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THEORY AND STRUCTURE OF THE AFTON CODES

John G. Trulio

Nortronics
A Division of Northrop Corporation
Newbury Park, California

Contract AF 29(601)-6683

TECHNICAL REPORT NO. AFWL-TR-66-19

June 1966

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Research and Technology Division
Air Force Systems Command
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FOREWORD

This report was prepared by Nortronics, A Division of Northrop Corporation, Newbury Park, California, under Contract AF29(601)-6683. The research was performed under Program Element 7.60.06.01.D, Project 5710, and was funded by the Defense Atomic Support Agency under Project FERRIS WHEEL.

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This report has been reviewed and is approved.

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ABSTRACT

A procedure for writing finite difference analogs of the principles of continuum mechanics is presented. The method leads to analogs of the integral statements of mass and momentum conservation, and the first law of thermodynamics, which are exact under two simple discretization assumptions, and which imply an exactly conservative finite difference equation for the total energy. The method and the equations which follow from it apply to general systems of continuous media, hydrodynamic or otherwise. The finite difference equations form the basis of a set of computer codes for the calculation of motion described by one and two spatial coordinates. The codes permit the use of arbitrary time dependent coordinate systems to solve specific problems.

The AFTON I code, which deals with linear, cylindrical, and spherical one-dimensional systems, has been expanded to include general stresses and strains. Some preliminary attempts have been made to define an optimum coordinate mesh to describe continuum motion, and specific problems have been solved by AFTON I using these coordinate systems. For spherically diverging waves in an elastic medium, the solutions obtained have been more accurate than those given by numerical Lagrangian methods with the same number of mesh points, although some shock front erosion is evident, apparently as a result of deficiencies in the coordinate systems employed.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS

SECTION 1.0

THE CONSTRUCTION OF FINITE DIFFERENCE EQUATIONS FOR TRANSIENT CONTINUUM MOTION IN TWO SPACE DIMENSIONS

1.1 THE AFTON CODES: GENERAL REMARKS

The name "AFTON" is used to denote a set of computer codes which are used to solve transient continuum motion problems. Work on these codes was begun about six years ago at the Lawrence Radiation Laboratory in Livermore, California. However, their development has been pursued most intensively in the past two or three years under Air Force Contracts AF29(601)-5971, "Development of a Computer Program for Predicting Free Field Ground Motion," and AF29(601)-6683 (same title) as part of Project Ferris Wheel. Code modifications which are particularly useful in the solution of viscous compressible fluid flow problems, were made under NASA Contract NAS8-11400, "Calculation of Two-Dimensional Turbulent Flow Fields."

Mainly as a result of work on the contracts cited, there are now three AFTON codes, namely, AFTON 1, AFTON 2A, and AFTON 2P. AFTON 1 solves transient continuum motion problems in systems so symmetric as to require just one spatial coordinate for their description. It includes the three geometrically possible one-dimensional cases, namely, linear, cylindrical and spherical motions. The AFTON 2P code solves transient continuum motion problems in plane symmetric systems whose motion is the same in every plane normal to some one direction, and which can therefore be described in terms of two Cartesian position coordinates and the time. The AFTON 2A code solves problems of transient continuum motion in axisymmetric systems, i.e., systems whose motion is the same in every half-plane bounded by some one straight line, and which can therefore be described in terms of the radial and axial position coordinates of a cylindrical coordinate system, and the time.

The main purpose of this report is to provide a detailed description of the AFTON computer codes which have come into being in the past year under Contract AF29(601)-6683. The report is also intended to give an account of the method of construction of finite difference equations for continuum motion on which all the AFTON codes are based. Two-dimensional motion with plane symmetry is complicated enough to afford a reasonably complete description of the method, and is at the same time simple enough to avoid much of the algebraic complexity encountered in our formulation of finite difference equations for more general types of motion. The explanation of the finite difference method embodied in the AFTON codes, and the derivation of specific finite difference equations, is therefore presented here chiefly for two-dimensional plane-symmetric continuum motion — the case to which AFTON 2P specifically applies.

1.2 FINITE DIFFERENCE MESHES AND ZONES IN AFTON 2P AND AFTON 2A

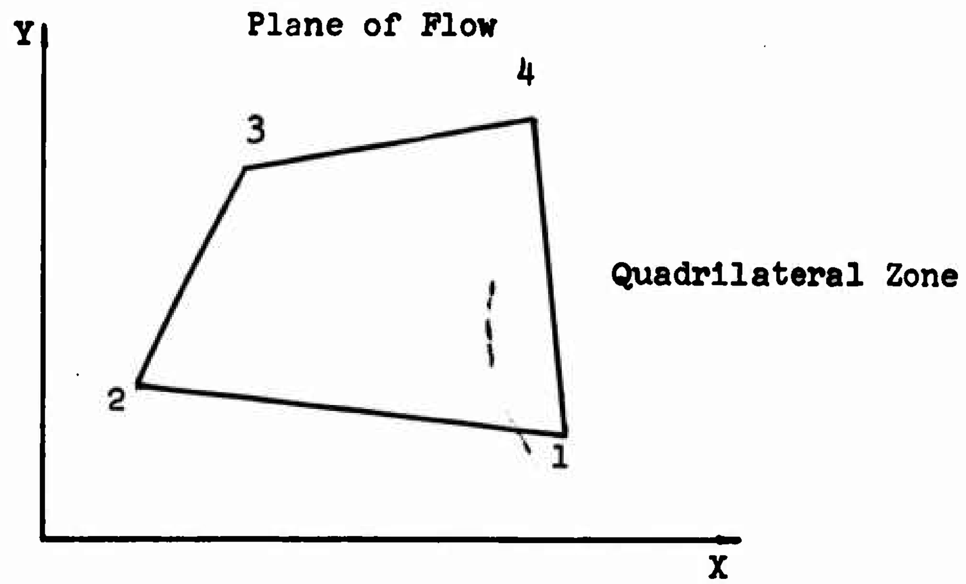
Numerical procedures for solving the equations of continuum mechanics all begin by replacing the continuous variables of space and time by a discrete set of points. As the density of its points is increased, the point set more and more closely approximates the space-time continuum, at least in the sense that any piecewise continuous function can be represented more and more accurately by specifying its discrete values at the points of the set. Finite difference equations are then written which are approximate expressions of the principles of continuum mechanics, and high-speed computers are programmed to perform the operations of arithmetic and logic required by the finite difference equations.

The most basic statement of the principles of continuum motion consists of integral equations for conservation of mass, energy and momentum, and for the First Law of thermodynamics (Ref. 1), although less fundamental differential equations have served as a starting point for most numerical procedures which describe continuum motion. The integral equations take on their simplest form for a closed finite region whose boundary surface moves with the local velocity of matter, and which, therefore, always contains the same material particles. This description of continuum motion is termed "Lagrangian," and a sheet of material particles is called a Lagrangian coordinate surface. The reason for the special importance of the Lagrangian form of the continuum mechanical laws is simply that Newton's Second Law, on which all classical mechanics rests, applies in the first instance to particles of constant mass. The statement of the principles of continuum motion in integral form for finite Lagrangian regions is here termed "more basic" than related differential statements, because such a formulation places lighter continuity restrictions on the various possible flow fields.

The AFTON codes are based on a specific method for constructing finite difference approximations to the laws of continuum mechanics in integral (not necessarily Lagrangian) form (Refs. 2, 3, and 4). Broadly stated, the central ideas of the method are that the finite difference equations should be as self-consistent as possible, and also should constitute as direct a statement as possible of the underlying principles of continuum motion on finite regions. The particular aspect of consistency deemed most important is the complete and exact equivalence of mass conservation, energy conservation and the First Law of thermodynamics, when these are coupled with momentum conservation. Thus, we insist that the finite difference equations for mass and momentum conservation, and the First Law, imply an exactly conservative finite difference equation for total energy. Application of the criterion of consistency has led to finite difference equations with an exact energy conservation property in the sense just defined; these equations have the satisfying property that they can each be given a precise meaning in elementary physical and geometric terms.

The finite difference technique used in the AFTON codes is of the "time-marching" kind. That is, the space continuum is replaced by a discrete mesh of points, and, starting with a system in a known state at some initial time, the variables of the motion are updated by a discrete time increment at all points of the space mesh, according to some finite difference equations of motion. The updating process is then repeated using the just-calculated values of the variables of the motion as fresh initial value data, and so on. Owing to the assumed symmetry of the motion, a space mesh for AFTON 2P need only be defined as an array of points in a single plane, the variables of the motion having identical values at corresponding points of all planes parallel to this one; for AFTON 2A, the variables of the motion have identical values at corresponding points on all half-planes (azimuthal planes) bounded by some one straight line. As is customary (but not necessary) in computer codes describing motion in two space dimensions, the points of an AFTON 2P or AFTON 2A finite difference mesh are topologically equivalent to the corner points of a set of unit squares which cover a rectangular region in one-to-one fashion. The mesh points are, therefore, the vertices of quadrilaterals which can be produced by the continuous distortion of a rectangular array of unit squares. The region of two-dimensional plane flow is thus covered by elementary quadrilaterals; these quadrilaterals are the "zones" of the finite difference mesh. Actually, it is basic to the method of differencing which underlies the AFTON codes that real physical systems have finite extension in a direction normal to the symmetry plane in which the quadrilaterals lie. What appears in the plane of flow as a side of a quadrilateral zone actually represents the intersection of the flow plane with another plane at right angles to it. Thus, in the case of AFTON 2P, we consider the medium to be divided into quadrilateral slabs of unit thickness, each of which can be generated by moving a quadrilateral zone through a unit distance normal to the plane of flow. A quadrilateral zone is then just a cross-section of a quadrilateral slab in a symmetry plane. The quadrilateral slab, which is a solid figure, is the basic geometric entity of the AFTON 2P finite difference mesh. It is a polyhedron with two parallel congruent quadrilateral faces and four rectangular faces normal to the quadrilaterals. These geometric figures are shown in Figure 1. In the case of AFTON 2A, the system is divided into "quadrilateral wedges", a quadrilateral wedge being a polyhedron bounded by two nearly parallel azimuthal planes, and having a quadrilateral cross-section in any azimuthal plane between these two. Figure 12 of Appendix I depicts this polyhedron. (The figure appears in an Appendix because the discussion of two-dimensional motion in the text of this report is limited almost entirely to the plane-symmetric case.)

The integral equations (Ref. 1) and associated finite difference equations which underlie AFTON 2P have been written in sufficient generality to include non-Lagrangian as well as Lagrangian descriptions of continuum motion. Correspondingly, the code itself contains a subroutine which defines the coordinate system to be used for any given problem. However, the Lagrangian case



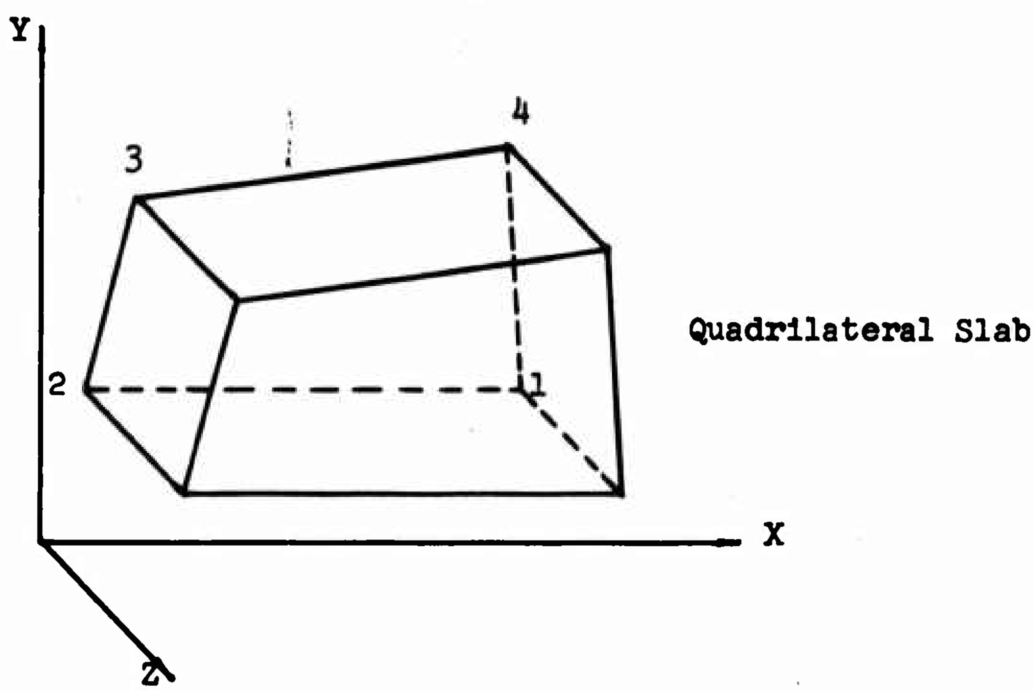


FIGURE 1

DIAGRAM OF A QUADRILATERAL ZONE, AND ITS ASSOCIATED QUADRILATERAL SLAB, USED IN AFTON 2P TO DESCRIBE TWO-DIMENSIONAL PLANE SYMMETRIC FLOW will be discussed first, since the finite difference technique as it applies to AFTON 2P is most simply explained for this case. The points of the finite difference mesh are then mass points whose velocities provide a discrete approximation to the material velocity field of the continuous medium. It is also true in the Lagrangian case that a quadrilateral slab is a finite mass element consisting of the same material particles at one time as at any other time, and a quadrilateral zone — a cross-section of a quadrilateral slab in a symmetry plane — is defined by one specific set of co-planar particles. Motion of the vertices of a quadrilateral zone therefore produces distortion ("strain") and attendant changes in all the flow variables, for a finite element of material. We now discuss the calculation of these changes.

1.3 THE CALCULATION OF THERMODYNAMIC VARIABLES IN AFTON 2P FOR LAGRANGIAN MESHES (HYDRODYNAMIC MOTION)

The variables of the motion are divided into two classes, namely, those associated with the vertices of zones, and those associated with their centers or interiors. The first class consists of mesh point positions and their time derivatives, e.g., their velocities (dynamic variables), while the second class consists essentially of strain, stress, and internal energy (thermodynamic variables). The calculation of zone-centered variables, which we describe first, proceeds under two assumptions which are fundamentally alike:

(a) A material element which initially occupies a quadrilateral slab region, always has the shape of a quadrilateral slab.

(b) Zone-centered variables are constant in value throughout a quadrilateral slab region at any given time, and also change at a constant rate during any particular time step.

With respect to assumption (a), we note that the particles initially comprising a side of a quadrilateral zone will in general not remain co-linear; likewise, the corresponding face of the quadrilateral slab associated with the zone usually will not, in physical reality, remain rectangular. Rather, the initially rectangular Lagrangian surfaces of a quadrilateral slab will ordinarily deform into more general curved shapes. Assumption (a) therefore imposes a nonphysical constraint on the system, which is part of the price paid for replacing the space continuum by a discrete mesh of points. Obviously, assumption (b) entails a similar nonphysical restriction; real physical stresses and strains generally vary over finite distances. If the error from these sources is unacceptable, then it can be reduced by increasing the density of mesh points to provide a better approximation to a continuum. Moreover, while it is not entirely obvious, increasing the density of mesh points is the only way to reduce this decretization error; a close look at the rate of decay of numerical solution error with increasing mesh point density shows that the discretization error cannot be made to vanish more rapidly by permitting the sides of a quadrilateral zone to be more general curves than straight lines — straight lines with "higher-order" corrections. As is shown elsewhere (Ref. 4), the hyperbolic character of the equations of continuum motion makes it impossible to increase the rates of decay of numerical solution errors by means of higher-order differencing techniques.

The calculation of the change in the volume of a quadrilateral slab produced by the motion of the vertices of its associated quadrilateral zone provides the key to the construction of the finite difference equations of AFTON 2P. In making the calculation, we adopt the following definitions and conventions:

(1) Y, $\underline{r}$, $\underline{U}$, $\underline{A}$ denote volume, position, material velocity, and vector area, respectively.

(2) The superscripts 1 and o refer to a "later time" t^1, and an "earlier time" t^o, separated by the interval $\Delta t = t^1 - t^o$.

(3) If no superscript is attached to a variable, it is understood to be defined at some time between t^o and t^1. In particular, the position vector of a point, without a superscript, is by definition equal to the arithmetic mean of the positions of the point at the two times t^1 and t^o, i.e.,

$$\underline{r} = \tfrac{1}{2}(\underline{r}^1 + \underline{r}^o). \tag{1}$$

(4) Position and velocity subscripts refer to the mesh points labeled as in Figure 1.

(5) The vector area $\underline{A}_{\beta\alpha}$ is the rectangular surface generated by moving the side of the quadrilateral zone of Figure 1 between the vertices β, α, through a unit distance normal to the plane of the figure. The sense of the vector area $\underline{A}_{\beta\alpha}$ is that of the inner normal to the quadrilateral. Thus if one encounters point α, and then the point β, as the perimeter of the quadrilateral is traversed clockwise, then

$$\underline{A}_{\beta\alpha} = (\underline{r}_\beta - \underline{r}_\alpha) \times \underline{k} \tag{2}$$

where $\underline{k}$ is a unit vector normal to the plane of flow.

(6) The velocity of a point is related to its position $\underline{r}^1$ and $\underline{r}^o$ at the times t^1 and t^o according to

$$\underline{U} = (\underline{r}^1 - \underline{r}^o)/\Delta t \tag{3}$$

It can be seen that Eq. 3 involves the kind of discretization error entailed in assumption (b) above; in this case the velocity is taken to be constant over a finite time interval, namely Δt. One can now show by an exact calculation of the volume of a quadrilateral slab that

$$- (Y^1 - Y^o)/\Delta t = \tfrac{1}{2}(\underline{U}_2 + \underline{U}_1)\cdot\underline{A}_{21} + \tfrac{1}{2}(\underline{U}_3 + \underline{U}_2)\cdot\underline{A}_{32}$$

$$+ \tfrac{1}{2}(\underline{U}_4 + \underline{U}_3)\cdot\underline{A}_{43} + \tfrac{1}{2}(\underline{U}_1 + \underline{U}_4)\cdot\underline{A}_{14} \tag{4}$$

or

$$- (Y^1 - Y^o)/\Delta t = \underline{U}_1\cdot\tfrac{1}{2}(\underline{A}_{14} + \underline{A}_{21}) + \underline{U}_2\cdot\tfrac{1}{2}(\underline{A}_{21} + \underline{A}_{32})$$

$$+ \underline{U}_3\cdot\tfrac{1}{2}(\underline{A}_{32} + \underline{A}_{43}) + \underline{U}_4\cdot\tfrac{1}{2}(\underline{A}_{43} + \underline{A}_{14})$$

$$= \underline{U}_1\cdot(\underline{A}_{1\underline{a}} + \underline{A}_{\underline{d}1}) + \underline{U}_2\cdot(\underline{A}_{2\underline{d}} + \underline{A}_{\underline{2}2})$$

$$+ \underline{U}_3\cdot(\underline{A}_{3\underline{2}} + \underline{A}_{\underline{3}3}) + \underline{U}_4\cdot(\underline{A}_{4\underline{3}} + \underline{A}_{\underline{a}4}) \tag{5}$$

where the underlined subscripts a, etc., refer to the midpoints of the sides of zone (a) as shown schematically in Figure 2.

Equation 4 has the geometric interpretation that the change in the volume of a quadrilateral slab in a time interval Δt is equal to the algebraic sum of the volumes swept out by the four

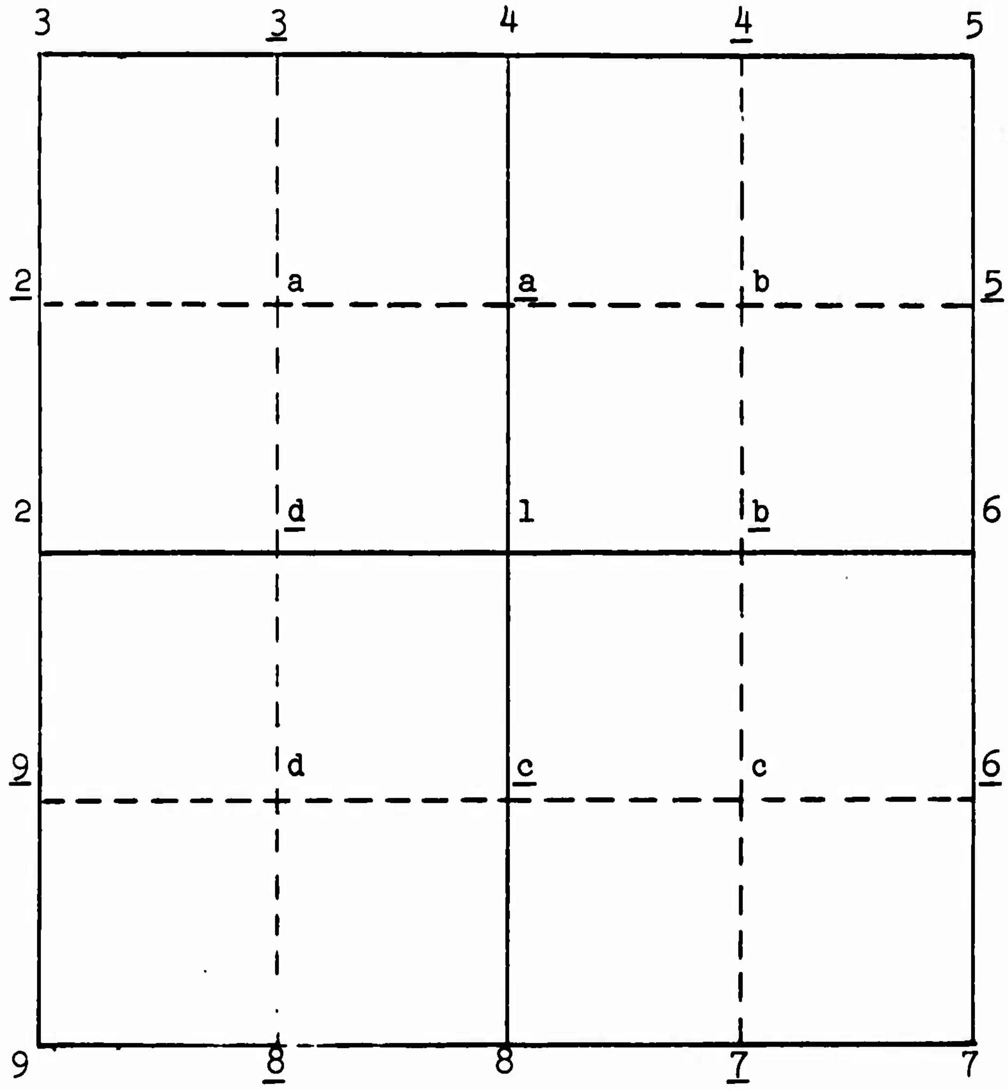


Figure 2

SCHEMATIC DIAGRAM OF THE POINTS AND SIDES OF THE FOUR QUADRILATERAL ZONES SHARING A GIVEN MESH POINT AS A COMMON VERTEX rectangular faces of the slab normal to the plane of flow, if each face moves with a velocity equal to the arithmetic mean of the velocities of its end edges. Two points should be emphasized here. First, this geometric representation is concrete and precise; by time-averaging the positions of the quadrilateral zone vertices, one obtains the quadrilateral whose sides define the moving areas of the quadrilateral slab, and each of these areas moves uniformly with the average of the velocities of the two vertices it subtends. Secondly, the volume change so calculated is exact, regardless of the time interval Δt or of the positions of the vertices of the quadrilateral zone at the beginning and end of this interval. However, this geometric interpretation of the volume change is not unique. For example, the righthand side of Eq. 4 can be rewritten in the form shown in Eq. 5. It is then natural to associate half of each rectangular face of the quadrilateral slab with one of the two edges of this face normal to the plane of flow. If each pair of half-faces meeting at such an edge is allowed to move uniformly with the velocity of the edge, then the resulting rates at which the half-face pairs sweep out volume, summed over the four pairs, is exactly the rate of change of volume of the quadrilateral slab.

According to assumption (b), thermodynamic variables such as stresses and internal energies are considered to be properties of quadrilateral slabs as a whole. These variables are updated for general stresses and strains by an extension of a standard numerical hydrodynamic procedure in which a finite difference analog of the First Law is satisfied simultaneously with the constitutive equation for a given medium (Ref. 5). In the hydrodynamic case, the change in the internal energy of a quadrilateral slab is just its volume change (given by Eq. 4), multiplied by the negative of the arithmetic mean of the pressures in the slab at the times t^1 and t^o. If an equation of state is used to eliminate the new pressure (i.e., the pressure at time t^1) from the finite difference analog of the First Law, then the fact that equations of state generally involve the internal energy renders the First Law analog an implicit equation for the new internal energy. In this calculation, it is worth noting that if the pressure in the quadrilateral slab were indeed uniform and equal to its mean value on the time interval Δt, then the calculation of the change in the internal energy of the slab, as well as its volume change, would be exact. Thus, under assumptions (a) and (b), all thermodynamic variables are computed exactly. The relevant equations for hydrodynamic motion are the First Law analog

$$E^1 - E^o = - (P + Q)(Y^1 - Y^o) \qquad (6)$$

and the equation of state

$$P^1 = G(E^1/m, Y^1/m) \qquad (7)$$

Here G is some (known) function of two variables, and P, E, m denote the pressure, internal energy and mass of the quadrilateral slab, respectively, the mass being constant in the Lagrangian case under discussion. Also, Q is a generalization of the artificial viscosity of Richtmyer and von Neumann, such as that given by Noh (Ref. 6); Q is computed explicitly knowing Y, while P^1 and E^1 must be obtained by solving Eqs. 6 and 7 simultaneously.

1.4 THE CALCULATION OF THERMODYNAMIC VARIABLES IN AFTON 2P FOR LAGRANGIAN MESHES (GENERAL STRESS AND STRAIN)

For general plane two-dimensional motion, the procedure for writing an exact finite difference analog of the First Law, even under assumptions (a) and (b), is not so obvious as for hydrodynamic motion. In fact, it will be seen later that an exact analog of the First Law can be written only for triangular zones and not for more general polygons such as quadrilaterals.

In obtaining our finite difference analog of the First Law for general stress and strain, the change in the volume of the zone, as given in Eq. 5, is of prime importance. Introducing this expression for the volume change into Eq. 6 leads directly to a finite difference analog of the First Law which can be used for any stress, hydrodynamic or otherwise, and which is exact in the hydrodynamic case under assumptions (a) and (b). This combination of Eqs. 5 and 6 is

$$E^1 - E^0 = \Delta t \sum_{i=1}^{4} \underline{U}_i \cdot \underline{F}_i \; . \qquad (8)$$

For hydrodynamic motion it follows from Eqs. 5 and 6, that the forces $\underline{F}_1, \ldots, \underline{F}_4$ in Eq. 8 are given by the equations

$$\begin{aligned} \underline{F}_1 &= (P+Q)\tfrac{1}{2}(\underline{A}_{14}+\underline{A}_{21}) \\ &= (P+Q)(\underline{A}_{1\underline{a}}+\underline{A}_{\underline{d}1}) \quad , \text{ etc.} \end{aligned} \qquad (9)$$

To compute the change in the internal energy for general stresses we replace the scalar hydrodynamic stress (P+Q) of Eq. 8 by the stress tensor σ; σ might be the sum of a thermodynamic stress tensor P and an artificial viscosity tensor Q, but there is no point here in specializing the definition of σ in this way. Again, in accord with assumption (b), σ is assumed to be constant during a time step throughout any particular quadrilateral slab.

The definitions of the forces $\underline{F}_1$, ..., $\underline{F}_4$ then become

$$\underline{F}_1 = \sigma (\underline{A}_{1\underline{a}} + \underline{A}_{d1}), \text{ etc.,} \tag{10}$$

where the multiplication called for in Eq. 10 is that of a matrix with a vector.

As Eq. 8 is written, it does not consist of terms related in any self-evident way to internal energy changes, even in the hydrodynamic case. To make Eq. 8 more plausible, it is useful to recall that even for hydrodynamic materials, the familiar expression $-P\dot{Y}$ for the rate of change for internal energy refers only to an overall volume change, which is not the most elementary process for producing an internal energy change. The less-than-fundamental status of $-P\dot{Y}$ as the rate of change of internal energy is evident at once when one has to deal with nonhydrodynamic stresses. The stress acting on an element of area then depends upon the orientation of the element's normal, and changes in total volume can no longer be related uniquely to changes in internal energy for a given stress field. Simple extensions (i.e., one-dimensional linear expansions and contractions) are more elementary and basic processes for describing internal energy changes than are volume dilatations, as evidenced by the fact that total volume changes can be expressed in terms of simple extensions, but not the reverse. By interpreting the right-hand member of Eq. 8 in terms of one-dimensional linear displacements, Eq. 8 can be made more reasonable than it now appears as an expression of the First Law - and no less plausible for general stresses than for hydrodynamic media.

As an expression for the change of internal energy, the right-hand member of Eq. 8 presents one obvious problem; namely, its terms are all defined only on the surface of a material element, whereas "internal" energy is in fact a quantity associated in an essential way with the interior of a material region. Changes in internal energy cannot be calculated simply from the forces exerted on the surface of a piece of material. They must be computed as a sum of changes taking place throughout the material's entire volume. If this were not so, we would have a conservation theorem for the internal energy itself; the fundamental difference between a quantity which is conserved and one which is not lies precisely in whether or not changes in the total amount of the quantity within a given region can be computed from variables defined only on the surface of the region. For internal energy, the increments of change to be summed throughout the region must be computed on subregions small enough so that the stress in each subregion can be taken with negligible error to be constant. According to assumption (b), a quadrilateral slab - however large - is small enough so that the stress can be considered constant throughout its volume. It is for this reason that the right-hand side of Eq. 8, which consists only of terms defined on the surface of a quadrilateral slab is an exact expression for the change of internal energy, even though the calculation of an internal energy change must generally be made by summation over tiny elements which fill the interior of the slab. Nevertheless, since internal energy changes are fundamentally volume-computed quantities, Eq. 8 will have to be rewritten in such a way that the forces appearing in it act on interior areas, rather than surface areas, of a quadrilateral slab.

To transform Eq. 8 so that it involves only interior areas of a quadrilateral slab, we invoke an elementary geometric theorem. This theorem, which is a cornerstone of the finite difference method embodied in the AFTON codes, simply states that the sum of the vector areas of any polyhedral surface is zero, where the sense of the vector area associated with each plane face of the polyhedron is understood to be that of the outer normal to the enclosed volume. The truth and meaning of the theorem can be exhibited in the following intuitive way. Viewed from any aspect at a sufficiently great distance, a polyhedron presents a cross-section which is at one and the same time the projection of the front side of the polyhedron on a plane normal to the viewer's line of sight, and also of its back side. The area of the cross section is equal in magnitude to the component of the resultant vector area of the plane surfaces making up the front side of the polyhedron, and is also the negative of the corresponding component of the resultant area of the faces of the back side. Since the faces of the front and back side make up the entire (closed) polyhedral surface, the sum of all the vector areas is plainly zero. The theorem is not subtle and certainly not new, but is so central to our differencing technique as to call for more than cursory mention here.

With respect to our discussion of the calculation of internal energy changes, we can now transform Eq. 8 so that its forces refer only to surfaces in the interior of the quadrilateral slab. The theorem just discussed implies, for example, that $\underline{A}_{1\underline{a}} + \underline{A}_{\underline{d}1} + \underline{A}_{\underline{a}\underline{d}} + \underline{A}_{\underline{a}\underline{a}}$, plus the sum of the areas of the two plane parallel quadrilateral surfaces of the slab, is zero. Since the surfaces of any quadrilateral slab parallel to the symmetry plane have equal area but opposite sense, their vector sum vanishes. We therefore conclude that

$$\underline{A}_{1\underline{a}} + \underline{A}_{\underline{d}1} = -\left(\underline{A}_{\underline{a}\underline{d}} + \underline{A}_{\underline{a}\underline{a}}\right) \tag{11}$$

Thus Eq. 8 can be written in the form

$$\begin{aligned} E^1 - E^0 = \Delta t \Big[&\underline{F}_{\underline{a}\underline{a}} \cdot \left(\underline{U}_1 - \underline{U}_4\right) + \underline{F}_{2a} \cdot \left(\underline{U}_2 - \underline{U}_3\right) \\ &+ \underline{F}_{3a} \cdot \left(\underline{U}_3 - \underline{U}_4\right) + \underline{F}_{a\underline{d}} \cdot \left(\underline{U}_2 - \underline{U}_1\right) \Big]. \end{aligned} \tag{12}$$

In the rearranged form of Eq. 12, Eq. 8 can now be interpreted as a sum of internal energy changes produced by the simple extension of material in directions normal to the forces exerted on specific interior surfaces of the quadrilateral slab. Each of the four interior surfaces corresponding to the line segments aa, 2a, 3a, ad is represented on the right-hand side of Eq. 12 by one such term. These surfaces are "complete" in the sense that they exhaustively subdivide the slab into mutually exclusive volumes. The velocity difference appearing in a term of Eq. 12 has a component in the direction of the force acting on the interior area relevant to that term. This component of the velocity difference measures the rate of uniaxial spreading or contraction of material which, multiplied by the magnitude of the force, gives the rate of production of internal energy due to particle displacements along the line of the force.

While it introduces the essential feature of uniaxial contributions to the overall internal energy change of a zone, Eq. 12 can, nevertheless, be shown to be quantitatively exact under assumptions (a) and (b) only for simple displacement fields. For example, if the quadrilateral slabs are rectangular, and displacements take place parallel to one set of faces, then Eq. 12 clearly gives the change in internal energy correctly whether the medium is hydrodynamic or not.

However, as noted earlier, internal energy changes computed from Eq. 8 under assumptions (a) and (b) cannot generally be exact. This situation stems from the fact that under assumption (a) a linear displacement is required to produce the homogeneous strain of assumption (b). The displacement field must be such as to distort a quadrilateral zone of material from a strain-free state to the arbitrarily strained configuration presented by the zone at a given instant of time in the course of the numerical calculation. Hence, the constant coefficients of a linear coordinate transformation must be determined in such a way that the transformation will distort a given polygon into another given polygon. Now, the most general linear transformation relating two sets of two variables will, including additive constants which correspond to pure translation, permit the arbitrary specification of six constants. This is just the number of parameters needed to determine the positions of three points in a plane. Hence, except for triangles, the specification of the vertex positions of a polygon in two strain states places more conditions on a linear displacement field than there are constant coefficients in the equations which define the field; the appropriate linear transformation usually will not exist. It therefore appears that only with triangular zones can one obtain finite difference equations for motion in two space dimensions by applying the same discretization assumptions to the First Law as to each of the other principles of continuum motion, while at the same time minimizing the number of such assumptions. In any case, triangular zones are necessary if our finite difference equations are to be exact under assumptions (a) and (b). That the general practice of employing quadrilateral zones has been followed so far with the AFTON codes is felt to be an error which should be corrected in the future. We now proceed to show that for a triangular zone, a finite difference equation can be written which is indeed an exact statement of the First Law, given hypotheses (a) and (b). For simplicity, the discussion is limited to isotropic materials.

A triangular zone and its associated triangular slab are shown in Figure 3. The counterpart of Eq. 8 for the change in the internal energy of a triangular slab of material is

$$E^1 - E^o = \Delta t \sum_{i=1}^{3} \underline{U}_i \cdot \underline{F}_i \qquad (13)$$

where

$$\underline{F}_1 = \sigma \tfrac{1}{2} \left(\underline{A}_{13} + \underline{A}_{21} \right).$$

On the other hand the change in the internal energy of a triangular slab of isotropic material is given by

$$E^1 - E^o = - \int_{t^o}^{t^1} \int_{Y(t)} \left(\sum_{i=1}^{3} P_i \frac{\dot{E}_i}{E_i} \right) dxdydz \; dt \qquad (14)$$

where E_1, E_2, E_3 are the principal extensions of the strain field, P_1, P_2, P_3 are principal stresses and x, y, z are the usual Cartesian coordinates; the stress and strain axes coincide for an isotropic medium.

Under assumptions (a) and (b) Eq. 14 becomes

$$E^1 - E^o = - \left[P_1 \left(E_1^1 - E_1^o \right) / \bar{E}_1 + P_2 \left(E_2^1 - E_2^o \right) / \bar{E}_2 \right] \bar{Y} \Delta t \qquad (15)$$

where

$$\bar{E}_1 = \tfrac{1}{2} \left(E_1^1 + E_1^o \right), \text{ etc.}$$

and $\bar{Y}$ is the "mean-time" volume of the triangular slab, i.e., the volume computed from the vertex position $\underline{r}_1$ (see Eq. 1). Our problem is now to show that the change in the internal energy in the triangular slab computed according to Eq. 13 is identical to that given by Eq. 15; Eq. 13 is an exact expression for the change in internal energy under assumptions (a) and (b). For this purpose it is necessary to recall the calculation of strain used in the AFTON codes. In the case of plane strain, the pertinent equations are Eqs. 42 through 57 and 62 through 64 of Appendix I, except that the points labeled α, β, γ of the Appendix are now understood to be the points 2, 3, 1, respectively, of Figure 3. Without loss of generality, we can assume that all vectors and tensors are expressed in the system of the principal stress axes. In this coordinate system we have

$$\xi_1 = E_1 \, \xi_1^*$$

$$\xi_2 = E_1 \, \xi_2^*$$

$$\zeta_1 = E_2 \, \zeta_1^*$$

$$\zeta_2 = E_2 \, \zeta_2^* .$$

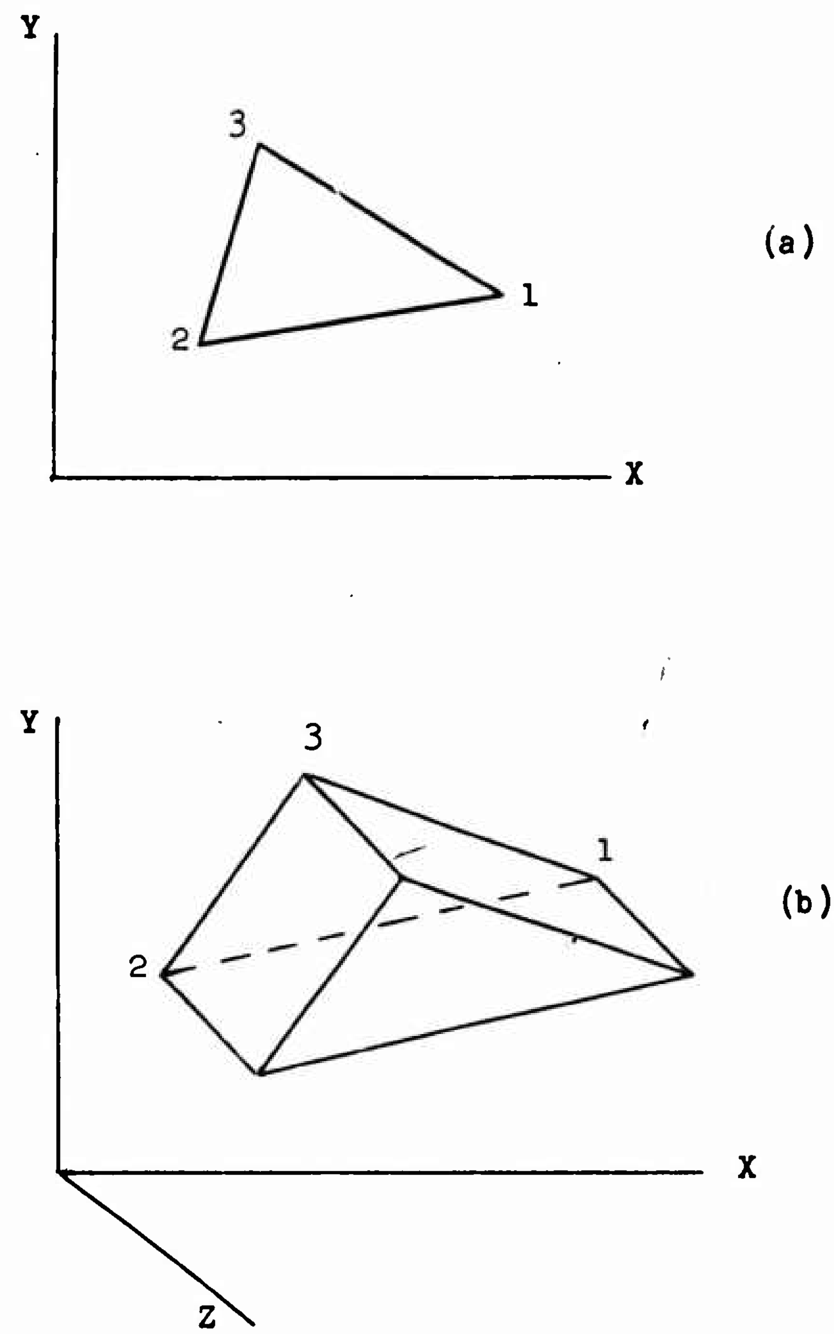


FIGURE 3

(a) TRIANGULAR ZONE; (b) TRIANGULAR SLAB where the * superscript refers to the triangular slab of material in its unstrained state. It then follows from Eq. 15 that

$$E^1-E^o = \frac{-\Delta t}{2}\left[P_1\left(E_1^1-E_1^o\right)\left(E_2^1+E_2^o\right) + P_2\left(E_2^1 - E_2^o\right)\left(E_1^1+E_1^o\right)\right]Y^*$$

which, in view of Eq. 3 and the definitions of Appendix I, can be written as

$$E^1 - E^o = \frac{-\Delta t}{2}\left\{P_x\left[u_1\left(y_2 - y_3\right) + u_2\left(y_3 - y_1\right) + u_3\left(y_1 - y_2\right)\right] - P_y\left[v_1\left(x_2 - x_3\right) + v_2\left(x_3 - x_1\right) + v_3\left(x_1 - x_2\right)\right]\right\} \qquad (16)$$

On the other hand, in the principal axis system we find from Eq. 13 that

$$E^1 - E^o = -\left[P_x\left(u_1a_1 + u_2a_2 + u_3a_3\right) + P_y\left(v_1b_1 + v_2b_2 + v_3b_3\right)\right]\Delta t$$

where a, b denote the x and y components, respectively, of the vector area A. Then, making use of the relations

$$\underline{A}_1 = \tfrac{1}{2}\left(\underline{A}_{21} + \underline{A}_{13}\right) = \left(\underline{r}_2 - \underline{r}_3\right) \times \underline{k}, \quad \text{etc.}$$

we deduce that

$$E^1 - E^o = \frac{-\Delta t}{2}\left\{P_x\left[u_1\left(y_2 - y_3\right) + u_2\left(y_3 - y_1\right) + u_3\left(y_1 - y_2\right)\right) - P_y\left[v_1\left(x_2 - x_3\right) + v_2\left(x_3-x_1\right) + v_3\left(x_1 - x_2\right)\right]\right\} \qquad (17)$$

Thus the internal energy Eq. 13 does in fact constitute an exact expression for the change in the internal energy of a rectangular slab. It is particularly satisfying that Eq. 13 was originally derived to insure conservation of energy rather than to express the First Law exactly under assumptions (a) and (b). In a later section we will discuss the energy conservation property of the finite difference equations.

1.5 THE CALCULATION OF MOMENTUM IN AFTON 2P FOR LAGRANGIAN MESHES

In a finite difference scheme for solving the equations of continuum mechanics, it is necessary not only to provide for the updating of thermodynamic variables, but also for the calculation of new mesh point positions and velocities. The method used in AFTON 2P to update the velocity field is similar in most respects to that just described for thermodynamic fields, although it now expresses the physical principle of momentum conservation rather than the First Law of thermodynamics. It is again the essence of the finite difference procedure that the finite difference analog of momentum conservation be exact under assumptions (a) and (b), by which the variables of the motion known only at a discrete set of points are defined throughout the space continuum.

Since positions and velocities are associated with mesh points rather than zone centers, the elemental regions on which momentum is conserved, i.e., the momentum zones, are centered at mesh points. The momentum zone assigned to any given mesh point is made up of portions of each of the four quadrilateral zones, like those of Figure 2, which share that mesh point as a common vertex. In physical reality, the same particles of mass which experience strain also possess a material's momentum. To be consistent with this aspect of the real world, we must therefore require that the mass of a quadrilateral zone be assigned to each of its corner points in such a way that each particle of mass contributes its momentum to one and only one momentum zone. Moreover, if (as in the present case) the momentum zones are to be Lagrangian, then each particle must always contribute its momentum to the same momentum zone.

These conditions can be met without invoking any assumptions other than (a) and (b). To this end, we recall the geometric fact that a point can always be found which, when joined to the mid-points of the sides of a quadrilateral by straight lines, will divide the quadrilateral into four pieces of equal area. The corresponding quadrilateral slab is then divided into four corner pieces of equal volume, each of which itself has the shape of a quadrilateral slab. On the assumption that the density of material is constant within any given quadrilateral slab [assumption (b)], each of the four corner pieces will contain exactly one quarter of the mass of the quadrilateral slab throughout the course of the motion. In addition, we note that the four interior surfaces of a quadrilateral slab which divide it into its four corner sections, are plane surfaces. It is consistent with the fact that these interior surfaces bound regions of constant mass, that they be considered as Lagrangian surfaces, i.e., mass-point sheets. The requirement that these sheets of mass points always be planar represents a nonphysical constraint on the motions of the points. This constraint is just another instance of the discretization error implied by assumption (a). The momentum zone of AFTON 2P is then the eight-sided polygon shown schematically in Figure 4. Four lines emanating from a mesh point, such as point 1 of Figure 4, are sides of the four quadrilateral zones sharing that point as a common vertex. The midpoints of these four lines, and the center points of the four quadrilateral zones, are the vertices of the octagonal momentum zone around the given mesh point.

With regard to momentum conservation, the basic geometric object contemplated by the numerical method is the three-dimensional octagonal slab generated by moving the octagonal momentum zone through a unit distance normal to the plane of flow. The octagonal slab consists of a quarter-section of each of the four quadrilateral slabs associated with the mesh point, and it therefore contains a mass of material equal to one quarter of the sum of the masses of these quadrilateral slabs. The material of the octagonal slab undergoes acceleration under the action of forces exerted on its eight rectangular faces

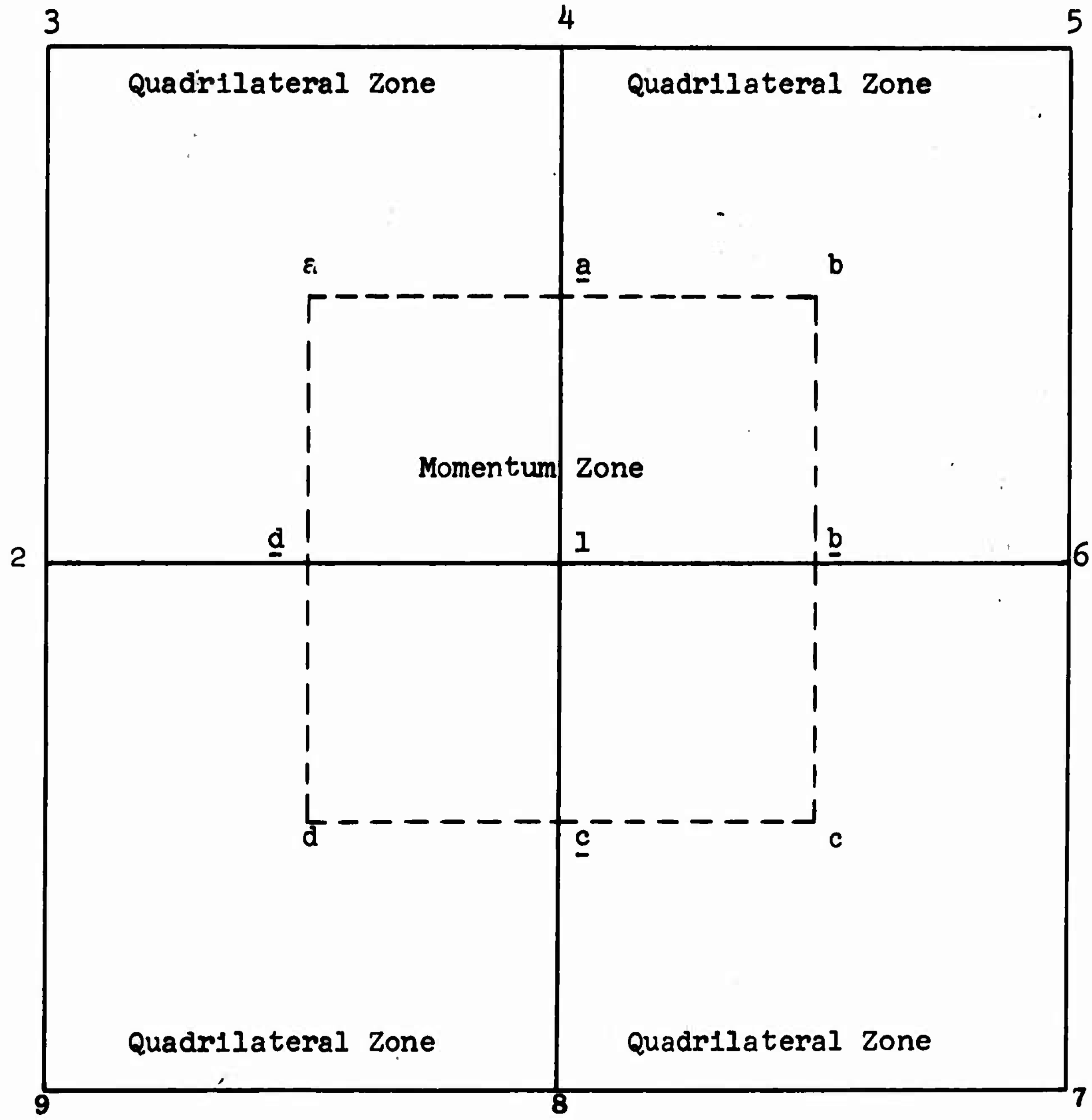


FIGURE 4

SCHEMATIC DIAGRAM OF AN AFTON 2P SPACE MESH, SHOWING A MOMENTUM ZONE AND THE FOUR QUADRILATERAL ZONES WHOSE CORNER PIECES MAKE UP THE MOMENTUM ZONE.

normal to the plane of flow. Each of the four quadrilateral slabs contributes two of these faces, which are among the four interior faces dividing that slab into quarter sections. According to assumption (b), such a pair of surfaces, being interior to a quadrilateral slab, are acted on at all points by the same constant stress for an entire time step. If we now extend assumption (b) to the octagonal momentum slab by assuming a uniform momentum density (= velocity) on this region, then the change in the slab's momentum in a time step can be calculated exactly. For this purpose, let $\underline{M}$ be the momentum of the octagonal slab associated with the momentum zone of Figure 4, whose vertices, in clockwise order, are the points a, $\underline{a}$, b, $\underline{b}$, c, $\underline{c}$, d, $\underline{d}$. If we let $\underline{F}$ denote force and now let subscripts refer to the points a, $\underline{a}$, etc., then, retaining the definitions used in Eq. 4 and 5 we have

$$\underline{F}_{\beta\alpha} = \mathbb{P}\underline{A}_{\beta\alpha} \tag{18}$$

where $\mathbb{P}$ is the stress in the zone for which $\underline{A}$ is an interior area, and the stress-area product of Eq. 18 is just a matrix-vector multiplication. (In the hydrodynamic case, the matrix-vector multiplication reduces to the multiplication of a vector area by a scalar pressure.) Under assumptions (a) and (b), conservation of momentum is now expressed exactly for the octagonal slab of material by the equation

$$\begin{aligned}(\underline{M}^1 - \underline{M}^0)/\Delta t = {} & \underline{F}_{a\underline{d}} + \underline{F}_{\underline{a}a} \\ & + \underline{F}_{b\underline{a}} + \underline{F}_{\underline{b}b} \\ & + \underline{F}_{c\underline{b}} + \underline{F}_{\underline{c}c} \\ & + \underline{F}_{d\underline{c}} + \underline{F}_{\underline{d}d}\end{aligned} \tag{19}$$

Under assumption (b), by which the momentum per unit mass of material is constant over octagonal momentum slab, the velocity of the mesh point on which the slab is centered is related to the momentum of the slab according to

$$\underline{U}^1 = \underline{M}^1/m \tag{20}$$

where m, the mass of the momentum region, is equal to a quarter of the sum of the masses of the quadrilateral slabs associated with its central mesh point; m has not been superscripted since mass does not change with time on a Lagrangian region.

The foregoing explanation of the finite difference technique on which AFTON 2P is based is sufficiently detailed that we have derived a few of the more important finite difference equations around which the code is written. The only important aspect of the finite difference technique which has not been discussed for the Lagrangian case is its energy conservation property. As mentioned earlier, the finite difference equations for mass conservation (mass is automatically conserved in a Lagrangian coordinate system), momentum conservation, and the First Law were selected in the first place to satisfy the condition that they imply an exactly conservative finite difference analog of the integral equation for conservation of total energy. The energy conservation equation will be derived in the next section from the equations already discussed. Although this is a reversal of the steps actually taken in developing the AFTON codes, we are more concerned here with the numerical method than with the process of reasoning by which the method was developed from the criterion of consistency of the finite difference equations.

1.6 ENERGY CONSERVATION

That the finite difference equations for mass and momentum conservation and the First Law rigorously imply a total energy conservation theorem was the consideration which originally led to the scheme of differencing employed in the AFTON codes. To demonstrate this property of the finite difference equations, we first form the scalar product of Eq. 19 for momentum conservation, with the particle velocity $\underline{U}$. It is important at this point to note that we actually define two velocities, centered differently in time. One of these is the ratio of momentum to mass given in Eq. 20. This is the primary velocity derived from the finite difference equations, although it does not explicitly enter our equations again. The other velocity is that appearing in Eq. 2, and in the subsequent equations of section 1.3 and 1.4. However, Eq. 3 is used to compute the change in the position of a mesh point over a time step rather than to compute the velocity $\underline{U}$ which is centered at the "middle" of the time-step, i.e., the equation shows how the velocity $\underline{U}$ is related to the position coordinates of a mesh point, but does not define $\underline{U}$. Actually, $\underline{U}$ is defined by the condition that the arithmetic mean of its values on two consecutive time steps be equal to the primary velocity, which is the ratio of momentum to mass. Making use of half-integer superscripts to denote time at about the middle of a time-step, the equation used to advance the velocity $\underline{U}$ from one time-step to the next is

$$\underline{U}^{\frac{1}{2}} = 2\underline{M}^{o}/m - \underline{U}^{-\frac{1}{2}} \equiv 2\underline{U}^{o} - \underline{U}^{-\frac{1}{2}} \equiv 2\underline{U}^{o} - \underline{U} \qquad (21)$$

Thus, the velocity from which a mesh point position change is computed, is found from the primary velocity for the point by a forward extrapolation in time. Alternatively, the primary velocity of a point is equal to the arithmetic means of the velocities used to move the point on two consecutive time-steps. We then find from Eq. 19 that

$$\underline{U}^{-\frac{1}{2}}\cdot\left(\underline{M}^{1} - \underline{M}^{o}\right)/\Delta t = \underline{U}^{-\frac{1}{2}}\cdot\left(\underline{F}_{a\underline{d}} + \underline{F}_{a\underline{a}} + \underline{F}_{b\underline{a}} + \underline{F}_{b\underline{b}} + \underline{F}_{c\underline{b}} + \underline{F}_{c\underline{c}} + \underline{F}_{d\underline{c}} + \underline{F}_{d\underline{d}}\right) \qquad (22)$$

or, in view of Eq. 21 and the fact that the momentum mass associated with the mesh point does not change with time,

$$T^1 - T^o = \underline{U} \cdot \left(\underline{F}_{a\underline{d}} + \underline{F}_{\underline{a}a} + \underline{F}_{b\underline{a}} + \underline{F}_{\underline{b}b} + \underline{F}_{c\underline{b}} + \underline{F}_{\underline{c}c} + \underline{F}_{d\underline{c}} + \underline{F}_{\underline{d}d}\right)\Delta t \ , \qquad (23)$$

where

$$T^o = \tfrac{1}{2}m\underline{U}^{\frac{1}{2}} \cdot \underline{U}^{-\frac{1}{2}} \qquad (24)$$

is the finite difference analog of the kinetic energy for an octagonal slab of material associated with a mass point. To exhibit the fact that total energy is conserved, it is only necessary to observe that if this last equation and the internal energy equation in the form of Eq. 12 are summed over the entire set of mesh points, then all the scalar velocity-force products appearing in Eq. 23 for interior mesh points exactly cancel the same products in Eq. 12 for interior zones. As a result, the sum of the internal and kinetic energies for the entire system will change in a time step by an amount determined entirely by conditions at its boundary. These boundary conditions will give rise to terms which, since they determine the overall energy change of the system, are a finite difference expression for the net work done on it. By the same token, since there is no contribution to the overall work done on the system from any of its interior surfaces, the net rate of working of interior forces is zero.

Although the simple observation made above is sufficient to establish energy conservation, the conservation theorem can be made more complete and satisfying. For example, while we have concluded that the net rate of working interior forces is zero, no expression for the rate of work on an interior surface has been formulated. A truly satisfactory energy conservation theorem should include an explicit expression for the total energy quantity conserved in an arbitrary interior zone, along with an explicit formulation of the work done on the zone in a time step. The fact that a momentum zone does not coincide with a thermodynamic zone somewhat complicates the achievement of this result. However, ultimately we can and will obtain an equation for total energy conservation for each type of region.

Let us first consider, as the region for which a total energy conservation equation must be developed, a quadrilateral slab (which is the basic region of definition of thermodynamic variables). We then proceed by considering a momentum zone to consist of four pieces, which are just the quarters of the quadrilateral slabs from which (as discussed in section 1.5) the momentum zones were originally made up. Referring to Figure 4 it can be seen that the surfaces of contact of the quadrilateral slabs, i.e., the boundary surfaces of these slabs, are interior surfaces of the momentum slabs, across which there is no net rate of production of kinetic energy. Thus Eq. 23 can be written in the following form:

$$T^1 - T^o = \underline{U}\cdot\Big[\big(\underline{F}_{a\underline{d}} + \underline{F}_{\underline{a}a} + \underline{F}_{1\underline{a}} + \underline{F}_{\underline{d}1}\big) + \big(\underline{F}_{b\underline{a}} + \underline{F}_{\underline{b}b} + \underline{F}_{1\underline{b}} + \underline{F}_{\underline{a}1}\big) + \big(\underline{F}_{c\underline{b}} + \underline{F}_{\underline{c}c} + \underline{F}_{1\underline{c}} + \underline{F}_{\underline{b}1}\big) + \big(\underline{F}_{d\underline{c}} + \underline{F}_{\underline{d}d} + \underline{F}_{1\underline{d}} + \underline{F}_{\underline{c}1}\big)\Big]\Delta t \quad (25)$$

where

$$\underline{F}_{\underline{d}1},\ \underline{F}_{\underline{a}1},\ \underline{F}_{\underline{b}1},\ \underline{F}_{\underline{c}1}$$

are the forces acting on those quadrilateral slab half-faces which appear in the interior of the momentum slab; these half-faces bound the pieces of the momentum slab contributed by each of the four surrounding quadrilateral slabs. Also, of course, $\underline{F}_{\underline{d}1}$ is the negative of $\underline{F}_{1\underline{d}}$, etc. Now, the mass of a momentum slab is the sum of quarters of the masses of the four surrounding quadrilateral slabs. The kinetic energy Eq. 25 can therefore be written as the sum of four equations, one for each of the quadrilateral quarter-zones which make up the momentum zone. The quarter-zone contribution to the kinetic energy Eq. 25 from zone (a) of Figure 4 is then

$$\frac{1}{8} m_a \underline{U}_1^{3/2} \cdot \underline{U}_1^{1/2} - \frac{1}{8} m_a \underline{U}_1^{\frac{1}{2}} \cdot \underline{U}_1^{-\frac{1}{2}} = \underline{U}_1 \cdot \left(\underline{F}_{ad} + \underline{F}_{d1} + \underline{F}_{1a} + \underline{F}_{aa} \right) \Delta t \qquad (26)$$

Similar equations hold for the changes of kinetic energy in the quarter sections of slabs b, c and d; these four quarter-zone sections together make up the momentum slab associated with the point 1 of Figure 4. The kinetic energy equations for the four quarter-zones add up to the kinetic energy equation for the entire momentum slab. Furthermore, one can also select the four quarter-zone kinetic energy equations like Eq. 26 which correspond to the sections of a given quadrilateral slab. Thus by adding to Eq. 26 the three quarter-zone kinetic energy equations which represent the contribution of zone (a) to the momentum slabs centered at points 2, 3, and 4 of Figure 4, we obtain the following equation for the change of kinetic energy of the entire quadrilateral slab centered at (a):

$$\begin{aligned} T_a^1 - T_a^o = \Big[& \underline{U}_1 \cdot \left(\underline{F}_{d1} + \underline{F}_{1a} \right) + \underline{U}_2 \cdot \left(\underline{F}_{2d} + \underline{F}_{22} \right) + \underline{U}_3 \cdot \left(\underline{F}_{32} + \underline{F}_{33} \right) \\ & + \underline{U}_4 \cdot \left(\underline{F}_{43} + \underline{F}_{a4} \right) + \underline{U}_1 \cdot \left(\underline{F}_{ad} + \underline{F}_{aa} \right) + \underline{U}_2 \cdot \left(\underline{F}_{da} + \underline{F}_{a2} \right) \\ & + \underline{U}_3 \cdot \left(\underline{F}_{2a} + \underline{F}_{a3} \right) + \underline{U}_4 \cdot \left(\underline{F}_{3a} + \underline{F}_{aa} \right) \Big] \Delta t \end{aligned} \qquad (27)$$

where

$$T_a^o = \frac{1}{8} m_a \left(\underline{U}_1^{\frac{1}{2}} \cdot \underline{U}_1^{-\frac{1}{2}} + \underline{U}_2^{\frac{1}{2}} \cdot \underline{U}_2^{\frac{1}{2}} + \underline{U}_3^{\frac{1}{2}} \cdot \underline{U}_3^{-\frac{1}{2}} + \underline{U}_4^{\frac{1}{2}} \cdot \underline{U}_4^{-\frac{1}{2}} \right).$$

Since we assume a constant stress on the face of a quadrilateral slab, and $\underline{a}$ bisects the line $\overline{14}$, we have

$$\underline{F}_{1a} = \underline{F}_{a4} = \tfrac{1}{2} \underline{F}_{14} \qquad (28)$$

with similar equations for the other forces. Hence, we obtain

$$T_a^1 - T_a^o = \Big[\tfrac{1}{2}\left(\underline{U}_2 + \underline{U}_1\right)\cdot\underline{F}_{21} + \tfrac{1}{2}\left(\underline{U}_3 + \underline{U}_2\right)\cdot\underline{F}_{32} + \tfrac{1}{2}\left(\underline{U}_4 + \underline{U}_3\right)\cdot\underline{F}_{43} + \tfrac{1}{2}\left(\underline{U}_1 + \underline{U}_4\right)\cdot\underline{F}_{14}\Big]\Delta t - \Big[\left(\underline{U}_2 - \underline{U}_1\right)\cdot\underline{F}_{a\underline{d}} + \left(\underline{U}_3 - \underline{U}_2\right)\cdot\underline{F}_{a\underline{2}} + \left(\underline{U}_4 - \underline{U}_3\right)\cdot\underline{F}_{a\underline{3}} + \left(\underline{U}_1 - \underline{U}_4\right)\cdot\underline{F}_{a\underline{a}}\Big]\Delta t \tag{29}$$

By combining this last equation with Eq. 12 we find the following equation for conservation of energy in the quadrilateral slab of zone (a):

$$\left(H_a^1 - H_a^o\right) = \dot{W}_a\Delta t \tag{30}$$

where

$$H_a^o = T_a^o + E_a^o$$

and

$$\dot{W}_a = \tfrac{1}{2}\left(\underline{U}_2 + \underline{U}_1\right)\cdot\underline{F}_{21} + \tfrac{1}{2}\left(\underline{U}_3 + \underline{U}_2\right)\cdot\underline{F}_{32} + \tfrac{1}{2}\left(\underline{U}_4 + \underline{U}_3\right)\cdot\underline{F}_{43} + \tfrac{1}{2}\left(\underline{U}_1 + \underline{U}_4\right)\cdot\underline{F}_{14}$$

Equation 30 is one of the two main statements of exact energy conservation implied by our equations for mass and momentum conservation, and the First Law. Each of the terms appearing in the expression for the rate of working $\dot{W}_a$ on the quadrilateral slab associated with zone (a) gives the rate at which work is done across one of the rectangular faces of the slab; the same face serves as a boundary for the adjacent slab (b), and in this role the work done on the face in any given time interval is the negative of that done across it on slab (a).

Therefore, there is no net work done by the forces acting in the interior of the system. Of course, up to now the stresses acting on the slab faces have not been defined - nor is it really necessary to define them. Since they act on interior faces of the momentum slabs these stresses contribute nothing to the acceleration of mesh points; neither do they appear in Eq. 12 to influence the internal energy. However, for completeness, and for certain types of boundary conditions, it is worth noting that in AFTON 2P the stress acting on the face of a quadrilateral slab is taken to be the arithmetic mean of the stresses of the quadrilateral slabs in contact across a given face.

The other important statement of energy conservation is one in which the region of conservation is a momentum zone rather than an internal energy zone. To find an energy conservation equation for this region, an expression must be developed for the change in internal energy of a quarter-zone of material associated with a momentum slab, just as in the previous case it was necessary to develop a quarter-zone kinetic energy equation. The reason why these quarter-zone expressions are needed is that quarter-zones are the largest regions on which both the kinetic energy density and internal energy density are constant. This follows because in the AFTON code (as in most other two-dimensional time-marching schemes for the solution of the equations of continuum mechanics), the dynamic variables are mesh-point-centered while the thermodynamic variables are zone-centered. To obtain the desired quarter-zone internal energy equation we simply associate half of each term of Eq. 12 with each of the corner points whose velocity appears in the term. Thus, for example, for the quarter of zone (a) associated with the mesh point 1 we have

$$E^1_{a1} - E^o_{a1} = - \Delta t \left[\tfrac{1}{2} \left(\underline{U}_4 - \underline{U}_1 \right) \cdot \underline{F}_{a\underline{a}} + \tfrac{1}{2} \left(\underline{U}_1 - \underline{U}_2 \right) \cdot \underline{F}_{a\underline{d}} \right] \tag{31}$$

The internal energy of the momentum slab associated with point 1 is then governed by the equation

$$E_1^1 - E_1^o = - \Delta t \left[\tfrac{1}{2} \left(\underline{U}_4 - \underline{U}_1 \right) \cdot \underline{F}_{a\underline{a}} + \tfrac{1}{2} \left(\underline{U}_1 - \underline{U}_2 \right) \cdot \underline{F}_{a\underline{d}} \right. \tag{32}$$

$$+ \tfrac{1}{2} \left(\underline{U}_4 - \underline{U}_1 \right) \cdot \underline{F}_{a\underline{b}} + \tfrac{1}{2} \left(\underline{U}_6 - \underline{U}_1 \right) \cdot \underline{F}_{b\underline{b}}$$

$$+ \tfrac{1}{2} \left(\underline{U}_6 - \underline{U}_1 \right) \cdot \underline{F}_{\underline{b}c} + \tfrac{1}{2} \left(\underline{U}_1 - \underline{U}_8 \right) \cdot \underline{F}_{\underline{c}c}$$

$$\left. + \tfrac{1}{2} \left(\underline{U}_1 - \underline{U}_8 \right) \cdot \underline{F}_{d\underline{c}} + \tfrac{1}{2} \left(\underline{U}_1 - \underline{U}_2 \right) \cdot \underline{F}_{\underline{d}d} \right]$$

and

$$H_1^1 - H_1^o = \dot{W}_1 \Delta t \tag{33}$$

where

$$H_1^o = \tfrac{1}{2} m_1 \left(\underline{U}_1^{\frac{1}{2}} \cdot \underline{U}_1^{\frac{1}{2}} \right) + \tfrac{1}{4} \left(m_a E_a^o + m_b E_b^o + m_c E_c^o + m_d E_d^o \right)$$

and

$$-\dot{W}_1 = \tfrac{1}{4} \left(\underline{U}_1 + \underline{U}_6 \right) \cdot \left(\underline{F}_{b\underline{b}} + \underline{F}_{\underline{b}c} \right) + \tfrac{1}{4} \left(\underline{U}_1 + \underline{U}_8 \right) \cdot \left(\underline{F}_{c\underline{c}} + \underline{F}_{\underline{c}d} \right)$$

$$+ \tfrac{1}{4} \left(\underline{U}_1 + \underline{U}_2 \right) \cdot \left(\underline{F}_{d\underline{d}} + \underline{F}_{\underline{d}a} \right) + \tfrac{1}{4} \left(\underline{U}_1 + \underline{U}_4 \right) \cdot \left(\underline{F}_{a\underline{a}} + \underline{F}_{\underline{a}b} \right)$$

1.7 NON-LAGRANGIAN COORDINATE SYSTEMS

In developing the AFTON codes so that they apply to arbitrary time-dependent coordinate systems, the key idea has been to retain the Lagrangian form of the equations for actually updating the variables of the motion. The events taking place in a time step are then the following: at the start of a time-step, a quadrilateral slab of material happens instantaneously to coincide with a quadrilateral slab of space associated with a generalized zone. The equations of motion being essentially

Lagrangian, the variables of the motion are updated by a time step for the quadrilateral material slab; this is a completely Lagrangian calculation. At this point, a new generalized coordinate mesh is laid down. Since its zones will in most cases overlap two or more Lagrangian zones, a non-Lagrangian coordinate system now presents the additional problem of distributing the updated variables of the motion, such as mass or internal energy, among the various generalized zones over which a given Lagrangian zone is spread. The distribution of the material of a Lagrangian zone over other regions can be effected in many ways without negating the conservation properties of the finite difference equations of motion. The reason for this is that the material which moves from one region into another need only be accounted for in the finite difference equations in such a way that the material lost by the one region appears precisely as a gain to the other. Estimates of the flow of mass, for example, can be physically unreasonable and still be treated conservatively by insuring that the mass which leaves each and every zone enters neighboring zones.

A simple and reasonable procedure for updating the variables of the motion in a generalized zone would be to adhere strictly to assumptions (a) and (b) of section 1.3. In fact, taken with the Lagrangian calculations described earlier, this is the most consistent method of distribution of the properties of a Lagrangian zone among the generalized zones which it overlaps. It would, however, require a rather lengthy calculation of the volumes of polyhedral solids. To avoid such computation, a simpler method has been used in the AFTON codes to account for the transport of material from one zone to another. We assign to each coordinate surface of a quadrilateral slab normal to the plane of flow a material velocity ($\underline{U}$ - $\underline{S}$) relative to the surface ($\underline{S}$ will be used in general to denote the velocity of a coordinate surface or of a mesh point). The scalar product of $(\underline{U} - \underline{S})$ with the vector area of the relevant surface of the quadrilateral slab then gives the rate at which material volume crosses the surface, e.g., cm^3/sec. Multiplying this rate by Δt we obtain an estimate of the volume of material which flows across the surface during a time-step. Then, by estimating the density, i.e., the amount per unit volume, of any particular material property, and performing a further multiplication by this density, the total amount of the property which flows across the surface in a time step is determined. By summing the quantities so somputed over all the faces of a polyhedral region the net change of that material property in a time step is found for the region. In the case of mass conservation, the equation embodying this procedure in AFTON 2P is as follows:

$$m^1 = m^o - \Delta t \left[(\rho WA)_{12} + (\rho WA)_{23} + (\rho WA)_{34} + (\rho WA)_{41} \right] \quad (34)$$

where

$$(\rho WA)_{12} = \rho_{12} \underline{W}_{12} \cdot \underline{A}_{12}$$

and $(\rho WA)_{23}$, $(\rho WA)_{34}$, $(\rho WA)_{41}$ are computed in a similar manner. ρ_{12} is the density of material flowing across the surface whose area is $\underline{A}_{21}$ (See Appendix I, Eq. 81).

The flow of internal energy, momentum, etc., from one polygonal slab to another, is calculated in analogous fashion.

SECTION 2.0

THE CALCULATION OF GENERAL ONE-DIMENSIONAL STRESSES AND STRAINS IN AN ARBITRARY TIME-DEPENDENT COORDINATE SYSTEM AND THE PROPERTIES OF SOME TIME-DEPENDENT MESHES

With regard to the use of numerical methods to predict one-dimensional continuum motion the main results achieved in the program have been of two kinds. First, the AFTON 1 code (Ref. 3) has been expanded to handle general stresses and strains for the three cases of one-dimensional motion (linear, cylindrical and spherical). Previously, only hydrodynamic motion could be described by the code. Again, the code permits the use of virtually any time-dependent coordinate mesh in which to describe motion and as in all the AFTON codes, the underlying finite difference equations satisfy exact conservation theorems for mass, momentum, and energy. Secondly, progress has been made in defining an optimum time-dependent coordinate system for the numerical description of continuum motion. With the generalized coordinate system definitions adopted in the program, AFTON 1 has been used to solve some specific problems of spherical motion which have also been computed by numerical Lagrangian methods. Although the time-dependent coordinate systems employed have some deficiencies which are now obvious, the results thus far obtained provide evidence that the accuracy of numerical solutions can be significantly improved by properly distributing a given set of mesh points at each instant of time.

The calculation of strains in non-Lagrangian finite difference meshes is carried out by a method similar in spirit to that suggested in the Final Report (Ref. 3) on the first year's work, although it is quite different in detail.

Strain is basically a property of individual mass elements and its evaluation is therefore most naturally carried out in a

Lagrangian coordinate system. This state of affairs is reflected in our procedure for the calculation of strain-even in an arbitrary time dependent coordinate system, changes in strain are determined only by material motion, in a calculation made explicitly for regions of fixed finite mass. In fact, the search for a satisfactory procedure for updating the strain variables in a generalized coordinate zone has led us to divorce completely the principles of motion from the calculation of transport. The laws of motion apply in their most basic and elementary form to elements of fixed mass, just as does the definition of strain; transport results from the essentially arbitrary choice of a coordinate system by an observer to help him describe the motion he observes. Specifically, AFTON 1 now updates the variables of the motion by a time step in two distinct and sequential calculations. First, the elements of mass which happen to be contained within the boundaries of a zone at some "earlier time" are moved to some "later time" positions according to Newton's Second Law, which as stated is basically Lagrangian. When this Lagrangian calculation has been completed, the finite difference mesh selected by the problem solver is overlaid on the updated Lagrangian mesh, and the contents of each generalized zone are examined for the purpose of defining the updated variables of the motion in these zones. Thus, for example, if the density in each Lagrangian zone is assumed constant, then the mass encompassed by the boundaries of any given generalized zone can be found at the later time from the densities resulting from the Lagrangian calculation. It is likewise possible, in the one-dimensional cases, to compute unambiguously and exactly the mean principal strains of each generalized zone, knowing the strains in the Lagrangian zones at the earlier and later times. The corresponding calculation is not unambiguous in two and three space dimensions.

With regard to strain, the procedure just outlined for spherical symmetry is illustrated more fully by Figures 5a and 5b. Figure 5a shows a portion of the finite mesh at an "earlier time" t^{n-1}. Figure 5b shows the same four zones at a later time t^n. In Figure 5b the dashed lines indicate the later time positions of those particles which happen to coincide with the various zone boundaries at the earlier time t^{n-1} (Figure 5a); the solid lines indicate the later-time positions of the generalized zone boundaries themselves. The numerical calculation then proceeds as follows. The positions of the mesh points which coincide with zone boundaries at t^{n-1} are updated to their new values according to **Eq. 35.**

$$X^n_{L_j} = X^{n-1}_j + U^{n-\frac{1}{2}}_j \Delta^{n-\frac{1}{2}} t \tag{35}$$

where $X^n_{L_j}$ is the new position of the jth mass element boundary; X^{n-1}_j its previous position; $U^{n-\frac{1}{2}}_j$ its velocity, and $\Delta^{n-\frac{1}{2}}t$ the current time step. The new specific volume $V^{n-\frac{1}{2}}_{j-\frac{1}{2}}$, and the dilatation $\Delta^{n-\frac{1}{2}}_{j-\frac{1}{2}}$ can now be **found from Eqs. 36 and 37.**

$$V^{n-\frac{1}{2}}_{j-\frac{1}{2}} = \left[\left(X^{n-\frac{1}{2}}_j\right)^3 - \left(X^{n-\frac{1}{2}}_{j-1}\right)^3\right] / 3m^{n-1}_{j-\frac{1}{2}} \tag{36}$$

where $m^{n-1}_{j-\frac{1}{2}}$ is the mass between the zone boundaries j and j-1.

$$\Delta^{n-\frac{1}{2}}_{j-\frac{1}{2}} = \Delta^{n-3/2}_{j-\frac{1}{2}} + \left(V^{n-\frac{1}{2}}_{j-\frac{1}{2}} - V^{n-3/2}_{j-\frac{1}{2}}\right) / V_o \tag{37}$$

To find the radial strain $\epsilon^n_{L_{j-\frac{1}{2}}}$ in zone "B" of Figure 5b we note that the positions of the boundaries of the Lagrangian mass element are known at both the earlier and later times along with the

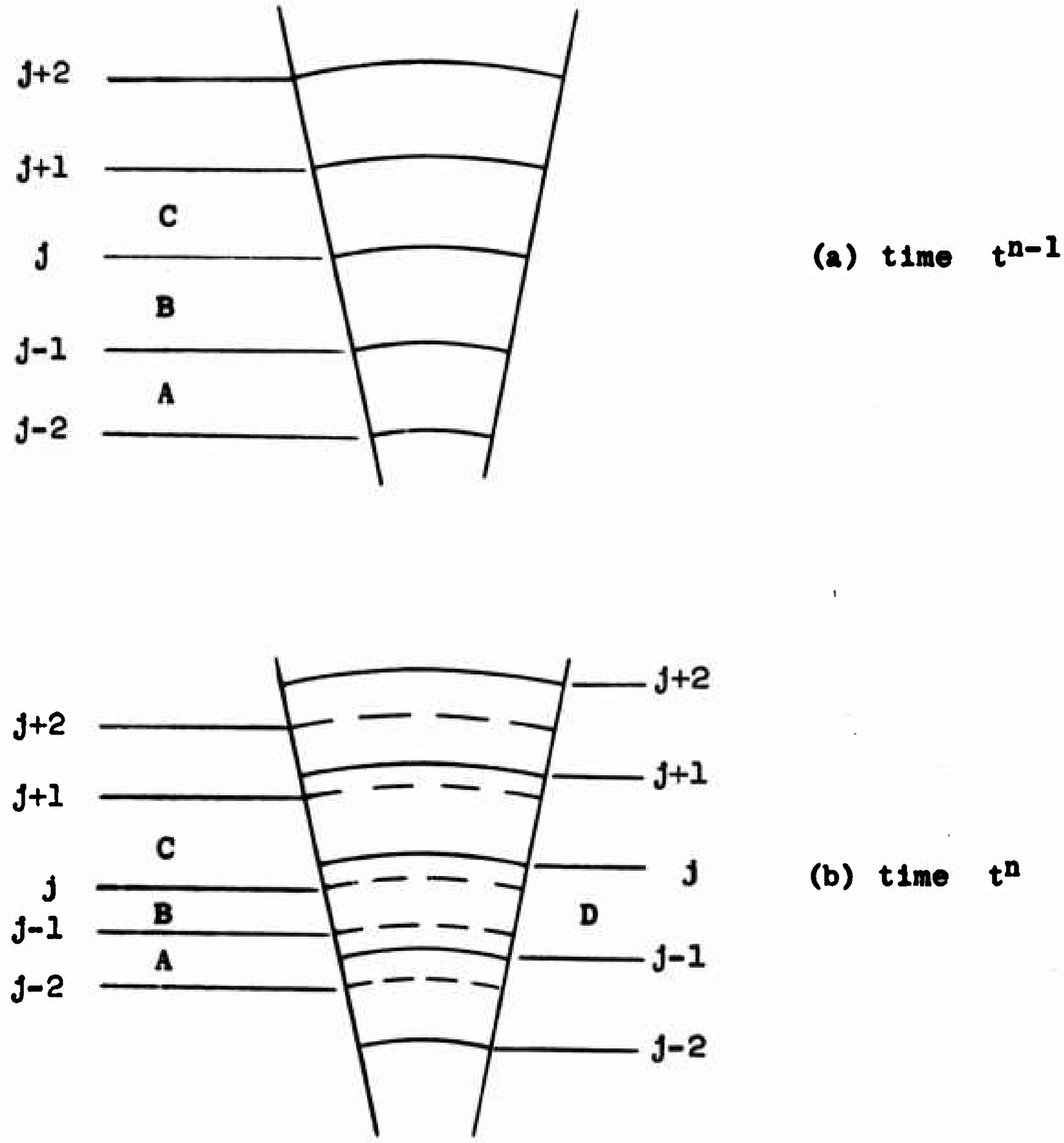


Figure 5

SCHEMATIC OF A PORTION OF A FINITE DIFFERENCE

MESH FOR ONE-DIMENSIONAL SPHERICAL MOTION

(a) Positions of the zone boundaries at t^{n-1}.

(b) Dashed lines indicate the positions at t^n of those particles which happen to coincide with the various zone boundaries at the earlier time t^{n-1}; the solid lines indicate the generalized zone boundaries at t^n.

state of strain of the element at the earlier time. The principal radial strain of zone "B" at the later time is then given by

$$\epsilon^n_{L_{j-\frac{1}{2}}} = \epsilon^{n-1}_{j-\frac{1}{2}} + \left(1 + \epsilon^{n-1}_{j-\frac{1}{2}}\right) \frac{U^{n-\frac{1}{2}}_{L_j} - U^{n-\frac{1}{2}}_{L_{j-1}}}{X^{n-1}_j - X^{n-1}_{j-1}} \Delta^{n-\frac{1}{2}}t \qquad (38)$$

Equation 38 gives exactly the mean strain of the element at time t^n, if the values of the variables on the right hand side of the equation are exact. Since the line of mass points between the boundaries of a generalized zone consists of segments which fall in a set of contiguous mass elements, the unstrained length of each segment, and hence of the entire line, can be readily computed. The mean principal radial extension of the material in that generalized zone is then just the radial distance across the zone divided by the unstrained length of the radial line of mass points between its boundaries. The principal radial strain is just this ratio minus one. For example, the zone "D" of Figure 5b has its boundaries at the radial positions X^n_j, X^n_{j-1} and consists of part or all of the three Lagrangian zones bounded by the radial positions $X^n_{L_{j+1}}, X^n_{L_j}, X^n_{L_{j-1}}$, and $X^n_{L_{j-2}}$. The three Lagrangian zones in question are "A," "B," and "C" of Figure 5b. If L^n_a is the length of any radial mass line contained within zone "A" at time n, then its unstrained length is just equal to $L^n_a/\left(1 + \epsilon^n_{L_a}\right)$, where $\epsilon^n_{L_a}$ is the principal radial strain in zone "A" at time n. In particular the mass-line segment between $X^n_{L_{j-1}}$ and X_{j-1}, which is that portion of zone A's radial mass line contained within zone "D," must have an unstrained length equal to $\left(X^n_{L_{j-1}} - X^n_{j-1}\right)/\left(1 + \epsilon^n_a\right)$. Making a similar computation for zone "B," which lies entirely within zone "D," and for zone "C," which lies partially in zone "B," we find that the radial mass line contained within zone "D" has an unstrained length given by

$$L_D^n = \frac{X_{Lj-1}^n - X_{j-1}^n}{1 + \epsilon_A^n} + \frac{X_{Lj} - X_{Lj-1}^n}{1 + \epsilon_B^n} + \frac{X_j^n - X_{Lj}^n}{1 + \epsilon_C^n} \qquad (39)$$

The principal radial strain of zone "D" is therefore given by

$$\epsilon_D^n = \frac{X_j^n - X_{j-1}^n}{L_D^n} - 1 \qquad (40)$$

It is assumed for simplicity that each Lagrangian zone is homogeneously strained, and in this case the value of ϵ_D^n just computed is exact for the mean principal radial strain of zone "D" at time t^n. If a more complicated strain distribution is assumed in the interiors of the Lagrangian zones, then, while a calculation of the principal radial strain in a generalized zone proceeds in steps identical to those just taken, the algebraic form of the result will be more involved.

The treatment of strain just described for non-Lagrangian coordinate systems has been incorporated into one-dimensional computer codes and tested in some non-Lagrangian time dependent coordinate systems. The principal non-Lagrangian coordinate systems investigated so far are an "accordion" coordinate system, and an "activity" coordinate system. In the accordion coordinate system the space between the boundaries of a material at any given time is divided into zones of equal width. The activity coordinate system uses a measure of local activity, γ_j, to determine the relative thicknesses of the zones contained within the boundaries of a given material. In the activity coordinate system, the greater the activity quantity γ_j, for a zone, the thinner that zone is made. Two measures of activity have been used so far. They are given by,

$$\gamma_j = \frac{1}{\frac{|U_{j-1} - U_{j-2}| + 2|U_j - U_{j-1}| + |U_{j+1} - U_j|}{4|\Delta U|_{max}} + \alpha} \quad (39)$$

and

$$\gamma_j = \frac{1}{\frac{|A_{j-1}| + 2|A_j| + |A_{j+1}|}{4\ A_{max}} + \alpha} \quad (40)$$

Here, $|U_j - U_{j-1}|$ is the magnitude of the velocity difference across the jth zone at time t^n, and $|A_j|$, the magnitude of the mean of the accelerations experienced by the jth zone boundary at time t^{n-1} and t^n. The width of a zone is then made inversely proportional to its activity. The parameter α, which appears in both definitions of γ_j, is an input quantity which may be used to control the ratio between the maximum to minimum zone size in any given problem. The ratio γ_{max} to γ_{min} is given by

$$\gamma_{max}/\gamma_{min} = (\alpha + 1)/\alpha = k + 1 \quad (41)$$

where $k = 1/\alpha$. Thus, for example, if $k = 3$, the ratio of the maximum to minimum zone width is 4.

