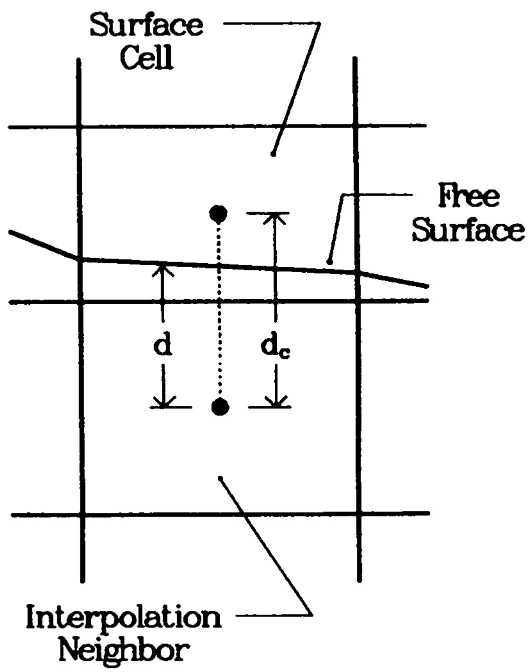

Fig. 3. Definition of quantities used in the free-surface boundary condition Eq. (27). The fluid is assumed to be below the free surface in this example.

In most cases, convergence of the SOR iterations may be accelerated by multiplying the δp from Eq. (21) by an over-relaxation parameter ω (OMG in the program). A meshwise constant value of 1.8 is often used, but the optimal value is flow-dependent. A value of two or greater gives an unstable iteration. This parameter is incorporated into the BETA array in the code.

We have found empirically that the free-surface condition, Eq. (27), requires that the interpolation neighbor cell of any surface cell must have a modified ω parameter. We employ the correction of Eq. (15) of the SOLA-VOF report,[2] noting that the $\underline{P}$ of that report is our $p\rho^{-1}$, and that further corrections to the denominator of Eq. (15) (included in the present code) occur when some interpolation neighbor cell has several surface cells as neighboring cells. This stabilizes the coupling between the surface cell and the interpolation neighbor cell pressures. This modified relaxation is incorporated into the pressure iteration through the PETA array.

A second procedure for finding the advanced time velocity and pressure fields may be invoked by switching the input variable ISOR from a value of unity to zero. For most problems this alternate procedure is more efficient than the successive-over-relaxation (SOR) method just described. It is based on the conjugate residual solution technique[18] for solving linear systems of equations.

First, Eqs. (18)-(20) are converted into a Poisson equation for the advanced time pressure field. We begin by rewriting Eqs. (2) and (3) in vector form:

$$\underset{\sim}{u}^{n+1} = \underset{\sim}{\tilde{u}} - \frac{\delta t}{\rho} \nabla p^{n+1} \quad , \tag{28}$$

where the viscous, body, and advective terms have been absorbed into the auxiliary quantity $\underset{\sim}{\tilde{u}}$. The pressure equation is derived by substituting Eq. (28) into the continuity equation

$$\nabla \cdot (\theta\, \underset{\sim}{u}^{n+1}) = 0 \quad , \tag{29}$$

which yields

$$\frac{\delta t}{\rho} V \nabla \cdot (\theta \nabla p^{n+1}) = V \nabla \cdot (\theta \underset{\sim}{\tilde{u}}) \quad , \tag{30}$$

where V is the volume of the computational cell (i,j). The cell volume is required to insure that the linear system created by the finite-difference approximation to Eq. (30) is conservative and therefore symmetric. The exact form of the difference operators may be seen by substituting Eqs. (18) and (19) into (20), but it is not useful to write them out in detail here. We merely note that Eq. (30) leads to a sparse, symmetric linear system when the free-surface, obstacle, and perimeter boundary conditions are algebraically incorporated into the system of equations in such a way that symmetry is retained. We write this system as

$$A\underset{\sim}{P} = \underset{\sim}{h} \quad , \tag{31}$$

where A is the symmetric coefficient matrix, $\underset{\sim}{P}$ is the solution vector (that is, the unknown $p^{n+1}_{i,j}$,s), and $\underset{\sim}{h}$ is the right-hand side of the linear system. We use the conjugate residual technique to solve this system. Daly and Torrey[19] discuss the motivation for using this procedure in detail. However, one important feature of the method is that $\underset{\sim}{P}$ is found iteratively in such a way that the ν^{th} iterate $\underset{\sim}{p}^{(\nu)}$ has an associated residual $A\,\underset{\sim}{p}^{(\nu)} - \underset{\sim}{h}$ that is equal to $V\,\nabla\cdot(\theta\underset{\sim}{u}^{n+1})$. Therefore, convergence of the iteration on the linear system is equivalent to driving the divergence of the velocity to zero, as in the SOR method.

There is one exception to the rule that $\nabla\cdot(\theta\underset{\sim}{u})$ is driven to zero. In a fluid cell (NF = 0), the F-transport algorithm can generate tiny spurious bubbles, or voids, when the divergence is zero, and these voids persist once generated. To suppress this, a small positive number is added to S when NF = 0, as described below, and the modified S is driven to zero by the iterations. The result is an actual net negative divergence in these cells (corresponding to a net inflow of fluid during the F-transport). The velocity field is slightly nonconservative, but the conservation of the total volume of fluid is not affected.

After the velocity and pressure fields have been found for a fixed F-field, we advance F in time. We combine Eqs. (1) and (4) to obtain

$$\frac{\partial(\theta F)}{\partial t} + \frac{1}{r}\frac{\partial(r\theta F u)}{\partial x} + \frac{\partial\,(\theta F v)}{\partial y} = 0 \quad , \tag{32}$$

where θ is the partial cell parameter defined in Appendix A, and r is a factor that is unity in Cartesian coordinates or x in cylindrical coordinates. This conservative form of Eq. (1) allows us to write a difference approximation that conserves fluid volume; namely,

$$F^{n+1}_{i,j} = F_{i,j} - \frac{\delta t}{AC_{i,j}}\left[\frac{1}{\delta x_i}\left(AR_{i+1/2,j}u^{n+1}_{i+1/2,j}F_{i+1/2,j} - AR_{i-1/2,j}u^{n+1}_{i-1/2,j}F_{i-1/2,j}\right) + \frac{1}{\delta y_j}\left(AT_{i,j+1/2}v^{n+1}_{i,j+1/2}F_{i,j+1/2} - AT_{i,j-1/2}v^{n+1}_{i,j-1/2}F_{i,j-1/2}\right)\right] \quad , \tag{32.1}$$

which serves as the basis for the convection of F.

The convection algorithm must (1) preserve the sharp definition of free boundaries, which we denote here as fluid instances; (2) avoid negative diffusion truncation errors; and (3) not flux more fluid, or more void, across a computing cell interface than the cell losing the flux contains. To accomplish this, the SOLA-VOF technique adopts a type of donor-acceptor flux approximation,[4] in which both the fluid velocities and the F values of the computing cell boundaries, or interfaces, appearing in Eq. (32.1), are redefined, as necessary.

It should be noted in Eq. (32.1) that F_{ij} (our shorthand for F_{ij}^{n}) should really be understood as $F_{ij}^{n+1/2}$ and F_{ij}^{n+1} really denotes $F^{n+3/2}$, while δt is really $\frac{1}{2}(\delta t_n + \delta t_{n+1})$. The code ignores the change in F that occurs during the first half time step of the calculation and uses initial values of F_{ij} for $F_{ij}^{1/2}$. The code graphics displays F_{ij}^{n} at t_n instead of at the more correct $t_n + \frac{1}{2}\,\delta t_n$. These imprecisions are not usually significant: typically the fluid starts from rest, while the time step is usually uniform, or it changes slowly if it is being controlled by a time step limiter. However, in one test problem (of slug flow), it was necessary to display F_{ij} at the correct time to obtain precise graphical correspondence with an analytic solution.

At each boundary of each computing cell, the two cells immediately adjacent to the interface are distinguished, one becoming a donor cell and the other an acceptor cell, and cell quantities are given the subscripts D and A, respectively, e.g., F_D and F_A. The labeling is accomplished by means of the algebraic sign of the fluid velocity normal to the boundary; the donor cell is always upstream, and the acceptor cell downstream, of the boundary. We emphasize that the D and A labels are assigned separately for each cell boundary. Thus, each computational cell will have four separate assignments of D or A corresponding to each of its cell boundaries. The boundary value of F, denoted by F_{AD}, which appears at the four boundaries in Eq. (32.1), will be either F_D or F_A, according to an algorithm chosen to partially accomplish purposes (1) and (2) above. Once F_{AD} is chosen, the actual value of F used at the boundaries in Eq. (32.1) is redefined further by a simple algorithm, which accomplishes purpose (3) and further assists in carrying out purposes (1) and (2). We denote the final value of the boundary F by $\hat{F}_{AD}$. It is the final $\hat{F}_{AD}$ that, when convected with the fluid velocity normal to the interface, will not remove more fluid per unit area, nor more void per unit area, than the donor cell contains, even when the boundary is completely open to flow.

We illustrate the redefinition $\hat{F}_{AD}$, assuming that F_{AD} has already been determined at the right-hand cell boundary, discussing first the original SOLA-VOF algorithm.[2] For this case

$$\hat{F}_{AD}\, u^{n+1}_{i+1/2,j}\ \delta t = \mathrm{sgn}\left(u^{n+1}_{i+1/2,j}\right) \mathrm{MIN}(F_{AD}|V_x| + CF,\ F_D \delta x_D) \quad , \tag{33}$$

where

$$V_x = u^{n+1}_{i+1/2,j}\ \delta t$$

and

$$CF = \mathrm{MAX}([1.0 - F_{AD}]|V_x| - (1.0 - F_D)\delta x_D,\ 0.0) \quad .$$

For numerically stable computations, i.e., for $|V_x| < \delta x_D$, the MIN statement of Eq. (33) prevents fluxing more fluid per unit area than the donor cell contains, while the MAX statement prevents fluxing of more void per unit area than the donor cell contains, namely $F_D \delta x_D$ and $[1.0 - F_D]\delta x_D$ respectively, provided that $\hat{F}_{AD}$ is fluxed at the fluid normal velocity $u_{i+1/2,j}$. Note, however, that it is the <u>entire</u> left-hand side of Eq. (33) that appears at the right-hand cell boundary in Eq. (32.1). Thus, $\hat{F}_{AD}$ never appears as an independently defined symbol in the code.

For the present code, the CF given above and in the SOLA-VOF report[2] is modified to be more restrictive in the amount of void fluxed by the operation of the CF term. This is done to improve the accuracy of the fluid convection and to suppress the appearance of spurious small wisps of fluid in the void cells of the computing mesh. We define the DM cell to be the cell upstream of the donor cell and then specify

$$CF = \mathrm{MAX}([\langle F\rangle - F_{AD}]|V_x| - [\langle F\rangle - F_D]\delta x_D,\ 0.0) \quad , \tag{34}$$

where

$$\langle F\rangle = \mathrm{MAX}(F_D,\ F_{DM},\ 0.1) \quad . \tag{34.1}$$

The first two options for <F> increase the accuracy of the representation of the fluid convection process, while the third option prevents the convection of fluid by the CF term until either the D or the DM cell becomes at least 0.1 full of fluid, which suppresses the spurious wisps of fluid.

To determine whether F_{AD} is F_D or F_A, we use F_D when the D cell is a fluid cell, which is automatically incorporated into a standard donor-acceptor algorithm. For surface cells, we determine the primary orientation of the donor cell fluid and of the fluid interface from NF_D and determine by inspection whether convection of donor cell fluid across the computing cell boundary is primarily normal or primarily tangential to the fluid interface. For most cases, we set $F_{AD} = F_A$ when the convection is primarily normal to the fluid interface and $F_{AD} = F_D$ when it is primarily tangential to the fluid interface. However, if the A cell or the DM cell is empty, then we always take $F_{AD} = F_A$. This requires that a donor cell must be nearly full before any fluid is convected to a downstream empty cell.

The complete fluxing algorithm is applied completely independently at the four computing cell boundaries appearing in Eq. (32.1). When the necessary fluxes have been computed, F is advanced through one time step using Eq. (32.1).

The full operation of the F-convection algorithm at a computing cell boundary, namely, the choice of F_{AD} and the application of Eqs. (33), (34), and (34.1), is equivalent to the <u>implicit</u> construction in the donor cell of intra-cell interfaces that govern the convection of fluid into the acceptor cell. The interfaces are independently determined for each of the four computing cell boundaries, are not the same as the local mean free surface, and may be of three general shapes, two of which are illustrated in Fig. 4. The intra-cell interfaces may be a single horizontal or vertical line, with all fluid pushed toward the main volume of adjacent fluid, as illustrated in Figs. 4b and 4c; they may be a pair of lines, one horizontal and one vertical, confining the fluid into the cell corner adjacent to the main body of fluid, as illustrated in Fig. 4d; or they may be a step function whose height is determined by F_A and F_{DM}.

Sometimes the VOF F-advection algorithm will generate nonphysical filaments of fluid that propagate throughout large regions of void. The appearance of 0.1 as a lower bound for <F> in Eq. (34.1) helps suppress these filaments. If a surface cell is trying to flux material into an empty cell, the flux is set to zero until F is greater than 0.1 in the surface cell. The limiting value of 0.1 may not be optimal for all problems. The original SOLA-VOF schemes may be recovered by setting the limiting value to zero.

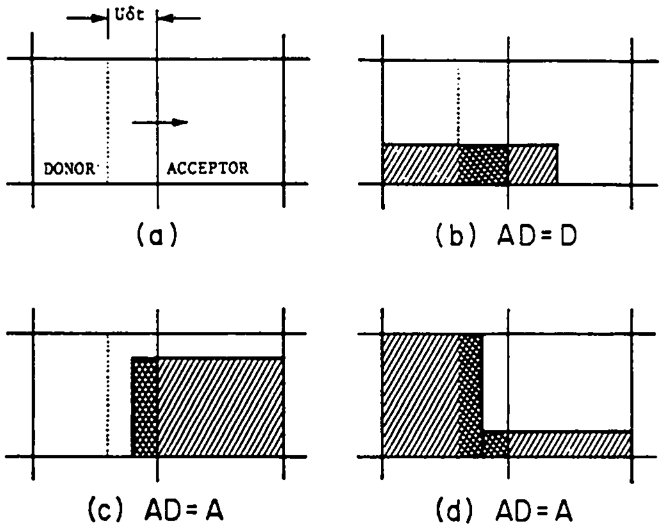

Fig. 4. Examples of the free-surface shapes used in the advection of F. The donor-acceptor arrangement is shown in (a) where the dashed line indicates the left boundary of the total volume being advected. The cross-hatched regions shown in (b-d) are the actual amounts of F fluxed.

Next we apply several fine-tuning procedures to the new values of F. The first is an optional algorithm for suppressing nonphysical fluid voids or filaments. It is invoked by setting the off/on flag NPACK to unity. Used only for problems in which the fluid lies against the bottom of the tank and has a simple surface shape, this scheme forces the code to start at the bottom of each column of cells and to pack all of the fluid down, producing a single-valued surface-height function. Unfortunately, this scheme is not easy to generalize to problems with a multivalued surface-height function, such as fuel reorientation problems.

A second algorithm utilized to suppress spurious voids, mentioned in discussing the pressure iteration earlier, overcomes these restrictions. The modified divergence ($\underset{\sim}{S}_{i,j}$) that is driven to zero is defined as

$$\underset{\sim}{S}_{i,j} = S_{i,j} + \mathrm{MIN}(\mathrm{ADEFM*EPSI},\ \mathrm{BDEFM}*(1.0 - F_{i,j})/\delta t) \quad ,$$

where ADEFM is typically 10^2 to 10^3, BDEFM is typically 0.10, and the convergence criterion EPSI is normally 10^{-3}. The first term represents the maximum allowable increment to be added to the computed divergence on a single time step, while the second is a fraction of the current deficit that will tend to zero as the cell fills. BDEFM is actually the reciprocal of the number of time steps in which the deficiency is to be removed. The input variable IDEFM is an off/on flag for this option (0 = off, 1 = on).

The next optional algorithm is controlled with the off/on flag IDIV, and it usually improves the accuracy and robustness of the program. This scheme recognizes that the divergence of $\underset{\sim}{u}^{n+1}$ $(S = \nabla \cdot (\theta\, \underset{\sim}{u}^{n+1}))$ is not exactly zero because of the finite number of pressure iterations and rounding errors, and it adjusts the value of F in each cell proportional to the actual value of its divergence. If IDEFM = 1, this algorithm must be skipped. The algorithms controlled by IDEFM, NPACK, and IDIV are referred to as "defoamers" because they are sometimes needed on problems to prevent void regions from filling with a froth of tiny F's or the formation of spurious voids within the fluid interior.

Truncation errors and rounding errors can cause the F-values determined by the above procedure to occasionally have values slightly less than zero or slightly greater than unity. Therefore, after the advection calculation has been completed, a pass is made through the mesh to reset values of F less than zero back to zero and values of F greater than one back to one. Accumulated errors in fluid volume introduced by these adjustments are recorded and may be printed at any time.

There is one final adjustment needed in F so that it may be used as a boundary cell flag. Boundary cells have values of F lying between zero and one. However, in a numerical solution, F-values cannot be tested against exact numbers like zero and one because rounding errors would cause spurious results. Instead, a cell is defined to be empty of F when F is less than ε_F (EMF in the program) and full when F is greater than $1 - \varepsilon_F$, where ε_F is typically 10^{-6}. If, after advection, a cell has an F value less than ε_F, this F is set to zero and all neighboring full cells become surface cells by having their F-values reduced from unity by an amount $1.1\ \varepsilon_F$. These changes in F are also included in the accumulated volume error. Volume errors after hundreds of cycles are typically observed to be a fraction of 1% of the total F volume.

Following the calculation of the new F-values the code sweeps the mesh redefining the new cell types and assigning appropriate flags $NF_{i,j}$. At the same time the approximate orientation of the fluid in each surface cell is determined, and a pressure interpolation neighbor cell is assigned.

Determination of whether the fluid is mostly horizontal or vertical in a surface cell relies on estimating the local slope of the fluid/void interface. We assume that the interface is a straight line segment partitioning the cell. The slope is estimated by introducing two surface-height functions Y(x) and X(y) based on the value of F in the surface cell and its eight neighbors. A good approximation to Y(x) is

$$Y_i = Y(x_i) = F_{i,j-1}\delta y_{j-1} + F_{i,j}\delta y_j + F_{i,j+1}\delta y_{j+1} \quad , \tag{35}$$

where $Y = 0$ has been taken as the bottom of the j-1 row of cells. For fluid cells the slope is given by

$$\left(\frac{dY}{dx}\right)_i = [(Y_{i+1} - Y_i)\ \delta x_{i-1/2}/\delta x_{i+1/2}$$

$$+ (Y_i - Y_{i-1})\ \delta x_{i+1/2}/\delta x_{i-1/2}]/(\delta x_{i-1/2} + \delta x_{i+1/2}) \quad , \tag{36}$$

where $\delta x_{i+1/2} = (\delta x_i + \delta x_{i+1})/2$. Interchanging the roles of x and y, we can write a similar equation for $(dX/dy)_j$. When evaluating the X- and Y-functions, one must be careful to include any obstacle volume in F that modifies the algorithm.

If $|dY/dx|$ is smaller than $|dX/dy|$, the boundary is more nearly horizontal than vertical. Otherwise, it is more nearly vertical. The side of the interface containing the fluid is then chosen depending on the sign of the larger derivative. For example, if $|dY/dx|$ is the smaller, the interface is horizontal. If dX/dy is negative, fluid lies below the interface, NF = 3, and cell (i,j-1) is used as the interpolation neighbor in Eq. (27). If dX/dy is positive, the fluid lies at the top of the cell, NF = 4, and cell (i,j+1) is chosen as the interpolation neighbor.

For a free-surface cell the surface-tension and wall-adhesion forces are evaluated and expressed as a surface pressure p_s[PS(I,J) in the program]. The surface pressure enters the calculation through Eq. (27).

The surface-tension, wall-adhesion algorithm must take account of the facts that the code has a very imprecise knowledge of the nature and the location of obstacles and that the code is usually used at the limits of flow resolution to save computational costs. (Frequently flows along the tank walls will be only one or two computational cells wide.) Thus it is essential that the surface-tension, wall-adhesion routine be robust (that is, should accept very imprecise data, should not make large errors in processing the data, should yield smooth output, and should never cause a catastrophic failure of the calculation) and simple.

For each free-surface cell, the program uses the array NF to specify whether the fluid lies primarily at the bottom, top, left, or right side of the cell. We illustrate how the surface-tension, wall-adhesion model works in the case of a free-surface cell in which the fluid is located at the bottom of the cell (that is, NF = 3). The other three cases are treated by analogous means. We also assume Cartesian coordinates. The extension to cylindrical coordinates will be discussed afterwards.

The surface-tension force acting across the faces of the computational cell is computed from [20]

$$\underset{\sim}{f} = - \sigma \int_c \underset{\sim}{n} \times d\underset{\sim}{x} \quad , \tag{37}$$

where σ is the surface tension, $\underset{\sim}{n}$ is the outward unit normal (that is, directed into the void) to the fluid surface, and the path c denotes the counter clockwise-traversed intersection of the fluid interface with the faces of the computational cell. For this NF = 3, Cartesian coordinate example, we consider the cell to be three-dimensional with unit depth in the third direction. Thus, the path c is a closed loop around the four vertical cell faces. This equation is valid if the free surface continues beyond the current cell in all directions and does not terminate on an obstacle wall in the current cell. Then the surface pressure p_s may be computed from the vertical force as follows:

$$p_s(I,J)\ \delta x_i\ \delta z = -\underset{\sim}{f}\cdot\underset{\sim}{y} = - \sigma\ \delta z\ [\sin(\beta_E) - \sin(\beta_W)] \quad , \tag{38}$$

where β denotes the local angle that the tangent (in the x-y plane) to the interface makes (rotated counterclockwise) with the x-axis (or the angle the normal makes with the y-axis), while the subscript E or W denotes the east (right) or west (left) boundary of cell (I,J). The unit normal in the y-direction is denoted by $\underset{\sim}{y}$.

For the NF = 3 case, the program determines an average fluid height AVFR in the column to the east of (I,J), an average fluid height AVFCX in cell (I,J), and an average fluid height AVFL in the column to the west of cell (I,J) from a weighting scheme that involves the F values in (I,J) and its eight neighboring cells. The β angles are determined from the defining relations

$$\tan(\beta_E) = \frac{2\ (\text{AVFR} - \text{AVFCX})}{\delta x_i + \delta x_{i+1}} \tag{39}$$

and

$$\tan(\beta_W) = \frac{2\ (AVFCX - AVFL)}{\delta x_{i-1} + \delta x_i} \tag{40}$$

after which we use relations of the form

$$\sin(\beta_E) = \frac{\tan(\beta_E)}{[1 + \tan^2(\beta_E)]^{1/2}} \tag{41}$$

to evaluate quantities appearing in the p_s formulas.

Suppose the fluid surface ends on an obstacle at the east wall, its tangent making the contact angle Θ_c with the east wall instead of continuing on into the east column of cells, as assumed in the previous formula for p_s. Then the vertical force at the east wall needs to be modified to allow for the fact that the true force is a wall-adhesion force rather than a surface-tension force. Specifically, assume that the surface cell (I,J) is a partial flow cell whose right, or east, boundary is a line segment running from its bottom point $\underset{\sim}{r}_b$ = (x_b, y_b) to its top point $\underset{\sim}{r}_t = (x_t, y_t)$, where $y_t > y_b$, and the fluid lies to the left, or west, of this boundary. Then we define the angle Θ_E that this east wall makes with the vertical by

$$\tan(\Theta_E) = \frac{x_t - x_b}{y_t - y_b} \quad . \tag{42}$$

That is, $\Theta_E > 0$ if $(\underset{\sim}{r}_t - \underset{\sim}{r}_b)$ is in the first quadrant, while $\Theta_E < 0$ if $(\underset{\sim}{r}_t - \underset{\sim}{r}_b)$ is in the second quadrant. Then the vertical component of the east wall-adhesion force on the fluid is

$$f_{zE} = \sigma\ \delta z\ CSANG \equiv \sigma\ \delta z\ \cos(\Theta_E + \Theta_c) \quad , \tag{43}$$

and the surface pressure is properly given by

$$p_s = -\left(\frac{\sigma}{\delta x_i}\right) [\mathrm{CSANG} - \sin(\beta_W)] \quad . \tag{44}$$

Similarly, if $\mathbf{r}_t$ and $\mathbf{r}_b$ define a line segment representing the west wall of a partial flow cell, with the fluid lying to the east of this boundary, then we define the angle Θ_W that the west wall makes with the vertical by

$$\tan(\Theta_W) = -\frac{x_t - x_b}{y_t - y_b} \quad . \tag{45}$$

That is, in this case $\Theta_W > 0$ if $(\mathbf{r}_t - \mathbf{r}_b)$ is in the second quadrant and $\Theta_W < 0$ if $(\mathbf{r}_t - \mathbf{r}_b)$ is in the first quadrant. The vertical component of the west wall-adhesion force is still given by

$$f_{zW} = \sigma\ \delta z\ \mathrm{CSANG} \equiv \sigma\ \delta z\ \cos(\Theta_W + \Theta_c) \quad , \tag{46}$$

and the surface pressure is given by

$$p_s = \left(\frac{\sigma}{\delta x_i}\right) [\mathrm{CSANG} - \sin(\beta_E)] \quad . \tag{47}$$

Unfortunately, the implementation of the above physically correct determination of p_s requires, in general, an expensive and complex front-tracking procedure to determine precisely whether it is wall adhesion or surface tension that is appropriate at any surface cell boundary at any time in the calculation. In partial flow cells in cylindrical geometry, it is also important to know on exactly which cell wall and at exactly what radius each surface force is delivered. Such an increase in calculational complexity would be incompatible with our goal of a simple and robust algorithm. Thus we give up the attempt at precise front tracking and precise evaluation of the surface-tension, wall-adhesion force and evaluate the appropriate surface force on each wall of the computational cell by means of an algorithm, which has the generic form in Cartesian geometry typified by

$$f_{zE} = \sigma\, \delta z\ [AFE \sin(\beta_E) + (1 - AFE)\ CSANG] \quad . \tag{48}$$

It is these latter expressions that are used in the program to evaluate p_s.

When the code escapes the general surface force algorithms by setting the flag INW to INW = 0 (designed to provide the capability to treat walls with porous baffles in them) then, for example, AFE is the fractional area open to flow and the surface force is taken to be a linear combination of surface tension and wall adhesion. Even though such an expression will not be correct at any moment in any particular flow, it will represent the behavior of an ensemble average (and, in some cases, a time average) of flows. This mode of treatment of AFE is the simplest reasonable treatment of the surface tension/wall adhesion dichotomy, and is well suited for a first, inexpensive, cut at the complexities of the porous baffle option.

Otherwise, INW = 1 (this will be the normal case in a partial flow cell) and we will have either surface tension or wall adhesion. That is, the computer algorithms will force a choice AFE = 1.0 or AFE = 0.0. This forces any wall-adhesion force to appear on the appropriate wall and ignores the exact radial location, and thus the exact numerical magnitude, of the actually occurring wall adhesion. This permits us to reduce the complexities of front tracking to a manageable level. In addition, we make the physically very reasonable approximation that $\Theta_c = 0$, which further reduces the number of cases that must be analyzed.

The basic decision algorithms are implemented by introducing another cell index NW(I,J) for partial flow cells, which, together with NF and the F values of the neighboring cells, determines AFE and the other analogous quantities on the other cell walls. The index NW labels the geometry of the obstacle to flow in a partial flow cell. If NW = 0, the cell volume is fully open to flow, but the cell surfaces may be partially or wholly closed to flow. We set INW = 0 in this case, with the consequences described previously. Otherwise INW = 1, we have a partial flow cell and NW describes the nature of the obstacle to flow.

A seemingly unnatural ordering of the numerical values of NW is adopted, which simplifies the tests to be made on NW and NF. Specifically, we adopt:

NW = 1; when the right wall is closed and the top and bottom walls are partially open

NW = 2; when the left wall is closed and the top and bottom walls are partially open

NW = 3; when the top wall is closed and the left and right walls are partially open

NW = 4; when the bottom wall is closed and the left and right walls are partially open

NW = 5; when the top and the right walls are closed

NW = 6; when the bottom and the right walls are closed

NW = 7; when the top and the right walls are partially open, but the other walls are open

NW = 8; when the bottom and the right walls are partially open, but the other wall are open.

We return to the discussion of how AFE and the other cell wall flags are set when INW = 1. We start with default values of 1.0 for these flags, which puts surface tension only on the appropriate cell walls. We specialize to the discussion of how AFE is changed to 0.0 (giving wall adhesion) when NF = 3. This happens for NW = 2. It happens for NW = 3 or 4 when the cell to the right is empty. It happens for NW = 5 when the cell below is empty, but for NW = 6 when the cell above is empty. It does not happen for NW = 7. Finally, it happens for NW = 8 when the cell to the right is empty. Analogous rules are given for the other cell wall flags AFW, AFN, and AFS; other NF values also generate appropriate values for all four cell flags.

In cylindrical geometry the above prescriptions for slab geometry must be supplemented by an additional contribution to p_S. In terms of the principal radii of curvature in an axisymmetric case,

$$p_S = -\sigma\left(\frac{1}{R_{xy}} + \frac{1}{R_\tau}\right) \quad , \tag{49}$$

where R_{xy} is the principal radius of curvature in the x-y plane and R_τ is the principal radius of curvature in the τ direction. The expressions we have just described correspond to the R_{xy} term only. The R_τ term is evaluated the same way as in NASA SOLA-VOF.[10] This term is of simple universal form (that is, it is independent of the shape of the curve in the x-y plane) and is unmodified by wall-adhesion effects. The near-horizontal and near-vertical cases are considered separately. For a near-horizontal surface, the surface slope PFX = $\tan(\tau_S)$, where τ_S is the angle the surface makes with the horizontal. Then $R_\tau = x_i/\sin(\tau_S)$. The sign of R_τ is opposite that of PFX. For near-vertical surfaces, PFY = $\tan(\tau_S)$; only now τ_S is the angle between the surface and the vertical. Then $R_\tau = (x_{i\pm1/2} \mp F_{i,j}\ \delta x_i)/\cos(\tau_s)$. The top signs of the choices $\pm$ and $\mp$ are taken if fluid is to the right of the free surface, and the bottom signs are chosen if the fluid is to the left of the interface. The sign of R_τ is determined by PFX as in the horizontal case.

In the code, a pressure p_{sat} is added to the p_s calculated above. This pressure represents the void pressure appropriate to the problem being run. For example, in a passive tank-draining problem, p_{sat} is the liquid vapor pressure, while under forced tank draining conditions, p_{sat} is the total forcing pressure. In the latter case, p_{sat} may be taken to be a function of time, but this must be done by hand.

For certain problems, namely those in which an initial steady-state meniscus is required in a right circular cylindrical section of a tank (such as we have in the two sample problems), SUBROUTINE EQUIB can be called to generate the initial surface shape. We start with a flat interface, and the subroutine then calculates the deviations from flatness, Υ. Both Υ and the radial coordinate ζ are scaled in units of the tank radius. The surface displacement is calculated by numerically solving

$$\frac{1}{\zeta}\frac{d}{d\zeta}\left[\frac{\zeta\ (d\Upsilon/d\zeta)}{(1 + (d\Upsilon/d\zeta)^2)^{1/2}}\right] - \mathrm{Bo}\ \Upsilon - 2\cos(\tau_c) = 0 \quad , \tag{50}$$

where Bo is the Bond number. The boundary conditions are $d\Upsilon/d\zeta = 0$ at $\zeta = 0$ and $d\Upsilon/d\zeta = \tan(\tau_c)$ at $\zeta = 1$. The constraint

$$2\ \pi \int_0^1 \zeta\ \Upsilon\ d\zeta = 0 \tag{51}$$

is enforced. The numerical method is essentially the same as that of Hotchkiss.[10]

For convenience, NASA-VOF2D has five different boundary condition options on each side of the mesh. These options are controlled by setting four flags, KL, KR, KB, and KT, that control the left, right, bottom, and top boundaries, respectively. The choices for KL are as follows: KL = 1, rigid free-slip wall; KL = 2, rigid no-slip wall; KL = 3, continuative boundary; KL = 4, periodic boundary (KR must equal four as well); and KL = 5, specified pressure outflow boundary. The same options apply to the other three boundaries. The details of how these are implemented are described in the SOLA-VOF report,[2] or they may be gleaned from SUBROUTINE BC with little effort, so they will not be repeated here. Other types of boundary conditions, such as the tank-drain hole in the numerical example in Sec. III, must be supplied by the user at the end of SUBROUTINE BC.

The final consideration of the numerical algorithm is stability. Since many terms are evaluated explicitly, that is, at time level n, the time step δt must be smaller than a certain critical value to prevent the unbounded growth of parasitic solutions of the difference equations. Once the mesh has been chosen, several restrictions are placed on δt to insure that it is below the critical value. First, material cannot move more than one cell width per time step. Therefore,

$$\delta t < \min \left\{ \frac{\delta x_i}{|u_{i,j}|}, \frac{\delta y_j}{|v_{i,j}|} \right\} , \tag{52}$$

where the minimum is taken over every cell in the mesh. Typically δt is chosen to be some fairly small fraction, say 0.25, of the minimum. Centered differencing ($\alpha = 0$) is unconditionally unstable, and it is necessary to make α at least approximately 1.2 to 1.5 times larger than the value of the minimum function in Eq. (52) divided into the actual δt.

The explicit differencing of the viscous terms also limits the time step. We require

$$\nu \, \delta t < 0.5 \, \frac{\delta x_i^2 \, \delta y_j^2}{\delta x_i^2 + \delta y_j^2} \quad . \tag{53}$$

For this stability limit, δt can be quite close to the critical value, unlike the convective limit [Eq. (52)].

Finally, the explicit treatment of the surface-tension forces requires that capillary waves not travel more than one cell width in one time step. A rough estimate for this limit is

$$\sigma \, \delta t^2 < \frac{\rho \, \delta x_m^3}{4 \, (1 + \xi)} \quad , \tag{54}$$

where δx_m is the minimum cell width in either direction anywhere in the mesh.

All of the above time step controls except the choice of α are automatically satisfied by the program if the user selects the automatic time step control by setting AUTOT = 1.0. Setting AUTOT = 0.0 will permit a constant δt to be used. The automatic option also adjusts the time step to keep pressure iterations at approximately 25 per cycle or less. In situations where the pressure iterations have not converged after 1000 iterations, or when an advective flux exceeds more than half the volume of a cell, the time step is automatically cut in half independent of the AUTOT selection. Further, in the case of an excessive advective flux, the cycle is restarted with the reduced δt.

Examples of the use of the numerous options of this code are presented and discussed in the context of several specific problems at the end of Sec. III, pp. 45-47, and in Sec. IV.

III. PROGRAM DESCRIPTION

The NASA-VOF2D program is highly structured so that individual components may be easily modified to fit specific problem requirements or to accept subsequent code upgrades. This approach allows greater efficiency in operation, simplifies problem setup, and facilitates code modification. While NASA-VOF2D can run many problems as is, in general a specific application will require changes to the logic for special inflow or outflow ports, complicated geometries, or unusual initial conditions. Seldom does anything have to be deleted; rather the modifications will be additions to the existing structure. Examples will be given of how to easily accomplish changes utilizing the UPDATE utility.

Figure 5 displays the code logical sequence, which is contained principally in the main program routine IIWI. The FILMSET block comprises a series of calls to system-dependent routines which define and initialize graphics output units. The user must substitute his own comparable routines or eliminate these statements. Subroutine SETUP is called to read the input data. Problem restart capability has been incorporated into the code. If the input parameter NDUMP > 0, SUBROUTINE TAPIN is called, dump tape 7 is read, and control is transferred back to the main calculational loop. Otherwise, problem setup and initialization occur. The mesh generator is called to construct the computing mesh and specify zoning variables. Next the obstacle generator is called to interpret input data and to produce the cell area and volume open-to-flow

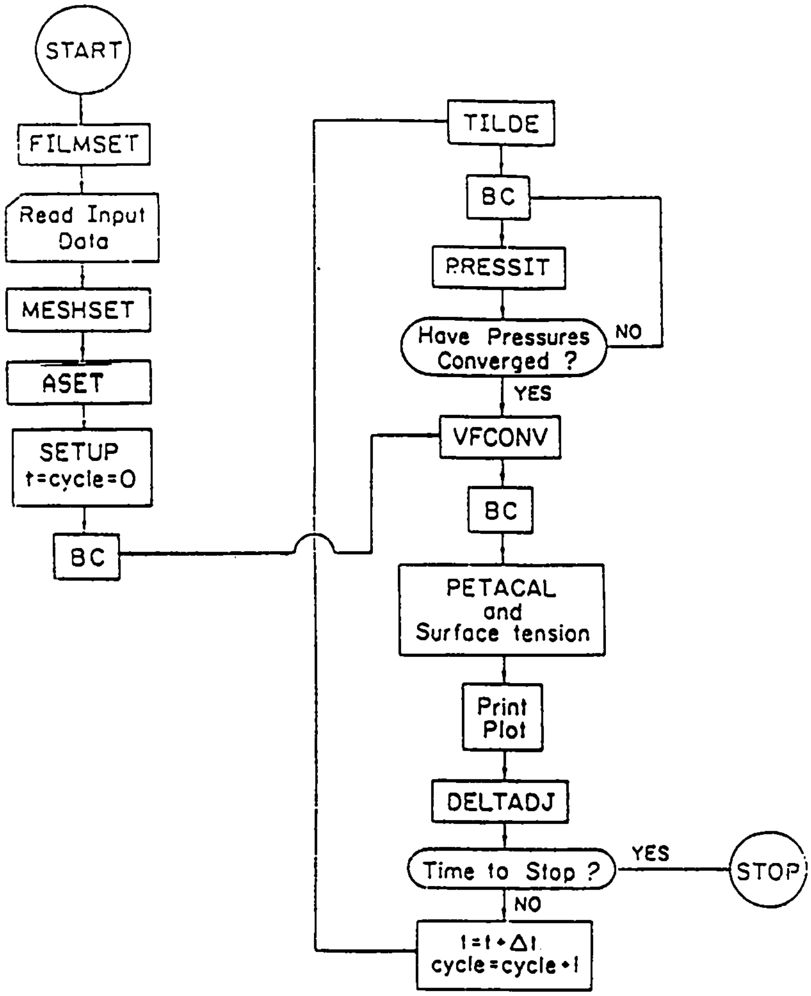

Fig. 5. Flow chart for NASA-VOF2D

variables that are used throughout the calculation to represent solid or porous interior boundaries. The fluid flow portion of the mesh is then initialized, a free surface constructed if indicated, and various parameters or variable arrays set. Control is returned to the main calculational loop. Boundary conditions are implemented by SUBROUTINE BC, which interprets the cell BETA values, the mesh input boundary flags, and the cell NF array values and sets appropriate quantities into interior obstacle cells, the fictitious mesh perimeter cells, and void cells adjacent to free surfaces.

Each cycle is started by calling SUBROUTINE TILDE to calculate the provisional time n+1 velocities using time n quantities for advective fluxes, pressure gradient accelerations, and viscous or body forces. Because the velocity field was changed, SUBROUTINE BC is called again to update the boundary cells. The block PRESSIT represents either of the two pressure iteration solution methods available. SUBROUTINE VFCONV is next called to advect fluid utilizing the new velocities determined following convergence of the pressure field. Boundary values are again updated with the new F's . Because the the fluid configuration has changed, SUBROUTINE PETACAL is called to redetermine the location and orientation of the surface or surfaces, to identify surface cells, and to calculate the pressure in these cells due to surface tension. At the same time, pressure interpolation neighbors are designated and the interpolation coefficients calculated. This completes the time advancement, all quantities now being at time n+1. Output indicators are tested, followed by an adjustment of the time step and testing of problem end parameters. The problem time is advanced along with the cycle counter and control returns to the beginning of the calculational loop.

It should be noted that although this program evolved from SOLA-VOF, not all of the capabilities of the latter code are available. In particular, the particle-tracking scheme, the two-material capability, and limited compressibility have not yet been made compatible with partial flow areas.

A brief description of each subroutine appears below.

IIWI (main program) Exercises logical control over the sequence of calculations, initiates output, and tests for problem termination conditions.

ASET (interior obstacle generator) Generates the problem variables, parameters, and flags to implement the partial flow areas feature.

BC (boundary conditions) Sets the appropriate fluid variables at the mesh boundaries and interior obstacles to produce specified boundary conditions; sets velocities on free surface and adjacent void cell boundaries in the absence of real pressure gradients. Proper place to incorporate special boundary conditions not built into code.

CAVOVO (calculates void volume) Computes the volume of disjoint void (F = 0.0) regions.

DELTADJ (time step adjustment) Computes maximum allowable δt for stability; adjusts δt considering stability limit and number of iterations required to converge pressures; recomputes relaxation factors (BETA) used with SOR method.

DRAW (generates graphical output) Draws velocity vector plots with free surfaces; provides mesh plot; and calls system utility for contour plots of F and P.

DRWOBS (draw obstacles) Draws lines around all obstacles.

DRWVEC (draw a vector) Provides a system-dependent call opportunity to draw a line between points (x_1,y_1) and (x_2,y_2); plots the symmetric form of a given line if requested.

DVCAL (additional boundary conditions) Provides free-slip boundary conditions for all obstacle surface flow cells.

EQUIB (generates equilibrium surface) Solves the two point boundary value problem to obtain the equilibrium shape of the free surface for time zero.

EXITLDC (exit message) Writes message upon termination indicating reason and location.

FRAME (graphics routine) Draws a frame around computing mesh.

LAVORE (label void regions) Detects and labels (NF values > 5) all disjoint (F = 0.0) regions.

MESHSET (mesh generator) Generates the computing mesh from NAMELIST/MSHSET/data Provides the necessary geometric variables for the code.

PETACAL (surface tension) Determines the local free-surface orientation (slope), the surface cell type [NF(I,J)], interpolation coefficients [PETA(I,J)] and the surface pressure [PS(i,j)] exerted by surface tension forces.

NF = 0	fluid cell--no void cells adjacent
NF = 1	surface cell--neighboring fluid cell to the left
NF = 2	surface cell--neighboring fluid cell to the right
NF = 3	surface cell--neighboring fluid cell on the bottom
NF = 4	surface cell--neighboring fluid cell on the top
NF = 5	surface cell--isolated, all adjacent cells are void
NF > 5	void cell--no fluid in cell

PLTPT (plot a point) Provides a system dependent call to graphics routine to plot a single point (x_1,y_1).

PRESCR (conjugate residual solution) Utilizes the conjugate residual method to bring the advanced time, pressure, and velocity fields into agreement.

PRESIT (successive over-relaxation solution) Utilizes the SOR method to bring the advanced time, pressure, and velocity fields into agreement.

PRTPLT (prints and plots) Output routine for paper prints, film data prints, and film plots.

SETUP (problem initialization) Sets necessary constants, computes scaling factors and other parameters for graphics, calls mesh generator, calls obstacle generator, initializes cell variables, and computes the relaxation factors used with SOR solution and as cell-type identifiers.

TAPIN (restart) Reads problem variables and control parameters from tape 7 to continue a previous problem.

TAPOUT (restart) Writes problem variables and control parameters to tape 7 for subsequent restart of problem.

TILDE (temporary velocity calculation) calculates explicitly provisional values of the velocities from time n advection fluxes, pressures, viscous stresses, and body forces.

VFCONV (volume fraction convection) Computes the advective fluxes of F(I,J) from the newly determined velocity field and updates the F(i,j) array.

VARIABLES LISTED IN COMMON (EXCLUDING INPUT PARAMETERS)

ADEFM	Defoam option parameter defined in SUBROUTINE PRESCR
BDEFM	Defoam option parameter
CYL	Mesh geometry indicator (= ICYL)
DTSFT	Maximum DELT value allowed by the surface-tension forces stability criterion (DELT is automatically adjusted)
DTVIS	Maximum DELT value allowed by the viscous forces stability criterion (DELT is automatically adjusted)
DXMIN	Variable usually equaling the local mesh size DELX(i)
DYMIN	Variable usually equaling the local mesh size DELY(j)
DUDB	y-derivative of u at bottom of cell at time level n
DUDL	x-derivative of u at left of cell at time level n
DUDR	x-derivative of u at right of cell at time level n
DUDT	y-derivative of u a top of cell at time level n
DVDB	y-derivative of v at bottom of cell at time level n
DVDL	x-derivative of v at left of cell at time level n
DVDR	x-derivative of v at right of cell at time level n
DVDT	y-derivative of v at top of cell at time level n
EMF	Small value, typically 1.0e-06, used to negate round-off error effects when testing f = 1.0 or f = 0.0
EMF1	=1.0-emf
EM6	=1.0e-06
EM6P1	=1.0+EM6
EM10	=1.0e-10
EP10	=1.0e+10
FCVLIM	Variable is used to control sizes of velocities; entered as data, it is also reset internally

FLG	Pressure iteration convergence test indicator (=0.0 when the convergence test is satisfied, =1.0 when the convergence test is not satisfied)
FLGX	Volume of fluid function convection limit indicator (DELT reduced and cycle started over if limit is exceeded)
FNOX	Pressure convergence failure indicator (=1.0, convergence failed and DELT is reduced, =0.0 otherwise)
FVOL	Volume of fluid in computational cell
I	Horizontal (radial) cell index
IBAR	Number of real cells in x-direction (excludes fictitious cells)
IBAR	Value of the index i at the next to the last real cell in the x-direction (=IMAX-2)
IBAR2	=IBAR+2, specified in parameter statement (=IBAR+3, if periodic in x-direction)
IEQIC	Flag indicating whether subroutine for equilibrium surface shape is to be called
IMAX	Total number of mesh cells in x-direction (=ibar+2) (=IBAR+3, if periodic in x-direction)
IM1	Value of the index i at the last real cell in the x-direction (=imax-1)
IPL	Leftmost pressure iteration index in x-direction (=3 for constant pressure boundary condition, =2 for all other cases)
IPR	Rightmost pressure iteration index in x-direction (=ibar for constant pressure boundary condition, =im1 for all other cases)
ITER	Pressure iteration counter
J	Vertical (axial) cell index
JBAR	Number of real cells in y-direction (excludes fictitious cells)
JBAR	Value of the index j at the next to the last real cell in the y-direction (=jmax-2)
JBAR2	=jbar+2, specified in parameter statement (=jbar+3, if periodic in y-direction)
JMAX	Total number of mesh cells in y-direction (=jbar+2) (=jbar+3, if periodic in y-direction)

JM1	Value of the index j at the last real cell in the y-direction (=jmax-1)
JPB	Bottom pressure iteration index in y-direction (=3 for constant pressure boundary condition, =2 for all other cases)
JPT	Top pressure iteration index in y-direction (=jbar for constant pressure boundary condition, =jm1 for all other cases)
LITER	Number of iterations on the previous cycle
NCYX	Calculational time cycle number
NDUMP	Tape 7 dump sequence number. Set to zero to skip tape restart. Otherwise, it must equal the sequence number on tape 7 to successfully restart.
NFLGX	Number of cycles the volume-of-fluid function convection limit (flgc) is exceeded
NMAT	(a fossil) The number of materials, always set to unity
NOBS	Number of obstacle functions being input
NOCON	Number of cycles pressure convergence has failed
NP	Total number of particles computed to be in mesh
NPRTS	Number of particles in mesh, specfied in parameter statement (used to set array size--must be 0)
NREQ	Number of void regions generated in calculation
NVOR	Maximum number of void regions allowed, specified in parameter statement
MESHX	Number of submesh regions in x-direction, specified in parameter statement
MESHY	Number of submesh regions in y-direction, specified in parameter statement
PI	=3.141592654
PSAT	Constant void pressure added to surface-tension pressure (can be converted by hand to a time-dependent driving pressure)
RCSQ	= 0 (for the present report)
RHOD	= 0 (for the present, one-material capability)
RPD	Degrees to radians conversion factor
SF	Plot scaling factor
T	Problem time
TWPLT	Problem time at which the next graphical output is made

TWPRT	Problem time at which the next printed output is made
TANGLE	Tangent of contact angle, cangle
VCHGT	Accumulated fluid volume change
VELMX1	Velmx normalized to minimum mesh cell dimension
XMAX	Location of right-hand side of mesh
XMIN	Location of left-hand side of mesh
XSHFT	Computed shift along the plotting abscissa to center the plot frame on film
YMAX	Location of the top of the mesh
YMIN	Location of the bottom of the mesh
YSHFT	Computed shift along the plotting ordinate to center the plot frame on film

ARRAYS IN COMMON (EXCLUDING MESH SETUP PARAMETERS)

ACOM(1)	First word in common
AC(i,j)	Fractional volume open to flow in cell (i,j)
AR(i,j)	Fractional area open to flow on right (east) wall in cell (i,j)
AT(i,j)	Fractional area open to flow on top (north) wall in cell (i,j)
BETA(i,j)	Pressure iteration relaxation factor in cell (i,j)
COSO(i,j)	Cosine of angle fluid makes under wall-adhesion in cell (i,j) when it is partial flow cell. Angle measured with respect to vertical
DELX(i)	Mesh spacing of the i-th cell along the x-axis
DELY(j)	Mesh spacing of the j-th cell along the y-axis
F(I,J)	Volume of fluid per unit volume of cell (I,J) at time level n+1
FN(i,j)	Volume of fluid per unit volume of cell (i,j) at time level n
IP(k)	Cell index for particle k along x-axis
JP(k)	Cell index for particle k along y-axis
LABS(5)	Temporary storage location for t, for internal use
NAME(10)	Problem identification line
NF(I,J)	Flag of surface cell (I,J) indicating the location of its neighboring pressure interpolation cell

NR(k)	Label of void region, k > 5
NW(I,J)	Flag of partial flow cell (I,J) indicating geometry of curved surface wall
P(i,j)	Pressure in cell (i,j) at time level n+1
PETA(i,j)	Pressure interpolation factor for cell (i,j)
PN(i,j)	Pressure in cell (i,j) at time level n
PR(k)	Pressure in void region nr(k)
PS(i,j)	Surface pressure in cell (i,j) computed from surface tension forces
RDX(i)	Reciprocal of delx(i)
RDY(j)	Reciprocal of dely(j)
RX(i)	Reciprocal of x(i)
RXI(i)	Reciprocal of xi(i)
RYJ(j)	Reciprocal of yj(j)
SINO(i,j)	Sine of angle fluid makes under wall-adhesion in cell (i,j) when it is partial flow cell. Angle measured with respect to vertical
TANTH(i,j)	Slope of fluid surface in cell (i,j)
U(i,j)	x-direction velocity component in cell (i,j) at time level n+1
UN(i,j)	x-direction velocity component in cell (i,j) at time level n
V(i,j)	y-direction velocity component in cell (i,j) at time level n+1
VN(i,j)	y-direction velocity component in cell (i,j) at time level n
VOL(k)	Volume of void region nr(k)
X(i)	Location of the right-hand boundary of the i-th cell along the x-axis
XI(i)	Location of the center of the i-th cell along the x-axis
XP(k)	x-coordinate of particle k
Y(j)	Location of the top boundary of the j-th cell along the y-axis
YJ(j)	Location of the center of the j-th cell along the y-axis
YP(k)	y-coordinate of particle k
ZC(20)	Storage for number of contour lines to be plotted

PROBLEM INPUT

Problem input data are furnished the code by the NAMELIST format-free option. The source deck prologue tabulates the several sets and identifies their function. Most have default values specified by DATA statements located in the main routine IIWI and SUBROUTINE SETUP just before the first executable statements. Problem input data sets need only reference variables or parameters whose values differ from these defaults.

