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INELASTIC RESPONSE OF PRIMARY REACTOR CONTAINMENT TO HIGH-ENERGY EXCURSIONS

by

Joseph Gvildys and Stanley H. Fistedis

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Reactor Technology

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Reactor Analysis and Safety Division

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ABSTRACT

The analytical part of the inelastic response of primary containment to high-energy excursions was presented in the first part of this report. This supplement integrates the effort in this area. It adds primarily the computer program and some other analytical considerations, such as a numerical stability criterion, equations of state of mixed materials, and some comparison of the code with experimental results.

I. INTRODUCTION

The mathematical formulations, finite-difference equations, and numerical techniques for calculating the inelastic response of primary containment to a high-energy axisymmetric excursion have been described in detail in the first part of ANL-7499. The main purpose of this second part (ANL-7499 Supplement) is the presentation of the corresponding computer program and the addition of developments making the overall report self-contained. Thus, this part gives a numerical stability criterion, new analytical considerations, and a comparison with experimental results, all of which had not been included in the first part of the report.

Since the material given in this part is a continuation of the preceding work, the same sequence of equations and figures is maintained. Whenever possible, the same nomenclature is used in this part of the report to preserve continuity. However, all symbols are identified wherever they first appear in the text.

II. STABILITY OF THE DIFFERENTIAL EQUATIONS

The stability equations (Eqs. 74 - 76) are used to determine the length of the time step Δt so that a small disturbance can extend no

further than the local zone spacing during Δt. In the meantime, a lower limit is chosen to avoid excessive computations resulting from Δt being unnecessarily small. Equation 74 is the simplified form of the White stability equation[6] derived for the pseudoviscosity method. After careful comparison of the results of the computer output with an existing known solution, it was found that Eq. 74 was inadequate. The restriction imposed by the first term on the right side of Eq. 74 was too severe for certain reactor materials. It was, therefore, decided to use the White stability criterion in its originally derived form, that is,

$$W = \left[\frac{c^2(\Delta t)^2}{A} + 4a^2 \left|\frac{\Delta V}{V}\right|\right]^{1/2} < 1,$$

where W is White stability number, c is the speed of sound, and ΔV is the change of specific volume. For enhanced computational stability, the range of W is limited to values[7] between 0.45 and 0.2245.

For each zone the White stability number is obtained from

$$\left(\frac{W}{1.2}\right)^2 = \frac{c^2}{A}\left(\frac{\Delta t}{1.2}\right)^2 + 4\left|\frac{\Delta V}{V}\right|, \tag{137}$$

where a is taken as 1.2, and the time interval Δt is selected so that the maximum of the stability numbers for all zones satisfies

$$0.035 < \left(\frac{W}{1.2}\right)^2_{max} < 0.14. \tag{138}$$

The speed of sound is given by

$$c^2 = -V^2\left(\frac{\partial p}{\partial V}\right)_s. \tag{139}$$

The adiabatic equation of state for gaseous materials is taken as

$$pV^{\eta} = \text{constant}, \tag{140}$$

where η is the isentropic exponent. Thus,

$$c = (\eta pV)^{1/2}. \tag{141}$$

For solids and liquids, the adiabatic equation of state is assumed to have the form

$$p = p_B \left[\left(\frac{V_0}{V} \right)^{\eta} - 1 \right]. \tag{142}$$

Upon applying Eq. 139, the speed of sound becomes

$$c - [\eta V(p + p_B)]^{1/2}. \tag{143}$$

In the above expression, the constants p_B and η are related by

$$c_0^2 = V_0 p_B \eta, \tag{144}$$

where c_0 is the speed of sound indicated in Fig. 9.

Substitution of Eqs. 141 and 143 into Eq. 137 gives White's stability criterion as

$$\left(\frac{W}{1.2} \right)^2 = \frac{\eta V(p + p_B)}{A} \left(\frac{\Delta t}{1.2} \right)^2 + 4 \left| \frac{\Delta V}{V} \right|. \tag{145}$$

The above applies both to condensed materials and gases. The value of p_B is taken as zero for gases.

III. EQUATION OF STATE FOR A GROUP OF MIXED MATERIALS

As stated in the first part of this report, solution of the basic conservation equations of mass, momentum, and energy requires an equation of state of the form

$$p = p_H + \frac{\gamma}{V} (E - E_H), \tag{54}$$

where p_H and E_H are the pressure and specific internal energy along the Hugoniot centered at p_0, V_0; V is the specific volume; and γ is the Mie-Grüneisen coefficient (see Sect. III.A of ANL-7499). Thus, analysis of the inelastic response of a primary reactor-containment structure to high-energy excursions requires knowledge of the equation of state of the reactor materials.

In the numerical solution, meshes represent the primary system media. No problem exists in representing single materials such as steel or sodium. There is sufficient experimental Hugoniot data for common materials. M. van Thiel[8] provides substantial experimental data. The results of these experiments, although performed under different environmental conditions than in reactors, can be made applicable for containment calculations.

A problem is created when media like the core blanket and plenum are divided into meshes. Individual meshes could involve more than one material. Extremely fine meshes are required to confine one material to each mesh zone. Thus, a Hugoniot curve is needed to represent the pressure-volume relations for material mixtures. Currently experimental data are not available for such mixtures. To remedy this situation it is necessary to develop a method to provide a Hugoniot curve for the mixture, from currently available Hugoniot data for individual materials.

The approach employed in this analysis is similar to that used by Goranson et al.[9] in describing the dynamic compressibility of metals. The two basic assumptions are: (1) all components of the mixture within a mesh zone experience the same temperature and pressure; and (2) all components under pressure maintain their integrity.

A. Mixtures Composed of Liquids and Solids

The Mie-Grüneisen type of equation of state applies to both solids and liquids and can be used for easy construction of an equation of state for a mixture of solids and liquids.

The initial volume for a hypothetical mixture with n components is

$$\mathcal{V}_0 = \sum_{i=1}^{n} \mathcal{V}_{0i}, \tag{146}$$

where $\mathcal{V}_{0i}$ represents the initial volume of component i. For a specific value of p_H, the total volume of the mixture is

$$\mathcal{V} = \sum_{i=1}^{n} \mathcal{V}_i = \sum_{i=1}^{n} \frac{\mathcal{V}_i}{\mathcal{V}_{0i}} \mathcal{V}_{0i} = \sum_{i=1}^{n} \left(\frac{V_i}{V_{0i}}\right)_{p_H} \mathcal{V}_{0i}, \tag{147}$$

where $\mathcal{V}_i$ is the volume, V_i the specific volume, and $(V_i/V_{0i})_{p_H}$ is the relative specific volume of the component i. The value of V_i/V_{0i} is obtained from the Hugoniot curve for the individual element.

The relative compression of the mixture is obtained from Eqs. 146 and 147:

$$\frac{\mathcal{V}}{\mathcal{V}_0} = \sum_{i=1}^{n} \left(\frac{V_i}{V_{0i}}\right)_{p_H} \frac{\mathcal{V}_{0i}}{\mathcal{V}_0}, \tag{148}$$

where $\mathcal{V}/\mathcal{V}_0$ is the relative volume of the mixture at pressure p_H, and $\mathcal{V}_{0i}/\mathcal{V}_0$ is the volume fraction of component i. A plot of p_H versus $(\mathcal{V}/\mathcal{V}_0)_{p_H}$ as determined by Eq. 148 yields the Hugoniot curve of the mixture of n components.

B. Mixtures Composed of Gases, Liquids, and Solids

For mixtures composed of gases, liquids, and solids, the phenomenon of shock compression is more complex than in mixtures containing only solids and liquids. A satisfactory approximation treats the gases as voids and the remainder of the mixture as porous material. As the shock compression starts, the work of the external pressure is expended in squeezing the voids and in packing the material, thus reducing it to a standard volume (standard volume refers to the condition without internal voids). The energy expended in compressing the gases is neglected. This approximation results in small errors.

1. Hydrodynamic Crushing

In the hydrodynamic crushing, the mixture is assumed to behave hydrodynamically, i.e., with zero shear stresses. The material in each mesh is allowed to be loaded up to its yield stress to overcome the initial

rigidity, and then to compact at constant stresses until the voids are completely closed.

Let V_0 be the standard specific volume of the mixture and V_{00} the specific volume of the porous mixture. Then a $p_H(V,V_0)$ curve can be constructed for the continuous mixture, containing no internal voids, using the approach outlined in Sect. III.A of the first part. If the Mie-Grüneisen coefficient γ is assumed to be a function of volume, the Hugoniot curve of the porous mixture can be approximated by

$$p_H(V,V_{00}) = p_H(V,V_0) + \frac{\gamma}{V}\left[E(V,V_{00}) - E(V,V_0)\right], \tag{149}$$

where

$$\left.\begin{aligned} E(V,V_{00}) &= \frac{1}{2}p_H(V,V_{00})(V_{00} - V) \\ &\text{and} \\ E(V,V_0) &= \frac{1}{2}p_H(V,V_0)(V_0 - V) \end{aligned}\right\} \tag{150}$$

Equation 150 gives the internal energy of the porous and continuous mixture, respectively.

Substitution of Eq. 150 into Eq. 149 and simplification gives

$$p_H(V,V_{00}) = \left[1 + \frac{1 + \dfrac{V_0}{V_{00}}}{\dfrac{V_0}{V_{00}} K - 1}\right] p_H(V,V_0), \tag{151}$$

where

$$K = \frac{2}{\gamma} + 1.$$

Thus, the Hugoniot plot of a mixture is represented by a straight line on the axis V from V_{00} to V_0 and then a curve from V_0 to V, according to Eq. 151.

2. Elastic-Plastic Crushing

In elastic-plastic crushing, the mixture is considered to be elastic-plastic, i.e., shearing and energy dissipation by plastic flow is included in the crushing of voids. For ductile porous materials, the constitutive equation for the dynamic compaction has been discussed by Herrmann.[10] The differential equation for the elastic compression or recompression curves shown in Fig. 9 is given by

$$\frac{d\left(\frac{V}{V_0}\right)}{dp} = \frac{V}{V_0 B_0}\left[1 - \frac{\frac{V}{V_0}}{h^2\left(\frac{V}{V_0}\right)}\right], \tag{152}$$

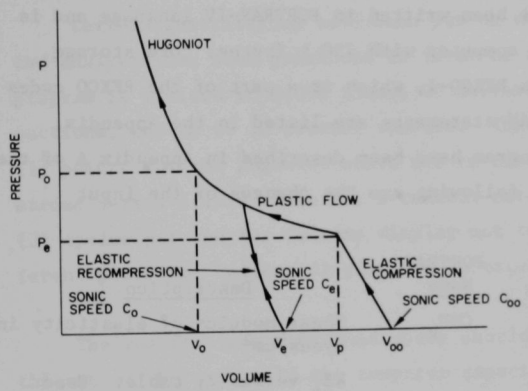

Fig. 9. Elastic-Plastic Behavior of Porous Material before Complete Compaction. ANL Neg. No. 900-807.

where V_0 and B_0 ($= c_0{}^2/V_0$) are the specific volume and bulk modulus of the solid material in the undeformed state, and c_0 is the speed of sound in the solid material. The function $h\left(\frac{V}{V_0}\right)$ is assumed to have a linear relation:

$$h\left(\frac{V}{V_0}\right) = a\frac{V}{V_0} + b, \tag{153}$$

where

$$\left.\begin{aligned} a &= \left(\frac{c_{00}}{c_0} - 1\right)\Big/\left(\frac{V_e}{V_0} - 1\right) \\ b &= 1 - a \end{aligned}\right\}, \tag{154}$$

in which c_0 is the speed of sound in the porous material. The plastic curve is represented by the following quadratic equation:

$$\frac{V - V_0}{V_p - V_0} = \left(\frac{p_0 - p}{p_0 - p_e}\right)^2, \tag{155}$$

The quantities p_0, p_e, V_e, and V_p are defined in Fig. 9. Thus, if sonic speeds c_0 and c_{00} and the elastic limits are known, one can construct an elastic and plastic compressive curve from V_{00} to V_0, when the mixture is fully compacted. After full compaction, one should use the Hugoniot for the hydrodynamic case as outlined above.

IV. DESCRIPTION OF COMPUTER PROGRAM

The computer program has been written in FORTRAN-IV language and is conducted with an IBM-360-75 computer with 750 k (bytes) core storage. The computer code is known as REXCO-I, which is a part of the REXCO codes developed at ANL. The FORTRAN statements are listed in the Appendix. Input instructions to the program have been described in Appendix A of the first part of ANL-7499. The following are the changes of the input instructions:

Card Type	Columns	Format	FORTRAN Name	Description
11	37-45		CNU_k	Shear modulus of elasticity in dynes/cm^2
16		(8F9.0)		KZ_I versus Z_I table. Used only when KPPX > 0 on card of type 15.
	1-9		CX_1	KZ_1
	10-18		CXD_1	Z_1
	19-27		CX_2	KZ_2
	28-36		CXD_2	Z_2

KZ_I is the spring force, in dynes, for the displacement Z_I, in cm.

