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THE FINITE ELEMENT METHOD IN NONLINEAR
DYNAMIC ANALYSIS OF AXISYMMETRIC SHELLS:
THEORY AND COMPUTER PROGRAM

by

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APPLIED TECHNOLOGY

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THE FINITE ELEMENT METHOD IN NONLINEAR DYNAMIC ANALYSIS OF
AXISYMMETRIC SHELLS: THEORY AND COMPUTER PROGRAM

B. J. Hsieh

Abstract

Nonlinear dynamic analysis for shells under arbitrary loadings is becoming more and more important in engineering. The nonlinearities arise from two major causes: large displacements and elastoplastic material behavior.

In this report, we eliminate most of the nonlinearities by introducing a corotational coordinate system for each element as reported in [1]. We also show how a shape function and constitutive laws that are conventionally used for small displacement problems can be used in each element's corotational coordinate to extend them to the case of large displacement.

The reader is expected to have some understanding of corotational coordinates [1]; however, no extended knowledge of the theory of shells is needed. For the case of axisymmetric shell analysis in which we are interested, the problem is reduced to two dimensions by studying the behavior of the generator of the shell in the x-y plane.

The corotational coordinate method can be applied in each segment of the generator, thereby separating the total displacement into rigid-body-motion and deformation parts. A noticeable difference between the axisymmetric shell problem and the general problem presented in [1] is that the seemingly rigid body motion of the shell generator in the x-y plane causes circumferential strains. The effect of this strain on the internal work must be considered.

This report derives the necessary equations for the equivalent nodal forces, and lists the conditions necessary to simplify some of these equations. A computer program is written in FORTRAN language that can treat uniformly distributed loadings. The modifications that are needed to treat other loadings are presented in the text. This program is written in a nondimensional form so that any consistent units used for the input produces consistent units in the output. Here by consistent units we mean that the units must be dimensionally consistent with Newton's second law.

INTRODUCTION

Axisymmetric shell structures are used widely in many engineering fields. The ability to economically analyze the response of such shells under various loadings is becoming more and more important. The classic shell theory for small displacements can be applied successfully for load-carrying shells (e.g., pressure vessels) subjected to nominal or design loadings. However, nonlinear shell theory must be employed to analyze this type of shell under extreme loadings and also must be used for nonload-carrying shells such as rupture discs.

Nonlinearities are generally catalogued into two types: geometric nonlinearities--those that arise from large displacement effects, and material nonlinearities--those caused by nonlinear constitutive equations. These nonlinearities can be greatly reduced by using the corotational formulation [1]. In this report, a rectilinear finite element formulation for axisymmetric shells using the corotational coordinates is presented. The assumptions used in deriving this shell element are: (1) the geometry, loadings, and the response of the shell are axisymmetric; (2) the thickness of the shell is small compared to the other shell dimensions, hence, transverse strains and stress can be neglected; and (3) planes normal to the meridian of the shell remain normal during motion. The material of the shell is assumed to be homogeneous and either linearly elastic or elastoplastic.

The equations of motion thus obtained by using the corotational coordinate formulation are integrated in time by the central finite difference scheme in a step by step manner. This corotational finite element can be used for axisymmetric shell problems where the shell's displacements can be many times larger than the thickness of the shell.

KINEMATIC

Consider a spatial cylindrical coordinate system with its vertical, horizontal and circumferential axes represented by x , y , and θ respectively. An axisymmetric shell presented in these coordinates is characterized by the fact that the geometry of the shell is independent of the circumferential coordinate, θ . Hence, the projection of the shell on the x - y plane suffices to describe the geometry of the shell.

To simplify the problem, the following assumptions are made:

- A1) The response of the shell is axisymmetric.
- A2) The thickness of the shell is small in comparison with other dimensions of the shell; transverse strain and stress can be neglected compared with other strains and stresses.
- A3) Planes normal to the midsurface of the shell remain normal to it during deformation.

Because of A1, the displacements of the shell at any point can only have two components: axial, $\tilde{u}$, and transverse, $\tilde{v}$. Furthermore, they can be functions of x and y only. From A2, we can show that $\tilde{v}$ can be closely approximated by the displacement at the midsurface, v . From A3, the difference in the axial displacement between points not on and on the midsurface can be shown to be a linear function of the distance from the point to the midsurface.

We can, hence, write the displacement field of a axisymmetric shell as follows:

$$\tilde{u}(\xi, \eta) = u(\xi) + \kappa(\xi)\eta \quad (1)$$

$$\tilde{v}(\xi, \eta) = v(\xi) \quad (2)$$

here κ is the curvature of the midsurface at ξ . The coordinate ξ is a parameter measured along the meridian of the midsurface; while the coordinate η is a parameter measured along the normal of the midsurface (see Fig. 1).

Let the shell be divided into N elements. The configurations of the midsurface of a typical element are depicted in Fig. 2 for two times: initially and during motion. The corotational coordinates for each element at any instant are generated as follows: the $\hat{x}$ axis is obtained by connecting the first end to the second end of the shell element at its midsurface; the $\hat{y}$ axis is obtained by making it normal to the $\hat{x}$ axis. The origin of this $\hat{x}$ - $\hat{y}$ coordinate system is always at the midsurface at the first end, and the direction of the coordinates coincide with the ξ - η system.

In order to define the displacements by using the corotational coordinate formulation, we further assume the following:

- A4) The initial curvature of the projection of the element on the $\hat{x}$ - $\hat{y}$ plane is zero, and
- A5) Each element is small enough so the rotation caused by the transverse displacements can be approximated by the rotation of the $\hat{x}$ axis.

According to [1], the displacements of an element can be decomposed into a deformation displacement and a rigid-body-motion displacement provided the rotation in the element is almost constant. Assume that the midsurface of an element has been deformed by the following displacement field:

$$\hat{u}^{\text{def}}(X) = \frac{X}{L} d_2^{\text{x,def}} \quad (3)$$

$$\hat{v}^{\text{def}}(X) = \left[L \frac{X}{L} \left(\frac{X}{L} - 1 \right)^2 \right] \phi_1^{\text{def}} + \left[L \left(\frac{X}{L} \right)^2 \left(\frac{X}{L} - 1 \right) \right] \phi_2^{\text{def}} \quad (4)$$

where X is the value of the $\hat{x}$ coordinate at time zero; L is the original length of the element; $\hat{d}_2^{x,def}$ is the nodal deformation displacement in the $\hat{x}$ direction at the second node, and $\hat{\phi}_1^{def}$, $\hat{\phi}_2^{def}$ are the nodal deformation rotations measured clockwise at the first and second node, respectively. Physically, eqs. (3) and (4) mean that the axial and transverse displacements are assumed as linear and cubic functions of the axial coordinate X , respectively.

Assume that each node i of an element has three degrees of freedom in the spatial coordinates: horizontal displacement, d_i^x , vertical displacement, d_i^y , and rotation in the x - y plane ϕ_i . The next step is to find the equations that isolate $\hat{d}_2^{x,def}$, $\hat{\phi}_1^{def}$, $\hat{\phi}_2^{def}$ from the global nodal displacements of an element. Since the corotational $\hat{x}$ always passes through the two nodes of an element, we can say that the rigid body motion of the midsurface is closely represented by that of the x axis by use of A5. Hence, from using eq. 19 of [1], the nodal deformation displacement $\hat{d}_2^{x,def}$ can be found to be

$$\hat{d}_2^{x,def} = (d_2^x - d_1^x)\cos(\theta + \theta_o) + (d_2^y - d_1^y)\sin(\theta + \theta_o) + (\cos\theta - 1)L \quad (5)$$

where θ is the angle between the initial and current $\hat{x}$ axes, and θ_o is the angle between the initial $\hat{x}$ axis and the spatial x axis. Both angles are measured counterclockwise.

Since the corotational $\hat{x}$ coordinate passes through the two ends of the element, no vertical deformation displacement can exist at these ends. Using this requirement and eq. (19) of [1], the rigid body rotation of the corotational $\hat{x}$ axis can be found as

$$\theta = \cot^{-1} \left[\frac{L + \cos\theta_o (d_2^x - d_1^x) + \sin\theta_o (d_2^y - d_1^y)}{\cos\theta_o (d_2^y - d_1^y) - \sin\theta_o (d_2^x - d_1^x)} \right] \quad (6)$$

where d_i^x , d_i^y are the global spatial nodal displacements at node i in the directions of x and y respectively. The relationship between the corotational nodal rotation $\hat{\phi}_i^{\text{def}}$ and the spatial nodal rotation ϕ_i at node i is simply

$$\hat{\phi}_i^{\text{def}} = \phi_i - \theta \quad (7)$$

Hence the deformation displacement field for the element on the middle surface is completely defined by eqs. (3)-(7) in terms of the generalized spatial nodal displacements-- d_i^x , d_i^y , and ϕ_i , etc. The deformation displacements for the points not on the middle surface can be found, by first noting that the change of curvature of the shell at its midsurface, κ , is given by

$$\kappa = \frac{\partial \hat{v}^{\text{def}}}{\partial X} = - \left[\left(\frac{X}{L} - 1 \right) \left(3 \frac{X}{L} - 1 \right) \hat{\phi}_1^{\text{def}} + \left(\frac{X}{L} \right) \left(3 \frac{X}{L} - 2 \right) \hat{\phi}_2^{\text{def}} \right], \quad (8)$$

to be

$$\hat{u}^{\text{def}}(X, Y) = \frac{X}{L} \hat{d}_2^{\text{def}} + Y \kappa \quad (9)$$

$$\hat{v}^{\text{def}}(X, Y) = \left[L \frac{X}{L} \left(\frac{X}{L} - 1 \right)^2 \right] \hat{\phi}_1^{\text{def}} + \left[L \left(\frac{X}{L} \right)^2 \left(\frac{X}{L} - 1 \right) \right] \hat{\phi}_2^{\text{def}}. \quad (10)$$

where Y is the $\hat{y}$ coordinate of a point at time zero.

The corotational strain components in the x - y plane are given by [1] as

$$\hat{\epsilon}_{xx} = \frac{\partial \hat{u}^{\text{def}}}{\partial X}; \quad \hat{\epsilon}_{xy} = \frac{1}{2} \left(\frac{\partial \hat{u}^{\text{def}}}{\partial Y} + \frac{\partial \hat{v}^{\text{def}}}{\partial X} \right); \quad \hat{\epsilon}_{yy} = \frac{\partial \hat{v}^{\text{def}}}{\partial Y} \quad (11)$$

By substituting eqs. (9) and (10) into eq. (11), we obtain the only nontrivial strain components in the x - y plane referred to the corotational coordinates as

$$\hat{\epsilon}_{xx}^{\text{x, def}}(X, Y) = \frac{\hat{d}_2^{\text{x, def}}}{L} - Y \left\{ \frac{1}{L} \left[\frac{6X}{L} - 4 \right] \hat{\phi}_1^{\text{def}} + \frac{1}{L} \left[\frac{6X}{L} - 2 \right] \hat{\phi}_2^{\text{def}} \right\} \quad (12)$$

It should be noted that though the strain components in the x - y plane are caused only by the deformation displacements, the circumferential strain components are generated by both the deformation and rigid body motions.

The global displacements referred to the spatial coordinates are given by the following equations :

$$U(X,Y) = \frac{X}{L} d_2^x + (1 - \frac{X}{L}) d_1^x - \hat{v}^{\text{def}} \sin(\theta + \theta_0) + Y \kappa \cos(\theta + \theta_0) \quad (13)$$

$$V(X,Y) = \frac{X}{L} d_2^y + (1 + \frac{X}{L}) d_1^y + \hat{v}^{\text{def}} \cos(\theta + \theta_0) + Y \kappa \sin(\theta + \theta_0) \quad (14)$$

where κ is defined by eq. (8) and U, V are in the x and y directions respectively.

Therefore, the circumferential strain $\epsilon_{\theta\theta}$ is obtained as

$$\epsilon_{\theta\theta} = \frac{U(X,Y)}{R} \quad (15)$$

where the initial Langrangian coordinate R for any point is given by

$$R(X,Y) = (1 - \frac{X}{L}) R_1 + \frac{X}{L} R_2 - Y \sin \theta_0 \quad (16)$$

and R_1 and R_2 are the initial horizontal Langrangian coordinates of the ends.

KINETICS

From the previous section, we found that for an axisymmetric shell element only two strain components exist; namely the axial strain $\hat{\epsilon}_{xx}$ and the circumferential strain $\epsilon_{\theta\theta}$. Since these two strains are the principle strains, the variation of internal work can be written in the following form:

$$\int_{V_0} \hat{\sigma}_{ij} \delta \hat{\epsilon}_{ij} dv = \int_{V_0} \hat{\sigma}_{xx} \delta \hat{\epsilon}_{xx} dv + \int_{V_0} \sigma_{\theta\theta} \delta \epsilon_{\theta\theta} dv, \quad (17)$$

where the terms on the right hand side are the internal work due to the corotational axial strain and the circumferential strain, respectively. Let this work be represented by

$$\delta W_p^{\text{int}} = \int_{V_0} \hat{\sigma}_{xx} \delta \hat{\epsilon}_{xx} dv \quad (18)$$

and

$$\delta W_c^{int} = \int_{V_0} \sigma_{\theta\theta} \delta \epsilon_{\theta\theta} dv \quad (19)$$

To compute the volume integration of the equivalent internal nodal forces, we first write

$$\int_{V_0} dv = \int_0^L \int_{-H/2}^{H/2} \int_0^{2\pi} R(X,0) dY dX d\theta \quad (20)$$

Since the problem is an axisymmetric problem, it will be sufficient to consider only the volume corresponding to one radian of the shell. Therefore, we can write eq. (20) as

$$\int_{V_0} dv = \int_0^L \int_{-H/2}^{H/2} R(X,0) dY dX \quad (21)$$

where H is the initial thickness of the shell, which is assumed constant for each element.

Substituting eq. (12) into eq. (18), we obtain the following equations for the internal nodal forces due to the strain $\hat{\epsilon}_{xx}$:

$$\delta W_p^{int} = \hat{i}_{f2}^x \delta \hat{d}_2^{def} + \hat{i}_{m2}^x \delta \hat{\phi}_2 + \hat{i}_{m1}^x \delta \hat{\phi}_1 \quad (22)$$

where

$$\hat{i}_{f2}^x = \frac{1}{L} \int_0^L \int_{-H/2}^{H/2} R(X,0) \hat{\sigma}_{xx} dY dX \quad (23)$$

$$\hat{i}_{m2}^x = \frac{1}{L} \int_0^L \int_{-H/2}^{H/2} Y \left(6 \frac{X}{L} - 2 \right) R(X,0) \hat{\sigma}_{xx} dY dX \quad (24)$$

$$\hat{i}_{m1}^x = \frac{1}{L} \int_0^L \int_{-H/2}^{H/2} Y \left(6 \frac{X}{L} - 4 \right) R(X,0) \hat{\sigma}_{xx} dY dX \quad (25)$$

Since the corotational strain $\hat{\epsilon}_{xx}$ is computed by separating the deformation displacements from the global displacements, the self-equilibrium condition derived in [1] gives the following remaining nodal forces:

$$\frac{i_{f1}^x}{p1} = -\frac{i_{f2}^x}{p2} \quad (26)$$

$$\frac{i_{f1}^y}{p1} = \frac{\frac{i_{m1}^x}{p1} + \frac{i_{m2}^x}{p2}}{L} \quad (27)$$

$$\frac{i_{f2}^y}{p2} = -\frac{i_{f1}^y}{p1} \quad (28)$$

Equations (23) to (28) give the equivalent internal nodal forces referred to the element's corotational coordinates due to the plane strain $\hat{\epsilon}_{xx}$. These nodal forces referred to the spatial coordinates are given by

$$\begin{Bmatrix} \frac{i_{fk}^x}{p_k} \\ \frac{i_{fk}^y}{p_k} \\ \frac{i_{mk}^x}{p_k} \end{Bmatrix} \begin{bmatrix} \cos(\theta + \theta_o) & -\sin(\theta + \theta_o) & 0 \\ \sin(\theta + \theta_o) & \cos(\theta + \theta_o) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} \frac{i_{fk}^x}{p_k} \\ \frac{i_{fk}^y}{p_k} \\ \frac{i_{mk}^x}{p_k} \end{Bmatrix}; \quad k = 1, 2 \quad (29)$$

To obtain the equivalent internal nodal forces due to the circumferential strain $\epsilon_{\theta\theta}$, we substitute eq. (15) into eq. (19). The following results are obtained after some algebraic manipulation:

$$\delta W_c^{int} = \frac{i_{f1}^x}{c1} \delta d_1^x + \frac{i_{f1}^y}{c1} \delta d_1^y + \frac{i_{f2}^x}{c2} \delta d_2^x + \frac{i_{f2}^y}{c2} \delta d_2^y + \frac{i_{m1}^x}{c1} \delta \phi_1 + \frac{i_{m1}^y}{c1} \delta \phi_2 \quad (30)$$

where

$$i_{c1}^m = - \left\{ \sin(\theta + \theta_0) \int_0^L \int_{-H/2}^{H/2} \frac{A}{R} R(X,0) \sigma_{\theta\theta} dYdX + \cos(\theta + \theta_0) \int_0^L \int_{-H/2}^{H/2} Y \frac{A'}{R} R(X,0) \sigma_{\theta\theta} dYdX \right\} \quad (31)$$

$$i_{c2}^m = - \left\{ \sin(\theta + \theta_0) \int_0^L \int_{-H/2}^{H/2} \frac{B}{R} R(X,0) \sigma_{\theta\theta} dYdX + \cos(\theta + \theta_0) \int_0^L \int_{-H/2}^{H/2} Y \frac{B'}{R} R(X,0) \sigma_{\theta\theta} dYdX \right\} \quad (32)$$

$$i_{c1}^y = \frac{\cos(\theta + \theta_0)}{l} f \quad (33)$$

$$i_{c2}^y = -i_{c1}^y \quad (34)$$

$$i_{c2}^x = \frac{\sin(\theta + \theta_0)}{l} f + \int_0^L \int_{-H/2}^{H/2} \frac{X}{L} \frac{R(X,0)}{R} \sigma_{\theta\theta} dYdX \quad (35)$$

$$i_{c1}^x = -i_{c2}^x + \int_0^L \int_{-H/2}^{H/2} \frac{R(X,0)}{R} \sigma_{\theta\theta} dYdX \quad (36)$$

$$A = L \left(\frac{X}{L} - 1 \right)^2 ; \quad A' = \left(\frac{X}{L} - 1 \right) \left(\frac{3X}{L} - 1 \right) \quad (37)$$

$$B = L \left(\frac{X}{L} \right)^2 \left(\frac{X}{L} - 1 \right) ; \quad B' = \frac{X}{L} \left(\frac{3X}{L} - 2 \right) \quad (38)$$

$$f = \cos(\theta + \theta_0) \int_0^L \int_{-H/2}^{H/2} (A\phi_1 + B\phi_2) \frac{R(X,0)}{R} \sigma_{\theta\theta} dYdX - \sin(\theta + \theta_0) \int_0^L \int_{-H/2}^{H/2} Y (A'\phi_1 + B'\phi_2) \frac{R(X,0)}{R} \sigma_{\theta\theta} dYdX \quad (39)$$

and l is the current length of the element.

The global equivalent internal nodal forces referred to the spatial coordinates are, therefore, given by:

$$\left. \begin{aligned} i_{f_k}^x &= i_{p_k}^x + i_{c_k}^x \\ i_{f_k}^y &= i_{p_k}^y + i_{c_k}^y \\ i_{m_k} &= i_{p_k}^m + i_{c_k}^m \end{aligned} \right\} ; \quad k = 1, 2 \quad (40)$$

The variation of external work done by the loading subjected to the variation of displacements is given by:

$$\delta W^{\text{ext}} = \int_{S_0} p \delta U dS + \int_{S_0} q \delta V dS \quad (41)$$

where U and V are the horizontal and vertical displacements; p and q are the horizontal and vertical components of the loading, respectively; and S_0 is the surface on which the load is applied. Substituting eqs. (13) and (14) into eq. (41), we obtain

$$\int_{S_0} p \delta U dS = \frac{e_{f1}^x}{h_1} \delta d_1^x + \frac{e_{f1}^y}{h_1} \delta d_1^y + \frac{e_{f2}^x}{h_2} \delta d_2^x + \frac{e_{f2}^y}{h_2} \delta d_2^y + \frac{e_{m1}}{h_1} \delta \phi_1 + \frac{e_{m2}}{h_2} \delta \phi_2 \quad (42)$$

$$\int_{S_0} q \delta V dS = \frac{e_{v1}^x}{v_1} \delta d_1^x + \frac{e_{v1}^y}{v_1} \delta d_1^y + \frac{e_{v2}^x}{v_2} \delta d_2^x + \frac{e_{v2}^y}{v_2} \delta d_2^y + \frac{e_{m1}}{v_1} \delta \phi_1 + \frac{e_{m2}}{v_2} \delta \phi_2 \quad (43)$$

where

$$\frac{e_{m1}}{h_1} = - \left\{ \sin(\theta + \theta_0) \int_0^L A p R(X, \pm \frac{H}{2}) dX \pm \frac{H}{2} \cos(\theta + \theta_0) \int_0^L A' p R(X, \pm \frac{H}{2}) dX \right\} \quad (44)$$

$$\frac{e_{m2}}{h_2} = - \left\{ \sin(\theta + \theta_0) \int_0^L B p R(X, \pm \frac{H}{2}) dX \pm \frac{H}{2} \cos(\theta + \theta_0) \int_0^L B' p R(X, \pm \frac{H}{2}) dX \right\} \quad (45)$$

$$\frac{e_{f1}^y}{h_1} = \frac{\sin(\theta + \theta_0)}{l} g \quad (46)$$

$$\frac{e_{fy}}{h_2} = -\frac{e_{fy}}{h_1} \quad (47)$$

$$\frac{e_{fx}}{h_2} = \frac{\sin(\theta + \theta_0)}{l} g + \int_0^L \frac{X}{L} pR(X, \pm \frac{H}{2}) dX \quad (48)$$

$$\frac{e_{fx}}{h_1} = -\frac{e_{fx}}{h_2} + \int_0^L pR(X, \pm \frac{H}{2}) dX \quad (49)$$

$$g = \cos(\theta + \theta_0) \int_0^L (A\phi_1 + B\phi_2) pR(X, \pm H/2) dX \mp \frac{H}{2} \sin(\theta + \theta_0) \int_0^L (A'\phi_1 + B'\phi_2) pR(X, \pm H/2) dX \quad (50)$$

$$\frac{e_{m1}}{v_1} = \cos(\theta + \theta_0) \int_0^L AqR(X, \pm \frac{H}{2}) dX \mp \frac{H}{2} \sin(\theta + \theta_0) \int_0^L A'qR(X, \pm \frac{H}{2}) dX \quad (51)$$

$$\frac{e_{m2}}{v_2} = \cos(\theta + \theta_0) \int_0^L BqR(X, \pm \frac{H}{2}) dX \mp \frac{H}{2} \sin(\theta + \theta_0) \int_0^L B'qR(X, \pm \frac{H}{2}) dX \quad (52)$$

$$\frac{e_{fx}}{v_2} = \frac{\sin(\theta + \theta_0)}{l} h \quad (53)$$

$$\frac{e_{fx}}{v_1} = -\frac{e_{fx}}{v_2} \quad (54)$$

$$\frac{e_{fy}}{v_2} = \int_0^L \frac{X}{L} qR(X, \pm \frac{H}{2}) dX - \frac{\cos(\theta + \theta_0)}{l} h \quad (55)$$

$$\frac{e_{fy}}{v_1} = -\frac{e_{fy}}{v_2} + \int_0^L qR(X, \pm \frac{H}{2}) dX \quad (56)$$

$$h = \sin(\theta + \theta_0) \int_0^L (A\phi_1 + B\phi_2) qR(X, \pm \frac{H}{2}) dX \pm \frac{H}{2} \cos(\theta + \theta_0) \int_0^L (A'\phi_1 + B'\phi_2) qR(X, \pm \frac{H}{2}) dX \quad (57)$$

and the integration in the θ direction is only taken over one radian because of symmetry; the upper one of the signs $\pm$ or $\mp$ should be used when the loading is applied over the surface $Y = H/2$ and the lower one should be used when the loading is applied over the surface $Y = -H/2$.

Hence, from eqs. (41), (42), and (43), the global equivalent external nodal forces are given by

$$\left. \begin{aligned} e_{f_k}^x &= e_{h_k}^x + e_{v_k}^x \\ e_{f_k}^y &= e_{h_k}^y + e_{v_k}^y \\ e_{m_k} &= e_{h_k}^m + e_{v_k}^m \end{aligned} \right\} ; \quad k = 1, 2 \quad (58)$$

It should be noted that the equivalent external nodal forces given by eqs. (44) to (58) are the exact formulation of the loadings. Since the problem is nonlinear, these equations show that the equivalent nodal forces are functions of the current configuration of the shell.

