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TRIOIL
A THREE-DIMENSIONAL VERSION OF THE OIL CODE

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FOREWORD

The TRIOIL computer code described herein is as it existed on July 1, 1967. The code has been in continuous development for three years and in its presented form has been applied in this report. However, the development and improvement in both the physics and mathematics of the code are being continued, so that duplication of results (or even close agreement) between problems run with the code as published and the code as it existed either before or after this time is not necessarily to be expected.

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1. INTRODUCTION

The TRIOIL code is a three-dimensional continuous Eulerian cartesian hydrodynamic code.* It is a natural extension of the two-dimensional OIL code (Ref. 1). The code is in an infant stage as of now but work is continuing to make it an operative tool for research in the field of numerical hydrodynamics. In this version of TRIOIL, the scalar pressure is the only stress. However, it appears to be straightforward to incorporate stresses due to strength and viscous forces as has been done for the two-dimensional version (Ref. 2) and adding two materials (Ref. 4).

The maximum size of the three-dimensional grid is limited by the present 32K to 64K storage computers. In this present version, the maximum number of cells in any single direction (IMAX for the x-direction, JMAX for the y-direction and KMAX for the z-direction) is limited to 30; further, the total number of cells is limited to 6000. But, with high speed disks and drums, as are currently being made available, one can store x-y slabs of data. This means, at any given time, we have in core memory only two slabs of x-y data, which is sufficient for the various phases of the program. This procedure will essentially remove the limitations on grid size, and enable one to apply this code to solving many types of three-dimensional problems.

A rezone routine, that increases all linear cell dimensions by a factor of two, is presently an operative feature of this code. This routine is programmed primarily for hypervelocity impact calculations into an infinite target. To use it for different applications will require some minor modifications. Eight cells in the old grid are combined into one for the new grid. Energy, mass, and momentum are conserved. This routine assumes the following:

(a) That IMAX, JMAX and KMAX are even integers. (IMAX, JMAX and KMAX are the total number of cells in the x, y, and z directions.)

*This work was funded jointly by the Systems and Research Department of Honeywell, Inc., at Minneapolis, Minnesota and General Atomic Division of General Dynamics Corporation.
(b) That the J value of the initial interface between projectile and target is $2^N$, allowing N rezones.

This routine can be called for whenever mass leaves any of the six grid boundaries.

The six slides of the grid can either be reflective or transmittive. Variable zoning of $\Delta x$, $\Delta y$ and $\Delta z$ is a working feature of the code. Active grid counters are calculated for all three directions. By doing this, one processes only that portion of the grid that is active.

Programs for displaying density, velocities and pressures are currently being programmed using the Stromberg-Carlson 4020 Plotter.

A subroutine called SETUP is available for generating the starting data for the TRIOIL code. This routine will only generate a rectangular parallelepiped for the projectile and target. For the more complicated geometries, we plan to modify the CLAM code (Ref. 1) to generate three-dimensional starting conditions for the TRIOIL code.

An accurate estimate of computer time required to run a realistic problem in three dimensions is not presently available, however, calculations reported here, have been run on the UNIVAC-1108 and Control Data 6600 computers to a point where the peak pressures have been attenuated by several orders of magnitude for computer times of approximately one hour.

The code is written in FORTRAN IV language and is operative on the IBM-7044 and the UNIVAC-1108 as well as the Control Data 6600.

2.1 Basic Equations

The Eulerian equations in cartesian geometry are:

\[
\begin{align*}
(A) & \quad \frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z} = 0 \\
(B) & \quad \rho \frac{\partial u}{\partial t} + \rho u \frac{\partial u}{\partial x} + \rho v \frac{\partial u}{\partial y} + \rho w \frac{\partial u}{\partial z} + \frac{\partial P}{\partial x} = 0 \\
& \quad \rho \frac{\partial v}{\partial t} + \rho u \frac{\partial v}{\partial x} + \rho v \frac{\partial v}{\partial y} + \rho w \frac{\partial v}{\partial z} + \frac{\partial P}{\partial y} = 0 \\
& \quad \rho \frac{\partial w}{\partial t} + \rho u \frac{\partial w}{\partial x} + \rho v \frac{\partial w}{\partial y} + \rho w \frac{\partial w}{\partial z} + \frac{\partial P}{\partial z} = 0
\end{align*}
\]
These equations are solved in two parts, as in the OIL code (Ref. 1) and the familiar particle-in-cell codes (Ref. 3). The transport terms on the left side of Eq. (B) and (C) are temporarily dropped, while we compute (in PHI) the momentum and energy contributions due to pressure forces only. The omitted transport contributions to the momentum and energy are later approximated when we solve equation (A) and move mass across the cell boundaries.

2.1.1. Effect of Pressure Forces Only (PHI)

Re-writing Eqs. (B) and (C) with the transport terms dropped

\[
\rho \frac{\partial u}{\partial t} = - \frac{\partial P}{\partial x} \tag{1}
\]
\[
\rho \frac{\partial v}{\partial t} = - \frac{\partial P}{\partial y} \tag{2}
\]
\[
\rho \frac{\partial w}{\partial t} = - \frac{\partial P}{\partial z} \tag{3}
\]
\[
\rho \frac{\partial E}{\partial t} = - \frac{\partial (pu)}{\partial x} - \frac{\partial (pv)}{\partial y} - \frac{\partial (pw)}{\partial z} \tag{4}
\]

\[
p = f(p, l) \text{ equation of state} \tag{5}
\]

These variables, in one consistent set of units are

\[
p = \text{density of cell (L)} \text{ in g/cm}^3.
\]
\[
x = \text{x coordinate in cm.}
\]
\[
y = \text{y coordinate in cm.}
\]
\[
z = \text{z coordinate in cm.}
\]
\[
u = \text{x component of velocity in cm/shake.}
\]
\[
v = \text{y component of velocity in cm/shake.}
\]
\[
w = \text{z component of velocity in cm/shake.}
\]
P = material pressure in jerks/cm³.
E = total specific energy in jerks/g.
I = specific internal energy in jerks/g

\( t = \) time in shakes

1 shake = \(10^{-8}\) sec
1 jerk = \(10^{16}\) ergs

There are no built-in units for this code, the user can select his own units in a given application by way of the equation of state constants and input data.

The density, pressure, velocities and internal energy are all cell-centered quantities referred to with the index \((L)\).

Rewriting Eq. 4:

\[
\rho \frac{\partial E}{\partial t} = - \frac{\partial P u}{\partial x} - \frac{\partial P v}{\partial y} - \frac{\partial P w}{\partial z}
\]

or

\[
\rho \frac{\partial}{\partial t} \left[ I + \frac{1}{2}(u^2 + v^2 + w^2) \right] = - \frac{\partial P u}{\partial x} - \frac{\partial P v}{\partial y} - \frac{\partial P w}{\partial z}
\]

\[
\rho \frac{\partial I}{\partial t} + \rho u \frac{\partial u}{\partial t} + \rho v \frac{\partial v}{\partial t} + \rho w \frac{\partial w}{\partial t} = - \frac{\partial P}{\partial x} u - \frac{\partial P}{\partial y} v - \frac{\partial P}{\partial z} w
\]

but

\[
\rho \frac{\partial u}{\partial t} = - \frac{\partial P}{\partial x} \quad \text{and} \quad \rho \frac{\partial v}{\partial t} = - \frac{\partial P}{\partial y} \quad \text{and} \quad \rho \frac{\partial w}{\partial t} = - \frac{\partial P}{\partial z}
\]

thus

\[
\rho \frac{\partial I}{\partial t} = - P \left[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right]
\]

Now we can write the four differential equations (1, 2, 3 and 6) in difference form.

The storage arrays for the cell centered quantities (mass, velocities, pressure and specific internal energy are as follows (Fig. 1).
The index of the cell is defined as:

\[ L = (j-1) \times \text{MAX} + 1 + (K-1) \times \text{MAX} \]

\[ \times \text{MAX} = (\text{IMAX}) (\text{JMAX}) \]
In the discussion to follow, please refer to Fig. 2. Re-writing the equations (1 to 3) in difference form results in:

The x-momentum equation (1) becomes in difference form

\[ \rho_L^n \left( \frac{u_L^n - u_L^{n-1}}{\Delta t} \right) = \frac{P_{L-1}^n - P_{L+1}^n}{2\Delta x(1)} \]

The y-momentum equation (2) becomes in difference form

\[ \rho_L^n \left( \frac{v_L^n - v_L^{n-1}}{\Delta t} \right) = \frac{P_{L-1}^{n-1} - P_{L+1}^{n+1}}{2\Delta y(1)} \]

The z-momentum equation (3) becomes in difference form

\[ \rho_L^n \left( \frac{w_L^n - w_L^{n-1}}{\Delta t} \right) = \frac{P_{L-1}^{n-1} - P_{L+1}^{n+1}}{2\Delta z(1)} \]

Here the acceleration of cell L is seen to depend only on the pressures in the neighboring cells (not that of L). Defining pressures at interfaces,

\[ P_{L}^{n} = \frac{P_{L-1}^{n} + P_{L}^{n}}{2}. \]
\[ P_{RR}^{n} = \frac{P_{L}^{n} + P_{L+1}^{n}}{2}. \]
\[ P_{L1}^{n} = \frac{P_{L-1}^{n-1} + P_{L}^{n}}{2}. \]
\[ P_{A}^{n} = \frac{P_{L}^{n} + P_{L+1}^{n+1}}{2}. \]
\[ P_{B1}^{n} = \frac{P_{L-1}^{n-1} + P_{L}^{n} + P_{L+1}^{n+1}}{2}. \]
\[ P_{B1}^{n} = \frac{P_{L-1}^{n+1} + P_{L}^{n} + P_{L+1}^{n+1}}{2}. \]
The index of the cell is defined as:

\[ L = (j-1)\text{MAX} + 1 + (k-1)\text{IX MAX} \]

\[ \text{IX MAX} = (i\text{MAX})(j\text{MAX}) \]

\[ x(i) = \sum_{k=1}^{l} \Delta x(i) \]

\[ y(j) = \sum_{j=1}^{l} \Delta y(j) \]

\[ z(k) = \sum_{k=1}^{l} \Delta z(k) \]

Fig. 2
Substituting these interface pressures into the three-momentum equations results in:

\[
\begin{align*}
\tilde{u}_L^n - u^n_L &= \frac{\Delta t}{\rho^n_L} \left[ \frac{P_L^n - P_{RR}^n}{\Delta x(1)} \right] \\
\tilde{v}_L^n - v^n_L &= \frac{\Delta t}{\rho^n_L} \left[ \frac{P_{BLO}^n - P_{ABOVE}^n}{\Delta y(j)} \right] \\
\tilde{w}_L^n - w^n_L &= \frac{\Delta t}{\rho^n_L} \left[ \frac{P_{BIND}^n - P_{ZR}^n}{\Delta z(j)} \right]
\end{align*}
\]

where the usual ~ (tilda) designates the new velocities (not at cycle \( n+1 \)), since we have temporarily dropped the transport terms).

The specific internal energy equation becomes

\[
\frac{\gamma - 1}{\rho_L} \frac{\Delta t}{\Delta t} = - \frac{p^n_L}{2A_y(j)} \left[ v_{n+\frac{1}{2}}^{L-\text{MAX}} - v_{n+\frac{1}{2}}^{L+\text{MAX}} + \frac{u_{n+\frac{1}{2}}^{L-1} - u_{n+\frac{1}{2}}^{L+1}}{2\Delta x(1)} \\
+ \frac{w_{n+\frac{1}{2}}^{L-\text{MAX}}(\text{MAX}) - w_{n+\frac{1}{2}}^{L+\text{MAX}}(\text{MAX})}{2\Delta z(k)} \right]
\]

The reason for the velocities at time \((n+\frac{1}{2})\) can be seen from energy conservation considerations, which we will discuss later in the text. Defining

\[
\begin{align*}
u_{L}^{n+\frac{1}{2}} &= \frac{u^n_L + \tilde{u}^n_L}{2} \\
v_{L}^{n+\frac{1}{2}} &= \frac{v^n_L + \tilde{v}^n_L}{2} \\
w_{L}^{n+\frac{1}{2}} &= \frac{w^n_L + \tilde{w}^n_L}{2}
\end{align*}
\]
and

\[
VBLO = \frac{v_L + v_{L-1\text{MAX}}}{2}
\]

\[
V\text{ABOVE} = \frac{v_L + v_{L+1\text{MAX}}}{2}
\]

\[
UL = \frac{U_L + U_{L-1}}{2}
\]

\[
URR = \frac{U_L + U_{L+1}}{2}
\]

\[
UB\text{IND} = \frac{W_L + W_{-(1\text{MAX})(1\text{MAX})}}{2}
\]

\[
WZR = \frac{W_L + W_{(1\text{MAX})(1\text{MAX})}}{2}
\]

Then

\[
p_L^n \left( \frac{Y_L^n - Y_L}{\Delta t} \right) = p_L^n \left[ \frac{VBLO^n + VBLO}{2\Delta Y(1)} - \frac{V\text{ABOVE}^n + V\text{ABOVE}}{2\Delta Y(1)} + \frac{UL^n + UL}{2\Delta X(1)} - \frac{URR^n + URR}{2\Delta X(1)} + \frac{UB\text{IND}^n + UB\text{IND}}{2\Delta Z(k)} - \frac{WZR^n + WZR}{2\Delta Z(k)} \right]
\]

The solution of the momentum equations are very straightforward, however, the solution to the energy equation requires the velocities at two different time steps (the old and new velocities). We have chosen to make two passes through the routine, the first pass to integrate the momentum equations, but formulate the interface velocities first for the work term contribution to the internal energy before integrating the momentum equations (since we have allowed only one array per velocity component).

The second pass, we bypass the momentum equations, and only compute the new interface velocities for their contribution to the work term. A single pass can be done by looking ahead two cells above; two cells to the right and two cells in front.
The choice of the velocities at \( n + \frac{1}{2} \) in the energy equation is apparent in the following discussion. For convenience we will go through the logic in the \( y \) direction. Since we have dropped the transport terms, our integration of the momentum and energy equations have not been advanced to time \( (n + 1) \). As before, we designate the phase 1 velocities and energy as \( \tilde{\mu}, \tilde{\nu}, \tilde{v}, \) and \( \tilde{Y} \).

\[ \tilde{v}_{j+\frac{1}{2}} = v^n_{j+\frac{1}{2}} + \frac{\Delta t}{p^n_{j+\frac{1}{2}}} \left[ \frac{p^n_{j+1/2} - p^n_{j-1/2}}{2\delta y(j)} \right] \]

and

\[ \tilde{Y}_{j+\frac{1}{2}} = I^n_{j+\frac{1}{2}} + \frac{\Delta t}{p^n_{j+\frac{1}{2}}} \left[ \frac{v^n_{j+1/2} - v^n_{j-1/2}}{2\delta y(j)} \right] \]

where

\[ \tilde{v}_{j-3/2} = \frac{v^n_{j-3/2} + v^n_{j-3/2}}{2} \]

and

\[ \tilde{v}_{j+3/2} = \frac{v^n_{j+3/2} + v^n_{j+3/2}}{2} \]

Before entering PHI, where the quantities are at time \( n \), the total energy of the system (considering one dimension, the \( y \) direction) is:

\[ E^n = \sum_{j=1}^{J_{\text{MAX}}} AMX_j^n \left[ I^n_{j+\frac{1}{2}} + \frac{1}{2} \right] \left( v^n_{j+\frac{1}{2}} \right)^2 \]

And the total energy at the end of PHI is then

\[ E = \sum_{j=1}^{J_{\text{MAX}}} AMX_j^n \left[ I^n_{j+\frac{1}{2}} + \frac{1}{2} \right] \left( \tilde{v}_{j+\frac{1}{2}} \right)^2 \]

The change, \( \Delta E = E^n - E \) should be zero for energy conservation or

\[ \Delta E = \sum_{j=1}^{J_{\text{MAX}}} AMX_j^n \left[ I^n_{j+\frac{1}{2}} - I^n_{j+\frac{1}{2}} + \frac{1}{2} \right] \left( \tilde{v}_{j+\frac{1}{2}} \right)^2 - \frac{1}{2} \left( \tilde{v}_{j+\frac{1}{2}} \right)^2 \]
the Δ kinetic terms can be represented by

\[
\Delta E = \sum_{j=1}^{J_{\text{MAX}}} A_{\text{MAX}}^n \left[ \frac{v_{j-1/2}^n + \bar{v}_{j+1/2}^n}{2} \right] \left[ v_{j-1/2}^n - \bar{v}_{j+1/2}^n \right]
\]

\[
\Delta E = \sum_{j=1}^{J_{\text{MAX}}} A_{\text{MAX}}^n \left[ \frac{1^n_{j-1/2} - \bar{v}_{j-1/2}^n + \bar{v}_{j-1/2}^n}{\rho_{j-1/2}^n} \left( \frac{v_{j-1/2}^n - \bar{v}_{j+1/2}^n}{2 \Delta y_j} \right) \right]
\]


\[
\Delta E = \sum_{j=1}^{J_{\text{MAX}}} A_{\text{MAX}}^n \left[ \frac{\Delta t}{\rho_{j-1/2}^n} \left( \frac{\bar{v}_{j-3/2}^n - \bar{v}_{j+1/2}^n}{2 \Delta y_j} \right) \right]
\]

\[
\Delta E = \Delta t \sum_{j=1}^{J_{\text{MAX}}} A_{\text{MAX}}^n \frac{\Delta t}{\rho_{j-1/2}^n} \left[ \frac{1^n_{j-1/2} - \bar{v}_{j-3/2}^n}{2 \Delta y_j} \right]
\]

\[
\Delta E = \Delta t \sum_{j=1}^{J_{\text{MAX}}} A_{\text{MAX}}^n \left[ \frac{\Delta t}{\rho_{j-1/2}^n} \left( \frac{\bar{v}_{j-3/2}^n - \bar{v}_{j+1/2}^n}{2 \Delta y_j} \right) \right]
\]

Thus, the last two terms in \( J \) being cancelled by the first two terms in \( J+1 \). By prescribing the proper boundary conditions, we will have energy conservation for the entire grid.
EXAMPLE:

for \( j = 1 \)

\[
P_\frac{1}{2} v_{\frac{3}{2}} + P_\frac{1}{2} v_{\frac{1}{2}} - P_\frac{3}{2} v_{\frac{1}{2}} - P_\frac{1}{2} v_{\frac{3}{2}}
\]

\( j = 2 \)

\[
P_\frac{3}{2} v_{\frac{3}{2}} + P_\frac{1}{2} v_{\frac{3}{2}} - P_\frac{5}{2} v_{\frac{3}{2}} - P_\frac{3}{2} v_{\frac{5}{2}}
\]

\( j = 3 \)

\[
P_\frac{5}{2} v_{\frac{3}{2}} + P_\frac{3}{2} v_{\frac{5}{2}} - P_\frac{7}{2} v_{\frac{5}{2}} - P_\frac{5}{2} v_{\frac{7}{2}}
\]

Note, the boundary terms do not cancel. For the example, assume the bottom boundary to be reflective. Referring to Eq. (A), the first two terms do not cancel. If, however we set the pressure of the mirror cell \( P_\frac{3}{2} = P_\frac{3}{2} \) (this does not imply that \( v_\frac{3}{2} = 0 \)) and \( v_\frac{1}{2} = -v_{\frac{3}{2}} \), this does lead to cancellation of the first two terms. If, however we designate the bottom boundary to be transmissive, our boundary conditions are \( v_\frac{1}{2} = 0 \), which implies \( P_\frac{3}{2} = P_\frac{3}{2} \) and that \( v_\frac{1}{2} = v_{\frac{3}{2}} \). This still leaves us with the two terms \( P_\frac{1}{2} v_{\frac{1}{2}} + P_\frac{3}{2} v_{\frac{3}{2}} \), thus we compensate for these terms, by adding or subtracting energy to the system. To keep all the books straight, \( E \) must be modified accordingly. Similar boundary conditions may exist for the other four sides of the grid.

