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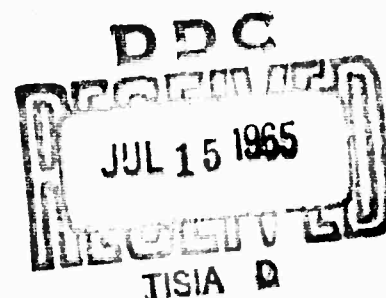
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**ANNUAL STATUS REPORT
ON THE THEORY OF HYPERVELOCITY IMPACT**

Advanced Research Projects Agency
ARPA Order No. 71-62
Monitored by
Ballistic Research Laboratories
Army Contract DA-04-495-AMC-116(X)



June 28, 1965

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GENERAL ATOMIC
DIVISION OF
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GA-6509

ANNUAL STATUS REPORT
ON THE THEORY OF HYPERVELOCITY IMPACT

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The revised Common and FORTRAN listings for the OIL code described herein are as they existed on July 1, 1965. The OIL code has been in continuous development for 3 years and in its presented form has been applied successfully by General Atomic to the kind of problems discussed later in this report. However, the development and improvement 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.

General Atomic has exercised due care in preparation, but does not warrant the merchantability, accuracy, and completeness of the code or of its description contained herein. The complexity of this kind of program precludes any guarantee to that effect. Therefore, any user must make his own determination of the suitability of the code for any specific use, and of the validity of the information produced by use of the code.

ABSTRACT

The three principal areas of activity,

1. Numerical solutions of problems in impact,
2. Code development for solving impact problems, and
3. Analytical work on the theory of the impact process,

are reviewed, utilizing wherever possible cited papers which have been published during this past year as part of the project work. The investigations covered in these papers are described only briefly in the present status report, familiarity with or availability of the original documents being assumed.

The major part of the present discussion is devoted to a status report of unfinished work on the problem of computing strength-dependent and viscous impact flows. A computer program is described for generalizing Eulerian hydrodynamic codes to include these effects and sample calculations are given.

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I. SUMMARY OF WORK AND INTRODUCTION

TO PRESENT REPORT

The major areas of work in the present contract period are summarized below to give the current status of each area and to cite where appropriate project documents that have been written.

1.1. STUDIES OF IMPACT HYDRODYNAMICS

Work in this area is the subject of the paper, "On the Theory of Hypervelocity Impact," by J. M. Walsh and W. E. Johnson, which appears in the Proceedings of the Seventh Hypervelocity Impact Symposium, Volume II, pages 1-76, February 1965. This paper is partially an exposition of the thick-target hydrodynamics studies given in our preceding annual report; it also contains a Part II which is devoted to a selection of impacts with thin-plate targets. The cited report is widely circulated, and many of the results will also be the subject of discussion in a joint report under preparation by General Atomic and the Ballistic Research Laboratories (see Section 1.5). Accordingly, it does not seem desirable to detail the work on impact hydrodynamics as part of the present report.

1.2. CODE DEVELOPMENT WORK IN HYDRODYNAMICS

This effort has consisted primarily of the development of improved computer programs for the solution of hydrodynamic flows which are functions of two space variables and time. The principal result is the continuous Eulerian code, OIL, developed over the preceding and present contract periods and documented in the report, "OIL - A Continuous Two-dimensional Eulerian Hydrodynamic Code," by W. E. Johnson, published as General Atomic Informal Report GAMD-5580 (Rev.), January 1965.

Additional improvements that have been made in the OIL code subsequent to the time the above report was issued are contained in the present report as part of Section III. The more significant changes are an improved treatment of free surfaces, and a capability for solving time-dependent x-y flows in addition to time-dependent axisymmetric flows.

1.3. CODE DEVELOPMENT WORK IN VISCOUS AND STRENGTH-DEPENDENT FLOWS

For most of the past year, the principal objective of the effort has been the development of a suitable code for the solution of two-dimensional viscous flows and two-dimensional flows in which strength-dependent deformation is important. Since Eulerian hydrodynamics codes have been more successful than Lagrangian codes in handling the large material distortions characteristic of impact, it was decided to retain the Eulerian code, OIL, and to generalize it to treat the tensor forces that arise from viscosity and strength.

In adding viscous and strength options to the OIL code, the approach used has been to leave the hydrodynamic capabilities of the code essentially unmodified and to add a separate phase in which viscous and strength forces are then taken into account to alter the velocities and specific internal energies. In other words, the average hydrostatic stress and compressions are accounted for in the hydrodynamics as usual; the task of the new phase (called PH3) is to take account of the stress deviator tensor which arises from the strain deviator tensor. For simplicity and to circumvent any need for storing components of the stress or strain deviators, the constitutive equations have so far been picked to be of special types. Specifically, the strength is represented by a rigid-plastic set of constitutive equations and the viscosity has so far been taken to be Newtonian. Generalization of these classical models will presumably be straightforward, although the retention of an elastic phase will require storing components of the stress tensor

The viscous and strength generalizations of the OIL code are given in considerable detail in the present report. The basic equations are the subject of discussion as Section II and the code is described in Section III and is reproduced as Section IV. The viscous and strength program, PH3, is of such a nature that it could be added to most multidimensional PIC-type or Eulerian hydrodynamic codes without disturbing the hydrodynamics capability, as was the case with OIL. It is then possible to add these effects in a hydrodynamics problem or to omit them by merely by-passing PH3 each time step. One rewarding feature of including viscosity, however, has been a significantly improved and smoother hydrodynamics. It seems probable that some viscosity will prove desirable in most purely hydrodynamic problems in order to smooth spurious oscillations. Examples of computations with and without viscosity are reproduced in Section III.

While the viscous option is apparently giving a smooth solution in a very satisfactory manner, there is a remaining difficulty in the form of small oscillations in the strength version of the code. These oscillations (which prevent the flow from being completely arrested) can be ignored, although additional code development work to remove them will probably be carried out prior to any extensive production applications.

It is expected that the completed code will provide a general capability for solving strength and viscous deformation problems and that its most important application may be to those flows where material distortions are sufficiently great that Lagrangian schemes become unmanageable. Our primary attention will be to cratering problems, such as those occurring in impact, and some work of this type is presented in Section III.

The computing time for the strength or viscous options in OIL is roughly equal to that for the purely hydrodynamic part of the calculation. Finally, FORTRAN listings for the hydrodynamic sections of OIL are also reproduced in Section IV, as a convenient way to document minor modifications which are described in the text.

1.4. ANALYTICAL WORK ON IMPACT AND RELATED PROBLEMS

Several analytical studies pertinent to various aspects of impact mechanics have been reported during the past contract period. These include:

"Late-stage Equivalence and Similarity Theory for One-dimensional Impacts," by J. K. Dienes. This paper is a discussion of simple ideal-gas impacts and exposes most of the physical principles underlying the more complex numerical work on axisymmetric solid-solid impact. Since the paper is presented in the Proceedings of the Seventh Hypervelocity Impact Symposium, Volume II, pages 187-220, February 1965, additional discussion here does not appear necessary.

"Approximate Treatment of Plane Shock Attenuation in a Solid," by J. M. Walsh, General Atomic Informal Report GAMD-5214, May 1964. This is an approximate theory of slab impacts of solids and has been previously distributed.

"Hydrodynamic Flow Equations with a Plasticity Resistance Law," by J. K. Dienes, General Atomic Informal Report GAMD-5910, December 1964. This is a summary of the relevant theoretical mechanics underlying the viscous and strength formulations and is also largely reproduced as Section II of the present report.

"A General Form for Matrix Functions of Nonsingular Second-degree Matrices," by T. Teichmann, General Atomic Report GA-6063, March 1965. This report does not apply directly to impact mechanics, but it does give a theorem in matrix algebra which was proved as an incidental result of work by Teichmann on a similarity theory of impact.

"Impact Crater Size and Target Strength," by F. E. Allison, J. K. Dienes, and J. M. Walsh, General Atomic Informal Report GAMD-6453, June 1965. Suitable simplifying assumptions are used to show that the dependencies of crater volume on impact velocity and target yield strength are closely related. For example, a proportionality of volume to impact

velocity leads to the result that crater volume varies inversely as the first power of the yield strength. The report has been distributed and additional work is planned.

"Remarks on Similarity Solutions for Hypervelocity Impact,"

T. Teichmann, General Atomic Informal Report GAMD-6501, July 1965.

This is a general mathematical discussion of the similarity methods which have so far been used on the hypervelocity impact problem. The report will be distributed in the near future.

1.5. PREPARATION OF A COMPREHENSIVE EXPERIMENTAL- THEORETICAL REPORT ON THE DYNAMICS OF IMPACT

In conjunction with appropriate members of the Ballistic Research Laboratories and the Drexel Institute of Technology, it has been decided that a joint experimental-theoretical report on impact might provide a timely and integrated picture of this general field of activity. Much of the past work by General Atomic will be presented in this report, which is planned for completion in the summer of this year. Accordingly, the emphasis in the present report has been on those subjects which will not be extensively reviewed in this forthcoming discussion.

II. EQUATIONS FOR VISCOUS AND STRENGTH-DEPENDENT FLOWS

The flow equations for the motion of a fluid with a general resistance law can be written, in tensor notation,¹ as

$$\frac{D\rho}{Dt} + \rho\theta = 0 ,$$

$$\rho \frac{Du_i}{Dt} = S_{ij,j} ,$$

$$\rho \frac{D}{Dt} \left(I + \frac{1}{2} u_k u_k \right) = (S_{ij} u_i)_{,j} ,$$

where the summation convention is understood and S_{ij} denotes a general stress tensor, I is the internal energy per unit mass, ρ the density, and u_i the velocity vector, $\theta = u_{i,i}$ is the divergence of the velocity, and

$$\frac{D}{Dt} = \frac{\partial}{\partial t} + u_i \frac{\partial}{\partial x_i}$$

denotes the convective derivative. It is appropriate to express the stress tensor, S_{ij} , as the sum of a hydrodynamic part, $-p\delta_{ij}$, and a deviator part, σ_{ij} .

$$S_{ij} = -p\delta_{ij} + \sigma_{ij}$$

such that

$$\sigma_{ii} = 0 , \quad p = -\frac{1}{3} S_{ii} .$$

The equations of motion can then be written as

$$\frac{D\rho}{Dt} + \rho\theta = 0 ,$$

¹W. Prager, Introduction to Mechanics of Continua, Ginn and Company, 1961.

$$\rho \frac{Du_i}{Dt} = -p_{,i} + \sigma_{ij,j},$$

$$\rho \frac{D}{Dt} \left(I + \frac{1}{2} u_k u_k \right) + p\theta = (\sigma_{ij} u_i)_{,j} = \sigma_{ij} e_{ij} + \sigma_{ij,j} u_i,$$

where

$$e_{ij} = \frac{1}{2} (u_{i,j} + u_{j,i})$$

is the strain-rate tensor.

Now the average stress, p , is a known function of the density, ρ , and specific internal energy, I , through an equation of state, $p = f(\rho, I)$. In order to complete the description of the flow, it is necessary that the stress deviator tensor be related to the strain deviator tensor through a constitutive equation, which in the OIL code is taken to be of the general form

$$\sigma_{ij} = b \epsilon_{ij}, \quad \epsilon_{ij} = e_{ij} - \delta_{ij} \theta/3.$$

Three special cases are of particular interest. If b is constant, the constitutive equation describes purely viscous flows and b is twice the viscosity, μ , of the fluid. The second case,

$$b = (2K^2/E_2)^{1/2}, \quad E_2 \equiv \epsilon_{ij} \epsilon_{ij},$$

describes a rigid-plastic material of the Prandtl-Reuss type for which the second stress invariant, $J_2 = \sigma_{ij} \sigma_{ij}$, can be shown to be constant and equal to $2K^2$, where K is the yield stress in pure shear. The third case defines equations of the Perzyna type in which strain-rate effects are accounted for by allowing b to have the general form $b = f(J_2)$, for which the function f has to be estimated in such a way that the solution to the equations of motion agrees with material-test observations. In the notation of Perzyna,²

²P. Perzyna, "The Study of the Dynamic Behavior of Rate-sensitive Plastic Materials," Division of Applied Mathematics, Brown University, Technical Report No. 77, May 1962.

$b = \sqrt{J_2}/\gamma \Phi(F)$, where $F = (\sqrt{J_2}/K) - 1$. In order to make use of the Perzyna equations in the current Eulerian code, OIL, the scalar b must be known as a function of the second strain invariant, E_2 , which in turn can be obtained from the known velocity field. This is done by deriving from the constitutive equation the relation

$$J_2 = b^2(J_2) E_2 ,$$

which must be solved to find b as a function of E_2 . Using the Perzyna notation, one finds

$$E_2 = \gamma^2 \Phi^2(F) .$$

The solution of this equation for J_2 in terms of E_2 is written, symbolically,

$$J_2 = K^2 \phi^2(E_2/\gamma^2) ,$$

and, in general, must be found by numerical methods. Then,

$$\sigma_{ij} = \frac{K\gamma}{\sqrt{E_2}} \phi(E_2/\gamma^2) \epsilon_{ij} ,$$

which is of the required form since the right-hand side can be obtained in terms of the velocity field and appropriate derivatives. From the point of view of the OIL code, the principal feature of the rigid-plastic model is that the constitutive equation does not depend on the total strain but only on the rate of strain, which can be determined by appropriate operations on the velocity field. The general elastic-plastic calculation, which is discussed in Ref. 3, would require that the strain itself be known and, therefore, would entail a significant increase in memory, in complexity of the code, and in computer time necessary to solve impact problems.

³J. K. Dienes, "Hydrodynamic Flow Equations with a Plasticity Resistance Law," General Atomic. Informal Report GAMD-5910, December 1964.

In cylindrical coordinates the strain-rate tensor is given by the matrix

$$(e_{ij}) = \begin{pmatrix} \frac{\partial u}{\partial r} & 0 & \frac{1}{2} \left(\frac{\partial u}{\partial z} + \frac{\partial v}{\partial r} \right) \\ 0 & \frac{u}{r} & 0 \\ \frac{1}{2} \left(\frac{\partial u}{\partial z} + \frac{\partial v}{\partial r} \right) & 0 & \frac{\partial v}{\partial z} \end{pmatrix},$$

where u denotes the radial velocity (u_1 in the generalized notation) and v denotes the axial velocity (u_3 in the generalized notation). The first strain-rate invariant, E_1 , is also the divergence of the velocity, and is, in cylindrical coordinates,

$$E_1 = \theta = e_{ii} = \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial v}{\partial z}.$$

The second strain-rate invariant is

$$E_2 = \left(e_{ij} - \frac{1}{3} \theta \delta_{ij} \right) \left(e_{ij} - \frac{1}{3} \theta \delta_{ij} \right) = e_{ij} e_{ij} - \theta^2/3,$$

which, in cylindrical coordinates, becomes

$$E_2 = \frac{2}{3} \left[\left(\frac{\partial u}{\partial r} \right)^2 + \left(\frac{\partial v}{\partial z} \right)^2 + \left(\frac{u}{r} \right)^2 \right] + \frac{1}{2} \left(\frac{\partial u}{\partial z} + \frac{\partial v}{\partial r} \right)^2.$$

The flow equations can be written in such a way that the local time derivatives appear on the left-hand side and the right-hand side is the sum of three terms. The first gives the effect of convection, the second the effect of hydrodynamic forces, and the third term gives the effect of the deviator stresses. The first two terms are accounted for in the original OIL code and are discussed separately.⁴ The additional increments due to the deviator stress terms are accounted for in the strength code and

⁴W. E. Johnson, "OIL, A Continuous Two-Dimensional Eulerian Hydrodynamic Code," General Atomic Informal Report GAMD-5580, October 15, 1964.

are the subject of this section. The full equations for the general case are:

$$\frac{\partial \rho}{\partial t} = -u_i \rho_{,i} - \rho \theta ,$$

$$\rho \frac{\partial u_1}{\partial t} = -\rho u_j u_{i,j} - p_{,i} + \sigma_{ij,j} ,$$

$$\rho \frac{\partial}{\partial t} \left(I + \frac{1}{2} u_k u_k \right) = -\rho u_j I_{,j} - p \theta + (\sigma_{ij} u_i)_{,j} .$$

Expressions for the co-variant derivatives in general coordinates are derived in tensor analysis. The appropriate expressions for cylindrical coordinates are given by Sokolnikoff.⁵ Denoting by a δ the increments due to stress deviator terms, the above equations lead to the following expressions for the effect of material strength in cylindrical coordinates:

$$\rho \frac{\delta u}{\delta t} = \frac{1}{r} \sigma_{rr} + \frac{\partial}{\partial r} \sigma_{rr} + \frac{\partial}{\partial z} \sigma_{rz} - \frac{1}{r} \sigma_{\theta\theta} ,$$

$$\rho \frac{\delta v}{\delta t} = \frac{\partial}{\partial r} \sigma_{rz} + \frac{\partial}{\partial z} \sigma_{zz} + \frac{1}{r} \sigma_{rz} ,$$

$$\rho \frac{\delta \left(I + \frac{1}{2} u_k u_k \right)}{\delta t} = \frac{1}{r} \frac{\partial}{\partial r} [r(u \sigma_{rr} + v \sigma_{rz})] + \frac{\partial}{\partial z} (u \sigma_{rz} + v \sigma_{zz}) .$$

These expressions can be integrated over the finite volumes associated with each cell to obtain expressions appropriate for the effects of deviator stresses alone. As a result of this calculation for the element of volume in Fig. 1, one finds

$$\delta u = \frac{2\pi \delta t}{\Delta m} \left\{ r \sigma_{rr} \Big|_r^{r+\Delta r} \Delta z + \sigma_{rz} \Big|_z^{z+\Delta z} \left(r + \frac{\Delta r}{2} \right) \Delta r - \sigma_{\theta\theta} \Delta z \Delta r \right\} ,$$

⁵ I. S. Sokolnikoff, Mathematical Theory of Elasticity McGraw-Hill Book Company, 1946.

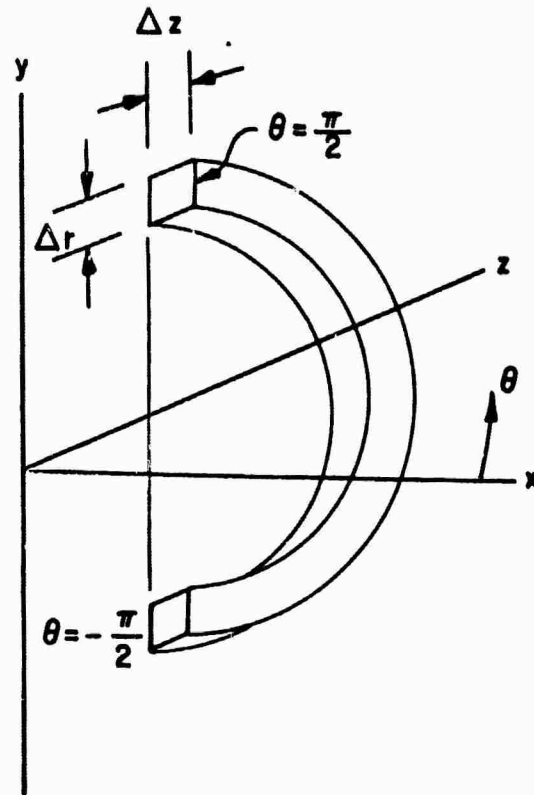


Fig. 1--The element of volume appropriate for deriving the flow equations in cylindrical coordinates; the contained mass is half the cell mass, Δm

$$\delta v = \frac{2\pi\delta t}{\Delta m} \left\{ r\sigma_{rz} \Big|_r^{r+\Delta r} \Delta z + \sigma_{zz} \Big|_z^{z+\Delta z} \left(r + \frac{\Delta r}{2} \right) \Delta r \right\},$$

$$\delta \left(I + \frac{1}{2} u_k u_k \right) = \frac{2\pi\delta t}{\Delta m} \left\{ r(\sigma_{rr} u_r + \sigma_{rz} u_z) \Big|_r^{r+\Delta r} + \left(r + \frac{\Delta r}{2} \right) (\sigma_{rz} u_r + \sigma_{zz} u_z) \Big|_z^{z+\Delta z} \right\}.$$

These are the expressions used in the viscous and strength options of OIL.

The stresses are evaluated at the cell boundaries in the code. The flux of each component of momentum and of energy across each cell boundary is added to one cell and subtracted from the other in such a way that the total energy and momentum are conserved in the finite difference approximation.

III. OIL WITH STRENGTH AND VISCOSITY

3.1. INTRODUCTION

In the hydrodynamic version⁴ of OIL, the only stress acting is the scalar pressure, which is computed from a given function of density and specific internal energy. The incorporation of material strength and viscous forces into the code gives rise, however, to tensor forces which must be computed using the constitutive equations and then accounted for by using the appropriate momentum and energy equations discussed in the preceding section. These calculations have been programmed into a single (optional) phase in the code and are performed each time step. This phase of the combined code, called PH3, is currently located after PH1 (where the field terms in the hydrodynamic equations are computed) and prior to PH2 (where material transport is performed). Provisions have been made for by-passing PH3 to perform a purely hydrodynamic calculation and also for subcycling PH3 in order to split the time step for that phase only.

The additional coding required for the present options and anticipated coding for further modifications necessitated a decrease in the maximum allowable number of cells from 3,500 to 2,500.

Most of the present section is devoted to a description of the strength and viscosity programs. Some changes have been made to the basic OIL code, however, and these are also described. Among these are options for changing physical units and for treating flows in x-y space as well as the axisymmetric case. An improved treatment of free-surface motion is also incorporated.

3.2. DIFFERENCE EQUATIONS FOR PH3

In the following discussion, we have assumed that $\Delta x(i)$ for all i is a constant and $\Delta y(j)$ for all j is a constant. The space is axisymmetric and cylindrical coordinates are used, although Δx and Δy are used to designate cell dimensions in the R and z directions, respectively, as depicted in Fig. 2.

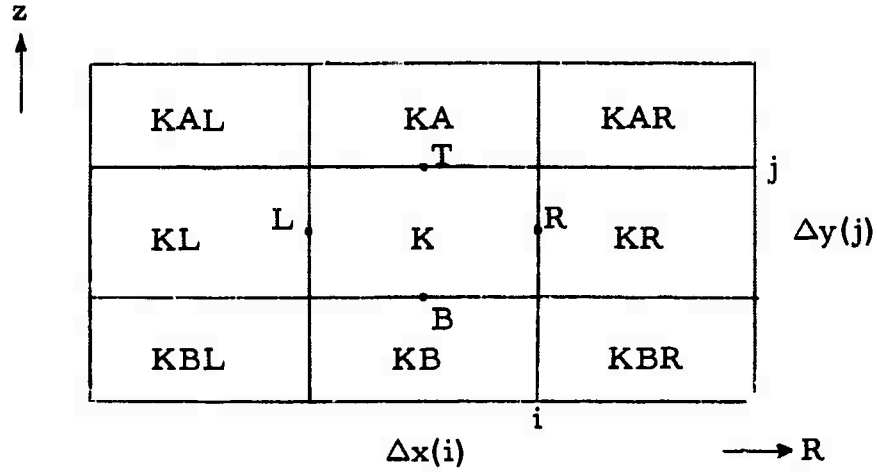


Fig. 2

To calculate the stresses at the cell boundaries, we compute the velocity gradients at points B, L, T, and R, as follows: The velocity gradients at points L and B have already been calculated from the previous row sweep and from the cell to the left, and it suffices to indicate the procedure at R and T. Referring to the position R,

$$\frac{du}{dR} = \frac{u_{(KR)} - u_{(K)}}{\Delta x(i)} = S1 \text{ (FORTRAN designation),}$$

$$\frac{dv}{dR} = \frac{v_{(KR)} - v_{(K)}}{\Delta x(i)} = S2 \text{ (FORTRAN designation),}$$

$$\frac{du}{dz} = \frac{\frac{u_{(KA)} + u_{(KAR)}}{2} - \frac{u_{(KB)} + u_{(KBR)}}{2}}{2\Delta y(j)} = S3 \text{ (FORTRAN designation),}$$

$$\frac{dv}{dz} = \frac{\frac{v_{(KA)} + v_{(KAR)}}{2} - \frac{v_{(KB)} + v_{(KBR)}}{2}}{2\Delta y(j)} = S4 \text{ (FORTRAN designation),}$$

and

$$\frac{u}{R} = \frac{u(KA) + u(K)}{x(i) + x(i-1)} = S10 \text{ (FORTRAN designation).}$$

With these velocity gradients, we can calculate the stresses at the cell boundaries. The stresses are defined as

$$\sigma_{ij} = b \left(e_{ij} - \delta_{ij} \frac{e_{aa}}{3} \right) \equiv b \epsilon_{ij},$$

$$\delta_{ij} = \text{Kronecker delta,}$$

$$e_{aa} = \frac{dv}{dR} + \frac{dv}{dz} + \frac{u}{R}.$$

For a rigid-plastic material, the Prandtl-Reuss equations are given by

$$b = \sqrt{\frac{2eK^2}{\epsilon_{ab} \epsilon_{ab}}}$$

where K is the yield strength and

$$\epsilon_{ab} \epsilon_{ab} = \frac{2}{3} \left[\left(\frac{du}{dR} \right)^2 + \left(\frac{dv}{dz} \right)^2 + \left(\frac{u}{R} \right)^2 \right] + \frac{1}{2} \left(\frac{du}{dz} + \frac{dv}{dR} \right)^2.$$

Eight of the nine stresses acting on a cell in the axisymmetric case are:

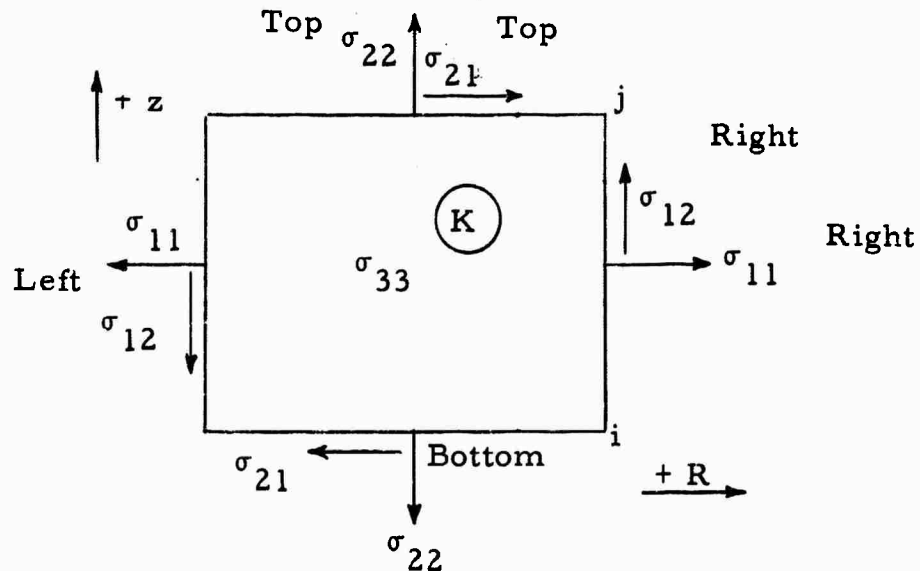


Fig. 3

Referring to Fig. 3, we define the hoop stress, which is normal to the plane of the paper, as shown here, and is positive in tension, as follows:

$$\sigma_{33} = b \epsilon_{33} = \text{DDVK (FORTRAN designation),}$$

where

$$\epsilon_{33} = e_{33} - \frac{1}{3} e_{aa} ,$$

$$e_{33} = \frac{2u(K)}{x(i) + x(i-1)} ,$$

and

$$b = \sqrt{\frac{2K^2}{\Delta}} .$$

Here again, K is the yield strength and

$$\begin{aligned} \Delta = \frac{2}{3} & \left[\left(\frac{u(KR) - u(KL)}{2\Delta y(j)} \right)^2 + \left(\frac{v(KA) - v(KB)}{2\Delta y(j)} \right)^2 + \left(\frac{2u(K)}{x(i) + x(i-1)} \right)^2 \right] \\ & + \frac{1}{2} \left(\frac{u(KA) - u(KB)}{2\Delta y(j)} + \frac{v(KR) - v(KL)}{2\Delta x(i)} \right)^2 . \end{aligned}$$

The five stresses produce forces on cell K in the radial direction as follows:

The force at the right side of the cell is $F_{11}^R = \sigma_{11}^R \Delta y(j) 2\pi x(i);$

at the left it is $F_{11}^L = -\sigma_{11}^L \Delta y(j) 2\pi x(i-1);$

at the top it is $F_{21}^T = \sigma_{21}^T \pi(x(i)^2 - x(i-1)^2);$

at the bottom it is $F_{21}^B = -\sigma_{21}^B \pi(x(i)^2 - x(i-1)^2);$

and the hoop stress has a radial contribution given by

$$F_{33} = -\sigma_{33} 2\pi \Delta x(i) \Delta y(j) .$$

From the equation of motion then, the sum of these five forces results in the change Δu of cell K as follows:

$$\Delta u_{(K)} = \frac{2\pi\Delta t}{AMX(K)} \left[\sigma_{11}^R \Delta y(j)x(i) - \sigma_{11}^L \Delta y(j)x(i-1) + \frac{\sigma_{21}^T}{2} (x(i)^2 - x(i-1)^2) - \frac{\sigma_{21}^B}{2} (x(i)^2 - x(i-1)^2) - \sigma_{33} \Delta x(i) \Delta y(j) \right]$$

Only four stresses acting on cell K produce a change Δv in the axial direction:

The force at the top of the cell is $F_{22}^T = +\sigma_{22}^T \pi(x(i)^2 - x(i-1)^2);$

at the bottom of the cell it is $F_{22}^B = -\sigma_{22}^B \pi(x(i)^2 - x(i-1)^2);$

at the right it is $F_{12}^R = \sigma_{12}^R 2\pi x(i) \Delta y(j);$

at the left it is $F_{12}^L = -\sigma_{12}^L 2\pi x(i-1) \Delta y(j) .$

These four forces then produce a change of Δv in cell K:

$$\Delta v_{(K)} = \frac{2\pi\Delta t}{AMX(K)} \left[\left(\frac{\sigma_{22}^T - \sigma_{22}^B}{2} \right) (x(i)^2 - x(i-1)^2) + \Delta y(j) (\sigma_{12}^R x(i) - \sigma_{12}^L x(i-1)) \right].$$

The change of total energy E of cell K that is due to the work done by these forces is

$$M \frac{dE}{dt} = \sum_1^4 FV$$

over all four sides of cell K or, introducing the specific internal energy I,

$$M \frac{d}{dt} \left[I + \frac{1}{2} (u^2 + v^2) \right] = \sum_1^4 FV .$$

Then, using the previous values for the interface forces and velocities, the internal energy I of cell K is

$$\begin{aligned} \Delta I_{(K)} = \frac{\Delta t}{AMX(K)} & \left[\frac{u_{(KR)} + u_{(K)}}{2.} \{2\pi x(i)\Delta y(j)\sigma_{11}^R\} \right. \\ & - \frac{u_{(K)} + u_{(KL)}}{2.} \{2\pi x(i-1)\Delta y(j)\sigma_{11}^L\} \\ & + \frac{u_{(K)} + u_{(KA)}}{2.} \{\sigma_{21}^T \pi(x(i)^2 - x(i-1)^2)\} \\ & - \frac{u_{(K)} + u_{(KB)}}{2.} \{\sigma_{21}^B \pi(x(i)^2 - x(i-1)^2)\} \\ & + \frac{v_{(KR)} + v_{(K)}}{2.} \{\sigma_{12}^R \Delta y(j)x(i)2\pi\} \\ & - \frac{v_{(K)} + v_{(KL)}}{2.} \{\sigma_{12}^L \Delta y(j)x(i-1)2\pi\} \\ & + \frac{v_{(K)} + v_{(KA)}}{2.} \{\sigma_{22}^T \pi(x(i)^2 - x(i-1)^2)\} \\ & \left. - \frac{v_{(K)} + v_{(KB)}}{2.} \{\sigma_{22}^B \pi(x(i)^2 - x(i-1)^2)\} \right] \\ & - \left[u_{(K)} \Delta u_{(K)} + v_{(K)} \Delta v_{(K)} + \frac{(\Delta u_{(K)})^2}{2.} + \frac{(\Delta v_{(K)})^2}{2.} \right] . \end{aligned}$$

All the velocities are those from the PH1 hydrodynamics calculation. The T, R, B, and L refer respectively to the top, right, bottom, and left boundary of the cell in question.