Use as many cards of type 16 as required.

Note: The KZ_I versus Z_I values are entered in pairs in decreasing order of Z_I, starting with Z_1 (largest displacement), Z_2, ..., to Z_{KPPX}.

Card Type	Columns	Format	FORTRAN Name	Description
17		(8F9.0)		$C\dot{Z}_I$ versus $\dot{Z}_I$ table. Used only when KPPC > 0 on card of type 15.
	1-9		CV_1	$C\dot{Z}_1$
	10-18		CVD_1	$\dot{Z}_1$
	19-27		CV_2	$C\dot{Z}_2$
	28-36		CVD_2	$\dot{Z}_2$

$C\dot{Z}_I$ is the damping force, in dynes, for the velocity $\dot{Z}_I$ in cm/sec.

Use as many cards of type 17 as required.

Note: The $C\dot{Z}_I$ versus $\dot{Z}_I$ values are entered in pairs in decreasing order of $\dot{Z}_I$, starting with $\dot{Z}_1$ (largest velocity), $\dot{Z}_2$, ..., to $\dot{Z}_{KPPC}$.

Certain restrictions have been put on the computer program, although the analysis has been presented in terms of any number of zones. The program is limited to 3,000 zones, 20 different materials, 20 different sections, and up to 10 reactor vessels. The other limitations are: (1) points for the Hugoniot curve not to exceed 50; (2) points for a stress versus strain table for a reactor material not to exceed 50; (3) cycles per run for Calcomp display not to exceed 1,000; and (4) different plots for Calcomp display not to exceed 7.

The restrictions mentioned above should not be regarded as limiting the use of the code. If the computer capacity is sufficiently large, the restrictions can be easily removed by changing the dimensions of the program.

V. COMPARISON WITH EXPERIMENTAL RESULTS

The accuracy of the numerical method has been evaluated by Ash and Julke[11] by comparison with experimental results. The experimental test selected for comparison was performed by the UKAEA. It consisted of an enclosed 2-oz charge of RDX/TNT 60/40 and a rigid containment tank (shown in Fig. 10). The cross section of the tank, positions of the pressure gauges, and the center of the charge are shown in Fig. 11. The idea of using an enclosed charge was to delay the time of arrival of the pressure

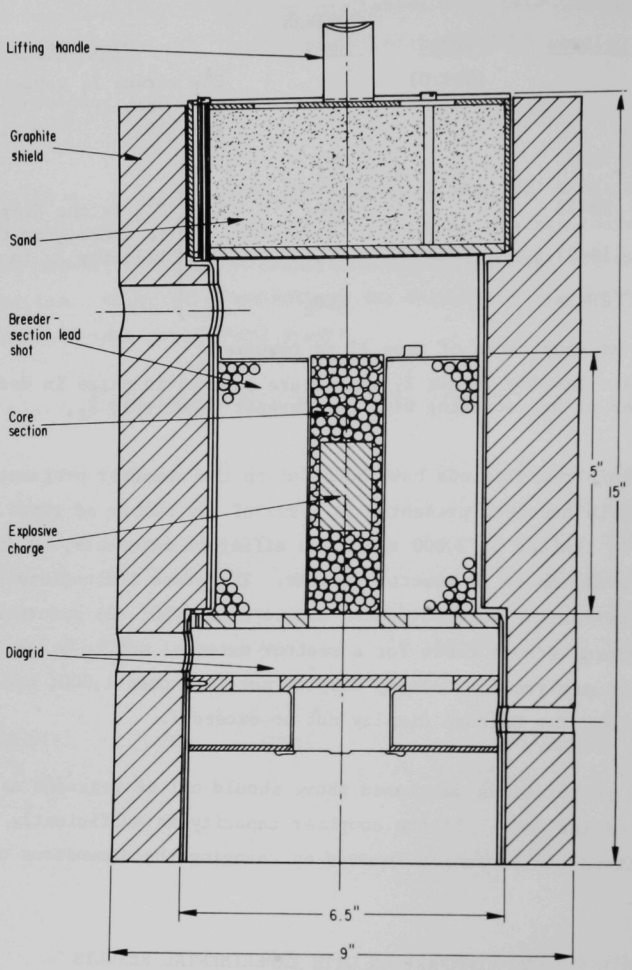

Fig. 10. Cross Section of Model Core and Breeder Structure for UKAEA Experiments [from N. J. M. Rees (UKAEA), A Model Investigation of Explosion Containment in Single Tank Fast Reactors, pp. 692-719 in ANL-7120, Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct. 11-14, 1965]. ANL Neg. No. 900-673.

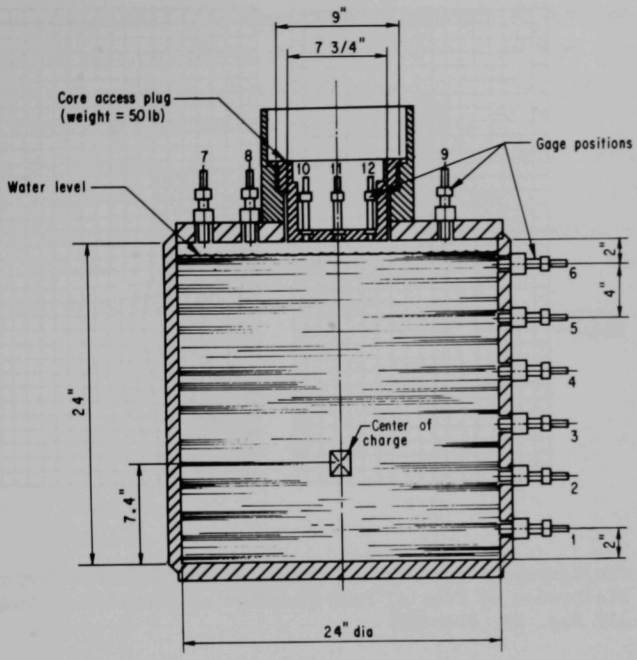

Fig. 11. Cross Section of Model Reactor Tank, Showing Positions of Pressure Gauges and the Center of Charge [from N. J. M. Rees (UKAEA), A Model Investigation of Explosion Containment in Single Tank Fast Reactors, pp. 692-719 in ANL-7120, Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct. 11-14, 1965]. ANL Neg. No. 900-654.

wave reaching the wall and to smear out the wave form. The mathematical model is shown in Fig. 12; because of axisymmetry, only half of the configuration is shown.

The computed pressure history at the position of gauge 3 is shown in Fig. 13. The peak pressure was 0.60 kbar, which was not as low as the measured peak value of 0.24 kbar.[12] The deformation of the grid at the time of peak pressure at the position of gauge 3 is shown in Fig. 12. Subsequent studies reveal that the source of error was in the equation of state of the materials. Particularly unreliable is the description of the lead shot. For instance, if the lead shot was assumed to be water saturated, the energy absorption of the confining structure became

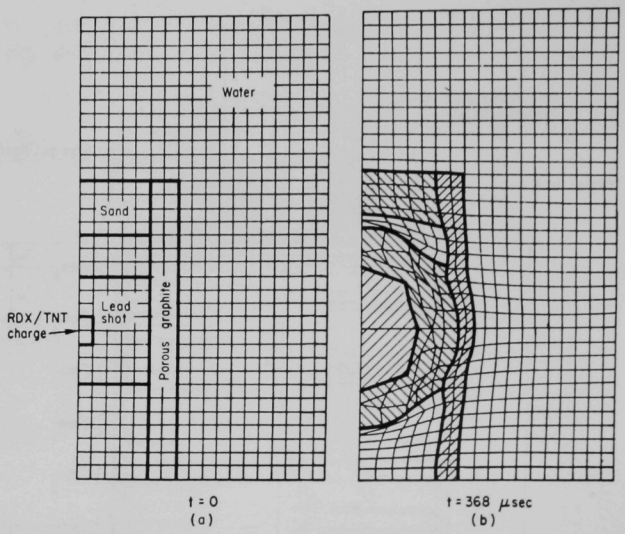

Fig. 12. Configuration of Confined Charge at Initial Time Compared with Distortion of Time of Peak Pressure at Position of Gauge 3. ANL Neg. No. 900-806.

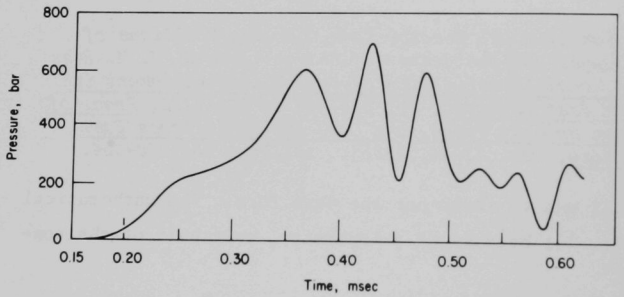

Fig. 13. The Computed Pressure Trace at the Position of Gauge 3 for the Confined Charge. ANL Neg. No. 900-678.

unrealistically low. If the lead shot was treated as a truly porous material and was allowed to absorb the energy in the crushing of the voids, the peak pressure was attenuated to one-half of the peak for the water-filled voids. Since the performance of a similar code, REXCO-H,[13] has been well-established by comparison with experimental results, it is fairly clear that the discrepancy is due largely to the inaccurate description of the lead shot rather than to deficiencies in the basic REXCO-I code. In one of the trial computations, all materials were

treated hydrodynamically; the computer peak pressure at the position of gauge 3 was 1.1 kbar, which was about twice as much as that calculated based upon elastic-plastic behavior of materials. This leads to the important conclusion that shear stress and plastic-flow effects cannot be ignored in the analysis, and that development of inelastic codes parallel to hydrodynamic codes is necessary. As a final remark, to obtain a better correlation with the experiments, an improvement on the equations of state is needed, especially when the material to be treated is not homogeneous and isotropic as in the case of lead shot.