2.1.2 Adding the Transport Terms (PH2)

Rewriting Eq. (A) the mass transport equation in finite difference form results in

\[
\frac{\rho_{n+1}^L - \rho_n^L}{\Delta t} = \left[ \frac{\rho_{n}^L \bar{v}_{n+1} - \rho_{n}^L \bar{v}_n}{\Delta Y(j)} + \frac{\rho_{n}^L \bar{u}_{n+1} - \rho_{n}^L \bar{u}_n}{\Delta X(i)} + \frac{\rho_{n}^L \bar{w}_{n+1} - \rho_{n}^L \bar{w}_n}{\Delta Z(k)} \right]
\]
or in the formulation for mass we have
\[ \Delta M_L = \Delta t \left[ (Av)_B^Y \rho - (Av)_T^Y \rho + (Au)_R^X \rho - (Av)_R^X \rho + (Av)_X^Z \rho - (Av)_F^Z \rho \right] \]
where the superscripts X, Y, Z, refer to the particular coordinate, and B = bottom, T = top, L = left, R = right, BH = behind and F = front. The mass that is moved from cell to cell, has then momentum and energy associated with it, thus these are the approximations to the transport terms that were omitted in PHI for the momentum and energy equations.

The \( \rho \) (density) is that of the donor cell, and the velocity is yet to be determined. Various techniques for the velocity weighting have been tried (Ref. 1). The velocity weighting scheme in this report is identical to that in the OIL report (Ref. 1).

2.1.3 Time Control
The time step (\( \Delta t \)) is controlled by the Courant condition and the condition that the mass flux equation will not empty more mass from a cell than is there.

Take the \( y \) direction (a similar treatment is done for the other two directions)
\[ \Delta M_y = \rho \bar{v} \Delta t \]
Let
\[ \bar{v} = v(L) \]
\[ \rho = \rho(L) \]
\[ \Delta M_y = A M_y(L) \]
then
\[ A M_y(L) = \rho(L) v(L) A j \Delta t \]
\[ = \frac{A M_y(L)}{D x(i) D y(j) D z(k)} v(L) D x(i) D z(k) \Delta t \]
\[ = \frac{A M_y(L)}{D y(j)} v(L) \Delta t \]
or $|v_{L}^{(L)}| \Delta t \leq Dy(j)$ such that the flux in the y direction will not empty the cell $(L)$.

The Courant condition is that $\frac{C}{C_{M}} \leq 1$ where $C$ = sound speed and $C_{M}$ is the maximum speed at which a disturbance can propagate in the given grid or $\frac{\Delta t}{\Delta x} \leq 1$, or $\frac{\Delta t}{\Delta y} \leq 1$, and $\frac{\Delta t}{\Delta z} \leq 1$.

2.1.4 Remarks

No corner coupling (that is, mass is constrained to move at right angles to the sides of the cell) exists in this version, and no attempt to systematically study this has been initiated. The movement of mass across the cell boundaries give rise to forces which are effective in reducing fluctuations that arise from the differencing technique. That is of the form of a "true" viscosity, being proportional to the velocity gradient. It is this force which enables the Eulerian codes to treat shocks, where again, as in the Q method used in Lagrangian codes, the shock is spread over two or three zones.

2.2 Logic of TRIOIL

The logic involved in following a given cell $(L)$ from $t$ to $t + \Delta t$ or cycle $n$ to $n + 1$ is as follows:

We assume we have integrated the mass, the three velocity components and the internal energy to cycle $n$, now all that remains to complete cycle $n$, and to begin cycle $n + 1$, is to update the pressures from the equation of state and calculate a new time step.

2.2.1 CDT Routine

Here we calculate the pressure $(P)$ array for the entire grid. The pressure $(P_{L}) = f (\rho_{L}, I_{L})$ where $L$ is the index of the cell in question, defined as $L = (j-1) i^{MAX} + i + (k-1) (i^{MAX})(j^{MAX})$. The density

$\rho_{L} = \frac{DX(1) Dy(j) DZ(k)}{AMX(L)}$

is not one of the variables, it must be calculated several times during the cycle. It is planned in the future, to replace the mass storage with density. The speed of sound $C = (\frac{2P}{\rho})^{1/2}$ for a polytropic equation of state or $(\frac{2P}{\rho P_{s}})^{1/2}$ for a general form is then calculated. From the particle velocities and speed of sound, a new $\Delta t$ is calculated.
(Options for At control are identical to that in OIL.) The cycle number and the time are now advanced.

2.2.2 The EDIT Routine

This code has three separate editing routines all included in the subroutine EDIT. The first of these is the routine called "Short Print". This displays the problem number, cycle number, time, internal and kinetic energy, energy check and indices of the cell that is controlling the time step. The next routine available is called "Long Print". Here one edits each column, the three velocity components, pressure, mass, density, specific internal energy and y, all versus j (the index of the rows). Thus there are kMAX sets of these, beginning with k=1. The normal units chosen are gram-cm-sh. which gives a logical unit for the pressure as $10^{16}$ ergs/cm$^3$ and for the specific internal energy as $10^{16}$ ergs/gram.

2.2.3 PHI Routine

Here we integrate the three momentum equations and the internal energy equation due to pressure forces only. No material is moved at this time, and the transport terms are dropped temporarily. Using the new pressure and At, we can solve the momentum and energy equations.

$PL(j)$, the pressure at interface (i-l) and $UL(j)$, the velocity at interface (i-l) are available from the previous column sweep on i-l:

$$ PL(j) = \frac{P^n_L + P^n_{L-l}}{2}. $$

$$ UL(j) = \frac{U^n_L + U^n_{L-l}}{2}. $$

The PBLO term which was the PABOVE for the cell below (L-iMAX) and VBLO which was VABOVE for cell below, are also available for interface j-l.

$$ PBLO = \frac{P^n_L + P^n_{L-iMAX}}{2}. $$

$$ VBLO = \frac{V^n_L + V^n_{L-iMAX}}{2}. $$
The PBIND term (the pressure at the back surface of the cell) which was PZR for cell \( L - (i_{\text{MAX}}) (j_{\text{MAX}}) \) and UBIND (the velocity at the back surface of the cell) which was WZR for cell \( L - (i_{\text{MAX}}) (j_{\text{MAX}}) \) are also available for interface \( K-l \).

\[
P_{\text{BIND}} = \frac{P_n^L + P_{n+1}^L - (i_{\text{MAX}}) (j_{\text{MAX}})}{2},
\]
\[
U_{\text{BIND}} = \frac{W_n^L + W_{n+1}^L - (i_{\text{MAX}}) (j_{\text{MAX}})}{2}.
\]

Thus, we need only to calculate quantities at the top, the right, and the front of cell \( L \). At the top we calculate

\[
\text{PABOVE} = \frac{P_n^L + P_{n+1}^L + i_{\text{MAX}}}{2},
\]

and \( \text{VABOVE} = \frac{V_n^L + V_{n+1}^L + i_{\text{MAX}}}{2} \); at the right we calculate

\[
\text{PR} = \frac{P_{n+1}^L + P_n^L + 1}{2},
\]

and \( \text{URR} = \frac{U_n^L + U_{n+1}^L + 1}{2} \); and in front as

\[
P_{\text{ZR}} = \frac{P_n^L + P_{n+1}^L + (i_{\text{MAX}}) (j_{\text{MAX}})}{2},
\]
\[
W_{\text{ZR}} = \frac{W_n^L + W_{n+1}^L + (i_{\text{MAX}}) (j_{\text{MAX}})}{2}.
\]

When the cell in question is void, the pressures at the top, right and front interface are set to zero and the velocities are set = to the velocity of the cell above, to the right, and in front respectively. If a occupied cell has a void neighbor, the pressure at that interface is set = 0, and the velocity at that interface is set = to the velocity of the occupied cell in question.

We now have sufficient information to integrate the three momentum equations and part of the internal energy equation.

\[
\rho \frac{\partial u}{\partial t} = -\frac{\partial p}{\partial x}
\]

or

\[
U_L = U_L^n + \frac{P_{L}(j) - P_{R}(j)}{AMX_L} \frac{Dy(j)}{DZ(k)} \Delta t
\]
and
\[ \rho \frac{\partial v}{\partial t} = -\frac{\partial P}{\partial y} \]
or
\[ \tilde{v}_L = v_L^n + \frac{PBLO^n - PABOVE^n}{AMX^n_L} DX(1) DZ(k) \Delta t \]
and
\[ \rho \frac{\partial w}{\partial t} = -\frac{\partial P}{\partial z} \]
or
\[ \tilde{w}_L = w_L^n + \frac{(PBIND(M)^n - PZR^n)}{AMX^n_L} Dy(j) DX(1) \Delta t \]

where the index \( m \) refers to the \((i,j)\) value of the slab \( x \cdot y \) just behind.

We can add the work terms due to velocities at cycle \( n \) to the change in internal energy as

\[ \gamma_L^{(1)} = r_L^n + \frac{p_L^n \Delta t}{AMX^n_L} \left[ \frac{PBLO^n - PABOVE^n}{2} \right] DX(1) DZ(k) \]
\[ + \left( \frac{UL(j)^n - URR^n}{2} \right) Dy(j) DZ(k) \]
\[ + \left( \frac{UBIND(m)^n - WZR^n}{2} \right) DX(1) Dy(j) \]

Now, one more pass is made through the entire grid, this time omitting the momentum equations but calculating the interface velocities, resulting in the integration of the internal energy to time \((\sim)\).

\[ \gamma_L = \gamma_L^{(1)} + \frac{p_L^n \Delta t}{AMX^n_L} \left[ \frac{PBLO - PABOVE}{2} \right] DX(1) DZ(k) \]
\[ + \left( \frac{UL(j) - URR}{2} \right) Dy(j) DZ(k) \]
\[ + \left( \frac{UBIND(m) - WZR}{2} \right) DX(1) Dy(j) \]
The option to integrate backwards from time (~) to n if a negative internal energy is encountered, is not available in this version.

2.2.1 PH2 Routine

Here, we move mass across the fixed boundaries. Momenta and energy is carried across with this mass and this approximates the transport terms omitted from the momentum and energy equations in PH1. Please refer to Fig. 2 for the following discussion.

The points A, B, C, D, E, F, G, and H are the eight corners of the cell. The following notation will be followed: side AEFB refers to the left, side ABCD refers to the top, CDHG refers to the right, BFCG to behind, EFGH to bottom, and ADEH to the front.

The five quantities associated with each interface are as follows:

<table>
<thead>
<tr>
<th>TOP</th>
<th>RIGHT</th>
<th>BOTTOM</th>
<th>LEFT</th>
<th>BEHIND</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPY</td>
<td>AMMP</td>
<td>AMMY</td>
<td>GAMC (j)</td>
<td>BMASS (M)</td>
</tr>
<tr>
<td>AMUY</td>
<td>AMUT</td>
<td>AMMU</td>
<td>FLEFT (j)</td>
<td>BXMOM (M)</td>
</tr>
<tr>
<td>AMVT</td>
<td>AMVR</td>
<td>AMMV</td>
<td>YMOM (j)</td>
<td>BYXOM (M)</td>
</tr>
<tr>
<td>AMWT</td>
<td>AMWR</td>
<td>AMMW</td>
<td>ZMOM (j)</td>
<td>BZXOM (M)</td>
</tr>
<tr>
<td>DELET</td>
<td>DELER</td>
<td>DELEB</td>
<td>SIGC (j)</td>
<td>BEHR (M)</td>
</tr>
</tbody>
</table>

AMPY = mass crossing the top
AMUT = X momentum of this mass
AMVT = Y momentum of this mass
AMWT = Z momentum of this mass
DELET = specific energy across the top

AMMP = mass crossing the right
AMUR = X momentum of this mass
AMVR = Y momentum of this mass
AMWR = Z momentum of this mass
DELER = specific energy across the right

AMMY = mass crossing the right
AMMU = X momentum of this mass
AMMV = Y momentum of this mass
AMMW = Z momentum of this mass
DELEB = specific energy across the bottom

GAMC (j) = mass crossing the left
FLEFT (j) = X momentum of this mass
YMOM (j) = Y momentum of this mass
ZMOM (j) = Z momentum of this mass
SIGC (j) = specific energy across the left

BMASS (M) = mass crossing the back surface
BXMOM (M) = X momentum of this mass
BYXOM (M) = Y momentum of this mass
BZXOM (M) = Z momentum of this mass
BEHR (M) = specific energy across the back surface
Following the typical cell (L) the masses, the momentas, and the specific energies are now available at the left and bottom and back boundaries of cell (L) from the previous column sweep, the cell below and the previous X-Y slab (K-1).

The proper boundary conditions are first set for the cell (L=1). We then begin by calculating

\[
\begin{align*}
V_{ABOVE} &= \frac{V_L + V_{L+1}}{2} \quad \text{for the top} \\
URR &= \frac{V_L + V_{L+1}}{2} \quad \text{for the right} \\
W_{OUT} &= \frac{W_L + W_{L+1}}{2} \quad \text{for in front}
\end{align*}
\]

Then form

\[
\begin{align*}
V_{ABOVE} &= \frac{V_{ABOVE}}{1 + \left( \frac{V_{L+1}}{V_{L}} - \frac{V_{L}}{V_{L}} \right) \Delta y(j)} \\
URR &= \frac{URR}{1 + \left( \frac{V_{L+1}}{V_{L}} - \frac{V_{L}}{V_{L}} \right) \Delta x(i)} \\
W_{OUT} &= \frac{W_{OUT}}{1 + \left( \frac{W_{L+1}}{W_{L}} - \frac{W_{L}}{W_{L}} \right) \Delta z(k)}
\end{align*}
\]

Now we can calculate the mass crossing the three boundaries as

\[
\begin{align*}
\Delta M_{TOP} &= AMP = \frac{AMX(M)^{N} V_{ABOVE} \Delta t}{\Delta y(j)} \\
\Delta M_{RIGHT} &= AMP = \frac{AMX(M)^{N} URR \Delta t}{\Delta x(i)}
\end{align*}
\]
\[ AM_{\text{FRONT}} = F_{\text{MASS}} = \frac{AMx(M)^n W_{\text{OUT}} \Delta t}{\Delta z(x)} \]

where \((M)\) is the index of the donor cell. The donor cell is calculated from the sign of the weighted velocity.

The momenta associated with these three masses are now calculated where the velocity in the momenta is from the donor cell. The total specific energy that these mass fluxes carry are calculated at this time also. The momenta associated with the flux at the top is:

- X component = \(AMUT = AMPY [U(N)]\)
- Y component = \(AMVT = AMPY [V(N)]\)
- Z component = \(AMWT = AMPY [W(N)]\)

Specific energy = \(DELET = Y(N) + \frac{[U^2(N) + V^2(N) + W^2(N)]}{2}\)

Those associated with the flux at the right are:

- X component = \(AMUR = AMPM [U(N)]\)
- Y component = \(AMVR = AMPM [V(N)]\)
- Z component = \(AMWR = AMPM [W(N)]\)

Specific energy = \(DELER = Y(N) + \frac{[U^2(N) + V^2(N) + W^2(N)]}{2}\)

Those associated with the flux in front are:

- X component = \(F_{\text{MASS}} [U(N)] = FXCM\)
- Y component = \(F_{\text{MASS}} [V(N)] = FYCM\)
- Z component = \(F_{\text{MASS}} [W(N)] = FZCM\)

Specific energy = \(Y(N) + \frac{[U^2(N) + V^2(N) + W^2(N)]}{2} = \text{FENR}\)

Where again \((N)\) = index of the donor cell.
The mass now in cell (L) is equal to
\[ \text{DELM} = \text{AMX}(L) + \text{GAMC}(j) + \text{AMMY} - \text{AMPY} - \text{AMMP} + \text{EMASS M} - \text{FMASS} \]
which equals the original mass plus the mass flow across the left, the bottom, behind, less the mass flow across the top, right and front.

The total X momenta that has come into or left cell (L) is
\[ \text{SIGMU} = \text{FXMOM} = \text{Fleft}(j) + \text{AMMU} + \text{BYMOM(M)} - \text{AMUT} - \text{AMUR} - \text{FXMOM} = \text{momenta crossing the left boundary plus the momenta crossing the bottom boundary plus the momenta crossing the back boundary less the momenta crossing the top, right and front boundary.} \]

The total Y momenta that has come into or left cell (L) is
\[ \text{SIGMV} = \text{FYMOM} = \text{YAKC}(j) + \text{AMMV} + \text{BYMOM(M)} - \text{AMVT} - \text{AMVR} - \text{FYMOM} = \text{momenta crossing the left, the bottom and behind less the momenta crossing the top, right and front boundary.} \]

The total Z momenta that has come into or left cell (L) is
\[ \text{SIGMW} = \text{FZMOM} = \text{ZMQM}(j) + \text{AMMW} + \text{BZMOM(M)} - \text{AMWT} - \text{AMWR} - \text{FZMOM} = \text{momenta crossing the left, the bottom and behind less the momenta crossing the top, right and front boundary.} \]

Now by conserving momenta and total energy, we can calculate new velocities and specific internal energy of cell (L)

\[ \text{MU}_{LE} + \text{MU}_{B} + \text{MU}_{BH} - \text{MU}_{T} - \text{MU}_{R} + \text{MU}_{F} + \text{MU}_{(L)} = \text{(DELM)} \text{V}_{(L)}^{n+1} \]
and
\[ \text{MV}_{LE} + \text{MV}_{B} + \text{MV}_{BH} - \text{MV}_{T} - \text{MV}_{R} + \text{MV}_{F} + \text{MV}_{(L)} = \text{(DELM)} \text{V}_{(L)}^{n+1} \]
and
\[ \text{MW}_{LE} + \text{MW}_{B} + \text{MW}_{BH} - \text{MW}_{T} - \text{MW}_{R} + \text{MW}_{F} + \text{MW}_{(L)} = \text{(DELM)} \text{V}_{(L)}^{n+1} \]
and solve for the three velocities at cycle \( n+1 \).

The new specific internal energy is the total less the kinetic
\[ I_{(L)}^{n+1} = \frac{F_{LE} + F_{B} + F_{BH} - E_{T} - E_{R} - E_{F} + E_{L}}{\text{DELM}} - \frac{(V_{L}^{n+1})^2 + (V_{L}^{n+1})^2 + (W_{L}^{n+1})^2}{2}. \]
DELM = the new mass. The subscripts LE, B, BH, T, R, F, L, refer to the left, bottom, behind, top, right, front and cell in question.

Now the five variables that were calculated for the top of cell (L) become the bottom quantities for cell (L + iMAX) and the variables that were calculated for the right of cell (L) become the left quantities for cell (L+1) and the variables that were calculated for the front of cell (L) become the back quantities for cell L + (iMAX)(jMAX). This completes the calculation for cell (L). After completion of PH2, all that remains to complete cycle n+1 is to update the pressures, which is done in the CDT routine.

3. TEST PROBLEMS

A series of test problems were undertaken to check out the TRIOIL code.

The early test problem consisted of 8 cells (2 in the x, 2 in the y and 2 in the z direction) containing internal energy only, free to expand into a vacuum. The purpose was to check the free surface treatment, the symmetry of disturbance in the three directions and the possible sphericity of the expansion at large distances. The results were encouraging, exact symmetry existed and the expansion was spherical considering the coarse zoning.

The second test problem (as shown in Fig. 3) consists of a grid 11 x 11 x 11. The corner cell has $10^{16}$ ergs/g, surrounded by like material but cold. The three adjacent sides were treated as reflective boundaries, while the three opposite sides were transmittive boundaries. A check of computer results were made against the G. I. Taylor strong shock-point source solution. The comparison is presented in Fig. 4. As indicated, the position of the shock front is in good agreement with theory, however the magnitude is somewhat less in the TRIOIL solution. The latter results are consistent with similar calculations performed with the OIL (Ref. 1) code.