3.3. LOGIC OF PH3

For either the strength or viscosity options, the forces are determined from velocity gradients, for which knowledge of velocities in neighboring cells to the particular one being treated is required. Furthermore, all of the velocities used in computing derivatives must correspond to the same time. These requirements necessitate retaining un-updated velocities for some cells as well as the updated values. These dual storage requirements are satisfied without additional working storage by equivalencing with working storage used in other parts of OIL; also, the sweep through the grid is done by rows rather than columns as elsewhere in OIL in order to take advantage of the fewer number of cells per row (52 maximum instead of 100 in a column). Hence, less storage is needed to retain old and new velocities for the two rows required.

The task of PH3, in general terms, is to compute the stresses from the old velocities and to use the stresses in the difference equations in order to update u , v , and I . A special check feature is also employed: If the sign of the velocity difference between two adjacent cells changes during a time step, then we set the corresponding driving force to zero* within the time step when this occurs (actually accomplished by using the average driving force for the entire step). This is called an overshoot correction and serves to avoid cell-to-cell oscillations in the velocity.

The need to save old and new velocities for some cells and the provision to prevent overshoot offer some special problems in the programming. In the present version, the procedure which is used involves working on three rows of cells in each sweep. In the most advanced row, stresses are computed from the old velocities and tentative values of Δu , Δv are computed. In the second row, for the cell immediately below, the tentative Δu , Δv are finalized unless overshoot occurs. Overshoot is checked at the upper and right boundaries and for the hoop stress

* Similarly, for the hoop stress, the driving force is set to zero within the time step when the sense of the corresponding strain-rate term, ϵ_{33} , changes.

and is prevented by reduction of the appropriate driving stresses, as described above. Finally, ΔI is computed for this second row cell, using the final values of the stresses. This ΔI calculation requires old velocities from the surrounding cells, necessitating retention of these velocities for the third row of cells. Special procedures are used for those cells lying on the grid boundaries.

Notes explaining various portions of the code are also given in the FORTRAN listings of Section IV.

Timings to date of computations using the strength or viscosity options indicate that such problems are a factor of two longer in computer time than equivalent hydrodynamics problems without these effects.

The main logic for the strength or viscosity is done in subroutine PH3. In addition, PH3 refers to the following subroutines:

GRADR	Calculates the velocity gradients at the right boundary of the cell in question.
GRADZ	Calculates the velocity gradients at the top boundary of the cell in question.
STRESR	Calculates the two stresses (normal and shear) at the right boundary of the cell in question.
STRESZ	Calculates the two stresses (normal and shear) at the top boundary of the cell in question.
HOOP	Calculates the hoop stress for the cell in question.
DELTAU	Calculates the radial acceleration of the cell in question due to stress forces.
DELTAV	Calculates the axial acceleration of the cell in question due to the stress forces.
ECALC	Calculates the change of the specific internal energy of the cell in question, due to the work done by the stress forces.

In addition to the normal input required for OIL,⁴ the strength version requires the following additional quantities:

<u>Location</u>	<u>Symbol</u>	<u>Description</u>
21	AMDM	Cutoff for strength based on density; if $\rho_{(K)} < \text{AMDM } \rho_0$, forces due to strength are not applied on cell K.
25	FeF	Flag, if = 0., PH3 (the strength subroutine) will be called, if $\neq 0$, no strength.
49	i3	The number of times to subcycle through the strength routine (time step $\Delta t/i3$, where Δt is the hydro time step used in PH1 and PH2).
66	DXN	Cutoff for the stresses.
71	RSTOP	The factor to multiply the equation-of-state constants by to convert units to cgs system.
72	SHELL	The factor to multiply the coefficient of pressure in the speed-of-sound calculation.
107	Z(107)	Velocity gradient cutoff.
5841	DDXN	K_0 = yield strength, in the appropriate units.
5843	DKE	η_0 = Newtonian viscosity coefficient, in the appropriate units.
8517	TABLM	Factor on dV/dz critical, shifts the point where the full yield strength is applied.
13583	VT	Minimum ρ to trigger rezone.
13586	VVABOV	Epsilon for energy cutoff, to cut down on the precursor.
13587	VVBLO	Epsilon for velocity cutoff, to cut down on the precursor.

The code is currently being modified to incorporate all the strength constants and flags on the dump tape. Until this is completed, the various quantities, such as DDXN, DKE, TABLM, VVABOV, VVBLO, and VT, must be loaded on every restart.

3.4. OTHER GENERALIZATIONS OF OIL

Two additional modifications have been made to improve OIL. One is the capability of treating two-dimensional x-y flows as well as axisymmetric ones. The other is an improved representation of free surfaces that distinguishes between condensed and vaporized materials and provides an improved transport scheme for the condensed case. These two modifications are described below.

3.4.1. Axisymmetric and Plane Flows

Whether a problem is to be in axisymmetric or plane coordinates is designated by a single flag. If CLAM is used to generate the problem, this flag is the fourth word of card number 2 (input cards for CLAM) and is 0. for axisymmetric geometry, and any number other than 0. is used to designate x-y Cartesian geometry.

When the CLAM code is used, the changes required are listed below. The referenced card numbers and pages are described in Ref. 4.

The following statements replace the cards labelled 1790 through 1810 in the input subroutine (page 77):

```

      IF (Q000FL) 3000, 3002, 3000
3000  TAU(i) = Dx(1)
      WS = 1.
      GO TO 1008
3002  WSB = WSA
      WSA = x(i) * * 2
      TAU(i) = WS* (WSA-WSB)
1008  CONTINUE

```

Replace cards numbered 1250 through 1260 in the routine PH3 (page 89) by:

```

      IF (Q000FL) 6000, 6001, 6000
6000  TAM = WS5 * Dy(j)/FMX

```

GO TO 6002

6001 TAM = WPIDy * WS5 * Dy(j)

6002 E = 0.0

Replace card number 2050 in routine PH3 (page 91) by:

IF (Q000FL) 6004, 6005, 6004

6004 AM(n) = TAM * WSR

GO TO 4341

6005 AM(N) = TAM * TX * WSR

After statement 7162 (card number 1380) in routine Output (page 100)

insert

GAM = Q00FL

If the subroutine SETUP is used to generate the problem, then the flag is located in the variable GAM (location 10 for the CARDS routine).

Referring to Eqs. (1) through (4) of Ref. 4, Eq. (1) is changed to

$$\frac{\partial \rho}{\partial t} = - \frac{\partial \rho u}{\partial r} - \frac{\partial \rho v}{\partial z} ;$$

the two momenta equations remain unchanged; and for Eq. (4),

$$\rho \frac{\partial E}{\partial t} = - \frac{\partial P u}{\partial r} - \frac{\partial P v}{\partial z} .$$

3.4.2. Free Surface Modification

A modification has been made to the scheme of handling free surfaces in the transport routine of OIL. As reported in Ref. 4, the OIL write-up, a velocity change in the projectile was the criterion for ensuring that the bottom of the projectile empty properly as it continues to move upward. However, this scheme was not operative after the reflected shock broke through the bottom surface of the projectile.

The new scheme is, again, concerned with the emptying of cells. The criterion for applying the scheme is that the energy of the cell be less

than the energy required to vaporize the material. Thus, if the material is a gas, no special modification is required if the material is a solid, the transport is done using the density and velocity of the receptor cell.

Another feature of the code is the ability to convert to the cgs units. Two additional input numbers are required, RSTOP and SHELL. Their definitions are listed in the revised Common list in Section IV.

3.5. TEST PROBLEMS

A number of test problems have been computed during the course of the present code development, and in this section some representative results are presented. It is expected that extensive application of the code to impact problems, and the associated discussion of impact mechanics, will be the subject of future reports.

Two one-dimensional impacts have been computed in which wax plates strike wax targets at a velocity of 3.5×10^4 cm/sec. One of these impacts was treated using the unmodified OIL hydrodynamics code and the second was a viscous flow problem with viscosity $\eta_0 = 2 \times 10^5$ ergs sec/cm³. Cell dimensions in the two problems were 1 cm. The most interesting results of the calculations are the pressure-pulse and velocity-pulse profiles seen in Figs. 4 and 5. The viscous version of the problem is seen to be effective in eliminating the oscillations which are characteristic of the unmodified version. Some viscous smearing of the shock front is also evident.

Two axisymmetric wax-on-wax impacts were also computed, with an impact velocity of 4×10^5 cm/sec. One was run with the hydrodynamic version of the code, which differs from previous calculations of this impact only in the improved treatment of the free surface (Section 3.4.) and a somewhat coarser zoning. The other impact was treated as a problem in viscous flow with viscosity 1×10^4 ergs sec/cm³. Initial cell size in both problems was 0.0525 cm. Successive stages of the viscous

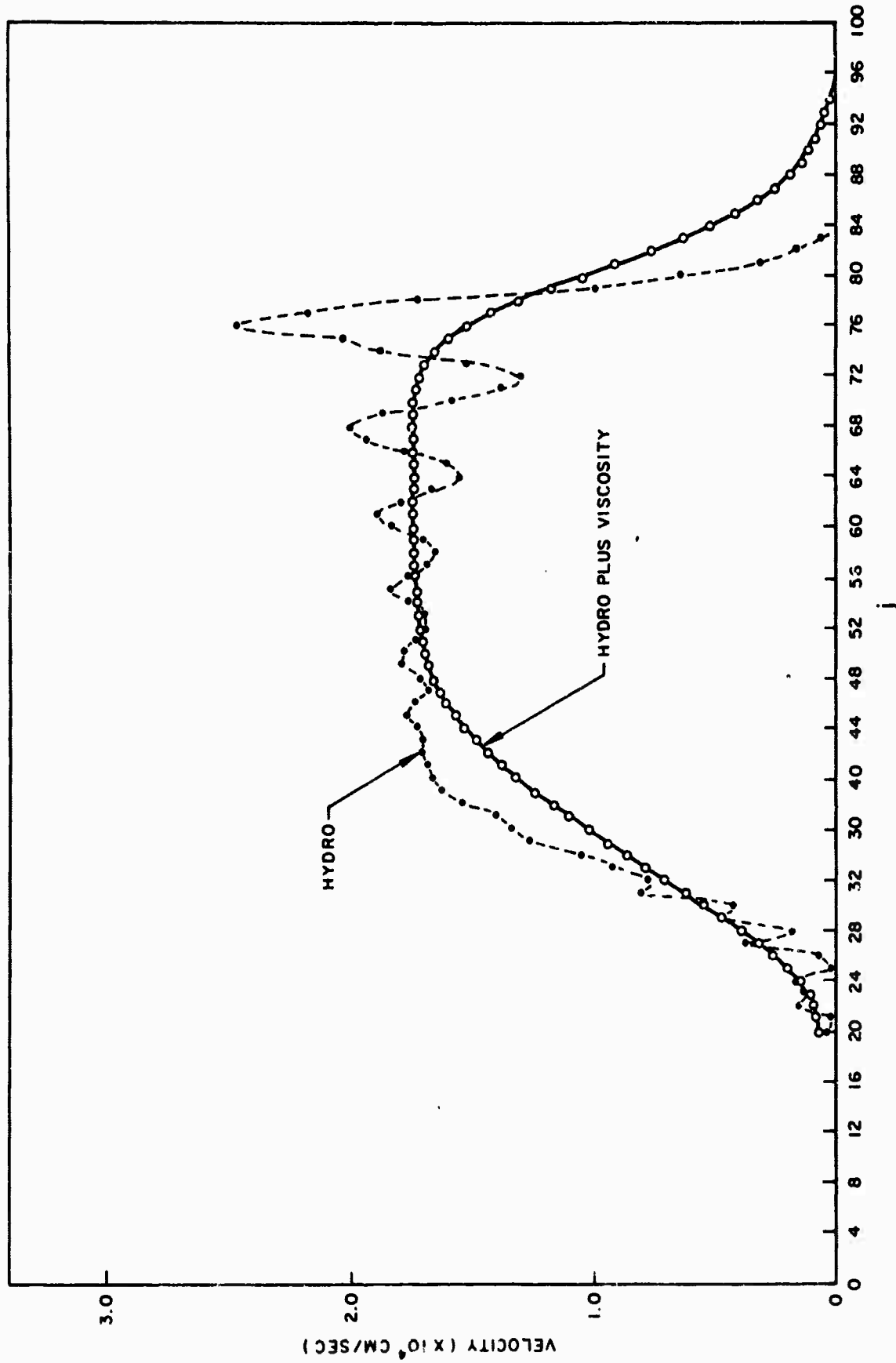


Fig. 4--Velocity profiles for the purely hydrodynamic and viscous-hydrodynamic versions of OIL, in the case of a slab-geometry impact

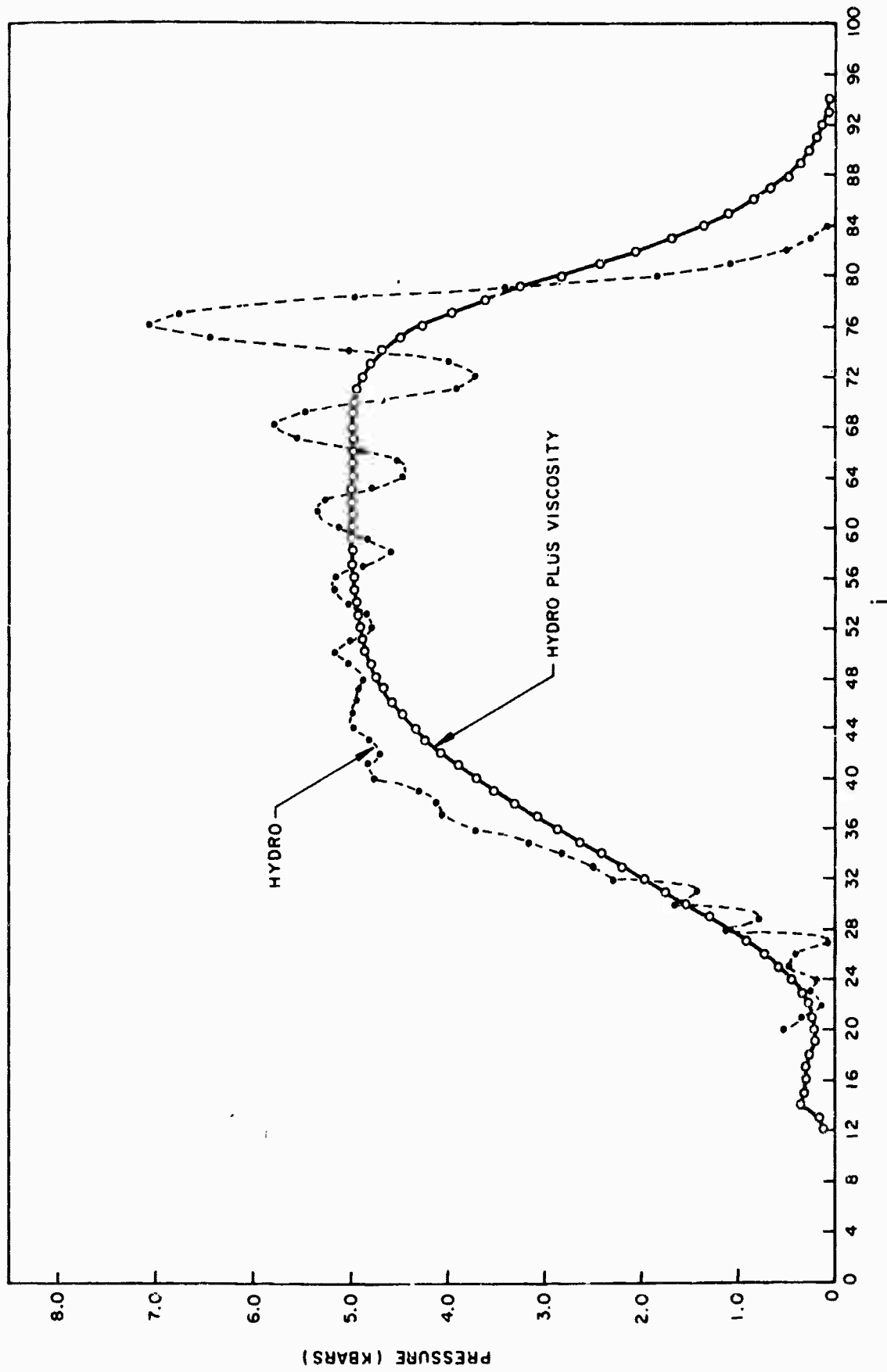


Fig. 5--Pressure profiles for the purely hydrodynamic and viscous-hydrodynamic versions of OIL, in the case of a slab-geometry impact

flow are given in Fig. 6, and the crater growth in these two problems is compared in the mass distribution plots of Figs. 7 and 8. It is seen that the gross features of the mass motion are in very good agreement with the experimental crater growth data by Karpov,⁶ especially for the viscous flow. The viscosity problem is also in better agreement with the experimental shock-pressure-attenuation data, as can be seen from Fig. 9. The results are merely illustrative of the code, however, since no attempt has been made to formulate a realistic constitutive equation for wax.

The above axisymmetric impact was also run as a problem in strength-dependent deformation using the Prandtl-Reuss constitutive equations described in previous sections. A modification to this representation was included in order to reduce the yield strength as the velocity gradients became small and thus to avoid oscillations in the form of overcorrections. The results were very satisfactory at high pressures but still exhibited some oscillatory behavior as pressures became comparable to the yield strength, which was taken to be 5 kbars in this exploratory calculation.

A spherically symmetric test problem was computed in cylindrical coordinates in order to test the strength code against preferential treatment in the axial and radial directions. A hot sphere of plastic (density 0.92 g/cm^3 and specific energy 7×10^{10} ergs/g, sufficient to exert a pressure of 103 kbars) was allowed to explode in a cold plastic atmosphere (density 0.92 g/cm^3 , zero pressure and energy). A yield strength of 5 kbars was assumed, and this yield strength was again diminished as velocity gradients became small. Figures 10 and 11 bear out the spherical character of the solution. Similar tests of sphericity have previously been reported⁴ for the purely hydrodynamic part of the code.

⁶B. G. Karpov, "Transient Response of Wax Targets to Pellet Impact at 4 km/sec," Ballistic Research Laboratories, Report No. 1226, October, 1963.

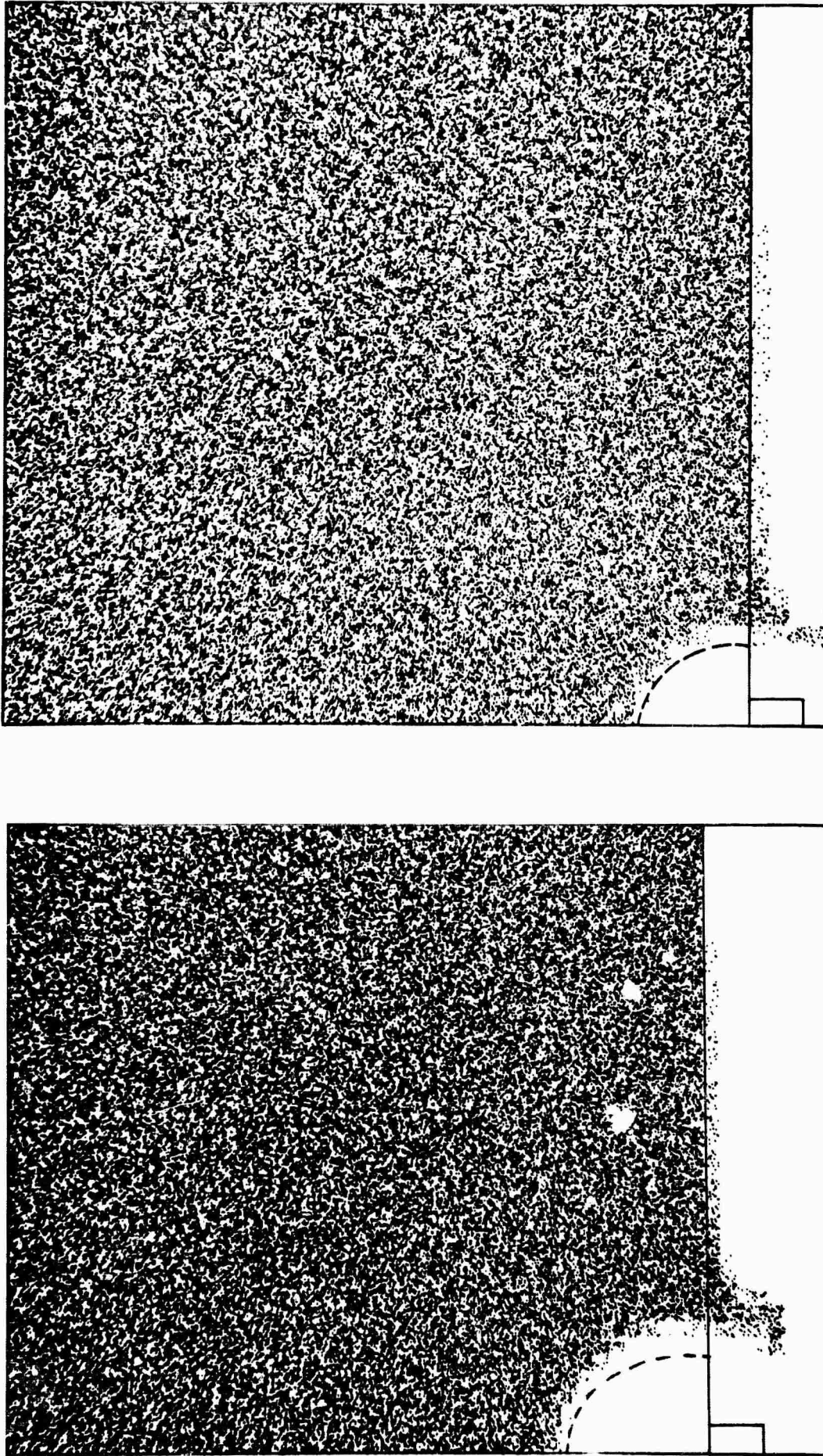


Fig. 7--Successive stages in the viscous-hydrodynamic axisymmetric impact

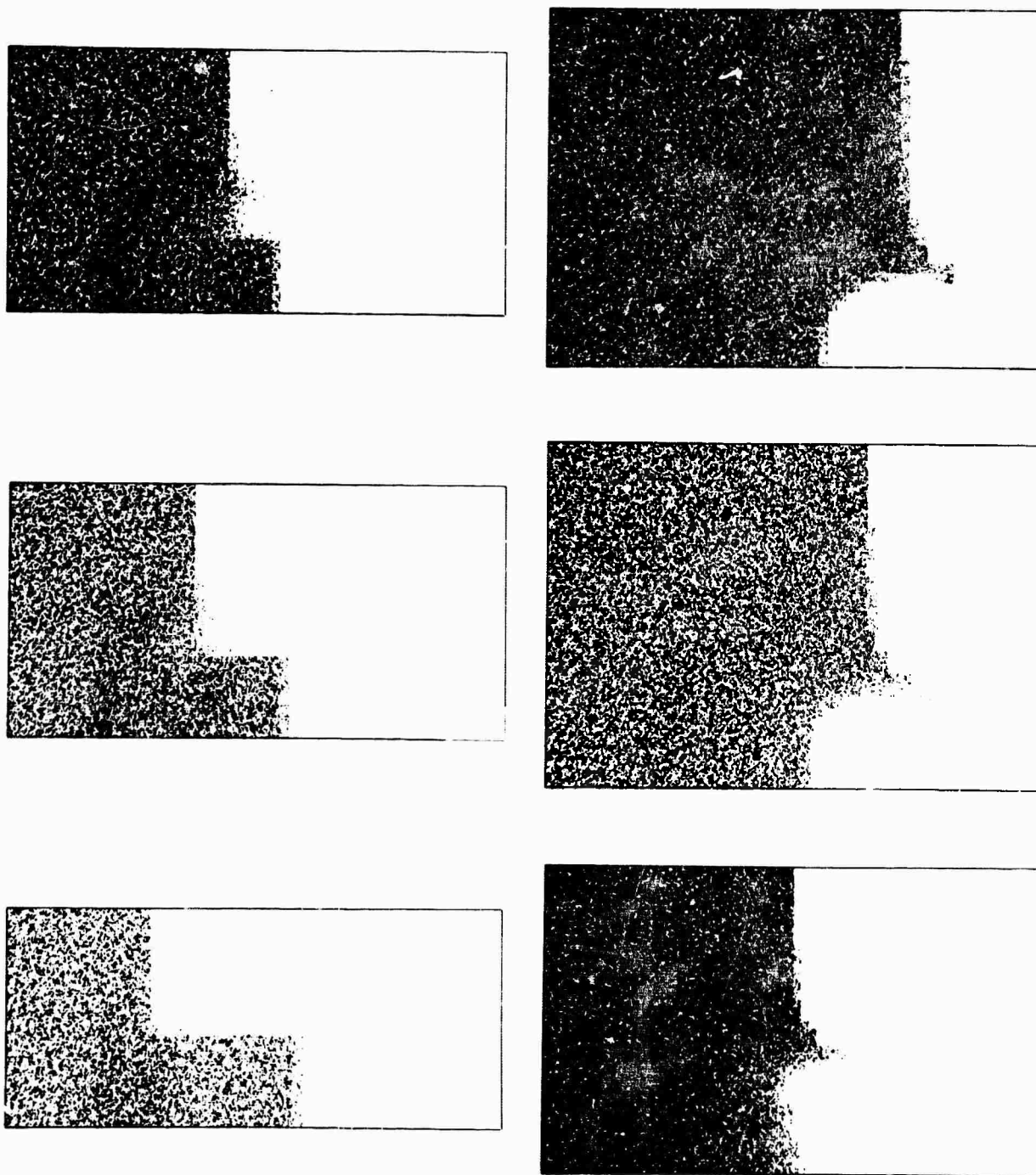


Fig. 6---Mass distribution plots for the purely hydrodynamic axisymmetric impact problem. The dashed profile is an experimental curve.