To test the validity of the finite difference equations used to calculate strain in a generalized time-dependent coordinate system and to gain some insight into the proper choice of an activity quantity, γ_j, calculations have been made for a shock running outward from a spherical cavity into an elastic medium with Lame' constants $\lambda = 1$, $\mu = 0$ (the hydrodynamic limit) and with $\lambda = \mu = 1/3$. The code runs were made using a Lagrangian coordinate system and a time-dependent coordinate system which is intended to cluster zones in regions of maximum activity, as described above. The spherical compression wave in the elastic medium is generated by the uniform adiabatic expansion of a gas in the spherical cavity. This problem was chosen because it has an exact analytical solution for the radial velocity as a function of time. Lt. H. Cooper of the Air Force Weapons Laboratory has provided a convenient form of this exact solution.

Figures 6 and 7 compare the results of three different code runs with the exact analytical solution for the hydrodynamic case. In these figures the radial velocity is plotted as a function of a radial coordinate for a given time τ. Of these three code runs, two used Lagrangian coordinates. The first, Problem I, had a fixed number of zones per unit radial distance. In the second Lagrangian run, Problem II, twice as many zones were used per unit radial distance as in Problem I. The third, Problem III, employed a generalized coordinate system whose activity quantity, γ_j, is given by Eq. (40). The initial coordinate mesh in Problem III was identical to that of Problem I.

It is clear from these figures that, in the hydrodynamic case, accurate numerical solutions can be obtained in both types of coordinate system. Only in the immediate vicinity of a shock front do sizable percentage errors in the velocity appear. These errors take the form of a diffusion or spreading out of the ideally discontinuous velocity which is unavoidable in a discrete mesh and, perhaps more importantly, are evidenced by oscillations in the velocity about the correct values. Such differences as are evident indicate that the time-dependent coordinate system leads to more accurate results than a Lagrangian coordinate system with the same number of zones and produces smaller errors even than a Lagrangian problem with twice the number of zones. Mainly, this reflects the smoothing of the oscillations behind the shock front by the backward treatment of transport in the code. However, since the particle velocity of the shock front is itself small relative to the peak velocity of compressed material found at the cavity wall, the errors in velocity appear in all cases to be insignificant for hydrodynamic motion.

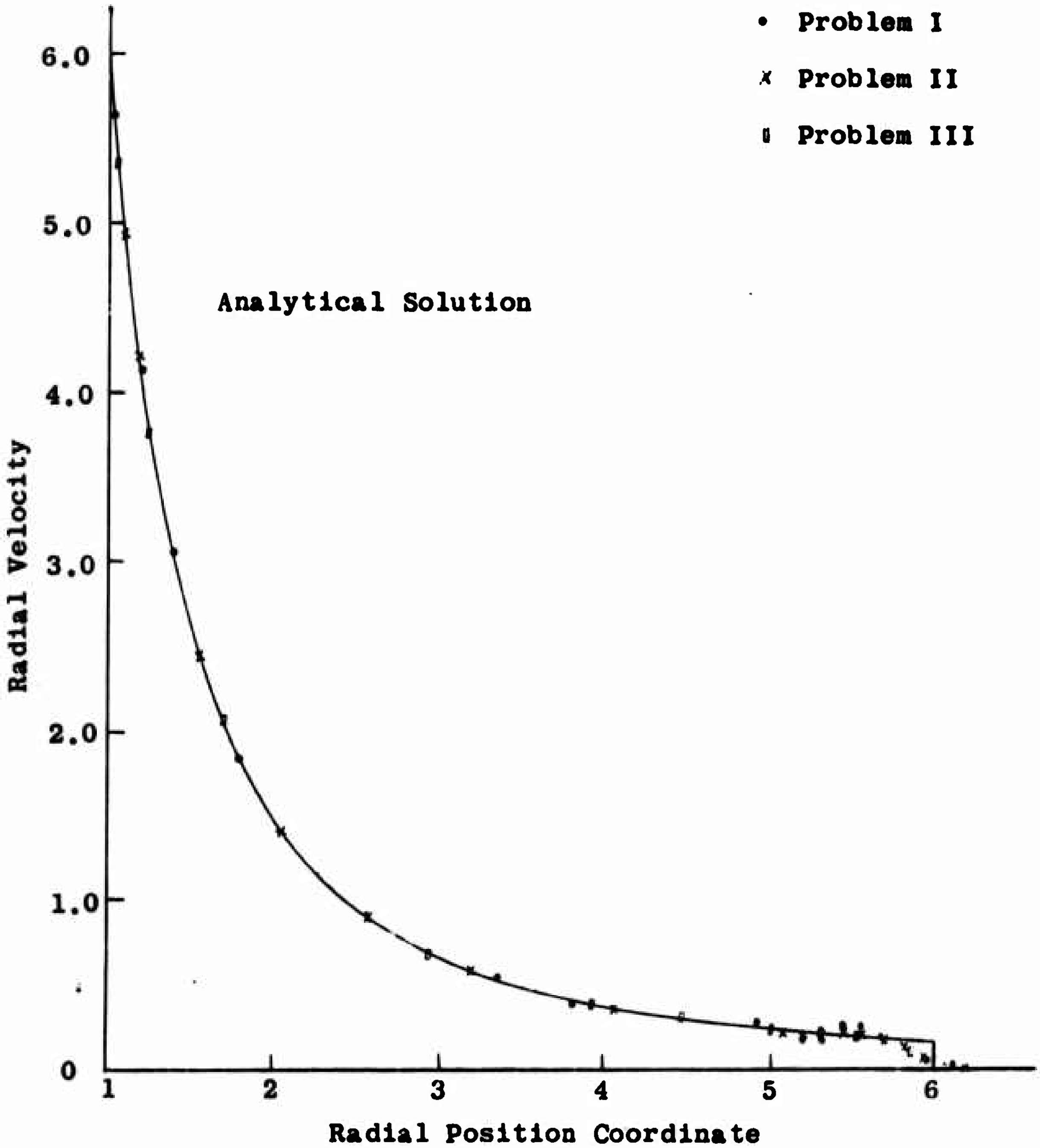


Figure 6

COMPARISONS OF THE NUMERICAL AND ANALYTICAL SOLUTIONS OF A SPHERICALLY DIVERGING COMPRESSION WAVE IN AN ELASTIC MEDIUM WHOSE LAME' CONSTANTS ARE

$\lambda = 1, \mu = 0$ (Hydrodynamic Limit)

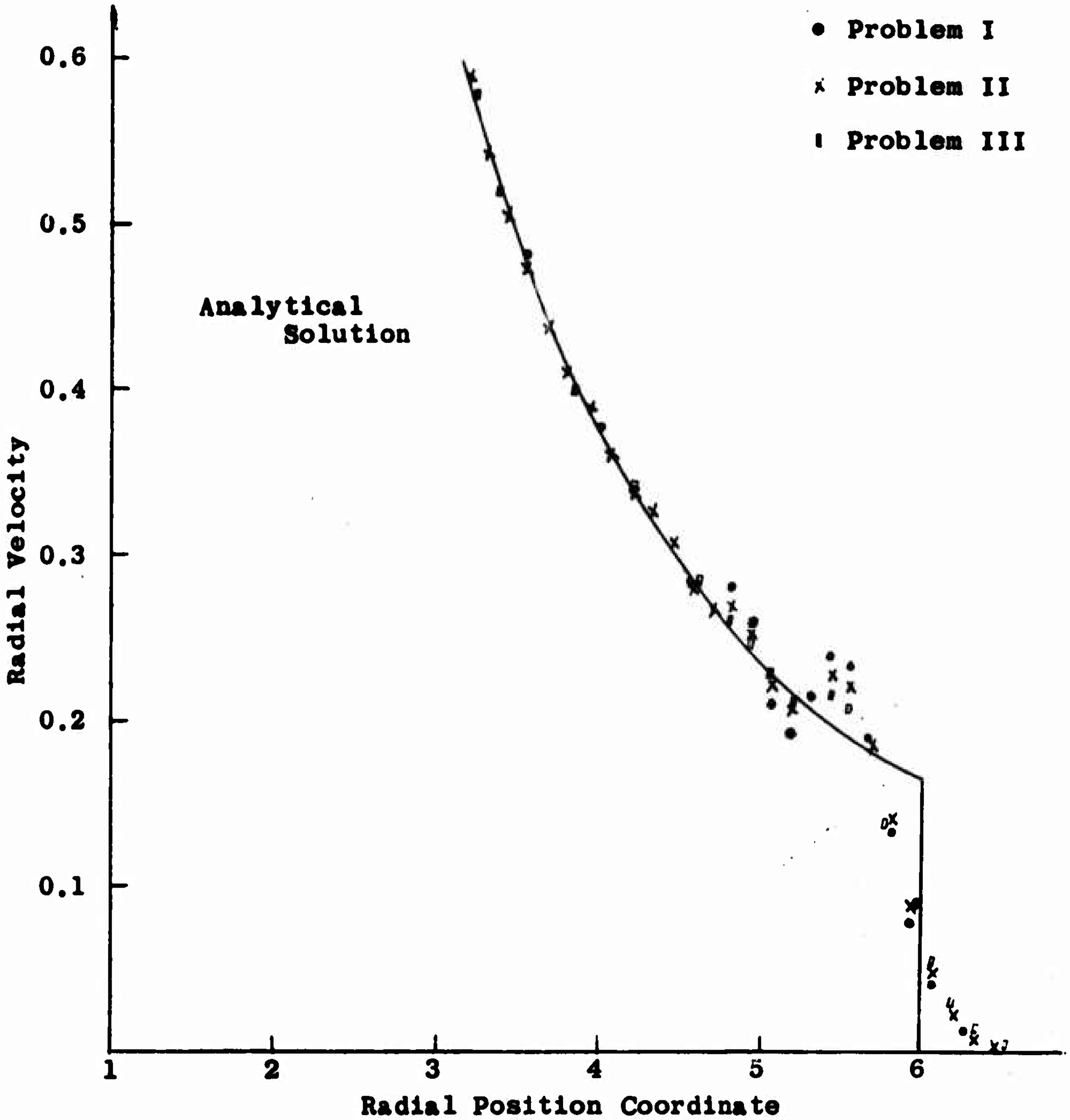


Figure 7

DETAIL OF SOLUTIONS AT THE SHOCK FRONT OF A SPHERICALLY DIVERGING COMPRESSION WAVE IN AN ELASTIC MEDIUM WHOSE LAME' CONSTANTS ARE $\lambda = 1, \mu = 0$ (Hydrodynamic Limit)

In the case of $\lambda = \mu = 1/3$, where hoop stresses are comparable to pressures, the situation is different. The velocity at the shock front is the same as in the hydrodynamic case but is now the largest velocity to be found in the shocked material. Errors significant compared to this velocity no longer appear negligible. In fact, the whole scale of significant velocities is reduced by at least an order of magnitude, and this case therefore provides a more stringent test of the numerical calculational procedure. The results are shown in Figures 8, 9, and 10 where the numerical solution is again compared to the exact analytical solution at a given time τ. Except for the Lame' constants, these problems are identical to Problems I, II, and III. Once more, Figure 8 shows the Lagrangian result with the zoning of Problem I. Figure 9 shows the Lagrangian results with the zoning of Problem II, and Figure 10 shows the results obtained using a time-dependent coordinate system in which the initial coordinate mesh was identical to that of Problem I.

In the case of equal Lame' constants, the Lagrangian solutions are accurate only in a time- or space-averaged sense. At a single time, zone by zone oscillations appear in velocity, radial stresses, etc., which can constitute errors of 50 percent or more at specific mesh points. (See Figure 8.) It was found that these errors decrease as the mesh is refined (Figure 9), although at a somewhat less rapid rate than was expected (Ref. 3). For the equations of Von Neumann and Richtmyer (Ref. 7), these oscillations represent a basic limitation on the accuracy of solutions to problems of this kind. On the whole, the results obtained with the generalized coordinate system were significantly better than the results shown in Figures 8 or 9, although the shock front itself was considerably eroded. This erosion is due to a combination of two effects: diffusion of mass and momentum arising from backward differencing, and the failure of the coordinate mesh to provide fine zoning at the shock front. This result is shown in Figure 11 where v_j is superimposed over the exact solution.

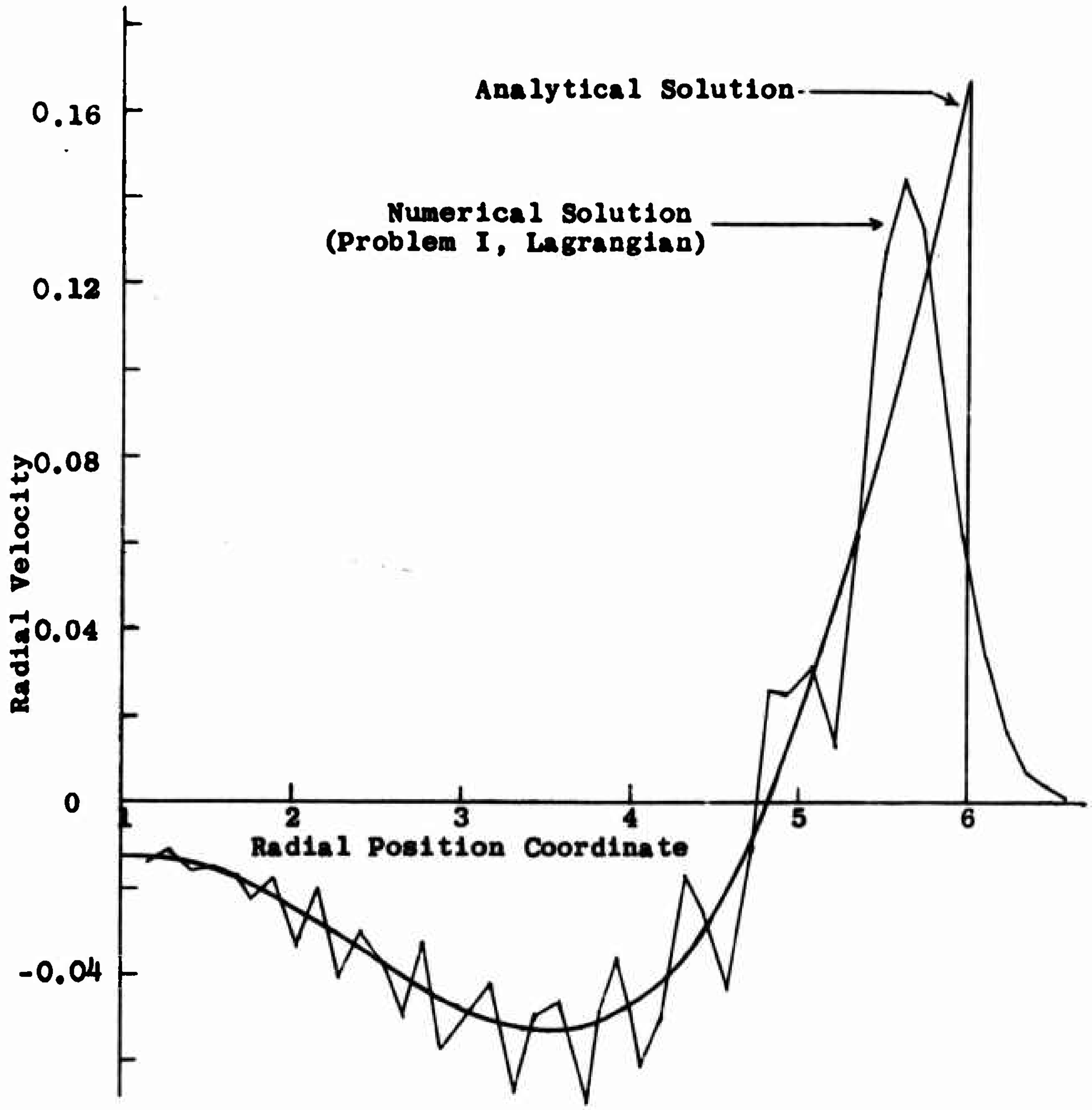


Figure 8

COMPARISONS OF THE NUMERICAL AND ANALYTICAL SOLUTIONS OF A SPHERICALLY DIVERGING COMPRESSION WAVE IN AN ELASTIC MEDIUM WHOSE LAME' CONSTANTS ARE

$\lambda = \mu = 1/3$

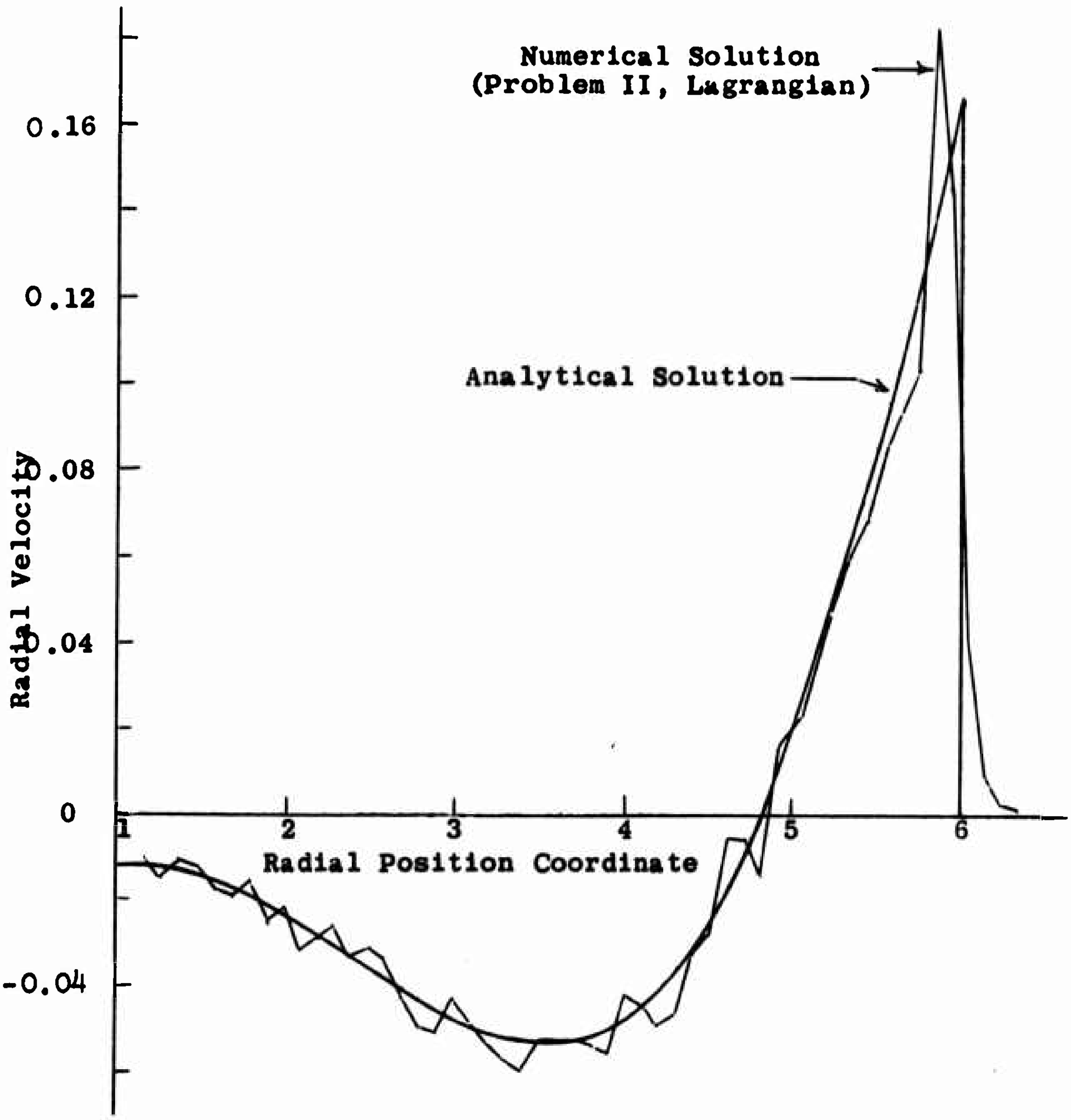


Figure 9

COMPARISONS OF THE NUMERICAL AND ANALYTICAL SOLUTIONS OF A SPHERICALLY DIVERGING COMPRESSION WAVE IN AN ELASTIC MEDIUM WHOSE LAME' CONSTANTS ARE

$\lambda = \mu = 1/3$

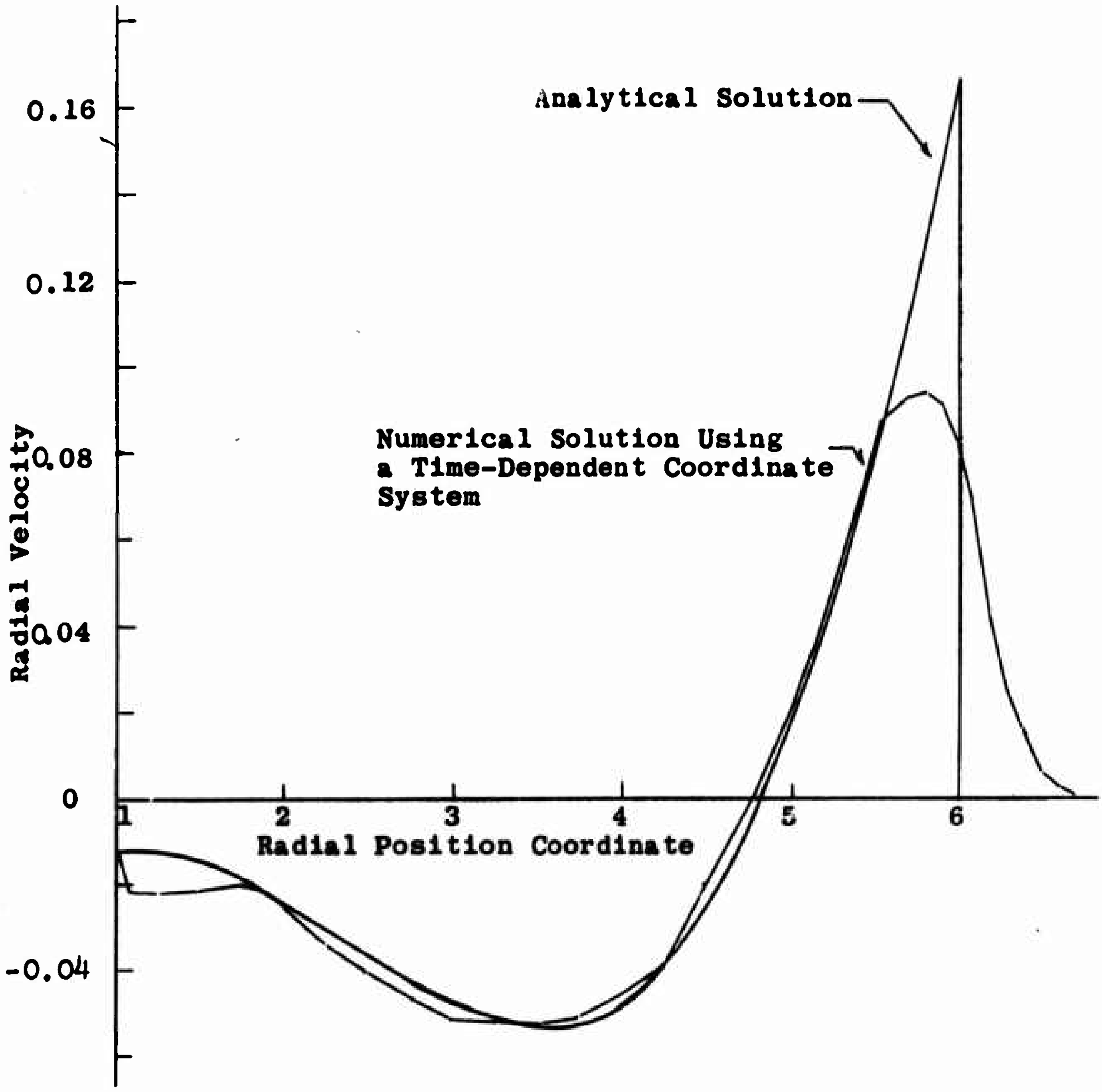


Figure 10

COMPARISON OF THE NUMERICAL SOLUTION USING A TIME-DEPENDENT COORDINATE SYSTEM WITH THE ANALYTICAL SOLUTION OF A SPHERICALLY DIVERGING COMPRESSION WAVE IN AN ELASTIC MEDIUM WHOSE LAME' CONSTANTS ARE $\lambda = \mu = 1/3$

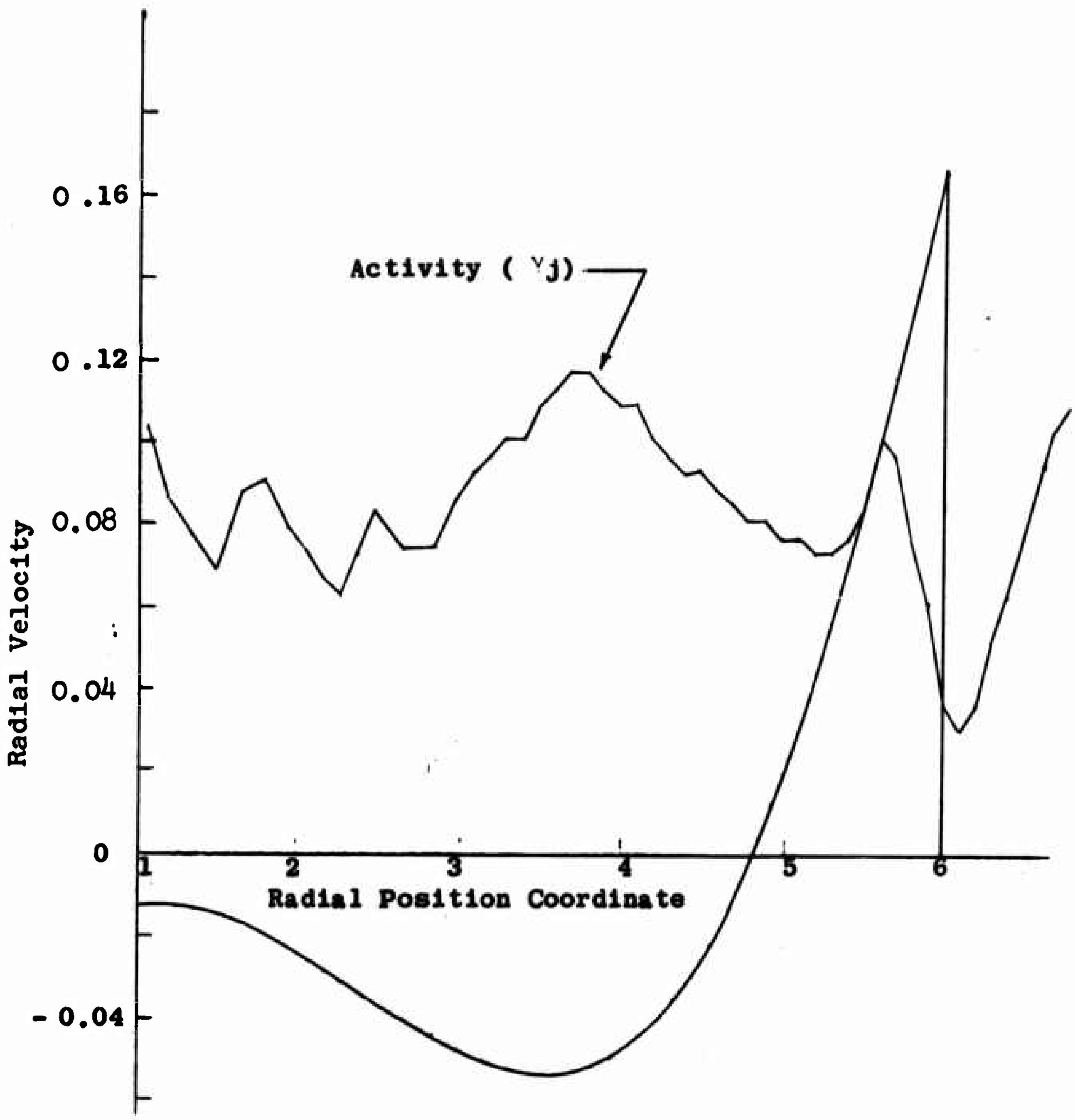


Figure 11

ACTIVITY QUANTITY, γj, OF PROBLEM III OVERLAID ON THE ANALYTICAL SOLUTION

The two definitions of activity led to essentially identical results in the case of spherically outgoing elastic compression waves, and both suffer from the defect that they imply relatively little activity at the peak of a compression pulse, where fine zoning is desired. Nevertheless, it appears that the effort made in AFTON 1 to achieve great flexibility in the choice of a coordinate system will in fact lead to the economical solution of continuum motion problems originally intended. As a result of the work done to date, some specific ways of improving on the coordinate system definitions used in this program are now evident, and the resulting coordinate system definitions appear capable of relatively simple extension to two-dimensional motion where the potential economies of solution are substantially greater than in one space dimension. To obtain the maximum possible accuracy of numerical solutions by an optimum distribution of mesh points, further studies of activity definitions and coordinate systems should be made.

APPENDIX I

INTERIOR AND BOUNDARY EQUATIONS FOR AFTON 2A

NOTATION

E_1, E_2, E_3	Principal extensions
E_a^n	Internal energy of zone "a" at time t^n
$E_{\ell m}$	Energy of material transported across zone boundary "ℓ_m"
F_W	Force on the quarter zone wedge face area
$\underline{F}_{ai}^n$	Vector force associated with vertex point (i) of zone "a" at time t^n
$\mathcal{H}^n$	Energy of the total system at time t^n
H_a^n	Total energy of zone "a" at time t^n
$\underline{M}_i^n$	Vector momentum of mesh point "i" at time t^n
m_i	Momentum mass associated with mesh point "i"
$\underline{\mathcal{M}}^n$	Momentum of the total system at time t^n
m_a^n	Mass of zone "a" at time t^n
q	Diagonal element of the artificial viscosity tensor
$\underline{U}_i^{n-\frac{1}{2}}$	Vector velocity of mesh point "i" at time $t^{n-\frac{1}{2}}$ having components u and v in the radial and axial directions respectively
$\dot{W}$	Rate of work on the total system
$\dot{W}_{m\ell}$	Rate of work on face "$m\ell$"
V_a^n	Specific volume of zone "a" at time t^n
y^n	Radial position coordinate at time t^n
z^n	Axial position coordinate at time t^n

P	Stress tensor defined in the coordinate system of the principal strains; its components are $\begin{matrix} P_y & 0 & 0 \\ 0 & P_z & 0 \\ 0 & 0 & P_x \end{matrix}$
P_a^n	Stress tensor defined in the external coordinate system; its components are $\begin{matrix} P_{11} & P_{12} & 0 \\ P_{21} & P_{22} & 0 \\ 0 & 0 & P_x \end{matrix}$
R	Rotation matrix; its components are $\begin{matrix} \lambda_{y1} & \lambda_{z1} & 0 \\ \lambda_{y2} & \lambda_{z2} & 0 \\ 0 & 0 & 1 \end{matrix}$
$\underline{\Lambda}_y = \begin{pmatrix} \lambda_{y1} \\ \lambda_{y2} \\ 0 \end{pmatrix}$	Principal strain direction; radial component λ_{y1}, axial component λ_{y2}
$\underline{\Lambda}_z = \begin{pmatrix} \lambda_{z1} \\ \lambda_{z2} \\ 0 \end{pmatrix}$	Principal strain direction; radial component λ_{z1}, axial component λ_{z2}
Δ	Volume dilatation
$\Delta^{n-\frac{1}{2}}t$	Time step used to advance the variables from t^{n-1} to t^n

ϵ_y, ϵ_z, ϵ_x	Principal Strains
η_a^n	Compression of zone "a" at time t^n
μ_a^n	Excess compression of zone "a" at time t^n
$\rho_{\lambda m}$	Density of material transported across zone boundary "λm"
ρ_a^n	Density of zone "a" at time t^n
V_a^n	Volume of zone "a" at time t^n

Constants

λ, μ	Lame' constants
Cq	Input constant to control the number of zones over which shocks are spread
a, b, A, B α, β, V_s, E_s	Tillotson Equation of State constants

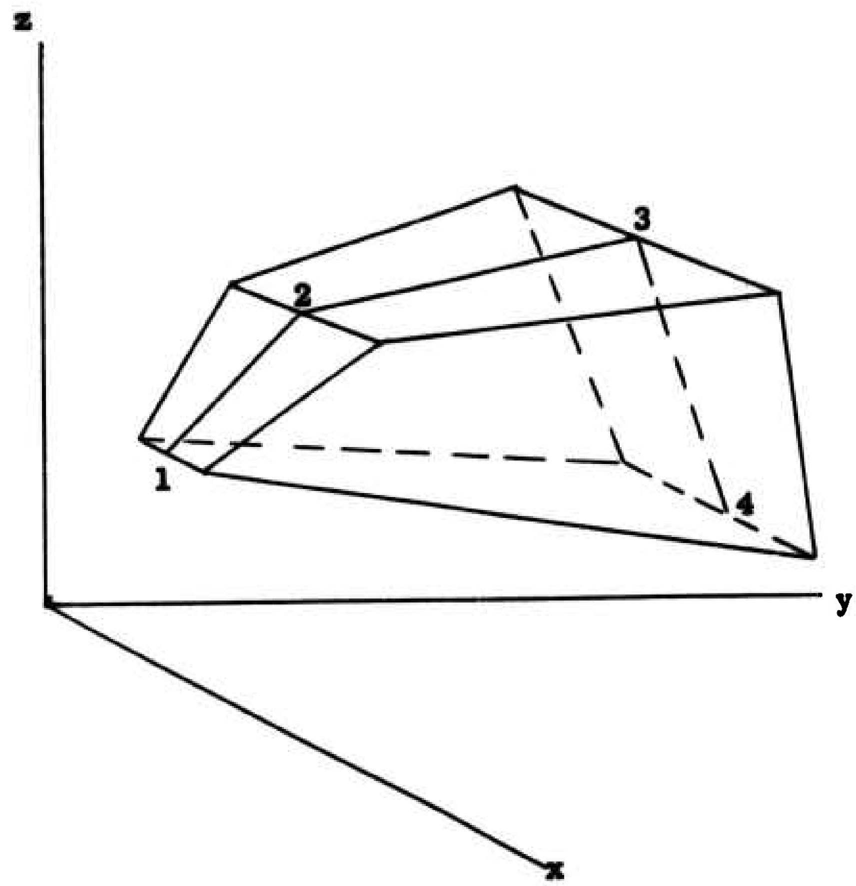


Figure 12

SCHEMATIC OF A QUADRILATERAL WEDGE

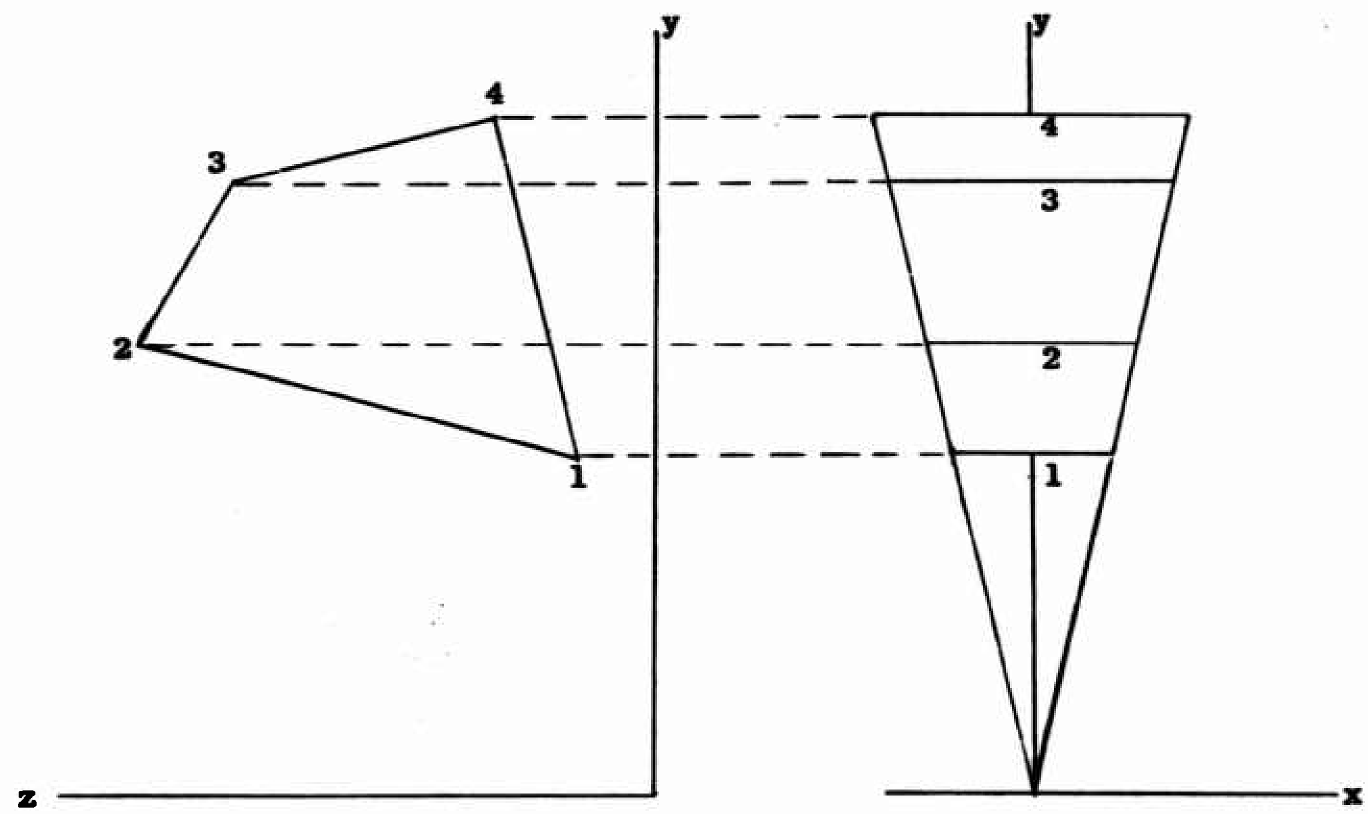


Figure 13

CROSS SECTIONS OF A QUADRILATERAL WEDGE IN BOTH THE y-z AND x-y PLANES

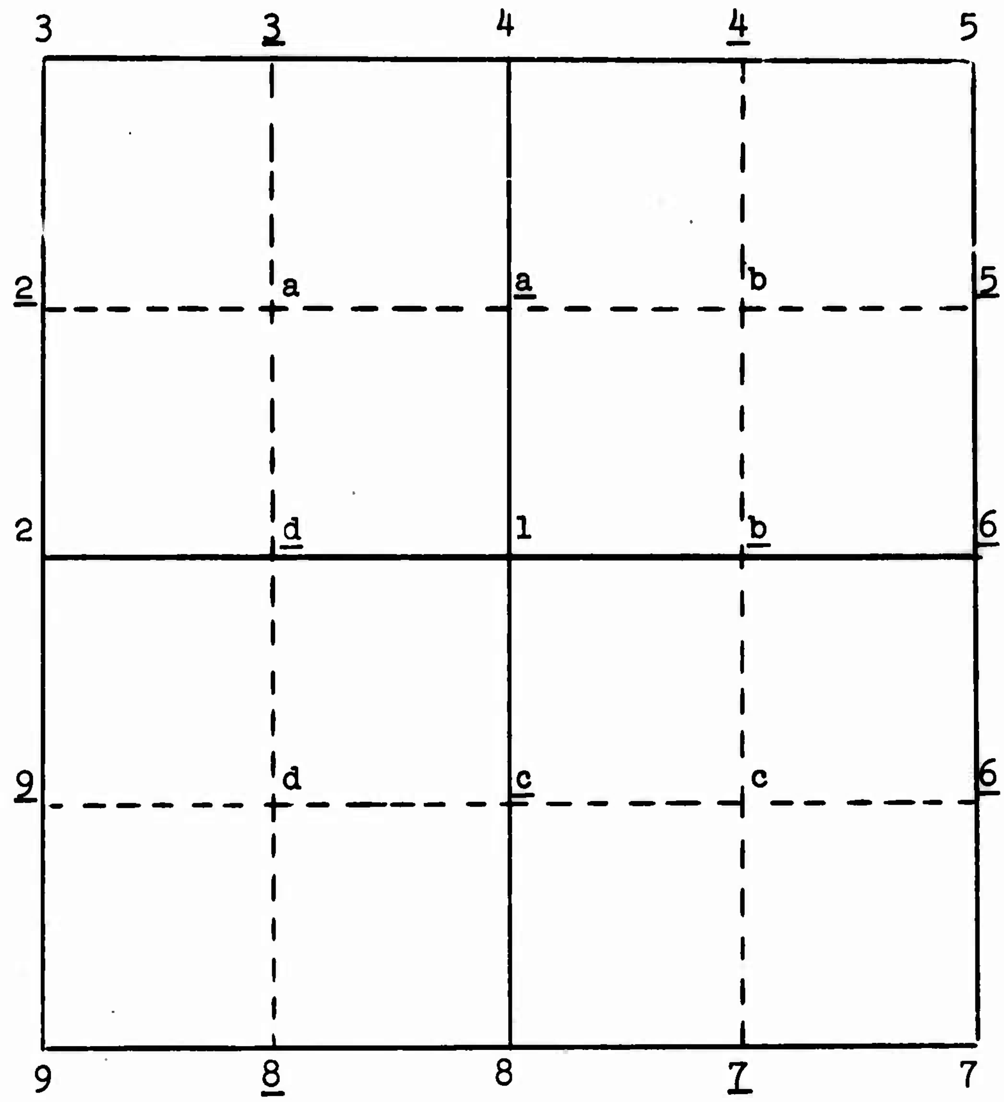


Figure 14

SCHEMATIC OF THE POINTS AND SIDES OF THE FOUR QUADRILATERAL ZONES (a, b, c, d).

The labeling of this figure is consistent with the notation used in the equations of Appendix I, which describe the calculations for interior and boundary zones both.

Strain Calculation

Let a quadrilateral zone be divided into two triangles by a diagonal connecting two of its vertices α, β. Let α, β, γ be a clockwise ordering of the vertices of one of the triangles. Also let $\underline{r}_\alpha$ be the position vector of the point α, etc. for the unstrained quadrilateral and $\underline{r}'_\alpha$, etc. the corresponding vectors for the strained quadrilateral.

$$\xi_\alpha = y_\alpha - y_\gamma \tag{42}$$

$$\xi'_\alpha = y'_\alpha - y'_\gamma \tag{43}$$

$$\zeta_\alpha = z_\alpha - z_\gamma \tag{44}$$

$$\zeta'_\alpha = z'_\alpha - z'_\gamma \tag{45}$$

$$\xi_\beta = y_\beta - y_\gamma \tag{46}$$

$$\xi'_\beta = y'_\beta - y'_\gamma \tag{47}$$

$$\zeta_\beta = z_\beta - z_\gamma \tag{48}$$

$$\zeta'_\beta = z'_\beta - z'_\gamma \tag{49}$$

$$A = \xi_\alpha \zeta_\beta - \xi_\beta \zeta_\alpha \tag{50}$$

$$a_{22} = (\zeta_\beta \xi'_\alpha - \zeta_\alpha \xi'_\beta)/A \tag{51}$$

$$a_{23} = -(\xi_\beta \xi'_\alpha - \xi_\alpha \xi'_\beta)/A \tag{52}$$

$$a_{32} = (\zeta_\beta \zeta'_\alpha - \zeta_\alpha \zeta'_\beta)/A \tag{53}$$

$$a_{33} = -(\xi_\beta \zeta'_\alpha - \xi_\alpha \zeta'_\beta)/A \tag{54}$$

Repeat Eqs. 42 through 54 for each of the four triangles into which the quadrilateral can be divided by its two diagonals ; compute $\bar{a}_{22}$, etc., as the arithmetic mean of the four values of a_{22}, etc. so generated. Then calculate :

$$t_{22} = \bar{a}_{22}^{\;2} + \bar{a}_{32}^{\;2} \tag{55}$$

$$t_{23} = \bar{a}_{22}\bar{a}_{23} + \bar{a}_{32}\bar{a}_{33} \tag{56}$$

$$t_{33} = \bar{a}_{23}^{\;2} + \bar{a}_{33}^{\;2} \tag{57}$$

If $t_{23} = 0$, set

$$\lambda_+ = \begin{cases} t_{22}, & \text{if } t_{22} > t_{33} \\ t_{33}, & \text{if } t_{22} < t_{33} \end{cases} \tag{58}$$

$$\lambda_- = \begin{cases} t_{33}, & \text{if } t_{22} > t_{33} \\ t_{22}, & \text{if } t_{22} < t_{33} \end{cases} \tag{59}$$

$$\underline{\Lambda}_y = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \tag{60}$$

$$\underline{\Lambda}_z = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} \tag{61}$$

If $t_{23} \neq 0$, compute

$$\lambda_\pm = \tfrac{1}{2}\{(t_{22} + t_{33}) \pm [(t_{22} - t_{33})^2 + 4t_{33}^{\;2}]^{\frac{1}{2}}\} \tag{62}$$

$$E_1 = \lambda_+^{\frac{1}{2}} \tag{63}$$

$$E_2 = \lambda_-^{\frac{1}{2}} \tag{64}$$

$$E_3 = (V/V_o)/(E_1 E_2) \tag{65}$$

$$\Lambda_{\pm} = \left[t_{23}^{2} + \left(t_{22} - \lambda_{\pm}\right)^{2}\right]^{-\frac{1}{2}} \begin{pmatrix} t_{23} \\ t_{22} - \lambda_{\pm} \\ 0 \end{pmatrix} \quad (66)$$

Of the four unit vectors $\Lambda_{\pm}$ and their negatives choose as the strain axes the two having the largest positive y and z components respectively. These are called $\underline{\Lambda}_y$ and $\underline{\Lambda}_z$.

$$\epsilon_y = E_1 - 1 \quad (67)$$

$$\epsilon_z = E_2 - 1 \quad (68)$$

$$\epsilon_x = E_3 - 1 \quad (69)$$

$$\Delta = \left(Y^n / Y_o\right) - 1 \quad (70)$$

$$\eta^n = \rho^n/\rho_o \quad (71)$$

$$\mu^n = \eta^n - 1 \quad (72)$$

For simplicity, the transport calculation defined by Eqs.74 through 82 refers to a mesh of Eulerian rectangular zones. The general case requires the additional calculation of the relevant interior vector areas for momentum transport, and the inclusion of the mesh point motion in the definition of transport velocity.

By definition, for any variable f (scalar, vector, or tensor), let

$$\bar{f} = \tfrac{1}{2}(f^{n-1} + f^{n}) \qquad (73)$$

Then compute

$$^{m}a_{m\ell} = \tfrac{1}{6}\left(2\bar{y}_m + \bar{y}_\ell\right)\begin{pmatrix}\bar{z}_\ell - \bar{z}_m \\ \bar{y}_m - \bar{y}_\ell \\ 0\end{pmatrix} \qquad (74)$$

$$^{\ell}a_{m\ell} = \tfrac{1}{6}(\bar{y}_m + 2\bar{y}_\ell)\begin{pmatrix}\bar{z}_\ell - \bar{z}_m \\ \bar{y}_m - \bar{y}_\ell \\ 0\end{pmatrix} \qquad (75)$$

$$a_{m\ell} = {}^{\ell}a_{m\ell} + {}^{m}a_{m} \qquad (76)$$

where the point m follows the point ℓ as the perimeter of a zone is traversed clockwise.

$$\underline{W}_{12}^{n-\frac{1}{2}} = \tfrac{1}{2}\left(\underline{U}_1^{n-\frac{1}{2}} + \underline{U}_2^{n-\frac{1}{2}}\right) \qquad (77)$$

$$\underline{W}_{23}^{n-\frac{1}{2}} = \tfrac{1}{2}\left(\underline{U}_2^{n-\frac{1}{2}} + \underline{U}_3^{n-\frac{1}{2}}\right) \qquad (78)$$

$$(\rho WA)_{12} = \rho_{12} \underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21} \tag{79}$$

$$(\rho WA)_{23} = \rho_{23} \underline{W}_{23}^{n-\frac{1}{2}} \cdot \underline{a}_{32} \tag{80}$$

where, depending on the smoothness of the density field in the neighborhood of the zone at time t^n, either

$$\rho_{12} = \tfrac{1}{2}\left(\rho_a^{n-1} + \rho_d^{n-1}\right) - \left(\underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21}\right)\Delta^{n-\frac{1}{2}}t\,\rho_a^{n-1}/\left(z_4^n - z_1^n\right) \tag{81}$$

or

$$\rho_{12} = \begin{cases} \rho_a^{n-1}, \text{ if } \left(\underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21}\right) > 0 \\ \\ \rho_d^{n-1}, \text{ if } \left(\underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21}\right) < 0 \end{cases} \tag{82}$$

An analogous computation is made for ρ_{23}

$$Y^n = Y^{n-1} = Y^o \tag{83}$$

$$m^n = m^{n-1} - \Delta^{n-\frac{1}{2}}t\left[(\rho WA)_{12} + (\rho WA)_{23} + (\rho WA)_{34} + (\rho WA)_{41}\right] \tag{84}$$

$$\rho^n = m^n/Y^n$$

Stress Calculation

$$\mathbb{R} = (\underline{\Lambda}_y, \underline{\Lambda}_z) \tag{86}$$

$$\mathbb{P} = \begin{pmatrix} P_y & 0 & 0 \\ 0 & P_z & 0 \\ 0 & 0 & P_x \end{pmatrix} \tag{87}$$

$$\mathbb{P}^n = \mathbb{R} \; \mathbb{P} \; \mathbb{R}^{tr} \tag{88}$$

Where the components P_y, P_z, P_x of P are given by

$$P_y = -(\lambda\Delta + 2\mu\epsilon_y) \tag{89}$$

$$P_z = -(\lambda\Delta + 2\mu\epsilon_z) \tag{90}$$

$$P_x = -(\lambda\Delta + 2\mu\epsilon_x) \tag{91}$$

for an elastic medium, or $P_y = P_z = P_x = P$ if the material can be described hydrodynamically. One such hydrodynamic description for TUFF is the Tillotson (Ref. 8) Equation of State:

$$P = \left|a + b/g\right| \left|E^n/V^n\right| + A\mu^n + B\mu^{n2} \tag{92}$$

when $V/V_o < 1$ for all $E^n > 0$

$V/V_o < V_S$ for all $E^n < E_S$

or

$$P = aE^n\rho^n + \left[\left(bE^n\rho^n/g\right) + A\mu^n \exp\left(\beta\mu^n/\eta^n\right)\right] \exp\left[-\alpha\left(\mu^n/\eta^n\right)^2\right] \tag{93}$$

when

$$1 < V/V_o < V_S \quad \text{for } E^n > E_S$$

and

$$V/V_c > V_S \text{ for all } E^n > 0 \quad .$$

Here

$$g = \frac{E^n}{E_o \eta^{n2}} + 1$$

Then

$$P_a^n = R_a P_a R_a^{tr} = \begin{pmatrix} P_{11} & P_{12} & 0 \\ P_{12} & P_{22} & 0 \\ 0 & 0 & P_x \end{pmatrix} \tag{94}$$

$$P_{11} = \lambda_{y1}^2 P_y + \lambda_{z1}^2 P_z \tag{95}$$

$$P_{12} = \lambda_{y1}\lambda_{y2} P_y + \lambda_{z1}\lambda_{z2} P_z \tag{96}$$

$$P_{22} = \lambda_{y2}^2 P_y + \lambda_{z2}^2 P_z \tag{97}$$

and

$$Q^{n-\frac{1}{2}} = \begin{pmatrix} q & 0 & 0 \\ 0 & q & 0 \\ 0 & 0 & q \end{pmatrix} \tag{98}$$

$$q = Cq\, \rho^{n-\frac{1}{2}} \left[(y_1^n - y_2^n)^2 + (z_4^n - z_1^n)^2 \right] \left[\frac{Y^n - Y^{n-1}}{\Delta^{n-\frac{1}{2}} t \; Y^{n-\frac{1}{2}}} \right]^2 \tag{99}$$

$$PQ_a^n = P^n + Q^{n-\frac{1}{2}} \tag{100}$$

$$A_{j,i} = y_j^n z_i^n - y_i^n z_j^n \quad ; \qquad i,j = 1,2,3,4$$

$$\underline{Q}_i = \begin{pmatrix} Q_{iy} \\ Q_{iz} \\ 0 \end{pmatrix} = \frac{1}{6} \begin{pmatrix} \bar{z}_{i-1}(\bar{y}_{i-1} + \bar{y}_i) - \bar{z}_{i+1}(\bar{y}_i + \bar{y}_{i+1}) + A_{i-1,i} + A_{i,i+1} \\ -\bar{y}_{i-1}(\bar{y}_{i-1} + \bar{y}_i) + \bar{y}_{i+1}(\bar{y}_i + \bar{y}_{i+1}) \\ 0 \end{pmatrix} \quad (101)$$

For non-Eulerian coordinate systems, Y_a^n is calculated as

$$\dot{Y}_a = \sum_{i=1}^{4} \underline{U}_i^{n-\frac{1}{2}} \cdot \underline{Q}_i \qquad (102)$$

$$Y_a^n = Y_a^{n-1} + \dot{Y}_a \, \Delta^{n-\frac{1}{2}} t \qquad (103)$$

Define

$$y_{\underline{d}} = \left[\left(y_1^2 + y_1 y_2 + y_2^2\right)/3\right]^{\frac{1}{2}} \qquad (104)$$

$$z_{\underline{d}} = \frac{(y_2 - y_d)z_1 + (y_d - y_1)z_2}{(y_2 - y_1)} \qquad (105)$$

Similar definitions hold for the points $\underline{2}$, $\underline{3}$, and $\underline{a}$ of Figure 13

$$A_1 = \left(y_1^n - y_{\underline{d}}^n\right)\left(z_{\underline{a}}^n - z_1^n\right) \qquad \text{for } i=1 \qquad (106)$$

An analogous definition holds for $i=2,3,4$.

$$\underline{F}_{ai} = \begin{pmatrix} FQ_{11}(a_{1y} - A_1) + FQ_{12}\,a_{1z} + FQ_x A_1 \\ FQ_{12}(a_{1y} - A_1) + FQ_{22}\,a_{1z} \\ 0 \end{pmatrix} \tag{107}$$

$$(\rho WAE)_{12} = (\rho WA)_{12}\, E_{12} \tag{108}$$

where, depending on the smoothness of the energy field in the neighborhood of a zone at time t^n, either

$$E_{12} = \tfrac{1}{2}\left(E_a^{n-1} + E_d^{n-1}\right) - \left(\underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21}\right)\Delta^{n-\frac{1}{2}}t\; E_a^{n-1}/\left(z_4^n - z_1^n\right) \tag{109}$$

or

$$E_{12} = \begin{cases} E_a^{n-1}, & \text{if } \left(\underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21}\right) > 0 \\ E_d^{n-1}, & \text{if } \left(\underline{W}_{12}^{n-\frac{1}{2}} \cdot \underline{a}_{21}\right) < 0 \end{cases} \tag{110}$$

$$E_t = (\rho WAE)_{12} + (\rho WAE)_{23} + (\rho WAE)_{34} + (\rho WAE)_{41} \tag{111}$$

$$E_a^n = E_a^{n-1} - \Delta^{n-\frac{1}{2}}t\;\left[E_t + \sum_{i=1}^{4} \underline{F}_i \cdot \underline{U}_i\right] \tag{112}$$

$$\underline{M}_1^n = \underline{M}_1^{n-1} + \Delta^{n-\frac{1}{2}}t\left(\underline{F}_{a1} + \underline{F}_{b1} + \underline{F}_{c1} + \underline{F}_{d1}\right) \tag{113}$$

$$\delta a1 = |\,{}^{l}a_{ml}| \,/\, |a_{ml}| \tag{114}$$

$$\delta a2 = |\,{}^{m}a_{ml}| \,/\, |a_{ml}| \tag{115}$$

$$m_1 = \tfrac{1}{2}\left(\delta_{a1}m_a + \delta_{b2}m_b + \delta_{c2}m_c + \delta_{d1}m_d\right) \quad (116)$$

$$\underline{U}_1^{n+\frac{1}{2}} = \left(2M_1^n/m_1\right) - \underline{U}_1^{n-\frac{1}{2}} \quad (117)$$

$$H_a^n = E_a^n + \frac{1}{8}\, m_a \left[\sum_{i=1}^{4} \underline{U}_i^{n-\frac{1}{2}} \cdot \underline{U}_i^{n+\frac{1}{2}}\right] \quad (118)$$

$$\mathcal{H}^n = \sum_{\text{all zones}} H^n \quad (119)$$

Let $P_{m\ell}$ be the given (input) stress tensor acting on the face $m\ell$. Then

$${}^m\underline{F}_{m\ell} = -P_{m\ell}\; {}^m\underline{a}_{m\ell} \quad (120)$$

$${}^\ell\underline{F}_{m\ell} = -P_{m\ell}\; {}^\ell\underline{a}_{m\ell} \quad (121)$$

$$\dot{W}_{m\ell}^{n-\frac{1}{2}} = \underline{U}_m^{n-\frac{1}{2}} \cdot {}^m\underline{F}_{m\ell} + \underline{U}^{n-\frac{1}{2}} \cdot {}^\ell\underline{F}_{m\ell} \quad (122)$$

$$\dot{W}^{n-\frac{1}{2}} = \Sigma\, \dot{W}_{m\ell}^{n-\frac{1}{2}} \quad (123)$$

$$\underline{F} = \Sigma\left({}^m\underline{F}_{m\ell} + {}^\ell\underline{F}_{m\ell}\right) \quad (124)$$

where the summations are taken over all boundary faces $m\ell$.

$$\mathcal{M}^n = \sum_p M_p^n \quad (125)$$

where the summation is taken over all mesh points p

$$F_W = \sum_{qz} \left(P_x A_i\right)_{qz} \quad (126)$$

where the summation is taken over all quarter zones qz

$$\mathcal{F} = \underline{F} + \begin{pmatrix} F_W \\ 0 \\ 0 \end{pmatrix} \qquad (127)$$

$$\mathcal{H}^{n} - \mathcal{H}^{n-1} = \dot{W}^{n-\frac{1}{2}} \Delta^{n-\frac{1}{2}}t \qquad (128)$$

$$\mathcal{M}^{n} - \mathcal{M}^{n-1} = \mathcal{F} \Delta^{n-\frac{1}{2}}t \qquad (129)$$

At the axis of symmetry (z-axis) J = 1):

$$U = (\underline{M}^n)_y = 0 \qquad (130)$$

$$^{l}a_{ml} = {}^{m}a_{ml} = 0 \qquad (131)$$

If point 2 of Figure 4 is a point on the axis of symmetry then,

$$(\underline{M}_2^n)_z = (\underline{M}_2^{n-1})_z + (\underline{F}_{a2} + \underline{F}_{d2})_z \, \Delta^{n-\frac{1}{2}}t \qquad (132)$$

$$m_2 = \tfrac{1}{4}(m_a + m_d) \qquad (133)$$

$$v_{L2}^{n+\frac{1}{2}} = [2(\underline{M}_2^n)_z/m_2] - v_2^{n-\frac{1}{2}} \qquad (134)$$

At the boundary logically parallel to the axis of symmetry (J = JMAX):

$$u = (\underline{M}^n)_y = 0 \qquad (135)$$

If point 6 of Figure 4 is a point of the JMAX boundary, then $({}^6\underline{F}_{76} + {}^6\underline{F}_{65})_z$ is assumed to be given. If $({}^6\underline{F}_{76} + {}^6\underline{F}_{65})_z = 0$, the boundary condition is one of "free sliding." Next,

$$({}^6\underline{F}_{76} + {}^6\underline{F}_{65})_y = -(\underline{F}_{c6} + \underline{F}_{b6})_y \qquad (136)$$

Now both components of $({}^6\underline{F}_{76} + {}^6\underline{F}_{65})$ are known.

$$(\underline{M}_6^n)_z = ({}^6\underline{F}_{76} + \underline{F}_{c6} + \underline{F}_{b6} + {}^6\underline{F}_{65})_z \, \Delta^{n-\frac{1}{2}}t + (\underline{M}_6^{n-1})_z \qquad (137)$$

$$m_6 = \tfrac{1}{4}(m_c + m_b) \qquad (138)$$

$$\dot{\upsilon}_{L6}^{n+\frac{1}{2}} = \left[2(\underline{M}_6^n)_z/m_6\right] - \dot{\upsilon}_6^{n-\frac{1}{2}} \qquad (139)$$

The resultant applied force $\left({}^6\underline{F}_{76} + {}^6\underline{F}_{65}\right)$ contributes an amount $\underline{U}_6^{n-\frac{1}{2}}\cdot\left({}^6\underline{F}_{76} + {}^6\underline{F}_{65}\right)$ to the overall rate of work $\dot{W}^{n-\frac{1}{2}}$ on the entire system. It also contributes $\left({}^6\underline{F}_{76} + {}^6\underline{F}_{65}\right)\Delta^{n-\frac{1}{2}}t$ to the total impulse delivered to the system in time $\Delta^{n-\frac{1}{2}}t$.

Boundary (K=1) with velocity prescribed (i.e., if point 8 of Figure 4 is a point of the K=1 boundary, then $\underline{U}_8^{n+\frac{1}{2}}$ is given for all n).

$$m_8 = \tfrac{1}{4}\left(m_d + m_c\right) \qquad (140)$$

$$\underline{M}_8^n = \tfrac{1}{2}m_8\left(\underline{U}_8^{n+\frac{1}{2}} + \underline{U}_8^{n-\frac{1}{2}}\right) \qquad (141)$$

$${}^8\underline{F}_{87} + {}^8\underline{F}_{98} = \left(\underline{M}_8^n - \underline{M}_8^{n-1}\right)/\Delta^{n-\frac{1}{2}}t - \left(\underline{F}_{d8} + \underline{F}_{c8}\right) \qquad (142)$$

The resultant applied force ${}^8\underline{F}_{87} + {}^8\underline{F}_{98}$ contributes an amount $\underline{U}_8^{n-\frac{1}{2}}\cdot\left({}^8\underline{F}_{87} + {}^8\underline{F}_{98}\right)$ to the overall rate of work $\dot{W}^{n-\frac{1}{2}}$ on the entire system. In the time-step $\Delta^{n-\frac{1}{2}}t$, it also contributes $\left({}^8\underline{F}_{87} + {}^8\underline{F}_{98}\right)\Delta^{n-\frac{1}{2}}t$ to the impulse delivered to the entire system.

Top boundary (K = KMAX) with velocity prescribed (i.e., if point 4 of Figure 5 is a point of the KMAX boundary, then $\underline{U}_4^{n+\frac{1}{2}}$ is given for all n)

$$m_4 = \tfrac{1}{4}\left(m_b + m_a\right) \qquad (143)$$

$$\underline{M}_4^n = \tfrac{1}{2}m_4\left(\underline{U}_4^{n+\frac{1}{2}} + \underline{U}_4^{n-\frac{1}{2}}\right) \qquad (144)$$

$${}^4\underline{F}_{43} + {}^4\underline{F}_{54} = \left(\underline{M}_4^n - \underline{M}_4^{n-1}\right)/\Delta^{n-\frac{1}{2}}t - \left(\underline{F}_{b4} + \underline{F}_{a4}\right) \qquad (145)$$

The resultant applied force ${}^4\underline{F}_{43} + {}^4\underline{F}_{54}$ contributes an amount $\underline{U}_4^{n-\frac{1}{2}} \cdot ({}^4\underline{F}_{43} + {}^4\underline{F}_{54})$ to the overall rate of work $\dot{W}^{n-\frac{1}{2}}$ on the entire system. In the time-step $\Delta^{n-\frac{1}{2}}t$, it also contributes $({}^4\underline{F}_{43} + {}^4\underline{F}_{54})\Delta^{n-\frac{1}{2}}t$ to the impulse delivered to the entire system.

Southwest corner (j=1, k=1) with velocity prescribed(i.e., if point 9 of Figure 5 is the southwest corner point then $\underline{U}_9^{n+\frac{1}{2}}$ is given for all n, and $U_9^{n+\frac{1}{2}} = (\underline{M}_9^n)_y = 0$).

$$m_9 = \tfrac{1}{4} m_d \tag{146}$$

$${}^9\underline{F}_{98} = (\underline{M}_9^n - \underline{M}_9^{n-1})/\Delta^{n-\frac{1}{2}}t - \underline{F}_{d9} \tag{147}$$

Northwest corner (J=1, K=KMAX) with velocity prescribed (i.e., if point 3 of Figure 5 is the northwest corner point, then $\underline{U}_3^{n+\frac{1}{2}}$, is given for all n, and $U_3^{n+\frac{1}{2}} = (\underline{M}_3{}^n)_y = 0$).

$$m_3 = \tfrac{1}{4} m_a \tag{148}$$

$${}^3\underline{F}_{43} = (\underline{M}_3^n - \underline{M}_3^{n-1})/\Delta^{n-\frac{1}{2}}t - \underline{F}_{a3} \tag{149}$$

Northeast corner (j=JMAX, k=KMAX) with velocity prescribed (i.e., if point 5 of Figure 5 is the northeast corner point, then $\underline{U}_5^{n+\frac{1}{2}}$ is given for all n, and $U_5^{n+\frac{1}{2}} = (\underline{M}_5^n)_y = 0$).

$$m_5 = \tfrac{1}{4} m_b \tag{150}$$

$${}^5\underline{F}_{54} + {}^5\underline{F}_{65} = (\underline{M}_5^n - \underline{M}_5^{n-1})/\Delta^{n-\frac{1}{2}}t - \underline{F}_{65} \tag{151}$$

Southeast corner (J=JMAX, K=1) with velocity prescribed (i.e., if point 7 of Figure 5 is the southeast corner point, then $\underline{U}_7^{n+\frac{1}{2}}$ is given for all n, and $U_7^{n+\frac{1}{2}} = \left(\underline{M}_7^n\right)_y = 0$).

$$m_7 = \tfrac{1}{4}m_c \tag{152}$$

$$^7\underline{F}_{76} + \underline{F}_{87} = \left(\underline{M}_7^n - \underline{M}_7^{n-1}\right)/\Delta^{n-\frac{1}{2}}t - \underline{F}_{c7} \tag{153}$$

APPENDIX II

INTERFACE EQUATIONS FOR AFTON 2A

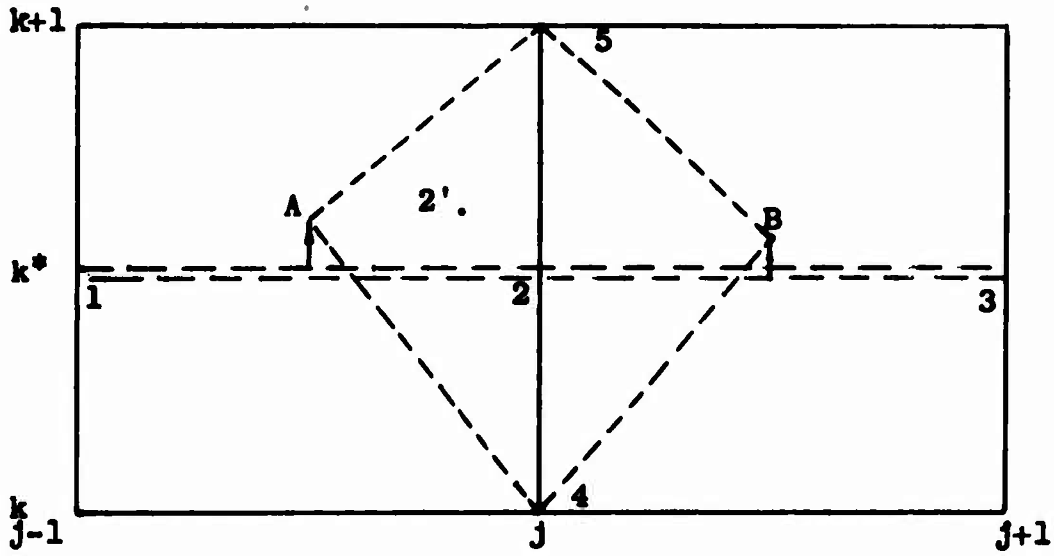


Figure 15

SCHEMATIC ARRANGEMENT OF MESH POINTS, HALF-ZONES, AND TRIANGLES AROUND AN INTERFACE POINT

All subscripts used in Eq. 154 through 178 which determine motions of an interface point, refer to the labeling shown in this figure.

$$\underline{n}_{12} = \underline{k} \times (\underline{r}_2^{n-1} - \underline{r}_1^{n-1}) / |\underline{r}_2^{n-1} - \underline{r}_1^{n-1}| \quad (154)$$

$$= \frac{1}{|\underline{r}_2^{n-1} - \underline{r}_1^{n-1}|} \begin{pmatrix} -(z_2^{n-1} - z_1^{n-1}) \\ y_2^{n-1} - y_1^{n-1} \\ 0 \end{pmatrix} \quad (155)$$

$$y_A = \left\{ \left[(y_1^{n-1})^2 + (y_1^{n-1})(y_2^{n-1}) + (y_2^{n-1})^2 \right] / 3 \right\}^{\frac{1}{2}} \quad (156)$$

$$z_A = \left[(y_A - y_1^{n-1}) z_2^{n-1} + (y_2^{n-1} - y_A) z_1^{n-1} \right] / (y_2^{n-1} - y_1^{n-1}) \quad (157)$$

$$\underline{r}_A^n = \underline{r}_A + \tfrac{1}{2}(\underline{U}_1^{n-3/2} + \underline{U}_2^{n-3/2}) \Delta^{n-\frac{1}{2}} t \quad (158)$$

The final position 2' of the interface point 2 is found by iteration. Each iteration is begun with a guess at the proper value of the variable α, which is the component of the particle velocity at the point 2 normal to the interface; $\alpha^{(1)}$ is the first guess at α.

$$\underline{n}_2 = \tfrac{1}{2}(\underline{n}_{12} + \underline{n}_{23}) \quad (159)$$

$$\underline{t}_2 = \underline{n}_2 \times \underline{k} = \begin{pmatrix} n_{z2} \\ -n_{y2} \\ 0 \end{pmatrix} \quad (160)$$

$$\underline{r}_{2'}^n = \underline{r}_2^{n-1} + \alpha^{(1)} \underline{n}_2 \Delta^{n-\frac{1}{2}} t$$

$$+ \Delta^{n-\frac{1}{2}} t \left[(\underline{U}_2^{n-3/2})_y \, n_{2z} - (\underline{U}_2^{n-3/2})_z \, n_{2y} \right] \underline{t}_2 \quad (161)$$

$$\bar{z}_5 = \tfrac{1}{2}\left(z_5^n + z_5^{n-1}\right) \qquad (162)$$

$$\bar{z}_{2'} = \tfrac{1}{2}\left(z_{2'}^n + z_{2'}^{n-1}\right) \text{ [use guessed value for } z_{2'}^n \text{]} \qquad (163)$$

$$\bar{z}_A = \tfrac{1}{2}\left(z_A^n + z_A\right), \text{etc.} \qquad (164)$$

Referring to triangle $\overline{2'A5} \equiv I$:

$$\mathcal{Q}_{2'}^{n-\frac{1}{2}} = \frac{1}{6}\begin{pmatrix} \bar{z}_5\left(\bar{y}_5 + \bar{y}_{2'}\right) - \bar{z}_A\left(\bar{y}_{2'} + \bar{y}_A\right) + \bar{A}_{2'5} + \bar{A}_{A2'} \\ - \bar{y}_5\left(\bar{y}_5 + \bar{y}_{2'}\right) + \bar{y}_A\left(\bar{y}_{2'} + \bar{y}_A\right) \\ 0 \end{pmatrix} \qquad (165)$$

Similar expressions hold for the other two corner points of the triangle. Next,

$$\underline{U}_{2'}^{n-\frac{1}{2}} = \left(\underline{r}_{2'}^n - \underline{r}_2^{n-1}\right)/\Delta^{n-\frac{1}{2}}t \qquad (166)$$

$$\underline{U}_A^{n-\frac{1}{2}} = \left(\underline{r}_A^n - \underline{r}_A\right)/\Delta^{n-\frac{1}{2}}t \qquad (167)$$

Compute

$$\dot{Y}_I = \underline{U}_{2'}^{n-\frac{1}{2}} \cdot \underline{\mathcal{Q}}_{2'}^{n-\frac{1}{2}} + \underline{U}_A^{n-\frac{1}{2}} \cdot \underline{\mathcal{Q}}_A^{n-\frac{1}{2}} + \underline{U}_5^{n-\frac{1}{2}} \cdot \underline{\mathcal{Q}}_5^{n-\frac{1}{2}} \qquad (168)$$

$$Y_I^n = Y_I^{n-1} + \dot{Y}_I\, \Delta^{n-\frac{1}{2}}t. \qquad (169)$$

Calculate principal strains and strain axis directions for triangle I, using $\underline{r}_1^o$ and $\underline{r}_2^o$ to obtain $\underline{r}_A^o$. Repeat the calculations for triangles II, III, IV. Iterate to solve the following equations for the principal stresses P^n_{yI}, P^n_{zI}, P^n_{xI} and the internal energy E^n_I:

$$P^n_{yI} = P_{yI}\left(\eta^n_I,\ \epsilon^n_{yI},\ \epsilon^n_{zI};\ E^n_I/m_I\right), \text{etc.}$$

Form P^n_{11}, P^n_{12}, P^n_{22} for triangle I

Calculate:

$$A_{2'} = A_A = A_5 = \frac{1}{6}\left[\left(y^n_{2'} - y^n_A\right)\left(z^n_5 - z^n_A\right) - \left(z^n_{2'} - z^n_A\right)\left(y^n_5 - y^n_A\right)\right] > 0 \quad (170)$$

$$\underline{F}_{2'} = \begin{pmatrix} P^{n-\frac{1}{2}}_{11}\left(\alpha^{n-\frac{1}{2}}_{2'y} - A_{2'}\right) + P^{n-\frac{1}{2}}_{12}\ \alpha^{n-\frac{1}{2}}_{2'z} + P^{n-\frac{1}{2}}_{x}\ A_{2'} \\ P^{n-\frac{1}{2}}_{12}\left(\alpha^{n-\frac{1}{2}}_{2'y} - A_{2'}\right) + P^{n-\frac{1}{2}}_{22}\ \alpha^{n-\frac{1}{2}}_{2'z} \\ 0 \end{pmatrix} \quad (171)$$

$$E^n_I = E^{n-1}_I - \Delta^{n-\frac{1}{2}}t\left(\underline{U}^{n-\frac{1}{2}}_{2'}\cdot\underline{F}_{2'} + \underline{U}^{n-\frac{1}{2}}_{A}\cdot\underline{F}_{A} + \underline{U}^{n-\frac{1}{2}}_{5}\cdot\underline{F}_{5}\right) \quad (172)$$

Repeat the calculations for triangles II, III, IV.

Calculate:

$$2\alpha_{B2'} = \left(y_B + y^n_{2'}\right)\begin{pmatrix} z^n_{2'} - z^n_B \\ y^n_B - y^n_{2'} \\ 0 \end{pmatrix} \quad (173)$$

$$2\underline{\Delta F}_{B2'} = (P_{II} - P_{III}) 2\underline{a}_{B2'} \tag{174}$$

$$2\underline{\Delta F}_{2'A} = (P_{I} - P_{IV}) 2\underline{a}_{2'A} \tag{175}$$

$$2\underline{\Delta F} = 2\underline{\Delta F}_{2'A} + 2\underline{\Delta F}_{B2'} \tag{176}$$

$$2\Delta F_{n} = \underline{n}_2 \cdot 2\underline{\Delta F}. \tag{177}$$

Form the next guess at α, and repeat the calculation starting with Equation (161). Successive α-guesses are intended to reduce ΔF_n systematically to zero.

Compute:

$$U_t^{n-\frac{1}{2}} = \tfrac{1}{2}\left(\underline{U}_4^{n-\frac{1}{2}} + \underline{U}_5^{n-\frac{1}{2}}\right) \cdot \underline{t}_2 \tag{178}$$

$$U_n^{n-\frac{1}{2}} = \text{Converged value of } \alpha \tag{179}$$

$$\underline{U}_2^{n-\frac{1}{2}} = \mathbb{R}_2 \begin{pmatrix} U_t^{n-\frac{1}{2}} \\ \alpha \end{pmatrix} \tag{180}$$

where

$$\mathbb{R}_2 = \begin{vmatrix} n_{z2} & n_{y2} \\ -n_{y2} & n_{z2} \end{vmatrix} \tag{181}$$

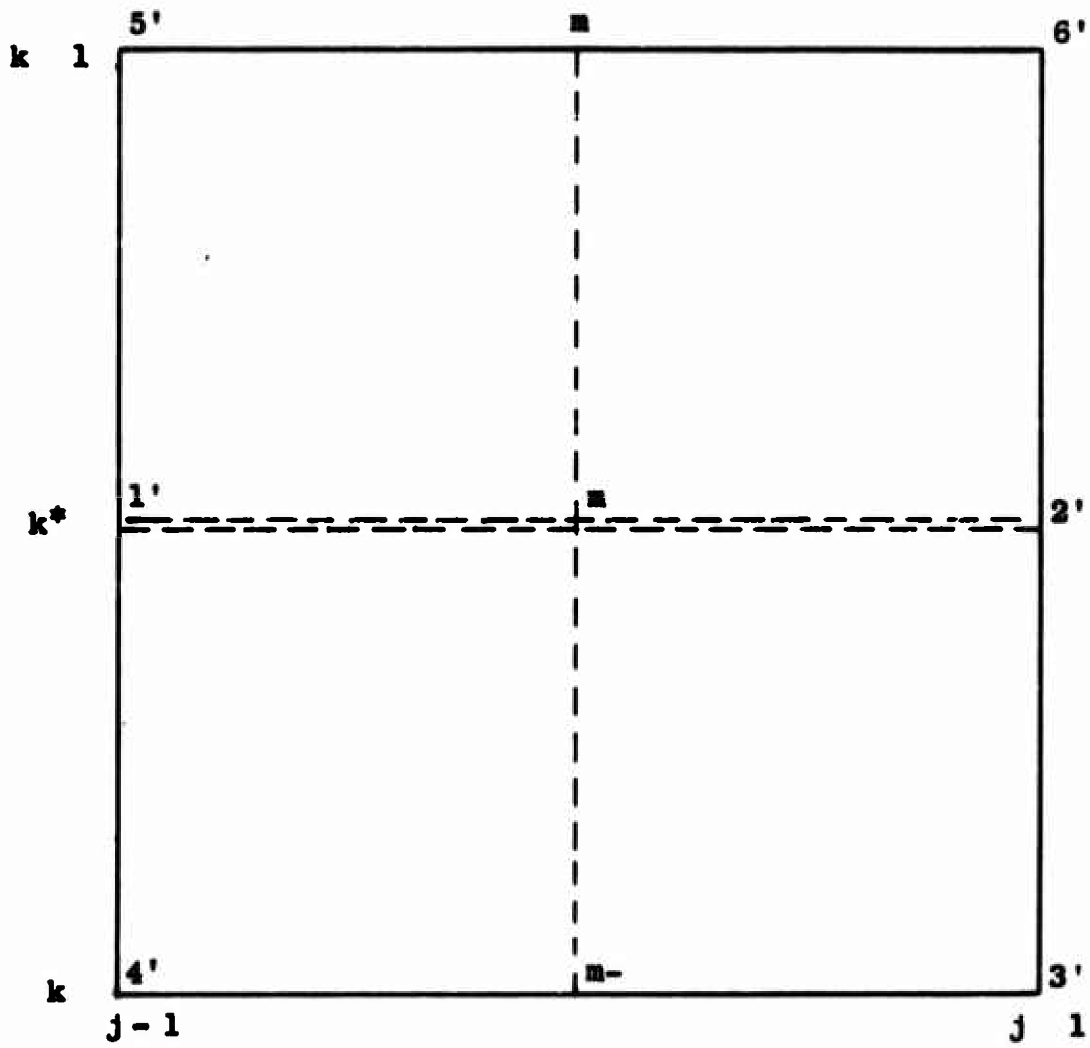


Figure 16

SCHEMATIC OF THE INTERFACE AND HALF-ZONES

All subscripts used in Eqs. 178 through 212 which determine the half-zone variables, refer to the labeling shown in this figure.

Calculate strain in $\mathcal{G}_-$

Calculate stress in $\mathcal{G}_-$, using the old internal energy $E^{n-1}_{\mathcal{G}_-}$.

Calculate:

$$\underline{a}_{4'3'} = -\tfrac{1}{2}\left(y^n_{4'} + y^n_{3'}\right)\begin{pmatrix} z^n_{3'} - z^n_{4'} \\ y_{4'} - y_{3'} \\ 0 \end{pmatrix} \tag{182}$$

$P_{4'3'}$ = Average of the stress in $\mathcal{G}_-$ with the stress in the zone sharing face 4'3' with $\mathcal{G}_-$

$$\underline{F}_{4'3'} = P_{4'3'}\,\underline{a}_{4'3'}$$

Similarly, calculate $\underline{F}_{1'4'}$, $\underline{F}_{3'2'}$, $\underline{F}_{6'5'}$, $\underline{F}_{5'1'}$ and $\underline{F}_{2'6'}$.

Calculate:

$$A_- = \tfrac{1}{2}\left[\left(y^n_{3'} - y^n_{1'}\right)\left(z^n_{2'} - z^n_{4'}\right) - \left(y^n_{2'} - y^n_{4'}\right)\left(z^n_{3'} - z^n_{1'}\right)\right] \tag{183}$$

$$A_+ = \tfrac{1}{2}\left[\left(y^n_{2'} - y^n_{5'}\right)\left(z^n_{6'} - z^n_{1'}\right) - \left(y^n_{6'} - y^n_{1'}\right)\left(z^n_{2'} - z^n_{5'}\right)\right] \tag{184}$$

$$\underline{F}_{W-} = \begin{pmatrix} P_{x-}A_- \\ 0 \\ 0 \end{pmatrix} \tag{185}$$

$$\underline{F}_{W+} = \begin{pmatrix} P_{x+}A_+ \\ 0 \\ 0 \end{pmatrix} \tag{186}$$

$$\underline{t}_{2'1'} = \frac{1}{\underline{r}_{2'} - \underline{r}_{1'}} \begin{pmatrix} y_{2'} - y_{1'} \\ z_{2'} - z_{1'} \\ 0 \end{pmatrix} \tag{187}$$

The condition for a strongly glued, or nonsliding interface is then expressed as follows:

$$\begin{aligned} F_{2'1'} \cdot t_{2'1'} = \Big\{ \Big[& m_+\left(\underline{F}_{1'4'} + \underline{F}_{4'3'} + \underline{F}_{3'2'} + \underline{F}_{W-}\right) \\ & -m_-\left(\underline{F}_{2'6'} + \underline{F}_{6'5'} + \underline{F}_{5'1'} \right. \\ & \left. + \underline{F}_{W+}\right)\Big] \cdot t_{2'1'} \Big\} \frac{1}{m_+ + m_-} \end{aligned} \tag{188}$$

$$\bar{y}_m = \left[\left(\bar{y}_{1'}^2 + \bar{y}_{1'}\bar{y}_{2'} + \bar{y}_{2'}^2\right)/3\right]^{\frac{1}{2}} \tag{189}$$

$$\bar{z}_m = \left[\left(\bar{y}_m - \bar{y}_{1'}\right)\bar{z}_{2'} + \left(\bar{y}_{2'} - \bar{y}_m\right)\bar{z}_{1'}\right] / \left(y_{2'} - y_{1'}\right) \tag{190}$$

There are similar expressions for $\bar{y}_{m+}$, $\bar{y}_{m-}$, $\bar{z}_{m+}$, $\bar{z}_{m-}$; these were formed as part of the interior (i.e., nonboundary) motion calculation

$$A_{3'} = \tfrac{1}{2}\left[\left(\bar{y}_{3'} - \bar{y}_m\right)\left(\bar{z}_{2'} - \bar{z}_{m-}\right) - \left(\bar{y}_{2'} - \bar{y}_{m-}\right)\left(\bar{z}_{3'} - \bar{z}_m\right)\right] \tag{191}$$

$$A_{4'} = \tfrac{1}{2}\left[\left(\bar{y}_{m-} - \bar{y}_{1'}\right)\left(\bar{z}_m - \bar{z}_{4'}\right) - \left(\bar{y}_m - \bar{y}_{4'}\right)\left(\bar{z}_{m-} - \bar{z}_{1'}\right)\right] \tag{192}$$

$A_{3'}$ and $A_{4'}$ are associated with the half-zone $\mathcal{B}_-$; corresponding areas $A_{5'}$ and $A_{6'}$ must be calculated for the half-zone $\mathcal{B}_+$.