The global displacement functions defined by eqs. (13) and (14) are not linear in terms of the global nodal displacements because of the existence of terms such as cosine and sine; hence the second time derivative of these functions will involve cross products of rotations and their time derivatives at the nodes of the element. This means that the rigorous derivation of the equivalent nodal inertial forces will not only generate a coupled mass matrix but also a coupled "damping" matrix and a coupled "stiffness" matrix, where all these matrices depend on the current configuration of the element. In other words, the simple equations of motion that contain only the nodal accelerations and equivalent internal and external forces cannot be achieved for the displacements defined by eqs. (13) and (14).

To resolve this difficulty and also to save computation efforts, a lumped mass matrix is used. The main advantages of using a lumped mass matrix are first the matrix is diagonal and second the matrix is invariant under coordinate transformation. The main disadvantage of it is that the lumped mass matrix

cannot be generated uniquely by a systematic method. If we consider that the effect of mass of an element is separated by its midpoint along the axis of the shell, we find the following lumped masses for the nodes:

$$\begin{aligned}
 M_1^t &= \frac{1}{8} \rho HL (3R_1 + R_2) \\
 M_2^t &= \frac{1}{8} \rho HL (R_1 + 3R_2) \\
 M_1^r &= \frac{1}{192} \rho HL^3 (5R_1 + 3R_2) \\
 M_2^r &= \frac{1}{192} \rho HL^3 (3R_1 + 5R_2)
 \end{aligned} \tag{59}$$

where the subscripts 1 and 2 refer to the first and second nodes; superscripts t and r stand for translational and rotational, respectively; and ρ is the initial density of the element. Again, it should be noted that eq. (59) is not the only lumped mass we can obtain for this element; other values for the masses can be obtained by taking other position rather than the midpoint as the border of effects of the nodes.

The equations of motion for the system are obtained, as outlined in [1], as follows

$$[M] \{\ddot{D}\} = \{F^e\} - \{F^i\} \tag{60}$$

where $\{\ddot{D}\}$ is the generalized global nodal displacement vector; $[M]$ is the lumped mass matrix; and $\{F^e\}$ and $\{F^i\}$ are the generalized global external and internal nodal forces, respectively.

CONSTITUTIVE EQUATIONS

The general formulation for corotational constitutive equations were presented in [1]. In this study of shells, we have only two nonvanishing strain components, namely $\hat{\epsilon}_{xx}$ and $\epsilon_{\theta\theta}$. The circumferential strain $\epsilon_{\theta\theta}$ is independent of the transformation between the corotational and spatial coordinates since the transformation is confined to the x-y plane. Therefore the strain $\epsilon_{\theta\theta}$ referred to the spatial coordinates has the same value when it is referred to the corotational coordinates, i.e., $\hat{\epsilon}_{\theta\theta} = \epsilon_{\theta\theta}$. Similarly, we also obtain $\hat{\sigma}_{\theta\theta} = \sigma_{\theta\theta}$. Hence, the results derived in [1] can be used directly.

Since both the corotational strains and stresses are the principal strains and stresses, respectively, the constitutive equations are readily obtained for the elastic and elastoplastic materials.

(A) Linearly elastic materials. The constitutive equation is obtained by imposing the condition that all the stress components but $\hat{\sigma}_{xx}$ and $\hat{\sigma}_{\theta\theta}$ must vanish in the general three-dimensional constitutive equation, as

$$\begin{Bmatrix} \hat{\sigma}_{xx} \\ \hat{\sigma}_{\theta\theta} \end{Bmatrix} = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu \\ \nu & 1 \end{bmatrix} \begin{Bmatrix} \hat{v}_{xx} \\ \hat{v}_{\theta\theta} \end{Bmatrix} \quad (61)$$

where E and ν are the Young's modulus and Poisson's ratio, respectively; and the corotational rate of deformation $\hat{v}_{xx}$ and $\hat{v}_{\theta\theta}$ are given by [1]

$$\begin{Bmatrix} \hat{v}_{xx} \\ \hat{v}_{\theta\theta} \end{Bmatrix} = \begin{Bmatrix} \hat{\epsilon}_{xx} / (1 + \hat{\epsilon}_{xx}) \\ \hat{\epsilon}_{\theta\theta} / (1 + \hat{\epsilon}_{\theta\theta}) \end{Bmatrix} \quad (62)$$

and the superscript dot represents partial time derivative.

It is noted that the condition of state of plane stress in the $\hat{y}$ direction (i.e., normal direction of the shell) had to be used in deriving eq. (61).

Furthermore, eq. (61) shows that the elastic coefficient tensor C_{ijkl} which relates the strains and stresses [1] for an elastic material is given by

$$\left. \begin{aligned} C_{xxxx} &= C_{\theta\theta\theta\theta} = \frac{E}{1 - \nu^2} \\ C_{xx\theta\theta} &= C_{\theta\theta xx} = \frac{\nu E}{1 - \nu^2} \\ \text{all other } C_{ijkl} &= 0 \end{aligned} \right\} \quad (63)$$

(B) Linearly elastoplastic materials: Let the yield function be given by the widely used Von Mises' criterion

$$f = \hat{\sigma}_{xx}^2 + \hat{\sigma}_{\theta\theta}^2 - \hat{\sigma}_{xx}\hat{\sigma}_{\theta\theta} = \sigma_o^2 \quad (64)$$

where σ_o is the one-dimensional yield stress of the material, which is a function of the plastic work only.

The yield function gradient tensor, g_{ij} and the deviatoric stress tensor s_{ij} are given by

$$\left. \begin{aligned} g_{xx} &= 2 \hat{\sigma}_{xx} - \hat{\sigma}_{\theta\theta} \\ g_{\theta\theta} &= 2 \hat{\sigma}_{\theta\theta} - \hat{\sigma}_{xx} \\ \text{all other } g_{ij} &= 0 \end{aligned} \right\} \quad (65)$$

and

$$\left. \begin{aligned} \hat{s}_{xx} &= \hat{\sigma}_{xx} - (\hat{\sigma}_{xx} + \hat{\sigma}_{\theta\theta})/3 \\ \hat{s}_{\theta\theta} &= \hat{\sigma}_{\theta\theta} - (\hat{\sigma}_{xx} + \hat{\sigma}_{\theta\theta})/3 \\ \hat{s}_{yy} &= -(\hat{\sigma}_{xx} + \hat{\sigma}_{\theta\theta})/3 \\ \text{all other } \hat{s}_{ij} &= 0 \end{aligned} \right\} \quad (66)$$

The flow rule for the plastic rate of deformation $\hat{V}_{ij}^P$ is derived in [1] as

$$\hat{V}_{ij}^P = \frac{g_{ij} g_{mn} C_{pqmn} \hat{V}_{pq}}{g_{rs} C_{rsur} g_{ur} + m \hat{s}_{rs} g_{rs}} \quad (67)$$

Substituting eqs. (63), (65), and (66) into eq. (67), we obtain

$$\begin{Bmatrix} \hat{V}_{xx}^P \\ \hat{V}_{\theta\theta}^P \end{Bmatrix} = \frac{1}{A} \begin{bmatrix} (C_{xxxx} g_{xx} + C_{xx\theta\theta} g_{\theta\theta}) g_{xx} & (C_{\theta\theta xx} g_{xx} + C_{\theta\theta\theta\theta} g_{\theta\theta}) g_{xx} \\ (C_{xxxx} g_{xx} + C_{xx\theta\theta} g_{\theta\theta}) g_{\theta\theta} & (C_{\theta\theta xx} g_{xx} + C_{\theta\theta\theta\theta} g_{\theta\theta}) g_{\theta\theta} \end{bmatrix} \begin{Bmatrix} \hat{V}_{xx} \\ \hat{V}_{\theta\theta} \end{Bmatrix} \quad (68)$$

where A is given by

$$A = C_{xxxx} [g_{xx}^2 + g_{\theta\theta}^2 + 2\nu g_{xx} g_{\theta\theta}] + m [\hat{s}_{xx} g_{xx} + \hat{s}_{\theta\theta} g_{\theta\theta}] \quad (69)$$

and the value of m for a bilinear elastoplastic material is given by

$$m = \frac{2 E E_p}{3(E + E_p)} \quad (70)$$

where E_p is the plastic modulus.

In numerically applying these constitutive equations, a trial stress state is first computed by assuming that all the deformations are elastic, then the stresses are substituted into the yield function to see whether the computed stress state is inside the yield surface. If so, the trial stress is the true stress; otherwise, the plastic rate of deformation is computed using eq. (68), and a new yield stress is found by subtracting the plastic part from the rate of deformation and the yield surface is also updated to the new stress state.

COMPUTER PROGRAM

The principle of the corotational finite element method for a shell element is outlined in the previous sections. However, some of the equations can be further simplified when we assume appropriate conditions. These simplifications are listed below:

(A) The strains $\hat{\epsilon}_{xx}$ are so small that the current length of an element used in computing the rigid body rotation can be approximated by its original length such as in eq. (29) etc.

(B) The strains $\hat{\epsilon}_{xx}$ and $\hat{\epsilon}_{\theta\theta}$ are so small that the corotational rate of deformation can be approximated by the corotational strain rate. In other words the strains can be neglected in comparison to unit as used in eq. (62).

(C) The global displacement in the horizontal direction is approximately represented when we neglected the third term in eq. (13).

(D) When the shell is thin, the equivalent external nodal forces can be computed by considering only the motion of the midsurface. The nodal forces for a uniformly distributed normal pressure loading of intensity p are given, for example, by

$$\left. \begin{aligned} e_{f1}^x &= \frac{Pl}{2} \sin(\theta + \theta_0) \left[R_1 + \frac{1}{3} \cos(\theta + \theta_0)l \right] \\ e_{f2}^x &= \frac{Pl}{2} \sin(\theta + \theta_0) \left[R_1 + \frac{2}{3} \cos(\theta + \theta_0)l \right] \\ e_{f1}^y &= \frac{Pl}{2} \cos(\theta + \theta_0) \left[R_1 + \frac{1}{3} \cos(\theta + \theta_0)l \right] \\ e_{f2}^y &= \frac{Pl}{2} \cos(\theta + \theta_0) \left[R_1 + \frac{2}{3} \cos(\theta + \theta_0)l \right] \\ e_{m1} &= \frac{Pl^2}{12} \left[R_1 + \frac{2}{5} l \cos(\theta + \theta_0) \right] \\ e_{m2} &= \frac{-Pl^2}{12} \left[R_1 + \frac{3}{5} l \cos(\theta + \theta_0) \right] \end{aligned} \right\} \quad (71.)$$

(E) The integration over the volume of the element can be adequately computed by using the Gaussian quadrature formulas that take two points and five points along the axial and normal directions respectively.

(F) The equation of motion, eq. (60) can be integrated timewise by using the central difference technique. The difference equations for velocity and displacement are given by

$$\{D(t + \Delta t)\} = \{D(t)\} + \Delta t \{\dot{D}(t)\} + \frac{\Delta t^2}{2} \{\ddot{D}(t)\} \quad (72)$$

$$\{\dot{D}(t + \Delta t)\} = \{\dot{D}(t)\} + \frac{\Delta t}{2} [\{\ddot{D}(t)\} + \{\ddot{D}(t + \Delta t)\}] \quad (73)$$

where Δt is the time increment. The above equations are equivalent to a special case of the Newmark β -method with the parameter β set to zero [2].

For a typical cycle, the step by step integration of equations of motion is done in the following sequence: (1) compute the new displacements by using eq. (73); (2) compute the new equivalent internal and external nodal forces by using eqs. (40), (71), and the results of (1); (3) compute the new accelerations by solving the equation of motion, eq. (60); and (4) compute the new velocities by using eq. (72) and the results of (3).

It is noted that this step by step integration scheme does not require any iteration; however, it is not numerically stable unless the time increment satisfies the stability criterion. The conditions on the time increment can be derived by requiring that no disturbance can travel the characteristic length of an element within the time increment.

(G) The one dimensional elastoplastic constitutive equation of the material of the structure can be adequately represented by a trilinear stress-strain curve. In other words, the material behaves linearly elastically until

the stress reaches the value of σ_0 with an elastic modulus E , then it may kinematically harden to the stress σ_u with a plastic modulus E_p , and no stress greater than σ_u is permitted. The stress-strain curve for a typical material is shown in Fig. 3.

A computer program has been written in FORTRAN language by utilizing conditions (A) through (F). This program contains a small main program and thirteen subroutines. Their names and functions are listed below in an alphabetical order:

ASSBLE:	Assembling the inverse lumped mass matrix of the structure; computing the stability requirement on time increment; updating output control parameter and time increment when necessary.
DECODE:	Decoding a coded integer that may be either a boundary condition or an output control parameter.
EXTREM:	Finding the extreme values, i.e., maximum and minimum of an array.
FRCIN:	Computing the generalized equivalent internal nodal forces of the structure.
FREEFD:	Computing the generalized equivalent external nodal forces of the structure.
INPUT:	Reading the input data.
MAIN:	Allocating array dimensions and their maximum allowable values.
MISES2:	Computing the stress from known strains by using the elasto- plastic constitutive law.
OUTPUT:	Writing the desired output.
PLOTTER:	Plotting the arrays by using the printer.
ROTATE:	Transforming a vector from one coordinate system to another.

SHELL: Transferring and initializing variable.
 SOLVEN: Integrating the discretized equations of motion.
 THERMO: Not used currently.

Only two of these subroutines are of user-supplied type; namely MAIN and FREEFD. The subroutine FREEFD is used to compute the generalized external nodal forces that are functions of the loading. In the current version of FREEFD, the external nodal forces are computed for loading that is uniformly distributed over the whole structure. For other types of loading the user is expected to write his own version of FREEFD according to the equations developed in the previous sections.

To use the computer core storage most optimally, the user is required to supply appropriate dimensions for the arrays used by the program. Furthermore, the program will automatically check to see that the discretized finite element model can be treated within the dimensions of the arrays to avoid unnecessary waste of resources. The allocation of arrays and initialization of maximum allowable values are done in the subprogram MAIN. The correct dimensions of arrays used in the MAIN are as follows:

E(8,MMATD),IX(3,MELED),THICK(MELED),XC(MPTD),YC(MPTD),NODDIS(MDPTD),
 ANGLE(MDPTD),INDEX(MELED),STRS(MSTRSD),AO(NDOF),A1(NDOF),V(NDOF),
 XO(NDOF),X1(NDOF),FEXT(NDOF),FINT(NDOF),SMASS(NDOF),ITITLE(17,MXMUS),
 IUOT(MSNPRU),ISOT(MXNPRS),NPOUT(2,MXNPIC),PSU(NUMPLT),US(MXMUS),
 KPLOT(MXMUS),J1(MXMUS),J2(MXMUS),J3(MXMUS),J4(MXMUS),P1(MXMUS),
 P2(MXMUS),K3(MXMUS),P4(MXMUS)

where the following conditions should be observed:

$$MPTD = MELED + 1$$

$$\text{NDOF} = (\text{MELE} + 1) \times 3$$

$$\text{NSTRSD} = \text{MELE} \times 62$$

$$\text{MXMUS} = \text{MXNPRU} + \text{MXNPRS}$$

and the meanings of the independent variables and their current values are:

MMATD: Maximum number of different materials; 2

MELE: Maximum number of elements; 30

MDPTD: Maximum number of boundary nodes; 2

MXNPRU: Maximum number of displacement, velocity, or acceleration output; 10

MXNPRS: Maximum number of stress or strain output; 20

MXNPIC: Maximum number of the output of the state of the structure (i.e., configurations, stresses, strains) at some specific time; 10

NUMPLT: Maximum number of total stored data for printer plotting. This number depends on how many histories and configurations are to be plotted. Its value can be computed by the following formula:

$$\text{NUMPLT} = (\text{KKK} + 1) \times (\text{DT}/\text{DELT})/\text{NPFREQ} + 2(\text{NELE} + 1) \times \text{NPIC}$$

where KKK and NPIC are the total numbers of the histories and configurations to be plotted, DT and DELT are the final time and time increment, NELE is the total number of the elements, and NPFREQ is the frequency of the output (i.e., the results will be stored or printed every NPFREQth time step). Current value used is 3210.

The program checks the input data to see that they do not exceed the maximum allowable values. The program will stop with some printed information indicating what data have exceeded their maxima, by how much, and

which subroutine has caused the termination. The printer plotter will print an * for any data pair; the symbol M will appear when more than one point occupies the same position. Since the printer plotting gives only very coarse picture of the curve, it is only to be used as a guide to get some general idea. Furthermore, the printer plotting subroutine PLOTTER is written to treat one hundred data pairs; hence only the initial one hundred data of any curve will be plotted, and the rest of the data will be ignored without interfering with other functions of the program. Modifications on the dimensions and indices in PLOTTER can be easily made to increase the amount of data that can be treated when necessary.

For better qualitative plots, other types of plotting hardware rather than the printer is needed. Since the availability of hardware and software for plotting is institute dependent, it is difficult to write a plotting program other than the printer plotting type, which can be used at other institutes without major changes. It is for this reason that no other type of plotting is intended in this program. However, the desired results can be written onto a secondary storage so that the user can write his own program to retrieve these data and to plot these results using any hardware and software that are available to him. The writing of results onto the secondary storage is done through Unit 7; hence, when no additional job control statement is used, the default device for secondary storage is punched card. The retrieving of plotting data is explained later.

Following are lists of cross reference for the subroutines, description for input data, description for retrieving stored data, example problem.

SUBROUTINE NAME	SUBROUTINE THAT CALLS COLUMN 1	SUBROUTINE THAT ARE CALLED BY COLUMN 1
ASSBLE	SHELL	-
DECOD	INPUT, OUTPUT, SOLVEN	-
EXTREM	OUTPUT	-
FRCIN	SOLVEN	MISES2
FREEFD	SOLVEN	-
INPUT	SHELL	DECOD
MAIN	-	SHELL
MISES2	FRCIN	-
OUTPUT	SOLVEN	DECOD, EXTREM, PLOTTER
PLOTTER	OUTPUT	-
ROTATE	SOLVEN	-
SHELL	MAIN	INPUT, ASSBLE, SOLVEN
SOLVEN	SHELL	THERMO, FREEFP, FRCIN, ROTATE, OUTPUT
THERMO	FRCIN	-

INPUT DATA DESCRIPTION

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
1	TITLE	20A4	Title of the problem
2		3I5,2E10.6	
	NELE		Number of elements of the problem
	NUMMAT		Number of different types of material
	NUMDIS		Number of boundary nodes
	DELT		Time increment

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
			<p>DELT > 0: The time increment limit will be computed by the program. The smaller one of this computed time increment and input value will be used as the time increment.</p> <p>DELT < 0: The absolute value of the input value will be used as time increment regardless of whether it satisfies the stability requirement or not.</p>
	DT		Final time
3	MTYP	I5	Material type number
3-1		8E10.4	
	E(1,MTYP)		Density of the element
	E(2,MTYP)		Elastic modulus of the element
	E(3,MTYP)		Initial yield stress of the element
	E(4,MTYP)		Plastic modulus of the element
	E(5,MTYP)		Ultimate stress of the element
	E(6,MTYP)		Poisson's ratio of the element
	E(7,MTYP)		Thickness of the element
	E(8,MTYP)		Thermo constant; not used in current version
			NOTE: A total number of NUMMAT sets of cords type 3 and 3-1 are needed.
4		I5,5X,2E10.6	
	N		Nodal number
	XC(N)		Horizontal coordinate of node N
	YC(N)		Vertical coordinate of node N
			NOTE: Nodes that are equally spaced between any two nodes can be skipped. The nodal number and its coordinates will be automatically generated by the program from the information at the initial and final nodes. Hence at least two cards of card type 4 are needed.

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
5		4I5,E10.6	
	M		Element number
	NODE(1,M)		Nodal number of the first node of element M
	NODE(2,M)		Nodal number of the second node of element M
	NODE(3,M)		Material number of element M
	THICK(M)		Thickness of element M
		<p>NOTE: The thickness for an element can be read into the program either as the parameter E(7,MTYP) or as the parameter THICK(M). The values of the former is used as the default value, while the value of the latter dominates when its value is greater than zero.</p> <p>NOTE: Data for those elements whose thickness and material type, MTYP = NODE(3,M), are the same as the previous element and whose nodal number are obtainable by adding one to the respective nodes of the previous element can be skipped. However data for the last element must be entered.</p>	
6		I10,E10.4	
	NODDIS(I)		<p>Coded boundary condition for the Ith boundary node. The general form of NODDIS can be written as NIJK where N occupies columns 1 to 7 and I, J, and K occupy columns 8, 9, and 10 respectively. Imbedded blanks will be treated as zeroes. The meaning of NIJK is:</p> <p>N: nodal number of the boundary node I: I=1; no movements allowed in the local horizontal direction I=0; movements allowed in the local horizontal direction J: J=1; no movements allowed in the local vertical direction J=0; movements allowed in the local vertical direction K: K=1; no rotation in the circumferential direction allowed K=0; rotation in the circumferential direction allowed.</p> <p>where the local coordinate system is obtained by rotating the spatial coordinate ANGLE(I) degrees counterclockwise.</p>

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
7	ANGLE(I)		The angle in degree that is needed to define the local coordinate system.
		NOTE: A total number of NUMDIS set of card type 6 is needed.	
		4I10	
	NPFREQ		Output control parameter; desired results will be stored or printed at every NPFREQth time step.
	NPRU		Total number of displacement, velocity, or acceleration output at nodes
8	NPRS		Total number of strain and stress output at Gaussian stations
	NPIC		Total number of state-of-the-structure output
	IUOT(I)	I10,1X,17A4	<p>Coded parameter for the Ith displacement, velocity, or acceleration output. The general form of IUOT is NIJK where N occupies columns 1 to 7 and I, J, and K occupy columns 8,9, and 10 respectively. Imbedded blanks will be treated as zeroes. The meaning of NIJK is:</p> <p>N: nodal number at which displacement, velocity, or acceleration is desired.</p> <p>I: I=1; horizontal component is desired. I=2; vertical component is desired. I=3; rotational component is desired.</p> <p>J: J=0; displacement is desired. J=1; velocity is desired. J=2; acceleration is desired.</p> <p>K: K=0; printed output at specified cycles. K=1; above and printer plot of the time history K=2; above and writing of the history onto a secondary storage.</p>

CARD
TYPEFORTRAN
NAME

FORMAT

DESCRIPTION

(ITITLE(J,I),
J=1,17)

Title of the plot of the time history

NOTE: A total number of NPRU set of card type 8 is needed.

9

I10,IX,17A4

ISOT(I)

Coded parameter for the Ith strain or strain output. The general form of ISOT is MLK where M occupies columns 1 to 7, L occupies columns 8 to 9, and K occupies column 10. The meaning of MLK is:

- M: Element number at which strain or stress output is desired.
- L: Output identification number. The assigning of value for L is explained below.

Since 5 points and 2 points are used in the axial and normal direction for evaluation of any volume integration, there are ten Gaussian stations for each element. Let these stations be numbered from one to ten in the order that its y coordinates increases faster than its x coordinate as shown in the following sketch.

Then the output identification number L for an element is given by the following table:

CARD
TYPEFORTRAN
NAME

FORMAT

DESCRIPTION

station output	1	2	3	4	5	6	7	8	9	10
$\hat{\epsilon}_{xx}$	1	2	3	4	5	6	7	8	9	10
$\hat{\sigma}_{xx}$	11	12	13	14	15	16	17	18	19	20
$\hat{\epsilon}_{\theta\theta}$	21	22	23	24	25	26	27	28	29	30
$\hat{\sigma}_{\theta\theta}$	31	32	33	34	35	36	37	38	39	40
σ_y	41	42	43	44	45	46	47	48	49	50
T	51	52	53	54	55	56	57	58	59	60

where σ_y is the current yield stress and T is the current temperature. T will have value of zero for the current program since no thermal analysis is performed.

K: K=0; printer output at specified cycle
K=1; above and printer plot of the time history
K>2; above and writing of the history onto a secondary storage

Title of the plot of the time history.

NOTE: A total of NPRS set of card type is needed.

2I10

10

ITITLE(J,I)
J=1,17

NPOUT(1,I)

Cycle number at which the information of the whole structure is desired.

NPOUT(2,I)

Output control parameter; its value may be:

- 1; displacements and rotations at all nodes
- 2; above and deformed coordinates at all nodes. Also the printer plot of the deformed configuration of the structure is printed.
- 3; above and velocities and accelerations at all nodes.
- 4; above and all the strains and stresses at all the Gaussian stations of the structure.

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
			5; above and writing the deformed configuration of the structure onto a secondary storage.
			NOTE: The cycle number for any time is simply obtained as the quotient of the time and time increment.
			Though the program may use a different time increment other than the input value due to stability requirement, however, the program will automatically update the values of cycle in NPOUT(1,I) and NPFREQ such that the desired output is obtained at the same physical time separated by the same physical time internal. Therefore, when deciding the values for these cycles, the input value of DT and DELT used on Card Type 1 should be used.
			NOTE: A total number of NPIC set of card type 10 is needed.
			NOTE: All the above data are read by the subroutine INPUT.
11	MPNT	I10	Total number of intersections between the segments of the piecewise linear pressure time curve. Maximum value allowed is eight.
11-1	TM(I),I=1,8	8E10.4	Time coordinates of the intersections.
11-2	PRSS(I),I=1,8	8E10.4	Pressure coordinates of the intersections.
			NOTE: Card type 11, 11-1, and 11-2 are read in by the subroutine FREEFD. This subroutine is written only for pressure loading uniformly distributed over the whole structure. The pressure loading is positive when it is in the same direction as the $\hat{y}$ coordinate of an element. For other types of loadings, the user has to write his own FREEFD.

