AD-781 619

USER'S GUIDE TO THE SHORE CODE

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30 January 1973

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LMSC-D244589

USER'S GUIDE
TO THE
SHORE CODE

by

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Prepared Under the Independent Research Program
Lockheed Palo Alto Research Laboratory

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ABSTRACT

This report presents the SHORE code user's manual. The SHORE code computes the transient response of shells of revolution to initial velocities and surface pressure histories; it includes nonlinear material and geometric effects.

This document presents the theoretical development of the SHORE code and two sample problems to illustrate the use of the code.

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NOMENCLATURE

E_ϕ, E_θ, G	elastic moduli
H	linear strain hardening modulus
I	impulse
$N_\phi, N_\theta, N_{\phi\theta}$	stress resultants
$M_\phi, M_\theta, M_{\phi\theta}$	stress couples
Q_ϕ, Q_θ	transverse stress resultants
g	gravitational constant
h	shell wall thickness
i	index in ϕ-direction
j	index in θ-direction
k	time increment index
k_ϕ, k_θ, k_z	linear foundation springs
p_ϕ, p_θ, p_z	surface pressures
r	radius of shell in θ-direction normal to the shell wall
r_ϕ	radius of shell in ϕ-direction normal to the shell wall
t	time
u, v, w	displacement components
z	radial coordinate
$\Delta(r_i \theta \sin \phi_i)$	mesh spacing in θ-direction at the i^{th} meridional mesh point
$\Delta(r_\phi \phi)$	mesh spacing in the ϕ-direction
Δt	integration time step

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$\Delta u, \Delta v, \Delta w$	displacement increments
$\Psi_{\phi}, \Phi_{\theta}, \Phi$	rotations
$\delta\epsilon_{\phi}^{T}, \delta\epsilon_{\theta}^{T}, \delta\epsilon_{\phi\theta}^{T}$	total strain increments
$\delta\sigma_{\phi}, \delta\sigma_{\theta}, \delta\tau_{\phi\theta}$	stress increments
$\epsilon_{\phi}, \epsilon_{\theta}, \epsilon_{\phi\theta}$	strains in the mid-surface
θ	circumferential coordinate
$K_{\phi}, K_{\theta}, K_{\phi\theta}$	bending and twisting strains
λ	damping coefficient
μ	plasticity proportionality factor
ν_{ϕ}, ν_{θ}	Poisson's ratios
ρ	weight density
$\sigma_1, \sigma_2, \sigma_{12}$	yield stress
σ_o	effective yield stress
$\sigma_{\phi}, \sigma_{\theta}, \tau_{\varphi\theta}$	stresses
ϕ	angle between r and shell axis (meridional coordinate)

CONTENTS

Section		Page
	ABSTRACT	iii
	NOMENCLATURE	v
	INTRODUCTION	ix
1	PHILOSOPHY	1-1
2	ANALYSIS	2-1
	2.1 Basic Equations	2-1
	2.2 Solution Method	2-6
	2.3 Boundary Conditions	2-16
	2.4 Plasticity	2-24
	2.5 Shell Geometry	2-31
	2.6 Loading	2-35
3	INPUT DESCRIPTION	3-1
	3.1 Input Data Instructions	3-1
	3.2 Matrix Format	3-11
	3.3 Dimensioning	3-12
	3.4 Drum Allocations	3-13
4	Sample Problems	4-1
	4.1 Axisymmetric Elastic Plastic Cylinder	4-1
	4.2 Asymmetric Cylinder (Nonlinear Elastic Perfectly-Plastic)	4-2
5	REFERENCES	5-1

INTRODUCTION

The SHORE code computes the transient response of shells with midsurfaces defined by a surface of revolution. The equations solved by two-dimensional finite difference techniques are those derived by Sanders [1, 2] and include the nonlinear geometric effects. Time integration is by the central difference method. Inelastic material behavior based on Hill's anisotropic yield function [3] is valid for initially orthotropic materials for both perfect plasticity and linear strain hardening. A fracture criterion also is available. The loadings considered are initial radial velocity, initial step change in temperature (never checked out), and surface pressure histories; all of these can be specified for each mesh point. The shell can have either one or two different material layers obeying the Kirchoff assumptions with additional weight and coordinate direction springs at each mesh point. The boundary conditions include free and fixed simple supports, clamped supports, free edges, conditions of symmetry and antisymmetry, and inhomogeneous formulations. The code is checked out for cylinders and cones for elastic, inelastic, linear, and nonlinear kinematic response. Other shapes have been analyzed, but no real check cases are available.

The code development started as a extension to the work by Franke [4] and Hubka [5] to include more general geometry, boundary conditions, and material characteristics. Therefore, the preliminary versions of the SHORE code closely resemble the CYLINDER code [4]. As more experience was gained and more understanding developed, the SHORE code became independent. Now, all that exists of the original starting point is the framework of the overall logic and a few of the subroutine names.

The outstanding feature of the code is the relatively fast run times compared with other two-dimensional shell codes. This results from using lower order difference expressions $O(\Delta s^2)$ (Δs, a spatial increment) in conjunction with a checkerboard type half spacing grid system. This system appears to produce results equivalent in accuracy to those obtained by codes STAR [6] and GIRLS1 [7], using $O(\Delta s^4)$ finite difference expressions. The checkerboard grid is a slightly modified version of one employed by Cassell [8]. The use of the $O(\Delta s^2)$ difference expressions considerably reduces the number of computations per integration time step. In fact, algebraic forms are used throughout the coding wherever possible in order to avoid time consuming numerical techniques.

Section 1
PHILOSOPHY

This section contains both the philosophy of the actual code and the philosophy of the user's guide. These topics are probably the most important for the beginning user if one is to make maximum use of the SHORE code.

The code was written to provide an efficient, relatively easy-to-use response analysis code for two-dimensional shell structures. This task was not as easy as it may appear because it has taken a few years for the SHORE code to evolve to its present form. This present version may not be permanent, but apparently it has more permanency than past versions. The greatest struggles occur in (1) finding an accurate simple spatial finite differencing scheme and (2) understanding the proper implementation of boundary conditions.

Spatial grids employing whole stations with $O(\Delta s^2)$ and $O(\Delta s^4)$ finite difference expressions were tried before the present half-station, $O(\Delta s^2)$, technique now used. The whole-station, $O(\Delta s^4)$, technique is accurate, but requires a very large amount of time for computation. The whole station, $O(\Delta s^2)$, technique was not accurate when compared with other known solutions. For reasons not clearly understood, the half-station, $O(\Delta s^2)$, technique has the accuracy and – because of the very simple expression for the derivative – has computational efficiency; thus, the half-station technique is used in the code.

For the boundary conditions, the technique is used of evaluating fictitious points outside the boundary. Although techniques involving backward and forward derivatives without fictitious points were tried briefly with resulting stability problems, no real experiments have been conducted with the boundary condition solution technique. The technique of using fictitious points is so much easier, especially for the $O(\Delta s^2)$ finite difference expressions, that there is no apparent contest.

It is believed that the user's guide is adequately detailed. Hopefully, this detail will enable the user to research the code and make changes to work a wider variety of problems than those encompassed by the production version of the code; the second sample problem, Section 4.2, illustrates this. The user may want to make other changes, e.g., temperature dependent properties and alternatives to the built-in pressure histories.

A few remarks are appropriate concerning general use of the code. The run times can be quite large for many analyses; hence, it is most important that the problem is setup correctly. The first run should be for a very short period of time with ample printing of results. The input data should be carefully checked: is this the problem to be solved? The output should be checked: do the answers look reasonable? Judgment of reasonableness will come only through experience gained by studying the results. When it is certain that the problem has been set up correctly, the printed output may be reduced; the plots can be used for fast runs, and the analysis can be run to completion.

Run times vary with the amount of data printed and plotted; printed data are very costly. The following are rough estimates for typical output.

> Run time (seconds) = (Number of meridional stations)(Number of circumferential stations)(Number of integrations)(4.5×10^{-3}) for 1 layer elastic runs.

The factor (4.5×10^{-3}) becomes approximately (8×10^{-3}) for 4-layer elastic plastic analyses. For nonlinear geometry analyses, multiply the factors by approximately 1.6. If very short runs with a small number of stations are made, more run time will be required as the setup time will begin to dominate the run time. The setup time varies from 10 to 40 sec on the 1108 Exec 8 system. The maximum, 40 sec, includes recomplilation of several subroutines.

Section 2
ANALYSIS

2.1 BASIC EQUATIONS

The shell equations solved by the SHORE code are those resulting from Sanders [1,2] and include both the linear and nonlinear kinematics. For use in the SHORE code, the general equations presented by Sanders are specialized to a shell whose initial mid-surface is definable by a surface of revolution. This greatly reduces the number of derivatives in the circumferential direction without severely restricting the class of practical problems that can be solved. For the details, see Section 2.5 on shell geometry.

The equilibrium equations are

$$\begin{aligned}
&\frac{\partial N_\phi}{\partial(r_\phi \phi)} + \frac{N_\phi \cos\phi}{r \sin\phi} + \frac{\partial N_{\phi\theta}}{\partial(r\theta \sin\phi)} - \frac{N_\theta \cos\phi}{r \sin\phi} + \frac{Q_\phi}{r_\phi} \\
&+ \frac{1}{2}\left[\left(\frac{1}{r_\phi} - \frac{1}{r}\right)\frac{\partial M_{\phi\theta}}{\partial(r\theta \sin\phi)}\right] - \underline{\frac{1}{r_\phi}(\Phi_\phi N_\phi + \Phi_\theta N_{\phi\theta})} \\
&\qquad - \underline{\frac{1}{2}\left[\Phi \frac{\partial(N_\phi + N_\theta)}{\partial(r\theta \sin\phi)} + \frac{\partial\Phi}{\partial(r\theta \sin\phi)}(N_\phi + N_\theta)\right]} \\
&\qquad\qquad = -\left(p_\phi - k_\phi u - \lambda\frac{\partial u}{\partial t} - \rho\frac{h}{g}\frac{\partial^2 u}{\partial t^2}\right) \qquad (2.1\text{-}1a)
\end{aligned}$$

$$\frac{\partial N_{\phi\theta}}{\partial(r_\phi \phi)} + \frac{2N_{\phi\theta} \cos \phi}{r \sin \phi} + \frac{\partial N_\theta}{\partial(r\theta \sin \phi)} + \frac{Q_\theta}{r} + \frac{M_{\phi\theta}}{2}\left(\frac{\cos \phi}{r_\phi \; r \sin \phi} - \frac{\cos \phi}{r^2 \sin \phi} - \frac{\partial\left(\frac{1}{r_\phi}\right)}{\partial(r_\phi \phi)}\right) + \frac{1}{2}\left(\frac{1}{r} - \frac{1}{r_\phi}\right)\frac{\partial M_{\phi\theta}}{\partial(r_\phi \phi)} - \underline{\frac{1}{r}(\Phi_\theta N_\theta + \Phi_\phi N_{\phi\theta})}$$

$$+ \underline{\frac{1}{2}\left[\frac{\partial \Phi}{\partial(r_\phi \phi)}(N_\phi + N_\theta) + \Phi \frac{\partial N_\phi + N_\theta)}{\partial(r_\phi \phi)}\right]}$$

$$= -\left(p_\theta - k_\theta v - \lambda \frac{\partial v}{\partial t} - \rho \frac{h}{g} \frac{\partial^2 v}{\partial t^2}\right) \qquad (2.1\text{-}1b)$$

$$\frac{\partial Q_\phi}{\partial(r_\phi \phi)} + \frac{Q_\phi \cos \phi}{r \sin \phi} + \frac{\partial Q_\theta}{\partial(r\theta \sin \phi)} - \frac{N_\phi}{r_\phi} - \frac{N_\theta}{r}$$

$$- \underline{\frac{\partial}{\partial(r_\phi \phi)}(\Phi_\phi N_\phi + \Phi_\theta N_{\phi\theta})} - \underline{\frac{\partial}{\partial(r\theta \sin \phi)}(\Phi_\phi N_{\phi\theta} + \Phi_\theta N_\theta)}$$

$$= -\left(-p_z - k_z w - \lambda \frac{\partial w}{\partial t} - \rho \frac{h}{g} \frac{\partial^2 w}{\partial t^2}\right) \qquad (2.1\text{-}1c)$$

where

$$Q_\phi = \frac{\partial M_\phi}{\partial(r_\phi \phi)} + (M_\phi - M_\theta)\frac{\cos \phi}{r \sin \phi} + \frac{\partial M_{\phi\theta}}{\partial(r\theta \sin \phi)}$$

$$Q_\theta = \frac{\partial M_{\phi\theta}}{\partial(r_\phi \phi)} + \frac{2M_{\phi\theta} \cos \phi}{r \sin \phi} + \frac{\partial M_\theta}{\partial(r\theta \sin \phi)}$$

the terms Φ_ϕ, Φ_θ and Φ, rotations, are presented later in the discussion of the kinematic relationships. The underlined terms are those included for the nonlinear kinematics solution.