Solve simultaneously for E_+^n, E_-^n:

$$PQ_+^{n-\frac{1}{2}} = \tfrac{1}{2}\left(P_+^n + Q_+^n + PQ_+^{n-1}\right) \quad (193)$$

$$PQ_-^{n-\frac{1}{2}} = \tfrac{1}{2}\left(P_-^n + Q_-^n + PQ_-^{n-1}\right) \quad (194)$$

$$\underline{F}_{m+m} = \left(PQ_+^{n-\frac{1}{2}}\right)\cdot \tfrac{1}{2}\left(\bar{y}_{m+} + \bar{y}_m\right) \begin{pmatrix} \bar{z}_{m+} - \bar{z}_m \\ \bar{y}_m - \bar{y}_{m+} \\ 0 \end{pmatrix} \quad (195)$$

$$\underline{F}_{m-m} = \left(PQ_-^{n-\frac{1}{2}}\right)\cdot \tfrac{1}{2}\left(\bar{y}_{m-} + \bar{y}_m\right) \begin{pmatrix} \bar{z}_{m-} - \bar{z}_m \\ \bar{y}_m - \bar{y}_{m-} \\ 0 \end{pmatrix} \quad (196)$$

$$PQ^{n-\frac{1}{2}} = \tfrac{1}{2}\left(PQ_+^{n-\frac{1}{2}} + PQ_-^{n-\frac{1}{2}}\right) \quad (197)$$

$$\left(\underline{F}_{1'm}\right)_N = \begin{pmatrix} -\left(\underline{t}_{2'1'}\right)_z \\ \left(\underline{t}_{2'1'}\right)_y \\ 0 \end{pmatrix} \cdot \left\{ PQ^{n-\frac{1}{2}} \cdot \tfrac{1}{2}\left(\bar{y}_{1'} + \bar{y}_m\right) \begin{pmatrix} \bar{z}_{1'} - \bar{z}_m \\ \bar{y}_m - \bar{y}_{1'} \\ 0 \end{pmatrix} \right\} \quad (198)$$

$$\left(\underline{F}_{2'm}\right)_N = \begin{pmatrix} -\left(\underline{t}_{2'1'}\right)_z \\ \left(\underline{t}_{2'1'}\right)_y \\ 0 \end{pmatrix} \cdot \left\{ PQ^{n-\frac{1}{2}} \cdot \tfrac{1}{2}\left(\bar{y}_{2'} + \bar{y}_m\right) \begin{pmatrix} \bar{z}_{2'} - \bar{z}_m \\ \bar{y}_m - \bar{y}_{2'} \\ 0 \end{pmatrix} \right\} \quad (199)$$

$$\left|A_{2'1'}\right| = \tfrac{1}{2}\left(\bar{y}_{2'} + \bar{y}_{1'}\right) \left[\left(\bar{y}_{2'} - \bar{y}_{1'}\right)^2 + \left(\bar{z}_{2'} - \bar{z}_{1'}\right)^2\right]^{\frac{1}{2}} \quad (200)$$

$$P_T = \left(\underline{F}_{2'1'} \cdot t_{2'1'}\right) / \left|A_{2'1'}\right| \quad (201)$$

$$\underline{R}_m = \begin{pmatrix} \left(\underline{t}_{2'1'}\right)_y & \left(\underline{t}_{2'1'}\right)_z & 0 \\ -\left(\underline{t}_{2'1'}\right)_z & \left(\underline{t}_{2'1'}\right)_y & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (202)$$

$$(\underline{F}_{1'm})_T = \begin{pmatrix} P_T \\ 0 \\ 0 \end{pmatrix} \cdot \left\{ R_m \cdot \tfrac{1}{2}(\bar{y}_{1'} + \bar{y}_m) \begin{pmatrix} \bar{z}_{1'} - \bar{z}_m \\ \bar{y}_m - \bar{y}_{1'} \\ 0 \end{pmatrix} \right\} \tag{203}$$

$$(\underline{F}_{2'm})_T = \begin{pmatrix} P_T \\ 0 \\ 0 \end{pmatrix} \cdot \left\{ R_m \cdot \tfrac{1}{2}(\bar{y}_{2'} + \bar{y}_m) \begin{pmatrix} \bar{z}_{2'} - \bar{z}_m \\ \bar{y}_m - \bar{y}_{2'} \\ 0 \end{pmatrix} \right\} \tag{204}$$

$$\underline{F}_{1'm} = R_m^{tr} \begin{pmatrix} (F_{1'm})_T \\ (F_{1'm})_N \\ 0 \end{pmatrix} \tag{205}$$

$$\underline{F}_{2'm} = R_m^{tr} \begin{pmatrix} (F_{2'm})_T \\ (F_{2'm})_N \\ 0 \end{pmatrix} \tag{206}$$

$$\begin{aligned} E_+^n = E_+^{n-1} &+ \Big[(\underline{U}_{1'} - \underline{U}_{5'}) \cdot \underline{F}_{1'm} + (\underline{U}_{5'} - \underline{U}_{6'}) \cdot \underline{F}_{m+m} \\ &+ (\underline{U}_{6'} - \underline{U}_{2'}) \cdot \underline{F}_{2'm} \Big] \Delta^{n-\frac{1}{2}} t \\ &- (U_{5'})_y (P_{x+} A_{5'}) - (U_{6'})_y (P_{x+} A_{6'}) \end{aligned} \tag{207}$$

$$\begin{aligned} E_-^n = E_-^{n-1} &+ \Big[(\underline{U}_{2'} - \underline{U}_{3'}) \cdot \underline{F}_{1'm} + (\underline{U}_{3'} - \underline{U}_{4'}) \cdot \underline{F}_{m-m} \\ &+ (\underline{U}_{4'} - \underline{U}_{1'}) \cdot \underline{F}_{1'm} \Big] \Delta^{n-\frac{1}{2}} t \\ &- (U_{3'})_y (P_{x-} A_{3'}) - (U_{4'})_y (P_{x-} A_{4'}) \end{aligned} \tag{208}$$

The forces need to update the momenta at 3', 4', 5', and 6' are:

$$\underline{F}_{3'} = \underline{F}_{2'm} - \underline{F}_{m-m} + \begin{pmatrix} P_{x-}A_{3'} \\ 0 \\ 0 \end{pmatrix} \tag{209}$$

$$\underline{F}_{4'} = \underline{F}_{m-m} - \underline{F}_{1'm} + \begin{pmatrix} P_{x-}A_{4'} \\ 0 \\ 0 \end{pmatrix} \tag{210}$$

$$\underline{F}_{5'} = \underline{F}_{1'm} - \underline{F}_{m+m} + \begin{pmatrix} P_{x+}A_{5'} \\ 0 \\ 0 \end{pmatrix} \tag{211}$$

$$\underline{F}_{6'} = \underline{F}_{m+m} - \underline{F}_{2'm} + \begin{pmatrix} P_{x+}A_{6'} \\ 0 \\ 0 \end{pmatrix} \tag{212}$$

APPENDIX III

FORTRAN NOTATION

FOR AFTON 2A

Sense Switch Control

Sense Switch No.	Use
	(NOTE: All Sense Switches Are Normally Assumed to be OFF.)
1	S.S. #1 forces the current problem to edit, makes a restart dump, and returns control to the Monitor System.
2	S.S. #2 forces the current problem to edit, makes a restart dump, and then starts calculation of the next data run.

Equations of State

Tillotson Equation of State

Defininitions:

$$V = \frac{1}{\rho};\ \eta = \frac{\rho}{\rho_o};\mu = \eta - 1$$

Case I

$$V/V_o < 1 \text{ for all } E^n > 0$$

and $$V/V_o < V_s \text{ for all } E^n < E'_s$$

$$P^n = \left\{a + b/g\right\}\left(E^n/V^n\right) + A\mu^n + B\mu^{n^2}$$

where $$g = (E^n/E_o\eta^2) + 1$$

Case II $$1 < V/V_o < V_s \text{ for } E^n > E'_s$$

$$V/V_o > V_s \text{ for all } E^n > 0$$

$$P^n = aE^n\rho^n + \left\{(bE^n\rho^n/g) + A\mu\exp(-\beta h)\right\}\exp(-\alpha h^2)$$

where: $$g = (E^n/E_o\eta^2) + 1$$

$$h = (V/V_o) - 1 = \frac{1}{\eta} - 1 = \frac{-\mu}{\eta}$$

For TUFF

a = .5

b = 1.1

A = .064

B = .07

V_s = 1000

E_o = .005

E'_s = .1

α = 5.

β = 5.

Elastic Medium

$$P_y = -(\lambda\Delta + 2\mu\epsilon_y)$$

$$P_z = -(\lambda\Delta + 2\mu\epsilon_z)$$

$$P_x = -(\lambda\Delta + 2\mu\epsilon_x)$$

where

λ, μ are Lame' constants

Δ = Volume dilatation

ϵ_y, ϵ_z, ϵ_x = The three principal strains

Test Problem Data

For region 1 $\lambda=\mu=1.$

For region 2 $\lambda=\mu=1.1$

INITIAL INPUT DATA

CARD	FORMAT	VARIABLE	VALUE	MEANING
1	(I6)	ICON		Sentinel to define type of run
			0	Normal run, start from initial conditions given below
			Any Value	Restart dump number, which is used to search dump tape
			EOF	End of file; stops run, no more data to follow
2	(9A8)	TITLE	Any Value	Problem title or description NOTE: Column one should contain a zero for carriage control on printer
3	(6E12.5)	PROBNO	Any Value	Problem number. NOTE: Output format is (F7.2)
4	(12I6)	KSV1	0	No edit on MAXN or TMAX
			1	Edit on MAXN or TMAX
		KSV2	0	No dump taken on MAXN or TMAX
			1	Dump taken on MAXN or TMAX
		KSV3	---	(Available Variable)
		KSV4	0	No edit at start of calculation
			Any Value	Number of consecutive cycles to be edited at start of calculation
		KSV5	0	No editing on cycle count (N), ignore KSV6
			Any Value	Number of cycles between edits
		KSV6	Any Value	Number of cycles when next edit occurs
		KSV7	0	One cycle in each edit
			Any Value	Number of consecutive cycles in each edit
		KSV8	0	No dumping on cycle count, ignore KSV9
			Any Value	Number of cycles between dumps

CARD -	FORMAT -	VARIABLE -	VALUE -	MEANING
		KSV9	Any Value	Number of cycles when next dump occurs
		KSV10	---	(Available Variable)
		KSV11	0	Full edit all grid points, no extra card number 28
			Any Value	Number of short edits, see card 28 for J and K limits
		KSV12	0	Edit generator initial conditions
			1	No edit of generator initial conditions
5	(6E12.5)	SAV1	0	No editing on physical time, ignore SAV2
			Any Value	Amount of physical time between edits
		SAV2	Any Value	Physical time next edit occurs
		SAV3	0	No dumping on physical time, ignore SAV4
			Any Value	Amount of physical time between dumps
		SAV4	Any Value	Physical time when next dump occurs
6	(12I6)	JBOT	---	(Available Variable)
		JTOP	---	(Available Variable)
		KBOT	---	(Available Variable)
		KTOP	---	(Available Variable)
		KBUG	0	No debug print, no card number 22
			1	Take debug print see card 22 for J, K limits
		MOTION	1	Eulerian grid motion
			2	Lagrangian grid motion
			3	(Available Sentinel)
		KINT(K)	0	No interfaces
			Any Value	Number of a K Line to be treated as an interface. NOTE: Five interfaces maximum

CARD	FORMAT	VARIABLE	VALUE	MEANING
7	(6E12.5)	DTNM	Any Value	Size of initial time step
8	(6E12.5)	CUTOFF	Any Value	Sentinel used to set a minimum value of a variable
9	(I6,2E12.5)			
		MAXN	Any Value	Maximum number of cycles to run problem
		TMAX	Any Value	Maximum physical time to run problem
10	(12I6)	JMIN	1	First J Line
		JMAX	Any Value	Number of maximum J Line in a region. NOTE: Limit 55
		KMIN	1	First K Line in a region
		KMAX	Any Value	Number of maximum K Line in a region. NOTE: Limit 101
11	(2I6,5E12.5/6E12.5)			
		JYMIN	Any Value	Number of J Line for first radial component of position entry
		JYMAX	Any Value	Number of J Line for last radial component of position entry
		TX(J)	Any Value	Value of radial component of position for JYMIN to JYMAX. If JYMAX is greater than 5, 5 TX(J) follow JYMAX on the first card, 6 TX(J) per card follow until TX(JYMAX) is reached
12	(2I6,5E12.5/6E12.5)			
		KZMIN	Any Value	Number of K Line for first axial component of position entry
		KZMAX	Any Value	Number of K Line for last axial component of position entry

CARD	FORMAT	VARIABLE	VALUE	MEANING
		TY(K)	Any Value	Value of axial component of position for KZMIN to KZMAX. If KZMAX is greater than 5, 5 TY(K) follow KSMAX on the first card, 6 TY(K) per card follow until TY(KZMAX) is reached

NOTE: If JYMIN equals JMIN and JYMAX equals JMAX, no card 13 follows.

CARD	FORMAT	VARIABLE	VALUE	MEANING
13	(I6,2E12.5)			
		JTMAX	Any Value	Number of J Line for last radial component of position entry
		DELTAY	Any Value	Initial radial distance across a zone
		RATEY	Any Value	Rate of change in radial distance across a zone

NOTE: If JTMAX is less than JMAX repeat card 13.

NOTE: If KZMIN is equals KMIN and KZMAX equals KMAX, no card 14 follows.

CARD	FORMAT	VARIABLE	VALUE	MEANING
14	(I6,2E12.5)			
		KTMAX	Any Value	Number of K Line for last axial component of position entry
		DELTAZ	Any Value	Initial axial distance across a zone
		RATEZ	Any Value	Rate of change in axial distance across a zone

NOTE: If KZMIN is greater than KMIN or KTMAX is less than KMAX repeat card 14.

CARD	FORMAT	VARIABLE	VALUE	MEANING
15	(6E12.5)	UXLBIN	Any Value	Radial component of velocity at JMIN, KMIN
		UXBIN	Any Value	Radial component of velocity at an interior J, KMIN
		UXRBIN	Any Value	Radial component of velocity at JMAX, KMIN

CARD	FORMAT	VARIABLE	VALUE	MEANING
		UYLBIN	Any Value	Axial component of velocity at JMIN, KMIN
		UYBIN	Any Value	Axial component of velocity at an interior J, KMIN
		UYRBIN	Any Value	Axial component of velocity at JMAX, KMIN
16	(2I6,E12.5/2I6,E12.5)			
		JUMAX	Any Value	Number of last J entry for radial component of velocity at an interior K
		KUMAX	Any Value	Number of last K entry for radial component of velocity at an interior K
		UXIN	Any Value	Radial component of velocity at an interior K
		JVMAX	Any Value	Number of last J entry for axial component of velocity at an interior K
		KVMAX	Any Value	Number of last K entry for axial component of velocity at an interior K
		UYIN	Any Value	Axial component of velocity at an interior K
17	(6E12.5)	UXLTIN	Any Value	Radial component of velocity at JMIN, KMAX
		UXTIN	Any Value	Radial component of velocity at an interior J, KMAX
		UXRTIN	Any Value	Radial component of velocity at JMAX, KMAX
		UYLTIN	Any Value	Axial component of velocity at JMIN, KMAX
		UYTIN	Any Value	Axial component of velocity at an interior J, KMAX
		UYRTIN	Any Value	Axial component of velocity at JMAX, KMAX

CARD	FORMAT	VARIABLE	VALUE	MEANING
18	3(2I6,E12.5)			
		JZMAX	Any Value	Number of last J entry for R ZERO
		KZMAX	Any Value	Number of last K entry for R ZERO
		R ZERO	Any Value	Reference density (ρ_0), a constant
		JRMAX	Any Value	Number of last J entry for RHO 1
		KRMAX	Any Value	Number of last K entry for RHO 1
		RHO 1	Any Value	Initial material density
		JEMAX	Any Value	Number of last J entry for E1
		KEMAX	Any Value	Number of last K entry for E1
		E1	Any Value	Initial specific internal energy
19	(6E12.5)	TINY A	Any Value	Tillotson equation of state constant
		TINY B	Any Value	Tillotson equation of state constant
		BIG A	Any Value	Tillotson equation of state constant
		BIG B	Any Value	Tillotson equation of state constant
		RCP V S	Any Value	Tillotson equation of state constant
		E ZERO	Any Value	Tillotson equation of state constant
20	(6E12.5)	E S	Any Value	Tillotson equation of state constant

CARD	FORMAT	VARIABLE	VALUE	MEANING
		ALFA	Any Value	Tillotson equation of state constant
		BETA	Any Value	Tillotson equation of state constant
		QCON	Any Value	Q constant

NOTE: Cards 19 and 20 appear NREG times.

21	(6E12.5)	SFMLYR	Any Value	Radial component of the external force applied to a zone on the JMAX boundary
		SFMLZR	Any Value	Axial component of the external force applied to a zone on the JMAX boundary

NOTE: If KBUG is equal to 0, no card 22 follows.

22	(12I6)	JBMIN	Any Value	First J Line to be included in a debug edit
		JBMAX	Any Value	Last J Line to be included in a debug edit
		KBMIN	Any Value	First K Line to be included in a debug edit
		KBMAX	Any Value	Last K Line to be included in a debug edit

NOTE: If JUMAX x KUMAX is equal to 0 or equal to JMAX x KMAX, no card 23 follows.

23	(2I6,E12.5)			
		JUMAX	Any Value	Number of last J entry for radial component of velocity at an interior K
		KUMAX	Any Value	Number of K entry for radial component of velocity at an interior K
		UXIN	Any Value	Radial component of velocity at an interior K

NOTE: If JUMAX x KUMAX is greater than 0 and less than JMAX x KMAX, repeat card 23.

CARD - FORMAT - VARIABLE - VALUE - MEANING

NOTE: If JVMAX x KVMAX is equal to 0 or equal to JMAX x KMAX, no card 24 follows.

Card	Format	Variable	Value	Meaning
24	(2I6,E12.5)			
		JVMAX	Any Value	Number of last J entry for axial component of velocity at an interior K
		KVMAX	Any Value	Number of last K entry for axial component of velocity at an interior K
		UYIN	Any Value	Axial component of velocity at an interior K

NOTE: If JVMAX x KVMAX is greater than 0 and less than JMAX x KMAX repeat card 24.

NOTE: If JZMAX x KZMAX is equal to 0 or equal to JMAX x KMAX, no card 25 follows.

Card	Format	Variable	Value	Meaning
25	(2I6,E12.5)			
		JZMAX	Any Value	Number of last J entry for the reference density
		KZMAX	Any Value	Number of last K entry for the reference density
		R ZERO	Any Value	Reference density

NOTE: If JZMAX x KZMAX is greater than 0 and less than JMAX x KMAX, repeat card 25.

NOTE: If JRMAX x KRMAX is equal to 0 or equal to JMAX x KMAX, no card 26 follows.

Card	Format	Variable	Value	Meaning
26	(2I6,E12.5)			
		JRMAX	Any Value	Number of last J entry for density
		KRMAX	Any Value	Number of last K entry for density
		RHO 1	Any Value	Density

NOTE: If JRMAX x KRMAX is greater than 0 and less than JMAX x KMAX, repeat card 26.

CARD	FORMAT	VARIABLE	VALUE	MEANING

NOTE: If JEMAX x KEMAX is equal to 0 or equal to JMAX x KMAX, no card 27 follows.

CARD	FORMAT	VARIABLE	VALUE	MEANING
27	(2I6,E12.5)			
		JEMAX	Any Value	Number of last J entry for specific internal energy
		KEMAX	Any Value	Number of last entry K for specific internal energy
		E1	Any Value	Specific internal energy

NOTE: If JEMAX x KEMAX is greater than 0 and less than JMAX x KMAX, repeat card 27.

NOTE: If KSV11 equals 0, no card 28 follows.

CARD	FORMAT	VARIABLE	VALUE	MEANING
28	(4I6)	JJMIN	Any Value	First J Line to appear in an edit
		JJMAX	Any Value	Last J Line to appear in an edit
		KKMIN	Any Value	First K Line to appear in an edit
		KKMAX	Any Value	Last K Line to appear in an edit

This is the end of the Initial Input Data, it may be followed by another Initial Input Data Deck, a Restart Data Deck, or three blank cards signifying end of run, no more Data Decks to follow.

RESTART INPUT DATA

CARD	FORMAT	VARIABLE	VALUE	MEANING
1	(I6)	ICON	Any Value Greater Than 0	Number of restart dump from which to start calculation
2	(9A8)	TITLE	Any Value	Problem title or description. Column 1 should contain a 0 for carriage control on printer
3	(12I6)	KSV1-12		See card 4, Initial Input Data
4	(6E12.5)	SAV 1-4		See card 5, Initial Input Data
5	(I6,2E12.5)			
		MAXN	Any Value	New maximum cycle count, stop problem if cycle count (N) exceeds this number
		TMAX	Any Value	New physical time, stop problem if TIME exceeds this number

NOTE: If KSV11 equals 0, no card 6 follows.

6	(4I6)	JJMIN-KKMAX		See card 28, Initial Input Data

This is the end of Restart Input Data, it may be followed by another Restart Data Deck, and Initial Input Data Deck, or three blank cards signifying end of run, no more Data Deck to follow.

Variables in COMMON or DIMENSION and their Definitions

VARIABLE	DIMENSION	DEFINITION
NREG		Number of regions in problem
MOTION		Sentinel to specify the coordinate system to be used
PROBNO		Problem number
DUMPV	600	Special area in common, equivalent to NREG, first record of data dump
N		Cycle number
TIME		Physical time of problem
DTNM		Time step (Δt)
RDTNM		$1./\Delta t$
DTNMN		Time step calculated for the next cycle
DTNMP5		One-half the time step ($.5 \times \Delta t$)
DTNM2		Twice the time step ($2. \times \Delta t$)
CUTOFF		Sentinel used to set a minimum value of a variable
CUT1		$\Delta t \times$ CUTOFF
CUT2		DTNM2 x CUTOFF
MAXN		Maximum cycle count, stop problem N if exceeds this number
TMAX		Maximum physical time, stop problem if TIME exceeds this number
SAV	12	Floating point sentinels
KSV	24	Fixed point sentinels
TITLE	9	Title or description of problem (header card)
JMIN		First J Line in a region
JMAX		Last J Line in a region

VARIABLE	DIMENSION	DEFINITION
JL		JMIN + 1, J Line in a region
J3		JMIN + 2, J Line in a region
JR		JMAX - 1, J Line in a region
JRM		JMAX - 2, J Line in a region
JBMIN		Minimum J Line for debug edit
JBMAX		Maximum J Line for debug edit
KMIN		First K Line in a region
KMAX		Last K Line in a region
KB		KMIN + 1, K Line in a region
KBMIN		Minimum K Line for debug edit
KBMAX		Maximum K Line for debug edit
KINT	5	K index of an interface
KT		KMAX - 1, K line in a region
KTM		KMAX - 2, K Line in a region
ICON		Sentinel to define type of start, e.g., start from restart dump
LINCT		K Line count for output
LXI		K index for K Lines in core (I = 1,5)
KC		K Line count for calculation
NDPA		Data dump sentinel
NEDIT		Edit sentinel
NSIG		Sentinel to define action to be taken at the end of a cycle, e.g., read in new problem
NMASS		Negative mass sentinel
NDMP		Number of restart dump

VARIABLE	DIMENSION	DEFINITION
TX	55	Radial component of position of a mesh point
TY	101	Axial component of position of a mesh point
UYLBIN		Axial component of velocity at JMIN, KMIN
UYBIN		Axial component of velocity at an interior J, KMAX
UYRBIN		Axial component of velocity at JMAX, KMIN
UXLBIN		Radial component of velocity at JMIN, KMIN
UXBIN		Radial component of velocity at an interior J, KMIN
UXRBIN		Radial component of velocity at JMAX, KMIN
UYLTIN		Axial component of velocity at JMIN, KMAX
UYTIN		Axial component of velocity at an interior J, KMAX
UYRTIN		Axial component of velocity at JMAX, KMAX
UXLTIN		Radial component of velocity at JMIN, KMAX
UXTIN		Radial component of velocity at an interior J, KMAX
UXRTIN		Radial component of velocity at JMAX, KMAX
R ZERO	5	Reference density
EIN		Specific internal energy of an interior zone
RHOIN		Density of an interior zone

VARIABLE	DIMENSION	DEFINITION
UYIN		Axial component of velocity of an interior mesh point
UXIN		Radial component of velocity of an interior mesh point
QCON	5	Q constant
E S	5	Tillotson equation of state constant
ALFA	5	Tillotson equation of state constant
BIG A	5	Tillotson equation of state constant
BIG B	5	Tillotson equation of state constant
RCP V S	5	Tillotson equation of state constant
E ZERO	5	Tillotson equation of state constant
TINY A	5	Tillotson equation of state constant
TINY B	5	Tillotson equation of state constant
BETA	5	Tillotson equation of state constant
ICASE	55	Sentinel to distinguish between the two algebraic forms appearing in the Tillotson equation of state
H	55	Working storage for Tillotson equation of state
BETAH	55	Working storage for Tillotson equation of state
ALFAH	55	Working storage for Tillotson equation of state
AMUBH	55	Working storage for Tillotson equation of state
AMUBMU	55	Working storage for Tillotson equation of state

VARIABLE	DIMENSION	DEFINITION
LAMMA	5	Lame' constant Lambda
EMU	5	Lame' constant Mu
RXZ	55 x 5	Initial radial position coordinate
RYZ	55 x 5	Initial axial position coordinate
RXM	55 x 5	Radial position coordinate at the start of a time step
RYM	55 x 5	Axial position coordinate at the start of a time
RX	55 x 5	Radial position coordinate at the end of a time step
RY	55 x 5	Axial position coordinate at the end of a time step
UNMX	55 x 5	Radial component of velocity at the start of a time step
UNMY	55 x 5	Axial component of velocity at the start of a time step
UNPX	55 x 5	Radial component of velocity at the end of a time step
UNPY	55 x 5	Axial component of velocity at the end of a time step
U2	55 x 2	Square of the velocity
VOL	55 x 5	Specific volume
Q11	55 x 5	Element of the artificial viscosity tensor
Q12	55 x 5	Element of the artificial viscosity tensor
Q22	55 x 5	Element of the artificial viscosity tensor
QX	55 x 5	Element of the artificial viscosity tensor
PNM	55 x 5	Element of the stress tensor, without an artificial viscosity contribution, at the start of a time step
PN	55 x 5	Element of the stress tensor, without an artificial viscosity contribution, at the end of a time step

VARIABLE	DIMENSION	DEFINITION
P11	55 x 5	Element of the stress tensor minus Q11
P12	55 x 5	Element of the stress tensor minus Q12
P22	55 x 5	Element of the stress tensor minus Q22
PX	55 x 5	Principal stress along the azimuthal stress axis minus QX
PY	55	One of the three principal stresses, without an artificial viscosity contribution
PZ	55	One of the three principal stresses, without an artificial viscosity contribution
PQNMXX	55 x 5	Element of the total stress tensor at the start of a time step
PQNMXY	55 x 5	Element of the total stress tensor at the start of a time step
PQNMYY	55 x 5	Element of the total stress tensor at the start of a time step
PQMX	55 x 5	Total principal stress along the azimuthal stress axic at the start of a time step
PQNXX	55 x 5	Element of the total stress tensor at the end of a time step
PQNXY	55 x 5	Element of the total stress tensor at the end of a time step
PQNYY	55 x 5	Element of the total stress tensor at the end of a time step
PQX	55 x 5	Total principal stress along the azimuthal stress axis at the end of a time step
RHO	55 x 5	Density
VO	55 x 5	Reference specific volume
ETA	55 x 5	Compression = VO x RHO

VARIABLE	DIMENSION	DEFINITION
GMU	55	Working store for Tillotson equation of state. Excess compression = ETA-1.
ENM	55 x 5	Specific internal energy at the start of a time step
EN	55 x 5	Specific internal energy at the end of a time step
FMASNM	55 x 5	Zone mass at the start of a time step
FMASN	55 x 5	Zone mass at the end of a time step
FMSNZ	55 x 5	Momentum mass
CMASSI	55 x 5	Mass of a zone associated with its vertex I (I = 1,2)
AIY	55 x 5	Radial component of the vector area subtended between wedge planes by the side of a zone (I = 1,4)
AIZ	55 x 5	Axial component of the vector area subtended between wedge planes by the side of a zone (I = 1,4)
AWI	55 x 5	Area of a zone associated with one of its vertices (I = 1,4)
FIY	55 x 5	Radial component of force associated with the vertex point (I) of a zone (I = 1,4)
FIZ	55 x 5	Axial component of force associated with the vertex point (I) of a zone (I = 1,4)
FMNMX	55 x 5	Radial component of momentum at the start of a time step
FMNMY	55 x 5	Axial component of momentum at the start of a time step
FMNX	55 x 5	Radial component of momentum at the end of a time step
FMNY	55 x 5	Axial component of momentum at the end of a time step
RH3Z	55 x 5	Density of material transported across a zone boundary in one coordinate direction

VARIABLE	DIMENSION	DEFINITION
RH1Z	55 x 5	Density of material transported across a zone boundary in the other coordinate direction
E3Z	55 x 5	Specific internal energy of a material transported across a zone boundary in one coordinate direction
E1Z	55 x 5	Specific internal energy of a material transported across a zone boundary in the other coordinate direction
RWA3Z	55 x 5	Rate of transport of mass across a zone boundary in one coordinate direction
RWA1Z	55 x 5	Rate of transport of mass across a zone boundary in the other coordinate direction
RWAE3Z	55 x 5	Rate of transport of internal energy across a zone boundary in one coordinate direction
RWAE1Z	55 x 5	Rate of transport of internal energy across a zone boundary in the other coordinate direction
NTPT	55 x 5	Sentinel to determine the proper form of the transport density
YDB	55	Radial position coordinate of a special point S on the line segment joining two adjacent mesh points
YTERM	55	Difference between YDB and the radial coordinate of one of the two mesh points defining the line segment on which S lies
Y2TERM	55	Difference between YDB and the radial coordinate of the other mesh point defining the line segment on which S lies
TAI	55	The point S divides the side of a zone and its associated area into two parts. TAI is the fraction of this area residing in one of the two parts (I = 1,2)

VARIABLE	DIMENSION	DEFINITION
A	55	Table of signs of second differences of the density of one coordinate direction
B	55 x 4	Table of signs of the second differences of the density in the other coordinate direction
DIL	55	Volume dilatation
EPX	55	Principal strain along the azimuthal strain axis
EPY	55	One of the three principal strains
EPZ	55	One of the three principal strains
FMLYB	55	Radial component of the external force applied to a zone on the KMIN boundary
FMLZB	55	Axial component of the external force applied to a zone on the KMIN boundary
FMLYR	101	Radial component of the external force applied to a zone on the JMAX boundary
FMLZR	101	Axial component of the external force applied to a zone on the JMAX boundary
FMLYT	55	Radial component of the external force applied to a zone on the KMAX boundary
FMLZT	55	Axial component of the external force applied to a zone on the KMAX boundary
LYI	55	Radial component of a unit vector along the principal strain axis (I), (I = 1,2)
LZI	55	Axial component of a unit vector along the principal strain axis (I), (I = 1,2)

VARIABLE	DIMENSION	DEFINITION
RIH	55	Radial component of position for mesh point at time $t^{n-\frac{1}{2}}$; I(=1,4) dintinguishes the vertices of a single zone
ZIH	55	Axial component of position for mesh point at time $t^{n-\frac{1}{2}}$; I (= 1,4) distinguishes the vertices of a single zone
AYQ	55	Radial component of a vector area associated with a zone for the calculation of the artificial viscosity of the zone
AZQ	55	Axial component of a vector area associated with the zone for the calculation of the artificial viscosity of the zone
TRAPV	55	Radial component of the mid point of the side of a zone in one coordinate direction
TRAPYH	101	Radial component of the mid point of the side of a zone in the other coordinate direction
TRAPZH	101	Axial component in the mid point of the side of a zone in the other coordinate direction
YDELTA	55	Difference between radial position coordinates of the two points defining the side of a zone
ALPHA	100	Working storage, value of particle velocity normal to an interface
DF	100	Difference between the normal stresses at the two sides of an interface
DIST	2	Distance between two adjacent interface points
Z21	2	Negative of the axial component of the vector joining two adjacent interface points
Y21	2	Radial component of the vector joining two adjacent interface points

VARIABLE	DIMENSION	DEFINITION
NY12	2	Radial component of a unit vector normal to a vector joining two adjacent interface points
NZ12	2	Axial component of a unit vector normal to a vector joining two adjacent interface points
YA	2	Radial position coordinate of a special point on the line segment joining two adjacent interface points, at the start of a time step
ZA	2	Axial position coordinate of a special point on the line segment joining two adjacent interface points, at the start of a time step
YAN	2	Radial position coordinate of a special point on the line segment joining two adjacent interface points, at the end of a time step
ZAN	2	Axial position coordinate of a special point on the line-segment joining two adjacent interface points, at the end of a time step
UNAY	2	Radial component of velocity at an interface point averaged over a time step
UNAZ	2	Axial component of velocity at an interface point averaged over a time step
UNORM	55 x 5	Component of particule velocity normal to the interface averaged over a time step
YAZ	55 x 5	Radial component of the initial position of the point corresponding to (YAN,ZAN)
ZAZ	55 x 5	Axial component of the initial position of the point corresponding to (YAN,ZAN)
AIYT	4	Radial component of the vector area subtended between wedge planes by the side of an interface triangle
AIZT	4	Axial component of the vector area subtended between wedge planes by the side of an interface triangle

VARIABLE	DIMENSION	DEFINITION
FMASST	4	Mass of an interface triangle
DILT	4	Volume dilatation in an interface triangle
LYIT	4	Radial component of a unit vector along the principal strain axis (I), for an interface triangle (I = 1,2)
LZIT	4	Axial component of a unit vector along the principal strain axis (I), for an interface triangle (I = 1,2)
EPYT	4	One of three principal strains in an interface triangle
EPZT	4	One of three principal strains in an interface triangle
EPXT	4	Principal strain along the azimuthal strain axis in an interface triangle
PYT	4	One of the three principal stresses in an interface triangle
PZT	4	One of the three principal stresses in an interface triangle
PXT	4	Principal stress along the azimuthal stress axis in an interface triangle
P11T	4	Element of the stress tensor for an interface triangle
P12T	4	Element of the stress tensor for an interface triangle
P22T	4	Element of the stress tensor for an interface triangle
P11BT	4	Element of the stress tensor for an interface triangle, averaged over a time step
P12BT	4	Element of the stress tensor for an interface triangle, averaged over a time step
P22BT	4	Element of the stress tensor for an interface triangle, averaged over a time step

VARIABLE	DIMENSION	DEFINITION
PXBT	4	Element of the stress tensor for an interface triangle
ENT	4	Specific internal energy in an interface triangle
ART	4	Area of an interface triangle
FIYT	4	Radial component of force associated with vertex point (I), for an interface triangle (I = 1,3)
FIZT	4	Axial component of force associated with vertex point (I), for an interface triangle (I = 1,3)
Q11T	4	Element of the artificial viscosity tensor in an interface triangle
Q12T	4	Element of the artificial viscosity tensor in an interface triangle
Q22T	4	Element of the artificial viscosity tensor in an interface triangle
QXT	4	Element of the artificial viscosity tensor in an interface triangle
VOLM	4	Specific volume in an interface triangle at the start of a time step
VOLT	4	Specific volume in an interface triangle at the end of a time step
YB	2	Radial position coordinate of a mesh point which lies on the interface, averaged over a time step
ZB	2	Axial position coordinate of a mesh point which lies on the interface, averaged over a time step
YBU	2	Radial position coordinate of a mesh point which lies on the KINT+1 K-Line, averaged over a time step
ZBU	2	Axial position coordinate of a mesh point which lies on the KINT+1 K-Line, averaged over a time step

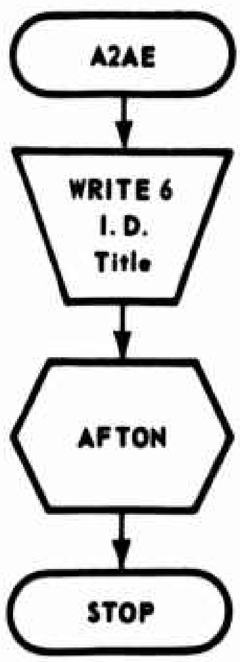
VARIABLE	DIMENSION	DEFINITION
YBD	2	Radial position coordinate of a mesh point which lies on the KINT-1 K-Line, averaged over a time step
ZBD	2	Axial position coordinate of a mesh point which lies on the KINT-1 K-Line, averaged over a time step
FY	55	Radial component of a force used to compute the tangential stress at an interface
FZ	55	Axial component of a force used to compute the tangential stress at an interface
T21Y	55	Radial component of the unit vector tangential to the interface
T21Z	55	Axial component of the unit vector tangential to the interface
SUMIE		Total internal energy contained within the boundaries of a system at an instant of time
SUMKE		Total kinetic energy contained within the boundaries of a system at an instant of time
SUMTE		Total energy contained within the boundaries of a system at an instant of time
SMSTPT		Net mass transported into a system in a time step
SMASSI		Mass of a system at the start of a time step + SMSTPT
SMASS		Total mass contained within the boundaries of a system at an instant of time
FIMPZ		Total axial impulse delivered to a system in a time step
SMZTPT		Total axial momentum transported across the boundaries of a system
SMOMZI		Initial axial momentum + FIMPZ + SMZTPT

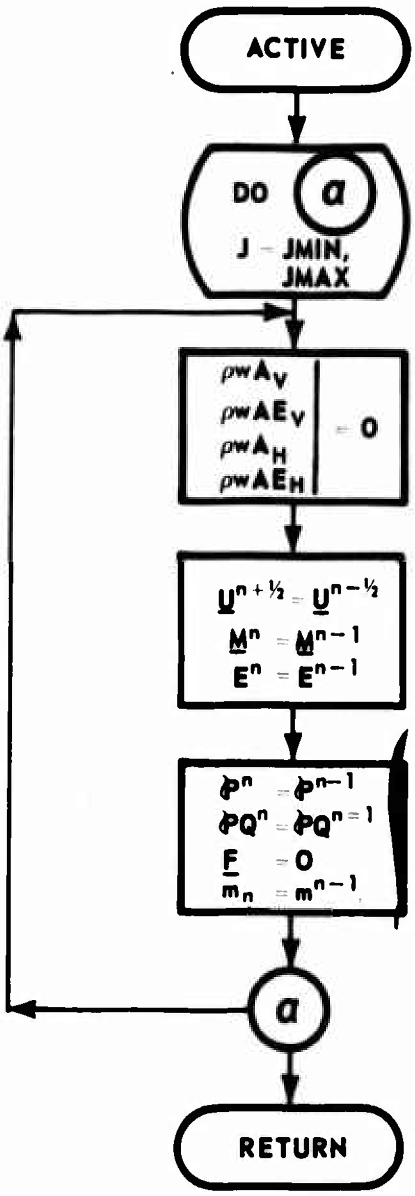
VARIABLE	DIMENSION	DEFINITION
SMOMZ		Total axial momentum contained within the boundaries of the system at an instant of time
SFW		Total radial component of force acting on the azimuthal plane boundaries of a system during a time step
FIMPY		Total radial impulse delivered to a system in a time step
SMYTPT		Total radial momentum transported across the boundaries of a system
SMOMYI		Initial radial momentum + FIMPY + SMYTPT
SMOMY		Total radial momentum contained within the boundaries of the system at an instant of time
SIETPT		Total internal energy transported into a system across its boundaries
SKETPT		Total kinetic energy transported into a system across its boundaries
USQ	2	Twice the kinetic energy per unit mass for transport
WORK		Total work done on a system
SENERI		Total initial energy of a system + SIETPT + SKETPT + WORK
PTMASS	55	Working storage for the edit subroutine
S1	55	Working storage for input/output buffers
S2	101	Working storage for input/output buffers
S1	55	Working storage for input/output buffers, (I = 3, 33)
TEM	55	Working storage for the stress subroutine
KBOT		(Available Variable)
KTOP		(Available Variable)
VACANT	15	(Available Variable)

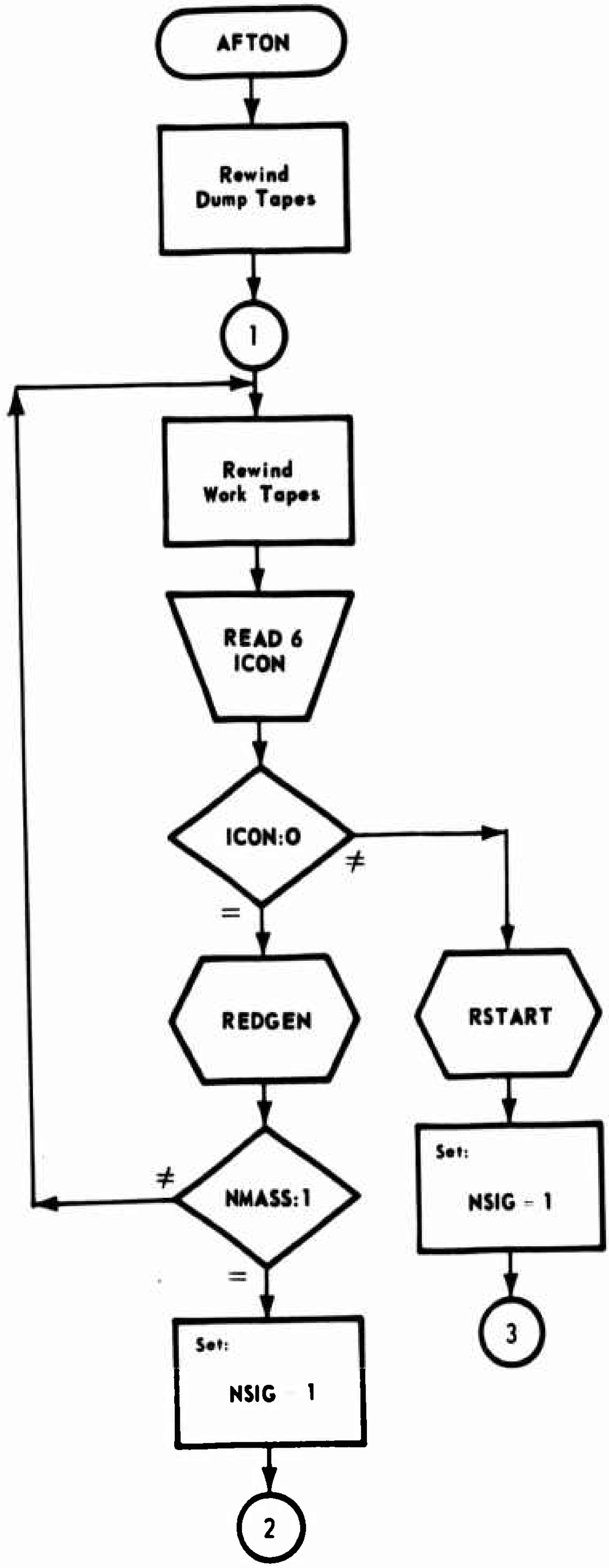
APPENDIX IV

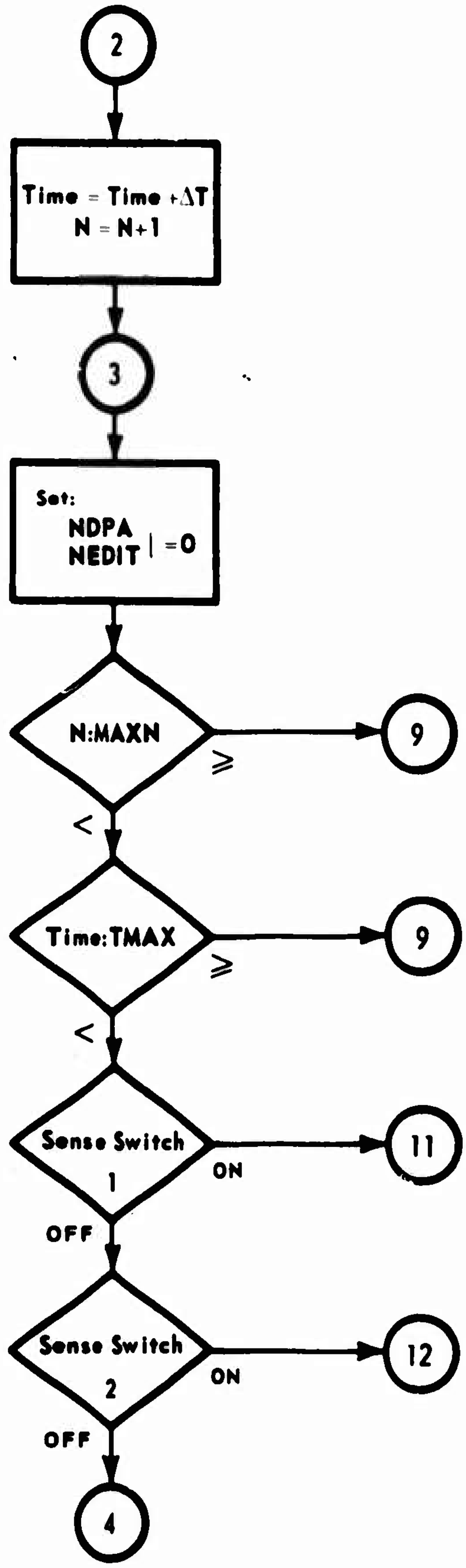
FLOW DIAGRAM

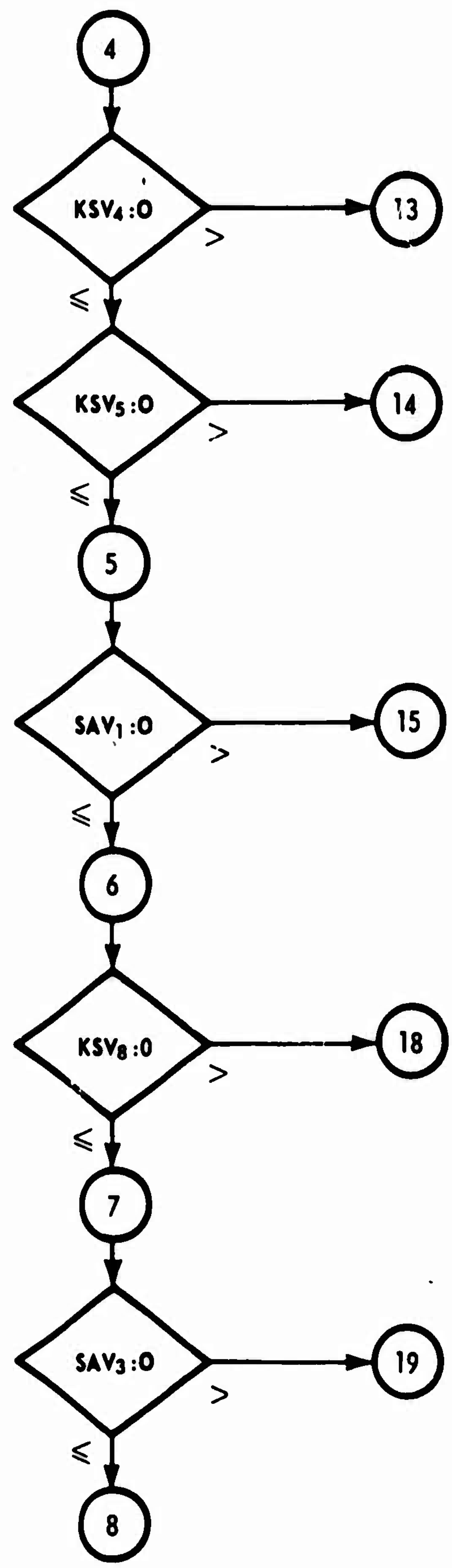
FOR AFTON 2A

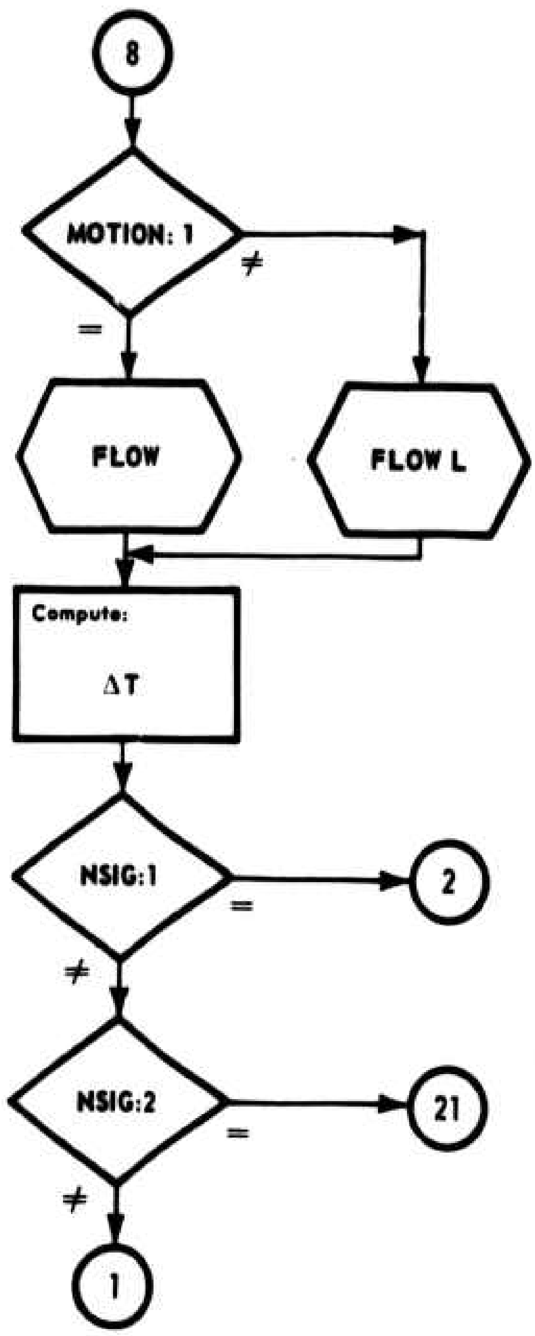

A2AE
WRITE 6
I. D.
Title
AFTON
STOP


ACTIVE
DO
a
J = JMIN,
JMAX
ρwA_V
ρwAE_V
ρwA_H
ρwAE_H
= 0
U^{n+½} = U^{n−½}
M^n = M^{n−1}
E^n = E^{n−1}
a
RETURN

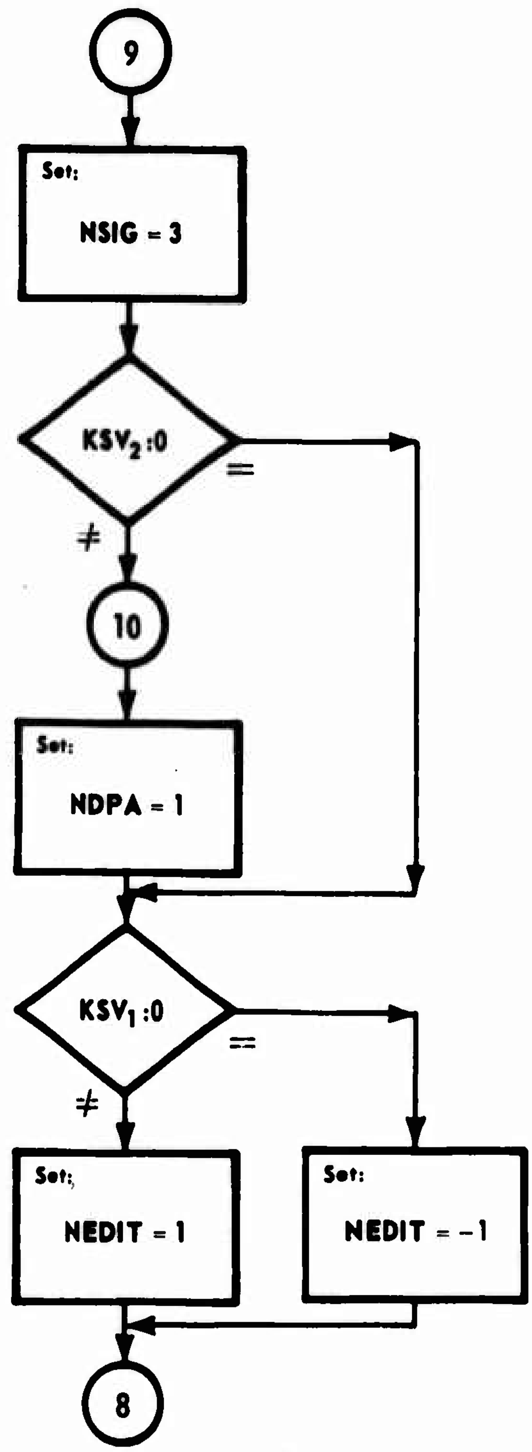

AFTON
Rewind
Dump Tapes
1
Rewind
Work Tapes
READ 6
ICON
ICON:0
≠
=
REDGEN
RSTART
Set:
NSIG = 1
3
≠
NMASS:1
=
Set:
NSIG = 1
2

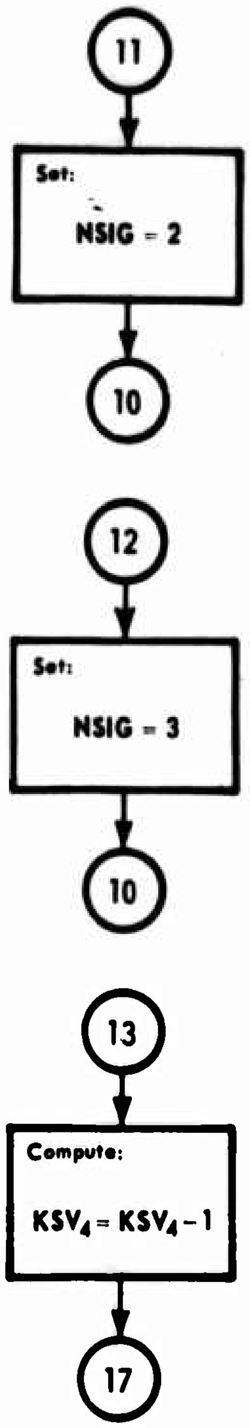

2
Time = Time +ΔT
N = N+1
3
Set:
NDPA
NEDIT
=0
N:MAXN
≥
9
<
Time:TMAX
≥
9
<
Sense Switch
1
ON
11
OFF
Sense Switch
2
ON
12
OFF
4

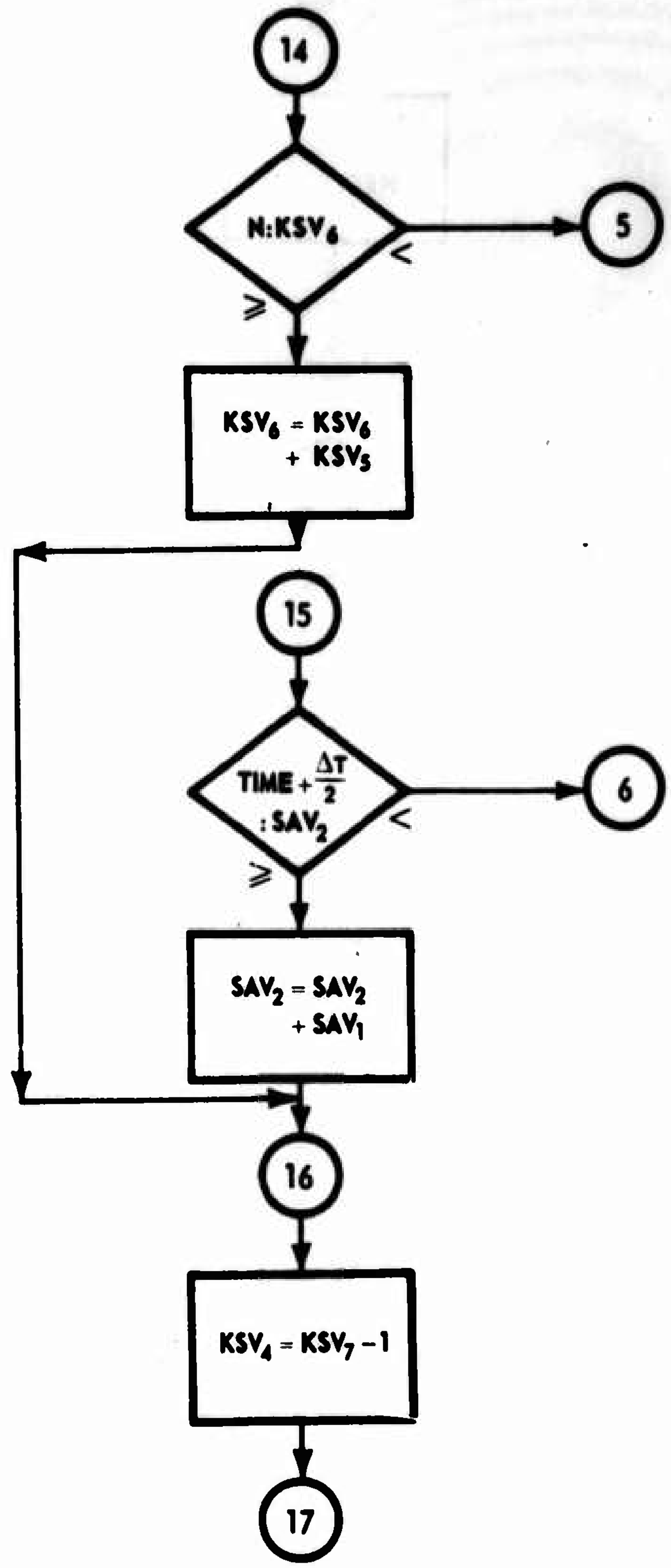

4
KSV4 :0
13
>
≤
KSV5 :0
14
>
≤
5
SAV1 :0
15
>
≤
6
KSV8 :0
18
>
≤
7
SAV3 :0
19
>
≤
8



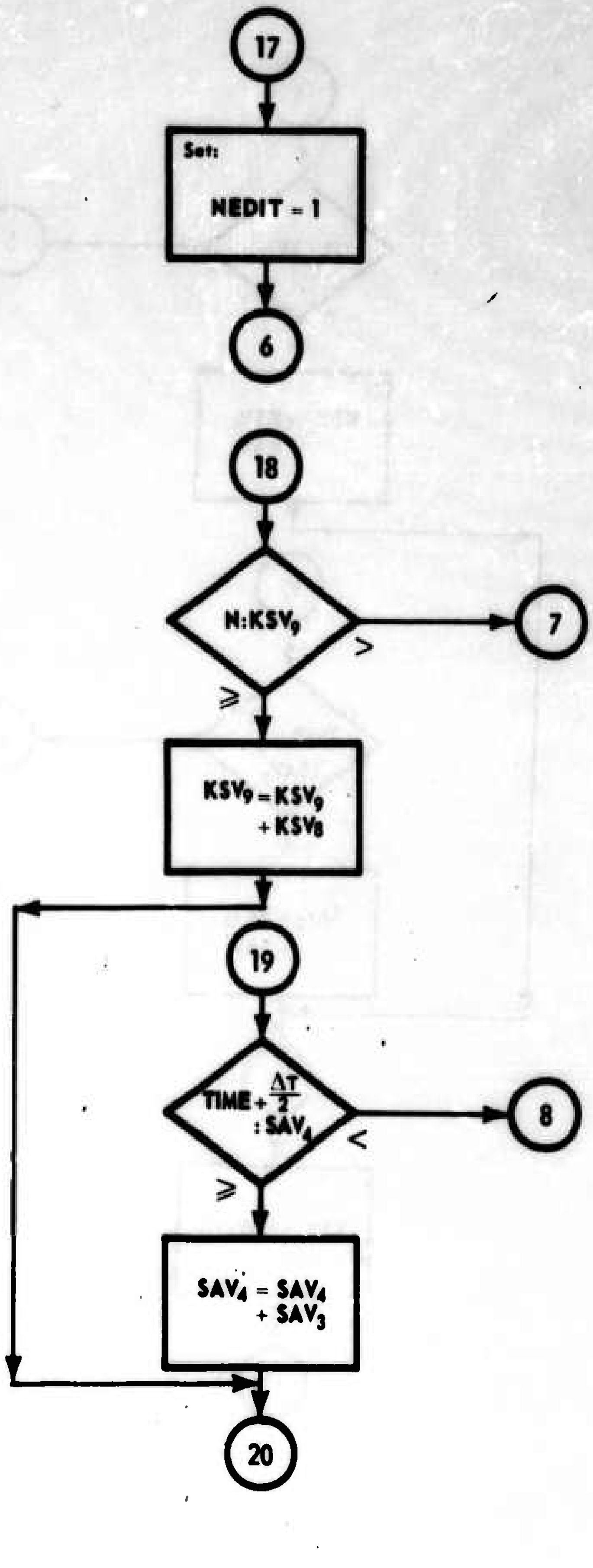
8
MOTION: 1
≠
=
FLOW
FLOW L
Compute:
ΔT
NSIG:1
=
2
≠
NSIG:2
=
21
≠
1

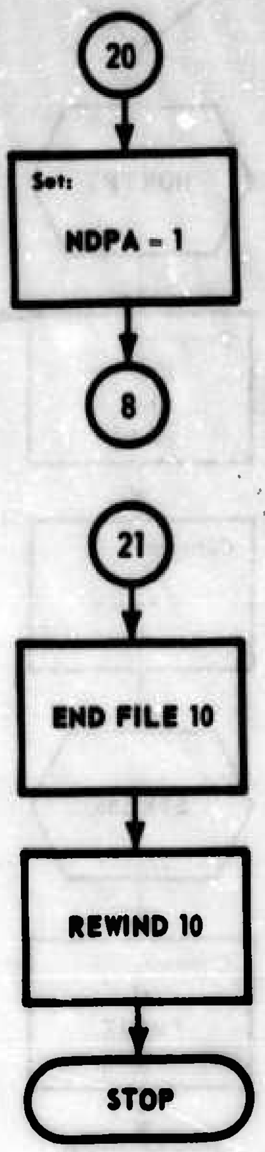

9
Set:
NSIG = 3
KSV2 :0
=
≠
10
Set:
NDPA = 1
KSV1 :0
=
≠
Set:
NEDIT = 1
Set:
NEDIT = -1
8

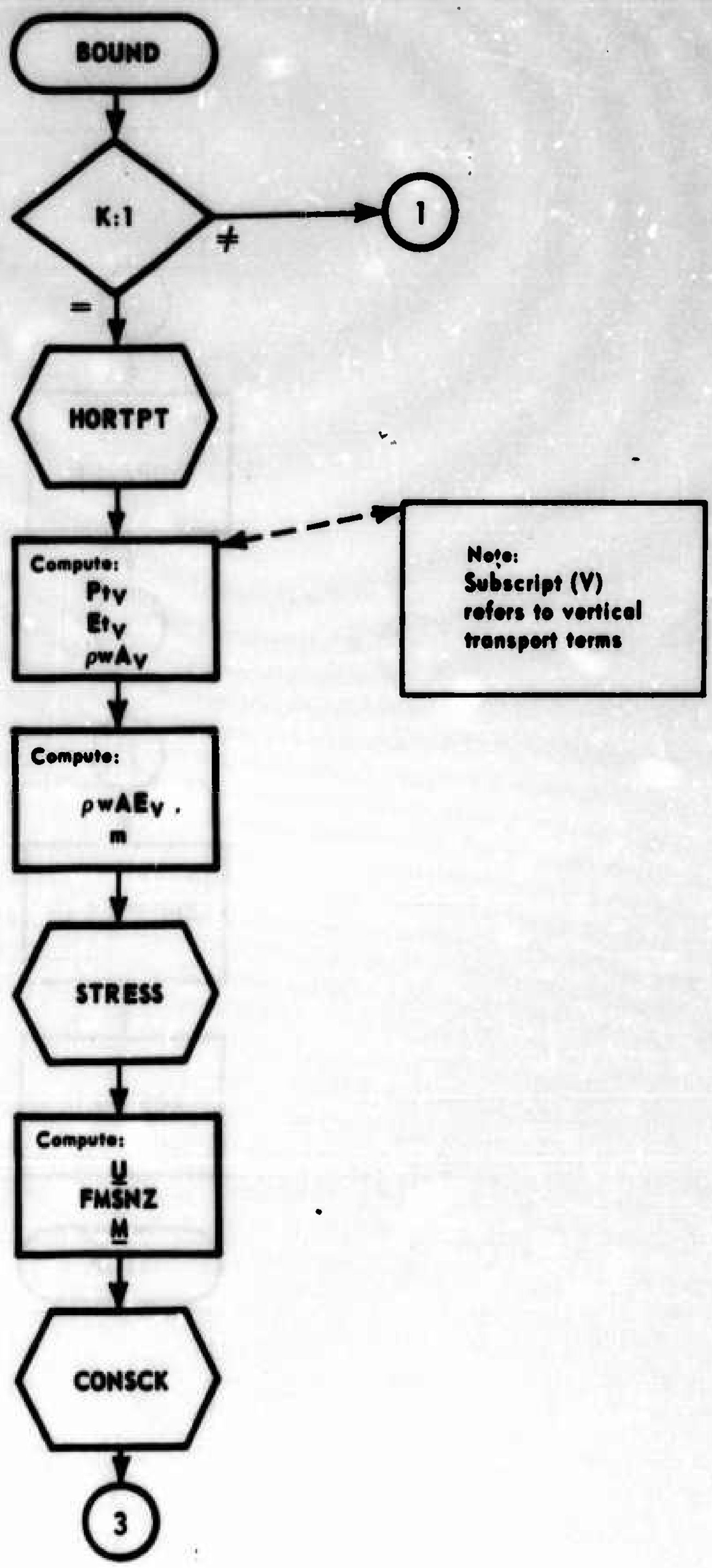

11
Set:
NSIG = 2
10
12
Set:
NSIG = 3
10
13
Compute:
$KSV_4 = KSV_4 - 1$
17



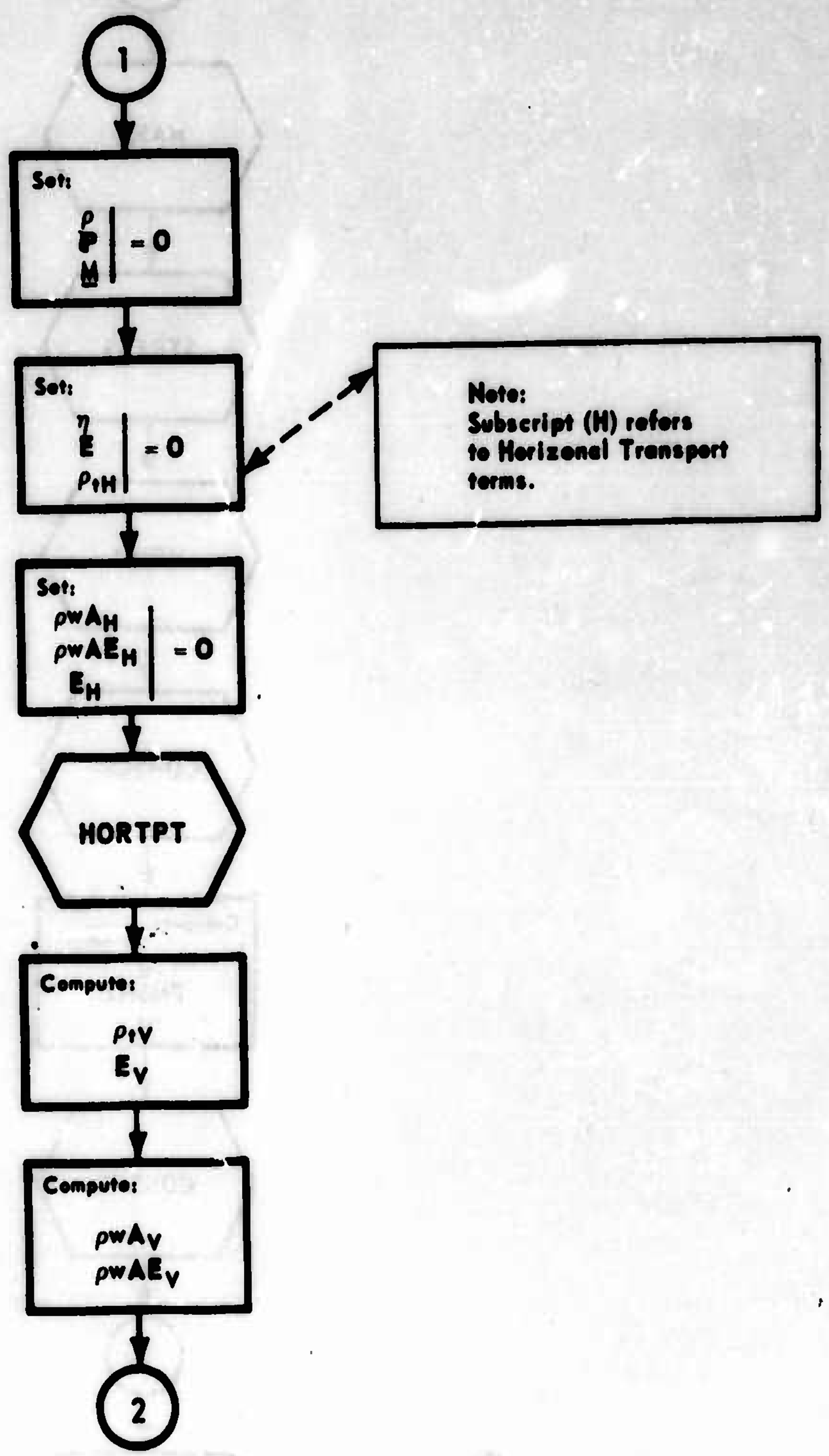
14
N:KSV6
<
5
≥
KSV6 = KSV6
+ KSV5
15
TIME + ΔT/2
: SAV2
<
6
≥
SAV2 = SAV2
+ SAV1
16
KSV4 = KSV7 − 1
17

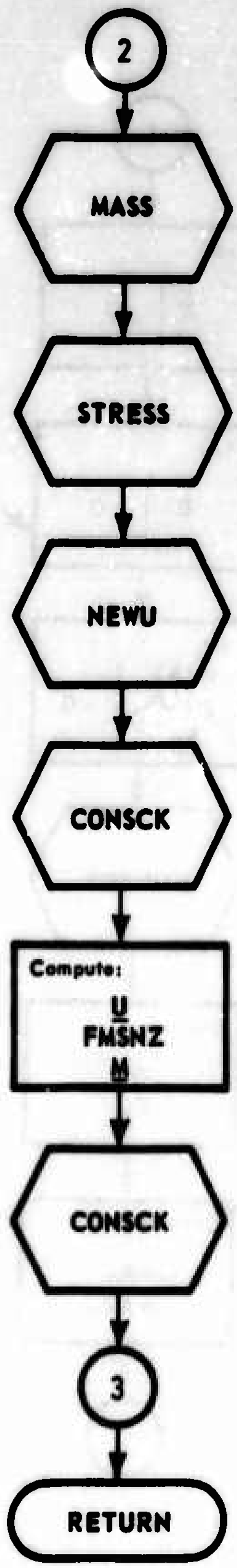

17
Set:
NEDIT = 1
6
18
N:KSV9
>
7
≥
KSV9 = KSV9
+ KSV8
19
TIME + ΔT/2
: SAV4
<
8
≥
SAV'4 = SAV4
+ SAV3
20

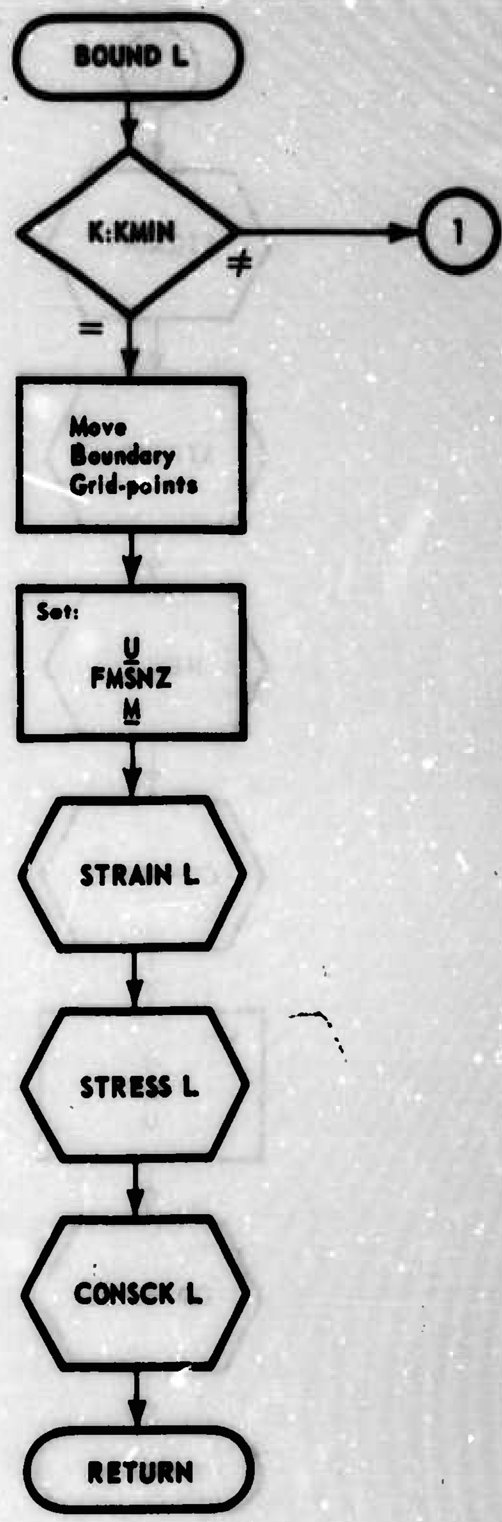

20
Set:
NDPA = 1
8
21
END FILE 10
REWIND 10
STOP

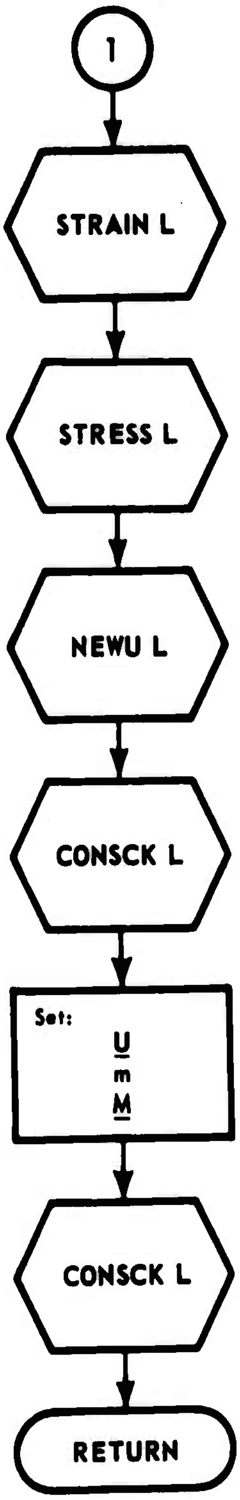


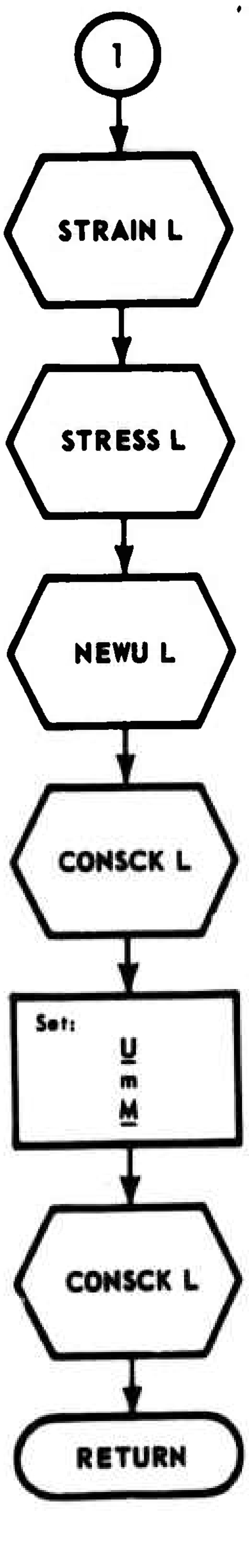
BOUND
K:1
≠
1
=
HORTPT
Compute:
Pt_V
Et_V
ρwA_V
Note:
Subscript (V)
refers to vertical
transport terms
Compute:
$\rho wAE_{V,m}$
STRESS
Compute:
U
FMSNZ
M
CONSCK
3

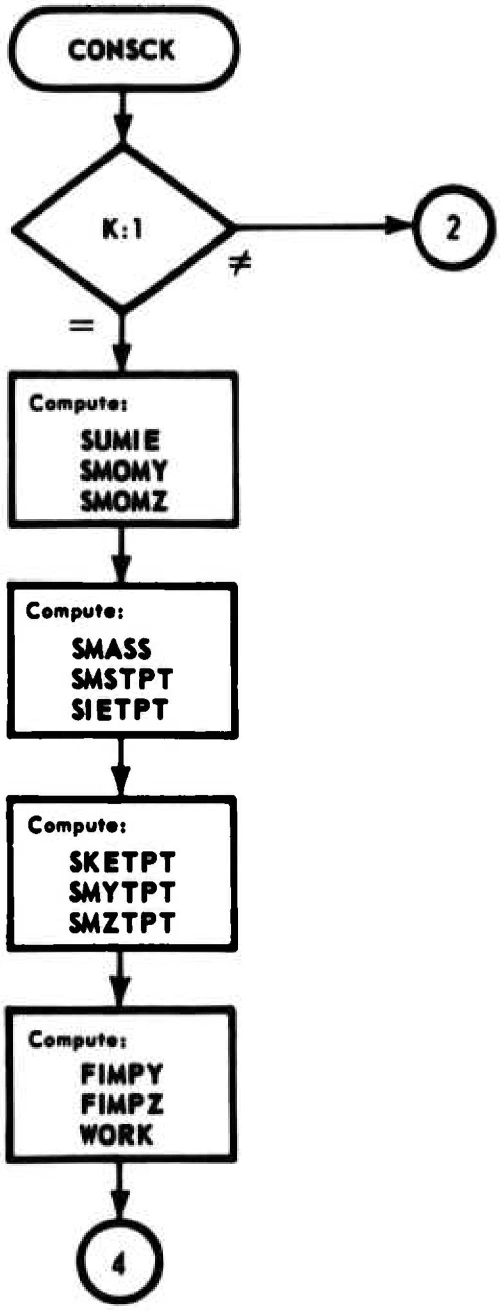

1
Set:
ρ
P
M
= 0
Set:
η
E
ρtH
= 0
Note:
Subscript (H) refers
to Horizonal Transport
terms.
Set:
ρwAH
ρwAEH
EH
= 0
HORTPT
Compute:
ρtV
EV
Compute:
ρwAV
ρwAEV
2

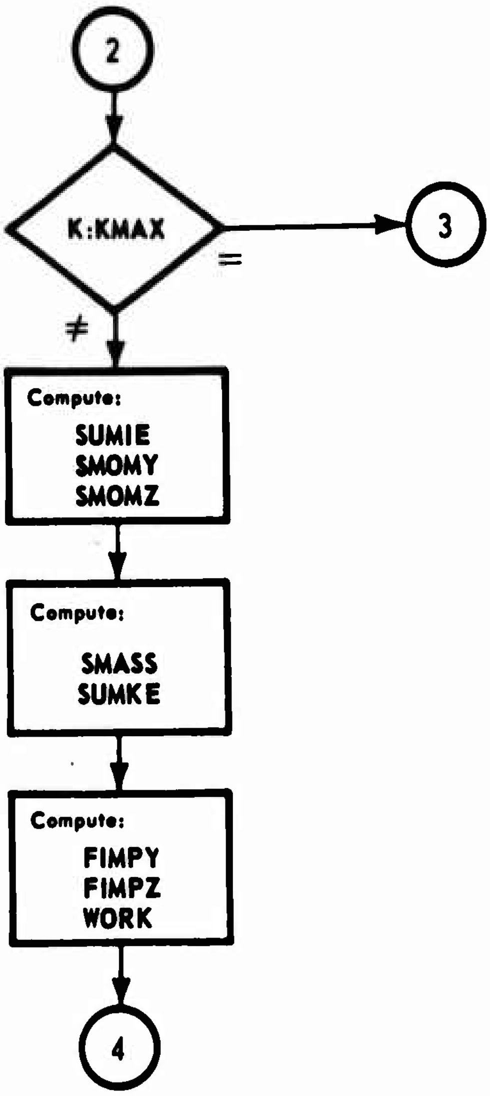

2
MASS
STRESS
NEWU
CONSCK
Compute:
U
FMSNZ
M
CONSCK
3
RETURN

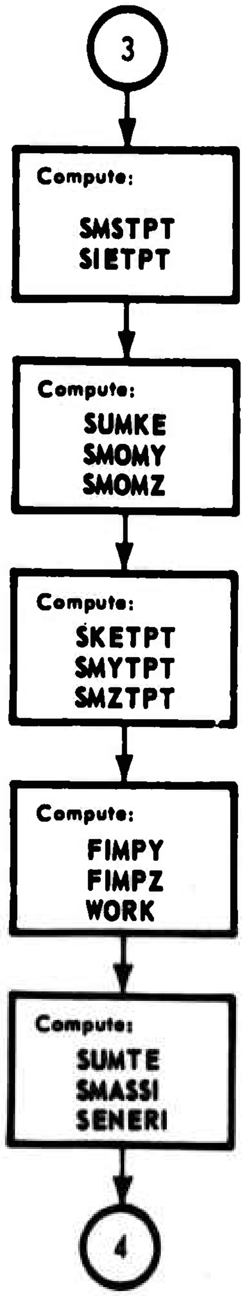

BOUND L
K:KMIN
≠
1
=
Move
Boundary
Grid-points
Set:
U
FMSNZ
M
STRAIN L
STRESS L
CONSCK L
RETURN

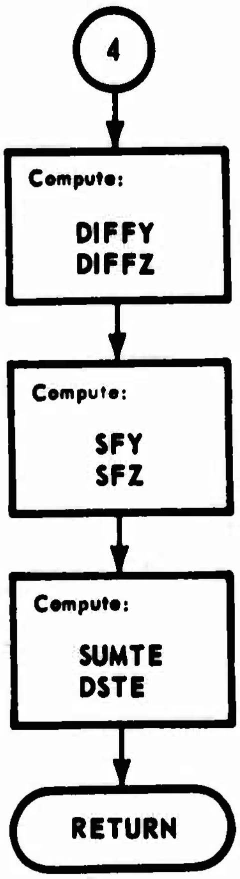

1
STRAIN L
STRESS L
NEWU L
CONSCK L
Set:
U
m
M
CONSCK L
RETURN

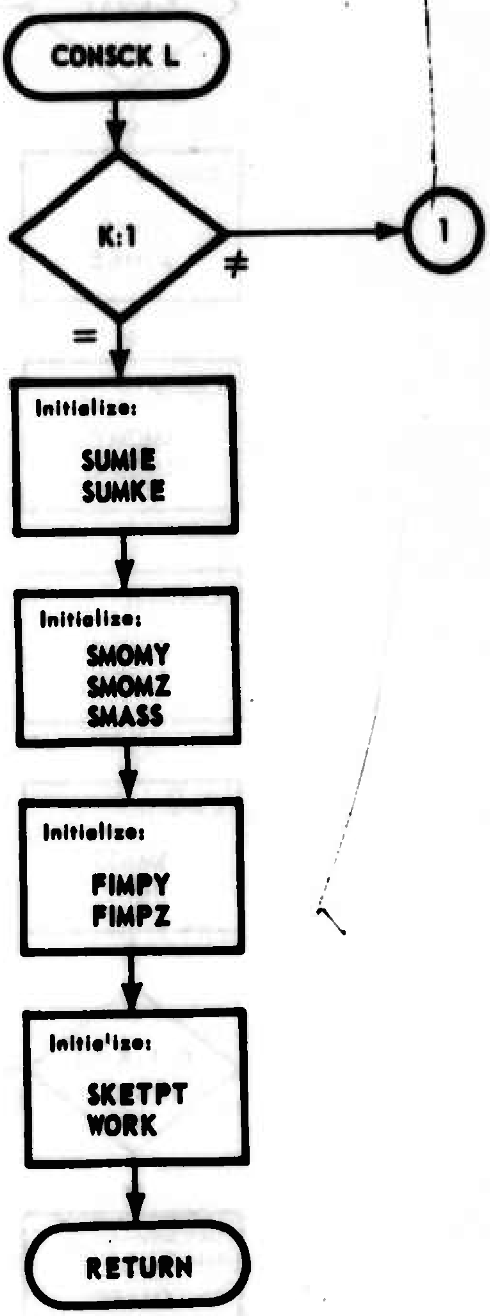

1
STRAIN L
STRESS L
NEWU L
CONSCK L
Set:
U
m
M
CONSCK L
RETURN


CONSCK
K:1
≠
2
=
Compute:
SUMIE
SMOMY
SMOMZ
Compute:
SMASS
SMSTPT
SIETPT
Compute:
SKETPT
SMYTPT
SMZTPT
Compute:
FIMPY
FIMPZ
WORK
4