NAMELIST XPUT parameters specify the material properties of the fluid, the solution method options, problem-dependent code parameters, and output requirements.

INPUT PARAMETERS (NAMELIST /XPUT/)

ALPHA Controls amount of donor-cell fluxing (=1.0 for full donor-cell differencing, =0.0 for central differencing)

AUTOT Automatic time step flag (=1.0 for automatic DELT adjustment, =0.0 for constant DELT)

CANGLE Contact angle, in degrees, between fluid and wall

CON C.F.L.condition--cell width fraction moved in time step

DELT Time step

DTCRMX Maximum DELT using conjugate residual solution method

EPSI Pressure iteration convergence criterion

FLHT Fluid height, in y-direction

GX Body acceleration in positive x-direction

GY Body acceleration in positive y-direction

ICYL Mesh geometry indicator (=1 for cylindrical coordinates, =0 for plane coordinates)

IDEFM Defoamer option flag on = 1, off = 0

IDIV Divergence correction flag on = 1, off = 0

IMOVY Movie indicator (=1 for movie film output, =0 for other film output)

ISOR Pressure iteration solution method (conjugate residual = 0, SOR = 1)

ISURF10 Surface tension indicator (=1 for surface tension, =0 for no surface tension)

ISYMPLT Symmetry plot indicator (=1 for symmetry plot, =0 for no symmetry plot)

KB Indicator for boundary condition to be used along the bottom of the mesh (=1 for rigid free-slip wall, =2 for rigid no-slip wall, =3 for continuative boundary, =4 for periodic boundary, =5 for constant pressure boundary)

KL	Indicator for boundary condition along left side of mesh (see kb)
KR	Indicator for boundary condition along right side of mesh (see kb)
KT	Indicator for boundary condition along top of mesh (see kb)
NAME	Problem identification
NDUMP	Dump number for problem restart
NPACK	Flag to activate packing (on = 1, off = 0)
NPX	Number of particles in x-direction in rectangular setup
NPY	Number of particles in y-direction in rectangular setup
XNU	Coefficient of kinematic viscosity
OMG	Over-relaxation factor used in pressure iteration
PLTDT	Time increment between plots and/or prints to be output on film
PRTDT	Time increment between prints on paper
QVOL	Available to specify flow rate (inflow or outflow) if required
RHOF	Fluid density (for f = 1.0 region)
RHOFC	=rhof (for the present, one-material, capability)
SIGMA	Surface-tension coefficient
TWFIN	Problem time to end calculation
UI	x-direction velocity used for initializing mesh
VI	y-direction velocity used for initializing mesh
VELMX	Maximum velocity expected in problem, used to scale velocity vectors
XPL	Location of left side of rectangular particle region
XPR	Location of right side of rectangular particle region
YPB	Location of bottom of rectangular particle region
YPT	Location of top of rectangular particle region

NAMELIST MSHSET is used to define the computational region dimensions and the zoning within that region. The computing mesh is constructed from a number of submeshes defined in each coordinate direction. The namelist input specifies the boundaries, the number of cells, the minimum cell dimension, and the convergence point of each submesh. Variable spacings are accommodated by linking a group of submeshes together to achieve any desired distribution of cell spacing. This is done in the same manner in both directions. The number of cells is specified in each submesh on each side (i.e., to the left and to the right) of the convergence point. Both cells directly adjacent to the convergence point will have a cell spacing equal to the minimum value specified in the input as DXMN or DYMN. The cell spacing is then expanded quadratically from these cells to the left and right edges of the submesh in accordance with the desired number of cells (NXR,NXL or NYR,NYL) in the input list. If the number of cells specified on the left (right) should produce a uniform cell size that is less than the minimum specified cell size DXMN (or DYMN), a uniform spacing is then used on the left (right). The number of cells to the left and to the right of the convergence point need not be equal, but there must be at least one on both sides.

When two or more submeshes are linked together, it is imperative that the location of the left edge of the right submesh be the same as the location of the right edge of the left submesh. In addition, large disparities in cell spacing should be avoided within a submesh and going from one submesh to another by adjusting the number of cells in the various submeshes. As a general rule the spacing of adjacent cells should not differ by more than 10-20%. The aspect ratio (DELX/DELY) for a given cell should not exceed 1.5 and should be greater than 0.67.

An example of the proper format to be used to specify a mesh spanning the x-dimension LW < x < RW with n submeshes is

$NKX = n$, $XL = LW, XL_2, XL_3, \ldots, XL_n$,
$XC = XC_1, XC_2, \ldots XC_n$, $XR = XL_2, XL_3, \ldots, XL_n, RW$,
$NXL = NL_1, NL_2, \ldots, NL_n$, $NXR = NR_1, NR_2, \ldots, NR_n$,
$DXMN = DXMN_1, DXMN_2, \ldots, DXMN_n$

in which NL_i represents the number of cells to the left of XC_i and NR_i is the number of cells to the right of XC_i in each submesh i, i = 1, 2, ..., n.

References [2] and [10] contain several examples of mesh generation input and resultant computational meshes.

MESH SETUP INPUT (NAMELIST /MSHSET/)

DXMN(n)	Minimum space increment in x-direction in submesh n
DYMN(n)	Minimum space increment in y-direction in submesh n
NKX	Number of submesh regions in x-direction
NKY	Number of submesh regions in y-direction
NXL(n)	Number of cells between locations XL(n) and XL(n) in submesh n
NXR(n)	Number of cells between locations XL(n) and XL(n+1) in submesh n
NYL(n)	Number of cells between locations YL(n) and YC(n) in submesh n
NYR(n)	Number of cells between locations YC(n) and YL(n+1) in submesh n

XC(n) x-coordinate of the convergence point in submesh n

XL(n) Location of the left edge of submesh n [NKX+1 values of XL(n) are necessary because the right edge (XR) of submesh n is determined by the left edge of submesh n+1]

YC(n) y-coordinate of the convergence point in submesh n

YL(n) Location of the bottom of submesh n [NKY+1 values of YL(n) are necessary because the top edge (YR) of submesh n is determined by the bottom edge of submesh n+1]

NAMELIST ASETIN provides information to the interior-obstacle-generating subroutine. Interior obstacles are defined as any nonflow regions within the computational mesh. As with the mesh generator, it is convenient to have the necessary flags and parameters produced automatically by the code for arbitrary-shaped obstacles. The generator uses a series of conic sections to define obstacle surfaces plus an additional parameter that directs the generator to designate computational cells as either flow or nonflow regions. The conic sections may overlap one another and this feature is utilized to form complex surfaces.

The procedure is as follows: Coefficients of the general conic function

$$F(x,y) = a_2x^2 + a_1x + b_2y^2 + b_1y + c_2xy + c_1$$

are chosen such that some portion of the defined surface coincides with that of the desired internal obstacle. Computational cells partially or completely inside the conic surface [i.e., $F(x_c,y_c) < 0.0$, x_c and y_c being cell boundary coordinates] are flagged closed to flow, partially closed to flow, or fully open to flow depending upon the additional parameter IOH (=1.0 closed, =0.0 open) associated with each function. Generally additional functions can be utilized to remove unwanted obstacle cells added by other functions. For example, given reasonable zoning, a 1.0- x 1.0-cm obstacle in the lower right corner of a 2.0- x 2.0-cm mesh would result from $f_1 = -x+1.0$, $IOH_1 = 1.0$, which defines all cells, regardless of y value, to the right of x = 1.0 to be obstacles, and followed by $f_2 = -y+1.0$, $IOH_2 = 0.0$, which removes all obstacle cells above y = 1.0.

After all sets of obstacle data have been processed, the computing mesh is swept and individual cell area and volume open-to-flow variables are assigned. Aside from geometric factors for cylindrical coordinates, they range from 0.0 (not open to flow) to 1.0 (fully open to flow).

OBSTACLE SETUP INPUT (NAMELIST /ASETIN/)

IOH(n)	Indicator to add obstacles inside function n (=1) or subtract obstacles (=0)
OA2(n)	Coefficient of x^2-term in function n
OA1(n)	Coefficient of x-term in function n
OB2(n)	Coefficient of y^2-term in function n
OB1(n)	Coefficient of y-term in function n
OC2(n)	Coefficient of xy-term in function n
OC1(n)	Coefficient of constant term in function n

Problem output consists of data prints on either paper or film and film plots of the velocity field including free surface contours and obstacles outlines. Mesh generation data, partial flow area data, and cell variables data for cycles 0 and 1 are output automatically to both media. Thereafter the frequency of the cell data prints or plots is determined by print or plot increments specified in the problem input data set. In addition, graphic system packages are utilized to secure contour plots of F and P. Calls to these routines appear in SUBROUTINE DRAW.

Provision is available to produce a plot file that can be processed into a movie. The input parameter IMOVY suppresses all references to the film file other than those from velocity vector plot routines.

The main task in using the code is to formulate the problem correctly and to present the code with proper input. The theoretical study or experimental simulation should be analyzed as to the regions of principal interest and a mesh constructed of sufficient fineness to resolve the phenomena of interest. Unconfined flows require attention to the selection of appropriate boundary conditions and a mesh large enough to minimize boundary perturbations. The importance of physical processes not specifically addressed in the code should be evaluated. Some of the problem control parameters are best determined by experience.

Table 2 is an example of a typical input data set. The code is to simulate a near-full cylindrical tank with hemispherical bottom draining under the influence of reduced gravity, surface-tension, and wall-adhesion forces. The

TABLE II

EXAMPLE INPUT

```
$XPUT
NAME=55HHOTCHKISS CASE 1 4/28/85
NDUMP=0, ISOR=0, NPACK=0, QVOL=3.139E01, IDEFM=1,
DELT=.0002,    GY=-14.72,    ICYL=1,  DTCRMX=0.0004,
CANGLE=5., SIGMA= 18.6, ISURF10=1, IEQIC=1,
XNU=4.43E-03, RHOF=1.58, EPSI=1.E-03,
VELMX=10.,    TWFIN=2.301,    PRTDT=1.E+10,
PLTDT=.05,    FLHT=6.,     ISYMPLT=1, AUTOT=1.
$END
$MSHSET
NKX=2, XL=0.0,.4,2., XC=0.2,1.9, NXL=1,8,   NXR=1,1, DXMN=0.2,0.1,
NKY=1,  YL=0.0, 7.2,  YC=3.6,  NYL=18,  NYR=18, DYMN=0.2,
$END
$ASETIN
NOBS=2,
OA2(1)=-1.,  OB2(1)=-1.,  OB1(1)=4.,   IOH(1)=1.,
OB1(2)=-1.,  OC1(2)=2., IOH(2)=0.
$END
```

discharge flow rate is specified and is constant with time. Input and output will be in CGS units, although any consistent set of units is allowed. Referring to the tabulated input parameters section, note that the conjugate residual method was chosen (ISOR = 0), the packing option is on (NPACK = 1), and the volumetric flow rate specified (QVOL = 31.39). The initial fluid volume in the tank is specified by giving the fluid height above the tank bottom (FLHT = 6.0). The surface-tension flag is on (ISURF10 = 1), cylindrical coordinates chosen (ICYL = 1), the equilibrium surface calculation is requested (IEQIC = 1) along with automatic time step adjustment (AUTOT = 1). The initial DELT is computed from the outflow rate, discharge opening area, and mesh spacing to satisfy stability constraints. The convergence criterion (EPSI = 0.001) is picked to be sufficiently small to assure that negligible pressure errors result from nonzero $(\nabla \cdot \underline{u})$'s. Paper output is suppressed by the large print interval.

Figure 6 displays the computing mesh generated from MSHSET data and its mirror reflection across the cylindrical axis. This full cross section plot for cylindrical geometry is obtained when the input parameter ISYMPLT = 1. The x-coordinate has two submeshes with a total of 11 real cells, the spacing being finer near the tank wall. The y-coordinate has a single submesh with 36 real cells. The curved boundary at the bottom was drawn from code variables and parameters produced by the obstacle generator subroutine from the ASETIN data set. Computational cells whose areas are bisected by the curve are defined to be partial flow cells whose boundaries are identified as partial flow areas and treated accordingly throughout the calculation. Curved boundaries are simulated within the code by use of these partial flow areas. Computing mesh cells to the right and below the curve are designated obstacle cells, while those above and to the left are fluid flow cells.

Figure 7 shows the time zero fluid configuration generated from XPUT data. The initial surface shape is furnished by SUBROUTINE EQUIB, which solves the two-point boundary value problem for the equilibrium position of the free-surface. The parameters of the equation are the contact angle (cangle) and the Bond number ($\rho g R^2/\sigma$, where R is the tank radius). This free surface configuration is utilized to specify void cells, partially filled fluid cells, and completely full fluid cells in the computational mesh. The free surface is represented in the plot by the F = 0.5 contour, which generally does not correctly display the surface meniscus at the walls.

Table 3 contains code changes necessary to run the example. Programs for maintaining and updating source decks (UPDATE or HISTORIAN) afford a convenient way to incorporate problem-dependent modifications into the executable code. These particular modifications arise since we wish to simulate a small pipe

TABLE III

EXAMPLE CODE MODIFICATIONS

```
*IDENT HOTCH1
*D,COMMON1.2
C
C       SET MESH DIMENSIONS - IF CR SOLUTION : IBAR2=IMAX  JBAR2=JMAX
C
      PARAMETER(IBAR2=13,JBAR2=38,MESHX=3,MESHY=2,NVOR=25,NOBD=20)
C
*I,ASET.171
C
C      SET AREA AND VOLUME OPEN TO FLOW FOR DESIGNATED OUTFLOW CELLS
C
      DO 2400 I=2,2
      AT(I,1)=1.0
      AC(I,1)=1.0
      AC(I,2)=1.0
 2400 CONTINUE
C
*I,BC.164
C
C      SET SPECIFIED OUTFLOW VELOCITIES FOR DESIGNATED OUTFLOW CELLS
C
      DO 500 I=2,2
      U(I,1)=0.0
      V(I,1)=-QVOL/(PI*X(2)**2)
  500 CONTINUE
C
*I,PRESCR.137
C
C       INSERT SPECIAL TEST IN CONJUGATE RESIDUAL SOLUTION ALGORITHM
C       TO RECOGNIZE OUTFLOW CELL AND CALCULATE PROPER COUPLING
C
      IF(I.EQ.2.AND.J.EQ.2) GO TO 40
C
*I,PRESCR.81
      IF(F(I-1,J+1).LT.EMF.AND.BETA(I-1,J+1).GT.0.0) GO TO 5
      IF(F(I-1,J).LT.EMF.AND.BETA(I-1,J).GT.0.0) GO TO 5
      IF(F(I-1,J-1).LT.EMF.AND.BETA(I-1,J-1).GT.0.0) GO TO 5
      IF(F(I,J-1).LT.EMF.AND.BETA(I,J-1).GT.0.0) GO TO 5
      IF(F(I+1,J-1).LT.EMF.AND.BETA(I+1,J-1).GT.0.0) GO TO 5
      IF(F(I+1,J).LT.EMF.AND.BETA(I+1,J).GT.0.0) GO TO 5
      IF(F(I+1,J+1).LT.EMF.AND.BETA(I+1,J+1).GT.0.0) GO TO 5
```

located on the tank bottom at the cylindrical axis, whereas the code lacks provision for partially open mesh boundaries.

First the PARAMETER statement (no. 2 of COMMON1) is replaced, specifying the minimum storage requirements for the various arrays. A comment is included regarding the selection of the conjugate residual method. Next, statements are inserted at the end of SUBROUTINE ASET to redefine the cell area open to flow variables for cell i = 2, j = 1 so that a discharge port is created. A second insertion at the end of SUBROUTINE BC specifies the constant outflow velocity for this port. Finally a change is required in SUBROUTINE PRESCR to correctly apply outflow velocity boundary conditions for discharge port cells in the pressure iteration.

Table 4 lists dimensional variables resulting from the mesh generator. Spacing in the x-direction is nonuniform, whereas the y-direction is uniform. Table 5 is a partial list of the over-relaxation parameters, area, and volume open-to-flow variables associated with each cell. BETA(i,j) = -1.0 identifies cells completely closed to flow. Also tabulated are the sine and cosine of the angles (made with the vertical) of the surface of the partial flow volumes representing curved walls. Table 6 tabulates problem control, mesh, and obstacle input data or parameters. A complete cycle print is included in Table 7 as an example of code output and as a checkout aid. This is the solution after one time step when the flow field is established and the pressure and velocity fields are consistent. Surface pressures are defined only for surface cells [0 < NF(i,j) < 6] and are negative indicating that the unbalanced surface-tension forces are directed upward and acting to straighten the surface. Cell i = 2, j = 30 has F = 0.111 and NF = 3 showing that the surface passes through and is nearly horizontal, and that fluid is in its bottom portion. Figure 8 is the velocity vector plot at this time.

IV. SAMPLE APPLICATIONS

In this section we show results for four examples. The first two cases are a falling slug and a sloshing tank of water. These cases have known analytical solutions and are useful for testing the performance of the NASA-VOF2D program. We then discuss a tank-draining problem and a fuel reorientation problem.

We first consider the one-dimensional falling slug problem. Both cylindrical and Cartesian cases were run with the same results. The problem is to consider a slug of fluid well above the bottom of a tall cylindrical

TABLE IV

MESH VARIABLES

X(1)= 0.00000E+00	RX(1)= 0.00000E+00	DELX(1)= 2.00000E-01	RDX(1)= 5.00000E+00	XI(1)=-9.99999E-02	RXI(1)=-1.00000E+01
X(2)= 2.00000E-01	RX(2)= 5.00000E+00	DELX(2)= 2.00000E-01	RDX(2)= 5.00000E+00	XI(2)= 9.99999E-02	RXI(2)= 1.00000E+01
X(3)= 4.00000E-01	RX(3)= 2.50000E+00	DELX(3)= 2.00000E-01	RDX(3)= 5.00000E+00	XI(3)= 3.00000E-01	RXI(3)= 3.33334E+00
X(4)= 6.75000E-01	RX(4)= 1.48148E+00	DELX(4)= 2.75000E-01	RDX(4)= 3.63636E+00	XI(4)= 5.37500E-01	RXI(4)= 1.86047E+00
X(5)= 9.25000E-01	RX(5)= 1.08108E+00	DELX(5)= 2.50000E-01	RDX(5)= 4.00000E+00	XI(5)= 8.00000E-01	RXI(5)= 1.25000E+00
X(6)= 1.15000E+00	RX(6)= 8.69565E-01	DELX(6)= 2.25000E-01	RDX(6)= 4.44444E+00	XI(6)= 1.03750E+00	RXI(6)= 9.63855E-01
X(7)= 1.35000E+00	RX(7)= 7.40741E-01	DELX(7)= 2.00000E-01	RDX(7)= 5.00000E+00	XI(7)= 1.25000E+00	RXI(7)= 8.00000E-01
X(8)= 1.52500E+00	RX(8)= 6.55738E-01	DELX(8)= 1.75000E-01	RDX(8)= 5.71429E+00	XI(8)= 1.43750E+00	RXI(8)= 6.95652E-01
X(9)= 1.67500E+00	RX(9)= 5.97015E-01	DELX(9)= 1.50000E-01	RDX(9)= 6.66667E+00	XI(9)= 1.60000E+00	RXI(9)= 6.25000E-01
X(10)= 1.80000E+00	RX(10)= 5.55556E-01	DELX(10)= 1.25000E-01	RDX(10)= 8.00000E+00	XI(10)= 1.73750E+00	RXI(10)= 5.75540E-01
X(11)= 1.90000E+00	RX(11)= 5.26316E-01	DELX(11)= 1.00000E-01	RDX(11)= 1.00000E+01	XI(11)= 1.85000E+00	RXI(11)= 5.40541E-01
X(12)= 2.00000E+00	RX(12)= 5.00000E-01	DELX(12)= 9.99999E-02	RDX(12)= 1.00000E+01	XI(12)= 1.95000E+00	RXI(12)= 5.12821E-01
X(13)= 2.10000E+00	RX(13)= R	DELX(13)= 9.99999E-02	RDX(13)= 1.00000E+01	XI(13)= 2.05000E+00	RXI(13)= 4.87805E-01

Y(1)= 0.00000E+00	DELY(1)= 2.00000E-01	RDY(1)= 5.00000E+00	YJ(1)=-1.00000E-01	RYJ(1)=-1.00000E+01
Y(2)= 2.00000E-01	DELY(2)= 2.00000E-01	RDY(2)= 5.00000E+00	YJ(2)= 1.00000E-01	RYJ(2)= 1.00000E+01
Y(3)= 4.00000E-01	DELY(3)= 2.00000E-01	RDY(3)= 5.00000E+00	YJ(3)= 3.00000E-01	RYJ(3)= 3.33333E+00
Y(4)= 6.00000E-01	DELY(4)= 2.00000E-01	RDY(4)= 5.00000E+00	YJ(4)= 5.00000E-01	RYJ(4)= 2.00000E+00
Y(5)= 8.00000E-01	DELY(5)= 2.00000E-01	RDY(5)= 5.00000E+00	YJ(5)= 7.00000E-01	RYJ(5)= 1.42857E+00
Y(6)= 1.00000E+00	DELY(6)= 2.00000E-01	RDY(6)= 5.00000E+00	YJ(6)= 9.00000E-01	RYJ(6)= 1.11111E+00
Y(7)= 1.20000E+00	DELY(7)= 2.00000E-01	RDY(7)= 5.00000E+00	YJ(7)= 1.10000E+00	RYJ(7)= 9.09091E-01
Y(8)= 1.40000E+00	DELY(8)= 2.00000E-01	RDY(8)= 5.00000E+00	YJ(8)= 1.30000E+00	RYJ(8)= 7.69231E-01
Y(9)= 1.60000E+00	DELY(9)= 2.00000E-01	RDY(9)= 5.00000E+00	YJ(9)= 1.50000E+00	RYJ(9)= 6.66667E-01
Y(10)= 1.80000E+00	DELY(10)= 2.00000E-01	RDY(10)= 5.00000E+00	YJ(10)= 1.70000E+00	RYJ(10)= 5.88235E-01
Y(11)= 2.00000E+00	DELY(11)= 2.00000E-01	RDY(11)= 5.00000E+00	YJ(11)= 1.90000E+00	RYJ(11)= 5.26316E-01
Y(12)= 2.20000E+00	DELY(12)= 2.00000E-01	RDY(12)= 5.00000E+00	YJ(12)= 2.10000E+00	RYJ(12)= 4.76190E-01
Y(13)= 2.40000E+00	DELY(13)= 2.00000E-01	RDY(13)= 5.00000E+00	YJ(13)= 2.30000E+00	RYJ(13)= 4.34783E-01
Y(14)= 2.60000E+00	DELY(14)= 2.00000E-01	RDY(14)= 5.00000E+00	YJ(14)= 2.50000E+00	RYJ(14)= 4.00000E-01
Y(15)= 2.80000E+00	DELY(15)= 2.00000E-01	RDY(15)= 5.00000E+00	YJ(15)= 2.70000E+00	RYJ(15)= 3.70370E-01
Y(16)= 3.00000E+00	DELY(16)= 2.00000E-01	RDY(16)= 5.00000E+00	YJ(16)= 2.90000E+00	RYJ(16)= 3.44828E-01
Y(17)= 3.20000E+00	DELY(17)= 2.00000E-01	RDY(17)= 5.00000E+00	YJ(17)= 3.10000E+00	RYJ(17)= 3.22581E-01
Y(18)= 3.40000E+00	DELY(18)= 2.00000E-01	RDY(18)= 5.00000E+00	YJ(18)= 3.30000E+00	RYJ(18)= 3.03030E-01
Y(19)= 3.60000E+00	DELY(19)= 2.00000E-01	RDY(19)= 5.00000E+00	YJ(19)= 3.50000E+00	RYJ(19)= 2.85714E-01
Y(20)= 3.80000E+00	DELY(20)= 2.00000E-01	RDY(20)= 5.00000E+00	YJ(20)= 3.70000E+00	RYJ(20)= 2.70270E-01
Y(21)= 4.00000E+00	DELY(21)= 2.00000E-01	RDY(21)= 5.00000E+00	YJ(21)= 3.90000E+00	RYJ(21)= 2.56410E-01
Y(22)= 4.20000E+00	DELY(22)= 2.00000E-01	RDY(22)= 5.00000E+00	YJ(22)= 4.10000E+00	RYJ(22)= 2.43902E-01
Y(23)= 4.40000E+00	DELY(23)= 2.00000E-01	RDY(23)= 5.00000E+00	YJ(23)= 4.30000E+00	RYJ(23)= 2.32558E-01
Y(24)= 4.60000E+00	DELY(24)= 2.00000E-01	RDY(24)= 5.00000E+00	YJ(24)= 4.50000E+00	RYJ(24)= 2.22222E-01
Y(25)= 4.80000E+00	DELY(25)= 2.00000E-01	RDY(25)= 5.00000E+00	YJ(25)= 4.70000E+00	RYJ(25)= 2.12766E-01
Y(26)= 5.00000E+00	DELY(26)= 2.00000E-01	RDY(26)= 5.00000E+00	YJ(26)= 4.90000E+00	RYJ(26)= 2.04082E-01
Y(27)= 5.20000E+00	DELY(27)= 2.00000E-01	RDY(27)= 5.00000E+00	YJ(27)= 5.10000E+00	RYJ(27)= 1.96078E-01
Y(28)= 5.40000E+00	DELY(28)= 2.00000E-01	RDY(28)= 5.00000E+00	YJ(28)= 5.30000E+00	RYJ(28)= 1.88679E-01
Y(29)= 5.60000E+00	DELY(29)= 2.00000E-01	RDY(29)= 5.00000E+00	YJ(29)= 5.50000E+00	RYJ(29)= 1.81818E-01
Y(30)= 5.80000E+00	DELY(30)= 2.00000E-01	RDY(30)= 5.00000E+00	YJ(30)= 5.70000E+00	RYJ(30)= 1.75439E-01
Y(31)= 6.00000E+00	DELY(31)= 2.00000E-01	RDY(31)= 5.00000E+00	YJ(31)= 5.90000E+00	RYJ(31)= 1.69492E-01
Y(32)= 6.20000E+00	DELY(32)= 2.00000E-01	RDY(32)= 5.00000E+00	YJ(32)= 6.10000E+00	RYJ(32)= 1.63934E-01
Y(33)= 6.40000E+00	DELY(33)= 2.00000E-01	RDY(33)= 5.00000E+00	YJ(33)= 6.30000E+00	RYJ(33)= 1.58730E-01
Y(34)= 6.60000E+00	DELY(34)= 2.00000E-01	RDY(34)= 5.00000E+00	YJ(34)= 6.50000E+00	RYJ(34)= 1.53846E-01
Y(35)= 6.80000E+00	DELY(35)= 2.00000E-01	RDY(35)= 5.00000E+00	YJ(35)= 6.70000E+00	RYJ(35)= 1.49254E-01
Y(36)= 7.00000E+00	DELY(36)= 2.00000E-01	RDY(36)= 5.00000E+00	YJ(36)= 6.90000E+00	RYJ(36)= 1.44928E-01
Y(37)= 7.20000E+00	DELY(37)= 2.00000E-01	RDY(37)= 5.00000E+00	YJ(37)= 7.10000E+00	RYJ(37)= 1.40845E-01
Y(38)= 7.40000E+00	DELY(38)= 2.00000E-01	RDY(38)= 5.00000E+00	YJ(38)= 7.30000E+00	RYJ(38)= 1.36986E-01

TABLE V

CELL FLOW PARAMETERS

I	J	BETA	AC	AR	AT	SINO	COSO
1	1	0.00000E+00	1.00000E+00	1.00000E+00	1.00000E+00	R	R
2	1	0.00000E+00	1.00000E+00	0.00000E+00	1.00000E+00	R	R
3	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
4	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
5	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
6	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
7	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
8	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
9	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
10	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
11	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
12	1	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
1	2	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	2	1.37760E+02	1.00000E+00	9.49761E-01	1.00000E+00	8.71557E-02	9.96195E-01
3	2	1.85612E+02	8.73854E-01	7.97946E-01	1.00000E+00	9.88672E-01	1.50095E-01
4	2	1.97020E+02	6.05599E-01	4.13252E-01	1.00000E+00	9.63020E-01	2.69431E-01
5	2	8.73983E+01	1.62619E-01	0.00000E+00	7.87021E-01	9.21960E-01	3.87285E-01
6	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
7	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
8	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
9	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
10	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
11	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
12	2	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
1	3	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	3	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	3	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	3	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	3	1.77939E+02	9.85745E-01	8.66137E-01	1.00000E+00	8.93416E-01	4.49230E-01
6	3	1.61138E+02	5.23847E-01	1.81556E-01	1.00000E+00	8.54267E-01	5.19835E-01
7	3	2.99393E+01	2.26944E-02	0.00000E+00	2.49998E-01	8.09137E-01	5.87621E-01
8	3	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
9	3	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
10	3	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
11	3	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
12	3	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
1	4	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	4	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	4	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	4	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	4	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	4	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	4	1.61445E+02	7.66813E-01	3.78170E-01	1.00000E+00	7.69820E-01	6.38261E-01
8	4	5.16259E+01	8.46092E-02	0.00000E+00	4.47467E-01	7.19276E-01	6.94725E-01
9	4	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
10	4	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
11	4	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
12	4	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
1	5	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	5	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	5	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	5	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	5	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	5	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	5	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	5	1.39222E+02	8.53553E-01	4.69907E-01	1.00000E+00	6.73866E-01	7.38854E-01
9	5	5.11007E+01	1.17477E-01	0.00000E+00	5.00000E-01	6.23755E-01	7.81620E-01

10	5	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
11	5	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
12	5	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
1	6	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	6	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	6	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	6	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	6	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	6	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	6	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	6	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	6	1.16114E+02	8.66104E-01	4.64415E-01	1.00000E+00	5.73555E-01	8.19167E-01
10	6	3.80003E+01	1.05994E-01	0.00000E+00	4.56461E-01	5.23424E-01	8.52072E-01
11	6	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
12	6	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
1	7	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	7	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	7	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	7	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	7	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	7	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	7	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	7	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	7	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	7	9.32413E+01	8.25762E-01	3.58875E-01	1.00000E+00	4.68203E-01	8.83621E-01
11	7	2.02562E+01	5.92684E-02	0.00000E+00	3.30301E-01	4.18048E-01	9.08425E-01
12	7	-1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
1	8	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	8	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	8	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	8	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	8	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	8	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	8	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	8	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	8	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	8	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	8	7.16635E+01	7.06284E-01	1.22841E-01	1.00000E+00	3.56640E-01	9.34242E-01
12	8	4.66335E+00	4.84017E-03	0.00000E+00	7.88039E-02	3.05429E-01	9.52215E-01
1	9	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	9	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	9	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	9	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	9	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	9	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	9	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	9	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	9	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	9	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	9	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	9	3.96504E+01	3.37487E-01	0.00000E+00	5.96170E-01	2.50439E-01	9.68132E-01
1	10	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	10	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	10	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	10	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	10	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	10	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	10	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	10	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	10	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	10	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	10	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	10	7.44992E+01	7.47952E-01	0.00000E+00	8.99734E-01	1.50063E-01	9.88676E-01
1	11	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R

2	11	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	11	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	11	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	11	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	11	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	11	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	11	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	11	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	11	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	11	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	11	8.83107E+01	9.53002E-01	0.00000E+00	1.00000E+00	5.00702E-02	9.98746E-01
1	12	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	12	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	12	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	12	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	12	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	12	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	12	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	12	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	12	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	12	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	12	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	12	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	13	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	13	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	13	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	13	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	13	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	13	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	13	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	13	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	13	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	13	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	13	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	13	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	14	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	14	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	14	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	14	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	14	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	14	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	14	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	14	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	14	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	14	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	14	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	14	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	15	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	15	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	15	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	15	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	15	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	15	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	15	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	15	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	15	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	15	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	15	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	15	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	16	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	16	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	16	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	16	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	16	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01

6	16	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	16	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	16	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	16	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	16	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	16	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	16	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	17	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	17	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	17	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	17	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	17	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	17	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	17	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	17	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	17	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	17	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	17	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	17	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	18	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	18	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	18	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	18	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	18	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	18	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	18	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	18	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	18	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	18	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	18	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	18	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	19	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	19	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	19	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	19	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	19	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	19	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	19	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	19	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	19	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	19	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	19	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	19	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	20	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	20	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	20	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	20	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	20	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	20	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	20	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	20	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	20	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	20	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	20	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	20	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	21	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	21	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	21	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	21	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	21	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	21	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	21	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	21	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	21	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01

10	21	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	21	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	21	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	22	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	22	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	22	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	22	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	22	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	22	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	22	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	22	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	22	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	22	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	22	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	22	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	23	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	23	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	23	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	23	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	23	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	23	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	23	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	23	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	23	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	23	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	23	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	23	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	24	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	24	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	24	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	24	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	24	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	24	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	24	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	24	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	24	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	24	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	24	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	24	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	25	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	25	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	25	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	25	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	25	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	25	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	25	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	25	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	25	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	25	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	25	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	25	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	26	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	26	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	26	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	26	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	26	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	26	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	26	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	26	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	26	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	26	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	26	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	26	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	27	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R

2	27	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	27	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	27	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	27	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	27	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	27	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	27	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	27	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	27	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	27	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	27	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	28	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	28	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	28	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	28	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	28	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	28	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	28	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	28	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	28	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	28	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	28	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	28	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	29	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	29	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	29	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	29	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	29	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	29	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	29	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	29	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	29	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	29	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	29	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	29	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	30	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	30	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	30	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	30	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	30	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	30	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	30	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	30	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	30	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	30	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	30	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	30	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	31	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	31	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	31	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	31	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	31	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	31	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	31	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	31	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	31	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	31	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	31	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	31	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	32	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	32	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	32	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	32	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	32	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01

6	32	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	32	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	32	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	32	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	32	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	32	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	32	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	33	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	33	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	33	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	33	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	33	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	33	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	33	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	33	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	33	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	33	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	33	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	33	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	34	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	34	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	34	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	34	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	34	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	34	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	34	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	34	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	34	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	34	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	34	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	34	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	35	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	35	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	35	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	35	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	35	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	35	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	35	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	35	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	35	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	35	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	35	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	35	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	36	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	36	1.34300E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
3	36	1.41761E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
4	36	1.70451E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
5	36	1.63122E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
6	36	1.49443E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
7	36	1.33702E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
8	36	1.15849E+02	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
9	36	9.60245E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
10	36	7.47116E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
11	36	5.61480E+01	1.00000E+00	1.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
12	36	9.10903E+01	1.00000E+00	0.00000E+00	1.00000E+00	8.71557E-02	9.96195E-01
1	37	0.00000E+00	1.00000E-10	0.00000E+00	0.00000E+00	R	R
2	37	1.79066E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
3	37	1.92581E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
4	37	2.49671E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
5	37	2.34254E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
6	37	2.07038E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
7	37	1.78006E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
8	37	1.47702E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
9	37	1.16925E+02	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01

10	37	8.67806E+01	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
11	37	6.27016E+01	1.00000E+00	1.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01
12	37	1.09690E+02	1.00000E+00	0.00000E+00	0.00000E+00	8.71557E-02	9.96195E-01

TABLE VI

INPUT DATA ECHO PRINT

```
OTCHKISS CASE 1 4/28/85                                   H'H'H'H'H'H'H'H'H'H'H'H'H'
       IBAR=  11
       JBAR=  36
       DELT=  2.00000E-04
         NU=  4.43000E-03
       ICYL=  1
       EPSI=  1.00000E-03
         GX=  0.00000E+00
         GY= -1.47200E+01
         UI=  0.00000E+00
         VI=  0.00000E+00
      VELMX=  1.00000E+01
      TWFIN=  2.30100E+00
      PRTDT=  1.00000E-04
      PLTDT=  5.00000E-02
        OMG=  1.70000E+00
      ALPHA=  1.00000E+00
         KL=  1
         KR=  1
         KT=  1
         KB=  1
      IMOVY=  0
      AUTOT=  1.00000E+00
       FLHT=  6.00000E+00
       PSAT=  0.00000E+00
    ISYMPLT=  1
      SIGMA=  1.86000E+01
    ISURF10=  1
     CANGLE=  8.72665E-02
       RHOF=   1.58000E+00

NKX=     2
MESH-X=     1   XL=  0.00000E+00   XC=  2.00000E-01   XR=  4.00000E-01   NXL=    1   NXR=    1   DXMN=  2.00000E-01
MESH-X=     2   XL=  4.00000E-01   XC=  1.90000E+00   XR=  2.00000E+00   NXL=    8   NXR=    1   DXMN=  1.00000E-01
NKY=     1
MESH-Y=     1   YL=  0.00000E+00   YC=  3.60000E+00   YR=  7.20000E+00   NYL=   18   NYR=   18   DYMN=  2.00000E-01
NOBS=  2
I= 1  OA2=-1.00000E+00  OA1= 0.00000E+00  OB2= -1.00000E+00  OB1=  4.00000E+00  OC2=  0.00000E+00  OC1=  0.00000E+00  IOH=  1
I= 2  OA2= 0.00000E+00  OA1= 0.00000E+00  OB2=  0.00000E+00  OB1= -1.00000E+00  OC2=  0.00000E+00  OC1=  2.00000E+00  IOH=  0
    ITER=      0     TIME=  0.00000E+00     DELT=  2.00000E-04     CYCLE=       0  VCHGT=  0.00000E+00  FY=  0.00000E+00
```

TABLE VII

CYCLE PRINT

HOTCHKISS CASE 1 4/28/85

ITER= 0 TIME= 0.00000E+00 DELT= 2.00000E-04 CYCLE= 0 VCHGT= 0.00000E+00 FY=

NREG= 1

K VOL(K) PR(K)

6 1.51516E+01 0.00000E+00

FLUID VOLUME = 6.694039E+01 ON CYCLE 0 YCENT OF FLUID= 5.622963E+00

I	J	U	V	P	D	PS	F	NF	BETA
1	1	0.00000E+00	0.00000E+00	1.28451E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	2	0.00000E+00	0.00000E+00	1.28451E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	3	0.00000E+00	0.00000E+00	1.23799E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	4	0.00000E+00	0.00000E+00	1.19148E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	5	0.00000E+00	0.00000E+00	1.14496E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	6	0.00000E+00	0.00000E+00	1.09845E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	7	0.00000E+00	0.00000E+00	1.05193E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	8	0.00000E+00	0.00000E+00	1.00542E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	9	0.00000E+00	0.00000E+00	9.58902E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	10	0.00000E+00	0.00000E+00	9.12387E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	11	0.00000E+00	0.00000E+00	8.65872E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	12	0.00000E+00	0.00000E+00	8.19357E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	13	0.00000E+00	0.00000E+00	7.72841E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	14	0.00000E+00	0.00000E+00	7.26326E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	15	0.00000E+00	0.00000E+00	6.79811E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	16	0.00000E+00	0.00000E+00	6.33296E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	17	0.00000E+00	0.00000E+00	5.86781E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	18	0.00000E+00	0.00000E+00	5.40265E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	19	0.00000E+00	0.00000E+00	4.93750E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	20	0.00000E+00	0.00000E+00	4.47235E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	21	0.00000E+00	0.00000E+00	4.00720E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	22	0.00000E+00	0.00000E+00	3.54205E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	23	0.00000E+00	0.00000E+00	3.07689E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	24	0.00000E+00	0.00000E+00	2.61174E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	25	0.00000E+00	0.00000E+00	2.14659E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	26	0.00000E+00	0.00000E+00	1.68144E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	27	0.00000E+00	0.00000E+00	1.21629E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	28	0.00000E+00	0.00000E+00	7.51133E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	29	0.00000E+00	0.00000E+00	2.85981E+00	0.00000E+00	0.00000E+00	1.14813E-01	0	1.00000E+00
1	30	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
2	1	0.00000E+00	-2.49794E+02	1.28451E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	2	0.00000E+00	0.00000E+00	1.18781E+02	1.24897E+03	0.00000E+00	1.00000E+00	0	1.00000E+00
2	3	0.00000E+00	0.00000E+00	1.14129E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	4	0.00000E+00	0.00000E+00	1.09478E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	5	0.00000E+00	0.00000E+00	1.04826E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	6	0.00000E+00	0.00000E+00	1.00175E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	7	0.00000E+00	0.00000E+00	9.55234E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	8	0.00000E+00	0.00000E+00	9.08719E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	9	0.00000E+00	0.00000E+00	8.62203E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00

2	10	0.00000E+00	0.00000E+00	8.15688E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	11	0.00000E+00	0.00000E+00	7.69173E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	12	0.00000E+00	0.00000E+00	7.22658E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	13	0.00000E+00	0.00000E+00	6.76143E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	14	0.00000E+00	0.00000E+00	6.29627E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	15	0.00000E+00	0.00000E+00	5.83112E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	16	0.00000E+00	0.00000E+00	5.36597E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	17	0.00000E+00	0.00000E+00	4.90082E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	18	0.00000E+00	0.00000E+00	4.43567E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	19	0.00000E+00	0.00000E+00	3.97051E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	20	0.00000E+00	0.00000E+00	3.50536E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	21	0.00000E+00	0.00000E+00	3.04021E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	22	0.00000E+00	0.00000E+00	2.57506E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	23	0.00000E+00	0.00000E+00	2.10991E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	24	0.00000E+00	0.00000E+00	1.64475E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	25	0.00000E+00	0.00000E+00	1.17960E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	26	0.00000E+00	0.00000E+00	7.14450E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	27	0.00000E+00	0.00000E+00	2.49298E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	28	0.00000E+00	0.00000E+00	-2.15854E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	29	0.00000E+00	0.00000E+00	-6.81006E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	7.89723E-01
2	30	0.00000E+00	0.00000E+00	-9.66987E+00	0.00000E+00	-9.66987E+00	1.14813E-01	3	1.62651E+00
2	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
3	1	0.00000E+00	0.00000E+00	1.28693E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	2	0.00000E+00	0.00000E+00	1.18105E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	3	0.00000E+00	0.00000E+00	1.13454E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	4	0.00000E+00	0.00000E+00	1.08802E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	5	0.00000E+00	0.00000E+00	1.04151E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	6	0.00000E+00	0.00000E+00	9.94992E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	7	0.00000E+00	0.00000E+00	9.48477E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	8	0.00000E+00	0.00000E+00	9.01962E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	9	0.00000E+00	0.00000E+00	8.55447E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	10	0.00000E+00	0.00000E+00	8.08931E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	11	0.00000E+00	0.00000E+00	7.62416E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	12	0.00000E+00	0.00000E+00	7.15901E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	13	0.00000E+00	0.00000E+00	6.69386E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	14	0.00000E+00	0.00000E+00	6.22871E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	15	0.00000E+00	0.00000E+00	5.76355E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	16	0.00000E+00	0.00000E+00	5.29840E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	17	0.00000E+00	0.00000E+00	4.83325E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	18	0.00000E+00	0.00000E+00	4.36810E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	19	0.00000E+00	0.00000E+00	3.90295E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	20	0.00000E+00	0.00000E+00	3.43779E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	21	0.00000E+00	0.00000E+00	2.97264E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	22	0.00000E+00	0.00000E+00	2.50749E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	23	0.00000E+00	0.00000E+00	2.04234E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	24	0.00000E+00	0.00000E+00	1.57719E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	25	0.00000E+00	0.00000E+00	1.11203E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	26	0.00000E+00	0.00000E+00	6.46882E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	27	0.00000E+00	0.00000E+00	1.81730E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	28	0.00000E+00	0.00000E+00	-2.83422E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	29	0.00000E+00	0.00000E+00	-7.48574E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	8.16927E-01
3	30	0.00000E+00	0.00000E+00	-1.05877E+01	0.00000E+00	1.05877E+01	1.66871E-01	3	1.49954E+00
3	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00

3	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
4	1	0.00000E+00	0.00000E+00	1.29312E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	2	0.00000E+00	0.00000E+00	1.18873E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	3	0.00000E+00	0.00000E+00	1.14221E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	4	0.00000E+00	0.00000E+00	1.09570E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	5	0.00000E+00	0.00000E+00	1.04918E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	6	0.00000E+00	0.00000E+00	1.00267E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	7	0.00000E+00	0.00000E+00	9.56153E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	8	0.00000E+00	0.00000E+00	9.09638E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	9	0.00000E+00	0.00000E+00	8.63123E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	10	0.00000E+00	0.00000E+00	8.16608E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	11	0.00000E+00	0.00000E+00	7.70093E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	12	0.00000E+00	0.00000E+00	7.23577E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	13	0.00000E+00	0.00000E+00	6.77062E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	14	0.00000E+00	0.00000E+00	6.30547E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	15	0.00000E+00	0.00000E+00	5.84032E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	16	0.00000E+00	0.00000E+00	5.37517E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	17	0.00000E+00	0.00000E+00	4.91001E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	18	0.00000E+00	0.00000E+00	4.44486E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	19	0.00000E+00	0.00000E+00	3.97971E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	20	0.00000E+00	0.00000E+00	3.51456E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	21	0.00000E+00	0.00000E+00	3.04941E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	22	0.00000E+00	0.00000E+00	2.58425E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	23	0.00000E+00	0.00000E+00	2.11910E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	24	0.00000E+00	0.00000E+00	1.65395E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	25	0.00000E+00	0.00000E+00	1.18880E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	26	0.00000E+00	0.00000E+00	7.23646E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	27	0.00000E+00	0.00000E+00	2.58494E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	28	0.00000E+00	0.00000E+00	-2.06658E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	29	0.00000E+00	0.00000E+00	-6.71810E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	8.81148E-01
4	30	0.00000E+00	0.00000E+00	-1.04391E+01	0.00000E+00	-1.04391E+01	2.99962E 01	3	1.25006E+00
4	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
5	1	0.00000E+00	0.00000E+00	1.30487E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	2	0.00000E+00	0.00000E+00	1.18650E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	3	0.00000E+00	0.00000E+00	1.13998E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	4	0.00000E+00	0.00000E+00	1.09347E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	5	0.00000E+00	0.00000E+00	1.04695E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	6	0.00000E+00	0.00000E+00	1.00044E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	7	0.00000E+00	0.00000E+00	9.53924E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	8	0.00000E+00	0.00000E+00	9.07409E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	9	0.00000E+00	0.00000E+00	8.60894E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	10	0.00000E+00	0.00000E+00	8.14379E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	11	0.00000E+00	0.00000E+00	7.67863E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	12	0.00000E+00	0.00000E+00	7.21348E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	13	0.00000E+00	0.00000E+00	6.74833E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	14	0.00000E+00	0.00000E+00	6.28318E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	15	0.00000E+00	0.00000E+00	5.81803E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	16	0.00000E+00	0.00000E+00	5.35287E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	17	0.00000E+00	0.00000E+00	4.88772E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	18	0.00000E+00	0.00000E+00	4.42257E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	19	0.00000E+00	0.00000E+00	3.95742E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	20	0.00000E+00	0.00000E+00	3.49227E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	21	0.00000E+00	0.00000E+00	3.02711E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	22	0.00000E+00	0.00000E+00	2.56196E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	23	0.00000E+00	0.00000E+00	2.09681E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00