The kinematic relationships are

$$\epsilon_{\phi} = \frac{\partial u}{\partial(r_{\phi}\phi)} + \frac{w}{r_{\phi}} + \underline{\frac{1}{2}\Phi_{\phi}^{2} + \frac{1}{2}\Phi^{2}} \qquad (2.1\text{-}2a)$$

$$\epsilon_{\theta} = \frac{\partial v}{\partial(r\theta \sin\phi)} + \frac{u \cos\phi}{r \sin\phi} + \frac{w}{r} + \underline{\frac{1}{2}\Phi_{\theta}^{2} + \frac{1}{2}\Phi^{2}} \qquad (2.1\text{-}2b)$$

$$\epsilon_{\phi\theta} = \frac{1}{2}\left(\frac{\partial v}{\partial(r_{\phi}\theta)} + \frac{\partial u}{\partial(r\theta \sin\phi)} - \frac{v \cos\phi}{r \sin\phi}\right) + \underline{\frac{1}{2}\Phi_{\phi}\Phi_{\theta}} \qquad (2.1\text{-}2c)$$

$$K_{\phi} = \frac{1}{r_{\phi}}\frac{\partial u}{\partial(r_{\phi}\phi)} + u\frac{\partial\left(\frac{1}{r_{\phi}}\right)}{\partial(r_{\phi}\phi)} - \frac{\partial^{2} w}{\partial(r_{\phi}\phi)^{2}} \qquad (2.1\text{-}2d)$$

$$K_{\theta} = \frac{1}{r}\frac{\partial v}{\partial(r\theta \sin\phi)} - \frac{\partial^{2} w}{\partial(r\theta \sin\phi)^{2}} + \frac{u \cos\phi}{r r_{\phi} \sin\phi} - \frac{\cos\phi}{r \sin\phi}\frac{\partial w}{\partial(r_{\phi}\phi)} \qquad (2.1\text{-}2e)$$

$$K_{\phi\theta} = \frac{1}{2}\left[\frac{\partial v}{\partial(r_{\phi}\phi)}\left(\frac{3}{2r} - \frac{1}{2r_{\phi}}\right) + v\left(\frac{\cos\phi}{2rr_{\phi} \sin\phi} - \frac{3 \cos\phi}{2r^{2} \sin\phi}\right)\right.$$
$$\left. - 2\frac{\partial^{2} w}{\partial(r_{\phi}\phi)\,\partial(r\theta \sin\phi)} + \frac{\partial u}{\partial(r\theta \sin\phi)}\left(\frac{3}{2r_{\phi}} - \frac{1}{2r}\right) + \frac{\cos\phi}{r \sin\phi}\frac{\partial w}{\partial(r\theta \sin\phi)}\right]$$

(2.1-2f)

where

$$\Phi_{\phi} = -\frac{\partial w}{\partial(r_{\phi}\phi)} + \frac{u}{r_{\phi}}$$

$$\Phi_{\theta} = -\frac{\partial w}{\partial(r\theta \sin\phi)} + \frac{v}{r}$$

and

$$\Phi = \frac{1}{2}\left[\frac{v \cos \phi}{r \sin \phi} + \frac{\partial v}{\partial (r_\phi \phi)} - \frac{\partial u}{\partial (r\theta \sin \phi)}\right]$$

The elastic constitutive equations are

$$\sigma_\phi = \frac{E_\phi}{(1 - \nu_\phi \nu_\theta)}\left[\epsilon_\phi + zK_\phi + \nu_\theta (\epsilon_\theta + zK_\theta)\right] \tag{2.1-3a}$$

$$\sigma_\theta = \frac{E_\theta}{(1 - \nu_\phi \nu_\theta)}\left[\epsilon_\theta + zK_\theta + \nu_\phi (\epsilon_\phi + zK_\phi)\right] \tag{2.1-3b}$$

$$\tau_{\phi\theta} = 2G (\epsilon_{\phi\theta} + zK_{\phi\theta}) \tag{2.1-3c}$$

If yield occurs, the stresses are determined through an incremental plasticity theory which is discussed in Section 2.4.

The stress resultants $N_\phi, N_\theta, N_{\phi\theta}, M_\phi, M_\theta$, and $M_{\phi\theta}$ – used in the equilibrium Eqs. (2.1-1a–c) – are defined as follows.

$$\begin{Bmatrix} N_\phi \\ N_\theta \\ N_{\phi\theta} \end{Bmatrix} = \int_{-h/2}^{h/2} \begin{Bmatrix} \sigma_\phi \\ \sigma_\theta \\ \tau_{\phi\theta} \end{Bmatrix} dz \tag{2.1-4a}$$

and

$$\begin{Bmatrix} M_\phi \\ M_\theta \\ M_{\phi\theta} \end{Bmatrix} = \int_{-h/2}^{h/2} \begin{Bmatrix} \sigma_\phi \\ \sigma_\theta \\ \tau_{\phi\theta} \end{Bmatrix} zdz \tag{2.1-4b}$$

Equations (2.1-1) through (2.1-4) constitute the complete set of equations needed to solve the response of a shell of revolution. The next section describes the solution technique employed in the SHORE code.

2.2 SOLUTION METHOD

Both the time integration and spatial shell equations are solved by finite difference techniques. In both cases, simplicity has been emphasized and the lowest possible order derivatives have been used to effect a proper solution. Table 1 lists the differencing expressions used in the SHORE code.

For the time integration, a simple procedure is employed using the central difference expression with displacement increments. The displacement increments are velocities, so instead of computing accelerations as is done in many codes, the lower order velocities are used in the SHORE code. References 9 and 10 are excellent source material for for this subject.

For a function F

$$\left.\begin{aligned} \frac{\partial^2 F}{\partial t^2} &= \frac{F_{k-1} - 2F_k + F_{k+1}}{\overline{\Delta t}^2} \\ &\text{and} \\ \frac{\partial F}{\partial t} &= \frac{-F_{k-1} + F_{k+1}}{2\Delta t} \end{aligned}\right\} \qquad (2.2\text{-}1)$$

Now, define

$$\delta F = F_k - F_{k-1}$$

and

$$\Delta F = F_{k+1} - F_k$$

Table 1

FINITE DIFFERENCE EXPRESSIONS USED IN THE SHORE CODE

Central

$$\frac{\partial F_i}{\partial s} = (-F_{i-1} + F_{i+1})/2\Delta s$$

$$\frac{\partial^2 F_i}{\partial s^2} = (F_{i-1} - 2F_i + F_{i+1})/\overline{\Delta s}^2$$

$$\frac{\partial^2 F_{i,j}}{\partial r \partial s} = (-F_{i-1,j+1} + F_{i+1,j+1} - F_{i+1,j-1} + F_{i-1,j-1})/4\Delta r\Delta s$$

Backwards

$$\frac{\partial F_i}{\partial s} = (3F_i - 4F_{i-1} + F_{i-2})/2\Delta s$$

$$\frac{\partial^2 F_i}{\partial s^2} = (2F_i - 5F_{i-1} + 4F_{i-2} - F_{i-2})\overline{\Delta s}^2$$

Forwards

$$\frac{\partial F_i}{\partial s} = (-3F_i + 4F_{i+1} - F_{i+2})/2\Delta s$$

$$\frac{\partial^2 F_i}{\partial s^2} = (2F_i - 5F_{i+1} + 4F_{i+2} - F_{i+3})/\overline{\Delta s}^2$$

where δF is the past increment in F and ΔF is the next increment in F. Thus, Eq. (2.2-1) can be written as

$$\frac{\partial^2 F}{\partial t^2} = \frac{\Delta F - \delta F}{\overline{\Delta t}^2} \qquad \text{and} \qquad \frac{\partial F}{\partial t} = \frac{\Delta F + \delta F}{2\Delta t}$$

Refering to the equilibrium equations (Eqs. 2.1-1a–c), we can write them in the following form.

$$-\left[p_f - k_f F - \lambda\left(\frac{\Delta F + \delta F}{2\Delta t}\right) - \frac{\rho h}{g}\left(\frac{\Delta F - \delta F}{\overline{\Delta t}^2}\right)\right] = \mathcal{L}(N, M)_K$$

or

$$\Delta F = \left[-\delta F\left(\frac{\lambda}{2\Delta t} - \frac{\rho h}{g\overline{\Delta t}^2}\right) + p_f - k_f F + \mathcal{L}(N, M)_K\right] \Big/ \left(\frac{\lambda}{2\Delta t} + \frac{\rho h}{g\overline{\Delta t}^2}\right)$$

So at any given time (k) – and with δF (the past increment) known – the next increment in F, ΔF, can be determined. Of course, when ΔF is computed it becomes the δF for the next increment in time, Δt, so one need only store the variable ΔF. Indeed, a recursion relationship for ΔF can be written as follows in terms of computer manipulation.

$$\Delta F = \left[-\Delta F\left(\frac{\lambda}{2\Delta t} - \frac{\rho h}{g\Delta t^2}\right) + p_f - k_f F + \mathcal{L}(N, M)_K\right] \Big/ \left(\frac{\lambda}{2\Delta t} + \frac{\rho h}{g\overline{\Delta t}^2}\right) \tag{2.2-2}$$

The total value of F at any time k is simply

$$F_k = \sum_{j=1}^{k} \Delta F_j$$

or expressed in a computational form

$$F_k = F_{k-1} + \Delta F$$

The real advantage of using these increments in displacement will become evident when we deal with the plasticity theory.

As shown by many investigators, this explicit time integration is stable for the following Δt.

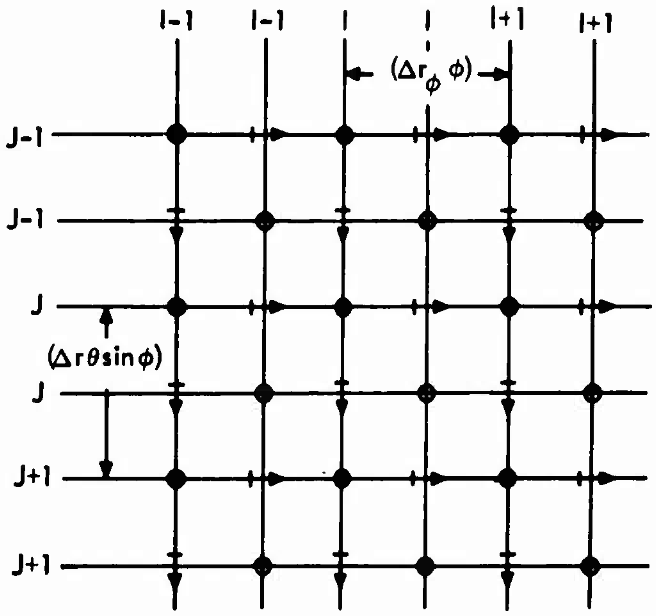
$$\Delta t \leq \Delta x \sqrt{\frac{\rho}{gE}} \qquad (2.2\text{-}3)$$

where Δx indicates the smallest spatial mesh size and $\sqrt{\rho/gE}$ represents the reciprocal of the maximum sound speed in shell wall. For the input data, a check is made in subroutine RDINPT. If input Δt is larger than that for stability, the code will run with its own value of Δt. In cases where additional springs or mass have been added to the shell, even this Δt may prove to be unstable, if the added terms result in a higher system frequency. This smaller Δt can be estimated from the following formula.

$$\Delta t \leq \Delta x \left[\frac{1}{\dfrac{1}{\dfrac{\rho + (\text{added weight})/\text{thickness}}{gE}} + \dfrac{1}{\dfrac{\rho(\text{thickness}) + (\text{added weight})}{gr^2 k}}} \right]^{1/2} \qquad (2.2\text{-}4)$$

Experience indicates that Δt should be chosen as 80 percent of Δt_{max} to ensure stability under all conditions.

The spatial solution of the equilibrium equations is not as straightforward; however, it is simple if the user has previously worked with finite differences. The following grid system [8] is used.



● $w, N_\phi, N_\theta, M_\phi, M_\theta, \epsilon_\phi, \epsilon_\theta, \sigma_\phi, \sigma_\theta, p_z$

→ u, p_ϕ

↓ v, p_θ

o $N_{\phi\theta}, M_{\phi\theta}, \epsilon_{\phi\theta}, \tau_{\phi\theta}$ *

---

*Discussed in subsequent test.

Fig. 2.2-1 Mesh Configuration

The main feature of this grid system is the half spacing of the u, v displacements between the radial, w, displacement. This provides a strong coupling between the three equilibrium equations not generally provided in lower order difference expressions. A problem in using this grid exists in solving the plasticity problem in which it is necessary to have the stresses and strains known at the same point to properly apply the yield condition and compute the stress increments. This is done by shifting the points for shear quantities, o , to the same pivotal points used for w , ●. This destroys some of the simplicity of the various required derivatives, but it eliminates the problem without any apparent loss of accuracy.

To illustrate application of the finite difference formulas, the two following expressions are presented.

$$\epsilon_{\phi_{i,j}} = \frac{-u_{i-1,j} + u_{i,j}}{\Delta(r_\phi \phi)} + \frac{w_{i,j}}{r_{\phi_i}} \quad , \text{(linear only)}$$

and

$$Q_{\phi_{i,j}} = \frac{-M_{\phi_{i-1,j}} + M_{\phi_{i+1,j}}}{2\Delta\,(r_\phi \phi)} + \left(M_{\phi_{i,j}} - M_{\theta_{i,j}}\right)\frac{\cos \phi_i}{r_i \sin \phi_i} + \frac{-M_{\phi\theta_{i,j-1}} + M_{\phi\theta_{i,j+1}}}{2\Delta\,(r_i\, \theta \sin \phi_i)}$$

evaluated for w. Continuing in this way with the mesh configuration of Fig. 2.2-1 and the finite difference expressions in Table 1, all of the basic equations in Section 2.1 can be written in finite difference form.