RETRIEVING OUTPUT DATA

When correct parameters are used in the input data of the shell analysis program, the desired output will be written onto a secondary storage device. These data may contain the coordinates of the deformed structure at specified times and the time histories of the specified responses. A program that reads the stored data and plots them using a software package called DISSPLA is written as an example to show how the data is retrieved and plotted. This program needs two input data sets: one is the set that stored the output from the shell program, and the other one is the data for controlling this plotting program. The former one is read in through unit 7, the latter is through unit 5.

The correct dimensions for arrays are listed below:

```
REAL*4  TIME(MPNT), HSTRY(MTPNT), TFIN(NPIC), XC(MND), YC(MND)
REAL*8  DTIME(MPNT), DHSTRY(MTPNT), DTFIN(NPIC), DXC(MND), DYC(MND)
DIMENSION LTITLE(MT), KNTRL(KKK)
```

where the following rules should be followed:

$$MTPNT = MPNT * KKK$$

$$MND = NUMNP * NPIC$$

$$MT = 17 \times KKK$$

and KKK and NPIC are the numbers of history and configuration output, MPNT and NUMNP are the number of data points in the history curve and number of nodes in the configuration curve, respectively. These numbers can be easily adjusted to treat problems that might exceed the present ceiling.

Following is the descriptions of input data for unit 5:

CARD TYPE	FORTRAN NAME	FORMAT	DESCRIPTION
1		3I5	
	K8OR4		Control parameter indicating the length of the real numbers of the data on unit 7 K8OR4=4; standard length or single precision K8OR4=8; extended length or double precision
			NOTE: IBM FORTRAN H-extended compiler has an option to increase the single precision real variables to double precision. In other words, the real data on unit 7 can be either single or double precision.
	KAUTOC		Control parameter indicating the desire of automatic scaling for configuration curves. KAUTOC=0: automatic scaling is desired KAUTOC>0: scaling factors are to be read
	KAUTOP		Control parameter indicating the desire of automatic scaling for history curves. KAUTOP=0: automatic scaling is desired. KAUTOC>0: scaling factors are to be read
2		6E10.4,I5	
	XMIN		Minimum of the horizontal coordinate of the configurations to be plotted.
	XMAX		Maximum of the horizontal coordinate of the configurations to be plotted.
	XLNTH		The length of the horizontal axis of the plot in inch. The value of XLNTH should not exceed eight.
	YMIN		Minimum of the vertical coordinate of the configurations to be plotted.
	YMAX		Maximum of the vertical coordinate of the configurations to be plotted.
	YLNTH		The length of the vertical axis of the plot in inch. The value of YLNTH should not exceed ten and a half.

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
	IMARK		Number of points between each drawn mark.
		NOTE:	Card type 2 is needed only when KAUTO C is greater than zero. Otherwise, the extreme values of the coordinates will be computed; the values for XLNTH and YLNTH will be seven and the value of IMARK will be zero.
		NOTE:	All of the NPIC curves of the configurations will be drawn in one plot. The order of the curve drawings is (1) solid line, (2) dotted line, (3) dashed line (4) chain-dotted line, and (5) chain-dashed line. The sequency is repeated if the number of configurations NPIC exceeds five.
3	KNTRL(J), J=1, NCRV	16I5	Control parameters for each history curve. KNTRL(J)≤1; no plotting for the Jth history desired. KNTRL(J)=2; automatic scaling is desired KNTRL(J)≥3; scaling factors are read
		NOTE:	Card type 3 is needed only when KAUTOP is greater than zero.
		NOTE:	The parameters KNTRL(J) are the same as those output control parameters K used for NPRS and NPRU in the previously studied shell analysis program. Hence when KAUTOP is zero, the values of the K's and their corresponding titles that had already been read through unit 7 will dominate the control of this program. Therefore, if inconsistent values of K had been used in the shell program, the option of KAUTOP > 0 should be used, and correct values of KNTRL be entered through card type 3 to take over the control of this program.
4		6E10.4,I5	
	TMIN		Minimum of the horizontal coordinate, i.e. time axis, of the history curve to be plotted.
	TMAX		Maximum of the time axis of the history curve to be plotted.
	TLNTH		The length of the time axis of the plot in inches. The value of TLNTH should not exceed ten and a half.

CARD TYPE	FORTTRAN NAME	FORMAT	DESCRIPTION
	HMIN		Minimum of the vertical coordinate of the history curve to be plotted.
	HMAX		Maximum of the vertical coordinate of the history curve to be plotted.
	HLNTH		The length of the vertical axis of the plot in inches. The value of HLNTH should not exceed eight.
	IMARK		Number of points between each drawn mark.
NOTE: When KAUTOP is zero, one card type 4 is needed for each K that has a value greater than two; when KAUTOP is greater than zero, one card type 4 is needed for each KNTRL that is greater than two.			

EXAMPLE:

Consider a spherical thin shell whose edge is fixed with the following geometric and material properties: radius of curvature = 4.76 inch; base diameter = 1.8 inch; thickness = 0.016 inch; density = 2.928×10^2 pound mass per cubic inch; Young's modulus = 1×10^7 psi; Poisson's ratio = 0.3; initial yield stress = 40,000 psi; plastic modulus = 10,000 psi; and ultimate stress = ∞ . The shell is subjected to a uniformly distributed pressure loading on the convex side.

Due to symmetry, only the projection of the shell in the x-y plane in the first quadrant needs consideration. Ten equal length elements are used in this example; the numberings of the elements and the nodes are such that the larger the angle the higher the numbers where the angle is measured clockwise from the apex. The boundary conditions are: no rotation and horizontal displacement at node 1 due to symmetry, and no rotation and displacements at node 11 due to edge condition.

The pressure loading is a step function in time. A time increment of

3 microseconds and a final time of 0.3 minisecond are used. The input data and the printed output for this problem is shown in Appendix A. Since the plotting control variable used for the stored data is for automatic scaling; the input for the plotting program on Unit 5 is simply a four on column 5 of the data card when no overriding control statements are intended. It should be noted that this example is for illustration purposes, hence no attempt is made to check convergence a function of the number of elements.

As can be seen from the printed output that the maximum vertical tip displacement is about 2.6 times larger than the height of the shell or about 13.9 times larger than the thickness of the shell. Also it is noted that all the Gaussian stations of the shell have developed plastic strain. From the printer plot of the apex displacement and the printer plot of the shell configuration at 0.3 milisecond, we notice the phenomenon called snap through.

LISTING OF PROGRAMS

The listing of the source statements of the shell analysis program and data retrieving and plotting program are presented in Appendices B and C, respectively.

REFERENCE

- [1] Hsieh, B. J., "On Nonlinear Formulation of Finite Element by Corotational Coordinates", ANL-CT-77-9.

Fig. 1.

Fig. 2.

Fig. 3.

ELASTOPL/ C ANALYSIS FOR SHALLOW SHELL UNDER 100 PSI PRESSURE

```

10      2  3.000E-6  300.0E-6
1
2.440E-4  10.00E+6  40.00E+3  10.00E+3  1.000E50  3.000E-1  1.6000E-2
1      0.000000  4.760000
2      0.090540  4.759139
3      0.181046  4.756556
4      0.271488  4.752252
5      0.361831  4.746228
6      0.452043  4.738487
7      0.542092  4.729031
8      0.631944  4.717365
9      0.721568  4.704991
10     0.810931  4.690415
11     0.900000  4.674142
1      1      2      1
10     10     11     1
1101
11111
2      4      8      2
1202 THE Y-DISPLACEMENT HISTORY AT NODE 1 $
7102 THE X-DISPLACEMENT HISTORY AT NODE 7 $
7202 THE Y-DISPLACEMENT HISTORY AT NODE 7 $
7302 THE ROTATION HISTORY AT NODE 7 $
1031 THE MERIDIAN-STRAIN HISTORY AT ST.3 OF ELE.1 $
1130 THE MERIDIAN-STRESS HISTORY AT ST.3 OF ELE.1 $
1231 THE HOOP-STRAIN HISTORY AT ST.3 OF ELE.1 $
1330 THE HOOP-STRESS HISTORY AT ST.3 OF ELE.1 $
10080 THE MERIDIAN-STRAIN HISTORY AT ST.8 OF ELE.10 $
10180 THE MERIDIAN-STRESS HISTORY AT ST.8 OF ELE.10 $
10280 THE HOOP-STRAIN HISTORY AT ST.8 OF ELE.10 $
10380 THE HOOP-STRESS HISTORY AT ST.8 OF ELE.10 $
1      5
100     5
2
0.000E00  1.000E00
-100.0E00 -100.0E00

```

APPENDIX A

INPUT AND OUTPUT DATA

(A) INPUT DATA

ELASTOPLASTIC ANALYSIS FOR SHALLOW SHELL UNDER 100 PSI PRESSURE

NUMBER OF NODES 11
 NUMBER OF ELEMENTS 10
 NUMBER OF MATERIALS 1
 NO. OF DISP. NODES 2
 D.O.F. PER NODE 3
 TIME INCREMENT 3.00000E-06
 FINAL TIME 3.00000E-04

AXISYMMETRIC PROBLEM

MATERIAL NUMBER 1	SHELL ELEMENT
DENSITY 2.4400E-04	E ELAS MOD 1.0000E+07
SIG-Y YIELD 40000.	E-P PLAS MOD 10000.
SIG-ULT 1.0000E+50	POISSON RATIO .30000
THICKNESS 1.6000E-02	THERMO CONSTANT .0

NODE NO.	X-CORDINATE	Y-CORDINATE
1	.0	4.76000
2	.905400E-01	4.75914
3	.181046	4.75656
4	.271488	4.75225
5	.361831	4.74623
6	.452043	4.73849
7	.542092	4.72903
8	.631944	4.71786
9	.721568	4.70499
10	.810931	4.69042
11	.900000	4.67414

ELEMENT NO.	N1	N2	MTYPE	THICKNESS
1	1	2	1	1.60000E-02
2	2	3	1	1.60000E-02
3	3	4	1	1.60000E-02
4	4	5	1	1.60000E-02
5	5	6	1	1.60000E-02
6	6	7	1	1.60000E-02
7	7	8	1	1.60000E-02
8	8	9	1	1.60000E-02
9	9	10	1	1.60000E-02
10	10	11	1	1.60000E-02

BOUNDARY DISPLACEMENT NODE(S)

NO.	NODE	X	Y	R	ANGLE
1	1	1	0	1	0.0
2	11	1	1	1	0.0

OUTPUT CODE

NFFFEQ=	2
NFRU =	4
NFRS =	8
NPIC =	2

ROUT: DISP./VEL./ACC. OUTPUT

1202	THE Y-DISPLACEMENT HISTORY AT NODE 1 \$
7102	THE X-DISPLACEMENT HISTORY AT NODE 7 \$
2	THE Y-DISPLACEMENT HISTORY AT NODE 7 \$
2	THE ROTATION HISTORY AT NODE 7 \$

SOUT: STRESS/STRAIN OUTPUT

(B) OUTPUT DATA

11 THE MERIDIAN-STRAIN HISTORY AT ST.3 OF ELE.1 \$
 10 THE MERIDIAN-STRESS HISTORY AT ST.3 OF ELE.1 \$
 1231 THE HOOP-STRAIN HISTORY AT ST.3 OF ELE.1 \$
 1330 THE HOOP-STRESS HISTORY AT ST.3 OF ELE.1 \$
 10080 THE MERIDIAN-STRAIN HISTORY AT ST.8 OF ELE.10 \$
 10180 THE MERIDIAN-STRESS HISTORY AT ST.8 OF ELE.10 \$
 10280 THE HOOP-STRAIN HISTORY AT ST.8 OF ELE.10 \$
 10380 THE HOOP-STRESS HISTORY AT ST.8 OF ELE.10 \$

NPOUT PICTURE OUTPUT

AT STEP	CODE
1	5
100	5

MAXIMUM TIME INCREMENT IN SHELL 0.22362434E-06
 FINAL STOP TIME= 0.300000E-03 NO. OF STEPS= 1400

TIME STEP = 0.21428565E-06

INTERNAL ADJUSTING FACTOR, MFACTOR= 14
 THE NEW VALUE FOR NPFREQ= 28
 THE NEW VALUE FOR NPOUT(1,I)= 14 1400

THE TIME TICS FOR THE LOADING-TIME CURVE ARE;

.0 1.00000

THE PRESSURE TICS FOR THE LOADING-TIME CURVE ARE;

-100.000 -100.000

TIME = .299999E-05

DISPLACEMENTS

NODE	X-DIRECTION	Y-DIRECTION	X-Y ROTATION
1	.0	-.111232E-03	.0
2	.208760E-05	-.105348E-03	-.163324E-03
3	.404308E-05	-.107356E-03	-.754819E-04
4	.587777E-05	-.107202E-03	-.510391E-04
5	.704965E-05	-.106973E-03	-.378201E-04
6	.666153E-05	-.106484E-03	-.289880E-04
7	.420805E-05	-.105538E-03	-.220969E-04
8	.382160E-06	-.104056E-03	-.160813E-04
9	-.448798E-05	-.102878E-03	-.310823E-04
10	-.849718E-05	-.886667E-04	.544146E-03
11	.0	.0	.0

DISPLACEMENTS

NODE	X-DIRECTION	Y-DIRECTION
1	.0	-.111232E-03
2	.208760E-05	-.105348E-03
3	.404308E-05	-.107356E-03
4	.587777E-05	-.107202E-03
5	.704965E-05	-.106973E-03
6	.666153E-05	-.106484E-03
7	.420805E-05	-.105538E-03
8	.382160E-06	-.104056E-03
9	-.448798E-05	-.102878E-03
10	-.849718E-05	-.886667E-04
11	.0	.0

DEFORMED COORINATES

NODE	X-DIRECTION	Y-DIRECTION
1	.0	4.75989
2	.905421E-01	4.75903
3	.181050	4.75645
4	.271494	4.75214
5	.361838	4.74612
6	.452050	4.73838
7	.542096	4.72892
8	.631944	4.71776
9	.721563	4.70489
10	.810923	4.69033
11	.900000	4.67414

0.4760E+01

0.4674E+01

0.0

0.4500E+00

0.9000E+00

STRUCTURAL CONFIGURATION AT TIME=

2.999994E-06

NODE	VEL-X	VEL-Y	ACC-X	ACC-Y
1	0.0	-6.72460E+01	0.0	-2.10191E+07
2	1.33968E+00	-7.27543E+01	2.15194E+05	-2.57263E+07
3	2.49075E+00	-7.45035E+01	-2.89737E+05	-2.58832E+07
4	2.96108E+00	-7.43928E+01	-2.99990E+06	-2.57555E+07
5	1.59828E+00	-7.39933E+01	-8.53927E+06	-2.49856E+07
6	-1.92931E+00	-7.31550E+01	-1.20734E+07	-2.40414E+07
7	-5.36211E+00	-7.19842E+01	-8.42057E+06	-2.37483E+07
8	-7.00915E+00	-7.07251E+01	-5.46302E+06	-2.35331E+07
9	-8.92430E+00	-7.08993E+01	-6.35774E+06	-2.52312E+07
10	-7.94126E+00	-5.34939E+01	-2.13180E+06	-9.53458E+06
11	0.0	0.0	0.0	0.0

ELF IS INFORMATION

ELE NO.	1	ELE TYPE P 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		1.90644E-02	4.75257E+00	7.66835E+02	8.86274E+02	5.00953E-05	6.56225E-05	4.00000E+04	0.0
2		1.90924E-02	4.75551E+00	5.86572E+02	6.59474E+02	3.88730E-05	4.83503E-05	4.00000E+04	0.0
3		1.91333E-02	4.75982E+00	3.22597E+02	3.27351E+02	2.24392E-05	2.30572E-05	4.00000E+04	0.0
4		1.91743E-02	4.76412E+00	5.86228E+01	-4.77142E+00	6.00543E-06	-2.23587E-06	4.00000E+04	0.0
5		1.92023E-02	4.76707E+00	-1.21640E+02	-2.31571E+02	-5.21688E-06	-1.95081E-05	4.00000E+04	0.0
6		7.13376E-02	4.75207E+00	-2.62669E+02	1.70098E+02	-3.13700E-05	2.48899E-05	4.00000E+04	0.0
7		7.13656E-02	4.75501E+00	-2.51790E+01	2.33908E+02	-9.53524E-06	2.41462E-05	4.00000E+04	0.0
8		7.14066E-02	4.75932E+00	3.22597E+02	3.27351E+02	2.24392E-05	2.30572E-05	4.00000E+04	0.0
9		7.14476E-02	4.76363E+00	6.70374E+02	4.20794E+02	5.44137E-05	2.19682E-05	4.00000E+04	0.0
10		7.14755E-02	4.76657E+00	9.07864E+02	4.84604E+02	7.62484E-05	2.12246E-05	4.00000E+04	0.0

ELE NO.	2	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		1.09459E-01	4.75135E+00	6.84667E+02	4.02442E+02	5.63935E-05	1.97042E-05	4.00000E+04	0.0
2		1.09543E-01	4.75429E+00	5.36437E+02	3.70552E+02	4.25272E-05	2.09621E-05	4.00000E+04	0.0
3		1.09666E-01	4.75859E+00	3.19371E+02	3.23853E+02	2.22216E-05	2.28041E-05	4.00000E+04	0.0
4		1.09789E-01	4.76290E+00	1.02306E+02	2.77153E+02	1.91598E-06	2.46462E-05	4.00000E+04	0.0
5		1.09873E-01	4.76584E+00	-4.59236E+01	2.45263E+02	-1.19503E-05	2.59040E-05	4.00000E+04	0.0
6		1.61713E-01	4.74985E+00	9.77174E+01	2.55192E+02	2.11598E-06	2.25877E-05	4.00000E+04	0.0
7		1.61797E-01	4.75279E+00	1.87143E+02	2.81329E+02	1.02744E-05	2.25186E-05	4.00000E+04	0.0
8		1.61920E-01	4.75710E+00	3.18097E+02	3.19604E+02	2.22216E-05	2.24175E-05	4.00000E+04	0.0
9		1.62043E-01	4.76141E+00	4.49050E+02	3.57879E+02	3.41687E-05	2.23164E-05	4.00000E+04	0.0
10		1.62127E-01	4.76435E+00	5.38476E+02	3.84015E+02	4.23272E-05	2.22473E-05	4.00000E+04	0.0

ELE NO.	3	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		1.99814E-01	4.74840E+00	5.16414E+02	3.74699E+02	4.04006E-05	2.19775E-05	4.00000E+04	0.0
2		1.99954E-01	4.75134E+00	4.26368E+02	3.48330E+02	3.21869E-05	2.20420E-05	4.00000E+04	0.0
3		2.00159E-01	4.75565E+00	2.94504E+02	3.09715E+02	2.01590E-05	2.21364E-05	4.00000E+04	0.0
4		2.00363E-01	4.75995E+00	1.62640E+02	2.71100E+02	8.13103E-06	2.22308E-05	4.00000E+04	0.0
5		2.00503E-01	4.76289E+00	7.25931E+01	2.44730E+02	-8.26112E-08	2.22953E-05	4.00000E+04	0.0
6		2.52031E-01	4.74592E+00	1.14738E+02	2.54745E+02	3.83140E-06	2.20324E-05	4.00000E+04	0.0
7		2.52171E-01	4.74886E+00	1.87171E+02	2.75344E+02	1.04568E-05	2.19192E-05	4.00000E+04	0.0
8		2.52375E-01	4.75316E+00	2.93242E+02	3.05507E+02	2.01590E-05	2.17535E-05	4.00000E+04	0.0
9		2.52580E-01	4.75746E+00	3.99312E+02	3.35671E+02	2.98611E-05	2.15878E-05	4.00000E+04	0.0
10		2.52720E-01	4.76040E+00	4.71745E+02	3.56269E+02	3.64865E-05	2.14746E-05	4.00000E+04	0.0

ELE NC.	4	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		2.90097E-01	4.74374E+00	3.66895E+02	3.20762E+02	2.70667E-05	2.10694E-05	4.00000E+04	0.0
2		2.90293E-01	4.74668E+00	3.03049E+02	3.01651E+02	2.12554E-05	2.10737E-05	4.00000E+04	0.0
3		2.90580E-01	4.75098E+00	2.09554E+02	2.73666E+02	1.27454E-05	2.10800E-05	4.00000E+04	0.0
4		2.90866E-01	4.75528E+00	1.16058E+02	2.45680E+02	4.23544E-06	2.10863E-05	4.00000E+04	0.0
5		2.91062E-01	4.75821E+00	5.22122E+01	2.26569E+02	-1.57587E-06	2.10906E-05	4.00000E+04	0.0
6		3.42257E-01	4.74027E+00	7.18717E+01	2.21542E+02	5.40911E-07	1.99980E-05	4.00000E+04	0.0
7		3.42453E-01	4.74320E+00	1.26090E+02	2.37190E+02	5.49327E-06	1.99363E-05	4.00000E+04	0.0
8		3.42739E-01	4.74750E+00	2.05486E+02	2.60105E+02	1.27454E-05	1.98460E-05	4.00000E+04	0.0
9		3.43026E-01	4.75180E+00	2.84881E+02	2.83020E+02	1.99976E-05	1.97556E-05	4.00000E+04	0.0
10		3.43222E-01	4.75473E+00	3.39099E+02	2.98669E+02	2.49499E-05	1.96939E-05	4.00000E+04	0.0

ELE NO.	5	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1	3.80275E-01	4.73737E+00	1.33307E+02	2.23386E+02	6.62913E-06	1.83394E-05	4.00000E+04	0.0	
2	3.80527E-01	4.74030E+00	8.25837E+01	2.07980E+02	2.01898E-06	1.83205E-05	4.00000E+04	0.0	
3	3.80895E-01	4.74459E+00	8.30534E+00	1.85419E+02	-4.73204E-06	1.82928E-05	4.00000E+04	0.0	
4	3.81263E-01	4.74888E+00	-6.59730E+01	1.62859E+02	-1.14831E-05	1.82651E-05	4.00000E+04	0.0	
5	3.81515E-01	4.75181E+00	-1.16696E+02	1.47452E+02	-1.60932E-05	1.82461E-05	4.00000E+04	0.0	
6	4.32359E-01	4.73290E+00	-1.09545E+02	1.24145E+02	-1.46789E-05	1.57008E-05	4.00000E+04	0.0	

7	4.32611E-01	4.73583E+00	-6.53598E+01	1.36889E+02	-1.06427E-05	1.56497E-05	4.00000E+04	0.0
8	4.32979E-01	4.74012E+00	-6.55121E-01	1.55551E+02	-4.73204E-06	1.55748E-05	4.00000E+04	0.0
9	4.33347E-01	4.74441E+00	6.40496E+01	1.74213E+02	1.17857E-06	1.54998E-05	4.00000E+04	0.0
10	4.33599E-01	4.74734E+00	1.08235E+02	1.86957E+02	5.21482E-06	1.54487E-05	4.00000E+04	0.0

ELE NO.	STATION	ELE TYPE	F 1	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
6	1			4.70315E-01	4.72928E+00	-1.57899E+02	8.38887E+01	-1.83066E-05	1.31259E-05	4.00000E+04	0.0
	2			4.70623E-01	4.73220E+00	-2.01417E+02	7.04871E+01	-2.22564E-05	1.30912E-05	4.00000E+04	0.0
	3			4.71073E-01	4.73649E+00	-2.65145E+02	5.08621E+01	-2.80403E-05	1.30406E-05	4.00000E+04	0.0
	4			4.71522E-01	4.74077E+00	-3.28871E+02	3.12371E+01	-3.38243E-05	1.29899E-05	4.00000E+04	0.0
	5			4.71830E-01	4.74370E+00	-3.72389E+02	1.78355E+01	-3.77740E-05	1.29552E-05	4.00000E+04	0.0
	6			5.22305E-01	4.72382E+00	-3.72749E+02	-2.01454E+01	-3.66705E-05	9.16793E-06	4.00000E+04	0.0
	7			5.22612E-01	4.72674E+00	-3.34442E+02	-9.18756E+00	-3.31686E-05	9.11450E-06	4.00000E+04	0.0
	8			5.23062E-01	4.73103E+00	-2.78345E+02	6.85852E+00	-2.80403E-05	9.03626E-06	4.00000E+04	0.0
	9			5.23512E-01	4.73531E+00	-2.22249E+02	2.29054E+01	-2.29121E-05	8.95802E-06	4.00000E+04	0.0
	10			5.23820E-01	4.73824E+00	-1.83942E+02	3.38633E+01	-1.94101E-05	8.90459E-06	4.00000E+04	0.0