APPENDIX

FORTRAN Program Listing

```
C       MAIN PROGRAM
C       J.GVILDYS-2/27/68
C       TWO-DIMENSIONAL REACTOR ACCIDENT ANALYSIS
        IMPLICIT REAL*8(A-H,O-Z)
        COMMON /O/ R(3000),Z(3000),RDOT(3000),ZDOT(3000),E(3000),P(3000),
       1RHO(3000),VP(3000),SC(3000),SDR(3000),SDZ(3000),SDT(3000),SRZ(3000
       2),MZERO(3000),RO(3000),ZO(3000),SSR(3000),SSZ(3000),SST(3000),
       3SSRZ(3000),STR(3000),STZ(3000),KTX(3000),KTY(3000)
        DIMENSION TITLE(20)
        DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
       1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
       2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
        DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20)
        DIMENSION CIJ(50),CXIJ(1000)
        COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
       1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
       2,KXP(20),KYP(20),KXYP(1000)
        COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
        COMMON    KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
        COMMON I11(10),I12(10),I21(10),I22(10),J11(10),J12(10),J21(10),
       1J22(10),I1X,I2X,J1X,J2X,KK(120)
        COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
       1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
       1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
       3,PLGF(1000),TME(1000),PRS(6,1000)
        REAL*4 TME,PLGF,PRS,TIN
        REAL*4 TITLE
        REAL*8 MZERO
        INTEGER*2 KTX,KTY
C       FORMATS FOR MAIN PROGRAM
  500 FORMAT(18A4)
  502 FORMAT(5I6,3F12.0)
  503 FORMAT(6F12.0)
  504 FORMAT(12I6)
  505 FORMAT(3I6,2F12.0)
  506 FORMAT(1H1,20X,18A4)
  508 FORMAT(1H0,' NO OF R ZONES =',I3,' NO OF Z ZONES =',I3,
     1' INITIAL D-TIME =',E15.7)
  510 FORMAT(1H0,' LIMITING CONSTANTS'/1H0,' MAX CYCLES =',I5,
     1' MAX TIME =',E15.7,' MAX DISTORTION =',E15.7,
     2' MAX D-TIME =',E15.7)
  512 FORMAT(1H0,' OUTPUT PARAMETERS')
  514 FORMAT(1H0,' DETAILED FULL ACCURACY PRINTOUT EVERY ',I3,
     1' CYCLE UNTIL',I6,' PRINTOUT')
  516 FORMAT(1H0,' LIMITED ACCURACY DISPLAY PRINTOUT OF 2D RESULTS EVERY
     1',I3,' CYCLE')
  518 FORMAT(1H0,' PICTURE DISPLAY EVERY ',I3,' CYCLE')
  520 FORMAT(1H0,' INITIAL WMAX=',E15.7,' D-TIME=',E15.7)
  522 FORMAT(1H0,' CHANGED WMAX=',E15.7,' D-TIME=',E15.7)
  524 FORMAT(1H0,' AT CYCLE',I5,' TIME=',E15.7,' D-TIME=',E15.7,
     1' DISTORT=',E15.7,' AT ZONE ',2I4,/'  WMAX=',E15.7,' AT ZONE',2I4)
  526 FORMAT(////,'   HYDRODYNAMICS ERROR STOP')
  528 FORMAT(1H0,' CALCULATED WMAX=',E15.7,' D-TIME=',E15.7)
  530 FORMAT(1H0,' ADJUSTED   WMAX=',E15.7,' D-TIME=',E15.7)
  532 FORMAT(1H0,' STOP  WMAX GREATER THAN 0.14')
```

```
534 FORMAT(1H1,5HCYCLE,5X,4HTIME,7X,10HPLUG FORCE,2X,12HPRESSURE AT ,
   12I3,5(8X,2I3))
536 FORMAT(I6,2E14.6,4X,6E14.6)
    DO 20 I=1,3000
    R(I)=0.
    Z(I)=0.
    RDOT(I)=0.
    ZDOT(I)=0.
    RO(I)=0.
    ZO(I)=0.
    MZERO(I)=C.
    E(I)=0.
    P(I)=0.
    RHO(I)=0.
    VP(I)=0.
    SC(I)=0.
    SSR(I)=0.
    SSZ(I)=0.
    SST(I)=0.
    SDR(I)=0.
    SDZ(I)=0.
    SDT(I)=0.
    SRZ(I)=0.
    STR(I)=0.
    STZ(I)=0.
    KTX(I)=0
    SSRZ(I)=0.
    KTY(I)=0
 20 CONTINUE
    DC 25 I=1,20
    PO(I)=0.
    EO(I)=0.
    GO(I)=0.
    CO(I)=0.
    AA(I)=0.
    BB(I)=0.
    CC(I)=0.
    CRHO(I)=0.
    CE(I)=0.
    CP(I)=0.
    CYO(I)=0.
    CNU(I)=0.
    VO(I)=0.
    CCP(I)=0.
    CCK(I)=0.
    CPLG(I)=0.0
    CWB(I)=0.
    CWN(I)=0.
    CO 25 J=1,50
    PP(I,J)=0.
    VV(I,J)=0.
 25 CONTINUE
    DO 26 J=1,50
    CIJ(J)=0.
    CX(J)=0.
```

```
      CV(J)=0.
      CXD(J)=0.
      CVD(J)=0.
      KI1(J)=0
      KI2(J)=0
      KJ1(J)=0
      KJ2(J)=0
   26 CONTINUE
      DO 27 I=1,1000
      KXI(I)=0
      KXJ(I)=0
      KXYP(I)=0
      CXIJ(I)=0.
      PLGF(I)=0.
      TME(I)=0.
      DO 27 J=1,6
      PRS(J,I)=C.
   27 CONTINUE
      READ 500,(TITLE(I),I=1,18)
C     INITIAL CONFIGURATION
      READ 502,IMAX,JMAX,KB1,KB2,KB3,TIME,DELT,DELTM
C     LIMITING CRITERIA CONSTANTS
      READ 503,CYCLM,TMAX,DISTM,DE1,DE2
      TIN=TIME
      IF(CYCLM)60,40,60
   40 CYCLM=10000.
   60 IF(TMAX)100,80,100
   80 TMAX=10000.
  100 IF(DISTM)120,110,120
  110 DISTM=10000.
C     OUTPUT CONSTANTS
  120 READ 504,IOUA,INUMBA,IOUB,IOUC,IOUT
      JQQ=IOUB
      MCYCL=CYCLM
      CX1=1.
      CX2=1.
      CX3=1.
      IF(KB1.EQ.0)GO TO 122
      CX1=-1.
  122 IF(KB2.EQ.0)GO TO 124
      CX2=-1.
  124 IF(KB3.EQ.0)GO TO 126
      CX3=-1.
  126 CONTINUE
      IF(DE1.NE.0.0)GO TO 128
      DE1=0.001
      DE2=0.005
  128 CONTINUE
      PRINT 506,(TITLE(I),I=1,18)
      PRINT 508,IMAX,JMAX,DELT
      PRINT 510,MCYCL,TMAX,DISTM,DELTM
      PRINT 512
      IF(IOUA)140,140,130
  130 PRINT 514,IOUA,INUMBA
      INUMBA=INUMBA-1
```

```
140 IF(IOUB)160,160,150
150 PRINT 516,IOUB
160 IF(IOUC)180,180,170
170 PRINT 518,IOUC
180 CONTINUE
    IMAX1=IMAX+1
    IMAX2=IMAX+2
    IMAX3=IMAX+3
    JMAX1=JMAX+1
    JMAX2=JMAX+2
    JMAX3=JMAX+3
    IP1=2
    IP2=26
    IX=IMAX1/25
    IF(IX)186,186,182
182 DO 184 I=1,IX
    I11(I)=IP1
    I12(I)=IP2
    I21(I)=IP1
    I22(I)=IP2
    IP1=IP1+25
    IP2=IP2+25
184 CONTINUE
186 IXX=IMAX1-IX*25
    IF(IXX)190,190,188
188 I1X=IX+1
    I2X=I1X
    I11(I1X)=IP1
    I12(I1X)=IMAX1
    I21(I2X)=IP1
    I22(I2X)=IMAX2
    GO TO 192
190 I1X=IX
    I2X=IX+1
    I21(I2X)=IP1
    I22(I2X)=IMAX2
192 JP1=2
    JP2=51
    JX=JMAX1/50
    IF(JX)198,198,194
194 DO 196 I=1,JX
    J11(I)=JP1
    J12(I)=JP2
    J21(I)=JP1
    J22(I)=JP2
    JP1=JP1+50
    JP2=JP2+50
196 CONTINUE
198 JXX=JMAX1-JX*50
    IF(JXX)202,202,200
200 J1X=JX+1
    J2X=J1X
    J11(J1X)=JP1
    J12(J1X)=JMAX1
    J21(J2X)=JP1
```

```
      J22(J2X)=JMAX2
      GO TO 204
  202 J1X=JX
      J2X=JX+1
      J21(J2X)=JP1
      J22(J2X)=JMAX2
  204 CONTINUE
      DO 208 I=1,120
      KK(I)=I
  208 CONTINUE
      ITIMA=0
      NCL=0
      ISTOP=0
      NCYCL=0
      IQQ=0
      LAST=-1
      IF(IOUT-1)215,215,210
  210 CALL OTAPE (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
     1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY,IOUT)
      TIN=TIME
      GO TO 470
  215 CONTINUE
      CALL HYDROI(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
     1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
      IF(IOUC.EQ.0)GO TO 220
      CALL PICT(R,Z,P,LAST)
  220 INDEXA=1
      IF(IOUA)240,240,650
  240 IF(IOUB)260,260,700
  260 PRINT 520,WMAX,DELT
  280 IF(WMAX.LT.0.14)GO TO 300
      DELT=0.5*DELT
      WMAX=0.25*WMAX
      PRINT 522,WMAX,DELT
      GO TO 280
  300 IF(WMAX.GT.0.035)GO TO 350
      IF(DELT.GT.0.5*DELTM)GO TO 350
      DELT=2.0*DELT
      WMAX=4.0*WMAX
      PRINT 522,WMAX,DELT
      GO TO 300
  350 CALL HYDRO (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
     1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
      IF(DABS(EZERO-EB)/EZERO.LT.DE1)GO TO 360
      IOUA=1
      INUMBA=MCYCL
      IF(DABS(EZERO-EB)/EZERO.GT.DE2)ISTOP=1
  360 CONTINUE
      NCYCL=NCYCL+1
      PRINT 524,NCYCL,TIME,DELT,DIST,IDM,JDM,WMAX,IW,JW
      IF(ISTOP.EQ.0)GO TO 370
      GO TO 450
  370 INDEXA=2
      IF(IOUA.EQ.0)GO TO 375
      IF(MOD(NCYCL,IOUA).EQ.0.AND.ITIMA.LE.INUMBA)GO TO 380
```

```
375 CONTINUE
    INDEXB=0
    GO TO 390
380 ITIMA=ITIMA+1
    INDEXB=1
    GO TO 650
390 IF(IOUB.EQ.0)GO TO 400
    IF(MOD(NCYCL,IOUB).EQ.0)GO TO 700
400 IF(IOUC.EQ.0)GO TO 405
    IF(MOD(NCYCL,IOUC).EQ.0)
   1CALL PICT(R,Z,P,LAST)
405 CONTINUE
410 IF(NCYCL-MCYCL)420,450,450
420 IF(TIME  - TMAX)430,450,450
430 IF(DIST  - DISTM)470,450,450
450 LAST=1
    IF(IOUB.EQ.0)GO TO 455
    INDEXA=3
    GO TO 700
455 CONTINUE
    IF(IOUC.NE.0)
   1CALL PICT(R,Z,P,LAST)
    IF(INDEXB.EQ.1.OR.IOUA.EQ.0)GO TO 750
    INDEXA=3
    GO TO 650
470 CONTINUE
475 IF(WMAX.GT.20.0)GO TO 490
    IF(WMAX.LT.0.14)GO TO 480
    DELT=0.5*DELT
    WMAX=0.25*WMAX
    PRINT 530,WMAX,DELT
    GO TO 475
480 IF(WMAX.GT.0.035)GO TO 350
    IF(DELT.GT.(0.5*DELTM))GO TO 350
    DELT=2.0*DELT
    WMAX=4.0*WMAX
    PRINT 530,WMAX,DELT
    GO TO 480
490 PRINT 532
    GO TO 450
650 CONTINUE
    CALL PRINTF(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
   1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
    GO TO (240,390,750),INDEXA
700 CONTINUE
    CALL PRINTL(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
   1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
    GO TO (260,400,455),INDEXA
750 CONTINUE
    IF(NPP.LE.0)GO TO 777
    PRINT 534,(KXP(L),KYP(L),L=1,NPP)
    DO 776 I=1,NCL
    PRINT 536,KXYP(I),TME(I),PLGF(I),(PRS(L,I),L=1,NPP)
776 CONTINUE
    GO TO 779
```

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777 CONTINUE
    IF(KPL1.LE.0)GO TO 779
    PRINT 535
535 FORMAT(1H1,5HCYCLE,5X,4HTIME,7X,10HPLUG FORCE)
    DO 778 I=1,NCL
    PRINT 536,KXYP(I),TME(I),PLGF(I)
778 CONTINUE
779 CONTINUE
    CALL CALC(NCL,NPP,KPL1,KXP,KYP,TME,PLGF,PRS,TITLE,TIN)
    IF(IOUT-1)770,760,770
760 CALL OTAPE (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
   1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY,IOUT)
770 STOP
    END
```

```
    SUBROUTINE CALC(NCL,NPP,KPL1,KXP,KYP,TME,PLGF,PRS,TITLE,TIN)
    DIMENSION KXP(20),KYP(20),TME(1000),PLGF(1000),PRS(6,1000),
   1DATA(1000),TITLE(18),CXY(1000)
    DIMENSION U1(2),U2(3),U3(5),U4(5),U6(4),U7(2),U5(2)
    DIMENSION SCTK(10)
    DATA U1/'  TIME  '/,U2/'PLUG FORCE'/,U3/'AXIAL DISPLACEMENT'/,
   1U4/'RADIAL DISPLACEMENT'/,U5/'AT ZONE'/,U6/'AT MESH POINT'/,
   2U7/'PRESSURE'/
501 FORMAT(I6,(6F12.0))
502 FORMAT(I6,7E15.7)
    IF(NPP.NE.0)GO TO 16
    READ 501,KCAL,SCT,SCT1
    PRINT 502,KCAL,SCT,SCT1
    GO TO 18
 16 CONTINUE
    READ 501,KCAL,SCT,SCT1,(SCTK(K),K=1,NPP)
    PRINT 502,KCAL,SCT,SCT1,(SCTK(K),K=1,NPP)
 18 CONTINUE
    IF(KCAL)200,200,20
 20 CALL PLOTS(DATA(1),4000,49)
    CALL PLOT(5.0,0,-3)
    CALL SYMBOL(0,5.0,0.14,TITLE(1),0,72)
    CALL PLOT(11.0,0,-3)
    IF(SCT.LE.0.0)SCT=.0001
    XMAX=(TME(NCL)-TIN)/SCT
    IF(KPL1)60,60,30
 30 CALL AXIS(0,0,U1,-8,XMAX,0,TIN,SCT,10.0)
    CALL SCALE(PLGF,10.0,NCL,1,10.0)
    PMIN=PLGF(NCL+1)
    PDEL=PLGF(NCL+2)
    IF(SCT1.NE.0.0)PDEL=SCT1
    CALL AXIS(0,0,U2,10,10.0,90.0,PMIN,PDEL,10.0)
    X=0.
    Y=(PLGF(1)-PMIN)/PDEL
    IF(Y.GE.10.0)Y=10.0
    CALL PLOT(X,Y,3)
```