By referring to Fig. 2.2-2 which shows the SHORE code flowchart, the computational sequence of events can be quickly understood.

Initialization. A few quantities used in the code are initialized to avoid diagnosistics relating to having a value assigned for quantities used later in the code but for which no value may have been computed for the case being run. No initialization is made that would enable one to stack cases.

Set Up Drum. Next, the drum allocations needed for the plot routines are set up.

RDINPT. This subroutine is called from SHORE, and it reads the input data from cards and prints out the input data.

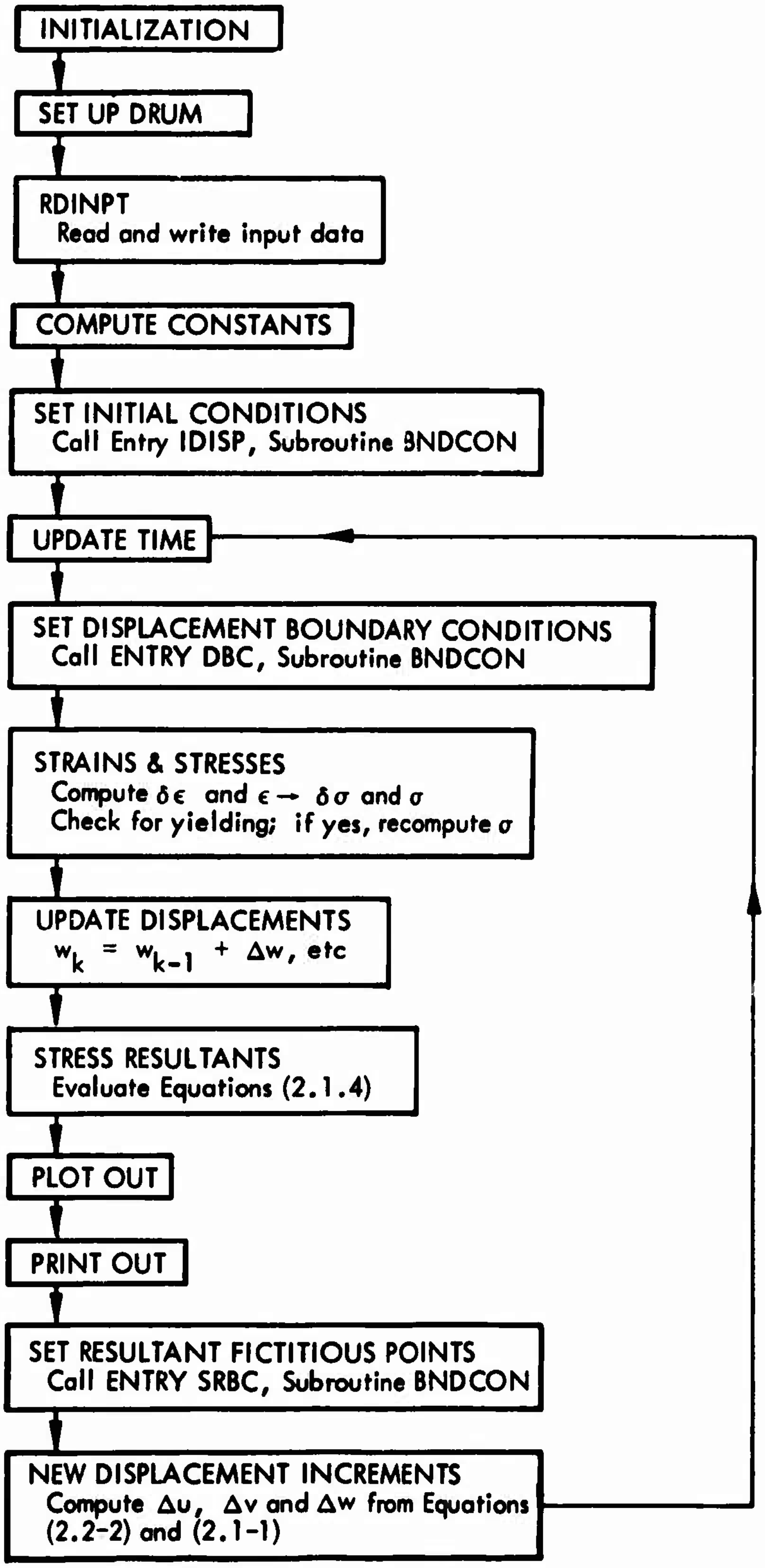


Fig. 2.2-2 SHORE Code Flowchart

Constants. Various constants used throughout the program are evaluated from the input data.

Initial Conditions. Either initial thermal strains or thermal excitation (never checked out or used yet) or the initial velocity is computed (see Section 2.6, Loading).

Update Time. This is the beginning of the time integration loop; at this point, the value of k, the time index, is incremented by one.

Displacement Boundary Conditions. The desired boundary conditions are set (ENTRY DBC in Subroutine BNDCON), (see Section 2.3). Because the code actually computes the displacement increments, the boundary conditions are set on the increments only.

Strains and Stresses. The increments in strain are computed based on the displacement increments and their derivatives. The total strain is computed from $\epsilon_k = \epsilon_{k-1} + \delta\epsilon$. The increment in stress is computed based on the elastic constitutive relationships, Eqs. (2.1-3). The total stress is computed from $\sigma_k = \sigma_{k-1} + \delta\sigma$, then a check on the yield condition is made. If yielding has occurred, the total strain, stress and the strain increments are used in the subroutine INELST, see Section 2.4, to determine the proper total stress.

In addition, a fracture criterion is available. The criterion results from Hoffman [11] and accounts for differences in tensile and compressive fracture stresses. If this criterion is exceeded, the function YIELD is set equal to -1. and the stresses at this point will be zero afterwards.

Update Displacements. The present displacement increment is added to the sum of the past displacement increments.

Stress Resultants. The values of the stress resultants, Eq. (2.1-4) are computed. For elastic cases, an algebraic form of the integration through the thickness is used. For inelastic cases, the stresses are determined at five points through the thickness; Simpson's rule is used for the integrations.

Plot Out. Different computed quantities are plotted at various spatial locations and times as specified in the input data. The subroutine PLTNG selects the desired data and then calls subroutine SCPLT which stores the data on a drum for actual plotting after the computations have been completed. After the shell response has been computed in subroutine SHORE, control returns to BEGIN, the driving program, at which point PLOT1 is called and the plots are prepared. The following subroutines are connected with the plotting: SCPLT, PLOT1, PLOT2, DXDY2, NREAD and NWRITE.

Print Out. Various computed quantities at various times as specified in the input data are printed out by calling subroutine PRNT.

Resultant Boundary Conditions. As discussed in Section 2.3, the fictitious points for the stress resultants are set by calling ENTRY SRBC in subroutine BNDCON.

New Displacement Increments. Using the time integration technique outlined at the beginning of this section, Eq. (2.2-2) is applied to the three equilibrium Eqs. (2.1-1) expressed in finite difference form to compute the next displacement increment. At this point, the code returns to the Update Time statement, and the entire sequence is repeated to compute the next displacement increments.

This completes the outline of the flow of computations in the SHORE code, but a few general comments are still in order. The production version of the code uses the grid with the shear quantities computed at the w pivotal points. If interest exists only in elastic analysis, a version of the code with the grid in Fig. 2.2-1 is available. Although the code is called SHORE, it is actually only a subroutine which is called from BEGIN. BEGIN is the main program – a very simple driver program. PLOT1 also is called from BEGIN. Because the code is very large there are several segments and overlays; these can be determined from the map obtained from a listing. Also, at each time step the foregoing sequence of operations is performed for each spatial point associated with the shell.

The following nomenclature is used in SHORE:

SC1	$1/\Delta(r_\phi \phi)$
SC2	$1/\Delta\theta$
TXTL	temperature matrix
EPP	ϵ_ϕ
EPT	ϵ_θ
GPT	$\epsilon_{\phi\theta}$
SP	σ_ϕ
ST	σ_θ
TTP	$\tau_{\phi\theta}$
U, V, W	u, v, w
DU, DV, DW	$\Delta u, \Delta v, \Delta w$
NP	N_ϕ
NT	N_θ
NPT	$N_{\phi\theta}$
MP	M_ϕ
MT	M_θ
MPT	$M_{\phi\theta}$
ZZ	z
T, TU, TV, TA, TUA, TVA	thickness of inner shell layer at w, u, v, respectively and outer shell layer at w, u, v, respectively
I	meridional direction index
J	circumferential direction index
K	time increment index
L	thickness direction index

2.3 BOUNDARY CONDITIONS by Charles Rankin

In principle, there are 16 possible boundary conditions at each end of the shell, as described by the following combinations which apply at $s = 0$ and $S = L$:

$$N_\phi = 0 \quad \text{or} \quad u = 0 \tag{2.3-1}$$

$$N_{\phi\theta} + \frac{1}{2}\left(\frac{3}{r} - \frac{1}{r_\phi}\right)M_{\phi\theta} + \frac{1}{2}(N_\phi + N_\theta)\Phi = 0 \quad \text{or} \quad v = 0 \tag{2.3-2}$$

$$Q_\phi + \frac{\partial M_{\phi\theta}}{\partial(r\theta \sin \phi)} - \Phi_\phi N_\phi - \Phi_\theta N_{\phi\theta} = 0 \quad \text{or} \quad w = 0 \tag{2.3-3}$$

$$M_\phi = 0 \quad \text{or} \quad \Phi_\phi = 0 \tag{2.3-4}$$

Additional conditions arise when using symmetry to cut down on the calculation. For w or v symmetric,

$$\frac{\partial w}{\partial s} = 0 \quad \text{and} \quad \frac{\partial^3 w}{\partial s^3} = 0$$

$$\frac{\partial v}{\partial s} = 0 \quad \text{and} \quad \frac{\partial^3 v}{\partial s^3} = 0$$

Because of half-spacing, only one equation is needed for symmetric u (because w and v are 0 at the boundary): $du/ds = 0$ at boundaries.

Antisymmetric conditions for w, v, and u are

$$w = 0 \quad \text{and} \quad \frac{\partial^2 w}{\partial s^2} = 0$$

$$v = 0 \quad \text{and} \quad \frac{\partial^2 v}{\partial s^2} = 0$$

$$u = 0$$

SHORE can operate with the following boundary conditions at either $s = 0$ or $s = L$:

(1) Clamped $(u = w = dw/ds = v = 0)$
(2) Fixed simple support $(u = w = 0 , M_\phi = 0 , v = 0)$
(3) Free simple support $(w = 0 , N_\phi = 0 , M_\phi = 0 , v = 0)$
(4) Free edge. $v = 0$ (axisymmetric case)
(5) Unrestricted free edge
(6) All symmetry combinations of u , v , and w

All boundary conditions, except for the two free edge cases, require that one fictitious point outside the shell be used to set the boundary conditions. By setting these points, central difference formulas expressing the derivatives in the boundary condition equations are satisfied. Other points not required by the boundary equations but needed for quantities in the equilibrium expression are extrapolated by a second-order formula, which for a variable y is

$$y_{i-1} = 3y_i - 3y_{i+1} + y_{i+2}$$

Points treated like this shall be referred to as extrapolated.

The clamped condition requires that $u = w = dw/ds = 0$. Let $(u_{1,j} , v_{1,j} , w_{1,j})$ represent a fictitious point at the $s = 0$ boundary at gridpoint y along the circumference, and let $(u_{NC,j} , v_{NC+1,j} , w_{NC+1,j})$ represent the same fictitious point at the right boundary. (Note that there is one less u point because the u points are halfway between the w points; see Fig. 2.2-1 and discussion.) Then, at $s = 0$ and $s = L$,

$$\begin{array}{llll} w_{1,j} = w_{3,j} & ; & w_{NC+1,j} = w_{NC-1,j} & \left(\text{for } \frac{\partial w}{\partial s} = 0\right) \\ u_{1,j} = u_{2,j} & ; & u_{NC,j} = u_{NC-1,j} & (\text{for } u = 0) \\ w_{2,j} = 0 & ; & w_{NC,j} = 0 & (\text{for } w = 0) \\ v_{2,j} = 0 & ; & v_{NC,j} = 0 & (\text{for } v = 0) \end{array}$$

The term v_1 is extrapolated.