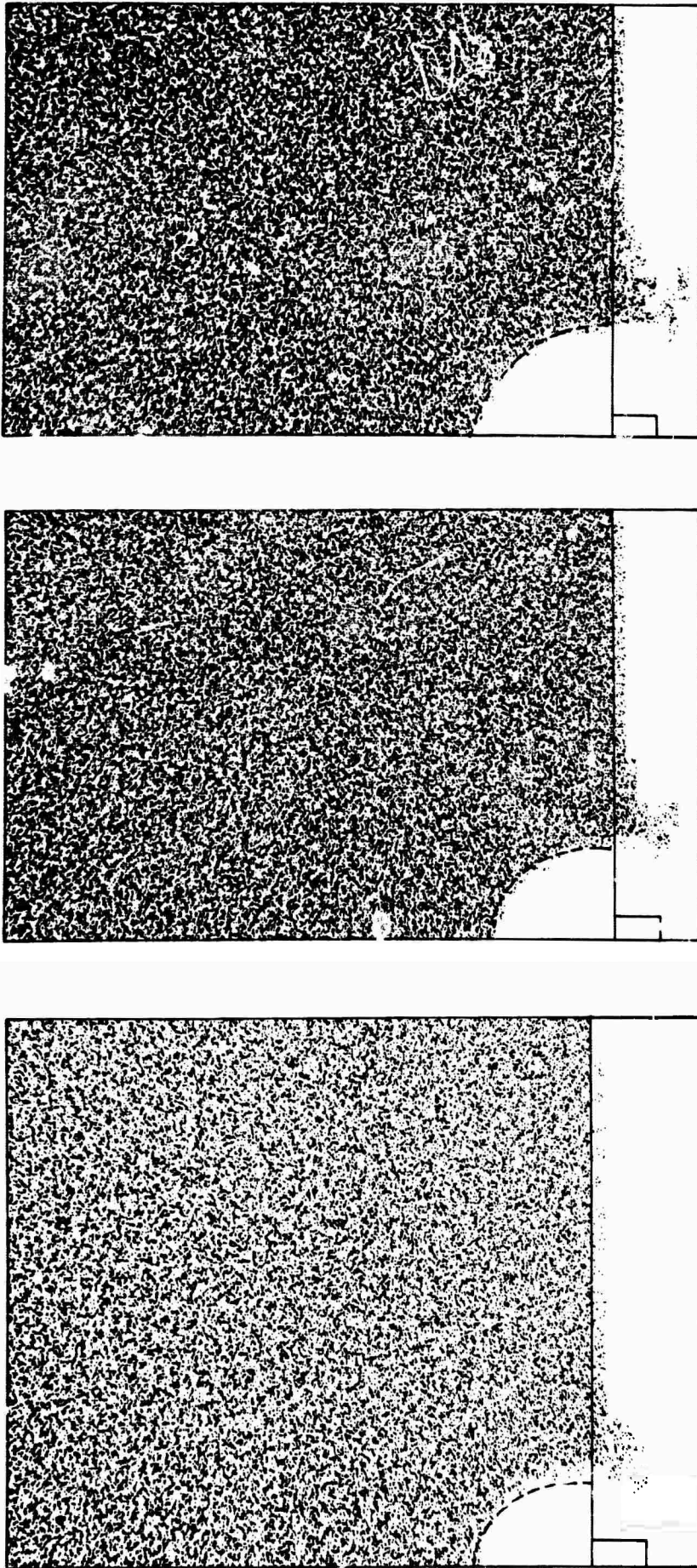


Fig. 8--Mass distribution plots for the viscous-hydrodynamic axisymmetric impact problem. The dashed profile is an experimental curve.

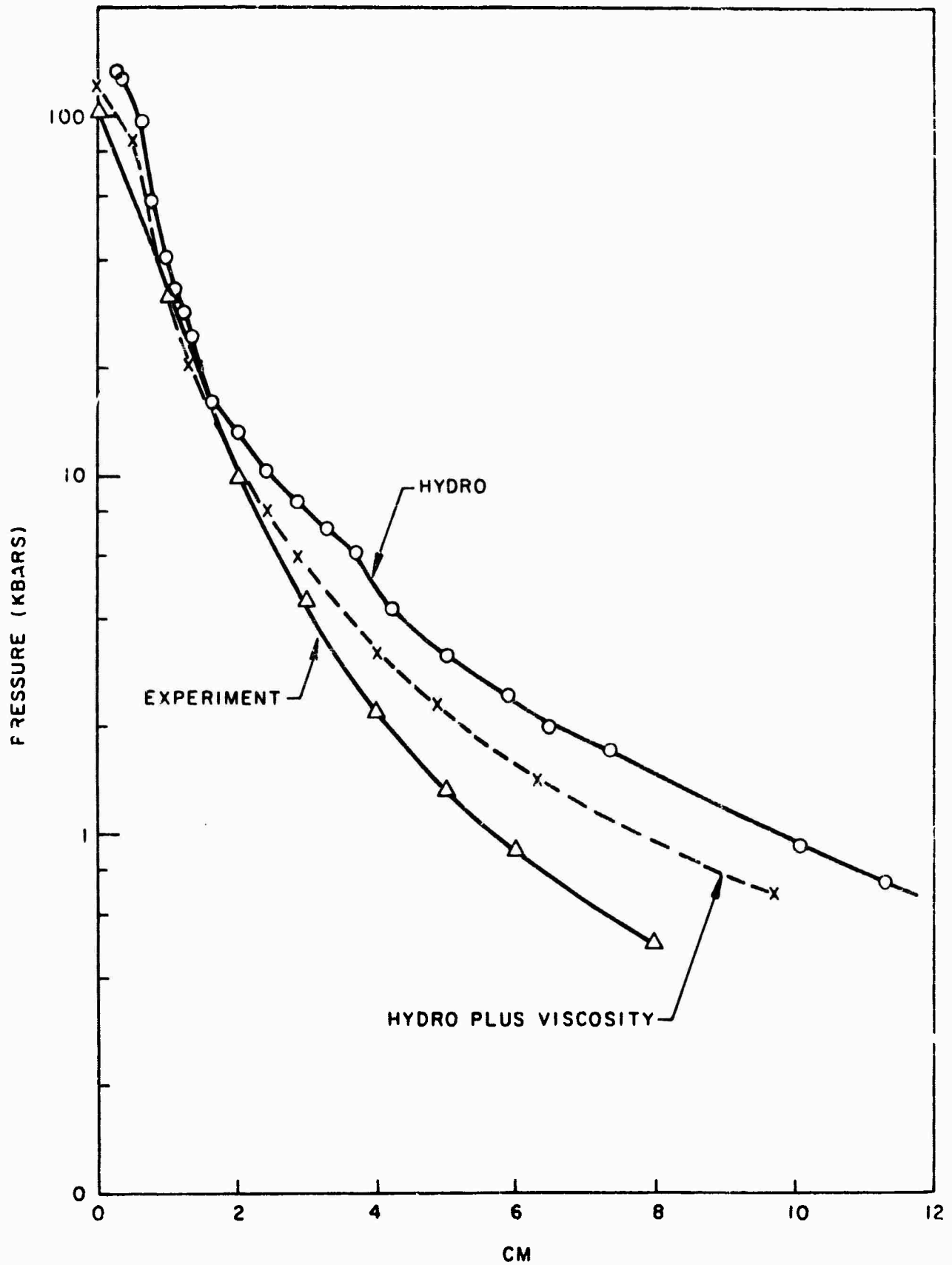


Fig. 9--Experimental, hydrodynamic, and viscous-hydrodynamic shock attenuation curves for wax

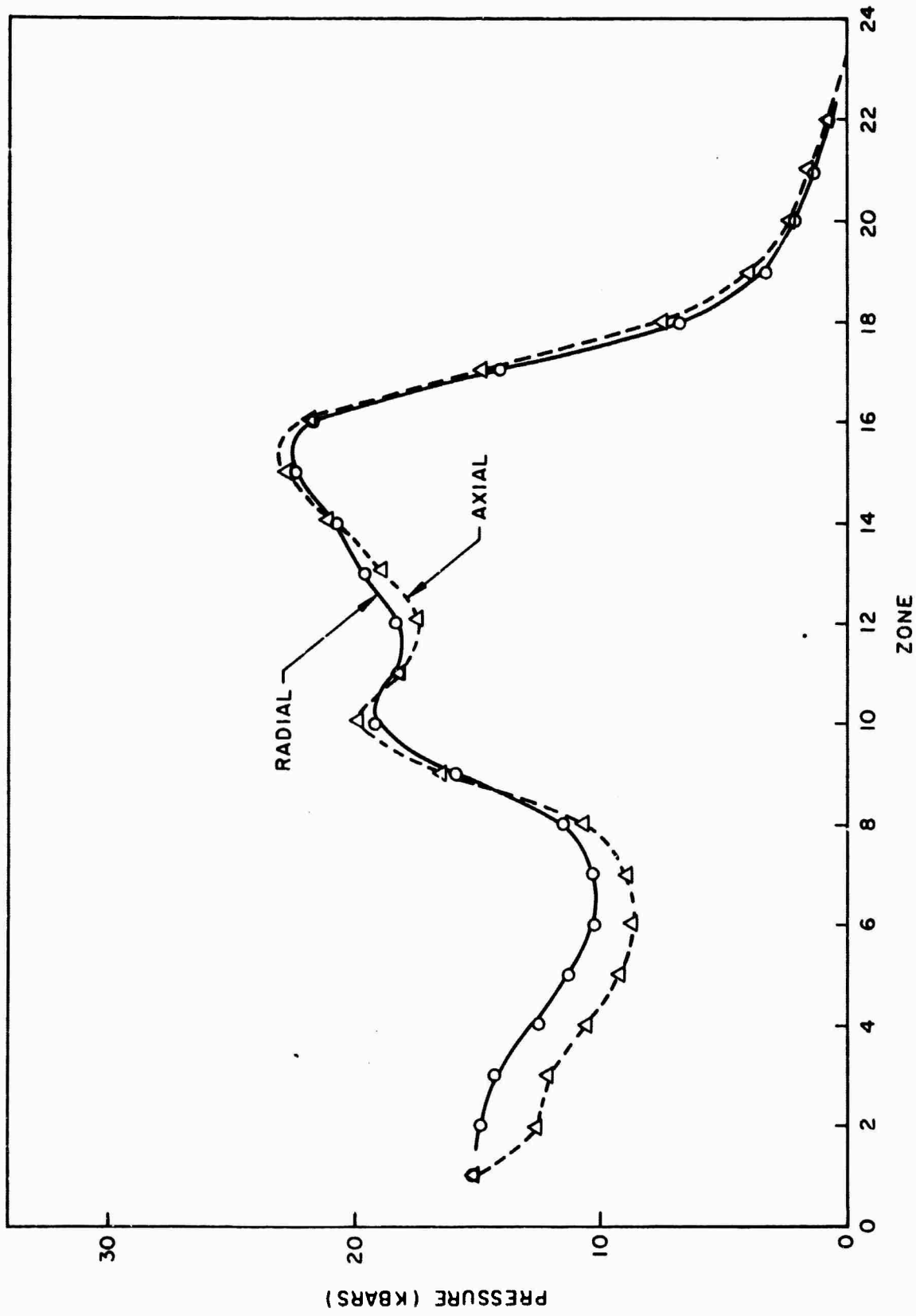


Fig. 10--Computed pressure profiles in the axial and radial directions, for the spherically symmetric problem as treated in cylindrical coordinates

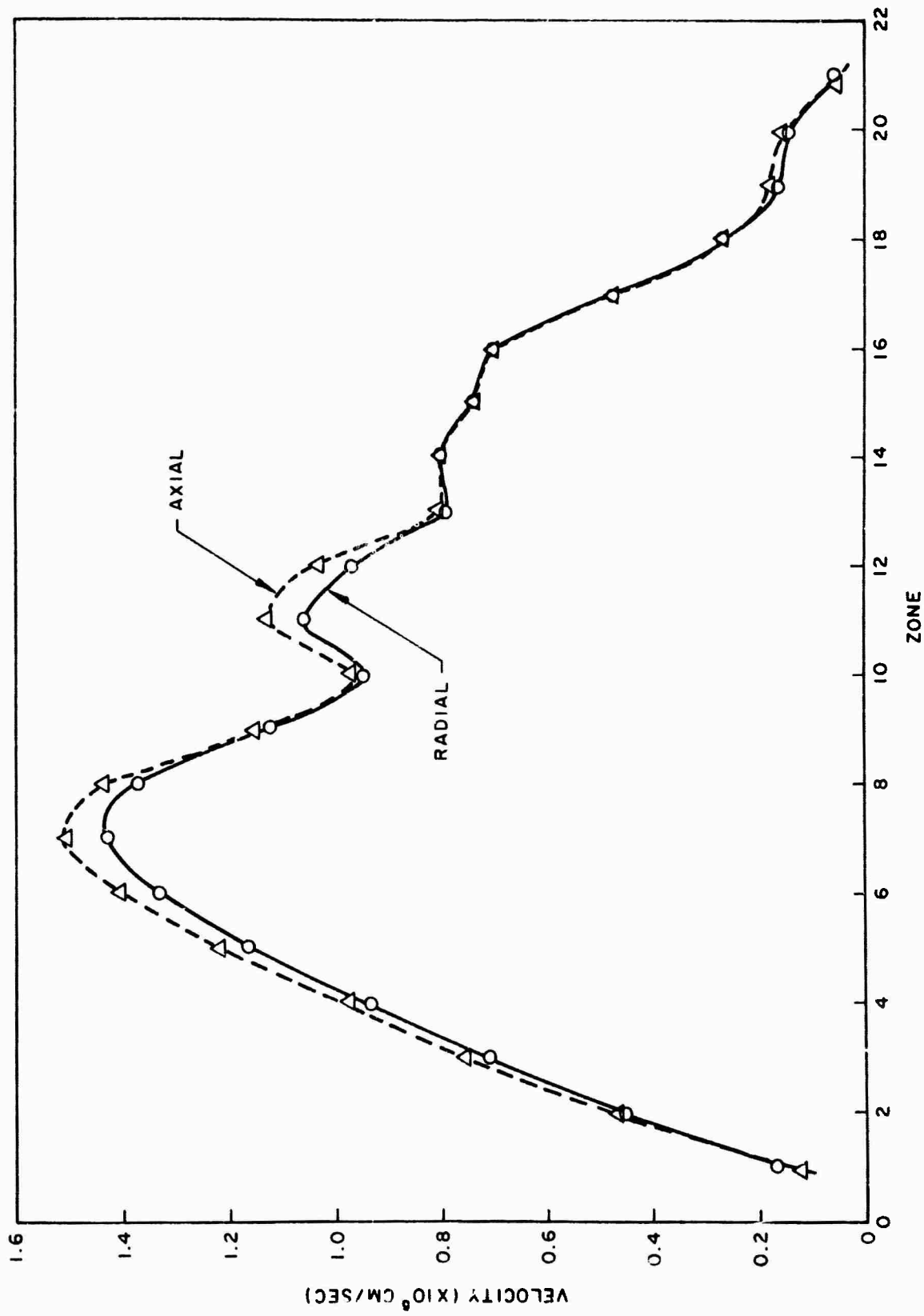


Fig. 11--Computed velocity profiles in the axial and radial directions, for the spherically symmetric problem as treated in cylindrical coordinates

IV. LIST OF REVISED COMMON AND FORTRAN LISTINGS FOR OIL WITH STRENGTH AND VISCOSITY

In the following list of the revised Common, location refers to the location of that symbol relative to the beginning of Common. Since the beginning of Common is assigned the same location for each subroutine, a program (CARDS) is available for changing any word in Common.

If changes are made in the length of the dimensional arrays, it will be necessary to change the locations in the following Common list.

The revised FORTRAN listing for OIL follows the revised Common. Note that the C's denoting explanatory remarks are at the far left margin.

REVISED COMMON

<u>Symbol</u>	<u>Location</u>	<u>No. of Words</u>	<u>Units</u>	<u>Description</u>
XX	151	53	cm	$XX(2) = X(1)$
UR	205	200	None	Note the many equivalence statements
PR	405	200	None	Note the many equivalence statements
YY	605	101	cm	$YY(2) = Y(1)$
AID	706	1	None	Not used, this is a single material code
AIX	707	2500	jerks or ergs/gram	Specific internal energy (X) for cell (K)
AM	3207	130	None	Mass of particle (N) for SHELL code
AMD	3337	1	None	Not used, this is a single material code
AMX	3338	2500	grams	Total (X) mass in cell (K)
AREA	5838	1	None	Tag, used in PH2
BIG	5839	1	sh^{-1} or sec^{-1}	$= dV/dZ$ critical, computed in PH3
BOUNCE	5840	1	None	Tag used in PH2
DDXN	5841	1	ergs or jerks/cm ³	$=$ yield strength for the material
DDVK	5842	1	ergs or jerks/cm ³	$=$ hoop stress for cell (K)
DKE	5843	1	ergs or jerks /cm ³ sec or sh	$= \eta_0 =$ the coefficient of viscosity
DVK	5844	1	sec^{-2} or sh^{-2}	$= DDXN / [\rho_0 DX^2]$
DX	5845	52	cm	$DX(i) = X(i) - X(i-1)$
DY	5897	100	cm	$DY(j) = Y(j) - Y(j-1)$
E	5997	1	None	Used in hoop routine
FD	5998	1	None	Used in hoop routine
FS	5999	1	None	Flag in PH2
FX	6000	1	None	Not used
OUT	6001	1	None	Tag in particle PH2
P	6002	2500	jerks or ergs/cm ³	Material pressure in cell (K)
PABOVE	8502	1	jerks or ergs/cm ³	$= [P(K) + P(\text{cell above})]/2$
PBLO	8503	1	jerks or ergs/cm ³	$= [P(K) + P(\text{cell below})]/2$
PIDTS	8504	1	1/cm sh	$1./[\Delta t \pi DY(j)]$ in PH1, $1./\pi \Delta t$ in PH2
PPABOV	8505	1	None	Not used

PRR	8506	1	jerks or ergs/cm ³	$= [P(K) + P(\text{cell to the right})]/2$
PUL	8507	1	None	Not used
QDT	8508	1	None	Not used
RC	8509	1	cm	$[X(i) + X(i-1)]/2$. in PH1
ReZ	8510	1	None	If material leaves grid in PH2, ReZ set = 1.
RHO	8511	1	gm/cm ³	Density of material in a cell
RL	8512	1	None	Not used
RR	8513	1	cm	$= [X(i) + X(I+1)]/2$. in PH1
SIG	8514	1	cm	Minimum ΔX or ΔY in CDT routine
QOOOFL	8515	1	None	Not used
SWITCH	8516	1	None	Not used
TABLM	8517	1	None	Factor on dV/dZ critical
TAU	8518	52	cm ²	$= \pi (X(i)^2 - X(i-1)^2)$ = area in Z direction
TAUDTS	8570	1	cm ² (sh or sec)	$= \text{TAU}(i) \Delta t$ in PH1
TAUDTX	8571	1	None	Not used
U	8572	2500	cm/sh or/ sec	= R component of velocity in cell (K)
UK	11072	1	cm/sh or/ sec	= R component of velocity in cell (K) used in SHELL transport
URR	11073	1	cm ² /sh or/ sec	$= [U(K) RC + U(K+1) RR]/2$.
UT	11074	1	None	Signal in PH1, decrease Δt next pass
UU	11075	1	sh or sec	New Δt in PH1, for integrating backwards
UUU	11076	1	None	Used in PH3
UTEF	11077	1	cm/sh or/ sec	R velocity component used to move particles in SHELL
UVMAX	11078	1	sh ⁻¹ or sec ⁻¹	Max velocity /Min (ΔX or ΔY)
V	11079	2500	cm/sh or/ sec	Axial (Z) component of velocity for cell (K)
VABOVE	13579	1	cm/sh or/ sec	$[V(K) + V(\text{cell above})]/2$.
VBLO	13580	1	cm/sh or/ sec	$[V(K) + V(\text{cell below})]/2$.
VEL	13581	1	None	Used as tag in PH1 and PH2

VK	13582	1	cm/sh or/ sec	Axial component of velocity in cell (K) for SHELL
VT	13583	1	gram/cm ³	Rezone trigger set if mass of $\rho=VT$ leaves the grid
VTEF	13584	1	cm/sh or sec	Z velocity component used to move particles in SHELL
VV	13585	1	None	Used in PH3
VVABOV	13586	1	jerks/gram or ergs/gram	Minimum specific internal energy allowed as a result of PH3
VVBLO	13587	1	cm/sh or sec	Minimum velocity allowed as a result of PH3
W2	13588	1	None	Not used
W3	13589	1	None	Not used
WPS	13590	1		Working Storage
WS	13591	1		↓
WSA	13592	1		
WSB	13593	1		
WSC	13594	1		
XL	13595	130	cm	R coordinate of particle N
XLW	13725	1	None	Used in velocity weighting for SHELL transport
XN	13726	1	cm	R coordinate of particle N at cycle (n-1)
XR	13727	1	None	Used in velocity weighting for SHELL transport
YL	13728	130	cm	Z coordinate of particle N
YLW	13858	1	None	Used in velocity weighting for SHELL transport
YN	13859	1	cm	Z coordinate of particle N at cycle (n-1)
YU	13860	1	None	Used in velocity weighting for SHELL transport
ZMAX	13861	1	cm	The largest Z value of any particle in SHELL transport
i	13862	1		Indices (working storage)
i1	13863	1		↓
iN	13864	1		
iR	13865	1		
iWS	13866	1		

iWSA	13867	1		Indices (working storage)
iWSB	13868	1		↓
iWSC	13869	1		
iW1	13870	130	None	i of the cell (K) where particle (N) is for SHELL transport
j	14000	1		Indices (working storage)
jN	14001	1		↓
jP	14002	1		
jR	14003	1		
K	14004	1	None	Index of cell defined such that $K = (j-1) iMAX + i+1$
KN	14005	1		Indices (working storage)
KP	14006	1		↓
KR	14007	1		
KRM	14008	1		
L	14009	1		
M	14010	1		
MA	14011	1		
MB	14012	1		
MC	14013	1		
MD	14014	1		
ME	14015	1		
MZ	14016	1	None	Set by input, for length of Z block, also used in EDIT
N	14017	1		Indices (working storage)
NK	14018	1		↓
NKMAX	14019	1		
NK1	14020	1		
NO	14021	1		
NR	14022	1	None	Maximum number of radiation cycles/hydro $NR \leq NRM$
iW2	14023	130	None	= (j) value of cell (K) where particle (N) is used in SHELL transport
X	152	53	cm	$X(i)$ = right dimension of zone (i,j)

UL	205	200
FLEFT	205	200
YAMC	304	100
SIGC	504	100
PL	405	200
GAMC	405	100
TAB	205	15
AMK	220	15
PK	235	15
QK	250	15
Y	606	100
ASN	3207	52
AST	3259	52
ASNB	13595	52
ASTB	13647	52
RSN	13728	52
RST	13780	52
SIG33	13870	52
DUDOT	13922	52
DVDOT	14023	52
DAIX	14075	52
KL	14009	1
KAR	14010	1
KA	14011	1
KAL	14012	1
KBR	14013	1
KB	14014	1
KBL	14015	1

cm

Note
the
equivalence
statements

Note the equivalence statements

Y(j) = top dimension of zone (i,j)
 Array for normal stress at top
 Array for shear stress at top
 Array for normal stress at bottom
 Array for shear stress at bottom
 Array for normal stress at the right
 Array for shear stress at the right
 Array for hoop stress
 Array for the R component of acceleration
 Array for the Z component of acceleration
 Not used

Note the equivalence statements

<u>Location</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
Z(1)	PROB	-	Problem number (if positive, this is an OIL run; If negative, this is a SHELL run.)
Z(2)	CYCLE	-	Cycle number (floating point value)
Z(3)	DT	sh. or sec	$\Delta t_{\text{hydro}} = t^n - t^{(n-1)}$
Z(4)	PRINT3	-	Cycle frequency for short print
Z(5)	PRINTL	-	Cycle frequency for long print
Z(6)	DUMPT7	-	Cycle frequency for binary tape dumps
Z(7)	CSTOP	-	Cycle number at which problem will stop
Z(8)	PIDY	-	$\pi = 3.1415927$
Z(9)	TMZ	gm	Total (x + .) mass at t = 0 (calculated in CLAM code.)
Z(10)	GAM	-	If = 0. (cylindrical geometry); otherwise Cartesian
Z(11)	GAMD	-	$1./(\gamma_- - 1.)$ computed in input routine
Z(12)	GAMX	-	$1./(\gamma_x - 1.)$ computed in input routine
Z(13)	ETH	jerk or erg	Total energy (computed in CLAM for t = 0). Changed in PH1 at transmissive boundaries and in PH2 as mass leaves the grid.
Z(14)	FFA	-	Upper limit for stability and used to calculate Δt , only if CABLN = 0.
Z(15)	FFB	-	Lower limit for stability and used to calculate Δt , only if CABLN = 0.
Z(16)	TMDZ	gm	Total (.) mass at t = 0, calculated in CLAM code
Z(17)	TMXZ	gm	Total (x) mass at t = 0, calculated in CLAM code
Z(18)	XMAX	cm	= x(iMAX)
Z(19)	TXMAX	cm	2(XMAX) at t = 0, calculated in CLAM code
Z(20)	TYMAX	cm	2(YMAX) at t = 0, calculated in CLAM code
Z(21)	AMDM	-	If the density of a cell is less than AMDM times the initial density (ρ_0), strength is bypassed for this cell
Z(22)	AMXM	gm	Minimum particle (x) mass/2. calculated in CLAM
Z(23)	DNN	-	$(ETH - E)^{N-NPC}/ETH$
Z(24)	DMIN	-	If (ECK) > DMIN, problem will stop and the edit routine will call dump
Z(25)	FeF	-	Flag for omitting strength
Z(26)	DTNA	sh. or sec	Δt^{n-1}

<u>Location</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
Z(27)	CVIS	-	If < 0, bottom boundary is transmittive; otherwise it is reflective.
Z(28)	NPR	-	Index (working storage)
Z(29)	NPRi	-	Index (working storage)
Z(30)	NC	-	Cycle number (fixed point)
Z(31)	NPC	-	Number of cycles between short prints
Z(32)	NRC	-	Index
Z(33)	iMAX	-	Maximum number of zones in the R direction
Z(34)	iMAXA	-	iMAX + 1
Z(35)	jMAX	-	Maximum number of zones in the Z direction
Z(36)	JMAXA	-	jMAX + 1
Z(37)	KMAX	-	(iMAX)(jMAX) + 1
Z(38)	KMAXA	-	KMAX + 1
Z(39)	NMAX	-	Total number of particles + 1, generated in CLAM, for SHELL problems only.
Z(40)	ND	-	Total number of (.) particles + 1, generated in CLAM
Z(41)	KDT	-	If = 0, Δt has changed, if $\neq 0$, Δt remains constant
Z(42)	ixMAX	-	Not used
Z(43)	NOD	-	Index
Z(44)	NOFP	-	Index
Z(45)	NiMAX	-	New iMAX before adding new zones
Z(46)	NjMAX	-	New jMAX before adding new zones
Z(47)	i1	-	Maximum i disturbance
Z(48)	i2	-	Maximum j disturbance
Z(49)	i3	-	Not used
Z(50)	i4	-	Not used
Z(51)	N1	-	Scratch tape number for particles if this is a SHELL run
Z(52)	N2	-	Scratch tape number for particles if this is a SHELL run
Z(53)	N3	-	Number of particle records generated if this is a SHELL run
Z(54)	N4	-	Number of particles - 1 per record (MAX = 127) if this is a SHELL run
Z(55)	N5	-	Not used

<u>Location</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
Z(56)	N6	-	Number of particles on last particle record if this is a SHELL run
Z(57)	N7	-	Not used
Z(58)	N8	-	Not used
Z(59)	N9	-	Not used
Z(60)	N10	-	= i value of zone that is controlling Δt
Z(61)	N11	-	= j value of zone that is controlling Δt
Z(62)	NRM	-	= maximum number of radiation cycles/hydro cycle, input number
Z(63)	TRAD	sh.	= $NR \cdot \Delta t \text{ RAD} = \Delta t \text{ HYDRO}$
Z(64)	XNRG	jerk or erg	Total energy of (x) material
Z(65)	SN	-	If = 0, code will decrease Δt to correct for $I < 0$, otherwise those $I < 0$ are left alone
Z(66)	DXN	-	Cutoff for the stresses
Z(67)	RADER	gm- cm/sh	Total positive radial momentum ((x) only)
Z(68)	RADET	"	Total positive axial momentum ((x) only)
Z(69)	RADEB	"	Total positive radial momentum (x) for material under the target
Z(70)	DTRAD	-	Not used
Z(71)	REZFCT	-	If = 0, 1H2 will not trigger rezone.
Z(72)	RSTOP	-	Factor for converting units for energy
Z(73)	SHELL	-	Factor for converting units for speed of sound calculation
Z(74)	BBOUNL	-	Not used in this version
Z(75)	TOZONE	gm/cm ³	Minimum density for mass flow at the free surface. The mass flux is held up unless it produces a density that is > than TOZONE
Z(76)	ECK	-	$\left[\left(\frac{ETH - E}{ETH} \right)^N - \left(\frac{ETH - E}{ETH} \right)^{N-NPC} \right] / NPC$
Z(77)	SBOUND	-	Fraction of Λ in mass weighting velocity
Z(78)	X1	cm/sh ²	Acceleration (R direction) due to the stresses
Z(79)	X2	cm/sh ²	Acceleration (Z direction) due to the stresses
Z(80)	Y1	-	Not used
Z(81)	Y2	-	Not used