The third test problem was a normal impact to be compared with the OIL code. The configuration (as indicated in Fig. 5) for the TRIOIL code was a cube of 4 x 4 x 4 cells impacting normal to a semi-infinite target.
TEST PROBLEM

Fig. 3--The initial configuration for a point source calculation using the 3-D code for a 1-D problem
Fig. 4--Comparison of theory and computer results for a strong shock-point source solution.
Fig. 5--Initial configuration of the OIL (top) and TRIOIL (bottom) problems
The configuration for OIL consisted of a right circular cylinder (D = L) where the diameter was equal to the side of the cube in TRIOIL. The OIL problem had 2 radial zones and 1 axial in the projectile. The velocity of the projectile was $2.6 \times 10^6$ cm/sec, and the projectile and target were both aluminum.

The momentum and times of the two problems were scaled by the ratio of their masses, the distances by the cube root of the ratio. Figure 6 presents the total positive y momentum (axial, in the case of OIL) versus time for the 2 codes. The agreement is excellent. Figure 7 displays the pressure attenuation into the target (along the axis for OIL and in either of the 2 inner original columns for the TRIOIL). Here again, we expect some difference at early times since one projectile is a cylinder and the other a cube, but the agreement is very good.

Figure 8 is a velocity (in the x-y plane) plot for the plane of symmetry, $z = 0$. Figure 9 is a velocity plot (in the y-z plane at a value of $x$ in the center of the projectile. Exact symmetry is indicated by these two plots. Figure 10 is at a later time, presenting the velocity (in the x-y plane) plot for the plane of symmetry, $z = 0$.

Figure 11 is a velocity (in the x-y plane) plot for the plane of symmetry, $z = 0$, for an oblique impact ($45^\circ$). The dark lines indicate the position of the original projectile to target at time $t = 0$. Figure 12 is a velocity plot in the y-z plane at a value of $x$ at the right hand side of the original projectile.

Since the original formulation of the TRIOIL code, investigations into the effect of obliquity, and velocity, for semi-infinite and thin targets have been completed successfully.
Fig. 6--Total positive y momentum as a function of time for the two codes
Fig. 7--Pressure attenuation into the target comparison for the 2 codes
Fig. 8: Velocities (X-Y) in the plane of symmetry (z=0) for 90 degrees
Fig. 9--Velocities (Y-Z) in the Y-Z plane at a X position of the original center of projectile for 90 degrees.
Fig. 10--Velocities (X-Y) in the plane of symmetry (Z=0) for 90 degrees
Fig. 11--Velocities (X-Y) in the plane of symmetry (Z=0) for 45 degrees
**FORTRAN LISTING**

1 WALLY

** *** NOTE: THE FOLLOWING SET OF DIMENSION, COMMON, AND EQUIVALENCE IS TO BE USED FOR ALL SUBROUTINES WITH THE EXCEPTION OF SUBROUTINE CARDS.  

DIMENSION AIX(6000), AMX(6000), U(6000), V(6000), W(6000), P(6000), 
1UX(30), DY(30), DZ(30), UL(30), PL(30), X(30), Y(30), ZCOR(30), 
2Z150), IX(150), FLLEFT(30), YAMC(30), SIGC(30), GAMC(30), ZMOM(30), 
3PIND(700), UBIN(700), BMASS(700), BXMOM(700), BYMOM(700), 
4ZMON(700), BENV(700), 
DIMENSION PR(50), PK(30) 
COMMON Z, AIX, AMX, U, V, W, P, DX, DY, DZ, 
1UX, IUX, IY, ZCOR, PR, SIGC, GAMC, 
2XOM, UBIN, BMASS, BYMOM, 
3ZMON, UBIN, AREA, BIG, BOUNCE, PABOVE, PBLO, 
4PIOTS, PRH, RHO, SIG, UMAX, VABOVE, VBLO, 
5VEL, WPS, WS, WSA, wSg, wSC, I1, IN, IR, 
6LS, LWSA, LWSB, LWSG, I1, JP, JR, K, KDT, Kn, 
7KPL, KPLM, L, M, MA, KB, MC, ND, ME, MZ, N 
COMMON REZ, TRAD, DTRAD, RADEB, RADEK, RADET, X1, X2, Y1, Y2, IMAXA 
EQUIVALENCE (Z, IZ, PROB), (Z(2), CYCLE), (Z(3), DT), 
1(Z(4), PRINTS), (Z(5), PRINTL), (Z(6), DUMP7), (Z(7), CSTOP), (Z(8), PIDY) 
2, (Z(9), GAM), (Z(10), GAM0), (Z(11), GAMX), (Z(12), ETH), (Z(13), FFA), 
3(Z(14), FFB), (Z(15), TMASS), (Z(16), XMAX), (Z(17), YMXP), (Z(18), ZMAX), 
4(Z(19), DNN), (Z(20), DMN), (Z(21), DTMA), (Z(22), REZCT), (Z(23), TOZONE) 
5, (Z(24), ECK), (Z(25), SOUND), (Z(26), CUBLN), (Z(27), T), (Z(28), GMAX), 
6(Z(29), WSGD), (Z(30), WSGX), (Z(31), BMASS), (Z(32), BMAKL), (Z(33), DTCHK) 
7, (Z(46), PCSTAB), (Z(47), CNOT), (Z(48), BFACT), (Z(49), EPSI), (Z(50), S1) 
8, (Z(51), S2), (Z(52), S3), (Z(53), S4), (Z(54), S5), (Z(55), S6), 
9(Z(56), S7), (Z(57), S8), (Z(58), S9), (Z(59), S10) 
EQUIVALENCE (Z60, XMLOST), (Z(61), ELSTOP), (Z(62), XMOLOST), 
1(Z(63), YMLOST), (Z(64), XMLOST), (Z(65), ENEG), (Z(66), RHONOT), 
2(Z(67), VEL0C), (Z(68), BUG), (Z(69), NPR), (Z(70), NPRS), 
3(Z(83), NC), (Z(84), NPP), (Z(85), NR), (Z(86), IMAX), (Z(87), JMAX), 
4(Z(88), KMAX), (Z(89), KMAXA), (Z(90), IXMAX), (Z(91), NOD), 
5(Z(92), NOTP), (Z(93), I1), (Z(94), I2), (Z(95), I3), (Z(96), I4) 
6(Z(97), N1), (Z(98), N2), (Z(99), N3), (Z(100), N4), (Z(101), N5) 
7(Z(102), NB), (Z(103), N7), (Z(104), N8), (Z(105), N9), (Z(106), N10) 
8(Z(107), N11), (Z(108), N1), (Z(109), N2), 
9(Z(110), J1), (Z(111), J2) 
EQUIVALENCE (BMASS, PBIND), (BXMOM, UBIN), 
1(UFL, FLEFT), (PL, YAMC, PK) 

*** FOR MAIN/S, MAIN/S, MAIN/SS 

** *** 3DOIL *********************** 

THE INPUT ROUTINE WILL READ A TRIOIL BINARY DUMP TAPE OR WILL CALL FOR SUBROUTINE SET-UP WHICH WILL GENERATE A DATA TAPE FOR RESTRICTED GEOMETRY 

CALL INPUT
CDT ROUTINE CALLS FOR THE EQUATION OF STATE,
CALCULATES THE DT (HYDRODYNAMICS TIME STEP) AND
ADVANCES THE CYCLE NUMBER.

10 CALL CDT

IN EDIT, DETERMINE WHETHER TO EXECUTE A
SHORT PRINT, LONG PRINT, BINARY TAPE DUMP
OR TO STOP THE PROBLEM.

CALL EDIT
*** SENSE LITE 1 SIGNIFIES THAT THIS
IS THE LAST CYCLE OF THIS RUN.
THE LITE IS TURNED ON IN THE EDIT ROUTINE............

CALL SLITET(1,K000FX)
GO TO(30,20),K000FX

PH1 INTEGRATES THE MOMENTUM AND
ENERGY EQUATIONS DUE TO
TO PRESSURE FORCES ONLY, THE CONVECTIVE
TERMS ARE TEMPORARILY DROPPED.

20 CALL PH1

PH2 SOLVES THE MASS TRANSPORT EQUATIONS
AND MOVES MOMENTUM AND ENERGY
ACROSS THE FIXED CELL BOUNDARIES
TO APPROXIMATE THE CONVECTIVE TERMS THAT
WERE OMITTED IN PH1.

CALL PH2

ALL CELL QUANTITIES, EXCEPT THE PRESSURE
HAVE NOW BEEN ADVANCED TO
CYCLE N+1

GO TO 10

30 CALL EXIT
END

FOR CARDS/S,CARDS/S,CARDS/SS

SUBROUTINE CARDS
DIMENSION TABLE(1),CARD(7),LABEL(1)
COMMON TABLE
A 2 IN COLUMN 1, ROUTINE WILL FIX THE
FLOATING PT. NO.
A 1 IN COLUMN 1, MEANS THIS IS LAST CARD TO
READ IN.
EQUIVALENCE(TABLE(1),LABEL(1))
WRITE(6,10)
1 READ (5,11)IEND,LOC,NUMWPC,(CARD(I),I=1,NUMWPC)
WRITE(6,12)IEND,LOC,NUMWPC,(CARD(I),I=1,NUMWPC)
DO 4 I=1,NUMWPC
J=LOC+1+I-1
IF(IEND-2)2,5,2
5 LABEL(J)=IFIX(CARD(I))
GO TO 4
2 TABLE(J)=CARD(I)
4 CONTINUE
IF(IEND-1)1,3,1
3 RETURN
C FORMATS
10 FORMAT(20H1,T10I1) INPUT CARDS///)
11 FORMAT(11,15,11,0P7E9.4)
12 FORMAT(1H I4,17,13,1P7E14.6)
END
@1 FOR UNCLE/S,UNCLE/S,UNCLE/SS
SUBROUTINE UNCLE
!*IND N7
C SUBROUTINE (( UNCLE))) IS CALLED WHENEVER
C A CODED ERROR IS ENCOUNTERED
C IN ANY SUBROUTINE, ITS MAIN FUNCTION
C IS TO PRINT THE CELL QUANTITIES OUT IN THE FORM
C OF THE NORMAL LONG PRINT
K=90
WRITE(6,8120)NC
8120 FORMAT(1HO///60H AN ERROR HAS OCCURRED AND SUBROUTINE UNCLE HAS BEEN CALLED AT CYCLE15///) 5000 WRITE(6,8116)PROB,NC,T,DTNA,TRAD,DTRAD,NR,N1,N2,N3,N4
UO 1126 KK=K1,K2
WRITE(6,9041)KK,ZCOR(KK),DZ(KK)
5004 UO 5050 I=11,12
WS1=11,
J=J2+1
K=J*IMAX+1+(KK-1)*IMAX
UO 5046 L=J1,J2
J=J-1
K=K-IMAX
5012 IF(AMX(K)) 5046
5016 IF(WS1)5019#.5016
      WRITE(6,8135)I,X(I),DX(I)
5019 ..SC=P(K)*1.E+4
5046 CONTINUE
5050 CONTINUE
1126 CONTINUE
RETURN
6108 FORMAT(I3L1P8£l2.5)
8116 FORMAT(6H PROBLEM6A,5HCYCLE9X,4HTIME13X,2hDT13X,4HTRAD11X,5HTRAD1EDIT3380
12X,2HNR6X,2HN14X,2HN24X,2HN34X,2HN4/(F7.1,111.2,1P4E16.7,110,2X,4EDIT3390
216))
8135 FORMAT(1H ///4H I =I3,6X,6HX(I) =F12.3,6X,7HDX(I) =F12.3///3H J8X,EDIT3520
11H1A10X,1HY10X,3HFA9X,3HAMX9X,3HRHO8X,3HAIX9X,4H W 8X,2H Y/) 9041 FORMAT(1H ///4H K =I3,6X,9HZCOR(K) =F12.3,6X,7HDZ(K) =F12.3)
END
@1 FOR SETUP/S,SETUP/S,SETUP/SS
SUBROUTINE SETUP
C C    CALCULATE THE ADDITIONAL INDICES THAT ARE FUNCTIONS OF IMAX,JMAX, AND KMAX
C I=MAX=(IMAX) *(JMAX)
K=MAX= KMAX * IMAX
C SET ALL CELL CENTERED QUANTITIES TO ZERO

C
DO 1 K=1,KMAXA
U(K)=0.
V(K)=0.
W(K)=0.
AUX(K)=0.
AMX(K)=0.
P(K)=0.
1 CONTINUE
X(1)=DX(1)

CALCULATE ALL X'S
DO 10 I=2,IMAX
X(I)=X(I-1)+DX(1)

NOTE, DX IS CONSTANT FOR ALL I
10 CONTINUE
Y(1)=DY(1)

CALCULATE ALL Y'S
DO 11 J=2,JMAX
Y(J)=Y(J-1)+DY(1)

NOTE, DY IS CONSTANT FOR ALL J
11 CONTINUE
ZCOR(1)=DZ(1)

CALCULATE ALL ZCOR'S
DO 12 K=2,KMAX
ZCOR(K)=ZCOR(K-1)+DZ(1)

NOTE, DZ IS CONSTANT FOR ALL K
12 CONTINUE

RHONOT IS INITIAL DENSITY FOR ALL MATERIAL
J3=S1
DO 100 K=1,KMAX
LL=(K-1)*IXMAX
DO 100 I=1,IMAX
DO 100 J=J3,JMAX
L=LL+(J-1)*IXMAX+I
AMX(L)=DX(I)*DY(J)*DZ(K)*RHONOT
100 CONTINUE

S1=INTERFACE(J) VALUE +1 BETWEEN PROJECTILE AND TARGET
S2=BACK BOUNDARY +1 OF THE PROJECTILE(K) VALUE
S3= FRONT BOUNDARY OF PROJECTILE(K) VALUE
S4= LEFT BOUNDARY(I) VALUE +1 OF THE PROJECTILE
S6= RIGHT BOUNDARY(I) OF THE PROJECTILE
S7= TOP BOUNDARY(J) OF THE PROJECTILE
ETH=0.
K11=S2
K22=S3
I11=S4
I22=55
J11=56
J22=57
DO 200 K=K11,K22
LL=(K-1)*IXMAX
DO 200 I=I11,I22
DO 200 J=J11,J22
L=LL+(J-1)*IXMAX+1
AMX(L)=DX(I)*DY(J)*DZ(K)*RHONOT
C VELOC=INITIAL Y COMPONENT OF VELOCITY
V(L)=VELOC
C S9= INITIAL X COMPONENT OF VELOCITY
U(L)=S9
C S10= INITIAL Z COMPONENT OF VELOCITY
w(L)=S10
ETH=ETH+AMX(L)*(U(L)**2+V(L)**2+W(L)**2)/2.
200 CONTINUE
C PRINT THE QUANTITIES ASSOCIATED WITH THE GRID
C
WRITE(6,8000)IMAX,(X(I),I=1,IMAX)
WRITE(6,8003)IMAX,(DX(I),I=1,IMAX)
WRITE(6,8001)JMAX,(Y(J),J=1,JMAX)
WRITE(6,8004)JMAX,(DY(J),J=1,JMAX)
WRITE(6,8002)KMAX,(ZCOR(K),K=1,KMAX)
WRITE(6,8005)KMAX,(DZ(K),K=1,KMAX)
WRITE(6,8006)JMAX,KMAX,IXMAX,KMAXA
8000 FORMAT(1H/10H X(I) I=1,12/(5F16.6))
8001 FORMAT(1H/10H Y(J) J=1,12/(5F16.6))
8002 FORMAT(1H/13H ZCOR(K) K=1,12/(5F16.6))
8003 FORMAT(1H/11H DX(I) I=1,12/(5F16.6))
8004 FORMAT(1H/11H DY(J) J=1,12/(5F16.6))
8005 FORMAT(1H/11H DZ(K) K=1,12/(5F16.6))
8006 FORMAT(718)
C WRITE A DUMP TAPE FOR T=0. FOR THE TROIOL CODE
REWIND N7
WS=555.0
WRITE(N7)WS,CYCILE,N3
WRITE(N7)(Z(I),I=1,150)
WRITE(N7)(U(I),V(I),W(I),AMX(I),AIX(I),I=1,KMAXA)
WRITE(N7)(X(I),I=1,IMAX)
WRITE(N7)(Y(J),J=1,JMAX)
WRITE(N7)(ZCOR(K),K=1,KMAX)
WS=666.
WRITE(N7)WS,WS,WS
RETURN
END
C FOR INPUT/S,INPUT/S,INPUT/SS
SUBROUTINE INPUT
C CALL SLITE (3)
C IWSA=THE NUMBER OF BCD HEADER CARDS TO READ IN
READ(5,8007)IWSA
DO 7 I=1,1WSA
HEAD (5,8004) IWS
WRITE (6,8004) IWS
7 CONTINUE
6 CALL CARDS
C NOTE, PROVISIONS FOR CALLING A GENERATOR
C CODE SUCH AS (CLAM) DOES NOT EXIST IN
C 3 DIMENSIONS AT THIS TIME
IF(PK(0))8887,8888,8888
8888 CALL CARDS
CALL SETUP
8887 CONTINUE
GO TO 1000
10 CONTINUE
CALL CARDS
GO TO 2000
40 DO 45 K=1,KMAX
45 P(K)=0.0
C INTEGRATE (THE TIME AND CYCLE NUMBER ) BACKWARDS, SINCE THEY
C WILL BE ADVANCED IN CDT SUBROUTINE
T=T-UTNA
NC=NC-1
CYCLE=NC
NPC=NPC-1
UVMAX=0.0
C CALCULATE DX, DY, DZ SINCE THEY ARE NOT ON THE TAPE
WS=0.
DO 50 I=1,IMAX
WS=X(I)
50 CONTINUE
WS=0.
DO 55 J=1,JMAX
WS=Y(J)
55 CONTINUE
WS=0.
DO 65 K=1,KMAX
WS=ZCOR(K)
65 CONTINUE
C DUMP THE Z BLOCK
K=1
DO 80 I=1,9
L=K+8
WRITE (6,8005) K, (Z(N), N=K, L)
80 K=L+1
K=81
DO 81 I=1,8
L=K+8
WRITE (6,8006) K, (IZ(N), N=K, L)
81 K=L+1
GO TO 10000

C

READ THE BINARY TAPE FOR A RESTART

1000 MZ=150
IN=$0

1003 READ(N7) N7
1004 READ(N7) PR(1), PR(2), N3
NR=N2+6

1006 IF(PR(1)-555.0) 1010, 1016, 1010

1010 N=S=1 X+1
1011 IF(NJ+1)=902, 903, 1003
1016 IF(PR(2)) 1016, 1018, 1010
1018 IF(PR(2)-PR(2)) 1023, 1023, 1020

C READ OVER THIS IS NOT THE CORRECT CYCLE
1020 JD=122 L=2, NR
1022 READ(N7)wS
GO TO 1004

1023 READ(N7) X(1), I=1, N2
C CHECK FOR CORRECT PROBLEM NUMBER
IF(ALS(PR(2)-PK(1))-.01) 1024, 1024, 9901

1024 READ(N7) U(I), V(I), W(I), AX(I), AIX(I), I=1, KMAXA)
READ(N7) X(I), I=1, KMAX
READ(N7) Y(J), J=1, JMAX
READ(N7) ZCON(K), K=1, KMAX