ELE NO.	STATION	ELE TYPE	F 1	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
7	1			5.60186E-01	4.71948E+00	-3.65502E+02	-4.78693E+01	-3.51142E-05	6.17815E-06	4.00000E+04	0.0
	2			5.60549E-01	4.72239E+00	-4.05067E+02	-6.02225E+01	-3.87001E-05	6.12977E-06	4.00000E+04	0.0
	3			5.61080E-01	4.72667E+00	-4.63005E+02	-7.83123E+01	-4.39511E-05	6.05892E-06	4.00000E+04	0.0
	4			5.61611E-01	4.73094E+00	-5.20943E+02	-9.64021E+01	-4.92022E-05	5.98807E-06	4.00000E+04	0.0
	5			5.61974E-01	4.73386E+00	-5.60507E+02	-1.08755E+02	-5.27881E-05	5.93969E-06	4.00000E+04	0.0
	6			6.12062E-01	4.71303E+00	-5.62605E+02	-1.47858E+02	-5.18248E-05	2.09240E-06	4.00000E+04	0.0
	7			6.12425E-01	4.71595E+00	-5.27696E+02	-1.37993E+02	-4.86298E-05	2.03157E-06	4.00000E+04	0.0
	8			6.12956E-01	4.72022E+00	-4.76575E+02	-1.23548E+02	-4.39511E-05	1.94250E-06	4.00000E+04	0.0
	9			6.13487E-01	4.72450E+00	-4.25455E+02	-1.09102E+02	-3.92725E-05	1.85342E-06	4.00000E+04	0.0
	10			6.13850E-01	4.72742E+00	-3.90546E+02	-9.92380E+01	-3.60775E-05	1.79259E-06	4.00000E+04	0.0

ELE NO.	STATION	ELE TYPE	F 1	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
8	1			6.49853E-01	4.70797E+00	-5.33708E+02	-1.68999E+02	-4.83009E-05	-8.88674E-07	4.00000E+04	0.0
	2			6.50271E-01	4.71088E+00	-5.64125E+02	-1.78552E+02	-5.10560E-05	-9.31439E-07	4.00000E+04	0.0
	3			6.50884E-01	4.71514E+00	-6.08668E+02	-1.92541E+02	-5.50907E-05	-9.94064E-07	4.00000E+04	0.0
	4			6.51496E-01	4.71941E+00	-6.53211E+02	-2.06530E+02	-5.91253E-05	-1.05669E-06	4.00000E+04	0.0
	5			6.51914E-01	4.72232E+00	-6.83629E+02	-2.16083E+02	-6.18804E-05	-1.09945E-06	4.00000E+04	0.0
	6			7.01597E-01	4.70053E+00	-7.22599E+02	-2.65915E+02	-6.42826E-05	-4.91347E-06	4.00000E+04	0.0
	7			7.02016E-01	4.70345E+00	-6.81624E+02	-2.53659E+02	-6.05527E-05	-4.91720E-06	4.00000E+04	0.0
	8			7.02628E-01	4.70771E+00	-6.21620E+02	-2.35713E+02	-5.50907E-05	-4.92265E-06	4.00000E+04	0.0
	9			7.03241E-01	4.71198E+00	-5.61615E+02	-2.17766E+02	-4.96287E-05	-4.92811E-06	4.00000E+04	0.0
	10			7.03659E-01	4.71489E+00	-5.20640E+02	-2.05510E+02	-4.58988E-05	-4.93183E-06	4.00000E+04	0.0

ELE NO.	STATION	ELE TYPE	F 1	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
9	1			7.39286E-01	4.69476E+00	-6.07432E+02	-2.56048E+02	-5.30618E-05	-7.38184E-06	4.00000E+04	0.0
	2			7.39759E-01	4.69766E+00	-6.78075E+02	-2.76525E+02	-5.95119E-05	-7.31022E-06	4.00000E+04	0.0
	3			7.40453E-01	4.70191E+00	-7.81525E+02	-3.06511E+02	-6.89573E-05	-7.20535E-06	4.00000E+04	0.0
	4			7.41146E-01	4.70616E+00	-8.84975E+02	-3.36497E+02	-7.84027E-05	-7.10047E-06	4.00000E+04	0.0
	5			7.41620E-01	4.70907E+00	-9.55620E+02	-3.56974E+02	-8.48528E-05	-7.02885E-06	4.00000E+04	0.0
	6			7.90879E-01	4.68634E+00	5.72728E+01	-5.10520E+01	7.25876E-06	-6.82337E-06	4.00000E+04	0.0
	7			7.91353E-01	4.68924E+00	-2.86376E+02	-1.65651E+02	-2.36683E-05	-7.97378E-06	4.00000E+04	0.0
	8			7.92046E-01	4.69349E+00	-7.89612E+02	-3.33468E+02	-6.89573E-05	-9.65843E-06	4.00000E+04	0.0
	9			7.92740E-01	4.69775E+00	-1.29285E+03	-5.01285E+02	-1.14246E-04	-1.13431E-05	4.00000E+04	0.0
	10			7.93213E-01	4.70065E+00	-1.63650E+03	-6.15884E+02	-1.45173E-04	-1.24935E-05	4.00000E+04	0.0

ELE NO.	STATION	ELE TYPE	F 1	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
10				8.28451E-01	4.67984E+00	7.70974E+02	2.48278E+02	6.96492E-05	1.69858E-06	4.00000E+04	0.0
				8.28979E-01	4.68274E+00	7.62923E+01	2.08126E-01	7.62299E-06	-2.26796E-06	4.00000E+04	0.0
	3			8.29753E-01	4.68698E+00	-9.40990E+02	-3.63062E+02	-8.32073E-05	-8.07651E-06	4.00000E+04	0.0

"	8.30528E-01	4.69121E+00	-1.95827E+03	-7.26332E+02	-1.74038E-04	-1.38851E-05	4.00000E+04	0.0
"	8.31056E-01	4.69411E+00	-2.65296E+03	-9.74402E+02	-2.36064E-04	-1.78516E-05	4.00000E+04	0.0
"	8.79875E-01	4.67045E+00	-3.53639E+03	-1.01467E+03	-3.23199E-04	4.62431E-06	4.00000E+04	0.0
7	8.80403E-01	4.67334E+00	-2.47515E+03	-7.23334E+02	-2.25815E-04	1.92095E-06	4.00000E+04	0.0
8	8.81177E-01	4.67758E+00	-9.21083E+02	-2.96703E+02	-8.32073E-05	-2.03780E-06	4.00000E+04	0.0
9	8.81952E-01	4.68182E+00	6.32981E+02	1.29929E+02	5.94003E-05	-5.99656E-06	4.00000E+04	0.0
10	8.82480E-01	4.68471E+00	1.69422E+03	4.21267E+02	1.56784E-04	-8.69991E-06	4.00000E+04	0.0

TIME	(U 1) 1 202 (S 2) 1 130 (S 7) 10 280	(U 2) 7 102 (S 3) 1 231 (S 8) 10 380	(U 3) 7 202 (S 4) 1 330	(U 4) 7 302 (S 5) 10 060	(S 1) 1 031 (S 6) 10 180
6.0000E-06	(U 1) -4.4248E-04 (S 2) -1.2891E+03 (S 7) -9.0053E-06	(U 2) -3.9284E-05 (S 3) -9.0066E-05 (S 8) -5.0534E+02	(U 3) -4.2745E-04 (S 4) -1.2874E+03	(U 4) 4.5223E-05 (S 5) -1.2327E-04	(S 1) -9.0292E-05 (S 6) -1.3843E+03
1.2000E-05	(U 1) -1.7186E-03 (S 2) -3.6776E+03 (S 7) -1.9347E-05	(U 2) -1.5139E-04 (S 3) -2.5791E-04 (S 8) -1.5206E+03	(U 3) -1.6812E-03 (S 4) -3.6824E+03	(U 4) -9.7173E-04 (S 5) -3.5677E-04	(S 1) -2.5729E-04 (S 6) -4.4239E+03
1.8000E-05	(U 1) -3.6634E-03 (S 2) -8.1204E+03 (S 7) -2.4691E-05	(U 2) -3.4091E-04 (S 3) -5.6877E-04 (S 8) -2.8473E+03	(U 3) -3.8750E-03 (S 4) -8.1238E+03	(U 4) -2.5377E-03 (S 5) -7.8138E-04	(S 1) -5.6833E-04 (S 6) -8.6679E+03
2.4000E-05	(U 1) -5.9282E-03 (S 2) -1.2696E+04 (S 7) -2.5929E-05	(U 2) -5.6210E-04 (S 3) -8.9848E-04 (S 8) -4.0793E+03	(U 3) -6.6062E-03 (S 4) -1.2794E+04	(U 4) 1.4380E-03 (S 5) -1.1509E-03	(S 1) -8.8584E-04 (S 6) -1.2733E+04
2.9999E-05	(U 1) -9.0150E-03 (S 2) -1.6101E+04 (S 7) -2.2728E-05	(U 2) -7.6331E-04 (S 3) -1.2446E-03 (S 8) -5.1646E+03	(U 3) -9.4019E-03 (S 4) -1.7876E+04	(U 4) 9.8780E-03 (S 5) -1.4909E-03	(S 1) -1.2738E-03 (S 6) -1.6458E+04
3.5999E-05	(U 1) -1.1755E-02 (S 2) -2.1789E+04 (S 7) -1.6029E-05	(U 2) -9.2194E-04 (S 3) -1.4908E-03 (S 8) -5.9901E+03	(U 3) -1.1974E-02 (S 4) -2.1445E+04	(U 4) 2.1228E-02 (S 5) -1.7636E-03	(S 1) -1.5356E-03 (S 6) -1.9433E+04
4.1999E-05	(U 1) -1.2066E-02 (S 2) -2.2350E+04 (S 7) -6.7519E-06	(U 2) -1.0342E-03 (S 3) -1.5367E-03 (S 8) -6.5286E+03	(U 3) -1.4204E-02 (S 4) -2.2072E+04	(U 4) 3.6186E-02 (S 5) -1.5579E-03	(S 1) -1.5728E-03 (S 6) -2.1537E+04
4.7999E-05	(U 1) -9.8610E-03 (S 2) -1.7053E+04 (S 7) 3.0384E-06	(U 2) -1.1197E-03 (S 3) -1.2874E-03 (S 8) -6.6025E+03	(U 3) -1.6128E-02 (S 4) -1.7990E+04	(U 4) 5.4776E-02 (S 5) -2.0130E-03	(S 1) -1.1657E-03 (S 6) -2.2110E+04
5.3998E-05	(U 1) -6.1070E-03 (S 2) -4.0913E+03 (S 7) 1.5001E-05	(U 2) -1.1642E-03 (S 3) -7.4936E-04 (S 8) -6.2845E+03	(U 3) -1.7588E-02 (S 4) -8.7207E+03	(U 4) 7.2530E-02 (S 5) -1.9564E-03	(S 1) -1.4753E-04 (S 6) -2.1449E+04
5.9998E-05	(U 1) -3.2182E-03 (S 2) 1.9533E+04 (S 7) 2.1408E-05	(U 2) -1.2132E-03 (S 3) 6.0976E-04 (S 8) -5.5863E+03	(U 3) -1.8622E-02 (S 4) 1.1958E+04	(U 4) 9.1036E-02 (S 5) -1.7659E-03	(S 1) 1.5945E-03 (S 6) -1.9335E+04
6.5998E-05	(U 1) -2.4944E-03 (S 2) 3.4429E+04 (S 7) 1.9096E-05	(U 2) -1.2810E-03 (S 3) 1.5379E-03 (S 8) -4.8302E+03	(U 3) -1.9361E-02 (S 4) 2.5708E+04	(U 4) 1.1054E-01 (S 5) -1.5289E-03	(S 1) 2.6717E-03 (S 6) -1.6738E+04
7.1998E-05	(U 1) -4.6430E-03 (S 2) 3.5764E+04 (S 7) 1.6307E-05	(U 2) -1.3131E-03 (S 3) 1.6706E-03 (S 8) -4.5290E+03	(U 3) -2.0099E-02 (S 4) 2.7435E+04	(U 4) 1.2442E-01 (S 5) -1.4283E-03	(S 1) 2.7534E-03 (S 6) -1.5641E+04
7.7997E-05	(U 1) -9.1660E-03 (S 2) 2.7284E+04 (S 7) 2.2605E-05	(U 2) -1.2549E-03 (S 3) 1.1477E-03 (S 8) -4.9917E+03	(U 3) -2.1142E-02 (S 4) 1.9662E+04	(U 4) 1.2972E-01 (S 5) -1.5896E-03	(S 1) 2.1386E-03 (S 6) -1.7393E+04

FI	(U 1) 1 202 (S 2) 1 130 (S 7) 10 280	(U 2) 7 102 (S 3) 1 231 (S 8) 10 380	(U 3) 7 202 (S 4) 1 330	(U 4) 7 302 (S 5) 10 080	(S 1) 1 031 (S 6) 10 180
8.3997E-05	(U 1) -1.4473E-02 (S 2) 1.7578E+04 (S 7) 2.9042E-05	(U 2) -1.1535E-03 (S 3) 4.9335E-04 (S 8) -5.6268E+03	(U 3) -2.2323E-02 (S 4) 1.0107E+04	(U 4) 1.3175E-01 (S 5) -1.8038E-03	(S 1) 1.4545E-03 (S 6) -1.9725E+04
8.9997E-05	(U 1) -1.9511E-02 (S 2) 1.1901E+04 (S 7) 3.7293E-05	(U 2) -1.0776E-03 (S 3) 9.4885E-05 (S 8) -5.7578E+03	(U 3) -2.3404E-02 (S 4) 4.5193E+03	(U 4) 1.4234E-01 (S 5) -1.8710E-03	(S 1) 1.0545E-03 (S 6) -2.0437E+04
9.5997E-05	(U 1) -2.3930E-02 (S 2) 1.4194E+04 (S 7) 3.6606E-05	(U 2) -1.0282E-03 (S 3) 3.5119E-04 (S 8) -5.0432E+03	(U 3) -2.4444E-02 (S 4) 7.7700E+03	(U 4) 1.6190E-01 (S 5) -1.6520E-03	(S 1) 1.1863E-03 (S 6) -1.8032E+04
1.0200E-04	(U 1) -2.7174E-02 (S 2) 2.5273E+04 (S 7) 3.6252E-05	(U 2) -1.0193E-03 (S 3) 1.0121E-03 (S 8) -3.7817E+03	(U 3) -2.5528E-02 (S 4) 1.7704E+04	(U 4) 1.8721E-01 (S 5) -1.2682E-03	(S 1) 1.9962E-03 (S 6) -1.3815E+04
1.0800E-04	(U 1) -3.1334E-02 (S 2) 3.8383E+04 (S 7) 3.4775E-05	(U 2) -1.0244E-03 (S 3) 1.6333E-03 (S 8) -2.8130E+03	(U 3) -2.6964E-02 (S 4) 2.7848E+04	(U 4) 2.0684E-01 (S 5) -9.6938E-04	(S 1) 3.0029E-03 (S 6) -1.0537E+04
1.1400E-04	(U 1) -3.9719E-02 (S 2) 3.3474E+04 (S 7) 3.1122E-05	(U 2) -1.0545E-03 (S 3) 1.3733E-03 (S 8) -2.9679E+03	(U 3) -2.8892E-02 (S 4) 2.3775E+04	(U 4) 2.1853E-01 (S 5) -1.0042E-03	(S 1) 2.6342E-03 (S 6) -1.0932E+04
1.2000E-04	(U 1) -5.1136E-02 (S 2) 1.9971E+04 (S 7) 2.1254E-05	(U 2) -1.1287E-03 (S 3) 6.0105E-04 (S 8) -3.7839E+03	(U 3) -3.1324E-02 (S 4) 1.2002E+04	(U 4) 2.2598E-01 (S 5) -1.2188E-03	(S 1) 1.6371E-03 (S 6) -1.3323E+04
1.2600E-04	(U 1) -6.3722E-02 (S 2) 1.0620E+04 (S 7) 5.4461E-06	(U 2) -1.2200E-03 (S 3) 9.5440E-05 (S 8) -4.1970E+03	(U 3) -3.4332E-02 (S 4) 4.1802E+03	(U 4) 2.3790E-01 (S 5) -1.2915E-03	(S 1) 9.3659E-04 (S 6) -1.4173E+04
1.3200E-04	(U 1) -7.7073E-02 (S 2) 1.0236E+04 (S 7) -7.1621E-06	(U 2) -1.3495E-03 (S 3) 1.8814E-04 (S 8) -3.4859E+03	(U 3) -3.7796E-02 (S 4) 4.9521E+03	(U 4) 2.5550E-01 (S 5) -1.0337E-03	(S 1) 8.7507E-04 (S 6) -1.1382E+04
1.3799E-04	(U 1) -9.2523E-02 (S 2) 1.1655E+04 (S 7) -2.7110E-05	(U 2) -1.5130E-03 (S 3) 4.8248E-04 (S 8) -2.4080E+03	(U 3) -4.1954E-02 (S 4) 8.3212E+03	(U 4) 2.7587E-01 (S 5) -6.4025E-04	(S 1) 9.1590E-04 (S 6) -7.1240E+03
1.4399E-04	(U 1) -1.1180E-01 (S 2) 9.4025E+03 (S 7) -6.1048E-05	(U 2) -1.7149E-03 (S 3) 6.2733E-04 (S 8) -1.7328E+03	(U 3) -4.7080E-02 (S 4) 9.0939E+03	(U 4) 2.9245E-01 (S 5) -3.2232E-04	(S 1) 6.6747E-04 (S 6) -3.7420E+03
1.4999E-04	(U 1) -1.3537E-01 (S 2) 2.5318E+04 (S 7) -9.9824E-05	(U 2) -1.9588E-03 (S 3) 1.6756E-03 (S 8) -1.9266E+03	(U 3) -5.3192E-02 (S 4) 2.4352E+04	(U 4) 2.9804E-01 (S 5) -2.5187E-04	(S 1) 1.8013E-03 (S 6) -3.0958E+03
1.5599E-04	(U 1) -1.6031E-01 (S 2) 4.1646E+04 (S 7) -1.5030E-04	(U 2) -2.1526E-03 (S 3) 8.0695E-03 (S 8) -2.8406E+03	(U 3) -6.0615E-02 (S 4) 3.8406E+04	(U 4) 2.9542E-01 (S 5) -3.5918E-04	(S 1) 9.8761E-03 (S 6) -4.4430E+03

TIME	(U 1) 1 202 (S 2) 1 130 (S 7) 10 280	(U 2) 7 102 (S 3) 1 231 (S 8) 10 380	(U 3) 7 202 (S 4) 1 330	(U 4) 7 302 (S 5) 10 080	(S 1) 1 031 (S 6) 10 180
1.6199E-04	(U 1) -1.7908E-01 (S 2) 4.0843E+04 (S 7) -2.2482E-04	(U 2) -2.3095E-01 (S 3) 1.3009E-02 (S 8) -3.3932E+03	(U 3) -6.9118E-02 (S 4) 3.9596E+04	(U 4) 2.9941E-01 (S 5) -2.8007E-04	(S 1) 1.5746E-02 (S 6) -3.8177E+03
1.6799E-04	(U 1) -1.8589E-01 (S 2) 2.5769E+04 (S 7) -2.9721E-04	(U 2) -2.2634E-03 (S 3) 1.3049E-02 (S 8) -4.1849E+03	(U 3) -7.8357E-02 (S 4) 3.3295E+04	(U 4) 2.9847E-01 (S 5) -2.7893E-04	(S 1) 1.4661E-02 (S 6) -4.0438E+03
1.7399E-04	(U 1) -1.8895E-01 (S 2) 4.1064E+03 (S 7) -3.4671E-04	(U 2) -1.9596E-03 (S 3) 1.1737E-02 (S 8) -3.7561E+03	(U 3) -8.8406E-02 (S 4) 1.3673E+04	(U 4) 3.0564E-01 (S 5) 1.6111E-05	(S 1) 1.3083E-02 (S 6) -9.6473E+02
1.7999E-04	(U 1) -1.9149E-01 (S 2) -1.0221E+04 (S 7) -3.7359E-04	(U 2) -1.2231E-03 (S 3) 1.0997E-02 (S 8) -5.6545E+02	(U 3) -1.0002E-01 (S 4) 1.9767E+03	(U 4) 3.1782E-01 (S 5) 1.0736E-03	(S 1) 1.2002E-02 (S 6) 1.0567E+04
1.8599E-04	(U 1) -1.9425E-01 (S 2) -2.1647E+04 (S 7) -3.7192E-04	(U 2) -1.0717E-04 (S 3) 1.0581E-02 (S 8) 5.0574E+03	(U 3) -1.1262E-01 (S 4) -5.6068E+03	(U 4) 3.2041E-01 (S 5) 2.7736E-03	(S 1) 1.1086E-02 (S 6) 2.9254E+04
1.9199E-04	(U 1) -1.9874E-01 (S 2) -1.4105E+04 (S 7) -3.2396E-04	(U 2) 9.4531E-04 (S 3) 1.1120E-02 (S 8) 1.1426E+04	(U 3) -1.2388E-01 (S 4) 2.0388E+03	(U 4) 2.9318E-01 (S 5) 4.5492E-03	(S 1) 1.1611E-02 (S 6) 4.4479E+04
1.9799E-04	(U 1) -2.0286E-01 (S 2) -9.7982E+03 (S 7) -2.8649E-04	(U 2) 1.5500E-03 (S 3) 1.1493E-02 (S 8) 2.0458E+04	(U 3) -1.3208E-01 (S 4) 7.0660E+03	(U 4) 2.6060E-01 (S 5) 9.5308E-03	(S 1) 1.1891E-02 (S 6) 4.6197E+04
2.0399E-04	(U 1) -2.0652E-01 (S 2) -1.0477E+04 (S 7) -2.5124E-04	(U 2) 1.6280E-03 (S 3) 1.1499E-02 (S 8) 2.3138E+04	(U 3) -1.3692E-01 (S 4) 6.9209E+03	(U 4) 2.4910E-01 (S 5) 1.7383E-02	(S 1) 1.1828E-02 (S 6) 4.6406E+04
2.0999E-04	(U 1) -2.1103E-01 (S 2) -7.1060E+03 (S 7) -1.9136E-04	(U 2) 1.4685E-03 (S 3) 1.1608E-02 (S 8) 2.3455E+04	(U 3) -1.3907E-01 (S 4) 9.0210E+03	(U 4) 2.4344E-01 (S 5) 2.3724E-02	(S 1) 1.2102E-02 (S 6) 4.6490E+04
2.1599E-04	(U 1) -2.1493E-01 (S 2) 5.8440E+02 (S 7) -2.2743E-04	(U 2) 1.2781E-03 (S 3) 1.1976E-02 (S 8) 2.1939E+04	(U 3) -1.3867E-01 (S 4) 1.5012E+04	(U 4) 2.5912E-01 (S 5) 2.4427E-02	(S 1) 1.2691E-02 (S 6) 4.2829E+04
2.2199E-04	(U 1) -2.1650E-01 (S 2) -4.9304E+03 (S 7) -3.2569E-04	(U 2) 7.6162E-04 (S 3) 1.1620E-02 (S 8) 1.8705E+04	(U 3) -1.3656E-01 (S 4) 9.7969E+03	(U 4) 2.6957E-01 (S 5) 2.3773E-02	(S 1) 1.2296E-02 (S 6) 3.5325E+04
2.2799E-04	(U 1) -2.1730E-01 (S 2) -1.0102E+04 (S 7) -3.6820E-04	(U 2) -1.3854E-05 (S 3) 1.1399E-02 (S 8) 1.5434E+04	(U 3) -1.3266E-01 (S 4) 6.0358E+03	(U 4) 2.8783E-01 (S 5) 2.2923E-02	(S 1) 1.1892E-02 (S 6) 2.5836E+04
2.3399E-04	(U 1) -2.2042E-01 (S 2) -4.8895E+03 (S 7) -3.7303E-04	(U 2) -7.7807E-04 (S 3) 1.1279E-02 (S 8) 1.3329E+04	(U 3) -1.2812E-01 (S 4) 6.3981E+03	(U 4) 2.8669E-01 (S 5) 2.2300E-02	(S 1) 1.2402E-02 (S 6) 1.8983E+04