<u>Location</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
Z(82)	CABLX	-	If < 0, code controls Δt but, at Z(139) of instability
Caution: You must load a Δt for this option. This holds if SN $\neq$ 0			If = 0, code controls the Δt, decreasing Δt if $\left \frac{U \Delta t}{\Delta x} \right$ or $\left \frac{V \Delta t}{\Delta y} \right$ exceed FFA and increasing Δt if less than FFB If greater than 0, Δt will remain constant
Z(83)	VISC	jk/g	The change (ΔI) due to the stresses
Z(84)	T	sh or sec	Total time up to cycle N, $t^n = t^{n-1} + \Delta t$
Z(85)	GMAX	-	Maximum of γ_x or γ_y
Z(86)	WSGD	-	γ_y
Z(87)	WSGX	-	γ_x and ($\gamma_{max}-1$) in the CDT routine
Z(88)	GMADR	-	$\gamma_y / (\gamma_y - 1.)$
Z(89)	GMAXR	-	$\gamma_x / (\gamma_x - 1.)$
Z(90)	S1	sh ⁻¹ or sec ⁻¹	du/dR
Z(91)	S2	"	dv/dR
Z(92)	S3	"	du/dZ
Z(93)	S4	"	dv/dZ
Z(94)	S5	"	u/R
Z(95)	S6	"	du/dZ
Z(96)	S7	"	dv/dZ
Z(97)	S8	"	du/dR
Z(98)	S9	"	dv/dR
Z(99)	S10	"	u/R
Z(100)		g	Mass thrown away (PH2) if any cell has a $\rho < \text{TOZONE}$
Z(101)		jk or erg	Total energy of this mass thrown away.
Z(102)		g-cm/sh	Total radial momentum of this mass thrown away
Z(103)		"	Total axial momentum of this mass thrown away
Z(104)		jk or erg	Energy (internal) added to system when the internal is set to 0. if I < 0. (PH2)
Z(105)	SNL	jk or erg/cm ³	The normal stress at the left boundary of cell (K)
Z(106)	STL	"	The shear stress at the left boundary of cell (K)
Z(107)		sh ⁻¹ or sec ⁻¹	Velocity gradient cutoff

<u>Location</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
Z(108)		-	Not used
Z(109)		-	Not used
Z(110)		jk or erg/g	Critical energy E_S , same value as Z(122) used in PH2
Z(111)		g/cm ³	Initial density (ρ_0) of the material
Z(112)		cm/sh or sec	Initial velocity of the projectile
Z(113)		-	Not used
Z(114)		-	Not used
Z(115)		g/cm ³	Density (ρ_0)
Z(116)		-	a
Z(117)		jk/g	E_0
Z(118)		-	b
Z(119)		jk/cm ³	A
Z(120)		-	V_S
Z(121)		-	-
Z(122)		jk/g	E_S
Z(123)		-	α
Z(124)		-	β
Z(125)		-	-
Z(126)		jk/cm ³	B
Z(127)	SS1	-	For equation of state
Z(128)	SS2	-	
Z(129)	SS3	-	
Z(130)	SS4	-	
Z(131)	SS5	-	
Z(132)	SS6	-	
Z(133)	SS7	-	
Z(134)	SS8	-	
Z(135)	SS9	-	
Z(136)	SS10	-	
Z(137)	SS11	-	
Z(138)		g/cm ³	Density check; if $\rho(K) < Z(138)$, the stability check for cell (K) is bypassed

<u>Location</u>	<u>Symbol</u>	<u>Units</u>	<u>Description</u>
Z(139)		-	Percent of instability, used in CDT if $CABL_N < 0$
Z(140)	SNR	jk or erg, cm ³	The normal stress at the right boundary of cell K
Z(141)	STR	"	The shear stress at the right boundary of cell K
Z(142)	SNT	"	The normal stress at the top boundary of cell K
Z(143)	STT	"	The shear stress at the top boundary of cell K
Z(144)	SNB	"	The normal stress at the bottom of cell K
Z(145)	STB	"	The shear stress at the bottom of cell K
Z(146)		-	Not used
Z(147)		-	The j interface (projectile-target)
Z(148)	A	10 ⁵ cm/sec	
Z(149)	B	-	$C = A + BP^6$ where $A = C_0$ and P is pressure in megabars
Z(150)	c	-	

REVISED FORTRAN LISTING
FOR OIL

4(Z(55),N5),	(Z(56),N6),	(Z(57),N7),	(Z(58),N8),	PH2 0570
5(Z(59),N9),	(Z(60),N10),	(Z(61),N11),	(Z(62),NRM),	PH2 0580
6(Z(63),TRAD),	(Z(64),XNRG),	(Z(65),SN),	(Z(66),DXN),	PH2 0590
7(Z(67),RADER),	(Z(68),RADET),	(Z(69),RADEB),	(Z(70),DTRAD),	PH2 0600
8(TZET,REZFACT),	(Z(72),RSTOP),	(Z(73),SHELL),	(Z(74),BBOUND),	PH2 0610
9(Z(75),TOZONE),	(Z(76),ECK),	(Z(77),SBOUND),	(Z(78),X1)	PH2 0620
OEQUIVALENCE	(Z(79),X2),	(Z(80),Y1),	(Z(81),Y2),	PH2 0630
1(Z(82),CABL),	(Z(83),VISC),	(Z(84),T),	(Z(85),GMAX),	PH2 0640
2(Z(86),WSGD),	(Z(87),WSGX),	(Z(88),GMADR),	(Z(89),GMAXR),	PH2 0650
3(Z(90),S1),	(Z(91),S2),	(Z(92),S3),	(Z(93),S4),	PH2 0660
4(Z(94),S5),	(Z(95),S6),	(Z(96),S7),	(Z(97),S8),	PH2 0670
5(Z(98),S9),	(Z(99),S10)			PH2 0680

EQUIVALENCE(Z(127),SS1),(Z(128),SS2),(Z(129),SS3),(Z(130),SS4),
 1(Z(131),SS5),(Z(132),SS6),(Z(133),SS7),(Z(134),SS8),(Z(135),SS9),
 2(Z(136),SS10),(Z(137),SS11)

EQUIVALENCE(Z(140),SNR),(Z(141),STR),(Z(142),SNT),
 1(Z(143),STT),(Z(144),SNB),(Z(145),STB)

OEQUIVALENCE	(XX(2),X(1)),	(UR,UL,FLEFT),	(UR(100),YAMC),	PH2 0690
1(PR(100),SIGC),	(PR,PL,GAMC),	(UR,TAB),		PH2 0700
2(UR(16),AMK),	(UR(31),PK),	(UR(46),QK),	(YY(2),Y(1))	PH2 0720

EQUIVALENCE(AM,ASN),(AM(53),AST),(XL,ASNB),
 1(XL(53),ASTB),(YL,RSN),(YL(53),RST),(IW1,SIG33),
 2(IW1(53),DU DOT),(IW2,DV DOT),(IW2(53),DAIX)
 EQUIVALENCE(L,KL),(M,KAR),(MA,KA),(MB,KAL),
 1(MC,KBR),(MD,KB),(ME,KBL)
 EQUIVALENCE (Z(105),SNL),(Z(106),STL)

PH2 0730
 PH2 0740
 PH2 0760
 MAIN0020
 MAIN0030
 MAIN0050

***** NOTE 1 MATERIAL ONLY (X) *****

INPUT READS OIL DUMP TAPE OR
 WILL CALL SUBROUTINE SET'UP WHICH
 WILL MAKE A DUMP TAPE FOR CERTAIN TYPES OF PROBLEM
 (SEE SECTION ON SET'UP)
 ALSO CALCULATES DX AND DY AND EQUATION OF STATE DATA
 CALL INPUT

MAIN0060

CDT ROUTINE CALCULATES DT(HYDRO TIME STEP)
 AND PRESSURES, ADVANCE CYCLE NO. ETC.

10 CALL CDT

MAIN0070

IN EDIT, DETERMINE WHETHER TO EXECUTE A LONG
 PRINT, A SHORT PRINT, A TAPE DUMP, ETC. AND
 CALCULATE TOTAL ENERGY IN SYSTEM(COMPARE
 WITH ETH) TOTAL MASS, INTEGRATE TOTAL
 COMPONENTS OF MOMENTA.

CALL EDIT

MAIN0080

CALL SLITET(1,K000FX)

MAIN0090

SENSE LITE 1 SIGNIFIES THIS

```

C      IS THE LAST CYCLE OF THIS RUN $$$$$$$$$$$$$$$$
C      LITE TURNED ON IN THE EDIT ROUTINE *****
C      GO TO(30,20),K000FX
C      PH1, INTEGRATE THE MOMENTA EQS. INTEGRATE
C      ENERGY EQUATION(ONLY CHANGES DUE TO WORK
C      TERMS). NO MOVEMENT OF MASS HERE
20 CALL PH1
C      ***** PH3 CALCULATES THE CHANGE IN THE VELOCITY
C      COMPONENTS AND INTERNAL ENERGY DUE TO THE
C      STRESSES ACTING ON THE CELL ...
C      CALL PH3
C      TRANSPORT MASS ACROSS BOUNDARIES (SOLVE
C      MASS TRANSPORT EQ.) TRANSPORT TERMS IN
C      THE MOMENTA AND ENERGY EQS. LEFT OUT OF
C      PH1, HERE APROXIMATED BY MASS MOVEMENT. CONSERVE
C      MASS, MOMENTA AND TOTAL ENERGY.
C      CALL PH2
C
C
C      GO TO 10
30 CALL EXIT
END

```

```

$IBFTC CARDS  LIST,DECK,REF
      SUBROUTINE CARDS
      DIMENSION TABLE(1),CARD(7),LABEL(1)
MAIN010(      COMMON      TABLE
C          A 2 IN COLUMN 1, ROUTINE WILL FIX THE
C          FLOATING PT. NO.
C          A 1 IN COLUMN 1, MEANS THIS IS LAST CARD TO
MAIN011(      C          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+I-1
      IF(IEND-2)2,5,2
5 LABEL(J)=IFIX(CARD(I))
      GO TO 4
MAIN012(      2 TABLE(J)=CARD(I)
MAIN013(      4 CONTINUE
MAIN014(      IF(IEND-1)1,3,1
MAIN015(      3 RETURN
MAIN016(      C          FORMATS
MAIN017(      10 FORMAT(20H1  RPM  INPUT CARDS///)
      11 FORMAT(11,15,11,OP7E9.4)
      12 FORMAT(1H 14,17,13,1P7E14.6)
      END

```

```

      $IBFTC SETUP  LIST,DECK,REF
      SUBROUTINE SETUP
C      WILL ONLY GENERATE (1) MATERIAL.
C      PACKAGES MUST BE RECTANGLES.
CARD0010 C      ASSUMPTION OF = DX AND = DY
CARD0020 C      LOAD PK(4)=1.
CARD0030 C      M=PK(4)
C      LOAD PK(5)=RIGHT BOUNDARY OF PELLET(1).
C      MA=PK(5)
C      LOAD PK(6)=BOTTOM(J)+1 OF PELLET.
C      MB=PK(6)
CARD0050 C      LOAD PK(7)=TOP(J) OF PELLET.
CARD0070 C      MC=PK(7)
CARD0080 C      LOAD PK(8)=1.
CARD0090 C      MD=PK(8)
CARD0100 C      LOAD PK(9)=RIGHT(1) BOUNDARY OF TARGET.
CARD0110 C      ME=PK(9)
CARD0120 C      LOAD PK(10)=BOTTOM(J)+1 OF TARGET.
CARD0130 C      MZ=PK(10)
CARD0140 C      LOAD PK(11)=TOP(J) OF TARGET.
CARD0150 C      N=PK(11)
CARD0160 C      LOAD INITIAL DENSITY INTO Z(111).
CARD0170 C      RHO=Z(111)
CARD0180 C      LOAD INITIAL PELLET VELOCITY INTO Z(112).
CARD0190 C      VTEF=Z(112)
CARD0210 C      KMAX=IMAX*JMAX+1
CARD0220 C      KMAXA=KMAX+1
CARD0230 C      JMAXA=JMAX+1
C      IMAXA=IMAX+1
C      CLEAR ALL CELL ARRAYS.
C      DO 1 K=1,KMAX
C      U(K)=0.0
C      V(K)=0.0
C      P(K)=0.0
C      AMX(K)=0.0
C      AIX(K)=0.0
1 CONTINUE
C      DX(1)=DX(1)
C      X(1)=DX(1)
C      WS=X(1)**2
C      IF(GAM) 4,2,4
4 PIDY=1.
C      TAU(1)=DX(1)
C      GO TO 3
2 PIDY=3.1415927
C      TAU(1)=WS*PIDY
C      CALCULATE DX,X,TAU
3 DO 10 I=2,IMAX
C      X(I)=X(I-1)+DX(1)
C      DX(I)=DX(1)

```

```

      WSA=X(I)**2
      IF(GAM)5,6,5
SETU0010  5 TAU(I)=DX(I)
      GO TO 10
      6 TAU(I)=PIDY*(WSA-WS)
SETU0980  WS=WSA
      10 CONTINUE
SETU0990  Y(1)=DY(1)
      C  CALCULATE DY AND Y.
SETU1000  DO 20 J=2,JMAX
      Y(J)=Y(J-1)+DY(1)
SETU1010  DY(J)=DY(1)
      20 CONTINUE
SETU1020  ETH=0.0
      DO 30 I=M,MA
SETU1030  K=(MB-1)*IMAX+I+1
      C  CALCULATE MASS, AND VELOCITY OF PELLET.
SETU1040  DO 40 J=MB,MC
      AMX(K)=RHO*DY(J)*TAU(I)
SETU1050  V(K)=VTEF
      C  CALCULATE TOTAL ENERGY (ETH.)
SETU1060  ETH=ETH+AMX(K)*(V(K)**2)/2.0
      40 K=K+IMAX
SETU1070  30 CONTINUE
      C  CALCULATE MASS OF TARGET.
SETU1080  DO 50 I=MD,ME
SETU1090  K=(MZ-1)*IMAX+I+1
SETU1100  DO 60 J=MZ,N
SETU1110  AMX(K)=RHO*DY(J)*TAU(I)
SETU1120  60 K=K+IMAX
      50 CONTINUE
SETU1130  IMAX=IMAX
SETU1140  JMAX=JMAX
SETU1150  SHELL=2.0
SETU1160  CYCLE=0.0
SETU1170  DT=0.0
SETU1180  NMAX=0
SETU1190  N1=2
SETU1200  N2=3
SETU1210  N3=0
SETU1220  N4=127
      XMAX=X(IMAX)
      TXMAX=XMAX*2.0
      YMAX=Y(JMAX)
      TYMAX=YMAX*2.0
      REWIND 7
SETU1240  WS=555.0
      C  WRITE OUTPUT FOR OIL ON TAPE.
      WRITE (7)WS,CYCLE,N3
SETU1260  WRITE (7)(Z(I),I=1,150)
SETU1270

```

```
SETU1280      WRITE ( 7)(U(I),V(I),AMX(I),AIX(I),P(I),I=1,KMAXA)
               WRITE ( 7)X(0),(X(I),TAU(I),I=1,IMAX)
               WRITE ( 7)(Y(I),I=0,JMAX)
               WS=666.0
               WRITE ( 7)WS,WS,WS
SETU1300      REWIND 7
SETU1310      RETURN
SETU1320      END

SETU1330
SETU1340
SETU1350
SETU1360
SETU1370
SETU1380
SETU1390

SETU1400
SETU1410
SETU1420

SETU1430
SETU1440
SETU1450

SETU1460
SETU1470
SETU1480
SETU1490
SETU1500
SETU1510
SETU1520
SETU1530
SETU1540
SETU1550
SETU1560
SETU1570
SETU1580
SETU1590
SETU1600
SETU1610
SETU1620
SETU1630
SETU1640
SETU1650

SETU1670
```

\$IBFTC INPUT LIST,DECK,REF
SUBROUTINE INPUT

C		INPU0010
C		INPU0760
C		INPU0900
C	TURN ON SENSE LITE 3.	
C	CALL SLITE (3)	INPU0980
C		INPU0990
C	READ HEADER CARD (COLUMNS 2-72).	
C	READ (5,8004)IWS	INPU1000
C	WRITE (6,8004)IWS	INPU1010
C	CALL DATA.	
C	6 CALL CARDS	INPU1020
C	IF PK(3) = OR GREATER THAN ZERO, CALL ROUTINE	
C	SET-UP, OTHERWISE, BINARY OIL TAPE HAS BEEN MADE.	
C	READ IN DATA FROM OIL DUMP TAPE, OR	
C	GENERATE A DUMP TAPE FOR OIL, AND	
C	CALCULATE DX AND DY FROM THE X AND	
C	Y VALUES FROM TAPE.	
C	IF(PK(3))8887,8888,8888	INPU1030
C	8888 CALL CARDS	INPU1040
C	CALL SETUP	INPU1050
C	8887 CONTINUE	INPU1060
C		INPU1070
C		INPU1080
C	READ TAPE	
C	GO READ BINARY TAPE.	
C	GO TO 1000	INPU1090
C		INPU1100
C	READ IN REMAINING INPUT CARDS	INPU1110
C	10 CONTINUE	INPU1120
C	CALL CARDS	INPU1130
C	GO TO 2000	INPU1140
C		INPU1150
C	SET THE PRESSURES TO ZERO.	
C	40 DO 45 K=1,KMAXA	INPU1160
C	45 P(K)=0.0	INPU1170
C	INTEGRATE BACKWARDS ON CYCLE, TIME AND NO. OF	
C	CYCLES BETWEEN ENERGY CHECK, SINCE THESE	
C	ARE ADVANCED IN CDT.	
C	NOTE, RSTOP = ENERGY FACTOR AND	
C	SHELL = FACTOR ON SPEED OF SOUND CALC.	
C	CONVERT FROM JERKS TO ERGS.	
C	Z(117)=Z(117)*RSTOP	
C	Z(119)=Z(119)*RSTOP	
C	Z(122)=Z(122)*RSTOP	
C	Z(126)=Z(126)*RSTOP	
C	Z(110)=Z(110)*RSTOP	
C	RSTOP=1.0	INPU1178
C	T=T-DTNA	INPU1180
C	NC=NC-1	INPU1190
C	IF(Z(149))3000,3001,3000	

3000	Z(148)=SQRT(Z(119)/Z(115))	
	Z(149)=Z(149)*SHELL	
	SHELL=1.0	INPU1200
3001	CYCLE=NC	
	NPC=NPC-1	INPU1210
	UVMAX=0.0	INPU1220
C	CALCULATE THE DX'S, SINCE THESE ARE NOT ON	
C	TAPE.	
	DO 50 I=1,IMAX	INPU1230
50	DX(I)=X(I)-X(I-1)	INPU1240
C	CALCULATE THE DY'S, SINCE THESE ARE NOT ON	
C	TAPE.	
	DO 55 J=1,JMAX	INPU1250
55	DY(J)=Y(J)-Y(J-1)	INPU1260
	J=MZ-8	
C	PRINT 2 BLOCK.	
62	DO 80 I=1,J,8	
	K=I+7	INPU1290
	DO 65 J=I,K	INPU1300
	IF(Z(J))70,65,70	INPU1310
65	CONTINUE	INPU1320
	GO TO 80	INPU1330
70	K=I+7	INPU1340
	WRITE (6,8111)I,(Z(I),L=I,K)	INPU1350
80	CONTINUE	INPU1360
C		
C	ASSUMPTION THAT ALL DX AND DY ARE =	
C	NOTE, DVK=K(0)/(RHO(0)*DX SQ.)	
	WS=DX(1)*DX(1)	
	DVK=DDXN/(Z(111)*WS)	
C		
	GO TO 10000	INPU1370
C		INPU1380
C		INPU1390
C		INPU1400
C	READ BINARY TAPE.	
1000	MZ=150	INPU1410
	IWS=0	INPU1420
1003	REWIND 7	
1004	READ(7)PR(1),PR(2),N3	
	NR=N3+5	INPU1450
1006	IF(PR(1)-555.0)1010,1016,1010	INPU1460
1010	IWS=IWS+1	INPU1470
1011	IF(MOD(IWS,3))9902,9902,1003	INPU1480
1016	IF(PR(2))1010,1018,1018	INPU1490
C	CHECK HERE FOR THE CORRECT CYCLE NUMBER.	
1018	IF(PR(2)-PR(2))1023,1023,1020	INPU1500
C	SKIP OVER, LOOK AT NEXT CYCLE.	
1020	DO 1022 L=2,NR	INPU1510
1022	READ(7)	

GO TO 1004	INPU1530
1023 READ(7)(Z(I),I=1,MZ)	
C CHECK FOR THE CORRECT PROBLEM NO.	
IF(ABS(PROB-PK(1))-0.01)1024,1024,9901	INPU1550
1024 READ(7)(U(I),V(I),AMX(I),AIX(I),P(I),I=1,KMAXA)	
READ(7)(X(I),TAU(I),I=1,IMAX)	
READ(7)(Y(I),I=0,JMAX)	
1025 CONTINUE	INPU1650
1034 READ(7)PR(1),PR(2),PR(3)	
1036 IF(PR(1)-555.0)9904,1040,1038	INPU1680
1038 IF(PR(2)-666.0)9905,1040,9905	INPU1690
1040 GO TO 10	INPU1700
C**** END OF READ TAPE ****	INPU1710
C	INPU1720
C	INPU1730
C CALCULATE MAX. GAMMA AND GAMMA/(GAMMA-1.).	
C	INPU1740
2000 IF(WSGX)9906,2010,2005	INPU1750
2005 GAMX=1.0/(WSGX-1.0)	INPU1760
2010 WSGX=(GAMX+1.0)/GAMX	INPU1770
GMAXR=GAMX*WSGX	INPU1780
2012 IF(WSGD)9907,2020,2015	INPU1790
2015 GAMD=1.0/(WSGD-1.0)	INPU1800
2020 WSGD=(GAMD+1.0)/GAMD	INPU1810
GMADR=GAMD*WSGD	INPU1820
GMAX=WSGD	INPU1830
IF(WSGD-WSGX)2025,2030,2030	INPU1840
2025 GMAX=WSGX	INPU1850
2030 GO TO 40	INPU1860
C**** END OF R E S ****	INPU1870
C	INPU1880
C	INPU1890
C ERROR	INPU1900
9901 NK=1023	INPU1910
GO TO 9999	INPU1920
9902 NK=1011	INPU1930
GO TO 9999	INPU1940
9904 NK=1036	INPU1950
GO TO 9999	INPU1960
9905 NK=1038	INPU1970
GO TO 9999	INPU1980
9906 NK=2000	INPU1990
GO TO 9999	INPU2000
9907 NK=2012	INPU2010
9999 NR=1	INPU2020
CALL DUMP	INPU2030
C	INPU2040
10000 RETURN	INPU2050
C	INPU2060
C FORMATS	INPU2070

8000 FORMAT(7E10.3,12)
80040FORMAT(11,71H
1
8111 FORMAT(14,8014)
C
END

INPU20
INPU20
INPU21
INPU21
INPU21
INPU21

\$
C
C
C
C
C
C
C

C
C
C

C
C

C
C
C
C
C

CDT 0010
CDT 0020
CDT 0990
CDT 1000
CDT 1010
CDT 1020

CDT 1030
CDT 1040
CDT 1050
CDT 1060
CDT 1070
CDT 1080
CDT 1090
CDT 1100

CDT 1110

CDT 1120

CDT 1130

CDT 1140

CDT 1150

CDT 1160

CDT 1170

CDT 1180

CDT 1190

CDT 1200

CDT 1210

CDT 1220

CDT 1230

CDT 1240

CDT 1250

CDT 1260

CDT 1270

CDT 1280

CDT 1290

CDT 1300

CDT 1310

CDT 1330

3205	WS=WS/SIG	CDT 1350
3210	IF(UVMAX-WS)3215,3220,3220	CDT 1360
3215	N10=I	CDT 1370
	N11=J	CDT 1380
	UVMAX=WS	CDT 1390
3220	CONTINUE	
C	EULERIAN CHECK FOR RADIAL PARTICLE VELOCITY.	
1	IF(GAM)2,3,2	
3	WS=ABS(U(K))/TAU(I)*X(I)/.5*PIDY	CDT 1420
	GO TO 3225	CDT 1430
C	FOR CARTESIAN CODE	
2	WS=ABS(U(K))/DX(I)	CDT 1440
3225	IF(UVMAX-WS)3230,3235,3235	CDT 1450
3230	UVMAX=WS	CDT 1460
	N10=I	CDT 1470
	N11=J	CDT 1480
3235	WS=ABS(V(K))/DY(J)	CDT 1490
3240	IF(UVMAX-WS)3245,3250,3250	CDT 1500
3245	N10=I	CDT 1510
	N11=J	CDT 1520
	UVMAX=WS	CDT 1530
3250	CONTINUE	CDT 1540
3255	K=K+IMAX	CDT 1550
	IF(UVMAX)9912,9912,3260	
C	FOR OPTIONS ON CABLN, CHECK	
C	SECTION 3.4 IN GAMD-5580.	
3260	IF(CABLN)90,91,3300	CDT 1560
90	DT=.5/VEL/UVMAX*Z(139)	CDT 1570
	GO TO 3295	CDT 1580
91	WS=UVMAX*DT	CDT 1590
	WSA=0.5/VEL	CDT 1600
3265	IF(FFA-WSA)3276,3276,3270	CDT 1610
3270	FFA=WSA	CDT 1620
3276	IF(WS-FFA)3285,3300,3280	CDT 1630
3280	DT=DT/WS*FFB/0.9	CDT 1640
	GO TO 3295	CDT 1650
3285	IF(WS-FFB)3290,3290,3300	CDT 1660
3290	DT=DT*FFA/WS*0.9	CDT 1670
3295	KDT=0	CDT 1680
C	INTEGRATE THE TIME AND CYCLE COUNTER.	
3300	T=T+DTNA	CDT 1690
85	IF(DTRAD)9911,80,81	CDT 1700
80	NR=NRM	CDT 1710
84	WS=NR	CDT 1720
	TRAD=DT/WS	CDT 1730
	GO TO 82	CDT 1740
81	IWS=DT/DTRAD	CDT 1750
	NR=IWS+1	CDT 1760
83	IF(NR-NRM)84,84,80	CDT 1770
82	NC=NC+1	CDT 1780

CYCLE=NC		CDT 1790
NPC=NPC+1		CDT 1800
3305 IF(T)9909,3320,3310		CDT 1810
3310 IF(KDT)9910,3315,3320		CDT 1820
3315 WRITE (6,8000)T,DTNA,DT		CDT 1830
3320 DTNA=DT		CDT 1840
GO TO 3325		CDT 1850
C NEGATIVE MASS		CDT 1860
9901 NK=3020		CDT 1870
GO TO 9999		CDT 1880
9909 NK=3305		CDT 1890
GO TO 9999		CDT 1900
9910 NK=3310		CDT 1910
GO TO 9999		CDT 1920
C THE DT WILL BE 0. OR NEGATIVE ,STOP		
9912 NK=1		
GO TO 9999		
9911 NK=85		CDT 1930
9999 NR=2		CDT 1940
CALL DUMP		CDT 1950
3325 RETURN		CDT 1960
80000FORMAT (17HOCHANGE DT ... T=1PE9.3,11H	DT(N)=1PE9.3,13H	DTCDT 1970
1(N+1)=1PE9.3)		CDT 1980
END		CDT 1990

```

.SIBFTC PH1      LIST,DECK,REF
SUBROUTINE PH1

```

PH1 001
PH1 090

C
C VELOCITIES, ENERGIES, PRESSURES ARE AT THE
C CENTER OF THE CELL.
C (2) PASSES THRU PH1 ARE REQUIRED. NO
C MASS IS MOVED IN PH1.
C ***** NOTE 1 MATERIAL ONLY (X) *****

PH1 098
PH1 099

=====

PH1 101
PH1 102

```

C      NRT=0
C      NRC=0
C      UU=1.E+15
C      UT=0.0
C      YOU WILL GET BACK HERE IF AIX WAS LESS
C      THAN 0. AND PROVIDED SN=0.

```

PH1 103
PH1 104
PH1 105

```

      8000 VEL=1.0
C      INITIALIZE MID-POINTS OF FIRST AND SECOND
C      CELL IN R DIRECTION.
      IF(GAM)9000,3301,9000

```

PH1 1070
PH1 1080

```

9000 RC=1.
      RR=RC
      GO TO 3304
3301 RC=DX(1)/2.0
      RR=(X(1)+X(2))/2.0
3304 K=2
C     AXIS OF SYMMETRY BOUNDARY CONDITIONS.
      DO 3302 J=1,JMAX
      PL(J)=P(K)
      UL(J)=0.0

```

PH1 109

```

3302 K=K+IMAX
C     FIRST PASS THRU, CALCULATE U AND V AT
C     CYCLE N+1, AND THE WORK TERMS USING U AND V
C     FROM CYCLE N.
C     SECOND PASS THRU, CALCULATE ONLY THE
C     CONTRIBUTION TO THE CHANGE IN INTERNAL ENERGY
C     FROM WORK TERMS EVALUATED FROM U AND V
C     AT CYCLE N+1.