1034 READ(N7) PR(1), PR(2), PR(3)

1036 IF(PR(1)-555.0) 9904, 1040, 1036
1038 IF(PR(2)-66.0) 9905, 1040, 9905

1040 GO TO 10

2000 IF(WSGX) 9906, 2010, 2005

C CALCULATE 1/(GAMMA-1.) AND GAMMA/(GAMMA-1.)
2005 GAMX=1.0/(WSGX-1.0)
2010 WSGX=(GAMX+1.0)/GAMX
GMAX=GAMX*WSGX

2012 IF(WSGD) 9907, 2005, 2015
2015 GAMD=1.0/(WSGD-1.0)
2020 WSGD=(GAMD+1.0)/GAMD
GMADN=GAMD*WSGD
GMD=WSGD

C SEARCH FOR MAX GAMMA
IF(WSGD-WSGX) 2025, 2030, 2030
2025 GMAX=WSGX
2030 GO TO 40

C ERROR
9901 NR=1023
GO TO 9999
9902 NR=1011
GO TO 9999
9904 NR=1036
GO TO 9999
9905 NR=1038
GO TO 9999
9906 NR=2069
GO TO 9999
9907 NR=2012
9999 NR=1
WRITE(6,8000)PR(1),PR(2),PK(1),PK(2),PK(3),IWS
CALL UNCLE
CALL DUMP
C
10600 RETURN
C
FORMAT
8000 FORMAT(1P5E14.6,1S)
80040 FORMAT(11,71H1)
8005 FORMAT(14,1X,1P9E12.5)
8006 FORMAT(14,1X,917)
8007 FORMAT(613)
C
END
C FOR CLT/S, CDT/S, CDT/SS
SUBROUTINE CDT
C
3000 VEL=0.0
C
SET UP THE LOOPS FOR CALCULATING THE MATERIAL PRESSURE
C
DO 3050 K=K1,K2
LL=(K-1)*IXMAX
3050 DO 3050 I=I1,I2
3010 L=I+LL+(J1-1)*IMAX
3015 DO 3050 J=J1,J2
3020 IF(AMX(L))9901,3050,3025
C
THE ES ROUTINE CALCULATES THE PRESSURE, FOR INPUT IT NEEDS I,J,K,L
C AND THE AIX(ENERGY) AND AMX(MASS)
C
3025 CALL ES
C
THE OUTPUT FROM ES IS THE P(PRESSURE) AND MAX (GAMMA-1.)
C
3030 IF(ABS(P(L))-1.E-20)3035,3035,3040
3035 P(L)=0.
3040 IF(WGX-VEL)3050,3050,3045
3045 VEL=WGX
3050 L=L+1MAX
3055 KDT=1
UVMAX=-1.0
C
NOW SET UP THE LOOP FOR CALCULATING DT FROM THE PARTICLE VELOCITIES AND THE COURANT CONDITION
C
WE FLAG THE CELL THAT IS CONTROLLING THE TIME STEP AND STORE THE VALUES OF I,J,K INTO N10,N11, AND N9 RESPECTIVELY.
C
DO 3255 K=K1,K2
LL=(K-1)*IXMAX
3070 DO 3255 I=I1,I2
3075 L=I+LL+(J1-1)*IMAX
3095 DO 3255 J=J1,J2
3100 CONTINUE
C IF Z(69) > 1.0 THEN 90, 91, 94
25 Z(69) = Z(69) + 2(70)
GO TO 90

C HERE, CHECK THE 3 POSSIBLE OPTIONS FOR CALCULATING THE
NEW DT

CDT 1560

C HERE OPTIONS EXIST FOR STARTING THE PROBLEM
C WITH SMALL TIME STEPS (A SMALL FRACTION OF STABILITY)
C FOR PROBLEMS WHERE THE INITIAL ENERGY IS
C PRIMARILY INTERNAL... 

CDT 1260
CDT 1270
CDT 1280

C PREPARE TO CALCULATE THE SPEED OF SOUND, THE PERFECT GAS SPEED OF
C SOUND OR, OTHERWISE FROM THE THERMAL EQUATION OF STATE

CDT 1310

C NATOR MCTP(J)/MCTP(I)

CDT 1340
CDT 1350
CDT 1360
CDT 1370
CDT 1380
CDT 1390

C CONTINUE

CDT 1450
CDT 1460
CDT 1470
CDT 1480
CDT 1500
CDT 1510
CDT 1520
CDT 1550
CDT 1540

CDT 1560
94 \( Z(69) = 1.0 \)
95 \( \Delta T = 0.5/\text{VEL}/\text{UVMAX} \times \text{PCSTAB} \times Z(69) \)
   GO TO 3295
91 \( k = \text{UVMAX} \times \Delta T \)
   \( \text{WSA} = 0.5 / \text{VLL} \)
3265 IF (\( \text{FFA} = \text{WSA} \)) 3276, 3276, 3270
3270 \( \text{FFA} = \text{WSA} \)
3276 IF (\( \text{WS} = \text{FFA} \)) 3285, 3285, 3280
3280 \( \Delta T = \Delta T / \text{WS} \times \text{FFA} / 0.9 \)
   GO TO 3295
3285 IF (\( \text{WS} = \text{FFA} \)) 3290, 3290, 3300
3290 \( \Delta T = \Delta T / \text{FFA} \times \text{WS} / 0.9 \)
3295 \( k = 0 \)
3300 \( T = T + \Delta T \text{NA} \)
   \( N = N + 1 \)
   CYCLE = NC
   UVMAX = UVMAX \times \Delta T
   NPC = NPC + 1
3305 IF (\( T \)) 3320, 3320, 3310
3310 IF (\( k = 0 \)) 3315, 3315, 3320
3315 WRITE (6, 8000) T, \( \Delta T \), \( \Delta T \text{NA}, \Delta T \)
3320 \( \Delta T \text{NA} = \Delta T \)
   GO TO 3325
9900 \( \text{NK} = 3020 \)
   GO TO 9999
9909 \( \text{NK} = 3305 \)
   GO TO 9999
9910 \( \text{NK} = 3310 \)
   GO TO 9999
9912 \( \text{NK} = 1 \)
   GO TO 9999
9999 \( \text{NR} = 2 \)
   WRITE (6, 8002) \( I, J, K, L, \text{NK}, \text{NR}, \text{NC} \)
   WRITE (6, 8001) \( \text{UVMAX}, \text{AMX}(L), \text{P}(L), \Delta T, \text{VEL} \)
8001 FORMAT (1P5E14.6)
8002 FORMAT (81S)
   CALL UNCLE
   CALL DUMP
3325 RETURN
8000 FORMAT (17H0CHANGE DT ... \( T = 1 \times 10^3, 1 \times 1 \) \( \Delta T(N) = 1 \times 10^3, 1 \times 2 \) \( \Delta T \)
   \( 1(N+1) = 1 \times 10^3 \))
   END
   \( I \) FOR \( \text{PH1/S,PH1/S,PH1/SS} \)
   SUBROUTINE Phl
C
C THE VELOCITIES, ENERGIES, PRESSURE AND MASS ARE AT
C CELL CENTERS
C FIRST PASS, CALCULATE \( U, V \) AND \( W \) FOR CYCLE \( N+1 \), AND THE WORK
C TERMS USING THE VELOCITIES AT CYCLE \( N \).
C SECOND PASS, CALCULATE THE CONTRIBUTION TO THE CHANGE IN
C INTERNAL ENERGY FROM WORK TERMS EVALUATED FROM \( U, V \) AND \( W \)
C AT CYCLE \( N+1 \).
C 2 PASSES REQUIRED
C
C REMEMBER, WE ARE NOT ADVANCING THE VELOCITIES AND ENERGY TO CYCLE
C \( N+1 \), SINCE WE HAVE NOT AS YET SOLVED THE TRANSPORT TERMS, AS
C USUAL, WE REFER TO THE VELOCITIES AND ENERGY FROM THIS ROUTINE
AS TILDA QUANTITIES

CELL IN QUESTION = L=(J-1)*IMAX+I+(K-1)*IMAX*JMAX

IXMAX=IMAX*JMAX

KMAXA=(IMAX)(JMAX)(KMAX)

CELL TO THE RIGHT= L+1

CELL ABOVE =N= L+IMAX

CELL IN FRONT =NN =L+IXMAX

N1 =FLAG AT THE LEFT

N2 =FLAG AT THE RIGHT

N3 =FLAG AT THE TOP

N4 =FLAG AT THE BOTTOM

N5 =FLAG AT THE BEHIND

N6 =FLAG AT THE IN FRONT

SET THE FLAGS FOR INCREASING OR DECREASING ACTIVE GRID COUNTERS TO ZERO

IX1=0
IX2=0
JY1=0
JY2=0
KZ1=0
KZ2=0

SET FLAG FOR SUBCYCLING

V5L=1.

RETURN HERE FOR THE SECOND PASS

SET UP THE K LOOP FIRST

2 DO 3 K=K1,K2
7 L=(K-1)*(IXMAX)+1

CHECK FOR BOUNDARY CONDITIONS AT THE LEFT

8 DO 3502 J=1,JMAX
6 IF(N1)9,99,9

TRANSMITIVE LEFT BOUNDARY

99 PL(J)=0.
UL(J)=UL(L)
GO TO 10

REFLECTIVE LEFT BOUNDARY

9 PL(J)=P(L)
UL(J)=0.
10 L=L+IMAX
3502 CONTINUE
11 IF(K-1)8999,12,7001
7001 IF((K-K1)15,12,15
   BACK SIDE BC. HAVE ALREADY BEEN SET
12 CONTINUE
   BACK SIDE IS TRANS, BUT WILL TAKE CARE OF IT LATER
   BACK SIDE IS REFLECTIVE
13 DO 2302 N=1,IXMAX
   IF(N5)6010,6011,6010
   6011 PBIND(N)=0.
   UBIND(N)=W(N)
   GO TO 2302
   6010 PBIND(N)=P(N)
   UBIND(N)=0.
2302 CONTINUE
   LL=(K-1)*IXMAX
   SET DO LOOP IN X DIRECTION
   DO 4 I=I1,I2
      M=(J1-1)*IMAX+I
      L=LL+I+(J1-1)*IMAX
   4 SET DO LOOP IN Y DIRECTION
   DO 5 J=J1,J2
      NN=L+IAMAX
5      N=L+IAMAX
   IF(J-1)9902,21,7003
   7003 IF(J1-J)3305,23,3305
   WE HAVE ALREADY CALCULATED THE BOTTOM BC.
   CHECK FOR BOTTOM BOUNDARY
21 IF(N4)22,23,22
   BOTTOM BOUNDARY IS TRANS
   VBLO=V(L)
   P8LO=0.
   GO TO 3305
   BOTTOM BOUNDARY IS REFLECTIVE
22 VBLO=0.
   P8LO=P(L)
   NOW WE HAVE THE LEFT BC.(IF REFLECTIVE) AND THE BOTTOM(IF REFLECT)
3305 IF(AMX(L))9900,3340,3306
   CELL IN QUESTION IS VOID, GET OUT AND CONTINUE THE LOOP
3306 IF(IMAX-I)9901,3311,3307
   WE ARE AT THE RIGHT BOUNDARY OF THE GRID
THE TOP IS REFLECTIVE

30 PAHOVEL=P(L)
   VAHOVEL=0.
   GO TO 3328

THE TOP IS TRANS

31 PAHOVEL=PULC

MODIFY ETH FOR TRANS BOUNDARY

ETH=LTH-PAHOVEL/2.*V(L)+DT*DX(I)*DZ(K)
   GO TO 3323

WE ARE NOT AT THE TOP

3320 IF(AMX(N))9965,3322,3324

CLLL ABOVE IS VOID

3322 PAHOVEL=0.
   3323 VAHOVEL=V(L)
   GO TO 3328

NORMAL FLOW FOR ALL CLLLS OCCUPIED

3324 PAHOVEL=(P(L)+P(N))/2.
   32 IF(I-J)3325,33,9966

BOTTOM BOUNDARY HAS BEEN SET

WE ARE AT THE BOTTOM

33 IF(N4)3325,7000,3325

REFLECTIVE BOTTOM BOUNDARY CONDITION HAS ALREADY BEEN SET.

7000 PULC=PAHOVEL
   LTH=LTH+PULC/2.*V(L)+DT*DX(I)*DZ(K)
   3325 VAHOVEL=(V(L)+V(N))/2.

CHECK THE Z DIRECTION

3328 IF(KMAX-K)9987,4418,4420

WE ARE AT THE FRONT OF THE GRID

4418 IF(NO)2999,34,2999

FRONT IS REFLECTIVE

2999 Pzk=P(L)
   WzR=0.
   GO TO 432a
C FRONT IS TRANS
34 PZR=PZBND(M)
C MODIFY ETH FOR TRANS BOUNDARY
4419 ETH=ETH+PZR/2.*W(L)*DT*DX(I)*DY(J)
GO TO 4323
C CHECK CELL IN FRONT
C 4420 IF(AMX(NN))9900,35,4324
C CELL IN FRONT IS OCCUPIED
C CELL IN FRONT IS VOID
C 35 PZR=0.
4323 WZR=W(L)
GO TO 4328
C NORMAL FLOW IN Z DIRECTION FOR ALL CELLS OCCUPIED
4324 PZR=(P(L)+P(NN))/2.
    IF(1-K)4325,37,9909
C BC. BEHIND HAVE ALREADY BEEN SET
C WE ARE IN THE FIRST (X-Y) PLANE K=1
37 IF(N5)4325,8000,4325
C REFLECTIVE BC. BEHIND HAVE ALREADY BEEN SET
C TRANS BC. IN THE BACK
8000 PZBND(M)=PZR
C MODIFY ETH FOR TRANS BOUNDARY
LTH=ETH+PZR/2.*W(L)*DT*DY(J)*DX(I)
4325 WZR=(W(L)+W(NN))/2.
C CHECK FOR FIRST OR SECOND PASS
C 4328 IF(VLL)9910,42,3400
C THIS IS THE SECOND PASS; SKIP THE MOMENTA EQUATIONS
C INTEGATE THE Y COMPONENT OF VELOCITY (V)
3400 V(L)=V(L)+(PULO-PABOVE)/AMX(L)*DT*DX(I)*DZ(K)
C CHECK THE MASS TO THE RIGHT
3307 IF(ANX(L+1)>9903,3312,3314
C THIS IS THE UC. AT THE RIGHT OF A OCCUPIED CELL WITH THE
C NEIGHBOR VOID.
C
3312 PRR=0.
3313 URR=U(L)
   GO TO 3316
C
C HERE, WE ARE AT THE RIGHT BOUNDARY OF GRID (I=IMAX)
C CHECK HERE FOR REFLECT OR TRANS UC.
C
3311 IF(N2)>3309,3314,3310
C REFLECTIVE
C
3309 PRR=P(L)
   URR=0.
   GO TO 3310
C
C TRANSMITTIVE
C
3310 PRR=PL(J)
C MODIFY ETH HERE AT THE TRANS BOUNDARY
C ETH=ETH-PRR/2.*U(L)*UT*DY(J)*DZ(K)
   GO TO 3313
C
C HERE IS NORMAL FLOW FOR ALL CELLS OCCUPIED
3314 PRR=(P(L)+P(L+1))/2.
   URR=(U(L)+U(L+1))/2.
C
C CHECK HERE FOR ALONG THE LEFT BOUNDARY (I=1) FOR TRANS
3316 IF(I-1)>9911,50,3310
   50 IF(N1)>3310,51,3316
C
C REFLECTIVE (BUT UC. HAVE ALREADY BEEN SET)
C
C TRANSMITTIVE
C
51 PL(J)=PRR
C
C MODIFY ETH AT TRANS BOUNDARY
52 ETH=ETH+PRR/2.*U(L)*UT*DY(J)*DZ(K)
   GO TO 3310
3310 IF(JMAX-J)>9904,3318,3320
C
C WE ARE AT THE TOP OF THE GRID
3318 IF(N3)>30,31,30
IF(ABS(V(L)) - 1.0, 1.0) 3401, 3401, 3402
3401 V(L) = 0.
C
C INTEGRATE THE X COMPONENT OF VELOCITY (U)
3402 U(L) = U(L) + (PL(J) - PRR) / AMX(L) * DT * DY(J) * DZ(K)
40 IF(Abs(U(L)) - 1.0, 1.0) 3403, 3403, 3404
3403 U(L) = 0.
C
C INTEGRATE THE Z COMPONENT OF VELOCITY (W)
3404 W(L) = W(L) + (PBIND(M) - PZR) / AMX(L) * DT * DY(J) * DX(I)
40 IF(Abs(W(L)) - 1.0, 1.0) 3405, 3405, 3406
3405 W(L) = 0.
C
C HERE CALCULATE THE CHANGE IN INTERNAL ENERGY DUE TO THE
C WORK TERMS
42 WS = P(L) * DT / AMX(L) * (VBLO - VABOVE) / 2. * DX(I) * DZ(K)
1 + (UL(J) - URR) / 2. * DY(J) * DZ(K)
2 + (UBIND(M) - WZR) / 2. * DX(I) * DY(J))
43 AIX(L) = AIX(L) + WS
C
C CHECK ON ADVANCING OR DECREASING GRID COUNTERS
C
5600 IF(I - 1) 5999, 5801, 5801
5801 IF(I2) 5999, 5802, 5999
5802 IF(Abs(U(L)) + Abs(V(L)) + Abs(W(L)) + Abs(AIX(L)) 5803, 5999, 5803
5803 IX2 = 1
5804 GO TO 5999
5999 IF(K = K2) 4999, 5804, 5804
5804 IF(K2) 4999, 5805, 4999
5805 IF(Abs(U(L)) + Abs(V(L)) + Abs(W(L)) + Abs(AIX(L)) 5806, 4999, 5806
5806 KZ2 = 1
5807 GO TO 4999
4999 IF(KZ1) 5300, 5222, 5300
5222 IF(K1 = 1) 5300, 5300, 5000
5000 IF(K1 = K) 5300, 5001, 5001
5001 IF(Abs(U(L)) + Abs(V(L)) + Abs(W(L)) + Abs(AIX(L)) 5002, 5300, 5002
5002 KZ1 = 1
5300 IF(JY1) 5600, 5304, 5600
5304 IF(J1 = 1) 5600, 5600, 5301
5301 IF(J1 = J) 5600, 5302, 5302
5302 IF(Abs(U(L)) + Abs(V(L)) + Abs(W(L)) + Abs(AIX(L)) 5303, 5600, 5303
5303 JY1 = 1
5600 IF(I1) 3342, 5604, 3342
5604 IF(I1 = I) 3342, 3342, 5601
5601 IF(I1 = I1) 3342, 5602, 5602
5602 IF(Abs(U(L)) + Abs(V(L)) + Abs(W(L)) + Abs(AIX(L)) 5603, 3342, 5603
5603 IX1 = 1
5604 GO TO 3342
C
C CAME HERE BECAUSE THE CELL IN QUESTION (L) IS VOID
C
3340 PRR = 0.
3341 URR = U(L+1)
3342 PABOVE = 0.
3343 VABOVE = V(N)
PZR = 0.
C SET THE ABOVE QUANTITIES TO BELOW
  3342 VLLO=VABOVE
  PLLO=PABOVE

C SET THE RIGHT QUANTITIES TO THE LEFT
PL(J)=PRR
UL(J)=URR

C SET THE FRONT QUANTITIES TO BEHIND
PLIND(M)=PZR
UBIND(M)=NZR

C UPDATE THE INDICES
L=N
M=M+IMAX

C TERMINATION OF LOOP ON J---(Y)
  5 CONTINUE
C CHECK ON ADVANCING OR DECREASING GRID COUNTERS
  5700 LJ=L-IMAX
      IF(JY2)5701+5701+5702
  5701 IF(ABS(U(LJ))+ABS(V(LJ))+ABS(W(LJ))+AIX(LJ))5702+4,5702
  5702 JY2=1
      GO To 4