5	24	0.00000E+00	0.00000E+00	1.63166E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	25	0.00000E+00	0.00000E+00	1.16651E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	26	0.00000E+00	0.00000E+00	7.01354E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	27	0.00000E+00	0.00000E+00	2.36202E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	28	0.00000E+00	0.00000E+00	-2.28950E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	29	0.00000E+00	0.00000E+00	-6.94102E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.02640E+00
5	30	0.00000E+00	0.00000E+00	-1.15925E+01	0.00000E+00	-1.15925E+01	5.52445E-01	3	9.50168E-01
5	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
6	1	0.00000E+00	0.00000E+00	1.28943E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	2	0.00000E+00	0.00000E+00	1.13804E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	3	0.00000E+00	0.00000E+00	1.12261E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	4	0.00000E+00	0.00000E+00	1.07609E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	5	0.00000E+00	0.00000E+00	1.02958E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	6	0.00000E+00	0.00000E+00	9.83063E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	7	0.00000E+00	0.00000E+00	9.36548E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	8	0.00000E+00	0.00000E+00	8.90032E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	9	0.00000E+00	0.00000E+00	8.43517E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	10	0.00000E+00	0.00000E+00	7.97002E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	11	0.00000E+00	0.00000E+00	7.50487E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	12	0.00000E+00	0.00000E+00	7.03972E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	13	0.00000E+00	0.00000E+00	6.57456E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	14	0.00000E+00	0.00000E+00	6.10941E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	15	0.00000E+00	0.00000E+00	5.64426E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	16	0.00000E+00	0.00000E+00	5.17911E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	17	0.00000E+00	0.00000E+00	4.71396E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	18	0.00000E+00	0.00000E+00	4.24880E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	19	0.00000E+00	0.00000E+00	3.78365E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	20	0.00000E+00	0.00000E+00	3.31850E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	21	0.00000E+00	0.00000E+00	2.85335E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	22	0.00000E+00	0.00000E+00	2.38820E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	23	0.00000E+00	0.00000E+00	1.92304E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	24	0.00000E+00	0.00000E+00	1.45789E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	25	0.00000E+00	0.00000E+00	9.92740E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	26	0.00000E+00	0.00000E+00	5.27588E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	27	0.00000E+00	0.00000E+00	6.24361E 01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	28	0.00000E+00	0.00000E+00	-4.02716E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	29	0.00000E+00	0.00000E+00	-8.67868E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.15263E+00
6	30	0.00000E+00	0.00000E+00	-1.33302E+01	0.00000E+00	-1.33302E+01	8.88909E-01	3	7.19989E-01
6	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
7	1	0.00000E+00	0.00000E+00	1.29336E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	2	0.00000E+00	0.00000E+00	1.14005E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	3	0.00000E+00	0.00000E+00	1.14005E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	4	0.00000E+00	0.00000E+00	1.09354E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	5	0.00000E+00	0.00000E+00	1.04702E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	6	0.00000E+00	0.00000E+00	1.00051E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	7	0.00000E+00	0.00000E+00	9.53992E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	8	0.00000E+00	0.00000E+00	9.07477E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	9	0.00000E+00	0.00000E+00	8.60962E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	10	0.00000E+00	0.00000E+00	8.14447E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	11	0.00000E+00	0.00000E+00	7.67931E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00

7	12	0.00000E+00	0.00000E+00	7.21416E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	13	0.00000E+00	0.00000E+00	6.74901E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	14	0.00000E+00	0.00000E+00	6.28386E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	15	0.00000E+00	0.00000E+00	5.81871E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	16	0.00000E+00	0.00000E+00	5.35355E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	17	0.00000E+00	0.00000E+00	4.88840E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	18	0.00000E+00	0.00000E+00	4.42325E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	19	0.00000E+00	0.00000E+00	3.95810E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	20	0.00000E+00	0.00000E+00	3.49295E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	21	0.00000E+00	0.00000E+00	3.02779E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	22	0.00000E+00	0.00000E+00	2.56264E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	23	0.00000E+00	0.00000E+00	2.09749E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	24	0.00000E+00	0.00000E+00	1.63234E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	25	0.00000E+00	0.00000E+00	1.16719E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	26	0.00000E+00	0.00000E+00	7.02033E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	27	0.00000E+00	0.00000E+00	2.36881E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	28	0.00000E+00	0.00000E+00	-2.28271E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	29	0.00000E+00	0.00000E+00	-6.93423E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	30	0.00000E+00	0.00000E+00	-1.15857E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	9.07106E-01
7	31	0.00000E+00	0.00000E+00	-1.53308E+01	0.00000E+00	-1.53308E+01	3.05130E-01	3	1.24204E+00
7	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
8	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
8	2	0.00000E+00	0.00000E+00	-1.90858E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
8	3	0.00000E+00	0.00000E+00	1.09065E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	4	0.00000E+00	0.00000E+00	1.07879E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	5	0.00000E+00	0.00000E+00	1.03227E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	6	0.00000E+00	0.00000E+00	9.85759E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	7	0.00000E+00	0.00000E+00	9.39243E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	8	0.00000E+00	0.00000E+00	8.92728E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	9	0.00000E+00	0.00000E+00	8.46213E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	10	0.00000E+00	0.00000E+00	7.99698E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	11	0.00000E+00	0.00000E+00	7.53183E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	12	0.00000E+00	0.00000E+00	7.06667E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	13	0.00000E+00	0.00000E+00	6.60152E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	14	0.00000E+00	0.00000E+00	6.13637E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	15	0.00000E+00	0.00000E+00	5.67122E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	16	0.00000E+00	0.00000E+00	5.20607E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	17	0.00000E+00	0.00000E+00	4.74091E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	18	0.00000E+00	0.00000E+00	4.27576E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	19	0.00000E+00	0.00000E+00	3.81061E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	20	0.00000E+00	0.00000E+00	3.34546E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	21	0.00000E+00	0.00000E+00	2.88031E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	22	0.00000E+00	0.00000E+00	2.41515E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	23	0.00000E+00	0.00000E+00	1.95000E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	24	0.00000E+00	0.00000E+00	1.48485E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	25	0.00000E+00	0.00000E+00	1.01970E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	26	0.00000E+00	0.00000E+00	5.54546E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	27	0.00000E+00	0.00000E+00	8.93944E-01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	28	0.00000E+00	0.00000E+00	-3.75758E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	29	0.00000E+00	0.00000E+00	-8.40910E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	30	0.00000E+00	0.00000E+00	-1.30606E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.09121E+00
8	31	0.00000E+00	0.00000E+00	-1.77121E+01	0.00000E+00	-1.77121E+01	7.95313E-01	3	7.72014E-01
8	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00

8	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	2	0.00000E+00	0.00000E+00	-2.04557E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	3	0.00000E+00	0.00000E+00	-2.04557E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	4	0.00000E+00	0.00000E+00	1.05485E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	5	0.00000E+00	0.00000E+00	1.04461E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	6	0.00000E+00	0.00000E+00	9.98093E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	7	0.00000E+00	0.00000E+00	9.51577E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	8	0.00000E+00	0.00000E+00	9.05062E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	9	0.00000E+00	0.00000E+00	8.58547E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	10	0.00000E+00	0.00000E+00	8.12032E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	11	0.00000E+00	0.00000E+00	7.65517E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	12	0.00000E+00	0.00000E+00	7.19001E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	13	0.00000E+00	0.00000E+00	6.72486E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	14	0.00000E+00	0.00000E+00	6.25971E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	15	0.00000E+00	0.00000E+00	5.79456E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	16	0.00000E+00	0.00000E+00	5.32941E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	17	0.00000E+00	0.00000E+00	4.86425E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	18	0.00000E+00	0.00000E+00	4.39910E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	19	0.00000E+00	0.00000E+00	3.93395E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	20	0.00000E+00	0.00000E+00	3.46880E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	21	0.00000E+00	0.00000E+00	3.00365E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	22	0.00000E+00	0.00000E+00	2.53849E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	23	0.00000E+00	0.00000E+00	2.07334E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	24	0.00000E+00	0.00000E+00	1.60819E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	25	0.00000E+00	0.00000E+00	1.14304E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	26	0.00000E+00	0.00000E+00	6.77885E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	27	0.00000E+00	0.00000E+00	2.12733E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	28	0.00000E+00	0.00000E+00	-2.52419E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	29	0.00000E+00	0.00000E+00	-7.17571E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	30	0.00000E+00	0.00000E+00	-1.18272E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
9	31	0.00000E+00	0.00000E+00	-1.64787E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	9.50981E-01
9	32	0.00000E+00	0.00000E+00	-2.04557E+01	0.00000E+00	2.04557E+01	3.54972E-01	3	1.16963E+00
9	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	2	0.00000E+00	0.00000E+00	-2.57888E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	3	0.00000E+00	0.00000E+00	-2.57888E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	4	0.00000E+00	0.00000E+00	-2.57888E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	5	0.00000E+00	0.00000E+00	9.82609E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	6	0.00000E+00	0.00000E+00	9.73941E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	7	0.00000E+00	0.00000E+00	9.27426E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	8	0.00000E+00	0.00000E+00	8.80911E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	9	0.00000E+00	0.00000E+00	8.34395E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	10	0.00000E+00	0.00000E+00	7.87880E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	11	0.00000E+00	0.00000E+00	7.41365E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	12	0.00000E+00	0.00000E+00	6.94850E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	13	0.00000E+00	0.00000E+00	6.48335E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	14	0.00000E+00	0.00000E+00	6.01819E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	15	0.00000E+00	0.00000E+00	5.55304E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	16	0.00000E+00	0.00000E+00	5.08789E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	17	0.00000E+00	0.00000E+00	4.62274E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	18	0.00000E+00	0.00000E+00	4.15759E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	19	0.00000E+00	0.00000E+00	3.69243E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	20	0.00000E+00	0.00000E+00	3.22728E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	21	0.00000E+00	0.00000E+00	2.76213E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	22	0.00000E+00	0.00000E+00	2.29698E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	23	0.00000E+00	0.00000E+00	1.83183E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	24	0.00000E+00	0.00000E+00	1.36667E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	25	0.00000E+00	0.00000E+00	9.01523E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00

10	26	0.00000E+00	0.00000E+00	4.36371E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	27	0.00000E+00	0.00000E+00	-2.87813E-01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	28	0.00000E+00	0.00000E+00	-4.93933E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	29	0.00000E+00	0.00000E+00	-9.59085E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	30	0.00000E+00	0.00000E+00	-1.42424E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	31	0.00000E+00	0.00000E+00	-1.88939E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.08334E+00
10	32	0.00000E+00	0.00000E+00	-2.35454E+01	0.00000E+00	-2.35454E+01	9.82300E-01	3	6.74627E-01
10	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	2	0.00000E+00	0.00000E+00	-2.16491E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	3	0.00000E+00	0.00000E+00	-2.16491E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	4	0.00000E+00	0.00000E+00	2.16491E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	5	0.00000E+00	0.00000E+00	-2.16491E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	6	0.00000E+00	0.00000E+00	1.00839E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	7	0.00000E+00	0.00000E+00	1.00143E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	8	0.00000E+00	0.00000E+00	9.54918E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	9	0.00000E+00	0.00000E+00	9.08403E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	10	0.00000E+00	0.00000E+00	8.61888E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	11	0.00000E+00	0.00000E+00	8.15372E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	12	0.00000E+00	0.00000E+00	7.68857E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	13	0.00000E+00	0.00000E+00	7.22342E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	14	0.00000E+00	0.00000E+00	6.75827E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	15	0.00000E+00	0.00000E+00	6.29312E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	16	0.00000E+00	0.00000E+00	5.82796E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	17	0.00000E+00	0.00000E+00	5.36281E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	18	0.00000E+00	0.00000E+00	4.89766E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	19	0.00000E+00	0.00000E+00	4.43251E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	20	0.00000E+00	0.00000E+00	3.96736E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	21	0.00000E+00	0.00000E+00	3.50220E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	22	0.00000E+00	0.00000E+00	3.03705E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	23	0.00000E+00	0.00000E+00	2.57190E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	24	0.00000E+00	0.00000E+00	2.10675E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	25	0.00000E+00	0.00000E+00	1.64160E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	26	0.00000E+00	0.00000E+00	1.17644E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	27	0.00000E+00	0.00000E+00	7.11291E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	28	0.00000E+00	0.00000E+00	2.46139E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	29	0.00000E+00	0.00000E+00	-2.19013E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	30	0.00000E+00	0.00000E+00	-6.84165E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	31	0.00000E+00	0.00000E+00	-1.14932E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	32	0.00000E+00	0.00000E+00	-1.61447E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	33	0.00000E+00	0.00000E+00	-2.07962E+01	0.00000E+00	-2.07962E+01	6.83365E-01	2	8.45048E-01
11	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
11	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
11	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
11	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
11	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	2	0.00000E+00	0.00000E+00	-4.60248E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	3	0.00000E+00	0.00000E+00	-4.60248E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	4	0.00000E+00	0.00000E+00	-4.60248E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	5	0.00000E+00	0.00000E+00	-4.60248E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	6	0.00000E+00	0.00000E+00	-4.60248E+01	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	7	0.00000E+00	0.00000E+00	7.55602E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	8	0.00000E+00	0.00000E+00	7.53529E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	9	0.00000E+00	0.00000E+00	7.07013E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	10	0.00000E+00	0.00000E+00	6.60498E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	11	0.00000E+00	0.00000E+00	6.13983E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	12	0.00000E+00	0.00000E+00	5.67468E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	13	0.00000E+00	0.00000E+00	5.20953E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00

12	14	0.00000E+00	0.00000E+00	4.74437E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	15	0.00000E+00	0.00000E+00	4.27922E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	16	0.00000E+00	0.00000E+00	3.81407E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	17	0.00000E+00	0.00000E+00	3.34892E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	18	0.00000E+00	0.00000E+00	2.88377E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	19	0.00000E+00	0.00000E+00	2.41861E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	20	0.00000E+00	0.00000E+00	1.95346E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	21	0.00000E+00	0.00000E+00	1.48831E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	22	0.00000E+00	0.00000E+00	1.02316E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	23	0.00000E+00	0.00000E+00	5.58006E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	24	0.00000E+00	0.00000E+00	9.28541E-01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	25	0.00000E+00	0.00000E+00	-3.72298E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	26	0.00000E+00	0.00000E+00	-8.37450E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	27	0.00000E+00	0.00000E+00	-1.30260E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	28	0.00000E+00	0.00000E+00	-1.76775E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	29	0.00000E+00	0.00000E+00	-2.23291E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	30	0.00000E+00	0.00000E+00	-2.69806E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	31	0.00000E+00	0.00000E+00	-3.16321E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	32	0.00000E+00	0.00000E+00	-3.62836E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	33	0.00000E+00	0.00000E+00	-4.09351E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.16471E+00
12	34	0.00000E+00	0.00000E+00	-4.55867E+01	0.00000E+00	-4.55867E+01	5.94202E-01	2	1.00000E+00
12	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
12	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
12	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
12	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	5	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	6	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	7	0.00000E+00	0.00000E+00	1.21585E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	8	0.00000E+00	0.00000E+00	1.21378E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	9	0.00000E+00	0.00000E+00	1.16726E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	10	0.00000E+00	0.00000E+00	1.12075E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	11	0.00000E+00	0.00000E+00	1.07423E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	12	0.00000E+00	0.00000E+00	1.02772E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	13	0.00000E+00	0.00000E+00	9.81201E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	14	0.00000E+00	0.00000E+00	9.34686E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	15	0.00000E+00	0.00000E+00	8.88171E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	16	0.00000E+00	0.00000E+00	8.41655E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	17	0.00000E+00	0.00000E+00	7.95140E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	18	0.00000E+00	0.00000E+00	7.48625E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	19	0.00000E+00	0.00000E+00	7.02110E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	20	0.00000E+00	0.00000E+00	6.55595E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	21	0.00000E+00	0.00000E+00	6.09079E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	22	0.00000E+00	0.00000E+00	5.62564E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	23	0.00000E+00	0.00000E+00	5.16049E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	24	0.00000E+00	0.00000E+00	4.69534E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	25	0.00000E+00	0.00000E+00	4.23019E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	26	0.00000E+00	0.00000E+00	3.76503E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	27	0.00000E+00	0.00000E+00	3.29988E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	28	0.00000E+00	0.00000E+00	2.83473E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	29	0.00000E+00	0.00000E+00	2.36958E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	30	0.00000E+00	0.00000E+00	1.90443E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	31	0.00000E+00	0.00000E+00	1.43927E+01	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	32	0.00000E+00	0.00000E+00	9.74122E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	33	0.00000E+00	0.00000E+00	5.08970E+00	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	34	0.00000E+00	0.00000E+00	4.38183E-01	0.00000E+00	0.00000E+00	5.94202E-01	0	1.00000E+00
13	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00

ITER= 87 TIME= 2.04000E 04 DELT= 2.04000E-04 CYCLE= 1 VCHG1= 6.40357E 03 Fx= 0.00000E+00

HOTCHKISS CASE 1 4/28/85 H'H'H'H'H'H'H'H'H'H'H'H'

ITER= 87 TIME= 2.04000E-04 DELT= 2.04000E-04 CYCLE= 1 VCHGI= 6.40357E-03 FY=

NREG= 1

K	VOL(K)	PR(K)
6	1.51578E+01	0.00000E+00

FLUID VOLUME = 6.693399E+01 ON CYCLE 1 YCENT OF FLUID= 5.622234E+00

I	J	U	V	P	D	PS	F	NF	PETA
1	1	0.00000E+00	0.00000E+00	-3.47465E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	2	0.00000E+00	-8.50906E+01	-3.47465E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	3	0.00000E+00	-3.47907E+01	-2.15672E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	4	0.00000E+00	-1.76200E+01	-1.61785E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	5	0.00000E+00	-1.06476E+01	-1.34496E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	6	0.00000E+00	-7.33713E+00	-1.18007E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	7	0.00000E+00	-5.55785E+00	-1.06646E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	8	0.00000E+00	-4.51073E+00	-9.80417E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	9	0.00000E+00	-3.85427E+00	-9.10592E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	10	0.00000E+00	-3.42496E+00	-8.50935E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	11	0.00000E+00	-3.13661E+00	-7.97928E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	12	0.00000E+00	-2.93995E+00	-7.49388E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	13	0.00000E+00	-2.80489E+00	-7.03894E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	14	0.00000E+00	-2.71212E+00	-6.60492E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	15	0.00000E+00	-2.64883E+00	-6.18528E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	16	0.00000E+00	-2.60643E+00	-5.77543E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	17	0.00000E+00	-2.57917E+00	-5.37216E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	18	0.00000E+00	-2.56334E+00	-4.97310E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	19	0.00000E+00	-2.55678E+00	-4.57650E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	20	0.00000E+00	-2.55860E+00	-4.18092E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	21	0.00000E+00	-2.56905E+00	-3.78505E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	22	0.00000E+00	-2.58953E+00	-3.38756E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	23	0.00000E+00	-2.62281E+00	-2.98691E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	24	0.00000E+00	-2.67327E+00	-2.58109E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	25	0.00000E+00	-2.74746E+00	-2.16746E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	26	0.00000E+00	-2.85467E+00	-1.74234E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	27	0.00000E+00	-3.00778E+00	-1.30061E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	28	0.00000E+00	-3.22404E+00	-8.35166E+03	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	29	0.00000E+00	-3.52442E+00	-3.36222E+03	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
1	30	0.00000E+00	-3.92608E+00	2.09074E+03	0.00000E+00	0.00000E+00	1.11171E-01	0	1.00000E+00
1	31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
1	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
2	1	0.00000E+00	-2.49794E+02	-3.47465E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
2	2	-8.67078E+01	-8.50906E+01	-3.47465E+05	6.68479E-10	0.00000E+00	1.00000E+00	0	1.00000E+00
2	3	-2.51499E+01	-3.47907E+01	-2.15672E+05	6.08331E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	4	-8.58531E+00	-1.76200E+01	-1.61785E+05	4.81693E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	5	-3.48618E+00	-1.06476E+01	-1.34496E+05	8.32867E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	6	-1.65525E+00	-7.33713E+00	-1.18007E+05	2.85962E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
2	7	-8.89641E-01	-5.55785E+00	1.06646E+05	4.32571E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
2	8	-5.23563E-01	-4.51073E+00	-9.80417E+04	5.00719E 05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	9	-3.28235E-01	-3.85427E+00	-9.10592E+04	-2.68303E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	10	-2.14660E-01	-3.42496E+00	8.50935E+04	-6.93700E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	11	-1.44183E-01	-3.13661E+00	-7.97928E+04	-1.01990E 04	0.00000E+00	1.00000E+00	0	1.00000E+00
2	12	-9.83394E-02	-2.93995E+00	-7.49388E+04	-6.36183E 05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	13	-6.75413E-02	-2.80489E+00	-7.03894E+04	-1.26702E-04	0.00000E+00	1.00000E+00	0	1.00000E+00
2	14	-4.63923E-02	-2.71212E+00	-6.60492E+04	-6.08951E-05	0.00000E+00	1.00000E+00	0	1.00000E+00

2	15	-3.16436E-02	-2.64883E+00	-6.18528E+04	8.22815E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
2	16	-2.11961E-02	-2.60643E+00	-5.77543E+04	4.00136E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	17	-1.36234E-02	-2.57917E+00	-5.37216E+04	7.53635E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	18	-7.90690E-03	-2.56334E+00	-4.97310E+04	9.99002E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	19	-3.27055E-03	-2.55678E+00	-4.57650E+04	7.99099E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	20	9.15683E-04	-2.55860E+00	-4.18092E+04	4.33704E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	21	5.22671E-03	-2.56905E+00	-3.78505E+04	4.06038E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	22	1.02456E-02	-2.58953E+00	-3.38756E+04	3.12505E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	23	1.66396E-02	-2.62281E+00	-2.98691E+04	3.37200E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
2	24	2.52366E-02	-2.67327E+00	-2.58109E+04	4.96123E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	25	3.70917E-02	-2.74746E+00	-2.16746E+04	-1.22022E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	26	5.35997E-02	-2.85467E+00	-1.74234E+04	-3.26556E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	27	7.65530E-02	-3.00778E+00	-1.30061E+04	-6.22149E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	28	1.08119E-01	-3.22404E+00	-8.35166E+03	-7.90774E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
2	29	1.50189E-01	-3.52442E+00	-3.36222E+03	-4.31593E-05	0.00000E+00	1.00000E+00	0	7.87162E-01
2	30	2.00827E-01	-3.92608E+00	2.09074E+03	7.99361E-14	-9.67370E+00	1.11171E-01	3	1.63620E+00
2	31	3.27850E-02	0.00000E+00	0.00000E+00	1.99582E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
2	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
2	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
3	1	-2.94888E+01	0.00000E+00	-2.13153E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
3	2	-2.94888E+01	-2.35272E+01	-2.13153E+05	-2.32120E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	3	-1.65508E+01	-1.82261E+01	-1.76714E+05	1.62864E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
3	4	-8.57152E+00	-1.25209E+01	-1.48486E+05	4.87266E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	5	-4.52122E+00	-8.81671E+00	-1.29096E+05	2.78228E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	6	-2.51152E+00	-6.57152E+00	-1.15443E+05	-9.00998E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
3	7	-1.47964E+00	-5.19177E+00	-1.05268E+05	-4.37637E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	8	-9.19062E-01	-4.31540E+00	-9.72307E+04	-2.18757E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	9	-5.95157E-01	-3.74069E+00	-9.05507E+04	-4.07616E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	10	-3.96999E-01	-3.35448E+00	-8.47610E+04	-8.19389E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	11	-2.69887E-01	-3.09077E+00	-7.95695E+04	-6.95864E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	12	-1.85391E-01	-2.90915E+00	-7.47865E+04	-4.02271E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	13	-1.27830E-01	-2.78374E+00	-7.02848E+04	-2.20808E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	14	-8.79809E-02	-2.69737E+00	-6.59774E+04	-3.76426E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	15	-6.00575E-02	-2.63838E+00	-6.18037E+04	1.76450E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	16	-4.02356E-02	-2.59886E+00	-5.77215E+04	4.40177E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	17	-2.58598E-02	-2.57345E+00	-5.37005E+04	4.17530E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	18	-1.50017E-02	-2.55870E+00	-4.97188E+04	1.13248E-04	0.00000E+00	1.00000E+00	0	1.00000E+00
3	19	-6.20539E-03	-2.55259E+00	-4.57600E+04	6.74317E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	20	1.73722E-03	-2.55429E+00	-4.18106E+04	3.97107E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	21	9.91747E-03	-2.56403E+00	-3.78586E+04	6.92412E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
3	22	1.94545E-02	-2.58314E+00	-3.38915E+04	-4.88316E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
3	23	3.16298E-02	-2.61421E+00	-2.98948E+04	2.37232E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	24	4.80246E-02	-2.66142E+00	-2.58500E+04	1.46173E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	25	7.06956E-02	-2.73095E+00	-2.17321E+04	3.16677E-07	0.00000E+00	1.00000E+00	0	1.00000E+00
3	26	1.02365E-01	-2.83171E+00	-1.75064E+04	-3.41541E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	27	1.46653E-01	-2.97622E+00	-1.31247E+04	-2.29761E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	28	2.08362E-01	-3.18197E+00	-8.51914E+03	-6.22130E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
3	29	2.93956E-01	-3.47379E+00	-3.59486E+03	-1.89399E-05	0.00000E+00	1.00000E+00	0	8.14484E-01
3	30	4.12853E-01	-3.89037E+00	1.77990E+03	-2.36848E-14	-1.05950E+01	1.63250E-01	3	1.50773E+00
3	31	1.22380E-01	0.00000E+00	0.00000E+00	2.01584E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
3	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
3	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
4	1	-1.21134E+01	0.00000E+00	-1.58910E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
4	2	-1.21134E+01	-8.16333E+00	-1.58910E+05	-1.43913E-05	0.00000E+00	1.00000E+00	0	1.00000E+00

4	3	-9.16482E+00	-8.75065E+00	-1.46269E+05	-2.40071E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	4	-6.21755E+00	-7.71116E+00	-1.32719E+05	6.30914E-07	0.00000E+00	1.00000E+00	0	1.00000E+00
4	5	-4.08179E+00	-6.43019E+00	-1.20779E+05	2.07094E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	6	-2.67521E+00	-5.34616E+00	-1.10823E+05	3.51065E-07	0.00000E+00	1.00000E+00	0	1.00000E+00
4	7	-1.77473E+00	-4.52609E+00	-1.02546E+05	-6.00343E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
4	8	-1.19646E+00	-3.93077E+00	-9.55402E+04	2.27260E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	9	-8.18458E-01	-3.50538E+00	-8.94560E+04	-5.07008E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	10	-5.65758E-01	-3.20354E+00	-8.40307E+04	-4.66473E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	11	-3.93270E-01	-2.99043E+00	-7.90730E+04	-3.36473E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	12	-2.73703E-01	-2.84080E+00	-7.44454E+04	-1.39923E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	13	-1.90043E-01	-2.73642E+00	-7.00496E+04	-4.64027E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	14	-1.31201E-01	-2.66421E+00	-6.58155E+04	-3.78824E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
4	15	-8.96366E-02	-2.61485E+00	-6.16933E+04	1.03790E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	16	-6.00337E-02	-2.58179E+00	5.76475E+04	2.35737E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	17	-3.85533E-02	-2.56056E+00	-5.36529E+04	6.67316E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	18	-2.23552E-02	-2.54825E+00	-4.96912E+04	3.45327E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	19	-9.24234E-03	-2.54316E+00	-4.57485E+04	5.28369E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	20	2.58613E-03	-2.54458E+00	-4.18138E+04	3.01427E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	21	1.47790E-02	-2.55270E+00	-3.78768E+04	2.06874E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	22	2.90286E-02	-2.56868E+00	-3.39273E+04	2.97622E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	23	4.72845E-02	-2.59474E+00	-2.99530E+04	1.08500E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	24	7.19849E-02	-2.63450E+00	-2.59384E+04	2.81178E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
4	25	1.06326E-01	-2.69334E+00	-2.18621E+04	1.34195E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
4	26	1.54577E-01	-2.77912E+00	-1.76947E+04	-1.12494E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	27	2.22465E-01	-2.90294E+00	-1.33945E+04	-4.10091E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	28	3.17687E-01	-3.08032E+00	-8.90242E+03	-3.29200E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
4	29	4.50405E-01	-3.33260E+00	-4.13558E+03	-3.25656E-05	0.00000E+00	1.00000E+00	0	8.78829E-01
4	30	6.32035E-01	-3.68640E+00	1.02109E+03	2.64388E-14	-1.04421E+01	2.96424E-01	3	1.25561E+00
4	31	3.46995E-01	0.00000E+00	0.00000E+00	1.96854E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
4	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
4	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
5	1	0.00000E+00	0.00000E+00	-1.34282E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
5	2	0.00000E+00	-4.29336E+00	-1.34282E+05	-8.88553E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	3	-5.84499E+00	-4.88235E+00	-1.27636E+05	-1.10285E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	4	-4.50944E+00	-4.90797E+00	-1.20078E+05	3.78574E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
5	5	-3.32876E+00	-4.58406E+00	-1.12480E+05	1.81739E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	6	-2.40600E+00	-4.16428E+00	-1.05384E+05	2.01586E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	7	-1.72446E+00	-3.76710E+00	-9.89383E+04	3.16555E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
5	8	-1.23250E+00	-3.43465E+00	-9.31077E+04	-2.15339E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	9	-8.79352E-01	-3.17371E+00	-8.77920E+04	-2.36535E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	10	-6.25360E-01	-2.97715E+00	-8.28805E+04	-4.29555E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	11	-4.42282E-01	-2.83350E+00	-7.82735E+04	-3.47939E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	12	-3.10549E-01	-2.73099E+00	-7.38890E+04	8.16144E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
5	13	-2.16299E-01	-2.65919E+00	-6.96633E+04	1.22416E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	14	-1.49291E-01	-2.60966E+00	-6.55488E+04	1.93516E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
5	15	-1.01800E-01	-2.57599E+00	-6.15110E+04	2.15001E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	16	-6.80154E-02	-2.55359E+00	-5.75254E+04	2.92969E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	17	-4.35820E-02	-2.53930E+00	-5.35745E+04	2.87545E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	18	-2.52266E-02	-2.53104E+00	-4.96457E+04	5.47880E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	19	-1.04240E-02	-2.52764E+00	-4.57297E+04	1.94991E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	20	2.90793E-03	-2.52857E+00	-4.18190E+04	3.36405E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	21	1.66570E-02	-2.53400E+00	-3.79069E+04	2.62966E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	22	3.27782E-02	-2.54472E+00	-3.39863E+04	3.35353E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	23	5.35414E-02	-2.56232E+00	-3.00492E+04	1.23948E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	24	8.18285E-02	-2.58942E+00	-2.60847E+04	1.34554E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	25	1.21472E-01	-2.63001E+00	-2.20783E+04	2.25094E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
5	26	1.77656E-01	-2.69002E+00	-1.80090E+04	-5.46136E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	27	2.57403E-01	-2.77796E+00	-1.38468E+04	-3.09456E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
5	28	3.70383E-01	-2.90613E+00	-9.54830E+03	-3.92230E-05	0.00000E+00	1.00000E+00	0	1.00000E+00

5	29	5.31997E-01	-3.09421E+00	-5.05130E+03	-1.30657E-05	0.00000E+00	1.00000E+00	0	1.02471E+00
5	30	7.80865E-01	-3.38989E+00	-2.62729E+02	4.44089E-14	-1.15524E+01	5.49012E-01	3	9.53278E-01
5	31	6.91010E-01	0.00000E+00	0.00000E+00	1.89742E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
5	32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
5	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
6	1	0.00000E+00	0.00000E+00	-1.25584E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	2	0.00000E+00	0.00000E+00	-1.25584E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
6	3	-4.00102E+00	-3.29639E+00	-1.16885E+05	-1.95296E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	4	-3.41450E+00	-3.50591E+00	-1.11783E+05	-3.50812E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	5	-2.69537E+00	-3.48829E+00	-1.06357E+05	1.68569E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	6	-2.07059E+00	-3.35494E+00	-1.00958E+05	2.56090E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	7	-1.56167E+00	-3.18290E+00	-9.57662E+04	4.48141E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	8	-1.16149E+00	-3.01528E+00	-9.08405E+04	-6.48122E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	9	-8.52636E-01	-2.87209E+00	-8.61744E+04	-1.94211E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	10	-6.17041E-01	-2.75974E+00	-8.17302E+04	-1.70036E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	11	-4.39660E-01	-2.67707E+00	-7.74599E+04	-4.99566E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	12	-3.08652E-01	-2.61907E+00	-7.33177E+04	5.84014E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	13	-2.14019E-01	-2.57962E+00	-6.92654E+04	1.83555E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	14	-1.46828E-01	-2.55326E+00	-6.52742E+04	1.42724E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	15	-9.95282E-02	-2.53587E+00	-6.13238E+04	1.86890E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	16	-6.61623E-02	-2.52458E+00	-5.74003E+04	3.56744E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	17	-4.22327E-02	-2.51750E+00	-5.34943E+04	2.99084E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	18	-2.43851E-02	-2.51347E+00	-4.95993E+04	1.47187E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	19	-1.00670E-02	-2.51180E+00	-4.57106E+04	1.62230E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	20	2.78905E-03	-2.51225E+00	-4.18244E+04	6.94173E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	21	1.60526E-02	-2.51486E+00	-3.79375E+04	2.81582E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	22	3.16543E-02	-2.52006E+00	-3.40466E+04	2.44313E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	23	5.18689E-02	-2.52873E+00	-3.01476E+04	8.62316E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	24	7.96366E-02	-2.54235E+00	-2.62352E+04	4.70176E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	25	1.18969E-01	-2.56330E+00	-2.23017E+04	9.78528E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
6	26	1.75393E-01	-2.59532E+00	-1.83358E+04	-2.12685E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	27	2.56240E-01	-2.64380E+00	-1.43202E+04	-1.86951E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	28	3.69384E-01	-2.71421E+00	-1.02296E+04	-1.95178E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
6	29	5.13631E-01	-2.79868E+00	-6.02989E+03	-2.64665E-05	0.00000E+00	1.00000E+00	0	1.15134E+00
6	30	1.65133E+00	-3.80685E+00	-1.69803E+03	2.73944E-14	-1.34039E+01	8.84928E-01	3	7.22059E-01
6	31	1.28823E+00	-6.58593E-01	0.00000E+00	1.93495E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
6	32	3.88973E-01	0.00000E+00	0.00000E+00	5.20919E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
6	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
7	1	0.00000E+00	0.00000E+00	-1.10300E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	2	0.00000E+00	0.00000E+00	-1.10300E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
7	3	0.00000E+00	-2.67322E+00	-1.10300E+05	-7.59782E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	4	-2.61450E+00	-2.74183E+00	-1.06164E+05	-2.38106E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	5	-2.21953E+00	-2.82447E+00	-1.01921E+05	6.81795E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	6	-1.77333E+00	-2.81421E+00	-9.75506E+04	2.15188E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	7	-1.38263E+00	-2.75771E+00	-9.31960E+04	1.42931E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	8	-1.05478E+00	-2.68712E+00	-8.89289E+04	-6.39615E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	9	-7.86826E-01	-2.62177E+00	-8.47711E+04	-3.83618E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	10	-5.72389E-01	-2.57127E+00	-8.07146E+04	-8.42650E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	11	-4.05453E-01	-2.53787E+00	-7.67363E+04	5.00244E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	12	-2.80838E-01	-2.51852E+00	-7.28098E+04	1.25995E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	13	-1.91841E-01	-2.50823E+00	-6.89132E+04	1.78384E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	14	-1.29907E-01	-2.50301E+00	-6.50325E+04	1.91930E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	15	-8.71728E-02	-2.50042E+00	-6.11600E+04	2.03325E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	16	-5.75277E-02	-2.49915E+00	-5.72914E+04	3.02822E-05	0.00000E+00	1.00000E+00	0	1.00000E+00

7	17	-3.65389E-02	-2.49854E+00	-5.34248E+04	3.92319E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	18	-2.10330E-02	-2.49825E+00	-4.95592E+04	2.60521E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	19	-8.67481E-03	-2.49814E+00	-4.56940E+04	3.02927E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	20	2.38346E-03	-2.49815E+00	-4.18290E+04	-4.61364E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	21	1.37897E-02	-2.49828E+00	-3.79639E+04	-4.94493E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	22	2.72456E-02	-2.49858E+00	-3.40987E+04	-1.05886E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	23	4.47797E-02	-2.49923E+00	-3.02330E+04	-1.84405E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	24	6.90734E-02	-2.50056E+00	-2.63663E+04	3.66547E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	25	1.03930E-01	-2.50335E+00	-2.24975E+04	2.33738E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	26	1.55027E-01	-2.50942E+00	-1.86245E+04	-2.43006E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	27	2.31391E-01	-2.52358E+00	-1.47420E+04	-1.20026E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	28	3.49259E-01	-2.56095E+00	-1.08376E+04	-2.05666E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
7	29	5.46200E-01	-2.67831E+00	-6.87524E+03	-5.40782E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
7	30	9.46385E-01	-2.18118E+00	-2.73114E+03	1.58960E-05	0.00000E+00	9.99828E-01	0	9.05299E-01
7	31	1.09738E+00	-2.18118E+00	6.41993E+02	2.84217E-14	-1.53537E+01	3.01943E-01	3	1.24724E+00
7	32	8.70012E-01	0.00000E+00	0.00000E+00	1.38147E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
7	33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
7	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
8	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
8	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
8	3	0.00000E+00	0.00000E+00	-1.06333E+05	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
8	4	0.00000E+00	-2.37155E+00	-1.02367E+05	-4.33522E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	5	-1.82059E+00	-2.40615E+00	-9.86979E+04	3.31900E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	6	-1.53537E+00	-2.44793E+00	-9.49754E+04	2.83674E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	7	-1.22197E+00	-2.45035E+00	-9.11881E+04	1.89235E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	8	-9.45651E-01	-2.43591E+00	-8.73971E+04	6.83751E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	9	-7.09051E-01	-2.42074E+00	-8.36285E+04	-1.03831E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	10	-5.11626E-01	-2.41477E+00	-7.98834E+04	-2.20710E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	11	-3.53752E-01	-2.42104E+00	-7.61475E+04	1.22226E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	12	-2.37026E-01	-2.43509E+00	-7.24019E+04	9.44900E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	13	-1.57391E-01	-2.45016E+00	-6.86346E+04	4.11593E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	14	-1.04459E-01	-2.46294E+00	-6.48439E+04	4.85019E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	15	-6.91798E-02	-2.47263E+00	-6.10334E+04	2.54699E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	16	-4.52739E-02	-2.47948E+00	-5.72079E+04	2.06916E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	17	-2.86074E-02	-2.48400E+00	-5.33718E+04	4.18635E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	18	-1.64194E-02	-2.48667E+00	-4.95286E+04	1.47706E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	19	-6.76791E-03	-2.48778E+00	-4.56814E+04	-2.96474E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	20	1.84413E-03	-2.48746E+00	-4.18324E+04	-2.59054E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	21	1.07218E-02	-2.48566E+00	-3.79840E+04	-2.51450E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	22	2.12163E-02	-2.48215E+00	-3.41383E+04	-7.40256E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	23	3.49448E-02	-2.47646E+00	-3.02980E+04	-1.51032E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	24	5.40779E-02	-2.46788E+00	-2.64666E+04	2.64967E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	25	8.17479E-02	-2.45544E+00	-2.26485E+04	2.24778E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	26	1.22705E-01	-2.43783E+00	-1.88496E+04	-2.46368E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	27	1.84428E-01	-2.41308E+00	-1.50780E+04	1.14878E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	28	2.78861E-01	-2.37632E+00	-1.13447E+04	-2.90366E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
8	29	4.23161E-01	-2.30313E+00	-7.66843E+03	1.93388E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
8	30	6.20438E-01	-2.03962E+00	-4.10549E+03	3.56110E-06	0.00000E+00	1.00000E+00	0	1.09055E+00
8	31	1.40588E+00	-2.56633E+00	-9.49667E+02	8.89723E-14	-1.75911E+01	7.92805E-01	3	7.73512E-01
8	32	1.19317E+00	-4.70887E-01	0.00000E+00	1.30415E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
8	33	4.20102E-01	0.00000E+00	0.00000E+00	4.90114E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
8	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
9	4	0.00000E+00	0.00000E+00	-9.93867E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00

9	5	0.00000E+00	-2.17441E+00	-9.64065E+04	1.36977E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	6	-1.30366E+00	-2.19330E+00	-9.30430E+04	4.45494E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	7	-1.08922E+00	-2.22585E+00	-8.96502E+04	2.15870E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	8	-8.48195E-01	-2.24367E+00	-8.62070E+04	6.41788E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	9	-6.33622E-01	-2.26033E+00	-8.27361E+04	-7.94884E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	10	-4.47061E-01	-2.28650E+00	-7.92395E+04	1.22881E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	11	-2.93626E-01	-2.32620E+00	-7.57023E+04	4.13448E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	12	-1.84151E-01	-2.37038E+00	-7.21036E+04	-9.99362E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	13	-1.16952E-01	-2.40716E+00	-6.84365E+04	-1.36349E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	14	-7.56761E-02	-2.43428E+00	-6.47124E+04	-1.56688E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	15	-4.94259E-02	-2.45321E+00	-6.09463E+04	-6.22962E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	16	-3.20987E-02	-2.46594E+00	-5.71509E+04	1.77446E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	17	-2.01953E-02	-2.47410E+00	-5.33358E+04	1.47463E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	18	-1.15627E-02	-2.47882E+00	-4.95080E+04	6.74383E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	19	-4.76155E-03	-2.48078E+00	-4.56729E+04	-4.57093E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	20	1.28857E-03	-2.48025E+00	-4.18348E+04	-6.03451E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	21	7.52751E-03	-2.47714E+00	-3.79975E+04	-4.33851E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	22	1.49082E-02	-2.47099E+00	-3.41650E+04	-3.69219E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	23	2.45896E-02	-2.46091E+00	-3.03420E+04	-2.00271E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	24	3.81298E-02	-2.44540E+00	-2.65347E+04	5.47984E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	25	5.77890E-02	-2.42216E+00	-2.27514E+04	4.95853E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	26	8.70097E-02	-2.38768E+00	-1.90040E+04	3.33547E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	27	1.31143E-01	-2.33635E+00	-1.53101E+04	5.98875E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	28	1.98528E-01	-2.25907E+00	-1.16957E+04	2.13147E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	29	3.02000E-01	-2.14285E+00	-8.20102E+03	7.06964E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
9	30	4.65238E-01	-2.00377E+00	-4.88636E+03	-2.11895E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
9	31	8.02588E-01	-1.33741E+00	-1.78712E+03	2.62386E-06	0.00000E+00	9.99627E-01	0	9.49754E-01
9	32	1.08632E+00	-1.33741E+00	2.79221E+02	-2.96059E-14	-2.06924E+01	3.52089E-01	3	1.17410E+00
9	33	1.06607E+00	0.00000E+00	0.00000E+00	1.14579E+01	0.00000E+00	0.00000E+00	6	1.00000E+00
9	34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
9	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
10	5	0.00000E+00	0.00000E+00	-9.40306E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
10	6	0.00000E+00	-2.04587E+00	-9.16547E+04	1.43930E-04	0.00000E+00	1.00000E+00	0	1.00000E+00
10	7	-9.30930E-01	-2.06014E+00	-8.84902E+04	1.47678E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	8	-7.67567E-01	-2.09616E+00	-8.53037E+04	-1.54408E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	9	-5.67952E-01	-2.13207E+00	-8.20613E+04	4.11219E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	10	-3.86491E-01	-2.18101E+00	-7.87634E+04	-2.11286E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	11	-2.31048E-01	-2.25094E+00	-7.53896E+04	-8.54677E-08	0.00000E+00	1.00000E+00	0	1.00000E+00
10	12	-1.27176E-01	-2.32418E+00	-7.19075E+04	-1.03866E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	13	-7.58940E-02	-2.37878E+00	-6.83119E+04	-8.46370E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	14	-4.78286E-02	-2.41623E+00	-6.46318E+04	-1.94840E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	15	-3.08747E-02	-2.44129E+00	-6.08937E+04	-6.17202E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	16	-1.99391E-02	-2.45775E+00	-5.71167E+04	3.43931E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	17	-1.25072E-02	-2.46816E+00	-5.33143E+04	3.54747E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	18	-7.15056E-03	-2.47415E+00	-4.94957E+04	-1.11026E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	19	-2.94498E-03	-2.47662E+00	-4.56678E+04	-4.39829E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	20	7.92209E-04	-2.47596E+00	-4.18361E+04	-5.85946E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	21	4.64405E-03	-2.47206E+00	-3.80055E+04	-9.14774E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	22	9.20621E-03	-2.46434E+00	-3.41809E+04	-4.02507E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	23	1.51962E-02	-2.45160E+00	-3.03682E+04	-2.22733E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	24	2.35898E-02	-2.43188E+00	-2.65753E+04	3.53098E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	25	3.58008E-02	-2.40207E+00	-2.28129E+04	6.53048E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	26	5.39781E-02	-2.35733E+00	-1.90967E+04	1.61363E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	27	8.14288E-02	-2.29003E+00	-1.54498E+04	3.30446E-07	0.00000E+00	1.00000E+00	0	1.00000E+00
10	28	1.23153E-01	-2.18794E+00	-1.19071E+04	1.04312E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
10	29	1.86118E-01	-2.03062E+00	-8.52263E+03	3.56056E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	30	2.76811E-01	-1.77184E+00	5.38181E+03	7.24373E-06	0.00000E+00	1.00000E+00	0	1.00000E+00

10	31	3.67077E-01	-1.14234E+00	-2.64184E+03	9.61580E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
10	32	8.75444E-01	-9.17849E-01	8.75468E+02	1.63578E-14	1.67986E+01	9.81360E-01	2	6.51543E-01
10	33	2.38647E-01	-3.39292E-01	0.00000E+00	3.35115E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	34	1.62849E-01	0.00000E+00	0.00000E+00	3.04611E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
10	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	5	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
11	6	0.00000E+00	0.00000E+00	-8.96669E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
11	7	0.00000E+00	-1.96825E+00	-8.76791E+04	-3.25174E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	8	-6.33653E-01	-1.98387E+00	-8.46349E+04	1.69378E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	9	-5.15604E-01	-2.03000E+00	-8.15665E+04	2.99722E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
11	10	-3.35202E-01	-2.09358E+00	-7.84266E+04	5.13278E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	11	-1.70723E-01	-2.19251E+00	-7.51883E+04	2.52058E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	12	-7.04255E-02	-2.29534E+00	7.17967E+04	-2.93496E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	13	-3.89619E-02	-2.36299E+00	-6.82458E+04	6.66491E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
11	14	-2.40384E-02	-2.40669E+00	-6.45901E+04	-2.97067E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	15	-1.54040E-02	-2.43514E+00	-6.08668E+04	-3.58721E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	16	-9.91480E-03	-2.45357E+00	-5.70993E+04	2.14076E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	17	-6.21014E-03	-2.46515E+00	-5.33034E+04	1.66379E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	18	-3.54873E-03	-2.47178E+00	-4.94894E+04	-3.34352E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	19	-1.46099E-03	-2.47452E+00	-4.56653E+04	-2.71670E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	20	3.91274E-04	-2.47379E+00	-4.18368E+04	-5.35052E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	21	2.30081E-03	-2.46950E+00	-3.80095E+04	-8.41699E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	22	4.56267E-03	-2.46097E+00	-3.41889E+04	-6.20207E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	23	7.53558E-03	-2.44688E+00	-3.03814E+04	-2.66437E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	24	1.17060E-02	-2.42501E+00	-2.65958E+04	3.15754E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	25	1.77755E-02	-2.39185E+00	-2.28441E+04	4.55527E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	26	2.68167E-02	-2.34189E+00	-1.91437E+04	1.85768E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
11	27	4.04671E-02	-2.26656E+00	-1.55207E+04	1.82987E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	28	6.11586E-02	-2.15252E+00	-1.20144E+04	4.57576E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	29	9.21380E-02	-1.97961E+00	-8.68480E+03	-2.76248E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	30	1.36370E-01	-1.72107E+00	-5.62300E+03	-4.20509E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
11	31	1.95019E-01	-1.40734E+00	-2.96168E+03	-1.50749E-05	0.00000E+00	1.00000E+00	0	1.16471E+00
11	32	3.86279E-01	-4.97215E-01	-7.86340E+02	-1.90296E-05	0.00000E+00	9.99969E-01	0	1.16471E+00
11	33	2.26087E-01	-4.97215E-01	-5.23324E+01	0.00000E+00	-2.08192E+01	6.82384E-01	2	8.45749E-01
11	34	0.00000E+00	-7.03311E-02	0.00000E+00	5.49943E-01	0.00000E+00	0.00000E+00	6	1.00000E+00
11	35	0.00000E+00	0.00000E+00	0.00000E+00	3.51656E-01	0.00000E+00	0.00000E+00	6	1.00000E+00
11	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
11	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
11	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	5	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	6	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
12	7	0.00000E+00	0.00000E+00	-8.59116E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
12	8	0.00000E+00	-1.92485E+00	-8.41441E+04	-2.46000E-04	0.00000E+00	1.00000E+00	0	1.00000E+00
12	9	0.00000E+00	-1.93980E+00	-8.11671E+04	5.49004E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	10	0.00000E+00	-2.01134E+00	-7.81670E+04	1.51255E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	11	0.00000E+00	-2.14236E+00	-7.50560E+04	3.45482E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	12	0.00000E+00	-2.27961E+00	-7.17421E+04	1.31776E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	13	0.00000E+00	-2.35553E+00	-6.82156E+04	5.83094E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	14	0.00000E+00	-2.40238E+00	-6.45715E+04	-1.19962E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	15	0.00000E+00	-2.43240E+00	-6.08548E+04	6.26139E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	16	0.00000E+00	-2.45172E+00	-5.70917E+04	-8.35168E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	17	0.00000E+00	-2.46382E+00	-5.32985E+04	5.93308E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	18	0.00000E+00	-2.47074E+00	-4.94867E+04	-1.68371E-05	0.00000E+00	1.00000E+00	0	1.00000E+00

12	19	0.00000E+00	-2.47359E+00	-4.56641E+04	-2.96422E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	20	0.00000E+00	-2.47284E+00	-4.18371E+04	-3.32684E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	21	0.00000E+00	-2.46837E+00	-3.80113E+04	-6.59705E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	22	0.00000E+00	-2.45948E+00	-3.41924E+04	-2.72473E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	23	0.00000E+00	-2.44479E+00	-3.03873E+04	5.95824E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	24	0.00000E+00	-2.42198E+00	-2.66049E+04	1.94345E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	25	0.00000E+00	-2.38733E+00	-2.28579E+04	5.00243E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	26	0.00000E+00	-2.33507E+00	-1.91645E+04	1.13382E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	27	0.00000E+00	-2.25621E+00	-1.55521E+04	-2.47010E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	28	0.00000E+00	-2.13703E+00	-1.20618E+04	-6.72635E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	29	0.00000E+00	-1.95749E+00	-8.75616E+03	-5.33246E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	30	0.00000E+00	-1.69174E+00	-5.72862E+03	-9.54095E-06	0.00000E+00	1.00000E+00	0	1.00000E+00
12	31	0.00000E+00	-1.31171E+00	-3.11273E+03	-1.99543E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	32	0.00000E+00	-5.58967E-01	-1.08552E+03	-3.44693E-05	0.00000E+00	1.00000E+00	0	1.00000E+00
12	33	0.00000E+00	-1.18386E-01	-2.24318E+02	5.54262E-06	0.00000E+00	1.00000E+00	0	1.16471E+00
12	34	0.00000E+00	-1.18386E-01	-4.55867E+01	0.00000E+00	-4.55599E+01	5.94081E-01	2	1.00000E+00
12	35	0.00000E+00	0.00000E+00	0.00000E+00	5.91932E-01	0.00000E+00	0.00000E+00	6	1.00000E+00
12	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
12	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6	1.00000E+00
12	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	5	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	6	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	7	0.00000E+00	0.00000E+00	-8.59116E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	8	0.00000E+00	-1.92485E+00	-8.41441E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	9	0.00000E+00	-1.93980E+00	-8.11671E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	10	0.00000E+00	-2.01134E+00	-7.81670E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	11	0.00000E+00	-2.14236E+00	-7.50560E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	12	0.00000E+00	-2.27961E+00	-7.17421E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	13	0.00000E+00	-2.35553E+00	-6.82156E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	14	0.00000E+00	-2.40238E+00	-6.45715E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	15	0.00000E+00	-2.43240E+00	-6.08548E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	16	0.00000E+00	-2.45172E+00	-5.70917E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	17	0.00000E+00	-2.46382E+00	-5.32985E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	18	0.00000E+00	-2.47074E+00	-4.94867E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	19	0.00000E+00	-2.47359E+00	-4.56641E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	20	0.00000E+00	-2.47284E+00	-4.18371E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	21	0.00000E+00	-2.46837E+00	-3.80113E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	22	0.00000E+00	-2.45948E+00	-3.41924E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	23	0.00000E+00	-2.44479E+00	-3.03873E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	24	0.00000E+00	-2.42198E+00	-2.66049E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	25	0.00000E+00	-2.38733E+00	-2.28579E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	26	0.00000E+00	-2.33507E+00	-1.91645E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	27	0.00000E+00	-2.25621E+00	-1.55521E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	28	0.00000E+00	-2.13703E+00	-1.20618E+04	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	29	0.00000E+00	-1.95749E+00	-8.75616E+03	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	30	0.00000E+00	-1.69174E+00	-5.72862E+03	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	31	0.00000E+00	-1.31171E+00	-3.11273E+03	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	32	0.00000E+00	-5.58967E-01	-1.08552E+03	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	33	0.00000E+00	-1.18386E-01	-2.24318E+02	0.00000E+00	0.00000E+00	1.00000E+00	0	1.00000E+00
13	34	0.00000E+00	-1.18386E-01	-4.55867E+01	0.00000E+00	0.00000E+00	5.94081E-01	0	1.00000E+00
13	35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00
13	38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	1.00000E+00

container. The void behaves as a vacuum. It starts from rest and undergoes free fall until it hits the bottom of the cylinder, where it comes to rest and establishes the hydrostatic pressure profile.