```
      DO 50 I=1,NCL
      X=(TME(I) -TIN)/SCT
      Y=(PLGF(I)-PMIN)/PDEL
      IF(Y.GE.10.0)Y=10.0
      CALL PLOT(X,Y,2)
   50 CONTINUE
      KNEW=XMAX+2.
      XNEW=KNEW
      CALL PLOT(XNEW,0,-3)
      IF(NPP)180,180,60
   60 DO 150 L=1,NPP
      DO 70 I=1,NCL
      CXY(I)=PRS(L,I)
   70 CONTINUE
      CALL SCALE(CXY,10.0,NCL,1,10.0)
      FMIN=CXY(NCL+1)
      FDEL=CXY(NCL+2)
      IF(SCTK(L).NE.0.0)FDEL=SCTK(L)
      IF(KXP(L).GT.0)GO TO 80
      CALL SYMBCL(0,5.0,0.14,U4,0.0,19)
   75 CALL SYMBCL(0,4.5,0.14,U6,0.0,13)
      KXPL=IABS(KXP(L))
      KYPL=IABS(KYP(L))
      CALL NUMBER(1.8,4.5,0.14,FLOAT(KXPL),0.0,-1)
      CALL NUMBER(2.4,4.5,0.14,FLOAT(KYPL),0.0,-1)
      GO TO 100
   80 IF(KYP(L).GT.0)GO TO 90
      CALL SYMBCL(0,5.0,0.14,U3,0.0,18)
      GO TO 75
   90 CALL SYMBCL(0,5.0,0.14,U7,0.0,8)
      CALL SYMBCL(0,4.5,0.14,U5,0.0,7)
      CALL NUMBER(1.0,4.5,0.14,FLOAT(KXP(L)),0.0,-1)
      CALL NUMBER(1.5,4.5,0.14,FLOAT(KYP(L)),0.0,-1)
  100 CALL PLOT(3.0,0.0,-3)
      CALL AXIS(0,0,U1,-8,XMAX,0,TIN,SCT,10.0)
      CALL AXIS(0,0,2H  ,2,10.0,90.0,FMIN,FDEL,10.0)
      X=0.
      Y=(CXY(1)-FMIN)/FDEL
      IF(Y.GE.10.0)Y=10.0
      CALL PLOT(X,Y,3)
      DO 120 I=1,NCL
      X=(TME(I)-TIN)/SCT
      Y=(CXY(I)-FMIN)/FDEL
      IF(Y.GE.10.0)Y=10.0
      CALL PLOT(X,Y,2)
  120 CONTINUE
      KNEW=XMAX+2.
      XNEW=KNEW
      CALL PLOT(XNEW,0,-3)
  150 CONTINUE
  180 CALL PLOT(0,0,999)
  200 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OTAPE (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,
     1SST,SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY,IOUT)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION KR1(50),KR2(50),KZ1(50),KZ2(50),KTM(50),CRHO(20),
     1CE(20),CP(20),KT1(20),KT2(20)
      DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3),
     1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX
     23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3),
     3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3)
      DIMENSION TITLE(20)
      DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3)
      DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ(I
     1MAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3)
      DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
     1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
     2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
      DIMENSION CYO(20),CNU(20)
      DIMENSION CIJ(50),CXIJ(1000)
      COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
     1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
     2,KXP(20),KYP(20),KXYP(1000)
      COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
      COMMON    KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
      COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
     1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
     1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
     3,PLGF(1000),TME(1000),PRS(6,1000)
      REAL*4 TME,PLGF,PRS,TIN
      REAL*4 TITLE
      REAL*8 MZERO
      INTEGER*2 KTX,KTY
      REWIND 8
      REWIND 9
      GO TO (100,200,300),IOUT
  100 WRITE (8)NCYCL,TIME,DELT,DIST,DELTO,WMAX,IW,JW,KB1,KB2,KB3,
     1IQQ,JQQ,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG,CPLG
      WRITE(8)R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,KTX,KTY,
     1PP,VV,PO,EO,GO,CO,AA,BB,CC,VO,SSR,SSZ,SST,CCP,CCK,KXI,KXJ
     2,CV,CVD,CX,CXD,CRHO,CE,CP,EZERO,CWB,CWN,IDM,JDM
     3,SDR,SDZ,SRZ,STR,STZ,SSRZ,CIJ,CXIJ,CNU,CYO,KXP,KYP,KXYP
      END FILE 8
      GO TO 450
  200 CONTINUE
  220 READ (9)NCYCL,TIME,DELT,DIST,DELTO,WMAX,IW,JW,KB1,KB2,KB3,
     1IQQ,JQQ,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG,CPLG
      READ (9)R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,KTX,KTY,
     1PP,VV,PO,EO,GO,CO,AA,BB,CC,VO,SSR,SSZ,SST,CCP,CCK,KXI,KXJ
     2,CV,CVD,CX,CXD,CRHO,CE,CP,EZERO,CWB,CWN,IDM,JDM
     3,SDR,SDZ,SRZ,STR,STZ,SSRZ,CIJ,CXIJ,CNU,CYO,KXP,KYP,KXYP
      GO TO 450
  300 IOUT=1
      GO TO 220
  450 RETURN
      END
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      SUBROUTINE HYDROI(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,
     1SST,SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION KR1(50),KR2(50),KZ1(50),KZ2(50),KTM(50),CRHO(20),
     1CE(20),CP(20),KT1(20),KT2(20)
      DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3),
     1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX
     23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3),
     3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3)
      DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3)
      DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ(I
     1MAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3)
      DIMENSION TITLE(20)
      DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
     1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
     2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
      DIMENSION CYO(20),CNU(20)
      DIMENSION CIJ(50),CXIJ(1000)
      COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
     1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
     2,KXP(20),KYP(20),KXYP(1000)
      COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
      COMMON    KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
      COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
     1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
     1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
     3,PLGF(1000),TME(1000),PRS(6,1000)
      REAL*4 TME,PLGF,PRS,TIN
      REAL*4 TITLE
      REAL*8 MZERO
      INTEGER*2 KTX,KTY
      DATA PI/3.1415926536/
  502 FORMAT(8F9.0)
  504 FORMAT(I6)
  506 FORMAT(12I6)
  508 FORMAT(6F9.0,I3)
  510 FORMAT(2I3,7F9.0,2I3)
  512 FORMAT(1HC,' ERROR IN THE INPUT CARDS  ',/'  ZONE('I3,','I3,
     1')-R AND Z ON CARDS ARE ',2F9.3,' V.S. EXPECTED '2F9.3)
  514 FORMAT(1HO,' TOTAL ENERGY AT START=',E15.7)
  516 FORMAT(8F9.0)
  520 FORMAT('O MATERIAL CONSTANTS')
  522 FORMAT(1HC,I3,6E15.7,I4)
  524 FORMAT(4X,8E15.7)
  526 FORMAT(1HC,3X,5E15.7)
  528 FORMAT(5I6,F12.0,2I6,F12.0)
  529 FORMAT(2I5,7E15.7,2I3)
  534 FORMAT(1HC,' PLUG CONSTANTS ',/5I6,E15.7,/18X,2I6,E15.7)
      PI2=2.*PI
C     READ R AND Z COORDINATES
      READ 502,(R(I,2),I=2,IMAX2)
      READ 502,(Z(2,J),J=2,JMAX2)
      DO 100 J=2,JMAX2
      DO 100 I=2,IMAX2
      R(I,J)=R(I,2)
```

```
      Z(I,J)=Z(2,J)
  100 CONTINUE
      READ 504,NSEC
      PRINT 504,NSEC
C     NSEC-NO OF RECTANGULAR SECTIONS IN THE SYSTEM
      DO 120 K=1,NSEC
      READ 506,KR1(K),KR2(K),KZ1(K),KZ2(K),KT1(K),KT2(K),KTM(K)
      PRINT 506,KR1(K),KR2(K),KZ1(K),KZ2(K),KT1(K),KT2(K),KTM(K)
  120 CONTINUE
C     KR1 AND KZ1 ARE INITIAL ZONE NUMBERS,KR2 AND KZ2 ARE FINAL
C     ZONE NUMBERS IN R AND Z DIRECTIONS-KTM IS MATERIAL CARD INDICATOR
      READ 504,NMAT
C     NMAT-NO OF DIFFERENT MATERIAL CARDS
      PRINT 520
      DO 140 K=1,NMAT
      READ 508,AA(K),BB(K),CC(K),CRHO(K),CE(K),CP(K),KKK
      PRINT 522,K,AA(K),BB(K),CC(K),CRHO(K),CE(K),CP(K),KKK
      READ  502,CWN(K),CWB(K),CPLG(K),CYO(K),CNU(K)
      PRINT 526,CWN(K),CWB(K),CPLG(K),CYO(K),CNU(K)
      IF(KKK)140,140,130
  130 READ 516, (PP(K,I),VV(K,I),I=1,KKK)
      PRINT 524,(PP(K,I),VV(K,I),I=1,KKK)
      READ  502,PO(K),ROK,EO(K),GO(K),CO(K)
      PRINT 526,PO(K),ROK,EO(K),GO(K),CO(K)
      VO(K)=1./ROK
  140 CONTINUE
C     CRHO,CE,CP,KT1,KT2 ARH THE INITIAL RHO,E,P,KTX AND KTY VALLIES
      DO 250 K=1,NSEC
      L=KT1(K)
      I1=KR1(K)
      I2=KR2(K)
      J1=KZ1(K)
      J2=KZ2(K)
      IF(KTM(K))200,200,160
  160 DO 180 J=J1,J2
      DO 180 I=I1,I2
      RHO(I,J)=CRHO(L)
      E(I,J)=CE(L)
      P(I,J)=CP(L)
      RDOT(I,J)=0.
      ZDOT(I,J)=0.
      KTX(I,J)=KT1(K)
      KTY(I,J)=KT2(K)
  180 CONTINUE
      GO TO 250
  200 CONTINUE
C     CARD INPUT FOR THE CORE SECTION
      DO 210 J=J1,J2
      DO 210 I=I1,I2
      READ 510,II,JJ,RC1,ZC1,RDOT(I,J),ZDOT(I,J),RHO(I,J),E(I,J),P(I,J),
     1KTX(I,J),KTY(I,J)
      PRINT 529,II,JJ,RC1,ZC1,RDOT(I,J),ZDOT(I,J),RHO(I,J),E(I,J),P(I,J)
     1,KTX(I,J),KTY(I,J)
      IF(RC1.EQ.R(I,J).AND.ZC1.EQ.Z(I,J))GO TO 210
      PRINT 512,II,JJ,RC1,ZC1,R(I,J),Z(I,J)
```

```
      STOP
  210 CONTINUE
  250 CONTINUE
      WMAX=0.
      DO 260 I=2,IMAX2
      R(I,1)=R(I,3)
      Z(I,1)=Z(I,2)-(Z(I,3)-Z(I,2))
      R(I,JMAX3)=R(I,JMAX1)
      Z(I,JMAX3)=Z(I,JMAX2)+(Z(I,JMAX2)-Z(I,JMAX1))
  260 CONTINUE
      DO 270 J=1,JMAX3
      R(1,J)=-R(3,J)
      Z(1,J)=Z(3,J)
      R(IMAX3,J)=R(IMAX2,J)+(R(IMAX2,J)-R(IMAX1,J))
      Z(IMAX3,J)=Z(IMAX1,J)
  270 CONTINUE
      DO 275 J=1,JMAX2
      RHO(IMAX2,J)=RHO(IMAX1,J)
  275 CONTINUE
      DO 300 J=2,JMAX1
      DO 300 I=2,IMAX2
      A1=0.5*((Z(I+1,J+1)-Z(I,J))*(R(I+1,J)-R(I,J+1))
     1-(R(I+1,J+1)-R(I,J))*(Z(I+1,J)-Z(I,J+1)))
      IF(I.EQ.IMAX2)GO TO 280
      LX=KTX(I,J)
      W=(CWN(LX)*(P(I,J)+CWB(LX))/(RHO(I,J)*A1))*(DELT/1.2)**2
      IF(W.LE.WMAX)GO TO 280
      WMAX=W
      IW=I
      JW=J
  280 CONTINUE
      RBAR1=0.25*(R(I,J+1)+R(I+1,J+1)+R(I+1,J)+R(I,J))
  300 MZERO(I,J)=A1*RBAR1*RHO(I,J)
      DO 340 I=2,IMAX1
      KTX(I,1)=KTX(I,2)
      KTY(I,1)=KTY(I,2)
      KTX(I,JMAX2)=KTX(I,JMAX1)
      KTY(I,JMAX2)=KTY(I,JMAX1)
      MZERO(I,1)=MZERO(I,2)
      MZERO(I,JMAX2)=MZERO(I,JMAX1)
  340 CONTINUE
      DO 360 J=1,JMAX2
      KTX(1,J)=KTX(2,J)
      KTY(1,J)=KTY(2,J)
      KTX(IMAX2,J)=KTX(IMAX1,J)
      KTY(IMAX2,J)=KTY(IMAX1,J)
      MZERO(1,J)=MZERO(2,J)
  360 CONTINUE
      MZERO(IMAX2,JMAX2)=MZERO(IMAX2,JMAX1)
      MZERO(IMAX2,1)=MZERO(IMAX2,2)
      EZERO=0.
      DO 380 J=2,JMAX2
      DO 380 I=2,IMAX2
      IF(I.EQ.IMAX2.OR.J.EQ.JMAX2)GO TO 370
      EZERO=EZERO+PI2*MZERO(I,J)*E(I,J)
```