C TERMINATION OF LOOP ON I---(X)
  4 CONTINUE
C TERMINATION OF LOOP ON K---(Z)
  3 CONTINUE

C CHECK FOR FIRST OR SECOND PASS
  44 IF(VEL-1.)46,45,46
  45 VEL=0.
C RECYCLE
      GO TO 2
C HAVE COMPLETED BOTH PASSES
  46 CONTINUE
C INCREASE OR DECREASE COUNTERS AS REQUIRED
C 11=I1-IX1
  5900 IF(I1)5901,5901,5902
  5901 I1=1
  5902 I2=I2+IX2
  5903 IF(I2=IMAX)5905,5905,5904
  5904 I2=IMAX
  5905 J1=J1-JY1
      IF(J1)5906,5906,5907
  5906 J1=1
  5907 J2=J2+JY2
      IF(J2-JMAX)5909,5909,5908
**SUBROUTINE PH2**

**DIMENSION** AI(6000), AMX(6000), U(6000), V(6000), W(6000), P(6000),

**HERE, WE APPROXIMATE THE TRANSPORT TERMS LEFT OUT OF THE MOMENTUM AND ENERGY EQUATIONS IN PH1 BY MOVING MASS, (SOLVING THE MASS CONSERVATION EQUATION) THIS MASS THEN CARRIES ENERGY AND MOMENTUM ACROSS THE FIXED GRID LINES**

**AMPY** = MASS FLOW AT THE TOP

**AMUT** = X MOMENTUM COMPONENT OF THIS MASS

**AMVT** = Y MOMENTUM COMPONENT OF THIS MASS

**AMWT** = Z MOMENTUM COMPONENT OF THIS MASS

**DELET** = SPECIFIC ENERGY OF THIS MASS
AMMP = MASS FLOW AT THE RIGHT
AMUR = X MOMENTUM COMPONENT OF THIS MASS
AMVR = Y MOMENTUM COMPONENT OF THIS MASS
AMWR = Z MOMENTUM COMPONENT OF THIS MASS
DELEH = SPECIFIC ENERGY OF THIS MASS

AMMY = MASS FLOW AT THE BOTTOM
AMMY = X MOMENTUM COMPONENT OF THIS MASS
AMMV = Y MOMENTUM COMPONENT OF THIS MASS
AMMW = Z MOMENTUM COMPONENT OF THIS MASS
DELEB = SPECIFIC ENERGY OF THIS MASS

AMMC = MASS FLOW AT THE LEFT
FLEFT = X MOMENTUM COMPONENT OF THIS MASS
YAMC = Y MOMENTUM COMPONENT OF THIS MASS
ZMOM = W MOMENTUM COMPONENT OF THIS MASS
SIGC = SPECIFIC ENERGY OF THIS MASS

BMASS = MASS FLOW AT THE BACK
UXMOM = X MOMENTUM COMPONENT OF THIS MASS
UYMOM = Y MOMENTUM COMPONENT OF THIS MASS
UZMOM = Z MOMENTUM COMPONENT OF THIS MASS
BENR = SPECIFIC ENERGY OF THIS MASS

FMASS = MASS FLOW IN FRONT
FXMOM = X MOMENTUM COMPONENT OF THIS MASS
FYMOM = Y MOMENTUM COMPONENT OF THIS MASS
FZMOM = Z MOMENTUM COMPONENT OF THIS MASS
FENR = SPECIFIC ENERGY OF THIS MASS

KEZ = 0.

INITIALIZE THE FLAGS FOR ADVANCING THE ACTIVE GRID COUNTERS TO ZERO
IX1 = 0
IX2 = 0
JY1 = 0
JY2 = 0
KZ1 = 0
KZ2 = 0
SUM = 0.
CALL SLITE(O)

DO LOOP ON K

5 DO 1 K=K1,K2
LL = (K-1)*IXMAX
1 DO LOOP ON I
6 DO 2 I=I1,I2

NOTE (L) IS THE CELL INDEX = (J-1)*IMAX + I
       + (K-1)*IXMAX (NOTE IMAX=(IMAX)(JMAX)

L = LL + I + (J1-1)*IMAX
DO LOOP ON J

7 DO 3 J=J1,J2

NN = THE INDEX OF THE CELL IN FRONT = L+ IXMAX
NN=L+IXMAX

N= THE INDEX OF THE CELL ABOVE = L+ IMAX
N=L+IMAX

M= INDEX OF THE CELL IN QUESTION FOR A SINGLE PLANE
M=(J-1)*IMAX+I

N1,N2,N3,N4,N5,N6 ARE FLAGS TO SET BOUNDARY CONDITIONS
AT THE 6 FACES OF THIS GRID

N1 REFERS TO THE LEFT
N2 REFERS TO THE RIGHT
N3 REFERS TO THE TOP
N4 REFERS TO THE BOTTOM
N5 REFERS TO BEHIND
N6 REFERS TO IN FRONT

FREE SURFACES WITHIN THE GRID ARE TREATED AS FOLLOWS,
IF THE MASS FLOW INTO A EMPTY CELL PRODUCES A
DENSITY THAT IS LESS THAN TOZONE(A INPUT NUMBER LIKE
.001 OF RHO NOT), THE MASS FLUX IS SET TO ZERO

600 IF(J-1)9903,601,9302
9302 IF(J1=J)9,603,9

BOTTOM BC. HAS BEEN SET

601 IF(AMX(L))9904,603,602

WE ARE AT THE BOTTOM OF THE X-Y PLANE
602 IF(V(L))604,603,603

SET Y COMPONENT OF MOMENTUM TO 0.
603 AMMV=0.
GO TO 698

CALCULATE THE MASS FLUX AT THE BOTTOM
604 AMMY=AMX(L)/DY(J)*V(L)*DT

CHECK SO MASS FLUX DOES NOT MORE THAN EMPTY THE CELL
605 IF(AMMY+AMX(L))9300,607,607
9300 AMMY=-AMX(L)
607 IF(N4)609,608,609

BOTTOM BOUNDARY IS TRAN
608 AMMU=AMMY*U(L)

CALCULATE THE 3 MOMENTAS, THE ENERGY
SUBTRACT THIS ENERGY LOSS FROM ETH
AMMV=AMMY*V(L)
AMMW=AMMY*W(L)
WS=(U(L)**2+V(L)**2+W(L)**2)/2.
DELEB = AIX(L) + WS
ETH = ETH + AMMY * DELEB

IF(-AMMY/(DX(I) * DY(J) * DZ(K)) - Z(80)) <= 610, 610, 6600
   REZ = 1.0
   GO TO 610

C
BOTTOM BOUNDARY IS REFLECTIVE, NET MOMENTA CHANGE = 2MV
   AMMV = 2. * AMMY * V(L)
C
SET MASS, X AND Z MOMENTA AND SPECIFIC ENERGY TO 0.
   AMMY = 0.
   AMMU = 0.
   AMMW = 0.
   DELEB = 0.
   CONTINUE
C
*** FINISHED WITH THE BOTTOM BC. ************
* **************************************************
9 IF(I - I) <= 999, 10, 9301
9301 IF(I - I) <= 506, 9310, 506
9310 JJ = J
   GO TO 20
C
WE ARE ALONG THE LEFT BOUNDARY (I = 1)
   10 NL = L
   11 JJ = J
   15 IF(AMX(NL)) <= 9900, 20, 16
   20 FLEFT(JJ) = 0.
      GO TO 5504
   16 IF(U(NL)) <= 17, 20
   C
   CALCULATE MASS FLUX
   17 GAMC(JJ) = AMX(NL) / DX(I) * U(NL) * DT
   21 IF(GAMC(JJ) + AMX(NL)) <= 2500, 500, 500
   22 GAMC(JJ) = -AMX(NL)
      IF(NL) <= 501, 502, 501
   C
   LEFT BOUNDARY IS TRANS
   C
   Calculates the 3 momentas, the energy
   SUBTRACT THIS ENERGY LOSS FROM ETH
   502 FLEFT(JJ) = GAMC(JJ) * U(NL)
      YAMC(JJ) = GAMC(JJ) * V(NL)
      ZMOM(JJ) = GAMC(JJ) * W(NL)
      WS = U(NL) * V(NL) * W(NL) / 2.
      SIGC(JJ) = AIX(NL) + WS
      ETH = ETH + GAMC(JJ) * SIGC(JJ)
      IF(-GAMC(JJ) / (DX(I) * DY(J) * DZ(K)) - Z(75)) <= 503, 503, 6610
   6610 REZ = 1.0
      GO TO 503
C
LEFT BOUNDARY IS REFLECTIVE, NET MOMENTA CHANGE = 2MV
   501 FLEFT(JJ) = 2. * GAMC(JJ) * U(NL)
C
SET MASS, Y AND Z MOMENTA AND SPECIFIC ENERGY TO 0.
   5504 GAMC(JJ) = 0.
      YAMC(JJ) = 0.
      ZMOM(JJ) = 0.
SIGC(JJ)=0.
503 CONTINUE
103 CONTINUE
C
C     FINISHED WITH LEFT BOUNDARY CONDITIONS
C
C
506 IF(K-1)9901,23,9303
9303 IF(KI-K)31,250,31
23 IF(AMX(L))9902,250,24
250 BZMOM(M)=0.
    GO TO 25
C
C CHECK Z COMPONENT OF VELOCITY
24 IF(W(L))26,250,250
C
SET THE 5 DATA BEHIND TO 0.
25 BMASS(M)=0.
    BXMOM(M)=0.
    BYMOM(M)=0.
    BENR(M)=0.
    GO TO 31
C
VELLOCITY IS -R CALCULATE THE MASS FLUX
26 BMASS(M)=AMX(L)/DZ(K)*W(L)*DT
C
CHECK SO WE DONT EMPTY MORE MASS THAN THERE IS
27 IF(BMASS(M)+AMX(L))28,40,40
28 BMASS(M)=-AMX(L)
C
CHECK FOR TRANS OR REFLECT
40 IF(N5)41,29,41
C
REFLECTIVE
41 BZMOM(M)=2.*BMASS(M)*W(L)
    GO TO 25
C
TRANSMITITIVE
CALCULATE THE MOMENTAS OF THIS MASS
29 BXMOM(M)=BMASS(M)*U(L)
    BYMOM(M)=BMASS(M)*V(L)
    BZMOM(M)=BMASS(M)*W(L)
C
CALCULATE THE TOTAL ENERGY CARRIED BY THIS MASS
30 WS=(U(L)**2+V(L)**2+W(L)**2)/2.
    BENR(M)=AIX(L)+WS
C
REMOVE THE ENERGY LOSS FROM ETH
ETH=ETH+BMASS(M)*BENR(N)
    IF(-BMASS(M)/(DX(I)*DY(J)*DZ(K))-Z(78))31,31,6620
6620 REZ=1.0
C
HAVE CALCULATED THE DATA BEHIND, NOW CHECK ON JMAX
C
C
NOW, UP TO THIS POINT, WE HAVE TAKEN CARE OF
C       BOTH REFLECTIVE AND TRANSMITTIVE BOUNDARIES
C       AT THE BOTTOM, LEFT, AND BACK
**********************************************************************
**********************************************************************

VABOVE CALC.
**********************************************************************
31 VEL=0.

SET UP TO CALCULATE VABOVE
IF(JMAX-J)211,211,207

WE ARE AT THE TOP OF THE GRID
211 VEL=1.
   GO TO 208

CHECK CELL ABOVE
207 IF(AMX(N))215,215,214

CELL ABOVE IS VOID
214 IF(AMX(L))216,216,209

CELL (L) IS VOID, BUT CELL ABOVE IS OCCUPIED
216 VABOVE=V(N)
   GO TO 212
   215 IF(AMX(L))205,205,208

BOTH CELLS ARE VOID
205 VABOVE=0.
   GO TO 212
   208 VABOVE=V(L)
   GO TO 212

BOTH CELLS ARE OCCUPIED
209 VABOVE=(V(L)+V(N))/2.
   212 FS=0.

U RIGHT CALC.
**********************************************************************

NOW BEGIN CALCULATION OF URR

404 IF(IXAX-I)412,412,405
405 IF(AMX(L+1))411,411,409
409 IF(AMX(L))410,410,407

CELL (L) IS VOID, BUT CELL TO THE RIGHT IS FILLED
   410 URR=U(L+1)
   GO TO 408

MASS ON THE RIGHT=0.
   411 IF(AMX(L))403,403,406
   403 URR=0.
GO TO 408

WE ARE AT THE RIGHT OF THE GRID

FS=1.

URR=U(L)

GO TO 408

THIS IS THE NORMAL PATH

BOTH CELLS ARE FILLED

URR=(U(L)+U(L+1))/2.

408 CONTINUE

W IN FRONT CALC.

NOW, WE HAVE VABOVE (V AT THE TOP) AND URR(V AT THE RIGHT)

5503 AREA=0.

LETS CALCULATE WOUT (THE Z COMPONENT)

504 IF(KMAX-K)512,512,505

505 IF(AMX(NN))511,511,509

509 IF(AMX(L))510,510,507

CELL (L) IS VOID, BUT CELL IN FRONT IS OCCUPIED

510 WOUT=W(NN)

GO TO 508

MASS IN FRONT IS 0.

511 IF(AMX(L))5513,5513,5066

5513 WOUT=0.

GO TO 508

WE ARE AT THE FRONT BOUNDARY

512 AREA=1.

5066 WOUT=W(L)

GO TO 508

NORMAL PATH

BOTH CELLS ARE FILLED

507 WOUT=(W(L)+W(NN))/2.

IF VEL IS GREATER THAN 0., WE ARE IN THE TOP CELL (J=JMAX)

IF FS IS GREATER THAN 0., WE ARE IN THE RIGHT COLUMN

THAT IS (I=IMAX)

IF AREA IS GREATER THAN 0., WE ARE IN THE FRONT SLAB(X-YPLANE)

THAT IS (K=KMAX)

508 CONTINUE

NOW, FINALLY, WE HAVE ALL 3 INTERFACE VELOCITIES

HERE WE BEGIN THE CALCULATION OF THE 3 FLUXES

IF TOP IS TRANS., THE ENERGY LOSS IS CALCULATED LATER

100 IF(VABOVE)102,101,1103
C Y FLUX IS POSITIVE
1103 IF(AMX(L))9910, 101, 104
c
C SET INDICES
104 IF(J-1)9910, 6104, 6105
6105 KPL=L-IMAX
IF(AMX(KP))9910, 6106, 6104
6106 IF(ABS(VABOVE-VELOC)/VELOC-BUG)107, 6104, 6104
6104 LY=L
JY=J
IF(VEL)105, 105, 109
c
C Y FLUX = 0.
101 AMPY=0.
AMUT=0.
AMVT=0.
AMWT=0.
DELET=0.
GO TO 115
c
C Y FLUX IS NEGATIVE (DOWN)
C FLUX IS NEGATIVE FROM CELL (L)
102 IF(VEL)106, 106, 101
c
C FLUX IS - BUT FROM THE TOP CELL
CHECK CELL ABOVE
106 IF(AMX(N))9911, 101, 107
c
C FLUX IS NEGATIVE, BUT CELL MASS = 0.
107 LY=N
JY=J+1
105 VABOVE= (VABOVE)/(1.+(V(N)-V(L))/DY(JY)*DT/SBOUND)
C CALCULATE FLUX AT THE TOP
C
109 AMPY=AMX(LY)*VABOVE/DY(JY)*DT
110 IF(VEL)115, 115, 111
c
C WE ARE AT THE TOP, CHECK THE BC. AT THE TOP
111 IF(N3)112, 115, 112
c
C REFLECT THE MASS
112 IF(AMPY)115, 115, 113
113 AMVT=-2.*AMPY*V(L)
114 AMPY=0.
AMUT=0.
AMWT=0.
DELET=0.

*********************
IF RIGHT IS TRANS. THE ENERGY LOSS IS CALCULATED LATER.
*********************

BEGIN CALCULATING THE FLUX AT THE RIGHT
115 IF(UVR)118, 116, 117
116 AMMP=0.
 AMUR=0.
CALCULATE THE MASSFLOW IN THE Z DIRECTION

GO TO 300
117 IF(AMX(L))9911,116,120
120 LX=L
   IX=I
   IF(FS)119,119,122

C
C RIGHT FLUX IS NEGATIVE
118 IF(FS)130,130,116
C
C FLUX IS NEGATIVE BUT CELL MASS IS ZERO ALSO
C
C CHECK THE CELL TO THE RIGHT
130 IF(AMX(L+1))9911,116,121
121 LX=L+1
   IX=I+1
119 WS=(U(L+1)-U(L))/DX(IX)*DT/SBOUND
   URR=URR/(1.+WS)

C
C CALCULATE THE MASS FLUX AT THE RIGHT
** ** ** ** ** ** ** ** ** ** ** **
122 AMMP=AMX(LX)/DX(IX)*URR*DT
   IF(FS)123,300,123
C
C CHECK THE BOUNDARY CONDITION
123 IF(N2)124,300,124
C
C TRANS
124 IF(AMMP)300,300,125
C
C REFLECT THE MASS
125 AMUR=-2.*AMMP*U(L)
   AMMP=0.
   AMVR=0.
   AMWR=0.
   DELER=0.

C
C IF FRONT IS TRANS. THE ENERGY LOSS IS TAKEN CARE OF LATER.

C
C DO THE Z COMPONENT NOW
C
C SET THE 5 DATA IN FRONT TO 0.
300 IF(WOUT)318,316,317
316 FMASS=0.
   FXMOM=0.
   FYMOM=0.
   FZMOM=0.
   FENR=0.
   GO TO 700
317 IF(AMX(L))9912,316,3200
3200 LZ=L
   IZZ=I
IF(AREA)319,319,322

FRONT FLUX IS NEGATIVE

318 IF(AREA)320,320,316

FLUX IS NEGATIVE, BUT FROM IN FRONT

320 IF(AMX(NN))9912,316,321

FLUX IS NEGATIVE, BUT CELL MASS = 0.