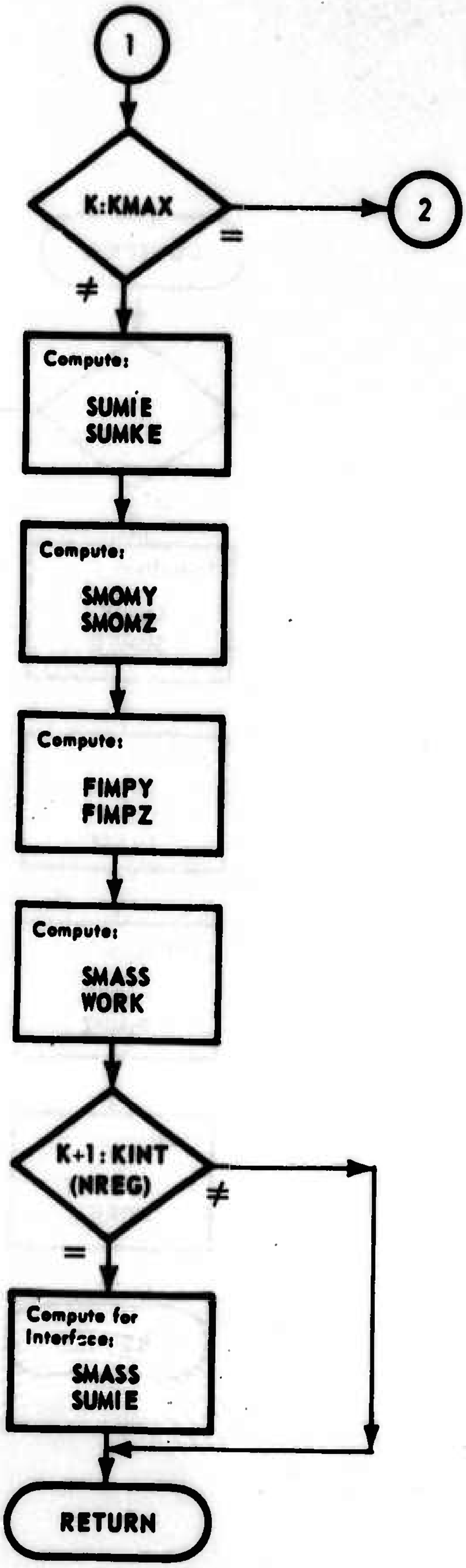

2
K:KMAX
=
3
≠
Compute:
SUMIE
SMOMY
SMOMZ
Compute:
SMASS
SUMKE
Compute:
FIMPY
FIMPZ
WORK
4

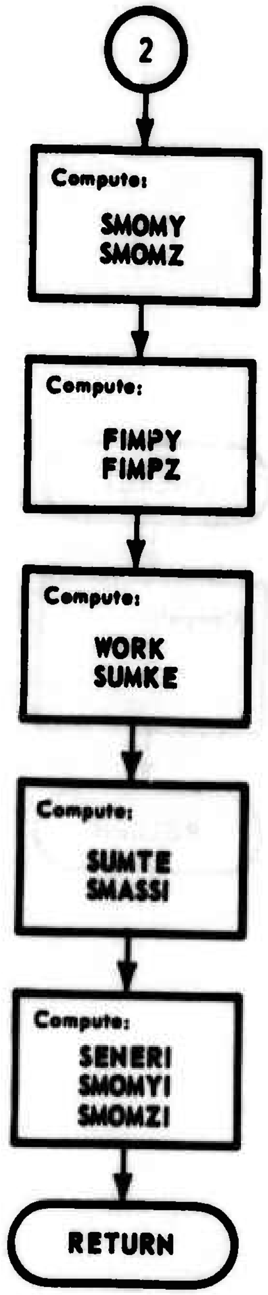

3
Compute:
SMSTPT
SIETPT
Compute:
SUMKE
SMOMY
SMOMZ
Compute:
SKETPT
SMYTPT
SMZTPT
Compute:
FIMPY
FIMPZ
WORK
Compute:
SUMTE
SMASSI
SENERI
4

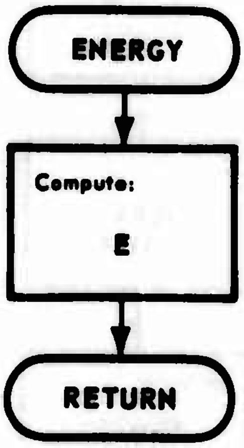

4
Compute:
DIFFY
DIFFZ
Compute:
SFY
SFZ
Compute:
SUMTE
DSTE
RETURN

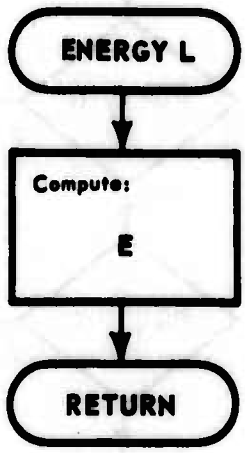


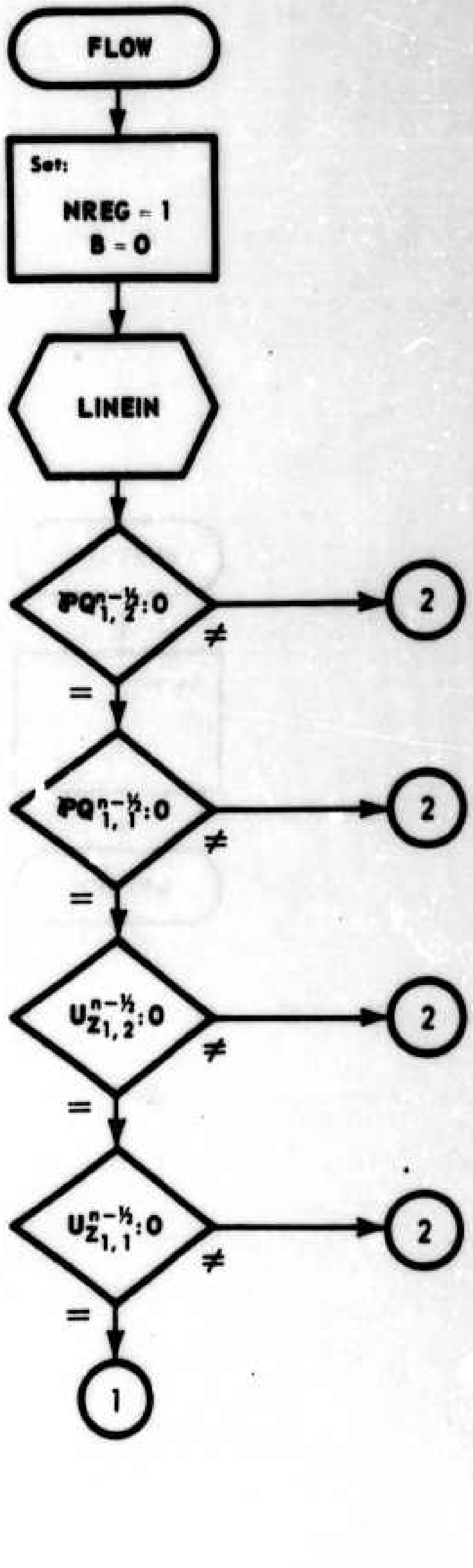
CONSCK L
K:1
≠
1
=
Initialize:
SUMIE
SUMKE
Initialize:
SMOMY
SMOMZ
SMASS
Initialize:
FIMPY
FIMPZ
Initialize:
SKETPT
WORK
RETURN

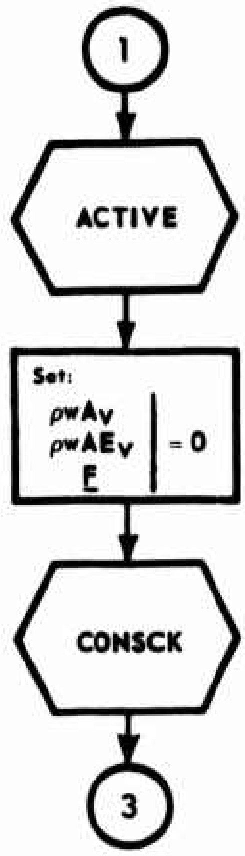

1
K:KMAX
=
2
≠
Compute:
SUMIE
SUMKE
Compute:
SMOMY
SMOMZ
Compute:
FIMPY
FIMPZ
Compute:
SMASS
WORK
K+1:KINT
(NREG)
≠
=
Compute for
Interface:
SMASS
SUMIE
RETURN

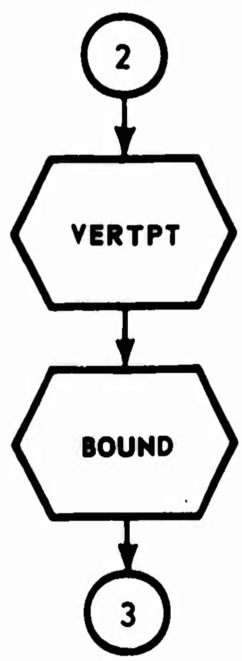

2
Compute:
SMOMY
SMOMZ
Compute:
FIMPY
FIMPZ
Compute:
WORK
SUMKE
Compute:
SUMTE
SMASSI
Compute:
SENERI
SMOMYI
SMOMZI
RETURN

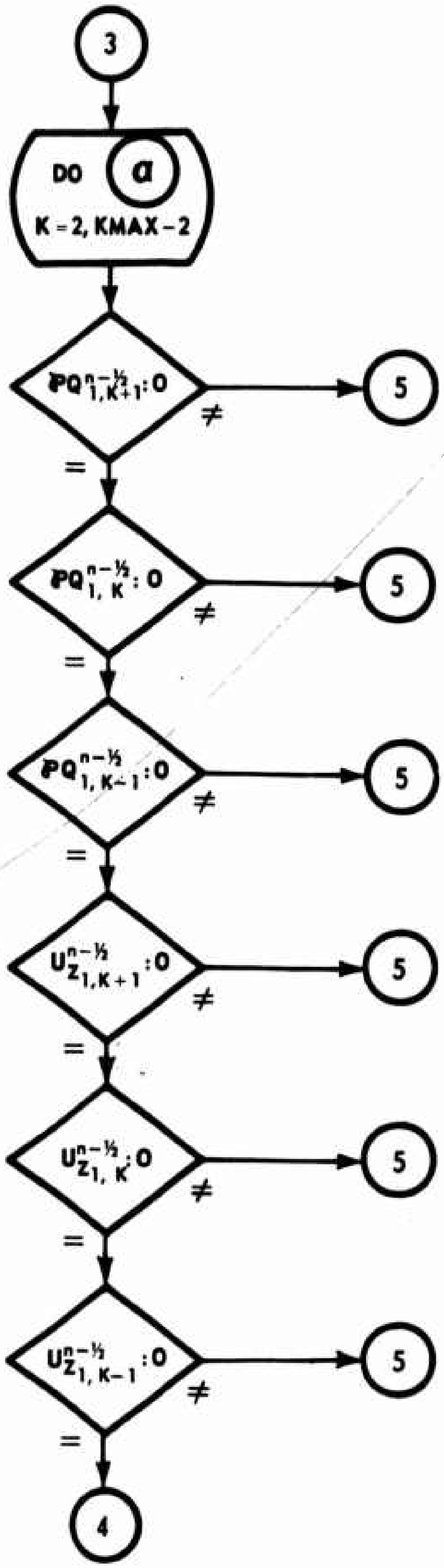

ENERGY
Compute:
E
RETURN

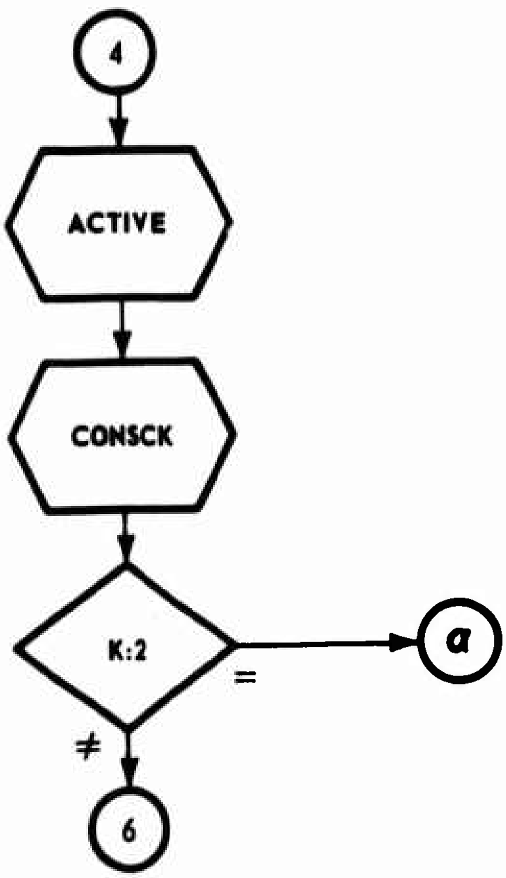

ENERGY L
Compute:
E
RETURN


FLOW
Set:
NREG = 1
B = 0
LINEIN
PQ$^{n-1/2}_{1,2}$:0
PQ$^{n-1/2}_{1,1}$:0
U$^{n-1/2}_{Z1,2}$:0
U$^{n-1/2}_{Z1,1}$:0
=
≠
2
1

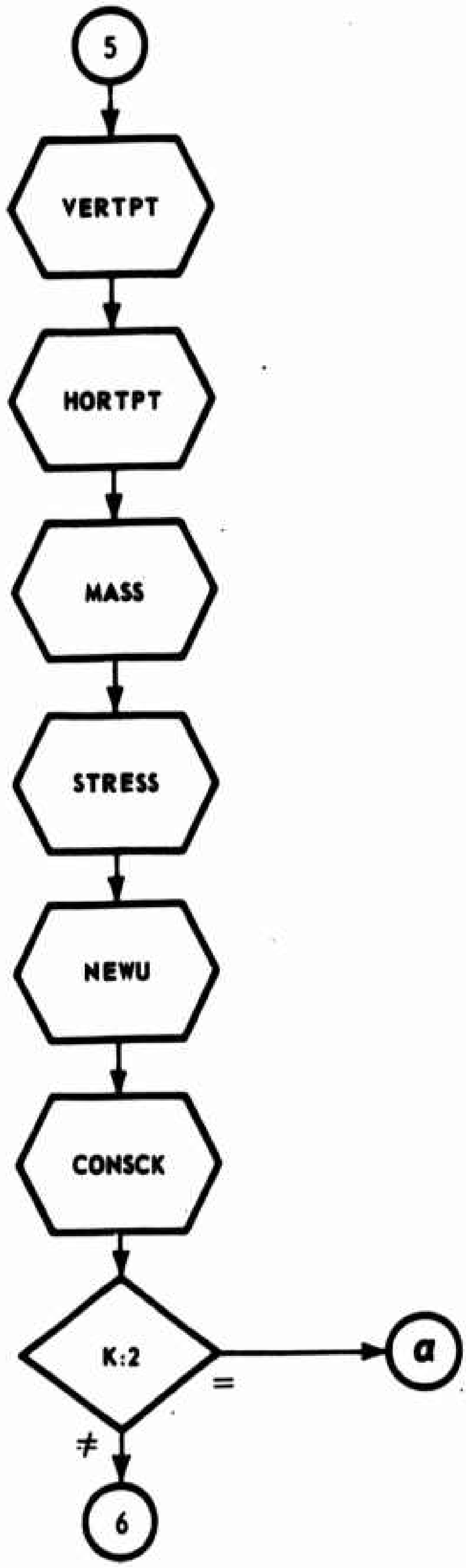

1
ACTIVE
Set:
$\rho w A_V$
$\rho w AE_V$
$\underline{E}$
= 0
CONSCK
3

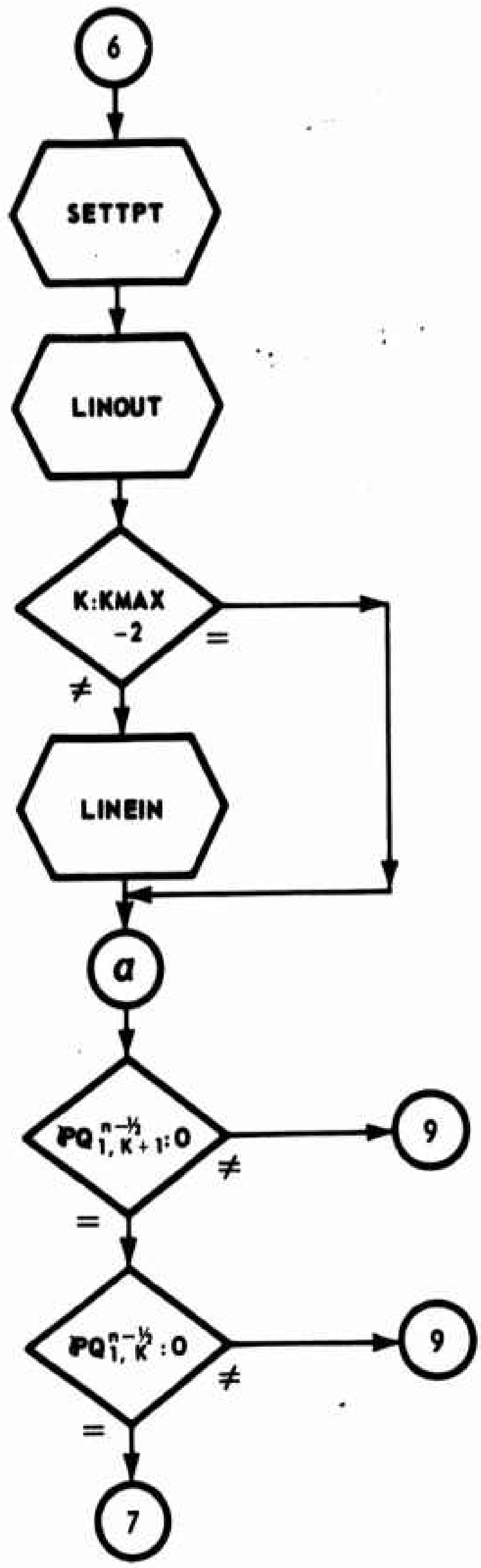

2
VERTPT
BOUND
3

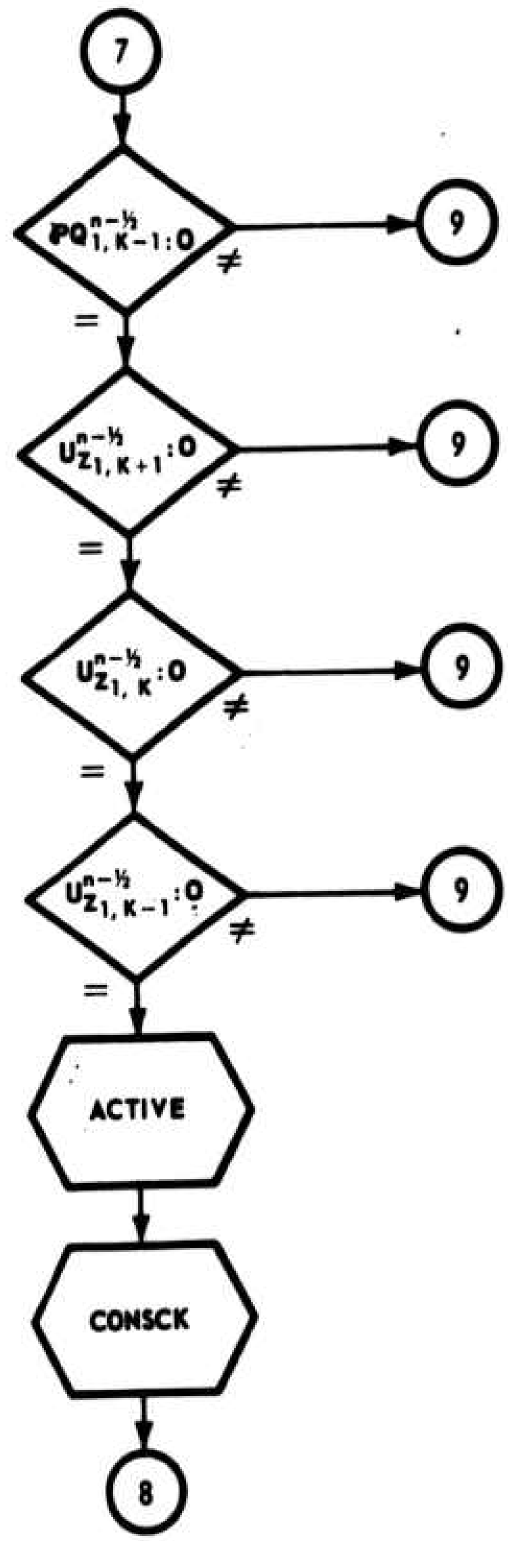

3
DO a
K = 2, KMAX − 2
PQ n−½ 1, K+1 : 0
PQ n−½ 1, K : 0
PQ n−½ 1, K−1 : 0
U n−½ Z1, K+1 : 0
U n−½ Z1, K : 0
U n−½ Z1, K−1 : 0
=
≠
5
4

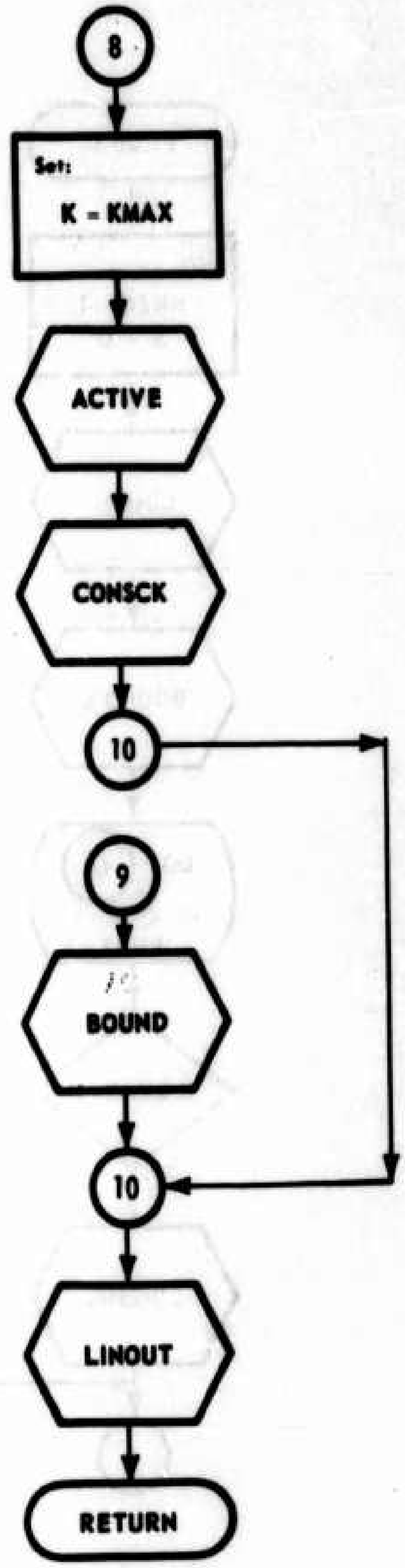


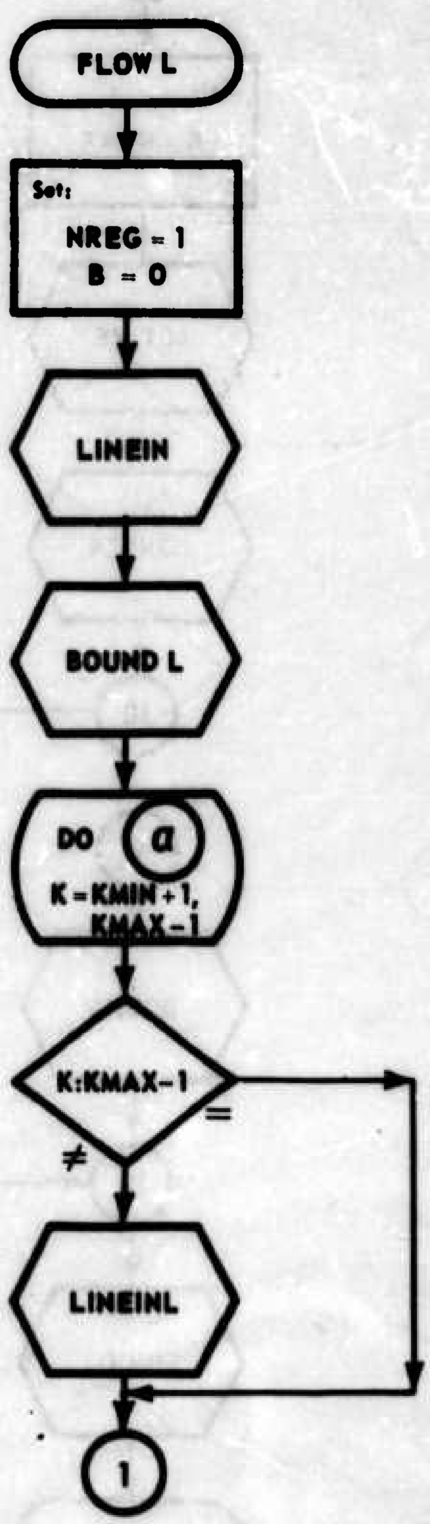
4
ACTIVE
CONSCK
K:2
=
a
≠
6

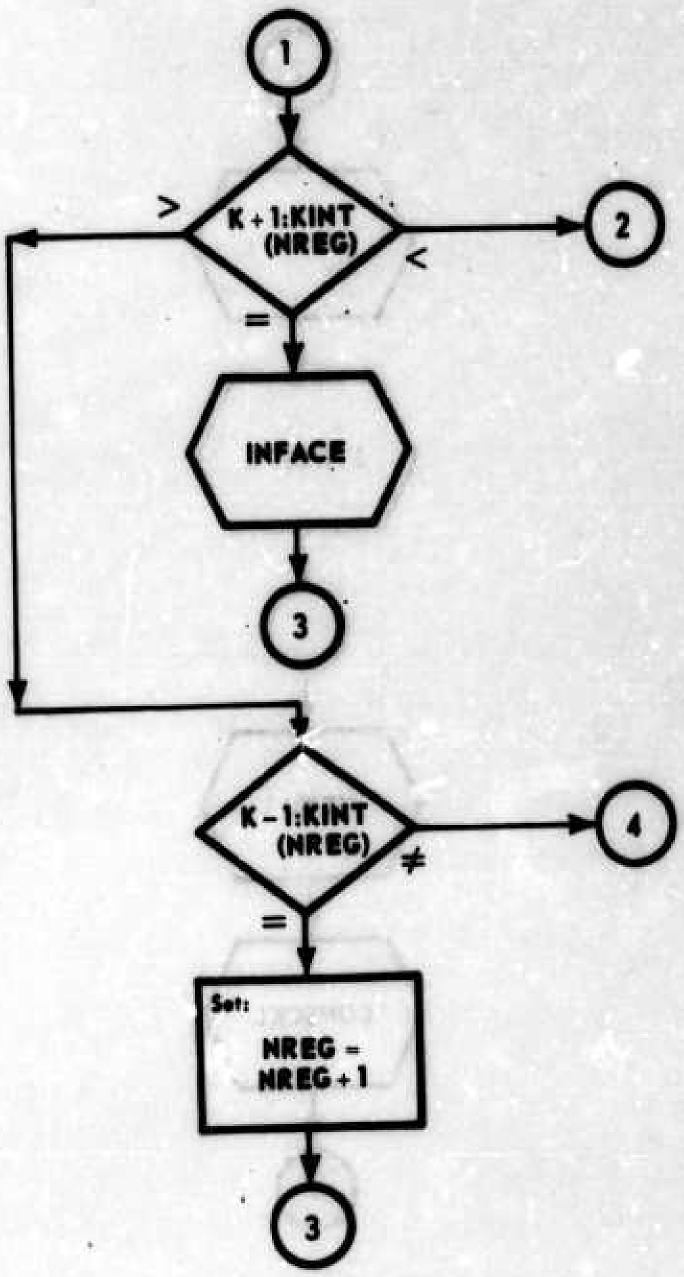

5
VERTPT
HORTPT
MASS
STRESS
NEWU
CONSCK
K:2
=
a
≠
6

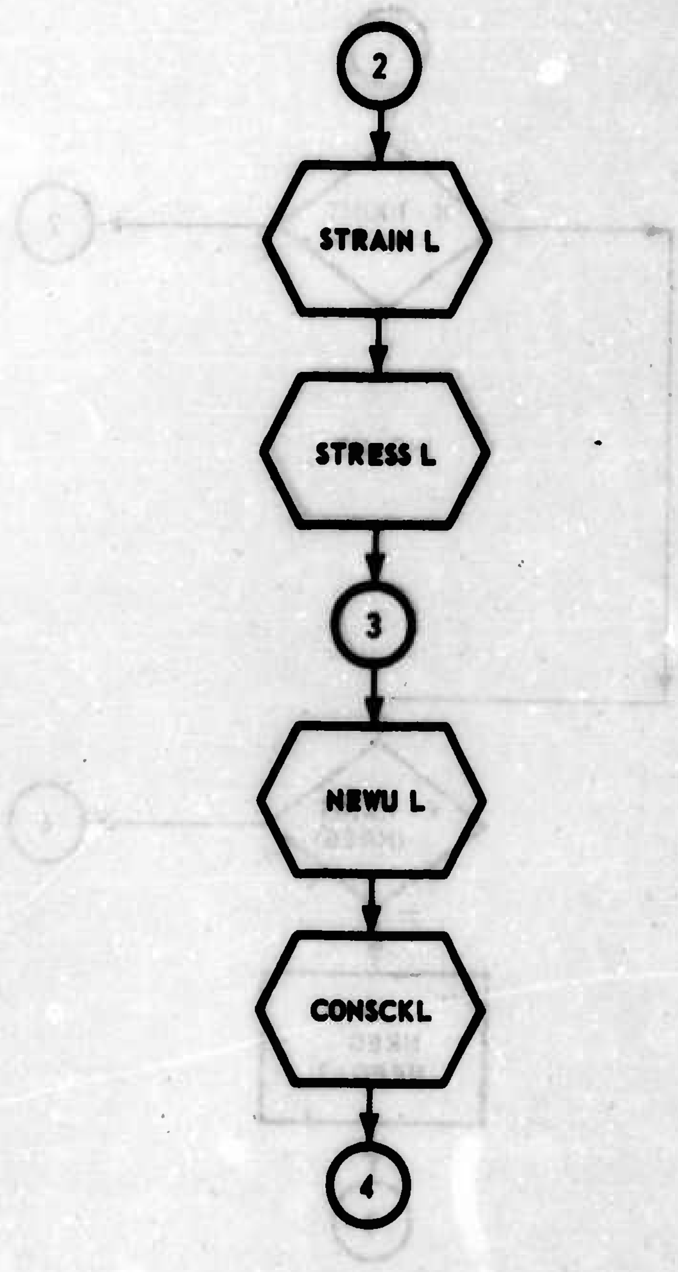

6
SETTPT
LINOUT
K:KMAX -2
=
≠
LINEIN
a
PQ 1, K+1 n-½ : 0
≠
9
=
PQ 1, K n-½ : 0
≠
9
=
7

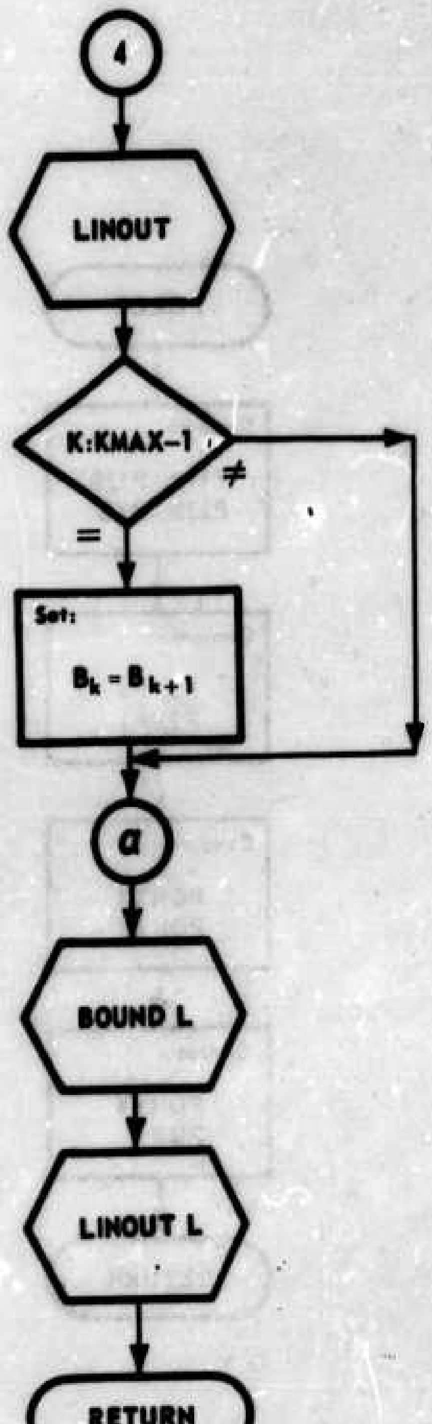

7
$PQ^{n-1/2}_{1,K-1}:0$
≠
9
=
$U^{n-1/2}_{Z_{1,K+1}}:0$
≠
9
=
$U^{n-1/2}_{Z_{1,K}}:0$
≠
9
=
$U^{n-1/2}_{Z_{1,K-1}}:0$
≠
9
=
ACTIVE
CONSCK
8

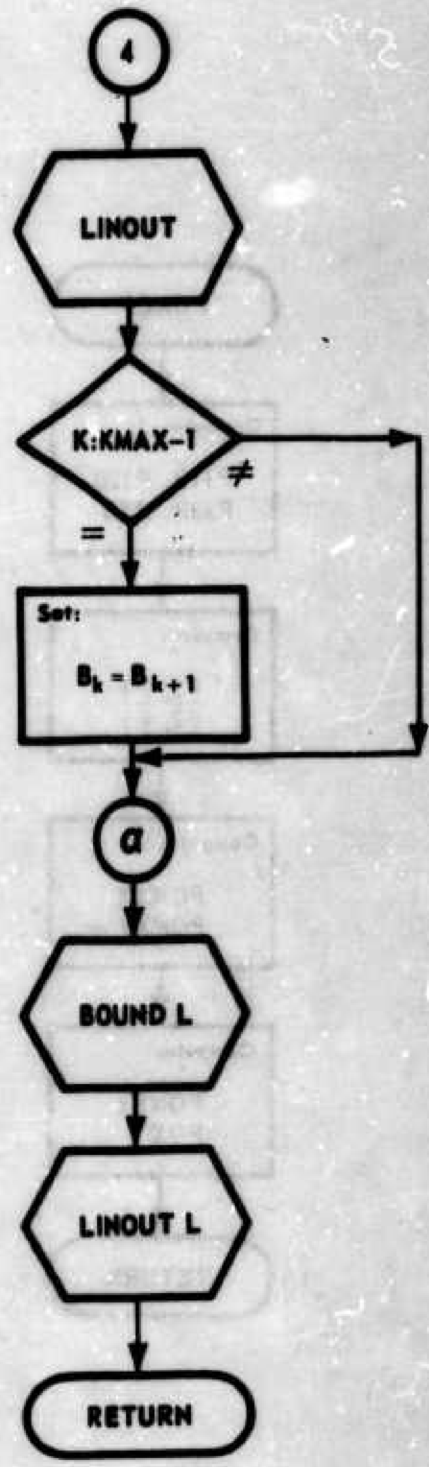

8
Set:
K = KMAX
ACTIVE
CONSCK
10
9
BOUND
10
LINOUT
RETURN


FLOW L
Set:
NREG = 1
B = 0
LINEIN
BOUND L
DO a
K = KMIN + 1,
KMAX - 1
K:KMAX-1
=
≠
LINEINL
1

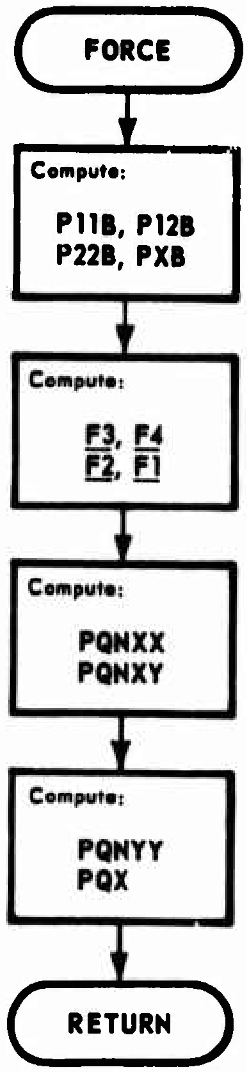

1
K + 1:KINT (NREG)
>
<
=
2
INFACE
3
K - 1:KINT (NREG)
≠
=
4
Set:
NREG = NREG + 1
3

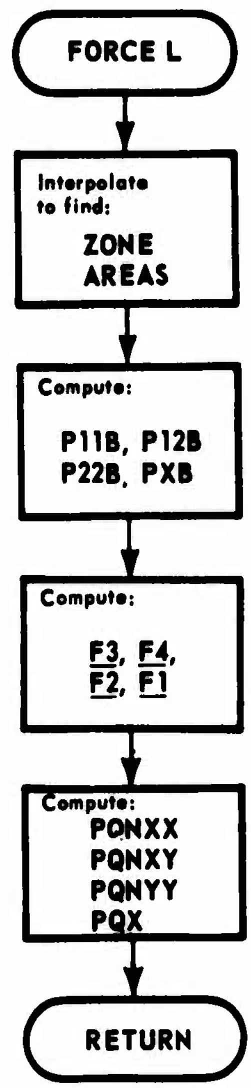

2
STRAIN L
STRESS L
3
NEWU L
CONSCKL
4

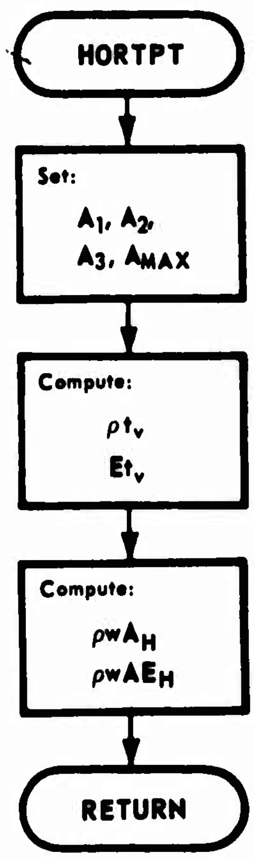

4
LINOUT
K:KMAX-1
≠
=
Set:
B_k = B_k+1
a
BOUND L
LINOUT L
RETURN

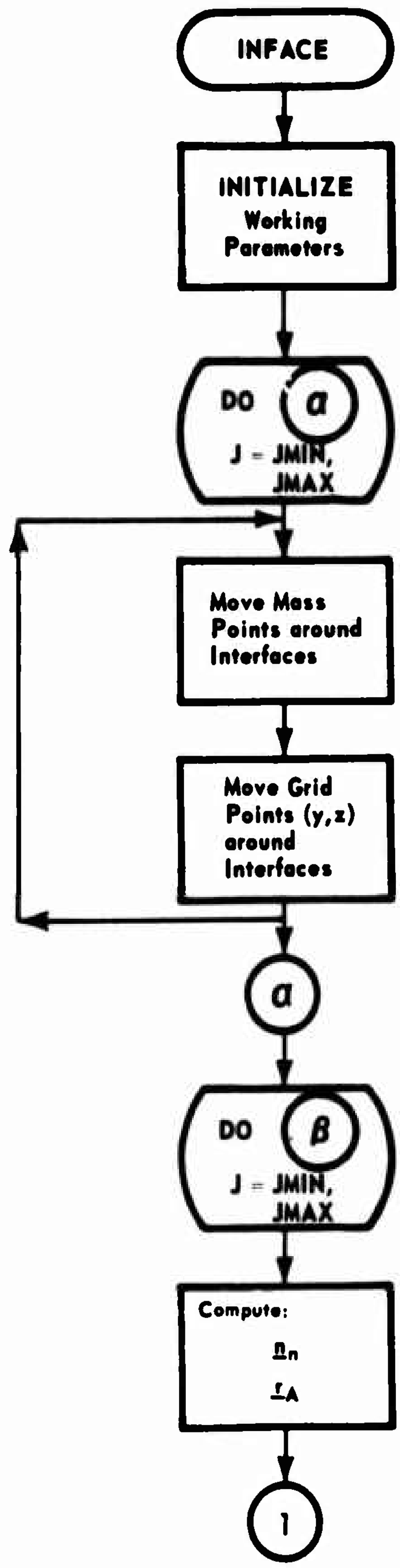


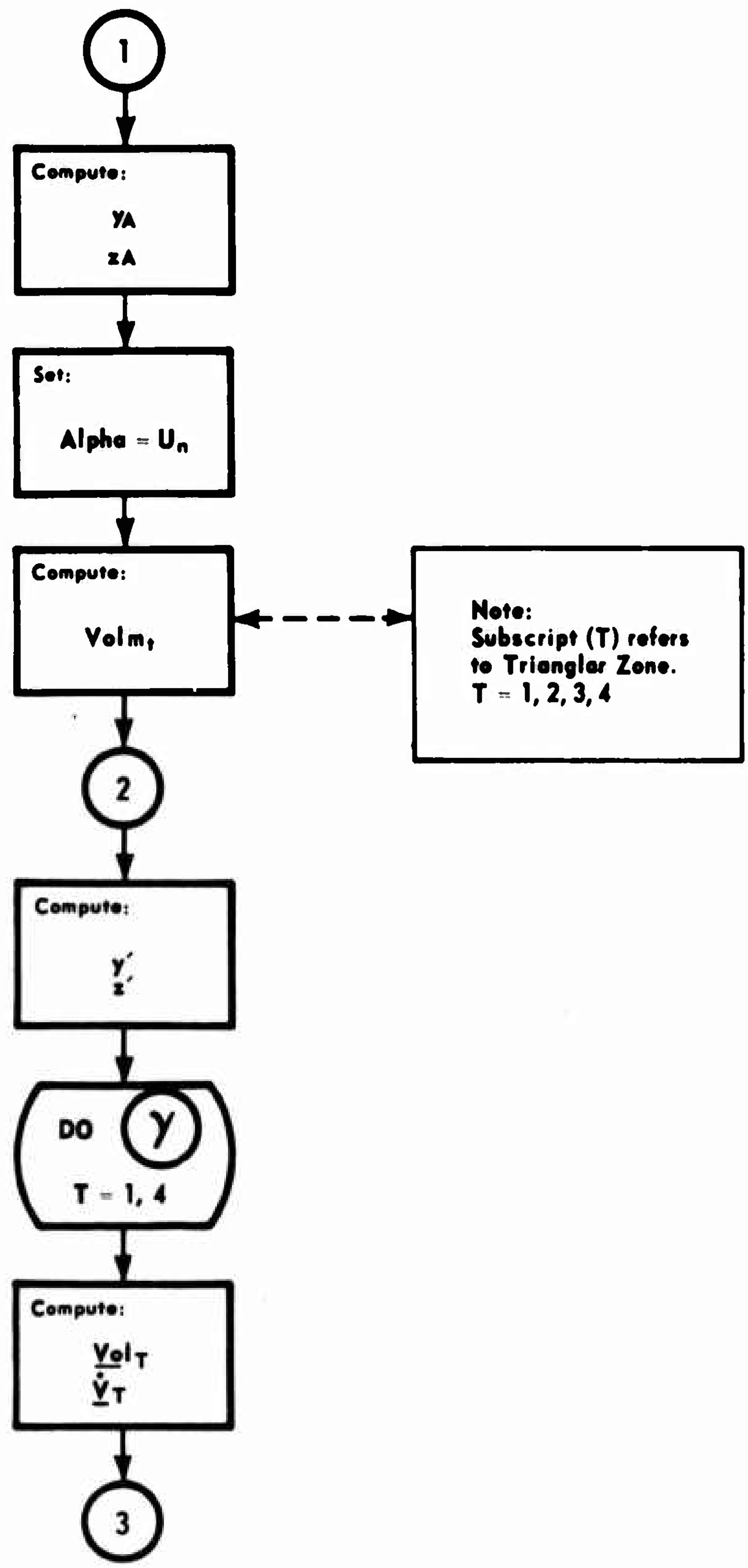
4
LINOUT
K:KMAX-1
≠
=
Set:
B_k = B_k+1
a
BOUND L
LINOUT L
RETURN

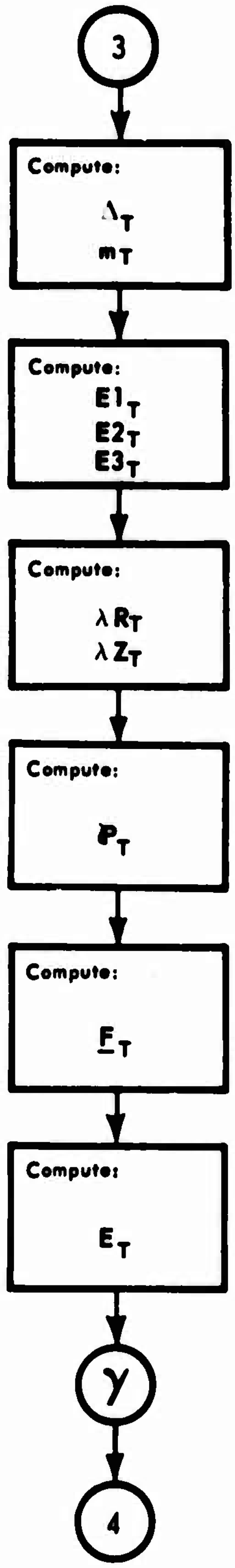

FORCE
Compute:
P11B, P12B
P22B, PXB
Compute:
F3, F4
F2, F1
Compute:
PQNXX
PQNXY
Compute:
PQNYY
PQX
RETURN

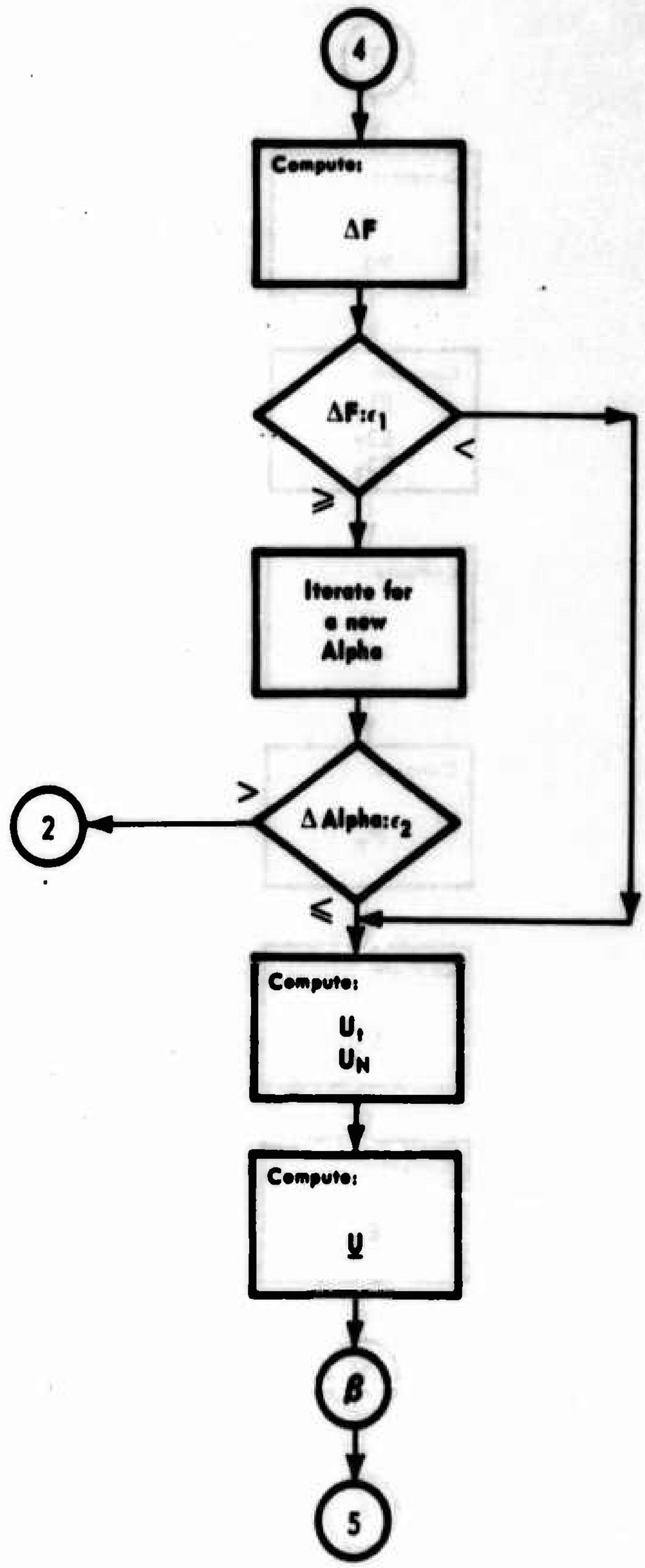

FORCE L
Interpolate to find:
ZONE AREAS
Compute:
P11B, P12B
P22B, PXB
Compute:
F3, F4,
F2, F1
Compute:
PQNXX
PQNXY
PQNYY
PQX
RETURN

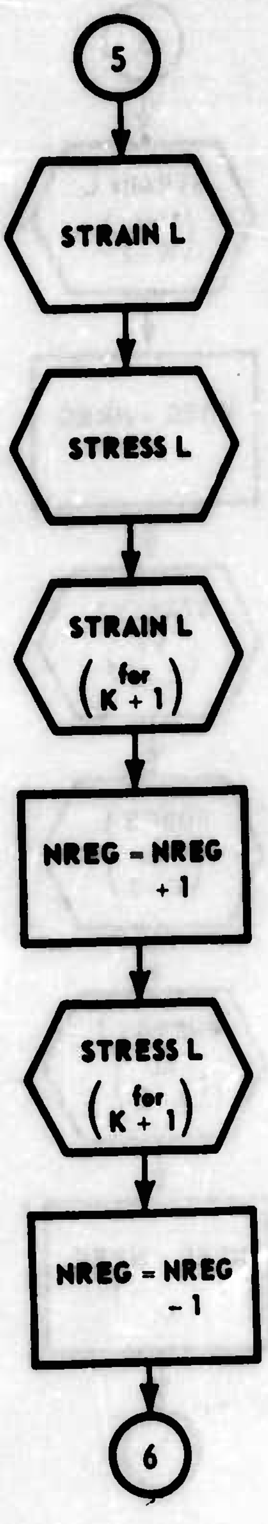

HORTPT
Set:
A1, A2,
A3, AMAX
Compute:
ρtv
Etv
Compute:
ρwAH
ρwAEH
RETURN

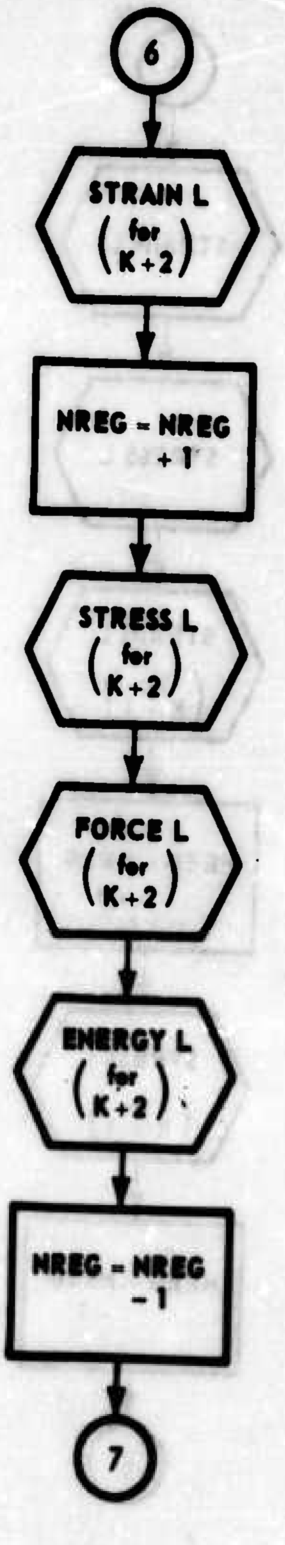

INFACE
INITIALIZE Working Parameters
DO α J = JMIN, JMAX
Move Mass Points around Interfaces
Move Grid Points (y,z) around Interfaces
α
DO β J = JMIN, JMAX
Compute:
$\underline{n}_n$
$\underline{r}_A$
1

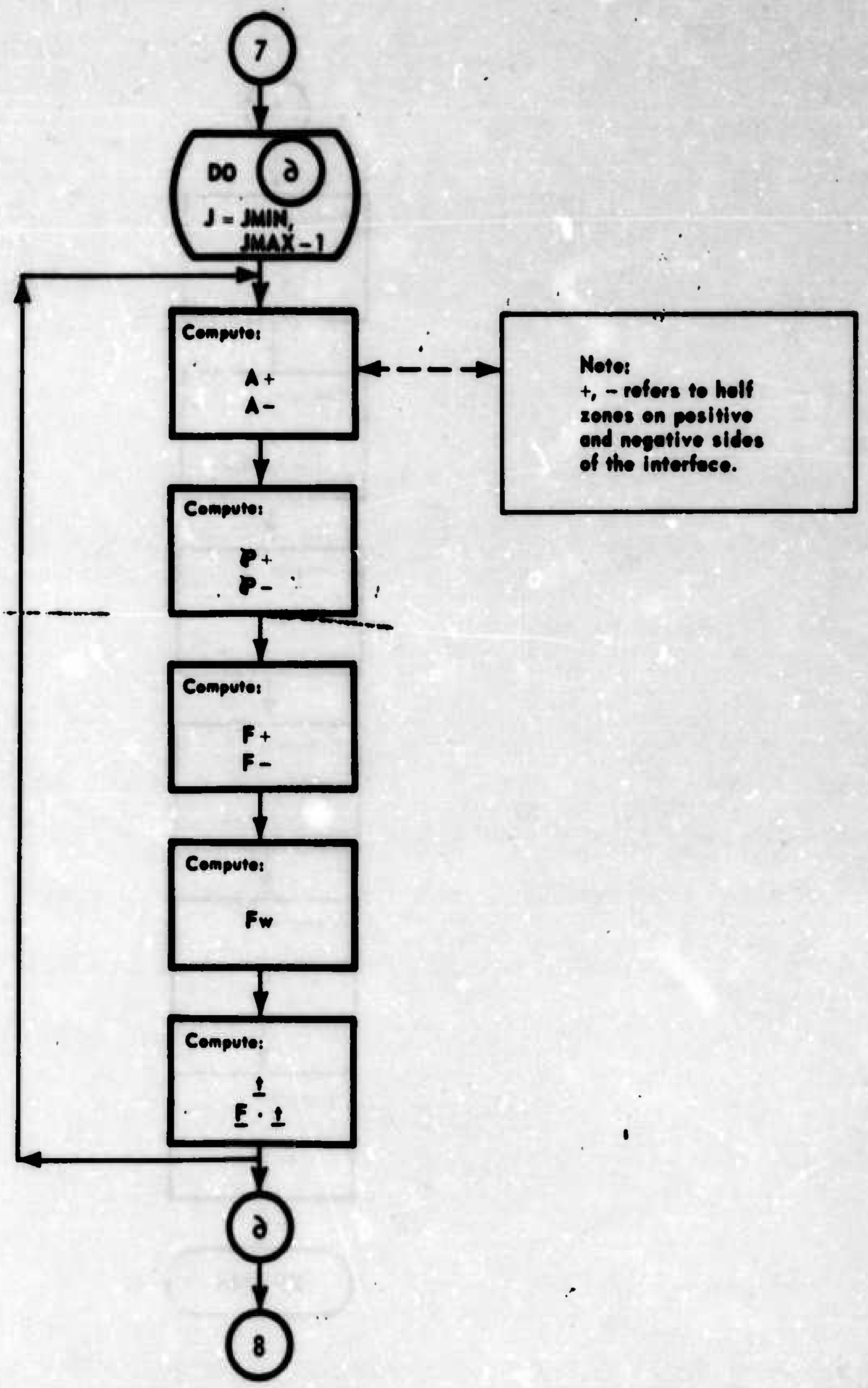

1
Compute:
yA
zA
Set:
Alpha = Un
Compute:
Volm,
Note:
Subscript (T) refers
to Trianglar Zone.
T = 1, 2, 3, 4
2
Compute:
y'
z'
DO
γ
T = 1, 4
Compute:
VolT
ẎT
3

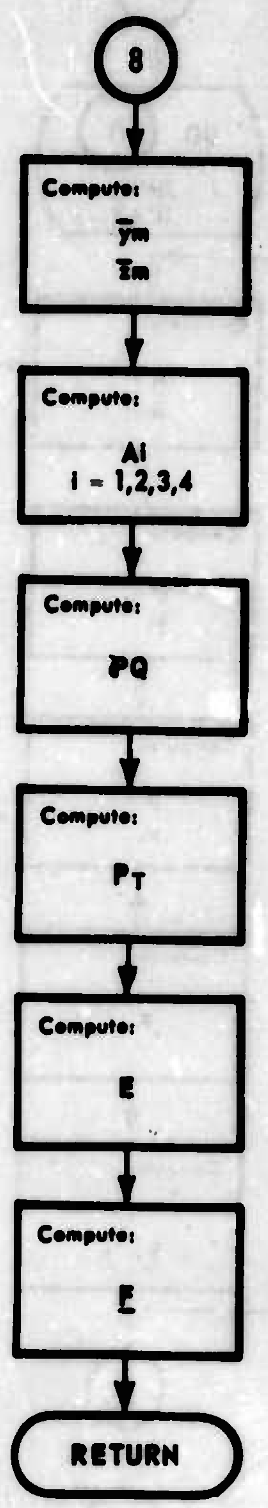

3
Compute:
Λ_T
m_T
Compute:
$E1_T$
$E2_T$
$E3_T$
Compute:
λR_T
λZ_T
Compute:
P_T
Compute:
$\underline{F}_T$
Compute:
E_T
γ
4

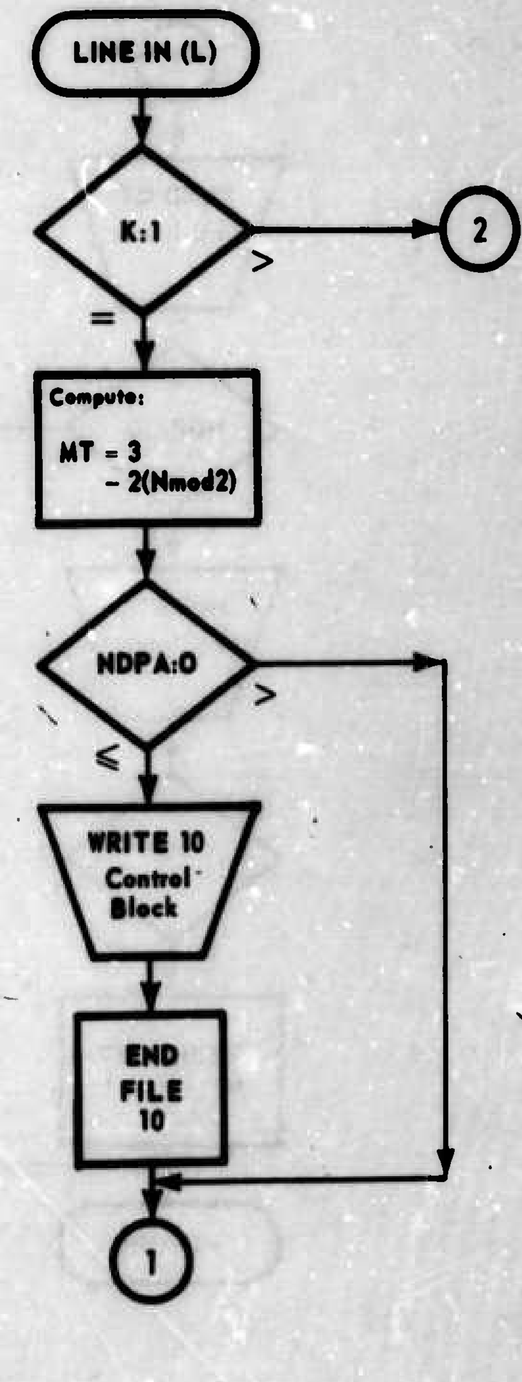

4
Compute:
ΔF
ΔF:ε1
<
≥
Iterate for
a new
Alpha
>
2
Δ Alpha:ε2
≤
Compute:
U1
UN
Compute:
U
β
5

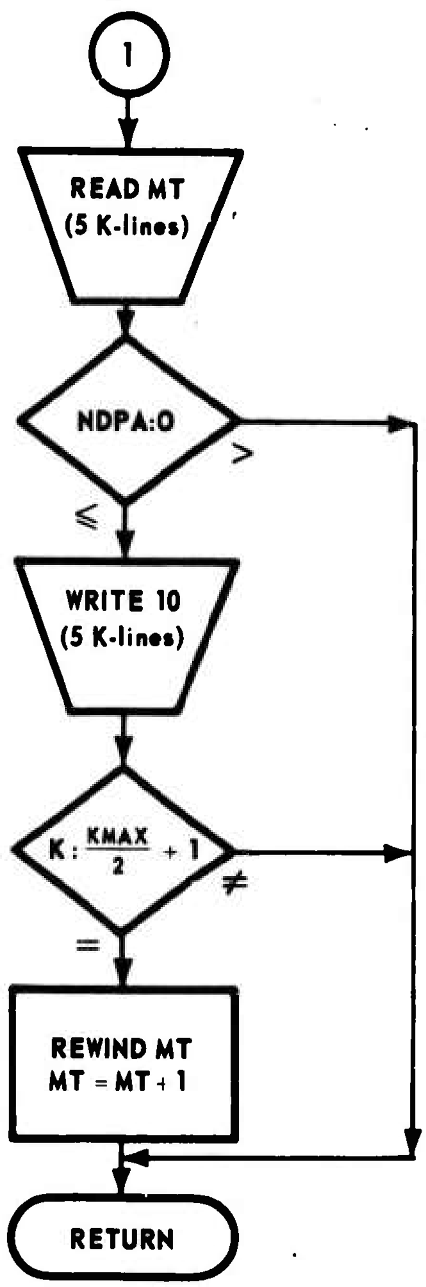

5
STRAIN L
STRESS L
STRAIN L
(for K + 1)
NREG = NREG + 1
STRESS L
(for K + 1)
NREG = NREG - 1
6


6
STRAIN L (for K+2)
NREG = NREG + 1
STRESS L (for K+2)
FORCE L (for K+2)
ENERGY L (for K+2)
NREG = NREG - 1
7

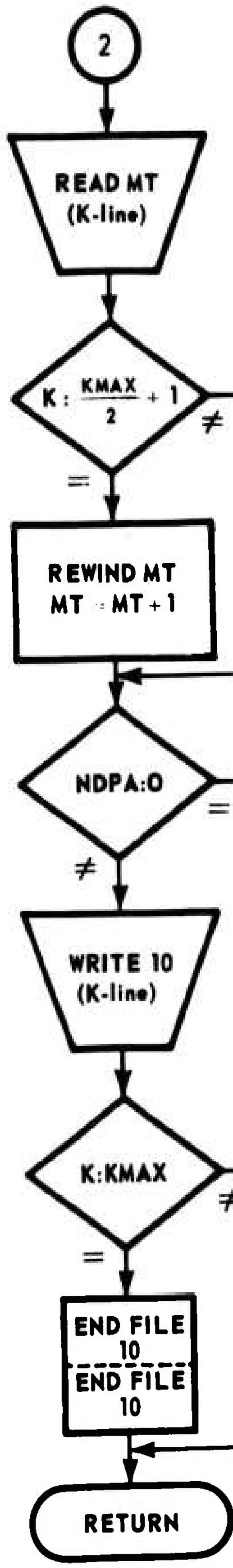

7
DO ∂
J = JMIN, JMAX − 1
Compute:
A+
A−
Compute:
P+
P−
Compute:
F+
F−
Compute:
Fw
Compute:
F · t
∂
8
Note:
+, − refers to half zones on positive and negative sides of the interface.

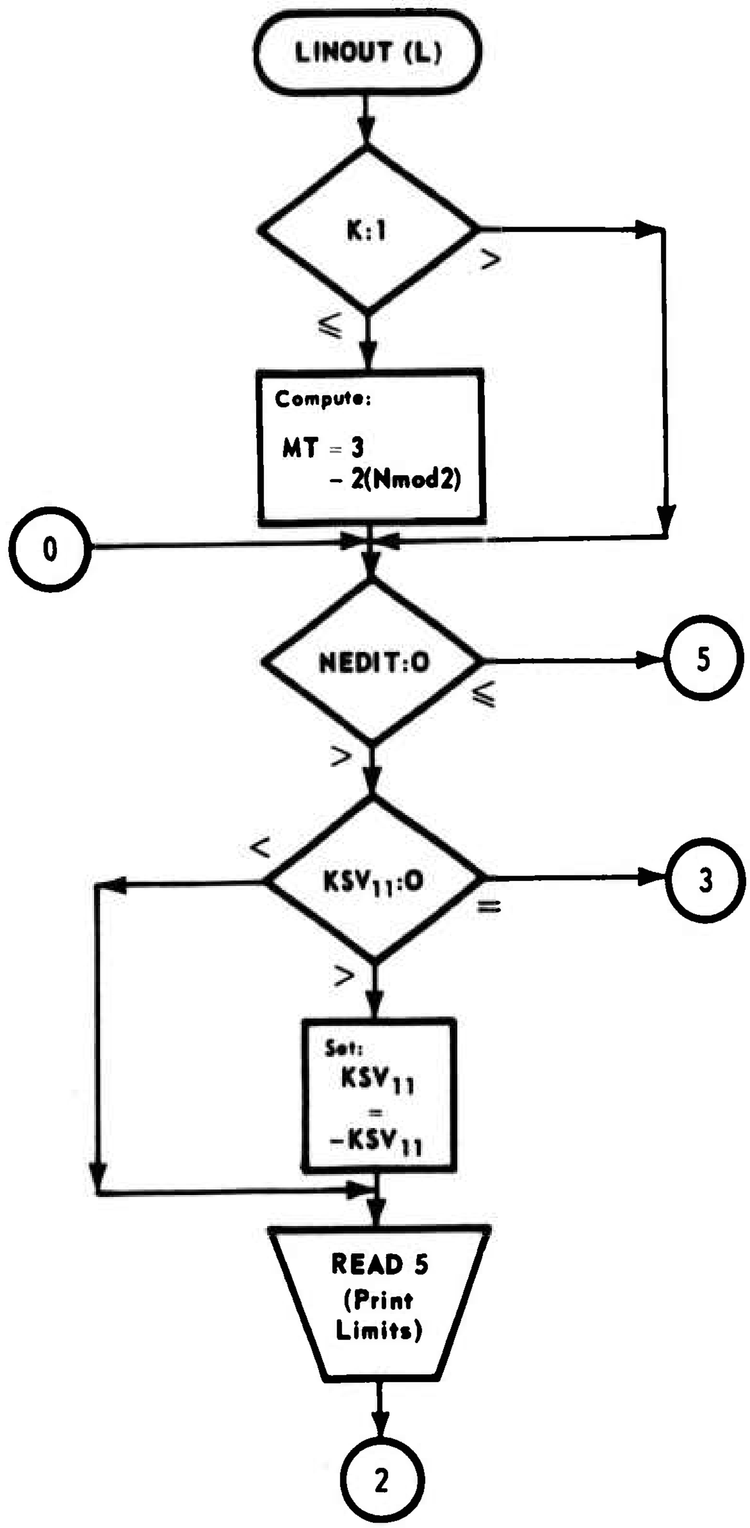

8
Compute:
ȳm
z̄m
Compute:
Ai
i = 1,2,3,4
Compute:
PQ
Compute:
PT
Compute:
E
Compute:
F
RETURN

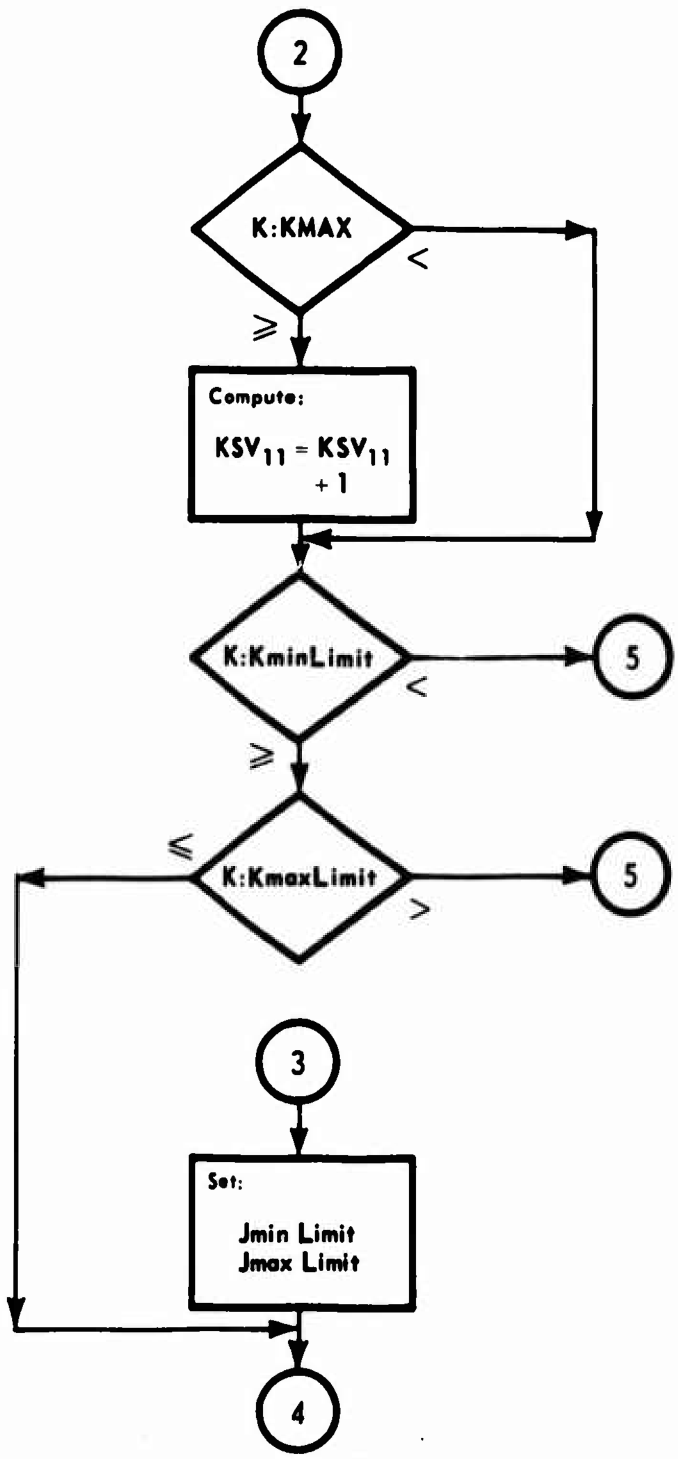

LINE IN (L)
K:1
>
2
=
Compute:
MT = 3
- 2(Nmod2)
NDPA:0
>
≤
WRITE 10
Control
Block
END
FILE
10
1

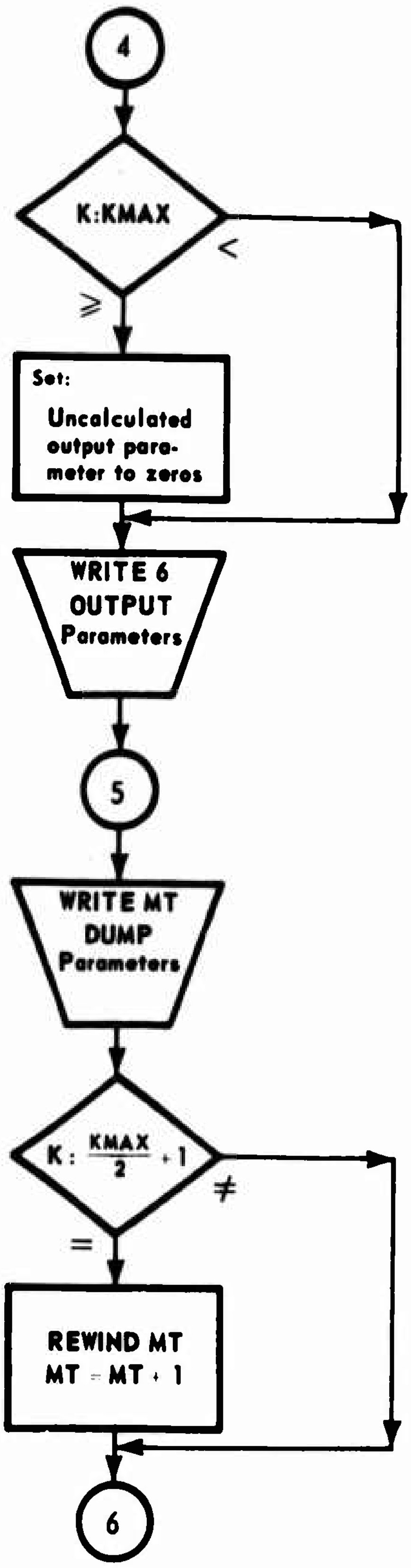


1
READ MT
(5 K-lines)
NDPA:0
>
≤
WRITE 10
(5 K-lines)
K : KMAX/2 + 1
≠
=
REWIND MT
MT = MT + 1
RETURN

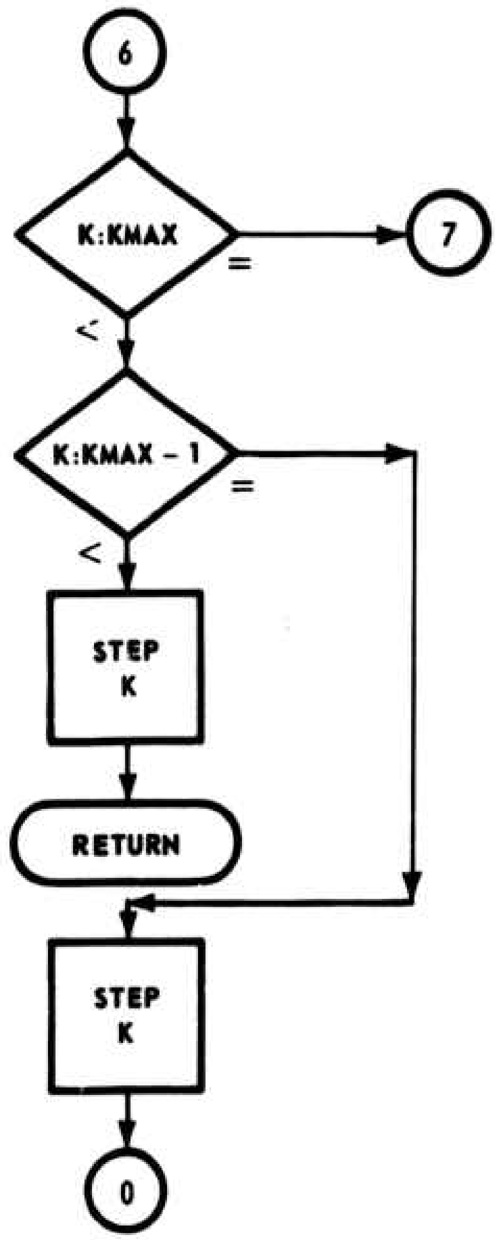

2
READ MT
(K-line)
K : KMAX/2 + 1
≠
=
REWIND MT
MT = MT + 1
NDPA:O
=
≠
WRITE 10
(K-line)
K:KMAX
≠
=
END FILE
10
END FILE
10
RETURN

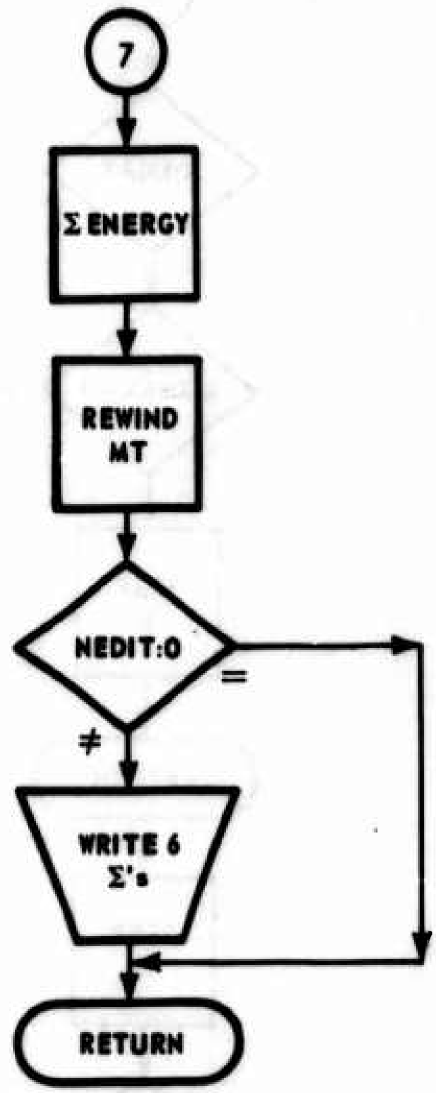

LINOUT (L)
K:1
>
≤
Compute:
MT = 3 - 2(Nmod2)
0
NEDIT:O
5
≤
>
<
KSV11:O
3
=
>
Set:
KSV11 = -KSV11
READ 5 (Print Limits)
2

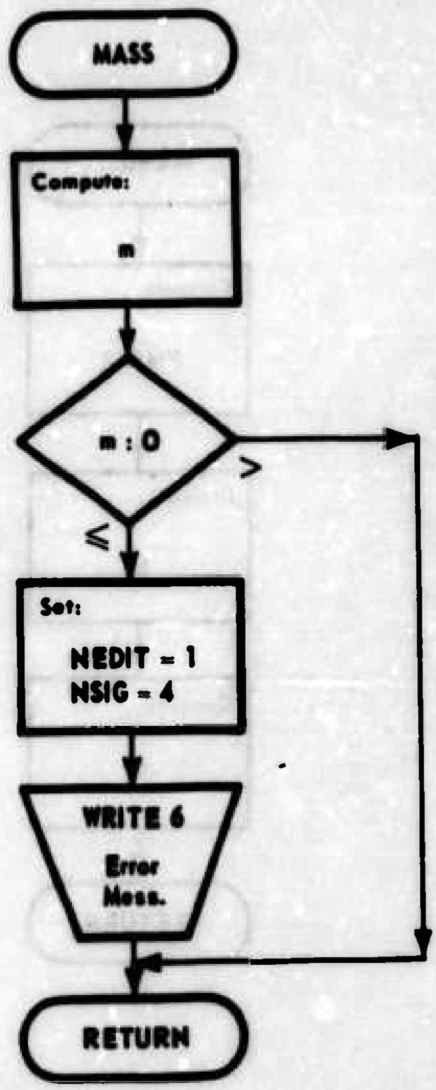

2
K:KMAX
<
≥
Compute:
KSV11 = KSV11 + 1
K:KminLimit
<
5
≥
≤
K:KmaxLimit
>
5
3
Set:
Jmin Limit
Jmax Limit
4



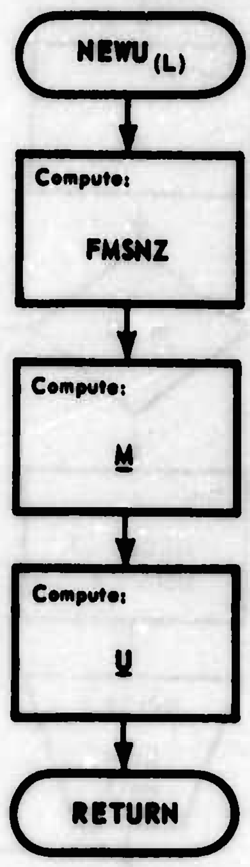
4
K:KMAX
<
≥
Set:
Uncalculated output parameter to zeros
WRITE 6 OUTPUT Parameters
5
WRITE MT DUMP Parameters
K : KMAX/2 + 1
≠
=
REWIND MT
MT = MT + 1
6

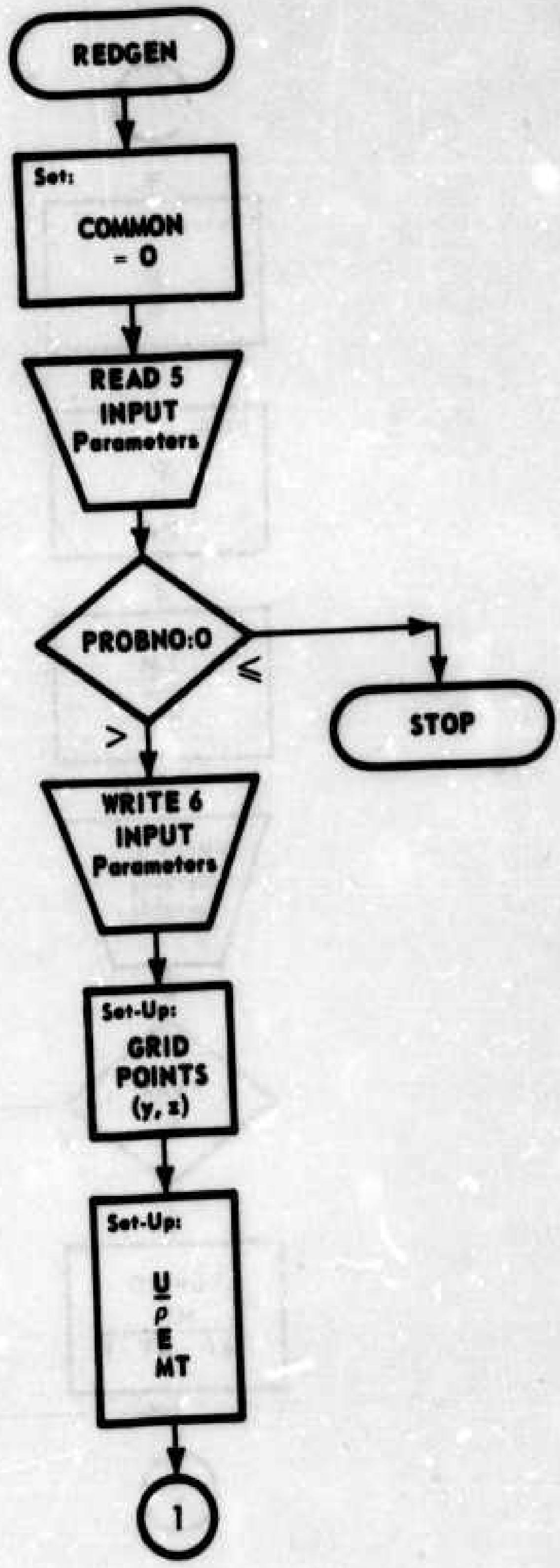

6
K:KMAX
=
7
<
K:KMAX - 1
=
<
STEP
K
RETURN
STEP
K
0

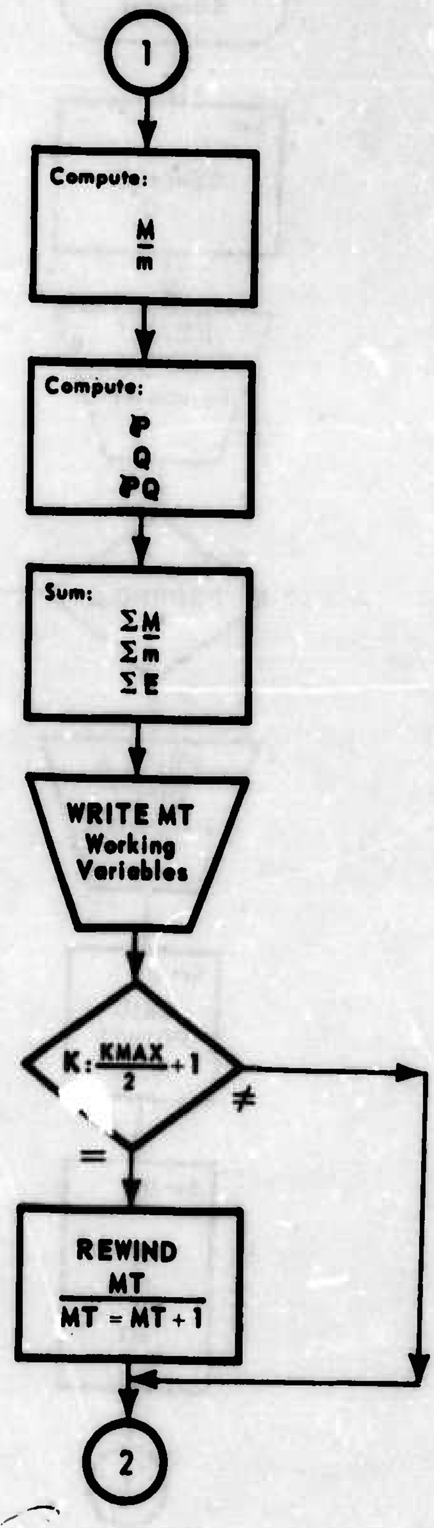

7
Σ ENERGY
REWIND
MT
NEDIT:0
=
≠
WRITE 6
Σ's
RETURN

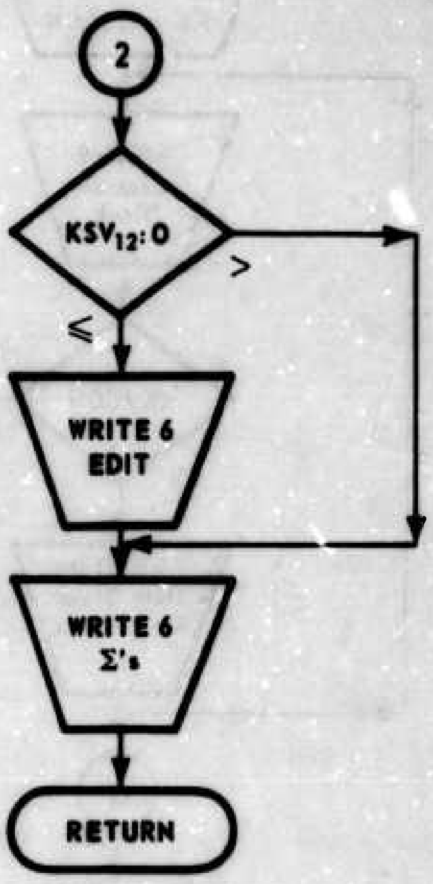


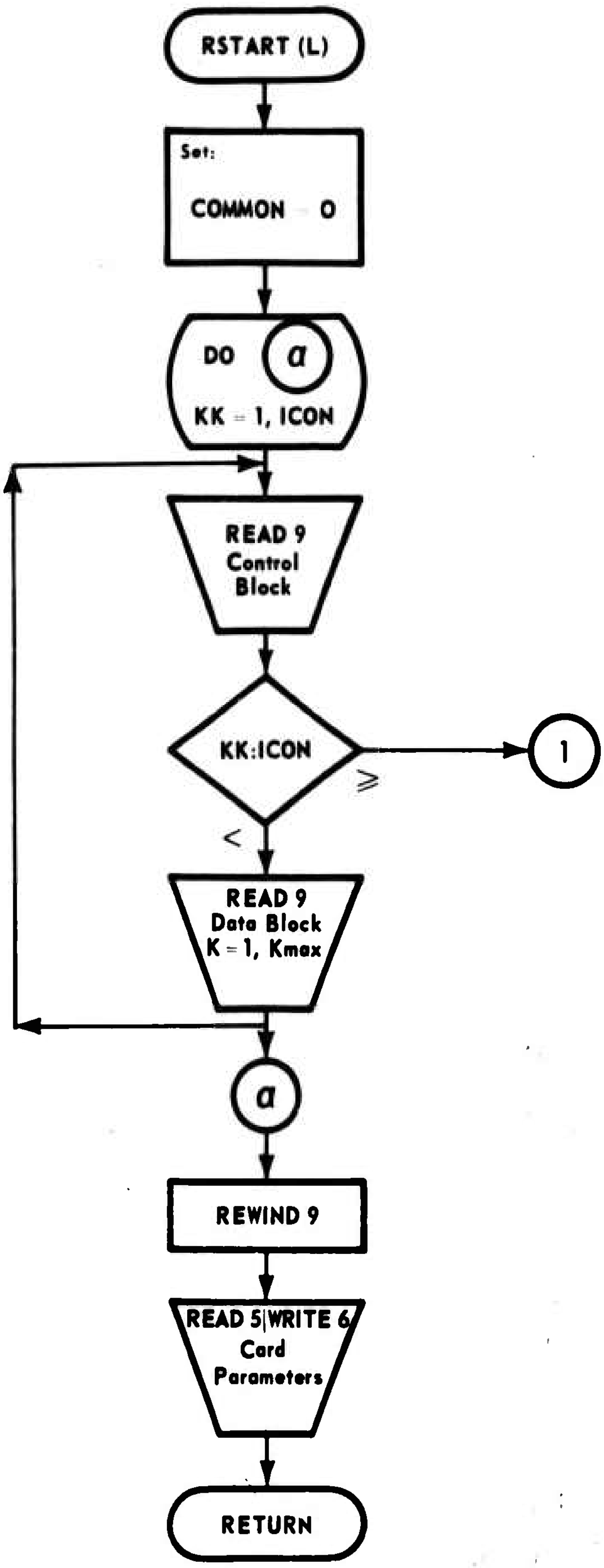
MASS
Compute:
m
m : 0
>
≤
Set:
NEDIT = 1
NSIG = 4
WRITE 6
Error
Mess.
RETURN