```

PH1 1100
PH1 1110
PH1 1120

```

DO 3360 I=1,I1
K=I+1
IF(CVIS)7002,7003,7003
C  BOTTOM BOUNDARY IS TRANSMISSIVE.

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PH1 113
PH1 114

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7002 VBLO=V(K)
      PBLO=0.0
      GO TO 7004
C      BOTTOM BOUNDARY IS REFLECTIVE.

```

PH1 116

PH1 117
PH1 118

PHI 120

PH1 121
PH1 122

7003	VBLO=0.0	PH1 1230
	PBLO=P(K)	PH1 1240
7004	TAUDTS=TAU(I)*DT	PH1 1250
C	I1= MAX.(I) OF DISTURBANCE IN R DIRECTION.	
C	I2= MAX(J) OF DISTURBANCE IN Z DIRECTION.	
C	DO LOOP IN J DIRECTION	
	DO 3348 J=1,I2	PH1 1260
	PIDTS=1.0/(PIDY*DT*DY(J))	PH1 1270
	IF(GAM)9002,9004,9002	
9002	PIDTS=2.*PIDTS	
C	K= INDEX OF CELL IN QUESTION.	
C	N= INDEX OF CELL ABOVE.	
9004	N=K+IMAX	
3305	IF(AMX(K))9902,3340,3306	PH1 1290
3306	IF(IMAX-I)9903,3311,3310	PH1 1300
3310	IF(AMX(K+1))9904,3312,3314	PH1 1310
C	WE ARE AT THE RIGHT BOUNDARY, SET PRESSURE	
C	GRADIENT TO 0. IN R DIRECTION, MODIFY ETH.	
C	FOR RIGHT BOUNDARY BEING TRANSMITTIVE.	
3311	PRR=PL(J)	PH1 1320
3307	ETH=ETH-PRR*U(K)/PIDTS*RC	PH1 1330
	GO TO 3313	PH1 1340
C	RIGHT BOUNDARY CONDITION FOR THE MOMENTUM EQ.	
C	ADJACENT TO EMPTY CELL.	
3312	PRR=0.0	PH1 1350
3313	URR=RC*U(K)	PH1 1360
	GO TO 3316	PH1 1370
C	CALCULATE PRESSURE AT INTERFACE(I) AND	
C	(RU) FOR WORK TERM.	
3314	PRR=(P(K)+P(K+1))/2.0	PH1 1380
3315	URR=(U(K)*RC+U(K+1)*RR)/2.0	PH1 1390
3316	IF(JMAX-J)9905,3318,3320	PH1 1400
C	SET PRESSURE GRADIENT TO 0. THIS IS FOR TOP	
C	BOUNDARY BEING TRANSMITTIVE.	
3318	PABOVE=PBLO	PH1 1410
C	MODIFY ETH FOR TOP BOUNDARY CONDITION.	
3319	ETH=ETH-PABOVE*V(K)/2.0*TAUDTS	PH1 1420
	GO TO 3323	PH1 1430
3320	IF(AMX(N))9906,3322,3324	PH1 1440
C	TOP BOUNDARY CONDITION (EMPTY CELL ABOVE.)	
C	TOP BOUNDARY CONDITION FOR VELOCITY (EMPTY CELL ABOVE).	
3322	PABOVE=0.0	PH1 1450
3323	VABOVE=V(K)	PH1 1460
	GO TO 3328	PH1 1470
C	CALCULATE PRESSURE AT INTERFACE(J)	
3324	PABOVE=(P(K)+P(N))/2.0	PH1 1480
	IF(CVIS)7001,3325,3325	PH1 1490
7001	IF(1-J)3325,7000,9905	PH1 1500
C	BOTTOM BOUNDARY IS TRANSMITTIVE, SET PRESSURE	
C	GRADIENT TO 0.	

```

C      AND MODIFY ETH.
7000  PBLO=PABOVE
      ETH=ETH+PBLO*V(K)/2.0*TAUDTS
C      VELOCITY AT INTERFACE(J)
3325  VABOVE=(V(K)+V(N))/2.0
3328  IF(VEL)9907,3404,3400
C      COMPUTE DELTA U AND DELTA V.
3400  V(K)=V(K)+(PBLO-PABOVE)*TAUDTS/(AMX(K))
C      **** NOTE, EPSILON IS FOR C.G.S. UNITS ****
C      *** FOR OIL UNITS SET IT TO 1.E-8 ****
      IF(ABS(V(K))-1.)3401,3401,3402
3401  V(K)=0.0
3402  U(K)=U(K)+(PL(J)-PRR)/(AMX(K))*RC/PIDTS*2.0
      IF(ABS(U(K))-1.)3403,3403,3404
3403  U(K)=0.0
C      CHECK FOR ADVANCING COUNTERS OF THE ACTIVE
C      GRID IN THE R DIRECTION.
3404  IF(I-I1)6016,6005,6005
6005  IF(U(K))6605,6606,6605
6605  NRC=1
6606  IF(V(K))6607,6004,6607
6607  NRC=1
6004  IF(AIX(K))6015,6016,6015
6015  NRC=1
6016  CONTINUE
C      HERE CALCULATE CHANGE IN INTERNAL ENERGY
C      DUE TO WORK TERMS ONLY.
      WS=(VBLO-VABOVE)*TAUDTS/2.0*P(K)
      RHO=WS+(UL(J)-URR)/PIDTS*P(K)
C      CONVERT TO SPECIFIC INTERNAL ENERGY.
3332  WSX=AIX(K)+RHO/AMX(K)
      GO TO 1000
C      CHECK FOR NEGATIVE INTERNAL ENERGIES.
1000  IF(WSX)1011,1001,1001
1001  AIX(K)=WSX
      GO TO 3342
1011  UT=1.0
C      COMPUTE NEW DT(STORE IN UU) ASSUMING
C      THAT DI/DT WILL BE THE SAME FOR A SMALLER
C      TIME STEP, THE NEW DT IS CHOSEN SUCH
C      THAT AIX(AT N+1)=2/3 OF AIX(N).
      WSA=2.0*AIX(K)/3.0*DT/(AIX(K)-WSX)
1013  IF(WSA-UU)1014,1001,1001
1014  UU=WSA
      GO TO 1001
C      CELL (K) IS EMPTY, SET INTERFACE QUANTITIES,
C      ASSUMING CELL TO THE RIGHT AND TOP ARE
C      NOT VOID.
3340  PRR=0.0
      URR=U(K+1)*RR

```

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

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PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PH1 15

PABOVE=0.0	PH1 1830
VABOVE=V(N)	PH1 1840
C SET RIGHT QUANTITIES TO THE LEFT (FOR NEXT	
C COLUMN SHEEP) AND SET ABOVE QUANTITIES TO	
C BELOW FOR NEXT CELL ABOVE.	
3342 VBLO=VABOVE	PH1 1850
PL(J)=PRR	PH1 1860
UL(J)=URR	PH1 1870
K=N	PH1 1880
3348 PBLO=PABOVE	PH1 1890
LL=K-1MAX	PH1 1900
C CHECK FOR ADVANCING COUNTERS OF THE ACTIVE	
C GRID IN Z DIRECTION.	
IF(U(LL))6000,6001,6000	PH1 1910
6000 NRT=1	PH1 1920
6001 IF(V(LL))6002,6003,6002	PH1 1930
6002 NRT=1	PH1 1940
6003 IF(AIX(LL))6017,6018,6017	PH1 1950
6017 NRT=1	PH1 1960
6018 CONTINUE	PH1 1970
3355 RC=RR	PH1 1980
IF(GAM)3360,9007,3360	
9007 RR=(X(I+1)+X(I+2))/2.0	
3360 CONTINUE	PH1 2000
3361 IF(VEL)9911,10000,3363	PH1 2010
3363 VEL=0.0	PH1 2020
GO TO 3301	PH1 2030
C ERROR	PH1 2040
9902 NK=3305	PH1 2050
GO TO 9999	PH1 2060
9903 NK=3306	PH1 2070
GO TO 9999	PH1 2080
9904 NK=3310	PH1 2090
GO TO 9999	PH1 2100
9905 NK=3316	PH1 2110
GO TO 9999	PH1 2120
9906 NK=3320	PH1 2130
GO TO 9999	PH1 2140
9907 NK=3328	PH1 2150
GO TO 9999	PH1 2160
9911 NK=3361	PH1 2170
9999 NR=3	PH1 2180
CALL DUMP	PH1 2190
C IF SN(NT=0.) ANY NEGATIVE ENERGIES WILL	
C REMAIN. IF=0, CODE WILL TRY ANOTHER PASS	
C WITH A SMALLER DT.	
10000 IF(SN)7030,7031,7030	PH1 2200
7031 IF(UT)7020,7030,7010	PH1 2210
C NEGATIVE ENERGIES HAVE OCCURED, INTEGRATE	
C BACK TO CYCLE N WITH (-DT).	

7010	UT=-1.0	PH1 2220
	DT=-DT	PH1 2230
C	YOU NOW HAVE INTEGRATED BACK TO CYCLE N. NOW	
C	INTEGRATE TO CYCLE N+1 WITH NEW DT(STORED IN UU).	
	GO TO 8000	PH1 2240
7020	UT=0.0	PH1 2250
	DT=UU	PH1 2260
	NR=DT/TRAD+1.0	PH1 2270
	WS=NR	PH1 2280
	TRAD=DT/WS	PH1 2290
	DTNA=DT	PH1 2300
	GO TO 8000	PH1 2310
C	INCREASE ACTIVE GRID COUNTERS IF NEEDED.	
7030	I1=I1+NRC	PH1 2320
	I2=I2+NRT	PH1 2330
	IF(I1-IMAX)6100,6100,6200	PH1 2340
6200	I1=IMAX	PH1 2350
6100	IF(I2-JMAX)6201,6201,6202	PH1 2360
6202	I2=JMAX	PH1 2370
6201	RETURN	PH1 2380
	END	PH1 2390

\$IBFTC PH2 LIST,DECK,REF

SUBROUTINE PH2

PH2 0010

NOTE MIN. DENSITY FOR REZONE IS A INPUT NO. (VT))

Z(110)= CRITICAL ENERGY(BETWEEN GAS AND CONDENSED STATE)

Z(111)= INITIAL DENSITY

Z(112)= INITIAL VELOCITY OF PELLET

TOZONE = MINIMUM DENSITY FOR MASS FLOW

PH2 0900

PH2 0980

AMPY=MASS ACROSS TOP BOUNDARY OF CELL

AMUT=RADIAL MOMENTA OF THIS MASS

AMVT=AXIAL MOMENTA OF THIS MASS

DELET=TOTAL SPECIFIC ENERGY OF THIS MASS

AMMP=MASS ACROSS RIGHT BOUNDARY OF CELL

AMUR=RADIAL MOMENTA OF THIS MASS

AMVR=AXIAL MOMENTA OF THIS MASS

DELER=TOTAL SPECIFIC ENERGY OF THIS MASS

AMMY=MASS ACROSS BOTTOM BOUNDARY OF CELL

AMMU=RADIAL MOMENTA OF THIS MASS

AMMV=AXIAL MOMENTA OF THIS MASS

DELEB=TOTAL SPECIFIC ENERGY OF THIS MASS

GAMC=MASS ACROSS LEFT BOUNDARY OF CELL

FLEFT=RADIAL MOMENTA OF THIS MASS

YAMC=AXIAL MOMENTA OF THIS MASS

SIGC=TOTAL SPECIFIC ENERGY OF THIS MASS

=====

PH2 0990

PH2 1010

NRT=0

PH2 1020

NRC=0

PH2 1030

REZ=0.0

PH2 1040

CALL SLITE (0)

PH2 1050

PIDTS=1.0/(PIDY*DT)

PH2 1060

101 DO 103 J=1,JMAX

PH2 1070

102 GAMC(J)=0.0

PH2 1080

FLEFT(J)=0.0

PH2 1090

YAMC(J)=0.0

PH2 1100

SIGC(J)=0.0

PH2 1110

103 CONTINUE

PH2 1120

104 DO 547 I=1,I1

PH2 1130

J=1

PH2 1140

105 K=I+1

PH2 1150

80 IF(AMX(K))9900,97,81

PH2 1160

81 IF(V(K))82,97,97

PH2 1170

97 AMMV=0.0

PH2 1180

GO TO 98

PH2 1190

82 AMMY=AMX(K)*V(K)*DT/DY(J)

PH2 1200

83 IF(AMMY+AMX(K))84,85,85

PH2 1210

84	AMMY=-AMX(K)	PH2 1220
85	IF(CVIS)106,99,99	PH2 1230
C	BOTTOM BOUNDARY IS TRANSMITTIVE, MATERIAL IS MOVING	
C	OUT, REMOVE ITS ENERGY FROM ETH.	
106	AMMU=AMMY*U(K)	PH2 1240
	AMMV=AMMY*V(K)	PH2 1250
	DELEB=AIX(K)+(U(K)**2+V(K)**2)/2.0	PH2 1260
	WS=(U(K)**2+V(K)**2)/2.0	PH2 1270
	ETH=ETH+AMMY*(AIX(K)+WS)	PH2 1280
	GO TO 107	PH2 1290
C	BOTTOM BOUNDARY IS REFLECTIVE, NET MOMENTA CHANGE	
C	IN Z DIRECTION IS 2 MV.	
99	AMMV=2.0*AMMY*V(K)	PH2 1300
98	AMMY=0.0	PH2 1310
	AMMU=0.0	PH2 1320
	DELEB=0.0	PH2 1330
C	BEGIN DO LOOP IN J(Z) DIRECTION.	
107	DO 546 J=1,12	PH2 1340
108	L=K+IMAX	PH2 1350
	I=I	PH2 1360
	J=J	PH2 1370
	AREA=0.0	PH2 1380
	VEL=0.0	PH2 1390
	FS=0.0	PH2 1400
210	IF(JMAX-J)211,211,207	PH2 1410
211	VEL=1.0	PH2 1420
	GO TO 208	PH2 1430
207	IF(AMX(L))215,215,214	PH2 1440
214	IF(AMX(K))216,216,209	PH2 1450
216	VABOVE=V(L)	PH2 1460
	GO TO 212	PH2 1470
215	IF(AMX(K))205,205,208	PH2 1480
205	VABOVE=0.0	PH2 1490
	GO TO 212	PH2 1500
208	VABOVE=V(K)	PH2 1510
	GO TO 212	PH2 1520
209	VABOVE=(V(K)+V(L))/2.0	PH2 1530
212	CONTINUE	PH2 1540
	I=I	PH2 1550
	J=J	PH2 1560
	FS=0.0	PH2 1570
404	IF(IMAX-I)412,412,405	PH2 1580
405	IF(AMX(K+1))411,411,409	PH2 1590
409	IF(AMX(K))410,410,407	PH2 1600
410	URR=U(K+1)	PH2 1610
	GO TO 408	PH2 1620
411	IF(AMX(K))403,403,406	PH2 1630
403	URR=0.0	PH2 1640
	GO TO 408	PH2 1650
C	WE ARE AT THE RIGHT BOUNDARY OF THE GRID, THE	

C BOUNDARY CONDITION HERE IS TRANSMITTIVE.

412 FS=1.0	PH2 1660
406 URR=U(K)	PH2 1670
GO TO 408	PH2 1680
407 URR=(U(K)+U(K+1))/2.0	PH2 1690
408 CONTINUE	PH2 1700
109 IF(AREA)9901,301,547	PH2 1710
301 IF(VABOVE)300,304,302	PH2 1720
302 IF(AMX(K))9900,304,8800	PH2 1730
8800 IF(J-1)9900,303,8801	PH2 1740
8801 KP=K-IMAX	PH2 1750
IF(AMX(KP))9900,8803,303	PH2 1760

C A CHECK HERE TO INSURE THAT THE BOTTOM ZONES

C OF THE PROJECTILE EMPTY (FOR HYPERVELOCITY) UP UNTIL

8803 IF(AIX(K)-Z(122))350,303,303	
350 IF(AMX(L))9900,303,306	
303 M=K	PH2 1780
JJ=J	PH2 1790
GO TO 307	PH2 1800
304 AMPY=0.0	PH2 1810
308 AMUT=0.0	PH2 1820
AMVT=0.0	PH2 1830
DELET=0.0	PH2 1840
GO TO 501	PH2 1850
300 IF(VEL)9901,305,304	PH2 1860
305 IF(AMX(L))9903,304,306	PH2 1870
306 M=L	PH2 1880
JJ=J+1	PH2 1890
307 IF(VEL)6130,6130,6140	PH2 1900
6130 WSA=(V(K)+V(L))/2.0	PH2 1910
WSB=1.0+(V(L)-V(K))/(DY(JJ)*SBOUND)*DT	PH2 1920
VABOVE=WSA/WSB	PH2 1930

C CALCULATE THE MASS FLUX AT THE TOP OF CELL K.

6140 AMPY=AMX(M)*VABOVE/DY(JJ)*DT	PH2 1940
501 IF(URR)500,504,502	PH2 1950
502 IF(AMX(K))9900,504,503	PH2 1960
503 IF(I-1)7001,7001,7002	
7001 M=K	
N=I	PH2 1980
GO TO 508	PH2 1990
7002 KP=K-1	
IF(AMX(KP))9900,7003,7001	
7003 IF(AIX(K)-Z(122))357,7001,7001	
357 IF(I-IMAX)351,7001,7001	
351 IF(AMX(K+1))9900,7001,507	
504 AMMP=0.0	PH2 2000
AMUR=0.0	PH2 2010
AMVR=0.0	PH2 2020
DELER=0.0	PH2 2030
GO TO 1	PH2 2040

500	IF(FS)9905,506,504	PH2 2050
506	IF(AMX(K+1))9904,504,507	PH2 2060
507	M=K+1	PH2 2070
	N=I+1	PH2 2080
508	IF(FS)6100,6100,6110	PH2 2090
6100	WSA=(U(K)+U(K+1))/2.0	PH2 2100
	WSB=1.0+(U(K+1)-U(K))/(DX(N)*SBOUND)*DT	PH2 2110
	URR=WSA/WSB	PH2 2120
C	CALCULATE THE MASS FLUX AT THE RIGHT OF CELL K.	
6110	DEN=AMX(M)/TAU(N)	PH2 2130
	IF(GAM)9989,9990,9989	
9989	CART=1.	
	GO TO 9991	
9990	CART=X(I)/.5	
9991	AMMP=DEN/PI*DT*S*CART*URR	
1	IF(AMMP)16,16,8820	PH2 2150
8820	IF(GAMC(J))74,74,8821	PH2 2160
8821	IF(FS)6120,6120,74	PH2 2170
6120	IF(AMX(K+1))9903,8822,74	PH2 2180
8822	IF(AMX(K)/(TAU(I)*DY(J))-Z(111))8823,74,74	PH2 2190
8823	IF(AIX(K)-Z(110))8824,74,74	PH2 2200
8824	WS=GAMC(J)+AMX(K)-TAU(I)*DY(J)*Z(111)	PH2 2210
	IF(WS)8826,8826,8825	PH2 2220
8825	AMMP=WS	PH2 2230
	GO TO 74	PH2 2240
8826	AMMP=0.0	PH2 2250
74	JTAG=0	PH2 2260
C	BEGIN CHECKING TO SEE IF THEIR IS ANY	
C	PREFERENTIAL MASS FLUX BECAUSE OF CHOICE OF	
C	INDEXING DIRECTION.	
2	IF(AMPY)3,4,4	PH2 2270
C	TOP FLUX IS INTO CELL K.	
3	ITAG=1	PH2 2280
	WSB=AMPY	PH2 2290
	AMPY=0.0	PH2 2300
	GO TO 64	PH2 2310
4	ITAG=0	PH2 2320
64	IF(AMMY)9,5,5	PH2 2330
C	BOTTOM FLUX IS INTO CELL K.	
5	IF(GAMC(J))7,6,6	PH2 2340
C	LEFT FLUX IS INTO CELL K.	
6	WS=AMX(K)	PH2 2350
	GO TO 11	PH2 2360
C	LEFT FLUX IS OUT.	
7	WS=AMX(K)+GAMC(J)	PH2 2370
	GO TO 11	PH2 2380
C	BOTTOM FLUX IS OUT OF CELL K.	
9	IF(GAMC(J))10,8,8	PH2 2390
-C	LEFT FLUX IS INTO CELL K.	
8	WS=AMX(K)+AMMY	PH2 2400

	GO TO 11	PH2 2410	
C	LEFT FLUX IS OUT OF CELL K.		
	10 WS=AMX(K)+GAMC(J)+AMMY	PH2 2420	
	11 WSA=AMPY+AMMP	PH2 2430	
	12 IF(WSA-WS)75,75,13	PH2 2440	
C	CHANGE TOP AND RIGHT FLUX TO BE THE		
C	OLD FLUX TIMES THE MASS OF THE CELL/THE SUM		
C	OF THE OLD FLUXES.		
	13 AMPY=AMPY*WS/WSA	PH2 2450	
	AMMP=AMMP*WS/WSA	PH2 2460	
	75 IF(JTAG)14,73,14	PH2 2470	
	73 WSC=AMMP	PH2 2480	
	14 IF(ITAG)15,7000,15	PH2 2490	
	15 AMPY=WSB	PH2 2500	
	ITAG=0	PH2 2510	
C	GO CHECK CELL ABOVE.		
	GO TO 40	PH2 2520	
C	RIGHT FLUX IS INTO CELL K.		
	16 IF(FS)76,17,76	PH2 2530	
	76 WSC=AMMP	PH2 2540	
C	I=IMAX, SO CHECK CELL ABOVE K.		
	GO TO 40	PH2 2550	
	17 IF(I+1-IMAX)19,18,9908	PH2 2560	
	18 URRR=U(K+1)/2.0	PH2 2570	
	GO TO 20	PH2 2580	
	19 URRR=(U(K+1)+U(K+2))/2.0	PH2 2590	
	20 IF(URRR)39,39,21	PH2 2600	
C	FLUX IS OUT OF THE RIGHT OF CELL(K+1).		
	21 IF(GAM)9992,9993,9992		
	9993 CART=X(I+1)*2.		
	GO TO 9994		
	9992 CART=1.		
	9994 URRR=URRR/TAU(I+1)*AMX(K+1)/PIDTS*CART		
	22 IF(J-1)9909,23,24	PH2 2620	
	23 VBLO=V(K+1)/2.0	PH2 2630	
	GO TO 26	PH2 2640	
	24 KP=K+1-IMAX	PH2 2650	
	VBLO=(V(K+1)+V(KP))/2.0	PH2 2660	
	26 IF(VBLO)25,38,38	PH2 2670	
C	FLUX IS OUT OF THE BOTTOM OF CELL(K+1).		
	25 VBLO=AMX(K+1)/DY(J)*VBLO*DT	PH2 2680	
	27 IF(VEL)28,29,28	PH2 2690	
	28 VAB=V(K+1)/2.0	PH2 2700	
	GO TO 31	PH2 2710	
	29 KP=K+IMAX+1	PH2 2720	
	VAB=(V(K+1)+V(KP))/2.0	PH2 2730	
	31 IF(VAB)36,36,30	PH2 2740	
C	FLUX IS OUT OF TOP.		
	30 VAB=AMX(K+1)/DY(J)*VAB*DT	PH2 2750	
	32 WS=AMX(K+1)	PH2 2760	

33	WSA=URRR-AMMP-VBLO+VAB	PH2 2770
34	IF(WSA-WS)77,77,35	PH2 2780
35	AMMP=AMMP*WS/WSA	PH2 2790
77	JTAG=1	PH2 2800
	WSC=AMMP	PH2 2810
	AMMP=0.0	PH2 2820
	GO TO 2	PH2 2830
C	FLUX AT TOP IS INTO CELL (K+1).	
36	WS=AMX(K+1)	PH2 2840
37	WSA=URRR-AMMP-VBLO	PH2 2850
	GO TO 34	PH2 2860
C	FLUX IS IN FROM BOTTOM INTO CELL (K+1).	
38	VBLO=0.0	PH2 2870
	GO TO 27	PH2 2880
C	FLUX IS INTO CELL (K+1) FROM RIGHT.	
39	URRR=0.0	PH2 2890
	GO TO 22	PH2 2900
C	RIGHT FLUX OUT OF CELL (K) IS POSITIVE AND TOP	
C	FLUX IS COMING INTO CELL (K) FROM (K+IMAX).	
40	IF(VEL)7000,41,7000	PH2 2910
41	IF(FS)42,43,42	PH2 2920
C	WE ARE AT THE RIGHT BOUNDARY OF THE GRID.	
42	KP=K+IMAX	PH2 2930
	URT=U(KP)/2.0	PH2 2940
	GO TO 45	PH2 2950
43	KP=K+IMAX	PH2 2960
	URT=(U(KP)+U(KP+1))/2.0	PH2 2970
45	IF(URT)46,46,70	PH2 2980
C	FLUX AT RIGHT (CELL M) IS NEGATIVE.	
46	URT=0.0	PH2 2990
	GO TO 47	PH2 3000
70	KP=K+IMAX	PH2 3010
	IF(GAM)9996,9997,9996	
9997	CART=X(I)*2.	
	GO TO 9998	
9996	CART=1.	
9998	URT=URT/TAU(I)*AMX(KP)/PIDTS*CART	
C	FLUX AT RIGHT (CELL M) IS POSITIVE.	
47	IF(J+1-JMAX)48,49,9910	PH2 3030
48	KP=K+IMAX	PH2 3040
	KLL=KP+IMAX	
	VABT=(V(KP)+V(KLL))/2.	
	GO TO 51	PH2 3070
49	KP=K+IMAX	PH2 3080
	KLL=KP+IMAX	
	VABT=V(KP)/2.0	PH2 3100
51	IF(VABT)8810,71,72	PH2 3110
C	FLUX IS IN FROM TOP OF CELL M.	
8810	IF(AMX(K))9903,8811,71	PH2 3120
C	CHECK FOR SOLID OR VAPOR.	