II.	(U 1) 1 202 (S 2) 1 130 (S 7) 10 280	(U 2) 7 102 (S 3) 1 231 (S 8) 10 380	(U 3) 7 202 (S 4) 1 330	(U 4) 7 302 (S 5) 10 080	(S 1) 1 031 (S 6) 10 180
2.3999E-04	(U 1) -2.2135E-01 (S 2) -1.2441E+03 (S 7) -3.4698E-04	(U 2) -1.0217E-03 (S 3) 1.1345E-02 (S 8) 1.2621E+04	(U 3) -1.2583E-01 (S 4) 8.1527E+03	(U 4) 2.6470E-01 (S 5) 2.1999E-02	(S 1) 1.2714E-02 (S 6) 1.5752E+04
2.4599E-04	(U 1) -2.2023E-01 (S 2) -6.8290E+02 (S 7) -3.2317E-04	(U 2) -7.6988E-04 (S 3) 1.1834E-02 (S 8) 1.2690E+04	(U 3) -1.2614E-01 (S 4) 1.3213E+04	(U 4) 2.4295E-01 (S 5) 2.1940E-02	(S 1) 1.2618E-02 (S 6) 1.5189E+04
2.5199E-04	(U 1) -2.2251E-01 (S 2) 2.9327E+04 (S 7) -2.8334E-04	(U 2) -1.9833E-04 (S 3) 1.2728E-02 (S 8) 1.4347E+04	(U 3) -1.2865E-01 (S 4) 3.1148E+04	(U 4) 2.2423E-01 (S 5) 2.2310E-02	(S 1) 1.5081E-02 (S 6) 1.9385E+04
2.5799E-04	(U 1) -2.1670E-01 (S 2) 1.8E92E+04 (S 7) -2.5119E-04	(U 2) 5.0271E-04 (S 3) 1.2371E-02 (S 8) 1.5909E+04	(U 3) -1.3203E-01 (S 4) 2.4448E+04	(U 4) 2.2754E-01 (S 5) 2.2677E-02	(S 1) 1.4239E-02 (S 6) 2.3523E+04
2.6398E-04	(U 1) -2.0703E-01 (S 2) -5.5069E+03 (S 7) -2.4017E-04	(U 2) 1.1560E-03 (S 3) 1.1170E-02 (S 8) 1.7397E+04	(U 3) -1.3592E-01 (S 4) 5.1220E+03	(U 4) 2.3655E-01 (S 5) 2.3092E-02	(S 1) 1.2379E-02 (S 6) 2.8115E+04
2.6998E-04	(U 1) -1.9715E-01 (S 2) -2.9110E+04 (S 7) -2.8077E-04	(U 2) 1.4134E-03 (S 3) 1.0016E-02 (S 8) 1.8311E+04	(U 3) -1.3797E-01 (S 4) -1.3499E+04	(U 4) 2.5126E-01 (S 5) 2.3504E-02	(S 1) 1.0577E-02 (S 6) 3.2515E+04
2.7598E-04	(U 1) -1.8606E-01 (S 2) -4.5005E+04 (S 7) -2.8034E-04	(U 2) 1.2543E-03 (S 3) 8.2460E-03 (S 8) 1.8744E+04	(U 3) -1.3815E-01 (S 4) -3.2748E+04	(U 4) 2.7240E-01 (S 5) 2.3634E-02	(S 1) 8.2066E-03 (S 6) 3.3944E+04
2.8198E-04	(U 1) -1.7335E-01 (S 2) -1.5258E+04 (S 7) -3.0813E-04	(U 2) 8.6428E-04 (S 3) 8.9486E-03 (S 8) 1.7234E+04	(U 3) -1.3614E-01 (S 4) -1.6021E+04	(U 4) 2.7355E-01 (S 5) 2.3268E-02	(S 1) 1.0471E-02 (S 6) 2.9836E+04
2.8797E-04	(U 1) -1.6526E-01 (S 2) 3.8444E+04 (S 7) -3.20E3E-04	(U 2) 4.1645E-04 (S 3) 9.8105E-03 (S 8) 1.5728E+04	(U 3) -1.3343E-01 (S 4) 8.7080E+03	(U 4) 2.6394E-01 (S 5) 2.2854E-02	(S 1) 1.5099E-02 (S 6) 2.5240E+04
2.9397E-04	(U 1) -1.6827E-01 (S 2) 2.0868E+04 (S 7) -2.9725E-04	(U 2) 1.1055E-04 (S 3) 9.1717E-03 (S 8) 1.3819E+04	(U 3) -1.3087E-01 (S 4) -2.9524E+03	(U 4) 2.6106E-01 (S 5) 2.2196E-02	(S 1) 1.3691E-02 (S 6) 1.8091E+04
2.9997E-04	(U 1) -1.7599E-01 (S 2) -9.7098E+03 (S 7) -2.9573E-04	(U 2) 6.3984E-05 (S 3) 8.2082E-03 (S 8) 1.2537E+04	(U 3) -1.2950E-01 (S 4) -2.1760E+04	(U 4) 2.4832E-01 (S 5) 2.1833E-02	(S 1) 1.1198E-02 (S 6) 1.4101E+04

TIME = .299969E-03

DISPLACEMENTS

NODE	X-DIRECTION	Y-DIRECTION	X-Y ROTATION
1	.0	-.175991	.0
2	.743171E-03	-.182218	-.110310
3	.565202E-03	-.186271	.250364E-01
4	.579795E-03	-.180450	.101753
5	.602276E-03	-.169202	.159697
6	.311877E-03	-.151237	.231692
7	.639841E-04	-.129495	.248321
8	.257139E-03	-.104634	.300922
9	.133650E-03	-.739508E-01	.382396
10	-.123313E-02	-.364111E-01	.455677
11	.0	.0	.0

DISPLACEMENTS

NCDE	X-DIRECTION	Y-DIRECTION
1	.0	-.175991
2	.743171E-03	-.182218
3	.565202E-03	-.186271
4	.579795E-03	-.180450
5	.602276E-03	-.169202
6	.311877E-03	-.151237
7	.639841E-04	-.129495
8	.257139E-03	-.104634
9	.133650E-03	-.739508E-01
10	-.123313E-02	-.364111E-01
11	.0	.0

DEFORMED COORINATES

NODE	X-DIRECTION	Y-DIRECTION
1	.0	4.58401
2	.912831E-01	4.57692
3	.181611	4.57028
4	.272068	4.57180
5	.362433	4.57703
6	.452355	4.58725
7	.542156	4.59953
8	.632201	4.61323
9	.721702	4.63104
10	.809698	4.65400
11	.900000	4.67414

0.4674E+01

0.4622E+01

0.4570E+01

0.0

0.4500E+00

0.9000E+00

STRUCTURAL CONFIGURATION AT TIME=

2.999692E-04

NODE	VEL-X	VEL-Y	ACC-X	ACC-Y
1	0.0	-1.39702E+03	0.0	5.12220E+07
2	-2.99697E+01	-1.04685E+03	-2.39951E+07	-1.12323E+07
3	1.36420E+01	-3.39840E+02	-1.35347E+07	-2.61663E+07
4	-3.23821E+00	1.31295E+02	-2.04563E+07	-6.43369E+07
5	-2.58460E+01	3.76323E+02	-4.90681E+07	1.10943E+06
6	-5.75004E+00	2.15775E+02	5.85307E+06	-2.23179E+07
7	9.11357E+00	7.46844E+01	1.92908E+07	-6.72224E+07
8	2.49591E+01	-8.97978E+01	9.44930E+06	-3.19060E+07
9	1.17662E+01	-1.89470E+01	-1.23890E+07	-1.52015E+07
10	2.08607E+00	5.41759E+00	6.52862E+06	-6.09529E+06
11	0.0	0.0	0.0	0.0

ELE S INFORMATIONS

ELE NC.	1	ELE TYPE	F 1						
STATION	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE	
1	1.90644E-02	4.75257E+00	-2.90268E+04	-2.48903E+04	-1.19330E-03	-5.48549E-03	4.13081E+04	0.0	
2	1.90924E-02	4.75551E+00	-3.75654E+04	-3.69536E+04	3.83473E-03	7.11481E-05	4.08987E+04	0.0	
3	1.91333E-02	4.75982E+00	-9.70882E+03	-2.17605E+04	1.11977E-02	8.20820E-03	4.03050E+04	0.0	
4	1.91743E-02	4.76412E+00	-3.24004E+04	-2.16801E+04	1.85607E-02	1.63453E-02	4.06512E+04	0.0	
5	1.92023E-02	4.76707E+00	-4.54324E+04	-3.42006E+04	2.35887E-02	2.19019E-02	4.09874E+04	0.0	
6	7.13376E-02	4.75207E+00	1.87738E+03	2.34512E+01	5.92469E-03	-1.92648E-03	4.16751E+04	0.0	
7	7.13656E-02	4.75501E+00	-2.48982E+04	-3.18989E+04	8.06437E-03	2.18598E-03	4.11069E+04	0.0	
8	7.14066E-02	4.75932E+00	-9.70880E+03	-2.17606E+04	1.11977E-02	8.20820E-03	4.03051E+04	0.0	
9	7.14476E-02	4.76363E+00	-4.56380E+04	-3.21978E+04	1.43310E-02	1.42304E-02	4.06212E+04	0.0	
10	7.14755E-02	4.76657E+00	-4.47939E+04	-3.60377E+04	1.64707E-02	1.83429E-02	4.11210E+04	0.0	

ELE NO.	2	ELE TYPE	F 1						
STATION	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE	
1	1.09459E-01	4.75135E+00	1.63982E+02	4.39721E+03	1.05522E-02	8.91499E-04	4.21597E+04	0.0	
2	1.09543E-01	4.75429E+00	-7.23255E+03	-1.57402E+04	6.39866E-03	3.14043E-03	4.12259E+04	0.0	
3	1.09666E-01	4.75859E+00	-2.79608E+04	-1.07003E+04	3.16338E-04	6.43372E-03	4.01405E+04	0.0	
4	1.09789E-01	4.76290E+00	-4.01751E+04	-3.04426E+03	-5.76598E-03	9.72701E-03	4.04784E+04	0.0	
5	1.09873E-01	4.76584E+00	-4.65218E+04	-2.46377E+04	-9.91949E-03	1.19759E-02	4.16091E+04	0.0	
6	1.61713E-01	4.74985E+00	2.43124E+04	1.90659E+04	1.17539E-02	3.46637E-03	4.23796E+04	0.0	
7	1.61797E-01	4.75279E+00	1.48016E+03	-7.56489E+03	7.11275E-03	3.57046E-03	4.06823E+04	0.0	
8	1.61920E-01	4.75710E+00	-1.71700E+04	4.17603E+03	3.16338E-04	3.72290E-03	4.01234E+04	0.0	
9	1.62043E-01	4.76141E+00	-4.20653E+04	-3.19875E+03	-6.48007E-03	3.87534E-03	4.05606E+04	0.0	
10	1.62127E-01	4.76435E+00	-4.81542E+04	-2.58471E+04	-1.11212E-02	3.97943E-03	4.17403E+04	0.0	

ELE NO.	3	ELE TYPE	F 1						
STATION	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE	
1	1.99814E-01	4.74840E+00	-6.63544E+03	1.56198E+04	5.57000E-03	4.36490E-03	4.08729E+04	0.0	
2	1.99954E-01	4.75134E+00	4.75214E+03	1.01468E+04	2.97351E-03	3.74579E-03	4.02261E+04	0.0	
3	2.00159E-01	4.75565E+00	-7.13755E+03	7.80895E+03	-8.28758E-04	2.83918E-03	4.00544E+04	0.0	
4	2.00363E-01	4.75995E+00	-3.38483E+04	-5.10604E+03	-4.63103E-03	1.93256E-03	4.04762E+04	0.0	
5	2.00503E-01	4.76289E+00	-2.58873E+04	-2.63702E+04	-7.22752E-03	1.31346E-03	4.14287E+04	0.0	
6	2.52031E-01	4.74592E+00	-1.55792E+04	1.71930E+04	5.05710E-03	4.76603E-03	4.06681E+04	0.0	
7	2.52171E-01	4.74886E+00	1.75662E+03	1.69928E+04	2.66874E-03	3.75933E-03	4.02274E+04	0.0	
8	2.52375E-01	4.75316E+00	-5.48560E+03	1.28010E+04	-8.28758E-04	2.28513E-03	4.00266E+04	0.0	
9	2.52580E-01	4.75746E+00	-3.17350E+04	-6.04929E+03	-4.32625E-03	8.10935E-04	4.03663E+04	0.0	
10	2.52720E-01	4.76040E+00	-1.69859E+04	-1.95674E+04	-6.71462E-03	-1.95767E-04	4.12939E+04	0.0	

ELE NO.	4	ELE TYPE	F 1						
STATION	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE	
1	2.90097E-01	4.74374E+00	-1.34516E+04	1.37988E+04	2.56732E-03	4.69033E-03	4.06281E+04	0.0	
2	2.90293E-01	4.74668E+00	4.52384E+03	1.63910E+04	1.40392E-03	3.60338E-03	4.01524E+04	0.0	
3	2.90580E-01	4.75098E+00	-1.48281E+03	1.25611E+04	-2.99742E-04	2.01165E-03	4.00233E+04	0.0	
4	2.90866E-01	4.75528E+00	-2.16426E+04	7.38630E+03	-2.00340E-03	4.19929E-04	4.01686E+04	0.0	
5	2.91062E-01	4.75821E+00	-1.46864E+04	-1.36726E+04	-3.16680E-03	-6.67030E-04	4.09636E+04	0.0	
6	3.42257E-01	4.74027E+00	-4.98285E+03	2.05737E+04	6.11185E-03	4.72044E-03	4.08369E+04	0.0	
7	3.42453E-01	4.74320E+00	3.66871E+03	1.83533E+04	3.51015E-03	3.51240E-03	4.02915E+04	0.0	
8	3.42739E-01	4.74750E+00	-2.43036E+03	1.15463E+04	-2.99742E-04	1.74338E-03	4.00276E+04	0.0	
9	3.43026E-01	4.75180E+00	-1.51769E+04	4.61297E+03	-4.10963E-03	-2.56465E-05	4.02236E+04	0.0	
10	3.43222E-01	4.75473E+00	-2.49286E+04	-7.72460E+03	-6.71133E-03	-1.23368E-03	4.07036E+04	0.0	

ELE NO.	5	ELE TYPE	F 1						
STATION	X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE	
1	3.80275E-01	4.73737E+00	-8.36451E+03	1.75579E+04	6.15948E-03	4.79606E-03	4.07306E+04	0.0	
2	3.80527E-01	4.74030E+00	-2.89748E+02	1.48761E+04	3.46946E-03	3.42616E-03	4.02386E+04	0.0	
3	3.80895E-01	4.74459E+00	-1.25669E+03	1.18165E+04	-4.69769E-04	1.42009E-03	4.00485E+04	0.0	
4	3.81263E-01	4.74988E+00	-5.01141E+03	6.36189E+03	-4.40899E-03	-5.85970E-04	4.02700E+04	0.0	
5	3.81515E-01	4.75181E+00	-1.45903E+04	-3.19576E-03	-7.09902E-03	-1.95587E-03	4.07817E+04	0.0	
6	4.32359E-01	4.73290E+00	-1.62719E+04	9.93428E+03	4.42960E-03	4.52530E-03	4.05221E+04	0.0	

7	4.32611E-01	4.73583E+00	-7.11740E+03	1.01090E+04	2.44154E-03	3.03882E-03	4.01479E+04	0.0
8	4.32979E-01	4.74012E+00	-1.50579E+03	9.12912E+03	-4.69769E-04	8.62039E-04	4.00324E+04	0.0
9	4.33347E-01	4.74441E+00	1.63568E+03	5.91898E+03	-3.38107E-03	-1.31474E-03	4.02606E+04	0.0
10	4.33599E-01	4.74734E+00	-7.04314E+03	-1.04185E+02	-5.36914E-03	-2.80123E-03	4.07467E+04	0.0

ELE NO.	6	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		4.70315E-01	4.72928E+00	-2.78217E+04	-3.67421E+03	2.52364E-03	4.15961E-03	4.01722E+04	0.0
2		4.70623E-01	4.73220E+00	-1.30238E+04	3.07091E+03	1.91775E-03	2.69525E-03	4.00791E+04	0.0
3		4.71073E-01	4.73649E+00	4.63079E+03	1.99714E+03	1.03049E-03	5.50850E-04	4.00296E+04	0.0
4		4.71522E-01	4.74077E+00	1.15499E+04	5.20225E+03	1.43235E-04	-1.59355E-03	4.01237E+04	0.0
5		4.71830E-01	4.74370E+00	1.12660E+04	7.87660E+03	-4.62656E-04	-3.05791E-03	4.03248E+04	0.0
6		5.22305E-01	4.72382E+00	-3.77328E+04	-4.60848E+03	2.20020E-03	3.60488E-03	4.01272E+04	0.0
7		5.22612E-01	4.72674E+00	-2.05330E+04	-4.29571E+02	1.72555E-03	2.23237E-03	4.01392E+04	0.0
8		5.23062E-01	4.73103E+00	4.52067E+03	1.26655E+03	1.03049E-03	2.22478E-04	4.00244E+04	0.0
9		5.23512E-01	4.73531E+00	1.15826E+04	1.00068E+04	3.35429E-04	-1.78741E-03	4.00622E+04	0.0
10		5.23820E-01	4.73824E+00	1.38990E+04	1.29839E+04	-1.39216E-04	-3.15993E-03	4.01343E+04	0.0

ELE NO.	7	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		5.60186E-01	4.71948E+00	-2.67359E+04	-1.77864E+04	1.01352E-02	3.51261E-03	4.02289E+04	0.0
2		5.60549E-01	4.72239E+00	-1.26227E+04	-1.01131E+04	8.43189E-03	2.16306E-03	4.02235E+04	0.0
3		5.61080E-01	4.72667E+00	6.58257E+03	-1.10723E+03	5.93756E-03	1.86787E-04	4.01785E+04	0.0
4		5.61611E-01	4.73094E+00	1.60158E+04	7.97447E+03	3.44322E-03	-1.78948E-03	4.01144E+04	0.0
5		5.61974E-01	4.73386E+00	-1.93656E+03	8.40652E+03	1.73989E-03	-3.13904E-03	4.01537E+04	0.0
6		6.12062E-01	4.71303E+00	-2.11300E+04	-1.00054E+04	1.01631E-02	3.75370E-03	4.04566E+04	0.0
7		6.12425E-01	4.71595E+00	-9.09851E+03	-2.69539E+03	8.44843E-03	2.37373E-03	4.03274E+04	0.0
8		6.12956E-01	4.72022E+00	6.14921E+03	3.83031E+03	5.93756E-03	3.52913E-04	4.03089E+04	0.0
9		6.13487E-01	4.72450E+00	1.38693E+04	1.11637E+04	3.42668E-03	-1.66790E-03	4.00896E+04	0.0
10		6.13850E-01	4.72742E+00	-2.22888E+04	-5.12129E+02	1.71206E-03	-3.04789E-03	4.01671E+04	0.0

ELE NO.	8	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		6.49853E-01	4.70797E+00	-1.14091E+04	-1.58786E+04	1.36668E-02	3.83403E-03	4.06933E+04	0.0
2		6.50271E-01	4.71088E+00	-2.81855E+03	-9.97706E+03	1.13092E-02	2.42227E-03	4.06372E+04	0.0
3		6.50884E-01	4.71514E+00	9.06243E+03	-1.32249E+03	7.85689E-03	3.54967E-04	4.03319E+04	0.0
4		6.51496E-01	4.71941E+00	8.75837E+03	5.25529E+03	4.40454E-03	-1.71234E-03	4.01291E+04	0.0
5		6.51914E-01	4.72232E+00	-3.11892E+04	-1.14054E+04	2.04700E-03	-3.12407E-03	4.01861E+04	0.0
6		7.01597E-01	4.70053E+00	-4.65916E+03	-6.98251E+03	1.50935E-02	3.93057E-03	4.06398E+04	0.0
7		7.02016E-01	4.70345E+00	1.75999E+03	-1.75638E+03	1.21570E-02	2.42783E-03	4.05669E+04	0.0
8		7.02628E-01	4.70771E+00	1.09843E+04	5.24718E+03	7.85689E-03	2.27355E-04	4.03935E+04	0.0
9		7.03241E-01	4.71198E+00	1.93665E+03	-1.39547E+03	3.55676E-03	-1.97317E-03	4.00937E+04	0.0
10		7.03659E-01	4.71489E+00	-4.20199E+04	-2.15975E+04	6.20287E-04	-3.47587E-03	4.01788E+04	0.0

ELE NO.	9	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		7.39286E-01	4.69476E+00	-5.82125E+02	-3.90729E+03	9.69972E-03	3.61498E-03	4.04001E+04	0.0
2		7.39759E-01	4.69766E+00	4.23751E+03	4.73514E+02	7.55318E-03	2.06305E-03	4.02453E+04	0.0
3		7.40453E-01	4.70191E+00	1.09664E+04	2.21143E+03	4.40981E-03	-2.09582E-04	4.01037E+04	0.0
4		7.41146E-01	4.70516E+00	-2.65002E+03	-1.79393E+04	1.26644E-03	-2.48221E-03	4.00432E+04	0.0
5		7.41620E-01	4.70907E+00	-3.93387E+04	-3.06420E+04	-8.80107E-04	-4.03414E-03	4.01610E+04	0.0
6		7.90879E-01	4.68634E+00	-2.89439E+03	4.39197E+02	1.08544E-02	2.76540E-03	4.02161E+04	0.0
7		7.91353E-01	4.68924E+00	3.42334E+03	4.50266E+03	8.23929E-03	1.15947E-03	4.01145E+04	0.0
8		7.92046E-01	4.69349E+00	1.26951E+04	1.42698E+03	4.40981E-03	-1.19223E-03	4.00966E+04	0.0
9		7.92740E-01	4.69775E+00	-1.02671E+04	-3.24396E+04	5.80323E-04	-3.54392E-03	4.00282E+04	0.0
10		7.93213E-01	4.70065E+00	-3.49596E+04	-2.88865E+04	-2.03476E-03	-5.14985E-03	4.04010E+04	0.0

ELE NO.	10	ELE TYPE F 1							
STATION		X-COORD	Y-COORD	SIG-AXIAL	SIG-THETA	EPS-AXIAL	EPS-THETA	SIG-YIELD	TEMPERATURE
1		8.28451E-01	4.67984E+00	1.42696E+04	6.22819E+03	3.31337E-02	3.39738E-03	4.04704E+04	0.0
2		8.28979E-01	4.68274E+00	1.37144E+04	7.64585E+03	2.85481E-02	1.54318E-03	4.03327E+04	0.0
3		8.29753E-01	4.68598E+00	1.31665E+04	9.80986E+03	2.18329E-02	-1.17209E-03	4.03601E+04	0.0

1	8.30528E-01	4.69121E+00	9.17728E+03	8.40550E+03	1.51178E-02	-3.88735E-03	4.03202E+04	0.0
5	8.31056E-01	4.69411E+00	-2.92259E+04	-8.57475E+03	1.05322E-02	-5.74154E-03	4.03570E+04	0.0
3	8.79875E-01	4.67045E+00	-8.47401E+03	-1.11678E+04	-6.24361E-02	1.87792E-03	4.07140E+04	0.0
7	8.80403E-01	4.67334E+00	-1.62636E+04	-8.54221E+03	-2.82414E-02	9.95893E-04	4.03164E+04	0.0
8	8.81177E-01	4.67758E+00	1.41012E+04	1.26374E+04	2.18329E-02	-2.95731E-04	4.02743E+04	0.0
9	8.81952E-01	4.68182E+00	-2.71813E+04	7.89326E+02	7.19072E-02	-1.58736E-03	4.08689E+04	0.0
10	8.82480E-01	4.68471E+00	-2.24836E+04	-7.55935E+03	1.06102E-01	-2.46938E-03	4.13535E+04	0.0

TIME HISTCRY PLOT OF RECORD NO. 1 CODE: 1202
COMME THE Y-DISPLACEMENT HISTORY AT NODE 1 \$

-0.3401E-03

-0.2309E-02

0.6000E-05

0.1530E-03

0.3000E-03

TIME HISTORY PLOT OF RECORD NO. 2 CODE: 7102
COMMENT: THE X-DISPLACEMENT HISTORY AT NODE 7 \$

-0.4274E-03

-0.6975E-01

-0.1391E+00

0.6000E-05

0.1530E-03

0.3000E-03

TIME HISTORY PLOT OF RECORD NO. 3 CODE: 7202
CCMMI THE Y-DISPLACEMENT HISTORY AT NODE 7 \$

0.3204E+00

0.1589E+00

-0.2538E-02

0.6000E-05

0.1530E-03

0.3000E-03

TIME HISTORY PLOT OF RECORD NO. 4 CODE: 7302
COMMENT: THE ROTATION HISTORY AT NODE 7 \$

0.1575E-01

0.7087E-02

-0.1573E-02

0.6000E-05

0.1530E-03

0.3000E-03

TIME HISTORY PLOT OF RECORD NO. 5 CODE: 1031
COMM THE MERIDIAN-STRAIN HISTORY AT ST.3 OF ELE.1 \$

0.1305E-01

0.5756E-02

-0.1537E-02

0.6000E-05

0.1530E-03

0.3000E-03

TIME HISTORY PLOT OF RECORD NO. 6 CODE: 1130
COMMENT: THE HOOP-STRAIN HISTORY AT ST.3 OF ELE.1 \$

APPENDIX B
SOURCE STATEMENTS OF SHELL ANALYSIS PROGRAM

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MEMBER NAME ASSBLE
  SUBROUTINE ASSBLF (NUMEL,NDGREE,MEQ,E,IX,THICK,XC,YC,SMASS,INDEX,
1    STRS,NPL,NPD,MAXSTR,MELED,MMATD,MPTD,NIOF,DELT,MSTEP,TFIN,
2    NPIC,MXNPIC,NFOUT,NPFREQ)
  DIMENSION IX (3,MELED),THICK (MELED),XC (MPTD),YC (MPTD),E (8,MMATD),
1    SMASS (NDOF),INDEX (MELED),STRS (MAXSTR),NFOUT (2,MXNPIC)
  IELE=6
  DO 1 JE=1,MEQ
    SMASS (JE)=0.0
1 CONTINUE
  IACC=NPL*NPD*IELE+2
  KH=IACC-2
  INDEX (1)=1
  MXSTR=MAXSTR-IACC+1
  DO 22 I=2, NUMEL
    IND=INDEX (I-1)+IACC
    IF ( IND .GT. MXSTR ) GO TO 900
22 INDEX (I)=IND
    DT=DELT
    BETA=0.5
    DO 2 I=1, NUMEL
      N1=IX (1,I)
      N2=IX (2,I)
      MTYP=IX (3,I)
      HT=THICK (I)
      IF ( HT .EQ. 0.0 ) GO TO 905
      X1=XC (N1)
      X2=XC (N2)
      XX=X2-X1
      Y1=YC (N1)
      Y2=YC (N2)
      YY=Y2-Y1
      IND=INDEX (I)-1
      ITEMP=IND+IACC
      STRS (ITEMP-1)=ATAN2 (YY,XX)
      XLSQ= (XX*XX+YY*YY)
      AL=SQRT (XLSQ)
      STRS (ITEMP)=AL
      DESITY=E (1,MTYP)
      EYMOD=E (2,MTYP)
      IF (EYMOD.EQ.0.0) GO TO 222
      DEALHT=DESIY*AL*HT
      RT=0.125*DEALHT
      RTI=RT* (3.*X1+X2)
      RTJ=RT* (3.*X2+X1)
      RM=DEALHT*AL*AL/192.
      RMI=RM* (5.*X1+3.*X2)
      RMJ=RM* (5.*X2+3.*X1)
      N1M1TD= (N1-1)*NDGREE
      N2M1TD= (N2-1)*NDGREE
      SMASS (N1M1TD+1)=SMASS (N1M1TD+1)+RTI
      SMASS (N1M1TD+2)=SMASS (N1M1TD+2)+RTI
      SMASS (N1M1TD+3)=SMASS (N1M1TD+3)+RMI
      SMASS (N2M1TD+1)=SMASS (N2M1TD+1)+RTJ
      SMASS (N2M1TD+2)=SMASS (N2M1TD+2)+RTJ
      SMASS (N2M1TD+3)=SMASS (N2M1TD+3)+RMJ
      DO 314 M=1, KH
        N=IND+M
314 STRS (N)=0.0