```
370 CONTINUE
    RO(I,J)=R(I,J)
    ZO(I,J)=Z(I,J)
380 CONTINUE
    READ 528,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG
    PRINT 534,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG
    IF(KPPX.LE.0)GO TO 80
    READ  516,(CX(I),CXD(I),I=1,KPPX)
    PRINT 524,(CX(I),CXD(I),I=1,KPPX)
 80 IF(KPPC.LE.0)GO TO 82
    READ 516,(CV(I),CVD(I),I=1,KPPC)
    PRINT 524,(CV(I),CVD(I),I=1,KPPC)
 82 CONTINUE
 86 CONTINUE
    READ 504,NPP
    PRINT 504,NPP
    IF(NPP.LE.0)GO TO 88
    READ  506,(KXP(L),KYP(L),L=1,NPP)
    PRINT 506,(KXP(L),KYP(L),L=1,NPP)
 88 CONTINUE
    PRINT 514,EZERC
    DELTO=0
    DIST=0.
    IQQ=0
    IX=0
    DO 450 I=2,IMAX2
    DO 450 J=2,JMAX2
    LX1=KTX(I,J)
    LX2=KTX(I-1,J)
    LX3=KTX(I-1,J-1)
    LX4=KTX(I,J-1)
    IF(CPLG(LX1).EQ.0)GO TO 434
    IF(CPLG(LX2).EQ.0)GO TO 428
    IF(CPLG(LX3).EQ.0)GO TO 424
    IF(CPLG(LX4).EQ.0)GO TO 422
    GO TO 450
422 IX=IX+1
    KXI(IX)=I
    KXJ(IX)=J
    CXIJ(IX)=3.
    GO TO 450
424 IF(CPLG(LX4).NE.0)GO TO 422
426 IX=IX+1
    KXI(IX)=I
    KXJ(IX)=J
    CXIJ(IX)=2.
    GO TO 450
428 IF(CPLG(LX3).NE.0)GO TO 422
    IF(CPLG(LX4).NE.0)GO TO 426
432 IX=IX+1
    KXI(IX)=I
    KXJ(IX)=J
    CXIJ(IX)=1.
    GO TO 450
434 IF(CPLG(LX2).NE.0)GO TO 436
```

```
      IF(CPLG(LX3).NE.0)GO TO 438
      IF(CPLG(LX4).NE.0)GO TO 432
      GO TO 450
  436 IF(CPLG(LX3).EQ.0)GO TO 432
      IF(CPLG(LX4).EQ.0)GO TO 426
      GO TO 422
  438 IF(CPLG(LX4).EQ.0)GO TO 432
      GO TO 426
  450 CONTINUE
      IQQ=IX
      RETURN
      END
```

```
      SUBROUTINE HYDRO (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,
     1SST,SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3),
     1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX
     23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3),
     3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3)
      DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3)
      DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ(I
     1MAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3)
      DIMENSION TITLE(20)
      DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
     1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
     2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
      DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20)
      DIMENSION CIJ(50),CXIJ(1000)
      COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
     1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
     2,KXP(20),KYP(20),KXYP(1000)
      COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
      COMMON     KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
      COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
     1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
     1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
     3,PLGF(1000),TME(1000),PRS(6,1000)
      REAL*4 TME,PLGF,PRS,TIN
      REAL*4 TITLE
      REAL*8 MZERO
      INTEGER*2 KTX,KTY
      DATA PI/3.1415926536/
  504 FORMAT(' PRESSURE-ENERGY ITERATION HAS NOT CONVERGED FOR POINT',
     12I5)
  506 FORMAT(1H0,7X,'TIME    INTERNAL ENERGY KINETIC ENERGY',3X,
     1'TOTAL ENERGY',/4E15.7)
  512 FORMAT(5X,' FORCE ON PLUG EXCEEDS ALLOWABLE VALUE ',2E15.7)
  513 FORMAT(5X,' ALLOWABLE STRAIN IS EXCEEDED')
  517 FORMAT(2I6,8E14.6,/12X,8E14.6)
  519 FORMAT(' PLASTICITY EXISTS AT ZONE ',2I3,' FAILURE INDEX =',E15.7)
```

```
      PIO4=PI/4.
      PI2=PI*2.
      PIO2=PI/2.
      TKE=0.
      TIE=0.
      WMAX=0.
      SOUND=2.5D5
      UEP=1.0
      REP=1.0E-6
      PEP=1.0E-4
      DIST=0.
      PHP=-CYO(3)/3.
      DELTB=0.5*(DELTO+DELT)
      TM=TIME+0.5*DELT
      TIME=TIME+DELT
      DELTO=DELT
      DO 40 I=2,IMAX2
      R(I,1)=R(I,3)
      Z(I,1)=Z(I,2)-(Z(I,3)-Z(I,2))
      R(I,JMAX3)=R(I,JMAX1)
      Z(I,JMAX3)=Z(I,JMAX2)+(Z(I,JMAX2)-Z(I,JMAX1))
   40 CONTINUE
      DO 60 J=1,JMAX3
      R(1,J)=-R(3,J)
      Z(1,J)=Z(3,J)
      R(IMAX3,J)=R(IMAX2,J)+(R(IMAX2,J)-R(IMAX1,J))
      Z(IMAX3,J)=Z(IMAX1,J)
   60 CONTINUE
      DO 80 I=2,IMAX1
      RHO(I,1)=RHO(I,2)
      P(I,1)=CX3*P(I,2)
      SDR(I,1)=CX3*SDR(I,2)
      SDZ(I,1)=CX3*SDZ(I,2)
      SDT(I,1)=CX3*SDT(I,2)
      SRZ(I,1)=-SRZ(I,2)
      RHO(I,JMAX2)=RHO(I,JMAX1)
      P(I,JMAX2)=CX1*P(I,JMAX1)
      SDR(I,JMAX2)=CX1*SDR(I,JMAX1)
      SDZ(I,JMAX2)=CX1*SDZ(I,JMAX1)
      SDT(I,JMAX2)=CX1*SDT(I,JMAX1)
      SRZ(I,JMAX2)=-SRZ(I,JMAX1)
   80 CONTINUE
      DO 100 J=1,JMAX2
      RHO(1,J)=RHO(2,J)
      P(1,J)=P(2,J)
      SDR(1,J)=SDR(2,J)
      SDZ(1,J)=SDZ(2,J)
      SDT(1,J)=SDT(2,J)
      SRZ(1,J)=SRZ(2,J)
      RHO(IMAX2,J)=RHO(IMAX1,J)
      P(IMAX2,J)=CX2*P(IMAX1,J)
      SDR(IMAX2,J)=CX2*SDR(IMAX1,J)
      SDZ(IMAX2,J)=CX2*SDZ(IMAX1,J)
      SDT(IMAX2,J)=CX2*SDT(IMAX1,J)
      SRZ(IMAX2,J)=-SRZ(IMAX1,J)
```

```
  100 CONTINUE
C LOOP 140 TO CALCULATE VELOCITIES AND ACCELERATIONS
      DO 140 J=2,JMAX2
      DO 140 I=2,IMAX2
      CTD1=.25*DABS(R(I,J+1)+R(I+1,J+1)+R(I+1,J)+R(I,J))
      CTD2=.25*DABS(R(I-1,J+1)+R(I,J+1)+R(I,J)+R(I-1,J))
      CTD3=.25*DABS(R(I-1,J)+R(I,J)+R(I,J-1)+R(I-1,J-1))
      CTD4=.25*DABS(R(I,J)+R(I+1,J)+R(I+1,J-1)+R(I,J-1))
      CONST=1./(MZERO(I,J)/CTD1+MZERO(I-1,J)/CTD2+MZERO(I-1,J-1)/CTD3
     1+MZERO(I,J-1)/CTD4)
      P1=P(I,J)-P(I-1,J-1)
      P2=P(I-1,J)-P(I,J-1)
      P4=-P2
      IF(SRZ(I,J).NE.0.0.OR.SRZ(I-1,J).NE.0.0.OR.SRZ(I,J-1).NE.0.0.OR.
     1SRZ(I-1,J-1).NE.0.0)GO TO 94
      KL=2
      GO TO 96
   94 KL=1
   96 CONTINUE
      GO TO (101,103),KL
  101 CONTINUE
      A1=-.5*((R(I,J+1)-R(I+1,J))*(Z(I+1,J+1)-Z(I,J))-(R(I+1,J+1)-R(I,J)
     1)*(Z(I,J+1)-Z(I+1,J)))
      A2=-.5*((R(I-1,J+1)-R(I,J))*(Z(I,J+1)-Z(I-1,J))-(R(I,J+1)-R(I-1,J)
     1)*(Z(I-1,J+1)-Z(I,J)))
      A3=-.5*((R(I-1,J)-R(I,J-1))*(Z(I,J)-Z(I-1,J-1))-(R(I,J)-R(I-1,J-1)
     1)*(Z(I-1,J)-Z(I,J-1)))
      A4=-.5*((R(I,J)-R(I+1,J-1))*(Z(I+1,J)-Z(I,J-1))-(R(I+1,J)-R(I,J-1)
     1)*(Z(I,J)-Z(I+1,J-1)))
      CDDD=0.25*((2.*SDR(I,J)+SDZ(I,J))*A1/MZERO(I,J)+(2.*SDR(I-1,J)+
     1SDZ(I-1,J))*A2/MZERO(I-1,J)+(2.*SDR(I-1,J-1)+SDZ(I-1,J-1))*A3/
     2MZERO(I-1,J-1)+(2.*SDR(I,J-1)+SDZ(I,J-1))*A4/MZERO(I,J-1))
      CDD=0.25*(SRZ(I,J)*A1/MZERO(I,J)+SRZ(I-1,J)*A2/MZERO(I-1,J)+
     1SRZ(I-1,J-1)*A3/MZERO(I-1,J-1)+SRZ(I,J-1)*A4/MZERO(I,J-1))
      R1=R(I+1,J)-R(I-1,J)
      R2=R(I,J-1)-R(I,J+1)
      Z1=Z(I+1,J)-Z(I-1,J)
      Z2=Z(I,J-1)-Z(I,J+1)
      R13=R1+R2
      Z13=Z1+Z2
      R24=R1-R2
      Z24=Z1-Z2
      SRZ1=SRZ(I,J)-SRZ(I-1,J-1)
      SRZ4=SRZ(I,J-1)-SRZ(I-1,J)
      IF(IQQ.EQ.0)GO TO 119
      DO 112 K=1,IQQ
      IF(I.EQ.KXI(K).AND.J.EQ.KXJ(K))GO TO 116
  112 CONTINUE
      GO TO 119
  116 CDDD=CDDD*4./CXIJ(K)
      CDD=CDD*4./CXIJ(K)
  119 CONTINUE
  103 CONTINUE
      IF(I.EQ.2)GO TO 110
      IF(I.NE.IMAX2)GO TO 108
```

```
      IF(KPP.EQ.2)GO TO 110
      IF(KB2.EQ.0)GO TO 110
  108 CONTINUE
      GO TO (105,107),KL
  105 CONTINUE
      RDDOT=-CONST*(P4*Z24-P1*Z13-((SDR(I,J-1)-SDR(I-1,J))*Z24
     1-(SDR(I,J)-SDR(I-1,J-1))*Z13)+SRZ4*R24-SRZ1*R13)+CODD
      GO TO 109
  107 CONTINUE
      RDDOT=-CONST*(P1*(Z(I,J+1)-Z(I,J-1)+Z(I-1,J)-Z(I+1,J))
     1-P2*(Z(I,J+1)-Z(I,J-1)+Z(I+1,J)-Z(I-1,J)))
  109 CONTINUE
      RDB=RDDOT*DELTB
      IF(DABS(RDB).LT.UEP)GO TO 110
      RDOT(I,J)=RDOT(I,J)+RDB
  110 CONTINUE
      IF(J.NE.JMAX2)GO TO 122
      IF(KPP.EQ.1)GO TO 140
      IF(KB1.EQ.0)GO TO 140
      GO TO 124
  122 IF(J.NE.2)GO TO 124
      IF(KPP.EQ.3)GO TO 140
      IF(KB3.EQ.0)GO TO 140
  124 CONTINUE
      GO TO (125,127),KL
  125 CONTINUE
      ZDDOT=CONST*(P4*R24-P1*R13-((SDZ(I,J-1)-SDZ(I-1,J))*R24
     1-(SDZ(I,J)-SDZ(I-1,J-1))*R13)+SRZ4*Z24-SRZ1*Z13)+CODD
      GO TO 129
  127 CONTINUE
      ZDDOT=CONST*(P1*(R(I,J+1)-R(I,J-1)+R(I-1,J)-R(I+1,J))
     2-P2*(R(I,J+1)-R(I,J-1)+R(I+1,J)-R(I-1,J)))
  129 CONTINUE
      ZDB=ZDDOT*DELTB
      IF(DABS(ZDB).LT.UEP)GO TO 140
      ZDOT(I,J)=ZDOT(I,J)+ZDB
  140 CONTINUE
C END OF LOOP 140
      IF(KPP.EQ.0)GO TO 498
      TOTP=0.0
      GO TO (410,470,480),KPP
  410 DO 420 I=KPP1,KPP2
  420 TOTP=TOTP+PIO2*P(I,JMAX1)*(R(I+1,JMAX2)**2-R(I,JMAX2)**2)
      XZ=Z(KPP1,JMAX2)-ZO(KPP1,JMAX2)
      XZZ=ZDOT(KPP1,JMAX2)
  415 IF(KPPX.LE.0)GO TO 432
      IF(XZ.GE.CXD(1))GO TO 434
      DO 430 L=1,KPPX
      IF(XZ-CXD(L))430,436,438
  430 CONTINUE
  432 CXXP=0.
      GO TO 440
  434 CXXP=CX(1)
      GO TO 440
  436 CXXP=CX(L)
```