8811 IF(AMX(KP)/(TAU(I)*DY(J+1))-Z(111))8812,71,71	PH2 3130
8812 IF(AIX(KP)-Z(110))8813,71,71	PH2 3140
8813 VABT=VABT*AMX(KLL)/DY(J+2)*DT	
8814 WS=-VABT+AMX(KP)-TAU(I)*DY(J+1)*Z(111)	PH2 3160
8815 IF(WS)8817,8817,8816	PH2 3170
8816 AMPY=-WS	PH2 3180
GO TO 71	PH2 3190
8817 AMPY=0.0	PH2 3200
71 VABT=0.0	PH2 3210
GO TO 60	PH2 3220
72 VABT=VABT*AMX(KP)/DY(J+1)*DT	PH2 3230
52 IF(GAMC(J+1))54,53,53	PH2 3240
53 WS=AMX(KP)	PH2 3250
GO TO 55	PH2 3260
54 WS=AMX(KP)+GAMC(J+1)	PH2 3270
55 WSA=VABT-AMPY+URT	PH2 3280
GO TO 57	PH2 3290
60 IF(GAMC(J+1))61,61,59	PH2 3300
61 WS=AMX(KP)+GAMC(J+1)	PH2 3310
GO TO 58	PH2 3320
59 WS=AMX(KP)	PH2 3330
58 WSA=-AMPY+URT	PH2 3340
57 IF(WSA-WS)7000,7000,56	PH2 3350
56 AMPY=AMPY*WS/WSA	PH2 3360
GO TO 7000	PH2 3370
7000 AMMP=WSC	PH2 3380
309 IF(AMPY)8834,8831,8833	PH2 3390
8833 IF(JMAX-J)9911,318,8835	PH2 3400
8835 KP=K+IMAX	PH2 3410
8836 IF(AMX(KP))9900,8837,318	PH2 3420
C **** NOTE ****	
C ACROSS FREE SURFACE, HOLD UP MASS FLUX	
C UNLESS THIS MASS PRODUCES A DENSITY GREATER THAN TOZONE.	
C ****	
8837 IF(AMPY/(TAU(I)*DY(J))-TOZONE)8838,318,318	PH2 3430
8838 AMPY=0.0	PH2 3440
GO TO 8831	PH2 3450
8834 IF(J-1)9911,325,8839	PH2 3460
8839 IF(AMX(K))9900,8840,325	PH2 3470
8840 IF(-AMPY/(TAU(I)*DY(J+1))-TOZONE)8841,325,325	PH2 3480
8841 AMPY=0.0	PH2 3490
GO TO 8831	PH2 3500
318 DELM=GAMC(J)+AMMY-AMPY	PH2 3510
322 IF(VEL)9901,324,323	PH2 3520
323 WS=U(K)**2+V(K)**2	PH2 3530
C MATERIAL HAS LEFT THE TOP, TRIGGER REZONE	
C FLAG, REMOVE ITS ENERGY FROM ETH(TOTAL ENERGY OF SYSTEM).	
ETH=ETH-AMPY*(AIX(K)+WS/2.0)	PH2 3540
IF(AMPY/(TAU(I)*DY(J))-VT)324,324,6900	
6900 REZ=1.0	PH2 3560

324	AMUT=AMPY*U(K)	PH2 3570
	AMVT=AMPY*V(K)	PH2 3580
	GO TO 326	PH2 3590
325	CONTINUE	PH2 3600
8831	AMUT=AMPY*U(L)	PH2 3610
	AMVT=AMPY*V(L)	PH2 3620
	DELM=GAMC(J)-AMPY+AMMY	PH2 3630
326	IF(AMPY)327,328,328	PH2 3640
327	DELET=AIX(L)+(U(L)**2+V(L)**2)/2.0	PH2 3650
	GO TO 333	PH2 3660
328	IF(AMMY)329,330,330	PH2 3670
329	DELET=DELEB	PH2 3680
	GO TO 333	PH2 3690
330	IF(GAMC(J))331,332,332	PH2 3700
331	DELET=SIGC(J)	PH2 3710
	GO TO 333	PH2 3720
332	DELET=AIX(K)+(U(K)**2+V(K)**2)/2.0	PH2 3730
C	SUM UP RADIAL MOMENTA FOR ALL FLUXES EXCEPT	
C	THE RIGHT AND STORE IN SIGMU.	
333	SIGMU=FLEFT(J)+AMMU-AMUT	PH2 3740
C	SUM UP AXIAL MOMENTA FOR ALL FLUXES EXCEPT THE	
C	RIGHT AND STORE IN SIGMV.	
	SIGMV=YAMC(J)+AMMV-AMVT	PH2 3750
C	SUM UP TOTAL ENERGY CARRIED BY THESE FLUXES	
C	EXCEPT THE RIGHT FLUX AND STORE IN DELEK.	
	DELEK=GAMC(J)*SIGC(J)+AMMY*DELEB-AMPY*DELET	PH2 3760
509	IF(AMMP)8843,518,8844	PH2 3770
8844	IF(IMAX-I)9911,518,8845	PH2 3780
8845	IF(AMX(K+1))9900,8846,518	PH2 3790
8846	IF(AMMP/(TAU(I)*DY(J))-TOZONE)8847,518,518	PH2 3800
8847	AMMP=0.0	PH2 3810
	GO TO 518	PH2 3820
8843	IF(I-I)9911,512,8848	PH2 3830
8848	IF(AMX(K))9900,8849,512	PH2 3840
8849	IF(-AMMP/(TAU(I+1)*DY(J))-TOZONE)8850,512,512	PH2 3850
8850	AMMP=0.0	PH2 3860
	GO TO 518	PH2 3870
512	DELM=DELM-AMMP+AMX(K)	PH2 3880
513	CONTINUE	PH2 3890
514	CONTINUE	PH2 3900
8828	AMUR=AMMP*U(K+1)	PH2 3910
	AMVR=AMMP*V(K+1)	PH2 3920
	GO TO 525	PH2 3930
518	DELM=DELM-AMMP+AMX(K)	PH2 3940
521	CONTINUE	PH2 3950
522	IF(FS)9905,524,523	PH2 3960
523	WS=U(K)**2+V(K)**2	PH2 3970
	ETH=ETH-AMMP*(AIX(K)+WS/2.0)	PH2 3980
	IF(AMMP/(TAU(I)*DY(J))-VT)524,524,6901	
6901	REZ=1.0	PH2 4000

524	AMUR=AMMP*U(K)	PH2 4010
	AMVR=AMMP*V(K)	PH2 4020
525	SIGMU=SIGMU-AMUR	PH2 4030
	SIGMV=SIGMV-AMVR	PH2 4040
526	TIC=0.0	PH2 4050
527	IF(AMMP) 528,529,529	PH2 4060
528	DELER=AIX(K+1)+(U(K+1)**2+V(K+1)**2)/2.0	PH2 4070
	GO TO 537	PH2 4080
529	IF(AMMY) 530,531,531	PH2 4090
530	DELER=DELEB	PH2 4100
	GO TO 536	PH2 4110
531	IF(GAMC(J)) 532,533,533	PH2 4120
532	DELER=SIGC(J)	PH2 4130
	GO TO 536	PH2 4140
533	IF(AMPY) 535,535,534	PH2 4150
534	DELER=DELET	PH2 4160
	GO TO 536	PH2 4170
535	DELER=AIX(K)+(U(K)**2+V(K)**2)/2.0	PH2 4180
536	TIC=1.0	PH2 4190
537	DELEK=DELEK-AMMP*DELER	PH2 4200
538	IF(TIC) 9907,539,550	PH2 4210
550	WS=DELER	PH2 4220
	GO TO 999	PH2 4230
539	WS=AIX(K)+(U(K)**2+V(K)**2)/2.0	PH2 4240
999	IF(DELM) 998,543,540	PH2 4250
998	IF(AMX(K)*1.E-6+DELM) 9906,997,997	PH2 4260
997	DELM=0.0	PH2 4270
	GO TO 543	PH2 4280
C	ENK=TOTAL ENERGY OF CELL (K) + ENERGY THAT	
C	HAS BEEN ADDED AND LOST.	
540	ENK=AMX(K)*WS+DELEK	PH2 4290
C	BY CONSERVING AXIAL MOMENTA, CALCULATE THE NEW	
C	AXIAL VELOCITY COMPONENT FOR CELL K.	
541	U(K)=(SIGMU+AMX(K)*U(K))/DELM	PH2 4300
C	BY CONSERVING RADIAL MOMENTA, CALCULATE THE NEW	
C	RADIAL VELOCITY COMPONENT FOR CELL K.	
601	V(K)=(SIGMV+AMX(K)*V(K))/DELM	PH2 4310
	IF(I-I1) 603,6604,6604	PH2 4320
6604	IF(U(K)) 6605,6606,6605	PH2 4330
6605	NRC=1	PH2 4340
6606	IF(V(K)) 6607,6608,6607	PH2 4350
6607	NRC=1	PH2 4360
6608	IF(AIX(K)) 6609,6610,6609	PH2 4370
6609	NRC=1	PH2 4380
6610	CONTINUE	PH2 4390
603	WS=U(K)**2+V(K)**2	PH2 4400
C	BY CONSERVING BOTH TOTAL ENERGY AND	
C	MOMENTA, CALCULATE THE NEW SPECIFIC	
C	INTERNAL ENERGY FOR CELL K.	
542	AIX(K)=ENK/DELM-WS/2.0	PH2 4410

543	AMX(K)=DELM	PH2	44
	IF(AMX(K))9900,2007,544	PH2	44
2007	AIX(K)=0.0	PH2	44
	U(K)=0.0	PH2	44
	V(K)=0.0	PH2	44
	P(K)=0.0	PH2	44
C	THE RIGHT VALUES OF CELL (K) BECOME THE LEFT		
C	VALUES OF CELL (K+1).		
544	GAMC(J)=AMMP	PH2	44
	FLEFT(J)=AMUR	PH2	44
	YAMC(J)=AMVR	PH2	45
	SIGC(J)=DELER	PH2	45
C	THE TOP VALUES OF CELL(K) BECOME THE		
C	BOTTOM VALUES FOR CELL (K+IMAX).		
545	AMMY=AMPY	PH2	45
	AMMU=AMUT	PH2	45
	AMMV=AMVT	PH2	45
	DELEB=DELET	PH2	45
546	K=K+IMAX	PH2	45
	LL=K-IMAX	PH2	45
	IF(U(LL))6500,6600,6500	PH2	45
6500	NRT=1	PH2	45
6600	IF(V(LL))6601,6602,6601	PH2	46
6601	NRT=1	PH2	46
6602	IF(AIX(LL))6611,547,6611	PH2	46
6611	NRT=1	PH2	46
547	CONTINUE	PH2	46
	I1=I1+NRC	PH2	46
	I2=I2+NRT	PH2	46
	IF(IMAX-I1)6700,6701,6702	PH2	46
6700	I1=IMAX	PH2	46
6701	CONTINUE	PH2	46
6702	IF(JMAX-I2)6800,6801,6802	PH2	47
6800	I2=JMAX	PH2	47
6801	CONTINUE	PH2	47
6802	GO TO 548	PH2	47
9901	NK=300	PH2	47
	GO TO 9999	PH2	47
9900	NK=302	PH2	47
	GO TO 9999	PH2	47
9903	NK=305	PH2	47
	GO TO 9999	PH2	47
9904	NK=506	PH2	48
	GO TO 9999	PH2	48
9905	NK=500	PH2	48
	GO TO 9999	PH2	48
9906	NK=513	PH2	48
	GO TO 9999	PH2	48
9911	NK=8833	PH2	48
	GO TO 9999	PH2	48

9908	NK= 17	PH2 4880,
	GO TO 9999	PH2 4890
9909	NK= 22	PH2 4900
	GO TO 9999	PH2 4910
9910	NK= 47	PH2 4920
	GO TO 9999	PH2 4930
9907	NK=538	PH2 4940
9999	NK=4	PH2 4950
	CALL DUMP	PH2 4960
548	SUM=0.0	PH2 4970
2005	DO 2001 I=1,I1	PH2 4980
	K=I+1	PH2 4990
	DO 2000 J=1,I2	PH2 5000
	IF(AMX(K))2000,2000,2009	PH2 5010
C	IF ANY RHO (CELL DENSITY) IS LESS THAN TOZONE,	
C	SET THE MASS TO ZERO, AND TALLY THE	
C	MOMENTAS AND ENERGIES IN THE Z STORAGE, ALSO	
C	CHECK FOR NEGATIVE INTERNAL ENERGIES, IF	
C	WE FIND SOME, SET THEM TO ZERO AFTER	
C	SUBTRACTING THEM FROM ETH..	
2009	IF(AMX(K)/(TAU(I)*DY(J))-TOZONE)2010,2008,2008	PH2 5020
2010	WS=(U(K)**2+V(K)**2)/2.0	PH2 5030
	Z(100)=Z(100)+AMX(K)	PH2 5040
	WS=AMX(K)*(AIX(K)+WS)	PH2 5050
	Z(101)=Z(101)+WS	PH2 5060
	ETH=ETH-WS	PH2 5070
	Z(102)=Z(102)+AMX(K)*U(K)	PH2 5080
	Z(103)=Z(103)+AMX(K)*V(K)	PH2 5090
	AMX(K)=0.0	PH2 5100
	AIX(K)=0.0	PH2 5110
	P(K)=0.0	PH2 5120
	U(K)=0.0	PH2 5130
	V(K)=0.0	PH2 5140
	GO TO 2000	PH2 5150
2008	IF(AIX(K))2004,2000,2000	PH2 5160
2004	SUM=SUM+AIX(K)*AMX(K)	PH2 5170
	AIX(K)=0.0	PH2 5180
2000	K=K+IMAX	PH2 5190
2001	CONTINUE	PH2 5200
2003	ETH=ETH-SUM	PH2 5210
	Z(104)=Z(104)+SUM	PH2 5220
8000	IF(REZ)8001,8001,8002	
8002	IF(REZFCT)8004,8004,8003	
8004	REZ=0.	
	GO TO 8001	
8003	CALL REZONE	
8001	RETURN	PH2 5260
	END	PH2 5270

\$IBFTC ES LIST,DECK,REF
SUBROUTINE ES

C		ES	0900
C	METALLIC EQUATION OF STATE, SEE		
C	GA-3216 REPORT.		
C		ES	0980
10	RHOW=AMX(K)/((AU(I)*DY(J))	ES	0990
	ETA=RHOW/Z(115)	ES	1000
	VOW=1.0/ETA	ES	1010
11	P1=AIX(K)*RHOW*Z(116)	ES	1020
12	P2=(Z(115)*IAU(I)*DY(J))**2*AIX(K)	ES	1030
13	P3=AMX(K)**2*Z(117)	ES	1040
14	P4=Z(118)/(P2/P3+1.0)*AIX(K)*RHOW	ES	1050
15	P5=Z(119)*(ETA-1.0)	ES	1060
16	IF(ETA-1.0)50,100,100	ES	1070
50	IF(VOW-Z(120))55,55,75	ES	1080
55	IF(AIX(K)-Z(122))100,100,75	ES	1090
75	P7=Z(123)*(VOW-1.0)	ES	1100
	IF(P7-88.0)4002,4002,4003	ES	1110
4003	P7=88.0	ES	1120
4002	CONTINUE	ES	1130
	P8=EXP(P7)	ES	1140
	P9=1.0/P8	ES	1150
	P10=Z(124)*1(VOW-1.0)**2)	ES	1160
	IF(P10-88.0)4000,4000,4001	ES	1170
4001	P10=88.0	ES	1180
4000	CONTINUE	ES	1190
	P11=EXP(P10)	ES	1200
	P12=1.0/P11	ES	1210
	P(K)=P1+(P4+P5*P9)*P12	ES	1220
	GO TO 119		
100	P6=Z(126)*1(ETA-1.0)**2)	ES	1230
	P(K)=P1+P4+P5+P6	ES	1240
119	IF(P(K))999,999,200	ES	1250
200	WSGX=.5	ES	1260
	GO TO 500	ES	1270
999	P(K)=0.0	ES	1280
	WSGX=.5+Z(125)	ES	1290
	GO TO 500	ES	1300
500	RETURN	ES	1310
	END	ES	1320

\$IBFTC REZONE LIST,DECK,REF
SUBROUTINE REZONE

REZ00010
REZ00980

C
C CONSERVE MOMENTUM AND TOTAL ENERGY, INCREASE
C ALL LINEAR DIMENSIONS BY 2. (THUS 4 CELLS
C IN THE OLD GRID ARE COMBINED INTO 1 FOR
C THE NEW GRID.)
NIMAX=IMAX/2
NJMAX=JMAX/2
DO 10 J=1,NJMAX
K=(J-1)*NIMAX+2
L=(J-1)*2*IMAX+2
DO 11 I=1,NIMAX
M=L+IMAX
12 WSA=AMX(L)+AMX(M)+AMX(L+1)+AMX(M+1)
WSB=AMX(L)*(U(L)**2+V(L)**2)+AMX(M)*(U(M)
1**2+V(M)**2)+AMX(L+1)*(U(L+1)**2+V(L+1)**2)
2+AMX(M+1)*(U(M+1)**2+V(M+1)**2)
U(K)=(U(L)*AMX(L)+U(M)*AMX(M)+U(L+1)*AMX(L+1)+
1U(M+1)*AMX(M+1))/WSA
V(K)=(V(L)*AMX(L)+V(M)*AMX(M)+V(L+1)*AMX(L+1)+
1V(M+1)*AMX(M+1))/WSA
AIX(K)=AIX(L)*AMX(L)+AIX(M)*AMX(M)+AIX(L+1)*
1AMX(L+1)+AMX(M+1)*AIX(M+1)
AMX(K)=WSA
WS=U(K)**2+V(K)**2
E=AIX(K)+WSB/2.0
AIX(K)=E/AMX(K)-.5*WS
IF(K-2)14,14,13
C SET CELL QUANTITIES OF OLD GRID TO ZERO.
13 AMX(L)=0.0
U(L)=0.0
V(L)=0.0
AIX(L)=0.0
P(L)=0.0
AMX(M)=0.0
U(M)=0.0
V(M)=0.0
AIX(M)=0.0
P(M)=0.0
AMX(L+1)=0.0
U(L+1)=0.0
V(L+1)=0.0
AIX(L+1)=0.0
P(L+1)=0.0
AMX(M+1)=0.0
U(M+1)=0.0
V(M+1)=0.0
AIX(M+1)=0.0
P(M+1)=0.0

REZ00990
REZ01000
REZ01010
REZ01020
REZ01030
REZ01040
REZ01050
REZ01060
REZ01070
REZ01080
REZ01090
REZ01100
REZ01110
REZ01120
REZ01130
REZ01140
REZ01150
REZ01160
REZ01170
REZ01180
REZ01190
REZ01200

REZ01210
REZ01220
REZ01230
REZ01240
REZ01250
REZ01260
REZ01270
REZ01280
REZ01290
REZ01300
REZ01310
REZ01320
REZ01330
REZ01340
REZ01350
REZ01360
REZ01370
REZ01380
REZ01390
REZ01400

14	K=K+1	REZ014
	L=L+2	REZ014
11	CONTINUE	REZ014
10	CONTINUE	REZ014
C	CALCULATE NEW DY AND Y (JMAX OF THEM).	
18	DO 999 J=1,JMAX	REZ014
	DY(J)=DY(J)*2.0	REZ014
999	CONTINUE	REZ014
	DO 99 J=1,JMAX	REZ014
	Y(J)=Y(J-1)+DY(J)	REZ014
99	CONTINUE	REZ015
16	DX(1)=2.0*DX(1)	REZ015
	X(1)=DX(1)	REZ015
	WS=X(1)**2	REZ015
	IF(GAM)3001,3000,3001	
3001	WS=DX(1)	
3000	TAU(1)=PIDY*WS	
C	CALCULATE NEW DX AND X, AND TAU(IMAX OF THEM)	
17	DO 98 I=2,IMAX	REZ015
	X(I)=X(I-1)+DX(1)	REZ015
	DX(I)=DX(1)	REZ015
	WSA=X(I)**2	REZ015
	IF(GAM)3002,3003,3002	
3002	TAU(I)=DX(I)	
	GO TO 98	
3003	TAU(I)=PIDY*(WSA-WS)	
	WS=WSA	REZ016
98	CONTINUE	REZ016
	IMAX=NIMAX	REZ016
	JMAX=NJMAX	REZ016
C	PREPARE NOW TO SHUFFLE THE K ARRAYS SUCH	
C	AS TO PRESERVE K=(J-1)*IMAX+I+1.	
	DO 20 N=1,JMAX	REZ016
	J=JMAX+1-N	REZ016
	K=(J-1)*IMAX+1+IMAX	REZ016
	L=(J-1)*(IMAX+IMAX)+1+IMAX	REZ016
	DO 21 I=1,IMAX	REZ016
1000	AMX(L)=AMX(K)	REZ016
	AIX(L)=AIX(K)	REZ017
	U(L)=U(K)	REZ017
	V(L)=V(K)	REZ017
	P(L)=P(K)	REZ017
	IF(J-1)1002,1002,1001	REZ017
1001	AMX(K)=0.0	REZ017
	AIX(K)=0.0	REZ017
	V(K)=0.0	REZ017
	U(K)=0.0	REZ017
	P(K)=0.0	REZ017
1002	K=K-1	REZ018
	L=L-1	REZ018

```

21 CONTINUE
20 CONTINUE
  IMAX=NIMAX*2
  JMAX=NJMAX*2
  II=NIMAX+1
  JJ=NJMAX+1
C  ADD ON NEW MASS WITH DENSITY=Z(111) IN TARGET
  DO 50 I=1,NIMAX
    K=(JJ-1)*IMAX+I+1
    DO 60 J=JJ,JMAX
      AMX(K)=Z(111)*TAU(I)*DY(J)
60  K=K+IMAX
50  CONTINUE
    JJ=(Z(147)/2.+2)
    JJ=JJ+1
    DO 61 I=II,IMAX
      K=I+1+(JJ-1)*IMAX
      DO 62 J=JJ,JMAX
        AMX(K)=Z(111)*TAU(I)*DY(J)
62  K=K+IMAX
61  CONTINUE
C  RESET ACTIVE GRID MARKERS.
C  ASSUMPTION THAT ALL DX AND DY ARE =
C  NOTE, DVK=K(0)/(RHO(0)*DX SQ. )
  WS=DX(1)*DX(1)
  DVK=DDXN/(Z(111)*WS)
C
  JJ=JJ-1
  Z(147)=JJ
  I1=NIMAX+2
  I2=NJMAX+2
  WS=T+DTNA
  NK=NC+1
C  EDIT THE NEW GRID.
  WRITE (6,8004)WS,NK,DX(1)
  WRITE (6,8007)IMAX,(X(I),I=0,IMAX)
  WRITE (6,8008)JMAX,(Y(J),J=0,JMAX)
  WRITE (6,8009)IMAX,(DX(I),I=1,IMAX)
  WRITE (6,8010)JMAX,(DY(J),J=1,JMAX)
  WRITE (6,8011)IMAX,(TAU(I),I=1,IMAX)
  KMAX=IMAX*JMAX+1
  IMAXA=IMAX+1
  JMAXA=JMAX+1
  KMAXA=KMAX+1
  RETURN
80040FORMAT(1H ///22H PROBLEM REZONED AT T=1PE12.6,6X,5HCYCLE14,6X,3HDRE
  1X=E12.6////)
8007 FORMAT(1H /10H X(I) I=0,I2/(5F16.6))
8008 FORMAT(1H /10H Y(J) J=0,I2/(5F16.6))
8009 FORMAT(1H /11H DX(I) I=1,I2/(5F16.6))

```

REZ01820
REZ01830
REZ01840
REZ01850

REZ02040
REZ02050
REZ02060
REZ02070

REZ02080
REZ02090
REZ02100
REZ02110
REZ02120
REZ02130
REZ02140
REZ02150
REZ02160
REZ02170
REZ02180

REZ02190
REZ02200
REZ02210
REZ02220
REZ02230

```
8010 FORMAT(1H /11H DY(J) J=1,12/(5F16.6))  
8011 FORMAT(1H /13H AREA(I) I=1,12/(F16.6,4F18.6)).  
END
```

REZ0224

REZ0226

\$IBFTC EDIT LIST,DECK,REF
SUBROUTINE EDIT

C		EDIT0010	
C		EDIT0990	
C		EDIT1000	C
C	SENSE LITE (1) INDICATES LAST CYCLE OF THIS		C
C	RUN.		
C	SENSE LITE (3) INDICATES FIRST CYCLE OF THIS		C
C	RUN.		
	104 CALL SLITET(3,K000FX)	EDIT1040	
	GO TO(106,108),K000FX	EDIT1050	
	106 CALL SLITE (3)	EDIT1060	
	GO TO 126	EDIT1070	
	108 IF(CYCLE-CSTOP)110,122,122	EDIT1080	
	110 IF(REZ)9901,112,124		
	112 IF(AMOD(CYCLE,DUMPT7))114,124,114	EDIT1100	
	114 IF(AMOD(CYCLE,PRINTL))120,126,120		
	120 IF(AMOD(CYCLE,PRINTS))140,128,140	EDIT1150	
C	NORMAL STOP ON THIS CYCLE.		
	122 CALL SLITE (1)	EDIT1160	
C	DUMP ON TAPE 7.		
	124 GO TO 1	EDIT1170	
	126 CALL SLITE (4)	EDIT1180	
	128 GO TO 6000	EDIT1190	
	130 GO TO 1000	EDIT1200	
	132 CALL SLITET(4,K000FX)	EDIT1210	
	GO TO(134,136),K000FX	EDIT1220	
	134 GO TO 5000	EDIT1230	
C	CHECK FOR ENERGY CHECK ERROR. WHERE		
C	ECK= PERCENT ERROR/PER CYCLE.		
C	$ECK = (ETH - E) / ETH$ AT CYCLE N- $(ETH - E) / ETH$		
C	AT CYCLE N-NPC ALL DIVIDED BY NPC, NOTE		C
C	NPC= NO. OF CYCLES BETWEEN ENERGY CHECK		
	136 IF(ABS(ECK)-DMIN)140,140,9905	EDIT1240	
	140 CALL SLITET(1,K000FX)	EDIT1250	
	GO TO(142,144),K000FX	EDIT1260	
	142 REWIND 7		
	CALL SLITE (1)	EDIT1280	
	144 GO TO 10000	EDIT1290	C
C		EDIT1300	C
C		EDIT1310	
C	DUMP ON TAPE 7	EDIT1320	
	1 IF(DUMPT7)30,3,3	EDIT1330	
	3 BACKSPACE 7		
	WS=555.0	EDIT1360	C
	WRITE (7)WS,CYCLE,N3		
	WRITE (7)(Z(L),L=1,MZ)		C
	6 WRITE (7)(U(K),V(K),AMX(K),AIX(K),P(K),K=1,KMAX)		C
	7 WRITE (7)(X(0),X(K),TAU(K),K=1,IMAX)		C
	WRITE (7)(Y(K),K=0,JMAX)		
	WS=666.0	EDIT1480	C

WRITE (7)WS,WS,WS	
WRITE (6,8120)NC	EDIT1500
30 GO TO 126	EDIT1510
C	EDIT1520
C	EDIT1530
6000 NK=12	EDIT1540
C TABS ARE TANGENT ALPHAS.	
TAB(1)=0.02	EDIT1550
TAB(2)=0.04	EDIT1560
TAB(3)=0.06	EDIT1570
TAB(4)=0.08	EDIT1580
TAB(5)=0.10	EDIT1590
TAB(6)=0.15	EDIT1600
TAB(7)=0.20	EDIT1610
TAB(8)=0.25	EDIT1620
TAB(9)=0.30	EDIT1630
TAB(10)=0.4	EDIT1640
TAB(11)=0.5	EDIT1650
TAB(12)=1.0	EDIT1660
6010 DO 6012 I=1,18	EDIT1670
6012 PR(1)=0.0	EDIT1680
NK1=NK+2	EDIT1690
DO 6014 I=1,NK1	EDIT1700
AMK(I)=0.0	EDIT1710
PK(I)=0.0	EDIT1720
6014 QK(I)=0.0	EDIT1730
DO 6028 K=2,KMAX	EDIT1740
6017 PR(1)=0.0	EDIT1760
PR(2)=0.0	EDIT1770
PR(4)=0.	
C CALCULATE KINETIC ENERGY IN CELL K.	
WSB=(U(K)**2+V(K)**2)*.5	
6019 IF(AMX(K))9917,6028,6020	EDIT1790
6020 I=NK1	EDIT1800
IF(V(K))6026,6026,6022	EDIT1810
6022 WSA=ABS(U(K))/V(K)	EDIT1820
DO 6024 I=1,NK	EDIT1830
C SEARCH FOR TAN ANGLE THAT VELOCITY VECTORS	
C MAKE.	
IF(TAB(I)-WSA)6024,6026,6026	EDIT1840
6024 CONTINUE	EDIT1850
I=NK+1	EDIT1860
6026 WS=AMX(K)	EDIT1870
C SUM UP MASS BETWEEN ANGLES.	
6027 AMK(I)=AMK(I)+AMX(K)	EDIT1880
C SUM UP RADIAL MOMENTA IN THE ANGLES.	
PK(I)=PK(I)+U(K)*AMX(K)	EDIT1890
C SUM UP AXIAL MOMENTA IN THE ANGLES.	
QK(I)=QK(I)+V(K)*AMX(K)	EDIT1900
C SUM UP TOTAL INTERNAL ENERGY	

	PR(5)=PR(5)+AIX(K)*AMX(K)	EDIT1910
C	SUM UP TOTAL KINETIC ENERGY	
	PR(6)=PR(6)+WSB*AMX(K)	EDIT1920
C	SUM UP TOTAL MASS	
	PR(8)=PR(8)+AMX(K)	EDIT1930
6028	CONTINUE	EDIT1940
	PR(3)=PR(1)+PR(2)	EDIT1950
	PR(7)=PR(5)+PR(6)	EDIT1960
	XNRG=PR(7)	EDIT1970
	PR(9)=PR(1)+PR(5)	EDIT1980
	PR(10)=PR(2)+PR(6)	EDIT1990
	PR(11)=PR(3)+PR(7)	EDIT2000
	PR(12)=PR(4)+PR(8)	EDIT2010
	WSA=(ETH-PR(11))/ETH	EDIT2020
	IF(CYCLE)9931,9931,9932	
9931	NPC=1	
9932	PR(18)=(WSA-DNN)/FLOAT(NPC)	
	ECK=PR(18)	EDIT2040
	DNN=WSA	EDIT2050
C	RESET CYCLE COUNTER BETWEEN ENERGY CHECK.	
	NPC=0	EDIT2060
	SUM=0.0	EDIT2070
	DO 800 I=1,13	EDIT2080
	SUM=SUM+QK(I)	EDIT2090
800	CONTINUE	EDIT2100
C	RADET= TOTAL POSITIVE AXIAL MOMENTUM IN GRID	
	RADET=SUM	EDIT2110
801	SUM=0.0	EDIT2120
	DO 810 K=2,KMAX	EDIT2130
	IF(AMX(K))810,810,802	EDIT2140
802	IF(U(K))810,810,803	EDIT2150
803	SUM=SUM+AMX(K)*U(K)	EDIT2160
810	CONTINUE	EDIT2170
C	RADER= TOTAL POSITIVE RADIAL MOMENTUM IN GRID.	
	RADER=SUM	EDIT2180
	SUM=0.0	EDIT2190
	JJ=Z(147)	EDIT2200
	DO 811 I=1,IMAX	EDIT2210
	K=I+1	EDIT2220
	DO 813 J=1,JJ	EDIT2230
	IF(AMX(K))813,813,814	EDIT2240
814	IF(U(K))813,813,816	EDIT2250
816	SUM=SUM+U(K)*AMX(K)	EDIT2260
813	K=K+IMAX	EDIT2270
811	CONTINUE	EDIT2280
C	RADEB= TOTAL POSITIVE RADIAL MOMENTUM BELOW	
C	INITIAL TARGET-PROJECTILE INTERFACE.	
	RADEB=SUM	EDIT2290
	PR(19)=0.0	EDIT2300
	DO 6029 I=1,NK	EDIT2310