321 LZ=NN
IZZ=K+1
WS=(W(NN)-W(L))/DZ(IZZ)*DT/SBOUND
WOUT=WOUT/(1.0+WS)

CALCULATE THE MASS FLUX IN FRONT

322 FMASS=AMX(LZ)/DZ(IZZ)*WOUT*DT
IF(AREA)323,700,323
323 IF(N6)324,700,324

TRANS

324 IF(FMASS)700,700,325

REFLECT WE ARE IN FRONT

325 FZMOM=-2.*FMASS*W(L)
FMASS=0.
FXMOM=0.
FYMOM=0.
FENR=0.

NOW WE HAVE ALL 3 FLUXES AND ALL
THE BOUNDARY CONDITIONS HAVE BEEN SET

700 IF(AMPY)760,980,761

TOP FLUX IS -

760 IF(AMPY+AMX(N))762,980,980
762 AMPY=-AMX(N)
GO TO 980
761 IF(-AMPY+AMX(L))763,980,980
763 AMPY=AMX(L)
980 IF(AMMP)7300,981,7301
7300 IF(AMMP+AMX(L+1))7302,981,981
7302 AMMP=-AMX(L+1)
GO TO 981
7301 IF(-AMMP+AMX(L))7303,981,981
7303 AMMP=AMX(L)
981 IF(FMASS)7400,982,7401
7400 IF(FMASS+AMX(NN))7402,982,982
7402 FMASS=-AMX(NN)
GO TO 982
7401 IF(-FMASS+AMX(L))7403,982,982
7403 FMASS=AMX(L)
982 WS=6AMC(J)
IF(WS) 902, 901, 901
901 WS=0.
902 WSA=AMMY
   IF(WSA) 904, 903, 903
903 WSA=0.
904 WSB=BMASS(M)
   IF(WSB) 906, 905, 905
905 WSB=0.
906 WSC=AMX(L)+WS+WSA+WSB
907 WS=AMPY
   IF(WS) 950, 950, 909
950 WS1=0.
   IF(K-K1) 951, 953, 951
951 IF(GAMC(J+1)) 952, 953, 953
952 WS1=GAMC(J+1)
953 WS2=0.
   NA=M+IMAX
   IF(K-K1) 955, 957, 955
955 IF(BMASS(NA)) 956, 957, 957
956 WSB=BMASS(NA)
957 WSC=WS1+WS2+AMX(N)
958 IF(AMMP+WS3) 959, 908, 908
959 AMMP=-WS3
   GO TO 908
908 WS=0.
909 WSA=AMMP
   IF(WSA) 970, 970, 911
970 WS1=0.
   IF(K-K1) 971, 973, 971
971 IF(BMASS(M+1)) 972, 973, 973
972 WS1=BMASS(M+1)
973 WS3=WS1+AMX(L+1)
974 IF(AMMP+WS3) 975, 910, 910
975 AMMP=-WS3
   GO TO 910
910 WSB=FMSS
   IF(WSB) 912, 912, 913
912 WSB=0.
913 WST=WS+WSA+WSB
   IF(WST) 921, 921, 931
931 IF(WSC) 932, 932, 933
932 IF(AMPY) 934, 934, 935
935 AMPY=0.
934 IF(AMMP) 936, 936, 937
937 AMMP=0.
936 IF(FMASS) 921, 921, 938
938 FMSS=0.
   GO TO 921
921 IF(WSC-WST) 914, 921, 921
914 WSD=WSC/WST
   WS=WST+WSD
   WSA=WSA+WSD
   WSB=WSB+WSD
915 IF(WS) 917, 917, 916
916 AMPY=WS
917 IF(WSA) 919, 919, 918
918 AMMP=USA
919 IF(WSB)921,920
920 FMASS=WSB
921 CONTINUE
   IF(AMPY)703,2700,02
2700 IF(J-JMAX)717,2701,2701
2701 IF(N3)716,717,716
717 AMUT=0.
   AMVT=0.
   AMWT=0.
   DELET=0.
   GO TO 716
C  TOP FLUX IS +
702 IF(JMAX-J)9913,704,705
C  CHECK CELL ABOVE
705 IF(AMX(N))9914,706,704
C  FREE SURFACE AT TOP
706 IF(AMPY/(DX(I)*DY(J)*DZ(K))-TOZONE)707,704,704
C  DENSITY IS TOO SMALL, SET FLUX =0.
707 AMPY=0.
   GO TO 717
C  TOP FLUX IS NEGATIVE
703 IF(J-1)9913,701,709
709 IF(AMX(L))9914,710,701
710 IF(-AMPY/(DX(I)*DY(J)*DZ(K))-Z(79))711,701,711
711 AMPY=0.
   GO TO 717
C  ADD UP THE MASSES (REMEMBER THEY HAVE DIRECTION)
704 DELM=GAMC(J)+AMMY+BMASS(M)-AMPY
   IF(VEL)9914,712,720
C  AT TOP OF GRID
720 IF(N3)713,714,713
C  TOP BOUNDARY IS TRANSMITTIVE
714 JS= U(L)**2+V(L)**2+W(L)**2
   ETH=ETH-AMPY*(AIX(L)+WS/2.)
   IF(AMPY/(DX(I)*DY(J)*DZ(K))-Z(79))712,712,6630
6630 REZ=1.
C  CALCULATE THE MOMENTUMS
712 AMUT=AMPY*U(L)
   AMVT=AMPY*V(L)
   AMWT=AMPY*W(L)
   GO TO 713
701 AMUT=AMPY*U(N)
   AMVT=AMPY*V(N)
   AMWT=AMPY*W(N)
   DELET=AIX(N)+(U(N)**2+V(N)**2+W(N)**2)/2.
716 DELM=GAMC(J)+AMMY+BMASS(M)-AMPY
   GO TO 715
DELET = AIX(L) + (U(L)**2 + V(L)**2 + W(L)**2)/2.
SIGHU = SIGFLET(J) + AMHU + AMUT + BMOM(M)
SIGHV = YAMC(J) + AMMV + AMVT + BMOM(M)
SIGGW = ZMOM(U) + AMNW + AMNT + BMOM(M)
GO TO 7000

NOW DO THE SAME FOR THE X DIRECTION
MASS FLUX AT THE RIGHT

7000 IF(AMMP) 7003, 2702, 7002
2702 IF(I = IMAX) 7017, 2703, 2703
2703 IF(N2) 7016, 7017, 7016

IF(FLUX IS POSITIVE
7002 IF(IMMAX = I) 9914, 7004, 7005
7017 AMUR = 0.
AMVR = 0.
AMWR = 0.
DELER = 0.
GO TO 7100

CHECK CELL TO THE RIGHT
7005 IF(AMX(L + 1)) 9915, 7006, 7007
7007 IF(AMMP/(DX(I) * DY(J) * DZ(K)) - TOZONE) 7008, 7009
7009 REM = U(L)**2 + V(L)**2 + W(L)**2
ETH = ETH - AMMP*(AIX(L) + WS**2.)
IF(AMMP/(DX(I) * DY(J) * DZ(K)) - Z(77)) 7011, 7001
7010 FLUX IS TOO SMALL, SET FLUX TO 0.
AMMP = 0.
GO TO 7017

RIGHT FLUX IS NEGATIVE
7003 IF(I = I + 1) 9914, 7001, 7009
7009 IF(AMX(L)) 9915, 7010, 7001
7010 IF(-AMMP/(DX(I) * DY(J) * DZ(K)) - TOZONE) 7011, 7001
7011 AMMP = 0.
GO TO 7017

LEFT FLUX IS TOO SMALL
7012 AMUR = AMMP * U(L)
AMVR = AMMP * V(L)
AMWR = AMMP * W(L)
DELER = AIX(L) + (U(L)**2 + V(L)**2 + W(L)**2)/2.
GO TO 7105
7001 AMUR=AMMP*U(L+1)
    AMVR=AMMP*V(L+1)
    AMWR=AMMP*W(L+1)
    DELER=AIX(L+1)+(U(L+1)**2+V(L+1)**2+W(L+1)**2)/2.
7016 DELM=DELM-AMMP

SUM UP TOTAL MOMENTA
7150 SIGMU=SIGMU-AMUR
    SIGMV=SIGMV-AMVR
    SIGMW=SIGMW-AMWR
    DELEK=DELEK-AMMP*DELER

DO THE SAME FOR THE FLUX IN FRONT

7100 IF(FMASS)7103,.2704,.9982
    2704 IF(K=KMAX)7117,.2705,.2705
    2705 IF(N6)4000,.7117,.4000

FLUX IS POSITIVE
9962 IF(KMAX-K)9916,.7104,.7105
7105 IF(AMX(L))9917,.7106,.7104

FREE SURFACE IN FRONT
7106 IF(FMASS/(DX(I)*DY(J)*DZ(K))-TOZONE)7107,.7104,.7104

DENSITY IS TOO SMALL, SET MASS =0.
7107 FMASS=0.
7117 FXMOM=0.
    FYMOM=0.
    FZMOM=0.
    FENR=0.
    GO TO 4000

FRONT FLUX IS -
7103 IF(K-1)9916,.7101,.7109
7109 IF(AMX(L))9917,.7110,.7101
7110 IF(-FMASS/(DX(I)*DY(J)*DZ(K))-TOZONE)7111,.7101,.7101

FLUX IS TOO SMALL
7111 FMASS=0.
    GO TO 7117
7104 DELM=DELM-FMASS+AMX(L)
    IF(AREA)9916,.7112,.7120
7120 IF(N6)8000,.7114,.8000

FRONT BOUNDARY IS TRANSMITIVE
7114 WS=U(L)**2+V(L)**2+W(L)**2
    ETH=ETH-FMASS*(AIX(L)+WS/2.)
    IF(FMASS/(DX(I)*DY(J)*DZ(K))-Z(76))7112,.7112,.6650
6650 REZ=1.
7112 FXMOM=FMASS*U(L)
    FYMOM=FMASS*V(L)
    FZMOM=FMASS*W(L)
    FENR=AIX(L)+(U(L)**2+V(L)**2+W(L)**2)/2.
    GO TO 8000
7101 FXMOM=FMASS*U(NN)
FYMOM=FMMASS*V(NN)
FZMOM=FMMASS*W(NN)
FENR=AMX(L) + (U(L)**2 + V(L)**2 + W(L)**2)/2.
DELM=DELM-FMMASS*AMX(L)
SIGMU=SIGMV-FYMOM
SIGMV=SIGMU-FZMOM
DELEK=DELEK-DELM-FMMASS*FENR

TOTAL MASS AT CYCLE N+1

IF(DELM)544,545,540
544 IF(AMX(L)*1.0E-6+DELM)9918,545,545
545 DELM=0.
GO TO 550
540 WS=U(L)**2+V(L)**2+W(L)**2
WS=WS/2.
ENK=AMX(L)*(AIX(L)+WS)+DELEK
GO TO 541

HERE WE CALCULATE THE 3 NEW CELL (L) VELOCITIES BY CONSERVING MOMENTUM. WE ALSO CONSERVE THE TOTAL ENERGY; THE TOTAL ENERGY LESS THE KINETIC IS THAN THE NEW SPECIFIC INTERNAL ENERGY.

NEW X VEL COMPONENT
541 U(L)=(SIGMU+AMX(L)*U(L))/DELM

NEW Y VEL COMPONENT
546 V(L)=(SIGMV+AMX(L)*V(L))/DELM

NEW Z VEL COMPONENT
547 W(L)=(SIGMW+AMX(L)*W(L))/DELM
548 WS=U(L)**2+V(L)**2+W(L)**2

NEW SPECIFIC INTERNAL ENERGY
549 AIX(L)=ENK/DELM-WS/2.
IF(AIX(L)-TMASS)7500,7500,7510
7500 SUM=SUM+AIX(L)*DELM
AIX(L)=0.
7510 IF(ABS(U(L))=XMAX)7501,7501,7502
7501 WS=U(L)**2
SUM=SUM+DELM*WS/2.
U(L)=0.
7502 IF(ABS(V(L))=XMAX)7503,7503,7504
7503 WS=V(L)**2
SUM=SUM+DELM*WS/2.
V(L)=0.
7504 IF(ABS(W(L))=XMAX)7505,7505,7506
7505 WS=W(L)**2
SUM=SUM+DELM*WS/2.
W(L)=0.
7506 IF(AIX(L))4001,550,550
4001 SUM=SUM+AIX(L)*DELM
AIX(L)=0.
550 AMX(L)=DELM
5800 IF(I=12)5999,5801,5801
5801 IF(IX2)5999,5802,5999
5802 IF(ABS(U(L))+ABS(V(L))+ABS(W(L))+AIX(L))5803,5999,5803
5803 IX2=1
GO TO 5999
5999 IF(K-K2)4999,5804,5804
5804 IF(K22)4999,5805,4999
5805 IF(ABS(U(L))+ABS(V(L))+ABS(W(L))+AIX(L))5806,4999,5806
5806 K22=1
GO TO 4999
4999 IF(KZ1)5300,5222,5300
5222 IF(K1-1)5300,5300,5000
5000 IF(K1-K)5300,5001,5001
5001 IF(ABS(U(L))+ABS(V(L))+ABS(W(L))+AIX(L))5002,5300,5002
5002 KZ1=1
5300 IF(JY1)5600,5304,5600
5304 IF(J1-1)5600,5600,5301
5301 IF(J1-J)5600,5302,5302
5302 IF(ABS(U(L))+ABS(V(L))+ABS(W(L))+AIX(L))5303,5600,5303
5303 JY1=1
5600 IF(I1)3342,5604,3342
5604 IF(I1-1)3342,3342,5601
5601 IF(I1-1)3342,5602,5602
5602 IF(ABS(U(L))+ABS(V(L))+ABS(W(L))+AIX(L))5603,3342,5603
5603 IX1=1
3342 CONTINUE
551 IF(AMX(L))9919,553,9980
9980 IF(AMX(L)/(DX(I)*DY(J)*DZ(K))-TOZONE)9981,552,552
9981 AMLOST=AMLOST+AMX(L)
WS=U(L)**2+V(L)**2+W(L)**2
WSR=AMX(L)*(AIX(L)+WS/2.)
SUM=SUM+WSR
ELOST=ELOST+WSR
XMLOST=XMLOST+AMX(L)*U(L)
YMLOST=YMLOST+AMX(L)*V(L)
ZMLOST=ZMLOST+AMX(L)*W(L)
AIX(L)=0.
553 AIX(L)=0.
U(L)=0.
V(L)=0.
W(L)=0.
P(L)=0.
HERE THE FLUX DATA FROM THE RIGHT IS SET TO THE LEFT
552 GAMC(J)=AMMP
FLEFT(J)=AMUR
YAMC(J)=AMVR
ZAMO(J)=AMWR
SIGC(J)=OELER
HERE THE FLUX DATA FROM THE TOP IS SET TO THE BOTTOM
554 AMMY=AMPY
AMMU=AMUT
AMMV=AMVT
AMMW=AMWT
DELEB=DELET
HERE THE FLUX DATA FROM IN FRONT IS SET TO THE BACK

BMSTM = FMASS
BYMOM = FYMOM
BXMOM = FXMOM
BZMOM = FZMOM
BENR = FENR

CONTINUE
L = L + IMAX

$\sum$ END OF J LOOP $\sum$ END OF I LOOP $\sum$ END OF K LOOP

LJ = L - IMAX

IF(JY2) $\sum$

JY2 = 1

CONTINUE

C $\sum$ END OF K LOOP

ETH = ETH - SUM
ENEG = ENEG - SUM

I1 = I1 - IX1

IF(I1) $\sum$

I1 = 1

I2 = I2 + IX2

IF(I2 - IMAX) $\sum$

I2 = IMAX

J1 = J1 - JY1

J1 = 1

J2 = J2 + JY2

IF(J2 - JMAX) $\sum$

J2 = JMAX

K1 = K1 - KZ1

K1 = 1

K2 = K2 + KZ2

IF(K2 - KMAX) $\sum$

K2 = KMAX

IF(REZ) $\sum$

CALL REZONE

RETURN

GO TO 9999

NK = 600

GO TO 9999

NK = 601

GO TO 9999

NK = 9

GO TO 9999

NK = 15

GO TO 9999

NK = 506

GO TO 9999

NK = 23

GO TO 9999

NK = 1103
9911 NK=106
GO TO 9999
9912 NK=317
GO TO 9999
9913 NK=702
GO TO 9999
9914 NK=705
GO TO 9999
9915 NK=7005
GO TO 9999
9916 NK=9982
GO TO 9999
9917 NK=7105
GO TO 9999
9918 NK=544
GO TO 9999
9919 NK=551
9999 NR=4
WRITE(6,8500)I,J,K,L,M,N,NN,NK,NR
WRITE(6,8501)AMC(J),FLEFT(J),YMAM(J),ZMOM(J),SIGC(J)
WRITE(6,8501)AMMP,AMUR,AMVR,AMWR,DELER
WRITE(6,8501)MMY,AMMU,AMMV,AMMW,DELEB
WRITE(6,8501)AMPY,AMUT,AMVT,AMWT,DELET
WRITE(6,8501)BMM(M),BMAM(M),BMOM(M),BZMOM(M),BENR(M)
WRITE(6,8501)FMAM,FMOM,FYMOM,FZMOM,FMNR
WRITE(6,8501)AMX(L),AIX(L),U(L),V(L),W(L),P(L),F(N)
WRITE(6,8501)AMX(L+1),U(L+1),V(L+1),W(L+1)
WRITE(6,8501)AMX(NN),U(NN),V(NN),W(NN)
WRITE(6,8501)AMX(L-1),U(L-1),V(L-1),W(L-1)
WRITE(6,8501)AMX(N),U(N),V(N),W(N)
LL=L-IMAX
LBJ=L-IJMAX
WRITE(6,8501)AMX(LL),U(LL),V(LL),W(LL)
WRITE(6,8501)AMX(LBJ),U(LBJ),V(LBJ),W(LBJ)
8501 FORMAT(1P8E12.5)
8500 FORMAT(9I6)
CALL UNCLE
CALL DUMP
END
SUBROUTINE REZONE
C CHANGE ALL CELL DIMENSIONS BY A FACTOR OF 2.
C NOTE: 8 CELLS BECOME ONE IN THE NEW GRID
C CALCULATE NEW INDICES
KKMAX=KMAX/2
IJMAX=IMAX/2
JJMAX=JMAX/2
C SET UP DO LOOP FOR NEW STORAGE
KN1=-IXMAX
DO 21 KKK=1,KMAX/2
LL=(KKK-1)*IXMAX
KN1=KN1+IXMAX
KN=KN1
DO 21 II=1,IMAX/2
I=LL+II
KN=KN+1
63
KK=Kn
DO 21 J=1,JMAX,2
K=I+1XMAX
J=I+1XMAX
L=K+1XMAX
WSA=AMX(I)+AMX(I+1)+AMX(J)+AMX(J+1)+
1AMX(K)+AMX(K+1)+AMX(L)+AMX(L+1)
IF(WSA)<.63 C

C CALCULATE TWICE THE KINETIC ENERGY
3 WSB=AMX(I)*(U(I)**2+V(I)**2+W(I)**2)+
1AMX(I+1)*(U(I+1)**2+V(I+1)**2+W(I+1)**2)+
2AMX(J)*(U(J)**2+V(J)**2+W(J)**2)+AMX(J+1)*(U(J+1)**2+
3+V(J+1)**2+W(J+1)**2)
WSB=WSB+AMX(K)*(U(K)**2+V(K)**2+W(K)**2)+AMX(K+1)*
1(U(K+1)**2+V(K+1)**2+W(K+1)**2)+AMX(L)*(U(L)**2+V(L)**2+
2+W(L)**2)+AMX(L+1)*(U(L+1)**2+V(L+1)**2+W(L+1)**2)
C

C CALCULATE THE NEW VELOCITIES
U(KK)=(AMX(I)^U(I)+AMX(I+1)^U(I+1)+AMX(J)^U(J)+AMX(J+1)^U(J+1)+
1AMX(K)^U(K)+AMX(K+1)^U(K+1)+AMX(L)^U(L)+AMX(L+1)^U(L+1))/WSA
V(KK)=(AMX(I)^V(I)+AMX(I+1)^V(I+1)+AMX(J)^V(J)+AMX(J+1)^V(J+1)+
1AMX(K)^V(K)+AMX(K+1)^V(K+1)+AMX(L)^V(L)+AMX(L+1)^V(L+1))/WSA
W(KK)=(AMX(I)^W(I)+AMX(I+1)^W(I+1)+AMX(J)^W(J)+AMX(J+1)^W(J+1)+
1AMX(K)^W(K)+AMX(K+1)^W(K+1)+AMX(L)^W(L)+AMX(L+1)^W(L+1))/WSA
C

C CALCULATE THE TOTAL INTERNAL ENERGY
WSC=AMX(I)*AIX(I)+AMX(I+1)*AIX(I+1)+AMX(J)*AIX(J)+
1AMX(J+1)*AIX(J+1)+AMX(L)*AIX(L)+AMX(L+1)*AIX(L+1)+AMX(K)*
2AIX(K)^AMX(K+1)*AIX(K+1)
P(KK)=0.
C

C SET THE NEW MASSES
AMX(KK)=WSA
C

C CALCULATE THE NEW KINETIC ENERGY (ACTUALLY TWICE)
WS=U(KK)**2+V(KK)**2+W(KK)**2
E=WSC+WSB/2.
C

C THE NEW SPECIFIC INTERNAL ENERGY IS THE TOTAL LESS THE KINETIC
AIX(KK)=E/WSA-.5*WS
AMX(J)=0.
AMX(J+1)=0.
AMX(K)=0.
AMX(K+1)=0.
AMX(L)=0.
AMX(L+1)=0.
AMX(1+1)=0.
U(J)=0.
U(J+1)=0.
U(K)=0.
U(K+1)=0.
U(L)=0.
U(L+1)=0.
U(1+1)=0.
V(J)=0.
V(J+1)=0.
V(K)=0.
V(K+1)=0.
V(L)=0.
V(L+1)=0.
V(I+1)=0.
W(J)=0.
W(J+1)=0.
W(K)=0.
W(K+1)=0.
W(L)=0.
W(L+1)=0.
W(I+1)=0.
AIX(I+1)=0.
AIX(J)=0.
AIX(J+1)=0.
AIX(K)=0.
AIX(K+1)=0.
AIX(L)=0.
AIX(L+1)=0.