NEWU (L)
Compute:
FMSNZ
Compute:
M
Compute:
U
RETURN

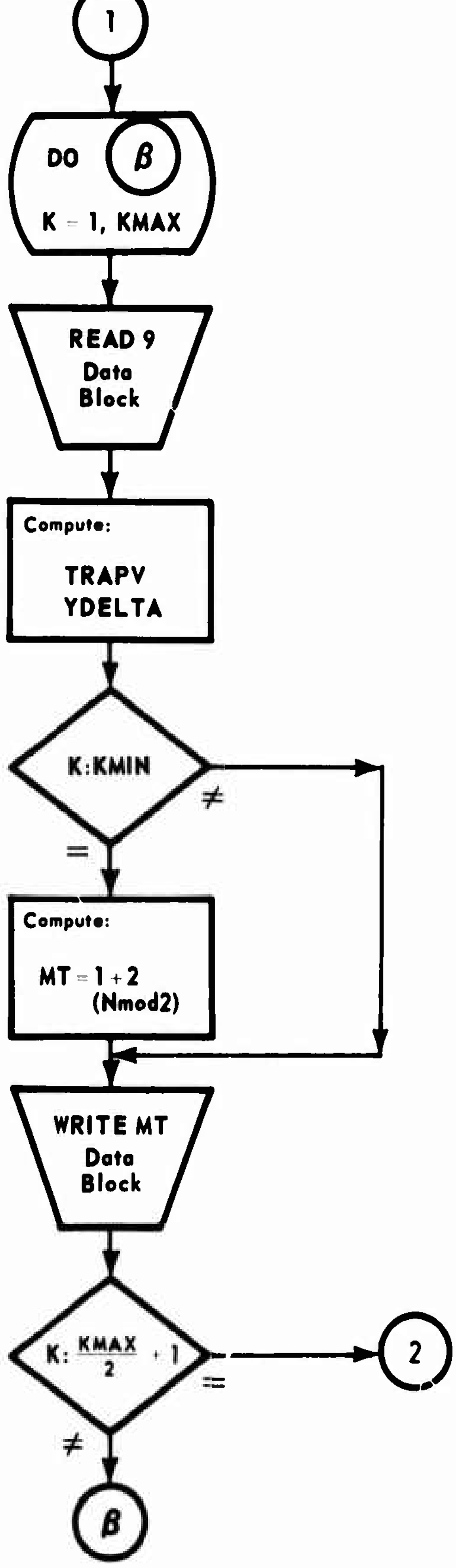

REDGEN
Set:
COMMON
= 0
READ 5
INPUT
Parameters
PROBNO:0
≤
STOP
>
WRITE 6
INPUT
Parameters
Set-Up:
GRID
POINTS
(y, z)
Set-Up:
U
ρ
E
MT
1

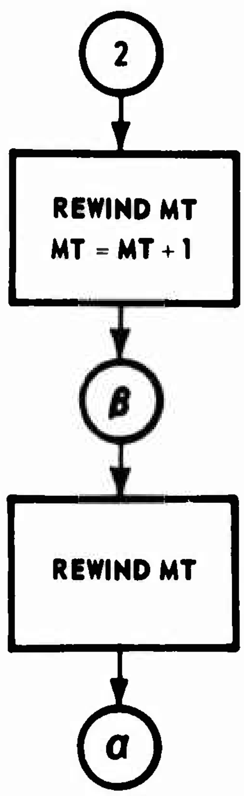

1
Compute:
M
m
Compute:
P
Q
PQ
Sum:
ΣM
Σm
ΣE
WRITE MT
Working
Variables
K: KMAX/2 +1
≠
=
REWIND
MT
MT = MT + 1
2

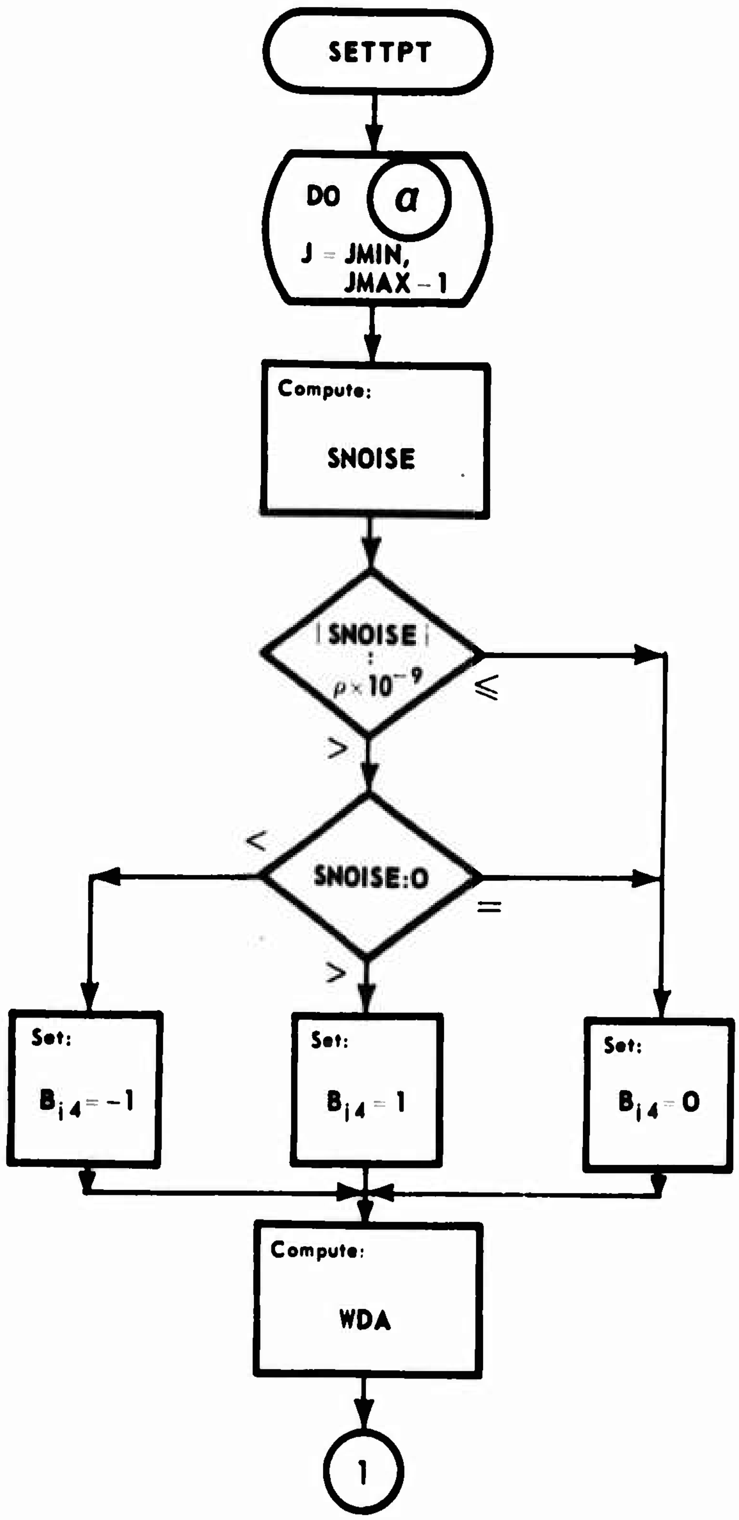

2
KSV_{12}: 0
>
≤
WRITE 6
EDIT
WRITE 6
Σ's
RETURN

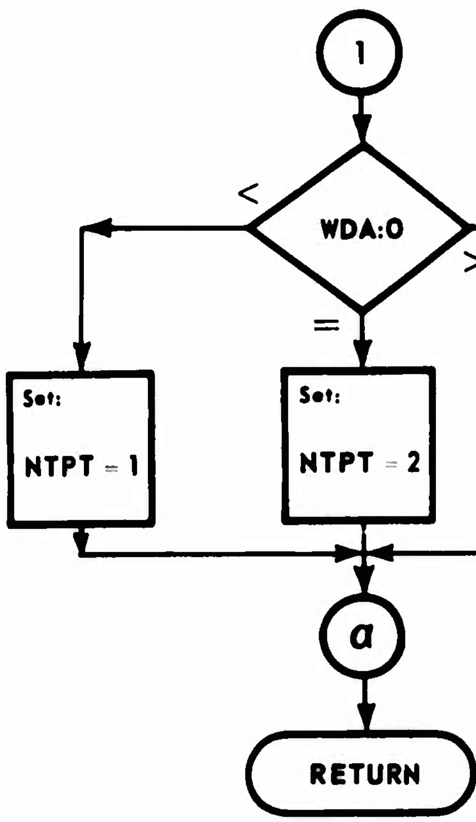


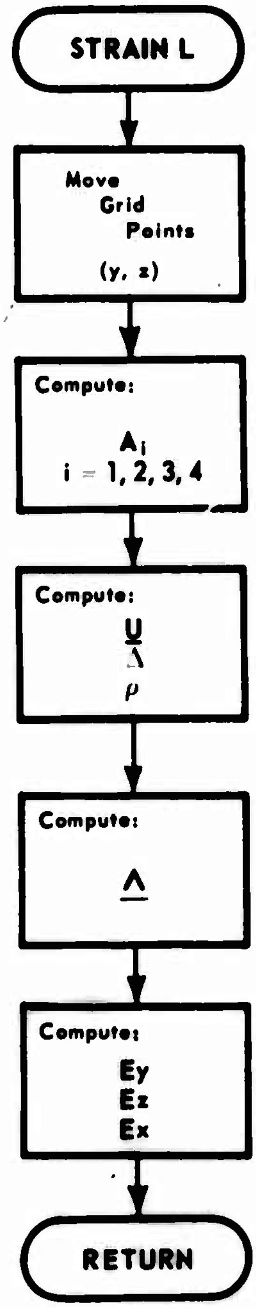
RSTART (L)
Set:
COMMON = 0
DO a
KK = 1, ICON
READ 9
Control
Block
KK:ICON
1
≥
<
READ 9
Data Block
K = 1, Kmax
a
REWIND 9
READ 5|WRITE 6
Card
Parameters
RETURN

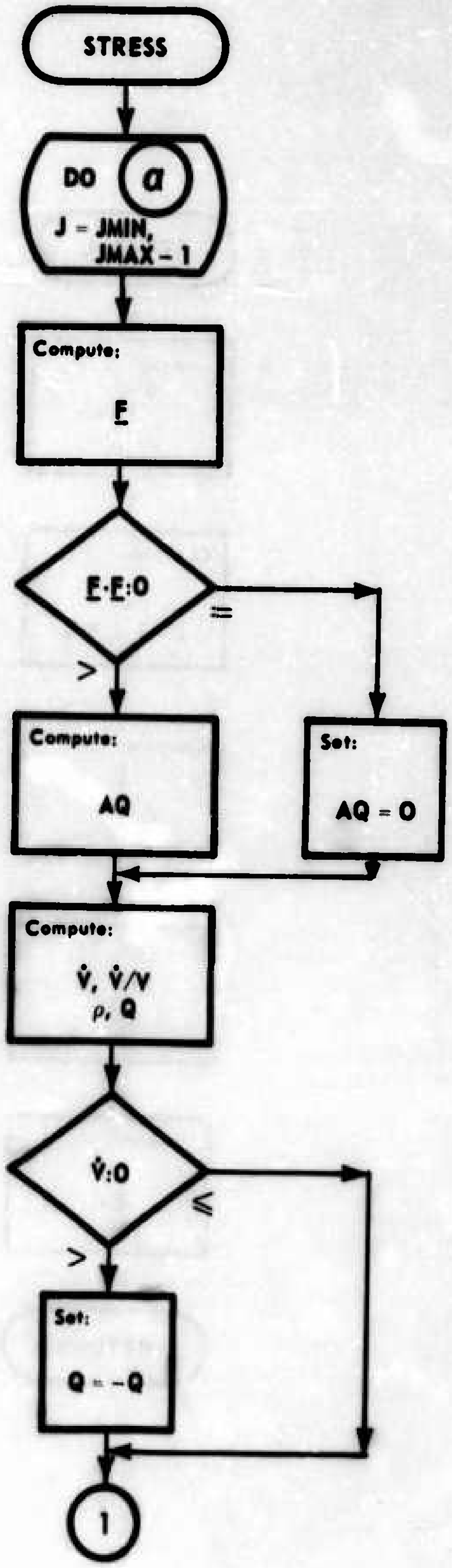

1
DO β
K = 1, KMAX
READ 9
Data
Block
Compute:
TRAPV
YDELTA
K:KMIN
≠
=
Compute:
MT = 1 + 2
(Nmod2)
WRITE MT
Data
Block
K: KMAX/2 + 1
=
2
≠
β

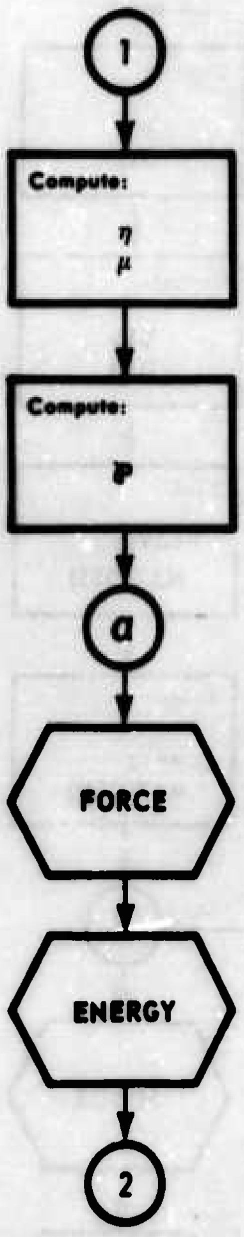

2
REWIND MT
MT = MT + 1
β
REWIND MT
a

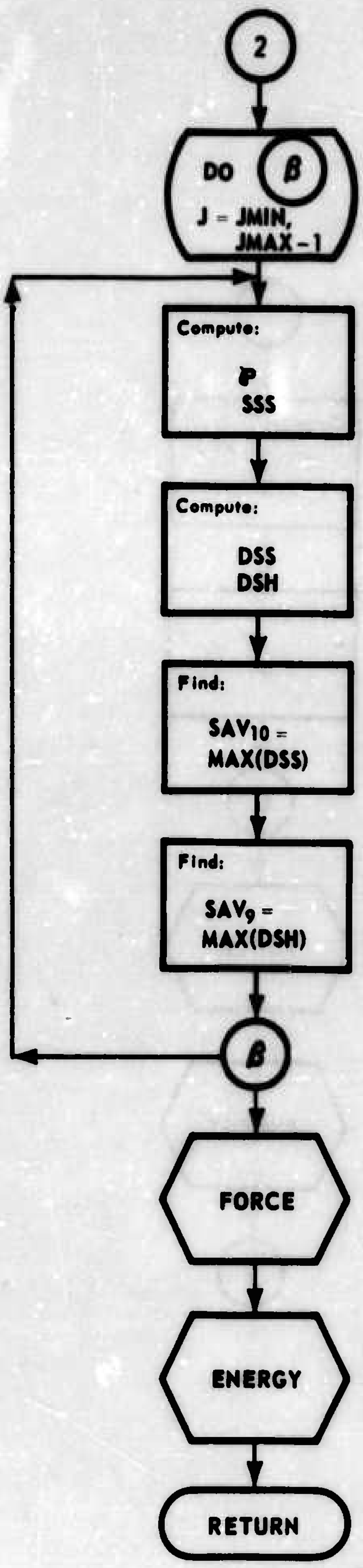

SETTPT
DO a
J = JMIN, JMAX − 1
Compute:
SNOISE
|SNOISE| : ρ × 10⁻⁹
≤
>
<
SNOISE:0
=
>
Set:
B_{i4} = −1
Set:
B_{i4} = 1
Set:
B_{i4} = 0
Compute:
WDA
1

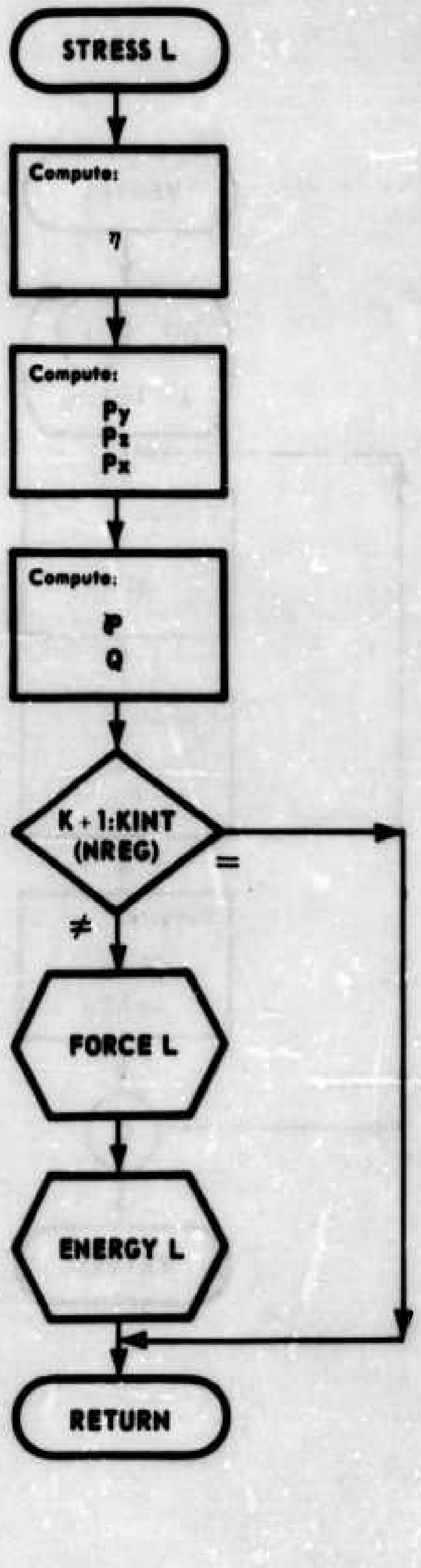

1
WDA:0
<
>
=
Set:
NTPT = 1
Set:
NTPT = 2
Set:
NTPT = 3
a
RETURN

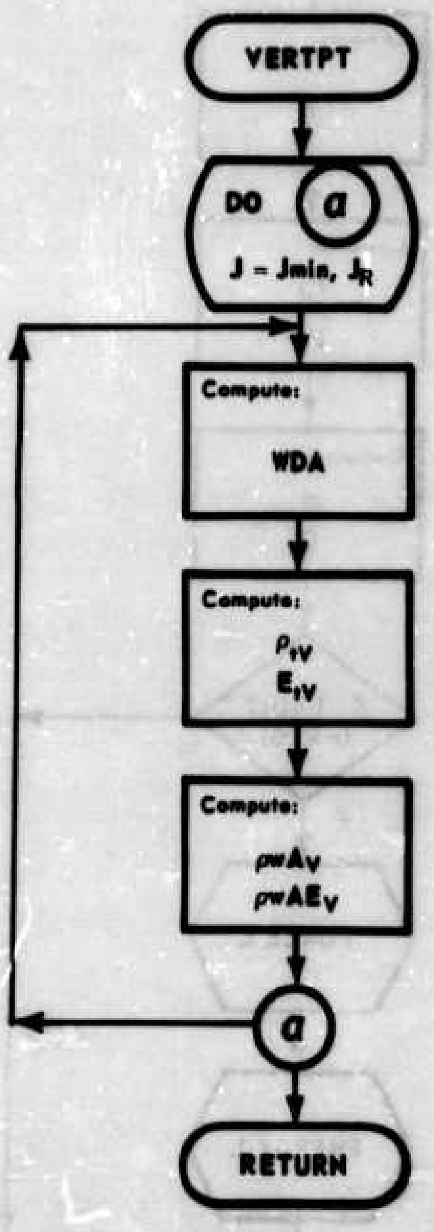

STRAIN L
Move
Grid
Points
(y, z)
Compute:
A
i = 1, 2, 3, 4
Compute:
U
ρ
Compute:
Compute:
Ey
Ez
Ex
RETURN


STRESS
DO a
J = JMIN, JMAX - 1
Compute:
E
E·E:0
=
>
Compute:
AQ
Set:
AQ = 0
Compute:
V̇, V̇/V
ρ, Q
V̇:0
≤
>
Set:
Q = -Q
1


1
Compute:
η
μ
Compute:
P̄
a
FORCE
ENERGY
2


2
DO β
J = JMIN,
JMAX - 1
Compute:
P
SSS
Compute:
DSS
DSH
Find:
SAV10 =
MAX(DSS)
Find:
SAV9 =
MAX(DSH)
β
FORCE
ENERGY
RETURN


STRESS L
Compute:
η
Compute:
Py
Pz
Px
Compute:
P
Q
K + 1:KINT
(NREG)
=
≠
FORCE L
ENERGY L
RETURN


VERTPT
DO a
J = Jmin, JR
Compute:
WDA
Compute:
ρtV
EtV
Compute:
ρwAV
ρwAEV
a
RETURN