```
      GO TO 440
  438 CXXP=CX(L-1)+(XZ -CXD(L-1))*(CX(L)-CX(L-1))/(CXD(L)-CXD(L-1))
  440 CONTINUE
      IF(KPPC.LE.0)GO TO 452
      IF(XZZ.GE.CVD(1))GO TO 454
      DO 450 L=1,KPPC
      IF(XZZ-CVD(L))450,456,458
  450 CONTINUE
  452 CXVP=0.
      GO TO 460
  454 CXVP=CV(1)
      GO TO 460
  456 CXVP=CV(L)
      GO TO 460
  458 CXVP=CV(L-1)+(XZZ-CVD(L-1))*(CV(L)-CV(L-1))/(CVD(L)-CVD(L-1))
  460 XDDOT=(TOTP-CXXP-CXVP)/PMASS
      XDB=XDDOT*DELTB
      IF(DABS(XDB).LT.UEP)GO TO 496
      GO TO (484,488,492),KPP
  470 DO 472 J=KPP1,KPP2
  472 TOTP=TOTP+PI*R(IMAX2,J)*P(IMAX1,J)*DABS(Z(IMAX2,J+1)-Z(IMAX2,J))
      XZ=R(IMAX2,KPP1)-RO(IMAX2,KPP1)
      XZZ=RDOT(IMAX2,KPP1)
      GO TO 415
  480 DO 482 I=KPP1,KPP2
  482 TOTP=TOTP+PIO2*P(I,2)*(R(I+1,2)**2-R(I,2)**2)
      XZ=DABS(Z(KPP1,2)-ZO(KPP1,2))
      XZZ=DABS(ZDOT(KPP1,2))
      GO TO 415
  484 DO 486 I=2,IMAX2
  486 ZDOT(I,JMAX2)=ZDOT(I,JMAX2)+XDDOT*DELTB
      GO TO 496
  488 DO 490 J=2,JMAX2
  490 RDOT(IMAX2,J)=RDOT(IMAX2,J)+XDDOT*DELTB
      GO TO 496
  492 DO 494 I=2,IMAX2
  494 ZDOT(I,2)=ZDOT(I,2)-XDDOT*DELTB
  496 CONTINUE
  498 CONTINUE
      DO 150 J=2,JMAX2
      DO 150 I=2,IMAX2
      R(I,J)=R(I,J)+RDOT(I,J)*DELT
      Z(I,J)=Z(I,J)+ZDOT(I,J)*DELT
      IF(J.EQ.JMAX2.OR.I.EQ.IMAX2)GO TO 150
      TKE=TKE+PIO4*MZERO(I,J)     *(RDOT(I,J)*RDOT(I,J)+ZDOT(I,J)*
     1ZDOT(I,J)+RDOT(I,J+1)*RDOT(I,J+1)+ZDOT(I,J+1)*ZDOT(I,J+1)+
     2RDOT(I+1,J+1)*RDOT(I+1,J+1)+ZDOT(I+1,J+1)*ZDOT(I+1,J+1)+
     3RDOT(I+1,J)*RDOT(I+1,J)+ZDOT(I+1,J)*ZDOT(I+1,J))
  150 CONTINUE
C LOOP 220 TO CALCULATE ZONE QUANTITIES
      DO 220 J=2,JMAX1
      DO 220 I=2,IMAX1
      DDTK=0.
      LY=KTY(I,J)
      LX=KTX(I,J)
```

```
      I1=I+1
      J1=J+1
      CDR=SDR(I,J)
      CDZ=SDZ(I,J)
      CDT=SDT(I,J)
      CRZ=SRZ(I,J)
      CDRS=SSR(I,J)
      CDZS=SSZ(I,J)
      CDTS=SST(I,J)
      CRZS=SSRZ(I,J)
      R1=R(I1,J)-R(I,J)
      Z1=Z(I1,J)-Z(I,J)
      D1=R1*R1+Z1*Z1
      V1=(RDOT(I1,J)-RDOT(I,J))*R1+(ZDOT(I1,J)-ZDOT(I,J))*Z1
      R2=R(I1,J1)-R(I1,J)
      Z2=Z(I1,J1)-Z(I1,J)
      D2=R2*R2+Z2*Z2
      V2=(RDOT(I1,J1)-RDOT(I1,J))*R2+(ZDOT(I1,J1)-ZDOT(I1,J))*Z2
      R3=R(I,J1)-R(I1,J1)
      Z3=Z(I,J1)-Z(I1,J1)
      D3=R3*R3+Z3*Z3
      V3=(RDOT(I,J1)-RDOT(I1,J1))*R3+(ZDOT(I,J1)-ZDOT(I1,J1))*Z3
      R4=R(I,J)-R(I,J1)
      Z4=Z(I,J)-Z(I,J1)
      D4=R4*R4+Z4*Z4
      V4=(RDOT(I,J)-RDOT(I,J1))*R4+(ZDOT(I,J)-ZDOT(I,J1))*Z4
      R5=R(I1,J1)-R(I,J)
      Z5=Z(I1,J1)-Z(I,J)
      D5=R5*R5+Z5*Z5
      X5=RDOT(I1,J1)-RDOT(I,J)
      Y5=ZDOT(I1,J1)-ZDOT(I,J)
      V5=X5*R5+Y5*Z5
      R6=R(I1,J)-R(I,J1)
      Z6=Z(I1,J)-Z(I,J1)
      D6=R6*R6+Z6*Z6
      X6=RDOT(I1,J)-RDOT(I,J1)
      Y6=ZDOT(I1,J)-ZDOT(I,J1)
      V6=X6*R6+Y6*Z6
      DMST=DMAX1(      DMAX1(D1,D3)/DMIN1(D1,D3),DMAX1(D2,D4)/DMIN1(D2,
     1D4),DMAX1(D5,D6)/DMIN1(D5,D6))
      IF(DMST.LE.DIST)GO TO 162
      DIST=DMST
      IDM=I
      JDM=J
  162 CONTINUE
      DELV=0.0
      AREA=0.5*(Z5*R6-R5*Z6)
      CTRD=0.25*(R(I,J)+R(I,J1)+R(I1,J)+R(I1,J1))
      VOL=AREA*CTRD
      IF(RDOT(I,J).NE.0.0. OR.RDOT(I1,J).NE.0.0. OR.RDOT(I,J1).NE.0.0.
     1 OR.RDOT(I1,J1).NE.0.0)GO TO 165
      IF(ZDOT(I,J).NE.0.0. OR.ZDOT(I1,J).NE.0.0. OR.ZDOT(I,J1).NE.0.0.
     1 OR.ZDOT(I1,J1).NE.0.0)GO TO 165
  155 CONTINUE
      RHOT=RHO(I,J)
```

```
      PTEMP=P(I,J)
      ETEMP=E(I,J)
      VP1=0.
      GO TO 200
  165 CONTINUE
      RHOT=MZERO(I,J)/VOL
      DELV=1.0/RHOT-1.0/RHO(I,J)
      IF(DELV.GE.0.0)GO TO 170
      VP1=1.44*AREA*CRHO(LX)*RHOT*RHOT*(DELV/DELT)**2
      GO TO 180
  170 VP1=0
  180 CONTINUE
      PSTAR=P(I,J)
      IF(CPLG(LX).EQ.0.0)GO TO 186
  182 CONTINUE
      A2A=AREA+AREA
      DSV=(1./RHOT+1./RHO(I,J))/2.
      DDLV=DELV/DSV
      SNW=-((X6*R5-X5*R6)+(Y6*Z5-Y5*Z6))*DELT/(A2A*2.)
      C2W=1-2.*SNW*SNW
      CNW=DSQRT(1.-SNW*SNW)
      S2W=2.*SNW*CNW
      DRDR=(X6*Z5-X5*Z6)/A2A
      DRDRT=DRDR*DELT
      DZDZ=-(Y6*R5-Y5*R6)/A2A
      DZDZT=DZDZ*DELT
      DTDT=DDLV/DELT-(DRDR+DZDZ)
      DTDTT=DTDT*DELT
      DRDZ=((Y6*Z5-Y5*Z6)-(X6*R5-X5*R6))/A2A
      DRDZT=DRDZ*DELT
      SSR(I,J)=SSR(I,J)+DRDRT
      SSZ(I,J)=SSZ(I,J)+DZDZT
      SST(I,J)=SST(I,J)+DTDTT
      SSRZ(I,J)=SSRZ(I,J)+DRDZT
      DZZ=(SDZ(I,J)-SDR(I,J))*(C2W-1.)/2.-SRZ(I,J)*S2W
      DRR=-DZZ
      DRZ=SRZ(I,J)*(C2W-1.)+(SDZ(I,J)-SDR(I,J))*S2W/2.
      UNU=2.*CNU(LX)
      DDLV3=DDLV/3.
      SDR(I,J)=SDR(I,J)+UNU*(DRDRT-DDLV3)+DRR
      SDZ(I,J)=SDZ(I,J)+UNU*(DZDZT-DDLV3)+DZZ
      SDT(I,J)=SDT(I,J)+UNU*(DTDTT-DDLV3)
      SRZ(I,J)=SRZ(I,J)+CNU(LX)*DRDZT+DRZ
      SJN=(SDR(I,J)**2+SDZ(I,J)**2+SDT(I,J)**2)+2.*SRZ(I,J)**2
      CKJ=SJN-2.*CYO(LX)**2/3.
      IF(CKJ.LE.0.)GO TO 184
      PRINT 519,I,J,SJN
      CKJJ=CYO(LX)*DSQRT(.666667/SJN)
      SDR(I,J)=SDR(I,J)*CKJJ
      SDZ(I,J)=SDZ(I,J)*CKJJ
      SDT(I,J)=SDT(I,J)*CKJJ
      SRZ(I,J)=SRZ(I,J)*CKJJ
  184 CONTINUE
      S22N=DSQRT((SDZ(I,J)-SDR(I,J))**2+(2.*SRZ(I,J))**2)/2.
      S12N=(SDR(I,J)+SDZ(I,J))/2.
```

```
      STR(I,J)=S12N+S22N
      STZ(I,J)=S12N-S22N
      SXX=(SDR(I,J)+CDR)/2.
      SYY=(SDZ(I,J)+CDZ)/2.
      STT=(SDT(I,J)+CDT)/2.
      SXY=(SRZ(I,J)+CRZ)/2.
      DDTK=DDTK+(SXX*DRDRT+SYY*DZDZT+STT*DTDTT+SXY*DRDZT)*DSV
      IF(SSR (I,J).GE.CPLG(LX))GO TO 183
      IF(SSZ (I,J).GE.CPLG(LX))GO TO 183
      IF(SST (I,J).GE.CPLG(LX))GO TO 183
      IF(SSRZ(I,J).GE.CPLG(LX))GO TO 183
      GO TO 186
  183 ISTOP=2
  186 CONTINUE
      GO TO (260,300),LY
  260 RATIO=1./(RHOT*VO(LX))
      IF(RATIO.LE.VV(LX,1))GO TO 278
      DO 270 L=1,50
      IF(VV(LX,L).EQ.0.)GO TO 279
      IF(RATIO-VV(LX,L))290,280,270
  270 CONTINUE
      PH=0.
      GO TO 295
  278 PH=PP(LX,1)
      GO TO 295
  279 L=L-1
  280 PH=PP(LX,L)
      GO TO 295
  290 PH=PP(LX,L-1)+(RATIO-VV(LX,L-1))*(PP(LX,L)-PP(LX,L-1))/(VV(LX,L)-
     1VV(LX,L-1))
  295 CONTINUE
      HP=PH
      PH=PH*1.0E9
      IF(LX.NE.3)GO TO 297
      IF(HP.LE.131.)GO TO 297
      IF(HP.GE.321.)GO TO 298
      G=GO(LX)+(CO(LX)-GO(LX))*(HP-131.)/190.
      GO TO 299
  297 G=GO(LX)
      GO TO 299
  298 G=CO(LX)
  299 CONTINUE
C     EQUATION OF STATE - SOLIDS AND LIQUIDS
      EH=EO(LX)+0.5*(PH+PO(LX))*(VO(LX)-1./RHOT)
      ETEMP=(E(I,J)+DDTK-0.5*(PH-G*RHOT*EH+VP1+P(I,J))*DELV)/
     1(1.+0.5*G*RHOT*DELV)
      PTEMP=PH+G*RHOT*(ETEMP-EH)+VP1
      GO TO 200
  300 CONTINUE
      DO 190 L=1,20
      ETEMP=E(I,J)+DDTK-0.5*(PSTAR+P(I,J))*DELV
      IF(LX.GT.1)GO TO 344
C     EQUATION OF STATE - ARGON
      PTEMP=AA(LX)*DEXP(-BB(LX)/(ETEMP+CC(LX)))
      GO TO 350
```