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MEMBER NAME ASSBLE

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      CL=SQRT(EYMOD/DESDITY)
      CB=EYMOD*HT*HT/(12.0*DESDITY)
      CB=SQRT(CB)
      DELT=BETA*XL5Q/(6.0*CB)
      IF ( I.EQ.1) DELTMX=DELT
      IF (DELT.LT.DELTMX) DELTMX=DELT
      DELT=BETA*AL/CL
      IF (DELT.LT.DELTMX) DELTMX=DELT
2     CONTINUE
      DO 888 I=1,MEQ
888    SMASS(I)=1.0/SMASS(I)
      IF (DT.GE.0.0) GO TO 15
      DELTMX=-DT
      GO TO 200
15    CONTINUE
      IF (ABS(DT).LT.1.0E-10) GO TO 200
      IF (DT.LT.DELTMX) DELTMX=DT
200   PRINT 501,DELTMX
501   FORMAT(1H0,5X,'MAXIMUM TIME INCREMENT IN SHELL',E20.8)
      MSTPO=(TFIN+0.75*ABS(DT))/ABS(DT)
      IF (AMOD(TFIN,ABS(DT)).GT. 1.E-3) MSTPO=MSTPO+1
      MSTEP=MSTPO
      IF ( DT.LT. DELTMX ) GO TO 6001
      MFACTR=(DT+0.75*DELTMX)/DELTMX
      IF (AMOD(DT,DELTMX).GT. 1.E-3) MFACTR=MFACTR+1
      NPFREQ=NPFREQ*MFACTR
      MSTEP=MSTPO*MFACTR
      DO 6212 J=1, NPIC
6212  NPOUT(1,J)=NPOUT(1,J)*MFACTR
6001  DELT=TFIN/MSTEP
      IF ( DT.LT. 0.0 ) MFACTR=1
      WRITE(6,5000) TFIN,MSTEP,DELT
5000  FORMAT(' ',5X,'FINAL STOP TIME=',E13.6,10X,'NO. OF STEPS=',I5,10X,
1      ' TIME STEP =',E16.8 /)
      WRITE(6,444) MFACTR,NPFREQ,(NPOUT(1,I),I=1,NPIC)
444   FORMAT(' ',5X,'INTERNAL ADJUSTING FACTOR,MFACTR=',I10/
1      6X,'THE NEW VALUE FOR NPFREQ=',I18/
2      6X,'THE NEW VALUE FOR NPOUT(1,I)=' ,4X,(8I10))
      RETURN
900   JE1= I+1
      WRITE(6,901) JE1
901   FORMAT(/5X,'DIMENSION OF STRS EXCEEDED IN ELEMENT',I3/6X,
1      'PROGRAM TERMINATED BY SUBROUTINE ''ASSBLE''')
      CALL EXIT
905   WRITE(6,903) I
903   FORMAT(/5X,'THICKNESS OF BEAM ELEMENT',I4,'IS ZERO'/6X,
1      'PROGRAM TERMINATED BY SUBROUTINE ''ASSBLE''')
      CALL EXIT
222   WRITE(6,333) JE,MTYP
333   FORMAT(/5X,'THE YOUNG'S MODULOUS FOR ELEMENT',I5,'MATERIAL',I5,
1      5X,'IS ZERO'/6X,'PROGRAM TERMINATED BY SUBROUTINE ''ASSBL
2      E''')
      STOP
      END

```

```
MEMBER NAME  DECOD
              SUBROUTINE DECOD (ML, JJ)
              DIMENSION JJ (4)
              MK=ML
              JJ (4) = MK/1000
              MK=MK-JJ (4) *1000
              DO 10 I=1, 2
              J=10** (3-I)
              JJ (I) =MK/J
10  MK=MK-JJ (I) *J
              JJ (3) =MK
              RETURN
              END
```

MEMBER NAME EXTREM

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```
SUBROUTINE EXTREM(N,X,XMIN,XMAX)
  DIMENSION X(N)
  XMIN= 1.E50
  XMAX=-1.E50
  DO 1 I=1, N
    IF ( X(I) .LT. XMIN ) XMIN=X(I)
    IF ( X(I) .GT. XMAX ) XMAX=X(I)
1 CONTINUE
  RETURN
  END
```

MEMBER NAME FRCIN

```

SUBROUTINE FRCIN (NUMEL, NUMNP, ND, MEQ, XC, YC, IX, THICK, E, UD, FINT,
+ STRS, NPL, NPD, INDEX, MPTD, MELED, MMATD, NDOF, MSTRSD)
  DIMENSION FINT (NDOF), XC (MPTD), YC (MPTD), UD (NDOF), INDEX (MELED)
  DIMENSION STRS (MSTRSD), IX (3, MELED), THICK (MELED), E (8, MMATD)
  DIMENSION AUX (10), WOK (4), AUXC (10), WOKC (4)
  DIMENSION EPO (2), EPN (2), SO (2), SN (2)
  COMMON /THRM/ TIME, TN (10)
  REAL*8 PTD (5) /-0.906179845938664D0, -0.538469310105683D0,
+ 0.0D0, 0.538469310105683D0, 0.906179845938664D0/
  REAL*8 PTL (2) /-0.577350269189626D0, 0.577350269189626D0/
  REAL*8 WTD (5) / 0.236926885056189D0, 0.478628670499366D0,
+ 0.568888888888889D0,
+ 0.478628670499366D0, 0.236926885056189D0/
  REAL*8 WTL (2) /2*1.0D0/
  IELE=6
  NES=NPL*NPD
  NES1=NES+NES
  NES2=NES1+NES
  NES3=NES2+NES
  NES4=NES3+NES
  IAL=NPL*NPD*IELE+1
  DO 1 I=1, MEQ
1 FINT ( I )=0.00
  DO 2 I=1, NUMEL
  MTYP=IX (3, I)
  N1=IX (1, I)
  N2=IX (2, I)
  AL=STRS (INDEX (I) + IAL)
  HT=THICK (I)
  X1=XC (N1)
  X2=XC (N2)
  XX=X2-X1
  YY= YC (N2) -YC (N1)
  N1N= (N1-1) *ND
  N2N= (N2-1) *ND
  DIX=UD (N1N+1)
  DIY=UD (N1N+2)
  DJX=UD (N2N+1)
  DJY=UD (N2N+2)
  DIJX=DJX-DIX
  DIJY=DJY-DIY
  DX=XX+DIJX
  DY=YY+DIJY
  R1N=X1+DIX
  R2N=X2+DJX
  AL2=AL*AL
  FAC=2. * (XX*DIJX+YY*DIJY) +DIJX*DIJX+DIJY*DIJY
  ALN2=AL2+FAC
  ALN=SQRT (ALN2)
  THETA= (XX*DIJY-YY*DIJX) /AL/ALN
  IF ( ABS (THETA) .GT. 0.01 ) THETA=ARSIN (THETA)
  PHIIH=UD (N1N+3) -THETA
  PHIJH=UD (N2N+3) -THETA
  STRECH=FAC/ (AL+ALN) /AL
  C=DX/ALN
  S=DY/ALN
  DO 105 JG=1, NPL
  NFAC= (JG-1) *2

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MEMBER NAME FRCIN

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CHI=PTL(JG)
WOK(NFAC+2)=PHIJH*(3.*CHI+1.)
WOK(NFAC+1)=PHIHH*(3.*CHI-1.)
WOKC(NFAC+1)=PHIHH*(3.*CHI*CHI-1.-2.*CHI)
105 WOKC(NFAC+2)=PHIJH*(3.*CHI*CHI-1.+2.*CHI)
FAC=-HT/AL*0.5
DO 110 JG=1, NPL
  NAUU=NPD*(JG-1)
  NFAC=(JG-1)*2
  DO 110 IG=1, NPD
    NAUX=NAUU+IG
    FAC1=PTD(IG)*FAC
    CHI=PTL(JG)
    R=X1+XX*(1.+CHI)*0.5
    FAC2=((1.-CHI)*DIX+(1.+CHI)*DJX)*0.5
    FAC3=FAC1+XX*(0.25*(WOKC(NFAC+1)+WOKC(NFAC+2))+THETA)
    AUXC(NAUX)=(FAC2+FAC3)/R
  110 AUX(NAUX)=STRECH+FAC1*(WOK(NFAC+1)+WOK(NFAC+2))
  IND=INDEX(I)
  IND=IND-1
  DO 111 IS=1, NES
    IM=IND+IS
    EPO(1)=STRS(IM)
    SO(1)=SIRS(IM+NES)
    EPO(2)=STRS(IM+NES1)
    SO(2)=SIRS(IM+NES2)
    DUM=STRS(IM+NES3)
    TOLD=STRS(IM+NES4)
    EPN(1)=AUX(IS)
    EPN(2)=AUXC(IS)
    TNEW=TN(IS)
    CALL MISES2(SN,SO,EPN,EPO,DUM,E(1,MTYP),TNEW,TOLD)
    STRS(IM)=EPN(1)
    STRS(IM+NES)=SN(1)
    STRS(IM+NES1)=EPN(2)
    STRS(IM+NES2)=SN(2)
    STRS(IM+NES3)=DUM
    STRS(IM+NES4)=TNEW
  111 CONTINUE
  FT1=0.0
  FT2=0.0
  FX1=0.0
  RMX1=0.0
  RMX2=0.0
  RMT1=0.0
  RMT2=0.0
  DO 305 JG=1, NPL
    WTLES=WTL(JG)
    CHIB=0.5*(PTL(JG)+1.)
    CHIB1=1.-CHIB
    CHIB2=CHIB*CHIB
    CHIB6=6.*CHIB
    CHIB23=3.*CHIB2
    R=R1N*CHIB1+R2N*CHIB
    CTF1=WTLES*CHIB1
    CTF2A=WTLES*CHIB
    CXF1=WTLES*R
    CXM1=WTLES*R*(CHIB6-4.)

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MEMBER NAME FRCIN

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    CXM2=WTLES*R*(CHIB6-2.)
    CTM1=WTLES*(.5-4.*CHIB+CHIB23)
    CTM2=WTLES*(CHIF23-2.*CHIB-.5)
    IS=IND*(JG-1)*NPD
    DO 305 IG=1, NPD
    IM=IS+IG
    XSTR=STRS(IM+NES)
    TSTR=STRS(IM+NES2)
    WTDEP=WTD(IG)
    DEP=PTD(IG)
    CTF2=WTDEP*TSTR
    CXP2=WTDEP*XSTR
    CTM=CTF2*DEP
    CXM=CXP2*DEP
    FT1=FT1+CTF1*CTF2
    FT2=FT2+CTF2A*CTF2
    FX1=FX1+CXP1*CXP2
    RMX1=RMX1+CXM1*CXM
    RMX2=RMX2+CXM2*CXM
    RMT1=RMT1+CTM1*CTM
    RMT2=RMT2+CTM2*CTM

```

305 CONTINUE

```

    CEFXF=-0.25*HT
    CEFTF=-CEXF*ALN
    CEFXM=-.125*HT*HT
    CEFTM=CEFXM*DX
    FT1=FT1+CEFTF
    FT2=FT2+CEFTF
    FX1=FX1+CEXF
    RMX1=RMX1+CEFXM
    RMX2=RMX2+CEFXM
    RMT1=RMT1+CEFTM
    RMT2=RMT2+CEFTM
    RM1=RMX1+RMT1
    RM2=RMX2+RMT2
    FX2=-FX1
    FY1=(RM1+RM2)/ALN
    FY2=-FY1
    FIX=C*FX1-S*FY1+FT1
    FJX=C*FX2-S*FY2+FT2
    FIY=S*FX1+C*FY1
    FJY=S*FX2+C*FY2
    AMI=RM1
    AMJ=RM2
    FINT(N1N+1)=FINT(N1N+1)+FIX
    FINT(N1N+2)=FINT(N1N+2)+FIY
    FINT(N1N+3)=FINT(N1N+3)+AMI
    FINT(N2N+1)=FINT(N2N+1)+FJX
    FINT(N2N+2)=FINT(N2N+2)+FJY
    FINT(N2N+3)=FINT(N2N+3)+AMJ

```

2 CONTINUE

```

    RETURN
    END

```

MEMBER NAME FREEFD

```

SUBROUTINE FREEFD(KW,ND,NELE,IX,XC,YC,DIS,VEL,ACC,FEXT,
+               STRS,ME,MMS,MP)
COMMON /THRM/ TIME,TN(10)
DIMENSION XC(MP),YC(MP),DIS(ME),VEL(ME),ACC(ME),FEXT(ME)
DIMENSION STRS(MMS),IX(3,NELE)
DIMENSION PRSS(8),TM(8),SLP(7)
DATA MXMPNT/8/
C THIS IS A USER SUPPLIED SUBROUTINE
C KW=0 IS CALLED ONLY ONCE FOR INPUTTING INITIAL CONDITIONS OTHER THAN TR
C KW=1 IS CALLED DURING EACH STEP AND IS USED FOR INPUTTING LOADING
IF (KW.EQ. 0) GO TO 1001
P=0.0
IF (TIME.LT.TM(1)) GO TO 3
IF (TIME.GT.TM(MPNT)) GO TO 4
DO 1 I=2, MPNT
J=JMPNT-I
IF (TIME.GE.TM(J)) GO TO 2
1 CONTINUE
4 P=PRSS(MPNT)
GO TO 3
2 DELT=TIME-TM(J)
P=PRSS(J)+SLP(J)*DELT
3 CONTINUE
DO 888 I=1,ME
888 FEXT(I)=0.0
DO 10 I=1, NELE
NODE1=IX(1,I)
NODE2=IX(2,I)
N1=(NODE1-1)*ND
N2=(NODE2-1)*ND
X1=XC(NODE1)+DIS(N1+1)
X2=XC(NODE2)+DIS(N2+1)
Y1=YC(NODE1)+DIS(N1+2)
Y2=YC(NODE2)+DIS(N2+2)
XX=X2-X1
YY=Y2-Y1
ALN2=XX*XX+YY*YY
ALN=SQRT(ALN2)
FEXT(N1+1)=0.5*P*Y*(X1+XX/3.)+FEXT(N1+1)
FEXT(N1+2)=0.5*P*X*(X1+XX/3.)+FEXT(N1+2)
FEXT(N1+3)= P*ALN2/12.*(X1+XX*2./5.)+FEXT(N1+3)
FEXT(N2+1)=0.5*P*Y*(X1+XX/3.*2.)+FEXT(N2+1)
FEXT(N2+2)=0.5*P*X*(X1+XX/3.*2.)+FEXT(N2+2)
FEXT(N2+3)=-P*ALN2/12.*(X1+XX*3./5.)+FEXT(N2+3)
10 CONTINUE
RETURN
1001 READ(5,100,END=400) MPNT
100 FORMAT(I10)
IF (MPNT.LE.0) GO TO 400
IF (MPNT.GT.MXMPNT) GO TO 4000
READ(5,200) (TM(I),I=1,MPNT)
READ(5,200) (PRSS(I),I=1,MPNT)
200 FORMAT(8E10.4)
IMPNT=MPNT-1
JMPNT=MPNT+1
DO 105 I=1, IMPNT
105 SLP(I)=(PRSS(I+1)-PRSS(I))/(TM(I+1)-TM(I))
WRITE(6,300) (TM(I),I=1,MPNT)

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MEMBER NAME FREEFD

```
      WRITE(6,450) (PRSS(I),I=1,MPNT)
300  FORMAT(/5X,'THE TIME TICS FOR THE LOADING-TIME CURVE ARE;'/5X,
      +      8G15.6)
450  FORMAT(5X,'THE PRESSURE TICS FOR THE LOADING-TIME CURVE ARE;'/5X,
      +      8G15.6)
      RETURN
400  WRITE(6,500) MPNT
500  FORMAT('1',5X,'PROGRAM TERMINATED BY ''FREEFD''/,5X,
      +      'NO INPUT DATA FOR THE LOADING; NUMBER OF DATA PAIR=',I5)
      CALL EXIT
4000 MPNT=MPNT-MXMPNT
      WRITE(6,600) MPNT
600  FORMAT('1',5X,'PPROGRAM TERMINATED BY ''FREEFD''/,5X,
      +      'NUMBER OF DATA PAIR FOR LOADING EXCEDED MAXIMUM BY',I5)
      CALL EXIT
      RETURN
      END
```

MEMBER NAME INPUT

```

SUBROUTINE INPUT (NELE,NNODE,NDGREE,NUMDIS,NODDIS,DT,NUMMAT,DELT,
1 NDOF,E,XC,YC,NODE,THICK,ANGLE,MMATD,MELED,MPTD,MDPTD,MEQ,NPRU,
2 NPRS,NPIC,NPFREQ,IUOT,ISOT,NPOUT,MUS,MXNPRU,MXNPRS,MXNPIC,MXMUS,
3 ITITLE)
  DIMENSION XC(MPTD),YC(MPTD),NODDIS(MDPTD),ANGLE(MDPTD)
  1  ,E(8,MMATD),NODE(3,MELED),THICK(MELED)
  3  ,IUOT(MXNPRU),ISOT(MXNPRS),NPOUT(2,MXNPIC)
  INTEGER*4 FMAT(4),JJ(4),ITITLE(20),ITITLE(17,MXMUS)
  DATA FMAT/'SHEL','L EL','EMEN','T' '/'
104  FORMAT(I10,1X,17A4)
366  FORMAT(' ',20X,6I10)
367  FORMAT('1PROGRAM TERMINATED BY ''INPUT'' OF ''SHELL''/'
+ ' FOLLOWING ITEMS MAY EXCEEDED THEIR DIMENSIONS IN',1X,
+ ' THE PROGRAM THAT CALLS SHELL'/20X,
+ ' THESE ITEMS ARE:NODE,NELE,NUMMAT,NUMDIS,NPRES,MEQ')
368  FORMAT('1PROGRAM TERMINATED BY ''READIN'' OF ''SHELL''/'
+ ' FOLLOWING ITEMS MAY EXCEEDED THEIR DIMENSIONS IN',1X,
+ ' THE PROGRAM THAT CALLS SHELL'/20X,
+ ' THE ITEMS ARE:NPRU,NPRS,NPIC,MUS')
400  FORMAT(8I10)
401  FORMAT(1H0,5X,'UOUT: DISP./VEL./ACC. OUTPUT'/
+ (4X,I10,5X,17A4))
402  FORMAT(1H0,5X,'SOUT: STRESS/STRAIN OUTPUT'/
+ (4X,I10,5X,17A4))
582  FORMAT(10X,I7,10X,I4)
589  FORMAT(1H0,5X,'NPOUT PICTURE OUTPUT'/10X,'AT STEP',10X,'CODE')
1003  FORMAT(15,5X,2E10.6)
1011  FORMAT(3I5,2E10.6)
1051  FORMAT(3E10.4)
1201  FORMAT(I10,E10.4)
1404  FORMAT('0',5X,'OUTPUT CODE')
1405  FORMAT(' ',9X,'NPFREQ=',I10/
1      10X,'NPRU'=' ,I10/
2      10X,'NPRS'=' ,I10/
3      10X,'NPIC'=' ,I10)
1701  FORMAT(4I5,E10.6)
2001  FORMAT('0',
1 5X,'NUMBER OF NODES' ,I10/
2 6X,'NUMBER OF ELEMENTS' ,I10/
3 6X,'NUMBER OF MATERIALS' ,I10/
4 6X,'NO. OF DISP. NODES' ,I10/
5 6X,'D.O.F. PER NODE' ,I10/
6 6X,'TIME INCREMENT' ,1PE14.5/
7 6X,'FINAL TIME',F20.5)
2003  FORMAT('0',6X,'NODE NO.',17X,'X-CORDINATE',9X,'Y-CORDINATE')
2004  FORMAT(3X,I10,10X,2G20.6)
2005  FORMAT(1H0,'NODAL POINT ERROR N=',I5)
2006  FORMAT('0',5X,'ELEMENT NO. N1 N2 MTYPE',10X,'THICKNESS')
2007  FORMAT(5X,I9,5X,3I5,7X,1PE14.5)
2050  FORMAT('0',5X,'MATERIAL NUMBER',I3,17X,4A4/
1 6X,'DENSITY',1PG18.5,10X,'E ELAS MOD',G20.5/
2 6X,'SIG-Y YIELD',G14.5,10X,'E-P PLAS MOD',G18.5/
3 6X,'SIG-ULT',G18.5,10X,'POISSON RATIO',G17.5/
4 6X,'THICKNESS',G16.5,10X,'THERMO CONSTANT',G13.3)
2201  FORMAT('0',5X,'BOUNDARY DISPLACEMENT NODE(S)'/
1 6X,'NO.',4X,'NODE',6X,'X Y R',8X,'ANGLE')
2202  FORMAT(5X,I3,5X,I4,5X,3I2,3X,F10.3)
2410  FORMAT(1H0,5X,'ERROR IN OUTPUT DATA'/6X,

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MEMBER NAME INPUT

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1      'PROGRAM TERMINATED BY SUBROUTINE ''INPUT''')
3012 FORMAT (//6X, 'AXISYMMETRIC PROBLEM')
5002 FORMAT (//5X, 'TOO MANY NODES ON LOAD LINES', I5/6X,
1      'PROGRAM TERMINATED BY SUBROUTINE ''INPUT''')
8001 FORMAT (20A4)
8002 FORMAT ('1', 5X, 20A4)
      READ (5, 8001, END=19191) TITLE
      WRITE (6, 8002) TITLE
      READ (5, 1011) NELE, NUMMAT, NUMDIS, DELT, DT
      NNODE=NELE+1
      NDGREE=3
      WRITE (6, 2001) NNODE, NELE, NUMMAT, NUMDIS, NDGREE, DELT, DT
      IF (NELE.GT.MELED) GO TO 663
      IF (NNODE.GT.MPTD) GO TO 663
      IF (NUMMAT.GT.MMATD) GO TO 663
      IF (NUMDIS.GT.MDPTD) GO TO 663
      MEQ=NNODE*NDGREE
      IF (MEQ.GT.NDCF) GO TO 663
      WRITE (6, 3012)
      DO 51 I=1, NUMMAT
      READ (5, 1011) MTYPE
      IF ( MTYPE .GT. MMATD ) GO TO 663
      READ (5, 1051) (E(J, MTYPE), J=1, 8)
      WRITE (6, 2050) MTYPE, FNAT, (E(J, MTYPE), J=1, 8)
51 CONTINUE
      WRITE (6, 2003)
      L=0
60 READ (5, 1003) N, XC(N), YC(N)
      NL=L+1
      IF (L.EQ.0) GO TO 70
      NML=N-L
      DS=NML
      DXC=(XC(N)-XC(L))/DS
      DYC=(YC(N)-YC(L))/DS
70 L=L+1
      IF (N-L) 100, 90, 80
80 XC(L)=XC(L-1)+DXC
      YC(L)=YC(L-1)+DYC
      GO TO 70
90 WRITE (6, 2004) (K, XC(K), YC(K), K=NL, N)
      IF (NNODE-N) 100, 110, 60
100 WRITE (6, 2005) N
      CALL EXIT
110 CONTINUE
      WRITE (6, 2006)
      N=0
130 READ (5, 1701) M, (NODE(I, M), I=1, 3), THICK(M)
      IF ( THICK(M) .LE. 0.0 ) THICK(M)=E(7, NODE(3, M))
140 N=N+1
      IF (M-N .LE. 0) GO TO 170
      DO 151 I=1, 2
151 NODE(I, N)=NODE(I, N-1)+1
      NODE(3, N)=NODE(3, N-1)
      THICK(N)=THICK(N-1)
170 CONTINUE
      WRITE (6, 2007) N, (NODE(I, N), I=1, 3), THICK(N)
      IF (M-N .GT. 0) GO TO 140
      IF (NELE-N .GT. 0) GO TO 130