The computational grid is 3 zones in the radial direction and 13 zones in the axial direction. Initially the bottom of the slug of fluid is four cell heights off the bottom of the cylinder, and the slug is six cells deep. The cells are squares 0.5 cm on each side. The fluid density is 1.0 g/cm^3, while viscosity and surface tension are neglected. The gravitational acceleration in the axial direction is -980 cm/s^2. The velocity and altitude of the bottom of the slug during free fall are

$$v = -980\ t \tag{55}$$

and

$$s = 2 - 490\ t^2\ , \tag{56}$$

where t is the time in seconds. The incompressibility condition requires the velocity in the slug to be uniform.

Figure 9 shows the velocity of the slug as a function of time. The problem was run with $\alpha = 1.0$ and, as discussed earlier, the results are plotted with F_{ij} evaluated at the correct time (i.e., F^n_{ij} is really $F^{n+1/2}_{ij}$). The solid line is the NASA-VOF2D solution with IDEFM = 1, the finely dotted line is a second numerical solution but with IDEFM = 0, and the dashed line is the analytic solution. The coarsely dashed line displays the performance of a correction, changing the definition of a free-surface cell, to the basic SOLA-VOF algorithm added by hand to accommodate this particular application. This curve stays with the analytic solution very well, but the algorithm giving this result does not have the generality required for permanent inclusion in the code. The numerical solutions used the CR method to find the pressures. The three solutions coincide through cycle 120, which is 0.0531 s. This is expected as the program should get the exact velocity because it is linear in t. However, the slug should hit the bottom of the cylinder and come to a stop at 0.0639 s rather than on cycle 121 as in the IDEFM = 0 solution.

In the IDEFM = 1 solution, the fluid slows abruptly as it enters the bottom row of cells, but the cells continue to fill slowly. This incorrect behavior is

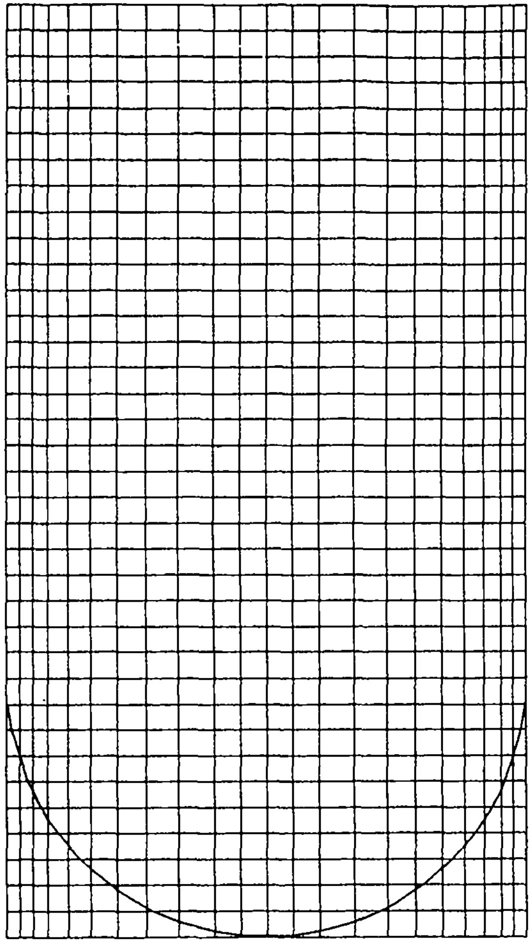

Fig. 6.

Example problem computing mesh.

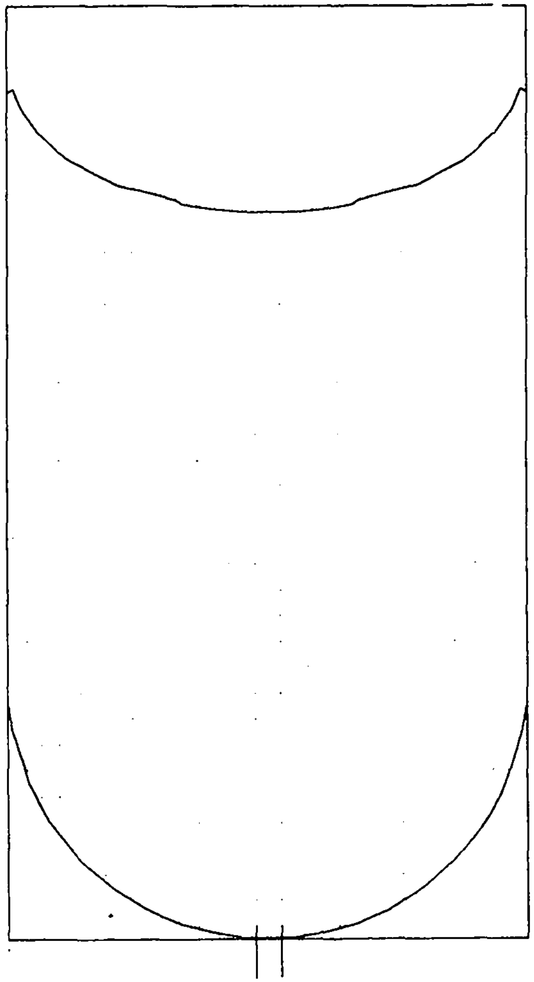

Fig. 7.

Example problem velocity vector and free-surface plot at $t = 0.0$ s.

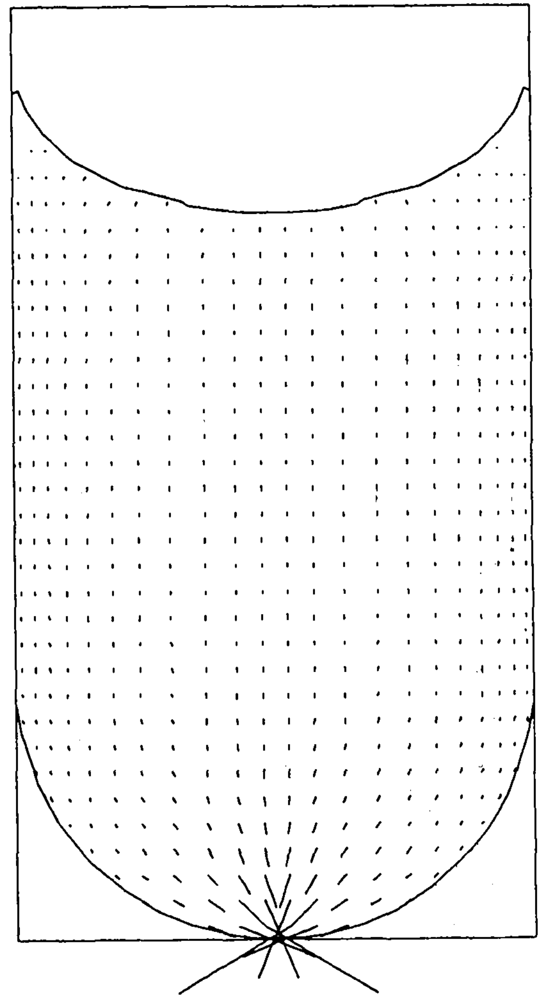

Fig. 8.

Example problem velocity vector and free-surface plot at $t = 0.0002$ s.

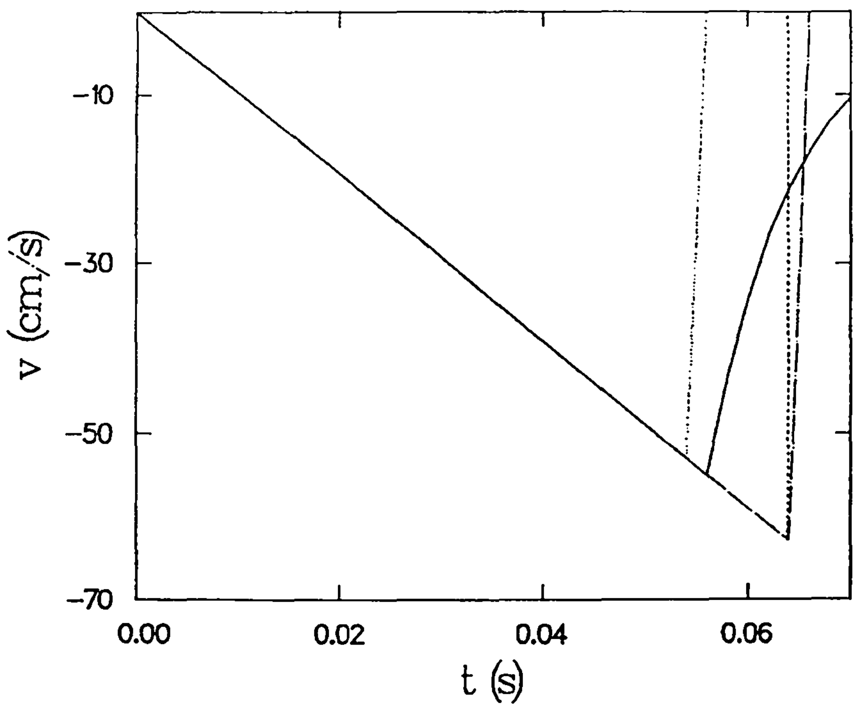

Fig. 9. Velocity of the fluid slug as a function of time. The solid line is a NASA-VOF2D solution with IDEFM = 0, the dotted line is a numerical solution with IDEFM = 1, and the dashed line is the analytical solution.

due to a peculiarity in the way the program defines a free surface, and it is found in all versions of the various VOF programs. A cell containing a free surface must by definition have at least one empty neighboring cell. When our one-dimensional slug first crosses into the bottom row of real cells, they have no empty neighbors. Thus the program treats them as if they were full, even though they are only partially full. This quirk of the method will not affect many problems, such as the next two described in this report, but it could significantly affect results for propellant reorientation problems where jets of fluid impact on dry tank walls.

The IDEFM = 1 option introduced into the pressure solution algorithm to close small voids was modified to reduce the severity of this difficulty. We raised the product ADEFM*EPSI to a very large value (10^6) before applying the minimum test to determine if the cell being computed had F < 1.0 and if that cell and its eight surrounding neighbors all had NF = 0. The result of this change is to force those particular cells to choose the second option in the MIN function (i.e., to close up in 1.0/BDEFM cycles). Otherwise, the gap in our present solution fills far too slowly.

Figure 10 shows the height of the bottom of the slug as a function of time. Considering the large time steps, approximately 0.0005 s, the accuracy is acceptable until the fluid stops prematurely, for the IDEFM = 0 and 1 cases. The coarsely dashed line overlays the analytic curve. The behavior of the program is consistent with the expectation that the time-marching errors are first order in δt.

The program does a very good job of predicting the pressure field in this problem. During the free fall, the pressure is zero in the fluid because we assume the void pressure is zero. On cycle 121 of the IDEFM = 0 case, the fluid must be brought to a halt in one time step. The water hammer effect causes the pressure at the center of the bottom row of cells to rise to 6.2×10^4 dyne/cm^2. On all subsequent cycles, the hydrostatic head is obtained, with agreement to at least four digits with the analytical solution

$$P = 980\ d \quad , \tag{57}$$

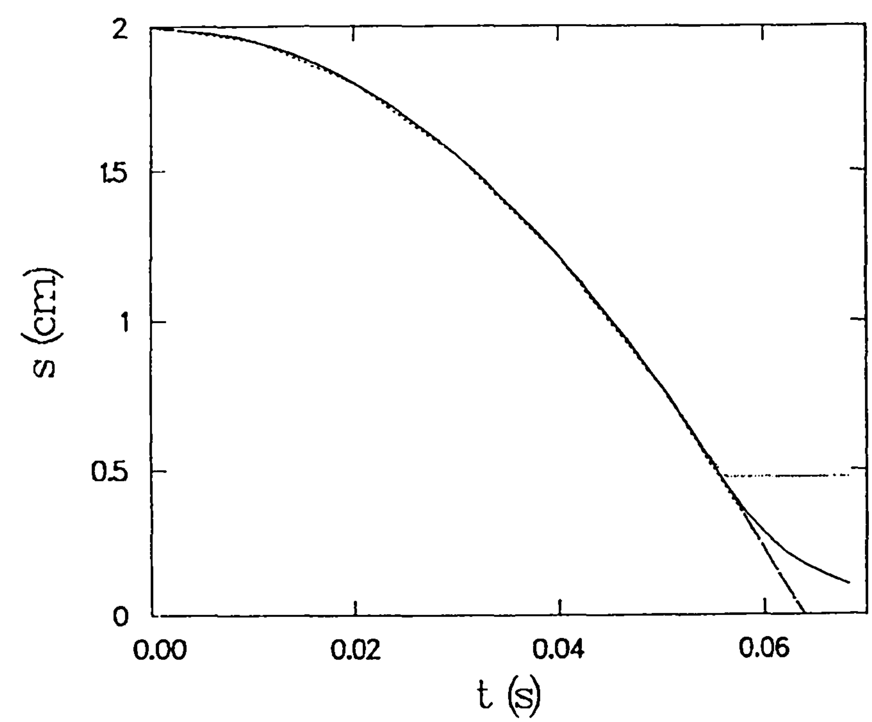

Fig. 10. Altitude of the bottom of the fluid slug as a function of time.

where d is the fluid depth. The conjugate residual solution agrees to the six digits printed by the program.

In the IDEFM = 1 solution, the pressure in the bottom row of cells peaks at 4.2×10^4 dyne/cm^2 on cycle 121, drops to 5000 on cycle 122, and relaxes toward the correct steady value of 2695 as the void closes.

The second test case is the sloshing motion of a tank of water. The tank is 10.0 cm wide and 6.5 cm deep, and it is covered by a uniform 20 by 13 mesh. The water is 5.0 cm deep on the average. The initial condition is the fluid at rest with a $0.5 \cos(\pi x/10)$ perturbation of the surface. The gravitational acceleration of 980 cm/s^2 starts the fluid sloshing back and forth across the tank in a mode in which the deviation of the surface height from the average depth is always proportional to the cosine term in the initial condition, and the slosh period is

$$P = 2\pi/(g\ k\ \tanh(kD))^{1/2} = 0.36417\ \mathrm{s} \quad , \tag{58}$$

where D = 6.5 cm is the average fluid depth, g = 980 cm/s^2 is the acceleration of gravity, and $k = \pi/10$ is the horizontal wavenumber of the surface disturbance.[12]

Four typical velocity vector and free-surface plots are shown in Fig. 11. The upper left panel shows the initial condition, and the next three panels are separated in time by 0.65 s. The analytical solution for the free surface is marked by asterisks. The lower right panel (t = 1.95 s) is just after the beginning of the sixth oscillation, and the computational free surface still agrees as well with the analytical solution as it does for all earlier times. There is a slight disagreement at all times, even t = 0.0, which is an artifact of the contour-plotting algorithm used to plot the computational free surface. This artifact appears to be the limiting factor in how well the calculation seems to agree with the analytical solution.

The next example was Case 1 previously computed by Hotchkiss.[10] This problem is the test case described in Sec. III. It is a drop-tower test of a glass vessel with a radius of 2 cm in the cylindrical section, the working fluid is a freon, and the gravitational acceleration is -14.72 cm/s^2. We find that NASA-VOF2D produces results in much better agreement with the experimental measurements of the location of the free surface reported by Symons[21], as shown in Fig. 12, than the earlier result from NASA SOLA VOF.

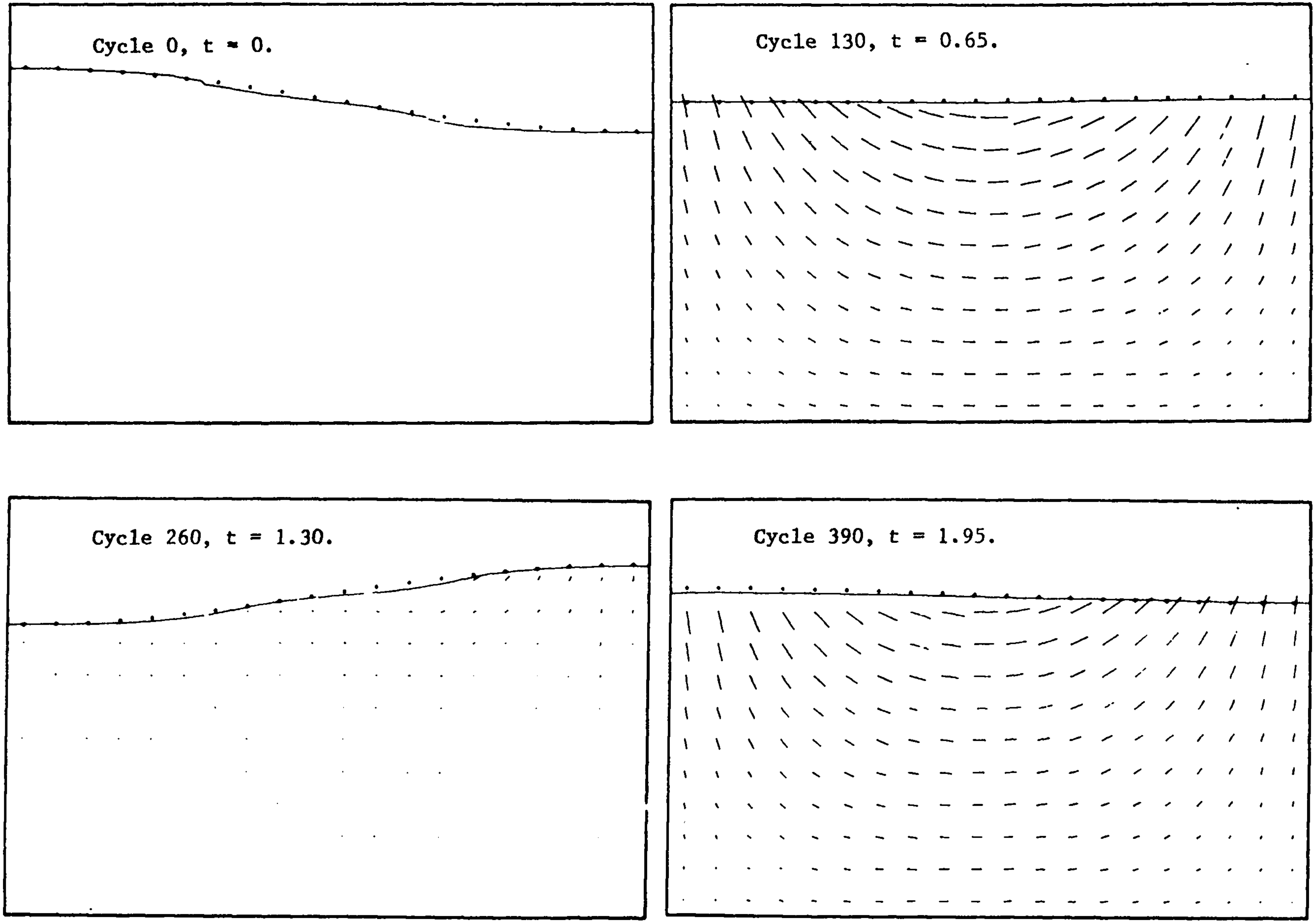

Fig. 11. Sloshing tank velocity vector plot and free-surface plot (solid line) at four different times. The asterisks near the free surface are the analytical solution for the free surface. Times are in sec.

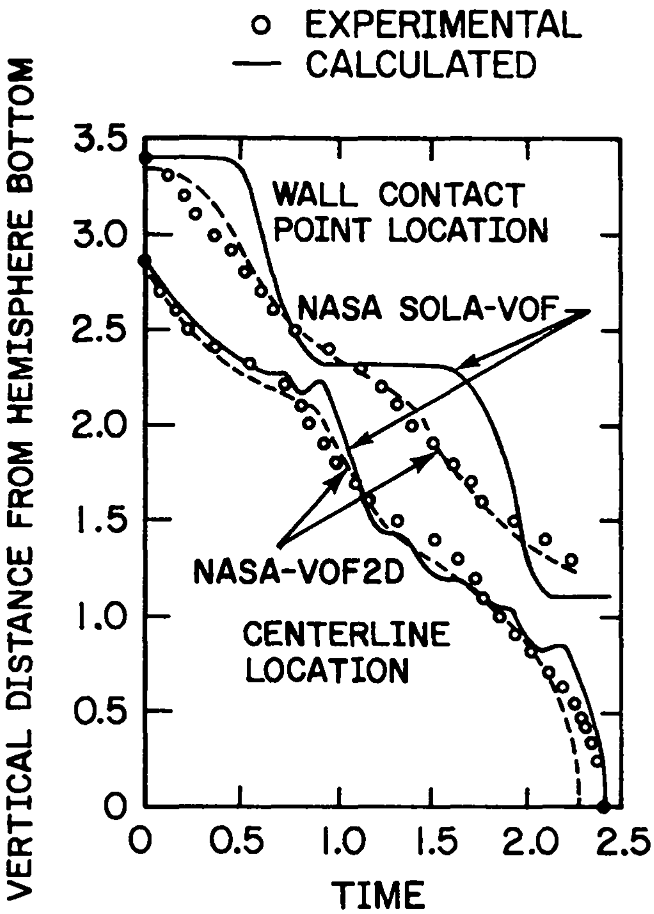

Fig. 12. Free-surface locations as a function of time for the tank-draining problem.

The final example is a simulation of a drop tower fuel reorientation experiment. A small cylindrical container (r = 2 cm, l = 9 cm) with hemispherical ends, half full of liquid (ethanol), and in free fall is suddenly subjected to a small constant downward acceleration. The liquid starts out at the top end of the tank. The free surface assumes an equilibrium shape under the influence of surface-tension and wall-adhesion forces. Following application of the additional force, the liquid flows along the sides of the container to the opposite end, meets at the axis, and jets upward. The Bond number of the flow is 4.1, the liquid density 0.789 g/cm^3, surface tension coefficient 22.33 dyne/cm, kinematic viscosity coefficient 0.001095 cm^2/s, and the applied acceleration is 29.0 cm/s^2.

Table 8 lists the problem input data set used to generate and execute this problem. Table 9 is a list of the UPDATE code modifications necessary to adapt the code logic for this application, as was shown earlier in the example problem. Figure 13 displays plots from the calculation at selected times showing the fluid flow and the free-surface configuration. Problem time t = 0.0 corresponds to the experimental time when the additional acceleration occurs. Sketches of the approximate free-surface shape at the same times are shown in Fig. 14 taken from a 16-mm movie of the drop-tower experiment. These data were obtained without densitometer or computer analysis of the film and are therefore very subjective. However the code solution roughly reproduces the actual flow history, differing mainly in the details of the jet formation.

TABLE VIII

FUEL REORIENTATION INPUT

```
$XPUT
NAME=60HFUEL REORIENTATION PROBLEM BOND=4.1 NASA-VOF2D SRCRPT SOURCE
NDUMP=0. ISOR=0. QVOL=0.0. IDEFM=1.
DELT=.001.    GY= -29.0.   ICYL=1. IMOVY=0.OMG=1.7.
CANGLE=0.15. SIGMA= 22.33. ISURF10=1. IEQIC=1.
XNU=1.52E-02. RHOF=0.789. EPSI=1.E-03.
VELMX=3..    TWFIN=1.0.    PRTDT=1.E+10.
PLTDT=.05.    FLHT=4.5.    ISYMPLT=1. AUTOT=1.
$END
$MSHSET
NKX=2. XL=0.0..4.2.. XC=0.2.1.9. NXL=1.10. NXR=1.1. DXMN=0.2.0.1.
NKY=1.   YL=0.0. 9.0.    YC=4.5.    NYL=20.    NYR=20.
DYMN=0.225
$END
$ASETIN
NOBS=4.
OA2(1)= 0.0. 0.0. 1.0. 1.0. OA1(1)=0.0. 0.0. 0.0. 0.0.
OB2(1)= 0.0. 0.0. 1.0. 1.0. OB1(1)=1.0.-1.0.-4.0.-14.0.
OC1(1)=-2.0. 7.0. 0.0. 45.0. OC2(1)=0.0. 0.0. 0.0. 0.0.
IOH(1)=1.1.0.0.
$END
```

TABLE IX

FUEL REORIENTATION CODE MODIFICATIONS

```
*IDENT REOMOD
*D.COMMON1.2
      PARAMETER (IBAR2=15.JBAR2=42.MESHX=5.MESHY=5.NVOR=200.NOBD=20)
*I.EQUIB.7
      EPS=1.0E-8
*D.DVCAL.5
      DATA ISLIP   1
*D.IIWI.216
      JJ=0
*D.IIWI.224
   40 CONTINUE
*D.SETUP.60.61
      BOND=-0.000001
*I.SETUP.117
      DELREQ=X(IM1)/FLOAT(NEQUIB-1)
*D.SETUP.121.128
      LUP=FLOAT(NEQUIB-1)*X(I)/X(IM1)+1.000001
      LLOW=FLOAT(NEQUIB-1)*X(I-1)/X(IM1)+1.000001
      LLOW=MAXO(LLOW.1)
      LUP=MINO(LUP.NEQUIB)
      H1=SFLHT-U(LLOW.1)*X(IM1)
      H2=SFLHT-U(LUP.1)*X(IM1)
      IF(Y(J).LT.H1.AND.Y(J).LT.H2) GO TO 94
      IF(Y(J-1).GT.H1.AND.Y(J-1).GT.H2) GO TO 110
      SUM=0.0
      DO 92 K=LLOW.LUP
      H3=SFLHT-U(K.1)*X(IM1)
      IF(H3.LT.Y(J-1)) H3=Y(J-1)
      SUM=SUM+AMAX1( Y(J)-H3. 0.0 )
   92 CONTINUE
      F(I.J)=SUM*DELREQ*RDX(I)*RDY(J)
      GO TO 110
   94 F(I.J)=0.0
*D.SETUP.199
      P(I.1)=0.0
*D.SETUP.201.204
      RHOYA=(AMIN1(F(I.J-1).0.5)*DELY(J-1)+AMAX1(0.0.F(I.J)-0.5)*
     1 DELY(J))*RHOF
      P(I.J)=P(I.J-1)+GY*RHOYA
```

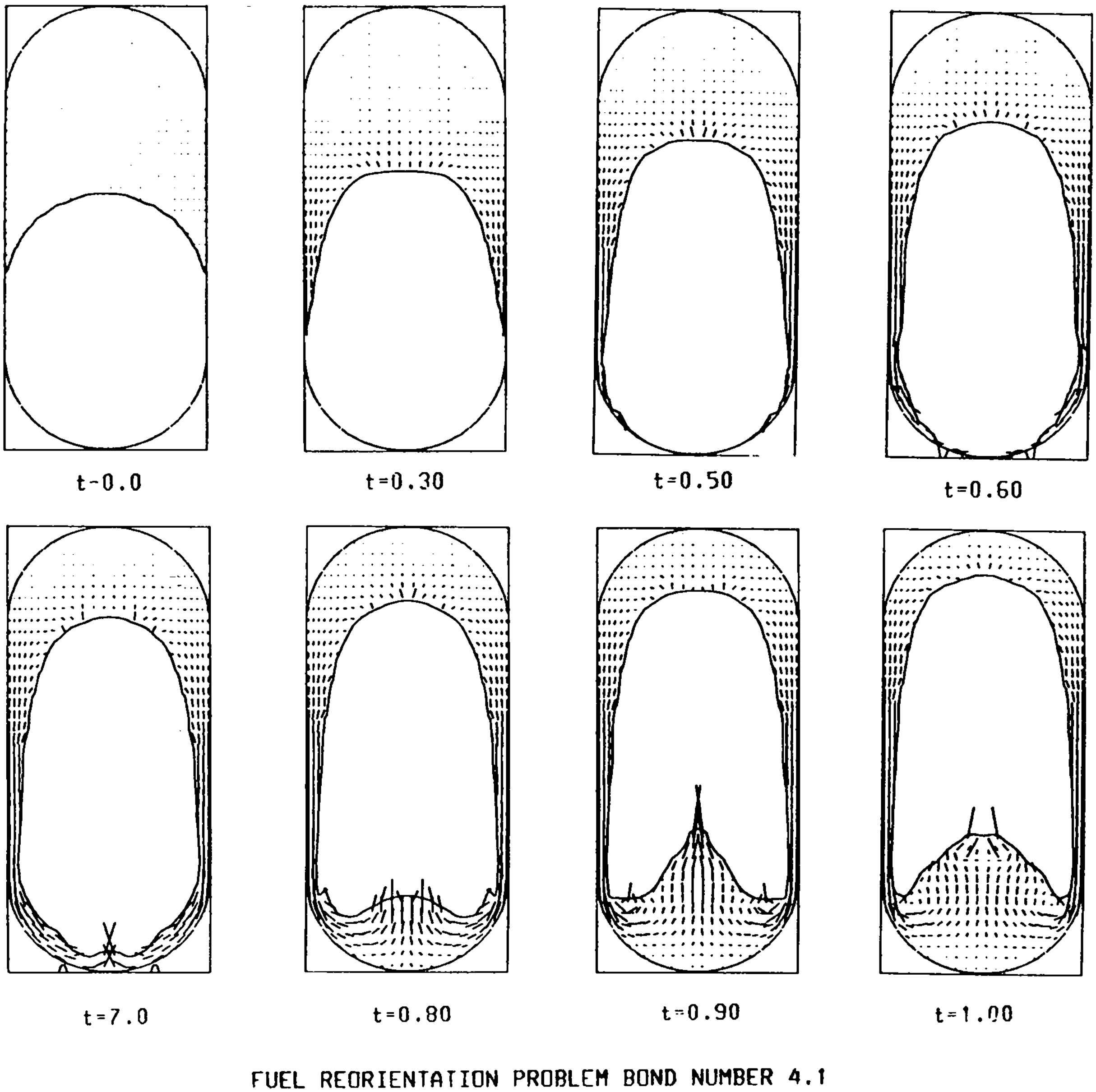

Fig. 13. Computed velocity vectors and free-surface configurations for the reorientation problem.

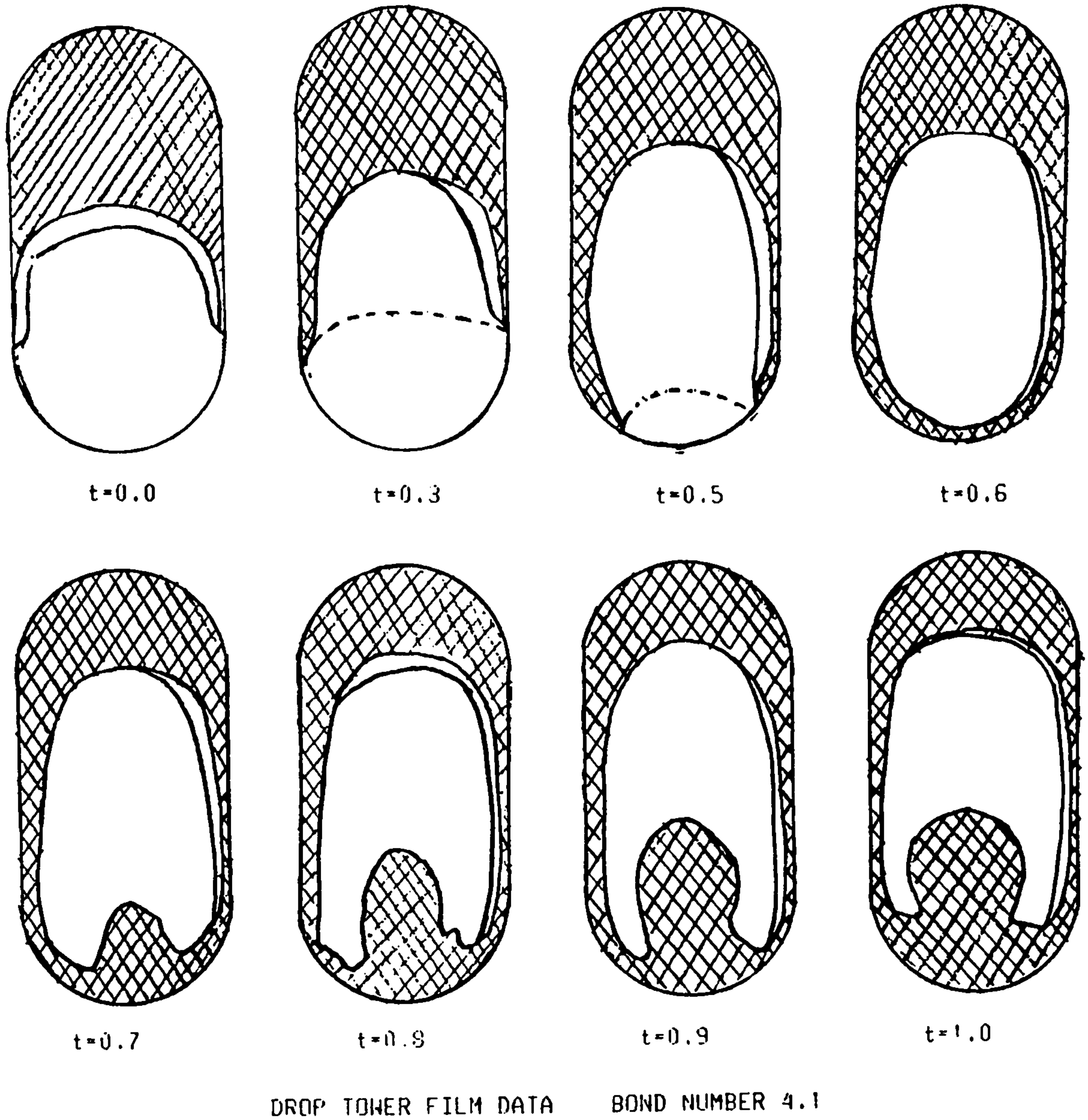

Fig. 14. Experimental free-surface configurations at the same set of times as in Fig. 13. The multiple free surfaces reflect the ambiguity of the free-surface location in the movie.

ACKNOWLEDGMENT

The authors wish to thank R. S. Hotchkiss for sharing his insight and experience gained from similar studies.

APPENDIX A.

THE PARTIAL CELL TREATMENT

The partial cell treatment may be motivated by considering it to be a special case of two-phase flow. If we specialize the two-fluid equations used in the K-FIX program[22,23] to the case where one of the fluids is fixed in space and time, and where the density of the other, moving, fluid is constant in space and time, then the continuity and momentum equations for the moving fluid are

$$\nabla\cdot(\theta\,\underset{\sim}{u}) = 0 \tag{A-1}$$

and

$$\frac{\partial(\theta\,\underset{\sim}{u})}{\partial t} + \nabla\cdot(\theta\,\underset{\sim}{u}\underset{\sim}{u}) = \theta\,[\underset{\sim}{g} - \nabla(p/\rho)] - \frac{K\,\underset{\sim}{u}}{\rho} + \nabla\cdot\left(\frac{\theta\,\underset{\approx}{\sigma}}{\rho}\right) \quad , \tag{A-2}$$

where θ is the volume fraction of the working fluid (that is, the fraction of the volume occupied by the motionless component), K is a coupling constant characterizing the drag between interpenetrating fluids, and $\underset{\approx}{\sigma}$ is the viscous stress tensor. Equation (4) completes the set of equations that we will require.

The program is based on nonconservative momentum equations, a choice made for SOLA-VOF[2] on the basis of an incomplete argument based on truncation error analysis. This choice has been retained in the present program, and it has the fortuitous property of allowing us to omit any mention of the partial cell treatment (that is, θ) in the momentum equation solver. If we make use of the assumption that θ is independent of time and use Eq. (A-1) to derive the nonconservative form of Eq. (A-2), we obtain

$$\frac{\partial\underset{\sim}{u}}{\partial t} + \underset{\sim}{u}\cdot\nabla\underset{\sim}{u} = \underset{\sim}{g} - \nabla p/\rho - \nabla\cdot\underset{\approx}{\sigma} - [\underset{\approx}{\sigma}\cdot\nabla\theta + K\,\underset{\sim}{u}/\theta] \quad . \tag{A-3}$$

Similarly, the nonconservative F, Eq. (4), may be cast into conservative form, Eq. (32), by using Eq. (A-1) and the time-independence of θ.

The connection between the two-fluid equations and the partial-cell treatment is made by specializing θ to a situation where θ is a step function with values of 0 and 1 in the obstacle material and moving fluid, respectively. First we note that $\underset{\sim}{u} = 0$ in the obstacle material and Θ is constant piecewise. Therefore we neglect the terms in square brackets in Eq. (A-3) because we are interested only in what is happening in the fluid. These terms serve only to enforce $\underset{\sim}{u} = 0$ inside the obstacle and either $\underset{\sim}{u} = 0$ or $\partial\underset{\sim}{u}/\partial\underset{\sim}{n} = 0$ on its surface. The result is that Eqs. (2) and (3) are the momentum equations that we desire.

The final part of the connection is a set of rules for including Θ in the difference equations. We do this by introducing three arrays into the program. First, $AC_{i,j}$ is the fraction of cell (i,j) open to fluid, times $2\pi r_i$ in cylindrical cases. For cases where a cell-centered value of $r\Theta$ is required, $AC_{i,j}$ is used. Second, $AR_{i+1/2,j}$ is the fraction of the area of the right face of cell (i,j) that is open to flow, times $2\pi r_{i+1/2}$ in the cylindrical case. This array is used as the value of $r\Theta$ on the cell face. Finally, the array $AT_{i,j+1/2}$ is the fraction of the area of the top face of cell (i,j) that is open to flow, times $2\pi r_i$ in the cylindrical case, and it is used as $r\Theta$ for the top cell face. These rules have the nice feature that the finite-difference form for the divergence of the velocity, Eq. (20), exactly conserves the volume of fluid flowing through the cell faces if one assumes $\underset{\sim}{u}$ is constant over each cell face. This procedure is admittedly not rigorous, but we expect it to produce the correct general features of flow in nonrectangular geometries.

The use of the partial cell variables AT, AR, and AC appears to be a powerful and simple procedure for embedding thin screens and baffles as well as solid obstacles in the grid. Baffles and screens can be approximated as zero-thickness surfaces on cell faces with appropriate flow losses, including the K term in the momentum equation. However, additional modeling efforts will be required before this capability can be added to the program. In addition, code modifications will be necessary to correctly account, through the fractional area/volume functions, for wall shear stresses (or their absence) on curved boundaries embedded in the computing grid.