APPENDIX V

COMPUTER LISTING

FOR AFTON 2A

```
      PROGRAM A2AEWC(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE3,
     1TAPE9,TAPE10)
      COMMON                NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN, UYLTIN,  UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,       EIN,        RHOIN,      UYIN,      UXIN,       KINT(5),
     A E S(5),    ALFA(5),    BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),    SAV(12),
     4 KSV(24),      YTERM(55),     Y2TERM(55),    TA1(55),       TA2(55),
     5 FMLYR(101),   FMLZR(101),    VACANT(15)
      COMMON                        A(55),         DIL(55),       EPX(55),
     2 EPY(55),      EPZ(55),       FMLYB(55),     FMLYT(55),     FMLZB(55),
     3 FMLZT(55),    LY1(55),       LY2(55),       LZ1(55),       LZ2(55),
     4 PY(55),       PZ(55),        R1H(55),       R2H(55),       R3H(55),
     5 R4H(55),      Z1H(55),       Z2H(55),       Z3H(55),       Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A                 RX(55,5),         RY(55,5),         UNMX(55,5),
     1 UNMY(55,5),     UNPX(55,5),       UNPY(55,5),       FMASNM(55,5),
     2 ENM(55,5),      EN(55,5),         PNM(55,5),        PN(55,5),
     3 PQNMXX(55,5),   PQNMXY(55,5),     PQNMYY(55,5),     PQNXX(55,5),
     4 PQNXY(55,5),    PQNYY(55,5),      RWA3Z(55,5),      RWA1Z(55,5),
     5 RWAE3Z(55,5),   RWAE1Z(55,5),     RH3Z(55,5),       RH1Z(55,5),
     6 E3Z(55,5),      E1Z(55,5),        RHO(55,5),        VOL(55,5),
     7 ETA(55,5),      A1Y(55,5),        A2Y(55,5),        A3Y(55,5),
     8 A4Y(55,5),      A1Z(55,5),        A2Z(55,5),        A3Z(55,5),
     9 A4Z(55,5),      F1Y(55,5),        F2Y(55,5),        F3Y(55,5),
     A F4Y(55,5),      F1Z(55,5),        F2Z(55,5),        F3Z(55,5),
     1 F4Z(55,5),      NTPT(55,5),       FMSNZ(55,5),      FMASN(55,5),
     2 FMNMX(55,5),    FMNMY(55,5),      FMNX(55,5),       FMNY(55,5),
     4 AW1(55,5),      AW2(55,5),        CMASS1(55,5),     CMASS2(55,5),
     5 RXM(55,5),      RYM(55,5),        RXZ(55,5),        RYZ(55,5),
     6 Q11(55,5),      Q12(55,5),        Q22(55,5),        QX(55,5),
     7 P11(55,5),      P12(55,5),        P22(55,5),        PX(55,5),
     8 PQX(55,5),      PQMX(55,5),       VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON          AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
CHANGES
C
C    4       34H REASON-ACTIVITY CHECK ON PRESSURE/)
C    4       34H REASON-TAPE VERSION FOR 6600     /)
C    4       34H REASON-NEW Q DEFINITION AND TRANS/)
C
C
C*********NOTE
C
C              STRAIN IS COUNTER CLOCK WISE,FORCE CLOCK WISE
C
C              IN STRAIN AAB IS 1./AAB
C
C
```

```
      WRITE(6,1)
1     FORMAT(36H1AFTON 2D AXIALLY SYMMETRIC EULERIAN//
   2        34H DATE OF LAST CHANGE       01-05-65//
   3        34H TIME                          1130//
   4        34H REASON-TIME STEP SHOCK ONLY      /)
      CALL AFTON
      STOP
      END
```

```
      SUBROUTINE ACTIVE
      COMMON               NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN, UYLTIN,  UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,        EIN,        RHOIN,       UYIN,       UXIN,        KINT(5),
     A E S(5),    ALFA(5),    BIG A(5), BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),     SAV(12),
     4 KSV(24),       YTERM(55),      Y2TERM(55),     TA1(55),       TA2(55),
     5 FMLYR(101),    FMLZR(101),     VACANT(15)
      COMMON                          A(55),          DIL(55),       EPX(55),
     2 EPY(55),       EPZ(55),        FMLYB(55),      FMLYT(55),     FMLZB(55),
     3 FMLZT(55),     LY1(55),        LY2(55),        LZ1(55),       LZ2(55),
     4 PY(55),        PZ(55),         R1H(55),        R2H(55),       R3H(55),
     5 R4H(55),       Z1H(55),        Z2H(55),        Z3H(55),       Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                  RX(55,5),         RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),       UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),         PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),     PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),      RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),     RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),        RHO(55,5),         VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),        A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),        A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),        F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),        F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),       FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),      FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),        CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),       RYM(55,5),        RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),        Q22(55,5),         QX(55,5),
     7 P11(55,5),       P12(55,5),        P22(55,5),         PX(55,5),
     8 PQX(55,5),       PQMX(55,5),       VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
C*****
      IF(KC.EQ.KMAX)GO TO 20
      L=LX1
      L2=LX2
      DO 4 J=JMIN,JMAX
      RWA1Z(J,L2)=0.
    4 RWAE1Z(J,L2)=0.
    5 DO 10 J=JMIN,JMAX
      RWA3Z(J,L)=0.
      RWAE3Z(J,L)=0.
      UNPX(J,L)=UNMX(J,L)
      UNPY(J,L)=UNMY(J,L)
      FMASN(J,L)=FMASNM(J,L)
      EN(J,L)=ENM(J,L)
      PN(J,L)=PNM(J,L)
      PQNXX(J,L)=PQNMXX(J,L)
      PQNXY(J,L)=PQNMXY(J,L)
      PQNYY(J,L)=PQNMYY(J,L)
      PQX(J,L)=PQMX(J,L)
      F3Y(J,L)=0.
```

```
      F3Z(J,L)=0.
      F4Y(J,L)=0.
      F4Z(J,L)=0.
      FMNX(J,L)=FMMMX(J,L)
10    FMNY(J,L)=FMMMY(J,L)
      FMLYR(KC)=0.
      RETURN
20    L=LX2
      GO TO 5
      END
```

```
      SUBROUTINE AFTON
      COMMON              NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,   TIME,     SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI,  SIETPT,   SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,   SMASSI,   SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,    KTOP,     MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,      CUT1,     CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN,  UYLTIN,   UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,    JMAX,     KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,        EIN,         RHOIN,      UYIN,        UXIN,         KINT(5),
     A E S(5),    ALFA(5),     BIG A(5), BIG B(5),    RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),     QCON(5),     SAV(12),
     4 KSV(24),      YTERM(55),       Y2TERM(55),     TA1(55),       TA2(55),
     5 FMLYR(101),   FMLZR(101),      VACANT(15)
      COMMON                          A(55),          DIL(55),       EPX(55),
     2 EPY(55),      EPZ(55),         FMLYB(55),      FMLYT(55),     FMLZB(55),
     3 FMLZT(55),    LY1(55),         LY2(55),        LZ1(55),       LZ2(55),
     4 PY(55),       PZ(55),          R1H(55),        R2H(55),       R3H(55),
     5 R4H(55),      Z1H(55),         Z2H(55),        Z3H(55),       Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A                RX(55,5),           RY(55,5),           UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),         UNPY(55,5),         FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),           PNM(55,5),          PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),       PQNMYY(55,5),       PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),        RWA3Z(55,5),        RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),       RH3Z(55,5),         RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),          RHO(55,5),          VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),          A2Y(55,5),          A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),          A2Z(55,5),          A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),          F2Y(55,5),          F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),          F2Z(55,5),          F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),         FMSNZ(55,5),        FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),        FMNX(55,5),         FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),          CMASS1(55,5),       CMASS2(55,5),
     5 RXM(55,5),     RYM(55,5),          RXZ(55,5),          RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),          Q22(55,5),          QX(55,5),
     7 P11(55,5),     P12(55,5),          P22(55,5),          PX(55,5),
     8 PQX(55,5),     PQMX(55,5),         VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON    AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      NDMP=0
      REWIND 9
      REWIND 10
4     REWIND 1
      REWIND 3
      READ(5,1)ICON
      IF(ICON.EQ.0) GO TO 20
   10 CALL RSTART
      NSIG=1
      GO TO 32
   20 CALL REDGEN
      GO TO (30,4),NMASS
   30 NSIG=1
31    TIME=TIME+DTNM
```

```
      N=N+1
32    SAV(9)=0.
      SAV(10)=0.
      NDPA=0
      NEDIT=0
C-----TEST FOR END OF PROBLEM
   33 IF(N.GE.MAXN) GO TO 65
      IF(TIME.GE.TMAX) GO TO 65
C-----TEST FOR FORCE OFF
      IF(SENSE SWITCH 1)85,40
C-----TEST FOR FORCE TO NEXT PROBLEM
   40 IF(SENSE SWITCH 2 ) 86,50
C-----TEST FOR EDIT
   50 IF(KSV(4).GT.0) GO TO 90
      IF(KSV(5).GT.0) GO TO 95
   51 IF(SAV(1).GT.0) GO TO 100
C-----TEST FOR DUMP
   52 IF(KSV(8).GT.0) GO TO 105
   53 IF(SAV(3).GT.0) GO TO 110
C-----FOR GENERAL COORDINATE SYSTEM
  55  IF (MOTION.EQ.2)  GO TO 56
      CALL FLOW
      GO TO 57
  56  CALL FLOW L
  57  CONTINUE
C-----TO CHANGE DT
      KSV(14)=KSV(18)
      KSV(15)=KSV(19)
      KSV(16)=KSV(20)
      KSV(17)=KSV(21)
      SAV(7)=SAV(9)
      SAV(8)=SAV(10)
      IF(SAV(9).GT.SAV(10)) GO TO 60
      IF(SAV(10).EQ.0) GO TO 62
      DTNMN=1./(4.*SQRT(SAV(10)))
      GO TO 61
60    DTNMN=1./(4.*SQRT(SAV(9)))
61    STEPMAX=1.05*DTNM
      IF(DTNMN.GT.STEPMAX)DTNMN=STEPMAX
      DTNM=DTNMN
      DTNMP5=.5*DTNM
      DTNM2=2.*DTNM
      CUT1=DTNM*CUTOFF
      CUT2=DTNM2*CUTOFF
      RDTNM=1./DTNM
62    GO TO (31,115,4,4),NSIG
   65 NSIG=3
      IF(KSV(2).EQ.0) GO TO 75
   70 NDPA=1
   75 IF(KSV(1).EQ.0) GO TO 80
   76 NEDIT=1
      GO TO 55
   80 NEDIT=-1
      GO TO 55
   85 NSIG=2
      GO TO 70
   86 NSIG=3
      GO TO 70
   90 KSV(4)=KSV(4)-1
      GO TO 102
   95 IF(N.LT.KSV(6)) GO TO 51
```

```
      KSV(6)=KSV(6)+KSV(5)
      GO TO 101
100   IF((TIME+.5*DTNM).LT.SAV(2))GO TO 52
      SAV(2)=SAV(2)+SAV(1)
101   KSV(4)=KSV(7)-1
102   NEDIT=1
      GO TO 52
105   IF(N.LT.KSV(9)) GO TO 53
      KSV(9)=KSV(9)+KSV(8)
      GO TO 111
110   IF((TIME+.5*DTNM).LT.SAV(4)) GO TO 55
      SAV(4)=SAV(4)+SAV(3)
111   NDPA =1
      GO TO 55
115   END FILE 10
      REWIND 10
      STOP
    1 FORMAT(I6)
    2 FORMAT(1H0,E16.7/)
      END
```

```
      SUBROUTINE BOUND
      COMMON           NREG,   RDTNM,  MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN, UYTIN,  UYRTIN, UXLTIN, UXTIN,  UXRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,       EIN,      RHOIN,      UYIN,       UXIN,      KINT(5),
     A E S(5),   ALFA(5),  BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5)
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),  QCON(5),   SAV(12),
     4 KSV(24),      YTERM(55),   Y2TERM(55),  TA1(55),      TA2(55),
     5 FMLYR(101),  FMLZR(101),  VACANT(15)
      COMMON                     A(55),      DIL(55),      EPX(55),
     2 EPY(55),      EPZ(55),     FMLYB(55),  FMLYT(55),    FMLZB(55),
     3 FMLZT(55),    LY1(55),     LY2(55),    LZ1(55),      LZ2(55),
     4 PY(55),       PZ(55),      R1H(55),    R2H(55),      R3H(55),
     5 R4H(55),      Z1H(55),     Z2H(55),    Z3H(55),      Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A               RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),   UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),    EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5), PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),  PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5), RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),    E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),    A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),    A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),    F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),    F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),    NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),  FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),    AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),    RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),    Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),    P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),    PQMX(55,5),      VO(55,5)
      COMMON   ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,     NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
      COMMON      AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      IF(KC.GT.1) GO TO 50
10    J=JMIN
15    CALL HORTPT
      WX=UXLBIN
      WY=UYLBIN
      RH1Z(J,1)=RHOIN
      E1Z(J,1)=EIN
      TRAP=.5*(RX(J,1)+RX(J+1,1))
      AX=RY(J+1,1)-RY(J,1)
      AY=RX(J,1)-RX(J+1,1)
      RWA1Z(J,1)=RH1Z(J,1)*TRAP*(WX*AX+WY*AY)
      RWAE1Z(J,1)=RWA1Z(J,1)*E1Z(J,1)
      FMASN(J,1)=FMASNM(J,1)+(RWA3Z(J,1)-RWA3Z(J+1,1)-RWA1Z(J,1)+
     2           RWA1Z(J,2))*DTNM
```

```
      IF(FMASN(J,1))16,16,17
16    NEDIT=1
      NSIG=4
      WRITE(6,200)J,FMASN(J,1)
17    GO TO(22,20,21),MOTION
20    FMASN(J,1)=FMASNM(J,1)
21    RX(J,1)=RXM(J,1)+UNMX(J,1)*DTNM
      RY(J,1)=RYM(J,1)+UNMY(J,1)*DTNM
22    JL=J+1
      DO 40 J=JL,JR
      GO TO (24,27,24),MOTION
24    WX=UXBIN
      WY=UYBIN
      RH1Z(J,1)=RHOIN
      E1Z(J,1)=EIN
      TRAP=.5*(RX(J,1)+RX(J+1,1))
      AX=RY(J+1,1)-RY(J,1)
      AY=RX(J,1)-RX(J+1,1)
      RWA1Z(J,1)=RH1Z(J,1)*TRAP*(WX*AX+WY*AY)
      RWAE1Z(J,1)=RWA1Z(J,1)*E1Z(J,1)
      FMASN(J,1)=FMASNM(J,1)+(RWA3Z(J,1)-RWA3Z(J+1,1)-RWA1Z(J,1)+
     2            RWA1Z(J,2))*DTNM
      IF(FMASN(J,1))25,25,26
25    NEDIT=1
      NSIG=4
      WRITE(6,200)J,FMASN(J,1)
26    GO TO (40,27,28),MOTION
27    FMASN(J,1)=FMASNM(J,1)
28    RX(J,1)=RXM(J,1)+UNMX(J,1)*DTNM
      RY(J,1)=RYM(J,1)+UNMY(J,1)*DTNM
   40 CONTINUE
      J=JMAX
      GO TO (42,41,41),MOTION
41    RX(J,1)=RXM(J,1)+UNMX(J,1)*DTNM
      RY(J,1)=RYM(J,1)+UNMY(J,1)*DTNM
42    CALL STRESS
      J=JMIN
      UNPX(J,1)=UXLBIN
      UNPY(J,1)=UYLBIN
      CMASS1(J,1)=AW1(J,1)*YTERM(J)*RHO(J,1)
      CMASS2(J,1)=AW2(J,1)*Y2TERM(J)*RHO(J,1)
      FMSNZ(J,1)=.5*CMASS2(J,1)
      FMNX(J,1)=0.
      FMNY(J,1)=FMSNZ(J,1)*   (UNMY(J,1)+UNPY(J,1))
      JL=J+1
      DO 45 J=JL,JR
      UNPX(J,1)=UXBIN
      UNPY(J,1)=UYBIN
      CMASS1(J,1)=AW1(J,1)*YTERM(1)*RHO(J,1)
      CMASS2(J,1)=AW2(J,1)*Y2TERM(1)*RHO(J,1)
      FMSNZ(J,1)=.5*(CMASS1(J-1,1)+CMASS2(J,1))
      FMNX(J,1)=FMSNZ(J,1)     *(UNMX(J,1)+UNPX(J,1))
45    FMNY(J,1)=FMSNZ(J,1)     *(UNMY(J,1)+UNPY(J,1))
      J=JMAX
      UNPX(J,1)=0.0
      UNPY(J,1)=UYRBIN
      FMSNZ(J,1)=.5*CMASS1(J-1,1)
      FMNX(J,1)=0.
      FMNY(J,1)=FMSNZ(J,1)     *(UNMY(J,1)+UNPY(J,1))
46    CALL CONSCK
      RETURN
```

```
   50 L=LX1
      L2=LX2
      L5=LX5
      DO 500 J=JMIN,JMAX
      RHO(J,L2)=0.0
      PN (J,L2)=0.0
      FMASN(J,L2)=0.0
      ETA(J,L2)=0.0
      EN (J,L2)=0.0
      RH3Z (J,L2)=0.0
      RWA3Z(J,L2)=0.0
      E3Z  (J,L2)=0.0
 500  RWAE3Z(J,L2)=0.0
 501  CALL HORTPT
      DO 502 J=JMIN,JR
      WX=UNMX(J,L2)+UNMX(J+1,L2)
      WY=UNMY(J,L2)+UNMY(J+1,L2)
      RH1Z(J,L2)=RHO(J,L)
      E1Z(J,L2)=ENM(J,L)
      TRAP=.25*(RX(J,L2)+RX(J+1,L2))
      AX=RY(J+1,L2)-RY(J,L2)
      AY=RX(J,L2)-RX(J+1,L2)
      RWA1Z(J,L2)=RH1Z(J,L2)*TRAP*(WX*AX+WY*AY)
 502  RWAE1Z(J,L2)=RWA1Z(J,L2)*E1Z(J,L2)
      CALL MASS
 504  CALL STRESS
      CALL NEWU
      CALL CONSCK
      J=JMIN
      KC=KMAX
 505  UNPX(J,L2)=UXLTIN
      UNPY(J,L2)=UYLTIN
      FMSNZ(J,L2)=.5*CMASS2(J,L)
      FMNX(J,L2)=0.0
      FMNY(J,L2)=FMSNZ(J,L2)    *(UNMY(J,L2)+UNPY(J,L2))
 51   JL=J+1
      DO 80 J=JL,JR
 56   UNPX(J,L2)=UXTIN
      UNPY(J,L2)=UYTIN
      FMSNZ(J,L2)=.5*(CMASS1(J-1,L)+CMASS2(J,L))
   60 FMNX(J,L2)=FMSNZ(J,L2)    *(UNMX(J,L2)+UNPX(J,L2))
      FMNY(J,L2)=FMSNZ(J,L2)    *(UNMY(J,L2)+UNPY(J,L2))
   80 CONTINUE
   90 J=JMAX
      UNPX(J,L2)=0.
      UNPY(J,L2)=UYRTIN
      FMSNZ(J,L2)=.5*CMASS1(J-1,L)
      FMNX(J,L2)=0.0
      FMNY(J,L2)=FMSNZ(J,L2)    *(UNMY(J,L2)+UNPY(J,L2))
      CALL CONSCK
  100 RETURN
 200  FORMAT(7HOFOR J=,I6,8H AND K+2,10H THE MASS=,E17.9,9H IN ERROR)
      END
```

```
      SUBROUTINE CONSCK
      COMMON              NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,      SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT,    SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI,    SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,      MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,      CUT2,   UYLBIN, UYBIN,  UYRBIN, UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN,    UYTIN,  UYRTIN, UXLTIN, UXTIN,  UXRTIN, KTM,
     8 JMIN,   JMAX,      KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,          EIN,          RHOIN,       UYIN,       UXIN,       KINT(5),
     A E S(5),      ALFA(5),      BIG A(5),    BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5),   TINY B(5),    R ZERO(5),BETA(5),       QCON(5),    SAV(12),
     4 KSV(24),         YTERM(55),       Y2TERM(55),      TA1(55),         TA2(55),
     5 FMLYR(101),      FMLZR(101),      VACANT(15)
      COMMON                             A(55),           DIL(55),         EPX(55),
     2 EPY(55),         EPZ(55),         FMLYB(55),       FMLYT(55),       FMLZB(55),
     3 FMLZT(55),       LY1(55),         LY2(55),         LZ1(55),         LZ2(55),
     4 PY(55),          PZ(55),          R1H(55),         R2H(55),         R3H(55),
     5 R4H(55),         Z1H(55),         Z2H(55),         Z3H(55),         Z4H(55),
     6 U2(55,2),        B(55,4)
      COMMON
     A                      RX(55,5),          RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),          UNPX(55,5),        UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),           EN(55,5),          PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),        PQNMXY(55,5),      PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),         PQNYY(55,5),       RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),        RWAE1Z(55,5),      RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),           E1Z(55,5),         RHO(55,5),         VOL(55,5),
     7 ETA(55,5),           A1Y(55,5),         A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),           A1Z(55,5),         A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),           F1Y(55,5),         F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),           F1Z(55,5),         F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),           NTPT(55,5),        FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),         FMNMY(55,5),       FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),           AW2(55,5),         CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),           RYM(55,5),         RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),           Q12(55,5),         Q22(55,5),         QX(55,5),
     7 P11(55,5),           P12(55,5),         P22(55,5),         PX(55,5),
     8 PQX(55,5),           PQMX(55,5),        VO(55,5)
      COMMON    ICON,    LINCT,   LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,   NMASS,  NDMP
      COMMON          AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
      DIMENSION USQ(2)
C*****
      IF(KC.GT.1) GO TO 10
      L=LX1
      L2=LX2
      L5=LX5
      J=JMIN
      JL=J+1
      JLEFT=1
      JRIGHT=2
      TFXY=0.
      TFXZ=0.
      STEM=SENERI
      KL=1
      KU=2
```

```
      SUMIE=EN(J,1)*FMASN(J,1)
      U2(J,1)=UNMX(J,1)*UNPX(J,1)+UNMY(J,1)*UNPY(J,1)
      SUMKE=0.
      SMOMY=FMNX(J,1)
      SMOMZ=FMNY(J,1)
      SKETPT=0.
      SMYTPT=0.
      SMZTPT=0.
      GO TO (1,2,1),MOTION
1     SMASS=FMASN(J,1)
      IF(SMASS.LT.0) WRITE(6,110) N,J,KC,(FMASN(I,L),FMASNM(I,L)
     2,RWA1Z(I,L),RWA1Z(I,L2),RWA3Z(I,L),RWA3Z(I+1,L),I=JMIN,JMAX)
      SMSTPT=RWA1Z(J,1)
      SIETPT=RWAE1Z(J,1)
      USQ(JLEFT)=UNMX(J,1)**2+UNMY(J,1)**2
      FXMST = 0. 25*(RWA1Z(J,2) + RWA1Z(J,1))*TA2(J)
      FXTX = FXMST     *(UNMX(J,2) + UNMX(J,1))
      FXTY = FXMST     *(UNMY(J,2) + UNMY(J,1))
      FXMSB =TA2(J)*RWA1Z(J,1)
      FXBX = FXMSB*UNMX(J,1)
      FXBY = FXMSB*UNMY(J,1)
      FXMSL = 0.5*RWA3Z(J,1)
      FXLX = FXMSL*UNMX(J,1)
      FXLY = FXMSL*UNMY(J,1)
      FXMSR = 0.125*(RWA3Z(J,1) + RWA3Z(J+1,1))
      FXRX = FXMSR     *(UNMX(J,1) + UNMX(J+1,1))
      FXRY = FXMSR     *(UNMY(J,1) + UNMY(J+1,1))
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
2     FMLYB(J)=-F2Y(J,1)-TFXY
      FMLZB(J)=(FMNY(J,1)-FMNMY(J,1))*RDTNM-F2Z(J,L)-TFXZ
      FIMPY=FMLYB(J)
      FIMPZ=FMLZB(J)
      WORK=FMLYB(J)*UNMX(J,1)+FMLZB(J)*UNMY(J,1)
      DO 5  J=JL,JR
      SUMIE=SUMIE+EN(J,1)*FMASN(J,1)
      U2(J,1)=UNMX(J,1)*UNPX(J,1)+UNMY(J,1)*UNPY(J,1)
      SMOMY=SMOMY+FMNX(J,1)
      SMOMZ=SMOMZ+FMNY(J,1)
      GO TO(3,4,3),MOTION
3     SMASS=SMASS+FMASN(J,1)
      IF(SMASS.LT.0) WRITE(6,110) N,J,KC,(FMASN(I,L),FMASNM(I,L)
     2,RWA1Z(I,L),RWA1Z(I,L2),RWA3Z(I,L),RWA3Z(I+1,L),I=JMIN,JMAX)
      SMSTPT=SMSTPT+RWA1Z(J,1)
      SIETPT=SIETPT+RWAE1Z(J,1)
      USQ(JRIGHT)=UNMX(J,1)**2+UNMY(J,1)**2
      SKETPT=SKETPT+RWA1Z(J-1,1)*(USQ(JLEFT)+USQ(JRIGHT))
      SMYTPT=SMYTPT+RWA1Z(J-1,1)*(UNMX(J-1,1)+UNMX(J,1))
      SMZTPT=SMZTPT+RWA1Z(J-1,1)*(UNMY(J-1,1)+UNMY(J,1))
      JLEFT=JRIGHT
      JRIGHT=MOD(JLEFT,2)+1
      FXMST=.25*(TA1(J-1)*(RWA1Z(J-1,2)+RWA1Z(J-1,1))+TA2(J)*
     2 (RWA1Z(J,2)+RWA1Z(J,1)))
      FXTX = FXMST     *(UNMX(J,2) + UNMX(J,1))
      FXTY = FXMST     *(UNMY(J,2) + UNMY(J,1))
      FXMSB=TA1(J-1)*RWA1Z(J-1,1)+TA2(J)*RWA1Z(J,1)
      FXBX = FXMSB*UNMX(J,1)
      FXBY = FXMSB*UNMY(J,1)
      FXLX = FXRX
      FXLY = FXRY
      FXMSR = 0.125*(RWA3Z(J,1) + RWA3Z(J+1,1))
```

```
      FXRX = FXMSR    *(UNMX(J,1) + UNMX(J+1,1))
      FXRY = FXMSR    *(UNMY(J,1) + UNMY(J+1,1))
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
4     FMLYB(J)=(FMNX(J,1)-FMNMX(J,1))*RDTNM-F1Y(J-1,1)-F2Y(J,1)-TFXY
      FMLZB(J)=(FMNY(J,1)-FMNMY(J,1))*RDTNM-F1Z(J-1,1)-F2Z(J,1)-TFXZ
      FIMPY=FIMPY+FMLYB(J)
      FIMPZ=FIMPZ+FMLZB(J)
5     WORK=WORK+FMLYB(J)*UNMX(J,1)+FMLZB(J)*UNMY(J,1)
      J=JMAX
      U2(J,1)=UNMX(J,1)*UNPX(J,1)+UNMY(J,1)*UNPY(J,1)
      SMOMY=SMOMY+FMNX(J,1)
      SMOMZ=SMOMZ+FMNY(J,1)
      GO TO (6,7,6),MOTION
6     USQ(JRIGHT)=UNMX(J,1)**2+UNMY(J,1)**2
      SKETPT=SKETPT+RWA1Z(J-1,1)*(USQ(JLEFT)+USQ(JRIGHT))
      SMYTPT=SMYTPT+RWA1Z(J-1,1)*(UNMX(J-1,1)+UNMX(J,1))
      SMZTPT=SMZTPT+RWA1Z(J-1,1)*(UNMY(J-1,1)+UNMY(J,1))
      FXMST=. 25*(RWA1Z(J-1,2)+RWA1Z(J-1,1))*TA1(J-1)
      FXTX=FXMST*(UNMX(J,2)+UNMX(J,1))
      FXTY=FXMST*(UNMY(J,2)+UNMY(J,1))
      FXMSB=   RWA1Z(J-1,1) *TA1(J-1)
      FXBX=FXMSB*UNMX(J,1)
      FXBY=FXMSB*UNMY(J,1)
      FXLX=FXRX
      FXLY=FXRY
      FXMSR=.5*RWA3Z(J,1)
      FXRX=FXMSR*UNMX(J,1)
      FXRY=FXMSR*UNMY(J,1)
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
7     FMLYB(J)=-F1Y(J-1,1)-TFXY
      FMLZB(J)=(FMNY(J,L)-FMNMY(J,1))*RDTNM-F1Z(J-1,1)-TFXZ
      FIMPY=FIMPY+FMLYB(J)
      FIMPZ=FIMPZ+FMLZB(J)
      WORK=WORK+FMLYB(J)*UNMX(J,1)+FMLZB(J)*UNMY(J,1)
      GO TO 100
10    IF(KC.EQ.KMAX) GO TO 39
      L=LX1
      L2=LX2
      L5=LX5
      J=JMIN
      JL=JMIN+1
      JLEFT=1
      JRIGHT=2
      TXXY=0
      TXXZ=0
      SUMIE=SUMIE+EN(J,L)*FMASN(J,L)
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      GO TO(15,20,15),MOTION
15    SMASS=SMASS+FMASN(J,L)
      IF(SMASS.LT.0) WRITE(6,110) N,J,KC,(FMASN(I,L),FMASNM(I,L)
     2,RWA1Z(I,L),RWA1Z(I,L2),RWA3Z(I,L),RWA3Z(I+1,L),I=JMIN,JMAX)
20    IF((KC.LT.KBOT).OR.(KC.GT.KTOP))GO TO 25
      FXMST = 0. 25*(RWA1Z(J,L) + RWA1Z(J,L2 ))*TA2(J)
      FXTX = FXMST    *(UNMX(J,L) + UNMX(J,L2 ))
      FX,Y = FXMST    *(UNMY(J,L) + UNMY(J,L2 ))
      FXMSB = 0. 25*(RWA1Z(J,L) + RWA1Z(J,L5 ))*TA2(J)
      FXBX = FXMSB    *(UNMX(J,L) + UNMX(J,L5 ))
```

```
      FXBY = FXMSB     *(UNMY(J,L) + UNMY(J,L5 ))
      FXMSL = 0.5*(RWA3Z(J,L) + RWA3Z(J,L5 ))
      FXLX = FXMSL*UNMX(J,L)
      FXLY = FXMSL*UNMY(J,L)
      FXMSR = .125*(RWA3Z(J,L) + RWA3Z(J+1,L) + RWA3Z(J,L5 ) +
     1 RWA3Z(J+1,L5 ))
      FXRX = FXMSR     *(UNMX(J,L) + UNMX(J+1,L))
      FXRY = FXMSR     *(UNMY(J,L) + UNMY(J+1,L))
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
      WRITE(6,108)
      STOP
25    DO 34 J=JL,JR
      SUMIE=SUMIE+EN(J,L)*FMASN(J,L)
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SUMKE=SUMKE+.5*(CMASS1(J-1,L5)*(U2(J,KL)+U2(J,KU))+CMASS2(J-1,L5)*
     2      (U2(J-1,KL)+U2(J-1,KU)))
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      GO TO(30,34,30),MOTION
30    SMASS=SMASS+FMASN(J,L)
      IF(SMASS.LT.0) WRITE(6,110) N,J,KC,(FMASN(I,L),FMASNM(I,L)
     2,RWA1Z(I,L),RWA1Z(I,L2),RWA3Z(I,L),RWA3Z(I+1,L),I=JMIN,JMAX)
34    CONTINUE
35    J=JMAX
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SUMKE=SUMKE+.5*(CMASS1(J-1,L5)*(U2(J,KL)+U2(J,KU))+CMASS2(J-1,L5)*
     2      (U2(J-1,KL)+U2(J-1,KU)))
      KL=KU
      KU=MOD(KL,2)+1
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      FIMPY=FIMPY+FMLYR(KC)
      FIMPZ=FIMPZ+FMLZR(KC)
      WORK=WORK+FMLYR(KC)*UNMX(J,L)+FMLZR(KC)*UNMY(J,L)
      GO TO 100
39    L=LX2
      L5=LX1
      J=JMIN
      JL=JMIN+1
      JLEFT=1
      JRIGHT=2
      TXXY=0
      TXXZ=0
40    U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      GO TO(45,50,45),MOTION
45    SMSTPT=SMSTPT-RWA1Z(J,L)
      SIETPT=SIETPT-RWAE1Z(J,L)
      USQ(JLEFT)=UNMX(J,L)**2+UNMY(J,L)**2
      FXMST=TA2(J)*RWA1Z(J,L)
      FXTX=FXMST*UNMX(J,L)
      FXTY=FXMST*UNMY(J,L)
      FXMSB=. 25*(RWA1Z(J,L)+RWA1Z(J,L5 ))*TA2(J)
      FXBX=FXMSB      *(UNMX(J,L)+UNMX(J,L5 ))
      FXBY=FXMSB      *(UNMY(J,L)+UNMY(J,L5 ))
      FXMSL=0.5*RWA3Z(J,L5 )
      FXLX=FXMSL*UNMX(J,L)
      FXLY=FXMSL*UNMY(J,L)
      FXMSR=.125*(RWA3Z(J,L5 )+RWA3Z(J+1,L5 ))
```

```
      FXRX=FXMSR     *(UNMX(J,L)+UNMX(J+1,L))
      FXRY=FXMSR     *(UNMY(J,L)+UNMY(J+1,L))
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
50    FMLYT(J)=-F3Y(J,L5)-TFXY
      FMLZT(J)=(FMNY(J,L)-FMNMY(J,L ))*RDTNM-F3Z(J,L5)-TFXZ
      FIMPY=FIMPY+FMLYT(J)
      FIMPZ=FIMPZ+FMLZT(J)
      WORK=WORK+FMLYT(J)*UNMX(J,L)+FMLZT(J)*UNMY(J,L)
      DO 65  J=JL,JR
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SUMKE=SUMKE+.5*(CMASS1(J-1,L5)*(U2(J,KL)+U2(J,KU))+CMASS2(J-1,L5)*
     2      (U2(J-1,KL)+U2(J-1,KU)))
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      GO TO (55,60,55),MOTION
55    SMSTPT=SMSTPT-RWA1Z(J,L)
      SIETPT=SIETPT-RWAE1Z(J,L)
      USQ(JRIGHT)=UNMX(J,L)**2+UNMY(J,L)**2
      SKETPT=SKETPT-RWA1Z(J-1,L)*(USQ(JLEFT)+USQ(JRIGHT))
      SMYTPT=SMYTPT-RWA1Z(J-1,L)*(UNMX(J-1,L)+UNMX(J,L))
      SMZTPT=SMZTPT-RWA1Z(J-1,L)*(UNMY(J-1,L)+UNMY(J,L))
      JLEFT=JRIGHT
      JRIGHT=MOD(JLEFT,2)+1
      FXMST=TA2(J)*RWA1Z(J,L)+TA1(J-1)*RWA1Z(J-1,L)
      FXTX=FXMST*UNMX(J,L)
      FXTY=FXMST*UNMY(J,L)
      FXMSB=.25*(TA1(J-1)*(RWA1Z(J-1,L)+RWA1Z(J-1,L5))+TA2(J)*
     2 (RWA1Z(J,L)+RWA1Z(J,L5)))
      FXBX=FXMSB     *(UNMX(J,L)+UNMX(J,L5 ))
      FXBY=FXMSB     *(UNMY(J,L)+UNMY(J,L5 ))
      FXLX=FXRX
      FXLY=FXRY
      FXMSR=.125*(RWA3Z(J,L5 )+RWA3Z(J+1,L5 ))
      FXRX=FXMSR     *(UNMX(J,L)+UNMX(J+1,L))
      FXRY=FXMSR     *(UNMY(J,L)+UNMY(J+1,L))
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
60    FMLYT(J)=(FMNX(J,L)-FMNMX(J,L))*RDTNM-F3Y(J,L5)-F4Y(J-1,L5)-TFXY
      FMLZT(J)=(FMNY(J,L)-FMNMY(J,L))*RDTNM-F3Z(J,L5)-F4Z(J-1,L5)-TFXZ
      FIMPY=FIMPY+FMLYT(J)
      FIMPZ=FIMPZ+FMLZT(J)
65    WORK=WORK+FMLYT(J)*UNMX(J,L)+FMLZT(J)*UNMY(J,L)
      J=JMAX
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SUMKE=SUMKE+.5*(CMASS1(J-1,L5)*(U2(J,KL)+U2(J,KU))+CMASS2(J-1,L5)*
     2      (U2(J-1,KL)+U2(J-1,KU)))
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      GO TO (70,75,70),MOTION
70    SMSTPT=SMSTPT-RWA1Z(J,L)
      SIETPT=SIETPT-RWAE1Z(J,L)
      USQ(JRIGHT)=UNMX(J,L)**2+UNMY(J,L)**2
      SKETPT=(SKETPT-RWA1Z(J-1,L)*(USQ(JLEFT)+USQ(JRIGHT)))*.25
      SMYTPT=(SMYTPT-RWA1Z(J-1  ,L)*(UNMX(J-1,L)+UNMX(J,L)))*.5
      SMZTPT=(SMZTPT-RWA1Z(J-1,L)*(UNMY(J-1,L)+UNMY(J,L)))*.5
      FXMST=TA1(J-1)*RWA1Z(J-1,L)
      FXTX=FXMST*UNMX(J   ,L)
      FXTY=FXMST*UNMY(J   ,L)
      FXMSB=. 25*(RWA1Z(J-1,L)+RWA1Z(J-1,L5 ))*TA1(J-1)
      FXBX=FXMSB     *(UNMX(J   ,L)+UNMX(J  ,L5 ))
```

```
      FXBY=FXMSB    *(UNMY(J   ,L)+UNMY(J   ,L5 ))
      FXLX=FXRX
      FXLY=FXRY
      FXMSR=0.5*RWA3Z(J   ,L5 )
      FXRX=FXMSR*UNMX(J   ,L)
      FXRY=FXMSR*UNMY(J   ,L)
      TFXY=FXLX-FXRX+FXTX-FXBX
      TFXZ=FXLY-FXRY+FXTY-FXBY
 75   FMLYT(J)=-F4Y(J-1,L5)-TFXY
      FMLZT(J)=(FMNY(J,L)-FMNMY(J,L))*RDTNM-F4Z(J-1,L5)-TFXZ
      FIMPY=FIMPY+FMLYT(J)
      FIMPZ=FIMPZ+FMLZT(J)
      WORK=WORK+FMLYT(J)*UNMX(J,L)+FMLZT(J)*UNMY(J,L)
  350 SUMTE=SUMIE+SUMKE
      SMSTPT=SMSTPT*DTNM
      SMASSI=SMASSI-SMSTPT
      SIETPT=SIETPT*DTNM
      SKETPT=SKETPT*DTNM
      WORK=WORK*DTNM
      SENERI=SENERI+WORK-SIETPT-SKETPT
      FIMP=(FIMPY+SFW)*DTNM
      FIMPZ=FIMPZ*DTNM
      SMYTPT=SMYTPT*DTNM
      SMZTPT=SMZTPT*DTNM
      SMOMYI=SMOMYI+FIMP -SMYTPT
      SMOMZI=SMOMZI+FIMPZ-SMZTPT
 100  CONTINUE
      DIFFY=SMOMY -SMOMYI
      DIFFZ=SMOMZ -SMOMZI
      SFY=FIMPY+SFW
      SFZ=FIMPZ
      SUMTE=SUMIE+SUMKE
      DSTE=SUMTE-STEM
      WT=WORK*DTNM
      TEM1=SFY*DTNM
      TEM2=SFZ*DTNM
      IF(KC.EQ.KMAX) FIMPY=FIMP
      RETURN
 104  FORMAT(1H0/
     163H    J      U2(J,KL)          U2(J+1,KL)         U2(J,KU)          U2(J+1,KU)
     2 /I4,4E15.7/)
 107  FORMAT(38H0 KSV3 NOT ZERO NO RIGHT SIDE BOUNDARY/)
 108  FORMAT(1H0/
     249H NO JMIN CONTRIBUTION CALCULATION IN THIS PROGRAM/)
 110  FORMAT(3I6/(6E16.8))
      END
```

```
      SUBROUTINE ENERGY
      COMMON             NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,   TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI,  SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,   SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,    KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,      CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN,  UYLTIN,  UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,    JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,         EIN,         RHOIN,       UYIN,        UXIN,        KINT(5),
     A E S(5),     ALFA(5),     BIG A(5),  BIG B(5),    RCP V S(5),E ZERO(5),
     2 TINY A(5),  TINY B(5), R ZERO(5),BETA(5),     QCON(5),     SAV(12),
     4 KSV(24),       YTERM(55),      Y2TERM(55),     TA1(55),        TA2(55),
     5 FMLYR(101),    FMLZR(101),     VACANT(15)
      COMMON                          A(55),          DIL(55),        EPX(55),
     2 EPY(55),       EPZ(55),        FMLYB(55),      FMLYT(55),      FMLZB(55),
     3 FMLZT(55),     LY1(55),        LY2(55),        LZ1(55),        LZ2(55),
     4 PY(55),        PZ(55),         R1H(55),        R2H(55),        R3H(55),
     5 R4H(55),       Z1H(55),        Z2H(55),        Z3H(55),        Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                RX(55,5),          RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),        UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),          PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),      PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),       RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),      RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),         RHO(55,5),         VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),         A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),         A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),         F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),         F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),        FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),       FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),         CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),     RYM(55,5),         RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),         Q22(55,5),         QX(55,5),
     7 P11(55,5),     P12(55,5),         P22(55,5),         PX(55,5),
     8 PQX(55,5),     PQMX(55,5),        VO(55,5)
      COMMON   ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON         AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      L=LX1
      L2=LX2
      TFXE=0.
      DO 100 J=JMIN,JR
      IF(MOTION.NE.2)TFXE=RWAE3Z(J,L)-RWAE3Z(J+1,L)-RWAE1Z(J,L)+
     2       RWAE1Z(J,L2)
      EN(J,L)=(ENM(J,L)*FMASNM(J,L)-DTNM*(UNMX(J+1,L)*F1Y(J,L)+UNMY(J+1,
     1 L)*F1Z(J,L)
     1 +UNMX(J,L)*F2Y(J,L)+UNMY(J,L)*F2Z(J,L)+UNMX(J,L2)*F3Y(J,L)+
     2  UNMY(J,L2)*F3Z(J,L)+UNMX(J+1,L2)*F4Y(J,L)+UNMY(J+1,L2)*F4Z(J,L)-
     3  TFXE))/FMASN(J,L)
      IF(ABS(EN(J,L)-ENM(J,L))-CUT1)10,10,100
10    EN(J,L)=ENM(J,L)
100   CONTINUE
```

```
105   RETURN
      END
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```
      SUBROUTINE FLOW
      COMMON          NREG,    RDTNM,  MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN, UYTIN,  UYRTIN, UXLTIN, UXTIN,  UXRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,       EIN,        RHOIN,      UYIN,      UXIN,       KINT(5),
     A E S(5),   ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),    SAV(12),
     4 KSV(24),       YTERM(55),    Y2TERM(55),   TA1(55),      TA2(55),
     5 FMLYR(101),  FMLZR(101),  VACANT(15)
      COMMON                     A(55),         DIL(55),      EPX(55),
     2 EPY(55),      EPZ(55),      FMLYB(55),     FMLYT(55),    FMLZB(55),
     3 FMLZT(55),    LY1(55),      LY2(55),       LZ1(55),      LZ2(55),
     4 PY(55),       PZ(55),       R1H(55),       R2H(55),      R3H(55),
     5 R4H(55),      Z1H(55),      Z2H(55),       Z3H(55),      Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A                RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),     RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),     P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),     PQMX(55,5),      VO(55,5)
      COMMON    ICON,    LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,    NEDIT,  NSIG,   NMASS,  NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON          S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      KC=1
      LINCT=1
      NREG=1
      LX1=1
      LX2=2
       LX3=3
      LX4=4
      LX5=5
      DO 10 L=1,4
      DO 10 J=JMIN,JMAX
   10 B(J,L)=0.0
C     READ IN 5 K LINES 1ST CALL ONLY
      CALL LINEIN
      J=JMIN
```

```
      IF((PQNMXX(J,2).NE.0).OR.(PQNMXX(J,1).NE.0)
     2 .OR.(UNMY(J,2).NE.0).OR.(UNMY(J,1).NE.0)) GO TO 15
      CALL ACTIVE
      SFW=0.
      DO 11 J=JMIN,JMAX
      RWA1Z(J,1)=0.
      RWAE1Z(J,1)=0.
      F1Y(J,1)=0.
      F1Z(J,1)=0.
      F2Y(J,1)=0.
   11 F2Z(J,1)=0.
      CALL CONSCK
      GO TO 21
   15 CALL VERTPT
   20 CALL BOUND
   21 LX0=LX1
      LX1=LX2
      LX2=LX3
      LX3=LX4
      LX4=LX5
      LX5=LX0
      KB=KMIN+1
      KTM=KT-1
      DO 50 K=KB,KTM
      J=JMIN
      KC=K
      IF((PQNMXX(J,LX2).NE.0).OR.(PQNMXX(J,LX1).NE.0).OR.
     2 (PQNXX(J,LX5).NE.0).OR.(UNMY(J,LX2).NE.0).OR.(UNMY(J,LX1).NE.0)
     3 .OR.(UNPY(J,LX5).NE.0)) GO TO 30
      CALL ACTIVE
      CALL CONSCK
      IF(K.EQ.KB) GO TO 45
      GO TO 410
   30 CALL VERTPT
      CALL HORTPT
      CALL MASS
   35 IF((K+1).LT.KINT(NREG))GO TO 41
      NREG=NREG+1
      STOP
   41 CALL STRESS
      CALL NEWU
      CALL CONSCK
      IF (K.EQ.KB) GO TO 45
      GO TO (410,415,410),MOTION
  410 CALL SETTPT
  415 CALL LINOUT
      IF(K.EQ.KTM)GO TO 45
   42 CALL LINEIN
      DO 43 L=1,3
      DO 43 J=JMIN,JMAX
   43 B(J,L)=B(J,L+1)
   45 LX0=LX1
      LX1=LX2
      LX2=LX3
      LX3=LX4
      LX4=LX5
      LX5=LX0
   50 CONTINUE
      J=JMIN
      KC=KT
      IF((PQNMXX(J,LX2).NE.0).OR.(PQNMXX(J,LX1).NE.0).OR.
```

```
     2 (PQNXX(J,LX5).NE.0).OR.(UNMY(J,LX2).NE.0).OR.(UNMY(J,LX1).NE.0)
     3 .OR.(UNPY(J,LX5).NE.0)) GO TO 500
      DO 5000 J=JMIN,JMAX
      RHO(J,LX2)=0.
      PN(J,LX2)=0.
      FMASN(J,LX2)=0.
      ETA(J,LX2)=0.
      EN(J,LX2)=0.
      RWA3Z(J,LX2)=0.
5000  RWAE3Z(J,LX2)=0.
      CALL ACTIVE
      CALL CONSCK
      KC=KMAX
      CALL ACTIVE
      CALL CONSCK
      GO TO 501
500   CALL BOUND
C-----WRITES OUT 4 K LINES LAST CALL ONLY
501   CALL LINOUT
      RETURN
      END
```

```
      SUBROUTINE FORCE
      COMMON              NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,   TIME,     SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI,  SIETPT,   SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,   SMASSI,   SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,    KTOP,     MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNMZ,
     6 KB,      CUT1,     CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN,  UYLTIN,   UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,    JMAX,     KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,        EIN,         RHOIN,       UYIN,        UXIN,        KINT(5),
     A E S(5),    ALFA(5),     BIG A(5),  BIG B(5),  RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),     SAV(12),
     4 KSV(24),      YTERM(55),      Y2TERM(55),     TA1(55),        TA2(55),
     5 FMLYR(101),   FMLZR(101),     VACANT(15)
      COMMON                         A(55),          DIL(55),        EPX(55),
     2 EPY(55),      EPZ(55),        FMLYB(55),      FMLYT(55),      FMLZB(55),
     3 FMLZT(55),    LY1(55),        LY2(55),        LZ1(55),        LZ2(55),
     4 PY(55),       PZ(55),         R1H(55),        R2H(55),        R3H(55),
     5 R4H(55),      Z1H(55),        Z2H(55),        Z3H(55),        Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A                RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),     RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),     P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),     PQMX(55,5),      VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON          S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      SAV(6)=1.-SAV(6)
1     L=LX1
      L2=LX2
      IF (KC.EQ.1)SFW=0.
      DO 100 J=JMIN,JR
502   ARH1=AW1(J,L)
      ARH2=AW2(J,L)
      ARH3=AW2(J,L)
      ARH4=AW1(J,L)
535   P11B=.5*(P11(J,L)+Q11(J,L)+PQNMXX(J,L))
      P12B=.5*(P12(J,L)+Q12(J,L)+PQNMXY(J,L))
      P22B=.5*(P22(J,L)+Q22(J,L)+PQNMYY(J,L))
      PXB=.5*(PX(J,L)+QX(J,L)+PQMX(J,L))
      A1YR=A2Y(J,L)-ARH1
```

```
      F1Y(J,L)=P11B*A1YR+P12B*A2Z(J,L)+PXB*ARH1
      F1Z(J,L)=P12B*A1YR+P22B*A2Z(J,L)
      A2YR=A1Y(J,L)-ARH2
      F2Y(J,L)=P11B*A2YR+P12B*A1Z(J,L)+PXB*ARH2
      F2Z(J,L)=P12B*A2YR+P22B*A1Z(J,L)
      A3YR=A4Y(J,L)-ARH3
      F3Y(J,L)=P11B*A3YR+P12B*A4Z(J,L)+PXB*ARH3
      F3Z(J,L)=P12B*A3YR+P22B*A4Z(J,L)
      A4YR=A3Y(J,L)-ARH4
      IF(SAV(6).EQ.0) SFW =PXB*(ARH1+ARH2+ARH3+ARH4)+SFW
      F4Y(J,L)=P11B*A4YR+P12B*A3Z(J,L)+PXB*ARH4
      F4Z(J,L)=P12B*A4YR+P22B*A3Z(J,L)
      PQN XX(J,L)=P11(J,L)+Q11(J,L)
      PQN XY(J,L)=P12(J,L)+Q12(J,L)
      PQN YY(J,L)=P22(J,L)+Q22(J,L)
      PQX(J,L)=PX(J,L)+QX(J,L)
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE HORTPT
      COMMON             NREG,   RDTNM,  MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNMZ,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN, UYTIN,  UYRTIN, UXLTIN, UXTIN,  UXRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,       EIN,        RHOIN,        UYIN,       UXIN,      KINT(5),
     A E S(5),     ALFA(5),    BIG A(5), BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),     SAV(12),
     4 KSV(24),       YTERM(55),     Y2TERM(55),    TA1(55),       TA2(55),
     5 FMLYR(101),    FMLZR(101),    VACANT(15)
      COMMON                         A(55),         DIL(55),       EPX(55),
     2 EPY(55),       EPZ(55),       FMLYB(55),     FMLYT(55),     FMLZB(55),
     3 FMLZT(55),     LY1(55),       LY2(55),       LZ1(55),       LZ2(55),
     4 PY(55),        PZ(55),        R1H(55),       R2H(55),       R3H(55),
     5 R4H(55),       Z1H(55),       Z2H(55),       Z3H(55),       Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                RX(55,5),         RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),       UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),         PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),     PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),      RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),     RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),        RHO(55,5),         VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),        A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),        A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),        F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),        F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),       FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),      FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),        CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),     RYM(55,5),        RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),        Q22(55,5),         QX(55,5),
     7 P11(55,5),     P12(55,5),        P22(55,5),         PX(55,5),
     8 PQX(55,5),     PQMX(55,5),       VO(55,5)
      COMMON    ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2 , YDELTA(55)
      COMMON        S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      L=LX1
      L2=LX2
      DO 100 J=JMIN,JMAX
100   AYQ(J )=TRAPZH(KC)*RX(J,L)
      A(JMIN)=0.0
      A(JMIN+1)=0.0
      A(JMAX)=0.0
  200 JL=JMIN+2
      DO 214 J=JL,JR
      SNOISE=RHO(J,L)-2.*RHO(J-1,L)+RHO(J-2,L)
      IF( ABS(SNOISE).LE.(RHO(J-1,L)*10.E-8)) GO TO 212
      IF(SNOISE)211,212,213
  211 A(J)=-1.0
      GO TO 214
```

```
  212 A(J)=0.0
      GO TO 214
  213 A(J)=1.0
  214 CONTINUE
      JL=JMIN+1
      DO 260 J=JL,JR
      WX = UNMX(J,L) + UNMX(J,L2)
C-----AY IS ZERO  RX(J,L)=RX(J,L2)
      WDA=.5*WX*AYQ(J)
C     BACKWARD TRANSPORT
      GO TO 236
  222 JP2=J+2
      JP=J+1
      JZ=J
      JM=J-1
223   IF(JL-J)226,224,226
  224 IF(WDA)225,260,255
  225 IF(A(JP)-A(JP2))265,270,265
  226 IF(JL+1-J)229,227,229
  227 IF(WDA)250,260,228
  228 IF(ABS(A(JZ)+A(JP)+A(JP2))-3.0)255,270,255
  229 IF(JR-1-J)232,230,232
  230 IF(WDA)231,260,245
  231 IF(ABS(A(JM)+A(JZ)+A(JP))-3.0)265,270,265
  232 IF(JR-J)235,233,235
  233 IF(WDA)265,260,234
  234 IF(A(JZ)-A(JM))255,270,255
  235 IF(ABS(-A(JP2)+A(JP)+A(JZ)-A(JM))-4.0)240,236,240
  236 IF(WDA)265,260,255
  240 IF(WDA)250,260,245
245   IF(ABS(A(J+1)-A(J)+A(J-1))-2.)270,255,255
250   IF(ABS(A(J+2)-A(J+1)+A(J))-2.)270,265,265
  255 RH3Z(J,L)=RHO(JM,L)
      E3Z(J,L)=ENM(JM,L)
      GO TO 275
  260 RH3Z(J,L)=0.0
      E3Z(J,L)=0.0
      GO TO 275
  265 RH3Z(J,L)=RHO(JZ,L)
      E3Z(J,L)=ENM(JZ,L)
      GO TO 275
270   D1=SQRT((RX(JZ,L2)+RX(JZ,L)-RX(JM,L2)-RX(JM,L))**2
     1 +(RY(JZ,L2 )+RY(JZ,L)-RY(JM,L2 )-RY(JM,L))**2)
      D2=SQRT((RX(JP,L2 )+RX(JP,L)-RX(JZ,L2 )-RX(JZ,L))**2
     1 +(RY(JP,L2 )+RY(JP,L)-RY(JZ,L2 )-RY(JZ,L))**2)
      D12=1.0/(D1+D2)
C-----AY IS ZERO  RX(J,L)=RX(J,L2)
      WDAMAG=ABS(AYQ(J))
      WN=WDA/WDAMAG
      RH3Z(J,L)=(D2*RHO(JM,L)+D1*RHO(JZ,L)-3.0*WN*(RHO(JZ,L)-RHO(JM,L))*
     1  DTNM)*D12
      E3Z(J,L)=(D2*ENM(JM,L)+D1*ENM(JZ,L)-3.0*WN*(ENM(JZ,L)-ENM(JM,L))*
     1  DTNM)*D12
  275 RWA3Z(J,L)=RH3Z(J,L)*WDA
      RWAE3Z(J,L)=RWA3Z(J,L)*E3Z(J,L)
  260 CONTINUE
  300 RETURN
      END
```

```
      SUBROUTINE LINEIN
      COMMON           NREG,   RDTNM,  MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN, UYTIN,  UYRTIN, UXLTIN, UXTIN,  UXRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,       EIN,      RHOIN,      UYIN,       UXIN,       KINT(5),
     A E S(5),   ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),     QCON(5),    SAV(12),
     4 KSV(24),       YTERM(55),      Y2TERM(55),     TA1(55),     TA2(55),
     5 FMLYR(101),    FMLZR(101),     VACANT(15)
      COMMON                          A(55),          DIL(55),     EPX(55),
     2 EPY(55),       EPZ(55),        FMLYB(55),      FMLYT(55),   FMLZB(55),
     3 FMLZT(55),     LY1(55),        LY2(55),        LZ1(55),     LZ2(55),
     4 PY(55),        PZ(55),         R1H(55),        R2H(55),     R3H(55),
     5 R4H(55),       Z1H(55),        Z2H(55),        Z3H(55),     Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                  RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),       RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),       P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),       PQMX(55,5),      VO(55,5)
      COMMON   ICON,   LINCT,  LX1,    LX2,     LX3,     LX4,      LX5,
     2 KC,     NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
      COMMON          AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON          S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
      DIMENSION DUMPV(600)
      EQUIVALENCE(NREG,DUMPV(1))
C*****
      IF(KC.EQ.1) GO TO 20
      L=LX4
    6 READ(MT)          (RX(J,L),      RY(J,L),       UNMX(J,L),     UNMY(J,L),
     2 FMASNM(J,L),  ENM(J,L),      PNM(J,L),      PQNMXX(J,L),  PQNMXY(J,L),
     3 PQNMYY(J,L),  VOL(J,L),      RHO(J,L),
     4 PQMX(J,L),    FMNMX(J,L),    FMNMY(J,L),    NTPT(J,L),     A1Y(J,L),
     5 A2Y(J,L),     A3Y(J,L),      A4Y(J,L),      A1Z(J,L),      A2Z(J,L),
     6 A3Z(J,L),     A4Z(J,L),      AW1(J,L),      AW2(J,L),      CMASS1(J,L),
     7 CMASS2(J,L),  RXZ(J,L),      RYZ(J,L),      VO(J,L),       J=JMIN,JMAX)
    8 IF(LCOUNT.EQ.KMAX) REWIND MT
      LCOUNT=LCOUNT+1
      IF(NDPA.EQ.0) RETURN
```

```
9     WRITE(10)(      RX (J,L),                RY (J,L),
     2 UNMX(J,L),     UNMY(J,L),               FMASNM(J,L),          ENM(J,L),
     3 PNM(J,L),      PQNMXX(J,L),             PQNMXY(J,L),          PQNMYY(J,L),
     4 VOL(J,L),      RHO(J,L),                PQMX(J,L),
     5 FMNMX(J,L),    FMNMY(J,L),
     6 NTPT(J,L),
     7 A1Y(J,L),      A2Y(J,L),                A3Y(J,L),             A4Y(J,L),
     8 A1Z(J,L),      A2Z(J,L),                A3Z(J,L),             A4Z(J,L),
     9 AW1  (J,L),    AW2  (J,L),              CMASS1(J,L),          CMASS2(J,L),
     A                VO(J,L),                          J=JMIN,JMAX)
      IF((KC+1).NE.(KMAX-2))RETURN
      END FILE 10
      END FILE 10
      NDMP=NDMP+1
      WRITE(6,100)NDMP,PROBNO,TIME,N
      RETURN
20    LCOUNT=1
      NBR=MOD(N,2)+1
      GO TO (21,22),NBR
21    MT=3
      GO TO 35
22    MT=1
   35 IF(NDPA)40,40,36
36    WRITE(10) (DUMPV(J),J=1,600)
      END FILE 10
40    DO 46 L=1,5
42    READ(MT)        (RX(J,L),      RY(J,L),      UNMX(J,L),     UNMY(J,L),
     2 FMASNM(J,L),   ENM(J,L),      PNM(J,L),     PQNMXX(J,L),   PQNMXY(J,L),
     3 PQNMYY(J,L),   VOL(J,L),      RHO(J,L),
     4 PQMX(J,L),     FMNMX(J,L),    FMNMY(J,L),   NTPT(J,L),     A1Y(J,L),
     5 A2Y(J,L),      A3Y(J,L),      A4Y(J,L),     A1Z(J,L),      A2Z(J,L),
     6 A3Z(J,L),      A4Z(J,L),      AW1(J,L),     AW2(J,L),      CMASS1(J,L),
     7 CMASS2(J,L),   RXZ(J,L),      RYZ(J,L),     VO(J,L),       J=JMIN,JMAX)
44    IF(NDPA)450,450,45
45    WRITE(10)(      RX (J,L),                RY (J,L),
     2 UNMX(J,L),     UNMY(J,L),               FMASNM(J,L),          ENM(J,L),
     3 PNM(J,L),      PQNMXX(J,L),             PQNMXY(J,L),          PQNMYY(J,L),
     4 VOL(J,L),      RHO(J,L),                PQMX(J,L),
     5 FMNMX(J,L),    FMNMY(J,L),
     6 NTPT(J,L),
     7 A1Y(J,L),      A2Y(J,L),                A3Y(J,L),             A4Y(J,L),
     8 A1Z(J,L),      A2Z(J,L),                A3Z(J,L),             A4Z(J,L),
     9 AW1  (J,L),    AW2  (J,L),              CMASS1(J,L),          CMASS2(J,L),
     A                VO(J,L),                          J=JMIN,JMAX)
450   LCOUNT=LCOUNT+1
   46 CONTINUE
   70 RETURN
  100 FORMAT(22H0A DUMP HAS BEEN TAKEN/12H0DUMP NUMBER,I6,23H IS FROM PR
     1OBLEM NUMBER,F7.2,8H AT TIME,1PE16.7,10H ON CYCLE ,I6)
      END
```

```
      SUBROUTINE LINOUT
      COMMON               NREG,   RDTNM,  MOTION, JBMIN,   JBMAX,  KBMIN,
     2 KBMAX,   TIME,    SMOMZI, SMZTPT, SMOMZ,  SMOMYI,  SMYTPT, SMOMY,
     3 SENERI,  SIETPT,  SKETPT, WORK,   SUMIE,  SUMKE,   SUMTE,  FIMPZ,
     4 FIMPY,   SMASSI,  SMSTPT, SMASS,  PROBNO, DTNM,    CUTOFF, N,
     5 KBOT,    KTOP,    MAXN,   TMAX,   DTNMN,  SFW,     DTNMP5, DTNM2,
     6 KB,      CUT1,    CUT2,   UYLBIN, UYBIN,  UYRBIN,  UXLBIN, UXBIN,
     7 UXRBIN,  UYLTIN,  UYTIN,  UYRTIN, UXLTIN, UXTIN,   UXRTIN, KTM,
     8 JMIN,    JMAX,    KMIN,   KMAX,   JL,     J3,      JR,     JRM,
     9 KT,         EIN,        RHOIN,       UYIN,       UXIN,       KINT(5),
     A E S(5),     ALFA(5),    BIG A(5), BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),      QCON(5),    SAV(12),
     4 KSV(24),       YTERM(55),      Y2TERM(55),     TA1(55),      TA2(55),
     5 FMLYR(101),    FMLZR(101),     VACANT(15)
      COMMON                          A(55),          DIL(55),      EPX(55),
     2 EPY(55),       EPZ(55),        FMLYB(55),      FMLYT(55),    FMLZB(55),
     3 FMLZT(55),     LY1(55),        LY2(55),        LZ1(55),      LZ2(55),
     4 PY(55),        PZ(55),         R1H(55),        R2H(55),      R3H(55),
     5 R4H(55),       Z1H(55),        Z2H(55),        Z3H(55),      Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                 RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),     UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),      EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),   PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),    PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),   RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),      E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),      A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),      A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),      F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),      F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),      NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),    FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),      AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),      RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),      Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),      P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),      PQMX(55,5),      VO(55,5)
      COMMON    ICON,    LINCT,  LX1,    LX2,     LX3,     LX4,    LX5,
     2 KC,      NDPA,    NEDIT,  NSIG,   NMASS,  NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON         S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
      DIMENSION PTMASS(55)
C*****
      IF(LINCT.GT.1) GO TO 100
      NBR=MOD(N,2)+1
      SAV(7)=SQRT(SAV(7))
      SAV(8)=SQRT(SAV(8))
      GO TO (20,30),NBR
20    MT=1
      GO TO 100
30    MT=3
100   L=LX4
      L2=LX5
      IF(SMASS.LT.0) WRITE(6,110) N,J,KC,(FMASN(I,L),FMASNM(I,L)
     2,RWA1Z(I,L),RWA1Z(I,L2),RWA3Z(I,L),RWA3Z(I+1,L),I=JMIN,JMAX)
110   FORMAT(3I6/(6E16.8))
```

```
 300 IF(NEDIT)327,327,3000
 3000 IF(KSV(11))30010,3002,3001
 3001 KSV(11)=-KSV(11)
      READ(5,3003)JJMIN,JJMAX,KKMIN,KKMAX
30010 IF(LINCT-KMAX)30012,30011,30011
30011 KSV(11)=KSV(11)+1
30012 IF(LINCT-KKMIN)327,30013,30013
30013 IF(LINCT-KKMAX)311,311,327
 3002 JJMIN=JMIN
      JJMAX=JMAX
311   DO 312 J=JJMIN,JJMAX
312   PTMASS(J)=2.*FMSNZ(J,L)
      IF(LINCT.LT.KMAX)          GO TO 316
      DO 315 J=JJMIN,JJMAX
      RHO(J,L )=0.0
      PN(J,L )=0.0
      FMASN(J,L )=0.0
      ETA(J,L )=0.0
      EN(J,L )=0.0
      RH3Z(J,L)=0.0
      RWA3Z(J,L)=0.0
      E3Z(J,L)=0.
      RWAE3Z(J,L)=0.
      VOL(J,L)=0.
      P11(J,L)=0.
      P12(J,L)=0.
      P22(J,L)=0.
      PX(J,L)=0.
      F1Y(J,L)=0.
      F2Y(J,L)=0.
      F3Y(J,L)=0.
      F4Y(J,L)=0.
      F1Z(J,L)=0.
      F2Z(J,L)=0.
      F3Z(J,L)=0.
      F4Z(J,L)=0.
      Q11(J,L)=0.
      Q12(J,L)=0.
      Q22(J,L)=0.
      QX(J,L)=0.
      A1Y(J,L)=0.
      A2Y(J,L)=0.
      A3Y(J,L)=0.
      A4Y(J,L)=0.
      A1Z(J,L)=0.
      A2Z(J,L)=0.
      A3Z(J,L)=0.
      A4Z(J,L)=0.
      AW1(J,L)=0.
      AW2(J,L)=0.
      CMASS1(J,L)=0.
315   CMASS2(J,L)=0.
316   DO 320 I=JJMIN,JJMAX,10
      JPRINT=I+9
      IF(JPRINT.GT.JJMAX) JPRINT=JJMAX
320   WRITE(6,1)      PROBNO,         TIME,           DTNM,
     1 KSV(14),     KSV(15),     SAV(7),     KSV(16),     KSV(17),     SAV(8),
     2              (               RX(J,L),        RY(J,L),
     3 VOL(J,L),      RHO(J,L),       ETA(J,L),       EN(J,L),        J, LINCT,N,
     4 UNMX(J,L),     UNMY(J,L),      FMASN(J,L),     RH1Z(J,L),      RWA1Z(J,L),
     5 E1Z(J,L),      RWAE1Z(J,L),    FMNX(J,L),      FMNY(J,L),      PTMASS(J),
```

```
     6 RH3Z(J,L),    RWA3Z(J,L),   E3Z(J,L),     RWAE3Z(J,L), P11(J,L),
     7 Q11(J,L),     A2Y(J,L),     A2Z(J,L),     AW1  (J,L),  F1Y(J,L),
     8 F1Z(J,L),     P12(J,L),     Q12(J,L),     A1Y(J,L),    A1Z(J,L),
     9 AW2  (J,L),   F2Y(J,L),     F2Z(J,L),     P22(J,L),    Q22(J,L),
     A A4Y(J,L),     A4Z(J,L),     CMASS1(J,L),  F3Y(J,L),    F3Z(J,L),
     1 PX(J,L),      QX(J,L),      A3Y(J,L),     A3Z(J,L),    CMASS2(J,L),
     2 F4Y(J,L),     F4Z(J,L),     J=I,JPRINT)
327   WRITE(MT)      (RX(J,L),     RY(J,L),      UNPX(J,L),   UNPY(J,L),
     2 FMASN(J,L),   EN(J,L),      PN(J,L),      PQNXX(J,L),  PQNXY(J,L),
     3 PQNYY(J,L),   VOL(J,L),     RHO(J,L),
     4 PQX(J,L),     FMNX(J,L),    FMNY(J,L),    NTPT(J,L),   A1Y(J,L),
     5 A2Y(J,L),     A3Y(J,L),     A4Y(J,L),     A1Z(J,L),    A2Z(J,L),
     6 A3Z(J,L),     A4Z(J,L),     AW1(J,L),     AW2(J,L),    CMASS1(J,L),
     7 CMASS2(J,L),  RXZ(J,L),     RYZ(J,L),     VO(J,L),     J=JMIN,JMAX)
  340 IF(LINCT-KMAX)370,350,350
  350 SUMTE=SUMIE+SUMKE
      REWIND MT
      IF((NDPA.GT.0) .OR.(NEDIT.LT.0)) GO TO 355
      IF(NEDIT.EQ.0) GO TO 368
355   WRITE(6,2)     PROBNO,       TIME,         DTNM,
     1 KSV(14),    KSV(15),    SAV(7),    KSV(16),    KSV(17),    SAV(8)
  360 WRITE(6,6)
      WRITE(6,7)SUMIE,SIETPT,SMYTPT,FIMPY,SMOMYI,SMOMY,SMSTPT,SUMKE
     1,SKETPT,SMZTPT,FIMPZ,SMOMZI,SMOMZ,SMASSI,SUMTE,WORK,SMASS,SENERI
C-----TO INSURE THAT ENERGY CHECKS PRINT OUT
      DO 365 L=1,5
  365 WRITE(6,9)
      RETURN
  370 IF(KC.GT.KT)GO TO 380
  368 LINCT=LINCT+1
      RETURN
  380 LX4=LX5
      LX5=LX1
      LX1=LX2
      LINCT=LINCT+1
      GO TO 100
1     FORMAT(12H1  PROBLEM= F7.2,3X6HTIME= E17.9,3X4HDT= E17.9,3X
     2 6HSH J= I3,3X6HSH K= I3,3X7HSH DT= E17.9/
     3 72X6HSS J= I3,3X6HSS K= I3,3X7HSS DT= E17.9//
     2119H     Y                   Z                   VOL              RHO
     3            ETA                 E                   *  J*  K*CYCLE*/
     4112H     U(N-1/2)            V(N-1/2)            ZONE MASS        RH10
     5            RWA10               E10                 RWAE10/
     6112H     MOM Y               MOM Z               PT. MASS         RH30
     7            RWA30               E30                 RWAE30//
     8109H     P11                 Q11                 A1Y              A1Z
     9            AW1                 F1Y                 F1Z/
     A109H     P12                 Q12                 A2Y              A2Z
     1            AW2                 F2Y                 F2Z/
     2109H     P22                 Q22                 A3Y              A3Z
     3            MP1                 F3Y                 F3Z/
     4109H     PX                  QX                  A4Y              A4Z
     5            MP2                 F4Y                 F4Z//
     6 (10(6E17.9,3H  *,I3,1H*,I3,1H*,I5,1H*/
     7 7E17.9/7E17.9//7E17.9/7E17.9/7E17.9/7E17.9///)))
2     FORMAT(12H0  PROBLEM= F7.2,3X6HTIME= E17.9,3X4HDT= E17.9,3X
     2 6HSH J= I3,3X6HSH K= I3,3X7HSH DT= E17.9/
     3 72X6HSS J= I3,3X6HSS K= I3,3X7HSS DT= E17.9//)
    6 FORMAT(1H0,9X,5HSUMIE,11X,6HSIETPT,10X,6HSMXTPT,10X,5HFIMPX,11X
     1,6HSMOMXI,10X,5HSMOMX,11X,6HSMSTPT/10X,5HSUMKE,11X,6HSKETPT,10X
     2,6HSMYTPT,10X,5HFIMPY,11X,6HSMOMYI,10X,5HSMOMY,11X,6HSMASSI/10X
```

```
     3,5HSUMTE,11X,4HWORK,76X,5HSMASS/26X,6HSENERI/)
   7 FORMAT(7X,  7E16.8/7X  7E16.8/7X,  2E16.8,64X,  E16.8/23X,  E16.8)
   9 FORMAT(1H )
3003  FORMAT(4I6)
      END
```

```
      SUBROUTINE MASS
      COMMON              NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN, UYLTIN,  UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,          EIN,        RHOIN,        UYIN,       UXIN,       KINT(5),
     A E S(5),      ALFA(5),    BIG A(5),  BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),     QCON(5),      SAV(12),
     4 KSV(24),         YTERM(55),       Y2TERM(55),      TA1(55),        TA2(55),
     5 FMLYR(101),      FMLZR(101),      VACANT(15)
      COMMON                             A(55),           DIL(55),        EPX(55),
     2 EPY(55),         EPZ(55),         FMLYB(55),       FMLYT(55),      FMLZB(55),
     3 FMLZT(55),       LY1(55),         LY2(55),         LZ1(55),        LZ2(55),
     4 PY(55),          PZ(55),          R1H(55),         R2H(55),        R3H(55),
     5 R4H(55),         Z1H(55),         Z2H(55),         Z3H(55),        Z4H(55),
     6 U2(55,2),        B(55,4)
      COMMON
     A               RX(55,5),          RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),        UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),          PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),      PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),       RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),      RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),         RHO(55,5),         VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),         A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),         A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),         F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),         F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),        FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),       FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),         CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),       RYM(55,5),         RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),         Q22(55,5),         QX(55,5),
     7 P11(55,5),       P12(55,5),         P22(55,5),         PX(55,5),
     8 PQX(55,5),       PQMX(55,5),        VO(55,5)
      COMMON      ICON,     LINCT,    LX1,      LX2,      LX3,      LX4,      LX5,
     2 KC,        NDPA,     NEDIT,    NSIG,     NMASS,    NDMP
      COMMON           AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON              S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      L=LX1
      L2=LX2
      DO 18 J=JMIN,JR
      FMASN(J,L)=FMASNM(J,L)+(RWA3Z(J,L)-RWA3Z(J+1,L)-RWA1Z(J,L)+
     1          RWA1Z(J,L2))*DTNM
      IF(FMASN(J,L))15,15,18
   15 NEDIT=1
      NSIG=4
   17 WRITE(6,77)J,FMASN(J,L)
      FMASN(J,L)=1.
18    CONTINUE
      RETURN
77    FORMAT(7HOFOR J=,I6,8H AND K+2,10H THE MASS=,1PE16.7,6H ERROR)
      END
```

```
      SUBROUTINE NEWU
      COMMON              NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI, SMZTPT, SMOMZ,   SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,   PROBNO, DTNM,    CUTOFF, N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5, DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN, UYBIN,   UYRBIN, UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN, UYTIN,   UYRTIN, UXLTIN, UXTIN,   UXRTIN, KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,       EIN,       RHOIN,      UYIN,       UXIN,       KINT(5),
     A E S(5),     ALFA(5),    BIG A(5), BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),    SAV(12),
     4 KSV(24),       YTERM(55),    Y2TERM(55),   TA1(55),      TA2(55),
     5 FMLYR(101),   FMLZR(101),   VACANT(15)
      COMMON                         A(55),        DIL(55),      EPX(55),
     2 EPY(55),      EPZ(55),      FMLYB(55),    FMLYT(55),    FMLZB(55),
     3 FMLZT(55),    LY1(55),      LY2(55),      LZ1(55),      LZ2(55),
     4 PY(55),       PZ(55),       R1H(55),      R2H(55),      R3H(55),
     5 R4H(55),      Z1H(55),      Z2H(55),      Z3H(55),      Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A               RX(55,5),       RY(55,5),       UNMX(55,5),
     1 UNMY(55,5),   UNPX(55,5),     UNPY(55,5),     FMASNM(55,5),
     2 ENM(55,5),    EN(55,5),       PNM(55,5),      PN(55,5),
     3 PQNMXX(55,5), PQNMXY(55,5),   PQNMYY(55,5),   PQNXX(55,5),
     4 PQNXY(55,5),  PQNYY(55,5),    RWA3Z(55,5),    RWA1Z(55,5),
     5 RWAE3Z(55,5), RWAE1Z(55,5),   RH3Z(55,5),     RH1Z(55,5),
     6 E3Z(55,5),    E1Z(55,5),      RHO(55,5),      VOL(55,5),
     7 ETA(55,5),    A1Y(55,5),      A2Y(55,5),      A3Y(55,5),
     8 A4Y(55,5),    A1Z(55,5),      A2Z(55,5),      A3Z(55,5),
     9 A4Z(55,5),    F1Y(55,5),      F2Y(55,5),      F3Y(55,5),
     A F4Y(55,5),    F1Z(55,5),      F2Z(55,5),      F3Z(55,5),
     1 F4Z(55,5),    NTPT(55,5),     FMSNZ(55,5),    FMASN(55,5),
     2 FMNMX(55,5),  FMNMY(55,5),    FMNX(55,5),     FMNY(55,5),
     4 AW1(55,5),    AW2(55,5),      CMASS1(55,5),   CMASS2(55,5),
     5 RXM(55,5),    RYM(55,5),      RXZ(55,5),      RYZ(55,5),
     6 Q11(55,5),    Q12(55,5),      Q22(55,5),      QX(55,5),
     7 P11(55,5),    P12(55,5),      P22(55,5),      PX(55,5),
     8 PQX(55,5),    PQMX(55,5),     VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON        S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      L=LX1
      L2=LX2
      L5=LX5
      TFXX=0.
      TFXY=0.
      DO 400 J=JMIN,JMAX
      IF(JMIN-J) 100,10,10
10    YRHO=YTERM(J)*RHO(J,L)
      Y2RHO=Y2TERM(J)*RHO(J,L)
      CMASS1(J,L)=AW1(J,L)*YRHO
      CMASS2(J,L)=AW2(J,L)*Y2RHO
      FMSNZ(J,L)=.5*(CMASS2(J,L)+CMASS2(J,L5))
      CUTON=CUT2*FMSNZ(J,L)
      FMNX(J,L)=0.0
```

```
      UNPX(J,L)=0.0
      IF((KC.GE.KBOT).AND.(KC.LE.KTOP))GO TO 410
      GO TO (15,20,15),MOTION
15    FXLY=0.0
      FXMST=. 25*(RWA1Z(J,L)+RWA1Z(J,L2 ))*TA2(J)
      FXTY=FXMST     *(UNMY(J,L)+UNMY(J,L2 ))
      FXMSR=.125*(RWA3Z(J+1,L)+RWA3Z(J+1,L5 ))
      FXRY=FXMSR     *(UNMY(J,L)+UNMY(J+1,L))
      FXMSB=. 25*(RWA1Z(J,L)+RWA1Z(J,L5 ))*TA2(J)
      FXBY=FXMSB     *(UNMY(J,L)+UNMY(J,L5 ))
      TFXY=FXLY-FXRY+FXTY-FXBY
20    FMOMCH=DTNM*(F2Z(J,L)+F3Z(J,L5)+TFXY)
      IF(ABS(FMOMCH)-CUTON)35,35,30
   30 FMNY(J,L)=FMNMY(J,L)+FMOMCH
      GO TO 40
   35 FMNY(J,L)=FMNMY(J,L)
40    UNPY(J,L)=FMNY(J,L)/FMSNZ(J,L)-UNMY(J,L)
      GO TO 400
  100 IF(J-JMAX) 110,300,300
110   YRHO=YTERM(J)*RHO(J,L)
      Y2RHO=Y2TERM(J)*RHO(J,L)
      CMASS1(J,L)=AW1(J,L)*YRHO
      CMASS2(J,L)=AW2(J,L)*Y2RHO
      FMSNZ(J,L)=.5*(CMASS2(J,L5)+CMASS1(J-1,L5)+CMASS1(J-1,L)+CMASS2(J,
     2 L))
      GO TO (111,115,111),MOTION
111   FXMSL=.125*(RWA3Z(J,L)+RWA3Z(J-1,L)+RWA3Z(J-1,L5 )+RWA3Z(J,L5 ))
      FXLX=FXMSL     *(UNMX(J,L)+UNMX(J-1,L))
      FXLY=FXMSL     *(UNMY(J,L)+UNMY(J-1,L))
      FXMST=.25*(TA1(J-1)*(RWA1Z(J-1,L)+RWA1Z(J-1,L2))+TA2(J)*
     2 (RWA1Z(J,L)+RWA1Z(J,L2)))
      FXTX=FXMST     *(UNMX(J,L)+UNMX(J,L2 ))
      FXTY=FXMST     *(UNMY(J,L)+UNMY(J,L2 ))
      FXMSR=.125*(RWA3Z(J,L)+RWA3Z(J+1,L)+RWA3Z(J+1,L5 )+RWA3Z(J,L5 ))
      FXRX=FXMSR     *(UNMX(J,L)+UNMX(J+1,L))
      FXRY=FXMSR     *(UNMY(J,L)+UNMY(J+1,L))
      FXMSB=.25*(TA1(J-1)*(RWA1Z(J-1,L5)+RWA1Z(J-1,L))+TA2(J)*
     2 (RWA1Z(J,L)+RWA1Z(J,L5)))
      FXBX=FXMSB     *(UNMX(J,L)+UNMX(J,L5 ))
      FXBY=FXMSB     *(UNMY(J,L)+UNMY(J,L5 ))
      TFXX=FXLX-FXRX+FXTX-FXBX
      TFXY=FXLY-FXRY+FXTY-FXBY
115   CUTON=CUT2*FMSNZ(J,L)
      FMOMCH=DTNM*(F1Y(J-1,L)+F2Y(J,L)+F3Y(J,L5)+F4Y(J-1,L5)+TFXX)
      IF(ABS(FMOMCH)-CUTON) 125,125,120
  120 FMNX(J,L)=FMNMX(J,L)+FMOMCH
      GO TO 130
  125 FMNX(J,L)=FMNMX(J,L)
130   FMOMCH=DTNM*(F1Z(J-1,L)+F2Z(J,L)+F3Z(J,L5)+F4Z(J-1,L5)+TFXY)
      IF(ABS(FMOMCH)-CUTON) 145,145,140
  140 FMNY(J,L)=FMNMY(J,L)+FMOMCH
      GO TO 150
  145 FMNY(J,L)=FMNMY(J,L)
  150 UNPX(J,L)=     FMNX(J,L)/FMSNZ(J,L)-UNMX(J,L)
      UNPY(J,L)=     FMNY(J,L)/FMSNZ(J,L)-UNMY(J,L)
      GO TO 400
300   FMSNZ(J,L)=.5*(CMASS1(J-1,L)+CMASS1(J-1,L5))
      GO TO (301,305,301),MOTION
301   FXMSL=.125*(RWA3Z(J-1,L)+RWA3Z(J-1,L5 ))
      FXLX=FXMSL     *(UNMX(J,L)+UNMX(J-1,L))
      FXLY=FXMSL     *(UNMY(J,L)+UNMY(J-1,L))
```

```
      FXMST=. 25*(RWA1Z(J-1,L)+RWA1Z(J-1,L2 ))*TA1(J-1)
      FXTX=FXMST     *(UNMX(J,L)+UNMX(J,L2 ))
      FXTY=FXMST     *(UNMY(J,L)+UNMY(J,L2 ))
      FXRX=0.0
      FXRY=0.0
      FXMSB=. 25*(RWA1Z(J-1,L)+RWA1Z(J-1,L5 ))*TA1(J-1)
      FXBX=FXMSB     *(UNMX(J,L)+UNMX(J,L5 ))
      FXBY=FXMSB     *(UNMY(J,L)+UNMY(J,L5 ))
      TFXX=FXLX-FXRX+FXTX-FXBX
      TFXY=FXLY-FXRY+FXTY-FXBY
305   CUTON=CUT2*FMSNZ(J,L)
      FMNX(J,L)=0.0
      FMLYR(KC)=- F4Y(J-1,L5)-F1Y(J-1,L)-TFXX
      FMOMCH=DTNM*(FMLZR(KC) +F4Z(J-1,L5)+F1Z(J-1,L)+TFXY)
      IF(ABS(FMOMCH)-CUTON) 315,315,310
  310 FMNY(J,L)=FMNMY(J,L)+FMOMCH
      GO TO 320
  315 FMNY(J,L)=FMNMY(J,L)
  320 UNPX(J,L)=0.0
      UNPY(J,L)=     FMNY(J,L)/FMSNZ(J,L)-UNMY(J,L)
400   CONTINUE
      RETURN
410   FMNY(J,L)=0.0
      UNPY(J,L)=0.0
      GO TO 400
      END
```

```
      SUBROUTINE REDGEN
      COMMON             NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,     SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,   SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,   SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,     MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,     CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN, UYLTIN,   UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,   JMAX,     KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,        EIN,          RHOIN,        UYIN,        UXIN,       KINT(5),
     A E S(5),    ALFA(5),      BIG A(5),  BIG B(5),  RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),     SAV(12),
     4 KSV(24),        YTERM(55),      Y2TERM(55),    TA1(55),        TA2(55),
     5 FMLYR(101),     FMLZR(101),     VACANT(15)
      COMMON                           A(55),         DIL(55),        EPX(55),
     2 EPY(55),        EPZ(55),        FMLYB(55),     FMLYT(55),      FMLZB(55),
     3 FMLZT(55),      LY1(55),        LY2(55),       LZ1(55),        LZ2(55),
     4 PY(55),         PZ(55),         R1H(55),       R2H(55),        R3H(55),
     5 R4H(55),        Z1H(55),        Z2H(55),       Z3H(55),        Z4H(55),
     6 U2(55,2),       B(55,4)
      COMMON
     A                   RX(55,5),          RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),       UNPX(55,5),        UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),        EN(55,5),          PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),     PQNMXY(55,5),      PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),      PQNYY(55,5),       RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),     RWAE1Z(55,5),      RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),        E1Z(55,5),         RHO(55,5),         VOL(55,5),
     7 ETA(55,5),        A1Y(55,5),         A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),        A1Z(55,5),         A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),        F1Y(55,5),         F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),        F1Z(55,5),         F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),        NTPT(55,5),        FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),      FMNMY(55,5),       FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),        AW2(55,5),         CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),        RYM(55,5),         RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),        Q12(55,5),         Q22(55,5),         QX(55,5),
     7 P11(55,5),        P12(55,5),         P22(55,5),         PX(55,5),
     8 PQX(55,5),        PQMX(55,5),        VO(55,5)
      COMMON   ICON,     LINCT,  LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,     NDPA,     NEDIT,  NSIG,    NMASS,   NDMP
      COMMON          AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON          S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      DIMENSION DUMPV(600)
      DIMENSION  TX( 55), TY(101), TITLE(9)
      DIMENSION YDB(55)
C*****
      EQUIVALENCE(NREG,DUMPV(1))
      EQUIVALENCE (YDB(1),FMLYB(1))
C*****
      INTEGER  P, Q, R
C*****
    1 FORMAT (9A8)
    2 FORMAT (6E12.5)
    3 FORMAT (12I6)
    4 FORMAT(I6,2E12.5)
    5 FORMAT (2I6, 5E12.5 / (6E12.5))
```

```
6     FORMAT(3(2I6,E12.5))
   51 FORMAT (15HOPROBLEM NUMBER , F7.2)
52    FORMAT(1H /
     272H  KSV1  KSV2  KSV3  KSV4  KSV5  KSV6  KSV7  KSV8  KSV9 KSV10 KS
     3V11 KSV12/12I6)
53    FORMAT(1H /
     293H   SAV1                SAV2                SAV3                SAV4
     3          SAV5                SAV6/6E17.9)
54    FORMAT(1H1/
     224H INPUT FOR REGION NUMBER,I3)
55    FORMAT(1H /
     241H     VZ                RHOIN               EIN/3E17.9)
56    FORMAT(1H /
     278H  JBOT  JTOP  KBOT  KTOP  KBUG  MOTION  KFACE1  KFACE2  KFACE3
     3 KFACE4  KFACE5/5I6,6I8)
60    FORMAT(1H /
     225H     UXIN              UYIN/2E17.9)
62    FORMAT(1H /
     2 8H     DTNM/E17.9)
64    FORMAT(1H /
     218H  MAXN     TIME MAX/I6,E17.9)
65    FORMAT(1H /
     210H     CUTOFF/E17.9)
70    FORMAT(14H1     PROBLEM= F7.2,5X6HTIME= E17.9,5X9HDELTA T= E17.9,
     B 1H //
     2119H     Y                Z                   VOL                 RHO
     3              ETA                 E                   *  J*  K*CYCLE*/
     4112H     U(N-1/2)         V(N-1/2)            ZONE MASS           MP1
     5              AW1                 PQNXX               PQNYY /
     6112H     MOM Y            MOM Z               PT. MASS            MP2
     7              AW2                 PQNXY               PQX    //
     6 13(6E17.9,3H   *,I3,1H*,I3,1H*,I5,1H*/7E17.9/7E17.9//)
     7      6E17.9,3H   *,I3,1H*,I3,1H*,I5,1H*/7E17.9/7E17.9)
   74 FORMAT (I7, 6E16.7 / 7X 6E16.7/)
   75 FORMAT (1HO 9X 6HSENERI 10X 6HSMASSI 10X 6HSMOMYI 10X 6HSMOMZI)
   76 FORMAT (7X 6E16.7)
   77 FORMAT (7HOFOR J= I6, 7H AND K= I6, 10H THE MASS= E16.7, 6H ERROR)
78    FORMAT(1H /
     253H     U(LEFT BOTTOM)     U(BOTTOM)           U(RIGHT BOTTOM)/
     353H     V                  V                   V                   //
     4(3E17.9))
79    FORMAT(1H /
     250H     U(LEFT TOP)        U(TOP)              U(RIGHT TOP)/
     350H     V                  V                   V        //
     4(3E17.9))
80    FORMAT(1H /
     227H  JMAX   KMAX     U(INTERIOR)/
     327H                  V           //
     4(2I6,E17.9))
81    FORMAT(1H /
     222H  JMAX   KMAX     R ZERO/
     331H                  INITIAL DENSITY/
     431H                                   ENERGY //
     5(2I6,E17.9))
83    FORMAT(1H /
     232H     FMLY(RIGHT)       FMLZ(RIGHT)/
     3 2E17.9/1H1/)
84    FORMAT(24HOJBMIN JBMAX KBMIN KBMAX/4I6)
85    FORMAT(1H /
     293H     TINY A             TINY B              BIG A               BIG B
     3          V(S)              E(0)/6E17.9/
```

```
      459H    E(S)                    ALPHA              BETA              QCON/
      5 4E17.9)
86     FORMAT(1H /
      2108H    J         Y                    J        Y                    J         Y
      3                 J         Y                    J        Y/
      4(5(I4,3X,E17.9)))
87     FORMAT(1H /
      2108H    K         Z                    K        Z                    K         Z
      3                 K         Z                    K        Z/
      4(5(I4,3X,E17.9)))
88     FORMAT(1H /
      224H  JMIN   JMAX   KMIN   KMAX/4I6)
89     FORMAT(1H /
      227H  JMAX   KMAX     U(INTERIOR)/
      3(2I6,E17.9))
90     FORMAT(1H /
      227H  JMAX   KMAX     V(INTERIOR)/
      3(2I6,E17.9))
91     FORMAT(1H /
      222H  JMAX   KMAX     R ZERO/
      3(2I6,E17.9))
92     FORMAT(1H /
      231H  JMAX   KMAX.    INITIAL DENSITY/
      3(2I6,E17.9))
93     FORMAT(1H /
      230H  JMAX   KMAX     INITIAL ENERGY/
      3(2I6,E17.9))
C*****
       DO 900 J=1,600
900    DUMPV(J)=0.0
       DO 901 J=1,19250
901    RX(J)=0.0
       DO 902 J=1,1595
902    A(J)=0.
       NMASS = 1
       IF (EOF,5) 101,100
 100   READ (5,1) TITLE
       WRITE(6,01)TITLE
       READ (5,2) PROBNO
       IF (PROBNO.GT.0.)   GO TO 103
       IF (NDMP.EQ.0)      GO TO 102
 101   END FILE 10
       REWIND 10
 102   STOP
103    WRITE(6,51)PROBNO
       READ(5,3)(KSV(J),J=1,12)
       WRITE (6,52) (KSV(J),J=1,12)
       READ (5,2) (SAV(J),J=1,6)
       WRITE (6,53) (SAV(J),J=1,6)
       READ(5,3)JBOT,JTOP,KBOT,KTOP,KBUG,MOTION,(KINT(J),J=1,5)
       WRITE(6,56) JBOT,JTOP,KBOT,KTOP,KBUG,MOTION,(KINT(J),J=1,5)
       READ (5,2) DTNM
       WRITE (6,62) DTNM
       READ (5,2) CUTOFF
       WRITE (6,65) CUTOFF
       READ (5,4) MAXN, TMAX
       WRITE (6,64) MAXN, TMAX
       MAXREG=1
       DO 10305 NREG=1,MAXREG
       WRITE(6,54)NREG
       READ(5,3) JMIN      ,JMAX       ,KMIN       ,KMAX
```

```
      WRITE(6,88)JMIN      ,JMAX      ,KMIN      ,KMAX
      READ(5,5) (JYMIN,JYMAX,(TX(J),J=JYMIN,JYMAX))
      READ(5,5) (KZMIN,KZMAX,(TY(K),K=KZMIN,KZMAX))
10300 IF((JYMIN.EQ.JMIN).AND.(JYMAX.EQ.JMAX)) GO TO 10303
      READ(5,4) JTMAX,DELTA Y,RATE Y
      IF(DELTA Y .LT.0) GO TO 10302
      JTMIN=JYMAX+1
      JYMAX=JTMAX
      DO 10301 J=JTMIN,JTMAX
      TX(J)=TX(J-1)+DELTA Y
10301 DELTA Y =RATE Y *DELTA Y
      GO TO 10300
10302 STOP
10303 IF((KZMIN.EQ.KMIN).AND.(KZMAX.EQ.KMAX)) GO TO 10308
      READ(5,4)KTMAX,DELTA Z,RATE Z
      IF(DELTA Z.LT. 0) GO TO 10306
      KTMIN=KZMAX+1
      KZMAX=KTMAX
      DO 10304 J=KTMIN,KTMAX
      TY(J)=TY(J-1)+DELTA Z
10304 DELTA Z= RATE Z*DELTA Z
      GO TO 10303
10306 KTMIN=KZMIN-1
      KZMIN=KTMAX
      DO 10307 J=KTMAX,KTMIN
      K=KTMIN+KTMAX-J
      TY(K)=TY(K+1)+DELTA Z
10307 DELTA Z=RATE Z*DELTA Z
      GO TO 10303
10308 WRITE(6,86) (J,TX(J),J=JMIN,JMAX)
      WRITE(6,87) (K,TY(K),K=KMIN,KMAX)
      SAV(12)=TY(KMAX)
      READ(5,2) UXLBIN,UXBIN,UXRBIN,UYLBIN,UYBIN,UYRBIN
      WRITE(6,78)UXLBIN,UXBIN,UXRBIN,UYLBIN,UYBIN,UYRBIN
      READ(5,6) JUMAX,KUMAX,UXIN,JVMAX,KVMAX,UYIN
      WRITE(6,80)JUMAX,KUMAX,UXIN,JVMAX,KVMAX,UYIN
      READ(5,2)UXLTIN,UXTIN,UXRTIN ,UYLTIN,UYTIN,UYRTIN
      WRITE(6,79)UXLTIN,UXTIN,UXRTIN,UYLTIN,UYTIN,UYRTIN
      READ(5,6)  JZMAX,KZMAX,R ZERO(1),JRMAX,KRMAX,RHO1,JEMAX,KEMAX,E1
      WRITE(6,81)JZMAX,KZMAX,R ZERO(1),JRMAX,KRMAX,RHO1,JEMAX,KEMAX,E1
      V ZERO=1./R ZERO
      RHOIN=RHO1
      EIN=E1
      READ(5,2)      TINY A(NREG),        TINY B(NREG),
     2 BIG A(NREG), BIG B(NREG),          RCP V S(NREG),
     3 E ZERO(NREG),E S(NREG),            ALFA(NREG),           BETA(NREG)
     4 ,QCON(NREG)
      WRITE(6,85)    TINY A(NREG),        TINY B(NREG),
     2 BIG A(NREG), BIG B(NREG),          RCP V S(NREG),
     3 E ZERO(NREG),E S(NREG),            ALFA(NREG),           BETA(NREG)
     4 ,QCON(NREG)
      RCP V S(NREG)=1./RCP V S (NREG)
      QCON(NREG)=.5*QCON(NREG)
      READ(5,2)SFMLYR,SFMLZR
      WRITE(6,83)SFMLYR,SFMLZR
      IF(KBUG.GT.0) GO TO 10320
      JBMIN=JMAX+1
      JBMAX=JMAX+1
      KBMIN=KMAX+1
      KBMAX=KMAX+1
      GO TO 10305
```

```
10320 READ(5,3) JBMIN,JBMAX,KBMIN,KBMAX
      WRITE(6,84)JBMIN,JBMAX,KBMIN,KBMAX
10305 CONTINUE
      JR = JMAX-1
      JL = JMIN+1
      KT = KMAX-1
      KB = KMIN+1
      MT=1
      NREG=1
      KL=1
      KU=2
      MAXU= JUMAX+(KUMAX-1)*JMAX
      MAXV= JVMAX+(KVMAX-1)*JMAX
      MAXZ= JZMAX+(KZMAX-1)*JMAX
      MAXR= JRMAX+(KRMAX-1)*JMAX
      MAXE= JEMAX+(KEMAX-1)*JMAX
      P = 3
      Q = 1
      R = 2
      DO 104 J=JMIN,JMAX
      RX(J,Q) = TX(J)
      RY(J,Q) = TY(1)
      RXZ(J,Q)=RX(J,Q)
      RYZ(J,Q)=RY(J,Q)
      IF(J.NE.JMIN) GO TO 1030
      UNMX(J,Q)=0.
      UNMY(J,Q)=UYLBIN
      GO TO 1035
1030  YDB(J-1)=SQRT((RX(J-1,Q)**2+RX(J-1,Q)*RX(J,Q)+RX(J,Q)**2)/3.)
      YTERM(J-1)=.5*(RX(J,Q)+YDB(J-1))
      Y2TERM(J-1)=.5*(RX(J-1,Q)+YDB(J-1))
      TRAPV(J-1)=.5*(RX(J,Q)+RX(J-1,Q))
      YDELTA(J-1)=RX(J-1,Q)-RX(J,Q)
      AZQ(J-1)=TRAPV(J-1)*YDELTA(J-1)
      IF(J.NE.JMAX) GO TO 1031
      UNMX(J,Q)=0.
      UNMY(J,Q)=UYRBIN
      GO TO 1035
1031  UNMX(J,Q)=UXBIN
      UNMY(J,Q)=UYBIN
1035  RHO(J,Q)=RHO1
      VO(J,Q)=V ZERO
      U2(J,KL)=UNMX(J,Q)**2+UNMY(J,Q)**2
104   ENM(J,Q)=E1
      RHO(JMAX,Q) = 0.
      VO(JMAX,Q)=0.
      ENM(JMAX,Q) = 0.
      DO 134 K=KMIN,KT
      JK=K*JMAX
      INT=NREG
      DO 107 J=JMIN,JMAX
      JK1=JK+J
      RX(J,R) = TX(J)
      RY(J,R) = TY(K+1)
      RXZ(J,R)=RX(J,R)
      RYZ(J,R)=RY(J,R)
      IF((JK1.LE.MAXU).OR.(MAXU.LE.0)) GO TO 1040
      READ(5,6)  JUMAX,KUMAX,UXIN
      WRITE(6,89)JUMAX,KUMAX,UXIN
      MAXU= JUMAX+(KUMAX-1)*JMAX
1040  IF((JK1.LE.MAXV).OR.(MAXV.LE.0)) GO TO 1041
```

```
      READ(5,6)  JVMAX,KVMAX,UYIN
      WRITE(6,90)JVMAX,KVMAX,UYIN
      MAXV= JVMAX+(KVMAX-1)*JMAX
1041  IF((JK1.LE.MAXZ).OR.(MAXZ.LE.0)) GO TO 1042
      READ(5,6) JZMAX,KZMAX,R ZERO(1)
      WRITE(6,91) JZMAX,KZMAX,R ZERO(1)
      V ZERO=1./R ZERO
      MAXZ= JZMAX+(KZMAX-1)*JMAX
1042  IF((JK1.LE.MAXR).OR.(MAXR.LE.0)) GO TO 1043
      READ(5,6)  JRMAX,KRMAX,RHO1
      WRITE(6,92)JRMAX,KRMAX,RHO1
      MAXR= JRMAX+(KRMAX-1)*JMAX
1043  IF((JK1.LE.MAXE).OR.(MAXE.LE.0)) GO TO 1044
      READ(5,6)  JEMAX,KEMAX,E1
      WRITE(6,93)JEMAX,KEMAX,E1
      MAXE= JEMAX+(KEMAX-1)*JMAX
1044  K1=K+1
      IF ((J.LT.JBOT).OR.(K1.LT.KBOT).OR.(J.GT.JTOP).OR.(K1.GT.KTOP)
     1.OR.(K1.EQ.KMAX)) GO TO 106
      UNMX(J,R) = 0.
      UNMY(J,R) = 0.
      GO TO 1065
 105  RHO (J,R) = 0.
      VO(J,R)=0.
      ENM (J,R) = 0.
      GO TO 107
106   IF(J.NE.JMIN) GO TO 10601
      TRAPYH(K)=RX(J,Q)-RX(J,R)
      TRAPZH(K)=RY(J,R)-RY(J,Q)
      UNMX(J,R)=0.
      IF(K.NE.KT) GO TO 10600
      UNMY(J,R)=UYLTIN
      GO TO 10605
10600 UNMY(J,R)=UYIN
      GO TO 10605
10601 IF(J.NE.JMAX) GO TO 10603
      UNMX(J,R)=0.
      IF(K.NE.KT) GO TO 10602
      UNMY(J,R)=UYRTIN
      GO TO 10605
10602 UNMY(J,R)=UYIN
      GO TO 10605
10603 IF(K.NE.KT) GO TO 10604
      UNMX(J,R)=UXTIN
      UNMY(J,R)=UYTIN
      GO TO 10605
10604 UNMX(J,R)=UXIN
      UNMY(J,R)=UYIN
10605 IF(K.EQ.KT) GO TO 105
 1065 CONTINUE
      RHO(J,R)=RHO1
      VO(J,R)=V ZERO
      ENM(J,R)=E1
107   U2(J,KU)=UNMX(J,R)**2+UNMY(J,R)**2
      RHO(JMAX,R) = 0.
      VO(JMAX,R)=0.
      ENM(JMAX,R) = 0.
      L=Q
      L2=R
 108  DO 110 J=JMIN,JR
      R1H(J)=2.*RX(J,L)
```

```
      Z1H(J)=2.*RY(J,L)
      R2H(J)=RX(J+1,L)*2.
      Z2H(J)=RY(J+1,L)*2.
      R3H(J)=RX(J+1,L2)*2.
      Z3H(J)=RY(J+1,L2)*2.
      R4H(J)=RX(J,L2)*2.
      Z4H(J)=RY(J,L2)*2.
      R41H=R4H(J)+R1H(J)
      R12H=R1H(J)+R2H(J)
      R23H=R2H(J)+R3H(J)
      R34H=R3H(J)+R4H(J)
      A41=RX(J,L)*RY(J,L2)-RX(J,L2)*RY(J,L)
      A12=RX(J+1,L)*RY(J,L)-RX(J,L)*RY(J+1,L)
      A23=RX(J+1,L2)*RY(J+1,L)-RX(J+1,L)*RY(J+1,L2)
      A34=RX(J,L2)*RY(J+1,L2)-RX(J+1,L2)*RY(J,L2)
      A41H=2.*A41
      A12H=2.*A12
      A23H=2.*A23
      A34H=2.*A34
8     A1Y(J,L)=((Z4H(J)*R41H-Z2H(J)*R12H)*.5+A41H+A12H)/(-12.)
      A1Z(J,L)=(R2H(J)*R12H-R4H(J)*R41H)/(-24.)
      A2Y(J,L)=((Z1H(J)*R12H-Z3H(J)*R23H)*.5+A12H+A23H)/(-12.)
      A2Z(J,L)=(R3H(J)*R23H-R1H(J)*R12H)/(-24.)
      A3Y(J,L)=((Z2H(J)*R23H-Z4H(J)*R34H)*.5+A23H+A34H)/(-12.)
      A3Z(J,L)=(R4H(J)*R34H-R2 H(J)*R23H)/(-24.)
      A4Y(J,L)=((Z3H(J)*R34H-Z1H(J)*R41H)*.5+A34H+A41H)/(-12.)
      A4Z(J,L)=(R1H(J)*R41H-R3H(J)*R34H)/(-24.)
      IF(J.EQ.JMIN) ZTERM=.5*(RY(J,R)-RY(J,Q))
      AW1(J,Q)=(RX(J+1,Q)-YDB(J))*ZTERM
      AW2(J,Q)=(YDB(J)-RX(J,Q))*ZTERM
      IF(K.NE.KMIN) GO TO 1081
      CVOL1=YTERM(J)*AW1(J,Q)
      CVOL2=Y2TERM(J)*AW2(J,Q)
      TA1(J)=CVOL1/(CVOL1+CVOL2)
      TA2(J)=1.-TA1(J)
      CMASS1(J,Q)=CVOL1*RHO(J,Q)
      CMASS2(J,Q)=CVOL2*RHO(J,Q)
      GO TO 1082
1081  CMASS1(J,Q)=AW1(J,Q)*YTERM(J)*RHO(J,Q)
      CMASS2(J,Q)=AW2(J,Q)*Y2TERM(J)*RHO(J,Q)
1082  Y1P2=RX(J+1,Q)+RX(J,Q)
      Z12=RY(J+1,Q)-RY(J,Q)
      Y2P3=RX(J,Q)+RX(J,R)
      Z23=RY(J,Q)-RY(J,R)
      Y3P4=RX(J,R)+RX(J+1,R)
      Z34=RY(J,R)-RY(J+1,R)
      Y4P1=RX(J+1,R)+RX(J+1,Q)
      Z41=RY(J+1,R)-RY(J+1,Q)
      VOL(J,Q)=(Z12*(Y1P2**2-RX(J+1,Q)*RX(J,Q))+Z23*(Y2P3**2-RX(J,Q)*
     1 RX(J,R))+Z34*(Y3P4-RX(J,R)*RX(J+1,R))+Z41*(Y4P1**2-RX(J+1,R)*
     2 RX(J+1,Q)))/6.
1085  FMASNM(J,Q)=RHO(J,Q)*VOL(J,Q)
      IF (FMASNM(J,Q).GT.0.)  GO TO 109
      KP = K
      WRITE (6,77) J, KP, FMASNM(J,Q)
      NMASS = 2
109   GO TO (1090,1091,1090),MOTION
1090  ETA(J,Q)=RHO(J,Q)*VO(J,Q)
      GMU=ETA(J,Q)-1.
      ERHO=ENM(J,Q)*RHO(J,Q)
      EZETA=EZERO*ETA(J,Q)**2
```

```
      G= ENM(J,Q)/EZETA+1.
      BOVERG=TINYB/G
      IF((ETA(J,Q).GE.1.).OR.((ENM(J,Q).LE.ES).AND.(ETA(J,Q).GT.RCPVS)))
     2   GO TO 10900
      H=-GMU/ETA(J,Q)
      BETAH=EXP(-BETA*H)
      ALFAH=EXP(-ALFA*H**2)
      AMUBH=BIGA*GMU*BETAH
      PNM(J,Q)= TINYA*ERHO+(BOVERG*ERHO+AMUBH)*ALFAH
      GO  TO 1092
10900 AMUBMU=GMU*(BIGA+BIGB*GMU)
      PNM(J,Q)=(TINYA+BOVERG)*ERHO+ AMUBMU
      GO TO 1092
1091  PNM(J,Q) = 0.0
1092  Q11(J,Q)=0.0
      Q12(J,Q)=0.0
      Q22(J,Q)=0.0
      QX(J,Q)=0.0
1095  PQNMXX(J,Q)=PNM(J,Q)+Q11(J,Q)
      PQNMXY(J,Q)=Q12(J,Q)
      PQNMYY(J,Q)=PNM(J,Q)+Q22(J,Q)
      PQMX(J,Q)=PNM(J,Q)+QX(J,Q)
      NTPT(J,Q)=3
      SMASSI = SMASSI+FMASNM(J,Q)
110   SENERI=SENERI+FMASNM(J,Q)*ENM(J,Q)+.5*(CMASS1(J,Q)*(U2(J+1,KL)+
     2         U2(J+1,KU))+CMASS2(J,Q)*(U2(J,KL)+U2(J,KU)))
1313  KL=KU
      KU=MOD(KL,2)+1
      IF(K.EQ.KINT(NREG))NREG=NREG+1
      FMLYR(K)=SFMLYR
      FMLZR(K)=SFMLZR
      IF(K.GT.KMIN) GO TO 121
      FMSNZ(JMIN,Q)=CMASS2(JMIN,Q)
      FMNMX(JMIN,Q)=0.
      DO 114 J=JL,JR
112   FMSNZ(J,Q)=CMASS2(J,Q)+CMASS1(J-1,Q)
113   FMNMX(J,Q)=FMSNZ(J,Q)*UNMX(J,Q)
      FMNMY(J,Q)=FMSNZ(J,Q)*UNMY(J,Q)
      SMOMYI = SMOMYI+FMNMX(J,Q)
 114  SMOMZI = SMOMZI+FMNMY(J,Q)
      FMSNZ(JMAX,Q)=CMASS1(JR,Q)
      FMNMX(JMAX,Q)=0.
      GO TO 131
121   FMSNZ(JMIN,Q)=CMASS2(JMIN,Q)+CMASS2(JMIN,P)
      FMNMX(JMIN,Q)=0.
      DO 125 J=JL,JR
123   FMSNZ(J,Q)=CMASS2(J,P)+CMASS1(J-1,P)+CMASS1(J-1,Q)+CMASS2(J,Q)
124   FMNMX(J,Q)=FMSNZ(J,Q)*UNMX(J,Q)
      FMNMY(J,Q)=FMSNZ(J,Q)*UNMY(J,Q)
      SMOMYI = SMOMYI+FMNMX(J,Q)
 125  SMOMZI = SMOMZI+FMNMY(J,Q)
      FMSNZ(JMAX,Q)=CMASS1(JR ,Q)+CMASS1(JR ,P)
      FMNMX(JMAX,Q)=0.
 126  IF (K.LT.KT)  GO TO 131
      FMSNZ(JMIN,R)=CMASS2(JMIN,Q)
      FMNMX(JMIN,R)=0.
      DO 130 J=JL,JR
128   FMSNZ(J,R)=CMASS1(J-1,Q)+CMASS2(J,Q)
129   FMNMX(J,R)=FMSNZ(J,R)*UNMX(J,R)
      FMNMY(J,R)=FMSNZ(J,R)*UNMY(J,R)
      SMOMYI = SMOMYI+FMNMX(J,R)
```

```
 130   SMOMZI = SMOMZI+FMNMY(J,R)
       FMSNZ(JMAX,R)=CMASS1(JR ,Q)
       FMNMX(JMAX,R)=0.
       FMNMY(JMIN,R)=FMSNZ(JMIN,R)*UNMY(JMIN,R)
       FMNMY(JMAX,R)=FMSNZ(JMAX,R)*UNMY(JMAX,R)
       SMOMYI = SMOMYI+FMNMX(JMAX,R)+FMNMX(JMIN,R)
       SMOMZI = SMOMZI+FMNMY(JMAX,R)+FMNMY(JMIN,R)
 131   FMNMY(JMIN,Q)=FMSNZ(JMIN,Q)*UNMY(JMIN,Q)
       FMNMY(JMAX,Q)=FMSNZ(JMAX,Q)*UNMY(JMAX,Q)
       SMOMYI = SMOMYI+FMNMX(JMAX,Q)+FMNMX(JMIN,Q)
       SMOMZI = SMOMZI+FMNMY(JMAX,Q)+FMNMY(JMIN,Q)
 1350  LS=P
       P = Q
       Q = R
       R = LS
       KMOUT = 1
 132   L=P
       WRITE(MT)       (RX(J,L),     RY(J,L),      UNMX(J,L),    UNMY(J,L),
      2 FMASNM(J,L), ENM(J,L),     PNM(J,L),     PQNMXX(J,L), PQNMXY(J,L),
      3 PQNMYY(J,L), VOL(J,L),     RHO(J,L),
      4 PQMX(J,L),    FMNMX(J,L),  FMNMY(J,L),   NTPT(J,L),    A1Y(J,L),
      5 A2Y(J,L),     A3Y(J,L),    A4Y(J,L),     A1Z(J,L),     A2Z(J,L),
      6 A3Z(J,L),     A4Z(J,L),    AW1(J,L),     AW2(J,L),     CMASS1(J,L),
      7 CMASS2(J,L), RXZ(J,L),     RYZ(J,L),     VO(J,L),      J=JMIN,JMAX)
 133   IF(KSV(12).GT.0) GO TO 1335
       DO 1330 I=JMIN,JMAX,14
       JPRINT=I+13
       IF(JPRINT.GT. JMAX) JPRINT= JMAX
       DO 13300 J=I,JPRINT
 13300 FMSNZ(J,P)=2.*FMSNZ(J,P)
 1330  WRITE(6,70)     PROBNO,       TIME,         DTNM,
      2                (             RX(J,P),      RY(J,P),
      3 VOL(J,P),      RHO(J,P),     ETA(J,P),     ENM(J,P),      J, K,N,
      4 UNMX(J,P),     UNMY(J,P),    FMASNM(J,P),  CMASS1(J,P), AW1(J,P),
      5 PQNMXX(J,P), PQNMYY(J,P), FMNMX(J,P),      FMNMY(J,P),    FMSNZ(J,P)
      6 CMASS2(J,P), AW2(J,P),       PQNMXY(J,P),  PQMX(J,P),
      7 J=I,JPRINT)
 1335  GO TO (134,140),KMOUT
  134  CONTINUE
       K=KMAX
       FMLYR(KMAX)=SFMLYR
       FMLZR(KMAX)=SFMLZR
       KMOUT = 2
       P = Q
       DO 1345 J=JMIN,JMAX
          VOL(J,P) = 0
         NTPT(J,P) = 0
       FMASNM(J,P) = 0
       PQNMXX(J,P)=0
       PQNMXY(J,P)=0
       PQMX(J,P)=0
 1345  PQNMYY(J,P)=0
       GO TO 132
 140   WRITE(6,75)
       REWIND MT
       WRITE (6,76) SENERI, SMASSI, SMOMYI, SMOMZI
       DTNMP5=.5*DTNM
       DTNM2=2.*DTNM
       CUT1=DTNM*CUTOFF
       CUT2=DTNM2*CUTOFF
       RDTNM=1./DTNM
```

```
RETURN
END
```

```
      SUBROUTINE RSTART
      COMMON             NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN, UYLTIN,  UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,         EIN,         RHOIN,        UYIN,        UXIN,        KINT(5),
     A E S(5),     ALFA(5),     BIG A(5),  BIG B(5),    RCP V S(5),E ZERO(5),
     2 TINY A(5),  TINY B(5),  R ZERO(5),BETA(5),     QCON(5),     SAV(12),
     4 KSV(24),        YTERM(55),     Y2TERM(55),     TA1(55),        TA2(55),
     5 FMLYR(101),  FMLZR(101),   VACANT(15)
      COMMON                           A(55),          DIL(55),        EPX(55),
     2 EPY(55),        EPZ(55),        FMLYB(55),      FMLYT(55),      FMLZB(55),
     3 FMLZT(55),      LY1(55),        LY2(55),        LZ1(55),        LZ2(55),
     4 PY(55),         PZ(55),         R1H(55),        R2H(55),        R3H(55),
     5 R4H(55),        Z1H(55),        Z2H(55),        Z3H(55),        Z4H(55),
     6 U2(55,2),       B(55,4)
      COMMON
     A                 RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),     UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),      EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),   PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),    PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),   RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),      E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),      A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),      A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),      F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),      F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),      NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),    FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),      AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),      RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),      Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),      P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),      PQMX(55,5),      VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON          AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON          S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      DIMENSION DUMPV(600)
C*****
      EQUIVALENCE(NREG,DUMPV(1))
C*****
      DO 900 J=1,600
900   DUMPV(J)=0.0
      DO 901 J=1,19250
901   RX(J)=0.0
      DO 902 J=1,1595
902   A(J)=0.
      DO 60 KK=1,ICON
      K=0
10    READ(9) (DUMPV(J),J=1,600)
      IF(IOCHECK,9)12,12
```

```
12      IF(KK-ICON)13,25,25
13      READ(9) DUMPV(600)
        IF(EOF,9)15,14
14      WRITE(6,54)KK,K
        NMASS=2
        RETURN
15      DO 20 K=KMIN,KMAX
        READ(9)DUMPV(1)
        IF(IOCHECK,9)20,20
20      CONTINUE
        READ(9) DUMPV(600)
        IF(EOF,9)22,21
21      DO 210 I=1,1000
        READ(9)DUMPV(600)
        IF(EOF,9)22,210
210     CONTINUE
215     WRITE(6,54)KK,K
        NMASS=2
        RETURN
22      READ(9) DUMPV(600)
        IF(EOF,9)60,23
23      WRITE(6,55)KK,K
        NMASS=2
        RETURN
25      JMX=JMAX
        KMX=KMAX
        READ(9) DUMPV(600)
        IF(EOF,9)30,26
26      WRITE(6,54)KK,K
        NMASS=2
        RETURN
   30   DO 45 K=KMIN,KMAX
        DO 31 J=JMIN,JMAX
        S1(J)=RXM(J,1)
31      S2(J)=RYM(J,1)
        READ(9)  (      RXM(J,1),            RYM(J,1),
     2  UNMX(J,1),      UNMY(J,1),           FMASNM(J,1),         ENM(J,1),
     3  PNM(J,1),       PQNMXX(J,1),         PQNMXY(J,1),         PQNMYY(J,1),
     4  VOL(J,1),       RHO(J,1),            PQMX(J,1),
     5  FMNMX(J,1),     FMNMY(J,1),
     6  NTPT(J,1),
     7  A1Y(J,1),       A2Y(J,1),            A3Y(J,1),            A4Y(J,1),
     8  A1Z(J,1),       A2Z(J,1),            A3Z(J,1),            A4Z(J,1),
     9  AW1  (J,1),     AW2  (J,1),          CMASS1(J,1),         CMASS2(J,1),
     A                        VO(J,1),                     J=JMIN,JMAX)
        IF(KK-ICON)45,35,35
35      IF(K.EQ.KMIN)GO TO 36
        J=JMIN
        TRAPYH(K-1)=S1(J)-RXM(J,1)
        TRAPZH(K-1)=RYM(J,1)-S2(J)
        GO TO 39
36      DO 37 J=JL,JMAX
        TRAPV(J-1)=.5*(RXM(J,1)+RXM(J-1,1))
        YDELTA(J-1)=RXM(J-1,1)-RXM(J,1)
37      AZQ(J-1)=TRAPV(J-1)*YDELTA(J-1)
        L=1
        NBR=MOD(N,2)+1
        GO TO(370,375),NBR
370     MT=3
        GO TO 39
375     MT=1
```

```
39      WRITE(MT)       (RXM(J,L),     RYM(J,L),      UNMX(J,L),     UNMY(J,L),
      2 FMASNM(J,L), ENM(J,L),     PNM(J,L),      PQNMXX(J,L), PQNMXY(J,L),
      3 PQNMYY(J,L), VOL(J,L),     RHO(J,L),
      4 PQMX(J,L),   FMNMX(J,L),   FMNMY(J,L),   NTPT(J,L),     A1Y(J,L),
      5 A2Y(J,L),    A3Y(J,L),     A4Y(J,L),      A1Z(J,L),      A2Z(J,L),
      6 A3Z(J,L),    A4Z(J,L),     AW1(J,L),      AW2(J,L),      CMASS1(J,L),
      7 CMASS2(J,L), RXZ(J,L),     RYZ(J,L),      VO(J,L),       J=JMIN,JMAX)
   45 CONTINUE
      REWIND MT
      READ(9) DUMPV(600)
      IF(EOF,9)47,46
46    WRITE(6,54)KK,K
      NMASS=2
      RETURN
47    READ(9) DUMPV(600)
      IF(EOF,9)60,48
48    WRITE(6,55)KK,K
      NMASS=2
      RETURN
   60 CONTINUE
      REWIND 9
      READ(5,4)
      READ(5,1)(KSV(J),J=1,12)
      READ(5,2)(SAV(J),J=1,6)
      READ(5,3)MAXN,TMAX,DTNMN,PROBNN
63    IF(PROBNN)70,70,64
64    PROBNO=PROBNN
70    WRITE(6,53)ICON,PROBNO,TIME,N
      WRITE(6,4)
      WRITE (6,50)(KSV(J),J=1,12)
      WRITE (6,51)(SAV(J),J=1,6)
      WRITE(6,52)MAXN,TMAX,DTNMN,PROBNN
      RETURN
 1    FORMAT(12I6)
 2    FORMAT(6E12.5)
    3 FORMAT(I6,5E12.5)
    4 FORMAT(72H
     1                                      )
50    FORMAT(1H /
     272H  KSV1  KSV2  KSV3  KSV4  KSV5  KSV6  KSV7  KSV8  KSV9 KSV10 KS
     3V11 KSV12/
     4(12I6))
51    FORMAT(1H /
     293H    SAV1                 SAV2                 SAV3                 SAV4
     3            SAV5                 SAV6/
     4(6E17.9))
52    FORMAT(1H /
     250H  MAXN    TMAX                 DTNMN                PROBNN/
     3 I6,3E17.9/)
53    FORMAT(22H1THIS IS A RESTART RUN/
     240H  DUMP    PROBLEM      TIME            CYCLE/
     3I6,F11.2,E17.9,I6)
54    FORMAT(2I6,15HTHERE IS 00 EOF)
55    FORMAT(2I6,15HTHERE IS 01 EOF)
      END
```

```
      SUBROUTINE SETTPT
      COMMON                NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,    TIME,     SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI,   SIETPT,   SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,    SMASSI,   SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,     KTOP,     MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,       CUT1,     CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN,   UYLTIN,   UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,     JMAX,     KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,          EIN,         RHOIN,       UYIN,        UXIN,        KINT(5),
     A E S(5),      ALFA(5),     BIG A(5),    BIG B(5),    RCP V S(5),E ZERO(5),
     2 TINY A(5),   TINY B(5),   R ZERO(5),BETA(5),      QCON(5),     SAV(12),
     4 KSV(24),       YTERM(55),       Y2TERM(55),     TA1(55),         TA2(55),
     5 FMLYR(101),    FMLZR(101),      VACANT(15)
      COMMON                           A(55),          DIL(55),         EPX(55),
     2 EPY(55),       EPZ(55),         FMLYB(55),      FMLYT(55),       FMLZB(55),
     3 FMLZT(55),     LY1(55),         LY2(55),        LZ1(55),         LZ2(55),
     4 PY(55),        PZ(55),          R1H(55),        R2H(55),         R3H(55),
     5 R4H(55),       Z1H(55),         Z2H(55),        Z3H(55),         Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                  RX(55,5),         RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),       UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),         PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),     PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),      RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),     RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),        RHO(55,5),         VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),        A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),        A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),        F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),        F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),       FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),      FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),        CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),       RYM(55,5),        RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),        Q22(55,5),         QX(55,5),
     7 P11(55,5),       P12(55,5),        P22(55,5),         PX(55,5),
     8 PQX(55,5),       PQMX(55,5),       VO(55,5)
      COMMON      ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,        NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON           AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2 , YDELTA(55)
      COMMON           S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      L=LX1
      L4=LX4
      L5=LX5
      DO 100 J=JMIN,JR
      SNOISE=RHO(J,L)-2.*RHO(J,L5)+RHO(J,L4)
      IF( ABS(SNOISE).LE.(RHO(J,L5)*10.E-8))GO TO 20
      IF(SNOISE)10,20,30
   10 B(J,4)=-1.0
      GO TO 40
   20 B(J,4)=0.0
      GO TO 40
   30 B(J,4)=1.0
C-----AX IS ZERO RY(J,L)=RY(J+1,L)
   40  WY = UNPY(J,L4) + UNPY(J+1,L4)
```

```
      WDA= .5*WY*AZQ(J)
C     BACKWARD TRANSPORT
      GO TO 55
      IF(KC.EQ.3) GO TO 55
   50 IF(ABS(-B(J,4)+B(J,3)+B(J,2)-B(J,1))-4.0) 60,55,60
   55 IF(WDA)75,80,85
   60 IF(WDA)65,80,70
   65 IF(ABS(B(J,3)-B(J,2)+B(J,1))-2.0) 90,75,75
   70 IF(ABS(B(J,4)-B(J,3)+B(J,2))-2.0) 90,85,85
75    NTPT(J,L4 )=1
      GO TO 100
80    NTPT(J,L4 )=2
      GO TO 100
85    NTPT(J,L4 )=3
      GO TO 100
90    NTPT(J,L4 )=4
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STRESS
      COMMON             NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,  KBMIN,
     2 KBMAX,  TIME,     SMOMZI,  SMZTPT,  SMOMZ,  SMOMYI,  SMYTPT, SMOMY,
     3 SENERI, SIETPT,   SKETPT,  WORK,    SUMIE,  SUMKE,   SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI,   SMSTPT,  SMASS,   PROBNO, DTNM,    CUTOFF, N,
     5 KBOT,   KTOP,     MAXN,    TMAX,    DTNMN,  SFW,     DTNMP5, DTNM2,
     6 KB,     CUT1,     CUT2,    UYLBIN,  UYBIN,  UYRBIN,  UXLBIN, UXBIN,
     7 UXRBIN, UYLTIN,   UYTIN,   UYRTIN,  UXLTIN, UXTIN,   UXRTIN, KTM,
     8 JMIN,   JMAX,     KMIN,    KMAX,    JL,     J3,      JR,     JRM,
     9 KT,        EIN,        RHOIN,       UYIN,        UXIN,       KINT(5),
     A E S(5),    ALFA(5),     BIG A(5), BIG B(5),    RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),      QCON(5),     SAV(12),
     4 KSV(24),      YTERM(55),     Y2TERM(55),    TA1(55),       TA2(55),
     5 FMLYR(101),   FMLZR(101),    VACANT(15)
      COMMON                        A(55),         DIL(55),       EPX(55),
     2 EPY(55),      EPZ(55),       FMLYB(55),     FMLYT(55),     FMLZB(55),
     3 FMLZT(55),    LY1(55),       LY2(55),       LZ1(55),       LZ2(55),
     4 PY(55),       PZ(55),        R1H(55),       R2H(55),       R3H(55),
     5 R4H(55),      Z1H(55),       Z2H(55),       Z3H(55),       Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON
     A                  RX(55,5),          RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),        UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),          PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),      PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),       RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),      RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),         RHO(55,5),         VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),         A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),         A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),         F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),         F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),        FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),       FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),         CMASS1(55,5),      CMASS2(55,5),
     5 RXM(55,5),       RYM(55,5),         RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),         Q22(55,5),         QX(55,5),
     7 P11(55,5),       P12(55,5),         P22(55,5),         PX(55,5),
     8 PQX(55,5),       PQMX(55,5),        VO(55,5)
      COMMON   ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,     NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2,YDELTA(55)
      COMMON            S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      DIMENSION TEM(55)
      L=LX1
      L2=LX2
      L5=LX5
200   DO 250 J=JMIN,JR
C     CHANGED FOR BACKWARD TRANSPORT 1-9-66
      GO TO 20004
      IF(J.GT.JMIN) GO TO 201
      P32=PQNMXX(J,L)*2.
      GO TO 202
201   P32=     PQNMXX(J,L)+PQNMXX(J-1,L)
202   P41=     PQNMXX(J,L)+PQNMXX(J+1,L)
      FY=ABS(AYQ(J)*P32-AYQ(J+1)*P41+4.*(AW1(J,L)+AW2(J,L))*PQNMXX(J,L))
      IF(KC.GT.KMIN) GO TO 203
```

```
      FZ=ABS(AZQ(J)*(PQNMXX(J,L2)-PQNMXX(J,L )))
      GO TO 204
203   FZ=ABS(AZQ(J)*(PQNMXX(J,L2)-PQNMXX(J,L5)))
204   DEM= FY**2+FZ**2
      IF(DEM.GT.(10.E-8*PQNMXX(J,L)**2*(TRAPZH(KC)**2+YDELTA(J)**2)) )
     2 GO TO 2040
20004 FY=UNMX(J,L)+UNMX(J+1,L)+UNMX(J,L2)+UNMX(J+1,L2)
      FZ=UNMY(J,L)+UNMY(J+1,L)+UNMY(J,L2)+UNMY(J+1,L2)
      DEM=FY**2+FZ**2
      IF(DEM.GT.0) GO TO 2040
      AQ=0
      GO TO 2041
2040  AQ=(FZ*TRAPZH(KC)-FY*YDELTA(J))**2/DEM
2041  COMPY=A1Y(J,L)*UNMX(J,L)+A2Y(J,L)*UNMX(J+1,L)+A3Y(J,L)*
     1 UNMX(J+1,L2)+A4Y(J,L)*UNMX(J,L2)
      COMPZ=A1Z(J,L)*UNMY(J,L)+A2Z(J,L)*UNMY(J+1,L)+A3Z(J,L)*
     2     UNMY(J+1,L2)+A4Z(J,L)*UNMY(J,L2)
      VDOT=COMPY+COMPZ
      TEM(J) = VDOT/ VOL(J,L)
205   RHOLD=RHO(J,L)
      RHO(J,L)=FMASN(J,L)/VOL(J,L)
      IF(VDOT.GT.0) GO TO 210
      Q11(J,L)= QCON* AQ*(RHO(J,L)+RHOLD)*TEM(J)**2
      GO TO 211
210   Q11(J,L)=-QCON* AQ*(RHO(J,L)+RHOLD)*TEM(J)**2
211   ETA(J,L)=RHO(J,L)*VO(J,L)
      Q22(J,L)=Q11(J,L)
      QX(J,L)=Q11(J,L)
      GMU(J)=ETA(J,L)-1.
      ERHO=ENM(J,L)*RHO(J,L)
      EZETA=EZERO*ETA(J,L)**2
      G= ENM(J,L)/EZETA+1.
      BOVERG=TINYB/G
      IF((ETA(J,L).GE.1.).OR.((ENM(J,L).LE.ES).AND.(ETA(J,L).GT.RCPVS)))
     2    GO TO 225
      ICASE(J)=1.
      H(J)=-GMU(J)/ETA(J,L)
      BETAH(J)=EXP(-BETA*H(J))
      ALFAH(J)=EXP(-ALFA*H(J)**2)
      AMUBH(J)=BIGA*GMU(J)*BETAH(J)
      PN(J,L)= TINYA*ERHO+(BOVERG*ERHO+AMUBH(J))*ALFAH(J)
      GO TO 230
225   AMUBMU(J)=GMU(J)*(BIGA+BIGB*GMU(J))
      ICASE(J)=2
      PN(J,L)=(TINYA+BOVERG)*ERHO+ AMUBMU(J)
230   P11(J,L)=PN(J,L)
      P12(J,L)=0.
      P22(J,L)=PN(J,L)
      PX(J,L)=PN(J,L)
250   CONTINUE
      CALL FORCE
      CALL ENERGY
      DO 350 J=JMIN,JR
      WW = 1./(ETA(J,L)**2)
      W1 = EN (J,L)*WW/EZERO
      W2 = TINYA*RHO(J,L)
      W3 = EN (J,L)*W2
      G = W1 + 1.
      W4 = TINYB/G
      W5 = EN (J,L)*W4
      W6 = RHO(J,L)*W5
```

```
      W7 = W1/G
      IF((ETA(J,L).GE.1.).OR.((EN (J,L).LE.ES).AND.(ETA(J,L).GT.RCPVS)))
     2 GO TO 320
      IF(ICASE(J).EQ.1)GO TO 300
      H(J)=-GMU(J)/ETA(J,L)
      BETAH(J)=EXP(-BETA*H(J))
      ALFAH(J)=EXP(-ALFA*H(J)**2)
      AMUBH(J)=BIGA*GMU(J)*BETAH(J)
300   W8=(W6+AMUBH(J))*ALFAH(J)
      WR = TINYA*EN (J,L) + 2.*ALFA*H(J)*W8*VO(J,L)*WW
     2 +((1.+2.*W7)*W5+BIGA*VO(J,L)*(1.+BETA*GMU(J)*WW)*BETAH(J))
     3     *ALFAH(J)
      WE = W2 + W5*(1.-W7)*ALFAH(J)
      GO TO 330
320   IF(ICASE(J).EQ.2) GO TO 325
      AMUBMU(J)=GMU(J)*(BIGA+BIGB*GMU(J))
  325 W9 = BIGB*GMU(J)*VO(J,L)
      W8 = W6 + AMUBMU(J)
      WR = TINYA*EN (J,L) + W5*(1.+W7+W7) + BIGA*VO(J,L) + W9+W9
      WE = W2 + W5*(1.-W7)
  330 PN(J,L) = W3 + W8
      P11(J,L)=PN(J,L)
      P12(J,L)=0.
      P22(J,L)=PN(J,L)
      PX(J,L)=PN(J,L)
      SSS = WR + PN(J,L)*WE/(RHO(J,L)**2)
      IF((-YDELTA(J)).GT.TRAPZH(KC)) GO TO 335
      DSS=SSS/YDELTA(J)**2
      GO TO 340
335   DSS=SSS/TRAPZH(KC)**2
  340 DSH = (8.*QCON*TEM(J))**2
      IF(SAV(10) .GT.DSS) GO TO 345
      SAV(10)=DSS
      KSV(20)=J
      KSV(21)=KC
345   IF(SAV(9).GT.DSH) GO TO 350
      SAV(9)=DSH
      KSV(18)=J
      KSV(19)=KC
350   CONTINUE
      CALL FORCE
      CALL ENERGY
      RETURN
      END
```

```
      SUBROUTINE VERTPT
      COMMON              NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,   TIME,     SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI,  SIETPT,   SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,   SMASSI,   SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,    KTOP,     MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,      CUT1,     CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UXLBIN,  UXBIN,
     7 UXRBIN,  UYLTIN,   UYTIN,   UYRTIN,  UXLTIN,  UXTIN,   UXRTIN,  KTM,
     8 JMIN,    JMAX,     KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,         EIN,        RHOIN,      UYIN,       UXIN,       KINT(5),
     A E S(5),     ALFA(5),    BIG A(5),  BIG B(5),   RCP V S(5),E ZERO(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),    SAV(12),
     4 KSV(24),       YTERM(55),     Y2TERM(55),   TA1(55),       TA2(55),
     5 FMLYR(101),   FMLZR(101),    VACANT(15)
      COMMON                         A(55),         DIL(55),       EPX(55),
     2 EPY(55),       EPZ(55),       FMLYB(55),     FMLYT(55),     FMLZB(55),
     3 FMLZT(55),     LY1(55),       LY2(55),       LZ1(55),       LZ2(55),
     4 PY(55),        PZ(55),        R1H(55),       R2H(55),       R3H(55),
     5 R4H(55),       Z1H(55),       Z2H(55),       Z3H(55),       Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON
     A                  RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),       CMASS1(55,5),    CMASS2(55,5),
     5 RXM(55,5),       RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),       P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),       PQMX(55,5),      VO(55,5)
      COMMON   ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,     NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
      COMMON        AZQ(55),TRAPV(55),TRAPYH(101),TRAPZH(101),AYQ(55)
     2 , YDELTA(55)
      COMMON        S1(55),S2(101)
      COMMON GMU(55),H(55),BETAH(55),ALFAH(55),AMUBH(55),AMUBMU(55),
     2 ICASE(55)
C*****
      L=LX2
      L2=LX3
      L5=LX1
      DO 60 J=JMIN,JR
C-----AX IS ZERO RY(J+1,L)=RY(J,L)
      WY = UNMY(J,L) + UNMY(J+1,L)
      WDA= .5*WY*AZQ(J)
      NBR=NTPT(J,L)
      GO TO (10,20,30,40),NBR
10    RH1Z(J,L)=RHO(J,L5 )
      E1Z(J,L)=ENM(J,L5 )
      GO TO 50
   20 RH1Z(J,L)=0.0
      E1Z(J,L)=0.0
```

```
      GO TO 50
   30 RH1Z(J,L)=RHO(J,L)
      E1Z(J,L)=ENM(J,L)
      GO TO 50
40    D1=SQRT((RX(J+1,L)+RX(J,L)-RX(J+1,L5)-RX(J,L5))**2
     1 +(RY(J+1,L)+RY(J,L)-RY(J,L5 )-RY(J+1,L5 ))**2)
      D2=SQRT((RX(J+1,L2 )+RX(J,L2 )-RX(J+1,L)-RX(J,L))**2
     1 +(RY(J+1,L2 )+RY(J,L2 )-RY(J+1,L)-RY(J,L))**2)
      D12=1.0/(D1+D2)
      WDAMAG=ABS(AZQ(J))
      WN=WDA/WDAMAG
      RH1Z(J,L)=(D2*RHO(J,L5)+D1*RHO(J,L)+3.0*WN*(RHO(J,L)-RHO(J,L5))*
     1  DTNM)*D12
      E1Z(J,L)=(D2*ENM(J,L5)+D1*ENM(J,L)+3.0*WN*(ENM(J,L)-ENM(J,L5))*
     1  DTNM)*D12
   50 RWA1Z(J,L)=RH1Z(J,L)*WDA
      RWAE1Z(J,L)=RWA1Z(J,L)*E1Z(J,L)
   60 CONTINUE
      RETURN
      END
```

```
C     SUBROUTINE  BOUND L
      SUBROUTINE BNDY00
      COMMON/INDUMP/   NREG,    RDTNM,   MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UZLBIN, UZBIN,
     7 UZRBIN, UYLTIN, UYTIN,  UYRTIN, UZLTIN, UZTIN,  UZRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,        EIN(5),    KINT(5),   RHOIN(5),  UYIN(5),   UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),
     A E S(5),    ALFA(5),   BIG A(5),  BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                      KSV(24),   SAV(12),   FMLYR(100)
      COMMON/THEREST/                  A(55),     DIL(55),   EPX(55),
     2 EPY(55),     EPZ(55),          FMLYB(55), FMLYT(55), FMLZB(55),
     3 FMLZT(55),   LY1(55),          LY2(55),   LZ1(55),   LZ2(55),
     4 PY(55),      PZ(55),           R1H(55),   R2H(55),   R3H(55),
     5 R4H(55),     Z1H(55),          Z2H(55),   Z3H(55),   Z4H(55),
     6 U2(55,2),    B(55,4)
      COMMON/AFTERALL/
     A                 RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),     UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),      EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),   PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),    PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),   RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),      E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),      A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),      A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),      F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),      F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),      NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),    FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),      AW2(55,5),       AW3(55,5),       AW4(55,5),
     5 RXM(55,5),      RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),      Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),      P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),      PQMX(55,5),      VO(55,5)
      COMMON   ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,     NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
C*****
10    J=JMIN
20    FMASN(J,1)=FMASNM(J,1)
21    RX(J,1)=RXM(J,1)+UNMX(J,1)*DTNM
      RY(J,1)=RYM(J,1)+UNMY(J,1)*DTNM
22    UNPX(J,1)=UYLBIN
      UNPY(J,1)=UZLBIN
      FMSNZ(J,1)=.125*FMASN(J,1)
      FMNX(J,1)=0.
      FMNY(J,1)=FMSNZ(J,1)*   (UNMY(J,1)+UNPY(J,1))
      DO 40 J=JL,JR
27    FMASN(J,1)=FMASNM(J,1)
28    RX(J,1)=RXM(J,1)+UNMX(J,1)*DTNM
      RY(J,1)=RYM(J,1)+UNMY(J,1)*DTNM
29    UNPX(J,1)=UYBIN
      UNPY(J,1)=UZBIN
   30 FMSNZ(J,1)=0.125*(FMASN(J,1)+FMASN(J-1,1))
   35 FMNX(J,1)=FMSNZ(J,1)     *(UNMX(J,1)+UNPX(J,1))
      FMNY(J,1)=FMSNZ(J,1)     *(UNMY(J,1)+UNPY(J,1))
   40 CONTINUE
```

```
      J=JMAX
      GO TO (42,41,41),MOTION
41    RX(J,1)=RXM(J,1)+UNMX(J,1)*DTNM
      RY(J,1)=RYM(J,1)+UNMY(J,1)*DTNM
42    UNPX(J,1)=0.0
      UNPY(J,1)=UZRBIN
      FMSNZ(J,1)=.125*FMASN(J-1,1)
      FMNX(J,1)=0.
      FMNY(J,1)=FMSNZ(J,1)     *(UNMY(J,1)+UNPY(J,1))
      CALL STRAIN
      CALL STRESS
      CALL CONSCK1
      RETURN
C*****
   50 L=LX1
      L2=LX2
504   CALL STRAIN
      CALL STRESS
      CALL NEWU
      CALL  CONSCKI
      J=JMIN
      KC=KMAX
505   UNPX(J,L2)=UYLTIN
      UNPY(J,L2)=UZLTIN
      FMSNZ(J,L2)=.125*FMASN(J,L)
      FMNX(J,L2)=0.0
      FMNY(J,L2)=FMSNZ(J,L2)    *(UNMY(J,L2)+UNPY(J,L2))
      DO 80 J=JL,JR
56    UNPX(J,L2)=UYTIN
      UNPY(J,L2)=UZTIN
      FMSNZ(J,L2)=.125*(FMASN(J,L)+FMASN(J-1,L))
   60 FMNX(J,L2)=FMSNZ(J,L2)    *(UNMX(J,L2)+UNPX(J,L2))
      FMNY(J,L2)=FMSNZ(J,L2)    *(UNMY(J,L2)+UNPY(J,L2))
   80 CONTINUE
   90 J=JMAX
      UNPX(J,L2)=0.
      UNPY(J,L2)=UZRTIN
      FMSNZ(J,L2)=.125*FMASN(J-1,L)
      FMNX(J,L2)=0.0
      FMNY(J,L2)=FMSNZ(J,L2)    *(UNMY(J,L2)+UNPY(J,L2))
      CALL CONSKMAX
  100 RETURN
200   FORMAT(7HOFOR J=,I6,8H AND K+2,10H THE MASS=,E17.9,9H IN ERROR)
      END
```

```
C       SUBROUTINE  CONSCK L
        SUBROUTINE CNCH00
        COMMON/INDUMP/    NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
      2 KBMAX,   TIME,    SMOMZI,  SMZTPT,  SMOMZ,  SMOMYI,  SMYTPT,  SMOMY,
      3 SENERI,  SIETPT,  SKETPT,  WORK,    SUMIE,  SUMKE,   SUMTE,   FIMPZ,
      4 FIMPY,   SMASSI,  SMSTPT,  SMASS,   PROBNO, DTNM,    CUTOFF,  N,
      5 KBOT,    KTOP,    MAXN,    TMAX,    DTNMN,  SFW,     DTNMP5,  DTNM2,
      6 KB,      CUT1,    CUT2,    UYLBIN,  UYBIN,  UYRBIN,  UZLBIN,  UZBIN,
      7 UZRBIN,  UYLTIN,  UYTIN,   UYRTIN,  UZLTIN, UZTIN,   UZRTIN,  KTM,
      8 JMIN,    JMAX,    KMIN,    KMAX,    JL,     J3,      JR,      JRM,
      9 KT,        EIN(5),      KINT(5),    RHOIN(5),  UYIN(5),    UZIN(5),
      2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),
      A E S(5),    ALFA(5),    BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
      4 FMLZR(100),                  KSV(24),       SAV(12),       FMLYR(100)
        COMMON/THEREST/              A(55),         DIL(55),       EPX(55),
      2 EPY(55),      EPZ(55),       FMLYB(55),     FMLYT(55),     FMLZB(55),
      3 FMLZT(55),    LY1(55),       LY2(55),       LZ1(55),       LZ2(55),
      4 PY(55),       PZ(55),        R1H(55),       R2H(55),       R3H(55),
      5 R4H(55),      Z1H(55),       Z2H(55),       Z3H(55),       Z4H(55),
      6 U2(55,2),     B(55,4)
        COMMON/AFTERALL/
      A                  RX(55,5),         RY(55,5),          UNMX(55,5),
      1 UNMY(55,5),      UNPX(55,5),       UNPY(55,5),        FMASNM(55,5),
      2 ENM(55,5),       EN(55,5),         PNM(55,5),         PN(55,5),
      3 PQNMXX(55,5),    PQNMXY(55,5),     PQNMYY(55,5),      PQNXX(55,5),
      4 PQNXY(55,5),     PQNYY(55,5),      RWA3Z(55,5),       RWA1Z(55,5),
      5 RWAE3Z(55,5),    RWAE1Z(55,5),     RH3Z(55,5),        RH1Z(55,5),
      6 E3Z(55,5),       E1Z(55,5),        RHO(55,5),         VOL(55,5),
      7 ETA(55,5),       A1Y(55,5),        A2Y(55,5),         A3Y(55,5),
      8 A4Y(55,5),       A1Z(55,5),        A2Z(55,5),         A3Z(55,5),
      9 A4Z(55,5),       F1Y(55,5),        F2Y(55,5),         F3Y(55,5),
      A F4Y(55,5),       F1Z(55,5),        F2Z(55,5),         F3Z(55,5),
      1 F4Z(55,5),       NTPT(55,5),       FMSNZ(55,5),       FMASN(55,5),
      2 FMNMX(55,5),     FMNMY(55,5),      FMNX(55,5),        FMNY(55,5),
      4 AW1(55,5),       AW2(55,5),        AW3(55,5),         AW4(55,5),
      5 RXM(55,5),       RYM(55,5),        RXZ(55,5),         RYZ(55,5),
      6 Q11(55,5),       Q12(55,5),        Q22(55,5),         QX(55,5),
      7 P11(55,5),       P12(55,5),        P22(55,5),         PX(55,5),
      8 PQX(55,5),       PQMX(55,5),       VO(55,5)
        COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,      LX5,
      2 KC,       NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
        DIMENSION USQ(2)
C*****
        L=LX1
        L2=LX2
        L5=LX5
        J=JMIN
        JLEFT=1
        JRIGHT=2
        TFXY=0.
        TFXZ=0.
        STEM=SENERI
        KL=1
        KU=2
        SUMIE=EN(J,1)*FMASN(J,1)
        U2(J,1)=UNMX(J,1)*UNPX(J,1)+UNMY(J,1)*UNPY(J,1)
        SUMKE=0.
        SMOMY=FMNX(J,1)
        SMOMZ=FMNY(J,1)
        SKETPT=SMYTPT=SMZTPT=0
1       SMASS=FMASN(J,1)
```

```
2     FMLYB(J)=-F2Y(J,1)-TFXY
      FMLZB(J)=(FMNY(J,1)-FMNMY(J,1))*RDTNM-F2Z(J,L)-TFXZ
      FIMPY=FMLYB(J)
      FIMPZ=FMLZB(J)
      WORK=FMLYB(J)*UNMX(J,1)+FMLZB(J)*UNMY(J,1)
      DO 5  J=JL,JR
      SUMIE=SUMIE+EN(J,1)*FMASN(J,1)
      U2(J,1)=UNMX(J,1)*UNPX(J,1)+UNMY(J,1)*UNPY(J,1)
      SMOMY=SMOMY+FMNX(J,1)
      SMOMZ=SMOMZ+FMNY(J,1)
3     SMASS=SMASS+FMASN(J,1)
4     FMLYB(J)=(FMNX(J,1)-FMNMX(J,1))*RDTNM-F1Y(J-1,1)-F2Y(J,1)-TFXY
      FMLZB(J)=(FMNY(J,1)-FMNMY(J,1))*RDTNM-F1Z(J-1,1)-F2Z(J,1)-TFXZ
      FIMPY=FIMPY+FMLYB(J)
      FIMPZ=FIMPZ+FMLZB(J)
5     WORK=WORK+FMLYB(J)*UNMX(J,1)+FMLZB(J)*UNMY(J,1)
      J=JMAX
      U2(J,1)=UNMX(J,1)*UNPX(J,1)+UNMY(J,1)*UNPY(J,1)
      SMOMY=SMOMY+FMNX(J,1)
      SMOMZ=SMOMZ+FMNY(J,1)
7     FMLYB(J)=-F1Y(J-1,1)-TFXY
      FMLZB(J)=(FMNY(J,L)-FMNMY(J,1))*RDTNM-F1Z(J-1,1)-TFXZ
      FIMPY=FIMPY+FMLYB(J)
      FIMPZ=FIMPZ+FMLZB(J)
      WORK=WORK+FMLYB(J)*UNMX(J,1)+FMLZB(J)*UNMY(J,1)
      RETURN
C*****
      ENTRY CONSCKI
      L=LX1
      L2=LX2
      L5=LX5
      J=JMIN
      JLEFT=1
      JRIGHT=2
      TXXY=0
      TXXZ=0
      SUMIE=SUMIE+EN(J,L)*FMASN(J,L)
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
15    SMASS=SMASS+FMASN(J,L)
25    DO 34 J=JL,JR
      SUMIE=SUMIE+EN(J,L)*FMASN(J,L)
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      IF(INT.EQ.1) GO TO 38
      SUMKE=SUMKE+.125*FMASN(J-1,L5)*(U2(J-1,KL)+U2(J,KL)+U2(J-1,KU)+
     2      U2(J,KU))
26    SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
30    SMASS=SMASS+FMASN(J,L)
34    CONTINUE
35    J=JMAX
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      IF(INT.EQ.1) GO TO 39
      SUMKE=SUMKE+.125*FMASN(J-1,L5)*(U2(J-1,KL)+U2(J,KL)+U2(J-1,KU)+
     2      U2(J,KU))
36    KL=KU
      KU=MOD(KL,2)+1
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
      FIMPY=FIMPY+FMLYR(KC)
```

```
      FIMPZ=FIMPZ+FMLZR(KC)
      WORK=WORK+FMLYR(KC)*UNMX(J,L)+FMLZR(KC)*UNMY(J,L)
      IF((KC+1).NE.KINT(NREG)) RETURN
      DO 37 J=JMIN,JR
      SMASS=SMASS+FMASN(J,L2)
37    SUMIE=SUMIE+EN(J,L2)*FMASN(J,L2)
      L4=L
      INT=1-INT
      RETURN
38    SUMKE=SUMKE+.25*(FMASN(J-1,L4)*(U2(J-1,KL)+U2(J,KL))+FMASN(J-1,L5)
     2*(U2(J-1,KU)+U2(J,KU)))
      GO TO 26
39    SUMKE=SUMKE+.25*(FMASN(J-1,L4)*(U2(J-1,KL)+U2(J,KL))+FMASN(J-1,L5)
     2*(U2(J-1,KU)+U2(J,KU)))
      INT=1-INT
      GO TO 36
C*****
      L=LX2
      L5=LX1
      J=JMIN
      JLEFT=1
      JRIGHT=2
      TXXY=0
      TXXZ=0
40    U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
50    FMLYT(J)=-F3Y(J,L5)-TFXY
      FMLZT(J)=(FMNY(J,L)-FMNMY(J,L ))*RDTNM-F3Z(J,L5)-TFXZ
      FIMPY=FIMPY+FMLYT(J)
      FIMPZ=FIMPZ+FMLZT(J)
      WORK=WORK+FMLYT(J)*UNMX(J,L)+FMLZT(J)*UNMY(J,L)
      DO 65  J=JL,JR
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SUMKE=SUMKE+.125*FMASN(J-1,L5)*(U2(J-1,KL)+U2(J,KL)+U2(J-1,KU)+
     2      U2(J,KU))
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
60    FMLYT(J)=(FMNX(J,L)-FMNMX(J,L))*RDTNM-F3Y(J,L5)-F4Y(J-1,L5)-TFXY
      FMLZT(J)=(FMNY(J,L)-FMNMY(J,L))*RDTNM-F3Z(J,L5)-F4Z(J-1,L5)-TFXZ
      FIMPY=FIMPY+FMLYT(J)
      FIMPZ=FIMPZ+FMLZT(J)
65    WORK=WORK+FMLYT(J)*UNMX(J,L)+FMLZT(J)*UNMY(J,L)
      J=JMAX
      U2(J,KU)=UNMX(J,L)*UNPX(J,L)+UNMY(J,L)*UNPY(J,L)
      SUMKE=SUMKE+.125*FMASN(J-1,L5)*(U2(J-1,KL)+U2(J,KL)+U2(J-1,KU)+
     2      U2(J,KU))
      SMOMY=SMOMY+FMNX(J,L)
      SMOMZ=SMOMZ+FMNY(J,L)
75    FMLYT(J)=-F4Y(J-1,L5)-TFXY
      FMLZT(J)=(FMNY(J,L)-FMNMY(J,L))*RDTNM-F4Z(J-1,L5)-TFXZ
      FIMPY=FIMPY+FMLYT(J)
      FIMPZ=FIMPZ+FMLZT(J)
      WORK=WORK+FMLYT(J)*UNMX(J,L)+FMLZT(J)*UNMY(J,L)
      SUMTE=SUMIE+SUMKE
      SMASSI=SMASSI-SMSTPT
      WORK=WORK*DTNM
      SENERI=SENERI+WORK-SIETPT-SKETPT
      FIMPY=(FIMPY+SFW)*DTNM
      FIMPZ=FIMPZ*DTNM
      SMOMYI=SMOMYI+FIMPY -SMYTPT
```

```
      SMOMZI=SMOMZI+FIMPZ-SMZTPT
      RETURN
108   FORMAT(1H0/
     249H NO JMIN CONTRIBUTION CALCULATION IN THIS PROGRAM/)
      END
```

```
C     SUBROUTINE  ENERGY L
      SUBROUTINE EGYL00
      COMMON/INDUMP/   NREG,   RDTNM,  MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UZLBIN, UZBIN,
     7 UZRBIN, UYLTIN, UYTIN,  UYRTIN, UZLTIN, UZTIN,  UZRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,      EIN(5),     KINT(5),  RHOIN(5),  UYIN(5),   UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),
     A E S(5),     ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),              KSV(24),      SAV(12),      FMLYR(100)
      COMMON/THEREST/           A(55),        DIL(55),      EPX(55),
     2 EPY(55),     EPZ(55),    FMLYB(55),    FMLYT(55),    FMLZB(55),
     3 FMLZT(55),   LY1(55),    LY2(55),      LZ1(55),      LZ2(55),
     4 PY(55),      PZ(55),     R1H(55),      R2H(55),      R3H(55),
     5 R4H(55),     Z1H(55),    Z2H(55),      Z3H(55),      Z4H(55),
     6 U2(55,2),    B(55,4)
      COMMON/AFTERALL/
     A                 RX(55,5),        RY(55,5),        UNMX(55,5),
     1 UNMY(55,5),     UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
     2 ENM(55,5),      EN(55,5),        PNM(55,5),       PN(55,5),
     3 PQNMXX(55,5),   PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
     4 PQNXY(55,5),    PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
     5 RWAE3Z(55,5),   RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
     6 E3Z(55,5),      E1Z(55,5),       RHO(55,5),       VOL(55,5),
     7 ETA(55,5),      A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
     8 A4Y(55,5),      A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
     9 A4Z(55,5),      F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
     A F4Y(55,5),      F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
     1 F4Z(55,5),      NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
     2 FMNMX(55,5),    FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
     4 AW1(55,5),      AW2(55,5),       AW3(55,5),       AW4(55,5),
     5 RXM(55,5),      RYM(55,5),       RXZ(55,5),       RYZ(55,5),
     6 Q11(55,5),      Q12(55,5),       Q22(55,5),       QX(55,5),
     7 P11(55,5),      P12(55,5),       P22(55,5),       PX(55,5),
     8 PQX(55,5),      PQMX(55,5),      VO(55,5)
      COMMON    ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
C*****
      ENTRY ENERGYP2
      L=LX3
      L2=LX4
      GO TO 1
C*****
      L=LX1
      L2=LX2
1     TFXE=0.
2     DO 100 J=JMIN,JR
      EN(J,L)=(ENM(J,L)*FMASNM(J,L)-DTNM*(UNMX(J+1,L)*F1Y(J,L)+UNMY(J+1,
     1 L)*F1Z(J,L)
     1 +UNMX(J,L)*F2Y(J,L)+UNMY(J,L)*F2Z(J,L)+UNMX(J,L2)*F3Y(J,L)+
     2  UNMY(J,L2)*F3Z(J,L)+UNMX(J+1,L2)*F4Y(J,L)+UNMY(J+1,L2)*F4Z(J,L)-
     3  TFXE))/FMASN(J,L)
      IF(ABS(EN(J,L)-ENM(J,L))-CUT1)10,10,100
10    EN(J,L)=ENM(J,L)
100   CONTINUE
105   RETURN
      END
```

```
C     SUBROUTINE  FLOW'L
      SUBROUTINE FLOWOO
      COMMON/INDUMP/     NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,     SMOMZI,  SMZTPT,  SMOMZ,  SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,   SKETPT,  WORK,    SUMIE,  SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,   SMSTPT,  SMASS,   PROBNO, DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,     MAXN,    TMAX,    DTNMN,  SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,     CUT2,    UYLBIN,  UYBIN,  UYRBIN,  UZLBIN,  UZBIN,
     7 UZRBIN, UYLTIN,   UYTIN,   UYRTIN,  UZLTIN, UZTIN,   UZRTIN,  KTM,
     8 JMIN,   JMAX,     KMIN,    KMAX,    JL,     J3,      JR,      JRM,
     9 KT,       EIN(5),      KINT(5),   RHOIN(5),   UYIN(5),    UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),
     A E S(5),     ALFA(5),    BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                    KSV(24),      SAV(12),     FMLYR(100)
      COMMON/THEREST/                 A(55),        DIL(55),     EPX(55),
     2 EPY(55),       EPZ(55),        FMLYB(55),    FMLYT(55),   FMLZB(55),
     3 FMLZT(55),     LY1(55),        LY2(55),      LZ1(55),     LZ2(55),
     4 PY(55),        PZ(55),         R1H(55),      R2H(55),     R3H(55),
     5 R4H(55),       Z1H(55),        Z2H(55),      Z3H(55),     Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON/AFTERALL/
     A                 RX(55,5),           RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),     UNPX(55,5),         UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),      EN(55,5),           PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),   PQNMXY(55,5),       PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),    PQNYY(55,5),        RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),   RWAE1Z(55,5),       RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),      E1Z(55,5),          RHO(55,5),         VOL(55,5),
     7 ETA(55,5),      A1Y(55,5),          A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),      A1Z(55,5),          A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),      F1Y(55,5),          F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),      F1Z(55,5),          F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),      NTPT(55,5),         FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),    FMNMY(55,5),        FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),      AW2(55,5),          AW3(55,5),         AW4(55,5),
     5 RXM(55,5),      RYM(55,5),          RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),      Q12(55,5),          Q22(55,5),         QX(55,5),
     7 P11(55,5),      P12(55,5),          P22(55,5),         PX(55,5),
     8 PQX(55,5),      PQMX(55,5),         VO(55,5)
      COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
C*****
      KC=1
      LINCT=1
      NREG=1
      LX1=1
      LX2=2
       LX3=3
      LX4=4
      LX5=5
      DO 10 L=1,4
      DO 10 J=JMIN,JMAX
   10 B(J,L)=0.0
C
C-----READ IN 4 K LINES 1ST CALL ONLY
C
      CALL LINEIN4
20    CALL BOUNDK1
      LX0=LX1
      LX1=LX2
      LX2=LX3
```

```
      LX3=LX4
      LX4=LX5
      LX5=LX0
      DO 50 K=KB,KTM
      KC=K
      IF(K.EQ.KTM)GO TO 35
      CALL LINEIN1
35    IF((K+1).LT.KINT(NREG))GO TO 41
      IF((K+1).GT.KINT(NREG))GO TO 36
      CALL INFACE
      GO TO 4100
36    IF((K-1).NE.KINT(NREG)) GO TO 415
      NREG=NREG+1
      GO TO 4100
41    CALL STRAIN
      CALL STRESS
4100  CALL NEWU
      CALL CONSCKI
415   CALL LINOUT
      IF (K.EQ.KB) GO TO 45
      DO 43 L=1,3
      DO 43 J=JMIN,JMAX
   43 B(J,L)=B(J,L+1)
   45 LX0=LX1
      LX1=LX2
      LX2=LX3
      LX3=LX4
      LX4=LX5
      LX5=LX0
   50 CONTINUE
      KC=KT
      CALL  BNDYKMAX
C
C-----WRITES OUT 3 K LINES LAST CALL ONLY
C
      CALL LINOUT
      RETURN
      END
```

```
C     SUBROUTINE  FORCE L
      SUBROUTINE FRCL00
      COMMON/INDUMP/   NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,   TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI,  SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,   SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,    KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,      CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UZLBIN,  UZBIN,
     7 UZRBIN,  UYLTIN,  UYTIN,   UYRTIN,  UZLTIN,  UZTIN,   UZRTIN,  KTM,
     8 JMIN,    JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,        EIN(5),     KINT(5),   RHOIN(5),   UYIN(5),    UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),
     A E S(5),    ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                KSV(24),       SAV(12),       FMLYR(100)
      COMMON/THEREST/             A(55),         DIL(55),       EPX(55),
     2 EPY(55),       EPZ(55),    FMLYB(55),     FMLYT(55),     FMLZB(55),
     3 FMLZT(55),     LY1(55),    LY2(55),       LZ1(55),       LZ2(55),
     4 PY(55),        PZ(55),     R1H(55),       R2H(55),       R3H(55),
     5 R4H(55),       Z1H(55),    Z2H(55),       Z3H(55),       Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON/AFTERALL/
     A                RX(55,5),         RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),       UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),         PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),     PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),      RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),     RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),        RHO(55,5),         VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),        A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),        A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),        F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),        F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),       FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),      FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),        AW3(55,5),         AW4(55,5),
     5 RXM(55,5),     RYM(55,5),        RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),        Q22(55,5),         QX(55,5),
     7 P11(55,5),     P12(55,5),        P22(55,5),         PX(55,5),
     8 PQX(55,5),     PQMX(55,5),       VO(55,5)
      COMMON     ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,       NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
C*****
      L=LX3
      L2=LX4
      SUMER=2.
      GO TO 2
C*****
      SUMER=2.
      SUMER=1.
    1 L=LX1
      L2=LX2
      IF(KC.EQ.1) SFW=0.
    2 DO 100 J=JMIN,JR
      IF((MOTION.EQ.1).AND.(N.GT.1)) GO TO 502
      RB1=R2H(J)*.5
      RB2=R1H(J)*.5
      RB3=R4H(J)*.5
      RB4=R3H(J)*.5
      ZB1=Z2H(J)*.5
      ZB2=Z1H(J)*.5
      ZB3=Z4H(J)*.5
```

```
      ZB4=Z3H(J)*.5
      YDB=SQRT((RB2    **2+RB2    *RB1    +RB1    **2)/3.)
      ZDB=((RB2    -YDB)*ZB1    +(YDB-RB1    )*ZB2    )/(RB2    -RB1    )
      DEMO=RB3    -RB2
      IF(DEMO.EQ.0)GO TO 5
      Y2B=SQRT((RB3    **2+RB3    *RB2    +RB2    **2)/3.)
      Z2B=((RB3    -Y2B)*ZB2    +(Y2B-RB2    )*ZB3    )/DEMO
      GO TO 10
5     Y2B=RB2
      Z2B=.5*(ZB2    +ZB3    )
10    Y3B=SQRT((RB3    **2+RB3    *RB4    +RB4    **2)/3.)
      Z3B=((RB4-Y3B)*ZB3+(Y3B-RB3)*ZB4)/(RB4-RB3)
      DEMO2=RB1-RB4
      IF(DEMO2.EQ.0) GO TO 15
      YAB=SQRT((RB4    **2+RB4    *RB1    +RB1    **2)/3.)
      ZAB=((RB1-YAB)*ZB4+(YAB-RB4)*ZB1)/DEMO2
      GO TO 20
15    YAB=RB1
      ZAB=.5*(ZB4    +ZB1    )
20    Y24=RB2    -RB4
      Z24=ZB2    -ZB4
      Y13=RB1    -RB3
      Z13=ZB1    -ZB3
      Y2P4=RB2    +RB4
      Z2P4=ZB2    +ZB4
      Y1P3=RB1    +RB3
      Z1P3=ZB1    +ZB3
      AR=.5*(Y24*Z13-Y13*Z24)
      Y1P2=RB1    +RB2
      Y2P3=RB2    +RB3
      Y3P4=RB3    +RB4
      Y4P1=RB4    +RB1
      Z12=ZB1    -ZB2
      Z23=ZB2    -ZB3
      Z34=ZB3    -ZB4
      Z41=ZB4    -ZB1
      YA =(Z12*(Y1P2**2-RB1    *RB2    )+Z23*(Y2P3**2-RB2    *RB3    )+
     1    Z34*(Y3P4**2-RB3    *RB4    )+Z41*(Y4P1**2-RB4    *RB1))/(6.*AR)
      ZA    =(Y24*Z13*Z1P3-Y13*Z24*Z2P4-Z13*Z24*(Y1P3-Y2P4))/(4.*AR)
24    DO 40 I=1,5
25    YDBAB =YDB-YAB
      ZDBAB =ZDB-ZAB
      Y1A=RB1    -YA
      Z1A=ZB1    -ZA
      YDBPAB=YDB+YAB
      ZDBPAB=ZDB+ZAB
      Y1PA=RB1    +YA
      Z1PA=ZB1    +ZA
      AR1=.5*(YDBAB*Z1A-Y1A*ZDBAB)
      Y1PDB=RB1    +YDB
      YDBPA =YDB+YA
      YAPAB =YA+YAB
      YABP1=YAB+RB1
      Z1DB=ZB1    -ZDB
      ZDBA    =ZDB-ZA
      ZAAB    =ZA-ZAB
      ZAB1=ZAB-ZB1
      Y1    =(Z1DB*(Y1PDB**2-RB1    *YDB)+ZDBA*(YDBPA**2-YDB*YA)+ZAAB*
     1 (YAPAB**2-YA*YAB)+ZAB1*(YABP1**2-YAB*RB1    ))/(6.*AR1)
      Z1    =(YDBAB*Z1A*Z1PA-Y1A*ZDBAB*ZDBPAB-Z1A*ZDBAB*(Y1PA-YDBPAB))/
     1       (4.*AR1)
```

```
      Y2A =RB2    -YA
      Z2A =ZB2    -ZA
      YDB2B  =YDB-Y2B
      ZDB2B  =ZDB-Z2B
      Y2PA=RB2    +YA
      Z2PA=ZB2    +ZA
      YDBP2B =YDB+Y2B
      ZDBP2B =ZDB+Z2B
      AR2 =.5*(Y2A*ZDB2B-YDB2B*Z2A)
      YDBP2=YDB+RB2
      Y2P2B=RB2   +Y2B
      Y2BPA  =Y2B+YA
      YAPDB   =YA+YDB
      ZDB2 =ZDB-ZB2
      Z22B =ZB2    -Z2B
      Z2BA     =Z2B-ZA
      ZADB     =ZA-ZDB
      Y2=(ZDB2*(YDBP2**2-YDB*RB2    )+Z22B*(Y2P2B**2-RB2    *Y2B)+Z2BA*
     1 (Y2BPA**2-Y2B*YA)+ZADB*(YAPDB**2-YA*YDB))/(6.*AR2)
      Z2       =(Y2A*ZDB2B*ZDBP2B-YDB2B*Z2A*Z2PA-ZDB2B*Z2A*(YDBP2B-Y2PA))
     1/        (4.*AR2)
      Y2B3B    =Y2B-Y3B
      Z2B3B    =Z2B-Z3B
      YA3=YA-RB3
      ZA3=ZA-ZB3
      Y2BP3B   =Y2B+Y3B
      Z2BP3B   =Z2B+Z3B
      YAP3=YA+RB3
      ZAP3=ZA+ZB3
      AR3=.5*(Y2B3B*ZA3-YA3*Z2B3B)
      YAP2B    =YA+Y2B
      Y2BP3=Y2B+RB3
      Y3P3B=RB3    +Y3B
      Y3BPA    =Y3B+YA
      ZA2B     =ZA-Z2B
      Z2B3=Z2B-ZB3
      Z33B=ZB3    -Z3B
      Z3BA     =Z3B-ZA
      Y3=(ZA2B*(YAP2B**2-YA*Y2B)+Z2B3*(Y2BP3**2-Y2B*RB3    )+Z33B*
     1 (Y3P3B**2-RB3    *Y3B)+Z3BA*(Y3BPA**2-Y3B*YA))/(6.*AR3)
      Z3       =(Y2B3B*ZA3*ZAP3-YA3*Z2B3B*Z2BP3B-ZA3*Z2B3B*(YAP3-Y2BP3B))
     1/        (4.*AR3)
      YA4=YA-RB4
      ZA4=ZA-ZB4
      YAB3B    =YAB-Y3B
      ZAB3B    =ZAB-Z3B
      YAP4=YA+RB4
      ZAP4=ZA+ZB4
      YABP3B   =YAB+Y3B
      ZABP3B   =ZAB+Z3B
      AR4=.5*(YA4*ZAB3B-YAB3B*ZA4)
      YABPA    =YAB+YA
      YAP3B    =YA+Y3B
      Y3BP4=Y3B+RB4
      Y4PAB=RB4    +YAB
      ZABA     =ZAB-ZA
      ZA3B     =ZA-Z3B
      Z3B4=Z3B-ZB4
      Z4AB=ZB4    -ZAB
      Y4       =(ZABA*(YABPA**2-YAB*YA)+ZA3B*(YAP3B**2-YA*Y3B)+
     1 Z3B4*(Y3BP4**2-Y3B*RB4    )+Z4AB*(Y4PAB**2-RB4    *YAB))/(6.*AR4)
```

```
      Z4       =(YA4*ZAB3B*ZABP3B-YAB3B*ZA4*ZAP4-ZAB3B*ZA4*(YABP3B-YAP4))
     1         /(4.*AR4)
      T1       =Y1*(YAB-YDB)
      T2       =Y3*(Y3B-Y2B)
      A11      =T1+T2
      T3       =Y1*(ZAB-ZDB)
      T4       =Y3*(Z3B-Z2B)
      A12    =T3+T4
      T5     =Y2*(YDB-Y2B)
      T6     =Y4*(YAB-Y3B)
      A21    =T5+T6
      T7     =Y2*(ZDB-Z2B)
      T8     =Y4*(ZAB-Z3B)
      A22    =T7+T8
      B1=RB1    *T3-ZB1    *T1+RB3    *T4-ZB3*T2
      B2=ZB2    *T5-RB2    *T7+ZB4    *T6-RB4*T8
      DEMO3 =A12*A21-A22*A11
      YAM=YA
      ZAM=ZA
      YA     =(A21*B1+A11*B2)/DEMO3
      ZA     =(A22*B1+A12*B2)/DEMO3
      IF((ABS(YAM-YA).LT.(YA*10.E-8)).AND.(ABS(ZAM-ZA).LT.(ZA*10.E-8)))
     1 GO TO 50
40    CONTINUE
50    GO TO (502,505,505),MOTION
502   ARH1=ARH4=AW1(J,L)
      ARH2=ARH3=AW2(J,L)
      IF(SUMER.EQ.2) GO TO 535
      Q11(J,L)=Q11(J,L)*(ARH1+ARH2+ARH3+ARH4)
      Q22(J,L)=QX(J,L)=Q11(J,L)
      GO TO 535
505   IF(RB2.EQ.RB1) GO TO 51
      GO TO 52
51    FDB=.5
      GDB=.5
      GO TO 53
52    FDB=(RB2-YDB)/(RB2-RB1)
      GDB=(YDB-RB1)/(RB2-RB1)
53    YDBN=FDB*RX(J+1,L)+GDB*RX(J,L)
      ZDBN=FDB*RY(J+1,L)+GDB*RY(J,L)
      YDBNM=FDB*RXM(J+1,L)+GDB*RXM(J,L)
      ZDBNM=FDB*RYM(J+1,L)+GDB*RYM(J,L)
      IF(RB3.NE.RB2) GO TO 531
      F2B=.5
      G2B=.5
      GO TO 532
531   F2B=(RB3-Y2B)/(RB3-RB2)
      G2B=(Y2B-RB2)/(RB3-RB2)
532   Y2BN=F2B*RX(J,L)+G2B*RX(J,L2)
      Z2BN=F2B*RY(J,L)+G2B*RY(J,L2)
      Y2BNM=F2B*RXM(J,L)+G2B*RXM(J,L2)
      Z2BNM=F2B*RYM(J,L)+G2B*RYM(J,L2)
      F3B=(RB4-Y3B)/(RB4-RB3)
      G3B=(Y3B-RB3)/(RB4-RB3)
      Y3BN =F3B*RX(J,L2)+G3B*RX(J+1,L2)
      Z3BN =F3B*RY(J,L2)+G3B*RY(J+1,L2)
      Y3BNM=F3B*RXM(J,L2)+G3B*RXM(J+1,L2)
      Z3BNM=F3B*RYM(J,L2)+G3B*RYM(J+1,L2)
      IF(RB4.NE.RB1) GO TO 533
      FAB=.5
      GAB=.5
```

```
      GO TO 534
533   FAB=(RB1-YAB)/(RB1-RB4)
      GAB=(YAB-RB4)/(RB1-RB4)
534   YABN =FAB*RX(J+1,L2)+GAB*RX(J+1,L)
      ZABN =FAB*RY(J+1,L2)+GAB*RY(J+1,L)
      YABNM=FAB*RXM(J+1,L2)+GAB*RXM(J+1,L)
      ZABNM=FAB*RYM(J+1,L2)+GAB*RYM(J+1,L)
      ARN1 =0.5*((YDBN-YABN)*(RY(J+1,L)-ZA)-(RX(J+1,L)-YA)*(ZDBN-ZABN))
      ARNM1=.5*((YDBNM-YABNM)*(RYM(J+1,L)-ZA)-(RXM(J+1,L)-YA)*
     1 (ZDBNM-ZABNM))
      ARN2 =.5*((RX(J,L)-YA)*(ZDBN-Z2BN)-(YDBN-Y2BN)*(RY(J,L)-ZA))
      ARNM2=.5*((RXM(J,L)-YA)*(ZDBNM-Z2BNM)-(YDBNM-Y2BNM)*(RYM(J,L)-ZA))
      ARN3 =.5*((Y2BN-Y3BN)*(ZA-RY(J,L2))-(YA-RX(J,L2))*(Z2BN-Z3BN))
      ARNM3=.5*((Y2BNM-Y3BNM)*(ZA-RYM(J,L2))-(YA-RXM(J,L2))*(Z2BNM-
     1 Z3BNM))
      ARN4 =.5*((YA-RX(J+1,L2))*(ZABN-Z3BN)-(YABN-Y3BN)*(ZA-RY(J+1,L2)))
      ARNM4=.5*((YA-RXM(J+1,L2))*(ZABNM-Z3BNM)-(YABNM-Y3BNM)*(ZA-
     1 RYM(J+1,L2)))
      AW1(J,L)=(AR1+ARN1+ARNM1)/3.
      AW2(J,L)=(AR2+ARN2+ARNM2)/3.
      AW3(J,L)=(AR3+ARN3+ARNM3)/3.
      AW4(J,L)=(AR4+ARN4+ARNM4)/3.
535   P11B=.5*(P11(J,L)+Q11(J,L)+PQNMXX(J,L))
      P12B=.5*(P12(J,L)+Q12(J,L)+PQNMXY(J,L))
      P22B=.5*(P22(J,L)+Q22(J,L)+PQNMYY(J,L))
      PXB=.5*(PX(J,L)+QX(J,L)+PQMX(J,L))
      A1YR=A2Y(J,L)-AW1(J,L)
      F1Y(J,L)=P11B*A1YR+P12B*A2Z(J,L)+PXB*AW1(J,L)
      F1Z(J,L)=P12B*A1YR+P22B*A2Z(J,L)
      A2YR=A1Y(J,L)-AW2(J,L)
      F2Y(J,L)=P11B*A2YR+P12B*A1Z(J,L)+PXB*AW2(J,L)
      F2Z(J,L)=P12B*A2YR+P22B*A1Z(J,L)
      A3YR=A4Y(J,L)-AW3(J,L)
      F3Y(J,L)=P11B*A3YR+P12B*A4Z(J,L)+PXB*AW3(J,L)
      F3Z(J,L)=P12B*A3YR+P22B*A4Z(J,L)
      A4YR=A3Y(J,L)-AW4(J,L)
      IF(SUMER.EQ.2) SFW=PXB*(AW1(J,L)+AW2(J,L)+AW3(J,L)+AW4(J,L))+SFW
      F4Y(J,L)=P11B*A4YR+P12B*A3Z(J,L)+PXB*AW4(J,L)
      F4Z(J,L)=P12B*A4YR+P22B*A3Z(J,L)
      PQN XX(J,L)=P11(J,L)+Q11(J,L)
      PQN XY(J,L)=P12(J,L)+Q12(J,L)
      PQN YY(J,L)=P22(J,L)+Q22(J,L)
      PQX(J,L)=PX(J,L)+QX(J,L)
      GO TO (100,54,54),MOTION
54    CONTINUE
60    CONTINUE
100   CONTINUE
110   CONTINUE
      RETURN
      END
```