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MEMBER NAME INPUT
      IF (NUMDIS.EQ.0) GO TO 200
      I=1
196 READ (5,1201) NODDIS(I),ANGLE(I)
      IF (I.EQ.NUMDIS) GO TO 199
      I=I+1
      GO TO 196
199 CONTINUE
      WRITE(6,2201)
      DO 195 I=1, NUMDIS
      CALL DECOD ( NODDIS(I), JJ )
      IF ( JJ(4) .GT. NNODE ) GO TO 405
      WRITE(6,2202) I,JJ(4),(JJ(J),J=1,3),ANGLE(I)
195 ANGLE(I)=1.745329E-2*ANGLE(I)
200 CONTINUE
      WRITE (6,1404 )
      READ (5,400 ) NPFREQ,NPRU,NPRS,NPIC
      WRITE(6,1405) NPFREQ,NPRU,NPRS,NPIC
      IF ( NPRU .GT. MXNPRU ) GO TO 6990
      IF ( NPRS .GT. MXNPRS ) GO TO 6990
      IF ( NPIC .GT. MXNPIC ) GO TO 6990
      MUS=NPRU+NPRS
      IF ( MUS .GT. MXMUS ) GO TO 6990
      IF ( NPFREQ .LE. 0 ) NPFREQ=1
      IF (NPRU .EQ. 0 ) GO TO 411
      READ (5,104) (IUOT(I),(ITITLE(J,I),J=1,17),I=1,NPRU )
      WRITE (6,401) (IUOT(I),(ITITLE(J,I),J=1,17),I=1,NPRU )
      DO 125 I=1, NPRU
      CALL DECOD ( IUOT (I),JJ )
      IF ( JJ(4) .GT. ENODE ) GO TO 405
125 CONTINUE
411 IF (NPRS .EQ. 0 ) GO TO 215
      READ (5,104) (ISOT(I),(ITITLE(J,I+NPRU),J=1,17),I=1,NPRS )
      WRITE (6,402) (ISOT(I),(ITITLE(J,I+NPRU),J=1,17),I=1,NPRS )
      DO 521 I=1, NPRS
      CALL DECOD ( ISOT(I),JJ)
      IF (JJ(4) .GT. NELE ) GO TO 405
521 CONTINUE
215 CONTINUE
      IF ( NPIC .LE. 0 ) GO TO 512
      WRITE(6,589)
      DO 591 K=1,NPIC
      READ(5,400) (NPOUT(I,K),I=1,2)
591 WRITE(6,582) (NPOUT(I,K),I=1,2)
512 CONTINUE
      RETURN
405 WRITE (6,2410 )
19191 CONTINUE
      CALL EXIT
6990 WRITE(6,368)
      WRITE(6,366) NPRU,NPRS,NPIC,MUS
      WRITE(6,366) MXNPRU,MXNPRS,MXNPIC,MXMUS
      CALL EXIT
5001 WRITE(6,5002) I
      CALL EXIT
663 WRITE(6,367)
      WRITE(6,366) NNODE,NELE,NUMMAT,NUMDIS,MEQ
      WRITE(6,366) MPTD,MELED,MMATD,MDETD,NDOF
      STOP

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MEMBER NAME INPUT
END

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MEMBER NAME MAIN

```
DIMENSION E(8,2),IX(3,30),THICK(30),XC(31),YC(31)
DIMENSION NODDIS(2),ANGLE(2),INDEX(30),STRS(1860)
DIMENSION AO(93),A1(93),V(93),XO(93),X1(93)
DIMENSION FEXT(93),FINT(93),SMASS(93),ITITLE(17,30)
DIMENSION IUOT(10),ISOT(20),NPOUT(2,10),PSU(3210),US(30),KPLOT(30)
DIMENSION J1(30),J2(30),J3(30),J4(30),P1(30),P2(30),K3(30),P4(30)
DATA NUMPLT/ 3210/,MXNPRU/ 10/,MXNPKS/ 20/,MXNPIC/10/,MXMUS/30/
DATA MMATD,MELED,MPTD,MSTRSD,NDOF,MDPTD/2,30,31,1860,93,2/
CALL SHELL(DT,NUMEL,NUMNP,NDGREE,MEQ,NUMMAT,NUMDIS,E,IX,
1 THICK,XC,YC,MSTRSD,STRS,AO,A1,V,XO,X1,NODDIS,ANGLE,FINT,FEXT,
2 INDEX,SMASS,DELT,DELTMX,NDOF,MMATD,MELED,MPTD,MDPTD,MXNPRU,
3 MXNPKS,MXMUS,NUMPLT,IUOT,ISOT,US,PSU,J1,J2,J3,J4,P1,P2,K3,P4,
4 KPLOT,NPOUT,MXNPIC,ITITLE)
STOP
END
```


MEMBER NAME MISES2

```

SUBROUTINE MISES2 (SN,SO,EPN,EPO,DUM,ZPAR,TN,TO)
DIMENSION SN(2),SO(2),EPN(2),EPO(2),ZPAR(8),EPD(2),EPPRIM(2)
VON(X1,X2)=X1*X1+X2*X2-X1*X2
SIGEFF(S1,S2)=SQRT(S1*S1+S2*S2-S1*S2)
F=ZPAR(2)
SY=ZPAR(3)
EP=ZPAR(4)
SIGULT=ZPAR(5)
AMU=ZPAR(6)
ALPH=ZPAR(8)
IF ( SIGULT .LE. 0. ) SIGULT=1.0E30
SEFFMX=DUM
IF( SEFFMX .LT. SY ) SEFFMX=SY
BETA=E/(1.-AMU*AMU)
EPTHMO=ALPH*(TN-TO)
DO 20 J=1,2
20 EPD(J)=EPN(J)-EPO(J)-EPTHMO
DSX=BETA*(EPD(1)+AMU*EPD(2))
DSY=BETA*(EPD(2)+AMU*EPD(1))
SN(1)=SO(1)+DSX
SN(2)=SO(2)+DSY
IF ( SY .LE. 0.0 ) GO TO 9
SEFF=SIGEFF(SN(1),SN(2))
IF ( SEFF .LE. SEFFMX ) GO TO 9
SEFFO=SIGEFF(SO(1),SO(2))
A=VON(DSX,DSY)
B=(2.*SO(1)-SO(2))*DSX+(2.*SO(2)-SO(1))*DSY
C=SEFFO*SEFFO-SEFFMX*SEFFMX
D=B*B-4.*A*C
IF ( A .EQ. 0. ) GO TO 99
IF ( C .EQ. 0. ) GO TO 100
IF ( D .LE. 0. ) GO TO 105
ALFA=(-B+SQRT(D))/A*0.5
GO TO 101
105 ALFA=0.5*B/A
GO TO 101
100 ALFA=0.0
IF ( B .LT. 0. ) ALFA=-B/A
GO TO 101
99 ALFA=-C/B
101 CONTINUE
ALFA1=1.-ALFA
SO(1)=SO(1)+ALFA*DSX
SO(2)=SO(2)+ALFA*DSY
EPD(1)=EPD(1)*ALFA1
EPD(2)=EPD(2)*ALFA1
IF ( SEFFMX .GE. SIGULT ) GO TO 1005
HPRIM= EP*E/(E-EP)*0.66666666
R1=0.6666666*(1.-AMU*AMU)*HPRIM/E
R2=0.5555555-0.4444444*AMU
R3=1.1111111*AMU-0.8888888
BET=(R1+R2)*(SO(1)*SO(1)+SO(2)*SO(2))+(R3-R1)*SO(1)*SO(2)
PET=1./BET
SM=(SO(1)+SO(2))/3.
S1=SO(1)-SM
S2=SO(2)-SM
S11=S1*S1
S12=S1*S2

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MEMBER NAME MISES2

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S22=S2*S2
S12A=S12*AMU
W11=1.-BET*(S11+S12A)
W12=-BET*(S12+AMU*S11)
W21=-BET*(S12+AMU*S22)
W22=1.-BET*(S22+S12A)
DSX=BETA*((W11+AMU*W21)*EPD(1)+(W12+AMU*W22)*EPD(2))
DSY=BETA*((AMU*W11+W21)*EPD(1)+(AMU*W12+W22)*EPD(2))
SN(1)=SO(1)+DSX
SN(2)=SO(2)+DSY
SEFFMX=SIGEFF(SN(1),SN(2))
IF (SEFFMX .LE. SIGULT) GO TO 9
A=VON(DSX,DSY)
B=(2.*SO(1)-SO(2))*DSX+(2.*SO(2)-SO(1))*DSY
C=VON(SO(1),SO(2))-SIGULT*SIGULT
D=B*B-4.*A*C
IF (A .EQ. 0.) GO TO 999
IF (C .EQ. 0.) GO TO 9100
IF (D .LE. 0.) GO TO 1105
ALFA=(-B+SQRT(D))/A*0.5
GO TO 9101
1105 ALFA=0.5*B/A
WRITE(5,3333) SO(1),SO(2),DSX,DSY,A,B,C,D
3333 FORMAT(10X,'.222'/8G13.4)
GO TO 9101
9100 ALFA=0.0
IF (B .LT. 0.) ALFA=-B/A
GO TO 9101
999 ALFA=-C/B
9101 CONTINUE
SO(1)=SO(1)+ALFA*DSX
SO(2)=SO(2)+ALFA*DSY
ALFA1=1.-ALFA
EPD(1)=EPD(1)*ALFA1
EPD(2)=EPD(2)*ALFA1
1005 F1=2.*SO(1)-SO(2)
F2=2.*SO(2)-SO(1)
F1F1=F1*F1
F2F2=F2*F2
F1F2=F1*F2
P=1./(F1F1+F2F2+2.*AMU*F1F2)
W11=1.-P*(F1F1+AMU*F1F2)
W12=-P*(AMU*F1F1+F1F2)
W21=-P*(AMU*F2F2+F1F2)
W22=1.-P*(F2F2+AMU*F1F2)
EPPRIM(1)=W11*EPD(1)+W12*EPD(2)
EPPRIM(2)=W21*EPD(1)+W22*EPD(2)
DSX=BETA*(EPPRIM(1)+AMU*EPPRIM(2))
DSY=BETA*(EPPRIM(2)+AMU*EPPRIM(1))
SN(1)=SO(1)+DSX
SN(2)=SO(2)+DSY
SEFFMX=SIGEFF(SN(1),SN(2))
IF (SEFFMX .LE. SIGULT) GO TO 9
ALFA=SIGULT/SEFFMX
SN(1)=SN(1)*ALFA
SN(2)=SN(2)*ALFA
SEFFMX=SIGULT
9 CONTINUE

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95

MEMBER NAME OUTPUT

```

SUBROUTINE OUTPUT(NUMEL,NUMNP,NDGREE,MEQ,TIME,DELT,MXSTEP,NTSTEP,
1 NPRU,MXNPRU,NPRS,MXNPRS,NPIC,MXNPIC,NPFREQ,IUOT,ISOT,MUS,MXMUS,
2 XC,YC,MXSTES,INDEX,MAXPLT,PSU,E,IX,THICK,NUMMAT,UD,UD1,UD2,NPL,
3 NPD,NPOUT,US,J1,J2,J3,J4,P1,P2,K3,P4,KPLOT,STRS,ITITLE)
DIMENSION XC(NUMNP),YC(NUMNP),INDEX(NUMEL),STRS(MXSTRS),
1 IUOT(MXNPRU),ISOT(MXNPRS),US(MXMUS),PSU(MAXPLT),J1(MXMUS),
2 J2(MXMUS),J3(MXMUS),J4(MXMUS),P1(MXMUS),P2(MXMUS),K3(MXMUS),
3 P4(MXMUS),UD(MEQ),UD1(MEQ),UD2(MEQ),KPLOT(MXMUS),ITITLE(17,MXMUS)
DIMENSION E(8,NUMMAT),IX(3,NUMEL),NPOUT(2,NPIC),THICK(NUMEL)
DIMENSION XORIG(10),YORIG(10),JJ(4),AUX(9)
DATA U,S/'U','S',PARL,PARR/'(','')',MXLINE/54/
REAL*8 PTD(5)/-0.906179845938664D0,-0.538469310105683D0,
+ 0.0D0,0.538469310105683D0,0.906179845938664D0/
REAL*8 PTL(2)/-0.577350269189626D0,0.577350269189626D0/
IF ( NPRU .LE. 0 .AND. NPRS .LE. 0 .AND. NPIC .LE. 0 ) GOTO 405
IF ( NTSTEP .NE. 1 ) GO TO 2202
CCCCCCCCC PSU(1) TO PSU(MPNT) HOLDS TIME FOR PLOTTING ARRAYS
IELE=6
IAL=NPL*NPD+IELE+1
IADD=(MUS+4)/5+1
MPNT=MXSTEP/NPFREQ
NES=NPL*NPD
NES1=NES+NES
NES2=NES1+NES
NES3=NES2+NES
NES4=NES3+NES
ILINE=1
KKK=0
DO 9873 I=1, MUS
IS=I-NPRU
IF ( IS .GT. 0 ) GO TO 9872
CALL DECOD( IUOT(I),JJ )
P2(I)=U
K3(I)=I
GO TO 9871
9872 CALL DECOD( ISOT(IS),JJ )
P2(I)=S
K3(I)=IS
9871 P1(I)=PARL
P4(I)=PARR
J1(I)=JJ(1)
J2(I)=JJ(2)
J3(I)=JJ(3)
J4(I)=JJ(4)
IF (J3(I).EQ.0) GO TO 9873
KKK=KKK+1
KPLOT(KKK)=I
9873 CONTINUE
IXNEW=(KKK+1)*MPNT
IYNEW=IXNEW+NUMNP*NPIC
NUMPLT=IYNEW-NUMNP*NPIC
IF ( MAXPLT .LT. NUMPLT ) GO TO 8408
2202 CONTINUE
NP=MOD(NTSTEP,NPFREQ)
IF ( NP .NE. 0 ) GO TO 224
KKK=0
NKN=NTSTEP/NPFREQ
PSU(NKN)=TIME

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MEMBER NAME OUTPUT

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      IF ( NPRU .LE. 0 ) GO TO 110
      DO 151 I=1, NPRU
      II=(J4(I)-1)*NDGREE +J1(I)
      J2KON=J2(I)+1
      GO TO (1,2,3), J2KON
1      ANS=UD(II)
      GO TO 15
2      ANS=UD1(II)
      GO TO 15
3      ANS=UD2(II)
15     US(I)=ANS
      IF ( J3(I) .EQ. 0 ) GO TO 151
      KKK=KKK+1
      JPSU=KKK*MPNT+NKN
      PSU(JPSU)=ANS
151    CONTINUE
110    CONTINUE
      IF ( NPRS .LE. 0 ) GO TO 220
      DO 221 I=1, NPRS
      IS=I+NPRU
      N4=J4(IS)
      J12=J1(IS)*10+J2(IS)
      IND=INDEX(N4)-1
      US(IS)=STRS(IND+J12)
      IF ( J3(IS) .EQ. 0 ) GO TO 221
      KKK=KKK+1
      JPSU=KKK*MPNT+NKN
      PSU(JPSU)=US(IS)
221    CONTINUE
220    CONTINUE
      IF ( ILINE .EQ. 1 ) WRITE(6,447)
+      (P1(J),P2(J),K3(J),P4(J),J4(J),J1(J),J2(J),J3(J), J=1,MUS)
447    FORMAT('1'/7X,'TIME=',3X,5(4X,2A1,I2,A1,I4,4X,3I1)/
+          (14X,5(4X,A1,A1,I2,A1,I4,4X,3I1)))
      WRITE(6,7403) TIME, (P1(J),P2(J),K3(J),P4(J),US(J), J=1, MUS)
7403   FORMAT('0',1PE13.4,5(4X,A1,A1,I2,A1,E11.4)/
+          (14X,5(4X,A1,A1,I2,A1,E11.4)))
      ILINE=ILINE+IADD
      IF( ILINE+IADD .GT. MXLINE ) ILINE=1
224    CONTINUE
      IF ( NPIC .LE. 0 ) GO TO 109
      DO 129 I=1,NPIC
      IF ( NTSTEP .NE. NPOUT(1,I) ) GO TO 129
      WRITE(6,302) TIME
302    FORMAT('1', 9X,'TIME =',G20.6//
1      10X,'DISPLACEMENTS'//
2      31X,'NODE',13X,'X-DIRECTION',13X,'Y-DIRECTION',
2      13X,'X-Y ROTATION')
      DO 130 LD=1,NUMNP
      L1=(LD-1)*NDGREE+1
      L2=L1+1
      L3=L2+1
130    WRITE(6,301) LD,UD(L1),UD(L2),UD(L3)
301    FORMAT( 26X,I5,4X,G20.6,4X,G20.6,4X,G21.6)
      ILINE=1
      IF ( NPOUT(2,I) .EQ. 1 ) GO TO 129
203    WRITE(6,303)
      FORMAT('1',

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MEMBER NAME OUTPUT

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1      10X,'DISPLACEMENTS',49X,'DEFORMED COORINATES'//
2      10X,'NODE',13X,'X-DIRECTION',13X,'Y-DIRECTION',10X,
3      'NODE',13X,'X-DIRECTION',13X,'Y-DIRECTION')
      DO 131 LD=1, NUMNP
      L1=(LD-1)*NDGREE+1
      L2=L1+1
      XNEW=UD(L1)+XC(LD)
      YNEW=UD(L2)+YC(LD)
      NWADD=(I-1)*NUMNP
      PSU(IXNEW+NWADD+LD)=XNEW
      PSU(IYNEW+NWADD+LD)=YNEW
131    WRITE(6,205) LD,UD(L1),UD(L2),LD,XNEW,YNEW
205    FORMAT(2(9X,I5,4X,G20.6,4X,G20.6))
      CALL EXTREM(NUMNP,PSU(IXNEW+NWADD+1),XMIN,XMAX)
      CALL EXTREM(NUMNP,PSU(IYNEW+NWADD+1),YMIN,YMAX)
      CALL PLOTTER(NUMNP,PSU(IXNEW+NWADD+1),PSU(IYNEW+NWADD+1),
1      XMIN,XMAX,YMIN,YMAX)
5587   WRITE(6,5587) TIME
      FORMAT(' ','STRUCTURAL CONFIGURATION AT TIME=',1P20.6)
      ILINE=1
      IF (NPOUT(2,I).EQ.2) GO TO 129
      WRITE(6,304)
304    FORMAT('1',11X,'MODE',T36,'VEL-X',T61,'VEL-Y',T86,'ACC-X',
+      T111,'ACC-Y')
      DO 132 LD=1, NUMNP
      L1=(LD-1)*NDGREE+1
      L2=L1+1
132    WRITE(6,305) LD,UD1(L1),UD1(L2),UD2(L1),UD2(L2)
305    FORMAT(' ',10X,I5,1P4E25.5)
      ILINE=1
      IF (NPOUT(2,I).EQ.3) GO TO 129
      WRITE(6,9713)
8713   FORMAT('1',5X,'ELEMENTS INFORMATIONS')
      DO 202 LD=1, NUMEL
      IND=INDEX(LD)
      N1=IX(1,LD)
      N2=IX(2,LD)
      LTYI=1
      MTYP=IX(3,LD)
      HT=THICK(LD)
      XC21=XC(N2)-XC(N1)
      YC21=YC(N2)-YC(N1)
      BAL=STRS(IND+IAL)
      CC=XC21/BAL
      SS=YC21/BAL
      KOLD=1
      DO 5944 L=1,NPL
      XOLD=XC(N1)+0.5*(1+PTL(L))*XC21
      YOLD=YC(N1)+0.5*(1+PTL(L))*YC21
      DO 5944 M=1,NPD
      YHAT=0.5*PTD(M)*HT
      XORIG(KOLD)=XOLD-YHAT*SS
      YORIG(KOLD)=YOLD+YHAT*CC
5944   KOLD=KOLD+1
      IND=IND+1
C      FOR AXISYMMETRIC BEAM ELEMENT
      WRITE(6,5922) LD,LTYI
5922   FORMAT('0',5X,'ELE NO.',I3,5X,'ELE TYPE F',I2/

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MEMBER NAME OUTPUT

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1 T7,'STATION',T22,'X-COORD',T36,'Y-COORD',T48,'SIG-AXIAL',T62,'SIG
2-THETA',T76,'EPS-AXIAL',T91,'EPS-THETA',T104,'SIG-YIELD',T116,'TEM
3PERATURE')
DO 5911 L=1, NES
INB=IND+L
AUX(1)=XORIG(L)
AUX(2)=YORIG(L)
AUX(3)=STRS(INB+NES)
AUX(4)=STRS(INB+NES2)
AUX(5)=STRS(INB)
AUX(6)=STRS(INB+NES1)
AUX(7)=STRS(INB+NES3)
AUX(8)=STRS(INB+NES4)
5911 WRITE(6,5900) L,(AUX(M), M=1,8)
5900 FORMAT(3X,I10,1X,1E8E14.5)
202 CONTINUE
ILINE=1
129 CONTINUE
109 CCNTINUE
CCCCCCCCC PSU(1) TO PSU(MPNT) HOLDS TIME FOR PLOTTING ARRAYS
IF ( NTSTEP.NE. MXSTEP ) RETURN
IF ( KKK .EQ. 0 ) GO TO 7301
DO 4999 I=1, KKF
INIP=I*MPNT+1
CALL EXTREM(MPNT,PSU(INIP),PMIN,PMAX)
CALL PLOTTER(MPNT,PSU(1),PSU(INIP),PSU(1),PSU(MPNT),PMIN,PMAX)
WRITE(6,7794) I,J4(I),J1(I),J2(I),J3(I),
+ (ITITLE(J,KPLOT(I)),J=1,17)
7794 FORMAT(' TIME HISTORY PLOT OF RECORD NO.',I5,5X,'CODE:',I5,3I1/
+ 5X,' COMMENT:',5X,17A4)
4999 CONTINUE
7301 CONTINUE
NCRV=0
IF(KKK.LE.0) GO TO 9444
DO 9445 I=1,KKK
IF(J3(KPLOT(I)) .LE. 1) GO TO 9445
NCRV=NCRV+1
9445 CONTINUE
9444 CONTINUE
NPCTR=0
IF(NPIC .LE. 0) GO TO 9555
DO 9333 I=1,NPIC
IF(NPCTR(2,I).LE.4) GO TO 9333
NPCTR=NPCTR+1
9333 CONTINUE
9555 CONTINUE
IF(NCRV.LE.0 .AND. NPCTR.LE.0) RETURN
WRITE(6,7430) NCRV,MPNT,NPCTR,NUMNP
7430 FORMAT('1',2X,'DATA ON FT07F001 STORED'/
+ 2X,' KEY PARAMETERS ARE: '/
1 2X,'NUMBER OF RESPONSE HISTORY WRITTEN',I11/
2 2X,'NUMBER OF POINTS IN EACH RESPONSE HISTORY',I5/
3 2X,'NUMBER OF CONFIGURATION CURVES WRITTEN',I8/
4 2X,'NUMBER OF POINTS IN EACH CONFIGURATION',I8)
WRITE(7) NCRV,MPNT,NPCTR,NUMNP
IF(NCRV.LE.0) GO TO 9003
WRITE(7) (PSU(I),I=1,MPNT)
DO 9004 I=1,KKK

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MEMBER NAME OUTPUT

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      KND=KPLT(I)
      IF (J3(KND).LE.1) GO TO 9004
      KBGN=I*MPNT+1
      KEND=KBGN+MPNT-1
      WRITE(7) J3(KND), (ITITLE(J,KND),J=1,17), (PSU(K),K=KBGN,KEND)
9004  CONTINUE
9003  CONTINUE
      IF (NPCTR.LE.0) RETURN
      DO 9005 I=1,NPIC
      IF (NPOUT(2,I).LE.4) GO TO 9005
      TFIN=NPOUT(1,I)*DELT
      KXBGN=IXNEW+(I-1)*NUMNP+1
      KXEND=KXBGN+NUMNP-1
      KYBGN=IYNEW+(I-1)*NUMNP+1
      KYEND=KYBGN+NUMNP-1
      WRITE(7) TFIN, (PSU(KX),KX=KXBGN,KXEND), (PSU(KY),KY=KYBGN,KYEND)
9005  CONTINUE
500   RETURN
405   IF (NTSTEP.NE.1) RETURN
      WRITE(6,2410)
2410  FORMAT(1H0,5X,'NO PRINTED OR PLOT OUTPUT SPECIFIED FROM MAIN')
      RETURN
8408  JPLT=NUMPLT-MAXPLT
      WRITE(6,8409)      NUMPLT, MAXPLT,      JPLT
8409  FORMAT('1',10X,'NO. OF PLOTTING POINTS IN INPUT IS      ',I5/
+       11X,'MAX. NO. OF PLOTTING POINTS ALLOWED IS      ',I5/
+       11X,'JOB TERMINATED BY OUTPUT, DEL POINTS      =' ,I5)
      CALL EXIT
      RETURN
      END

```

MEMBER NAME FLCTER