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6029 PR(I+19)=PR(I+18)+AMK(I)                                EDIT2320
      PR(NK+20)=0.0                                           EDIT2330
      PR(NK+21)=0.0                                           EDIT2340
      WRITE (6,8116)PROB,NC,T,DTNA,TRAD,DTRAD,NR,N1,N2,N3,N4 EDIT2350
      WRITE (6,8117)(PR(I),I=1,8)                             EDIT2360
      WRITE (6,8118)(PR(I),I=9,12)                             EDIT2370
      WRITE (6,8119)RADEB,RADER,RADET,UVMAX,ETH,ECK           EDIT2380
      WRITE (6,9040)N10,N11,I1,I2,I3,I4                       EDIT2390
      WRITE (6,8124)(I,AMK(I),PR(I+19),PK(I),QK(I),I=1,NK1)  EDIT2400
6090 GO TO 130                                                EDIT2410
C**** END OF S P SUBROUTINE *****                         EDIT2420
C                                                                 EDIT2430
C                                                                 EDIT2440
C**** SUBROUTINE PLOT *****                                EDIT2450
1000 GO TO 1030                                                EDIT2460
1030 WRITE (6,8116)PROB,NC,T,DTNA,TRAD,DTRAD,NR,N1,N2,N3,N4 EDIT2470
      JMAX=JMAX                                                 EDIT2480
      WRITE (6,8307)X1,X2,XMAX,Y1,Y2,Y(JMAX)                 EDIT2490
      M=1                                                        EDIT2500
      IF(JMAX-52)1034,1036,1036                                EDIT2510
1034 M=IABS(51-JMAX)/2                                         EDIT2520
1036 DO 1040 I=1,M                                             EDIT2530
      WRITE (6,8308)                                             EDIT2540
1040 CONTINUE                                                  EDIT2550
1044 J=I2                                                       EDIT2560
1100 K=(J-1)*IMAX+1                                           EDIT2570
1105 DO 1180 I=1,I1                                           EDIT2580
      K=K+1                                                     EDIT2590
C      REPLACE 600000000000 BY-17179869184                   EDIT2600
1126 PR(I)=(-ABS(-17179869184))                                EDIT2610
1150 IF(AMX(K))9917,1166,1160                                  EDIT2620
C      X PARTICLE ONLY                                         EDIT2630
C      REPLACE 67000000000 BY 922746880                      EDIT2640
1160 PR(I)=OR(PR(I), ABS( 922746880) )                        EDIT2650
      GO TO 1180                                                EDIT2660
C      REPLACE 60000000000 BY 805306368                      EDIT2670
1166 PR(I)=OR(PR(I), ABS( 805306368) )                        EDIT2680
1180 CONTINUE                                                  EDIT2690
1200 IF(MOD(J,5))1210,1204,1210                                EDIT2700
1204 IF(DY(J)-DY(J-1))1206,1208,1206                          EDIT2710
1206 WRITE (6,8211)DY(J),J,(PR(I),I=1,I1)                    EDIT2720
      GO TO 1224                                                EDIT2730
1208 WRITE (6,8201)J,(PR(I),I=1,I1)                           EDIT2740
      GO TO 1224                                                EDIT2750
1210 IF(DY(J)-DY(J-1))1212,1214,1212                          EDIT2760
1212 WRITE (6,8222)DY(J),(PR(I),I=1,I1)                       EDIT2770
      GO TO 1224                                                EDIT2780
1214 WRITE (6,8202)(PR(I),I=1,I1)                             EDIT2790
1224 J=J-1                                                     EDIT2800
1226 IF(J)1230,1230,1100                                       EDIT2810

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4

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      GO TO 9999
C      ENERGY CHECK
9905 NK=136
      GO TO 9999
C      NEGATIVE MASS
9917 NK=6015
      GO TO 9999
9920 NK=904
      GO TO 9999
9921 NK=912
      GO TO 9999
9922 NK=918
      GO TO 9999
9923 NK=922
      GO TO 9999
9924 NK=926
9999 NR=6
      CALL DUMP
10000 RETURN
C
C      FORMATS
8108 FORMAT(I3,1X,1P2E14.6,3E15.6,E14.6,E15.6,E14.6)
81160FORMAT(8H1PROBLEM6X,5HCYCLE9X,4HTIME13X,2HDT13X,4HTRAD11X,5HJTRAD1
12X,2HN6X,2HN14X,2HN24X,2HN34X,2HN4/(F7.1,I11,2X,1P4E16.7,I10,2X,4E
216))
81170FORMAT(1H0//17X2HAI16X,2HAK14X,5HAI+AK15X,2HAM/4H DOT3X,1P4E18.7/3
1H X4X,4E18.7)
81180FORMAT(12X,13H-----5X,13H-----5X,13H-----5E11,343
1X,13H-----/7H TOTALS1P4E18.7)
81190FORMAT(2H0 //16X,5HRADEB13X,5HRADEB13X,5HRADET12X,7HMAX VEL13X,3HTE
1HE12X,9HREL ERROR/7X,1P6E18.7//)
8120 FORMAT(1H0//21H TAPE 7 DUMP ON CYCLE15//)
81240FORMAT(3H K12X,5HAM(K)11X,9HSUM AM(K)11X,4HHP(K)13X,4HQ(K)/(I3,4X,
11P4E18.7))
8131 FORMAT(1H ///11H DY(J) J=1,I2//((10F12.3))
8133 FORMAT(1H ///11H Y(J) J=0,I2//((10F12.3))
81350FORMAT(1H ///4H I =I3,6X,6HX(I) =F12.3,6X,7HDX(I) =F12.3//3H J8X,
11HX13X,1HY13X,3HF/A12X,3HAMX12X,3HRHO11X,3HAI1X12X,4HCOMP11X,2H Y/)
8201 FORMAT(I10,2H I54A2)
8202 FORMAT(10X,2H I54A2)
8211 FORMAT(F7.1,I3,2H I54A2)
8222 FORMAT(F7.1,3X,2H I54A2)
8302 FORMAT(I12,10I10)
83070FORMAT(5H X1 =1PE12.6,3X,4HX2 =E12.6,3X,6HXXMAX =E12.6,6X,4HY1 =E12
1.6,3X,4HY2 =E12.6,3X,6HYMAX =E12.6)
8308 FORMAT(1H /)
9040 FORMAT(1H / 6I6)
      END

```

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EDIT316
EDIT317
EDIT318
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\$18FTC PH3 ...S DECK,REF

SUBROUTINE PH3

C	NOTE, THIS CODE IS CALLED RPM,	PH3 0000
C	RIGID PLASTIC MATERIAL.	PH3 0005
C	*** NOTE, BOUNDARY CONDITIONS ***	PH3 0010
C	AT FREE SURFACE (GRID BOUNDARY) SET	PH3 0015
C	THE STRESS AT THE RIGHT, TOP OR BOTTOM	PH3 0020
C	= TO THE STRESS AT THE LEFT, BOTTOM OR	PH3 0025
C	TOP RESPECTIVELY, INSURING THAT THE	PH3 0030
C	ACCELERATION OF THE BORDER CELLS BE	PH3 0035
C	ZERO.	PH3 0040
C	FOR AXIS OF SYMMETRY, SET THE NORMAL	PH3 0045
C	AND SHEAR STRESSES TO 0. SINCE REGARDLESS	PH3 0050
C	OF MANNER OF COMPUTING THEM, THE AREA	PH3 0055
C	OVER WHICH THEY ACT IS ZERO.	PH3 0060
C	FOR REFLECTIVE BOUNDARIES AT THE BOTTOM	PH3 0065
C	OR IN THE GRID, USING THE BOTTOM AS	PH3 0070
C	A EXAMPLE, SET U(BOTTOM) = U(K) BUT	PH3 0075
C	SNF=NORMAL STRESS AT THE TOP OF	PH3 0085
C	A CELL. (THE ARRAY=ASN(I)).	PH3 0090
C		PH3 0095
C	STF=SHEAR STRESS AT THE TOP OF	PH3 0100
C	A CELL. (THE ARRAY=AST(I)).	PH3 0105
C		PH3 0110
C	STR=SHEAR STRESS AT THE RIGHT OF	PH3 0115
C	A CELL. (THE ARRAY=RST(I+1)).	PH3 0120
C		PH3 0125
C	SNR=NORMAL STRESS AT THE RIGHT OF	PH3 0130
C	A CELL. (THE ARRAY=RSN(I+1)).	PH3 0135
C		PH3 0140
C	SNB=NORMAL STRESS AT THE BOTTOM OF	PH3 0145
C	A CELL. (THE ARRAY=ASNB(I)).	PH3 0150
C		PH3 0155
C	STB=SHEAR STRESS AT THE BOTTOM OF	PH3 0160
C	A CELL. (THE ARRAY=ASTB(I)).	PH3 0165
C		PH3 0170
C	SNL=NORMAL STRESS AT THE LEFT OF	PH3 0175
C	A CELL. (THE ARRAY=RSN(I)).	PH3 0180
C		PH3 0185
C	STL=SHEAR STRESS AT THE LEFT OF	PH3 0190
C	A CELL. (THE ARRAY=RST(I)).	PH3 0195
C		PH3 0200
C	DDVK=HOOP STRESS OF A CELL (ARRAY=SIG33(I)).	PH3 0205
C		PH3 0210
C	X1=UDOT OF A CELL, (ARRAY=DUDOT(I))	PH3 0215
C		PH3 0220
C	X2=VDOT OF A CELL, (ARRAY=DVDOT(I))	PH3 0225
C	SIGC(I)=U(K BELOW)	
C	GAMC(I)=V(K BELOW)	
C	FEF IS A FLAG TO BYPASS THE STRENGTH	PH3 0240

C	CALCULATIONS	PH3 024
	VSAVE=VT	
	IF(FEF)7778,7779,7778	
C	NOTE, CLEAR THE PRESSURE ARRAY.	
7779	DO 9600 K=2,KMAX	
	P(K)=0.	
9600	CONTINUE	
	WS=I3	
	DTI=DT	
	DT=DT/WS	
C	BIG=DV/DZ CRIT	
	BIG=DVK*DT*TABLM	
C	PROVISIONS FOR SUBCYCLING THE STRENGTH	
	DO 9000 NN=1,I3	
C		PH3 023
C	NOTE, SET THE FLAGS FOR INCREASING THE	
C	ACTIVE GRID COUNTERS TO 0.	
	NRC=0	
	NRT=0	
	SUM=0.	
C		
1	DO 3302 J=1,I2	PH3 026
C		PH3 026
C	NOTE, SET UP DO LOOP IN J DIRECTION FIRST, NOTE	PH3 027
C	THAT I2 IS THE LIMIT, NOT JMAX	PH3 027
C		PH3 028
2	K=(J-1)*IMAX+2	PH3 028
	N=K+IMAX	PH3 029
C		PH3 029
C	NOTE, K IS THE INDEX OF CELL IN QUESTION, N	PH3 030
C	IS THE INDEX OF CELL ABOVE.	PH3 030
C		PH3 031
C	***, NOTE, THE STRESSES AT THE AXIS OF SYMMETRY	PH3 031
C	ARE SET TO 0. SINCE REGARDLESS OF MANNER OF	PH3 032
C	CALCULATION, THE AREA IS 0.	PH3 032
C		PH3 033
3	SNL=0.	PH3 033
	STL=0.	PH3 034
C		PH3 034
C	SET UP DO LOOP IN THE I DIRECTION, NOTE THAT	PH3 035
C	I1 IS THE LIMIT, NOT IMAX.	PH3 035
C		PH3 036
4	DO 3361 I=1,I1	PH3 036
C		
C	AMDM= FACTOR FOR STRESS CUTOFF ON THE BASIS OF	
C	THE DENSITY BEING LESS THAN AMDM X THE INITIAL DENSITY	
C		
C	CHECK FOR RAREFIED MATERIAL IN CELL (K)	
40	IF(AMX(K)/(TAU(I)*DY(J))-AMDM*Z(115))3340,3340,38	
38	IF(J-1)720,720,721	

721	KBLO= K-IMAX	
	IF(AMX(KBLO)/(TAU(I)*DY(J-1))-AMD*Z(115))722,722,720	
722	DDVK=0.	
	GO TO 3306	
C		PH3 0375
720	VT=0.	
	II=I	
	JN=J	
C		
C	CHECK FOR 1D PROBLEM	
C		
	IF(IMAX-1)39,810,39	
C	SET HOOP STRESS TO ZERO	
810	DDVK=0.	
	GO TO 3306	
C		PH3 0385
C	NOW WE WILL SET INDICES FOR A HOOP	PH3 0390
C	STRESS CALC. OR A ECAL.	PH3 0395
C		PH3 0400
39	IF(J-1)9908,41,47	PH3 0405
C		PH3 0410
C	WE ARE IN THE BOTTOM ROW	PH3 0425
C		PH3 0430
41	KA=N	PH3 0435
	KB=K	PH3 0440
	VV=1.	
	UUU=1.	PH3 0450
42	IF(I-1)9907,43,44	PH3 0455
C		PH3 0460
C	WE ARE IN THE LOWER LEFT CORNER	PH3 0465
43	KL=K	PH3 0470
	KR=K+1	PH3 0475
	FD=1.	
	E=1.	PH3 0485
	GO TO 100	PH3 0490
44	IF(I-IMAX)46,45,9903	PH3 0495
C		PH3 0500
C	WE ARE IN THE LOWER RIGHT CORNER	PH3 0505
45	KR=K	PH3 0510
	KL=K-1	PH3 0515
	E=1.	
	FD=1.	PH3 0525
	GO TO 100	PH3 0530
C		PH3 0535
C	WE ARE IN BOTTOM ROW, BUT NOT AT	PH3 0540
C	AXIS OR RIGHT BOUNDARY OF GRID.	PH3 0545
C		PH3 0550
46	KR=K+1	PH3 0555
	KL=K-1	PH3 0560
	E=1.	PH3 0565

FD=1.	PH3 0570
GO TO 100	PH3 0575
C	PH3 0580
C NOT IN BOTTOM ROW	PH3 0585
47 IF(J-JMAX)54,48,9903	PH3 0590
C	PH3 0595
C WE ARE IN THE TOP ROW	PH3 0600
48 KA=K	PH3 0605
KB=K-IMAX	PH3 0610
UUU=1.	
VV=1.	PH3 0620
49 IF(I-1)9907,50,51	PH3 0625
C	PH3 0630
C WE ARE IN UPPER LEFT CORNER	PH3 0635
50 KR=K+1	PH3 0640
KL=K	PH3 0645
FD=1.	
E=1.	PH3 0655
GO TO 100	PH3 0660
51 IF(I-IMAX)53,52,9903	PH3 0665
C	PH3 0670
C WE ARE IN UPPER RIGHT CORNER	PH3 0675
52 KR=K	PH3 0680
KL=K-1	PH3 0685
E=1.	
FD=1.	PH3 0695
GO TO 100	PH3 0700
C	PH3 0705
C WE ARE AT THE TOP, BUT NOT AT	PH3 0710
C THE AXIS OR RIGHT BOUNDARY OF GRID	PH3 0715
53 KR=K+1	PH3 0720
KL=K-1	PH3 0725
E=1.	PH3 0730
FD=1.	PH3 0735
GO TO 100	PH3 0740
C	PH3 0745
C WE ARE NOT AT THE TOP OR BOTTOM,	PH3 0750
C CHECK OUR POSITION WITH RESPECT TO THE	PH3 0755
C AXIS AND RIGHT BOUNDARY OF GRID.	PH3 0760
54 VV=1.	PH3 0765
KA=N	PH3 0770
KB=K-IMAX	PH3 0775
UUU=1.	PH3 0780
55 IF(I-1)9907,59,56	PH3 0785
C	PH3 0790
C WE ARE ALONG THE AXIS	PH3 0795
59 KL=K	PH3 0800
KR=K+1	PH3 0805
E=1.	PH3 0810
FD=1.	

GO TO 100	PH3 0820
56 IF(I-1MAX)58,57,9903	PH3 0825
C	PH3 0830
C WE ARE ALONG THE RIGHT BOUNDARY OF GRID	PH3 0835
57 KR=K	PH3 0840
KL=K-1	PH3 0845
E=1.	
FD=1.	PH3 0855
GO TO 100	PH3 0860
C	PH3 0865
C WE ARE IN THE MESH, NOT AT ANY BOUNDARY	PH3 0870
58 E=1.	PH3 0875
FD=1.	PH3 0880
KR=K+1	PH3 0885
KL=K-1	PH3 0890
GO TO 100	PH3 0895
100 IF(VT)102,101,102	
C CALCULATE THE HOOP STRESS FOR CELL K.	
101 CALL HOOP	PH3 0905
GO TO 3306	PH3 0910
C CALCULATE THE CHANGE IN INTERNAL ENERGY	
C DUE TO THE WORK DONE BY THE STRESSES.	
102 CALL ECALC	PH3 0915
GO TO 801	PH3 0920
C	PH3 0935
C	PH3 0940
C CELL K IS VOID, SET ALL 9	PH3 0945
C STRESSES TO ZERO. *****	PH3 0950
C	PH3 0955
3340 SNT=0.	PH3 0960
STT=0.	PH3 0965
SNL=0.	PH3 0970
SNR=0.	PH3 0975
STL=0.	PH3 0980
STR=0.	PH3 0985
SNB=0.	PH3 0990
STB=0.	PH3 0995
DDVK=0.	PH3 1000
X1=0.	PH3 1005
X2=0.	PH3 1010
GO TO 3326	PH3 1015
C	PH3 1020
C RETURN TO HERE AFTER CALCULATING THE	PH3 1025
C HOOP STRESS	PH3 1030
3306 IF(1MAX-I)9901,3311,3310	PH3 1035
C CHECK FOR RAREFIED MATERIAL IN THE CELL TO THE	
C RIGHT.	
3310 IF(AMX(K+1))9902,3312,4000	
4000 IF(AMX(K+1)/(TAU(I+1)*DY(J))-AMDM*Z(115))3312,3312,14	
C	PH3 1045

C	WE ARE AT THE RIGHT BOUNDARY OF GRID	PH3 105
C	SET THE STRESSES ON THE RIGHT = TO	PH3 105
C	THOSE ON THE LEFT	PH3 106
3311	SNR=SNL	PH3 106
	STR=STL	PH3 107
	GO TO 3316	PH3 107
C		PH3 108
C		PH3 108
C	THE CELL TO THE RIGHT OF CELL K IS VOID.	PH3 109
C	SET THE STRESSES ON THE RIGHT TO 0.	PH3 109
C		PH3 110
3312	SNR=0.	PH3 110
	STR=0.	PH3 111
	DDVK=0.	
	S1=0.	
	S2=0.	
	S3=0.	
	S4=0.	
	S5=0.	
	GO TO 3316	PH3 111
C		PH3 112
C	WE ARE PREPARING TO CALCULATE THE STRESSES	PH3 112
C	AT THE RIGHT OF THIS CELL.	PH3 113
C	WE ARE NOT AT IMAX, BUT MAY BE AT J=1	PH3 113
C	OR J=JMAX OR IN THE MESH.	PH3 114
C		PH3 114
14	KR=K+1	PH3 115
	II=I	
	JN=J	
	IF(J-1)9908,28,27	PH3 115
C		PH3 116
C	NOT IN BOTTOM ROW	PH3 116
27	IF(J-JMAX)33,32,9903	PH3 117
C		PH3 117
C	WE ARE IN TOP ROW	PH3 118
32	KA=K	PH3 118
	KAR=KR	PH3 119
	KB=K-IMAX	PH3 119
	KBR=KB+1	PH3 120
	UUU=1.	PH3 120
	VV=1.	
	GO TO 31	PH3 121
C		PH3 122
C	WE ARE INSIDE THE MESH.	PH3 122
C	NOTE, THE SPECIAL BOUNDARY CONDITIONS	
C	FOR EMPTY CELLS ADJACENT TO CELL K.	
33	KB=K-IMAX	
723	KBR=KB+1	
724	IF(AMX(KB))725,725,726	
725	KB=K	

726 IF (AMX(KBR)) 727,727,730	
727 KBR=K+1	
730 VV=1.	
KA=N	PH3 1240
KAR=KA+1	PH3 1245
GO TO 31	PH3 1260
C	PH3 1265
C WE ARE IN THE BOTTOM ROW.	PH3 1270
28 KB=K	PH3 1275
KBR=KR	PH3 1280
KA=N	PH3 1285
KAR=N+1	PH3 1290
UUU=1.	
VV=1.	PH3 1300
31 CALL GRADR	PH3 1305
C	PH3 1310
C CALCULATE THE VELOCITY GRADIENTS AT THE	PH3 1315
C RIGHT	PH3 1320
29 CALL STRESR	PH3 1325
C	
C	PH3 1330
C CALCULATE THE NORMAL AND SHEAR STRESS	PH3 1335
C AT THE RIGHT.	PH3 1340
30 CONTINUE	PH3 1345
C	PH3 1350
C DONT PUT THE INDIVIDUAL STRESSES INTO	PH3 1355
C ARRAYS UNTIL LATER.	PH3 1360
GO TO 3316	PH3 1365
C	PH3 1370
3316 IF (JMAX-J) 9903,3315,3320	PH3 1375
C	PH3 1380
C WE ARE AT THE TOP OF THE GRID, SET THE	PH3 1385
C STRESSES AT THE TOP = THOSE AT BOTTOM OF	PH3 1390
C THE CELL.	PH3 1395
C	PH3 1400
C	PH3 1405
3315 SNT=ASN(I)	PH3 1410
STT=AST(I)	PH3 1415
DDVK=0.	
GO TO 3325	PH3 1420
C	PH3 1425
C WE ARE NOT AT THE TOP OF THE GRID.	PH3 1430
C	PH3 1440
C CHECK FOR RAREFIED MATERIAL IN CELL ABOVE.	
3320 IF (AMX(N)) 9904,3322,4010	
4010 IF (AMX(N)/(TAU(I)*DY(J+1))-1MDM*Z(115)) 3322,3322,12	
C	PH3 1445
C THE CELL ABOVE CELL (K) IS VOID	PH3 1450
C SET THE STRESSES ABOVE TO 0.	PH3 1455
3322 SNT=0.	PH3 1460

STT=0.	PH3 146
DDVK=0.	
S6=0.	
S7=0.	
S8=0.	
S9=0.	
S10=0.	
GO TO 3325	PH3 147
C	PH3 1475
C	PH3 148
C WE WILL CALCULATE THE VELOCITY	PH3 148
C GRADIENTS AND STRESSES AT THE TOP OF	PH3 149
C THE CELL.	PH3 149
C	PH3 150
C WE ARE NOT AT THE TOP(J=JMAX)	PH3 150
C	PH3 151
12 KA=N	PH3 151
II=I	
JN=J	
21 IF(I-1)9907,15,16	PH3 152
16 IF(I-IMAX)18,17,9901	PH3 152
C	PH3 153
C INSIDE THE MESH	PH3 153
C NOTE THE SPECIAL BOUNDARY CONDITIONS	
C FOR EMPTY CELLS ADJACENT TO CELL K.	
18 KAR=KA+1	
KR=K+1	
732 IF(AMX(KAR))733,733,734	
733 KAR=KA	
734 IF(AMX(KR))735,735,736	
735 KR=K	
736 UUU=1.	
VV=1.	PH3 154
KL=K-1	PH3 156
KAL=KA-1	PH3 156
GO TO 24	PH3 157
C	PH3 157
C ALONG THE RIGHT BOUNDARY	PH3 158
17 KAR=KA	PH3 158
KR=K	PH3 159
KAL=KA-1	PH3 159
KL=K-1	PH3 160
UUU=1.	PH3 160
VV=1.	
GO TO 24	PH3 161
C	PH3 162
C WE ARE ALONG THE AXIS	PH3 162
15 KL=K	PH3 163
KAL=KA	PH3 163
C	

C	CHECK FOR 1D PROBLEM	
C		
	IF(IMAX-1)811,812,811	
812	KAR=KA	
	KR=K	
	UUU=1.	
	GO TO 813	
811	KAR=KA+1	
	KR=K+1	PH3 1645
	UUU=1.	
813	VV=1.	
C		PH3 1660
C	CALCULATE THE VELOCITY GRADIENTS AT	PH3 1665
C	THE TOP OF THE CELL.	PH3 1670
	24 CALL GRADZ	PH3 1675
C		PH3 1680
C	CALCULATE THE STRESSES.	PH3 1685
	25 CALL STRESZ	PH3 1690
C		
	26 CONTINUE	PH3 1695
	GO TO 6999	PH3 1700
C		PH3 1705
C		PH3 1710
C	ARRIVED HERE AFTER COMPLETION OF THE	PH3 1715
C	CALCULATION OF THE STRESSES AT THE TOP.	PH3 1720
6999	IF(1-J)3325,7001,9908	PH3 1725
C		PH3 1730
C		PH3 1735
C	WE ARE IN THE BOTTOM ROW, NOW	PH3 1740
C	CHECK THE BOUNDARY CONDITION AT THE BOTTOM.	PH3 1745
	7001 IF(CVIS)7003,7002,7002	PH3 1750
C		PH3 1755
C		PH3 1760
C	BOTTOM BOUNDARY IS REFLECTIVE	PH3 1765
	7002 SNB=0.	PH3 1770
	STB=0.	PH3 1775
	GO TO 3325	PH3 1780
C		PH3 1785
C		PH3 1790
C	BOTTOM BOUNDARY IS TRANSMITTIVE, SET THE	PH3 1795
C	BOTTOM STRESSES TO THE TOP (WE JUST	PH3 1800
C	FINISHED CALCULATING THEM).	PH3 1805
C		PH3 1810
	7003 SNB=SNT	PH3 1815
	STB=STT	PH3 1820
	GO TO 3325	PH3 1825
C		PH3 1830
C	NOW, WE HAVE ALL THE STRESSES OF CELL K	PH3 1835
C	THUS WE CAN CALCULATE U DOT AND VDOT.	PH3 1840
	3325 CONTINUE	PH3 1845

300	CONTINUE	PH3 18
	JN=J	
	II=I	
C		PH3 18
C	CALL DELTAU(COMPUTES UDOT)	PH3 18
	IF(J-1)310,310,311	PH3 18
311	STB=AST(I)	PH3 18
310	CALL DELTAU	PH3 18
C		PH3 18
301	CONTINUE	PH3 18
C	NOW CALL DELTAV(COMPUTES VDOT)	PH3 18
302	CONTINUE	PH3 18
	IF(J-1)312,312,313	PH3 19
313	SNB=ASN(I)	PH3 19
312	CALL DELTAV	PH3 19
303	CONTINUE	PH3 19
C		PH3 19
C	BY NOW WE HAVE THE ACCELERATION	PH3 19
C	(BOTH COMPONENTS) OF CELL K DUE TO	PH3 19
C	THE STRESSES.	PH3 19
304	IF(I-1)9907,3326,305	PH3 19
305	IF(I-IMAX)306,3326,9901	PH3 19
C		PH3 19
C	////////////////////////////////////	
C	CHECK FOR OVERSHOOT IN THE RADIAL DIRECTION.	PH3 19
C	AT THE LEFT INTERFACE OF CELL(K),	
C	////////////////////////////////////	
C	CALCULATE DELTA U AT CYCLE N/	PH3 19
C	DELTA UDOT AT CYCLE N+1	PH3 19
306	WS=-(U(K)-U(K-1))/(X1-DUDOT(I-1))	PH3 19
307	IF(WS)450,308,308	PH3 19
308	IF(DT-WS)450,309,309	PH3 19
450	UPR=0.	PH3 19
	GO TO 400	PH3 19
C		PH3 19
C	CHECK IF WS IS BETWEEN 0. AND DT	PH3 20
C	IF LESS THAN ZERO, BYPASS CHECK.	PH3 20
C	IF IT IS LESS THAN DT, REDUCE THE	PH3 20
C	STRESS(NORMAL) BY THE RATIO WS/DT.	PH3 20
309	WS=WS/DT	PH3 20
	SNL=SNL*WS	PH3 20
	UPR=-1.	PH3 20
C		PH3 20
C	CHECK THE OTHER COMPONENT.	PH3 20
400	WS=-(V(K)-V(K-1))/(X2-DVDOT(I-1))	PH3 20
C		PH3 20
C	NOW CHECK THE SIGN AND MAGNITUDE WITH	PH3 20
C	RESPECT TO DT(HYDRO).	PH3 20
401	IF(WS)501,408,408	PH3 20
C		PH3 20

C	IF(-1)BYPASS CHECK	PH3 2080
C	IF GREATER THAN 0. CHECK AGAINST DT	PH3 2085
C	408 IF(DT-WS)501,409,409	PH3 2090
C		PH3 2095
C	IF(GREATER)BYPASS CHECK	PH3 2100
C	501 UPZ=0.	PH3 2105
C	GO TO 500	PH3 2110
C	409 WS=WS/DT	PH3 2115
C		PH3 2120
C	REDUCE SHEAR STRESS AT THE RIGHT	PH3 2125
C	BY WS/DT	PH3 2130
C	STL=STL*WS	PH3 2135
C	UPZ=-1.	PH3 2140
C		PH3 2145
C	IF P(K)=0. NO OVERSHOOT IN EITHER	
C	COMPONENT.	
C	IF P(K)=-1. THE SHEAR STRESS WAS	
C	MODIFIED.	
C	IF P(K)=1. THE NORMAL STRESS WAS	
C	MODIFIED.	
C	IF P(K)=2. BOTH OF THE STRESSES	
C	REQUIRED MODIFICATIONS.	
C	500 CONTINUE	
C	IF(UPR)9601,9602,9602	
C	9601 IF(UPZ)9603,9604,9604	
C	9603 P(K-1)=2.	
C	GO TO 3326	
C	9602 IF(UPZ)9605,3326,3326	
C	9605 P(K-1)=-1.	
C	GO TO 3326	
C	9604 P(K-1)=1.0	
C	GO TO 3326	
C	***** NOTE; WE ONLY SET THE COMPLETE ARRAY FOR THE	PH3 2435
C	FIRST ROW *****	PH3 2440
C	3326 IF(J-1)9902,3328,601	PH3 2445
C	3328 ASN(I)=SNT	PH3 2450
C	AST(I)=STT	PH3 2455
C	RSN(I)=SNL	PH3 2460
C	640 RSN(I+1)=SNR	PH3 2465
C	RST(I+1)=STR	PH3 2470
C	641 ASNB(I)=SNB	PH3 2475
C	RST(I)=STL	PH3 2480
C	ASTB(I)=STB	PH3 2485
C	SIG33(I)=DDVK	PH3 2490
C	DUDOT(I)=X1	PH3 2495
C	DVDOT(I)=X2	PH3 2500
C		
C	SET THE RIGHT STRESSES FROM CELL (K) TO	
C	= THE LEFT STRESSES FOR CELL (K+1).	
C	SNL=SNR	PH3 2505

STL=STR	PH3 25
GO TO 3360	
C	PH3 25
C	
//////////	
C CHECK FOR OVERSHOOT DUE TO STRESSES	PH3 25
C AT THE TOP OF CELL(K-IMAX) OR	
C THE BOTTOM OF CELL(K).	
C	
//////////	
C *****	PH3 25
C CAME HERE AFTER CALCULATING A CELL IN A	PH3 25
C ROW DIFFERENT THAN FOR J=1 .	PH3 25
C *****	PH3 25
601 KRM=K-IMAX	PH3 25
IF(AMX(KRM)/(TAU(I)*DY(J-1))-ANDM*Z(115))901,901,602	
C *****	PH3 25
C KRM=INDEX OF CELL BELOW	PH3 25
C *****	PH3 25
602 WS=-(U(K)-U(KRM))/(X1-DUDOT(I))	PH3 25
C *****	PH3 25
C REMEMBER, THE STRESSES,UDOT,VDOT, AND	PH3 25
C HOOP STRESS FOR CELL K HAVE NOT BEEN PLACED	PH3 25
C IN THE ARRAY.	PH3 25
C *****	PH3 26
603 IF(WS)604,605,605	PH3 26
605 IF(DT-WS)604,606,606	PH3 26
604 UPR=0.	PH3 26
GO TO 607	PH3 26
C *****	PH3 26
C REDUCE THE SHEAR STRESS ON THE TOP	PH3 26
C *****	PH3 26
606 WS=WS/DT	PH3 26
AST(I)=AST(I)*WS	PH3 26
UPR=-1.	PH3 26
C CHECK OTHER COMPONENT	PH3 26
607 WS=-(V(K)-V(KRM))/(X2-DVDOT(I))	PH3 26
608 IF(WS)614,615,615	PH3 26
615 IF(DT-WS)614,616,616	PH3 26
614 UPZ=0.	PH3 26
GO TO 617	PH3 26
C *****	PH3 26
C REDUCE THE NORMAL STRESS ON THE TOP	PH3 26
C *****	PH3 26
616 WS=WS/DT	PH3 27
ASN(I)=ASN(I)*WS	PH3 27
UPZ=-1.	PH3 27
C *****	PH3 27
C SET INDICES FOR CELL BELOW FOR POSSIBLE UPDATING	PH3 27
C OF UDOT AND VDOT	PH3 27
C *****	PH3 27
617 KK=K	PH3 27

	KKK=N	PH3 2740
	K=K-IMAX	PH3 2745
	N=KK	PH3 2750
	II=I	PH3 2755
	JN=J-1	PH3 2760
C	*****	PH3 2765
C	SAVE THE STRESSES OF CELL K	PH3 2770
C	TEMPORARY.	PH3 2775
C		PH3 2780
	SNB=ASN(I)	PH3 2785
	STB=AST(I)	PH3 2790
	PK(1)=SNB	PH3 2795
	PK(2)=STB	PH3 2800
	PK(3)=STR	PH3 2805
	PK(4)=SNR	PH3 2810
	PK(5)=SNT	PH3 2815
	PK(6)=STT	PH3 2820
	PK(7)=SNL	PH3 2825
	PK(8)=STL	PH3 2830
	PK(9)=DDVK	PH3 2835
	PK(10)=X1	PH3 2840
	PK(11)=X2	PH3 2845
C	NOW SET STRESSES FROM K-IMAX INTO	PH3 2850
C	THE CORRECT STORAGE FOR THE	PH3 2855
C	SUB-ROUTINES.	PH3 2860
626	SNB=ASN(I)	PH3 2865
	STB=AST(I)	PH3 2870
	STR=RST(I+1)	PH3 2875
	SNR=RSN(I+1)	PH3 2880
	SNT=ASN(I)	PH3 2885
	STT=AST(I)	PH3 2890
	SNL=RSN(I)	PH3 2895
	STL=RST(I)	PH3 2900
	DDVK=SIG33(I)	PH3 2905
	X1=DUDOT(I)	PH3 2910
	X2=DVDOT(I)	PH3 2915
620	IF(UPZ) 624, 9700, 9700	
624	CALL DELTAV	
	GO TO 9702	
9700	IF(P(K)-1.) 9710, 9701, 9710	
9710	IF(P(K)) 624, 9701, 624	
9701	CONTINUE	
9702	IF(UPR) 9703, 9704, 9704	
9703	CALL DELTAU	
	GO TO 9705	
9704	IF(P(K)-1.) 9705, 9703, 9703	
9705	CONTINUE	
625	IF(J-2) 800, 650, 651	
650	SIGC(I)=U(K)	
	GAMC(I)=V(K)	

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      GO TO 800
651 KBB=K-1MAX
      WSU=U(KBB)
      WSV=V(KBB)
      U(KBB)=SIGC(I)
      V(KBB)=GAMC(I)
C      SET FLAG TO 1.(USE THE LOOK-UP
C      ROUTINE THAT THE HOOP STRESS USES)
800 IF(I-2)802,803,803
C      SET THE VELOCITIES AT THE LEFT AND SAVE
C      THE OLD ONES.
803 UTEF=U(K-1)
      VTEF=V(K-1)
      U(K-1)=SIGC(I-1)
      V(K-1)=GAMC(I-1)
802 VT=1.
      GO TO 39
C      ** FINALLY GETTING AROUND TO CALCULATE
C      THE VELOCITIES AND INTERNAL ENERGIES.
C      CALCULATE THE RADIAL COMPONENT, AND AXIAL
801 AIX(K)=AIX(K)+VISC
670 CONTINUE
      IF(AIX(K)-VVABOV)700,700,656
700 SUM=SUM+AIX(K)*AMX(K)
      AIX(K)=0.
656 IF(I-2)652,805,805
C      RESET THE(N+1) VELOCITIES IN CELL (K-1)
805 U(K-1)=UTEF
      V(K-1)=VTEF
      GO TO 652
652 IF(J-3)653,654,654
654 SIGC(I)=U(K)
      GAMC(I)=V(K)
      U(KBB)=WSU
      V(KBB)=WSV
      GO TO 653
C
C      //////////////////////////////////////
C      NOTE, HERE WE CHECK ON THE
C      POSSIBLE OVERSHOOT FROM THE HOOP STRESS
653 WSA=X1*DT
      WS=U(K)+WSA
      IF(U(K))661,658,657
657 IF(WS)660,658,658
658 U(K)=WS
      GO TO 659
660 DX1=2.*PIDY/AMX(K)*DX(I)*DY(JN)
      DX1=-DX1*DDVK
      X1=X1-DX1
      DX1=DX1*ABS(U(K)/WSA)

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PH3 2995
PH3 3000

PH3 3010
PH3 3015
PH3 3020
PH3 3025