For w (or v) symmetric $(w' = w''' = 0)$, the third derivative terms require a difference expression shifted one point to the right (or left for $S = L$), and are as follows:

$$\left.\frac{d^3w}{ds^3}\right|_{s=0} = \frac{(w_{4,j} - 3w_{3,j} + 3w_{2,j} - w_{1,j})}{\Delta s^3}$$

$$\left.\frac{d^3w}{ds^3}\right|_{s=L} = -\frac{(w_{NC-2,j} - 3w_{NC-1,j} + 3w_{NC,j} - w_{NC+1,j})}{\Delta s^3}$$

The equations for symmetric w (or v) become

$$\begin{array}{lll} w_{1,j} = w_{3,j} & ; & w_{NC+1,j} = w_{NC-1,j} \\ w_{2,j} = \frac{1}{3}(4w_{3,j} - w_{4,j}) & ; & w_{NC,j} = \frac{1}{3}(4w_{NC-1,j} - w_{NC-2,j}) \end{array}$$

Symmetric u requires

$$u_{1,j} = u_{2,j} \quad ; \quad u_{NC,j} = u_{NC-1,j}$$

Similar treatment for antisymmetric conditions yields for w (or v)

$$w_{2,j} = 0 \quad ; \quad w_{NC,j} = 0$$

$$w_{1,j} = -w_{3,j} \quad ; \quad w_{NC+1,j} = -w_{NC-1,j}$$

and for u

$$u_{1,j} = -u_{2,j} \quad ; \quad u_{NC,j} = -u_{NC-1,j}$$

In the fixed simple-support case, $u = 0$ and $w = 0$ at the boundary, which requires that

$$u_{1,j} = -u_{2,j} \quad ; \quad u_{NC,j} = -u_{NC-1,j}$$

$$w_{2,j} = 0 \quad ; \quad w_{NC,j} = 0$$

In addition the requirement exists that $M_\phi = 0$ at the boundary. This relation forms a complicated nonlinear equation involving numerical integration (to find M_ϕ from stresses through the thickness) for the unknown quantity $w_{1,j}$ (or $w_{NC+1,j}$). The regula falsi method is used to find the root. Initial estimates for $w_{1,j}$ are found by requiring that the dominant term in M_ϕ (i.e., $k_\phi + \nu_\theta k_\theta$) be zero. [See Eqs. (2.1.2d) and (2.1.2e) for details.]

Only a very few iterations are required to find a good value for $w_{1,j}$.

The free simple support used in SHORE is a modification of the $v = 0$, $w = 0$, $N_\phi = 0$, and $M_\phi = 0$ condition [Eqs. (2.3-1) through (2.3-4)]. Instead of setting $w = 0$, the perpendicular distance from the boundary point ($w_\perp$) to the axis of the shell is kept constant. Thus, if the shell translates in the axial direction (as in the case of a cone with free simple-support condition at each end), no changes in the shell configuration will take place. The (translationally invariant) equation for w is

$$\frac{u \cos \phi}{\sin} + w = 0$$

which becomes

$$w_{2,j} = - \frac{(u_{1,j} + u_{2,j}) \cos \phi_2}{2 \sin \phi_2} \qquad (2.3\text{-}5a)$$

for $s = 0$ and

$$w_{NC,j} = - \frac{(u_{NC-1,j} + u_{NC,j}) \cos \phi_{NC}}{2 \sin \phi_{NC}} \qquad (2.3\text{-}5b)$$

at $s = L$. Equations $N_{\phi} = M_{\phi} = 0$ [together with Eqs. (2.3-5)] are sufficient to fix the values of $w_{1,j}$, $u_{1,j}$.

Here we have two nonlinear equations in two unknowns [after Eqs. (2.3-5)] have been absorbed] which must be solved numerically. To this end, a generalization of the regula falsi is used which was developed by Gauss [14] and is applicable to sets of equations. Although the method appears to be used infrequently and although a precise consideration of its convergence properties has not been carried out, the method seems to converge as well in many dimensions as the regula falsi (to which it reduces in one dimension) does in one. The advantage over the numerical versions of Newton's method is that only values of the equations (and not its derivatives) are needed. Coding for the regula falsi is in the subroutine ROOTS, which in turn needs SET to set values of the stress and moment resultants, STRESS to calculate these resultants, and LINEQ2 to effectively solve a set of linear equations for a possibly ill-conditioned matrix of coefficients. In case of lack of convergence, the latest values of the unknowns (usually near zero for the displacement increments used in SHORE) are returned and a message as follows is printed out:

```
TOO MANY ITERATIONS

TIME = XX MILLISEC  II = XX  JJ = XX NDEM = XX  KJ = XX
XXXX, XXXX. XXX ---
```

for iterations exceeding a safety value preset in BNDCON, or

```
ARGUMENT VALUES OUT OF RANGE

TIME  = XX MILLISEC    II = XXJJ = XX NDEM = XX KJ = XX
XXX. XXX
```

if the values for the unknown go out of a specified range (in BNDCON).

Here XX refers to printed values of specified quantities, time is the time step when the error occurred, II and JJ refer to grid points (do not include fictitious points except for free edge case; see Section 2.3), NDEM refers to the number of equations, and KJ is the number of iterations. The numbers below these are the argument values and the function values, respectively. For asymmetric runs, a few spurious points should not adversely affect the results.

For all the above (non-free-edge cases), only one fictitious point is needed. Basically, this results from the fact that the equilibrium equations do not need to be satisfied on the boundary for the clamped, simple-support, and symmetry conditions; indeed, the constraints imposed violate the equilibrium equations. The true solution actually starts one point in from the boundary. In the free case, on the other hand, the boundary is responding like the rest of the shell, and the equilibrium equation must be satisfied there just as in the interior. These equations are fourth order in w and second order in u and v; hence, theoretically two fictitious points in w and one in u and v are needed. Thus, one additional point is added to the left (right) wherever a free boundary is encountered. Unlike non-free cases, one of the fictitious points is treated as if part of the shell: It must have a thickness, initial temperatures (if applicable), or any other quantity that would be required to extrapolate the shell one point beyond the boundary. If the free edge is on the right (I = NC), this is a simple matter of adding one point. If on the left, however, each input grid point for these quantities is displaced one point. [Thus, pt. (3,J) for simple support becomes (4,J) for free edge on left.] Note that for R, RP, and PHI, two fictitious points are required. (See Section 3.) In all cases, this free edge fictitious point is treated as a real part of the shell with real physical input extrapolated from the interior. The plotting, on the other hand, is treated exactly the same, regardless of the boundary conditions.

Two free edge choices are available, v restricted and v not restricted. The $v = 0$ case is used primarily for axisymmetric jobs. If the user assigns his axisymmetric run to the unrestricted free edge, the program will correct the mistake. On the other hand, the $v = 0$ option is retained for asymmetric runs because of a possible cut in run time for cases where knowledge of v is not important.

From here on, only the left boundary will be discussed; the right is treated similarly. When $v = 0$, the points in question are $v_{2,j}$ ($I = 3$ at the boundary), $v_{1,j}$, $w_{2,j}$, $w_{1,j}$, $u_{2,j}$, $u_{1,j}$.

The terms $v_{1,j}$ and $u_{1,j}$ contribute but little (just as in the case of $v_{1,j}$ for clamped case) and are extrapolated; $v_{2,j}$ is set equal to $-v_{4,j}$ (which in any case is zero for axisymmetric runs), thus treating v as "antisymmetric"; $w_{2,j}$, $w_{1,j}$, $u_{2,j}$ form three unknowns for the three equations

$$N_\phi = 0 \tag{2.3-6a}$$

$$M_\phi = 0 \tag{2.3-6b}$$

$$Q_\phi + \frac{\partial M_{\phi\theta}}{2\,(r_\theta \sin\phi)} - \Phi_\theta N_{\phi\theta} = 0 \tag{2.3-6c}$$

at the boundary. Because Eqs. (2.3-6a) and (2.3-6b) do not contain $w_{1,j}$, they can be solved for the pair of unknowns $w_{2,j}$, $u_{2,j}$ using ROOTS. Then, $w_{1,j}$ is solved using Eq. (2.3-6c) after $w_{2,j}$ and $u_{2,j}$ are known.

In all cases, initial estimates for the unknowns $w_{2,j}$ and $u_{2,j}$ are taken from dominant terms in M_ϕ and N_ϕ, respectively:

$$w_{2,j} \quad \text{from} \quad k_\phi + \nu_\theta k_\theta = 0$$

$$u_{2,j} \quad \text{from} \quad \epsilon_\phi + \nu_\theta \epsilon_\theta = 0$$

The guess for $w_{1,j}$ is extrapolated.

The unrestricted free edge is treated similarly, except one more equation comes into play:

$$N_{\phi\theta} + \frac{1}{2}\left(\frac{3}{r} - \frac{1}{r_\phi}\right)M_{\phi\theta} + \frac{1}{2}N_{\theta\Phi} = 0 \qquad (2.3\text{-}6d)$$

Equation (2.3-6d) is included with Eq. (2.3-6a) and (2.3-6b) for the unknowns $u_{2,j}$, $v_{2,j}$ and $w_{2,j}$; $u_{1,j}$ and $v_{1,j}$ are extrapolated. Because cross terms in Eqs. (2.3-6) weakly couple all terms around the circumference, these three equations must be solved more than once around the circumference. They are solved for each J value one at a time around and around the shell until convergence is attained. In practice, only two rounds of the shell are needed; if the number of circuits exceeds three, the program prints out

```
OUCH, IT HURTS, KITER IS GREATER THAN 3.  HELP, HELP
```

and proceeds merrily along its way to solve for $w_{1,j}$ from Eq. (2.3-6c) as in the restricted free case.

In the circumferential direction, a plane of symmetry exists at $\theta = 0$ and θ_b, so that the displacement must be set as follows for all stations I along the length of the shell:

- Symmetric loading

$$u_{i,1} = u_{i,3} \quad ; \quad u_{i,NB+1} = u_{i,NB-1}$$

$$v_{i,1} = -v_{i,2} \quad ; \quad v_{i,NB} = -v_{i,NB-1}$$

$$w_{i,1} = w_{i,3} \quad ; \quad w_{i,NB+1} = w_{i,NB-1}$$

- Antisymmetric loading – Reverse signs on right-hand side.

The displacement boundary conditions are set in the BNDCON subroutine at the entry point DBC. Because the code actually computes displacement increments in u, v, and w called DU, DV, and DW in the code, these variables are seen in ENTRY DBC. CIRC computes the displacement boundary values for $\theta = 0$ and $\theta = \theta_b$.

Entry SRBC is called after the stress resultants are calculated to set M_ϕ and N_ϕ at zero wherever applicable. Fictitious values of the resultants also are calculated, but these values are needed only when the equilibrium equations are to be solved for $w_{2,j}(w_{NC,j})$ and $v_{2,j}(v_{NC,j})$, which include only the symmetry options. All values are calculated by extrapolation, except for the case symmetric v, w and antisymmetric u, whence Eqs. (2.1-2) also are symmetric or antisymmetric, resulting in

$$N_{\phi_{i,j}} = N_{\phi_{3,j}} \quad ; \quad N_{\phi_{NC+1,j}} = N_{\phi_{NC-1,j}}$$

$$M_{\phi_{1,j}} = M_{\phi_{3,j}} \quad ; \quad M_{\phi_{NC+1,j}} = M_{\phi_{NC-1,j}}$$

$$N_{\theta_{1,j}} = N_{\theta_{3,j}} \quad ; \quad N_{\theta_{NC+1,j}} = N_{\theta_{NC-1,j}}$$

$$M_{\theta_{1,j}} = M_{\theta_{3,j}} \quad ; \quad M_{\theta_{NC+1,j}} = M_{\theta_{NC-1,j}}$$

$$N_{\phi\theta_{1,j}} = -N_{\phi\theta_{3,j}} \quad ; \quad N_{\phi\theta_{NC+1,j}} = -M_{\phi\theta_{NC-1,j}}$$

$$M_{\phi\theta_{1,j}} = -M_{\phi\theta_{3,j}} \quad ; \quad M_{\phi\theta_{NC+1,j}} = -M_{\phi\theta_{NC-1,j}}$$

For antisymmetric w, v, and symmetric u, reverse the signs on the right-hand side. SRBC calls entry RCIRC which sets fictitious stress resultants according to the above symmetry condition for all points along the shell at $\theta = 0$ and θ_b.

Inhomogeneous boundary conditions can also be treated with SHORE. For the axisymmetric case, input the axisymmetric free edge boundary condition; for asymmetric runs, input the free edge. Two options are available. Either the user can alter subroutine SET (see next paragraph) or springs can be attached to the boundary. Springs treated in the boundary routine calculate an externally applied force proportional to the displacement in the direction of the spring, opposing motion in that direction.

These springs are inputted in the arrays KP(I,J) (meridional springs), KC(I,J) (circumferential springs), and KZ(I,J) (radial springs). No bending springs are available. Springs on the left occupy KP(1,J), KC(1,J), and KZ(1,J) and on the right occupy

KP(NDP+2+L,J)
KC(NDP+2+L,J)
KZ(NDP+2+L,J)

where J refers to any position on the circumference, NDP is the number of meridional shell segments, and $L = 1$ if there is also free edge on the left, and zero otherwise.

If one wants to put an arbitrary force on the edge, he calculates these forces and makes sure their values are available to SET at statement 1251 (sequence No. 48), and then subtracts these values somewhere in the statement beginning with seq. No. 48 (meridional), No. 50 (bending), and No. 52 (circumferential shear). Radial shear information must be made available separately at or after statement No. 1256 (seq. No. 58), and the statement from which the force must be subtracted begins at seq. No. 59.