APPENDIX B

PROGRAM LISTING

```
*COMDECK,COMMON1
      PARAMETER (IBAR2=40,JBAR2=40,MESHX=20,MESHY=20,NVOR=25,NOBD=20)
C
C   **** NOTE *****  ISOR=0 (CONJUGATE RESIDUAL SOLUTION) REQUIRES IBAR2
C                    =IMAX AND JBAR2=JMAX DUE TO USE OF CRAY SYSTEM
C                    UTILITIES FOR VECTOR AND MATRIX OPERATIONS
      PARAMETER (MSHX=MESHX+1, MSHY=MESHY+1)
C
      COMMON /FV/ ACOM(1), UN(IBAR2,JBAR2), VN(IBAR2,JBAR2), PN(IBAR2
     1 ,JBAR2), FN(IBAR2,JBAR2), U(IBAR2,JBAR2), V(IBAR2,JBAR2), P(IBAR2
     2 ,JBAR2), F(IBAR2,JBAR2), PETA(IBAR2,JBAR2), BETA(IBAR2,JBAR2), NF
     3 (IBAR2,JBAR2), PS(IBAR2,JBAR2), AR(IBAR2,JBAR2),
     4 AT(IBAR2,JBAR2),AC(IBAR2,JBAR2)
C
      COMMON /ME/ X(IBAR2), XI(IBAR2), RXI(IBAR2), DELX(IBAR2), RDX
     1 (IBAR2), RX(IBAR2), Y(JBAR2), YJ(JBAR2), RYJ(JBAR2), DELY(JBAR2),
     2 IEQIC, NDUMP, OVOL, CON, FCVLIM, RDY(JBAR2), XL(MSHX), XC(MESHX),
     3 DXMN(MESHX), NXL(MESHX), NXR(MESHX), YL(MSHY), YC(MESHY), DYMN
     4 (MESHY), NYL(MESHY), NYR(MESHY), ZC(20), R(IBAR2), RI(IBAR2),
     5  COSO(IBAR2,JBAR2), SINO(IBAR2,JBAR2), NW(IBAR2,JBAR2)
C
      COMMON /PV/ NR(NVOR), PR(NVOR), VOL(NVOR), NAME(10), FVOL
C
      COMMON /IV/ IBAR, JBAR, IMAX, JMAX, IM1, JM1, NKX, NKY, NCYC, DELT
     1 , T, AUTOT, PRTDT, TWPRT, PLTDT, TWPLT, TWFIN, FLHT, XNU,
     2 RHOF, NREG, VCHGT, ISURF10
     3 , SIGMA, CANGLE, ICYL, CYL, GX, GY, UI, VI, OMG, ALPHA, KL
     4 , KR, KB, KT, ITER, EPSI, FLG, FLGC, FNOC, NOCON, NFLGC,
     5 ISYMPLT, IMOVY, VELMX, VELMX1, XSHFT, YSHFT, XMIN, XMAX, YMIN,
     6 YMAX, SF, YPB, YPT, IPL, IPR, JPB, JPT, DTVIS
     8 ,I,J,DUDR,DUDL,DUDT,DUDB,DVDR,DVDL,DVDT,DVDB
     7 ,DTSFT,DXMIN,DYMIN,PSAT,LITER,ISOR,IDEFM,NPACK,LABS(5)
     8 ,ADEFM,BDEFM,DTCRMX,IDIV
C
      COMMON /CONST/ EMF, EMF1, EM6, EM10, EP10, PI, TPI, RPD, EM6P1
     1 , EM61
      COMMON /OBS/ NOBS, OA2(NOBD), OA1(NOBD), OB2(NOBD), OB1(NOBD), OC2
     1 (NOBD), OC1(NOBD), IOH(NOBD)

      PROGRAM IIWI (INPUT,TAPE5=INPUT,OUTPUT,TAPE6=OUTPUT,TAPE7,TAPE8
     1 ,TTY,TAPE59=TTY)
C
C ********************************************************************
C ********************************************************************
C
COPYRIGHT,  1985.  THE REGENTS OF THE UNIVERSITY OF CALIFORNIA.
C     THIS SOFTWARE WAS PRODUCED UNDER A U. S. GOVERNMENT CONTRACT
C     (W-7405-ENG-36) BY THE LOS ALAMOS NATIONAL LABORATORY, WHICH
C     IS OPERATED BY THE UNIVERSITY OF CALIFORNIA FOR THE U. S.
C     DEPARTMENT OF ENERGY.  THE U. S. GOVERNMENT IS LICENSED TO USE,
C     REPRODUCE, AND TO DISTRIBUTE THIS SOFTWARE.  PERMISSION IS
C     GRANTED TO THE PUBLIC TO COPY AND USE THIS SOFTWARE WITHOUT
C     CHARGE, PROVIDED THAT THIS NOTICE AND ANY STATEMENT OF
C     AUTHORSHIP ARE REPRODUCED ON ALL COPIES.  NEITHER THE GOVERNMENT
C     NOR THE UNIVERSITY MAKES ANY WARRANTY, EXPRESS OR IMPLIED,
C     OR ASSUMES ANY LIABILITY OR RESPONSIBILITY FOR THE USE OF THIS
C     SOFTWARE.
C
C ********************************************************************
C ********************************************************************
C
C +++
C +++ TAPE7 IS THE RESTART DUMP
C +++ TAPE8 IS THE OUTPUT FILE FOR EQUIB
C +++ TAPE12 IS THE FILM OUTPUT
C +++
C
C +++ VOLUME OF FLUID METHOD
C +++
C +++ LIST OF PRIMARY VARIABLES
C
C +++ INPUT PARAMETERS (NAMELIST /XPUT/)
C
C     ALPHA      CONTROLS AMOUNT OF DONOR CELL FLUXING (=1.0 FOR FULL
C                DONOR CELL DIFFERENCING, =0.0 FOR CENTRAL DIFFERENCING)
C     AUTOT      AUTOMATIC TIME STEP FLAG (=1.0 FOR AUTOMATIC DELT
C                ADJUSTMENT, =0.0 FOR CONSTANT DELT)
C     CANGLE     CONTACT ANGLE, IN DEGREES, BETWEEN FLUID AND WALL
C     CON        C.F.L.CONDITION - CELL WIDTH FRACTION MOVED IN TIME STEP
C     DELT       TIME STEP
```

```
C       DTCRMX      MAXIMUM DELT USING CONJUGATE RESIDUAL SOLUTION METHOD
C       EPSI        PRESSURE ITERATION CONVERGENCE CRITERION
C       FLHT        FLUID HEIGHT, IN Y-DIRECTION
C       GX          BODY ACCELERATION IN POSITIVE X-DIRECTION
C       GY          BODY ACCELERATION IN POSITIVE Y-DIRECTION
C       ICYL        MESH GEOMETRY INDICATOR (=1 FOR CYLINDRICAL COORDINATES
C                   =0 FOR PLANE COORDINATES)
C       IDEFM       DEFOAMER OPTION FLAG  ON = 1 *** OFF = o
C       ICIV        DIVERGENCE CORRECTION FLAG  1 =ON  0=OFF
C       IEQIC       FLAG USED To ACTIVATE EQUILIBRIUM FREE SURFACE
C                   CALCULATION DURING SETUP
C       IMOVY       MOVIE INDICATOR (=1 FOR MOVIE FILM OUTPUT, =0 FOR
C                   OTHER FILM OUTPUT)
C       ISOR        PRESSURE ITERATION SOLUTION METHOD
C                   CONJUGATE RESIDUAL = O ****  SDR = 1
C       ISURF1O     SURFACE TENSION INDICATOR (=1 FOR SURFACE TENSION,
C                   =0 FOR NO SURFACE TENSION)
C       ISYMPLT     SYMMETRY PLOT INDICATOR (=1 FOR SYMMETRY PLOT.
C                   =0 FOR NO SYMMETRY PLOT)
C       KB          INDICATOR FOR BOUND ARY CONDITION TO BE USED ALONG THE
C                   BOTTOM OF THE MESH (=1 FOR RIGID FREE-SLIP WALL,
C                   =2 FOR RIGID NO-SLIP WALL. =3 FOR CONTINUATIVE
C                   BOUNDARY, =4 FOR PERIODIC BOUNDARY, ‘5 FOR CONSTANT
C                   PRESSURE BOUNDARY)
C       KL          INDICATOR FOR BOUNDARY CONDITION ALONG LEFT SIDE OF
C                   MESH (SEE KB)
C       KR          INDICATOR FOR BOUNDARY CONDITION ALONG RIGHT SIDE OF
C                   MESH (SEE KB)
C       KT          INDICATOR FOR BOUNDARY CONDITION ALONG TOP OF MESH
C                   (SEE KB)
C       NAME        PROBLEM IDENTIFICATION
C       NDUMP       DUMP NUMBER FOR PROBLEM RESTART
C       NPACK       FLAG TO ACTIVATE PACKING O=OFF  1 =ON
C       OMG         OVER-RELAXATION FACTOR USED IN PRESSURE ITERATION
C       PSAT        LIQUID SATURATION PRESSURE - IF NONZERO CODE SIMULATES
C                   PHASE CHANGE IN NF = 5 CELLS
C       PLTDT       TIME INCREMENT BETWEEN PLOTS AND/OR PRINTS TO BE OUTPUT
C                   ON FILM
C       PRTDT       TIME INCREMENT BETWEEN PRINTS ON PAPER

C       OVOL        AVAILABLE TO SPECIFY FLOW RATE (INFLOW OR OUTFLOW)
C                   IF REQUIRED
C       RHOF        FLUID DENSITY (FOR F=I.O REGION)
C       SIGMA       SURFACE TENSION COEFFICIENT
C       TWFIN       PROBLEM TIME TC END CALCULATION
C       UI          XDoIRECTION VELOCITY USED FOR :NITIALIZING MESH
C       VI          DIRECTION vELOCITY USED FOR INITIALIZING MESH
C       VELMX       MAXIMUM VELOCITY EXPECTED Ihj PROBLEM USED TO SCALE
C                   VELOCITY VECTORS
C       XNU         COEFFICIENT OF KINEMATIC VISCOSITY
C
C +++   MESH SETUP IIJPUT (NAMELIST /mSHSET/)

C       DXMN(N)        MINIMUM SPACE INCREMENT IN X-DIRECTION IN SUBMESH N
c       DYMN(N)        MINIMUM SPACE INCREMENT IN Y-DIRECTION IN SUBMESH N
c       NKX            NUMBER OF SUBMESH REGIONS IN X-DIRECTION
c       NXL(N)         NUMBER OF CELLS BETWEEN LOCATIONS XL(N) AND XC(N) IN
c                      SUBMESH N
C       NXR(N)         NUMBER OF CELLS BETWEEN LOCATIONS XC(N) AND XL(N+l) IN
c                      SUBMESH N
c       NYL(N)         NUMBER OF CELLS BETWEEN LOCATIONS YL(N) AND YC (N) IN
c                      SUBMESH N
c       NYR(N)         NUMBER OF CELLS BETWEEN LOCATIONS YC(N) AND YL(N+l) IN
c                      SUBMESH N
C       XC(N)          X-COORDINATE OF THE CONVERGENCE POINT IN SUBMESH N
c       XL(N)          LOCATION OF THE LEFT EDGE OF SUBMESH N (NKX+l VALUES
c                      OF XL(N) ARE NECESSARY BECAUSE THE RIGHT EDGE (XR) OF
c                      SUBMESH N IS DETERMINE BY THE LEFT EDGE OF
c                      SUBMESH N+1 )
C       YC(N)          Y-COOROINATE OF THE CONVERGENCE POINT IN SUBMESH N
C       YL(N)          LOCATION OF THE BOTTOM OF SUBMESH N (NKY+l VALUES OF
C                      YL(N) ARE NECESSARY BECAUSE THE TOP EDGE (YR) OF
•                      SUBMESH N IS DETERMINED BY THE BOTTOM EDGE OF
C                      SUBMESH N+1)
C
C +++   INTERIOR OBSTACLE SETUP INPuT (NAMELIsT /ASETIN/)
C
C
```

```
*CALL,COMMON1
      DATA EMF /1.0E-06/, EM6 /1.0E-06/, EM10 /1.0E-10/
      DATA EP10 /1.0E+10/, FLGC /0./, FLG /0./
      DATA TQUIT /60./
      DATA PI /3.14159265359/, RPD /0.0174532925/, EM6P1 /1.000001/
      DATA TBEG /0./, TPI / 6.283185307 /
      DATA EM61 / 0.999999 /
C +++
C
C +++ DEFAULT INPUT DATA
C +++ NOTE    USER MUST SUPPLY THE FOLLOWING REGARDLESS
C                       OF DEFAULTS: DELT,TWFIN,PRTDT,PLTDT
C
      DATA XNU /0.0/, ICYL /0/, EPSI /1.0E-03/, GX /0.0/, GY /0.0/, UI /
     1 0.0/, VI /0.0/, VELMX /1.0/, IMOVY /0/, OMG /1.7/, ALPHA /1.0/,
     2 KL /1/, KR /1/, KT /1/, KB /1/, AUTOT /1.0/, ISYMPLT /0/,
     3 ISURF10 /0/, SIGMA /0.0/, CANGLE /90.0/, RHOF /1.0/, FLHT /0.0/,
     4  PSAT /0.0/
      DATA IEQIC /1/
C +++
C +++ CALL SYSTEM-DEPENDENT ROUTINES TO INITIALIZE FILM FILE
C +++
      CALL GPLOT (1HU,4HIIWI,4)
      CALL GRPHLUN (12)
      CALL LIB4020
      CALL GRPHCFT
      CALL SETFLSH
C +++ SYSTEM-DEPENDENT CALL TO GET THE JOB TIME LIMIT
      CALL GETJTL (TTL)
C +++
C +++ CALL THE INITIALIZATION ROUTINE
C +++
      CALL SETUP
C
C +++ PRINT INITIAL INPUT DATA
C
      CALL PRTPLT (1)
C
C +++ SET INITIAL BOUNDARY CONDITIONS
C
      CALL BC
C
      DTEND=0.002*DELT
      IF (NDUMP.LE.1) GO TO 30
C
C +++ START TIME CYCLE
C
   10 CONTINUE
      CALL SECOND (TBEG)
C +++
C +++ PROBLEM DEPENDENT - CALCULATIONAL SHUTOFF FOR SMALL TIMESTEP
      IF(DELT.GT.DTEND) GO TO 20
      WRITE (59,150) NCYC,T
      WRITE (12,150) NCYC,T
      TWFIN=T*0.999
   20 CONTINUE
      ITER=0
      FLG=1.0
      FNOC=0.0
C
C +++ EXPLICITLY APPROXIMATE NEW TIME-LEVEL VELOCITIES
C
      CALL TILDE
C
C +++ SET BOUNDARY CONDITIONS
C
      CALL BC
C
C +++ ITERATIVELY ADJUST CELL PRESSURE AND VELOCITY
C
      IF (ISOR.EQ.1) CALL PRESIT
      IF (ISOR.EQ.0) CALL PRESCR
      IF (FNOC.GT.0.5) CALL PRTPLT (4)
C
      IF (FNOC.GT.0.5) GO TO 40
C
C +++ UPDATE FLUID CONFIGURATION
C
   30 CALL VFCONV
```

```
C
      IF (FLGC.GT.0.5) GO TO 100
C
C +++ SET BOUNDARY CONDITIONS
C
      CALL BC
C
C +++ DETERMINE PRESSURE INTERPOLATION FACTOR AND NEIGHBOR
C +++ ALSO DETERMINE SURFACE TENSION PRESSURES AND
C +++ WALL ADHESION EFFECTS IN SURFACE CELLS
C
      CALL PETACAL
      CALL BC
      IF(NCYC.NE.O.OR.ISOR.NE.O) GO TO 34
      DO 32 I=2,IM1
      PSADD=0.0
      DO 32 J=2,JM1
      JJ=JM1-J+2
      IF(PS(I,JJ).NE.0.0) PSADD=PS(I,JJ)-P(I,JJ)
      P(I,JJ)=P(I,JJ)+PSADD
   32 CONTINUE
   34 CONTINUE
C
C +++ PRINT TIME AND CYCLE DATA ON PAPER AND/OR FILM
C
   40 CALL PRTPLT (2)
C
      IF (NCYC.LE.0) GO TO 50
      IF (T+EM6.LT.TWPLT.AND.T.LT.TWFIN) GO TO 60
      TWPLT=TWPLT+PLTDT
   50 CONTINUE
C
C +++ PRINT FIELD VARIABLE DATA ON FILM
C
      CALL PRTPLT (3)
C
C +++ PLOT VELOCITY VECTOR, FREE SURFACE, MESH,
C
      CALL DRAW
C
   60 CONTINUE
      IF (NCYC.LE.0) GO TO 70
      IF (T+EM6.LT.TWPRT) GO TO 80
      TWPRT=TWPRT+PRTDT
   70 CONTINUE
C
C +++ PRINT FIELD VARIABLE DATA ON PAPER
C
      CALL PRTPLT (4)
C
   80 CONTINUE
      IF (T.GT.TWFIN) GO TO 130
C
C +++ SET THE ADVANCE TIME ARRAYS INTO THE TIME-N ARRAYS
C
      DO 90 I=1,IMAX
      DO 90 J=1,JMAX
      UN(I,J)=U(I,J)
      VN(I,J)=V(I,J)
      U(I,J)=0.0
      V(I,J)=0.0
      PN(I,J)=P(I,J)
      FN(I,J)=F(I,J)
   90 CONTINUE
      NREGN=NREG
C
C +++ ADJUST DELT
C
  100 CALL DELTADJ
C
C +++ ADVANCE TIME
C
      T=T+DELT
C
C +++ ADVANCE CYCLE
C
      IF (NFLGC.LT.5) GO TO 110
      WRITE (12,170) NCYC,T
      WRITE (59,170) NCYC,T
```

```
      CALL EXITLDC (8HIIWI PIT)
  110 CONTINUE
      IF (NOCON.LT.5) GO TO 120
      WRITE (12,160) NCYC,T
      WRITE (59,160) NCYC,T
      CALL EXITLDC (8HIIWI FCV)
  120 CONTINUE
      NCYC=NCYC+1
 +++ TERMINATE GRACEFULLY IF OUT OF TIME
      CALL SECOND (TIME)
      TLEFT=TTL-TIME-TQUIT
      IF (TLEFT.LT.0.) CALL TAPOUT (0)
      IF (MOD(NCYC,200).NE.0) GO TO 10
      CALL SECOND (TEND)
      CALL SECOND (TENDD)
      GRIND=1000.*(TEND+TEND-TENDD-TBEG)/FLOAT(IBAR*JBAR)
      WRITE (59,140) NCYC,GRIND,ITER
      IF (IMOVY.EQ.0) WRITE (12,140) NCYC,GRIND,ITER
      WRITE (6,140) NCYC,GRIND,ITER
      GO TO 10
C
  130 CONTINUE
      CALL EXITLDC (4HIIWI)
C
  140 FORMAT (1X,5HCYCLE,I7,1X,6HGRIND=,1PE12.4,10H MS, ITER=,I5)
  150 FORMAT (1X,29HDELT LESS THAN DTEND ON CYCLE,I6,1X,3HT =,1PE15.7)
  160 FORMAT (//1X,25HTOO MANY PRESSIT FAILURES,3X,5HNCYC=,I7,1X,2HT=,1P
     1 E14.6//)
  170 FORMAT (//1X,24HTOO MANY VFCONV FAILURES,3X,5HNCYC=,I7,1X,2HT=,1PE
     1 14.6//)
      END
```

```
      SUBROUTINE ASET
*CALL,COMMON1
C +++
C +++ CONIC FCN=OA2*X*X+OA1*X+OB2*Y*Y+OB1*Y+OC2*X*Y+OC1
C +++ INSIDE FCN=NEGATIVE VALUE
C +++ IOH=1 ADD OBS INSIDE FCN, IOH=0 SUBTRACT OBS INSIDE FCN
C +++
      DIMENSION IFLG(5), DIS(4), XM(5), YM(5)
      IF (NOBS.LE.0) GO TO 240
      DO 230 K=1,NOBS
      DO 220 J=2,JM1
      DO 220 I=2,IM1
      RDXDY=1.0/(DELX(I)*DELY(J))
      DO 60 M=1,4
      GO TO (10,20,30,40), M
   10 X1=X(I)
      Y1=Y(J-1)
      DIS(1)=DELY(J)
      GO TO 50
   20 Y1=Y(J)
      X1=X(I)
      DIS(2)=DELX(I)
      GO TO 50
   30 X1=X(I-1)
      Y1=Y(J)
      DIS(3)=DELY(J)
      GO TO 50
   40 Y1=Y(J-1)
      X1=X(I-1)
      DIS(4)=DELX(I)
   50 IFLG(M)=0
      FCONIC=OA2(K)*X1*X1+OA1(K)*X1+OB2(K)*Y1*Y1+OB1(K)*Y1+OC2(K)*X1*Y1
     1 +OC1(K)
      IF (FCONIC.LE.0.0) IFLG(M)=1
      XM(M)=X1
      YM(M)=Y1
   60 CONTINUE
      IFLG(5)=IFLG(1)
      XM(5)=XM(1)
      YM(5)=YM(1)
      IFLGS=0
      DO 70 M=1,4
   70 IFLGS=IFLGS+IFLG(M)
      BRIJ=0.0
      BTIJ=0.0
      IF (IFLGS.EQ.0) GO TO 220
      IF (IFLGS.LT.4) GO TO 80
```

```
      BIJ=1.0
      BRIJ=1.0
      BTIJ=1.0
      GO TO 200
   80 IF (IFLG(1).EQ.1.AND.IFLG(2).EQ.1) BRIJ=1.0
      IF (IFLG(2).EQ.1.AND.IFLG(3).EQ.1) BTIJ=1.0
      DO 160 M=1,4
      IF (IFLG(M).EQ.IFLG(M+1)) GO TO 160
      X1=XM(M)
      Y1=YM(M)
      X2=XM(M+1)
      Y2=YM(M+1)
      IF (IFLG(M).EQ.0) GO TO 90
      X2=XM(M)
      Y2=YM(M)
      X1=XM(M+1)
      Y1=YM(M+1)
   90 EPSIF=0.001*(ABS(X2-X1)+ABS(Y2-Y1))
      SMN=0.0
      FMN=OA2(K)*X2*X2+OA1(K)*X2+OB2(K)*Y2*Y2+OB1(K)*Y2+OC2(K)*X2*Y2+OC1
     1 (K)
      SMX=1.0
      FMX=OA2(K)*X1*X1+OA1(K)*X1+OB2(K)*Y1*Y1+OB1(K)*Y1+OC2(K)*X1*Y1+OC1
     1 (K)
      S=0.5
  100 XT=S*X1+(1.0-S)*X2
      YT=S*Y1+(1.0-S)*Y2
      FS=OA2(K)*XT*XT+OA1(K)*XT+OB2(K)*YT*YT+OB1(K)*YT+OC2(K)*XT*YT+OC1
     1 (K)
      IF (ABS(FS).LT.EPSIF) GO TO 130
      IF (FS.GE.0.0) GO TO 110
      FDEN=ABS(FS-FMN)+1.0E-10
      SE=S-FS*(S-SMN)/FDEN
      IF (SE.GT.SMX) SE=SMX
      FMN=FS
      SMN=S
      GO TO 120
  110 FDEN=ABS(FMX-FS)+1.0E-10
      SE=S-FS*(SMX-S)/FDEN
      IF (SE.LT.SMN) SE=SMN
      FMX=FS
      SMX=S
  120 SI=S-FS*(SMX-SMN)/(FMX-FMN)
      S=0.5*(SE+SI)
      GO TO 100
  130 DIS(M)=SQRT((XT-X2)**2+(YT-Y2)**2)
      GO TO (140,150,160,160), M
  140 BRIJ=DIS(1)/DELY(J)
      GO TO 160
  150 BTIJ=DIS(2)/DELX(I)
  160 CONTINUE
      M=0
      BIJ=0.0
  170 CONTINUE
      M=M+1
      IF (M.EQ.5) GO TO 190
      IF (IFLG(M).EQ.0) GO TO 170
      MP1=M+1
      IF (MP1.EQ.5) MP1=1
      MM1=M-1
      IF (MM1.EQ.0) MM1=4
      BIJ=BIJ+DIS(M)*DIS(MM1)
      IF (IFLG(MP1).EQ.1) GO TO 180
      DIS2=DIS(M)
  180 CONTINUE
      IF (IFLG(MM1).EQ.1) GO TO 170
      DIS1=DIS(MM1)
      GO TO 170
  190 CONTINUE
      IF (IFLGS.EQ.3) BIJ=BIJ-DIS1*DIS2
      BIJ=0.5*BIJ*RDXDY
      IF (BIJ.GT.1.0) BIJ=1.0
  200 CONTINUE
      IF (IOH(K).EQ.0) GO TO 210
      BIJ=-BIJ
      BRIJ=-BRIJ
      BTIJ=-BTIJ
```

```
  210 AC(I,J)=AC(I,J)+BIJ
      IF(AC(I,J).GT.0.9999) AC(I,J)=1.0
      IF(AC(I,J).LT.0.0001) AC(I,J)=0.0
      AR(I,J)=AR(I,J)+BRIJ
      IF(AR(I,J).GT.0.9999) AR(I,J)=1.0
      IF(AR(I,J).LT.0.0001) AR(I,J)=0.0
      AT(I,J)=AT(I,J)+BTIJ
      IF(AT(I,J).GT.0.9999) AT(I,J)=1.0
      IF(AT(I,J).LT.0.0001) AT(I,J)=0.0
  220 CONTINUE
  230 CONTINUE
  240 CONTINUE
      DO 280 J=2,JM1
      IF (KL.GT.2) GO TO 270
      AR(1,J)=0.0
      AT(1,J)=0.0
      AC(1,J)=EM10
  270 IF (KR.GT.2) GO TO 280
      AR(IM1,J)=0.0
      AR(IMAX,J)=0.0
      AT(IMAX,J)=0.0
      AC(IMAX,J)=EM10
  280 CONTINUE
      DO 300 I=2,IM1
      IF (KB.GT.2) GO TO 290
      AT(I,1)=0.0
      AR(I,1)=0.0
      AC(I,1)=EM10
  290 IF (KT.GT.2) GO TO 300
      AT(I,JM1)=0.0
      AR(I,JMAX)=0.0
      AT(I,JMAX)=0.0
      AC(I,JMAX)=EM10
  300 CONTINUE
      DO 310 J=2,JM1
      DO 310 I=2,IM1
      IF (AC(I,J).GT.EM6) GO TO 310
      AR(I,J)=0.0
      AR(I-1,J)=0.0
      AT(I,J)=0.0
      AT(I,J-1)=0.0
      BETA(I,J)=-1.0
  310 CONTINUE
C +++
C +++ SET AR AND AT VALUES FOR IN AND OUT FLOW BOUNDARY SEGMENTS
C +++ HERE AS UPDATE MODIFICATION DEPENDING ON APPLICATION
C +++
C
C     START OF CURVED WALL OPTION SECTION
C
      DO 330 J=2,JM1
      DO 330 I=2,IM1
C
C     WE DEFINE ARRAY NW, WHICH LOCATES CURVED WALL IN A PARTIAL FLOW
C     CELL. DEFINITIONS TERMINATE AT:   315 CONTINUE
C     WE DEFINE ANGLE PHI THAT CURVED WALL MAKES WITH +Y AXIS. DEFINIT-
C     IONS TERMINATE AT:   325 COSO...
C     WE INTRODUCE DEFAULT VALUES FOR PHI AND NW
C
      PHI=CANGLE
      NW(I,J)=0
C
C     FOR FLUID CELL OR OBSTACLE CELL USE DEFAULT VALUES FOR PHI AND NW
C     BYPASS ALL OF DO LOOPS EXCEPT FOR DEFINING TRIG. FACTORS
C
      IF(AC(I,J).LT.EM6.OR.BETA(I,J).LT.0.0) GO TO 325
      IF(AC(I,J).GT.EM61) GO TO 325
C
C     SET NW FOR CELL
C
C
C     SET NW ARRAY FOR CELLS WITH TWO COMPLETELY CLOSED BOUNDARIES
C
      IF(AR(I,J).LT.EM6.AND.AT(I,J).LT.EM6) NW(I,J)=5
      IF(AR(I,J).LT.EM6.AND.AT(I,J-1).LT.EM6) NW(I,J)=6
C
C     SET NW ARRAY FOR CELLS WITH EXACTLY ONE CLOSED BOUNDARY
C
      IF(AR(I,J).LT.EM6.AND.NW(I,J).LT.5) NW(I,J)=1
      IF(AR(I-1,J).LT.EM6.AND.AT(I,J).GT.EM6.AND.AT(I,J-1).GT.
```

```
     1 EM6) NW(I,J)=2
      IF(AT(I,J).LT.EM6.AND.AR(I,J).GT.EM6.AND.AR(I-1,J).
     1 GT.EM6) NW(I,J)=3
      IF(AT(I,J).LT.EM6.AND.AR(I,J).GT.EM6.AND.I.EQ.2) NW(I,J) = 3
      IF(AT(I,J-1).LT.EM6.AND.AR(I,J).GT.EM6.AND.AR(I-1,J).GT.
     1 EM6) NW(I,J)=4
C
C     SET NW ARRAY FOR CELLS WHOSE NE OR SE CORNER IS CLOSED TO FLOW,
C     BUT WHICH HAS NO COMPLETELY CLOSED BOUNDARY
C     MORE INTRICATE NET OF IF STATEMENTS NEEDED TO ESTABLISH THIS CASE
C
      IF(AT(I,J-1).LT.EM6.AND.AR(I,J).GT.EM6.AND.I.EQ.2) NW(I,J) = 4
      IF(AR(I-1,J).LE.EM61) GO TO 315
      IF(AR(I,J).GT.EM6.AND.AR(I,J).LT.EM61) GO TO 305
      GO TO 315
  305 IF(AT(I,J-1).GT.EM61.AND.AT(I,J).GT.EM6.AND.AT(I,J).LT.
     1 EM61) NW(I,J)=7
      IF(AT(I,J).GT.EM61.AND.AT(I,J-1).GT.EM6.AND.AT(I,J-1).LT.
     1 EM61) NW(I,J)=8
  315 CONTINUE
C
C     CALCULATE APPROPIATE ANGLE FOR CURVED BOUNDARY
C
C
C     DEFINE FOR USE IN IF STATEMENTS: NON-INDEXED VARIABLE NWW=NW(I,J)
C
      NWW=NW(I,J)
C
C     IF NW = 0 OR 2, BYPASS REDEFINITION OF PHI AND COMPUTE SINO AND
C     COSO FROM DEFAULT VALUE: OTHERWISE REDEFINE PHI, STARTING AT 320
C
      IF(NWW.EQ.0) GO TO 325
      GO TO (320,325,320,320,320,320,320,320), NWW
C
C
C     SPECIFY VARIABLES FOR USE IN DEFINING TAN(PHI) IN VARIOUS CASES,
C     INCLUDING DEFAULT TO AVOID DIVISION BY ZERO
C
  320 CRATIO=DELX(I)/DELY(J)
      CELDEN=AR(I,J)-AR(I-1,J)
      IF(ABS(CELDEN).LT.0.001) CELDEN=0.001
C
C     RECOMPUTE PHI IN FOUR STRAIGHTFOREWARD CASES: NW = 1,6,3, OR 4
C     FOR NW .NE. 1, CONVERT NEGATIVE PHI TO PHI IN SECOND QUADRANT
C
      IF(NWW.EQ.1) PHI=ATAN(CRATIO*(AT(I,J)-AT(I,J-1)))
      IF(NWW.EQ.6) PHI=ATAN(CRATIO*(AT(I,J)/AR(I-1,J)))
      IF(NWW.EQ.3) PHI=ATAN(CRATIO/CELDEN)
      IF(NWW.EQ.4) PHI=ATAN(-CRATIO/CELDEN)
      IF(NWW.NE.1.AND.PHI.LT.0.0) PHI=PI+PHI
C
C     WE NEED WALL ADHESION OPTION EVEN FOR NW = 7 OR 8 CELLS: SO
C     RECOMPUTE PHI FOR THESE CASES HERE
C
      IF(NWW.EQ.8) PHI=ATAN(CRATIO*((1.0-AT(I,J-1))/(1.0-AR(I,J))))
      IF(NWW.EQ.7) PHI=ATAN2(CRATIO*(1.0-AT(I,J)),(AR(I,J)-1.0))
      IF(NWW.NE.5) GO TO 325
C
C     SIMPLEST FORMAT FOR NW = 5 IS SLIGHTLY DIFFERENT FROM THAT OF
C     OTHER CASES: SO TREAT NW = 5 SEPARATELY HERE
C
      PHI=PI - ATAN(CRATIO*(AT(I,J-1)/AR(I-1,J)))
C
C
C     EVALUATE TRIG. FACTORS USING EITHER THE DEFAULT PHI OR THE
C     RECALCULATED PHI, AS APPROPRIATE
C
  325 COSO(I,J)=COS(PHI)
      SINO(I,J)=SIN(PHI)
  330 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE BC
*CALL,COMMON1
C
C +++ SET BOUNDARY CONDITIONS
C
      DO 100 J=1,JMAX
      F(1,J)=F(2,J)
      F(IMAX,J)=F(IM1,J)
      P(1,J)=P(2,J)
      P(IMAX,J)=P(IM1,J)
      GO TO (10,20,30,40,30), KL
   10 U(1,J)=0.0
      V(1,J)=V(2,J)
      GO TO 50
   20 U(1,J)=0.0
      V(1,J)=-V(2,J)*DELX(1)/DELX(2)
      GO TO 50
   30 IF (ITER.GT.0) GO TO 50
      U(1,J)=U(2,J)*(X(2)*RX(1)*CYL+1.0-CYL)
      V(1,J)=V(2,J)
      GO TO 50
   40 U(1,J)=U(IBAR,J)
      V(1,J)=V(IBAR,J)
      F(1,J)=F(IBAR,J)
   50 GO TO (60,70,80,90,80), KR
   60 U(IM1,J)=0.0
      V(IMAX,J)=V(IM1,J)
      GO TO 100
   70 U(IM1,J)=0.0
      V(IMAX,J)=-V(IM1,J)*DELX(IMAX)/DELX(IM1)
      GO TO 100
   80 IF (ITER.GT.0) GO TO 100
      U(IM1,J)=U(IBAR,J)*(X(IBAR)*RX(IM1)*CYL+1.0-CYL)
      V(IMAX,J)=V(IM1,J)
      GO TO 100
   90 U(IM1,J)=U(2,J)
      V(IM1,J)=V(2,J)
      P(IM1,J)=P(2,J)
      PS(IM1,J)=PS(2,J)
      F(IM1,J)=F(2,J)
      V(IMAX,J)=V(3,J)
      F(IMAX,J)=F(3,J)
  100 CONTINUE
      DO 200 I=1,IMAX
      F(I,1)=F(I,2)
      F(I,JMAX)=F(I,JM1)
      P(I,1)=P(I,2)
      P(I,JMAX)=P(I,JM1)
      GO TO (110,120,130,140,130), KT
  110 V(I,JM1)=0.0
      U(I,JMAX)=U(I,JM1)
      GO TO 150
  120 V(I,JM1)=0.0
      U(I,JMAX)=-U(I,JM1)*DELY(JMAX)/DELY(JM1)
      GO TO 150
  130 IF (ITER.GT.0) GO TO 150
      V(I,JM1)=V(I,JBAR)
      U(I,JMAX)=U(I,JM1)
      GO TO 150
  140 V(I,JM1)=V(I,2)
      U(I,JM1)=U(I,2)
      P(I,JM1)=P(I,2)
      PS(I,JM1)=PS(I,2)
      F(I,JM1)=F(I,2)
      U(I,JMAX)=U(I,3)
      F(I,JMAX)=F(I,3)
  150 GO TO (160,170,180,190,180), KB
  160 V(I,1)=0.0
      U(I,1)=U(I,2)
      GO TO 200
  170 V(I,1)=0.0
      U(I,1)=-U(I,2)*DELY(1)/DELY(2)
      GO TO 200
  180 IF (ITER.GT.0) GO TO 200
      V(I,1)=V(I,2)
      U(I,1)=U(I,2)
      GO TO 200
  190 V(I,1)=V(I,JBAR)
      U(I,1)=U(I,JBAR)
      F(I,1)=F(I,JBAR)
```

```
  200 CONTINUE
C
C +++ FREE SURFACE AND SLOPED BOUNDARY CONDITIONS
C
      00 420 1=2. IM1
      DO 420 J=2.JMI
      IF (BETA(I.J)I.GT.O.O) GO TO 210
      BMR=O.O
      BMT=0.O
      BML=C.O
      BMB=O.O
      F(I,J)=O.O
      P(I.J)=O.O
      IF (BETA(I+1,J).GT.O.0) BMR=I.O
      IF (BETA(I.J+I).GT.O.0) BMT=I.O
      IF (BETA(I-I.J).GT.O.0) BML=1.0
      IF {BETA(I,J.I) GT.O.0) BMB=1.0
      BMTOT=BMR+BMT=B[BML+BMB
      IF (BMTOT.LE.O.O) GO TO 420
      F(I. J)=(BMR*F( I+1,J)+BMT*F (I,J+I)+BML*F( -1I,J)+BMB=F( I,J-1))/BMTOT
      P(I, J)=(BMR*P( I+I.J)+BMT*P (I,J+I)+BML+P( I-I,J)+BMB-P (1.d-1))/BMTOT
      GO TO 420
  210 CONTINUE
C
      IF(NF(I .J).EO.O.OR.NF(I ,J).GT.5) GO TO 420
      IF(I. EO.2.AND.KL.EQ.5) GO TO 380
      IF(I. EO. IM1.AND.KR. EQ.5 ) GO TO 380
      IF(J. EQ. IJMI.AND.KT. EQ.5 ) GO TO 380
      IF(J. EQ.2. AND.KB.EQ.5) GO TO 380
C
      IF(NF(I+I .J).LT.6.OR.AR( I.J).LT.EM6) GO TO 240
      U(I. J)=U(I. J)*AR( I-1 ,d)*R(I-1)/(AR(I.J)*R( I))
  240 IF(NF(I, J+I).LT.6.OR. AT(I. LJ).LT.EM6)G0 TO 250
      V(I,J)=V(I,J-1)
  250 IF(NF(I -I,d).LT.6.OR.AR( I-1.d).LT.EM6) GO TO 260
      U(I-I. tJ)=U(I.J)*AR(I.J )*R(I)/(AR(I-I.IJ)*R(I- 1))
  260 IF(NF(I, J-1 ).LT.6.OR.AT (1 .d-1).LT.EM6)" G0 TO 270
      v(I,d-I)=V(I,LJ)
  270 NFF=NF(I,J)
      DIJ=RDX( I)*(AR(I.J)*R( I)*U(I, tJ)-AR(I-I,J)=R( I-1 )*U(I-1.d))+
     1 RDY(J)=(AT( I.tJ)=RI(I )=V(I. J)-AT(I.LI-I)*RI (I)*V(I.J-1))
      LOOP= 0
  300 GO TO (310,320,330,340,350), NFF
  310 IF(NF(I+I .J).LT.6.OR.AR( I,J).LT.EM6) GO TO 350
      UII,J))=U(I,J)-DELX(I)*DId/ (AR(I,LJ)*R(I))
      GO TO 380
  320 IF(NF(I -I,J).LT.6.OR.AR( I-I,d).LT. EM6) GO TO 350
      U(I-I, J)=U(I-I,J)+DELX( I)*DIJ/(AR(I-1.J)=R(I-1 ))
      GO TO 380
  330 IF(NF(I .J+1). LT.6.OR.AT( I.J).LT.EM6) GO TO 350
      V(I.J)=V(I,J)-DELY(I.J)=DIJ/ (AT(I.J)*RI(I))
      GO TO 380
  340 IF(NF(I.J- 1).LT.6.OR.AT( I.J-I). LT.EM6) Go To 350
      V(I.J-I )=V(I,J-I)+DELY (J)*OIJ/(AT(I.J-I)*RI( I))
      GO TO 380
  350 NFF=NFF + 1
      IF(NFF.GT.4) NFF = 1
      LOOP=LOOP + 1
      IF(LOOP.LE.4) GO TO 300
C
C +++ SET VELOCITIES IN EMPTY CELLS ADJACENT TO PARTIAL FLUID CELLS
C
  380 CONTINUE
      IF(FLG. GT.0.5.AN0.1TER .GT.O.AND. ISOR.EO. I) GO TO 420
      IF (F(I+1.J).GT.EMF) GO TO 390
      IF (F(I+1. J+I).LT.EMF.AND .AT(I+1,o).GT. EM6) v(=1+J)=F(I.J)*V(I.J)
      IF (F(I1I, J-1).LT.EMF.AND .AT(I+1, J-1) .GT.EM6) v(I+1,J-I)=V(I,LJ-1)
     1 *F(I,J)
  390 IF (F(IJ+1).GT.EMF) GO TO 400
      IF (F(I+1,J+I ).LT.EMF.ANDO. AR(I,J+1).GT.EM6) U(I.J+1)=F(I,J)*U(I.J)
      IF (F(I1I, J+1).LT.EMF.AND. AR(I-1, J+1).GT.EM6) U(I-1,J+I)=U(I-1,J)
     1 *F(I,J)
  400 IF (F(I-1.J).GT.EMF) GO TO 410
      IF (F(I-1.J+1 ).LT.EMF.AND. AT(I-1, J).GT.EM6) V(I-1,J)=F(I,J)*V(I,J)
      IF (F(I-1,J- 1).LT.EMF.AND. AT(I-1, J-1) .GT.EM6) v(I-1,J-I)=V(I,J-1)
     1 *F(I,J)
  410 IF (F(I,J-1).GT.EMF) GO TO 420
      IF (F(I+1,J- 1) .LT.EMF.At4D.AR( I,J-1).GT.EM6) U(I,J-1)=F(I.J)*U(I,J)
      IF (F(I-1,J- 1).LT.EMF.AND. AR(I-1, J-1) .GT.EM6) U(I-1,J-I)=U(I-I,1J)
     1*F(I-J)
```

```
  420 CONTINUE
C
C +++ SPECIAL VELOCITY BOUNDARY CONDITIONS
C
      RETURN
      END


      SUBROUTINE CAVOVO
*CALL,COMMON1
C
C +++ CALCULATE VOID VOLUMES
C
C +++ INITIALIZE VOID VOLUMES
C
      DO 10 K=1,NVOR
   10 VOL(K)=0.0
C
C +++ COMPUTE VOID REGION VOLUMES
C
      DO 30 J=2,JM1
      DO 30 I=2,IM1
      INF=NF(I,J)
      IF (INF.GT.NVOR) GO TO 40
      IF (INF.EQ.0.OR.BETA(I,J).LT.0.0) GO TO 30
      VOLA=(1.0-F(I,J))*AC(I,J)*TPI*RI(I)*DELX(I)*DELY(J)
      IF (INF.GT.5) GO TO 20
      INFR=NF(I+1,J)
      INFT=NF(I,J+1)
      INFL=NF(I-1,J)
      INFB=NF(I,J-1)
      INF=MAX0(INFR,INFT,INFL,INFB)
   20 VOL(INF)=VOL(INF)+VOLA
   30 CONTINUE
      RETURN
   40 CONTINUE
      WRITE (59,50) I,J,INF,NVOR,NCYC
      WRITE (12,50) I,J,INF,NVOR,NCYC
      CALL EXITLDC (6HCAVOVO)
C
   50 FORMAT (1X,5H*****,1X,25HNVOR IS TOO SMALL - I,J =,2I5,1X,4HNF =
     1 ,I5,1X,6HNVOR =,I5,1X,7HCYCLE =,I7)
      END


      SUBROUTINE DELTADJ
*CALL,COMMON1
      DATA LITER / 15 /
      DATA ITMIN /5/, ITMOST /30/
      DATA ITCUR / 100 /
C
C +++ DELT (TIME STEP) ADJUSTMENT
C
      DELTN=DELT
      IF (FLGC.LT.0.5) GO TO 20
      T=T-DELT
      NCYC=NCYC-1
      DELT=0.8*DELT
      DO 10 I=1,IMAX
      DO 10 J=1,JMAX
      P(I,J)=PN(I,J)
      F(I,J)=FN(I,J)
      U(I,J)=0.0
      V(I,J)=0.0
   10 CONTINUE
      FLGC=0.0
      NFLGC=NFLGC+1
   20 CONTINUE
      IF (AUTOT.LT.0.5.AND.FNOC.LT.0.5) GO TO 40
      DUMX=EM10
      DVMX=EM10
      IF (FNOC.GT.0.5) DELT=DELT*0.8
      DO 30 I=1,IM1
      DO 30 J=2,JM1
      UDM=ABS(UN(I,J))/(XI(I+1)-XI(I))
      VDM=ABS(VN(I,J))/(YJ(J+1)-YJ(J))
      DUMX=AMAX1(DUMX,UDM)
      DVMX=AMAX1(DVMX,VDM)
```

```
   30 CONTINUE                                                                DELTADJ.35
      DTMP=1.01                                                               DELTADJ.36
      IF(ITER.LT.ITMIN) DTMP=1.02                                             DELTADJ.37
      IF(ISOR.EQ.0) GO TO 32                                                  DELTADJ.38
      IF(ITER.GT.ITMOST.AND.LITER.GT.ITMOST) DTMP=0.99                        DELTADJ.39
      GO TO 34                                                                DELTADJ.40
   32 IF(ITER.GT.ITCJR.AND.LITER.GT.ITCJR) DTMP=0.99                          DELTADJ.41
   34 CONTINUE                                                                DELTADJ.42
      DELTO=DELT*DTMP                                                         DELTADJ.43
      DELTO=AMIN1(DELTO,DTCRMX)                                               DELTADJ.44
      DELT=AMIN1(DELTO,CON/DUMX,CON/DVMX,DTVIS,DTSFT)                         DELTADJ.45
      IF (IMOVY.GT.0) DELT=AMIN1(DELT,PLTDT)                                  DELTADJ.46
   40 IF (DELT.EQ.DELTN) GO TO 60                                             DELTADJ.47
      DO 50 I=2,IM1                                                           DELTADJ.48
      DO 50 J=2,JM1                                                           DELTADJ.49
      IF (AC(I,J).LT.EM6) GO TO 50                                            DELTADJ.50
      RHXR=RHOF*(DELX(I+1)+DELX(I))                                           DELTADJ.51
      RHXL=RHOF*(DELX(I)+DELX(I-1))                                           DELTADJ.52
      RHYT=RHOF*(DELY(J+1)+DELY(J))                                           DELTADJ.53
      RHYB=RHOF*(DELY(J)+DELY(J-1))                                           DELTADJ.54
      XX=DELT*RDX(I)*(2.0*AR(I-1,J)*R(I-1)/RHXL+2.0*AR(I,J)*R(I)/RHXR)+       DELTADJ.55
     1 DELT*RDY(J)*(2.0*AT(I,J)*RI(I)/RHYT+2.0*AT(I,J-1)*RI(I)/RHYB)          DELTADJ.56
      XX=XX/(AC(I,J)*RI(I))                                                   DELTADJ.57
      BETA(I,J)=OMG/XX                                                        DELTADJ.58
   50 CONTINUE                                                                DELTADJ.59
   60 CONTINUE                                                                DELTADJ.60
      LITER=ITER                                                              DELTADJ.61
      RETURN                                                                  DELTADJ.62
      END                                                                     DELTADJ.63
```

```
      SUBROUTINE DRAW                                                         DRAW.2
*CALL,COMMON1                                                                 DRAW.3
C                                                                             DRAW.4
C +++ PLOT VELOCITY VECTOR, FREE SURFACE, MESH,                                DRAW.5
C                                                                             DRAW.6
      NTIMES=1                                                                DRAW.7
      DO 70 MESSUP=1,NTIMES                                                   DRAW.8
C +++                                                                         DRAW.9
C +++ DRAW VELOCITY VECTOR PLOT                                               DRAW.10
C +++                                                                         DRAW.11
      WRITE (59,170) T,NCYC,ITER,DELT                                         DRAW.12
C                                                                             DRAW.13
      CALL ADV (1)                                                            DRAW.14
      IF (IMOVY.EQ.1) CALL COLOR (0.)                                         DRAW.15
      CALL FRAME (XMIN,XMAX,YMAX,YMIN)                                        DRAW.16
      IF (IMOVY.NE.1) GO TO 10                                                DRAW.17
      CALL COLOR (2.)                                                         DRAW.18
      ENCODE (8,180,LABS) T                                                   DRAW.19
      CALL DLCH (650,100,8,LABS,3)                                            DRAW.20
      CALL DLCH (650,100,8,LABS,3)                                            DRAW.21
      ENCODE (15,190,LABS) FVOL                                               DRAW.22
      CALL DLCH (200,105,10,10HLOS ALAMOS,2)                                  DRAW.23
      CALL DLCH (200,105,10,10HLOS ALAMOS,2)                                  DRAW.24
      CALL COLOR (0.)                                                         DRAW.25
      GO TO 20                                                                DRAW.26
   10 CONTINUE                                                                DRAW.27
      CALL LINCNT (1)                                                         DRAW.28
      WRITE (12,200) T,NCYC,NAME                                              DRAW.29
   20 CONTINUE                                                                DRAW.30
      CALL DRWOBS                                                             DRAW.31
      IF (IMOVY.EQ.1) CALL COLOR (1.5)                                        DRAW.32
      VELNEW=0.                                                               DRAW.33
      DO 30 I=2,IM1                                                           DRAW.34
      ACELH=0.5*CYL+1.0-CYL                                                   DRAW.35
      DO 30 J=2,JM1                                                           DRAW.36
      IF (F(I,J).LT.0.5) GO TO 30                                             DRAW.37
      IF (AC(I,J).LT.ACELH) GO TO 30                                          DRAW.38
      XCC=XI(I)                                                               DRAW.39
      YCC=0.5*(Y(J)+Y(J-1))                                                   DRAW.40
      UMPL=0.0                                                                DRAW.41
      VMPL=0.0                                                                DRAW.42
      IF (AR(I,J).GT.EM6) UMPL=1.0                                            DRAW.43
      IF (AR(I-1,J).GT.EM6) UMPL=1.0/(1.0+UMPL)                               DRAW.44
      IF (AT(I,J).GT.EM6) VMPL=1.0                                            DRAW.45
      IF (AT(I,J-1).GT.EM6) VMPL=1.0/(1.0+VMPL)                               DRAW.46
      UPLT=UMPL*(U(I-1,J)+U(I,J))                                             DRAW.47
      VPLT=VMPL*(V(I,J-1)+V(I,J))                                             DRAW.48
      VELNEW=AMAX1(VELNEW,ABS(UPLT),ABS(VPLT))                                DRAW.49
```

```
      UVEC=UPLT*VELMX1+XCC
      VVEC=VPLT*VELMX1+YCC
      CALL DRWVEC (XCC,YCC,UVEC,VVEC,1)
      CALL PLTPT (XCC,YCC,53B,1)
   30 CONTINUE
C +++ IF(NCYC.GT.5)VELNEW=VELNEW
      IF (IMOVY.EQ.1) CALL COLOR (2.5)
C +++ COLOR CODE - O. WHITE, 1. RED, 1.5 YELLOW, 2. GREEN, 2.5 CYAN,
C +++ 3. BLUE, 3.5 MAGENTA
      VELMX1=AMIN1(DXMIN,DYMIN)/VELMX
C
C +++ DRAW FREE SURFACE
C
   40 CONTINUE
      FPL=0.5
      DO 60 I=2,IM1
      DO 60 J=2,JM1
      IF (BETA(I,J).LT.0.0) GO TO 60
      FATR=0.25*(F(I,J)+F(I+1,J)+F(I,J+1)+F(I+1,J+1))
      FXTR=0.5*(F(I+1,J+1)+F(I+1,J)-F(I,J+1)-F(I,J))/(XI(I+1)-XI(I))
      FYTR=0.5*(F(I,J+1)+F(I+1,J+1)-F(I,J)-F(I+1,J))/(YJ(J+1)-YJ(J))
      FTRS=FXTR**2+FYTR**2
      IF (FTRS.EQ.0.0) FTRS=EP10
      XTR=0.5*(XI(I+1)+XI(I))+(FPL-FATR)*FXTR/FTRS
      XTR=AMAX1(XTR,XI(I))
      XTR=AMIN1(XTR,XI(I+1))
      YTR=0.5*(YJ(J)+YJ(J+1))+(FPL-FATR)*FYTR/FTRS
      YTR=AMAX1(YTR,YJ(J))
      YTR=AMIN1(YTR,YJ(J+1))
      IF (F(I,J).GT.0.5.AND.F(I+1,J).GT.0.5) GO TO 50
      IF (F(I,J).LT.0.5.AND.F(I+1,J).LT.0.5) GO TO 50
      FABR=0.25*(F(I,J)+F(I+1,J)+F(I,J-1)+F(I+1,J-1))
      FXBR=0.5*(F(I+1,J)+F(I+1,J-1)-F(I,J)-F(I,J-1))/(XI(I+1)-XI(I))
      FYBR=0.5*(F(I,J)+F(I+1,J)-F(I,J-1)-F(I+1,J-1))/(YJ(J)-YJ(J-1))
      FBRS=FXBR**2+FYBR**2
      IF (FBRS.EQ.0.0) FBRS=EP10
      XBR=0.5*(XI(I+1)+XI(I))+(FPL-FABR)*FXBR/FBRS
      XBR=AMAX1(XBR,XI(I))
      XBR=AMIN1(XBR,XI(I+1))
      YBR=0.5*(YJ(J)+YJ(J-1))+(FPL-FABR)*FYBR/FBRS
      YBR=AMAX1(YBR,YJ(J-1))
      YBR=AMIN1(YBR,YJ(J))
      CALL DRWVEC (XBR,YBR,XTR,YTR,1)
   50 CONTINUE
      IF (F(I,J).GT.0.5.AND.F(I,J+1).GT.0.5) GO TO 60
      IF (F(I,J).LT.0.5.AND.F(I,J+1).LT.0.5) GO TO 60
      FATL=0.25*(F(I,J)+F(I,J+1)+F(I-1,J)+F(I-1,J+1))
      FXTL=0.5*(F(I,J+1)+F(I,J)-F(I-1,J+1)-F(I-1,J))/(XI(I)-XI(I-1))
      FYTL=0.5*(F(I-1,J+1)+F(I,J+1)-F(I-1,J)-F(I,J))/(YJ(J+1)-YJ(J))
      FTLS=FXTL**2+FYTL**2
      IF (FTLS.EQ.0.0) FTLS=EP10
      XTL=0.5*(XI(I-1)+XI(I))+(FPL-FATL)*FXTL/FTLS
      XTL=AMAX1(XTL,XI(I-1))
      XTL=AMIN1(XTL,XI(I))
      YTL=0.5*(YJ(J)+YJ(J+1))+(FPL-FATL)*FYTL/FTLS
      YTL=AMAX1(YTL,YJ(J))
      YTL=AMIN1(YTL,YJ(J+1))
      CALL DRWVEC (XTL,YTL,XTR,YTR,1)
   60 CONTINUE
   70 CONTINUE
      IF (IMOVY.EQ.1.AND.NCYC.EQ.1) CALL ADV (2)
      IF (IMOVY.EQ.1) CALL COLOR (0.)
      IF (IMOVY.EQ.1) GO TO 160
      DMPX=XI(IMAX)-XI(1)
      DMPY=YJ(JMAX)-YJ(1)
      CALL CONTRJB (XI,-IMAX,YJ,-JMAX,F,IBAR2,JBAR2,11,-1.,-1.,0.,ZC
     1 ,DMPX,DMPY,0,1HF,1,1HX,1,1HY,1)
      CALL CONTRJB (XI,-IMAX,YJ,-JMAX,P,IBAR2,JBAR2,11,-1.,-1.,0.,ZC
     1 ,DMPX,DMPY,0,1HP,1,1HX,1,1HY,1)
      CALL ADV(1)
C
C +++ MESH PLOT
C
      IF (T.GT.0.0) GO TO 100
      CALL ADV (1)
      CALL DRWOBS
      DO 80 J=1,JM1
      YCC=Y(J)
      CALL DRWVEC (XMIN,YCC,XMAX,YCC,0)
```

```
   80 CONTINUE
      DO 90 I=1,IM1
      XCC=X(I)
      CALL DRWVEC (XCC,YMIN,XCC,YMAX,1)
   90 CONTINUE
  100 CONTINUE
C
      CALL ADV(1)
  150 CONTINUE
  160 CONTINUE
      RETURN
C
  170 FORMAT (1X,2HT=,1PE12.5,6H NCYC=,I6,6H ITER=,I5,6H DELT=,E11.4,6H
     1PLOTS)
  180 FORMAT (4HT = ,F4.2)
  190 FORMAT (9HLIQ VOL =,F6.2)
  200 FORMAT (1X,2HT=,1PE11.4,2X,6HCYCLE=,I7,2X,10A8)
      END
```

```
      SUBROUTINE DRWOBS
*CALL,COMMON1
C
C +++ DRAW AROUND ALL OBSTACLES
C
      DO 170 I=2,IM1
      ATR=1.0-EM6
      ATL=1.0-EM6
      IF(I.EQ.2.AND.CYL.EQ.1.0) ATL=-EM6
      ATC=1.0-EM6
      DO 170 J=2,JM1
      IF (AC(I,J).LT.EM6) GO TO 170
      AFR=1.0
      AFT=1.0
      AFL=1.0
      AFB=1.0
      IF (AR(I,J).LT.ATR) AFR=AR(I,J)/ATR
      IF (AT(I,J).LT.ATC) AFT=AT(I,J)/ATC
      IF (AR(I-1,J).LT.ATL) AFL=AR(I-1,J)/ATL
      IF (AT(I,J-1).LT.ATC) AFB=AT(I,J-1)/ATC
      IF (AC(I,J).GE.ATC) GO TO 120
      IF (I.EQ.2) AFL=AFR-EM6
      IF (I.EQ.IM1) AFR=AFL-EM6
      IF (J.EQ.2) AFB=AFT-EM6
      IF (J.EQ.JM1) AFT=AFB-EM6
      IF ((AFT+AFB).LT.EM6.OR.(AFL+AFR).LT.EM6) GO TO 170
      M=1
      AMN=AFB+AFR
      IF ((AFR+AFT).GT.AMN) GO TO 10
      M=2
      AMN=AFR+AFT
   10 IF ((AFT+AFL).GT.AMN) GO TO 20
      M=3
      AMN=AFT+AFL
   20 IF ((AFL+AFB).GT.AMN) GO TO 30
      M=4
   30 GO TO (40,60,80,100), M
   40 X1=X(I-1)+AFT*DELX(I)
      Y1=Y(J)
      IF (AFT.LT.1.0) GO TO 50
      Y1=Y1-AFR*DELY(J)
   50 X2=X(I-1)
      Y2=Y(J)-AFL*DELY(J)
      IF (AFL.LT.1.0) GO TO 160
      X2=X2+AFB*DELX(I)
      GO TO 160
   60 X1=X(I-1)
      Y1=Y(J-1)+AFL*DELY(J)
      IF (AFL.LT.1.0) GO TO 70
      X1=X1+AFT*DELX(I)
   70 X2=X(I-1)+AFB*DELX(I)
      Y2=Y(J-1)
      IF (AFB.LT.1.0) GO TO 160
      Y2=Y2+AFR*DELY(J)
      GO TO 160
   80 X1=X(I)-AFB*DELX(I)
      Y1=Y(J-1)
      IF (AFB.LT.1.0) GO TO 90
      Y1=Y1+AFL*DELY(J)
```

```
   90 X2=X(I)                                                          DRWOBS.61
      Y2=Y(J-1)+AFR*DELY(J)                                            DRWOBS.62
      IF (AFR.LT.1.0) GO TO 160                                        DRWOBS.63
      X2=X2-AFT*DELX(I)                                                DRWOBS.64
      GO TO 160                                                        DRWOBS.65
  100 X1=X(I)                                                          DRWOBS.66
      Y1=Y(J)-AFR*DELY(J)                                              DRWOBS.67
      IF (AFR.LT.1.0) GO TO 110                                        DRWOBS.68
      X1=X1-AFB*DELX(I)                                                DRWOBS.69
  110 X2=X(I)-AFT*DELX(I)                                              DRWOBS.70
      Y2=Y(J)                                                          DRWOBS.71
      IF (AFT.LT.1.0) GO TO 160                                        DRWOBS.72
      Y2=Y2-AFL*DELY(J)                                                DRWOBS.73
      GO TO 160                                                        DRWOBS.74
  120 IF (AFR.GT.EM6) GO TO 130                                        DRWOBS.75
      X1=X(I)                                                          DRWOBS.76
      Y1=Y(J-1)                                                        DRWOBS.77
      X2=X1                                                            DRWOBS.78
      Y2=Y(J)                                                          DRWOBS.79
      CALL DRWVEC (X1,Y1,X2,Y2,1)                                      DRWOBS.80
  130 IF (AFT.GT.EM6) GO TO 140                                        DRWOBS.81
      X1=X(I-1)                                                        DRWOBS.82
      Y1=Y(J)                                                          DRWOBS.83
      X2=X(I)                                                          DRWOBS.84
      Y2=Y1                                                            DRWOBS.85
      CALL DRWVEC (X1,Y1,X2,Y2,1)                                      DRWOBS.86
  140 IF (AFL.GT.EM6) GO TO 150                                        DRWOBS.87
      X1=X(I-1)                                                        DRWOBS.88
      Y1=Y(J)                                                          DRWOBS.89
      X2=X1                                                            DRWOBS.90
      Y2=Y(J-1)                                                        DRWOBS.91
      CALL DRWVEC (X1,Y1,X2,Y2,1)                                      DRWOBS.92
  150 IF (AFB.GT.EM6) GO TO 170                                        DRWOBS.93
      X1=X(I-1)                                                        DRWOBS.94
      Y1=Y(J-1)                                                        DRWOBS.95
      X2=X(I)                                                          DRWOBS.96
      Y2=Y1                                                            DRWOBS.97
      CALL DRWVEC (X1,Y1,X2,Y2,1)                                      DRWOBS.98
  160 CALL DRWVEC (X1,Y1,X2,Y2,1)                                      DRWOBS.99
  170 CONTINUE                                                         DRWOBS.100
      RETURN                                                           DRWOBS.101
      END                                                              DRWOBS.102
```

```
      SUBROUTINE DRWVEC (XONE,YONE,XTWO,YTWO,ISYM)                     DRWVEC.2
*CALL,COMMON1                                                          DRWVEC.3
C                                                                      DRWVEC.4
C +++ DRAW A VECTOR                                                    DRWVEC.5
C +++ PROVIDES A SYSTEM DEPENDANT CALL                                 DRWVEC.6
C                                                                      DRWVEC.7
      IC=0                                                             DRWVEC.8
      X1=XONE                                                          DRWVEC.9
      Y1=YONE                                                          DRWVEC.10
      X2=XTWO                                                          DRWVEC.11
      Y2=YTWO                                                          DRWVEC.12
   10 XO1=(X1-XMIN)*SF+XSHFT                                           DRWVEC.13
      YO1=(Y1-YMIN)*SF+YSHFT                                           DRWVEC.14
      XO2=(X2-XMIN)*SF+XSHFT                                           DRWVEC.15
      YO2=(Y2-YMIN)*SF+YSHFT                                           DRWVEC.16
      IX1=50.+920.0*XO1                                                DRWVEC.17