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C       SUBROUTINE  INFACE
        SUBROUTINE INFCOO
        COMMON/INDUMP/    NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
       2 KBMAX,   TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
       3 SENERI,  SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
       4 FIMPY,   SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
       5 KBOT,    KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
       6 KB,      CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UZLBIN,  UZBIN,
       7 UZRBIN,  UYLTIN,  UYTIN,   UYRTIN,  UZLTIN,  UZTIN,   UZRTIN,  KTM,
       8 JMIN,    JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
       9 KT,         EIN(5),     KINT(5),   RHOIN(5),  UYIN(5),    UZIN(5),
       2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),
       A E S(5),     ALFA(5),    BIG A(5), BIG B(5), RCP V S(5),E ZERO(5),
       4 FMLZR(100),                KSV(24),      SAV(12),      FMLYR(100)
        COMMON/THEREST/             A(55),        DIL(55),      EPX(55),
       2 EPY(55),      EPZ(55),     FMLYB(55),    FMLYT(55),    FMLZB(55),
       3 FMLZT(55),    LY1(55),     LY2(55),      LZ1(55),      LZ2(55),
       4 PY(55),       PZ(55),      R1H(55),      R2H(55),      R3H(55),
       5 R4H(55),      Z1H(55),     Z2H(55),      Z3H(55),      Z4H(55),
       6 U2(55,2),     B(55,4)
        COMMON/AFTERALL/
       A                 RX(55,5),        RY(55,5),        UNMX(55,5),
       1 UNMY(55,5),     UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
       2 ENM(55,5),      EN(55,5),        PNM(55,5),       PN(55,5),
       3 PQNMXX(55,5),   PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
       4 PQNXY(55,5),    PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
       5 RWAE3Z(55,5),   RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
       6 E3Z(55,5),      E1Z(55,5),       RHO(55,5),       VOL(55,5),
       7 ETA(55,5),      A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
       8 A4Y(55,5),      A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
       9 A4Z(55,5),      F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
       A F4Y(55,5),      F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
       1 F4Z(55,5),      NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
       2 FMNMX(55,5),    FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
       4 AW1(55,5),      AW2(55,5),       AW3(55,5),       AW4(55,5),
       5 RXM(55,5),      RYM(55,5),       RXZ(55,5),       RYZ(55,5),
       6 Q11(55,5),      Q12(55,5),       Q22(55,5),       QX(55,5),
       7 P11(55,5),      P12(55,5),       P22(55,5),       PX(55,5),
       8 PQX(55,5),      PQMX(55,5),      VO(55,5)
        COMMON    ICON,    LINCT,  LX1,     LX2,     LX3,     LX4,     LX5,
       2 KC,      NDPA,    NEDIT,  NSIG,    NMASS,   NDMP
        COMMON/ITER/        ALPHA(100),      DF(100)
        COMMON/JHILO/       DIST(2),         Z21(2),          Y21(2),
       2     NY12(2),       NZ12(2),         YA(2),           ZA(2),
       3     YAN(2),        ZAN(2),          UNAY(2),         UNAZ(2)
        COMMON/JKFACE/      UNORM(55,5),     YAZ(55,5),       ZAZ(55,5)
        COMMON/T1234/       A1YT(4),         A1ZT(4),         FMASST(4),
       2     A2YT(4),       A2ZT(4),         A3YT(4),         A3ZT(4),
       3     DILT(4),       LY1T(4),         LY2T(4),         LZ1T(4),
       4     LZ2T(4),       EPYT(4),         EPZT(4),         EPXT(4),
       5     PYT(4),        PZT(4),          PXT(4),          P11T(4),
       6     P12T(4),       P22T(4),         P11BT(4),        P12BT(4),
       7     P22BT(4),      PXBT(4),         ENT(4),          ART(4),
       8     F1YT(4),       F1ZT(4),         F2YT(4),         F2ZT(4),
       9     F3YT(4),       F3ZT(4),         Q11T(4),         Q12T(4),
       A     Q22T(4),       QXT(4),          VOLT(4),         VOLM(4)
        DIMENSION LAMMA(5),EMU(5)
        DIMENSION FY(1),FZ(1),T21Y(1),T21Z(1),YB(1),ZB(1),YBD(1),ZBD(1),
       2 YBU(1),ZBU(1)
        EQUIVALENCE(LAMMA(1),TINY A(1)),(EMU(1),TINY B(1))
        EQUIVALENCE (PY(1),FY(1)),(PZ(1),FZ(1)),(EPY(1),T21Y(1)),
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      2 (EPZ(1),T21Z(1)),(YA(1),YB(1)),(ZA(1),ZB(1)),(YAN(1),YBD(1)),
      3 (ZAN(1),ZBD(1)),(Y21(1),YBU(1)),(Z21(1),ZBU(1))
       REAL                 NZ12,          NY2,          NZ2,
       1    LAMP,           LAMM,          LY1T,         LY2T,
       2    LZ1T,    LZ2T,     NY12,    LAMMA,    LAMDIL
C*****
       ITMAX=0
       ITMIN=0
       L=LX2
       L2=LX3
       L3=LX4
       L4=LX5
       L5=LX1
       GO TO (3,1,1),MOTION
1      DO 2 J=JMIN,JMAX
       FMASN(J,L5)=FMASNM(J,L5)
       FMASN(J,L )=FMASNM(J,L )
       FMASN(J,L2)=FMASNM(J,L2)
       RX(J,L2)=RXM(J,L2)+UNMX(J,L2)*DTNM
       RY(J,L2)=RYM(J,L2)+UNMY(J,L2)*DTNM
       RX(J,L3)=RXM(J,L3)+UNMX(J,L3)*DTNM
2      RY(J,L3)=RYM(J,L3)+UNMY(J,L3)*DTNM
3      JHI=1
       JLO=2
       MT=6
       DO 305 J=JMIN,JMAX
       IF(J.EQ.(JBMAX+1))MT=7
       IF(J.EQ.JMAX) GO TO 11
10     DIST(JHI   )=SQRT((RXM(J+1,L)-RXM(J,L))**2+(RYM(J+1,L)-RYM(J,L))*
      1 *2)
       Z21(JHI   )=RYM(J+1,L)-RYM(J,L)
       Y21(JHI   )=RXM(J+1,L)-RXM(J,L)
       NY12(JHI   )=-Z21(JHI   )/DIST(JHI   )
       NZ12(JHI   )= Y21(JHI   )/DIST(JHI   )
       YA(JHI   )=SQRT((RXM(J,L)**2+RXM(J,L)*RXM(J+1,L)+RXM(J+1,L)**2)/3.)
       ZA(JHI   )=((YA(JHI   )-RXM(J,L))*RYM(J+1,L)+(RXM(J+1,L)-YA(JHI   ))*
      1             RYM(J,L))/Y21(JHI   )
       YAN(JHI   )=YA(JHI)+DTNMP5*(UNMX(J,L)+UNMX(J+1,L))
       ZAN(JHI   )=ZA(JHI)+DTNMP5*(UNMY(J,L)+UNMY(J+1,L))
       UNAY(JHI)=(YAN(JHI)-YA(JHI))*RDTNM
       UNAZ(JHI)=(ZAN(JHI)-ZA(JHI))*RDTNM
       IF(J.GT.JMIN) GO TO 12
       NY2=NY12(JHI)
       NZ2=NZ12(JHI)
       GO TO 13
11     NY2=NY12(JLO)
       NZ2=NZ12(JLO)
       GO TO 13
12     NY2=.5*(NY12(JLO)+NY12(JHI))
       NZ2=.5*(NZ12(JLO)+NZ12(JHI))
13     TERM3=(UNMX(J,L)*NZ2-UNMY(J,L)*NY2)
       TERMY=TERM3*NZ2
       TERMZ=-TERM3*NY2
       WRITE(MT,502)KINT(NREG),J,JLO,JHI,NREG,
      2 NY12(JLO),NY12(JHI),YA(JLO),YAN(JLO),YA(JHI),YAN(JHI),
      3 NZ12(JLO),NZ12(JHI),ZA(JLO),ZAN(JLO),ZA(JHI),ZAN(JHI)
       IT=1
       ALPHA(IT)=UNORM(J,NREG)
       Y3P1=RXM(J,L2)+RXM(J,L)
       Z31=RYM(J,L2)-RYM(J,L)
       IF(J.EQ.JMIN) GO TO 131
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      Y1P2=RXM(J,L)+YA(JLO)
      YBG=Y1P2
      Z12=RYM(J,L)-ZA(JLO)
      ZBG=Z12
      Y2P3=YA(JLO)+RXM(J,L2)
      Z23=ZA(JLO)-RYM(J,L2)
      VOLM(1)=(Z12*(Y1P2**2-RXM(J,L)*YA(JLO))+Z23*(Y2P3**2-YA(JLO)*
     2      RXM(J,L2))+Z31*(Y3P1**2-RXM(J,L2)*RXM(J,L)))/6.
      IF(J.EQ.JMAX) GO TO 132
131   Y1P2=Y3P1
      Z12=-Z31
      Y2P3=RXM(J,L2)+YA(JHI)
      Z23=RYM(J,L2)-ZA(JHI)
      Y3P1=YA(JHI)+RXM(J,L )
      Z31=ZA(JHI)-RYM(J,L)
      VOLM(2)=(Z12*(Y1P2**2-RXM(J,L)*RXM(J,L2))+Z23*(Y2P3**2-RXM(J,L2)*
     2         YA(JHI))+Z31*(Y3P1**2-YA(JHI)*RXM(J,L)))/6.
      Y1P2=Y3P1
      Z12=-Z31
      Y2P3=YA(JHI)+RXM(J,L5)
      Z23=ZA(JHI)-RYM(J,L5)
132   Y3P1=RXM(J,L5)+RXM(J,L)
      Z31=RYM(J,L5)-RYM(J,L)
      IF(J.EQ.JMAX) GO TO 133
      VOLM(3)=(Z12*(Y1P2**2-RXM(J,L)*YA(JHI))+Z23*(Y2P3**2-YA(JHI)*
     2         RXM(J,L5))+Z31*(Y3P1**2-RXM(J,L5)*RXM(J,L)))/6.
      IF(J.EQ.JMIN) GO TO 14
133   Y1P2=Y3P1
      Z12=-Z31
      Y2P3=RXM(J,L5)+YA(JLO)
      Z23=RYM(J,L5)-ZA(JLO)
      VOLM(4)=(Z12*(Y1P2**2-RXM(J,L)*RXM(J,L5))+Z23*(Y2P3**2-RXM(J,L5)*
     2         YA(JLO))-ZBG*(YBG**2-YA(JLO)*RXM(J,L)))/6.
14    RX(J,L)=RXM(J,L)+DTNM*(ALPHA(IT)*NY2+TERMY)
      RY(J,L)=RYM(J,L)+DTNM*(ALPHA(IT)*NZ2+TERMZ)
      UNPX(J,L)=(RX(J,L)-RXM(J,L))*RDTNM
      UNPY(J,L)=(RY(J,L)-RYM(J,L))*RDTNM
      WRITE(MT,503)RX(J,L),NY2,ALPHA(IT),IT,RY(J,L),NZ2
      DO 165 I=1,4
      GO TO(15,50,65,71),I
15    RB1=.5*(RX(J,L)+RXM(J,L))
      RB3=.5*(RX(J,L2)+RXM(J,L2))
      ZB1  =.5*(RY(J,L)+RYM(J,L))
      ZB3=.5*(RY(J,L2)+RYM(J,L2))
      A31M =RYM(J,L2)*RXM(J,L)-RYM(J,L)*RXM(J,L2)
      A31N =RY(J,L2)*RX(J,L)-RY(J,L)*RX(J,L2)
      RA31   =RXZ(J,L2)-RXZ(J,L)
      RAP31  =RX(J,L2)-RX(J,L)
      ZA31   =RYZ(J,L2)-RYZ(J,L)
      ZAP31  =RY(J,L2)-RY(J,L)
16    IF(J.EQ.JMIN) GO TO 49
      RB2=.5*(YAN(JLO)+YA(JLO))
      RB4=RB2
      ZB2=.5*(ZAN(JLO)+ZA(JLO))
      ZB4=ZB2
      A12M=RYM(J,L)*YA(JLO)-ZA(JLO)*RXM(J,L)
      A23M=ZA(JLO)*RXM(J,L2)-RYM(J,L2)*YA(JLO)
      A12N=RY(J,L)*YAN(JLO)-ZAN(JLO)*RX(J,L)
      A23N=ZAN(JLO)*RX(J,L2)-RY(J,L2)*YAN(JLO)
17    A12H=.5*(A12M+A12N)
      A23H =.5*(A23M+A23N)
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```
      A31H=.5*(A31M+A31N)
      RB12   = RB1  +RB2
      RB23   = RB2  +RB3
      RB31   = RB3  +RB1
      A1YT(I)=(ZB3  *RB31  -ZB2  *RB12  +A31H+A12H)/6.
      A1ZT(I)=(RB2  *RB12  -RB3  *RB31  )/6.
      A2YT(I)=(ZB1  *RB12  -ZB3  *RB23  +A12H+A23H)/6.
      A2ZT(I)=(RB3  *RB23  -RB1  *RB12  )/6.
      A3YT(I)=(ZB2  *RB23  -ZB1  *RB31  +A23H+A31H)/6.
      A3ZT(I)=(RB1  *RB31  -RB2  *RB23  )/6.
      WRITE(MT,504)RB1,RB2,RB3,A1YT(I),A2YT(I),A3YT(I),I,
     2            ZB1, ZB2, ZB3, A1ZT(I),A2ZT(I),A3ZT(I)
      GO TO (20,60,70,80 ),I
20    VDOT1     =UNPX(J,L)*A1YT(I)+UNPY(J,L)*A1ZT(I)+UNAY(JLO)*A2YT(I)+
     1          UNAZ(JLO)*A2ZT(I)+UNMX(J,L2)*A3YT(I)+UNMY(J,L2)*A3ZT(I)
      FMASST(I)=VOLM(I)*RHO(J-1,L)
      VOLT(I)=VOLM(I)+VDOT1*DTNM
      DILT(I)=VOLT(I)/(FMASST(I)*VO(J-1,L))-1.
      RB21=YAZ(J-1,NREG)-RXZ(J,L)
      RBP21=YAN(JLO)-RX(J,L)
      RBG=RB21
      RBGP=RBP21
      ZB21=ZAZ(J-1,NREG)-RYZ(J,L)
      ZBP21=ZAN(JLO)-RY(J,L)
      ZBG=ZB21
      ZBGP=ZBP21
      WRITE(MT,505)VDOT1,VOLT(I),FMASST(I),DILT(I),VOLM(I)
      GO TO 85
49    I=I+1
      GO TO 55
50    IF(J.EQ.JMAX) GO TO 61
55    RB2=RB3
      RB3=.5*(YAN(JHI)+YA(JHI))
      ZB2=ZB3
      ZB3=.5*(ZAN(JHI)+ZA(JHI))
      A12M=-A31M
      A23M=RYM(J,L2)*YA(JHI)-ZA(JHI)*RXM(J,L2)
      A31M=ZA(JHI)*RXM(J,L)-RYM(J,L)*YA(JHI)
      A12N=-A31N
      A23N=RY(J,L2)*YAN(JHI)-ZAN(JHI)*RX(J,L2)
      A31N=ZAN(JHI)*RX(J,L)-RY(J,L)*YAN(JHI)
      GO TO 17
60    VDOT2     =UNPX(J,L)*A1YT(I)+UNPY(J,L)*A1ZT(I)+UNMX(J,L2)*A2YT(I)+
     1          UNMY(J,L2)*A2ZT(I)+UNAY(JHI)*A3YT(I)+UNAZ(JHI)*A3ZT(I)
      FMASST(I)=VOLM(I)*RHO(J,L)
      VOLT(I)=VOLM(I)+VDOT2*DTNM
      DILT(I)=VOLT(I)/(FMASST(I)*VO(J,L  ))-1.
      RB21=RA31
      RA31=YAZ(J,NREG)-RXZ(J,L)
      RBP21=RAP31
      RAP31=YAN(JHI)-RX(J,L)
      ZB21=ZA31
      ZA31=ZAZ(J,NREG)-RYZ(J,L)
      ZBP21=ZAP31
      ZAP31=ZAN(JHI)-RY(J,L)
      WRITE(MT,505)VDOT2,VOLT(I),FMASST(I),DILT(I),VOLM(I)
      GO TO 85
61    I=I+1
      GO TO 66
65    RB2=RB3
      ZB2=ZB3
```

```
      A12M=-A31M
      A23M=ZA(JHI)*RXM(J,L5)-RYM(J,L5)*YA(JHI)
      A12N=-A31N
      A23N=ZAN(JHI)*RX(J,L5)-RY(J,L5)*YAN(JHI)
      RB21=RA31
      RBP21=RAP31
      ZB21=ZA31
      ZBP21=ZAP31
66    RB3=.5*(RXM(J,L5)+RX(J,L5))
      ZB3=.5*(RYM(J,L5)+RY(J,L5))
      A31M=RYM(J,L5)*RXM(J,L)-RYM(J,L)*RXM(J,L5)
      A31N=RY(J,L5)*RX(J,L)-RY(J,L)*RX(J,L5)
      RA31=RXZ(J,L5)-RXZ(J,L)
      RAP31=RX(J,L5)-RX(J,L)
      ZA31=RYZ(J,L5)-RYZ(J,L)
      ZAP31=RY(J,L5)-RY(J,L)
      IF(J.EQ.JMAX) GO TO 700
      GO TO 17
70    VDOT3     =UNPX(J,L)*A1YT(I)+UNPY(J,L)*A1ZT(I)+UNAY(JHI) *A2YT(I)+
     1          UNAZ(JHI) *A2ZT(I)+UNMX(J,L5)*A3YT(I)+UNMY(J,L5)*A3ZT(I)
      FMASST(I)=VOLM(I)*RHO(J,L5)
      VOLT(I)=VOLM(I)+VDOT3*DTNM
      DILT(I)=VOLT(I)/(FMASST(I)*VO(J,L5 ))-1.
      WRITE(MT,505)VDOT3,VOLT(I),FMASST(I),DILT(I),VOLM(I)
      GO TO 85
700   I=I+1
      GO TO 75
71    IF(J.EQ.JMIN)GO TO 165
75    RB2=RB3
      RB3=RB4
      ZB2=ZB3
      ZB3=ZB4
      A12M=-A31M
      A23M=RYM(J,L5)*YA(JLO)-ZA(JLO)*RXM(J,L5)
      A31M=ZA(JLO)*RXM(J,L)-RYM(J,L)*YA(JLO)
      A12N=-A31N
      A23N=RY(J,L5)*YAN(JLO)-ZAN(JLO)*RX(J,L5)
      A31N=ZAN(JLO)*RX(J,L)-RY(J,L)*YAN(JLO)
      GO TO 17
80    VDOT4     =UNPX(J,L)*A1YT(I)+UNPY(J,L)*A1ZT(I)+UNMX(J,L5)*A2YT(I)+
     1          UNMY(J,L5)*A2ZT(I)+UNAY(JLO)*A3YT(I)+UNAZ(JLO)*A3ZT(I)
      FMASST(I)=VOLM(I)*RHO(J-1,L5)
      VOLT(I)=VOLM(I)+VDOT4*DTNM
      DILT(I)=VOLT(I)/(FMASST(I)*VO(J-1,L5))-1.
      RB21=RA31
      RA31=RBG
      RBP21=RAP31
      RAP31=RBGP
      ZB21=ZA31
      ZA31=ZBG
      ZBP21=ZAP31
      ZAP31=ZBGP
      WRITE(MT,505)VDOT4,VOLT(I),FMASST(I),DILT(I),VOLM(I)
85    AAB =RA31*ZB21-RB21*ZA31
      A22 =(ZB21  *RAP31  -ZA31  *RBP21  )/AAB
      A23 =(RA31  *RBP21  -RB21  *RAP31  )/AAB
      A32 =(ZB21  *ZAP31  -ZA31  *ZBP21  )/AAB
      A33 =(RA31  *ZBP21  -RB21  *ZAP31  )/AAB
      T22  =A22   **2+A32   **2
      T23  =A22   *A23   +A32   *A33
      T33  =A23   **2+A33   **2
```

```
      IF(T23.EQ.0) GO TO 110
      ROOT =SQRT((T22 -T33 )**2+4.*T23**2)
      TERM=(T22+T33)
      LAMP=.5*(TERM+ROOT)
      LAMM=.5*(TERM-ROOT)
      E1=SQRT(LAMP)
      E2=SQRT(LAMM)
      RROOT1=1./ SQRT(T23**2+(T22-LAMP)**2)
      LY1T(I)=T23*RROOT1
      LY2T(I)=(T22-LAMP)*RROOT1
      RROOT2=1./SQRT(T23**2+(T22-LAMM)**2)
      LZ1T(I)=T23*RROOT2
      LZ2T(I)=(T22-LAMM)*RROOT2
      IF(ABS(LY1T(I)).LT.ABS(LZ1T(I))) GO TO 95
      IF(LY1T(I).GT.0) GO TO 90
      LY1T(I)=-LY1T(I)
      LY2T(I)=-LY2T(I)
90    IF(LZ2T(I).GT.0) GO TO 115
      LZ1T(I)=-LZ1T(I)
      LZ2T(I)=-LZ2T(I)
      GO TO 115
95    IF(LZ1T(I).GT.0) GO TO 100
      LZ1T(I)=-LZ1T(I)
      LZ2T(I)=-LZ2T(I)
100   IF(LY2T(I).GT.0) GO TO 105
      LY1T(I)=-LY1T(I)
      LY2T(I)=-LY2T(I)
105   WS=LY1T(I)
      LY1T(I)=LZ1T(I)
      LZ1T(I)=WS
      WS=LY2T(I)
      LY2T(I)=LZ2T(I)
      LZ2T(I)=WS
      GO TO 115
110   E1=SQRT(T22)
      LY1T(I)=1.
      LY2T(I)=0.
      E2=SQRT(T33)
      LZ1T(I)=0.
      LZ2T(I)=1.
115   GO TO (116,117,118,119),I
116   E3=VOLT(I)/(FMASST(I)*VO(J-1,L )*E1*E2)
      GO TO 1190
117   E3=VOLT(I)/(FMASST(I)*VO(J  ,L )*E1*E2)
      GO TO 1190
118   E3=VOLT(I)/(FMASST(I)*VO(J  ,L5)*E1*E2)
      GO TO 1190
119   E3=VOLT(I)/(FMASST(I)*VO(J-1,L5)*E1*E2)
1190  EPYT(I)=E1-1.
      EPZT(I)=E2-1.
      EPXT(I)=E3-1.
      IF(I.LT.3)NREG=NREG+1
      LAMDIL=LAMMA(NREG)*DILT(I)
      EMU2=-2.*EMU(NREG)
      IF(I.LT.3) NREG=NREG-1
      PYT(I)=EMU2*EPYT(I)-LAMDIL
      PZT(I)=EMU2*EPZT(I)-LAMDIL
      PXT(I)=EMU2*EPXT(I)-LAMDIL
      P11T(I)=LY1T(I)**2*PYT(I)+LZ1T(I)**2*PZT(I)
      P12T(I)=LY1T(I)*LY2T(I)*PYT(I)+LZ1T(I)*LZ2T(I)*PZT(I)
      P22T(I)=LY2T(I)**2*PYT(I)+LZ2T(I)**2*PZT(I)
```

```
      Q11T(I)=Q12T(I)=Q22T(I)=QXT(I)=0.
      GO TO (120,125,130,135),I
120   ART(I)=((RX(J,L)-YAN(JLO))*(RY(J,L2)-ZAN(JLO))-(RY(J,L)-ZAN(JLO))*
     1      (RX(J,L5)-YAN(JLO)))/6.
      P11BT(I)=.5*(P11T(I)+Q11T(I)+PQNMXX(J-1,L ))
      P12BT(I)=.5*(P12T(I)+Q12T(I)+PQNMXY(J-1,L ))
      P22BT(I)=.5*(P22T(I)+Q22T(I)+PQNMYY(J-1,L ))
      PXBT(I)= .5*(PXT(I)+QXT(I)+PQMX(J-1,L ))
      GO TO 140
125   ART(I)=((RX(J,L)-RX (J,L2))*(ZAN(JHI)-RY (J,L2))-(RY(J,L)-
     1 RY (J,L2))*(YAN(JHI)-RX (J,L2)))/6.
      P11BT(I)=.5*(P11T(I)+Q11T(I)+PQNMXX(J,L))
      P12BT(I)=.5*(P12T(I)+Q12T(I)+PQNMXY(J,L))
      P22BT(I)=.5*(P22T(I)+Q22T(I)+PQNMYY(J,L))
      PXBT(I) =.5*(PXT(I)+QXT(I)+PQMX(J,L))
      GO TO 140
130   ART(I)=((RX(J,L)-YAN(JHI))*(RY(J,L5)-ZAN(JHI))-(RY(J,L)-ZAN(JHI))*
     1      (RX(J,L5)-YAN(JHI)))/6.
      P11BT(I)=.5*(P11T(I)+Q11T(I)+PQNMXX(J  ,L5))
      P12BT(I)=.5*(P12T(I)+Q12T(I)+PQNMXY(J  ,L5))
      P22BT(I)=.5*(P22T(I)+Q22T(I)+PQNMYY(J  ,L5))
      PXBT(I)= .5*(PXT(I)+QXT(I)+PQMX(J  ,L5))
      GO TO 140
135   ART(I)=((RX(J,L)-RX (J,L5))*(ZAN(JLO)-RY (J,L5))-(RY(J,L)-
     1        RY (J,L5))*(YAN(JLO)-RX (J,L5)))/6.
      P11BT(I)=.5*(P11T(I)+Q11T(I)+PQNMXX(J-1,L5))
      P12BT(I)=.5*(P12T(I)+Q12T(I)+PQNMXY(J-1,L5))
      P22BT(I)=.5*(P22T(I)+Q22T(I)+PQNMYY(J-1,L5))
      PXBT(I)= .5*(PXT(I)+QXT(I)+PQMX(J-1,L5))
140   ATERM1=A1YT(I)-ART(I)
      F1YT( I   )=P11BT(I)*ATERM1+P12BT(I)*A1ZT(I)+PXBT(I)*ART(I)
      F1ZT( I   )=P12BT(I)*ATERM1+P22BT(I)*A1ZT(I)
      ATERM2=A2YT(I)-ART(I)
      F2YT( I   )=P11BT(I)*ATERM2+P12BT(I)*A2ZT(I)+PXBT(I)*ART(I)
      F2ZT( I   )=P12BT(I)*ATERM2+P22BT(I)*A2ZT(I)
      ATERM3=A3YT(I)-ART(I)
      F3YT( I   )=P11BT(I)*ATERM3+P12BT(I)*A3ZT(I)+PXBT(I)*ART(I)
      F3ZT( I   )=P12BT(I)*ATERM3+P22BT(I)*A3ZT(I)
      GO TO (145,150,155,160),I
145   ENT(I)=ENM(J-1,L )-DTNM*(UNPX(J,L)*F1YT(I)+UNPY(J,L)*F1ZT(I)+
     2      UNAY(JLO)*F2YT(I)+UNAZ(JLO)*F2ZT(I)+UNMX(J,L2)*F3YT(I)+
     3      UNMY(J,L2)*F3ZT(I))
      WRITE(MT,507)UNPX(J,L),UNAY(JLO), UNMX(J,L2),
     2              UNPY(J,L),UNAZ(JLO), UNMY(J,L2)
      GO TO 164
150   ENT(I)=ENM(J   ,L )-DTNM*(UNPX(J,L)*F1YT(I)+UNPY(J,L)*F1ZT(I)+
     2      UNMX(J,L2)*F2YT(I)+UNMY(J,L2)*F2ZT(I)+UNAY(JHI)*F3YT(I)+
     3      UNAZ(JHI)*F3ZT(I))
      WRITE(MT,507)UNPX(J,L),UNMX(J,L2),UNAY(JHI),
     2              UNPY(J,L),UNMY(J,L2),UNAZ(JHI)
      GO TO 164
155   ENT(I)=ENM(J   ,L5)-DTNM*(UNPX(J,L)*F1YT(I)+UNPY(J,L)*F1ZT(I)+
     2      UNAY(JHI)*F2YT(I)+UNAZ(JHI)*F2ZT(I)+UNMX(J,L5)*F3YT(I)+
     3      UNMY(J,L5)*F3ZT(I))
      WRITE(MT,507)UNPX(J,L),UNAY(JHI), UNMX(J,L5),
     2              UNPY(J,L),UNAZ(JHI), UNMY(J,L5)
      GO TO 164
160   ENT(I)=ENM(J-1,L5)-DTNM*(UNPX(J,L)*F1YT(I)+UNPY(J,L)*F1ZT(I)+
     2      UNMX(J,L5)*F2YT(I)+UNMY(J,L5)*F2ZT(I)+UNAY(JLO)*F3YT(I)+
     3      UNAZ(JLO)*F3ZT(I))
      WRITE(MT,507)UNPX(J,L),UNMX(J,L5),UNAY(JLO) ,
```

```
     2               UNPY(J,L),UNMY(J,L5),UNAZ(JLO)
164   WRITE(MT,506)AAB,A22,A23,A32,A33,T22,T23,T33,LAMP,LAMM,
     2E1,E2,E3,LY1T(I),LZ1T(I),EPYT(I),EPZT(I),EPXT(I),LY2T(I),
     3LZ2T(I),PYT(I),PZT(I),PXT(I),ART(I), ENT(I),P11T(I),P12T(I),
     4 P22T(I),F1YT(I),F1ZT(I),F2YT(I),F2ZT(I),F3YT(I),F3ZT(I)
165   CONTINUE
      IF(J.EQ.JMAX)GO TO 170
      FAC23=.5*(YAN(JHI)+RX(J,L))
      AY23T=FAC23*(RY(J,L)-ZAN(JHI))
      AZ23T=FAC23*(YAN(JHI)-RX(J,L))
      FY23T=(P11BT(2)-P11BT(3))*AY23T+(P12BT(2)-P12BT(3))*AZ23T
      FZ23T=(P12BT(2)-P12BT(3))*AY23T+(P22BT(2)-P22BT(3))*AZ23T
      IF(J.GT.JMIN) GO TO 170
      FYT=FY23T
      FZT=FZ23T
      GO TO 180
170   FAC14=.5*(RX(J,L)+YAN(JLO))
      AY14T=FAC14*(ZAN(JLO)-RY(J,L))
      AZ14T=FAC14*(RX(J,L)-YAN(JLO))
      FY14T=(P11BT(1)-P11BT(4))*AY14T+(P12BT(1)-P12BT(4))*AZ14T
      FZ14T=(P12BT(1)-P12BT(4))*AY14T+(P22BT(1)-P22BT(4))*AZ14T
      IF(J.LT.JMAX) GO TO 175
      FYT=FY14T
      FZT=FZ14T
      GO TO 180
175   FYT=.5*(FY14T+FY23T)
      FZT=.5*(FZ14T+FZ23T)
180   DF(IT)=NY2*FYT+NZ2*FZT
      WRITE(MT,508)AY23T,AY14T,FY23T,FY14T,FYT,DF(IT),
     2              AZ23T,AZ14T,FZ23T,FZ14T,FZT
      IF(ABS(DF(IT)).LE. CUTOFF)GO TO 300
      IF((IT.GT.1).AND.(ABS(DF(IT)-DF(IT-1)).LE.(CUTOFF*ABS(DF(IT)))))
     1 GO TO 300
      IF(IT.LT.3   )GO TO 200
      GO TO 300
      WRITE(6,500)(IT,J,KC,N,DF(IT),ALPHA(IT),ITMIN,ITMAX,IT=1,100)
      WRITE(6,501)
200   IF(IT.GT.1) GO TO 220
      IF(DF(IT))205,300,210
205   ALPHA(IT+1)=1.01*ALPHA(IT)
      GO TO 215
210   ALPHA(IT+1)=.99*ALPHA(IT)
215   IF(ALPHA(IT+1).EQ.0)ALPHA(IT+1)=.1
      GO TO 230
220   IF(IT-30)225,235,265
225   ALPHA(IT+1)=ALPHA(IT)-DF(IT)*(ALPHA(IT)-ALPHA(IT-1))/(DF(IT)-
     1              DF(IT-1))
      IF(ABS(ALPHA(IT+1)-ALPHA(IT)).LE.(CUTOFF*ABS(ALPHA(IT))))GO TO 300
230   IT=IT+1
      GO TO 14
235   TMIN=-1000.
      TMAX=1000.
      IN=1
240   DO 260 IS=IN,IT
      IF(DF(IS))245,300,250
245   IF((DF(IS)-TMIN).LT.0) GO TO 260
      TMIN=DF(IS)
      ITMIN=IS
      GO TO 260
250   IF((DF(IS)-TMAX).GT.0) GO TO 260
      TMAX=DF(IS)
```

```
      ITMAX=IS
260   CONTINUE
      IMINMAX=1
      IF((ITMIN.EQ.0).OR.(ITMAX.EQ.0))IMINMAX= 2
      GO TO (290,225),IMINMAX
265   GO TO (275,270),IMINMAX
270   IN=IT
      GO TO 240
275   IF(DF(IT))280,300,285
280   ITMAX=IT
      GO TO 290
285   ITMIN=IT
290   ALPHA(IT+1)=.5*(ALPHA(ITMIN)+ALPHA(ITMAX))
      IF((ABS(ALPHA(IT+1)-ALPHA(IT))).GT.(CUTOFF*ABS(ALPHA(IT))))
     1 GO TO 230
300   UTAN=((UNMX(J,L5)+UNMX(J,L2))*NZ2-(UNMY(J,L5)+UNMY(J,L2))*NY2)*.5
      UNORM(J,NREG)=ALPHA(IT)
      JLO=JHI
      JHI=MOD(JLO,2)+1
      UNPX(J,L)=NZ2*UTAN+NY2*UNORM(J,NREG)
      UNPY(J,L)=NZ2*UNORM(J,NREG)-NY2*UTAN
      UNMX(J,L)=UNPX(J,L)
      UNMY(J,L)=UNPY(J,L)
305   WRITE(MT,510)UTAN,UNORM(J,NREG),UNPX(J,L),UNPY(J,L)
      CALL STRAIN
      CALL STRESS
      CALL STRAINP
      NREG=NREG+1
      KC=KINT(NREG)-1
      CALL STRESSP
      NREG=NREG-1
      KC=KINT(NREG)-1
      CALL STRAINP2
      NREG=NREG+1
      KC=KINT(NREG)-1
      CALL STRESSP2
      CALL FORCEP2
      CALL ENERGYP2
      NREG=NREG-1
      KC=KINT(NREG)-1
      NPATH=-NPATH+1
306   DO  325 J=JMIN,JR
      IF(NPATH.EQ.0) GO TO 326
      FACB=-.5*(RX(J,L5)+RX(J+1,L5))
      AYB =FACB*(RY(J+1,L5)-RY(J,L5))
      AZB =FACB*(RX(J,L5)-RX(J+1,L5))
3060  FACL=-.5*(RX(J,L)+RX(J,L5))
      FACR=-.5*(RX(J+1,L5)+RX(J+1,L))
      AYL =FACL*(RY(J,L5)-RY(J,L))
      AZL =FACL*(RX(J,L)-RX(J,L5))
      AYR =FACR*(RY(J+1,L)-RY(J+1,L5))
      AZR =FACR*(RX(J+1,L5)-RX(J+1,L))
      P11B=.5*(PQNXX(J,L4)+P11(J,L5)+Q11(J,L5))
      P12B=.5*(PQNXY(J,L4)+P12(J,L5)+Q12(J,L5))
      P22B=.5*(PQNYY(J,L4)+P22(J,L5)+Q22(J,L5))
      PXB=.5*(PQX(J,L4)+PX(J,L5)+QX(J,L5))
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```
      IF(J.GT.JMIN) GO TO 307
      P11L=P11(J,L5)+Q11(J,L5)
      P12L=P12(J,L5)+Q12(J,L5)
      P22L=P22(J,L5)+Q22(J,L5)
      PXL=PX(J,L5)+QX(J,L5)
      GO TO 310
307   P11L=.5*(P11(J,L5)+Q11(J,L5)+P11(J-1,L5)+Q11(J-1,L5))
      P12L=.5*(P12(J,L5)+Q12(J,L5)+P12(J-1,L5)+Q12(J-1,L5))
      P22L=.5*(P22(J,L5)+Q22(J,L5)+P22(J-1,L5)+Q22(J-1,L5))
      PXL=.5*(PX(J,L5)+QX(J,L5)+PX(J-1,L5)+QX(J-1,L5))
310   IF(J.LT.JR) GO TO 315
      P11R=P11(J,L5)+Q11(J,L5)
      P12R=P12(J,L5)+Q12(J,L5)
      P22R=P22(J,L5)+Q22(J,L5)
      PXR=PX(J,L5)+QX(J,L5)
      GO TO 320
315   P11R=.5*(P11(J,L5)+Q11(J,L5)+P11(J+1,L5)+Q11(J+1,L5))
      P12R=.5*(P12(J,L5)+Q12(J,L5)+P12(J+1,L5)+Q12(J+1,L5))
      P22R=.5*(P22(J,L5)+Q22(J,L5)+P22(J+1,L5)+Q22(J+1,L5))
      PXR=.5*(PX(J,L5)+QX(J,L5)+PX(J+1,L5)+QX(J+1,L5))
320   AW=.5*((RX(J+1,L5)-RX(J,L))*(RY(J+1,L)-RY(J,L5))-(RX(J+1,L)-
     2        RX(J,L5))*(RY(J+1,L5)-RY(J,L)))
      FYB=P11B*AYB  +P12B*AZB
      FZB=P12B*AYB  +P22B*AZB
      FYL=P11L*AYL  +P12L*AZL
      FZL=P12L*AYL  +P22L*AZL
      FYR=P11R*AYR  +P12R*AZR
      FZR=P12R*AYR  +P22R*AZR
      FW=AW*(PX(J,L5)+QX(J,L5))
      SFW=SFW+FW
      KPRINT=KC+1-NPATH
      WRITE(MT,509) J,AYB,AYL,AYR,P11B,P11L,P11R,AZB,AZL,AZR,P12B,P12L,
     2 P12R,FYB,FYL,FYR,P22B,P22L,P22R,FZB,FZL,FZR,PXB,PXL,PXR
     3,KPRINT,AW,FW
      IF(NPATH.EQ.0) GO TO 324
      FY(J)=FYB+FYR+FYL+FW
      FZ(J)=FZB+FZR+FZL
      GO TO 325
324   DIST=SQRT((RX(J+1,L5)-RX(J,L5))**2+(RY(J+1,L5)-RY(J,L5))**2)
      T21Y(J)=(RX(J+1,L5)-RX(J,L5))/DIST
      T21Z(J)=(RY(J+1,L5)-RY(J,L5))/DIST
      FY(J)=(FMASN(J,L5)*FY(J)-FMASN(J,L3)*(FYB+FYL+FYR+FW))*T21Y(J)/
     2       (FMASN(J,L5)+FMASN(J,L3))
      FZ(J)=(FMASN(J,L5)*FZ(J)-FMASN(J,L3)*(FZB+FZL+FZR))*T21Z(J)/
     2       (FMASN(J,L5)+FMASN(J,L3))
325   CONTINUE
      IF(NPATH.EQ.0)GO TO 330
      NPATH=1-NPATH
      L3=L5
      L4=L2
      L5=L
      L=L2
      GO TO 306
326   FACB=-.5*(RX(J+1,L )+RX(J,L ))
      AYB=FACB*(RY(J,L )-RY(J+1,L ))
      AZB=FACB*(RX(J+1,L )-RX(J,L ))
      GO TO 3060
330   L=L5
      L3=LX4
      L5=LX1
      JLO=1
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      JHI=2
      J=JMIN
      YB(JLO)=(RX(J,L)+RXM(J,L))*.5
      ZB(JLO)=(RY(J,L)+RYM(J,L))*.5
      YBD(JLO)=(RX(J,L5)+RXM(J,L5))*.5
      ZBD(JLO)=(RY(J,L5)+RYM(J,L5))*.5
      YBU(JLO)=.5*(RX(J,L2)+RXM(J,L2))
      ZBU(JLO)=.5*(RY(J,L2)+RYM(J,L2))
      DO 350 J=JMIN,JR
      YB(JHI)=(RX(J+1,L)+RXM(J+1,L))*.5
      ZB(JHI)=(RY(J+1,L)+RYM(J+1,L))*.5
      YBM=SQRT((YB(JLO)**2+YB(JLO)*YB(JHI)+YB(JHI)**2)/3.)
      ZBM=((YBM-YB(JLO))*ZB(JHI)+(YB(JHI)-YBM)*ZB(JLO))/(YB(JHI)-
     2    YB(JLO))
      YBD(JHI)=(RX(J+1,L5)+RXM(J+1,L5))*.5
      ZBD(JHI)=(RY(J+1,L5)+RYM(J+1,L5))*.5
      YBMM=SQRT((YBD(JLO)**2+YBD(JLO)*YBD(JHI)  +YBD(JHI)**2)/3.)
      ZBMM=((YBMM-YBD(JLO))*ZBD(JHI)+(YBD(JHI)-YBMM)*ZBD(JLO))/(YBD(JHI)
     2     -YBD(JLO))
      YBU(JHI)=.5*(RX(J+1,L2)+RXM(J+1,L2))
      ZBU(JHI)=.5*(RY(J+1,L2)+RYM(J+1,L2))
      YBMP=SQRT((YBU(JLO)**2+YBU(JLO)*YBU(JHI)+YBU(JHI)**2)/3.)
      ZBMP=((YBMP-YBU(JLO))*ZBU(JHI)+(YBU(JHI)-YBMP)*ZBU(JLO))/(YBU(JHI)
     2    -YBU(JLO))
      AW1(J,L5)=.5*((YBD(JHI)-YBM)*(ZB(JHI)-ZBMM)-(YB(JHI)-YBMM)*
     2          (ZBD(JHI)-ZBM))
      AW2(J,L5)=.5*((YBMM-YB(JLO))*(ZBM-ZBD(JLO))-(YBM-YBD(JLO))*
     2          (ZBMM-ZB(JLO)))
      AW3(J,L )=.5*((YBM-YBU(JLO))*(ZBMP-ZB(JLO))-(YBMP-YB(JLO))*
     2  (ZBM-ZBU(JLO)))
      AW4(J,L )=.5*((YB(JHI)-YBMP)*(ZBU(JHI)-ZBM)-(YBU(JHI)-YBM)*
     2 (ZB(JHI)-ZBMP))
      AW1(J,L)=0
      AW2(J,L)=0
      AW3(J,L5)=0
      AW4(J,L5)=0
      PXA3=PX(J,L5)*AW1(J,L5)
      PXA4=PX(J,L5)*AW2(J,L5)
      PXA5=PX(J,L)*AW3(J,L )
      PXA6=PX(J,L)*AW4(J,L )
      PQNXX(J,L5)=P11(J,L5)+Q11(J,L5)
      PQNXY(J,L5)=P12(J,L5)+Q12(J,L5)
      PQNYY(J,L5)=P22(J,L5)+Q22(J,L5)
      PQX(J,L5)=PX(J,L5)+QX(J,L5)
      PQNXX(J,L)=P11(J,L)+Q11(J,L)
      PQNXY(J,L)=P12(J,L)+Q12(J,L)
      PQNYY(J,L)=P22(J,L)+Q22(J,L)
      PQX(J,L)=PX(J,L)+QX(J,L)
      PQXXM=.5*(PQNXX(J,L5)+PQNMXX(J,L5))
      PQXYM=.5*(PQNXY(J,L5)+PQNMXY(J,L5))
      PQYYM=.5*(PQNYY(J,L5)+PQNMYY(J,L5))
      PQXM=.5*(PQX(J,L5)+PQMX(J,L5))
      PQXXP=.5*(PQNXX(J,L)+PQNMXX(J,L))
      PQXYP=.5*(PQNXY(J,L)+PQNMXY(J,L))
      PQYYP=.5*(PQNYY(J,L)+PQNMYY(J,L))
      PQXP=.5*(PQX(J,L)+PQMX(J,L))
      FAC=.5*(YBMP+YBM)
      FMPY=FAC*(PQXXP*(ZBMP-ZBM)+PQXYR*(YBM-YBMP))
      FMPZ=FAC*(PQXYP*(ZBMP-ZBM)+PQYYP*(YBM-YBMP))
      FAC=.5*(YBMM+YBM)
      FMMY=FAC*(PQXXM*(ZBMM-ZBM)+PQXYM*(YBM-YBMM))
```

```
      FMMZ=FAC*(PQXYM*(ZBMM-ZBM)+PQYYM*(YBM-YBMM))
      PQXXN=.5*(PQXXP+PQXXM)
      PQXYN=.5*(PQXYP+PQXYM)
      PQYYN=.5*(PQYYP+PQYYM)
      PQXN=.5*(PQXP+PQXM)
      FAC1=.5*(YB(JLO)+YBM)
      F1MY=FAC1*(T21Y(J)*(PQXYN*(ZB(JLO)-ZBM)+PQYYN*(YBM-YB(JLO)))-
     2 T21Z(J)*(PQXXN*(ZB(JLO)-ZBM)+PQXYN*(YBM-YB(JLO))))
      F1MZ= 0.
      FAC2=.5*(YB(JHI)+YBM)
      F2MY=FAC2*(T21Y(J)*(PQXYN*(ZB(JHI)-ZBM)+PQYYN*(YBM-YB(JHI)))-
     2 T21Z(J)*(PQXXN*(ZB(JHI)-ZBM)+PQXYN*(YBM-YB(JHI))))
      F2MZ= 0.
      A21=.5*(YB(JLO)+YB(JHI))*SQRT((YB(JHI)-YB(JLO))**2+(ZB(JHI)-ZB(JLO
     2  ))**2)
      PT=(FY(J)+FZ(J))/A21
      F1MYT=PT*(FAC1*(T21Y(J)*(ZB(JLO)-ZBM)+T21Z(J)*(YBM-YB(JLO))))
      F2MYT=PT*(FAC2*(T21Y(J)*(ZB(JHI)-ZBM)+T21Z(J)*(YBM-YB(JHI))))
      FY1M=T21Y(J)*F1MYT-T21Z(J)*F1MY
      FZ1M=T21Z(J)*F1MYT+T21Y(J)*F1MY
      FY2M=T21Y(J)*F2MYT-T21Z(J)*F2MY
      FZ2M=T21Z(J)*F2MYT+T21Y(J)*F2MY
      EN(J,L)=ENM(J,L)+(((UNPX(J,L)-UNMX(J,L2))*FY1M+(UNPY(J,L)-UNMY(J,L2
     2         ))*FZ1M+(UNMX(J,L2)-UNMX(J+1,L2))*FMPY+(UNMY(J,L2)-UNMY
     3         (J+1,L2))*FMPZ+(UNMX(J+1,L2)-UNPX(J+1,L ))*FY2M+(UNMY(J+1,
     4L2)-UNPY(J+1,L))*FZ2M)*DTNM-UNMX(J,L2)*PXA5-UNMX(J+1,L2)*PXA6
      EN (J,L5)=ENM(J,L5)+((UNPX(J+1,L)-UNMX(J+1,L5))*FY2M+(UNPY(J+1,L)-
     2           UNMY(J+1,L5))*FZ2M+(UNMX(J+1,L5)-UNMX(J,L5))*FMMY+
     3          (UNMY(J+1,L5)-UNMY(J,L5))*FMMZ+(UNMX(J,L5)-UNPX(J,L))*
     4          FY1M+(UNMY(J,L5)-UNPY(J,L))*FZ1M)*DTNM-UNMX(J+1,L5)*PXA3
     5          -UNMX(J,L5)*PXA4
      F1Y(J,L5)=FY2M-FMMY+PXA3
      F1Z(J,L5)=FZ2M-FMMZ
      F2Y(J,L5)=FMMY-FY1M+PXA4
      F2Z(J,L5)=FMMZ-FZ1M
      F3Y(J,L )=FY1M-FMPY+PXA5
      F3Z(J,L )=FZ1M-FMPZ
      F4Y(J,L )=FMPY-FY2M+PXA6
      F4Z(J,L )=FMPZ-FZ2M
      F1Y(J,L)=0
      F1Z(J,L)=0
      F2Y(J,L)=0
      F2Z(J,L)=0
      F3Y(J,L5)=0
      F3Z(J,L5)=0
      F4Y(J,L5)=0
      F4Z(J,L5)=0
      WRITE(MT,511) J,T21Y(J),FY(J),YBMM,YBM,YBMP,T21Z(J),FZ(J),ZBMM,
     2 ZBM,ZBMP,YBD(JLO),YBD(JHI),YB(JLO),YB(JHI),YBU(JLO),YBU(JHI),
     2 ZBD(JLC),ZBD(JHI),ZB(JLO),ZB(JHI),ZBU(JLO),ZBU(JHI),
     3PXA3,PXA4,PXA5,PXA6,PQXXP,PQXYP,PQYYP,PQXP,PQXXM,PQXYM,PQYYM,PQXM,
     4FMPY,FMPZ,FMMY,FMMZ,PQXXN,PQXYN,PQYYN,PQXN,F1MY,F1MZ,F2MY,F2MZ,
     5A21,PT,F1MYT,F2MYT,FY1M,FZ1M,FY2M,FZ2M
      JLO=JHI
  350 JHI=MOD(JLO,2)+1
      RETURN
  500 FORMAT(1H /
     1(4I8,2E17.9,2I8/))
  501 FORMAT(1H /
     118H ITERATION TROUBLE)
  502 FORMAT(1H1/
```

```
     232H       K       J      JA      JB   REGION/4I6,I8//
     394H      N12(Y)                N23(Y)              YA                 YA(N)
     4           YB                    YB(N)/
     594H      N12(Z)                N23(Z)              ZA                 ZA(N)
     6           ZB                    ZB(N)/
     7(6E17.9))
 503  FORMAT(1H /
     2115H      Y2PRIME(N)           N2(Y)                ALPHA(I)
     3                                                      ITERATION/
     426H      Z2PRIME(N)           N2(Z)/
     53E17.9,55X,I9/2E17.9/)
 504  FORMAT(1H /
     2114H      YBAR(1)              YBAR(2)              YBAR(3)             A1Y(T)
     3            A2Y(T)               A3Y(T)               TRIANGLE/
     495H      ZBAR(1)              ZBAR(2)              ZBAR(3)             A1Z(T)
     5           A2Z(T)               A3Z(T)/
     66E17.9,I8/6E17.9)
 505  FORMAT(1H /
     279H      VDOT(T)              VOL(T)               MASS(T)             DIL(T)
     3           MVOL(T)/5E17.9)
 506  FORMAT(1H /
     275H      A(AB)                A22                  A23                 A32
     3           A33/5E17.9/
     480H      T22                  T23                  T33                 LAMMA(+)
     5           LAMMA(-)/5E17.9/
     678H      E1                   E2                   E3                  LY1(T)
     7           LZ1(T)/5E17.9/
     878H      EPY(T)               EPZ(T)               EPX(T)              LY2(T)
     9           LZ2(T)/5E17.9/
     177H      PY(T)                PZ(T)                PX(T)               AREA(T)
     2           EN(T)/5E17.9/
     378H      P11(T)               P12(T)               P22(T)              F1Y(T)
     4           F1Z(T)/5E17.9/
     561H      F2Y(T)               F2Z(T)               F3Y(T)              F3Z(T)/
     64E17.9)
 507  FORMAT(1H /
     241H      UY1                  UY2                  UY3/
     241H      UZ1                  UZ2                  UZ3/
     42(3E17.9/))
 508  FORMAT(1H /
     295H      AY(B2)               AY(2A)               FY(B2)              FY(2A)
     3           FY                   DFN(I)/
     474H      AZ(B2)               AZ(2A)               FZ(B2)              FZ(2A)
     5           FZ/
     66E17.9/5E17.9)
 509  FORMAT(1H0/
     2101H      J     AY(43)              AY(14)              AY(32)              PQ1
     31(43)              PQ11(14)             PQ11(32)/
     4101H             Z                   Z                   Z                  1
     52                  12                  12     /
     6101H           FY(43)              FY(14)              FY(32)               2
     72                  22                  22     /
     8101H             Z                   Z                   Z                  X
     9                   X                   X      /
     A I4,6E17.9/3(4X,6E17.9/))
     127H    K     AW                   FW/
     2 I4,2E17.9)
 510  FORMAT(1H /
     264H      UTAN                 UNOR                 UX(N-1/2)           UY(N-1/2
     3)/4E17.9)
 511  FORMAT(1H0/
```

```
282H    J     TY(21)              FY(21)              YBMINUS             YBAR
3M              YBPLUS/
482H          TZ(21)              FZ(21)              Z                   Z
5               Z       /
6 14,5E17.9/4X,5E17.9/
798H          YB(4)               YB(3)               YB(1)               YB(2
8)              YB(5)               YB(6)/
998H          Z                   Z                   Z                   Z
A               Z                   Z       /
1 2(4X,6E17.9/)
263H          PXA3                PXA4                PXA5                PXA6
3/4X,4E17.9/
461H  (+)     PQ11                PQ12                PQ22                PX/
54X,4E17.9/
661H  (-)     PQ11                PQ12                PQ22                PX/
74X,4E17.9/
861H          FY(M+M)             FZ                  FY(M-M)             FZ/
94X,4E17.9/
B61H          PQ11(N-1/2)         PQ12                PQ22                PX/
14X,4E17.9/
261H NORM     FY(1M)              FZ                  FY(2M)              FZ/
34X,4E17.9/
466H          A21                 PT                  FY(1M)T             FY(2
5M)T/
64X,4E17.9/
761H          FY(1M)              FZ                  FY(2M)              FZ/
84X,4E17.9/)
 END
```