IF(II-1)380,380,390
380 IF(JJ-1)381,381,390
381 IF(KK-1)7,7,390
390 AMX(I)=0.
U(I)=0.
V(I)=0.
W(I)=0.
P(I)=0.
AIX(I)=0.
GO TO 7
c CAME HERE BECAUSE OF ZERO MASS
6 AMX(KK)=0.
U(KK)=0.
V(KK)=0.
W(KK)=0.
P(KK)=0.
AIX(KK)=0.
P(KK)=0.
7 KK=KK+IMAX
21 I=I+2*IMAX
c C CHANGE ALL CELL DIMENSIONS
WS=0.
DO 10 I=1,IMAX
DX(I)=2.0*DX(I)
X(I)=WS+DX(I)
WS=X(I)
10 CONTINUE
II=II+IMAX
WS=X(II)
DO 11 I=II+IMAX
DX(I)=DX(II)
X(I)=WS+DX(I)
WS=X(I)
11 CONTINUE
WS=0.
DO 13 J=1,JMAX
DY(J)=2.0*DY(J)
Y(J)=WS+DY(J)
WS=Y(J)
13 CONTINUE
JJ=JMAX+1
WS=Y(JJ)
DO 14 J=JJMAX
DY(J)=DY(JJMAX)
Y(J)=WS+DY(J)
WS=Y(J)
14 CONTINUE
WS=0.
DO 16 K=1,KKMAX
DZ(K)=2.0*DZ(K)
ZCOR(K)=WS+DZ(K)
WS=ZCOR(K)
16 CONTINUE
KK=KKMAX+1
WS=ZCOR(KKMAX)
DO 17 K=KKMAX
DZ(K)=DZ(KKMAX)
ZCOR(K)=WS+DZ(K)
WS=ZCOR(K)
17 CONTINUE
KK=KKMAX+1
DO 30 K=KKMAX
LL=(K-1)*IXMAX
DO 30 I=1,IMAX
L=LL+I
DO 30 J=1,JMAX
AMX(L)=0.
U(L)=0.
V(L)=0.
W(L)=0.
AIX(L)=0.
P(L)=0.
30 CONTINUE
LL=(K-1)*IXMAX
DO 100 I=1,IMAX
L=LL+IMAX+1-I
M=LL+IMAX+I+1-I
DO 100 J=1,JJMAX
AMX(M)=AMX(L)
U(M)=U(L)
V(M)=V(L)
W(M)=W(L)
AIX(M)=AIX(L)
P(M)=P(L)
AMX(L)=0.
U(L)=0.
V(L)=0.
W(L)=0.
AIX(L)=0.
P(L)=0.
M=M+IMAX
L=L+IMAX
100 CONTINUE
I3=I3/P
C NOW BEGIN ADDING ON MASS IN FRONT, BOTH
C SIDES AND ABOVE.
II=II+I4
JJ=I3+1
NOTE: I4=NO. OF ZONES TO THE RIGHT TO ADD.
I3= INITIAL INTERFACE BETWEEN PROJECTILE AND TARGET.

DO 200 K=1,KMAX
LL=(K-1)*IMAX
DO 200 I=I,I1
L=LL+I+I3*IMAX
DO 200 J=JJ,JMAX
AMX(L)=DX(I)*DY(J)*DZ(K)*RHONOT
200 L=L+IMAX
II=IMAX-I4
IL=IMAX-I4+1
JL=JJMAX+1
DO 300 K=1,KMAX
LL=(K-1)*IMAX
DO 300 I=IL,II
L=LL+I+JMAX*IMAX
DO 300 J=JL,JMAX
AMX(L)=DX(I)*DY(J)*DZ(K)*RHONOT
300 L=L+IMAX
II=IMAX-I4+1
JJ=J3+1
DO 400 K=1,KMAX
LL=(K-1)*IMAX
DO 400 I=II,IMAX
L=LL+I+IMAX
DO 400 J=JL,JMAX
AMX(L)=DX(I)*DY(J)*DZ(K)*RHONOT
400 L=L+IMAX
II=IMAX-I4
IL=IMAX-I4+1
JJ=J3+1
IF(JJ-JJMAX)700,700,800
700 KL=KKMAX+1
DO 500 K=KL,KMAX
LL=(K-1)*IMAX
DO 500 I=IL,II
L=LL+I+IMAX
DO 500 J=JL,JMAX
AMX(L)=DX(I)*DY(J)*DZ(K)*RHONOT
500 L=L+IMAX
800 WS=T+DTNA
C     RESET ACTIVE GRID COUNTERS
I1=I4-1
I2=IMAX-I4+2
J1=J1
J2=JJMAX+2
K1=K1
K2=KKMAX+2
NK=NC+1
WRITE(6,9000)WS,NK
9000 FORMAT(1H ///22H PROBLEM REZONED AT T=1PE12.6,6X,5HCYCLEI4///)
WRITE(6,8000)IMAX,(X(I),I=1,IMAX)
WRITE(6,8003)IMAX,(DX(I),I=1,IMAX)
WRITE(6,8001)JMAX,(Y(J),J=1,JMAX)
WRITE(6,8004)JMAX,(DY(J),J=1,JMAX)
WRITE(6,8002)KMAX,(ZCOR(K),K=1,KMAX)
WRITE(6,8005)KMAX,(DZ(K),K=1,KMAX)
SUBROUTINE ES

C *** FOR COMPLETE DETAILS, SEE GA-3216, METALLIC EQUATIONS OF STATE FOR HYPERVELOCITY IMPACT BY JAMES TILLOTSON

C IF THE MATERIAL IS COMPRESSED, USE THE CONDENSED FORM OF THE EQUATION OF STATE.

C IF THE MATERIAL IS RAREFIED AND IF THE SPECIFIC INTERNAL ENERGY IS GREATER THAN $E_{SUB S}$, USE THE RARIFIED FORM ...

C IF RAREFIED AND $E$ IS LESS THAN $E_{SUB S}$, USE THE CONDENSED FORM.

C $555$ NOTE: NO NEGATIVE(TENSION) Pressures ALLOWED

10 RHOW=AMX(L)/(DX(I)*DY(J)*DZ(K))
   ETA=RHOW/Z(33)
   VOW=1.0/ETA
11 P1=AIX(L)*RHOW*Z(34)
12 P2=AIX(L)
13 P3=Z(35)*ETA*ETA
14 P4=Z(36)/(P2/P3+1.0)*AIX(L)*RHOW
15 P5=Z(37)*(ETA-1.)
16 IF(ETA-1.0)50,100,100
50 IF(VOW-Z(38))55,55,75
55 IF(AIX(L)-Z(40))100,100,75
75 P7=Z(41)*(VOW-1.)
   IF(P7-88.0)400,4002,4003
4003 P7=88.0
4002 CONTINUE
   P8=EXP(P7)
   P9=1.0/P8
   P10=Z(42)*(VOW-1.)**2
   IF(P10-88.0)4000,4000,4001
4001 P10=88.0
4000 CONTINUE
   P11=EXP(P10)
   P12=1.0/P11
   P(L)=P1+(P4+P5+P9)*P12
   GO TO 119
400 P6=Z(44)*(ETA-1.)**2
   P(L)=P1+P4+P5+P6

END
119 IF(P(L))999,999,200
200 SGX=.5
GO TO 500
999 P(L)=u,
S GX=S+Z(43)
GO TO 500
500 RETURN
END
DI FOR EDIT/S,EDIT/S,EDIT/SS
SUBROUTINE EDIT

********** 3DOIL **********
HERE WE WILL DECIDE WHETHER TO HAVE A SHORT PRINT, LONG PRINT,
DUMP ON THE BINARY TAPE OR STOP THE PROBLEM

104 CALL SLITET(3,K000FX)
GO TO(106,108),K000FX
106 CALL SLITE (3)
GO TO 126
108 IF(CYCLE-CSTOP)110,122,122
110 IF(REZ)9901,112,124
112 IF(AMOD(CYCLE, DUMPT7))114,124,114
114 IF(AMOD(CYCLE,PRINTL))120,126,120
120 IF(AMOD(CYCLE,PRINTS))140,128,140
122 CALL SLITE (1)
124 GO TO 1
126 CALL SLITE (4)
128 GO TO 6000
130 GO TO 1000
132 CALL SLITET(4,K000FX)
GO TO(134,136),K000FX
134 GO TO 5000

CALCULATE THE ENERGY CHECK = (ETH-E)/ETH AT CYCLE N+1 -
(ETH-E)/ETH AT CYCLE M ALL DIVIDED THRU BY THE NUMBER OF CYCLE
BETWEEN ENERGY CHECKS =((CYCLE(N+1) -CYCLE M)

136 IF(ABS(ECK)-DMIN)140,140,9905
140 CALL SLITET(1,K000FX)
GO TO(142,144),K000FX
142 REWIND(N7)
CALL SLITE (1)
144 GO TO 10000
1 IF(DUMPT7)30,3,3

**** DUMP ALL THE CELL-CENTERED QUANTITIES, THE X'S AND Y'S
AND ZCOR'S AND THE ENTIRE Z BLOCK

3 BACKSPACE N7
WS=555.0
WRITE(N7)WS,CYCLE,N3
WRITE(N7)(Z(L),L=1,MZ)
WRITE(N7)(U(K),V(K),W(K),AMX(K),AIX(K),K=1,MAXA)
WRITE(N7)(X(1),I=1,MAX)
WRITE(N7)(Y(J),J=1,MAX)
WRITE(N7)(ZCOR(K),K=1,KMAX)
WS=666.0

CALCULATE THE ENERGY CHECK = (ETH-E)/ETH AT CYCLE N+1 -
(ETH-E)/ETH AT CYCLE M ALL DIVIDED THRU BY THE NUMBER OF CYCLE
BETWEEN ENERGY CHECKS = ((CYCLE(N+1) - CYCLE M)

136 IF(ABS(ECK)-DMIN)140,140,9905
140 CALL SLITET(1,K000FX)
GO TO(142,144),K000FX
142 REWIND(N7)
CALL SLITE (1)
144 GO TO 10000
1 IF(DUMPT7)30,3,3

**** DUMP ALL THE CELL-CENTERED QUANTITIES, THE X'S AND Y'S
AND ZCOR'S AND THE ENTIRE Z BLOCK

3 BACKSPACE N7
WS=555.0
WRITE(N7)WS,CYCLE,N3
WRITE(N7)(Z(L),L=1,MZ)
WRITE(N7)(U(K),V(K),W(K),AMX(K),AIX(K),K=1,MAXA)
WRITE(N7)(X(1),I=1,MAX)
WRITE(N7)(Y(J),J=1,MAX)
WRITE(N7)(ZCOR(K),K=1,KMAX)
WS=666.0
WRITE(N7)WS,WS,WS
WRITE(6,8120)NC
30 GO TO 126
6000 CONTINUE
DO 6012 I=1,18
6012 PR(I)=0.
6017 CALCULATE THE TOTAL INTERNAL AND KINETIC ENERGY AND THE TOTAL MASS.
DO 6028 K=1,KMAXA
6019 IF(AMX(K))9917,6028,6020
6020 WS=U(K)**2+V(K)**2+W(K)**2**.5
PR(5)=PR(5)+AMX(K)**2+AMX(K)
PR(6)=PR(6)+WS+AMX(K)
PR(8)=PR(8)+AMX(K)
6028 CONTINUE
PR(3)=PR(1)+PR(2)
PR(7)=PR(5)+PR(6)
XNRG=PR(7)
PR(9)=PR(1)+PR(5)
PR(10)=PR(2)+PR(6)
PR(11)=PR(3)+PR(7)
PR(12)=PR(4)+PR(8)
WSA=(ETH-PR(11))/ETH
IF(CYCLE)=9931,9931,9932
9931 NPC=1
9932 PR(18)=(WSA-DNN)/FLOAT(NPC)
ECK=PR(18)
DNN=WSA
NPC=0
SUM=0.0
C RADEB = TOTAL POSITIVE Z MOM.
C RADER = TOTAL POSITIVE X MOM.
C RADET = TOTAL POSITIVE Y MOM.
SUMB=0.
SUMR=0.
SUMT=0.
DO 810 K=1,KMAXA
802 IF(V(K))804,804,803
803 SUM=SUM+AMX(K)*V(K)
804 IF(U(K))805,805,806
805 IF(W(K))810,810,808
806 SUMR=SUMR+AMX(K)*U(K)
808 SUMB=SUMB+AMX(K)*W(K)
810 CONTINUE
RADEB=SUMB
RADER=SUMR
RADET=SUMT
WRITE(6,8116)PR,NC,NDTNA,TRAD,DTRAD,NR,N1,N2,N3,N4
WRITE(6,8117)(PR(I),I=1,8)
WRITE(6,8118)(PR(I),I=9,12)
WRITE(6,8119)RADEB,RADER,RADET,UVMAX,ETH,ECK
WRITE(6,9042)N0,N11,N9,J1,J2,K1,K2
WRITE(6,9042)AMLOST,ELOST,XMLOST,YMLOST,ZMLOST,ENE6
9042 FORMAT(1P7E14.7)
6090 GO TO 130
1000 GO TO 130
1030 WRITE(6,6116)PROB,NC,T,DTNA,TRAD,DTRAD,NR,N1,N2,N3,N4
JMAX=JMAX
WRITE(6,6307)X1,X2,XMAX,Y1,Y2,Y(JMAX)
GO TO 132
5000 WRITE(6,6116)PROB,NC,T,DTNA,TRAD,DTRAD,NR,N1,N2,N3,N4
C
NOTICE THE LIMITS OF THE DO LOOPS
DO 1126 KK=K1,K2
C
C HERE WE PREPARE FOR THE LONG PRINT
C
5004 DO 5050 I=I1,I2
CALL SLITE (4)
J=J2+1
K=J2*IMAX+1+(KK-1)*IXMAX
DO 5046 L=J1,J2
J=J-1
K=K-IMAX
5012 IF(AMX(K))9917,5046,5014
5014 CALL SLITET(4,K000FX)
GO TO 5019
5016 WRITE(6,8135)I,X(I),DX(I)
5019 WS=AMX(K)/((DX(I)*DY(J)*DZ(KK))
WSC=P(K)*1.E+4
CONTINUE
CONTINUE
CONTINUE
GO TO 136
1100 NK=II0
GO TO 9999
9905 NK=136
C
C 5018 WRITE(6,8108)J,U(K),V(K),WSC,AMX(K),WS,AIX(K),W(K),Y(J)
5046 CONTINUE
5050 CONTINUE
1126 CONTINUE
GO TO 136
9901 NK=II0
GO TO 9999
9905 NK=136
C
C
C
GO TO 9999
9917 NK=6015
9999 NR=6
WRITE(6,8002)I,J,K,IP,I2,NK, NR
8002 FORMAT(8IS)
CALL UNCLE
CALL DUMP
10000 RETURN
C
C FOMATS
8108 FORMAT(I3,1X,1PE12.5)
81160FORMAT(BH1PROBLEM6X,5HCYCLE9X,4HTIME13X,2HDT13X,4HTRAD11X,5HDTRAD1EDIT3380
12X,2HNR6X,2HN14X,2HN24X,2HN34X,2HN4/(F7.1,1I11,2X,1P4E16.7,I10,2X+4EDIT3390
216))
81170FORMAT(IH0//17X2H,II6X+2:1AK14X,5HA1AK15X,2HAM/4H DOT3X,1P4E18.7/3EDIT3410
1H X4X,4E18.7)
81180FORMAT(I12X,13H----------5X,13H----------5X,13H----------5EDIT3430
1X,13H----------/7H TOTALS1P4E18.7)
81190FORMAT(2H0//16X,5HRADE613X,5HRADE13X,5HRADE12X,7HMAX VEL13X,3H TEDIT3450
1H12X,9HREL ERROR/7X,1P6E18.7//)
8120 FORMAT(1H0//21H TAPE 7 DUMP ON CYCLE15///)
81350FORMAT(IH //4H I =I3,6X,6IX(I) =F12.3,6X,7H0X(I) =F12.3//3H J8X,EDIT3520
11HX10X,1HY10X,3H0X,3HAMX9X,3HR08X,3HAIX9X,4H W 8X,2H Y/)
8307 FORMAT(5H XI =1PE12.5,3X,4HX2 =E12.5,3X,6HMAX =E12.5,6X,4HY1 =E12
1.5,3X,4HY2 =E12.5,3X,6HMAX =E12.5)
9040 FORMAT(1H / 916)
9041 FORMAT(1H //4H K =I3,6X,9HZC0R(K) =F12.3,6X,7H0Z(K) =F12.3)
5. **INPUT AND DEFINITIONS OF THE VARIABLES**

5.1 **Normal Input for the TRIOIL Code**

An asterisk (*) implies that the data on the card is to be converted to fixed point data (requires a 2 punch in Column 1). All data loaded via the card routine is read by a floating point format. A double asterisk (**) signifies that this is the last data card in this set, and requires a one in Column 1.

### First Set

The number of BCD (header cards) that will be read in (Columns 1-3, format I3).

N BCD cards, alphanumeric and or numeric in Columns 2-72.