      IX2=50.+920.0*XO2                                                DRWVEC.18
      IY1=50.+920.0*(1.0-YO1)                                          DRWVEC.19
      IY2=50.+920.0*(1.0-YO2)                                          DRWVEC.20
      CALL DRV (IX1,IY1,IX2,IY2)                                       DRWVEC.21
      IF (ISYMPLT.EQ.0.OR.ISYM.EQ.0) GO TO 20                          DRWVEC.22
      IC=IC+1                                                          DRWVEC.23
      IF (IC.GT.1) GO TO 20                                            DRWVEC.24
      X1=-X1                                                           DRWVEC.25
      X2=-X2                                                           DRWVEC.26
      GO TO 10                                                         DRWVEC.27
   20 RETURN                                                           DRWVEC.28
      END                                                              DRWVEC.29
```

```
      SUBROUTINE DVCAL
*CALL,COMMON1

      DATA ISLIP / 0 /

C       ISLIP = 0    FREE-SLIP-LIKE FOR CURVED INTERIOR BOUNDARIES
C
C
C       ISLIP = 1    STANDARD FREE SLIP CONDITION MOST CODES
C
      DUDR=(UN(I+1,J)-UN(I,J))*RDX(I+1)
      DUDL=(UN(I,J)-UN(I-1,J))*RDX(I)
      DUDT=(UN(I,J+1)-UN(I,J))*2.0/(DELY(J)+DELY(J+1))
      DUDB=(UN(I,J)-UN(I,J-1))*2.0/(DELY(J)+DELY(J-1))
      DVDR=(VN(I+1,J)-VN(I,J))*2.0/(DELX(I)+DELX(I+1))
      DVDL=(VN(I,J)-VN(I-1,J))*2.0/(DELX(I)+DELX(I-1))
      DVDT=(VN(I,J+1)-VN(I,J))*RDY(J+1)
      DVDB=(VN(I,J)-VN(I,J-1))*RDY(J)
C
      IF(ISLIP.NE.0) GO TO 20
      IF(AR(I+1,J).LT.EM6)DUDR=0.0
      IF(AR(I-1,J).LT.EM6)DUDL=0.0
      IF(AR(I,J+1).LT.EM6)DUDT=0.0
      IF(AR(I,J-1).LT.EM6)DUDB=0.0
      IF(AT(I+1,J).LT.EM6)DVDR=0.0
      IF(AT(I-1,J).LT.EM6)DVDL=0.0
      IF(AT(I,J+1).LT.EM6)DVDT=0.0
      IF(AT(I,J-1).LT.EM6)DVDB=0.0
      GO TO 40
   20 IF(ISLIP.NE.1) GO TO 40
      IF(AR(I,J+1).LT.EM6) DUDT=0.0
      IF(AR(I,J-1).LT.EM6) DUDB=0.0
      IF(AT(I+1,J).LT.EM6) DVDR=0.0
      IF(AT(I-1,J).LT.EM6) DVDL=0.0
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE EQUIB (Y,Z,NX1,BOND,CANGLE,CYL)
      DIMENSION Y(NX1), Z(NX1)
      DATA PI /3.141592654/, EPS /1.E-04/
C +++
C +++ USEFUL INTERMEDIATE QUANTITIES
C +++
      RANGLE=CANGLE*PI/180..
      COSTST=COS(RANGLE)
      COSCA=(1.-CYL)*COS(RANGLE)
      OMCYL=1.-CYL
      NX=NX1-1
      DR=1./FLOAT(NX)
      ITER=0
C +++
C +++ SET INITIAL GUESS FOR Y(1)
C +++
      Y(1)=0.
      IF (ABS(BOND).GT.0.) Y(1)=-COSCA/(2.*ABS(BOND))
C +++
C +++ NUMERICAL INTEGRATION
C +++
   10 Z(1)=0.
      ITER=ITER+1
      Z(NX1+1)=0.
      WRITE (8,100) Y(1)
      DO 20 J=2,NX1
      RJM=DR*FLOAT(J-2)*CYL+OMCYL
      RJ=DR*FLOAT(J-1)*CYL+OMCYL
      RJH=0.5*(RJM+RJ)
      Z(J)=Z(J-1)*RJM/RJ+DR*(RJH/RJ)*(COSCA-BOND*(Y(J-1)+0.5*DR*Z(J-1)
     1 /SQRT(1.-Z(J-1)**2)))
      IF (ABS(Z(J)).GE.1.) GO TO 30
      SLOPE=Z(J)/SQRT(1.-Z(J)**2)
      SLOPF=Z(J-1)/SQRT(1.-Z(J-1)**2)
      Z(NX1+J)=(SLOPE-SLOPF)/(DR*(1.+SLOPE**2)**1.5)
      Y(J)=Y(J-1)+0.5*DR*(Z(J)/SQRT(1.-Z(J)**2)+Z(J-1)/SQRT(1.-Z(J-1)**2
     1 ))
   20 CONTINUE
      GO TO 40
```

```
   30 CONTINUE
      WRITE (8,110) J,Z(J)
      Y(1)=Y(1)*1.05
      WRITE (8,120) Z(NX1)
      IF (ITER.GT.400) GO TO 60
      GO TO 10
C +++
C +++ CHECK CONSTRAINT AND CONVERGENCE
C +++
   40 CONTINUE
      WRITE (8,130)
      YSUM=0.5*DR*Y(NX1)
      DO 50 J=2,NX
      YSUM=YSUM+(FLOAT(J-1)*DR*CYL+OMCYL)*DR*Y(J)
   50 CONTINUE
      WRITE (8,140) YSUM,Y(1),Z(NX1),COSTST
      IF (ABS(Z(NX1)-COS(RANGLE)).LE.EPS.AND.BOND.NE.0.) GO TO 70
      IF (ABS(YSUM).LT.EPS.AND.BOND.EQ.0.) GO TO 70
      Y(1)=Y(1)-YSUM/(OMCYL+CYL*2.)
      IF (ITER.GT.400) GO TO 60
      GO TO 10
C +++
C +++ EXIT IF CONVERGENCE FAILS
C +++
   60 CONTINUE
      WRITE (59,150)
      CALL EXITLDC (5HEQUIB)
   70 CONTINUE
      WRITE (8,80) (I,Y(I),Z(I),Z(NX1+I),I=1,NX1)
      WRITE (59,90)
      WRITE (8,90)
      RETURN
C
   80 FORMAT (///3X,1HI,8X,1HY,11X,1HZ,9X,3HKXY/(1X,I3,1P3E12.4))
   90 FORMAT (15H FINISHED EQUIB)
  100 FORMAT (1X,17HSTEP B WITH Y(1)=,1PE14.6)
  110 FORMAT (1X,9HZ TOO BIG,I5,1PE12.4)
  120 FORMAT (1X,17HGO TO STEP B   Z=,1PE12.4)
  130 FORMAT (1X,23HPARTS B AND C CONVERGED)
  140 FORMAT (1X,5HYSUM=,1PE13.5,4H Y1=,E13.5,4H ZN=E13.5,5H COS=,E13.5)
  150 FORMAT (1X,28H*** EQUIB FAILED TO CONVERGE)
      END
```

```
      SUBROUTINE EXITLDC (IILDC)
*CALL,COMMON1
      CALL ADV (1)
      WRITE (59,10) NCYC,IILDC
      WRITE (12,10) NCYC,IILDC
      CALL EXIT
C
   10 FORMAT (1X,20HTERMINATION ON CYCLE,I7,6H FROM ,A8)
      END
```

```
      SUBROUTINE FRAME (XXL,XXR,YYT,YYB)
C
C +++ DRAW A FRAME AROUND THE PLOT
C
      CALL DRWVEC (XXL,YYT,XXR,YYT,0)
      CALL DRWVEC (XXL,YYT,XXL,YYB,0)
      CALL DRWVEC (XXL,YYB,XXR,YYB,0)
      CALL DRWVEC (XXR,YYB,XXR,YYT,0)
      RETURN
      END
```

```
      SUBROUTINE LAVORE
*CALL,COMMON1
C
C +++ LABEL VOID REGIONS - - VOID REGIONS ARE NF.EQ.6 AND ABOVE
C
      NNR=6
      NVR=6
      DO 30 J=2,JM1
      DO 30 I=2,IM1
      IF (NF(I,J).LT.6) GO TO 30
      INFB=NF(I,J-1)
      INFL=NF(I-1,J)
      IF (INFB.LT.6.AND.INFL.LT.6) GO TO 20
      IF (INFB.LT.6.OR.INFL.LT.6) GO TO 10
      NF(I,J)=MINO(INFB,INFL)
      INRB=NR(INFB)
      INRL=NR(INFL)
      INRMN=MINO(INRB,INRL)
      INRMX=MAXO(INRB,INRL)
      NR(INRMX)=INRMN
      NR(INFB)=INRMN
      NR(INFL)=INRMN
      GO TO 30
   10 NF(I,J)=INFB
      IF (INFB.LT.6) NF(I,J)=INFL
      GO TO 30
   20 NF(I,J)=NVR
      NR(NVR)=NNR
      NVR=NVR+1
      NNR=NNR+1
      IF(NNR.LE.NVOR) GO TO 30
C
C      NVOR TOO SMALL
C
      WRITE (59,70) I,J,NNR,NVOR,NCYC
      WRITE (12,70) I,J,NNR,NVOR,NCYC
      CALL EXITLDC (6HLAVORE)
C
   70 FORMAT (1X,5H*****,1X,25HNVOR IS TOO SMALL - I,J =,2I5,1X,4HNF =
     1 ,I5,1X,6HNVOR =,I5,1X,7HCYCLE =,I7)
   30 CONTINUE
      NVR1=NVR-1
      NNR1=NNR-1

       REDUCE NR TO LOWEST VALUE

      DO 38 K=6,NVR1
      KK=NVR1+6-K
      KN=KK
   32 IF(NR(KN).EQ.KN) GO TO 34
      KN=NR(KN)
      GO TO 32
```

```
   34 NR(KK)=KN
   38 CONTINUE
C
C +++ REDEFINE REGION NUMBERS TO BE CONSECUTIVE
C
      KKN=6
      DO 50 KK=6,NNR1
      KFLG=0
      DO 40 K=KK,NVR1
      IF (NR(K).NE.KK) GO TO 40
      NR(K)=KKN
      KFLG=1
   40 CONTINUE
      IF (KFLG.EQ.1) KKN=KKN+1
   50 CONTINUE
      NREG=KKN-6
C
C +++ REDEFINE VOID NUMBERS TO BE CONSECUTIVE IF NREG.GT.1
C      CHECK FOR CORRESPONDENCE WITH OLD REGIONS
C
      DO 60 J=2,JM1
      DO 60 I=2,IM1
      INF=NF(I,J)
      IF (INF.LT.6) GO TO 60.
      NF(I,J)=NR(INF)
   60 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MESHSET
*CALL,COMMON1
C
C +++ MESH SETUP  (GENERATION)
C
      I=1
      J=1
      X(1)=XL(1)
      Y(1)=YL(1)
      DO 40 K=1,NKX
      IF (NXL(K).EQ.0) GO TO 20
      DXML=(XC(K)-XL(K))/NXL(K)
      NT=NXL(K)
      TN=NT
      TN=AMAX1(TN,1.0+EM6)
      DXMN1=AMIN1(DXMN(K),DXML)
      CMC=(XC(K)-XL(K)-TN*DXMN1)*TN/(TN-1.0)
      IF (NT.EQ.1) CMC=0.0
      BMC=XC(K)-XL(K)-CMC
      DO 10 L=1,NT
      I=I+1
      RLN=(FLOAT(L)-TN)/TN
   10 X(I)=XC(K)+BMC*RLN-CMC*RLN*RLN
   20 IF (NXR(K).EQ.0) GO TO 40
      DXMR=(XL(K+1)-XC(K))/NXR(K)
      NT=NXR(K)
      TN=NT
      TN=AMAX1(TN,1.0+EM6)
      DXMN1=AMIN1(DXMN(K),DXMR)
      CMC=(XL(K+1)-XC(K)-TN*DXMN1)*TN/(TN-1.0)
      IF (NT.EQ.1) CMC=0.0
      BMC=XL(K+1)-XC(K)-CMC
      DO 30 L=1,NT
      I=I+1
      RLN=FLOAT(L)/TN
   30 X(I)=XC(K)+BMC*RLN+CMC*RLN*RLN
   40 CONTINUE
      IF (KR.NE.4) GO TO 50
      I=I+1
      X(I)=X(I-1)+X(2)-X(1)
   50 CONTINUE
      DO 90 K=1,NKY
      IF (NYL(K).EQ.0) GO TO 70
      DYML=(YC(K)-YL(K))/NYL(K)
      NT=NYL(K)
      TN=NT
      TN=AMAX1(TN,1.0+EM6)
```

```
      DYMN1=AMIN1(DYMN(K),DYML)                                         MESHSET.49
      CMC=(YC(K)-YL(K)-TN*DYMN1)*TN/(TN-1.0)                            MESHSET.50
      IF (NT.EQ.1) CMC=0.0                                              MESHSET.51
      BMC=YC(K)-YL(K)-CMC                                               MESHSET.52
      DO 60 L=1,NT                                                      MESHSET.53
      J=J+1                                                             MESHSET.54
      RLN=(FLOAT(L)-TN)/TN                                              MESHSET.55
   60 Y(J)=YC(K)+BMC*RLN-CMC*RLN*RLN                                    MESHSET.56
   70 IF (NYR(K).EQ.0) GO TO 90                                         MESHSET.57
      DYMR=(YL(K+1)-YC(K))/NYR(K)                                       MESHSET.58
      NT=NYR(K)                                                         MESHSET.59
      TN=NT                                                             MESHSET.60
      TN=AMAX1(TN,1.0+EM6)                                              MESHSET.61
      DYMN1=AMIN1(DYMN(K),DYMR)                                         MESHSET.62
      CMC=(YL(K+1)-YC(K)-TN*DYMN1)*TN/(TN-1.0)                          MESHSET.63
      IF (NT.EQ.1) CMC=0.0                                              MESHSET.64
      BMC=YL(K+1)-YC(K)-CMC                                             MESHSET.65
      DO 80 L=1,NT                                                      MESHSET.66
      J=J+1                                                             MESHSET.67
      RLN=FLOAT(L)/TN                                                   MESHSET.68
   80 Y(J)=YC(K)+BMC*RLN+CMC*RLN*RLN                                    MESHSET.69
   90 CONTINUE                                                          MESHSET.70
      IF (KT.NE.4) GO TO 100                                            MESHSET.71
      J=J+1                                                             MESHSET.72
      Y(J)=Y(J-1)+Y(2)-Y(1)                                             MESHSET.73
  100 CONTINUE                                                          MESHSET.74
      NUMX=I                                                            MESHSET.75
      NUMY=J                                                            MESHSET.76
      NUMXM1=NUMX-1                                                     MESHSET.77
      NUMYM1=NUMY-1                                                     MESHSET.78
      NUMXP1=NUMX+1                                                     MESHSET.79
      NUMYP1=NUMY+1                                                     MESHSET.80
      IBAR=NUMX-1                                                       MESHSET.81
      JBAR=NUMY-1                                                       MESHSET.82
      IMAX=IBAR+2                                                       MESHSET.83
      JMAX=JBAR+2                                                       MESHSET.84
      IM1=IMAX-1                                                        MESHSET.85
      JM1=JMAX-1                                                        MESHSET.86
C                                                                       MESHSET.87
C +++ CALCULATE VALUES NEEDED FOR VARIABLE MESH                         MESHSET.88
C                                                                       MESHSET.89
      DO 120 I=1,NUMX                                                   MESHSET.90
      IF (X(I).EQ.0.0) GO TO 110                                        MESHSET.91
      RX(I)=1.0/X(I)                                                    MESHSET.92
      GO TO 120                                                         MESHSET.93
  110 RX(I)=0.0                                                         MESHSET.94
  120 CONTINUE                                                          MESHSET.95
      DO 130 I=2,NUMX                                                   MESHSET.96
      XI(I)=0.5*(X(I-1)+X(I))                                           MESHSET.97
      DELX(I)=X(I)-X(I-1)                                               MESHSET.98
      RXI(I)=1.0/XI(I)                                                  MESHSET.99
  130 RDX(I)=1.0/DELX(I)                                                MESHSET.100
      DELX(1)=DELX(2)                                                   MESHSET.101
      XI(1)=XI(2)-DELX(2)                                               MESHSET.102
      RXI(1)=1.0/XI(1)                                                  MESHSET.103
      RDX(1)=1.0/DELX(1)                                                MESHSET.104
      DELXA=DELX(NUMX)                                                  MESHSET.105
      IF (KR.EQ.4) DELXA=DELX(3)                                        MESHSET.106
      DELX(NUMXP1)=DELXA                                                MESHSET.107
      XI(NUMXP1)=XI(NUMX)+DELXA                                         MESHSET.108
      X(NUMXP1)=XI(NUMXP1)+0.5*DELX(NUMXP1)                             MESHSET.109
      RXI(NUMXP1)=1.0/XI(NUMXP1)                                        MESHSET.110
      RDX(NUMXP1)=1.0/DELX(NUMXP1)                                      MESHSET.111
      DO 140 I=2,NUMY                                                   MESHSET.112
      YJ(I)=0.5*(Y(I-1)+Y(I))                                           MESHSET.113
      RYJ(I)=1.0/YJ(I)                                                  MESHSET.114
      DELY(I)=Y(I)-Y(I-1)                                               MESHSET.115
      RDY(I)=1.0/DELY(I)                                                MESHSET.116
  140 CONTINUE                                                          MESHSET.117
      DELY(1)=DELY(2)                                                   MESHSET.118
      RDY(1)=1.0/DELY(1)                                                MESHSET.119
      YJ(1)=YJ(2)-DELY(2)                                               MESHSET.120
      RYJ(1)=1.0/YJ(1)                                                  MESHSET.121
      DELYA=DELY(NUMY)                                                  MESHSET.122
      IF (KT.EQ.4) DELYA=DELY(3)                                        MESHSET.123
      DELY(NUMYP1)=DELYA                                                MESHSET.124
      YJ(NUMYP1)=YJ(NUMY)+DELYA                                         MESHSET.125
      Y(NUMYP1)=YJ(NUMYP1)+0.5*DELY(NUMYP1)                             MESHSET.126
      RYJ(NUMYP1)=1.0/YJ(NUMYP1)                                        MESHSET.127
      RDY(NUMYP1)=1.0/DELY(NUMYP1)                                      MESHSET.128
```

```
C
C     SET R AND RI ARRAY FOR PLANE OR CYLINDRICAL GEOMETRY
      DO 145 I=1,IMAX
      R(I)=X(I)
      RI(I)=XI(I)
      IF(ICYL.EQ.1) GO TO 145
      R(I)=1.0
      RI(I)=1.0
  145 CONTINUE
      WRITE (6,210)
      DO 150 I=1,NUMXP1
      WRITE (6,220) I,X(I),I,RX(I),I,DELX(I),I,RDX(I),I,XI(I),I,RXI(I)
  150 CONTINUE
      WRITE (6,210)
      DO 160 I=1,NUMYP1
      WRITE (6,230) I,Y(I),I,DELY(I),I,RDY(I),I,YJ(I),I,RYJ(I)
  160 CONTINUE
      IF (IMOVY.EQ.1) GO TO 190
      WRITE (12,210)
      DO 170 I=1,NUMXP1
      WRITE (12,220) I,X(I),I,RX(I),I,DELX(I),I,RDX(I),I,XI(I),I,RXI(I)
  170 CONTINUE
      WRITE (12,210)
      DO 180 I=1,NUMYP1
      WRITE (12,230) I,Y(I),I,DELY(I),I,RDY(I),I,YJ(I),I,RYJ(I)
  180 CONTINUE
  190 CONTINUE
C
C +++ TEST ARRAY SIZE
C
      IF (IMAX.LE.IBAR2.AND.JMAX.LE.JBAR2.AND.ISOR.EQ.1) GO TO 200
      IF (IMAX.EQ.IBAR2.AND.JMAX.EQ.JBAR2.AND.ISOR.EQ.0) GO TO 200
      WRITE (6,240)
C
      CALL EXITLDC (7HMESHSET)
C
  200 CONTINUE
      RETURN
C
  210 FORMAT (1H1)
  220 FORMAT (1X,2HX(,I2,2H)=,1PE12.5,2X,3HRX(,I2,2H)=,1PE12.5,2X,5HDELX
     1(,I2,2H)=,1PE12.5,1X,4HRDX(,I2,2H)=,1PE12.5,2X,3HXI(,I2,2H)=,1PE12
     2 .5,2X,4HRXI(,I2,2H)=,1PE12.5)
  230 FORMAT (1X,2HY(,I2,2H)=,1PE12.5,3X,5HDELY(,I2,2H)=,1PE12.5,3X,4HRD
     1Y(,I2,2H)=,1PE12.5,3X,3HYJ(,I2,2H)=,1PE12.5,3X,4HRYJ(,I2,2H)=,1PE1
     2 2.5)
  240 FORMAT (45H  MESH SIZE INCONSISTENT WITH ARRAY DIMENSIONS)
      END
```

```
      SUBROUTINE PETACAL
*CALL,COMMON1
C
C +++ DETERMINE THE PRESSURE INTERPOLATION FACTOR PETA
C +++ DETERMINE THE SURFACE TENSION PRESSURE AND
C +++ WALL ADHESION EFFECTS IN SURFACE CELLS
C
      DATA KTRAN / 1 /
C
      GO TO (1,4),KTRAN
C
C     RESET KTRAN: PICK UP GEOMETRIC AND TRIGONOMETRIC FACTORS
C
    1 KTRAN=4
      FEWLIM=25.0/AMIN1(X(IM1),Y(JM1))
      FNSLIM=FEWLIM
      CSANG=COS(CANGLE)
      SANG=SIN(CANGLE)
    4 CONTINUE
C
C     SET DO LOOPS TO GIVE DEFAULT VALUES OF NF, PS, AND PETA IN ALL
C     CELLS: CELLS ARE FLUID CELLS,SURFACE TENSION PRESSURE IS ZERO AND
C     PETA = 1.0
C
      DO 10 I=1,IMAX
      DO 10 J=1,JMAX
      NF(I,J)=0
      PS(I,J)=0.0
   10 PETA(I,J)=1.0
```

```
C
C     DEFAULT VALUES ARE NOW AVAILABLE
CC     SET MAIN DO LOOPS FOR FINDING WHETHER (I,J) CELL IS A SURFACE
C     CELL; IF SO, LOOPS SET NF, CALCULATE PS AND PETA. LOOPS END AT 750
C
      DO 750 I=2,IM1
      DO 750 J=2,JM1
C
C     IF CELL IS OBSTACLE CELL SKIP TO END OF LOOPS
C
C
      IF (AC(I,J).LT.EM6.OR.BETA(I,J).LT.0.0) GO TO 750
C
C     DECLARE EMPTY CELL TO BE A VOID CELL
C
      IF (F(I,J).LT.EMF) NF(I,J)=6
C
C     IF CELL IS EMPTY (OR FULL BUT PSAT = 0.0) SKIP TO END OF LOOPS;
C     CELLS WILL HAVE DEFAULT VALUES
C
      IF (F(I,J).LT.EMF.OR.(F(I,J).GT.EMF1.AND.PSAT.EQ.0.0)) GO TO 750
C
C     FOUR TESTS TO SEE WHETHER ONE OF THE FOUR NEIGHBOR CELLS IS BOTH
C     EMPTY AND OPEN TO FLOW FROM (I,J) CELL; IF SO, ENTER MAIN DO
C     LOOPS THRU 190
C
      IF (F(I+1,J).LT.EMF.AND.AR(I,J).GT.EM6) GO TO 190
      IF (F(I-1,J).LT.EMF.AND.AR(I-1,J).GT.EM6) GO TO 190
      IF (F(I,J+1).LT.EMF.AND.AT(I,J).GT.EM6) GO TO 190
      IF (F(I,J-1).LT.EMF.AND.AT(I,J-1).GT.EM6) GO TO 190
C
C     CELL IS NOT A SURFACE CELL, OBSTACLE CELL,EMPTY CELL OR PARTIC-
C     ULAR TYPE OF FULL CELL. IF IT SATISFIES PRESSURE TEST, SET NF = 5
C     FOR ISOLATED CELL AND SKIP  TO END OF LOOPS; OTHERWISE CELL IS
C     FLUID CELL AND WE SKIP TO END OF LOOPS WITH DEFAULT VALUES
C
      IF (P(I,J).LE.PSAT*EM6P1.AND.PSAT.GT.0.0) NF(I,J)=5
      GO TO 750
C
C     WE NOW ENTER CALCULATIONAL PARTS OF MAIN DO LOOPS
C
  190 CONTINUE
C
C     *** CALCULATE THE PARTIAL DERIVATIVES OF F
C
C
C     DISTANCES FROM MIDPOINT OF CELL TO MIDPOINT OF NEIGHBOR CELLS
C     DISTANCE TO RIGHT AND LEFT NEIGHBORS
C
      DXR=0.5*(DELX(I)+DELX(I+1))
      DXL=0.5*(DELX(I)+DELX(I-1))
C
C     DISTANCE TO TOP AND BOTTOM NEIGHBORS
C
      DYT=0.5*(DELY(J)+DELY(J+1))
      DYB=0.5*(DELY(J)+DELY(J-1))
C
C     DENOMINATORS FOR FINITE DIFFERENCE FORMULAS FOR PARTIAL
C     DERIVATIVES IN X AND Y DIRECTIONS
C
      RXDEN=1.0/(DXR*DXL*(DXR+DXL))
      RYDEN=1.0/(DYT*DYB*(DYT+DYB))
C
C     FOFM   (AND FOFP) INDICATE WHETHER CELLS WITH LESSER (GREATER) IN-
C     DICES CONTRIBUTE TO AVERAGE FLUID HEIGHTS IN THREE CELL ARRAY
C     FOFM=1.0 WHEN CELL CONTRIBUTES;=0.0 OTHERWISE
C     INDEX IS J FOR VERTICAL HEIGHTS; I FOR HORIZONTAL HEIGHTS
C     OBSTACLE CELL DOES NOT CONTRIBUTE IF NO FLUID IN NEIGHBOR CELL OF
C     THREE CELL ARRAY
C
      FOFM=1.0
      IF(BETA(I+1,J-1).LE.0.0.AND.F(I,J-1).LT.EMF) FOFM=0.0
      FOFP=1.0
      IF(BETA(I+1,J+1).LE.0.0.AND.F(I,J+1).LT.EMF) FOFP=0.0
C
C     Y FLUID HEIGHT IN CELLS TO RIGHT = AVFR
C     Y HEIGHTS MEASURED FROM FLOOR OF ( J - 1 ) CELLS
```

```
C
      AVFR=(1.0+AC(I+1,J-1)*(F(I+1,J-1)-1.0))*FOFM*DELY(J-1)+
     1(1.0+AC(I+1,J)*(F(I+1,J)-1.0))*DELY(J)+
     2(1.0+AC(I+1,J+1)*(F(I+1,J+1)-1.0))*FOFP*DELY(J+1)
      FOFM=1.0
      IF(BETA(I-1,J-1).LE.0.0.AND.F(I,J-1).LT.EMF) FOFM=0.0
      FOFP=1.0
      IF(BETA(I-1,J+1).LE.0.0.AND.F(I,J+1).LT.EMF) FOFP=0.0
C
C     Y FLUID HEIGHT IN CELLS TO LEFT = AVFL
C
      AVFL=(1.0+AC(I-1,J-1)*(F(I-1,J-1)-1.0))*FOFM*DELY(J-1)+
     1(1.0+AC(I-1,J)*(F(I-1,J)-1.0))*DELY(J)+
     2(1.0+AC(I-1,J+1)*(F(I-1,J+1)-1.0))*FOFP*DELY(J+1)
      FOFM=1.0
      IF(BETA(I,J-1).LE.0.0.AND.F(I-1,J-1)+F(I+1,J-1).LT.EMF) FOFM=0.0
      FOFP=1.0
      IF(BETA(I,J+1).LE.0.0.AND.F(I-1,J+1)+F(I+1,J+1).LT.EMF) FOFP=0.0
C
C     Y FLUID HEIGHT IN CENTRAL CELLS = AVFCX
C
      AVFCX=(1.0+AC(I,J-1)*(F(I,J-1)-1.0))*FOFM*DELY(J-1)+
     1(1.0+AC(I,J)*(F(I,J)-1.0))*DELY(J)+
     2(1.0+AC(I,J+1)*(F(I,J+1)-1.0))*FOFP*DELY(J+1)
C
      FOFM=1.0
      IF(BETA(I-1,J+1).LE.0.0.AND.F(I-1,J).LT.EMF) FOFM=0.0
      FOFP=1.0
      IF(BETA(I+1,J+1).LE.0.0.AND.F(I+1,J).LT.EMF) FOFP=0.0
C
C     X FLUID WIDTH IN CELLS ABOVE = AVFT
C     X FLUID WIDTH MEASURED FROM FLOOR OF (I-1) CELLS
C
      AVFT=(1.0+AC(I-1,J+1)*(F(I-1,J+1)-1.0))*FOFM*DELX(I-1)+
     1(1.0+AC(I,J+1)*(F(I,J+1)-1.0))*DELX(I)+
     2(1.0+AC(I+1,J+1)*(F(I+1,J+1)-1.0))*FOFP*DELX(I+1)
      FOFM=1.0
      IF(BETA(I-1,J-1).LE.0.0.AND.F(I-1,J).LT.EMF) FOFM=0.0
      FOFP=1.0
      IF(BETA(I+1,J-1).LE.0.0.AND.F(I+1,J).LT.EMF) FOFP=0.0
C
C     X FLUID WIDTH IN CELLS BELOW = AVFB
C
      AVFB=(1.0+AC(I-1,J-1)*(F(I-1,J-1)-1.0))*FOFM*DELX(I-1)+
     1(1.0+AC(I,J-1)*(F(I,J-1)-1.0))*DELX(I)+
     2(1.0+AC(I+1,J-1)*(F(I+1,J-1)-1.0))*FOFP*DELX(I+1)
      FOFM=1.0
      IF(BETA(I-1,J).LE.0.0.AND.F(I-1,J-1)+F(I-1,J+1).LT.EMF) FOFM=0.0
      FOFP=1.0
      IF(BETA(I+1,J).LE.0.0.AND.F(I+1,J+1)+F(I+1,J-1).LT.EMF) FOFP=0.0
C
C     X FLUID WIDTH IN CENTRAL CELLS = AVFCY
C
      AVFCY=(1.0+AC(I-1,J)*(F(I-1,J)-1.0))*FOFM*DELX(I-1)+
     1(1.0+AC(I,J)*(F(I,J)-1.0))*DELX(I)+
     2(1.0+AC(I+1,J)*(F(I+1,J)-1.0))*FOFP*DELX(I+1)
C
C     AVFL SET BY CONVENTION IN FIRST COLUMN OF CELLS
C     IN BOTHX AND Y DIRECTIONS OBSTACLES ARE PLACED ON FLOOR FROM WHICH
C     DISTANCES ARE MEASURED; FLUID IS THEN ABOVE OBSTACLES
C     IF NF=2 OR 4 FLOOR IS AT TOP OF CELL; AT I+1 OR J+1 RESPECTIVELY
C
      IF(I.EQ.2) AVFL=AVFCX
C
C     THREE POINT FINITE DIFFERENCE FORMULAS FOR SURFACE SLOPES WITH
C     VARIABLE MESH SIZES; FORMULAS EXACT FOR QUADRATICS
C     SLOPE DH/DX FOR ALMOST HORIZONTAL FLUID = PFX
C
      PFX=RXDEN*((AVFR-AVFCX)*DXL**2+(AVFCX-AVFL)*DXR**2)
C
C     SLOPE DW/DY FOR ALMOST VERTICAL FLUID = PFY
C
      PFY=RYDEN*((AVFT-AVFCY)*DYB**2+(AVFCY-AVFB)*DYT**2)
C
C     PF = SUM OF SQUARES OF TANGENTS; USED AS FLAG TO DIFFERENTIATE
C     SURFACE CELLS FROM ISOLATED CELLS (NF=5)
C
      PF=PFX**2+PFY**2
C
C     IF PF VERY SMALL, CELL IS DECLARED ISOLATED (INSTEAD OF SURFACE)
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C       AND WE CONTINUE: OTHERWISE GO TO 660
C
        IF (PF.GT.EM10) GO TO 660
C
C       SET NF(I,J) AND P(I,J) FOR ISOLATED CELL; BYPASS DETERMINATION
C       OF PRESSURE INTERPOLATION CELL,CALCULATION OF SURFACE PRESSURE
C       AND CALCULATION OF PETA
C
  655 NF(I,J)=5
      P(I,J)=0.25*(P(I+1,J)+P(I,J+1)+P(I-1,J)+P(I,J-1))
C
C       HAVING SET NF AND P FOR THE ISOLATED CELL, WE NOW SKIP TO END OF
C       MAIN LOOPS
C
        GO TO 750
  660 CONTINUE
C
C       FOR SURFACE CELLS WE PICK UP CALCULATIONS OF MAIN LOOPS; HAVING
C       DETERMINED SLOPES AND SOME AUXILIARY QUANTITIES, WE NOW GET NF,
C       PS, AND PETA
C       IN ORDER TO SET FLAGS TO BE USED LATER, WE SUM THE F'S IN COLS.
C       TO RIGHT AND LEFT AND IN ROWS ABOVE AND BELOW THE (I,J) CELL
C       SFIM = SUM OF F'S IN (I-1) COL.
C       SFIP = SUM OF F'S IN (I+1) COL.
C       SFJP = SUM OF F'S IN (J+1) ROW
C       SFJM = SUM OF F'S IN (J-1) ROW
C       SFIC = SUM OF F'S IN I COL.
C       SFJC = SUM OF F'S IN J ROW
C
        SFIM=F(I-1,J+1)+F(I-1,J)+F(I-1,J-1)
        SFIC=F(I,J+1)+F(I,J)+F(I,J-1)
        SFIP=F(I+1,J+1)+F(I+1,J)+F(I+1,J-1)
        SFJP=F(I+1,J+1)+F(I,J+1)+F(I-1,J+1)
        SFJC=F(I+1,J)+F(I,J)+F(I-1,J)
        SFJM=F(I+1,J-1)+F(I,J-1)+F(I-1,J-1)
C
C       IF THERE IS LITTLE FLUID IN THREE BY THREE ARRAY OF CELLS: SET
C       CELL PRESSURE AS FOR AN ISOLATED CELL AND GO TO END OF MAIN LOOP
C       FLAGS ARE INITIALLY SET = 0
C
        IF(SFIM+SFIC+SFIP+SFJM+SFJC+SFJP.LT.0.10) GO TO 655
C
C       IF ANY CELL FACE IS COMPLETELY CLOSED TO FLOW: SKIP ROW AND
C       COLUMN TESTS
C
        IF(AR(I,J).LT.EM6.OR.AR(I-1,J).LT.EM6.OR.AT(I,J).LT.EM6.
      1 OR.AT(I,J-1).LT.EM6) GO TO 670
        IFLGX=0
        JFLGY=0
C
C       IF EITHER COL. TO LEFT OR COL. TO RIGHT IS EMPTY OR IS FULL: IFLG-
C       X = 1
C
        IF (SFIM.LT.EMF.OR.SFIM.GT.3.0-EMF) IFLGX=1
        IF (SFIP.LT.EMF.OR.SFIP.GT.3.0-EMF) IFLGX=1
C
C       IF EITHER ROW ABOVE OR ROW BELOW IS EMPTY OR IS FULL: JFLGY = 1
C
        IF (SFJP.LT.EMF.OR.SFJP.GT.3.0-EMF) JFLGY=1
        IF (SFJM.LT.EMF.OR.SFJM.GT.3.0-EMF) JFLGY=1
C
C       IF BOTH FLAGS = 1: CONTINUE EXECUTION AT 670 WITHOUT INTERVENTION
C
        IF (IFLGX.EQ.1.AND.JFLGY.EQ.1) GO TO 670
C
C       IF EXACTLY ONE FLAG = 1: CHANGE THE CORRESPONDING SLOPE
C
        IF (IFLGX.EQ.1) PFX=1.0E10*PFX
        IF (JFLGY.EQ.1) PFY=1.0E10*PFY
  670 CONTINUE
C
C       WE HAVE CONCLUDED SLOPE INCREASES
C
C
C       *** DETERMINE THE PRESSURE INTERPOLATION CELL NF
C
C       ALGORITHM GUARANTEES THAT A NEIGHBORING FLUID CELL (ONE OR MORE
C       ALWAYS EXIST) ALWAYS LIES AT FLOOR OF THE SURFACE CELL. THE FLUID
C       CELL AT THE FLOOR IS USED AS THE INTERPOLATION NEIGHBOR CELL IN
C       PRESIT OR PRESCR
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C
C     GET ABSOLUTE VALUE OF SLOPES; MINIMUM WILL DETERMINE WHETHER
C     SURFACE HAS NEAR HORIZONTAL OR NEAR VERTICAL ORIENTATION
C
      ABPFX=ABS(PFX)
      ABPFY=ABS(PFY)
C
C     SET DEFAULT VALUES OF THE INDICES OF THE INTERPOLATION NEIGHBOR
C     CELL (L,M): (L,M) = (I,J)
C
      L=I
      M=J
C
C     IF SURFACE IS MORE NEARLY HORIZONTAL: GO TO 680. OTHERWISE
C     SURFACE IS MORE NEARLY VERTICAL AND WE ASSIGN NF = 2 OR 1
C
      IF (ABPFY.GE.ABPFX) GO TO 680
C
C     SET MINIMUM SLOPE, L INDEX, AND NF CONSISTENTLY WITH NF = 2
C
      PFMN=PFY
      NF(I,J)=2
      L=I+1
C
C     COMPUTE LENGTH INTERVALS NEEDED FOR EVALUATING THE PRESSURE
C     INTERPOLATION (INTERVALS NEEDED IN BUILDING THE PETA ARRAY)
C
      DMX=DELX(I)
      DMIN=0.5*(DMX+DELX(I+1))
      DNBR=DELX(I+1)
C
C     ALGEBRAIC SIGN OF LARGER ABSOLUTE SLOPE (PFX) DETERMINES NF VALUE.
C     IF PFX > 0.0 THEN NF = 2 AND WE SKIP TO END OF NF ROUTINE AT 690
C
C     OTHERWISE NF = 1 AND WE GO ON, REPEATING IMMEDIATELY PREVIOUS
C     STEPS APPROPRIATELY FOR NF = 1
C
      IF (PFX.GT.0.0) GO TO 690
      NF(I,J)=1
      PFMN=-PFY
      L=I-1
      DMX=DELX(I)
      DMIN=0.5*(DMX+DELX(I-1))
      DNBR=DELX(I-1)
C
C     HAVING COMPLETED CALCULATIONS FOR NF = 1, WE SKIP TO END OF NF
C     ROUTINE HOLDING NF = 1 DATA
C
      GO TO 690
  680 CONTINUE
C
C     WE ARE NOW IN SURFACE MORE NEARLY HORIZONTAL CASE. WE START WITH
C     NF = 4
C     SET MINIMUM SLOPE, L INDEX AND NF CONSISTENTLY WITH NF = 4
C
      PFMN=-PFX
      NF(I,J)=4
      M=J+1
      DMX=DELY(J)
      DMIN=0.5*(DMX+DELY(J+1))
      DNBR=DELY(J+1)
C
C     ALGEBRAIC SIGN OF LARGER SLOPE (PFY) DETERMINES NF VALUE. IF PFY
C     > 0.0 THEN NF = 4 AND WE SKIP TO END OF NF ROUTINE
C     OTHERWISE NF = 3 AND WE GO ON, REPEATING IMMEDIATELY PREVIOUS
C     STEPS APPROPRIATELY FOR NF = 3
C
      IF (PFY.GT.0.0) GO TO 690
      NF(I,J)=3
      PFMN=PFX
      M=J-1
      DMX=DELY(J)
      DMIN=0.5*(DMX+DELY(J-1))
      DNBR=DELY(J-1)
  690 CONTINUE
C
C     WE HAVE COMPLETED SETTING NF AND (L,M) FOR THE PRESSURE INTERPO-
C     LATION
C
C
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C     DETERMINE AN INTERPOLATION LENGTH FOR THE PETA ARRAY
C
      IF(NF(I,J).EQ.1) SDFS=(1.0+AC(I-1,J)*(F(I-1,J)-1.0))*DELX(I-1)+
     1 (1.0+AC(I,J)*(F(I,J)-1.0))*DELX(I)
      IF(NF(I,J).EQ.2) SDFS=(1.0+AC(I+1,J)*(F(I+1,J)-1.0))*DELX(I+1)+
     1 (1.0+AC(I,J)*(F(I,J)-1.0))*DELX(I)
      IF(NF(I,J).EQ.3) SDFS=(1.0+AC(I,J-1)*(F(I,J-1)-1.0))*DELY(J-1)+
     1 (1.0+AC(I,J)*(F(I,J)-1.0))*DELY(J)
      IF(NF(I,J).EQ.4) SDFS=(1.0+AC(I,J+1)*(F(I,J+1)-1.0))*DELY(J+1)+
     1 (1.0+AC(I,J)*(F(I,J)-1.0))*DELY(J)
      DFS=0.5*DMX+DNBR-SDFS
      DFS=AMIN1(DFS,0.5*DMIN)
C
C     IF NO SURFACE TENSION BYPASS PS ROUTINE AND CALCULATE PETA(I,J)
C
      IF (ISURF10.LT.1) GO TO 740
C
C     *** DETERMINE THE SURFACE PRESSURE
C
C     WE DETERMINE ONLY THE SURFACE TENSION CONTRIBUTION TO PS; VOID
C     PRESSURE IS ADDED IN PRESIT OR IN PRESCR
C
C     SET NF AND NW INTO NON-INDEXED VARIABLES FOR USE IN IF STATEMENTS
C     SET DEFAULT VALUES OF FLGE,...,AFE,...,FLGU,INW,CSANG, AND SANG
C     FLAGS GIVE CHOICE OF WALL ADHESION OR SURFACE TENSION AND, IF WALL
C     ADHESION, THE DIRECTION OF THE FORCE
C
      NFF=NF(I,J)
      FLGE=1.0
      FLGW=1.0
      FLGN=1.0
      FLGS=1.0
      NWW=NW(I,J)
      CSANG=COSO(I,J)
      SANG=SINO(I,J)
      FLGU=1.0
      AFE=1.0
      AFW=1.0
      AFN=1.0
      AFS=1.0
      INW=0
C
C     NWW=0 INDICATES A FLUID CELL FULLY OPEN TO FLOW WHOSE FACES
C     MAY BE COMPLETELY OPEN TO FLOW, FULLY CLOSED, OR PARTIALLY
C     OPEN TO FLOW (SIMULATING POROUS BAFFLES) - SKIP TO STANDARD
C     SURFACE TENSION CALCULATION
C
      IF(NWW.EQ.0) GO TO 100
C
C     RESET INW: THIS FORECLOSES THE POROUS BAFFLE OPTION
C     (CELL FACES PARTIUALLY OPEN TO FLOW, PART SURFACE TENSION,
C     PART ADHESION)
C     RESET CSANG FOR NF=1 OR 2; WE NOW HAVE FINAL VALUES FOR CSANG
C     SO MAGNITUDE OF WALL ADHESION FORCE HAS NOW BEEN DETERMINED
C     IF NWW=NFF GO TO STANDARD CALCULATION OF SURFACE TENSION
C     USING PARAMETERS SET FOR CURVED BOUNDARY CASES
C
      INW=1
      IF(NFF.LE.2) CSANG=SINO(I,J)
      SANG=0.0
      IF(NWW.EQ.NFF) GO TO 100
C
C     CURVED BOUNDARY WALL ADHESION
C
C     FOR SOME CASES OF NW = 1,3,4,5,6,7, OR 8 SET WALL ADHESION RATHER
C     THAN SURFACE TENSION. CHOOSING THE WALL AND THE FORCE DIRECTION
C     USE NF AND NEIGHBORING F VALUES TO MAKE THE DETERMINATION
C
      GO TO (20,100,30,40,50,60,70,80),NWW
C
C     WE ARE IN NW = 1 BRANCH. WE HAVE ALREADY TREATED NF = 1. FOR NF =
C     3 OR 4 : BRANCH AHEAD TO 23 OR 24
C     FOR NF = 2: RESET FLGU; IF NO FLUID ABOVE, PUT WALL ADHESION ON
C     TOP WALL; IF NO FLUID BELOW, PUT WALL ADHESION ON BOTTOM WALL
C     ENTER NEXT STAGE OF CALCULATION
C
   20 IF(NFF.EQ.3) GO TO 23
      IF(NFF.EQ.4) GO TO 24
      FLGU=-1.0
      IF(F(I,J+1).LE.EMF) AFN=0.0
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      IF(F(I,J-1).LE.EMF) AFS=0.0
      GO TO 100
C
C     FOR NF = 3: IF NO FLUID ABOVE, PUT WALL ADHESION ON EAST WALL; IF
C     NO FLUID BELOW, PUT WALL ADHESION ON WEST WALL
C     ENTER NEXT STAGE OF CALCULATION
C
   23 IF(F(I,J+1).LE.EMF) AFE=0.0
      IF(F(I,J-1).LE.EMF) AFW=0.0
      GO TO 100
C
C     FOR NF = 4: IN THIS CASE WE ARE CALCULATING -Y COMPONENT OF
C     SURFACE FORCES. THUS WALL ADHESION ENTERS WITH OPPOSITE SIGN. IF
C     NO FLUID ABOVE, PUT WALL ADHESION ON WEST WALL; IF NO FLUID
C     BELOW, PUT WALL ADHESION ON EAST WALL
C     ENTER NEXT STAGE OF CALCULATION
C
   24 IF(F(I,J+1).LE.EMF) AFW=0.0
      IF(F(I,J-1).LE.EMF) AFE=0.
      GO TO 100
C
C     WE ARE IN NW=4 BRANCH.  WE HAVE ALREADY TREATED NF=1
C     FOR NF=1 OR 2: BRANCH AHEAD TO 41 OR 42
C     FOR NF=3: IF NO FLUID TO RIGHT, PUT ADHESION ON EAST WALL;
C     IF NO FLUID TO LEFT, PUT ADHESION ON WEST WALL
C     ENTER NEXT STAGE...
C
   40 GO TO (41,42,43,43), NFF
   43 IF(F(I+1,J).LE.EMF) AFE=0.0
      IF(F(I-1,J).LE.EMF) AFW=0.0
      GO TO 100
C
C     FOR NF=1: RESET FLGU; IF NO FLUID TO RIGHT, PUT ADHESION
C     ON SOUTH WALL; IF NO FLUID TO LEFT, PUT ADHESION ON NORTH WALL
C     ENTER NEXT STAGE...
C
   41 FLGU=-1.0
      IF(F(I+1,J).LE.EMF) AFS=0.0
      IF(F(I-1,J).LE.EMF) AFN=0.0
      GO TO 100
C
C     FOR NF=2: RESET FLGU; IF NO FLUID TO RIGHT PUT ADHESION ON
C     NORTH WALL; IF NO FLUID TO LEFT, PUT ADHESION ON SOUTH WALL
C     ENTER NEXT STAGE...
C
   42 IF(F(I-1,J).LE.EMF) AFS=0.0
      IF(F(I+1,J).LE.EMF) AFN=0.0
      FLGU=-1.0
      GO TO 100
C
C     WE ARE NOW IN NW=3 BRANCH. WE HAVE ALREADY TREATED NF=3
C     FOR NF=1 OR 2: BRANCH AHEAD TO 31 OR 32
C     FOR NF=4: RESET FLGU, IF NO FLUID TO RIGHT, PUT ADHESION
C     ON EAST WALL; IF NO FLUID TO LEFT, PUT ADHESION ON WEST WALL
C     ENTER NEXT STAGE...
C
   30 GO TO (31,32,33,33), NFF
   33 IF(F(I+1,J).LE.EMF) AFE=0.0
      IF(F(I-1,J).LE.EMF) AFW=0.0
      FLGU=-1.0
      GO TO 100
C
C     IF NO FLUID TO RIGHT, PUT ADHESION ON NORTH WALL; IF NO FLUID
C     TO LEFT, PUT ADHESION ON SOUTH WALL
C     ENTER NEXT STAGE...
C
   31 IF(F(I+1,J).LE.EMF) AFN=0.0
      IF(F(I-1,J).LE.EMF) AFS=0.0
      GO TO 100
C
C     IF NO FLUID TO RIGHT, PUT ADHESION ON SOUTH WALL; IF NO FLUID
C     TO LEFT, PUT ADHESION ON NORTH WALL
C     ENTER NEXT STAGE...
C
   32 IF(F(I-1,J).LE.EMF) AFN=0.0
      IF(F(I+1,J).LE.EMF) AFS=0.0
      GO TO 100
C
C     WE ARE NOW IN NW=6 BRANCH
C     RESET FLGU: IF NF=2 OR 4
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C     BRANCH AHEAD TO 64: IF NF=3 OR 4
C     FOR NF=1 OR 2: IF NO FLUID ABOVE, PUT ADHESION ON NORTH WALL;
C     IF NO FLUID TO LEFT, PUT ADHESION ON SOUTH WALL
C     ENTER NEXT STAGE...
C
   60 IF(NFF.EQ.2.OR.NFF.EQ.4) FLGU=-1.0
      IF(NFF.GT.2) GO TO 64
      IF(F(I,J+1).LT.EMF) AFN=0.0
      IF(F(I-1,J).LT.EMF) AFS=0.0
      GO TO 100
C
C     FOR NF=3 OR 4: IF NO FLUID ABOVE, PUT ADHESION ON EAST WALL;
C     IF NO FLUID TO THE LEFT, PUT ADHESION ON WEST WALL
C     ENTER NEXT STAGE...
C
   64 IF(F(I,J+1).LT.EMF) AFE=0.0
      IF(F(I-1,J).LT.EMF) AFW=0.0
      GO TO 100
C
C     WE ARE NOW IN NW=5 BRANCH
C     FOR NF=1 OR 4: RESET FLGU
C     FOR NF=3 OR 4: BRANCH AHEAD TO 54
C     FOR NF=1 OR 2: IF NO FLUID BELOW, PUT ADHESION ON SOUTH WALL;
C     IF NO FLUID TO THE LEFT, PUT ADHESION ON NORTH WALL
C     ENTER NEXT STAGE...
C
   50 IF(NFF.EQ.1.OR.NFF.EQ.4) FLGU=-1.0
      IF(NFF.GT.2) GO TO 54
      IF(F(I,J-1).LT.EMF) AFS=0.0
      IF(F(I-1,J).LT.EMF) AFN=0.0
      GO TO 100
C
C     FOR NF=3 OR 4: IF NO FLUID BELOW, PUT ADHESION ON EAST WALL;
C     IF NO FLUID TO THE LEFT, PUT ADHESION ON WEST WALL
C     ENTER NEXT STAGE...
C
   54 IF(F(I,J-1).LT.EMF) AFE=0.0
      IF(F(I-1,J).LT.EMF) AFW=0.0
      GO TO 100
C
C     WE ARE IN NW=7 BRANCH
C     FOR NF=1 OR 3: USE SURFACE TENSION ONLY
C     FOR NF=4: BRANCH AHEAD TO 74
C     FOR NF=2: IF NO FLUID ABOVE, PUT ADHESION ON NORTH WALL
C     ENTER NEXT STAGE...
C
   70 GO TO (100,72,100,74),NFF
   72 IF(F(I,J+1).LT.EMF) AFN=0.0
      GO TO 100
C
C     FOR NF=4: RESET FLGU; IF NO FLUID TO RIGHT, PUT ADHESION ON EAST
C     WALL
C     ENTER NEXT STAGE...
C
   74 IF(F(I+1,J).LT.EMF) AFE=0.0
      FLGU=-1.0
      GO TO 100
C
C     WE ARE IN NW=8 BRANCH
C     FOR NF=1 OR 4: USE SURFACE TENSION ONLY
C     FOR NF=3: BRANCH AHEAD TO 83
C     FOR NF=2: RESET FLGU: IF NO FLUID BELOW, PUT ADHESION ON SOUTH
C     WALL
C     ENTER NEXT STAGE...
C
   80 GO TO (100,82,83,100), NFF
   82 IF(F(I,J-1).LT.EMF) AFS=0.0
      FLGU=-1.0
      GO TO 100
C
C     FOR NF=3: IF NO FLUID TO THE RIGHT, PUT ADHESION ON EAST WALL
C
   83 IF(F(I+1,J).LT.EMF) AFE=0.0
C
C     CALCULATION OF SURFACE TENSION FORCE IS DIFFERENT FOR VERTICAL
C     AND HORIZONTAL SURFACES; GO TO APPROPIATE BRANCH TO BEGIN
C
  100 GO TO (700,700,710,710), NFF
C
C     WE HAVE A NEAR VERTICAL SURFACE
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C     CALCULATE A HORIZONTAL DISTANCE (RDEW) AND A RECIPROCAL Y
C     INTERVAL (RDNS) FOR LATER USE
C
  700 RDEW=RXI(I)
C
C     IF(INW=O: GO TO CALCULATION FOR POROUS BAFFLE CAPABILITY; CALCULAT
C     LINEAR COMBINATION OF SURFACE TENSION AND ADHESION FORCES
C     OTHERWISE, BYPASS POROUS BAFFLE ROUTINE AND CALCULATE EITHER
C     SURFACE TENSION OR WALL ADHESION
C
      IF(INW.EQ.O) GO TO 701
      RDNS=RDY(J)
      IF(I.EQ.2) GO TO 702
      IF(AR(I-1,J).GT.EM6) RDNS=RDY(J)/AR(I-1,J)
      GO TO 702
  701 FLGU=-1.0
      RDNS=RDY(J)
C
C     SET FRACTIONAL AREA OPEN TO FLOW ON EAST, OR RIGHT, CELL WALL
C     AND ON WEST, OR LEFT, WALL (I.E., AFE AND AFW) BY CONVENTION
C
      AFE=1.0
      AFW=1.0
C
C     SET FRACTIONAL AREA OPEN TO FLOW ON NORTH, OR TOP, WALL AND ON
C     SOUTH, OR BOTTOM, WALL ACCORDING TO OBSTACLE GEOMETRY
C
      AFN=AT(I,J)
      AFS=AT(I,J-1)
C
C     SET DEFAULT VALUE OF AFLOOR, FOR LATER USE IN WALL ADHESION FORCE
C
      AFLOOR=0.0
C
C     SET AFLOOR FOR NF = 1: EXCEPT FOR FIRST COL. OF CELLS AFLOOR =
C     FRACTIONAL AREA OPEN TO FLOW ON EAST CELL WALL
C
C     FOR NF = 2 AFLOOR = FRACTIONAL AREA OPEN TO FLOW ON WEST WALL
C
      IF (X(I-1).GT.EM6) AFLOOR=AR(I-1,J)
      IF (NFF.EQ.2) AFLOOR=AR(I,J)
C
C     IF TOP OR BOTTOM CELL WALL IS OPEN TO FLOW BUT CELL IS EMPTY, SET
C     CORRESPONDING FLAG TO AFLOOR VALUE
C
      IF (AFN.GT.EM6.AND.F(I,J+1).LT.EMF) FLGN=AFLOOR
      IF (AFS.GT.EM6.AND.F(I,J-1).LT.EMF) FLGS=AFLOOR
C
C     BEGIN CALCULATION OF SURFACE TENSION FORCES, ESPECIALLY OF THE
C     TANGENTS THAT APPEAR ON THE VARIOUS WALLS
C
  702 DHENE=0.0
      DHESE=0.0
      DHENW=0.0
      DHESW=0.0
      DHNNE=(AVFT-AVFCY)*2.0/(DELY(J)+DELY(J+1))
      DHNNW=DHNNE
      DHNSE=(AVFCY-AVFB)*2.0/(DELY(J)+DELY(J-1))
      DHNSW=DHNSE
C
C     IF PLANE GEOMETRY; SKIP TO 720, WHERE CALCULATION OF SURFACE
C     TENSION FORCES PROCEEDS
C
      IF(CYL.LT.0.5) GO TO 720
C
C     FOR CYLINDRICAL CASE WE CALCULATE EXTRA TERM DUE TO AZIMUTHAL
C     CURVATURE OF SURFACE; CALCULATE AN AVERAGE SLOPE, MULTIPLY BY SOME
C     GEOMETRIC FACTORS, SWITCH ALGEBRAIC SIGN WHEN NF = 2 (AS
C     SURFACE CURVATURE CHANGES SIGN), AND STORE RESULT IN FLGN AND FLGS
C
      DHNA=0.5*(DHNNE+DHNSE)
      FCYL=0.5*DELY(J)*DHNA*RXI(I)
      IF(NFF.EQ.2) FCYL=-FCYL
      FLGN=FLGN*(1.0+FCYL)
      FLGS=FLGS*(1.0-FCYL)
C
C     HAVING STORED CYLINDRICAL INFORMATION; PROCEED TO FURTHER
C     CALCULATION OF SURFACE TENSION FORCE AT 720
C
      GO TO 720
```

```
C
C     WE HAVE A NEAR HORIZONTAL SURFACE: CALCULATE RDEW AND RDNS
C     APPROPIATE TO THIS CASE
C
  710 RDNS=RXI(I)
C
C     IF INW=0 GO TO POROUS BAFFLE ROUTINE, GIVING LINEAR
C     COMBINATION OF SURFACE TENSION AND ADHESION FORCES
C     OTHERWISE ,BYPASS POROUS BAFFLE ROUTINE, CALCULATING EITHER
C     SURFACE TENSION OR ADHESION, EITHER HERE OR AFTER 713
C
      IF(INW.EQ.0) GO TO 711
      RDEW=RDX(I)
      IF(NW(I,J).EQ.3.OR.NW(I,J).EQ.5.OR.NW(I,J).EQ.7) GO TO 713
      IF(AT(I,J).GT.EM6) RDEW=RDX(I)/AT(I,J)
      GO TO 712
  713 IF(AT(I,J-1).GT.EM6) RDEW=RDX(I)/AT(I,J-1)
      GO TO 712
  711 FLGU=-1.0
      RDEW=RDX(I)
C
C     SET FOUR FRACTIONAL AREAS OPEN TO FLOW APPROPIATELY
C
      AFE=AR(I,J)
      AFW=0.0
      IF (X(I-1).GT.EM6) AFW=AR(I-1,J)
      AFN=1.0
      AFS=1.0
C
C     SET AFLOOR FOR LATER USE: TOP OR BOTTOM AREA OPEN TO FLOW
C
      AFLOOR=AT(I,J-1)
      IF (NFF.EQ.4) AFLOOR=AT(I,J)
C
C     IF LEFT OR RIGHT CELL IS OPEN TO FLOW BUT EMPTY, SET
C     CORRESPONDING FLAG TO AFLOOR VALUE
C
      IF (AFE.GT.EM6.AND.F(I+1,J).LT.EMF) FLGE=AFLOOR
      IF (AFW.GT.EM6.AND.F(I-1,J).LT.EMF) FLGW=AFLOOR
  712 IF (CYL.GT.0.5) FLGE=FLGE*X(I)*RXI(I)
      IF (CYL.GT.0.5) FLGW=FLGW*X(I-1)*RXI(I)
C
C     LOAD THE SURFACE TANGENTS IN THE SAME EIGHT VARIABLES:
C     ACCUMULATING IN MANNER APPROPIATE TO HORIZONTAL CASE
C
      DHNNE=0.0
      DHNSE=0.0
      DHNNW=0.0
      DHNSW=0.0
      DHENE=(AVFR-AVFCX)*2.0/(DELX(I)+DELX(I+1))
      DHESE=DHENE
      DHENW=(AVFCX-AVFL)*2.0/(DELX(I)+DELX(I-1))
      DHESW=DHENW
C
C     WE HAVE COLLECTED SURFACE TANGENTS AND GO ON TO FURTHER
C     EVALUATION OF SURFACE TENSION AND WALL ADHESION AT 720:
C     ALL PATHS THRU THIS ROUTINE MEET AT 720 AND GO ON TO
C     WE CONSOLIDATE VARIABLES FOR GIVING SURFACE TANGENTS
C
  720 DHEE=0.5*(DHENE+DHESE)
      DHNE=0.5*(DHNNE+DHNSE)
      DHEW=0.5*(DHENW+DHESW)
      DHNW=0.5*(DHNNW+DHNSW)
C
C     BEGIN TO ASSEMBLE TERMS THAT WILL PROVIDE DENOMINATORS IN
C     EXPRESSIONS FOR SIGN OF ANGLE SURFACE MAKES WITH APPROPIATE
C     AXIS: DIRECTLY NEEDED FOR SURFACE TENSION FORCE
C
      TERM1=1.0+DHNE*DHNE
      TERM2=1.0+DHNW*DHNW
C
C     NOW CONSTRUCT THE DENOMINATOR
C
      RHDE=SQRT(TERM1+DHEE*DHEE)
      RHDW=SQRT(TERM2+DHEW*DHEW)
C
C     CALCULATE SURFACE FORCES ON EAST AND WEST WALLS
C     FORCE IS FY FOR NF=3 AND -FY FOR NF=4
C     ONLY FOR INW=0 IS FORCE REALLY A LINEAR COMBINATION OF
C     SURFACE TENSION AND WALL ADHESION FORCES.  OTHERWISE, IT IS
```

```
C      EITHER SURFACE TENSION OR WALL ADHESION; ACCORDING TO RULES
C      GIVEN EARLIER
C
       FEW=FLGE*(AFE*DHEE/RHDE+FLGU*(1.0-AFE)*CSANG)-
      1 FLGW*(AFW*DHEW/RHDW+FLGU*(1.0-AFW)*CSANG)
       IF (CYL.LT.0.5.OR.NFF.GT.2) GO TO 730
C
C      IN CYLINDRICAL CASE ADD A TERM TO FEW WHEN NF = 1 OR NF = 2
C      (HELPS BUILD AZIMUTHAL CURVATURE FORCE, SO ALLOW FOR CHANGE
C      OF SIGN OF CURVATURE BETWEEN NF = 1 AND NF = 2)
C
       FEW=-0.5*(TERM1/RHDE+TERM2/RHDW)
       IF (NFF.EQ.2) FEW=-FEW
C
C      ASSEMBLE TERMS TO CONSTRUCT SINES OF ANGLES SURFACE MAKES WITH
C      NORTH AND SOUTH CELL WALLS
C
   730 DHEN=0.5*(DHENE+DHENW)
       DHNN=0.5*(DHNNE+DHNNW)
       DHES=0.5*(DHESE+DHESW)
       DHNS=0.5*(DHNSE+DHNSW)
       TERM1=1.0+DHEN*DHEN
       TERM2=1.0+DHES*DHES
       RHDN=SQRT(TERM1+DHNN*DHNN)
       RHDS=SQRT(TERM2+DHNS*DHNS)
C
C      CALCULATE SURFACE FORCES ON NORTH AND SOUTH WALLS
C      FORCE IS FX FOR NF=1 AND -FX FOR NF=2
C      ONLY FOR INW=0 IS FORCE REALLY A LINEAR COMBINATIONOF SURFACE
C      TENSION AND WALL ADHESION FORCES.  OTHERWISE, IT IS EITHER
C      SURFACE TENSION OR WALL ADHESION; ACCORDING TO RULES GIVEN EARLIER
C
       FNS=FLGN*(AFN*DHNN/RHDN+FLGU*(1.0-AFN)*CSANG)-
      1 FLGS*(AFS*DHNS/RHDS+FLGU*(1.0-AFS)*CSANG)
C
C      FOR THE POROUS BAFFLE OPTION (INW=0); COMPUTE ADDITIONAL SURFACE
C      FORCES, ALLOWING FOR SOME CASES OF WALL ADHESION WHICH THE
C      PRECEDING ALGORITHMS MISS WHEN INW=0
C
       FEW=FEW-(2.0-FLGE-FLGW)*SANG
       FNS=FNS-(2.0-FLGN-FLGS)*SANG
       AFEW=ABS(FEW)
C
C      LIMIT SIZE OF FEW AND FNS WHEN ALGOTITHMS GIVE UNPHYSICAL RESULTS
C      AND MULTIPLY BY GEOMETRIC FACTORS NEEDED FOR PS
C
       IF(NFF.LE.2) FEW=AMIN1(RDEW*AFEW,RX(2),FEWLIM)*SIGN(1.0,FEW)
       IF(NFF.GT.2) FEW=AMIN1(RDEW*AFEW,RDEW,FEWLIM)*SIGN(1.0,FEW)
       AFNS=ABS(FNS)
       FNS=AMIN1(RDNS*AFNS,RDNS,FNSLIM)*SIGN(1.0,FNS)
C
C      COMPUTE SURFACE TENSION PRESSURE AND CALL IT THE SURFACE PRESSURE
C      (PS). ANY VOID PRESSURE CONTRIBUTION TO PS IS ADDED IN PRESSURE
C      UPDATE ROUTINE
C
       PS(I,J)=-SIGMA*(FEW+FNS)
C
   740 CONTINUE
C
C      *** CALCULATE PETA
C
       NFSB=0
       IF (F(I+1,J).LT.EMF.OR.AR(I,J).LT.EM6) NFSB=NFSB+1
       IF (F(I,J+1).LT.EMF.OR.AT(I,J).LT.EM6) NFSB=NFSB+2
       IF (F(I-1,J).LT.EMF.OR.AR(I-1,J).LT.EM6) NFSB=NFSB+4
       IF (F(I,J-1).LT.EMF.OR.AT(I,J-1).LT.EM6) NFSB=NFSB+8
       IF (NFSB.EQ.15) PS(I,J)=0.0
       PETA(I,J)=1.0/(1.0-DFS/DMIN)
       IF (L.EQ.1.OR.L.EQ.IMAX) PETA(I,J)=1.0
       IF (M.EQ.1.OR.M.EQ.JMAX) PETA(I,J)=1.0
       IF (NF(L,M).NE.0) PETA(I,J)=1.0
       IF (NF(I,J).EQ.1.AND.AR(I-1,J).GT.EM6) GO TO 750
       IF (NF(I,J).EQ.2.AND.AR(I,J).GT.EM6) GO TO 750
       IF (NF(I,J).EQ.3.AND.AT(I,J-1).GT.EM6) GO TO 750
       IF (NF(I,J).EQ.4.AND.AT(I,J).GT.EM6) GO TO 750
       PETA(I,J)=1.0
   750 CONTINUE
C
       CALL LAVORE
```

```
C
      CALL CAVOVO
C
C     IF NECESSARY, DETERMINE PRESSURES PR FOR VOID REGIONS NF
C
C     *** SET PETA IN ADJACENT FULL CELL