```

      SUBROUTINE PLOTTER (NUMPNT,XARRAY,YARRAY,XMIN,XMAX,YMIN,YMAX)
      DIMENSION CHAR(101),YVAL(3)
C  DIMENSION FOR 100 POINT PLOTS
      DIMENSION IX(101),IY(101)
      DIMENSION XARRAY(NUMPNT),YARRAY(NUMPNT)
      DATA  BLANK,STAR,YENT,XPNT,DOT,PNTM / 1H ,1H*,1HY,1HX,1H.,1HM/
      IMAX=101
      DO 111 JDUM = 1, IMAX
      IX(JDUM) = 1
      IY(JDUM) = 1
111  CONTINUE
      NUMBER = 51
      FLNUMB = NUMBER
      YVAL(1) = YMAX
      YVAL(2) = (YMAX + YMIN) / 2.0
      YVAL(3) = YMIN
      IF (YMAX.EQ.0.0.AND.YMIN.EQ.0.0) GO TO 901
      IF (ABS((YMAX-YMIN)/(YMAX+YMIN)).LT.1.E-3) GO TO 901
      DO 900 JJ = 1, NUMPNT
      IY(JJ) = ( (YARRAY(JJ)-YMIN) / (YMAX-YMIN) ) * (FLNUMB-1.0) +.5
      IF ( IY(JJ) - NUMBER ) 10, 10, 5
5  IY(JJ) = NUMBER
10 IF ( IY(JJ) ) 15, 15, 20
15 IY(JJ) = 1
20 IX(JJ) = ( (XARRAY(JJ)-XMIN) / (XMAX-XMIN) ) * (100.0) + .5
      IF (IX(JJ) - 101 ) 30, 30, 25
25 IX(JJ) = 101
30 IF ( IX(JJ) ) 35, 35, 900
35 IX(JJ) = 1
900 CONTINUE
      LIM = NUMPNT - 1
6001 INT = 1
      DO 6003 I = 1, LIM
      IF ( IY(I+1) - IY(I) ) 6003, 6003, 6002
6002 TEMP = IX(I+1)
      IX(I+1) = IX(I)
      IX(I) = TEMP
      TEMP2 = IY(I+1)
      IY(I+1) = IY(I)
      IY(I) = TEMP2
      INT = I
6003 CONTINUE
      IF (INT - 1) 6004, 6777, 6004
6004 LIM = INT - 1
      GO TO 6001
6777 CONTINUE
      IXKODE = 0
      IYKODE = 0
      IF ( YMAX * YMIN ) 50, 50, 55
50 IXAXIS = ( YMAX / (YMAX - YMIN) ) * FLNUMB +0.5
      IF (IXAXIS) 500, 500, 501
500 IXAXIS = 1
501 IXKODE = 1
55 IF ( XMAX * XMIN ) 56, 56, 59
56 IYAXIS = ( (-XMIN) / (XMAX-XMIN) ) * 101.0 + 0.5
      IF (IYAXIS) 560, 560, 561
560 IYAXIS = 1
      IYKODE = 1

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MEMBER NAME FLOTER

```

59 CONTINUE
  PRINT 1
  1 FORMAT (1H1, //)
  KNTR = 1
  KNTYAX = 0
  DO 100 LL = 1, NUMBER
  IF (IXKODE) 67, 67, 66
66 IF (LL - IXAXIS) 67, 68, 67
68 DO 666 IJK = 1, 101
  CHAR(IJK) = XPNT
666 CONTINUE
  GO TO 7
67 CHAR(1) = DOT
  CHAR(101) = DCT
  DO 90 K = 2, 100
  IF (LL-1) 2, 3, 2
  2 IF (LL-NUMBER) 4, 3, 4
  4 CHAR(K) = BLANK
90 CONTINUE
  GO TO 91
  3 DO 33 KK = 2, 100
  CHAR(KK) = DOT
33 CONTINUE
91 IF (IYKODE) 7, 7, 6
  6 CHAR(IYAXIS) = YPNT
  7 CONTINUE
  IF ( IY(KNTR) - ( (NUMBER+1) - LL) ) 69, 60, 69
60 ICOL = IX(KNTR)
  IF ( CHAR(ICOL) - STAR ) 62, 63, 62
62 IF (CHAR(ICOL) - PTM ) 64, 63, 64
63 CHAR(ICOL) = PTM
  GO TO 65
64 CHAR(ICOL) = STAR
65 IF (KNTR - NUMPNT) 665, 69, 665
665 KNTR = KNTR + 1
  IF ( IY(KNTR-1) - IY(KNTR) ) 69, 60, 69
69 IF ( LL - 1 ) 75, 75, 70
70 IF ( LL - 26 ) 71, 75, 71
71 IF ( LL - NUMBER ) 72, 75, 72
72 PRINT 9200, CHAR
9200 FORMAT ( 20X, 101A1)
  GO TO 100
  75 KNTYAX = KNTYAX + 1
  PRINT 9201, YVAL(KNTYAX), DOT, DOT, CHAR
9201 FORMAT ( 4X, E11.4, 3X, 2A1, 101A1)
100 CONTINUE
  XMID = (XMIN + XMAX) / 2.
  PRINT 9050, XMIN, XMID, XMAX
9050 FORMAT ( 2(20X, '.', 49X, '.', 49X, '.', /), 15X, E11.4, 39X, E11.4,
  * 40X, E11.4, /)
  RETURN
901 PRINT 9051, YMAX
9051 FORMAT (///4X, 'PLOT IS A CONSTANT = ', E11.4)
  RETURN
END

```

```
MEMBER NAME ROTATE
SUBROUTINE ROTATE ( THETA, NDGREE, JNOD, U, KON12, NDOF )
  DIMENSION U(NDOF)
  C=COS(THETA)
  S=SIN(THETA)
  I1=(JNOD-1)*NDGREE+1
  I2=I1+1
  ENTRY ROTAT ( U, KON12, NDOF )
  UX=U(I1)
  UY=U(I2)
  GO TO (10,20), KON12
10 U(I1)=C*UX+S*UY
  U(I2)=-S*UX+C*UY
  RETURN
20 U(I1)=C*UX-S*UY
  U(I2)=S*UX+C*UY
  RETURN
END
```

MEMBER NAME SHELL

```

SUBROUTINE SHELL (DT, NUMEL, NUMNP, NDGREE, MEQ, NUMMAT, NUMDIS, E, IX,
1 THICK, XC, YC, MSTRSD, STRS, AO, A1, V, XO, X1, NODDIS, ANGLE, FINT, FEXT,
2 INDEX, SMASS, DELT, DELTMX, NDOF, MMATD, MELED, MPTD, MDPTD, MXNPRU,
3 MXNPRS, MXMUS, NUMPLT, IUOT, ISOT, US, PSU, J1, J2, J3, J4, P1, P2, K3, P4,
4 KPLT, NPOUT, MXNPIC, ITITLE)
  DIMENSION E (8, MMATD), IX (3, MELED), XC (MPTD), YC (MPTD), STRS (MSTRSD),
1 AO (NDOF), A1 (NDOF), V (NDOF), XO (NDOF), X1 (NDOF), FEXT (NDOF),
2 FINT (NDOF), SMASS (NDOF), NODDIS (MDPTD), ANGLE (MDPTD), INDEX (MELED),
3 IUOT (MXNPRU), ISOT (MXNPRS), US (MXMUS), ITITLE (17, MXMUS),
4 NPOUT (2, MXNPIC), PSU (NUMPLT), J1 (MXMUS), J2 (MXMUS), J3 (MXMUS),
5 J4 (MXMUS), P1 (MXMUS), P2 (MXMUS), K3 (MXMUS), P4 (MXMUS), KPLT (MXMUS),
6 THICK (MELED)
  DATA NPL, NPD, /2, 5/
  CALL INPUT (NUMEL, NUMNP, NDGREE, NUMDIS, NODDIS, DT, NUMMAT, DELT,
1 NDOF, E, XC, YC, IX, THICK, ANGLE, MMATD, MELED, MPTD, MDPTD, MEQ, NPRU, NPRS,
2 NPIC, NPFREQ, IUOT, ISOT, NPOUT, MUS, MXNPRU, MXNPRS, MXNPIC, MXMUS,
3 ITITLE)
  CALL ASSBLE (NUMEL, NDGREE, MEQ, E, IX, THICK, XC, YC, SMASS, INDEX, STRS,
1 NEL, NPD, MSTRSD, MELED, MMATD, MPTD, NDOF, DELT, MSTEP, DT, NPIC,
2 MXNPIC, NPOUT, NPFREQ)
  CALL SOLVEN (NUMEL, NUMNP, NDGREE, NUMDIS, NODDIS, SMASS, XC, YC, IX,
+ THICK, E, XO, X1, V, AO, A1, FEXT, FINT, ANGLE, NPL, NPD, STRS,
1 INDEX, DELT, MSTEP, MEQ, MDPTD, NDOF, MPTD, MELED, MMATD, MSTRSD,
2 NPRU, MXNPRU, NPRS, MXNPRS, NPIC, MXNPIC, NPFREQ, IUOT, ISOT,
3 NPOUT, MUS, MXMUS, US, NUMPLT, PSU, J1, J2, J3, J4, P1, P2, K3, P4,
4 KPLT, ITITLE)
  RETURN
END

```

MEMBER NAME SOLVEN

```

SUBROUTINE SOLVEN (NUMEL, NUMNP, NDGREE, NUMDIS, NODDIS, SMASS, XC, YC,
+   IX, THICK, E, XO, X1, V, AO, A1, FEXT, FINT, ANGLE, NPL, NPD, STRS,
1   INDEX, DELT, MSTEP, MEQ, MDPTD, NDOF, MPTD, MELED, MMATD, MSTRSD,
2   NPRO, MXNPRO, NPRS, MXNPRS, NPIC, MXNPIC, NPFREQ, IUOT, ISOT, NPOUT,
3   MUS, MXMUS, US, NUMPLT, PSU, J1, J2, J3, J4, P1, P2, K3, P4, KPLOT,
4   ITITLE)
COMMON /THRM/ TIME, TN(10)
DIMENSION XO(NDOF), X1(NDOF), V(NDOF), AO(NDOF), A1(NDOF),
1   FEXT(NDOF), NODDIS(MDPTD), XC(MPTD), YC(MPTD), ANGLE(MDPTD),
2   STRS(MSTRSD), INDEX(MELED), SMASS(NDOF), FINT(NDOF), THICK(MELED),
3   IUOT(MXNPRO), ISOT(MXNPRS), NPOUT(2, MXNPIC), PSU(NUMPLT),
4   US(MXMUS), J1(MXMUS), J2(MXMUS), J3(MXMUS), J4(MXMUS), P1(MXMUS),
5   P2(MXMUS), K3(MXMUS), P4(MXMUS), KPLOT(MXMUS), E(8, MMATD),
6   IX(3, MELED), ITITLE(17, MXMUS), JJ(4)
TIME=-1.0
DO 212 I=1, MEQ
FEXT(I)=0.0
FINT(I)=0.0
AO(I)=0.0
A1(I)=0.0
XO(I)=0.
X1(I)=0.
212 V(I)=0.
KTHRM=0
IF (E(8,1) .GT. 0.0) KTHRM=1
CALL THERMO(KTHRM, NES, NPL, NPD)
C   INITIAL CONDITIONS
CALL FREEFD(0, NDGREE, NUMEL, IX, XC, YC, XO, V, AC, FEXT,
+   STRS, MEQ, MSTRSD, NUMNP)
CALL FRCIN(NUMEL, NUMNP, NDGREE, MEQ, XC, YC, IX, THICK, E, XO, FINT,
1   STRS, NPL, NPD, INDEX, MPTD, MELED, MMATD, NDOF, MSTRSD)
NES=NPL*NPD
NES1=NES+NES
TIME=0.0
NSTEP=0
C1=0.5*DELT*DELT
C3=0.5*DELT
400 CONTINUE
NSTEP=NSTEP+1
TIME=TIME+DELT
IF (KTHRM .EQ. 1) CALL THERMO(NES, NPL, NPD)
DO 420 I=1, MEQ
420 X1(I)=XO(I)+V(I)*DELT+C1*AO(I)
CALL FREEFD(1, NDGREE, NUMEL, IX, XC, YC, X1, V, A1, FEXT,
+   STRS, MEQ, MSTRSD, NUMNP)
CALL FRCIN(NUMEL, NUMNP, NDGREE, MEQ, XC, YC, IX, THICK, E, X1, FINT,
+   STRS, NPL, NPD, INDEX, MPTD, MELED, MMATD, NDOF, MSTRSD)
IF (NUMDIS .LE. 0) GO TO 431
DO 430 I=1, NUMDIS
CALL DECOD(NODDIS(I), JJ)
J4TH=JJ(4)
IF (ANGLE(I) .EQ. 0.0) GO TO 4202
CALL ROTATE (ANGLE(I), NDGREE, J4TH, AO, 1, NDOF)
CALL ROTAT ( A1, 1, NDOF )
CALL ROTAT (FEXT, 1, NDOF)
CALL ROTAT (FINT, 1, NDOF)
4202 ML=NDGREE*(J4TH-1)
DO 429 J=1, NDGREE

```

MEMBER NAME SOLVEN

```
      ML=ML+1
      IF (JJ(J).EQ.0) GO TO 429
      A1(ML)=0.0
      AO(ML)=0.0
      FEXT(ML)=0.0
      FINT(ML)=0.0
429  CONTINUE
      IF (ANGLE(I).EQ.0.0) GO TO 430
      CALL ROTATE(ANGLE(I),NDGREE,J4TH,AO,2,NDOF)
      CALL ROTAT(A1,2,NDOF)
      CALL ROTAT(FEXT,2,NDOF)
      CALL ROTAT(FINT,2,NDOF)
430  CONTINUE
431  CONTINUE
      DO 515 I=1, MEQ
515  A1(I)=(FEXT(I)-FINT(I))*SMASS(I)
      DO 455 I=1,MEQ
      XO(I)=X1(I)
      V(I)=V(I)+C3*(A1(I)+AO(I))
455  AO(I)=A1(I)
      CALL OUTPUT(NUMEL,NUMNP,NDGREE,MEQ,TIME,DELT,MSTEP,NSTEP,
1  NPRU,MXNPRU,NPRS,MXNPRS,NPIC,MXNPIC,NPFREQ,IUOT,ISOT,MUS,MXMUS,
2  XC,YC,MSTRSD,INDEX,NUMPLT,PSU,E,IX,THICK,MMATD,X1,V,A1,NPL,
3  NPD,NPOUT,US,J1,J2,J3,J4,P1,P2,K3,P4,KPLOT,STRS,ITITLE)
      IF (NSTEP.GE.MSTEP) RETURN
      GO TO 400
      END
```

```
MEMBER NAME  THERMO
SUBROUTINE THERMO(KNTRL,NES,NPL,NPD)
COMMON /THRN/ TIME,TN(10)
IF ( TIME .GE. 0.0 ) RETURN
DO 301 I=1, 10
301 TN(I)=0.0
RETURN
END
```

APPENDIX C

SOURCE STATEMENTS OF DATA RETRIVING AND PLOTTING PROGRAM

```

C**** THE PROGRAM READS PLCT DATA FROM FILE(FT07F001) WHICH WAS
C**** WRITTEN BY THE HCT.FORT CODE
C**** THE PICTURE OUTPUT ALLOWED IS CURRENTLY FIVE(5). ALL THESE
C**** FIVE CONFIGURATIONS WILL BE PLOTTED ON ONE PLOT.
C**** THE HISTORY PLOTS ALLOWED IS CURRENTLY SET TO THIRTY(30).
C**** AUTOMATICAL SCALING WILL BE USED, IF KNTRL(J3) IS EQ 2.
C**** MANUAL SCALING WILL BE USED, IF KNTRL GT 3.
C**** THE SCALING INFORMATIONS WILL BE READ THROUGH FILE(FT05F001)
C**** K8OR4=8; ALL THE REAL VARIABLES ON F(FT07F001) ARE OF LENGTH 8
C**** K8OR4=4; ALL THE REAL VARIABLES ON F(FT07F001) ARE OF LENGTH 4
C**** IN BOTH CASES, THE INTEGERS ARE OF STANDARD LENGTH 4
C**** KAUTOC GT 0; MANUAL INPUT FOR CONFIGURATION PLOT IS INDICATED
C**** KAUTCC LT 0, CONFIGURATION PLOT IS SUPRESSED
C**** KAUTCF GT 0, NEW VALUES OF KNTRL(I) IS TO BE READ IN
REAL*4 TIME(100),HSTRY(1000),TFIN(5),XC(310),YC(310)
REAL*8 DTIME(100),DHSTRY(1000),DTFIN(5),DXC(310),DYC(310)
DIMENSION LTITLE(170),KNTRL(10)
CALL SIRTPL
READ(5,111) K8OR4,KAUTOC,KAUTOP
READ(7) NCRV,NDATA,NPCTR,NNODE
WRITE(6,999) NCRV,NDATA,NPCTR,NNODE
999 FORMAT(' NCRV,NDATA,NPCTR,NNODE='/'5X,5I5)
IF(NCRV.LE.0) GO TO 1
IF(K8OR4.EQ.4) READ(7) (TIME(I),I=1,NDATA)
IF(K8OR4.EQ.8) READ(7) (DTIME(I),I=1,NDATA)
IF(K8OR4.EQ.8) CALL CNVRT(DTIME,TIME,NDATA,1,NDATA,1)
DC 2 I=1,NCRV
KBGN=(I-1)*NDATA+1
KEND=KBGN+NDATA-1
LEGN=(I-1)*17+1
LEND=LEGN+17-1
IF(K8OR4.EQ.4) READ(7)
+KNTRL(I),(LTITLE(L),L=LBGN,LEND),(HSTRY(K),K=KBGN,KEND)
IF(K8OR4.EQ.8) READ(7)
+KNTRL(I),(LTITLE(L),L=LBGN,LEND),(DHSTRY(K),K=KBGN,KEND)
2 CCNTINUE
MXDATA=NCRV*NDATA
IF(K8OR4.EQ.8) CALL CNVRT(DHSTRY,HSTRY,MXDATA,1,MXDATA,1)
1 IF(NPCTR.LE.0) GO TO 3
IF(KAUTOC.LT.0) GO TO 7
DC 4 I=1,NPCTR
KBGN=(I-1)*NNODE+1
KEND=KBGN+NNODE-1
IF(K8OR4.EQ.4) READ(7)
+TFIN(I),(XC(KX),KX=KBGN,KEND),(YC(KY),KY=KBGN,KEND)
IF(K8OR4.EQ.8) READ(7)
+DTFIN(I),(DXC(KX),KX=KBGN,KEND),(DYC(KY),KY=KBGN,KEND)
4 CCNTINUE
IF(K8OR4.EQ.4) GO TO 25
MXNODE=NNODE*NPCTR
CALL CNVRT(DXC,XC,MXNODE,1,MXNODE,1)
CALL CNVRT(DYC,YC,MXNODE,1,MXNODE,1)
25 CCNTINUE
3 CONTINUE
IF(NICTA.LE.0) GO TO 7
C**** PLOTTING THE CONFIGURATIONS OF STRUCTURE
IMAFK=0
MXNODE=NNODE*NPCTR
IF(KAUTOC.GT.0) GO TO 12
CALL EXTREM(MXNODE,XC,XMIN,XMAX)
CALL EXTREM(MXNODE,YC,YMIN,YMAX)

```

```

DO 5 I=1,MXNODE
XC(I)=XC(I)-XMIN
YC(I)=YC(I)-YMIN
5 CCNTINUE
XMAX=XMAX-XMIN
YMAX=YMAX-YMIN
XMIN=0.0
YMIN=0.0
IF (XMAX.GT.YMAX) YMAX=XMAX
IF (YMAX.GT.XMAX) XMAX=YMAX
XYLNTH=7.0
XLNTH=XYLNTH
YLNTH=XYLNTH
GC TC 15
12 CONTINUE
READ (5,10) XMIN,XMAX,XLNTH,YMIN,YMAX,YLNTH,IMARK
15 CONTINUE
CALL EGNPL(1)
CALL AXSPLT(XMIN,XMAX,XLNTH,XORIG,XSTEP,XAXIS)
CALL AXSPLT(YMIN,YMAX,YLNTH,YORIG,YSTEP,YAXIS)
CALL TITLE('CONFIGURATION OF STRUCTURES',100,
1 'HORIZONTAL COORDINATES',100,
2 'VERTICAL COORDINATES',100,XAXIS,YAXIS)
CALL GRAPH(XORIG,XSTEP,YORIG,YSTEP)
DC 6 I=1,NPCTR
IBGN=(I-1)*NNODE+1
IRMN=I-(I-1)/5*5
IF (IRMN.EQ.2) CALL DOT
IF (IRMN.EQ.3) CALL DASH
IF (IRMN.EQ.4) CALL CHNDOT
IF (IRMN.EQ.5) CALL CHNDSH
CALL CURVE(XC(IBGN),YC(IBGN),NNODE,IMARK)
IF (IRMN.EQ.2) CALL RESET('DOT')
IF (IRMN.EQ.3) CALL RESET('DASH')
IF (IRMN.EQ.4) CALL RESET('CHNDOT')
IF (IRMN.EQ.5) CALL RESET('CHNDSH')
6 CONTINUE
CALL ENDPL(1)

```

```

C****
C**** PLOTTING FOR HISTORY OUTPUT
C**** THE NATURE OF HISTORY OUTPUT IS DICTATED BY THE VALUE OF KNTRL
C**** KNTRL=1; ONLY PRINTER PLOT IS REQUIRED BY HCT.FORT CODE
C**** KNTRL=2; THE DISPLA PLOT IS DONE BY AUTOMATIC SCALING
C**** KNTRL=3; THE DISPLA PLOT IS DONE BY EXTERNAL SPECIFIED SCALES.

```

```

7 CCNTINUE
IF (KAUTOP.GT.0) READ(5,111) (KNTRL(J),J=1,NCRV)
IF (NCRV.LE.0) RETURN
DO 8 I=1,NCRV
IND=KNTRL(I)
IF (IND.LE.1) GO TO 8
IF (IND.LE.2) GO TO 9
READ (5,10) TMIN,TMAX,TLNTH,HMIN,HMAX,HLNTH,IMARK
9 CCNTINUE
IBGN=(I-1)*NDATA+1
LBGN=(I-1)*17+1
IF (IND.GT.2) GO TO 11
CALL EXTREM(NDATA,TIME,TMIN,TMAX)
CALL EXTREM(NDATA,HSTRY(IBGN),HMIN,HMAX)
TLNTH=8.0
HINT=.0
IMAF
11 CCNTINUE

```



```

      CA:  GNPL(I)
      CA:  XSPLT(TMIN,TMAX,TLNTH,TORIG,TSTEP,TAXIS)
      CALL AXSPLT(HMIN,HMAX,HLNTH,HORIG,HSTEP,HAXIS)
      CALL TITLE(LITTLE(LBGN),-100,'TIME IN SECONDS$',100,
1      'RESPONSE HISTORY$',100,TAXIS,HAXIS)
      CALL GRAPH(TORIG,TSTEP,HORIG,HSTEP)
      CALL CURVE(TIME,HSTRY(IBGN),NDATA,IMARK)
      CALL ENDPL(I)
8  CCNTINUE
10  FCRMAT(6E10.4,I5)
111 FORMAT(16I5)
      STOP
      END
      SUBROUTINE EXTREM(N,X,XMIN,XMAX)
      DIMENSION X(N)
      XMIN= 1.E50
      XMAX=-1.E50
      DO 1 I=1, N
      IF ( X(I) .LT. XMIN )  XMIN=X(I)
      IF ( X(I) .GT. XMAX )  XMAX=X(I)
1  CCNTINUE
      RETURN
      END
      SUBROUTINE CNVRT(DARRAY,SARRAY,ID,IBGN,IEND,KON)
      REAL*8 DARRAY(ID)
      REAL*4 SARRAY(ID)
      IF(KCN.NE.1) GO TO 2
      DO 1 I=IBGN,IEND
      SARRAY(I)=DARRAY(I)
1  CONTINUE
      RETURN
2  CONTINUE
      DO 3 I=IBGN,IEND
      DARRAY(I)=SARRAY(I)
3  CCNTINUE
      RETURN
      END

```

```

*****
*                                     *
*          CLASSES OF STORAGE HAVING AN EXPORT INTERVAL OF .LT.  8 DAYS          *
*          2/7          8DAYS          LONG3330          *
*                                     *
*****

```