Note that I3 = 1 on the left boundary and I3 = -1 on the right boundary; this indicates the side that one is on when both edges are free. J refers to the point along the circumference, and COMMON/PIG/PI,G, TIME makes available the integration variable TIME (already available to SET) to user-supplied subprograms. TIME is in seconds.

The following example of change cards for SET is intended to show only one of the many ways a user can input time-dependent forces on boundaries. Here, it is assumed that a function is supplied by the user as follows:

FORCE (I3,J,L)	=	force or moment at edge
I3 < 0		right boundary
I3 > 0		left boundary
J –		point on circumference
L = 1		meridional force
L = 2		bending moment
L = 3		circumferential shear
L = 4		radial shear

The changes in SET become

```
@FOR,XS  SET,SET,SET
-49
        *-FORCE(I3,J,1)
-50
        *-FORCE(I3,J,2)
-56
        *-FORCE(I3,J,3)
-63
        *-FORCE(I3,J,4)
@MAP,S AMEN,AMENA
@XQT AMENA
   user's data
```

2.4 PLASTICITY

Theoretical Development.

Two plasticity formulations are available to users of the SHORE code. The first is based on perfect plasticity, and the second incorporates linear strain hardening. Because the code accomodates orthotropic elastic properties, the plasticity theory is based on Hill's anisotropic yield function. (Everything in this section is based on Ref. [3].) For the two-dimensional shell under consideration, Hill's yield function becomes (a form proposed in Ref. [2])

$$2F = \left(\frac{\sigma_\phi^2}{\sigma_1^2} - \frac{\sigma_\phi \sigma_\theta}{\sigma_1 \sigma_2} + \frac{\sigma_\theta^2}{\sigma_2^2} + \frac{\tau_{\phi\theta}^2}{\sigma_{12}^2} \right) = 1 \qquad (2.4\text{-}1)$$

where

σ_1 = yield stress in the ϕ-direction

σ_2 = yield stress in the θ-direction

σ_{12} = yield stress in shear

Hence, anytime 2F exceeds 1, there exists a yielding for the perfectly plastic material; for the linear strain hardening case, Eq. (2.4-1) is modified slightly. With the above definition of the yield surface, it is possible to derive the proper constitutive laws for the plasticity theories under consideration.

At any point in the material, the total strain can be written as the sum of the elastic strain and the plastic strain. Because the code computes increments in strain, the increments used will be in total, elastic and plastic strain, hence.

$$\delta\epsilon^t = \delta\epsilon^e + \delta\epsilon^p \qquad (2.4\text{-}2)$$

The code does not make this incremental formulation necessary; on the contrary, the plasticity theories are based on increments in plastic strain. The increment in total strain is known from the satisfications of the equilibrium equations, and it is desired to determine the increments in stress.

For plasticity, it is known that the plastic strain components are normal to the yield surface and proportional to the stress increments. This is expressed as

$$\delta\epsilon_{ij}^{p} = \mu \frac{\partial(2F)}{\partial\sigma_{ij}} \qquad (2.4\text{-}3)$$

for the perfectly plastic case, where μ incorporates the proportionality and stress increments. Now the increments in total strain can be written as

$$\left.\begin{aligned}
\delta\epsilon_{\phi}^{t} &= \frac{1}{E_{\phi}}(\delta\sigma_{\phi} - \nu_{\theta}\,\delta\sigma_{\theta}) + \mu\left[\frac{2}{\sigma_1^2}(\sigma_{\phi} + \delta\sigma_{\phi}) - \frac{1}{\sigma_1\sigma_2}(\sigma_{\theta} + \delta\sigma_{\theta})\right] \\
\delta\epsilon_{\theta}^{t} &= \frac{1}{E_{\theta}}(\delta\sigma_{\theta} - \nu_{\phi}\,\delta\sigma_{\phi}) + \mu\left[\frac{2}{\sigma_2^2}(\sigma_{\theta} + \delta\sigma_{\theta}) - \frac{1}{\sigma_1\sigma_2}(\sigma_{\phi} + \delta\sigma_{\phi})\right] \\
\delta\gamma_{\phi\theta}^{t} &= \frac{1}{2G}\delta\tau_{\phi\theta} + \mu\frac{1}{\sigma_{12}^2}(\tau_{\phi\theta} + \delta\tau_{\phi\theta})
\end{aligned}\right\} \qquad (2.4\text{-}4)$$

There are four unknowns $-\delta\sigma_{\phi}, \delta\sigma_{\theta}, \delta\tau_{\phi\theta}$, and λ – so a fourth equation is needed; this is the yield function.

$$\left(\frac{\sigma_\phi + \delta\sigma_\phi}{\sigma_1}\right)^2 + \left(\frac{\sigma_\theta + \delta\sigma_\theta}{\sigma_2}\right)^2 - \frac{(\sigma_\phi + \delta\sigma_\phi)(\sigma_\theta + \delta\sigma_\theta)}{\sigma_1\sigma_2} + \left(\frac{\tau_{\phi\theta} + \delta\tau_{\phi\theta}}{\sigma_{12}}\right)^2 - 1 = 0 \tag{2.4-5}$$

Equations (2.4-4) and (2.4-5) constitute a set of nonlinear algebraic equations; to solve them exactly, an iteration technique is used. From physical considerations, it is known that the correct μ is the smallest nonnegative positive number satisfying the above set of equations. Consequently, the iterative technique progresses as follows. First, guess $\mu = 0$, then solve Eq. (2.4-4) for $\delta\sigma_\phi, \delta\sigma_\theta, \delta\tau_{\phi\theta}$, and then determine the sign of Eq. (2.4-5). Next, guess $\mu = 1$, solve Eq. (2.4-4), and then determine the sign of Eq. (2.4-5). If a sign change has occurred, then $0 < \mu < 1$; if not, the next choice for μ is 2 times the last μ. When a sign change occurs, an interpolation scheme is used to find the exact value of μ and $\delta\sigma_\phi, \delta\sigma_\theta, \delta\tau_{\phi\theta}$.

For most cases of practical interest, an approximation can be made in Eqs. (2.4-4) and (2.4-5) to linearize the equations. Then, using Cramer's rule, it is possible to solve directly for $\delta\sigma_\phi$, $\delta\sigma_\theta$, $\delta\tau_{\phi\theta}$, and μ. The only time this technique will produce a completely erroneous result is if yielding occurs on the very first time step. This is easily noticed because a zero stress is computed for the printout of the very first time step. To linearize the equations, all terms quadratic in stress increments are dropped. Then, the following matrix equation is obtained.

$$\begin{bmatrix} \frac{1}{E_\phi} & -\frac{\nu_\theta}{E_\phi} & 0 & \left(\frac{2\sigma_\phi}{\sigma_1^2} - \frac{\sigma_\theta}{\sigma_1\sigma_2}\right) \\ -\frac{\nu_\phi}{E_\theta} & \frac{1}{E_\theta} & 0 & \left(\frac{2\sigma_\theta}{\sigma_2^2} - \frac{\sigma_{\phi\theta}}{\sigma_1\sigma_2}\right) \\ 0 & 0 & \frac{1}{2G} & \frac{\tau_{\phi\theta}}{\sigma_{12}} \\ \left(\frac{2\sigma_\phi}{\sigma_1^2} - \frac{\sigma_\theta}{\sigma_1\sigma_2}\right) & \left(\frac{2\sigma_\theta}{\sigma_2^2} - \frac{\sigma_{\phi\theta}}{\sigma_1\sigma_2}\right) & \frac{2\tau_{\phi\theta}}{\sigma_{12}^2} & 0 \end{bmatrix} \begin{Bmatrix} \delta\sigma_\phi \\ \delta\sigma_\theta \\ \delta\tau_{\phi\theta} \\ \mu \end{Bmatrix}$$

$$= \begin{Bmatrix} \delta\epsilon_\phi^t \\ \delta\epsilon_\theta^t \\ \delta\epsilon_{\phi\theta}^t \\ 1 - \frac{\sigma_\phi^2}{\sigma_1^2} - \frac{\sigma_\theta^2}{\sigma_2^2} + \frac{\sigma_\phi\sigma_\theta}{\sigma_1\sigma_2} - \frac{\tau_{\phi\theta}^2}{\sigma_{12}^2} \end{Bmatrix} \tag{2.4-6}$$

For the linear strain hardening theory, a very similar procedure is used, but it is slightly simpler in that μ is now known, and the stress increments are the only unknowns. For the linear strain hardening, we use the same yield function Eq. (2.4-1) and the strain hardening is assumed to be of the form

$$\sigma^p_{eff} = \sigma_o + H\, e^p_{eff} \qquad (2.4\text{-}7)$$

where σ_o is the current value of the effective yield stress and H is the strain hardening modulus. (Note, the initial value of σ_o is equal to the effective yield stress based on the von Mises' condition.) After first yielding the 1 in Eq. (2.4-1) is no longer used; instead, 2F must exceed its last maximum before yielding occurs. By manipulating several equations in Ref. [3] it can be determined that

$$\mu = \frac{\sigma_o^2}{4HY}\, \delta(2F)$$

where Y = current value of 2F

hence

$$\delta\epsilon^p_{ij} = \frac{\sigma_o^2}{4HY} \left(\frac{\partial(2F)}{\partial\sigma_{ij}}\right) \delta(2F) \qquad (2.4\text{-}8)$$

In this formulation, quadratic terms in the stress increments are dropped and no exact solution has been programmed. Before each solution, the portion of strain increment required to bring the stresses up to the yield surface is subtracted, so only the plastic increment of strain is used. [Note Eq. (2.4-8).] The following is the resulting set of linear equations for the stress increments

$$\left[\frac{1}{E_\phi} + \frac{\sigma_o^2}{YH}\left(\frac{\sigma_\phi^2}{\sigma_1^4} - \frac{\sigma_\phi \sigma_\theta}{\sigma_1^3 \sigma_2} + \frac{\sigma_\theta^2}{4\sigma_1^2\sigma_2^2}\right)\right]\delta\sigma_\phi + \left[-\frac{\nu_\theta}{E_\phi} + \frac{\sigma_o^2}{YH}\left(\frac{5\sigma_\phi\sigma_\theta}{4\sigma_1^2\sigma_2^2} - \frac{\sigma_\phi^2}{2\sigma_1^3\sigma_2} - \frac{\sigma_\theta^2}{2\sigma_1\sigma_2^3}\right)\right]\delta\sigma_\theta$$

$$+ \left[\frac{\sigma_o^2}{YH}\left(\frac{\sigma_\phi \tau_{\phi\theta}}{\sigma_1^2\sigma_{12}^2} - \frac{\sigma_\theta \tau_{\phi\theta}}{2\sigma_1\sigma_2\sigma_{12}^2}\right)\right]\delta\tau_{\phi\theta} = \delta\epsilon_\phi^t$$

$$\left[-\frac{\nu_\phi}{E_\theta} + \frac{\sigma_o^2}{YH}\left(\frac{5\sigma_\phi\sigma_\theta}{4\sigma_1^2\sigma_2^2} - \frac{\sigma_\theta^2}{2\sigma_1\sigma_2^3} - \frac{\sigma_\phi^2}{2\sigma_1^3\sigma_2}\right)\right]\delta\sigma_\phi + \left[\frac{1}{E_\theta} + \frac{\sigma_o^2}{YH}\left(\frac{\sigma_\theta^2}{\sigma_2^4} - \frac{\sigma_\phi\sigma_\theta}{\sigma_1\sigma_2^3} + \frac{\sigma_\phi^2}{4\sigma_1^2\sigma_2^2}\right)\right]\delta\sigma_\theta$$

$$+ \left[\frac{\sigma_o^2}{YH}\left(\frac{\sigma_\theta \tau_{\phi\theta}}{\sigma_2^2\sigma_{12}^2} - \frac{\sigma_\phi \tau_{\phi\theta}}{2\sigma_1\sigma_2\sigma_{12}^2}\right)\right]\delta\tau_{\phi\theta} = \delta\epsilon_\theta^t \tag{2.4-9}$$

and

$$\left[\frac{\sigma_o^2}{YH}\left(\frac{\sigma_\phi \tau_{\phi\theta}}{\sigma_2^2\sigma_{12}^2} - \frac{\sigma_\theta \tau_{\phi\theta}}{2\sigma_1\sigma_2\sigma_{12}^2}\right)\right]\delta\sigma_\phi + \left[\frac{\sigma_o^2}{YH}\left(\frac{\sigma_\theta \tau_{\phi\theta}}{\sigma_2^2\sigma_{12}^2} - \frac{\sigma_\phi \tau_{\phi\theta}}{2\sigma_1\sigma_2\sigma_{12}^2}\right)\right]\delta\sigma_\theta$$

$$+ \left[\frac{1}{2G} + \frac{\sigma_o^2}{YH} \cdot \frac{\tau_{\phi\theta}^2}{\sigma_{12}^4}\right]\delta\tau_{\phi\theta} = \delta\epsilon_{\phi\theta}^t$$

Computation (Subroutine INELST)

The options in INELST are INPB = 1, 2, or 3. Option 1 corresponds to a solution of Eq. (2.4-9). Option 2 corresponds to a solution of Eq. (2.4-6). Option 3 corresponds to a solution of Eqs. (2.4-4) and (2.4-5) The following nomenclature is used in INELST.