```
  344 CONTINUE
C     EQUATION OF STATE - CORE
      PTEMP=AA(LX)*ETEMP*RHOT
  350 CONTINUE
      PTEMP=PTEMP+VP1
      IF(DABS(PTEMP-PSTAR)/DABS(PTEMP+0.001).LT.0.001)GO TO 195
  190 PSTAR=PTEMP
      PRINT 504,I,J
      ISTOP=1
      RETURN
  195 CONTINUE
  200 TIE=TIE+PI*MZERO(I,J)*(ETEMP+E(I,J))
      W=(CWN(LX)*(PTEMP+CWB(LX))/(RHOT*AREA))*(DELT/1.2)**2+
     14.0*DABS(DELV*RHOT)
      IF(W.LE.WMAX)GO TO 210
      WMAX=W
      IW=I
      JW=J
      AC1=AREA
      AC2=RHO(I,J)
      AC3=P(I,J)
  210 RHO(I,J)=RHOT
      P(I,J)=PTEMP
      E(I,J)=ETEMP
      VP(I,J)=VP1
  220 CONTINUE
      IF(KPL1.EQ.0)GO TO 240
      TPL=0.0
      DO 230 I=KPL1,KPL2
  230 TPL=TPL+PIO2*P(I,JMAX1)*(R(I+1,JMAX2)**2-R(I,JMAX2)**2)
      IF(TPL.LE.PLUG)GO TO 240
      PRINT 512,TPL,PLUG
      ISTOP=1
  240 CONTINUE
      IF(ISTOP.NE.2)GO TO 245
      PRINT 513
      ISTOP=1
  245 CONTINUE
      EB=TIE+TKE
      PRINT 506,TIME,TIE,TKE,EB
      NCL=NCL+1
      NPN=1
      IF(NPP.GT.0)GO TO 243
      IF(KPL1.LE.0)GO TO 249
      GO TO 248
  243 CONTINUE
      IF(NPP.LE.0)GO TO 248
      NPN=NPP
      DO 247 L=1,NPP
      II=IABS(KXP(L))
      JJ=IABS(KYP(L))
      IF(KXP(L).GT.0)GO TO 244
      PRS(L,NCL)=R(II,JJ)-RO(II,JJ)
      GO TO 247
  244 IF(KYP(L).GT.0)GO TO 246
```

```
      PRS(L,NCL)=Z(II,JJ)-ZO(II,JJ)
      GO TO 247
  246 PRS(L,NCL)=P(II,JJ)
  247 CONTINUE
  248 CONTINUE
      PLGF(NCL)=TPL
      TME(NCL)=TIME
      KXYP(NCL)=NCYCL+1
      PRINT 536,KXYP(NCL),TME(NCL),PLGF(NCL),(PRS(L,NCL),L=1,NPN)
  536 FORMAT(I6,2E14.6,4X,6E14.6)
  249 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRINTF(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RC,ZO,SC,SSR,SSZ,
     1SST,SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3),
     1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX
     23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3),
     3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3)
      DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3)
      DIMENSION TITLE(20)
      DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
     1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
     2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
      DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20)
      DIMENSION CIJ(50),CXIJ(1000)
      COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
     1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
     2,KXP(20),KYP(20),KXYP(1000)
      COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
      COMMON    KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
      COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
     1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
     1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
     3,PLGF(1000),TME(1000),PRS(6,1000)
      REAL*4 TME,PLGF,PRS,TIN
      REAL*4 TITLE
      REAL*8 MZERO
      INTEGER*2 KTX,KTY
  510 FORMAT(1H ,30X,18A4//)
  512 FORMAT(1H0,' CYCLE NO=',I5,' AT TIME ',E15.7)
  514 FORMAT(1H0,'  ZONE',4X,'R',14X,'Z',12X,'RADIAL VEL.',4X,
     1'AXIAL VEL.',5X,'PRESSURE',7X,'ENERGY',9X,'DENSITY',8X,'MASS',
     2  9X,'MT PH',/'   R  Z',/)
  516 FORMAT(1H ,2I3,8E15.7,I3,I2)
  518 FORMAT(1H0,'  ZONE',4X,'R',14X,'Z',12X,'RADIAL VEL.',4X,
     1'AXIAL VEL.',5X,'PRESSURE',6X,'VISCOUS PRESS.  ENERGY',9X,'DENSITY
     2',6X,'MT PH',/'   R  Z',/)
```

```
520 FORMAT(1H1)
522 FORMAT(1H )
    PRINT 520
    PRINT 510,(TITLE(I),I=1,18)
    PRINT 512,NCYCL,TIME
    IF(NCYCL.NE.0)GO TO 30
    PRINT 514
    DO 25 J=2,JMAX2
    DO 20 I=2,IMAX2
    PRINT 516,I,J,R(I,J),Z(I,J),RDOT(I,J),ZDOT(I,J),P(I,J),E(I,J),
   1RHO(I,J),MZERO(I,J),KTX(I,J),KTY(I,J)
 20 CONTINUE
    PRINT 522
 25 CONTINUE
    GO TO 50
 30 PRINT 518
    DO 45 J=2,JMAX2
    DO 40 I=2,IMAX2
    PRINT 516,I,J,R(I,J),Z(I,J),RDOT(I,J),ZDOT(I,J),P(I,J),VP(I,J),
   1E(I,J),RHO(I,J),KTX(I,J),KTY(I,J)
 40 CONTINUE
    PRINT 522
 45 CONTINUE
 50 CONTINUE
    RETURN
    END
```

```
    SUBROUTINE PRINTL(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,
   1SST,SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY)
    IMPLICIT REAL*8(A-H,O-Z)
    DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3),
   1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX
   23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3),
   3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3)
    DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3)
    DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ(I
   1MAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3)
    DIMENSION TITLE(20)
    DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
   1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
   2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
    DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20)
    DIMENSION CIJ(50),CXIJ(1000)
    DIMENSION U1(12),U2(12),U3(12),U4(12),U5(12),U6(12),U7(12),
   1U8(12),UA(12),UB(12),UC(12),UD(12),UE(12),U(12)
   2,UF(12),UG(12),UH(12),UI(12),UJ(12)
    COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
   1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
   2,KXP(20),KYP(20),KXYP(1000)
    COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
    COMMON    KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
```

```
 CCMMON I11(10),I12(10),I21(10),I22(10),J11(10),J12(10),J21(10),
1J22(10),I1X,I2X,J1X,J2X,KK(120)
 CCMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GC,CO,AA,BB,
1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
3,PLGF(100C),TME(1000),PRS(6,1000)
 REAL*4 TME,PLGF,PRS,TIN
 REAL*4 TITLE
 REAL*8 MZERC
 REAL*4 U1,U2,U3,U4,U5,U6,U7,U8,UA,UB,UC,UD,UE,U
1,UF,UG,UH,UI,UJ
 INTEGER*2 KTX,KTY
 DATA U1 /'     RADIAL POSITION OF GRID POINTS AT TIME ='/,
1     U2 /'      AXIAL POSITION OF GRID POINTS AT TIME ='/,
2     U3 /'     RADIAL VELOCITY OF GRID POINTS AT TIME ='/,
3     U4 /'      AXIAL VELOCITY CF GRID POINTS AT TIME ='/,
4     U5 /'                 PRESSURE OF ZONES AT TIME ='/,
5     U6 /'          VISCOUS PRESSURE OF ZONES AT TIME ='/,
6     U7 /' SPECIFIC INTERNAL ENERGY OF ZONES AT TIME ='/,
7     U8 /'                  DENSITY OF ZONES AT TIME ='/,
8     UA /'RADIAL DISPLACEMENT OF GRID POINTS AT TIME ='/,
9     UB /' AXIAL DISPLACEMENT OF GRID POINTS AT TIME ='/,
A     UC /'              RADIAL STRAIN OF ZONES AT TIME ='/,
A     UD /'               AXIAL STRAIN OF ZONES AT TIME ='/,
B     UE /'             ANGULAR STRAIN OF ZONES AT TIME ='/,
B     UF /'               SHEAR STRAIN OF ZONES AT TIME ='/,
B     UG /'              RADIAL STRESS OF ZONES AT TIME ='/,
B     UH /'               AXIAL STRESS OF ZONES AT TIME ='/,
B     UI /'             ANGULAR STRESS OF ZONES AT TIME ='/,
B     UJ /'               SHEAR STRESS OF ZONES AT TIME ='/
 SMR=0.
 SMZ=0.
 SMT=0.
 SMD=0.
 SMSR=0.
 SMSZ=0.
 SMST=0.
 SMSD=0.
 RM=0.
 ZM=0.
 RDCTM=0
 ZDOTM=0
 PM=0
 VPM=0
 EM=0
 RHCM=0
 DC 80 J=2,JMAX2
 DO 80 I=2,IMAX2
 RM=DMAX1(RM,DABS(R(I,J)-RO(I,J)))
 ZM=DMAX1(ZM,DABS(Z(I,J)-ZO(I,J)))
 RDOTM=DMAX1(RDCTM,DABS(RDOT(I,J)))
 ZDOTM=DMAX1(ZDCTM,DABS(ZDOT(I,J)))
 IF(I.EQ.IMAX2.CR.J.EQ.JMAX2)GO TO 80
 PM=DMAX1(PM,DABS(P(I,J)))
 EM=DMAX1(EM,DABS(E(I,J)))
```

```
      VP1=VP(I,J)
      VPM=DMAX1(VPM,DABS(VP1))
      RHOM=DMAX1(RHOM,DABS(RHO(I,J)))
      SMRT=SSR(I,J)
      SMZT=SSZ(I,J)
      SMTT=SST(I,J)
      SMDT=SSRZ(I,J)
      SMR=DMAX1(SMR,DABS(SMRT))
      SMZ=DMAX1(SMZ,DABS(SMZT))
      SMT=DMAX1(SMT,DABS(SMTT))
      SMD=DMAX1(SMD,DABS(SMDT))
      SMSR=DMAX1(SMSR,DABS(SDR(I,J)))
      SMSZ=DMAX1(SMSZ,DABS(SDZ(I,J)))
      SMST=DMAX1(SMST,DABS(SDT(I,J)))
      SMSD=DMAX1(SMSD,DABS(SRZ(I,J)))
   80 CONTINUE
      IF(NCYCL)85,85,88
   85 CONTINUE
      RM=R(IMAX2,2)
      ZM=Z(2,JMAX2)
      DO 101 K=1,12
  101 U(K)=U1(K)
      CALL DISP(SC,R,RM,U ,I2X,J2X,I21,I22,J21,J22,KK)
      DO 102 K=1,12
  102 U(K)=U2(K)
      CALL DISP(SC,Z,ZM,U ,I2X,J2X,I21,I22,J21,J22,KK)
      GO TO 100
   88 CONTINUE
      DO 90 J=2,JMAX2
      DO 90 I=2,IMAX2
      SC(I,J)=R(I,J)-RO(I,J)
   90 CONTINUE
      DO 109 K=1,12
  109 U(K)=UA(K)
      CALL DISP(SC,SC,RM,U ,I2X,J2X,I21,I22,J21,J22,KK)
      DO 95 J=2,JMAX2
      DO 95 I=2,IMAX2
      SC(I,J)=Z(I,J)-ZO(I,J)
   95 CONTINUE
      DO 110 K=1,12
  110 U(K)=UB(K)
      CALL DISP(SC,SC,ZM,U ,I2X,J2X,I21,I22,J21,J22,KK)
  100 CONTINUE
      DO 103 K=1,12
  103 U(K)=U3(K)
      CALL DISP(SC,RDOT,RDOTM,U ,I2X,J2X,I21,I22,J21,J22,KK)
      DO 104 K=1,12
  104 U(K)=U4(K)
      CALL DISP(SC,ZDOT,ZDOTM,U ,I2X,J2X,I21,I22,J21,J22,KK)
      DO 105 K=1,12
  105 U(K)=U5(K)
      CALL DISP(SC,P,PM,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 106 K=1,12
  106 U(K)=U6(K)
      DO 225 J=2,JMAX2
```