```
C     SUBROUTINE  LINEIN L
      SUBROUTINE LINOO
      COMMON/INDUMP/    NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,  SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,  SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO, DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,  SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,  UYRBIN,  UZLBIN,  UZBIN,
     7 UZRBIN, UYLTIN,  UYTIN,   UYRTIN,  UZLTIN, UZTIN,   UZRTIN,  KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,     J3,      JR,      JRM,
     9 KT,        EIN(5),     KINT(5),    RHOIN(5),   UYIN(5),     UZIN(5),
     2 TINY A(5), TINY B(5),  R ZERO(5),BETA(5),      QCON(5),
     A E S(5),    ALFA(5),    BIG A(5),  BIG B(5),    RCP V S(5),E ZERO(5),
     4 FMLZR(100),                  KSV(24),       SAV(12),       FMLYR(100)
      COMMON/THEREST/               A(55),         DIL(55),       EPX(55),
     2 EPY(55),       EPZ(55),      FMLYB(55),     FMLYT(55),     FMLZB(55),
     3 FMLZT(55),     LY1(55),      LY2(55),       LZ1(55),       LZ2(55),
     4 PY(55),        PZ(55),       R1H(55),       R2H(55),       R3H(55),
     5 R4H(55),       Z1H(55),      Z2H(55),       Z3H(55),       Z4H(55),
     6 U2(55,2),      B(55,4)
      COMMON/AFTERALL/
     A                RX(55,5),        RY(55,5),         UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),      UNPY(55,5),       FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),        PNM(55,5),        PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),    PQNMYY(55,5),     PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),     RWA3Z(55,5),      RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),    RH3Z(55,5),       RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),       RHO(55,5),        VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),       A2Y(55,5),        A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),       A2Z(55,5),        A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),       F2Y(55,5),        F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),       F2Z(55,5),        F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),      FMSNZ(55,5),      FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),     FMNX(55,5),       FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),       AW3(55,5),        AW4(55,5),
     5 RXM(55,5),     RYM(55,5),       RXZ(55,5),        RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),       Q22(55,5),        QX(55,5),
     7 P11(55,5),     P12(55,5),       P22(55,5),        PX(55,5),
     8 PQX(55,5),     PQMX(55,5),      VO(55,5)
      COMMON    ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
      COMMON/S/       S1(55),   S2(55),   S3(55),   S4(55),   S5(55),
     2    S6(55),     S7(55),   S8(55),   S9(55),   S10(55),  S11(55),
     3   S12(55),    S13(55),  S14(55),  S15(55),  S16(55),  S17(55),
     4    S18(55),    S19(55),  S20(55),  S21(55),  S22(55),  S23(55),
     5    S24(55),    S25(55),  S26(55),  S27(55),  S28(55),  S29(55),
     6    S30(55),    S31(55),  S32(55),  S33(55)
      DIMENSION DUMPV(1)
      EQUIVALENCE(NREG,DUMPV(1))
C*****
      ENTRY LINEIN1
C*****
      L=LX4
    4 CALL MIN
      DO 5 J=JMIN,JMAX
      RXM(J,L)=S1(J)          $RYM(J,L)=S2(J)        $UNMX(J,L)=S3(J)
        UNMY(J,L)= S4(J)$FMASNM(J,L)= S5(J)$   ENM(J,L)= S6(J)
      PNM(J,L)=S7(J)       $PQNMXX(J,L)=S8(J)    $PQNMXY(J,L)=S9(J)
      PQNMYY(J,L)=S10(J)$   VOL(J,L)=S11(J)$    RHO(J,L)=S12(J)
      PQMX(J,L)=S13(J)         $FMNMX(J,L)=S14(J)  $FMNMY(J,L)=S15(J)
      NTPT(J,L)=S16(J)         $A1Y(J,L)=S17(J)     $A2Y(J,L)=S18(J)
```

```
      A3Y(J,L)=S19(J)            $A4Y(J,L)=S20(J)     $A1Z(J,L)=S21(J)
      A2Z(J,L)=S22(J)            $A3Z(J,L)=S23(J)     $A4Z(J,L)=S24(J)
      AW1   (J,L)=S25(J)         $AW2   (J,L)=S26(J)  $AW3   (J,L)=S27(J)
      AW4   (J,L)=S28(J)         $RXZ(J,L)=S29(J)     $RYZ(J,L)=S30(J)
      VO(J,L)=S31(J)
    5 CONTINUE
      GO TO 8
8     IF(NDPA.EQ.0) RETURN
      WRITE(10)(     RXM(J,L),              RYM(J,L),
    2 UNMX(J,L),     UNMY(J,L),             FMASNM(J,L),          ENM(J,L),
    3 PNM(J,L),      PQNMXX(J,L),           PQNMXY(J,L),          PQNMYY(J,L),
    4 VOL(J,L),      RHO(J,L),              PQMX(J,L),
    5 FMNMX(J,L),    FMNMY(J,L),
    6 NTPT(J,L),
    7 A1Y(J,L),      A2Y(J,L),              A3Y(J,L),             A4Y(J,L),
    8 A1Z(J,L),      A2Z(J,L),              A3Z(J,L),             A4Z(J,L),
    9 AW1   (J,L),   AW2   (J,L),           AW3   (J,L),          AW4   (J,L),
    A RXZ(J,L),       RYZ(J,L),          VO(J,L),         J=JMIN,JMAX)
      RETURN
C*****
      ENTRY LINEIN4
C*****
   35 IF(NDPA)40,40,36
36    WRITE(10) (DUMPV(J),J=1,400)
      NDMP=NDMP+1
      WRITE(6,100)NDMP,PROBNO,TIME,N
40    DO 46 L=1,4
   41 CALL MIN
      DO 12345 J=JMIN,JMAX
      RXM(J,L)=S1(J)           $RYM(J,L)=S2(J)       $UNMX(J,L)=S3(J)
        UNMY(J,L)= S4(J)$FMASNM(J,L)= S5(J)$   ENM(J,L)= S6(J)
         PNM(J,L)= S7(J)$PQNMXX(J,L)= S8(J)$PQNMXY(J,L)= S9(J)
      PQNMYY(J,L)=S10(J)$   VOL(J,L)=S11(J)$   RHO(J,L)=S12(J)
      PQMX(J,L)=S13(J)           $FMNMX(J,L)=S14(J)   $FMNMY(J,L)=S15(J)
      NTPT(J,L)=S16(J)           $A1Y(J,L)=S17(J)     $A2Y(J,L)=S18(J)
      A3Y(J,L)=S19(J)            $A4Y(J,L)=S20(J)     $A1Z(J,L)=S21(J)
      A2Z(J,L)=S22(J)            $A3Z(J,L)=S23(J)     $A4Z(J,L)=S24(J)
      AW1   (J,L)=S25(J)         $AW2   (J,L)=S26(J)  $AW3   (J,L)=S27(J)
      AW4   (J,L)=S28(J)         $RXZ(J,L)=S29(J)     $RYZ(J,L)=S30(J)
      VO(J,L)=S31(J)
12345 CONTINUE
44    IF(NDPA)46,46,45
45    WRITE(10)(     RXM(J,L),              RYM(J,L),
    2 UNMX(J,L),     UNMY(J,L),             FMASNM(J,L),          ENM(J,L),
    3 PNM(J,L),      PQNMXX(J,L),           PQNMXY(J,L),          PQNMYY(J,L),
    4 VOL(J,L),      RHO(J,L),              PQMX(J,L),
    5 FMNMX(J,L),    FMNMY(J,L),
    6 NTPT(J,L),
    7 A1Y(J,L),      A2Y(J,L),              A3Y(J,L),             A4Y(J,L),
    8 A1Z(J,L),      A2Z(J,L),              A3Z(J,L),             A4Z(J,L),
    9 AW1   (J,L),   AW2   (J,L),           AW3   (J,L),          AW4   (J,L),
    A RXZ(J,L),       RYZ(J,L),          VO(J,L),         J=JMIN,JMAX)
      GO TO 46
   46 CONTINUE
   70 RETURN
  100 FORMAT(22H0A DUMP HAS BEEN TAKEN/12H0DUMP NUMBER,I6,23H IS FROM PR
     1OBLEM NUMBER,F7.2,8H AT TIME,1PE16.7,10H ON CYCLE ,I6)
      END
```

```
C     SUBROUTINE  LINOUT L
      SUBROUTINE LOUTOO
      COMMON/INDUMP/   NREG,   RDTNM,  MOTION, JBMIN,  JBMAX,  KBMIN,
     2 KBMAX,  TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,   SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UZLBIN, UZBIN,
     7 UZRBIN, UYLTIN, UYTIN,  UYRTIN, UZLTIN, UZTIN,  UZRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,        EIN(5),    KINT(5),  RHOIN(5),  UYIN(5),   UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),
     A E S(5),    ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                KSV(24),     SAV(12),     FMLYR(100)
      COMMON/THEREST/             A(55),       DIL(55),     EPX(55),
     2 EPY(55),     EPZ(55),      FMLYB(55),   FMLYT(55),   FMLZB(55),
     3 FMLZT(55),   LY1(55),      LY2(55),     LZ1(55),     LZ2(55),
     4 PY(55),      PZ(55),       R1H(55),     R2H(55),     R3H(55),
     5 R4H(55),     Z1H(55),      Z2H(55),     Z3H(55),     Z4H(55),
     6 U2(55,2),    B(55,4)
      COMMON/AFTERALL/
     A                RX(55,5),       RY(55,5),       UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),     UNPY(55,5),     FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),       PNM(55,5),      PN(55,5),
     3 PQNMXX(55,5),  PQNMXY(55,5),   PQNMYY(55,5),   PQNXX(55,5),
     4 PQNXY(55,5),   PQNYY(55,5),    RWA3Z(55,5),    RWA1Z(55,5),
     5 RWAE3Z(55,5),  RWAE1Z(55,5),   RH3Z(55,5),     RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),      RHO(55,5),      VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),      A2Y(55,5),      A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),      A2Z(55,5),      A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),      F2Y(55,5),      F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),      F2Z(55,5),      F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),     FMSNZ(55,5),    FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),    FMNX(55,5),     FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),      AW3(55,5),      AW4(55,5),
     5 RXM(55,5),     RYM(55,5),      RXZ(55,5),      RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),      Q22(55,5),      QX(55,5),
     7 P11(55,5),     P12(55,5),      P22(55,5),      PX(55,5),
     8 PQX(55,5),     PQMX(55,5),     VO(55,5)
      COMMON    ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,   NEDIT,  NSIG,   NMASS,  NDMP
      COMMON/S/        S1(55),   S2(55),   S3(55),   S4(55),   S5(55),
     2     S6(55),     S7(55),   S8(55),   S9(55),   S10(55),  S11(55),
     3    S12(55),    S13(55),  S14(55),  S15(55),  S16(55),  S17(55),
     4     S18(55),   S19(55),  S20(55),  S21(55),  S22(55),  S23(55),
     5     S24(55),   S25(55),  S26(55),  S27(55),  S28(55),  S29(55),
     6     S30(55),   S31(55),  S32(55),  S33(55)
      DIMENSION PTMASS(55)
      EQUIVALENCE(PTMASS(1),PY(1))
C*****
      ENTRY LINOUT
C*****
100   L=LX5
  300 IF(NEDIT)327,327,3000
 3000 IF(KSV(11))30010,3002,3001
 3001 KSV(11)=-KSV(11)
      READ(5,3003)JJMIN,JJMAX,KKMIN,KKMAX
30010 IF(LINCT-KMAX)30012,30011,30011
30011 KSV(11)=KSV(11)+1
30012 IF(LINCT-KKMIN)327,30013,30013
30013 IF(LINCT-KKMAX)311,311,327
```

```
 3002 JJMIN=JMIN
      JJMAX=JMAX
 311  DO 312 J=JJMIN,JJMAX
 312  PTMASS(J)=2.*FMSNZ(J,L)
      IF(LINCT.LT.KMAX)       GO TO 316
      DO 315 J=JJMIN,JJMAX
      RHO(J,L )=0.0
      PN(J,L )=0.0
      FMASN(J,L )=0.0
      ETA(J,L )=0.0
      EN(J,L )=0.0
      RH3Z(J,L)=0.0
      RWA3Z(J,L)=0.0
      E3Z(J,L)=0.
      RWAE3Z(J,L)=0.
      VOL(J,L)=0.
      P11(J,L)=0.
      P12(J,L)=0.
      P22(J,L)=0.
      PX(J,L)=0.
      F1Y(J,L)=0.
      F2Y(J,L)=0.
      F3Y(J,L)=0.
      F4Y(J,L)=0.
      F1Z(J,L)=0.
      F2Z(J,L)=0.
      F3Z(J,L)=0.
      F4Z(J,L)=0.
      Q11(J,L)=0.
      Q12(J,L)=0.
      Q22(J,L)=0.
      QX(J,L)=0.
      A1Y(J,L)=0.
      A2Y(J,L)=0.
      A3Y(J,L)=0.
      A4Y(J,L)=0.
      A1Z(J,L)=0.
      A2Z(J,L)=0.
      A3Z(J,L)=0.
      A4Z(J,L)=0.
      AW1(J,L)=0.
      AW2(J,L)=0.
      AW3(J,L)=0.
 315  AW4(J,L)=0.
 316  DO 320 I=JJMIN,JJMAX,10
      JPRINT=I+9
      IF(JPRINT.GT.JJMAX) JPRINT=JJMAX
 320  WRITE(6,1)   PROBNO,      TIME,        DTNM,
     2             (            RX(J,L),     RY(J,L),
     3 VOL(J,L),   RHO(J,L),    ETA(J,L),    EN(J,L),     J, LINCT,N,
     4 UNMX(J,L),  UNMY(J,L),   FMASN(J,L),  RH1Z(J,L),   RWA1Z(J,L),
     5 E1Z(J,L),   RWAE1Z(J,L), FMNX(J,L),   FMNY(J,L),   PTMASS(J),
     6 RH3Z(J,L),  RWA3Z(J,L),  E3Z(J,L),    RWAE3Z(J,L), P11(J,L),
     7 Q11(J,L),   A2Y(J,L),    A2Z(J,L),    AW1(J,L),    F1Y(J,L),
     8 F1Z(J,L),   P12(J,L),    Q12(J,L),    A1Y(J,L),    A1Z(J,L),
     9 AW2(J,L),   F2Y(J,L),    F2Z(J,L),    P22(J,L),    Q22(J,L),
     A A4Y(J,L),   A4Z(J,L),    AW3(J,L),    F3Y(J,L),    F3Z(J,L),
     1 PX(J,L),    QX(J,L),     A3Y(J,L),    A3Z(J,L),    AW4(J,L),
     2 F4Y(J,L),   F4Z(J,L),    J=I,JPRINT)
  327 DO 12345 J=JMIN,JMAX
      S1(J)=    RX(J,L)$ S2(J)=    RY(J,L)$ S3(J)=  UNPX(J,L)
```

```
      S4(J)=  UNPY(J,L)$ S5(J)= FMASN(J,L)$ S6(J)=    EN(J,L)
      S7(J)=PN(J,L)$       S8(J)=PQNXX(J,L)$    S9(J)=PQNXY(J,L)
      S10(J)=PQNYY(J,L)$  S11(J)=VOL(J,L)$    S12(J)=RHO(J,L)
      S13(J)=PQX(J,L)          $S14(J)=FMN X(J,L)  $S15(J)=FMN Y(J,L)
      S16(J)=NTPT(J,L)
      S17(J)=A1Y(J,L)          $S18(J)=A2Y(J,L)    $S19(J)=A3Y(J,L)
      S20(J)=A4Y(J,L)          $S21(J)=A1Z(J,L)    $S22(J)=A2Z(J,L)
      S23(J)=A3Z(J,L)          $S24(J)=A4Z(J,L)
      S25(J)=AW1  (J,L)        $S26(J)=AW2  (J,L)  $S27(J)=AW3  (J,L)
      S28(J)=AW4  (J,L)
      S29(J)=RXZ(J,L)          $S30(J)=RYZ(J,L)
      S31(J)=VO(J,L)
12345 CONTINUE
      CALL MOUT
  340 IF(LINCT-KMAX)370,350,350
  350 SUMTE=SUMIE+SUMKE
      IF(NEDIT)360,368,360
  360 WRITE(6,6)
      WRITE(6,7)SUMIE,SIETPT,SMYTPT,FIMPY,SMOMYI,SMOMY,SMSTPT,SUMKE
     1,SKETPT,SMZTPT,FIMPZ,SMOMZI,SMOMZ,SMASSI,SUMTE,WORK,SMASS,SENERI
      RETURN
  370 IF(KC.GT.KT)GO TO 380
  368 LINCT=LINCT+1
      RETURN
  380 LX5=LX1
      LX1=LX2
      LX2=LX3
      LINCT=LINCT+1
      GO TO 100
1     FORMAT(14H1    PROBLEM= F7.2,5X6HTIME= E17.9,5X9HDELTA T= E17.9//
     B(1H //
     2119H    Y                   Z                   VOL                 RHO
     3           ETA                  E                  *  J*  K*CYCLE*/
     4112H    U(N-1/2)            V(N-1/2)            ZONE MASS           RH10
     5           RWA10                E10                 RWAE10/
     6112H    MOM Y               MOM Z               PT. MASS            RH30
     7           RWA30                E30                 RWAE30//
     8109H    P11                 Q11                 A1Y                 A1Z
     9           AW1                  F1Y                 F1Z/
     A109H    P12                 Q12                 A2Y                 A2Z
     1           AW2                  F2Y                 F2Z/
     2109H    P22                 Q22                 A3Y                 A3Z
     3           AW3                  F3Y                 F3Z/
     4109H    PX                  QX                  A4Y                 A4Z
     5           AW4                  F4Y                 F4Z///
     6(10(6E17.9,3H  *,I3,1H*,I3,1H*,I5,1H*/2(7E17.9/)/4(7E17.9/)//))))
    6 FORMAT(1H0,9X,5HSUMIE,11X,6HSIETPT,10X,6HSMXTPT,10X,5HFIMPX,11X
     1,6HSMOMXI,10X,5HSMOMX,11X,6HSMSTPT/10X,5HSUMKE,11X,6HSKETPT,10X
     2,6HSMYTPT,10X,5HFIMPY,11X,6HSMOMYI,10X,5HSMOMY,11X,6HSMASSI/10X
     3,5HSUMTE,11X,4HWORK,76X,5HSMASS/26X,6HSENERI/)
    7 FORMAT(7X,1P7E16.7/7X1P7E16.7/7X,1P2E16.7,64X,1PE16.7/23X,1PE16.7)
3003  FORMAT(4I6)
      END
```

```
C     SUBROUTINE  NEWU L
      SUBROUTINE NWUL00
      COMMON/INDUMP/   NREG,   RDTNM, MOTION, JBMIN, JBMAX, KBMIN,
     2 KBMAX, TIME,   SMOMZI, SMZTPT, SMOMZ,  SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,  SUMIE,  SUMKE,  SUMTE,  FIMPZ,
     4 FIMPY, SMASSI, SMSTPT, SMASS,  PROBNO, DTNM,   CUTOFF, N,
     5 KBOT,  KTOP,   MAXN,   TMAX,   DTNMN,  SFW,    DTNMP5, DTNM2,
     6 KB,    CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UZLBIN, UZBIN,
     7 UZRBIN, UYLTIN, UYTIN,  UYRTIN, UZLTIN, UZTIN,  UZRTIN, KTM,
     8 JMIN,  JMAX,   KMIN,   KMAX,   JL,     J3,     JR,     JRM,
     9 KT,        EIN(5),     KINT(5),  RHOIN(5),  UYIN(5),   UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),
     A E S(5),   ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                KSV(24),      SAV(12),      FMLYR(100)
      COMMON/THEREST/             A(55),        DIL(55),      EPX(55),
     2 EPY(55),     EPZ(55),      FMLYB(55),    FMLYT(55),    FMLZB(55),
     3 FMLZT(55),   LY1(55),      LY2(55),      LZ1(55),      LZ2(55),
     4 PY(55),      PZ(55),       R1H(55),      R2H(55),      R3H(55),
     5 R4H(55),     Z1H(55),      Z2H(55),      Z3H(55),      Z4H(55),
     6 U2(55,2),    B(55,4)
      COMMON/AFTERALL/
     A              RX(55,5),     RY(55,5),     UNMX(55,5),
     1 UNMY(55,5),  UNPX(55,5),   UNPY(55,5),   FMASNM(55,5),
     2 ENM(55,5),   EN(55,5),     PNM(55,5),    PN(55,5),
     3 PQNMXX(55,5), PQNMXY(55,5), PQNMYY(55,5), PQNXX(55,5),
     4 PQNXY(55,5), PQNYY(55,5),  RWA3Z(55,5),  RWA1Z(55,5),
     5 RWAE3Z(55,5), RWAE1Z(55,5), RH3Z(55,5),   RH1Z(55,5),
     6 E3Z(55,5),   E1Z(55,5),    RHO(55,5),    VOL(55,5),
     7 ETA(55,5),   A1Y(55,5),    A2Y(55,5),    A3Y(55,5),
     8 A4Y(55,5),   A1Z(55,5),    A2Z(55,5),    A3Z(55,5),
     9 A4Z(55,5),   F1Y(55,5),    F2Y(55,5),    F3Y(55,5),
     A F4Y(55,5),   F1Z(55,5),    F2Z(55,5),    F3Z(55,5),
     1 F4Z(55,5),   NTPT(55,5),   FMSNZ(55,5),  FMASN(55,5),
     2 FMNMX(55,5), FMNMY(55,5),  FMNX(55,5),   FMNY(55,5),
     4 AW1(55,5),   AW2(55,5),    AW3(55,5),    AW4(55,5),
     5 RXM(55,5),   RYM(55,5),    RXZ(55,5),    RYZ(55,5),
     6 Q11(55,5),   Q12(55,5),    Q22(55,5),    QX(55,5),
     7 P11(55,5),   P12(55,5),    P22(55,5),    PX(55,5),
     8 PQX(55,5),   PQMX(55,5),   VO(55,5)
      COMMON    ICON,   LINCT,  LX1,   LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,   NEDIT,  NSIG,  NMASS,  NDMP
C*****
      ENTRY NEWU
C*****
      L=LX1
      L2=LX2
      L5=LX5
      J=JMIN
      IF((KC+1).LT.KINT(NREG))GO TO 5
      FMSNZ(J,L)=.25*(FMASN(J,L)+.5*FMASN(J,L5))
      FMSNZ(J,L2)=0
      FMNX(J,L2)=0
      FMNY(J,L2)=0
      DO 4 J=JL,JR
      FMSNZ(J,L2)=0
      FMNX(J,L2)=0
      FMNY(J,L2)=0
 4    FMSNZ(J,L)=.25*(FMASN(J,L)+FMASN(J-1,L)+.5*(FMASN(J-1,L5)+
     2 FMASN(J,L5)))
      J=JMAX
      FMSNZ(J,L)=.25*(FMASN(J-1,L)+.5*FMASN(J-1,L5))
```

```
      FMSNZ(J,L2)=0
      FMNX(J,L2)=0
      FMNY(J,L2)=0
      INT=1-INT
      GO TO 9
5     IF(INT.EQ.0) GO TO 7
      FMSNZ(J,L)=.25*(.5*FMASN(J,L)+FMASN(J,L5))
      DO 6 J=JL,JR
6     FMSNZ(J,L)=.25*(.5*(FMASN(J,L)+FMASN(J-1,L))+FMASN(J-1,L5)+
     2 FMASN(J,L5))
      J=JMAX
      FMSNZ(J,L)=.25*(.5*FMASN(J-1,L)+FMASN(J-1,L5))
      INT=1-INT
       GO TO 9
7     FMSNZ(J,L)=.125*(  FMASN(J,L)+FMASN(J,L5))
      DO 8 J=JL,JR
8     FMSNZ(J,L)=.125*(   FMASN(J,L)+FMASN(J-1,L) +FMASN(J-1,L5)+
     2 FMASN(J,L5))
      J=JMAX
      FMSNZ(J,L)=.125*(  FMASN(J-1,L)+FMASN(J-1,L5))
9     TFXX=0.
      TFXY=0.
      DO 400 J=JMIN,JMAX
      IF(JMIN-J) 100,10,10
10    CONTINUE
      CUTON=CUT2*FMSNZ(J,L)
      FMNX(J,L)=0.0
      UNPX(J,L)=0.0
      IF((KC.GE.KBOT).AND.(KC.LE.KTOP))GO TO 410
20    FMOMCH=DTNM*(F2Z(J,L)+F3Z(J,L5)+TFXY)
      IF(ABS(FMOMCH)-CUTON)35,35,30
   30 FMNY(J,L)=FMNMY(J,L)+FMOMCH
      GO TO 40
   35 FMNY(J,L)=FMNMY(J,L)
40    UNPY(J,L)=FMNY(J,L)/FMSNZ(J,L)-UNMY(J,L)
      GO TO 400
  100 IF(J-JMAX) 110,300,300
110   CONTINUE
115   CUTON=CUT2*FMSNZ(J,L)
      FMOMCH=DTNM*(F1Y(J-1,L)+F2Y(J,L)+F3Y(J,L5)+F4Y(J-1,L5)+TFXX)
      IF(ABS(FMOMCH)-CUTON) 125,125,120
  120 FMNX(J,L)=FMNMX(J,L)+FMOMCH
      GO TO 130
  125 FMNX(J,L)=FMNMX(J,L)
130   FMOMCH=DTNM*(F1Z(J-1,L)+F2Z(J,L)+F3Z(J,L5)+F4Z(J-1,L5)+TFXY)
      IF(ABS(FMOMCH)-CUTON) 145,145,140
  140 FMNY(J,L)=FMNMY(J,L)+FMOMCH
      GO TO 150
  145 FMNY(J,L)=FMNMY(J,L)
  150 UNPX(J,L)=    FMNX(J,L)/FMSNZ(J,L)-UNMX(J,L)
      UNPY(J,L)=    FMNY(J,L)/FMSNZ(J,L)-UNMY(J,L)
      GO TO 400
300   CONTINUE
305   CUTON=CUT2*FMSNZ(J,L)
      FMNX(J,L)=0.0
      FMLYR(KC)=- F4Y(J-1,L5)-F1Y(J-1,L)-TFXX
      FMOMCH=DTNM*(FMLZR(KC) +F4Z(J-1,L5)+F1Z(J-1,L)+TFXY)
      IF(ABS(FMOMCH)-CUTON) 315,315,310
  310 FMNY(J,L)=FMNMY(J,L)+FMOMCH
      GO TO 320
  315 FMNY(J,L)=FMNMY(J,L)
```

```
  320 UNPX(J,L)=0.0
      UNPY(J,L)=     FMNY(J,L)/FMSNZ(J,L)-UNMY(J,L)
 400  CONTINUE
      RETURN
 410  FMNY(J,L)=0.0
      UNPY(J,L)=0.0
      GO TO 400
      END
```

```
C     SUBROUTINE  REDGEN L
      SUBROUTINE RGEN00
      COMMON/INDUMP/   NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,  KBMIN,
     2 KBMAX,   TIME,    SMOMZI, SMZTPT, SMOMZ,   SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,    SUMIE,   SUMKE,   SUMTE,  FIMPZ,
     4 FIMPY,  SMASSI, SMSTPT, SMASS,   PROBNO, DTNM,    CUTOFF, N,
     5 KBOT,   KTOP,   MAXN,   TMAX,    DTNMN,  SFW,     DTNMP5, DTNM2,
     6 KB,     CUT1,   CUT2,   UYLBIN, UYBIN,  UYRBIN, UZLBIN, UZBIN,
     7 UZRBIN, UYLTIN, UYTIN,  UYRTIN, UZLTIN, UZTIN,  UZRTIN, KTM,
     8 JMIN,   JMAX,   KMIN,   KMAX,    JL,     J3,      JR,     JRM,
     9 KT,       EIN(5),    KINT(5),  RHOIN(5),  UYIN(5),   UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),   QCON(5),
     A E S(5),    ALFA(5),   BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                KSV(24),      SAV(12),      FMLYR(100)
      COMMON/THEREST/             A(55),        DIL(55),      EPX(55),
     2 EPY(55),     EPZ(55),      FMLYB(55),    FMLYT(55),    FMLZB(55),
     3 FMLZT(55),   LY1(55),      LY2(55),      LZ1(55),      LZ2(55),
     4 PY(55),      PZ(55),       R1H(55),      R2H(55),      R3H(55),
     5 R4H(55),     Z1H(55),      Z2H(55),      Z3H(55),      Z4H(55),
     6 U2(55,2),    B(55,4)
      COMMON/AFTERALL/
     A                RX(55,5),     RY(55,5),      UNMX(55,5),
     1 UNMY(55,5),    UNPX(55,5),   UNPY(55,5),    FMASNM(55,5),
     2 ENM(55,5),     EN(55,5),     PNM(55,5),     PN(55,5),
     3 PQNMXX(55,5), PQNMXY(55,5), PQNMYY(55,5),  PQNXX(55,5),
     4 PQNXY(55,5),  PQNYY(55,5),  RWA3Z(55,5),   RWA1Z(55,5),
     5 RWAE3Z(55,5), RWAE1Z(55,5), RH3Z(55,5),    RH1Z(55,5),
     6 E3Z(55,5),     E1Z(55,5),    RHO(55,5),     VOL(55,5),
     7 ETA(55,5),     A1Y(55,5),    A2Y(55,5),     A3Y(55,5),
     8 A4Y(55,5),     A1Z(55,5),    A2Z(55,5),     A3Z(55,5),
     9 A4Z(55,5),     F1Y(55,5),    F2Y(55,5),     F3Y(55,5),
     A F4Y(55,5),     F1Z(55,5),    F2Z(55,5),     F3Z(55,5),
     1 F4Z(55,5),     NTPT(55,5),   FMSNZ(55,5),   FMASN(55,5),
     2 FMNMX(55,5),   FMNMY(55,5),  FMNX(55,5),    FMNY(55,5),
     4 AW1(55,5),     AW2(55,5),    AW3(55,5),     AW4(55,5),
     5 RXM(55,5),     RYM(55,5),    RXZ(55,5),     RYZ(55,5),
     6 Q11(55,5),     Q12(55,5),    Q22(55,5),     QX(55,5),
     7 P11(55,5),     P12(55,5),    P22(55,5),     PX(55,5),
     8 PQX(55,5),     PQMX(55,5),   VO(55,5)
      COMMON    ICON,   LINCT,  LX1,    LX2,    LX3,    LX4,    LX5,
     2 KC,      NDPA,   NEDIT,  NSIG,   NMASS, NDMP
      COMMON/S/      S1(55),   S2(55),   S3(55),   S4(55),   S5(55),
     2     S6(55),   S7(55),   S8(55),   S9(55),   S10(55),  S11(55),
     3   S12(55),  S13(55),  S14(55),  S15(55),  S16(55),  S17(55),
     4     S18(55),  S19(55),  S20(55),  S21(55),  S22(55),  S23(55),
     5     S24(55),  S25(55),  S26(55),  S27(55),  S28(55),  S29(55),
     6     S30(55),  S31(55),  S32(55),  S33(55)
      COMMON/JKFACE/     UNORM(55,5),   YAZ(55,5),     ZAZ(55,5)
      DIMENSION   TX(100), TY(100), TITLE(9)
      DIMENSION DUMPV(1)
      EQUIVALENCE(NREG,DUMPV(1))
      EQUIVALENCE(TX(1),B(1)),(TY(1),B(101)),(TITLE(1),B(201))
      INTEGER  P, Q, R
C
C-----FORMATS
C
    1 FORMAT (9A8)
    2 FORMAT (6E12.5)
    3 FORMAT (12I6)
    4 FORMAT (I6, E12.5)
    5 FORMAT (2I6, 5E12.5 / (6E12.5))
```

```
6       FORMAT(3(2I6,E12.5))
     51 FORMAT (15HOPROBLEM NUMBER , F7.2)
52      FORMAT(1H /
       272H  KSV1  KSV2  KSV3  KSV4  KSV5  KSV6  KSV7  KSV8  KSV9 KSV10 KS
       3V11 KSV12/12I6)
53      FORMAT(1H /
       293H     SAV1              SAV2              SAV3              SAV4
       3          SAV5              SAV6/6E17.9)
54      FORMAT(1H1/
       224H INPUT FOR REGION NUMBER,I3)
55      FORMAT(1H /
       241H     VZ                RHOIN             EIN/3E17.9)
56      FORMAT(1H /
       278H  JBOT  JTOP  KBOT  KTOP  KBUG  MOTION  KFACE1  KFACE2  KFACE3
       3 KFACE4  KFACE5/5I6,6I8)
60      FORMAT(1H /
       225H     UXIN              UYIN/2E17.9)
62      FORMAT(1H /
       2 8H     DTNM/E17.9)
64      FORMAT(1H /
       218H  MAXN     TIME MAX/I6,E17.9)
65      FORMAT(1H /
       210H     CUTOFF/E17.9)
70      FORMAT(14H1     PROBLEM= F7.2,5X6HTIME= E17.9,5X9HDELTA T= E17.9//
       8(1H //
       2119H     Y                 Z                 VOL               RHO
       3           ETA               E                 *  J*  K*CYCLE*/
       4112H     U(N-1/2)          V(N-1/2)          ZONE MASS         RH10
       5           RWA10             E10               RWAE10/
       6112H     MOM Y             MOM Z             PT. MASS          RH30
       7           RWA30             E30               RWAE30//
       6(30(6E17.9,3H   *,I3,1H*,I3,1H*,I5,1H*/2(7E17.9/)/))))
     73 FORMAT (1HO 5X 1HJ 3X 3HAZX 13X 3HA2X 13X 3HAZY 13X 3HA2Y 13X
       1          3HARX 13X 3HALX / 10X 3HA1X 13X 3HA3X 13X 3HA1Y 13X 3HA3Y
       2          13X 3HARY 13X 3HALY /)
     74 FORMAT (I7, 6E16.7 / 7X 6E16.7/)
     75 FORMAT (1HO 9X 6HSENERI 10X 6HSMASSI 10X 6HSMOMYI 10X 6HSMOMZI)
     76 FORMAT (7X 6E16.7)
     77 FORMAT (7HOFOR J= I6, 7H AND K= I6, 10H THE MASS= E16.7, 6H ERROR)
78      FORMAT(1H /
       253H     U(LEFT BOTTOM)    U(BOTTOM)         U(RIGHT BOTTOM)/
       353H     V                 V                 V                 //
       4(3E17.9))
79      FORMAT(1H /
       250H     U(LEFT TOP)       U(TOP)            U(RIGHT TOP)/
       350H     V                 V                 V              //
       4(3E17.9))
80      FORMAT(1H /
       227H  JMAX  KMAX     U(INTERIOR)/
       327H                 V            //
       4(2I6,E17.9))
81      FORMAT(1H /
       222H  JMAX  KMAX     R ZERO/
       331H                 INITIAL DENSITY/
       431H                           ENERGY //
       5(2I6,E17.9))
83      FORMAT(1H /
       232H     FMLY(RIGHT)       FMLZ(RIGHT)/
       3 2E17.9/1H1/)
84      FORMAT(24HOJBMIN JBMAX KBMIN KBMAX/4I6)
85      FORMAT(1H /
```

```
      293H    TINY A            TINY B            BIG A             BIG B
      3         V(S)              E(0)/6E17.9/
      459H    E(S)              ALPHA             BETA              QCON/
      5 4E17.9)
 86    FORMAT(1H /
      2108H   J       Y                 J       Y                  J       Y
      3             J       Y                 J       Y/
      4(5(I4,3X,E17.9)))
 87    FORMAT(1H /
      2108H   K       Z                 K       Z                  K       Z
      3             K       Z                 K       Z/
      4(5(I4,3X,E17.9)))
 88    FORMAT(1H /
      224H   JMIN   JMAX   KMIN   KMAX/4I6)
 89    FORMAT(1H /
      227H   JMAX   KMAX     U(INTERIOR)/
      3(2I6,E17.9))
 90    FORMAT(1H /
      227H   JMAX   KMAX     V(INTERIOR)/
      3(2I6,E17.9))
 91    FORMAT(1H /
      222H   JMAX   KMAX     R ZERO/
      3(2I6,E17.9))
 92    FORMAT(1H /
      231H   JMAX   KMAX     INITIAL DENSITY/
      3(2I6,E17.9))
 93    FORMAT(1H /
      230H   JMAX   KMAX     INITIAL ENERGY/
      3(2I6,E17.9))
 94    FORMAT(34HORSTART EXECUTE TIME IN SECONDS = F9.3)
 95    FORMAT(34HOREDGEN EXECUTE TIME IN SECONDS = F9.3)
C*****
       ENTRY REDGEN
C*****
       STARTIME=TIMEF(X)
       NDPA=0
       NEDIT=0
       READ(5,2)ICON
       IF(ICON.EQ.0) GO TO 99
       CALL RSTART
       NSIG=5
       STARTIME=(TIMEF(X)-STARTIME)/1000.
       WRITE(6,94)STARTIME
       RETURN
 99    NSIG=1
       NMASS = 1
       IF (EOF,5) 101,100
  100  READ (5,1) TITLE
       WRITE(6,01)TITLE
       READ (5,2) PROBNO
       IF (PROBNO.GT.0.)  GO TO 103
       IF (NDMP.EQ.0)     GO TO 102
  101  END FILE 10
       REWIND 10
  102  STOP
 103   WRITE(6,51)PROBNO
       READ(5,3)(KSV(J),J=1,12)
       WRITE (6,52) (KSV(J),J=1,12)
       READ (5,2) (SAV(J),J=1,6)
       WRITE (6,53) (SAV(J),J=1,6)
       READ(5,5) (JYMIN,JYMAX,(TX(J),J=JYMIN,JYMAX))
```

```
      WRITE(6,86)                  (J,TX(J),J=JYMIN,JYMAX)
      READ(5,5) (KZMIN,KZMAX,(TY(K),K=KZMIN,KZMAX))
      WRITE(6,87)                  (K,TY(K),K=KZMIN,KZMAX)
      READ(5,2) UYLBIN,UYBIN,UYRBIN,UZLBIN,UZBIN,UZRBIN
      WRITE(6,78)UYLBIN,UYBIN,UYRBIN,UZLBIN,UZBIN,UZRBIN
      READ(5,2)   UYTIN,UYTIN,UYRTIN  ,UZLTIN,UZTIN,UZRTIN
      WRITE(6,79) UYTIN,UYTIN,UYRTIN  ,UZLTIN,UZTIN,UZRTIN
      READ (5,6) JUMAX,KUMAX,UYIN(1),JVMAX,KVMAX,UZIN(1)
      WRITE(6,80)JUMAX,KUMAX,UYIN(1),JVMAX,KVMAX,UZIN(1)
      READ (5,6) JZMAX,KZMAX,R ZERO(1),JRMAX,KRMAX,RHOIN(1),JEMAX,KEMAX,
     2 EIN(1)
      WRITE(6,81)JZMAX,KZMAX,R ZERO(1),JRMAX,KRMAX,RHOIN(1),JEMAX,KEMAX,
     2 EIN(1)
      READ(5,2)SFMLYR,SFMLZR
      WRITE(6,83)SFMLYR,SFMLZR
      READ(5,3) JMIN      ,JMAX       ,KMIN       ,KMAX
      WRITE(6,88)JMIN      ,JMAX       ,KMIN       ,KMAX
      READ(5,3)JBOT,JTOP,KBOT,KTOP,KBUG,MOTION,(KINT(J),J=1,5)
      WRITE(6,56) JBOT,JTOP,KBOT,KTOP,KBUG,MOTION,(KINT(J),J=1,5)
      READ (5,2) DTNM
      WRITE (6,62) DTNM
      READ (5,2) CUTOFF
      WRITE (6,65) CUTOFF
      READ (5,4) MAXN, TMAX
      WRITE (6,64) MAXN, TMAX
      JL = JMIN+1
      J3=JL+1
      JR = JMAX-1
      JRM=JR-1
      KB = KMIN+1
      KT = KMAX-1
      KTM=KT-1
      MAXREG=KSV(1)
      E1=EIN
      RHO1=RHOIN
      V ZERO=1./R ZERO
      DO 10310 NREG=1,MAXREG
      WRITE(6,54)NREG
      READ(5,2)      TINY A(NREG),       TINY B(NREG),       BIG A(NREG),
     2 BIG B(NREG), RCP V S(NREG),       E ZERO(NREG),        E S(NREG),
     3 ALFA(NREG),  BETA(NREG),          QCON(NREG)
      WRITE(6,85)    TINY A(NREG),       TINY B(NREG),       BIG A(NREG),
     2 BIG B(NREG), RCP V S(NREG),       E ZERO(NREG),        E S(NREG),
     3 ALFA(NREG),  BETA(NREG),          QCON(NREG)
10310 RCP V S(NREG)=1./RCP V S (NREG)
      IF(KBUG.GT.0) GO TO 10320
      JBMIN=JMAX+1
      JBMAX=JMAX+1
      KBMIN=KMAX+1
      KBMAX=KMAX+1
      GO TO 10325
10320 READ(5,3) JBMIN,JBMAX,KBMIN,KBMAX
      WRITE(6,84)JBMIN,JBMAX,KBMIN,KBMAX
10325 JMX = JMAX   $ KMX = KMAX   $ CALL INIT(JMX,KMX)
      NREG=1
      KL=1
      KU=2
      MAXU= JUMAX+(KUMAX-1)*JMAX
      MAXV= JVMAX+(KVMAX-1)*JMAX
      MAXZ= JZMAX+(KZMAX-1)*JMAX
      MAXR= JRMAX+(KRMAX-1)*JMAX
```

```
      MAXE= JEMAX+(KEMAX-1)*JMAX
      P = 3
      Q = 1
      R = 2
      DO 104 J=JMIN,JMAX
      RX(J,Q) = TX(J)
      RY(J,Q) = TY(1)
      RXZ(J,Q)=RX(J,Q)
      RYZ(J,Q)=RY(J,Q)
      IF(J.NE.JMIN) GO TO 1030
      UNMX(J,Q)=0.
      UNMY(J,Q)=UZLBIN
      GO TO 1035
1030  IF(J.NE.JMAX) GO TO 1031
      UNMX(J,Q)=0.
      UNMY(J,Q)=UZRBIN
      GO TO 1035
1031  UNMX(J,Q)=UYBIN
      UNMY(J,Q)=UZBIN
1035  RHO(J,Q)=RHO1
      VO(J,Q)=V ZERO
      U2(J,KL)=UNMX(J,Q)**2+UNMY(J,Q)**2
104   ENM(J,Q)=E1
      RHO(JMAX,Q) = 0.
      VO(JMAX,Q)=0.
      ENM(JMAX,Q) = 0.
C
C-----MAIN K LOOP
C
      DO 134 K=KMIN,KT
      JK=K*JMAX
      DO 107 J=JMIN,JMAX
      JK1=JK+J
      RX(J,R) = TX(J)
      RY(J,R) = TY(K+1)
      RXZ(J,R)=RX(J,R)
      RYZ(J,R)=RY(J,R)
      IF((JK1.LE.MAXU).OR.(MAXU.LE.0)) GO TO 1040
      READ(5,6)  JUMAX,KUMAX,UYIN(1)
      WRITE(6,89)JUMAX,KUMAX,UYIN(1)
      MAXU= JUMAX+(KUMAX-1)*JMAX
1040  IF((JK1.LE.MAXV).OR.(MAXV.LE.0)) GO TO 1041
      READ(5,6)  JVMAX,KVMAX,UZIN(1)
      WRITE(6,90)JVMAX,KVMAX,UZIN(1)
      MAXV= JVMAX+(KVMAX-1)*JMAX
1041  IF((JK1.LE.MAXZ).OR.(MAXZ.LE.0)) GO TO 1042
      READ(5,6)  JZMAX,KZMAX,R ZERO(1)
      WRITE(6,91)JZMAX,KZMAX,R ZERO(1)
      V ZERO=1./R ZERO
      MAXZ= JZMAX+(KZMAX-1)*JMAX
1042  IF((JK1.LE.MAXR).OR.(MAXR.LE.0)) GO TO 1043
      WRITE(6,92)JRMAX,KRMAX,RHO1
      READ(5,6)  JRMAX,KRMAX,RHO1
      MAXR= JRMAX+(KRMAX-1)*JMAX
1043  IF((JK1.LE.MAXE).OR.(MAXE.LE.0)) GO TO 1044
      READ(5,6)  JEMAX,KEMAX,E1
      WRITE(6,93)JEMAX,KEMAX,E1
      MAXE= JEMAX+(KEMAX-1)*JMAX
1044  K1=K+1
      IF ((J.LT.JBOT).OR.(K1.LT.KBOT).OR.(J.GT.JTOP).OR.(K1.GT.KTOP)
     1.OR.(K1.EQ.KMAX)) GO TO 106
```

```
      UNMX(J,R) = 0.
      UNMY(J,R) = 0.
      GO TO 1065
  105 RHO (J,R) = 0.
      VO(J,R)=0.
      ENM (J,R) = 0.
      GO TO 1070
106   IF(J.NE.JMIN) GO TO 10601
      UNMX(J,R)=0.
      IF(K.NE.KT) GO TO 10600
      UNMY(J,R)=UZLTIN
      GO TO 10605
10600 UNMY(J,R)=UZIN
      GO TO 10605
10601 IF(J.NE.JMAX) GO TO 10603
      UNMX(J,R)=0.
      IF(K.NE.KT) GO TO 10602
      UNMY(J,R)=UZRTIN
      GO TO 10605
10602 UNMY(J,R)=UZIN
      GO TO 10605
10603 IF(K.NE.KT) GO TO 10604
      UNMX(J,R)=UYTIN
      UNMY(J,R)=UZTIN
      GO TO 10605
10604 UNMX(J,R)=UYIN
      UNMY(J,R)=UZIN
10605 IF(K.EQ.KT) GO TO 105
 1065 CONTINUE
      RHO(J,R)=RHO1
      VO(J,R)=V ZERO
      ENM(J,R)=E1
1070  IF((K+1).EQ.KINT(NREG))GO TO 107
      U2(J,KU)=UNMX(J,R)**2+UNMY(J,R)**2
107   CONTINUE
      RHO(JMAX,R) = 0.
      VO(JMAX,R)=0.
      ENM(JMAX,R) = 0.
  108 DO 110 J=JMIN,JR
      Y1P2=RX(J+1,Q)+RX(J,Q)
      Z12=RY(J+1,Q)-RY(J,Q)
      Y2P3=RX(J,Q)+RX(J,R)
      Z23=RY(J,Q)-RY(J,R)
      Y3P4=RX(J,R)+RX(J+1,R)
      Z34=RY(J,R)-RY(J+1,R)
      Y4P1=RX(J+1,R)+RX(J+1,Q)
      Z41=RY(J+1,R)-RY(J+1,Q)
      VOL(J,Q)=(Z12*(Y1P2**2-RX(J+1,Q)*RX(J,Q))+Z23*(Y2P3**2-RX(J,Q)*
     1 RX(J,R))+Z34*(Y3P4-RX(J,R)*RX(J+1,R))+Z41*(Y4P1**2-RX(J+1,R)*
     2 RX(J+1,Q)))/6.
1085  FMASNM(J,Q)=RHO(J,Q)*VOL(J,Q)
      IF (FMASNM(J,Q).GT.0.)  GO TO 1091
      KP = K
      WRITE (6,77) J, KP, FMASNM(J,Q)
      NMASS = 2
1091  PNM(J,Q)=0.
1092  Q11(J,Q)=Q12(J,Q)=Q22(J,Q)=QX(J,Q)=0.
      IF(K.NE.KINT(NREG)) GO TO 1095
      YAZ(J,NREG)=SQRT((RX(J,Q)**2+RX(J,Q)*RX(J+1,Q)+RX(J+1,Q)**2)/3.)
      ZAZ(J,NREG)=((YAZ(J,NREG)-RX(J,Q))*RY(J+1,Q)+(RX(J+1,Q)-YAZ(J,NREG
     1 ))*      RY(J,Q))/(RX(J+1,Q)-RX(J,Q))
```

```
      UNORM(J,NREG)=UNMY(J,Q)
1095  PQNMXX(J,Q)=PNM(J,Q)+Q11(J,Q)
      PQNMXY(J,Q)=Q12(J,Q)
      PQNMYY(J,Q)=PNM(J,Q)+Q22(J,Q)
      PQMX(J,Q)=PNM(J,Q)+QX(J,Q)
      NTPT(J,Q) = 1
      SMASSI = SMASSI+FMASNM(J,Q)
      IF((K+1).EQ.KINT(NREG))GO TO 110
      IF(K.NE.KINT(NREG))GO TO 1099
      SENERI=SENERI+FMASNM(J,P)*(ENM(J,P)+.25*(U2(J+1,KL)+U2(J,KL)))+
     2             FMASNM(J,Q)*(ENM(J,Q)+.25*(U2(J+1,KU)+U2(J,KU)))
      GO TO 110
1099  SENERI=SENERI+FMASNM(J,Q)*(ENM(J,Q)+.125*(U2(J+1,KL)+U2(J,KL)+
     2    U2(J,KU)+U2(J+1,KU)))
110   CONTINUE
      IF(K.EQ.KINT(NREG))UNORM(JMAX,NREG)=UNMY(JMAX,Q)
      FMLYR(K)=SFMLYR
      FMLZR(K)=SFMLZR
      IF(K.GT.KMIN)GO TO 115
      FMSNZ(JMIN,Q) =.125*FMASNM(JMIN,Q)
      FMNMX(JMIN,Q)=0.
      DO 114 J=JL,JR
 112  FMSNZ(J,Q) =.125*(FMASNM(J,Q)+FMASNM(J-1,Q))
 113  FMNMX(J,Q) = FMSNZ(J,Q)*UNMX(J,Q)*2.
      FMNMY(J,Q) = FMSNZ(J,Q)*UNMY(J,Q)*2.
      SMOMYI = SMOMYI+FMNMX(J,Q)
 114  SMOMZI = SMOMZI+FMNMY(J,Q)
      FMSNZ(JMAX,Q) =.125*FMASNM(JR,Q)
      FMNMX(JMAX,Q)=0.
      GO TO 131
115   IF((K+1).LT.KINT(NREG))GO TO 118
      IF((K+1).GT.KINT(NREG)) GO TO 117
      J=JMIN
      FMSNZ(J,Q)=.25*(FMASNM(J,Q)+.5*FMASNM(J,P))
      FMNMX(J,Q)=0.
      DO 116 J=JL,JR
      FMSNZ(J,Q)=.25*(FMASNM(J,Q)+FMASNM(J-1,Q)+.5*(FMASNM(J-1,P)+
     2            FMASNM(J,P)))
      FMNMX(J,Q)=FMSNZ(J,Q)*UNMX(J,Q)*2.
      FMNMY(J,Q)=FMSNZ(J,Q)*UNMY(J,Q)*2.
      SMOMYI=SMOMYI+FMNMX(J,Q)
116   SMOMZI=SMOMZI+FMNMY(J,Q)
      J=JMAX
      FMSNZ(J,Q)=.25*(FMASNM(J-1,Q)+.5*FMASNM(J-1,P))
      FMNMX(J,Q)=0.
      GO TO 131
117   INT=1-INT
      DO 11700 J=JMIN,JMAX
      FMSNZ(J,Q)=0.
      FMNMX(J,Q)=0.
11700 FMNMY(J,Q)=0.
      GO TO 1350
118   IF(INT.EQ.0) GO TO 121
      J=JMIN
      FMSNZ(J,Q)=.25*(.5*FMASNM(J,Q)+FMASNM(J,P))
      FMNMX(J,Q)=0.
      DO 119 J=JL,JR
      FMSNZ(J,Q)=.25*(.5*(FMASNM(J,Q)+FMASNM(J-1,Q))+FMASNM(J-1,P)+
     2            FMASNM(J,P))
      FMNMX(J,Q)=FMSNZ(J,Q)*UNMX(J,Q)*2.
      FMNMY(J,Q)=FMSNZ(J,Q)*UNMY(J,Q)*2.
```

```
      SMOMYI=SMOMYI+FMNMX(J,Q)
119   SMOMZI=SMOMZI+FMNMY(J,Q)
      J=JMAX
      FMNMX(J,Q)=0.
      FMSNZ(J,Q)=.25*(.5*FMASNM(J-1,Q)+FMASNM(J-1,P))
      INT=1-INT
      GO TO 131
121   FMSNZ(JMIN,Q) =.125*(FMASNM(JMIN,Q)+FMASNM(JMIN,P))
      FMNMX(JMIN,Q)=0.
      DO 125 J=JL,JR
123   FMSNZ(J,Q) =.125*(FMASNM(J,Q)+FMASNM(J-1,Q)+FMASNM(J-1,P)
     1              +FMASNM(J,P))
124   FMNMX(J,Q) = FMSNZ(J,Q)*UNMX(J,Q)*2.
      FMNMY(J,Q) = FMSNZ(J,Q)*UNMY(J,Q)*2.
      SMOMYI = SMOMYI+FMNMX(J,Q)
125   SMOMZI = SMOMZI+FMNMY(J,Q)
      FMSNZ(JMAX,Q) =.125*(FMASNM(JR,Q)+FMASNM(JR,P))
      FMNMX(JMAX,Q)=0.
126   IF (K.LT.KT)  GO TO 131
      FMSNZ(JMIN,R) =.125*FMASNM(JMIN,Q)
      FMNMX(JMIN,R)=0.
      DO 130 J=JL,JR
128   FMSNZ(J,R) =.125*(FMASNM(J,Q)+FMASNM(J-1,Q))
129   FMNMX(J,R) = FMSNZ(J,R)*UNMX(J,R)*2.
      FMNMY(J,R) = FMSNZ(J,R)*UNMY(J,R)*2.
      SMOMYI = SMOMYI+FMNMX(J,R)
130   SMOMZI = SMOMZI+FMNMY(J,R)
      FMSNZ(JMAX,R) =.125*FMASNM(JR,Q)
      FMNMX(JMAX,R)=0.
      FMNMY(JMIN,R) = FMSNZ(JMIN,R)*UNMY(JMIN,R)*2.
      FMNMY(JMAX,R) = FMSNZ(JMAX,R)*UNMY(JMAX,R)*2.
      SMOMYI = SMOMYI+FMNMX(JMAX,R)+FMNMX(JMIN,R)
      SMOMZI = SMOMZI+FMNMY(JMAX,R)+FMNMY(JMIN,R)
131   FMNMY(JMIN,Q)=FMSNZ(JMIN,Q)*UNMY(JMIN,Q)*2.
      FMNMY(JMAX,Q) = FMSNZ(JMAX,Q)*UNMY(JMAX,Q)*2.
      SMOMYI = SMOMYI+FMNMX(JMAX,Q)+FMNMX(JMIN,Q)
      SMOMZI = SMOMZI+FMNMY(JMAX,Q)+FMNMY(JMIN,Q)
1350  LS=P
      P = Q
      Q = R
      R = LS
      IF((K+1).EQ.KINT(NREG)) GO TO 1351
      KL=KU
      KU=MOD(KL,2)+1
1351  IF(K.EQ.KINT(NREG))NREG=NREG+1
      KMOUT = 1
132   DO 12345 J=JMIN,JMAX
       S1(J)=RX(J,P)      $ S2(J)=RY(J,P)       $ S3(J)=UNMX(J,P)
       S4(J)=UNMY(J,P)    $ S5(J)=FMASNM(J,P) $ S6(J)=ENM(J,P)
      S7(J)=PNM(J,P)$      S8(J)=PQNMXX(J,P)$   S9(J)=PQNMXY(J,P)
      S10(J)=PQNMYY(J,P)$  S11(J)=VOL(J,P)$     S12(J)=RHO(J,P)
      S13(J)=PQMX(J,P)          $S14(J)=FMNMX(J,P)  $S15(J)=FMNMY(J,P)
      S16(J)=NTPT(J,P)
      S17(J)=A1Y(J,P)          $S18(J)=A2Y(J,P)     $S19(J)=A3Y(J,P)
      S20(J)=A4Y(J,P)          $S21(J)=A1Z(J,P)     $S22(J)=A2Z(J,P)
      S23(J)=A3Z(J,P)          $S24(J)=A4Z(J,P)
      S25(J)=AW1   (J,P)       $S26(J)=AW2   (J,P)  $S27(J)=AW3   (J,P)
      S28(J)=AW4   (J,P)
      S29(J)=RXZ(J,P)          $S30(J)=RYZ(J,P)
      S31(J)=VO(J,P)
12345 CONTINUE
```

```
      CALL MOUT
133   IF(KSV(12).GT.0) GO TO 1335
      DO 1330 I=JMIN,JMAX,30
      JPRINT=I+29
      IF(JPRINT.GT. JMAX) JPRINT= JMAX
      DO 13300 J=I,JPRINT
13300 FMSNZ(J,P)=2.*FMSNZ(J,P)
1330  WRITE(6,70)    PROBNO,        TIME,        DTNM,
     2               (              RX(J,P),     RY(J,P),
     3 VOL(J,P),     RHO(J,P),      ETA(J,P),    ENM(J,P),      J, K,N,
     4 UNMX(J,P),    UNMY(J,P),     FMASNM(J,P),  RH1Z(J,P),    RWA1Z(J,P),
     5 E1Z(J,P),     RWAE1Z(J,P),   FMNMX(J,P),   FMNMY(J,P),    FMSNZ(J,P),
     6 RH3Z(J,P),    RWA3Z(J,P),    E3Z(J,P),    RWAE3Z(J,P),
     7 J=I,JPRINT)
1335  GO TO (134,140),KMOUT
 134  CONTINUE
      FMLYR(KMAX)=SFMLYR
      FMLZR(KMAX)=SFMLZR
      KMOUT = 2
      P = Q
      DO 1345 J=JMIN,JMAX
         PNM(J,P) = 0
         VOL(J,P) = 0
       NTPT(J,P) = 0
      FMASNM(J,P) = 0
      PQNMXX(J,P)=0
      PQNMXY(J,P)=0
1345  PQNMYY(J,P)=0
      GO TO 132
140   WRITE(6,75)
      WRITE (6,76) SENERI, SMASSI, SMOMYI, SMOMZI
      DTNMP5=.5*DTNM
      DTNM2=2.*DTNM
      CUT1=DTNM*CUTOFF
      CUT2=DTNM2*CUTOFF *2.
      RDTNM=1./DTNM
      STARTIME=(TIMEF(X)-STARTIME)/1000.
      WRITE(6,95)STARTIME
      KSV(13)=1
      RETURN
      END
```

```
C       SUBROUTINE  RSTART L
        SUBROUTINE RSRTOO
        COMMON/INDUMP/    NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
       2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,  SMOMYI,  SMYTPT,  SMOMY,
       3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,  SUMKE,   SUMTE,   FIMPZ,
       4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO, DTNM,    CUTOFF,  N,
       5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,  SFW,     DTNMP5,  DTNM2,
       6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,  UYRBIN,  UZLBIN,  UZBIN,
       7 UZRBIN, UYLTIN,  UYTIN,   UYRTIN,  UZLTIN, UZTIN,   UZRTIN,  KTM,
       8 JMIN,   JMAX,    KMIN,    KMAX,    JL,     J3,      JR,      JRM,
       9 KT,         EIN(5),    KINT(5),    RHOIN(5),   UYIN(5),    UZIN(5),
       2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),
       A E S(5),    ALFA(5),    BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
       4 FMLZR(100),                 KSV(24),       SAV(12),       FMLYR(100)
        COMMON/THEREST/              A(55),         DIL(55),       EPX(55),
       2 EPY(55),       EPZ(55),     FMLYB(55),     FMLYT(55),     FMLZB(55),
       3 FMLZT(55),     LY1(55),     LY2(55),       LZ1(55),       LZ2(55),
       4 PY(55),        PZ(55),      R1H(55),       R2H(55),       R3H(55),
       5 R4H(55),       Z1H(55),     Z2H(55),       Z3H(55),       Z4H(55),
       6 U2(55,2),      B(55,4)
        COMMON/AFTERALL/
       A                RX(55,5),        RY(55,5),        UNMX(55,5),
       1 UNMY(55,5),    UNPX(55,5),      UNPY(55,5),      FMASNM(55,5),
       2 ENM(55,5),     EN(55,5),        PNM(55,5),       PN(55,5),
       3 PQNMXX(55,5),  PQNMXY(55,5),    PQNMYY(55,5),    PQNXX(55,5),
       4 PQNXY(55,5),   PQNYY(55,5),     RWA3Z(55,5),     RWA1Z(55,5),
       5 RWAE3Z(55,5),  RWAE1Z(55,5),    RH3Z(55,5),      RH1Z(55,5),
       6 E3Z(55,5),     E1Z(55,5),       RHO(55,5),       VOL(55,5),
       7 ETA(55,5),     A1Y(55,5),       A2Y(55,5),       A3Y(55,5),
       8 A4Y(55,5),     A1Z(55,5),       A2Z(55,5),       A3Z(55,5),
       9 A4Z(55,5),     F1Y(55,5),       F2Y(55,5),       F3Y(55,5),
       A F4Y(55,5),     F1Z(55,5),       F2Z(55,5),       F3Z(55,5),
       1 F4Z(55,5),     NTPT(55,5),      FMSNZ(55,5),     FMASN(55,5),
       2 FMNMX(55,5),   FMNMY(55,5),     FMNX(55,5),      FMNY(55,5),
       4 AW1(55,5),     AW2(55,5),       AW3(55,5),       AW4(55,5),
       5 RXM(55,5),     RYM(55,5),       RXZ(55,5),       RYZ(55,5),
       6 Q11(55,5),     Q12(55,5),       Q22(55,5),       QX(55,5),
       7 P11(55,5),     P12(55,5),       P22(55,5),       PX(55,5),
       8 PQX(55,5),     PQMX(55,5),      VO(55,5)
        COMMON    ICON,    LINCT,   LX1,     LX2,     LX3,     LX4,     LX5,
       2 KC,      NDPA,    NEDIT,   NSIG,    NMASS,   NDMP
        COMMON/S/        S1(55),   S2(55),   S3(55),   S4(55),   S5(55),
       2    S6(55),    S7(55),   S8(55),   S9(55),   S10(55),  S11(55),
       3   S12(55),   S13(55),  S14(55),  S15(55),  S16(55),  S17(55),
       4    S18(55),   S19(55),  S20(55),  S21(55),  S22(55),  S23(55),
       5    S24(55),   S25(55),  S26(55),  S27(55),  S28(55),  S29(55),
       6    S30(55),   S31(55),  S32(55),  S33(55)
        DIMENSION DUMPV(1)
        EQUIVALENCE(NREG,DUMPV(1))
C*****
        ENTRY RSTART
C*****
        DO 60 KK=1,ICON
10      READ(9) (DUMPV(J),J=1,400)
        IF(IOCHECK,9)12,12
12      IF(KK.GE.ICON)GO TO 25
15      DO 20 K=KMIN,KMAX
        READ(9) DUMPV(1)
        IF(IOCHECK,9)20,20
20      CONTINUE
        GO TO 60
```

```
25      JMX=JMAX
        KMX=KMAX
        CALL INIT(JMX,KMX)
   30 DO 45 K=KMIN,KMAX
        READ(9)  (     RXM(J,1),                RYM(J,1),
     2 UNMX(J,1),     UNMY(J,1),               FMASNM(J,1),          ENM(J,1),
     3 PNM(J,1),      PQNMXX(J,1),             PQNMXY(J,1),          PQNMYY(J,1),
     4 VOL(J,1),      RHO(J,1),                PQMX(J,1),
     5 FMNMX(J,1),    FMNMY(J,1),
     6 NTPT(J,1),
     7 A1Y(J,1),      A2Y(J,1),                A3Y(J,1),             A4Y(J,1),
     8 A1Z(J,1),      A2Z(J,1),                A3Z(J,1),             A4Z(J,1),
     9 AW1   (J,1),   AW2   (J,1),             AW3   (J,1),          AW4   (J,1),
     A RXZ(J,1),        RYZ(J,1),          VO(J,1),         J=JMIN,JMAX)
        IF(KK.LT.ICON) GO TO 45
   39 DO 12345 J=JMIN,JMAX
        S1(J)=RXM(J,1)          $S2(J)=RYM(J,1)       $S3(J)=UNMX(J,1)
        S4(J)=UNMY(J,1)$S5(J)=FMASNM(J,1)$S6(J)=ENM(J,1)
        S7(J)=PNM(J,1)$      S8(J)=PQNMXX(J,1)$   S9(J)=PQNMXY(J,1)
        S10(J)=PQNMYY(J,1)$ S11(J)=VOL(J,1)$     S12(J)=RHO(J,1)
        S13(J)=PQMX(J,1)          $S14(J)=FMNMX(J,1)  $S15(J)=FMNMY(J,1)
        S16(J)=NTPT(J,1)
        S17(J)=A1Y(J,1)          $S18(J)=A2Y(J,1)     $S19(J)=A3Y(J,1)
        S20(J)=A4Y(J,1)          $S21(J)=A1Z(J,1)     $S22(J)=A2Z(J,1)
        S23(J)=A3Z(J,1)          $S24(J)=A4Z(J,1)
        S25(J)=AW1  (J,1)        $S26(J)=AW2  (J,1)   $S27(J)=AW3  (J,1)
        S28(J)=AW4  (J,1)
        S29(J)=RXZ(J,1)          $S30(J)=RYZ(J,1)
        S31(J)=VO(J,1)
12345 CONTINUE
        CALL MOUT
   45 CONTINUE
   60 CONTINUE
        REWIND 9
        READ(5,4)
        READ(5,1)(KSV(J),J=1,12)
        READ(5,2)(SAV(J),J=1,6)
        READ(5,3)MAXN,TMAX,DTNMN,PROBNN
63      IF(PROBNN)70,70,64
64      PROBNO=PROBNN
70      WRITE(6,53)ICON,PROBNO,TIME,N
        WRITE(6,4)
        WRITE (6,50)(KSV(J),J=1,12)
        WRITE (6,51)(SAV(J),J=1,6)
        WRITE(6,52)MAXN,TMAX,DTNMN,PROBNN
        RETURN
 1      FORMAT(12I6)
 2      FORMAT(6E12.5)
    3 FORMAT(I6,5E12.5)
    4 FORMAT(72H
     1                    )
50      FORMAT(1H /
     272H  KSV1   KSV2   KSV3   KSV4   KSV5   KSV6   KSV7   KSV8   KSV9  KSV10  KS
     3V11 KSV12/
     4(12I6))
51      FORMAT(1H /
     293H     SAV1                SAV2                SAV3                SAV4
     3           SAV5                SAV6/
     4(6E17.9))
52      FORMAT(1H /
     250H  MAXN     TMAX                DTNMN                PROBNN/
```

```
      3 I6,3E17.9/)
53     FORMAT(22H1THIS IS A RESTART RUN/
      240H  DUMP    PROBLEM    TIME              CYCLE/
      3I6,F11.2,E17.9,I6)
       END
```

```
C     SUBROUTINE  STRAIN L
      SUBROUTINE STRN00
      COMMON/INDUMP/   NREG,    RDTNM,   MOTION,  JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,  TIME,    SMOMZI,  SMZTPT,  SMOMZ,   SMOMYI,  SMYTPT,  SMOMY,
     3 SENERI, SIETPT,  SKETPT,  WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,  SMASSI,  SMSTPT,  SMASS,   PROBNO,  DTNM,    CUTOFF,  N,
     5 KBOT,   KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5,  DTNM2,
     6 KB,     CUT1,    CUT2,    UYLBIN,  UYBIN,   UYRBIN,  UZLBIN,  UZBIN,
     7 UZRBIN, UYLTIN,  UYTIN,   UYRTIN,  UZLTIN,  UZTIN,   UZRTIN,  KTM,
     8 JMIN,   JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,        EIN(5),     KINT(5),  RHOIN(5),  UYIN(5),    UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),    QCON(5),
     A E S(5),    ALFA(5),    BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),                KSV(24),      SAV(12),      FMLYR(100)
      COMMON/THEREST/             A(55),        DIL(55),      EPX(55),
     2 EPY(55),     EPZ(55),      FMLYB(55),    FMLYT(55),    FMLZB(55),
     3 FMLZT(55),   LY1(55),      LY2(55),      LZ1(55),      LZ2(55),
     4 PY(55),      PZ(55),       R1H(55),      R2H(55),      R3H(55),
     5 R4H(55),     Z1H(55),      Z2H(55),      Z3H(55),      Z4H(55),
     6 U2(55,2),    B(55,4)
      COMMON/AFTERALL/
     A              RX(55,5),       RY(55,5),       UNMX(55,5),
     1 UNMY(55,5),  UNPX(55,5),     UNPY(55,5),     FMASNM(55,5),
     2 ENM(55,5),   EN(55,5),       PNM(55,5),      PN(55,5),
     3 PQNMXX(55,5),PQNMXY(55,5),   PQNMYY(55,5),   PQNXX(55,5),
     4 PQNXY(55,5), PQNYY(55,5),    RWA3Z(55,5),    RWA1Z(55,5),
     5 RWAE3Z(55,5),RWAE1Z(55,5),   RH3Z(55,5),     RH1Z(55,5),
     6 E3Z(55,5),   E1Z(55,5),      RHO(55,5),      VOL(55,5),
     7 ETA(55,5),   A1Y(55,5),      A2Y(55,5),      A3Y(55,5),
     8 A4Y(55,5),   A1Z(55,5),      A2Z(55,5),      A3Z(55,5),
     9 A4Z(55,5),   F1Y(55,5),      F2Y(55,5),      F3Y(55,5),
     A F4Y(55,5),   F1Z(55,5),      F2Z(55,5),      F3Z(55,5),
     1 F4Z(55,5),   NTPT(55,5),     FMSNZ(55,5),    FMASN(55,5),
     2 FMNMX(55,5), FMNMY(55,5),    FMNX(55,5),     FMNY(55,5),
     4 AW1(55,5),   AW2(55,5),      AW3(55,5),      AW4(55,5),
     5 RXM(55,5),   RYM(55,5),      RXZ(55,5),      RYZ(55,5),
     6 Q11(55,5),   Q12(55,5),      Q22(55,5),      QX(55,5),
     7 P11(55,5),   P12(55,5),      P22(55,5),      PX(55,5),
     8 PQX(55,5),   PQMX(55,5),     VO(55,5)
      COMMON    ICON,    LINCT,  LX1,    LX2,     LX3,     LX4,     LX5,
     2 KC,      NDPA,    NEDIT,  NSIG,   NMASS,   NDMP
      REAL      LY1,      LY2,      LZ1,      LZ2
C*****
      ENTRY STRAINP2
C*****
      L=LX3
      L2=LX4
      GO TO 4
C*****
      ENTRY STRAINP
C*****
      L=LX2
      L2=LX3
      GO TO 4
C*****
      ENTRY STRAIN
C*****
      L=LX1
      L2=LX2
      IF(((KC+1).GE.KINT(NREG)).AND.((KC-2).LT.(KINT(NREG))))GO TO 4
      DO 3 J=JMIN,JMAX
```

```
      GO TO (4,1,2),MOTION
1     IF(KC.EQ.1 ) GO TO 2
      FMASN(J,L )=FMASNM(J,L )
2     RX(J,L2)=RXM(J,L2)+UNMX(J,L2)*DTNM
3     RY(J,L2)=RYM(J,L2)+UNMY(J,L2)*DTNM
4     DO 200 J=JMIN,JR
      IF((MOTION.EQ.1).AND.(N.GT.1))RETURN
      IF(MOTION.NE.1) GO TO 5
      R1H(J)=2.*RX(J,L)
      Z1H(J)=2.*RY(J,L)
      R2H(J)=RX(J+1,L)*2.
      Z2H(J)=RY(J+1,L)*2.
      R3H(J)=RX(J+1,L2)*2.
      Z3H(J)=RY(J+1,L2)*2.
      R4H(J)=RX(J,L2)*2.
      Z4H(J)=RY(J,L2)*2.
      GO TO 6
5     R1H(J)=RX(J,L)+RXM(J,L)
      Z1H(J)=RY(J,L)+RYM(J,L)
      R2H(J)=RX(J+1,L)+RXM(J+1,L)
      Z2H(J)=RY(J+1,L)+RYM(J+1,L)
      R3H(J)=RX(J+1,L2)+RXM(J+1,L2)
      Z3H(J)=RY(J+1,L2)+RYM(J+1,L2)
      R4H(J)=RX(J,L2)+RXM(J,L2)
      Z4H(J)=RY(J,L2)+RYM(J,L2)
      A41M=RXM(J,L)*RYM(J,L2)-RXM(J,L2)*RYM(J,L)
      A12M=RXM(J+1,L)*RYM(J,L)-RXM(J,L)*RYM(J+1,L)
      A23M=RXM(J+1,L2)*RYM(J+1,L)-RXM(J+1,L)*RYM(J+1,L2)
      A34M=RXM(J,L2)*RYM(J+1,L2)-RXM(J+1,L2)*RYM(J,L2)
6     R41H=R4H(J)+R1H(J)
      R12H=R1H(J)+R2H(J)
      R23H=R2H(J)+R3H(J)
      R34H=R3H(J)+R4H(J)
      A41=RX(J,L)*RY(J,L2)-RX(J,L2)*RY(J,L)
      A12=RX(J+1,L)*RY(J,L)-RX(J,L)*RY(J+1,L)
      A23=RX(J+1,L2)*RY(J+1,L)-RX(J+1,L)*RY(J+1,L2)
      A34=RX(J,L2)*RY(J+1,L2)-RX(J+1,L2)*RY(J,L2)
      IF(MOTION.NE.1) GO TO 7
      A41H=2.*A41
      A12H=2.*A12
      A23H=2.*A23
      A34H=2.*A34
      GO TO 8
7     A41H=A41+A41M
      A12H=A12+A12M
      A23H=A23+A23M
      A34H=A34+A34M
8     A1Y(J,L)=((Z4H(J)*R41H-Z2H(J)*R12H)*.5+A41H+A12H)/(-12.)
      A1Z(J,L)=(R2H(J)*R12H-R4H(J)*R41H)/(-24.)
      A2Y(J,L)=((Z1H(J)*R12H-Z3H(J)*R23H)*.5+A12H+A23H)/(-12.)
      A2Z(J,L)=(R3H(J)*R23H-R1H(J)*R12H)/(-24.)
      A3Y(J,L)=((Z2H(J)*R23H-Z4H(J)*R34H)*.5+A23H+A34H)/(-12.)
      A3Z(J,L)=(R4H(J)*R34H-R2 H(J)*R23H)/(-24.)
      A4Y(J,L)=((Z3H(J)*R34H-Z1H(J)*R41H)*.5+A34H+A41H)/(-12.)
      A4Z(J,L)=(R1H(J)*R41H-R3H(J)*R34H)/(-24.)
      GO TO (200,9,9),MOTION
9     CONTINUE
      COMPY=A1Y(J,L)*UNMX(J,L)+A2Y(J,L)*UNMX(J+1,L)+A3Y(J,L)*
     1 UNMX(J+1,L2)+A4Y(J,L)*UNMX(J,L2)
      COMPZ=A1Z(J,L)*UNMY(J,L)+A2Z(J,L)*UNMY(J+1,L)+A3Z(J,L)*
     2      UNMY(J+1,L2)+A4Z(J,L)*UNMY(J,L2)
```

```
      VOL(J,L)=VOL(J,L)+DTNM*(COMPY+COMPZ)
      DIL(J)=VOL(J,L)/(FMASN(J,L)*VO(J,L))-1.
      RHO(J,L)=FMASN(J,L)/VOL(J,L)
      RA32=RXZ(J+1,L2)-RXZ(J+1,L)
      ZA32=RYZ(J+1,L2)-RYZ(J+1,L)
      RB12=RXZ(J,L)-RXZ(J+1,L)
      ZB12=RYZ(J,L)-RYZ(J+1,L)
      RPA32=RX(J+1,L2)-RX(J+1,L)
      ZPA32=RY(J+1,L2)-RY(J+1,L)
      RPB12=RX(J,L)-RX(J+1,L)
      ZPB12=RY(J,L)-RY(J+1,L)
      RA14=RXZ(J,L)-RXZ(J,L2)
      ZA14=RYZ(J,L)-RYZ(J,L2)
      RB34=RXZ(J+1,L2)-RXZ(J,L2)
      ZB34=RYZ(J+1,L2)-RYZ(J,L2)
      RPA14=RX(J,L)-RX(J,L2)
      ZPA14=RY(J,L)-RY(J,L2)
      RPB34=RX(J+1,L2)-RX(J,L2)
      ZPB34=RY(J+1,L2)-RY(J,L2)
      AAB31=1./(RA32*ZB12-RB12*ZA32)
      AAB13=1./(RA14*ZB34-RB34*ZA14)
      AAB24=1./(RB12*ZA14-RA14*ZB12)
      AAB42=1./(RB34*ZA32-RA32*ZB34)
      A22=.25*(AAB31*(ZB12*RPA32-ZA32*RPB12)+AAB13*(ZB34*RPA14-ZA14*
     1        RPB34)+AAB24*(ZA14*RPB12-ZB12*RPA14)+AAB42*(ZA32*RPB34-
     2        ZB34*RPA32))
      A23A=.25*(AAB31*(RA32*RPB12-RB12*RPA32)-AAB13*(RB34*RPA14-RA14*
     1        RPB34)-AAB24*(RA14*RPB12-RB12*RPA14)-AAB42*(RA32*RPB34-
     2        RB34*RPA32))
      A32=.25*(AAB31*(ZB12*ZPA32-ZA32*ZPB12)+AAB13*(ZB34*ZPA14-ZA14*
     1        ZPB34)+AAB24*(ZA14*ZPB12-ZB12*ZPA14)+AAB42*(ZA32*ZPB34-
     2        ZB34*ZPA32))
      A33=.25*(AAB31*(RA32*ZPB12-RB12*ZPA32)-AAB13*(RB34*ZPA14-RA14*
     1        ZPB34)-AAB24*(RA14*ZPB12-RB12*ZPA14)-AAB42*(RA32*ZPB34-
     2        RB34*ZPA32))
      T22=A22**2+A32**2
      T23=A22*A23A+A32*A33
      T33=A23A**2+A33**2
      IF(T23.EQ.0.)GO TO 50
10    ROOT=SQRT((T22-T33)**2+4.*T23**2)
      TERM=   (T22+T33)
      E1    =SQRT(.5*(TERM+ROOT))
      E2    =SQRT(.5*(TERM-ROOT))
      ROOT1=SQRT(T23**2+(T22-E1**2)**2)
      RROOT1=1./ROOT1
      LY1(J)=T23*RROOT1
      LY2(J)=(T22-E1**2)*RROOT1
      ROOT2=SQRT(T23**2+(T22-E2**2)**2)
      RROOT2=1./ROOT2
      LZ1(J)=T23*RROOT2
      LZ2(J)=(T22-E2**2)*RROOT2
      IF(ABS(LY1(J)).LT.ABS(LZ1(J)))GO TO 30
      IF(LY1(J).GT.0) GO TO 20
      LY1(J)=-LY1(J)
      LY2(J)=-LY2(J)
20    IF(LZ2(J))21,21,100
21    LZ1(J)=-LZ1(J)
      LZ2(J)=-LZ2(J)
      GO TO 100
30    IF(LZ1(J).GT.0) GO TO 40
      LZ1(J)=-LZ1(J)
```

```
      LZ2(J)=-LZ2(J)
40    IF(LY2(J).GT.0) GO TO 45
      LY1(J)=-LY1(J)
      LY2(J)=-LY2(J)
45    WS=LY1(J)
      LY1(J)=LZ1(J)
      LZ1(J)=WS
      WS=LY2(J)
      LY2(J)=LZ2(J)
      LZ2(J)=WS
      GO TO 100
50    E1   =SQRT(T22)
      LY1(J)=1.
      LY2(J)=0.
      E2   =SQRT(T33)
      LZ1(J)=0.
      LZ2(J)=1.
100   E3=VOL(J,L)/(FMASN(J,L)*VO(J,L)*E1*E2)
      EPY(J)=E1-1.
      EPZ(J)=E2-1.
      EPX(J)=E3-1.
200   CONTINUE
      RETURN
      END
```

```
C     SUBROUTINE  STRESS L
      SUBROUTINE STRS00
      COMMON/INDUMP/   NREG,    RDTNM,   MOTION, JBMIN,   JBMAX,   KBMIN,
     2 KBMAX,   TIME,    SMOMZI, SMZTPT, SMOMZ,   SMOMYI, SMYTPT, SMOMY,
     3 SENERI, SIETPT, SKETPT, WORK,    SUMIE,   SUMKE,   SUMTE,   FIMPZ,
     4 FIMPY,   SMASSI, SMSTPT, SMASS,   PROBNO, DTNM,    CUTOFF, N,
     5 KBOT,    KTOP,    MAXN,    TMAX,    DTNMN,   SFW,     DTNMP5, DTNMZ,
     6 KB,      CUT1,    CUT2,    UYLBIN, UYBIN,   UYRBIN, UZLBIN, UZBIN,
     7 UZRBIN, UYLTIN, UYTIN,   UYRTIN, UZLTIN, UZTIN,   UZRTIN, KTM,
     8 JMIN,    JMAX,    KMIN,    KMAX,    JL,      J3,      JR,      JRM,
     9 KT,          EIN(5),     KINT(5),   RHOIN(5),   UYIN(5),    UZIN(5),
     2 TINY A(5), TINY B(5), R ZERO(5),BETA(5),     QCON(5),
     A E S(5),     ALFA(5),    BIG A(5), BIG B(5),  RCP V S(5),E ZERO(5),
     4 FMLZR(100),              KSV(24),        SAV(12),       FMLYR(100)
      COMMON/THEREST/            A(55),          DIL(55),       EPX(55),
     2 EPY(55),      EPZ(55),      FMLYB(55),      FMLYT(55),     FMLZB(55),
     3 FMLZT(55),    LY1(55),      LY2(55),        LZ1(55),       LZ2(55),
     4 PY(55),       PZ(55),       R1H(55),        R2H(55),       R3H(55),
     5 R4H(55),      Z1H(55),      Z2H(55),        Z3H(55),       Z4H(55),
     6 U2(55,2),     B(55,4)
      COMMON/AFTERALL/
     A                  RX(55,5),          RY(55,5),          UNMX(55,5),
     1 UNMY(55,5),      UNPX(55,5),        UNPY(55,5),        FMASNM(55,5),
     2 ENM(55,5),       EN(55,5),          PNM(55,5),         PN(55,5),
     3 PQNMXX(55,5),    PQNMXY(55,5),      PQNMYY(55,5),      PQNXX(55,5),
     4 PQNXY(55,5),     PQNYY(55,5),       RWA3Z(55,5),       RWA1Z(55,5),
     5 RWAE3Z(55,5),    RWAE1Z(55,5),      RH3Z(55,5),        RH1Z(55,5),
     6 E3Z(55,5),       E1Z(55,5),         RHO(55,5),         VOL(55,5),
     7 ETA(55,5),       A1Y(55,5),         A2Y(55,5),         A3Y(55,5),
     8 A4Y(55,5),       A1Z(55,5),         A2Z(55,5),         A3Z(55,5),
     9 A4Z(55,5),       F1Y(55,5),         F2Y(55,5),         F3Y(55,5),
     A F4Y(55,5),       F1Z(55,5),         F2Z(55,5),         F3Z(55,5),
     1 F4Z(55,5),       NTPT(55,5),        FMSNZ(55,5),       FMASN(55,5),
     2 FMNMX(55,5),     FMNMY(55,5),       FMNX(55,5),        FMNY(55,5),
     4 AW1(55,5),       AW2(55,5),         AW3(55,5),         AW4(55,5),
     5 RXM(55,5),       RYM(55,5),         RXZ(55,5),         RYZ(55,5),
     6 Q11(55,5),       Q12(55,5),         Q22(55,5),         QX(55,5),
     7 P11(55,5),       P12(55,5),         P22(55,5),         PX(55,5),
     8 PQX(55,5),       PQMX(55,5),        VO(55,5)
      COMMON     ICON,    LINCT,  LX1,     LX2,     LX3,     LX4,     LX5,
     2 KC,       NDPA,    NEDIT,  NSIG,    NMASS,  NDMP
      REAL       LY1,      LY2,      LZ1,      LZ2,       LAMMA,     LAMDIL
      EQUIVALENCE(LAMMA(1),TINY A(1)),(EMU(1),TINY B(1))
      DIMENSION LAMMA(5), EMU(5)
C*****
      ENTRY STRESSP2
C*****
      L=LX3
      L2=LX4
      GO TO 1
C*****
      ENTRY STRESSP
C*****
      L=LX2
      L2=LX3
      GO TO 1
C*****
      ENTRY STRESS
C*****
      L=LX1
      L2=LX2
```

```
      GO TO 1
1     EMU2=-2.*EMU(NREG)
      DO 41 J=JMIN,JR
      ETA(J,L)=RHO(J,L)*VO(J,L)
      LAMDIL=LAMMA(NREG)*DIL(J)
      PY(J)=EMU2*EPY(J)-LAMDIL
      PZ(J)=EMU2*EPZ(J)-LAMDIL
      PX(J,L)=EMU2*EPX(J)-LAMDIL
      P11(J,L)=LY1(J)**2*PY(J)+LZ1(J)**2*PZ(J)
      P12(J,L)=LY1(J)*LY2(J)*PY(J)+LZ1(J)*LZ2(J)*PZ(J)
      P22(J,L)=LY2(J)**2*PY(J)+LZ2(J)**2*PZ(J)
      Q11(J,L)=Q12(J,L)=Q22(J,L)=QX(J,L)=0.
41    CONTINUE
      IF((KC+1).EQ.KINT(NREG))RETURN
60    CALL FORCES
      CALL ENERGY
      RETURN
      END
```

REFERENCES

1. Trulio, J. and Trigger, K., "Numerical Solution of the One-Dimensional Hydrodynamic Equation," UCRL 6267 (1961).

2. Trulio, J. and Trigger, K., "Numerical Solution of the One-Dimensional Hydrodynamic Equations in an Arbitrary Time Dependent Coordinate System," UCRL 6522 (1961).

3. Trulio, J., Chapter 3, Vol. III, Methods in Computational Physics (Academic Press, 1964).

4. Trulio, J., "Studies of Finite Difference Equations for Continuum Mechanics," WL-TDR-64-72 (1964).

5. Noh, W., Chapter 4, Vol. III, Methods in Computational Physics (Academic Press, 1964).

6. Noh, W., Chapter 4, Vol. III, Methods in Computational Physics (Academic Press, 1964).

7. Von Neumann, J. and Richtmyer, R.D., J. Appl. Phys. 21, 232 (1950).

8. Tillotson, J.H., "Metallic Equations of State for Hypervelocity Impact," GA-3216 (1962).