C
      DO 830 J=1,JMAX
      DO 820 I=1,IMAX
      NFF=NF(I,J)
      IF (NFF.EQ.0.OR.BETA(I,J).LT.0.0) GO TO 820
      IF (NFF.LE.5) GO TO 760
      P(I,J)=PR(NFF)
      GO TO 820
  760 L=I
      M=J
      GO TO (770,780,790,800,820), NFF
  770 L=I-1
      DMX=DELX(L)
      DMIN=0.5*(DMX+DELX(I))
      AMN=AR(L,J)*R(L)
      GO TO 810
  780 L=I+1
      DMX=DELX(L)
      DMIN=0.5*(DMX+DELX(I))
      AMN=AR(I,J)*R(I)
      GO TO 810
  790 M=J-1
      DMX=DELY(M)
      DMIN=0.5*(DMX+DELY(J))
      AMN=AT(I,M)*RI(I)
      GO TO 810
  800 M=J+1
      DMX=DELY(M)
      DMIN=0.5*(DMX+DELY(J))
      AMN=AT(I,J)*RI(I)
  810 CONTINUE
      IF (NF(L,M).GT.0.OR.AMN.LT.EM6) GO TO 820
      BPD=1.0/PETA(L,M)-BETA(L,M)*(1.0-PETA(I,J))*AMN/
     1 (AC(L,M)*RI(I))*DELT/(DMIN*DMX)/RHOF
      PETA(L,M)=AMIN1(1.0/BPD,1.98/OMG)
  820 CONTINUE
  830 CONTINUE
      RETURN
      END


      SUBROUTINE PLTPT (XONE,YONE,ICHAR,ISYM)
*CALL,COMMON1
C
C +++ PLOT (DRAW) A POINT
C +++ PROVIDES A SYSTEM DEPENDANT CALL
C
      IC=0
      X1=XONE
      Y1=YONE
   10 XO1=(X1-XMIN)*SF+XSHFT
      YO1=(Y1-YMIN)*SF+YSHFT
      IX1=50.+920.0*XO1
      IY1=50.+920.0*(1.0-YO1)
      CALL PLT (IX1,IY1,42)
      IF (ABS(X1).LE.EM6) GO TO 20
      IF (ISYMPLT.EQ.0.OR.ISYM.EQ.0) GO TO 20
      IC=IC+1
      IF (IC.GT.1) GO TO 20
      X1=-X1
      GO TO 10
   20 RETURN
      END
```

```
      SUBROUTINE PRESCR
*CALL,COMMON1
C
      DIMENSION FF(IBAR2,JBAR2),AF(IBAR2,JBAR2),VLM(IBAR2,JBAR2),
     1 AD(IBAR2,JBAR2),QQ(IBAR2,JBAR2),SSM(IBAR2,JBAR2),
     2 RXR(IBAR2,JBAR2),RXL(IBAR2,JBAR2),D(IBAR2,JBAR2),
     3 RYT(IBAR2,JBAR2),RYB(IBAR2,JBAR2),DP(IBAR2,JBAR2)
C
      DATA ADEFM,BDEFM / 100.0, 0.10 /
      DATA ITMAX,ITMIN,ITMOST / 500, 5, 90 /
      DATA KTRAN / 1 /
C
C     THIS SUBROUTINE MUST BE MODIFIED FOR BOUNDARY CONDITIONS
C     OTHER THAN NORMAL VELOCITY EQUAL TO ZERO
C
      GO TO (1,2),KTRAN
    1 KTRAN=2
C
      EPSIP=2.0*EPSI
      EPSIM=0.5*EPSI
C
      IF(NCYC.GT.1) GO TO 2
      DO 750 J=1,JMAX
      DO 750 I=1,IMAX
      IF(AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 740
      NFF=NF(I,J)
      IF(NFF.EQ.0) GO TO 750
      IF(NFF.GT.5) GO TO 730
      L=I
      M=J
      GO TO (723,724,725,726,728), NFF
  723 L=I-1
      GO TO 727
  724 L=I+1
      GO TO 727
  725 M=J-1
      GO TO 727
  726 M=J+1
  727 NFEL=NF(I-1,J)
      NFER=NF(I+1,J)
      NFEB=NF(I,J-1)
      NFET=NF(I,J+1)
      NFE=MAX0(NFEL,NFER,NFEB,NFET)
      PSURF=PS(I,J)+PR(NFE)
      PLM=P(L,M)
      IF (NF(L,M).NE.0.AND.BETA(I,J).GT.0.0) PLM=PSURF
      P(I,J)=(1.0-PETA(I,J))*PLM+PETA(I,J)*PSURF
      GO TO 745
  728 IF(PSAT.LE.0.0) GO TO 736
      IF(F(I,J).LT.EMF1) GO TO 733
      PMPS=0.0
      IF(PN(I,J).LT.PSAT) PMPS=P(I,J)-PSAT
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
      DIJ=DIJ/(AC(I,J)*RI(I))-PMPS**2/DELT
      P(I,J)=PN(I,J)-DIJ*BETA(I,J)/(1.0-2.0*PMPS*BETA(I,J)/DELT)
      GO TO 745
  730 P(I,J)=PR(NFF)
      GO TO 745
  733 P(I,J)=PSAT
      GO TO 745
  736 P(I,J)=PN(I,J)
      GO TO 745
  740 P(I,J)=0.0
  745 PN(I,J)=P(I,J)
  750 CONTINUE
C
    2 CONTINUE
C
      DELTCR=DELT/RHOF
      C1=1.0
      DD=1.0
      LVEC=IMAX*JMAX
      DO 150 J=1,JMAX
      DO 150 I=1,IMAX
      IF(NF(I,J).GT.0.OR.AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 140
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
      VLM(I,J)=AC(I,J)*TPI*RI(I)*DELX(I)*DELY(J)
      D(I,J)=DIJ/(AC(I,J)*RI(I))*VLM(I,J)
```

```
C
      IF(IDEFM.EQ.0.OR.F(I,J).GE.EMF1) GO TO 5
C
      D(I,J)=D(I,J)+AMIN1(ADEFM*EPSI,BDEFM*(1.0-F(I,J))/DELT)
C
    5 CONTINUE
      SSM(I,J)=0.0
      RXR(I,J)=0.0
      RXRA=0.0
      RXRB=0.0
      IF(AR(I,J).LT.EM6) GO TO 10
      RXR(I,J)=AR(I,J)*TPI*R(I)*DELY(J)*2.0/(DELX(I)+DELX(I+1))
      SSM(I,J)=SSM(I,J)+DELTCR*RXR(I,J)
      IF(NF(I+1,J).EQ.0) GO TO 10
      IF(NF(I+1,J).GT.5) GO TO 9
      IF(NF(I+1,J).NE.1) GO TO 8
      RXRA=(1.0-PETA(I+1,J))*RXR(I,J)
      RXRB=((1.0-PETA(I+1,J))*PN(I,J)+PETA(I+1,J)*(PS(I+1,J)+PSAT)-
     1 PN(I+1,J))*RXR(I,J)
      GO TO 9
    8 RXRB=(P(I+1,J)-PN(I+1,J))*RXR(I,J)
    9 RXR(I,J)=0.0
   10 RXL(I,J)=0.0
      RXLA=0.0
      RXLB=0.0
      IF(AR(I-1,J).LT.EM6) GO TO 20
      RXL(I,J)=AR(I-1,J)*TPI*R(I-1)*DELY(J)*2.0/(DELX(I)+DELX(I-1))
      SSM(I,J)=SSM(I,J)+DELTCR*RXL(I,J)
      IF(NF(I-1,J).EQ.0) GO TO 20
      IF(NF(I-1,J).GT.5) GO TO 19
      IF(NF(I-1,J).NE.2) GO TO 18
      RXLA=(1.0-PETA(I-1,J))*RXL(I,J)
      RXLB=((1.0-PETA(I-1,J))*PN(I,J)+PETA(I-1,J)*(PS(I-1,J)+PSAT)-
     1 PN(I-1,J))*RXL(I,J)
      GO TO 19
   18 RXLB=(P(I-1,J)-PN(I-1,J))*RXL(I,J)
   19 RXL(I,J)=0.0
   20 RYT(I,J)=0.0
      RYTA=0.0
      RYTB=0.0
      IF(AT(I,J).LT.EM6) GO TO 30
      RYT(I,J)=AT(I,J)*TPI*RI(I)*DELX(I)*2.0/(DELY(J)+DELY(J+1))
      SSM(I,J)=SSM(I,J)+DELTCR*RYT(I,J)
      IF(NF(I,J+1).EQ.0) GO TO 30
      IF(NF(I,J+1).GT.5) GO TO 29
      IF(NF(I,J+1).NE.3) GO TO 28
      RYTA=(1.0-PETA(I,J+1))*RYT(I,J)
      RYTB=((1.0-PETA(I,J+1))*PN(I,J)+PETA(I,J+1)*(PS(I,J+1)+PSAT)-
     1 PN(I,J+1))*RYT(I,J)
      GO TO 29
   28 RYTB=(P(I,J+1)-PN(I,J+1))*RYT(I,J)
   29 RYT(I,J)=0.0
   30 RYB(I,J)=0.0
      RYBA=0.0
      RYBB=0.0
      IF(AT(I,J-1).LT.EM6) GO TO 40
      RYB(I,J)=AT(I,J-1)*TPI*RI(I)*DELX(I)*2.0/(DELY(J)+DELY(J-1))
      SSM(I,J)=SSM(I,J)+DELTCR*RYB(I,J)
      IF(NF(I,J-1).EQ.0) GO TO 40
      IF(NF(I,J-1).GT.5) GO TO 39
      IF(NF(I,J-1).NE.4) GO TO 38
      RYBA=(1.0-PETA(I,J-1))*RYB(I,J)
      RYBB=((1.0-PETA(I,J-1))*PN(I,J)+PETA(I,J-1)*(PS(I,J-1)+PSAT)-
     1 PN(I,J-1))*RYB(I,J)
      GO TO 39
   38 RYBB=(P(I,J-1)-PN(I,J-1))*RYB(I,J)
   39 RYB(I,J)=0.0
   40 SSM(I,J)=SSM(I,J)-DELTCR*(RXRA+RXLA+RYTA+RYBA)
      D(I,J)=(D(I,J)-DELTCR*(RXRB+RXLB+RYTB+RYBB))/SSM(I,J)
      FF(I,J)=0.0
      AF(I,J)=0.0
      QQ(I,J)=0.0
      AD(I,J)=0.0
      DP(I,J)=0.0
      GO TO 150
  140 VLM(I,J)=1.0
      D(I,J)=0.0
      FF(I,J)=0.0
      AF(I,J)=0.0
      AD(I,J)=0.0
```

```
      QQ(I,J)=0.0
      SSM(I,J)=1.0
      RXR(I,J)=0.0
      RXL(I,J)=0.0
      RYT(I,J)=0.0
      RYB(I,J)=0.0
      DP(I,J)=0.0
  150 CONTINUE
C
200   A=C1/DD
      CALL SAXPY(LVEC,A,FF,1,DP,1)
      CALL SAXPY(LVEC,-A,QQ,1,D,1)
      DMAX=0.0
      DO 350 J=1,JMAX
      DO 350 I=1,IMAX
      IF(NF(I,J).GT.0.OR.AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) D(I,J)=0.0
      DIV=D(I,J)*SSM(I,J)/VLM(I,J)*AC(I,J)*TPI*RI(I)
      DMAX=AMAX1(DMAX,ABS(DIV))
350   CONTINUE
      IF(DMAX.LE.EPSI) GO TO 500
      DO 250 J=1,JMAX
      DO 250 I=1,IMAX
      IF(NF(I,J).GT.0.OR.AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 245
      AD(I,J)=DELTCR*(RXR(I,J)*D(I+1,J)+RXL(I,J)*D(I-1,J)+
     1 RYT(I,J)*D(I,J+1)+RYB(I,J)*D(I,J-1))-SSM(I,J)*D(I,J)
      GO TO 250
  245 AD(I,J)=0.0
250   CONTINUE
      C2=SDOT(LVEC,D,1,AD,1)
      B=C2/C1
      DD=0.0
      CALL SSCAL(LVEC,B,FF,1)
      CALL SAXPY(LVEC,1.,D,1,FF,1)
      CALL SSCAL(LVEC,B,AF,1)
      CALL SAXPY(LVEC,1.,AD,1,AF,1)
      DO 450 J=1,JMAX
      DO 450 I=1,IMAX
      QQ(I,J)=AF(I,J)/SSM(I,J)
450   CONTINUE
      DD=SDOT(LVEC,QQ,1,AF,1)
      C1=C2
      ITER=ITER+1
      IF(ITER.GT.ITMAX) GO TO 230
      GO TO 200
500   IF(ITER.GT.ITMOST) EPSI=1.05*EPSI
      IF(ITER.LT.ITMIN) EPSI=0.95*EPSI
      EPSI=AMIN1(EPSI,EPSIP)
      EPSI=AMAX1(EPSI,EPSIM)
C
C
C +++ UNFOLD PRESSURE FOR INTERIOR FLUID CELLS
C
      DO 510 J=1,JMAX
      DO 510 I=1,IMAX
      IF(NF(I,J).GT.0.OR.AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 510
      P(I,J)=PN(I,J)+DP(I,J)
  510 CONTINUE
C
C +++ CALCULATE PRESSURE CHANGES FOR SURFACE CELLS
C
      DO 550 J=1,JMAX
      DO 550 I=1,IMAX
      IF(AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 540
      NFF=NF(I,J)
      IF(NFF.EQ.0) GO TO 550
      IF(NFF.GT.5) GO TO 530
      L=I
      M=J
      GO TO (523,524,525,526,528), NFF
  523 L=I-1
      GO TO 527
  524 L=I+1
      GO TO 527
  525 M=J-1
      GO TO 527
  526 M=J+1
  527 NFEL=NF(I-1,J)
      NFER=NF(I+1,J)
      NFEB=NF(I,J-1)
      NFET=NF(I,J+1)
```

```
      NFE=MAX0(NFEL,NFER,NFEB,NFET)
      PSURF=PS(I,J)+PR(NFE)
      PLM=P(L,M)
      IF (NF(L,M).NE.0.AND.BETA(I,J).GT.0.0) PLM=PSURF
      DP(I,J)=(1.0-PETA(I,J))*PLM+PETA(I,J)*PSURF-PN(I,J)
      GO TO 550
  528 IF(PSAT.LE.0.0) GO TO 536
      IF(F(I,J).LT.EMF1) GO TO 533
      PMPS=0.0
      IF(PN(I,J).LT.PSAT) PMPS=P(I,J)-PSAT
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
      DIJ=DIJ/(AC(I,J)*RI(I))-PMPS**2/DELT
      DP(I,J)=-DIJ*BETA(I,J)/(1.0-2.0*PMPS*BETA(I,J)/DELT)
      GO TO 550
  530 DP(I,J)=PR(NFF)-PN(I,J)
      GO TO 550
  533 DP(I,J)=PSAT-PN(I,J)
      GO TO 550
  536 DP(I,J)=0.0
      GO TO 550
  540 DP(I,J)=0.0
  550 CONTINUE
C
C      CALC NEW VELOCITIES CONSISTENT WITH SURFACE PRESSURE ASSUMPTIONS
C     NOTE: YIELDS D=0.0 FOR INTERIOR CELLS ADJACENT TO SURFACE CELLS
C
      DO 560 J=2,JM1
      DO 560 I=2,IM1
      IF(AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 560
      IF(AR(I,J).LT.EM6) GO TO 555
      IF(NF(I,J).EQ.0.AND.NF(I+1,J).EQ.0) GO TO 551
      IF(NF(I,J).EQ.0.AND.NF(I+1,J).NE.1) GO TO 552
      IF(NF(I,J).NE.2.AND.NF(I+1,J).EQ.0) GO TO 553
  551 U(I,J)=U(I,J)+DELTCR*(DP(I,J)-DP(I+1,J))*2.0/(DELX(I)+DELX(I+1))
      GO TO 555
  552 U(I,J)=U(I,J)+DELTCR*DP(I,J)*2.0/(DELX(I)+DELX(I+1))
      GO TO 555
  553 U(I,J)=U(I,J)+DELTCR*(-DP(I+1,J))*2./(DELX(I)+DELX(I+1))
      GO TO 555
555   IF(AT(I,J).LT.EM6) GO TO 560
      IF(NF(I,J).EQ.0.AND.NF(I,J+1).EQ.0) GO TO 556
      IF(NF(I,J).EQ.0.AND.NF(I,J+1).NE.3) GO TO 557
      IF(NF(I,J).NE.4.AND.NF(I,J+1).EQ.0) GO TO 558
  556 V(I,J)=V(I,J)+DELTCR*(DP(I,J)-DP(I,J+1))*2.0/(DELY(J)+DELY(J+1))
      GO TO 560
  557 V(I,J)=V(I,J)+DELTCR*DP(I,J)*2.0/(DELY(J)+DELY(J+1))
      GO TO 560
  558 V(I,J)=V(I,J)+DELTCR*(-DP(I,J+1))*2./(DELY(J)+DELY(J+1))
560   CONTINUE
C
C +++ PUT IN PRESSURES FOR SURFACE CELLS, ISOLATED CELLS, VOIDS
C
      DO 570 J=1,JMAX
      DO 570 I=1,IMAX
      IF(AC(I,J).LT.EMF.OR.BETA(I,J).LE.0.0) GO TO 570
      IF(NF(I,J).EQ.0) GO TO 570
      P(I,J)=PN(I,J)+DP(I,J)
  570 CONTINUE
C
      CALL BC
C
      RETURN
  230 CONTINUE
      WRITE (59,240) NCYC
      WRITE (12,240) NCYC
      WRITE (6,240) NCYC
      CALL EXITLOC (6HP ITER)
C
  240 FORMAT (1X,29HTOO MANY CR ITERATIONS, CYCLE,I7)
      END
```

```
      SUBROUTINE PRESIT
*CALL,COMMON1
      DATA ITMAX /1000/
C
C +++ PRESSURE ITERATION
C
C +++ TEST FOR CONVERGENCE
C
   10 IF (FLG.EQ.0.) GO TO 160
      ITER=ITER+1
      IF (ITER.LT.ITMAX) GO TO 20
      FNOC=1.0
      NOCON=NOCON+1
      WRITE (12,170) NCYC,T,NOCON
      WRITE (59,170) NCYC,T,NOCON
      GO TO 160
   20 FLG=0.0
C
C +++ COMPUTE UPDATED CELL PRESSURE AND VELOCITIES
C
      DO 150 J=JPB,JPT
      DO 150 I=IPL,IPR
      IF (BETA(I,J).LT.0.0) GO TO 150
      IF (NF(I,J).GT.5) GO TO 150
      IF (NF(I,J).EQ.0) GO TO 100
C
C +++ CALCULATE PRESSURE FOR SURFACE CELLS
C
      NFF=NF(I,J)
      L=I
      M=J
      GO TO (50,60,70,80,30), NFF
   30 IF (PSAT.LE.0.0) GO TO 150
      IF (F(I,J).LT.EMF1) GO TO 40
      PMPS=0.0
      IF (P(I,J).LT.PSAT) PMPS=P(I,J)-PSAT
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
      DIJ=DIJ/(AC(I,J)*RI(I))-PMPS**2/DELT
      DELP=-DIJ*BETA(I,J)/(1.0-2.0*PMPS*BETA(I,J)/DELT)
      GO TO 110
   40 DELP=PSAT-P(I,J)
      GO TO 110
   50 L=I-1
      GO TO 90
   60 L=I+1
      GO TO 90
   70 M=J-1
      GO TO 90
   80 M=J+1
   90 CONTINUE
      NFEL=NF(I-1,J)
      NFER=NF(I+1,J)
      NFEB=NF(I,J-1)
      NFET=NF(I,J+1)
      NFE=MAX0(NFEL,NFER,NFEB,NFET)
      PSURF=PS(I,J)+PR(NFE)
      PLM=P(L,M)
      IF (NF(L,M).NE.0.AND.BETA(I,J).GT.0.0) PLM=PSURF
      DELP=(1.0-PETA(I,J))*PLM+PETA(I,J)*PSURF-P(I,J)
      GO TO 110
  100 CONTINUE
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
      DIJ=DIJ/(AC(I,J)*RI(I))
C
      IF(IDEFM.EQ.0.OR.F(I,J).GE.EMF1) GO TO 5
C
      DIJ=DIJ+AMIN1(ADEFM*EPSI,BDEFM*(1.0-F(I,J))/DELT)
C
    5 CONTINUE
C
C +++ SET FLAG INDICATING CONVERGENCE
C
      IF (ABS(DIJ).GE.EPSI) FLG=1.0
      DELP=-BETA(I,J)*DIJ*PETA(I,J)
  110 CONTINUE
      P(I,J)=P(I,J)+DELP
      DPDT=2.0*DELT*DELP
      IF (AR(I,J).LT.EM6) GO TO 120
```

```
      RHOXR=RHOF*(DELX(I+1)+DELX(I))
      U(I,J)=U(I,J)+DPDT/RHOXR
  120 IF (AR(I-1,J).LT.EM6) GO TO 130
      RHOXL=RHOF*(DELX(I)+DELX(I-1))
      U(I-1,J)=U(I-1,J)-DPDT/RHOXL
  130 IF (AT(I,J).LT.EM6) GO TO 140
      RHOYT=RHOF*(DELY(J+1)+DELY(J))
      V(I,J)=V(I,J)+DPDT/RHOYT
  140 IF (AT(I,J-1).LT.EM6) GO TO 150
      RHOYB=RHOF*(DELY(J)+DELY(J-1))
      V(I,J-1)=V(I,J-1)-DPDT/RHOYB
  150 CONTINUE
      CALL BC
      GO TO 10
  160 CONTINUE
      RETURN
C
  170 FORMAT (1X,35HPRESIT CONVERGENCE FAILURE ON CYCLE,I7,1X,2HT=,1PE15
     1 .7,1X,I2,7HTH TIME)
      END


      SUBROUTINE PRTPLT (N)
*CALL,COMMON1
      FVOL=0.
      YCFL=1.E+99
      DO 10 J=2,JM1
      IF (F(2,J).LE.1.-EM6.AND.F(2,J).GE.EM6) YCFL=Y(J-1)+F(2,J)*(Y(J)-Y
     1 (J-1))
      IF (YCFL.GT.1.E+98.AND.F(2,J).LE.EM6) YCFL=Y(J-1)
      DO 10 I=2,IM1
      FVOL=FVOL+F(I,J)*AC(I,J)*TPI*RI(I)*(R(I)-R(I-1))*(Y(J)-Y(J-1))
   10 CONTINUE
C
C +++ PRINT AND PLOT
C +++ PROVIDES FORMATTED WRITES TO PAPER AND FILM
C
      GO TO (20,120,140,200), N
C
C +++ PRTPLT (1) WRITE OUT INITIAL DATA AND MESH DATA
C
   20 WRITE (6,290)
      WRITE (6,300) NAME
      WRITE (6,340) IBAR,JBAR,DELT,XNU,ICYL,EPSI,GX,GY,UI,VI,VELMX,TWFIN
     1 ,PRTDT,PLTDT,OMG,ALPHA,KL,KR,KT,KB,IMOVY,AUTOT,FLHT,PSAT,ISYMPLT
     2 ,SIGMA,ISURF10,CANGLE,RHOF
      IF (IMOVY.GT.0) GO TO 70
      WRITE (12,290)
      WRITE (12,300) NAME
      WRITE (12,340) IBAR,JBAR,DELT,XNU,ICYL,EPSI,GX,GY,UI,VI,VELMX
     1 ,TWFIN,PRTDT,PLTDT,OMG,ALPHA,KL,KR,KT,KB,IMOVY,AUTOT,FLHT,PSAT
     2 ,ISYMPLT,SIGMA,ISURF10,CANGLE,RHOF
C
C +++ WRITE ON FILM VARIABLE MESH INPUT DATA
C
      WRITE (12,370) NKX
      DO 30 I=1,NKX
      WRITE (12,380) I,XL(I),XC(I),XL(I+1),NXL(I),NXR(I),DXMN(I)
   30 CONTINUE
      WRITE (12,400) NKY
      DO 40 I=1,NKY
      WRITE (12,390) I,YL(I),YC(I),YL(I+1),NYL(I),NYR(I),DYMN(I)
   40 CONTINUE
      WRITE (12,440) NOBS
      IF (NOBS.LE.0) GO TO 60
      DO 50 I=1,NOBS
      WRITE (12,450) I,OA2(I),OA1(I),OB2(I),OB1(I),OC2(I),OC1(I),IOH(I)
   50 CONTINUE
   60 CONTINUE
   70 CONTINUE
C
C +++ PRINT VARIABLE MESH INPUT DATA
C
      WRITE (6,370) NKX
      DO 80 I=1,NKX
      WRITE (6,380) I,XL(I),XC(I),XL(I+1),NXL(I),NXR(I),DXMN(I)
   80 CONTINUE
      WRITE (6,400) NKY
      DO 90 I=1,NKY
      WRITE (6,390) I,YL(I),YC(I),YL(I+1),NYL(I),NYR(I),DYMN(I)
```

```
   90 CONTINUE
      WRITE (6,440) NOBS
      IF (NOBS.LE.0) GO TO 110
      DO 100 I=1,NOBS
      WRITE (6,450) I,OA2(I),OA1(I),OB2(I),OB1(I),OC2(I),OC1(I),IOH(I)
  100 CONTINUE
  110 CONTINUE
      GO TO 240
C
C +++ PRTPLT (2)  WRITE TIME STEP, CYCLE INFORMATION
C
  120 CONTINUE
      FORCE=0.0
      WRITE (6,330) ITER,T,DELT,NCYC,VCHGT,FORCE
      IF (IMOVY.EQ.1) GO TO 130
      IF (T.GT.0.) GO TO 130
      WRITE (12,330) ITER,T,DELT,NCYC,VCHGT,FORCE
  130 CONTINUE
      GO TO 240
C
C +++ PRTPLT (3)  WRITE FIELD VARIABLES TO FILM
C
  140 IF (IMOVY.EQ.1) GO TO 190
      CALL ADV (1)
      WRITE (12,360) NAME
      WRITE (12,330) ITER,T,DELT,NCYC,VCHGT,FORCE
      WRITE (12,350)
      WRITE (12,410) NREG
      WRITE (12,420)
      KNR=NREG+5
      DO 150 K=6,KNR
      WRITE (12,430) K,VOL(K),PR(K)
  150 CONTINUE
      WRITE (12,260) FVOL,NCYC,YCFL
      WRITE (12,310)
      DO 170 I=1,IMAX
      DO 170 J=1,JMAX
      DIJ=0.
      IF (J.EQ.1.OR.I.EQ.1.OR.J.EQ.JMAX.OR.I.EQ.IMAX) GO TO 160
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
      IF (AC(I,J).GT.0.0) DIJ=DIJ/(AC(I,J)*RI(I))
  160 CONTINUE
      WRITE (12,320) I,J,U(I,J),V(I,J),P(I,J),DIJ,PS(I,J),F(I,J),NF(I,J)
     1 ,PETA(I,J)
  170 CONTINUE
      WRITE (12,270) NCYC,T,DELT,(I,I=2,IMAX,2)
      DO 180 JJJ=1,JMAX
      J=JMAX+1-JJJ
      WRITE (12,280) J,(NF(I,J),I=1,IMAX)
  180 CONTINUE
      WRITE (12,275) NCYC,T,DELT,(I,I=2,IMAX,2)
      DO 185 JJJ=1,JMAX
      J=JMAX+1-JJJ
      WRITE (12,280) J,(NW(I,J),I=1,IMAX)
  185 CONTINUE
  190 CONTINUE
      GO TO 240
C
C +++ PRTPLT (4)  WRITE FIELD VARIABLES TO PAPER
C
  200 WRITE (6,290)
      WRITE (6,360) NAME
      WRITE (6,330) ITER,T,DELT,NCYC,VCHGT
      WRITE (6,350)
      WRITE (6,410) NREG
      WRITE (6,420)
      KNR=NREG+5
      DO 210 K=6,KNR
      WRITE (6,430) K,VOL(K),PR(K)
  210 CONTINUE
      WRITE (6,260) FVOL,NCYC,YCFL
      WRITE (6,350)
      WRITE (6,310)
      DO 230 I=1,IMAX
      DO 230 J=1,JMAX
      DIJ=0.
      IF (J.EQ.1.OR.I.EQ.1.OR.J.EQ.JMAX.OR.I.EQ.IMAX) GO TO 220
      DIJ=RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
```

```
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1))
       IF (AC(I,J).GT.0.0) DIJ=DIJ/(AC(I,J)*RI(I))
  220 CONTINUE
      WRITE (6,320) I,J,U(I,J),V(I,J),P(I,J),DIJ,PS(I,J),F(I,J),NF(I,J)
     1 ,PETA(I,J)
  230 CONTINUE
  240 RETURN
C
  250 FORMAT (1X,5HT(F)=,1PE14.6,2X,8HON CYCLE,I6)
  260 FORMAT (1X,14HFLUID VOLUME =,1PE14.6,9H ON CYCLE,I6,2X,15HYCENT OF
     1 FLUID=,E14.6)
  270 FORMAT (1H1,1X,43HNF FIELD (INCL. FICTITIOUS CELLS) FOR CYCLE,I6,2
     1 X,2HT=,1PE14.7,2X,5HDELT=,E12.5//5X,32I4)
  275 FORMAT (1H1,1X,43HNW FIELD (INCL. FICTITIOUS CELLS) FOR CYCLE,I6,2
     1 X,2HT=,1PE14.7,2X,5HDELT=,E12.5//5X,32I4)
  280 FORMAT (1X,I3,1X,63I2/(5X,63I2))
  290 FORMAT (1H1)
  300 FORMAT (10A8)
  310 FORMAT (4X,1HI,5X,1HJ,9X,1HU,14X,1HV,15X,1HP,15X,1HD,12X,2HPS,13X,
     1 1HF,11X,2HNF,9X,4HPETA)
  320 FORMAT (2X,I3,3X,I3,6(3X,1PE12.5),3X,I3,3X,E12.5)
  330 FORMAT (6X,6HITER= ,I5,5X,6HTIME= ,1PE12.5,5X,6HDELT= ,1PE12.5,5X,
     1 7HCYCLE= ,I6,2X,7HVCHGT= ,1PE12.5,2X,4HFY= ,E12.5)
  340 FORMAT (1H ,5X,6HIBAR= ,I3/6X,6HJBAR= ,I3/6X,6HDELT= ,1PE12.5/8X,4
     1 HNU= ,E12.5/6X,6HICYL= ,I2/6X,6HEPSI= ,E12.5/8X,4HGX= ,E12.5/8X,4
     2 HGY= ,E12.5/8X,4HUI= ,E12.5/8X,4HVI= ,E12.5/5X,7HVELMX= ,E12.5/5X
     3 ,7HTWFIN= ,E12.5/5X,7HPRTDT= ,E12.5/5X,7HPLTDT= ,E12.5/7X,5HOMG=
     4 ,E12.5/5X,7HALPHA= ,E12.5/8X,4HKL= ,I2/8X,4HKR= ,I2/8X,4HKT= ,I2/
     5 8X,4HKB= ,I2/5X,7HIMOVY= ,I2/5X,7HAUTOT= ,E12.5/6X,6HFLHT= ,E12.5
     6 /6X,6HPSAT= ,E12.5/3X,9HISYMPLT= ,I2/5X,7HSIGMA= ,E12.5/3X,9HISUR
     7F10= ,I2/4X,8HCANGLE= ,E12.5/7X,6HRHOF= ,E12.5/)
  350 FORMAT (1H0)
  360 FORMAT (1H ,18X,10A8,1X,A10,2(1X,A8))
  370 FORMAT (2X,5HNKX= ,I4)
  380 FORMAT (2X,8HMESH-X= ,I4,3X,4HXL= ,1PE12.5,3X,4HXC= ,E12.5,3X,4HXR
     1= ,E12.5,3X,5HNXL= ,I4,3X,5HNXR= ,I4,3X,6HDXMN= ,E12.5)
  390 FORMAT (2X,8HMESH-Y= ,I4,3X,4HYL= ,1PE12.5,3X,4HYC= ,E12.5,3X,4HYR
     1= ,E12.5,3X,5HNYL= ,I4,3X,5HNYR= ,I4,3X,6HDYMN= ,E12.5)
  400 FORMAT (2X,5HNKY= ,I4)
  410 FORMAT (2X,6HNREG= ,I4)
  420 FORMAT (15X,1HK,6X,6HVOL(K),9X,5HPR(K))
  430 FORMAT (13X,I3,2X,1PE12.5,3X,E12.5)
  440 FORMAT (2X,6HNOBS= ,I2)
  450 FORMAT (2X,2HI=,I2,2X,4HOA2=,1PE12.5,2X,4HOA1=,E12.5,2X,5HOB2=
     1 ,E12.5,2X,5HOB1= ,E12.5,2X,5HOC2= ,E12.5,2X,5HOC1= ,E12.5,2X,5HIO
     2H= ,I2)
      END
```

```
      SUBROUTINE SETUP
*CALL,COMMON1
      NAMELIST /XPUT/ DELT,XNU,ICYL,EPSI,GX,GY,UI,VI,VELMX,TWFIN,PRTDT
     1 ,PLTDT,OMG,ALPHA,KL,KR,KT,KB,IMOVY,AUTOT,FLHT,PSAT,ISYMPLT,SIGMA
     2 ,ISURF10,CANGLE,RHOF,IEQIC
     3 ,NAME,NDUMP,QVOL,ISOR,IDEFM,NPACK,CON,DTCRMX,IDIV
      NAMELIST /MSHSET/ NKX,XL,XC,NXL,NXR,DXMN,NKY,YL,YC,NYL,NYR,DYMN
      NAMELIST /ASETIN / NOBS,OA2,OA1,OB2,OB1,OC2,OC1,IOH
C +++
C +++ INITIALIZE SELECTED VARIABLES
C +++
      DATA T /0./, ITER /0/, FLGC /0./, FNOC /0./, NCYC /0/, NFLGC /0/,
     1 NOCON /0/, TWPLT /0./, TWPRT /0./, VCHGT /0./, NEQUIB /501/
      DATA ISOR,IDEFM,NPACK,NDUMP,NOBS,QVOL / 0, 0, 0, 0, 0, 0.0 /
      DATA CON,DTCRMX,IDIV / 0.30, 0.001, 1 /
C +++
C +++ READ INITIAL INPUT DATA
C +++
      READ (5,XPUT)
      WRITE(12,330) NAME
      WRITE(12,360) NDUMP, QVOL
      WRITE(12,320) ISOR,IDEFM
      READ (5,MSHSET)
      DO 30 K=1,NOBD
      OA2(K)=0.
      OA1(K)=0.
      OB2(K)=0.
      OB1(K)=0.
      OC2(K)=0.
      OC1(K)=0.
   30 CONTINUE
      READ (5,ASETIN)
C +++
C +++ IF THE DUMP SEQUENCE NUMBER IS GREATER THAN ZERO, READ A RESTART
C +++ DUMP AND SKIP THE REST OF THE SETUP ROUTINE.
C +++
      IF (NDUMP.LE.0) GO TO 40
      CALL TAPIN
      GO TO 290
   40 CONTINUE
      CALL MESHSET
C
C +++ COMPUTE CONSTANT TERMS AND INITIALIZE NECESSARY VARIABLES
C
C +++ SET PARAMETER STATEMENT VALUE INTO CONSTANT
C
      NDUMP=1
      IF(ICYL.EQ.0) TPI=1.0
      CYL=FLOAT(ICYL)
      EMF1=1.0-EMF
      IF (CANGLE.EQ.90.0) CANGLE=CANGLE-EM6
      DANGLE=CANGLE
      CANGLE=CANGLE*RPD
      IF (CON*1.3.LE.FCVLIM) GO TO 50
      WRITE (12,380) CON,FCVLIM
      WRITE (59,380) CON,FCVLIM
      FCVLIM=1.3*CON
   50 CONTINUE
      BOND=1.E+100
      IF (SIGMA.GT.0.) BOND=RHOF*GY*X(IM1)**2/SIGMA
      WRITE (59,390) BOND
      WRITE (12,390) BOND
      IPL=2
      IF (KL.EQ.5) IPL=3
      IPR=IM1
      IF (KR.EQ.5) IPR=IBAR
      JPB=2
      IF (KB.EQ.5) JPB=3
      JPT=JM1
      IF (KT.EQ.5) JPT=JBAR
C
C +++ SET CONSTANT TERMS FOR PLOTTING
C
      XMIN=X(1)
      XMAX=X(IM1)
      IF (ISYMPLT.GT.0) XMIN=-XMAX
      YMIN=Y(1)
      YMAX=Y(JM1)
      D1=XMAX-XMIN
      D2=YMAX-YMIN
```

```
      D3=AMAX1(D1,D2)
      SF=1.0/D3
      XSHFT=0.5*(1.0-D1*SF)
      YSHFT=0.5*(1.0-D2*SF)
      DXMIN=EP10
      DO 60 I=2,IM1
   60 DXMIN=AMIN1(DELX(I),DXMIN)
      DYMIN=EP10
      DO 70 I=2,JM1
   70 DYMIN=AMIN1(DELY(I),DYMIN)
      VELMX1=AMIN1(DXMIN,DYMIN)/VELMX
      DO 80 I=1,IMAX
      DO 80 J=1,JMAX
      BETA(I,J)=0.0
      AC(I,J)=1.0
      AR(I,J)=1.0
      AT(I,J)=1.0
   80 CONTINUE
C +++
C +++  SET SPECIAL A VALUES FOR OBSTACLES AND B.C.
C +++
      CALL ASET
C
C +++ DETERMINE SLOPED BOUNDARY LOCATION
C
C +++ COMPUTE INITIAL VOLUME FRACTION FUNCTION F IN CELLS
      IF(IEQIC.LE.0) GO TO 90
      IF (NEQUIB+2.LT.IBAR2*JBAR2) GO TO 90
      WRITE (59,400) NEQUIB,IBAR2,JBAR2
      WRITE (12,400) NEQUIB,IBAR2,JBAR2
      NEQUIB=IBAR2*JBAR2-2
      WRITE (59,410) NEQUIB
      WRITE (12,410) NEQUIB
   90 CONTINUE
      IF (IEQIC.GT.0) CALL EQUIB (U,V,NEQUIB,BOND,DANGLE,CYL)
      SFLHT=FLHT
      DO 120 I=1,IMAX
      DO 110 J=2,JMAX
      F(I,J)=1.0
      IF (IEQIC.LE.0) GO TO 100
      LDCK=FLOAT(NEQUIB-1)*XI(I)/X(IM1)+1.000001
      LDCK=MINO(NEQUIB,LDCK)
      LDCK=MAXO(1,LDCK)
      FLHT=SFLHT+U(LDCK,1)*X(IM1)
  100 CONTINUE
      IF (FLHT.GT.Y(J-1).AND.FLHT.LT.Y(J)) F(I,J)=RDY(J)*(FLHT-Y(J-1))
      IF (Y(J-1).GE.FLHT) F(I,J)=0.0
  110 CONTINUE
      F(I,1)=F(I,2)
  120 CONTINUE
      FLHT=SFLHT
C
C +++ GENERATE SPECIAL F-FUNCTION (FLUID) CONFIGURATION
C
C +++ CALCULATE DTVIS AND DTSFT
C
      DS=1.0E+10
      DTVIS=1.0E+10
      DTSFT=1.0E+10
      DST=1.0E10
      DO 130 I=2,IM1
      DO 130 J=2,JM1
      DXSQ=DELX(I)**2
      DYSQ=DELY(J)**2
      RDSQ=DXSQ*DYSQ/(DXSQ+DYSQ)
      RDSQ=RDSQ/(3.0*XNU+1.0E-60)
      DTVIS=AMIN1(DTVIS,RDSQ)
      DS=AMIN1(DELX(I),DELY(J),DS)
      DSTX=DELX(I)*DELX(I)/(3.0*DELY(J)*RDX(I)+CYL)
      DSTY=DELY(J)*DELY(J)/(3.0*(DELX(I)*RDY(J))**2+CYL)
      DST=AMIN1(DST,DSTX*DELX(I),DSTY*DELX(I))
  130 CONTINUE
      SIGX=SIGMA
      IF (SIGX.EQ.0.0) SIGX=EM10
      DTM=SQRT(RHOF*DST/(SIGX*4.0))
      DTSFT=AMIN1(DTSFT,DTM)
C
C +++ CALCULATE BETA(I,J) FOR MESH
C
      DO 140 I=2,IM1
```

```
      DO 140 J=2,JM1
      IF (AC(I,J).LT.EM6) GO TO 140
      RHXR=RHOF*(DELX(I+1)+DELX(I))
      RHXL=RHOF*(DELX(I)+DELX(I-1))
      RHYT=RHOF*(DELY(J+1)+DELY(J))
      RHYB=RHOF*(DELY(J)+DELY(J-1))
      XX=DELT*2.0*(RDX(I)*(AR(I-1,J)*R(I-1)/RHXL+AR(I,J)*R(I)/RHXR)+
     1 RDY(J)*(AT(I,J)*RI(I)/RHYT+AT(I,J-1)*RI(I)/RHYB))
      XX=XX/(AC(I,J)*RI(I))
      BETA(I,J)=OMG/XX
  140 CONTINUE
C
C +++ SET BETA(I,J)= -1.0 IN OBSTACLE CELLS
C         MUST BE DONE BY HAND IN GENERAL
C
C +++ PRINT BETA(I,J) ON FILM AND PAPER
C
      IF (IMOVY.EQ.1) GO TO 160
      WRITE (12,420)
      WRITE (12,430)
      DO 150 J=1,JM1
      DO 150 I=1,IM1
      WRITE (12,440) I,J,BETA(I,J),AC(I,J),AR(I,J),AT(I,J),SINO(I,J),
     1 COSO(I,J)
  150 CONTINUE
  160 CONTINUE
      WRITE (6,420)
      WRITE (6,430)
      DO 170 J=1,JM1
      DO 170 I=1,IM1
      WRITE (6,440) I,J,BETA(I,J),AC(I,J),AR(I,J),AT(I,J),SINO(I,J),
     1 COSO(I,J)
  170 CONTINUE
C
C +++ CALCULATE HYDROSTATIC PRESSURE
C
      DO 180 I=2,IM1
      P(I,JMAX)=0.0
      DO 180 J=2,JM1
      JJ=JM1-J+2
      RHOYA=(AMIN1(F(I,JJ+1),0.5)*DELY(JJ+1)+AMAX1(0.0,F
     1 (I,JJ)-0.5)*DELY(JJ))*RHOF
      P(I,JJ)=P(I,JJ+1)-GY*RHOYA
  180 CONTINUE
C
C +++ SET INITIAL SURFACE PRESSURE
C
      DO 260 J=2,JM1
      DO 260 I=2,IM1
      PS(I,J)=0.0
  260 CONTINUE
C
C +++ SET INITIAL VELOCITY FIELD INTO U AND V ARRAYS
C
      DO 270 I=1,IMAX
      DO 270 J=1,JMAX
      U(I,J)=UI
      V(I,J)=VI
      IF (AT(I,J).LT.EM6) V(I,J)=0.0
      IF (AR(I,J).LT.EM6) U(I,J)=0.0
      IF (F(I,J).GT.EMF) GO TO 270
      U(I,J)=0.0
      V(I,J)=0.0
  270 CONTINUE
C
C +++ SET INITIAL VOID REGION QUANTITIES
C
      DO 280 K=1,NVOR
      NR(K)=0
      PR(K)=PSAT
  280 VOL(K)=0.0
  290 RETURN
C
  300 FORMAT (1X,2HK=,1PE12.4,2X,3HXI=,E12.4,2X,4HPER=,E12.4)
  310 FORMAT (1X,11H***** ISOR=,I10,21H MUST BE O OR 1 *****)
  320 FORMAT (4X,6HISOR =,I5,4X,7HIDEFM =,I5)
  330 FORMAT (10A8)
  340 FORMAT (10X,I10)
  350 FORMAT (10X,E20.6)
  360 FORMAT (3X,7HNDUMP =,I10/4X,6HQVOL =,1PE20.6)
```

```
  370 FORMAT (10X,7I10)
  380 FORMAT (1X,4HCON=,1PE10.3,1X,11HAND FCVLIM=,E10.3,1X,41HARE INCOMP
     1ATIBLE. SETTING FCVLIM=1.3*CON.)
  390 FORMAT (1X,13HBOND NUMBER =,1PE12.4)
  400 FORMAT (/1X,8HNEQUIB =,I5,1X,29HIS TOO BIG FOR THE DIMENSIONS,2I5)
  410 FORMAT (1X,17HCUTTING NEQUIB TO,I5,15H AND CONTINUING,)
  420 FORMAT (1H1)
  430 FORMAT (4X,1HI,5X,1HJ,8X,4HBETA,11X,2HAC,13X,2HAR,13X,2HAT,12X,
     1 4HSINO,11X,4HCOSO)
  440 FORMAT (2X,I3,3X,I3,6(3X,1PE12.5))
      END
```

```
      SUBROUTINE TAPIN
*CALL,COMMON1
C +++
C +++ READ RESTART DUMP FROM TAPE7
C +++
      READ (7) MDUMP
      IF (MDUMP.EQ.NDUMP) GO TO 10
      WRITE (6,20) MDUMP,NDUMP
      WRITE (12,20) MDUMP,NDUMP
      WRITE (59,20) MDUMP,NDUMP
      CALL EXITLDC (8HTAPIN   )
   10 CONTINUE
      NDUMP=NDUMP+1
      READ (7) UN,VN,PN,FN,U,V,P,F,PETA,BETA,NF,PS,AR,AT,AC
      READ (7) X,XI,RXI,DELX,RDX,RX,Y,YJ,RYJ,DELY,RDY,XL,XC,DXMN,NXL,NXR
     1 ,YL,YC,DYMN,NYL,NYR,ZC
      READ (7) NR,PR,VOL,IBAR,JBAR,IMAX,JMAX,IM1,JM1,NKX,NKY,NCYC,DELT,T
     1 ,TWPRT,TWPLT,RHOF,NREG,VCHGT
     2 ,CANGLE,ICYL,CYL,ITER,FLG,FLGC,FNOC,NOCON,NFLGC,ISYMPLT
     3 ,IMOVY,VELMX,VELMX1,XSHFT,YSHFT,XMIN,XMAX,YMIN,YMAX,SF
     4 ,IPL,IPR,JPB,JPT,DTVIS,DTSFT,DXMIN,DYMIN,PSAT
     5 ,LITER,EMF1
      WRITE (6,30) NCYC,MDUMP,T
      WRITE (12,30) NCYC,MDUMP,T
      WRITE (59,30) NCYC,MDUMP,T
      RETURN
C
   20 FORMAT (1X,22HTAPIN ERROR - GOT DUMP,I4,16H, EXPECTING DUMP,I4)
   30 FORMAT (1X,19HRESTARTING ON CYCLE,I7,10H FROM DUMP,I3,4H T =,1PE13
     1 .6)
      END
```

```
      SUBROUTINE TAPOUT (NKKP)
*CALL,COMMON1
C +++
C +++ WRITE RESTART DUMP ON TAPE7
C +++ NKKP = -1, EQUILIBRIUM MESH DUMP
C +++      = 0, FINAL DUMP ON A RUN, TERMINATE
C +++      = 1, PERIODIC BACK-UP DUMP DURING A RUN
C +++
      IF (NKKP.GE.0) GO TO 20
      CALL ADV (1)
      WRITE (6,30) NCYC
      WRITE (12,30) NCYC
      WRITE (59,30) NCYC
      DO 10 I=1,IMAX
      DO 10 J=1,JMAX
      U(I,J)=0.
      V(I,J)=0.
   10 CONTINUE
   20 CONTINUE
      LCMS=7HBACK UP
      IF (NKKP.EQ.0) LCMS=7HRESTART
      WRITE (6,40) LCMS,NCYC,T
      IF (IMOVY.EQ.0) WRITE (12,40) LCMS,NCYC,T
      WRITE (59,40) LCMS,NCYC,T
      REWIND 7
      WRITE (7) NDUMP
      WRITE (7) UN,VN,PN,FN,U,V,P,F,PETA,BETA,NF,PS,AR,AT,AC
      WRITE (7) X,XI,RXI,DELX,RDX,RX,Y,YJ,RYJ,DELY,RDY,XL,XC,DXMN,NXL
     1 ,NXR,YL,YC,DYMN,NYL,NYR,ZC
      WRITE (7) NR,PR,VOL,IBAR,JBAR,IMAX,JMAX,IM1,JM1,NKX,NKY,NCYC,DELT
     1 ,T,TWPRT,TWPLT,RHOF,NREG,VCHGT
     2 ,CANGLE,ICYL,CYL,ITER,FLG,FLGC,FNOC,NOCON,NFLGC
     3 ,ISYMPLT,IMOVY,VELMX,VELMX1,XSHFT,YSHFT,XMIN,XMAX,YMIN,YMAX,SF
     4 ,IPL,IPR,JPB,JPT,DTVIS,QTSFT,DXMIN,DYMIN
     5 ,PSAT,LITER,EMF1
      IF (NKKP.LE.0) CALL EXITLDC (6HTAPOUT)
      RETURN
C
   30 FORMAT (1X,39HEQUILIBRIUM MESH DUMP TO TAPE7 ON CYCLE,I7)
   40 FORMAT (1X,A7,1X,13HDUMP ON CYCLE,I7,2X,3HT =,1PE13.5)
      END
```

```
      SUBROUTINE TILDE
*CALL,COMMON1
C
C +++ COMPUTE TEMPORARY U AND V EXPLICITLY
C
      VISX=0.0
      VISY=0.0.
      DO 20 J=2,JM1
      DO 20 I=2,IM1
      CALL DVCAL
      U(I,J)=0.0
      RDELX=1.0/(DELX(I)+DELX(I+1))
      RDELY=1.0/(DELY(J)+DELY(J+1))
      IF (NF(I,J)+NF(I+1,J).GE.12) GO TO 10
      IF (AR(I,J).LT.EM6) GO TO 10
      SGU=SIGN(1.0,UN(I,J))
      RDXA=DELX(I)+DELX(I+1)+ALPHA*SGU*(DELX(I+1)-DELX(I))
      RDXA=1.0/RDXA
      FUX=RDXA*UN(I,J)*(DELX(I)*DUDR+DELX(I+1)*DUDL+ALPHA*SGU*(DELX(I+1)
     1 *DUDL-DELX(I)*DUDR))
      VBT=(DELX(I)*VN(I+1,J)+DELX(I+1)*VN(I,J))*RDELX
      VBB=(DELX(I)*VN(I+1,J-1)+DELX(I+1)*VN(I,J-1))*RDELX
      VAV=0.5*(VBT+VBB)
      DYT=0.5*(DELY(J)+DELY(J+1))
      DYB=0.5*(DELY(J-1)+DELY(J))
      SGV=SIGN(1.0,VAV)
      DYA=DYT+DYB+ALPHA*SGV*(DYT-DYB)
      FUY=(VAV/DYA)*(DYB*DUDT+DYT*DUDB+ALPHA*SGV*(DYT*DUDB-DYB*DUDT))
      IF(XNU.EQ.0.0)GO TO 5
      DUDXSQ=(DUDR-DUDL)/(XI(I+1)-XI(I))
      DUDYSQ=(DUDT-DUDB)/(YJ(J+1)-YJ(J-1))
      RXDUDX=RX(I)*(DELX(I+1)*DUDL+DELX(I)*DUDR)/(DELX(I)+DELX(I+1))
      RXSQU=UN(I,J)*RX(I)**2
      VISX=XNU*(DUDXSQ+DUDYSQ+CYL*RXDUDX-CYL*RXSQU)
    5 CONTINUE
      RHOX=RHOF*(DELX(I+1)+DELX(I))
      U(I,J)=UN(I,J)+DELT*(GX-FUX-FUY+VISX)+DELT*(P(I,J)-P(I+1,J))*2.0
     1 /RHOX
   10 CONTINUE
      V(I,J)=0.0
      IF (NF(I,J)+NF(I,J+1).GE.12) GO TO 20
      IF (AT(I,J).LT.EM6) GO TO 20
      UBR=(DELY(J+1)*UN(I,J)+DELY(J)*UN(I,J+1))*RDELY
      UBL=(DELY(J+1)*UN(I-1,J)+DELY(J)*UN(I-1,J+1))*RDELY
      UAV=0.5*(UBR+UBL)
      DXR=0.5*(DELX(I)+DELX(I+1))
      DXL=0.5*(DELX(I)+DELX(I-1))
      SGU=SIGN(1.0,UAV)
      DXA=DXR+DXL+ALPHA*SGU*(DXR-DXL)
      FVX=(UAV/DXA)*(DXL*DVDR+DXR*DVDL+ALPHA*SGU*(DXR*DVDL-DXL*DVDR))
      SGV=SIGN(1.0,VN(I,J))
      DYA=DELY(J+1)+DELY(J)+ALPHA*SGV*(DELY(J+1)-DELY(J))
      FVY=(VN(I,J)/DYA)*(DELY(J)*DVDT+DELY(J+1)*DVDB+ALPHA*SGV*(DELY(J+1
     1 )*DVDB-DELY(J)*DVDT))
      IF(XNU.EQ.0.0)GO TO 15
      DVDXSQ=(DVDR-DVDL)/(XI(I+1)-XI(I-1))
      DVDYSQ=(DVDT-DVDB)/(YJ(J+1)-YJ(J))
      DVDXRX=0.5*(DVDR+DVDL)*RXI(I)
      VISY=XNU*(DVDXSQ+DVDYSQ+CYL*DVDXRX)
   15 CONTINUE
      RHOY=RHOF*(DELY(J+1)+DELY(J))
      V(I,J)=VN(I,J)+DELT*(GY-FVX-FVY+VISY)+DELT*(P(I,J)-P(I,J+1))*2.0
     1 /RHOY
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VFCONV
*CALL,COMMON1
      DATA FCVLIM /.9/
C
C +++ CONVECT THE VOLUME OF FLUID FUNCTION F
C
      IF (NCYC.LT.1) GO TO 100
      FLGC=0.0
      DO 50 J=1,JM1
      DO 50 I=1,IM1
      IF(BETA(I,J).LE.0.0) GO TO 50
      VX=U(I,J)*DELT
      VY=V(I,J)*DELT
      ABVX=ABS(VX)
      ABVY=ABS(VY)
      IF (ABVX.LE.FCVLIM*DELX(I).AND.ABVY.LE.FCVLIM*DELY(J)) GO TO 10
      FLGC=1.
      WRITE (59,150) NCYC,T,DELT,I,J,FCVLIM,ABVX,DELX(I),ABVY,DELY(J)
      WRITE (12,150) NCYC,T,DELT,I,J,FCVLIM,ABVX,DELX(I),ABVY,DELY(J)
   10 CONTINUE
      IF (AR(I,J).LT.EM6) GO TO 30
      IA=I+1
      ID=I
      IDM=MAX0(I-1,1)
      ARDM=AR(IDM,J)
      RB=AR(I,J)*R(I)
      RA=AC(I+1,J)*RI(I+1)
      RD=AC(I,J)*RI(I)
      IF (VX.GE.0.0) GO TO 20
      IA=I
      ID=I+1
      IDM=MIN0(I+2,IMAX)
      ARDM=AR(IDM-1,J)
      RA=AC(I,J)*RI(I)
      RD=AC(I+1,J)*RI(I+1)
   20 CONTINUE
      IAD=IA
      IF (NF(ID,J).EQ.3.OR.NF(ID,J).EQ.4) IAD=ID
      IF (FN(IA,J).LT.EMF.OR.FN(IDM,J).LT.EMF) IAD=IA
      FDM=AMAX1(FN(IDM,J),FN(ID,J),0.10)
      IF(ARDM.LT.EM6) FDM=1.0
      FX1=FN(IAD,J)*ABS(VX)+AMAX1((FDM-FN(IAD,J))*ABS(VX)-(FDM-FN(ID,J))
     1 *DELX(ID),0.0)
      FX=AMIN1(FX1,FN(ID,J)*DELX(ID)*RD/RB)
      F(ID,J)=F(ID,J)-FX*RDX(ID)*(RB/RD)
      F(IA,J)=F(IA,J)+FX*RDX(IA)*(RB/RA)
   30 IF (AT(I,J).LT.EM6) GO TO 50
      JA=J+1
      JD=J
      JDM=MAX0(J-1,1)
      ATDM=AT(I,JDM)
      RB=AT(I,J)
      RA=AC(I,J+1)
      RD=AC(I,J)
      IF (VY.GE.0.0) GO TO 40
      JA=J
      JD=J+1
      JDM=MIN0(J+2,JMAX)
      ATDM=AT(I,JDM-1)
      RA=AC(I,J)
      RD=AC(I,J+1)
   40 CONTINUE
      JAD=JA
      IF (NF(I,JD).EQ.1.OR.NF(I,JD).EQ.2) JAD=JD
      IF (FN(I,JA).LT.EMF.OR.FN(I,JDM).LT.EMF) JAD=JA
      FDM=AMAX1(FN(I,JDM),FN(I,JD),0.10)
      IF(ATDM.LT.EM6) FDM=1.0
      FY1=FN(I,JAD)*ABS(VY)+AMAX1((FDM-FN(I,JAD))*ABS(VY)-(FDM-FN(I,JD))
     1 *DELY(JD),0.0)
      FY=AMIN1(FY1,FN(I,JD)*DELY(JD)*RD/RB)
      F(I,JD)=F(I,JD)-FY*RDY(JD)*(RB/RD)
      F(I,JA)=F(I,JA)+FY*RDY(JA)*(RB/RA)
   50 CONTINUE
C +++ DEFOAM IT
      IF (NPACK.EQ.0) GO TO 70
      DO 60 I=2,IM1
      DO 60 J=2,JBAR
      IF (AT(I,J).LT.EMF) GO TO 60
      IF (NF(I,J).NE.0) GO TO 60
      IF (F(I,J).GE.EMF1) GO TO 60
```

```
      FADD=AMIN1(1.-F(I,J),F(I,J+1))
      F(I,J)=F(I,J)+FADD
      F(I,J+1)=F(I,J+1)-FADD
   60 CONTINUE
   70 CONTINUE
C    ++++++ DIVERGENCE CORRECTION TERM
      IF(IDIV.EQ.0) GO TO 90
      IF(IDEFM.EQ.1) GO TO 90
      DO 80 J=2,JM1
      DO 80 I=2,IM1
      IF (NF(I,J).NE.0.OR.AC(I,J).LE.0.) GO TO 80
      DIJ=(RDX(I)*(AR(I,J)*R(I)*U(I,J)-AR(I-1,J)*R(I-1)*U(I-1,J))+
     1 RDY(J)*(AT(I,J)*RI(I)*V(I,J)-AT(I,J-1)*RI(I)*V(I,J-1)))/
     2 (AC(I,J)*RI(I))
      F(I,J)=F(I,J)+DELT*FN(I,J)*DIJ
   80 CONTINUE
   90 CONTINUE
  100 CONTINUE
      DO 140 J=2,JM1
      DO 140 I=2,IM1
      IF (BETA(I,J).LT.0.0) GO TO 140
      VCHG=0.0
      IF (F(I,J).GT.EMF.AND.F(I,J).LT.EMF1) GO TO 120
      IF (F(I,J).GE.EMF1) GO TO 110
      VCHG=F(I,J)
      F(I,J)=0.0
      GO TO 120
  110 CONTINUE
      VCHG=-(1.0-F(I,J))
      F(I,J)=1.0
  120 CONTINUE
      VCHGT=VCHGT+VCHG*DELX(I)*DELY(J)*AC(I,J)*RI(I)*TPI
      IF (F(I,J).LT.EMF1) GO TO 140
      IF (F(I+1,J).LT.EMF.AND.AR(I,J).GT.EM6) GO TO 130
      IF (F(I-1,J).LT.EMF.AND.AR(I-1,J).GT.EM6) GO TO 130
      IF (F(I,J+1).LT.EMF.AND.AT(I,J).GT.EM6) GO TO 130
      IF (F(I,J-1).LT.EMF.AND.AT(I,J-1).GT.EM6) GO TO 130
      GO TO 140
  130 F(I,J)=F(I,J)-1.1*EMF
      VCHG=1.1*EMF
      VCHGT=VCHGT+VCHG*DELX(I)*DELY(J)*AC(I,J)*RI(I)*TPI
  140 CONTINUE
C
C +++ SPECIAL BOUNDARY CONDITIONS FOR F
C
      RETURN
C
  150 FORMAT (1X,12HVFCONV ERROR/1X,5HNCYC=,I7,1X,2HT=,1PE14.6,1X,5HDELT
     1=,E12.4,1X,4HI,J=,2I4,1X,7HFCVLIM=,E11.3/3X,5HABVX=,E12.4,1X,5HDEL
     2X=,E12.4,1X,5HABVY=,E12.4,1X,5HDELY=,E12.4)
      END
```

```
      SUBROUTINE EPI
C +++
C +++ EPILOGUE - ON-LINE DOCUMENTATION
C +++
C +++ VARIABLES LISTED IN COMMON (EXCLUDING INPUT PARAMETERS)
C
C     ADEFM     DEFOAM OPTION PARAMETER DEFINED IN PRESCR SUBROUTINE
C     BDEFM     DEFOAM OPTION PARAMETER
C     CYL       MESH GEOMETRY INDICATOR (= ICYL)
C     DTSFT     MAXIMUM DELT VALUE ALLOWED BY THE SURFACE TENSION FORCES
C               STABILITY CRITERION (DELT IS AUTOMATICALLY ADJUSTED)
C     DTVIS     MAXIMUM DELT VALUE ALLOWED BY THE VISCOUS FORCES
C               STABILITY CRITERION (DELT IS AUTOMATICALLY ADJUSTED)
C     DUDB      DERIVATIVE OF U VELOCITY RESPECT TO Y AT (I+1/2,J-1/2)
C     DUDL      DERIVATIVE OF U VELOCITY RESPECT TO X AT (I,J)
C     DUDT      DERIVATIVE OF U VELOCITY RESPECT TO Y AT (I+1/2,J+1/2)
C     DUDR      DERIVATIVE OF U VELOCITY RESPECT TO X AT (I+1,J)
C     DVDR      DERIVATIVE OF V VELOCITY RESPECT TO X AT  (I+1/2,J+1/2)
C     DVDL      DERIVATIVE OF V VELOCITY RESPECT TO X AT  (I-1/2,J+1/2)
C     DVDT      DERIVATIVE OF V VELOCITY RESPECT TO Y AT (I,J+1)
C     DVDB      DERIVATIVE OF V VELOCITY RESPECT TO Y AT (I,J)
C     DXMIN     SMALLEST DELX(I) IN MESH
C     DYMIN     SMALLEST DELY(J) IN MESH
C     EMF       SMALL VALUE, TYPICALLY 1.0E-06, USED TO NEGATE ROUND-OFF
C               ERROR EFFECTS WHEN TESTING F=1.0 OR F=0.0
C     EMF1      =1.0-EMF
C     EM6       =1.0E-06
C     EM6P1       =1.0-EM6
C     EM10      =1.0E-10
C     EP10      =1.0E+10
C     FCVLIM    F CONVECTION LIMIT ABS(UDT/DX) < FCVLIM
C                                  ABS(VDT/DY) < FCVLIM
C     FLG       PRESSURE ITERATION CONVERGENCE TEST INDICATOR (=0.0 WHEN
C               THE CONVERGENCE TEST IS SATISFIED, =1.0 WHEN THE
C               CONVERGENCE TEST IS NOT SATISFIED)
C     FLGC      VOLUME OF FLUID FUNCTION CONVECTION LIMIT INDICATOR
C               (DELT REDUCED AND CYCLE STARTED OVER IF LIMIT
C               IS EXCEEDED)
C     FNOC      PRESSURE CONVERGENCE FAILURE INDICATOR (=1.0,
C               CONVERGENCE FAILED AND DELT IS REDUCED, =0.0 OTHERWISE)
C     IBAR      NUMBER OF REAL CELLS IN X-DIRECTION (EXCLUDES FICTICIOUS
C               CELLS)
C     IBAR2     =IBAR+2, SPECIFIED IN PARAMETER STATEMENT
C               (=IBAR+3, IF PERIODIC IN X-DIRECTION)
C     IMAX      TOTAL NUMBER OF MESH CELLS IN X-DIRECTION (=IBAR+2)
C               (=IBAR+3, IF PERIODIC IN X-DIRECTION)
C     IM1       VALUE OF THE INDEX I AT THE LAST REAL CELL IN THE
C               X-DIRECTION (=IMAX-1)
C     IBAR      VALUE OF THE INDEX I AT THE NEXT TO THE LAST REAL CELL
C               IN THE X-DIRECTION (=IMAIN THE X-2)
C     IPL       LEFTMOST PRESSURE ITERATION INDEX IN X-DIRECTION
C               (=3 FOR CONSTANT PRESSURE BOUNDARY CONDITION, =2 FOR
C               ALL OTHER CASES)
C     IPR       RIGHTMOST PRESSURE ITERATION INDEX IN X-DIRECTION
C              (=IBAR FOR CONSTANT PRESSURE BOUNDARY CONDITION, =IM1 FOR
C               ALL OTHER CASES)
C     ITER      PRESSURE ITERATION COUNTER
C     JBAR      NUMBER OF REAL CELLS IN Y-DIRECTION (EXCLUDES FICTICIOUS
C               CELLS)
C     JBAR2     =JBAR+2, SPECIFIED IN PARAMETER STATEMENT
C               (=JBAR+3, IF PERIODIC IN Y-DIRECTION)
C     JMAX      TOTAL NUMBER OF MESH CELLS IN Y-DIRECTION (=JBAR+2)
C               (=JBAR+3, IF PERIODIC IN Y-DIRECTION)
C     JM1       VALUE OF THE INDEX J AT THE LAST REAL CELL IN THE
C               Y-DIRECTION (=JMAX-1)
C     JBAR       VALUE OF THE INDEX J AT THE NEXT TO THE LAST REAL CELL
C               IN THE Y-DIRECTION (=JMAX-2)
C     JPB       BOTTOM PRESSURE ITERATION INDEX IN Y-DIRECTION
C               (=3 FOR CONSTANT PRESSURE BOUNDARY CONDITION, =2 FOR
C               ALL OTHER CASES)
C     JPT       TOP PRESSURE ITERATION INDEX IN Y-DIRECTION
C              (=JBAR FOR CONSTANT PRESSURE BOUNDARY CONDITION, =JM1 FOR
C               ALL OTHER CASES)
C     LITER     NUMBER OF ITERATIONS ON THE PREVIOUS CYCLE
C     NCYC      CALCULATIONAL TIME CYCLE NUMBER
C     NDUMP     TAPE7 DUMP SEQUENCE NUMBER. SET TO ZERO TO
C               SKIP TAPE RESTART. OTHERWISE, IT MUST EQUAL THE
C               SEQUENCE NUMBER ON TAPE7 TO SUCCESSFULLY RESTART.
C     NFLGC     NUMBER OF CYCLES THE VOLUME OF FLUID FUNCTION CONVECTION
C               LIMIT (FLGC) IS EXCEEDED
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C      NOBD          NUMBER OF OBSTACLE DEFINING FUNCTIONS ALLOWED
C                    SPECIFIED IN PARAMETER STATEMENT
C      NOCON        NUMBER OF CYCLES PRESSURE CONVEGENCE HAS FAILED
C                   (USED TO SET ARRAY SIZE - MUST BE > 0)
C      NREG         NUMBER OF VOID REGIONS GENERATED IN CALCULATION
C      NVOR         MAXIMUM NUMBER OF VOID REGIONS ALLOWED, SPECIFIED IN
C                   PARAMETER STATEMENT
C      MESHX        NUMBER OF SUBMESH REGIONS IN X-DIRECTION, SPECIFIED
C                   IN PARAMETER STATEMENT
C      MESHY        NUMBER OF SUBMESH REGIONS IN Y-DIRECTION, SPECIFIED
C                   IN PARAMETER STATEMENT
C      PI           =3.141592654
C      RPD          DEGREES TO RADIANS CONVERSION FACTOR
C      SF           PLOT SCALING FACTOR
C      T            PROBLEM TIME
C      TPI          2.0*PI
C      VCHGT        ACCUMULATED FLUID VOLUME CHANGE
C      VELMX1       VELMX NORMALIZED TO MINIMUM MESH CELL DIMENSION
C      XMAX         LOCATION OF RIGHT-HAND SIDE OF MESH
C      XMIN         LOCATION OF LEFT-HAND SIDE OF MESH
C      XSHFT        COMPUTED SHIFT ALONG THE PLOTTING ABSCISSA TO CENTER
C                   THE PLOT FRAME ON FILM
C      YMAX         LOCATION OF THE TOP OF THE MESH
C      YMIN         LOCATION OF THE BOTTOM OF THE MESH
C      YSHFT        COMPUTED SHIFT ALONG THE PLOTTING ORDINATE TO CENTER THE
C                   PLOT FRAME ON FILM
C
C +++  ARRAYS IN COMMON (EXCLUDING MESH AND OBSTACLE SETUP PARAMETERS)
C
C      ACOM(1)        FIRST WORD IN COMMON
C      BETA(I,J)      PRESSURE ITERATION RELAXATION FACTOR IN CELL (I,J)
C      AC(I,J)        FRACTIONAL CELL VOLUME OPEN TO FLOW
C      AR(I,J)        FRACTIONAL CELL FACE ON RIGHT OPEN TO FLOW
C      AT(I,J)        FRACTIONAL CELL FACE ON TOP OPEN TO FLOW
C      COSO(I,J)      COSINE OF ANGLE THAT CURVED WALL MAKES WITH + Y AXIS
C      DELX(I)        MESH SPACING OF THE I-TH CELL ALONG THE X-AXIS
C      DELY(J)        MESH SPACING OF THE J-TH CELL ALONG THE Y-AXIS
C      F(I,J)         VOLUME OF FLUID PER UNIT VOLUME OF CELL (I,J) AT TIME
C                     LEVEL N+1
C      FN(I,J)        VOLUME OF FLUID PER UNIT VOLUME OF CELL (I,J) AT TIME
C                     LEVEL N
C      NAME(10)       PROBLEM IDENTIFICATION LINE
C      NF(I,J)        FLAG OF SURFACE CELL (I,J) INDICATING THE LOCATION
C                     OF ITS NEIGHBORING PRESSURE INTERPOLATION CELL
C      NR(K)          LABEL OF VOID REGION, K > 5
C      NW(I,J)        FLAG INDICATING TYPE OF CELL IN COMPUTING MESH
C      P(I,J)         PRESSURE IN CELL (I,J) AT TIME LEVEL N+1
C      PETA(I,J)      PRESSURE INTERPOLATION FACTOR FOR CELL (I,J)
C      PN(I,J)        PRESSURE IN CELL (I,J) AT TIME LEVEL N
C      PR(K)          PRESSURE IN VOID REGION NR(K)
C      PS(I,J)        SURFACE PRESSURE IN CELL (I,J) COMPUTED FROM SURFACE
C                     TENSION FORCES
C      R(I)           X COORDINATE DIMENSION FOR CYLINDRICAL/PLANE OPTIONS
C      RDX(I)         RECIPROCAL OF DELX(I)
C      RDY(J)         RECIPROCAL OF DELY(J)
C      RI(I)          X COORDINATE DIMENSION FOR CYLINDRICAL/PLANE OPTIONS
C      RX(I)          RECIPROCAL OF X(I)
C      RXI(I)         RECIPROCAL OF XI(I)
C      RYJ(J)         RECIPROCAL OF YJ(J)
C      SINO(I,J)      SINE OF ANGLE THAT CURVED WALL MAKES WITH + Y AXIS
C      U(I,J)         X-DIRECTION VELOCITY COMPONENT IN CELL (I,J) AT TIME
C                     LEVEL N+1
C      UN(I,J)        X-DIRECTION VELOCITY COMPONENT IN CELL (I,J) AT TIME
C                     LEVEL N
C      V(I,J)         Y-DIRECTION VELOCITY COMPONENT IN CELL (I,J) AT TIME
C                     LEVEL N+1
C      VN(I,J)        Y-DIRECTION VELOCITY COMPONENT IN CELL (I,J) AT TIME
C                     LEVEL N
C      VOL(K)         VOLUME OF VOID REGION NR(K)
C      X(I)           LOCATION OF THE RIGHT-HAND BOUNDARY OF THE I-TH CELL
C                     ALONG THE X-AXIS
C      XI(I)          LOCATION OF THE CENTER OF THE I-TH CELL ALONG THE
C                     X-AXIS
C      Y(J)           LOCATION OF THE TOP BOUNDARY OF THE J-TH CELL ALONG TH
C                     Y-AXIS
C      YJ(J)          LOCATION OF THE CENTER OF THE J-TH CELL ALONG THE
C                     Y-AXIS
C      ZC(N)          TEMPORARY STORAGE FOR CONTOUR ROUTINE
       RETURN
       END
```