<table>
<thead>
<tr>
<th>Location</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*103</td>
<td>N7</td>
<td>Binary tape number (data tape)</td>
</tr>
<tr>
<td>**36271</td>
<td>PK(1)</td>
<td>Problem number</td>
</tr>
<tr>
<td>36272</td>
<td>PK(2)</td>
<td>The cycle number to start the calculation</td>
</tr>
<tr>
<td>36273</td>
<td>PK(3)</td>
<td>If &lt; 0, code assumes that this is a re-start or that the CLAM code has generated the initial data. (NOTE: At this time of writing the report, a three-dimensional version of the CLAM code is not available.) If PK(3) ≤, the code will call subroutine set-up.</td>
</tr>
</tbody>
</table>

### Second Set

<table>
<thead>
<tr>
<th>Location</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PROB</td>
<td>Problem number, identical to the value in PK(1)</td>
</tr>
<tr>
<td>3</td>
<td>DT</td>
<td>The time step $\Delta t^n$ in shakes. (NOTE: 1 shake = $10^{-8}$ seconds)</td>
</tr>
<tr>
<td>4</td>
<td>PRINTS</td>
<td>Short print frequency in cycles</td>
</tr>
<tr>
<td>5</td>
<td>PRINTL</td>
<td>Long print frequency in cycles</td>
</tr>
<tr>
<td>6</td>
<td>DUMPT7</td>
<td>Binary tape dump frequency in cycles</td>
</tr>
<tr>
<td>Location</td>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>7</td>
<td>GSTOP</td>
<td>Cycle at which the problem will stop</td>
</tr>
<tr>
<td>13</td>
<td>FFA</td>
<td>Upper limit for stability and to calculate Δt if CABLN = 0.</td>
</tr>
<tr>
<td>14</td>
<td>FFB</td>
<td>Lower limit for stability and to calculate Δt if CABLN = 0.</td>
</tr>
<tr>
<td>20</td>
<td>DMIN</td>
<td>If ECK(Z(24)) &gt; DMIN, problem will stop because of poor energy conservation</td>
</tr>
<tr>
<td>23</td>
<td>TOZONE</td>
<td>( \sim 10^{-4} \rho_0 ) = minimum density for mass transport at a free surface within the grid</td>
</tr>
<tr>
<td>25</td>
<td>SBOUND</td>
<td>= 1.0, fraction of Δ in. the weighted velocity term in the calculation of the mass flux</td>
</tr>
<tr>
<td>26</td>
<td>CABLN</td>
<td>If (&lt; 0), the code will control Δt at PCSTAB (an input number) of stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If (= 0), the code will control Δt, decreasing Δt if</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If (&gt; 0), the Δt that is loaded at (t = 0), will remain constant, regardless of any stability considerations</td>
</tr>
<tr>
<td>29</td>
<td>WSGD</td>
<td>= GAMMA for the dot material</td>
</tr>
<tr>
<td>30</td>
<td>WSGX</td>
<td>= GAMMA for the x material</td>
</tr>
<tr>
<td>45</td>
<td>DTCHK</td>
<td>( \sim 10^{-4} \rho_0 ), any cell that has a density less than this value, will be bypassed for stability checks</td>
</tr>
<tr>
<td>46</td>
<td>PCSTAB</td>
<td>( \sim .25 ), fraction of stability as determined by the Courant condition or particle velocity</td>
</tr>
<tr>
<td>58</td>
<td>Z(58)</td>
<td>Initial x velocity component of the projectile in cm/shake</td>
</tr>
<tr>
<td>59</td>
<td>Z(59)</td>
<td>Initial z velocity component of the projectile in cm/shake</td>
</tr>
<tr>
<td>66</td>
<td>RHONOT</td>
<td>Initial density ((\rho_0)) of all material (since this is a one-material code)</td>
</tr>
<tr>
<td>67</td>
<td>VELOC</td>
<td>Initial y velocity component of the projectile in cm/shake</td>
</tr>
<tr>
<td>68</td>
<td>BUG</td>
<td>( \sim .05 ), epsilon for determining whether special features will be used to empty the bottom cells in the projectile</td>
</tr>
</tbody>
</table>

**NOTE:** These 2 options require that you load Δt (location 3) at time \(t = 0\).
<table>
<thead>
<tr>
<th>Location</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>Z(69)</td>
<td>= percent of (PCSTAB) at time ( t = 0 ), used for problems in which most of the energy at ( t = 0 ) is in the form of internal energy</td>
</tr>
<tr>
<td>70</td>
<td>Z(70)</td>
<td>Factor to increase Z(69) every cycle up until Z(69) is equal to 1.0</td>
</tr>
<tr>
<td>*86</td>
<td>iMAX</td>
<td>Maximum number of zones in the x direction</td>
</tr>
<tr>
<td>*87</td>
<td>jMAX</td>
<td>Maximum number of zones in the y direction</td>
</tr>
<tr>
<td>*88</td>
<td>kMAX</td>
<td>Maximum number of zones in the z direction</td>
</tr>
<tr>
<td>75</td>
<td>Z(75)</td>
<td>Density of material leaving the left boundary of grid in order to trigger rezone</td>
</tr>
<tr>
<td>76</td>
<td>Z(76)</td>
<td>Similar term for the front boundary of grid</td>
</tr>
<tr>
<td>77</td>
<td>Z(77)</td>
<td>Similar term for the right boundary of grid</td>
</tr>
<tr>
<td>78</td>
<td>Z(78)</td>
<td>Similar term for the back boundary of grid</td>
</tr>
<tr>
<td>79</td>
<td>Z(79)</td>
<td>Similar term for the top boundary of grid</td>
</tr>
<tr>
<td>80</td>
<td>Z(80)</td>
<td>Similar term for the bottom boundary of grid</td>
</tr>
<tr>
<td>*95</td>
<td>13</td>
<td>The original ( (j) ) value of projectile-target interface</td>
</tr>
<tr>
<td>*96</td>
<td>14</td>
<td>The number of zones to add on to the right side of grid after rezone. ( 14 + ) the number to add on the left is ( = iMAX/2 )</td>
</tr>
<tr>
<td>*97</td>
<td>N1</td>
<td>If = 0, the left side of grid is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>*98</td>
<td>N2</td>
<td>Similar term for the right side of grid</td>
</tr>
<tr>
<td>*99</td>
<td>N3</td>
<td>Similar term for the top side of grid</td>
</tr>
<tr>
<td>*100</td>
<td>N4</td>
<td>Similar term for the bottom side of grid</td>
</tr>
<tr>
<td>*101</td>
<td>N5</td>
<td>Similar term for the back side of grid</td>
</tr>
<tr>
<td>*102</td>
<td>N6</td>
<td>Similar term for the front side of grid</td>
</tr>
<tr>
<td>*103</td>
<td>N7</td>
<td>Binary tape number</td>
</tr>
<tr>
<td>36251</td>
<td>Dx</td>
<td>( = \Delta x ) to be used for all ( (i) )</td>
</tr>
<tr>
<td>36181</td>
<td>Dy</td>
<td>( = \Delta y ) to be used for all ( (j) )</td>
</tr>
<tr>
<td>36211</td>
<td>Dz</td>
<td>( = \Delta z ) to be used for all ( (k) )</td>
</tr>
<tr>
<td>50</td>
<td>S1</td>
<td>= interface ( (j) ) value + 1, between the projectile and the target</td>
</tr>
<tr>
<td>51</td>
<td>S2</td>
<td>= back ( (k) ) boundary + 1 of the projectile</td>
</tr>
<tr>
<td>52</td>
<td>S3</td>
<td>= front ( (k) ) boundary of the projectile</td>
</tr>
<tr>
<td>53</td>
<td>S4</td>
<td>= the left ( (i) ) boundary + 1, of the projectile</td>
</tr>
<tr>
<td>Location</td>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>54</td>
<td>S5</td>
<td>the right (i) boundary of the projectile</td>
</tr>
<tr>
<td>55</td>
<td>S6</td>
<td>the bottom (j) boundary + 1, of the projectile</td>
</tr>
<tr>
<td>56</td>
<td>S7</td>
<td>the top boundary of the projectile (j)</td>
</tr>
<tr>
<td>*93</td>
<td>i1</td>
<td>minimum and maximum values of the active grid in the x direction</td>
</tr>
<tr>
<td>*94</td>
<td>i2</td>
<td>minimum and maximum values of the active grid in the z direction</td>
</tr>
<tr>
<td>*108</td>
<td>k1</td>
<td>minimum and maximum values of the active grid in the y direction</td>
</tr>
<tr>
<td>*109</td>
<td>k2</td>
<td></td>
</tr>
<tr>
<td>*110</td>
<td>j1</td>
<td></td>
</tr>
<tr>
<td>*111</td>
<td>j2</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Z(47)</td>
<td>c = c_0 + A_1 (P)^{A_2}</td>
</tr>
<tr>
<td>48</td>
<td>Z(48)</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Z(49)</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Z(33)</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Z(34)</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Z(35)</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Z(36)</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Z(37)</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Z(38)</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Z(39)</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Z(40)</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Z(41)</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Z(42)</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Z(43)</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Z(44)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>xMAX</td>
<td>epsilonics on the velocity, if</td>
</tr>
<tr>
<td>15</td>
<td>TMASS</td>
<td>epsilonics on the specific internal energy. If l &lt; ε, it is set to 0. and the books are kept</td>
</tr>
<tr>
<td>**22</td>
<td>REZFCT</td>
<td>No meaning in this code</td>
</tr>
</tbody>
</table>

Last Set

<table>
<thead>
<tr>
<th>Location</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>**22</td>
<td>REZFCT</td>
<td>No meaning</td>
</tr>
</tbody>
</table>
5.2 List of Common for Trioil

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Location</th>
<th>No. of Words</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIX</td>
<td>151</td>
<td>6000</td>
<td>jerks/g</td>
<td>Specific internal energy for cell (L)</td>
</tr>
<tr>
<td>AMX</td>
<td>6151</td>
<td>6000</td>
<td>g</td>
<td>Mass in cell (L)</td>
</tr>
<tr>
<td>U</td>
<td>12151</td>
<td>6000</td>
<td>cm/shake</td>
<td>X component of velocity in cell (L)</td>
</tr>
<tr>
<td>V</td>
<td>18151</td>
<td>6000</td>
<td>cm/shake</td>
<td>Y component of velocity in cell (L)</td>
</tr>
<tr>
<td>W</td>
<td>24151</td>
<td>6000</td>
<td>cm/shake</td>
<td>Z component of velocity in cell (L)</td>
</tr>
<tr>
<td>P</td>
<td>30151</td>
<td>6000</td>
<td>jerks/cm³</td>
<td>Material pressure in cell (L)</td>
</tr>
<tr>
<td>DX</td>
<td>36151</td>
<td>30</td>
<td>cm</td>
<td>DX(i) = X(i) - X(i-1)</td>
</tr>
<tr>
<td>DY</td>
<td>36181</td>
<td>30</td>
<td>cm</td>
<td>DY(j) = Y(j) - Y(j-1)</td>
</tr>
<tr>
<td>EZ</td>
<td>36211</td>
<td>30</td>
<td>cm</td>
<td>DZ(k) = ZCOR(k) - ZCOR(k-1)</td>
</tr>
<tr>
<td>UL</td>
<td>36241</td>
<td>30</td>
<td>cm/shake</td>
<td>Velocity at the left of cell in PH1</td>
</tr>
<tr>
<td>FLEFT</td>
<td>36241</td>
<td>30</td>
<td>g cm/shake</td>
<td>X momenta of mass crossing left side of cell (PH2)</td>
</tr>
<tr>
<td>FL</td>
<td>36271</td>
<td>30</td>
<td>jerks/cm³</td>
<td>Temporary pressure array at the left interface in PH1</td>
</tr>
<tr>
<td>FK</td>
<td>36271</td>
<td>30</td>
<td>none</td>
<td>Not used (except input)</td>
</tr>
<tr>
<td>YAMC</td>
<td>36271</td>
<td>30</td>
<td>g cm/shake</td>
<td>Y momenta of mass crossing left side of cell PH2</td>
</tr>
<tr>
<td>X</td>
<td>36301</td>
<td>30</td>
<td>cm</td>
<td>X(i) = right dimension of cell (L)</td>
</tr>
<tr>
<td>Y</td>
<td>36331</td>
<td>30</td>
<td>cm</td>
<td>Y(j) = top dimension of cell (L)</td>
</tr>
<tr>
<td>ZCOR</td>
<td>36361</td>
<td>30</td>
<td>cm</td>
<td>ZCOR(k) = Z or front dimension of cell (L)</td>
</tr>
<tr>
<td>PR</td>
<td>36391</td>
<td>50</td>
<td>many</td>
<td>Used for editing in the EDIT routine</td>
</tr>
<tr>
<td>SIGC</td>
<td>36441</td>
<td>30</td>
<td>jerks/g</td>
<td>= specific energy of the mass crossing left side of cell (PH2)</td>
</tr>
<tr>
<td>GAVC</td>
<td>36471</td>
<td>30</td>
<td>g</td>
<td>Mass crossing left side of cell in (PH2)</td>
</tr>
<tr>
<td>Symbol</td>
<td>Location</td>
<td>No. of Words</td>
<td>Units</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>--------------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>ZMOM</td>
<td>36501</td>
<td>30</td>
<td>g cm/shake</td>
<td>Z momenta of mass crossing left side of cell (PH2)</td>
</tr>
<tr>
<td>BXOM</td>
<td>36531</td>
<td>30</td>
<td>g cm/shake</td>
<td>X momenta of mass crossing back side of cell (PH2)</td>
</tr>
<tr>
<td>UBIND</td>
<td>36531</td>
<td>30</td>
<td>cm/shake</td>
<td>Velocity at back interface of cell in PH1</td>
</tr>
<tr>
<td>PBIND</td>
<td>36531</td>
<td>30</td>
<td>g</td>
<td>Mass crossing back interface of cell in PH2</td>
</tr>
<tr>
<td>BMASW</td>
<td>36531</td>
<td>30</td>
<td>g cm/shake</td>
<td>Mass momenta of mass crossing back surface in PH2</td>
</tr>
<tr>
<td>BZMOM</td>
<td>36531</td>
<td>30</td>
<td>g cm/shake</td>
<td>Z momenta of mass crossing back surface in PH2</td>
</tr>
<tr>
<td>ZOM</td>
<td>36531</td>
<td>30</td>
<td>g</td>
<td>Specific energy of mass crossing the back surface in PH2</td>
</tr>
<tr>
<td>AREA</td>
<td>40031</td>
<td>30</td>
<td>g cm/shake</td>
<td>Pressure array at back interface of cell in (PH1)</td>
</tr>
<tr>
<td>BOUNC</td>
<td>40032</td>
<td>30</td>
<td>cm/shake</td>
<td>Pressure at the top of cell (L) in PHI</td>
</tr>
<tr>
<td>PABOE</td>
<td>40033</td>
<td>30</td>
<td>cm/shake</td>
<td>Pressure at the bottom of cell (L) in PHI</td>
</tr>
<tr>
<td>PHLO</td>
<td>40034</td>
<td>30</td>
<td>cm/shake</td>
<td>Pressure at the right of cell (L) in PHI</td>
</tr>
<tr>
<td>PIDTS</td>
<td>40035</td>
<td>30</td>
<td>cm/shake</td>
<td>Pressure at the top of cell (L) in PHI</td>
</tr>
<tr>
<td>PRR</td>
<td>40036</td>
<td>30</td>
<td>cm/shake</td>
<td>Pressure at the bottom of cell (L) in PHI</td>
</tr>
<tr>
<td>RHO</td>
<td>40037</td>
<td>30</td>
<td>cm/shake</td>
<td>Pressure at the right of cell (L) in PHI</td>
</tr>
<tr>
<td>SIG</td>
<td>40038</td>
<td>30</td>
<td>cm/shake</td>
<td>Minimum Δx, Δy or Δz for a cell in CDT routine</td>
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The Z Block

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<td>Floating point value of the cycle number</td>
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<td>$\Delta t = t^n - t^{n-1}$</td>
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<td>Z(4)</td>
<td>PRINTS</td>
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<td>Cycle frequency for short print</td>
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<td>Cycle frequency for long print</td>
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<td>Z(6)</td>
<td>DUMPT7</td>
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<td>Cycle frequency for binary tape dump</td>
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<td>GAM</td>
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<td>GAMD</td>
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<td>= $1/(\alpha - 1)$ computer in input</td>
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<td>= $1/(\alpha_x - 1)$ routine</td>
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<td>Z(12)</td>
<td>ETH</td>
<td>jerks</td>
<td>= total energy in the system</td>
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$$\sum_{L=1}^{\Lambda_{\text{MAX}}(L)}[I(L)^2+U(L)^2+V(L)^2+W(L)^2]$$

Changed to PHI at transmittive boundaries and in PH2 if mass leaves the system.
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<tr>
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<td>FFA</td>
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<td>Upper limit for stability and used to calculate $\Delta t$ only if CABLN = 0.</td>
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<td>Z(14)</td>
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<td>Z(19)</td>
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<td>$\Delta t = (E_{th} - E_{n}^{N-PFC}/E_{th})$ for energy check</td>
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<tr>
<td>Z(20)</td>
<td>DMIN</td>
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<td>if ECK (see definition in Z(24)) is &gt; DMIN, problem will stop because of energy violation $\Delta t^{n-1}$</td>
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<td>Z(23)</td>
<td>TOZONE</td>
<td>g/cm³</td>
<td>If the mass flow across a free surface within the grid produces a density &lt; TOZONE, the mass flow is set to zero</td>
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<td>Z(24)</td>
<td>ECK</td>
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<td>Is the energy check $(E_{th} - E_{n}/E_{th}) - (E_{th} - E_{n-PFC}/E_{th})/NPC$ Where NPC = cycle frequency at which the energy check is made</td>
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<td>Z(25)</td>
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<td>Fractions of $\Delta$ in mass weighted velocity (suggested number = 1.0)</td>
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<td>Z(26)</td>
<td>CABLN</td>
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<td>Z(27)</td>
<td>T</td>
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<td>Total time up to cycle NC $t^{n+1} = t^n + \Delta t$</td>
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<td>( \rho _0 )</td>
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<td>For metallic equations of state (Tillotson formulation)</td>
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<td>Maximum number of zones in X direction</td>
</tr>
<tr>
<td>Z(87)</td>
<td>J</td>
<td>none</td>
<td>Maximum number of zones in Y direction</td>
</tr>
<tr>
<td>Z(88)</td>
<td>K</td>
<td>none</td>
<td>Maximum number of zones in Z direction</td>
</tr>
<tr>
<td>Z(89)</td>
<td>KMAXA</td>
<td>none</td>
<td>Total number of zones = (I) (J) (K)</td>
</tr>
<tr>
<td>Z(90)</td>
<td>IXMAX</td>
<td>none</td>
<td>= (I)(J)(K)</td>
</tr>
<tr>
<td>Z(91)</td>
<td>NOD</td>
<td>none</td>
<td>Index (working storage)</td>
</tr>
<tr>
<td>Z(92)</td>
<td>NOPR</td>
<td>none</td>
<td>Index (working storage)</td>
</tr>
<tr>
<td>Z(93)</td>
<td>I</td>
<td>none</td>
<td>Minimum value of i in do loop on i</td>
</tr>
<tr>
<td>Z(94)</td>
<td>I</td>
<td>none</td>
<td>Maximum value of i in do loop on i</td>
</tr>
<tr>
<td>Z(95)</td>
<td>I</td>
<td>none</td>
<td>Original interface between projectile and target</td>
</tr>
<tr>
<td>Location</td>
<td>Symbol</td>
<td>Units</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>Z(96)</td>
<td>i4</td>
<td>none</td>
<td>Number of zones to the right for rezone</td>
</tr>
<tr>
<td>Z(97)</td>
<td>N1</td>
<td>none</td>
<td>Flag at left, if 0., boundary is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>Z(98)</td>
<td>N2</td>
<td>none</td>
<td>Flag at right, if 0., boundary is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>Z(99)</td>
<td>N3</td>
<td>none</td>
<td>Flag at top, if 0., boundary is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>Z(100)</td>
<td>N4</td>
<td>none</td>
<td>Flag at bottom, if 0., boundary is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>Z(101)</td>
<td>N5</td>
<td>none</td>
<td>Flag behind, if 0., boundary is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>Z(102)</td>
<td>N6</td>
<td>none</td>
<td>Flag in front, if 0., boundary is transmittive, otherwise reflective</td>
</tr>
<tr>
<td>Z(103)</td>
<td>N7</td>
<td>none</td>
<td>Binary tape number designation</td>
</tr>
<tr>
<td>Z(104)</td>
<td>N8</td>
<td>none</td>
<td>Not used</td>
</tr>
<tr>
<td>Z(105)</td>
<td>N9</td>
<td>none</td>
<td>k value of zone that is controlling Δt</td>
</tr>
<tr>
<td>Z(106)</td>
<td>N10</td>
<td>none</td>
<td>i value of zone that is controlling Δt</td>
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<tr>
<td>Z(107)</td>
<td>N11</td>
<td>none</td>
<td>j value of zone that is controlling Δt</td>
</tr>
<tr>
<td>Z(108)</td>
<td>k1</td>
<td>none</td>
<td>Minimum value of k in do loop on k</td>
</tr>
<tr>
<td>Z(109)</td>
<td>k2</td>
<td>none</td>
<td>Maximum value of k in do loop on k</td>
</tr>
<tr>
<td>Z(110)</td>
<td>j1</td>
<td>none</td>
<td>Minimum value of j in do loop on j</td>
</tr>
<tr>
<td>Z(111)</td>
<td>j2</td>
<td>none</td>
<td>Maximum value of j in do loop on j</td>
</tr>
<tr>
<td>Z(112) through Z(150)</td>
<td></td>
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REFERENCES