DEPP = $\delta\epsilon_{\phi}^{t}$

DEPT = $\delta\epsilon_{\theta}^{t}$

DGPT = $\delta\epsilon_{\phi\theta}^{t}$

SSX = σ_{ϕ}

SST = σ_{θ}

TXT = $\tau_{\phi\theta}$

SZ2 = σ_{o}^{2}

HB = H

A11, A12, etc. are the elements of the matrices

REXB = $1/E_{\phi}$

RETB = $1/E_{\theta}$

REXNUB = ν_{θ}/E_{ϕ}

RETNUB = ν_{ϕ}/E_{θ}

S1B = σ_{1}

S2B = σ_{2}

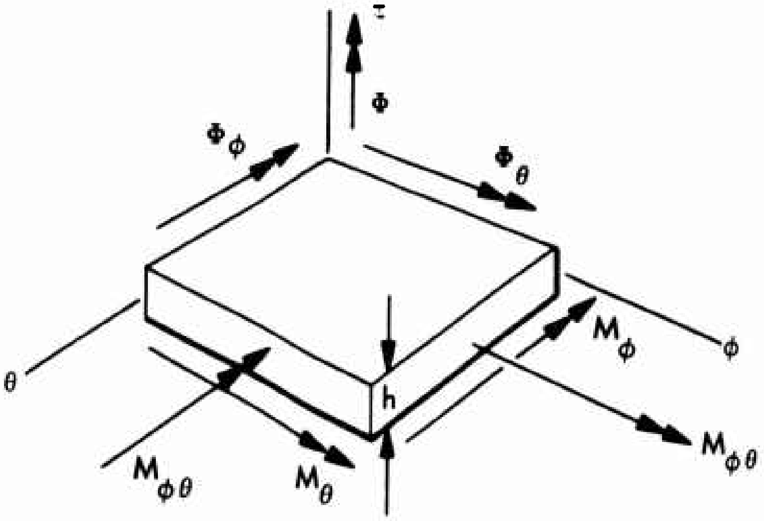
S12B = σ_{12}

MU = μ

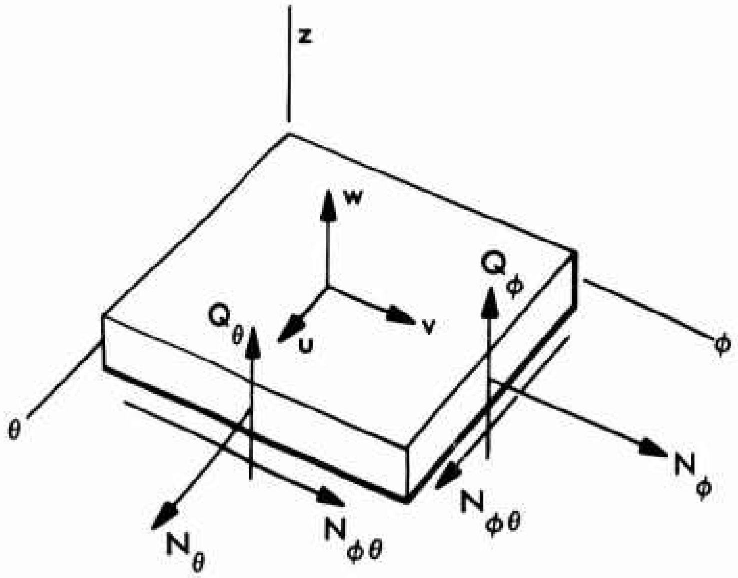
YIELD = Y

2.5 SHELL GEOMETRY

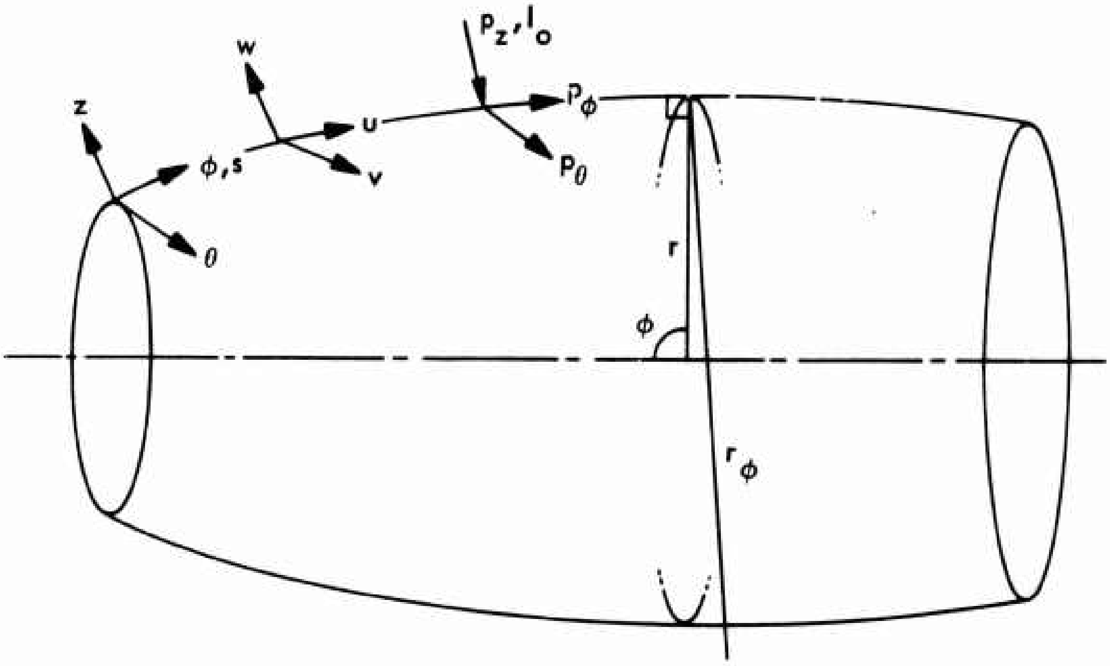
The basic shell element with the coordinate system and the stress resultants is shown below.



and



The overall reference surface geometry of the shell is illustrated below



where

s = arc length along the meridian,

r = radius of the shell in the θ-direction measured normal to the shell midsurface,

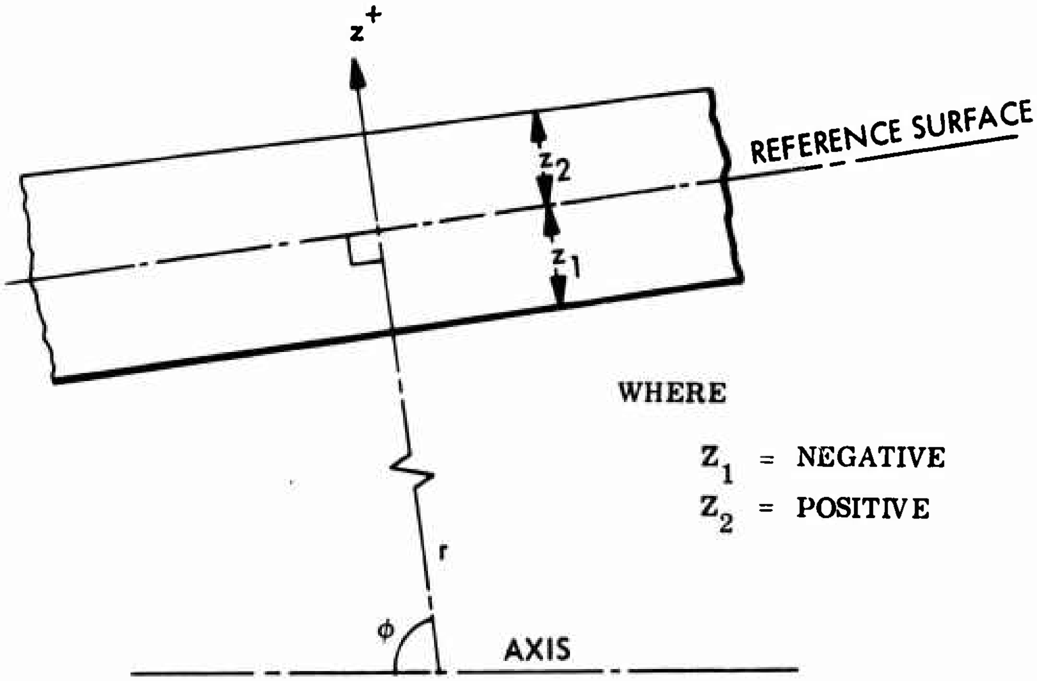
ϕ = angle between the axis of the shell and r,

r_ϕ = radius of the shell in the ϕ-direction measured normal to the shell midsurface,

θ = angle defining the circumferential location

The shell wall thickness is defined as distance from the reference surface as follows.

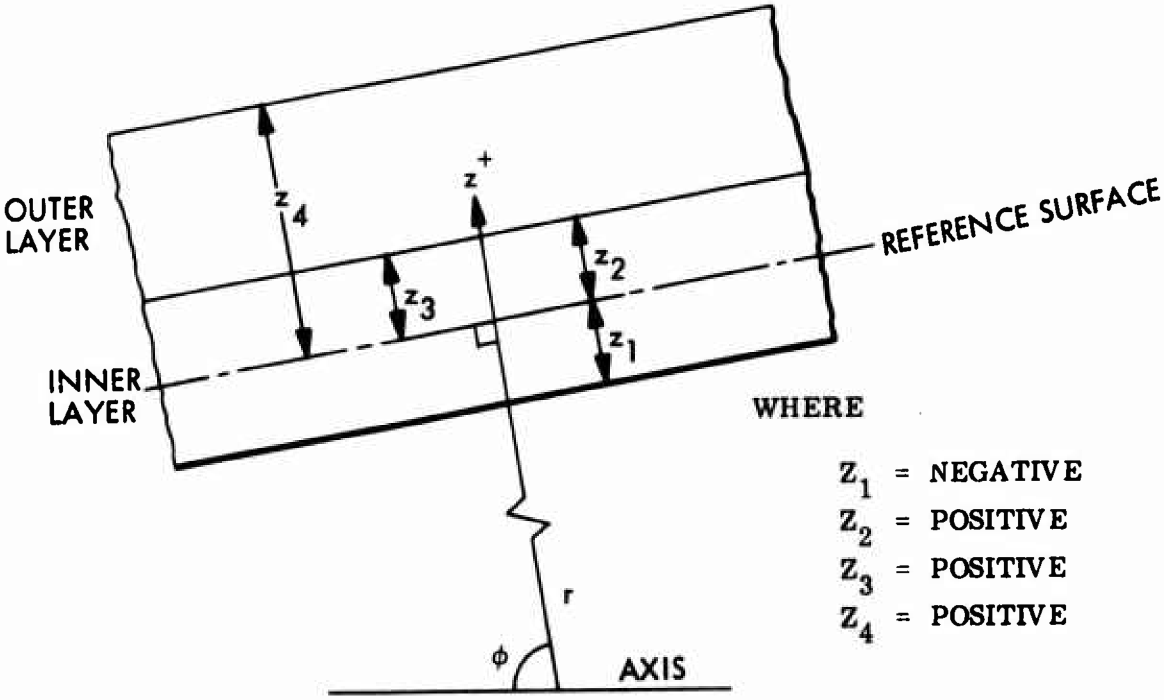
For the one layer shell:



WHERE

Z_1 = NEGATIVE
Z_2 = POSITIVE

For the two layer shell:



WHERE

Z_1 = NEGATIVE
Z_2 = POSITIVE
Z_3 = POSITIVE
Z_4 = POSITIVE

2.6 LOADING

Two loading conditions are available to the users of the SHORE code. One is an impulse or initial velocity condition; the other is a radially directed surface pressure loading which, in general, represents a blast loading on a shell.

The impulse condition is based on an impulse/unit area resulting in an initial radial velocity, $\partial w/\partial t$. This is implemented in the code by prescribing the value of Δw at the end of the first time step, Δt. From

$$\Delta v = \frac{\Delta w}{\Delta t}$$

and

$$I = m\Delta v$$

is obtained

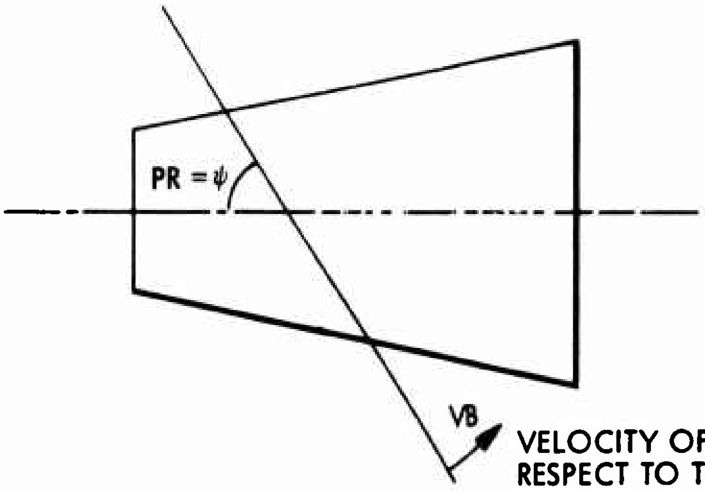
$$\Delta w = \frac{I\Delta t}{m}$$

The value of I is specified in the input data, and the Δw is evaluated in the BNDCON subroutine at the IDISP entry point. The formulation is

$$\Delta w_{ij} = \frac{- I_{ij}\Delta tg}{\rho h_{ij}}$$

where the minus is used because a positive impulse is in the negative w direction.