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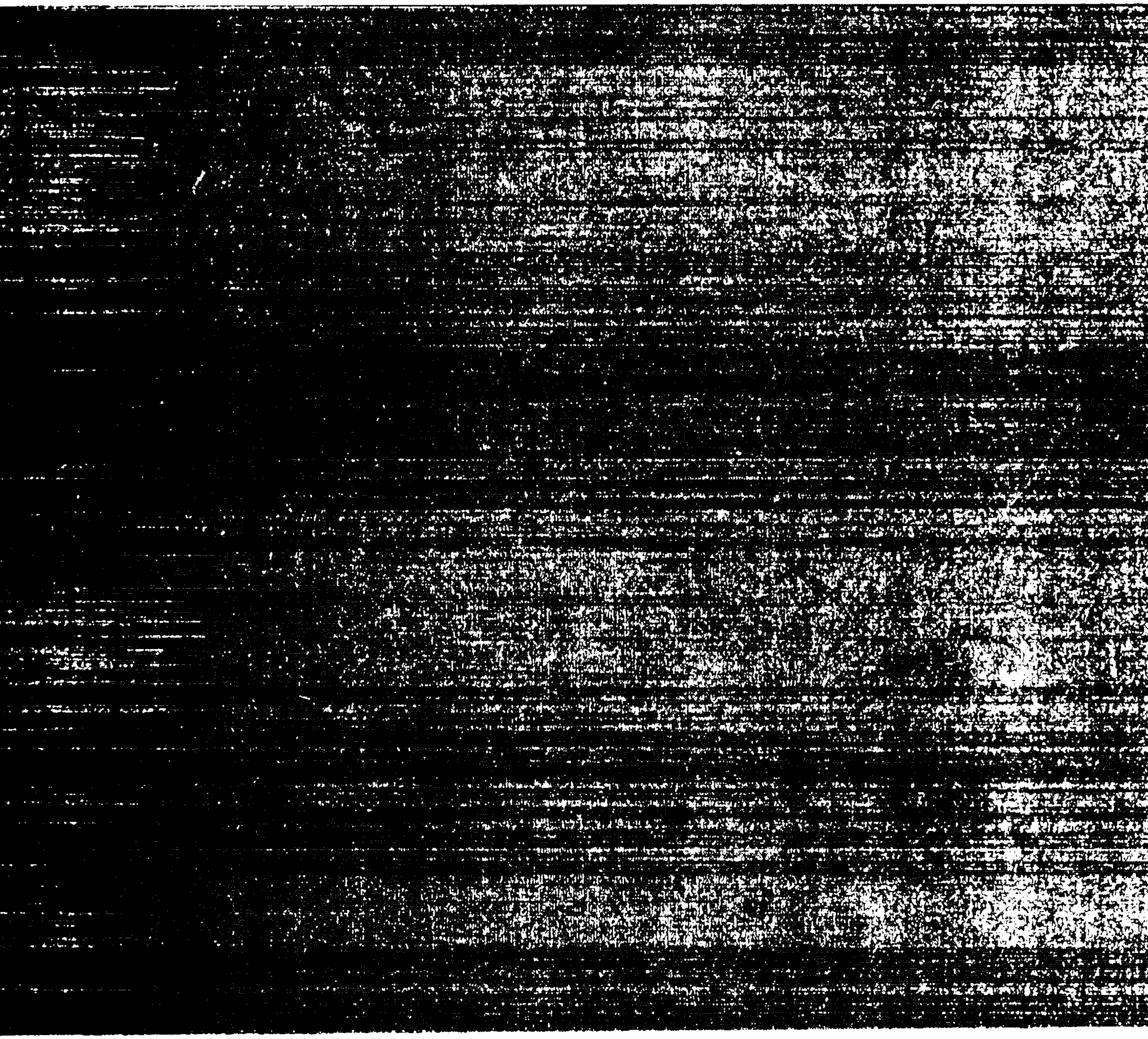

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