```
      DO 225 I=2,IMAX2
      SC(I,J)=VP(I,J)
  225 CONTINUE
      CALL DISP(SC,SC,VPM,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 107 K=1,12
  107 U(K)=U7(K)
      CALL DISP(SC,E,EM,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 108 K=1,12
  108 U(K)=U8(K)
      CALL DISP(SC,RHO,RHOM,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 111 K=1,12
  111 U(K)=UC(K)
      DO 221 J=2,JMAX2
      DO 221 I=2,IMAX2
      SC(I,J)=SSR(I,J)
  221 CONTINUE
      CALL DISP(SC,SC,SMR ,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 112 K=1,12
  112 U(K)=UD(K)
      DO 222 J=2,JMAX2
      DO 222 I=2,IMAX2
      SC(I,J)=SSZ(I,J)
  222 CONTINUE
      CALL DISP(SC,SC,SMZ ,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 113 K=1,12
  113 U(K)=UE(K)
      DO 223 J=2,JMAX2
      DO 223 I=2,IMAX2
      SC(I,J)=SST(I,J)
  223 CONTINUE
      CALL DISP(SC,SC,SMT ,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 114 K=1,12
  114 U(K)=UF(K)
      DO 224 J=2,JMAX2
      DO 224 I=2,IMAX2
      SC(I,J)=SSRZ(I,J)
  224 CONTINUE
      CALL DISP(SC,SC,SMD ,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 115 K=1,12
  115 U(K)=UG(K)
      CALL DISP(SC,SDR,SMSR,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 116 K=1,12
  116 U(K)=UH(K)
      CALL DISP(SC,SDZ,SMSZ,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 117 K=1,12
  117 U(K)=UI(K)
      CALL DISP(SC,SDT,SMST,U ,I1X,J1X,I11,I12,J11,J12,KK)
      DO 118 K=1,12
  118 U(K)=UJ(K)
      CALL DISP(SC,SRZ,SMSD,U ,I1X,J1X,I11,I12,J11,J12,KK)
      PRINT 530
  530 FORMAT(1H1)
      RETURN
      END
```

```
      SUBROUTINE DISP(KC,B,AMAX,U,IX,JX,I1,I2,J1,J2,KK)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION KC(IMAX3,JMAX3),B(IMAX3,JMAX3),U(12),I1(10),I2(10),
     1J1(10),J2(10),KK(120),TITLE(20)
      DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
     1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
     2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
      DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20)
      DIMENSION CIJ(50),CXIJ(1000)
      COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
     1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,ICM,JDM,NPP,NCL
     2,KXP(20),KYP(20),KXYP(1000)
      COMMON KB1,KE2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
      COMMON     KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
      COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
     1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
     1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
     3,PLGF(1000),TME(1000),PRS(6,1000)
      REAL*4 TME,PLGF,PRS,TIN
      REAL*4 TITLE
      REAL*4 U
500 FORMAT(1H1)
502 FORMAT(25X,18A4)
504 FORMAT(1HC,5X,11A4,E15.7,' AND D-TIME=',E15.7,' AT CYCLE-',I4)
508 FORMAT(1H ,5X,'MAXIMUM ABS. VALUE =',E15.7,' TO SMALL-NO PRINTOUT'
     1)
510 FORMAT(1H ,5X,'MAXIMUM ABS. VALUE =',E15.7,' SCALE FACTOR =',E10.2
     1)
512 FORMAT(1HC,2X,' R',25I5)
514 FORMAT(I4,1X,25I5)
516 FORMAT(3X,'Z')
      CMAX=AMAX
      IF(AMAX.EQ.0)GO TO 240
      I=0
      DO 30 J=1,100
      KAM=AMAX
      IF(KAM.EQ.0)GO TO 40
      AMAX=0.1*AMAX
      I=I+1
   30 CONTINUE
   40 DO 50 J=1,100
      AMAX=10.*AMAX
      KAM=AMAX
      IF(KAM.GT.0)GO TO 60
      I=I-1
   50 CONTINUE
      GO TO 240
   60 IF(AMAX.GT.9.999)I=I+1
      C=10.**(4-I)
      DO 80 J=2,JMAX2
      DO 80 I=2,IMAX2
      KC(I,J)=B(I,J)*C
   80 CONTINUE
      DO 200 I=1,IX
      DO 200 J=1,JX
```

```
      PRINT 500
      PRINT 502,(TITLE(K),K=1,18)
      PRINT 504,(U(K),K=1,11),TIME,DELT,NCYCL
      PRINT 510,CMAX,C
      K1=I1(I)
      K2=I2(I)
      PRINT 512,(KK(K),K=K1,K2)
      PRINT 516
      L1=J1(J)
      L2=J2(J)
      DO 140 L=L1,L2
      PRINT 514,L,(KC(K,L),K=K1,K2)
  140 CONTINUE
  200 CONTINUE
      GO TO 300
  240 PRINT 500
      PRINT 502,(TITLE(K),K=1,18)
      PRINT 504,(U(K),K=1,11),TIME,DELT,NCYCL
      PRINT 508,CMAX
  300 RETURN
      END
```

```
      SUBROUTINE PICT(R,Z,P,LAST)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION IX1(50),IX2(50),JX1(50),JX2(50)
      DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),P(IMAX3,JMAX3)
      DIMENSION LAME(50),LLAME(1),NX1(50)
      DIMENSION TITLE(20)
      DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),
     1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20)
     2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)
      DIMENSION CRHC(20),CE(20),CP(20),CYO(20),CNU(20)
      DIMENSION CIJ(50),CXIJ(1000)
      COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,
     1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL
     2,KXP(20),KYP(20),KXYP(1000)
      COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2
      COMMON    KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)
      COMMON I11(10),I12(10),I21(10),I22(10),J11(10),J12(10),J21(10),
     1J22(10),I1X,I2X,J1X,J2X,KK(120)
      COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB,
     1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS
     1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ
     3,PLGF(1000),TME(1000),PRS(6,1000)
      REAL*4 TME,PLGF,PRS,TIN
      REAL*4 TITLE,TMM,AX(20)
      REAL*8 MZERO
      REAL*4 DEL,R1,R2,RR,RR1,RR2,ZZ,ZZ1,ZZ2
      REAL*4 PMAX,PZ,PP1
      INTEGER*2 KTX,KTY
      IF(LAST)20,40,40
```

```
 20 CONTINUE
    READ 520,N
    PRINT 520,N
    IF(N)22,22,21
 21 READ 520,(IX1(L),IX2(L),JX1(L),JX2(L),L=1,N)
    PRINT 520,(IX1(L),IX2(L),JX1(L),JX2(L),L=1,N)
 22 CONTINUE
520 FORMAT(12I6)
530 FORMAT(18A4)
    READ 522,NNM,PMAX
    PRINT 523,NNM,PMAX
522 FORMAT(I6,F12.0)
    IF(NNM)32,32,30
 30 READ 520,(NX1(L),L=1,NNM)
    PRINT 520,(NX1(L),L=1,NNM)
    DO 31 L=1,NNM
    J=IABS(NX1(L))
    IF(NX1(L))27,31,29
 27 CALL CONVC('("Z=",I2)',LAME(L),0,KRR,J)
    GO TO 31
 29 CALL CONVC('("R=",I2)',LAME(L),0,KRR,J)
 31 CONTINUE
523 FORMAT(I6,E15.7)
531 FORMAT(1HC,18A4)
 32 CONTINUE
    NNN=0
    CALL FLINC(1)
    CALL FLINW(2)
    CALL FCHSZ(3)
    CALL FTEXT(TITLE,72,1,100,2000)
    CALL FCHSZ(2)
    CALL FMAREA(2200,2200)
    CALL FXYTRN(1000,1000)
    CALL FADV(4)
    R5=R(2,2)
    Z5=Z(2,2)
    R6=R(IMAX2,JMAX2)
    Z6=Z(IMAX2,JMAX2)
    R3=R6-R5
    Z3=Z6-Z5
    IF(R3-Z3)24,24,26
 24 R1=0.05*Z3
    R2=Z3+2.*R1
    GO TO 28
 26 R1=0.05*R3
    R2=R3+2.*R1
 28 CONTINUE
    LAST=0
    R1=-R1
 40 CONTINUE
    TMM=TIME
    CALL CONVC('("CYCLE=",I4," TIME=",F11.8)',AX,0,KRR,NCYCL,TMM)
    CALL FDATM(2)
    CALL FXYLIM(R1,R1,R2,R2)
    DO 60 I=2,IMAX2
```

```
      I1=I+1
      DO 60 J=2,JMAX2
      J1=J+1
      RR=R(I,J)-R5
      ZZ=Z(I,J)-Z5
      IF(I.EQ.IMAX2)GO TO 50
      RR1=R(I1,J)-R5
      ZZ1=Z(I1,J)-Z5
      CALL FLNSG(RR,ZZ,RR1,ZZ1)
   50 IF(J.EQ.JMAX2)GO TO 60
      RR1=R(I,J1)-R5
      ZZ1=Z(I,J1)-Z5
      CALL FLNSG(RR,ZZ,RR1,ZZ1)
   60 CONTINUE
      IF(N)79,79,64
   64 CONTINUE
      DO 78 L=1,N
      IP1=IX1(L)
      IP2=IX2(L)
      JP1=JX1(L)
      JP2=JX2(L)
      IF(IP2-IP1)66,66,72
   66 I=IP1
      KP2=JP2-1
      DO 70 J=JP1,KP2
      J1=J+1
      RR=R(I,J)-R5
      ZZ=Z(I,J)-Z5
      RR1=R(I,J1)-R5
      ZZ1=Z(I,J1)-Z5
      DO 68 K=1,3
      CALL FLNSG(RR,ZZ,RR1,ZZ1)
   68 CONTINUE
   70 CONTINUE
      GO TO 78
   72 J=JP1
      KP2=IP2-1
      DO 76 I=IP1,KP2
      I1=I+1
      RR=R(I,J)-R5
      ZZ=Z(I,J)-Z5
      RR1=R(I1,J)-R5
      ZZ1=Z(I1,J)-Z5
      DO 74 K=1,3
      CALL FLNSG(RR,ZZ,RR1,ZZ1)
   74 CONTINUE
   76 CONTINUE
   78 CONTINUE
   79 CONTINUE
      CALL FTEXT(AX,27,1,R2*0.05,R2*0.95)
      CALL FADV(4)
      IF(NNM)220,220,110
  110 RR1=PMAX*1.1
      CALL FXYLIM(R1,R1,R2,RR1)
      DO 200 K=1,NNM
```

```
      LLAME(1)=LAME(K)
      CALL FTEXT(AX,27,1,R2*0.05,PMAX*1.05)
      CALL FTEXT(LLAME,4,1,R2*0.05,PMAX*1.00)
      IF(NX1(K))120,160,160
  120 J=IABS(NX1(K))
      RR=R(2,2)-R5
      ZZ=0.
      RR1=R(IMAX2,2)-R5
      ZZ1=PMAX
      DO 122 L=1,3
      CALL FLNSG(RR,ZZ,RR1,ZZ)
      CALL FLNSG(RR,ZZ,RR,ZZ1)
  122 CONTINUE
      I1=2
      I2=IMAX1
      DO 140 I=I1,I2
      RR=R(I,J)-R5
      PZ=P(I,J)
      RR1=R(I+1,J)-R5
      PP1=P(I+1,J)
      CALL FLNSG(RR,PZ,RR1,PP1)
  140 CONTINUE
      GO TO 190
  160 I=NX1(K)
      RR=Z(2,2)-Z5
      ZZ=0.
      RR1=Z(2,JMAX2)-Z5
      ZZ1=PMAX
      DO 162 L=1,3
      CALL FLNSG(RR,ZZ,RR1,ZZ)
      CALL FLNSG(RR,ZZ,RR,ZZ1)
  162 CONTINUE
      J1=2
      J2=JMAX1
      DO 180 J=J1,J2
      RR=Z(I,J)-Z5
      PZ=P(I,J)
      RR1=Z(I,J+1)-Z5
      PP1=P(I,J+1)
      CALL FLNSG(RR,PZ,RR1,PP1)
  180 CONTINUE
  190 CONTINUE
      CALL FADV(4)
  200 CONTINUE
  220 CONTINUE
      IF(LAST)100,100,80
   80 CONTINUE
      CALL FADV(4)
      CALL FDATM(3)
      CALL FMAREA(4000,4000)
      CALL FXYTRN(0,0)
      CALL FCHSZ(3)
      CALL FTEXT(TITLE,72,1,100,2000)
      CALL FCHSZ(2)
      CALL FADV(4)
      CALL FEOF
  100 RETURN
      END
```

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