The pressure loading is based on an approximation to a planar blast wave traversing the shell as some incident angle, ψ, (see illustration).



VELOCITY OF BLAST WAVE WITH RESPECT TO THE SHELL VELOCITY

The formula for computing the radial pressure p_z is,

$$p_{z_i} = \frac{1}{2}\left(p_{w_i}(1 + \cos\theta) + p_{\ell_i}(1 - \cos\theta)\right)\exp\left[-\left(\frac{-(\text{time} - \text{intercept time})}{\tau_i}\right)\right] \quad (2.6\text{-}1)$$

where

p_w = peak windward pressure

p_ℓ = peak leeward pressure

τ = time value used to specify decay

The pressure loading is computed in the subroutine SURLDS. For points behind the wave front, the pressure is computed according to Eq. (2.6-1) and for points in front of the wave front, the the surface pressures are zero. The following notation is used in SURLDS:

PSI = ψ

THT = θ angle describing the circumferential location

X1 = distance from the initial contact point of the blast wave to the point on the shell at which p_z is being calculated

TJ = intercept time

VBT = distance the blast wave has travelled over the shell

PZT = p_z

PW = p_w

PL = p_ℓ

TAU = τ

Note that p_w, p_ℓ, and τ can be arbitrary along a meridian, but the circumferential variation is controlled by Eq. (2.6-1).

Section 3

INPUT DESCRIPTION

3.1 INPUT DATA INSTRUCTIONS

Cards 1 and 2 (12A6) Heading Information

(The first heading card is printed on the plots.)

Card 3 (12I5)

NDP – number of segments in the ϕ-direction $\leq 30 - \text{NFREE}$

NDT – number of segments in the θ-direction ≤ 18

NLAYS – Number of segments through the thickness
= 1 for one layer elasticity
= 4 for one layered shell (NSL=1), multilayered elasticity
= 5 for two layered shell (NSL=2), multilayered elasticity

KIMP – Loading Code
< 0 surface pressures from subroutine SURLDS
= 0 arbitrary impulse loading for each grid point
= 1 $I(\phi,\theta) = I_o \sin(\pi s/L) \cos\theta \qquad 0^\circ \leq \theta \leq 90^\circ$
$= 0 \qquad 90^\circ \leq \theta \leq 180^\circ$
= 2 $I(\phi,\theta) = I_o \sin(\pi s/L) \qquad 0^\circ \leq \theta \leq 90^\circ$
$= 0 \qquad 90^\circ \leq \theta \leq 180^\circ$
= 3 $I(\phi,\theta) = I_o \cos\theta \qquad 0^\circ \leq \theta \leq 90^\circ$
$= 0 \qquad 90^\circ \leq \theta \leq 180^\circ$
= 4 $I(\phi,\theta) = I_o \qquad 0^\circ \leq \theta \leq 90^\circ$
$= 0 \qquad 90^\circ \leq \theta \leq 180^\circ$

ITEMP – initial temperature distribution
= 0 no distribution
> 0 input distribution

IKP – springs in ϕ-direction
= 0 no springs
> 0 input springs

IKT – springs in θ-direction
= 0 no springs
> 0 input springs

IKZ – springs in radial direction
= 0 no springs
> 0 input springs

IMS – extra weight distribution
= 0 no distribution
> 0 input distribution

IAX – symmetry indicator
= 0 asymmetric
= -1 ring code (NDP = 0)
= 1 axisymmetric (NDT = 0)

NSL – shell layer indicator
= 1 one shell layer
= 2 two shell layers

NON – Kinematics indicator
= 0 linear kinematics
= 1 nonlinear kinematics

In this and all subsequent cards, NFREE = number of free edges (0, 1, or 2) in problem.

Card 4 (12I5) Boundary Condition – KBC (10)

KBC (1) through KBC (4) apply to the boundary at the left side of shell, S = 0. KBC (5) through KBC (8) are exactly like KBC (1) through KBC (4), except that they apply to the right side of shell, S = L. KBC (9) and KBC (10) apply to $\theta = 0°$ and θ = THD, respectively.

The only permissible values for KBC (1) through KBC (8) are shown in the following table.

KBC's 1 2 3 4	Boundary conditions to be specified (S symmetric and A antisymmetric in u, v, w)
1 1 1 1	clamped edge
1 3 1 1	simple support (no u displacement)
1 3 1 2	simple support (no edge meridional force)
1 3 1 3	free edge, v constrained (used for axisymmetric runs)
1 3 1 4	free edge, v free
2 1 1 3	S w, v A u (use when case to be solved has plane of symmetry)
1 2 2 1	A w, v S u
2 1 2 1	S w, u A v
2 1 1 1	S w A u, v
2 1 2 3	S u, v, w
1 2 1 1	A u, v, w
1 2 1 3	A w, u S v
1 2 2 3	A w S u, v

For KBC(9) and KBC(10)

= 1 symmetric u, w and antisymmetric v
= 2 antisymmetric u, w and symmetric v

Card 5 (12I5) Print out flags

IU – meridional displacements
IV – circumferential displacements
ISX – meridional stress

IST – circumferential stress
ITTX – shear stress
IEPX – meridional strain
IEPT – circumferential strain
IGXT – shear strain
IPZT – radial pressure
IPPT – meridional pressure
IPTT – circumferential pressure

If = 0 no print out of indicated quantity
$\neq$ 0 print out of indicated quantity

Card 6 (8E10.3)

X – length of shell in ϕ-direction (arc length) (in.)
RHO – density of shell wall (lb/in.^{3})
NUP – ϕ-direction Poisson's ratio
NUT – θ-direction Poisson's ratio
THD – angle of terminal boundary (deg)
LMD – damping parameter (lb-sec/in.^{3})

Card 7 (8E10.3)

EX – elastic modulus in ϕ-direction (psi)
ET – elastic modulus in θ-direction (psi)
GG – shear modulus (psi)
S1 – yield stress in ϕ-direction (psi)
S2 – yield stress in θ-direction (psi)
S12 – yield stress in shear (psi)
ALPHAX – coefficient of thermal expansion in ϕ-direction
ALPHAT – coefficient of thermal expansion in θ-direction

Card 8 (2E10.3,I5)

SZ – effective yield stress (psi)
H – strain hardening slope (psi)
INP – 1 for strain hardening, 2 for perfect plasticity and 3 for "exact" perfect plasticity

Card 9 (3E10. 3) (all positive numbers)

S1C – compressive fracture stress in ϕ-direction (psi)
S1T – tensile fracture stress in ϕ-direction (psi)
S2C – compressive fracture stress in θ-direction (psi)
S2T – tensile fracture stress in θ-direction (psi)
S12S – fracture stress in shear (psi)

Card 10 (8E10. 3) Only used for 2 layer shell

EXA – elastic modulus in ϕ-direction (psi)
ETA – elastic modulus in θ-direction (psi)
GGA – shear modulus (psi)
S1A – yield stress in ϕ-direction (psi)
S2A – yield stress in θ-direction (psi)
S12A – yield stress in shear (psi)

} outer layer

Card 11 (2E10. 3, I5) Only used for 2 layer shell

SZA – effective yield stress (psi)
HA – strain hardening slope (psi)
INPA – 1 for strain hardening,
2 for perfect plasticity
3 for "exact" perfect plasticity

} outer layer

Card 12 (8E10. 3) Only used for 2 layer shell

S1AC – compressive fracture stress in ϕ-direction (psi)
S1AT – tensile fracture stress in ϕ-direction (psi)
S2AC – compressive fracture stress in θ-direction (psi)
S2AT – tensile fracture stress in θ-direction (psi)
S12AS – fracture stress in shear (psi)

outer layer

Card 13 (8E10. 3) Only used for 2 layer shell

RHOA – density of shell wall (lb/in.^{3})
TA – thickness of shell wall (in.)
NUTA – ϕ-direction Poisson's ratio
NUPA – θ-direction Poisson's ratio

outer layer

Card 14 (8E10. 3)

IMP – I_o for impulse distribution (psi-sec)
VB – relative velocity of blast wave front to shell (ft/sec)
PR – angle between wave front and shell axis (radians)

Card 15 (8E10.3)

DT – integration time step (sec)
TT – total time (sec)
PRINT – printing time intervals (sec)
ESPT – time left in run before plotting will start (sec)

Card 16 (E10. 3, I5)

PLT – plotting time intervals (sec)
NPLT = 0 no plots
= 5 miniature plots only (3 per frame)
= 7 full and miniature plots
= 8 full frame plots only

Card 17 (8E10.3)

R(1) – (radius – the distance from the axis normal to the shell wall)(in.)
- (1) If positive R is constant
- (2) If nonpositive R is a variable and each value is input (see below)

RP(1) – radius of shell in ϕ-direction (i.e. for a cylinder or cone use a large number like 10^{10})(in.)
- (1) If positive RP is constant
- (2) If nonpositive RP is a variable and each value is input (see below)

T(1) – thickness of shell (in.)
- (1) If positive T is constant
- (2) If = 0.0, T is variable in ϕ-direction only and the Z array must be read (see below)
- (3) If < 0, T is variable in ϕ and θ direction and the Z matrix must be read (see below)

PHI(1) – angle between R and shell axis (i.e. PHI = $\pi/2$ for a cylinder) (radians)
- (1) If positive PHI is constant
- (2) If nonpositive PHI is a variable and each value is input (see below)

Cards 18 through 27 require special attention if a free edge is used. The shell has one fictitious point (or two, if two free edges are used) outside the shell which must be treated in every respect as if they were part of the shell itself. This includes temperature distribution, for example. Thus, if a free edge on the left is called for, TXTL (L,I,J) with values starting with I = 1 at the left shell edge becomes TXTL (1, I + 1, J), and TXTL (L, 1, J) becomes the fictitious value needed for the boundary condition routine. (See Section 2.3.)

In addition, Cards 18, 19, and 21 need one more fictitious value. For all but the free end conditions, this means that one value beyond the boundary of the shell is needed for the boundary value routine. For free end conditions, <u>two</u> fictitious points beyond each free boundary are needed.

Card 18 (8E10.3) Reads NDP+3 values of R if R(1) < 0.0

Please note that the first and last radii will be past the ends of the shell. You must input a fictitious point beyond the ends of the shell. Just extend the shell and compute the R as if the shell were really there. These values are needed for the boundary condition computations.

Card 19 (8E10.3) Reads NDP+3 values of RP if RP(1) < 0.0.

Please note as in Card 18 a fictitious point is required at each end of the shell.

Card 20 (8E10.3) (Thickness of layers)

If T(1) = 0.

$$\left.\begin{array}{l}\text{NDP+1+NFREE values of } Z(1,I,1),\\ \text{NDP+1+NFREE values of } Z(2,I,1),\\ \text{NDP+1+NFREE values of } Z(3,I,1),\\ \text{NDP+1+NFREE values of } Z(4,I,1) \text{ are read}\end{array}\right\}\ \text{only for the 2-layer shell}$$

If T(1) < 0.0 (Matrix Format)
NDP+1+NFREE, I values and NDT+1, J values of Z(1,I,J) and Z(2,I,J) and Z(2,I,J) (plus Z(3,I,J) and Z(4,I,J) for the 2 layer shell) are read with the matrix read routine.

I is the ϕ-index
J is the θ-index

(Note: fictitious points needed for free edges only.)

Card 21 (8E10.3) Reads NDP+3 values of PHI if PHI(1) < 0.0 (radians)

(All fictitious values required.)

Card 22 If KIMP < 0

reads (8E10.3)

(PW(I), I = 1, NDP+1+NFREE)
(PL(I), I = 1, NDP+1+NFREE)
(TAU(I,) I = 1, NDP+1+NFREE)

If KIMP = 0 (Matrix Format)
reads IXT (I, J) – psi-sec for each mesh point
(Free edge fictitious values only.)

Card 23 (Matrix Format) If ITEMP > 0

read TXTL (L,I,J) – initial temperatures for each point including thickness. (L = 1 inner fiber)
(Free edge fictitious values only.)

Cards 24 (Matrix Format) If IKP > 0

reads KP(I,J) – meridional springs (lb/in.^{3})
(Left and right free edge fictitious values can be used to input spring boundary conditions. Input 0 for left and right free edge fictitious values if no boundary springs are desired. No fictitious values needed for non-free boundaries.)

Cards 25 (Matrix Format) If IKT > 0

reads KT(I,J) – circumferential springs (lb/in.^{3})
(Same as Cards 24.)

Cards 26 (Matrix Format) If IKZ > 0

reads KZ(I,J) – radial springs (lb/in.^{3})
(Same as Cards 24.)

Cards 27 (Matrix Format) If IMS > 0

reads XMS(I,J) – extra weight (lb/in.^{2})
(Free edge fictitious values only; input data required, but the values are not used in the computations.)