```

      X1=X1+DX1
      U(K)=U(K)+X1*DT
      GO TO 659
661 IF(WS)658,658,660
659 V(K)=V(K)+X2*DT
      IF(ABS(U(K))-VVBLO)701,701,702
701 SUM=SUM+U(K)**2/2.*AMX(K)
      U(K)=0.
702 IF(ABS(V(K))-VVBLO)703,703,704
703 SUM=SUM+V(K)**2/2.*AMX(K)
      V(K)=0.
704 CONTINUE
C      VISC IS DI/DT
C      *** RESET THE INDICES NOW, K AND N
C      WERE TEMPORARY SET FOR CELL BELOW
873 K=KK
      N=KKK
C      *****
C
C      WE NOW HAVE COMPLETED THE INTEGRATION OF
C      THE MOMENTUM AND ENERGY EQUATIONS
C      FOR CELL K-IMAX
C
C      *****
C      WE CAN NOT PLACE ALL THE STRESSES OF CELL K
C      INTO THE (I)
C      ARRAY, SINCE THE OVERSHOOT(ON THE TOP) OF CELL
C      K-IMAX+1 HAS NOT BEEN CHECKED
C
C      SET THE STRESSES THAT WE STORED
C      TEMPORARY IN PK(1) THRU PK(9),BACK INTO
C      THE STORAGE THAT THE SUBROUTINES
C      RECOGNIZE.
900 SNB=PK(1)
      STB=PK(2)
      STR=PK(3)
      SNR=PK(4)
      SNT=PK(5)
      STT=PK(6)
      SNL=PK(7)
      STL=PK(8)
      DOVK=PK(9)
      X1=PK(10)
      X2=PK(11)
901 ASN(I)=ASN(I)
      ASTB(I)=AST(I)
      RSN(I)=SNL
      RST(I)=STL
      ASN(I)=SNT
      AST(I)=STT

```

PH3 3090
 PH3 3095
 PH3 3100
 PH3 3110
 PH3 3115
 PH3 3120
 PH3 3125
 PH3 3130
 PH3 3135
 PH3 3140
 PH3 3145
 PH3 3150
 PH3 3155
 PH3 3160
 PH3 3165
 PH3 3170
 PH3 3175
 PH3 3180
 PH3 3185
 PH3 3190
 PH3 3195
 PH3 3200
 PH3 3205
 PH3 3210
 PH3 3215
 PH3 3220
 PH3 3225
 PH3 3230
 PH3 3235
 PH3 3240
 PH3 3245
 PH3 3250
 PH3 3255
 PH3 3260
 PH3 3265
 PH3 3270
 PH3 3275

```

C      UPDATE CELL K IF STRESS WAS CHANGED
      IF(UPZ)850,851,851
850 CALL DELTAV
851 IF(UPR)860,861,861
860 CALL DELTAU
861 CONTINUE
C      *****
C      NOW SET THE UDOT AND VDOT AND
C      HOOP STRESS INTO THE PROPER ARRAY.
902 DUDOT(I)=X1
      DVDOT(I)=X2
      SIG33(I)=DDVK
904 CONTINUE
      IF(I-2)999,998,998
C      HERE, SET THE STRESS ON THE RIGHT INTO THE (I) ARRAY
998 RSN(I)=SNL
      RST(I)=STL
999 CONTINUE
C      SET THE STRESS AT THE LEFT OF CELL (K+1) TO THE
C      RIGHT OF CELL (K)
903 SNL=SNR
      STL=STR
      IF(I-IMAX) 3360,599,599
599 RSN(I+1)=SNR
      RST(I+1) = STR
      GO TO 3360
C
C      ***** END OF DO LOOP ON (I) *****
C
3360 K=K+1
      N=N+1
3361 CONTINUE
C      CHECK HERE AT THE RIGHT OF ACTIVE
C      GRID.
      KLAST=K-1
      IF (ABS(U(KLAST))+ABS(V(KLAST))+AIX(KLAST)) 952,953,952
952 NRC=1
953 CONTINUE
C      ***** END OF DO LOOP IN THE (J) DIRECTION *****
3302 CONTINUE
C      HERE WE WILL UPDATE THE LAST
C      ROW.
C      SAVE THE OLD VELOCITIES
C      HERE WE NEED THE OLD VELOCITIES
      K=(I2-1)*IMAX+2
      JN=I2
      N=K-IMAX
906 DO 980 I=1,I1
      IF(I-1)908,907,908
907 KL=K

```

PH3 3280
PH3 3285
PH3 3290
PH3 3295
PH3 3300
PH3 3305
PH3 3330
PH3 3335
PH3 3340
PH3 3345
PH3 3350
PH3 3355
PH3 3310
PH3 3315
PH3 3320
PH3 3325

PH3 3715
PH3 3720
PH3 3725
PH3 3730
PH3 3735
PH3 3740

PH3 3745
PH3 3750

```

      GO TO 909
908 KL=K-1
909 IF(I2-JMAX)911,910,911
910 KA=K
      GO TO 912
911 KA=K+IMAX
912 IF(I-IMAX)914,913,914
913 KR=K
      GO TO 915
914 KR=K+1
C      NOW WE HAVE THE INDICES FOR
C      SUBROUTINE ECALC.
915 IF(I-1)917,916,917
916 FLEFT(I)=U(K)
      YAMC(I)=V(K)
      WSU=U(N)
      WSV=V(N)
C      VELOCITIES(PHASE 1) FROM CELLS BELOW
C      ARE AVAILABLE FROM THE MAIN LOOP
C      AND ARE STORED IN THE ARRAYS(SIGC AND GAMC ).
      U(N)=SIGC(I)
      V(N)=GAMC(I)
      GO TO 919
917 WSU=U(N)
      WSV=V(N)
      UTEF=U(K-1)
      VTEF=V(K-1)
C      SAVE THE UPDATED VELOCITIES
918 U(N)=SIGC(I)
      V(N)=GAMC(I)
      U(K-1)=FLEFT(I-1)
      V(K-1)=YAMC(I-1)
919 II=I
      KB=N
C      SET THE STRESSES FROM THE ARRAYS
C      INTO THE SINGLE STORAGE.
      SNT=ASN(I)
      STT=AST(I)
      STR=RST(I+1)
      SNR=RSN(I+1)
      SNB=ASNB(I)
      STB=ASTB(I)
      S...=RSN(I)
      STL=RST(I)
      X1=DUDOT(I)
      X2=DVDOT(I)
      DDVK=SIG33(I)
      IF(JN-JMAX)930,940,930
C      IF WE ARE AT THE TOP BOUNDARY OF
C      THE GRID,SET THE STRESS GRADIENTS

```

```

C      TO ZERO
940  SNT=SNB
    STT=STB
930  IF(I=IMAX)943,941,943
C      IF WE ARE AT THE RIGHT BOUNDARY
C      OF THE GRID, SET THE STRSS GRADIENTS
C      TO ZERO
941  STR=STL
    SNR=SNL
943  CALL DELTAU
    CALL DELTAV
920  CALL ECALC
921  AIX(K)=AIX(K)+VISC
991  CONTINUE
994  CONTINUE
    IF(AIX(K)-VVABOV)705,705,922
705  SUM=SUM+AIX(K)*AMX(K)
    AIX(K)=0.
922  FLEFT(I)=U(K)
    YAMC(I)=V(K)
923  U(K)=U(K)+DT*X1
    V(K)=V(K)+DT*X2
    IF(ABS(U(K))-VVBLO)706,706,707
706  SUM=SUM+U(K)**2/2.*AMX(K)
    U(K)=0.
707  IF(ABS(V(K))-VVBLO)708,708,709
708  SUM=SUM+V(K)**2/2.*AMX(K)
    V(K)=0.
709  CONTINUE
951  IF(I=1) 925,926,925
926  U(N)=WSU
    V(N)=WSV
    GO TO 924
C      RESET THE NEW VELOCITIES FOR THE LEFT
C      AND BOTTOM CELLS.
925  U(N) = WSU
    V(N) = WSV
    U(K-1)=UTEF
    V(K-1)=VTEF
    GO TO 924
924  K=K+1
    N=N+1
980  CONTINUE
C      CHECK HERE AT THE TOP OF ACTIVE
C      MESH.
    K=K-1
    IF(ABS(U(K))+ABS(V(K))+AIX(K))950,954,950
950  NRT=1
954  CONTINUE
C      NOW INCREASE ACTIVE GRID COUNTERS IF

```

C	NEEDED.	
	I1= I1+NRC	
	I2= I2+NRT	
	IF(I1-IMAX)6100,6100,6200	
6200	I1= IMAX	
6100	IF(I2-JMAX)6201,6201,6202	
6202	I2=JMAX	
6201	CONTINUE	
	GO TO 7777	PH3 3765
9908	NK=39	PH3 3770
	GO TO 9999	PH3 3775
9907	NK=42	PH3 3780
	GO TO 9999	PH3 3785
9903	NK=44	PH3 3790
	GO TO 9999	PH3 3795
9901	NK=3306	PH3 3800
	GO TO 9999	PH3 3805
9902	NK=3310	PH3 3810
	GO TO 9999	PH3 3815
9904	NK=3320	PH3 3820
	GO TO 9999	PH3 3825
9900	NK=3305	PH3 3830
	GO TO 9999	PH3 3835
9999	NR=123	PH3 3840
	CALL DUMP	PH3 3845
7777	SUMX=0.	
	DO 9001 I=1,I1	
	K=I+1	
	DO 9002 J=1,I2	
	P(K)=0.	
	IF(AIX(K))71C,9002,9002	
710	SUMX=SUMX+AIX(K)*AMX(K)	
	AIX(K)=0.	
9002	K=K+IMAX	
9001	CONTINUE	
	ETH=ETH-SUM-SUMX	
9000	CONTINUE	
	VT=VSAVE	
	DT=DTT	
7778	RETURN	
	END	PH3 3855

*\$IBFTC GRADR LIST,DECK,REF

SUBROUTINE GRADR

C CALCULATES THE VELOCITY GRADIENTS ON
C THE RIGHT SIDE OF THE CELL
C GRADR REQUIRES THE FOLLOWING INDICES.

C I,J,K,KR,KA,KAR,KB,KBR.

C S1=DU/DR***

S1=(U(KR)-U(K))/DX(11)

IF(ABS(S1)-Z(107))1,1,2

1 S1=0.

2 CONTINUE

C S2=DV/DR***

S2=(V(KR)-V(K))/DX(11)

IF(ABS(S2)-Z(107))3,3,4

3 S2=0.

4 CONTINUE

WS=2.*DY(JN)

C S3=DU/DZ***

S3=((U(KA)+U(KAR))/2.-(U(KB)+U(KBR))/2.)/WS

IF(ABS(S3)-Z(107))5,5,6

5 S3=0.

6 CONTINUE

C S4=DV/DZ***

S4=((V(KA)+V(KAR))/2.*VV-(V(KB)+V(KBR))/2.*UUU)/WS

IF(ABS(S4)-Z(107))7,7,8

7 S4=0.

8 CONTINUE

C S5=U/R***

IF(GAM)9,12,9

12 S5=(U(KR)+U(K))/(2.*X(11))

IF(ABS(S5)-Z(107))9,9,10

9 S5=0.

10 CONTINUE

RETURN

END

*\$IBFTC GRADZ LIST,DECK,REF

SUBROUTINE GRADZ

C CALCULATES THE VELOCITY GRADIENTS AT THE
C TOP OF THE CELL

C S6=DU/DZ***

S6=(U(KA)-U(K))/DY(JN)

IF(ABS(S6)-Z(107))1,1,2

1 S6=0.

```

2 CONTINUE
C   S7=DV/DZ***
   S7=(V(KA)-V(KJ))/DY(JN)
   IF(ABS(S7)-Z(107))3,3,4
3   S7=0.
4   CONTINUE
   WS=2.*DX(II)
C   S8=DU/DR***
   S8=((U(KAR)+U(KR))/2.*VV-(U(KAL)+U(KL))/2.*UUU)/WS
   IF(ABS(S8)-Z(107))5,5,6
5   S8=0.
6   CONTINUE
C   S9=DV/DR *****
   S9=((V(KAR)+V(KR))/2.-(V(KAL)+V(KL))/2.)/WS
   IF(ABS(S9)-Z(107))7,7,8
7   S9=0.
8   CONTINUE
C   S10=U/R***
   IF(GAM)9,12,9
12  S10=(U(KA)+U(KJ))/(X(II)+X(II-1))
   IF(ABS(S10)-Z(107))9,9,10
9   S10=0.
10  CONTINUE
   RETURN
   END

```

```

.SIBFTC STRESR LIST,DECK,REF
      SUBROUTINE STRESR
C      THIS ROUTINE CALCULATES THE NORMAL
C      AND SHEAR STRESS AT THE RIGHT
C      HAND BOUNDARY OF THE CELL
C      CALCULATE SNR(SIGMA 11 AT THE RIGHT)
C      NOTE, WE CAN HAVE VISCOSITY OR STRENGTH OR BOTH
C
      NEWT=0
      IF(DKE)1,1,91
91 IF(DDXN)93,93,1
93 NEWT=1
      B=0.
      GO TO 100
1  WS=.66666*(S1*S1+S4*S4+S5*S5)+.5*
  1(S3+S2)**2
C      THAT WAS THE STRESS DEVIATOR=
C      EPSILON DOT (AB) * EPSILON DOT (AB)
C      K IS STORED IN DDXN
      WSA=WS*DX(11)*DX(11)
      IF(SQRT(WSA)-Z(112)*DXN)3,3,4
3  B=0.
      GO TO 100
4  CONTINUE
      WSA=BIG
C      NOTE, BIG IS CALCULATED IN PH3
      IF(ABS(S1)-WSA)10,10,11
11 BUGR=DDXN
      GO TO 12
10 BUGR=DDXN*ABS(S1)/WSA
12 B=SQRT(2.*BUGR*BUGR/WS)
100 EDOT11=S1
C      NOTE, S1=DU/DR
C      S1=DU/DR, S4=DV/DZ, S5=U/R
      EDOTAA=S1+S4+S5
      EPD11=EDOT11-EDOTAA/3.
C      NOW CALCULATE THE NORMAL STRESS
      SNR=(B+DKE)*EPD11
C      NOW THE SHEAR STRESS
C      DELTA 12 IS ZERO, THUS
C      EPD12=EDOT12
      EDOT12=(S3+S2)/2.
C      S3=DU/DZ, S2=DV/DR
      IF(NEWT)95,95,96
96 B=0.
      GO TO 97
95 IF(ABS(S4)-WSA)13,13,14
14 BUGZ=DDXN
      GO TO 15
13 BUGZ=DDXN*ABS(S4)/WSA

```

```

15 B=SQRT(2.*BUGZ*BUGZ/WS)
97 STR=(B+DKE)*EDOT12
RETURN
END

```

```

$IBFTC STRESZ LIST,DECK,REF
SUBROUTINE STRESZ
C THIS ROUTINE CALCULATES THE NORMAL AND SHEAR
C STRESS AT THE TOP OF THE CELL.
C CALCULATE SNT(SIGMA 22 AT THE TOP)
C
C NOTE, WE CAN HAVE VISCOSITY OR STRENGTH OR BOTH
NEWT=0
IF(DKE)1,1,91
91 IF(DDXN)93,93,1
93 NEWT=1
B=0.
GO TO 100
1 WS=.66666*(S8*S8+S7*S7+S10*S10)+.5*
1(S6+S9)**2
WSA=WS*DY(JN)*DY(JN)
IF(SQRT(WSA)-Z(112)*DXN)3,3,4
3 B=0.
GO TO 100
4 CONTINUE
C NOTE ,S7=DV/DZ
WSA=BIG
IF(ABS(S7)-WSA)6,6,7
7 BUGR=DDXN
GO TO 8
6 BUGR=DDXN*ABS(S7)/WSA
8 CONTINUE
B=SQRT(2.*BUGR*BUGR/WS)
C NOW SIGMA 22 = B*EPD22
100 EPD22=S7-(S8+S7+S10)/3.
SNT=(B+DKE)*EPD22
EPD21=(S6+S9)/2.
C NOTE, S8=DV/DR
IF(NEWT)95,95,96
96 B=0.
GO TO 97
95 IF(ABS(S8)-WSA)10,10,11
11 BUGZ=DDXN

```

```
GO TO 12
10 BUGZ=DDXN*ABS(S8)/WSA
12 B=SQRT(2.*BUGZ*BUGZ/WS)
97 STI=(B+DKE)*EPD21
RETURN
END
```

```

$IBFTC HOOP    LIST,DECK,REF
      SUBROUTINE HOOP
C      HERE WE WILL CALCULATE THE HOOP
C      STRESS FOR CELL K.
C      K IS IN (DDXN)
C      ETA ZERO(VISCOSITY) IS IN DKE
C      THE HOOP STRESS IS STORED IN DDVK
C      GAM IS A FLAG FOR THE TYPE OF
C      COORDINATE SYSTEM.
      IF(GAM)101,102,101
101 DDVK=0.
      GO TO 103
102 WS=X(II)+X(II-1)
      EDOT33=U(K)/WS*2.
      IF(DDXN)1,1,2
C      WE ASSUME WE HAVE A VISCOUS MATERIAL.
      1 B=DKE
      GO TO 100
C      CALCULATE B,WE HAVE A RIGID PLASTIC MATERIAL
      2 WSR=DX(II)
      WSZ=DY(JN)
      WSA=((U(KR)*E-U(KL)*FD)/(2.*WSR))**2
      IF(ABS(WSA)-Z(107))10,10,11
10 WSA=0.
11 CONTINUE
      WSB=((V(KA)*UUU-VV*V(KB))/(2.*WSZ))**2
      IF(ABS(WSB)-Z(107))12,12,13
12 WSB=0.
13 CONTINUE
      WSC=(2.*U(K)/WS)**2
      WSD=((U(KA)-U(KB))/(2.*WSZ)
      *SD=((V(KR)-V(KL))/(2.*WSR)+WSD)**2
      IF(ABS(WSD)-Z(107))14,14,15
14 WSD=0.
15 CONTINUE
      B=.66666*(WSA+WSB+WSC)+.5*WSD
      WSA=(DX(II)+DY(JN))/2.
      WSA=B*WSA*WSA
      IF(SQRT(WSA)-Z(112)*DDXN)3,3,4
      3 B=0.
      GO TO 100
      4 CONTINUE
      B=SQRT(2.*DDXN*DDXN/B)
C      NOW SIGMA 33=B*EDOT OF 33
100 DDVK=B*EDOT33
103 RETURN
      END

```

```

$IBFTC DELTAU LIST,DECK,REF
SUBROUTINE DELTAU
C THIS SUBROUTINE COMPUTES THE ACCELERATION
C OF THE CELL DUE TO THE STRESSES
C IN THE RADIAL DIRECTION.
C ACTING ON THIS CELL (5 OF THEM).
C STORE THE RADIAL COMPONENT OF THE
C ACCELERATION IN X1.
WS=TAU(II)/PIDY
IF(GAM)1,2,1
1 WSD=1.
WSE=1.
GO TO 3
2 WSD=X(II)
WSE=X(II-1)
3 WSA=DY(JN)*(SNR*WSD-SNL*WSE)
IF(GAM)6,7,6
6 WSF=1.
GO TO 4
7 WSF=2.
4 WSB=WS/WSF*(STT-STB)
WSC=DX(II)*DY(JN)*DDVK
X1=PIDY/AMX(K)*WSF*(WSA+WSB+WSC)
RETURN
END

```

```

$IBFTC DELTAV LIST,DECK,REF
SUBROUTINE DELTAV
C AXIAL COMPONENT
C THIS SUBROUTINE COMPUTES THE ACCELERATION OF
C THE CELL DUE TO THE STRESSES ACTING
C ON THIS CELL (4 OF THEM). STORE THE
C AXIAL COMPONENT IN X2.
IF(GAM)1,2,1
1 WSB=1.
WSD=1.
WSF=1.
GO TO 3
2 WSB=2.
WSD=X(II)
WSF=X(II-1)
3 WS=(SNT-SNB)/WSF*TAU(II)/PIDY
WSA=DY(JN)*(STR*WSD-STL*WSF)
X2=PIDY/AMX(K)*WSB*(WS+WSA)

```

RETURN
END

```

$IBFTC ECALC  LIST,DECK,REF
SUBROUTINE ECALC
C  THIS ROUTINE WILL CALCULATE THE CHANGE
C  IN SPECIFIC INTERNAL ENERGY DUE TO THE
C  WORK DONE BY THESE STRESSES.
C  STORE IT IN (VISC).
  WSD=TAU(II)*((U(K)+U(KA))/2.*STT+
1(V(K)+V(KA))/2.*SNT)
  WSE=TAU(II)*((U(K)+U(KB))/2.*STB+
1(V(K)+V(KB))/2.*SNB)
  IF(GAM)1,2,1
1  WSF=1.
   WSG=1.
   WSH=1.
   GO TO 3
2  WSF=2.
   WSG=X(1)
   WSH=X(II-1)
3  WS=WSF*PIDY*DY(JN)
   WSA=WS*WSG*((U(KR)+U(K))/2.*SNR+
1(V(KR)+V(K))/2.*STR)
   WSB=WS*WSH*((U(K)+U(KL))/2.*SNL+
1(V(K)+V(KL))/2.*STL)
   WSA=(WSA-WSB+WSD-WSE)/AMX(K)*DT
   WSE=X1*DT
   WSD=X2*DT
   WSB=WSE*(U(K)+WSE/2.)+WSD*(V(K)+WSD/2.)
   VISC=WSA-WSB
RETURN
END

```

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14. KEY WORDS	LINK A		LINK B		LINK C	
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