Cards 28, 29, and 30 are not read if NPLT = 0.

Card 28 (12I5) Plotting Flags

NPW – Number of radial displacements to be plotted
NPU – Number of meridional displacements to be plotted
NPV – Number of circumferential displacements to be plotted
NPEMO – Number of outer fiber meridional strains to be plotted
NPEMI – Number of inner fiber meridional strains to be plotted
NPECO – Number of outer fiber circumferential strains to be plotted
NPECI – Number of inner fiber circumferential strains to be plotted
NPETO – Number of outer fiber shear strains to be plotted
NPETI – Number of inner fiber shear strains to be plotted
NPSMO – Number of outer fiber meridional stresses to be plotted
NPSMI – Number of inner fiber meridional stresses to be plotted
NPSCO – Number of outer fiber circumferential stresses to be plotted
NPSCI – Number of inner fiber circumferential stresses to be plotted
NPSTO – Number of outer fiber shear stresses to be plotted
NPSTI – Number of inner fiber shear stresses to be plotted
NPMM – Number of meridional moment resultants to be plotted
NPMC – Number of circumferential moment resultants to be plotted
NPMT – Number of twisting moment resultants to be plotted
NPNM – Number of meridional stress resultants to be plotted
NPNC – Number of circumferential stress resultants to be plotted
NPNT – Number of shear stress resultants to be plotted

The sum of the flags cannot exceed 300. That is, only 300 unique plots can be made.

Cards 29 (12I5) NL-Plot Array

This reads in the mesh points at which the variables indicated on cards 28 are to be plotted.

For example, say NPW = 2 and all others are zero.

NL(1) = ϕ mesh location at which the first w is to be plotted
NL(2) = θ mesh location at which the first w is to be plotted
NL(3) = ϕ mesh location at which the second w is to be plotted
NL(4) = θ mesh location at which the second w is to be plotted

3.2 MATRIX FORMAT

Data Card Format (3I3, 6E10.3)

NR – row number
NC – column number
NL – layer number

$$\left.\begin{array}{l} A_{NR,NC,NL} \\ A_{NR,NC+1,NL} \\ A_{NR,NC+2,NL} \\ A_{NR,NC+3,NL} \\ A_{NR,NC+4,NL} \\ A_{NR,NC+5,NL} \end{array}\right\} \text{6 values in row NR, layer NL, and starting with column NC}$$

For a two-dimensional array NL = 1

A BLANK CARD OR ZERO ROW NUMBER
TERMINATES INPUT OF THE MATRIX

3.3 DIMENSION CHANGES IN SHORE

The standard dimensions of the code are set up for a maximum of

NDP = 30
NDT = 18
NLAYS = 5

If a ring problem or axisymmetric loading case with a finer mesh is desired or some other arrangement of dimensions, this can be changed easily. The following parameters are to be used:

NA = NDP + NFREE + 1
ND = NDT + 1
NF = NA + 2
NG = NDT + 3
NH = NLAYS + 1 (NLAYS = 1, 4, and 5 only),

where NFREE = number of free edges in the problem.

The following control cards for the 1108 EXEC 8 are needed:

```
@PDP, LFb, TRY TRY
-66,66
        PARAMETER NA = XX, ND = XX, NF = XX, NG = XX  NH = X
@ADD, P CHNG
```

Element CHNG, which resides on an ELT symbolic element in the SHORE program packet, contains the following control cards which are executed when the ADD, P CHNG is encountered:

```
@FOR BNDCON,BNDCON,BNDCON
@FOR CIRC,CIRC,CIRC
@FOR SET,SET,SET
@FOR STRESS,STRESS,STRESS
```

```
@FOR SAVE1,SAVE1,SAVE1
@FOR INELST,INELST,INELST
@FOR PLTNG.PLTNG,PLTNG
@FOR PRNT,PRNT,PRNT
@FOR RDINPT,RDINPT,RDINPT
@FOR SHORE,SHORE,SHORE
@FOR SURLDS,SURLDS,SURLDS
```

Each of the programs in this list is recompiled to change the dimensions.

Section 4
SAMPLE PROBLEMS

4.1 AXISYMMETRIC ELASTIC-PLASTIC CYLINDER

This is a relatively simple problem that illustrates the strain hardening plasticity option and the fracture criterion. The geometry material properties, and modeling of the shell are described below.

Shell Geometry:

radius = 3 in.
length = 6 in.
simple support boundary conditions loading, axisymmetric and uniform = 0.058 psi-sec (impulse)

Material Properties

modulus = $10. \times 10^6$ psi
yield = $40. \times 10^3$ psi
strain hardening modulus = $1. \times 10^6$ psi
fracture stress = $60. \times 10^3$ psi

Modeling:

20 segments along the length, time step = 1×10^{-6} sec

The first listing illustrates the data cards; the second listing illustrates the printed output followed by the plotted output.

4.2 ASYMMETRIC CYLINDER (NONLINEAR ELASTIC-PERFECTLY PLASTIC)

This sample problem is slightly more complex then the proceeding one because the loading is asymmetric and the code is slightly modified to take advantage of symmetry. The object of this computation was to compute the permanent deformation of a cylinder tested by SRI [13]. The loading is uniform along the length so the problem is symmetric about the midplane. Therefore, the shell length is input as half the actual shell length, and the boundary conditions are specified as symmetric at the midplane. In addition, the subroutine BNDCON is modified slightly so that the stress resultants also obey the symmetry conditions at the midplane. This is seen in the listing of the input data. The modification to BNDCON is not absolutely necessary, but from experience it has been found that this produces a more accurate satisfication of the boundary conditions. This illustrates the philosophy discussed in Section 1 that one must study the answers obtained and be prepared to "nudge" the code into the best solution obtainable.

The shell geometry, material properties, and modeling are listed below.

Shell Geometry:

radius = 3 in.
length = 6 in. (actual) → 3 in. (input)
clamped boundaries at $x = 0$
symmetry at $x = L/2$
loading impulse $= 0.122 \cos \theta \sim$ psi-sec $(0 \leq \theta \leq \pi/2)$
$= 0 \quad (\pi/2 \leq \theta < \pi)$

Material Properties (Elastic-Perfectly Plastic)

modulus $= 10. \times 10^6$ psi
shear modulus $= 4. \times 10^6$ psi
uniaxial yield $= 45. \times 10^3$ psi
shear yield $= 26. \times 10^3$ psi

Modeling

10 segments along the length
18 segments along one half the circumference
time step = $1. \times 10^{-6}$ sec

The first listing illustrates the input data cards. The second listing illustrates the printed output (not all the print out times are shown) followed by the plotted output.

```
@LOG      DD33015233  D PS JNDERWOOD 5233 2U5 45511
@DELETE,C SHORE.
@ASG,T SHORE,,T,51410
@ASG,T NUT1,,D4/1792
@USE 31,NUT1
@ASG,T NUT2,,D/5376
@USE 32,NUT2
@ASG,T NUT3,,D/1792
@USE 33,NUT3
@ADD SYS$*ASGS,
@S,PIC
@COPIN SHORE,,TPFS,
@FREE SHORE.
@XQT
     SHORE   AXISYMMETRIC  CHECK    ELASTIC PLASTIC
   ELASTIC  PLASTIC    H = 1000000,
   20    0    4    3    0    0    C    0    0    1    1    C
    1    3    3    1    1    3    3    1    1    1
    1    C    1    1    0    1    1    0    0    0    0
   6,C       ,1       ,3       ,3       160,      0,0
+10.    +06+10,   +06+4,    +06+40,   +03+40,   +03+23.   +03
+40.    +03+1,    +06     1
+60.    +03+60,   +03+60,   +03+60,   +03+60,   +03
   .058
+1,     -06+200,  -06+50,   -06    2,
+2,     -06      5
   3,0    +10,    +10    ,1      1,57078
    4    4    0    4    4    4    4    0    0    4    4    4
    4
    1    1    3    1    6    1   11    1    1    1    3    1
    6    1   11    1    1    1    3    1    6    1   11    1
    1    1    3    1    6    1   11    1    1    1    3    1
    6    1   11    1    1    1    3    1    6    1   11    1
    1    1    3    1    6    1   11    1    1    1    3    1
    6    1   11    1    1    1    3    1    6    1   11    1
    1    1    3    1    6    1   11    1
001   RADIAL DISPLACEMENT AT X = 0,0 INCHES
002   RADIAL DISPLACEMENT AT X = 0,6 INCHES
003   RADIAL DISPLACEMENT AT X = 1,5 INCHES
004   RADIAL DISPLACEMENT AT X = 3,0 INCHES
005  MERIDIONAL DISPLACEMENT AT X = 0,15 INCHES
006  MERIDIONAL DISPLACEMENT AT X = 0,75 INCHES
007  MERIDIONAL DISPLACEMENT AT X = 1,65 INCHES
008  MERIDIONAL DISPLACEMENT AT X = 3,15 INCHES
009  OUTER FIBER MERD. STRAIN AT X = 0.0 INCHES
010  OUTER FIBER MERD. STRAIN AT X = 0.6 INCHES
011  OUTER FIBER MERD. STRAIN AT X = 1.5 INCHES
012  OUTER FIBER MERD. STRAIN AT X = 3.C INCHES
013  INNER FIBER MERD. STRAIN AT X = 0.0 INCHES
014  INNER FIBER MERD. STRAIN AT X = 0.6 INCHES
015  INNER FIBER MERD. STRAIN AT X = 1.5 INCHES
016  INNER FIBER MERD. STRAIN AT X = 3.0 INCHES
017  OUTER FIBER CIRC. STRAIN AT X = 0.0 INCHES
018  OUTER FIBER CIRC. STRAIN AT X = 0.6 INCHES
019  OUTER FIBER CIRC. STRAIN AT X = 1.5 INCHES
020  OUTER FIBER CIRC. STRAIN AT X = 3.C INCHES
021  INNER FIBER CIRC. STRAIN AT X = 0.C INCHES
022  INNER FIBER CIRC. STRAIN AT X = 0.6 INCHES
023  INNER FIBER CIRC. STRAIN AT X = 1.5 INCHES
024  INNER FIBER CIRC. STRAIN AT X = 3.0 INCHES
025  OUTER FIBER MERD. STRESS AT X = 0.C INCHES
```

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026  OUTER FIBER MERD. STRESS AT X = 0.6 INCHES
027  OUTER FIBER MERD. STRESS AT X = 1.5 INCHES
028  OUTER FIBER MERD. STRESS AT X = 3.0 INCHES
029  INNER FIBER MERD. STRESS AT X = 0.0 INCHES
030  INNER FIBER MERD. STRESS AT X = 0.6 INCHES
031  INNER FIBER MERD. STRESS AT X = 1.5 INCHES
032  INNER FIBER MERD. STRESS AT X = 3.0 INCHES
033  OUTER FIBER CIRC. STRESS AT X = 0.0 INCHES
034  OUTER FIBER CIRC. STRESS AT X = 0.6 INCHES
035  OUTER FIBER CIRC. STRESS AT X = 1.5 INCHES
036  OUTER FIBER CIRC. STRESS AT X = 3.0 INCHES
037  INNER FIBER CIRC. STRESS AT X = 0.0 INCHES
038  INNER FIBER CIRC. STRESS AT X = 0.6 INCHES
039  INNER FIBER CIRC. STRESS AT X = 1.5 INCHES
040  INNER FIBER CIRC. STRESS AT X = 3.0 INCHES

@FIN
```

```
      SHORE    AXISYMMETRIC  CHECK     ELASTIC PLASTIC
   ELASTIC  PLASTIC     H = 1000000.



                       LINEAR KINEMATICS
                                ONE LAYER SHELL


N DELTA X            =   20
N DELTA THETA        =    0
N LAYERS             =    4
BOUNDARY CONDITIONS  =    1     3     3     1     1     3     3     1     1     1
IMPULSE  CONDITION   =    3
THERMAL  CONDITION   =    0
LENGTH                =    6.0000 IN.
DENSITY               =     .1000 LB/CU. IN.
POISSONS RATIOS  X,T =     .3000       .3000
ANGLE DEFINING BOUNDARY =     .1800+03 DEGREES
ELASTIC MODULI          X,T,S =       .100+08      .100+08      .400+07 PSI
YIELD STRESSES          X,T,S =       .400+05      .400+05      .230+05 PSI
FRACTURE STRESSES       XC,XT,TC,TT,S =      .600+05      .600+05      .600+05      .600+05      .600+05 PSI

EFFECTIVE YIELD STRESS   =      .400+05 PSI
STRAIN HARDENING MODULUS   =      .100+07 PSI
PLASTICITY FORMULATION   1
THERMAL EXPANSION COEFFS,  X,T =      .000         .000
MAXIMUM IMPULSE =       .05800 PSI-SEC.
WAVE VELOCITY   =    .0000     FT/SEC.
INCIDENCE ANGLE =    .0000     RADIANS


DAMPING COEFFICIENT =     .0005    LBF-SEC/IN**3


DELTA TIME =    1.00000 MICROSEC.(INPUT)
TOTAL TIME =      .20000 MILLISEC.
PRINT TIME =   5.00000 MICROSEC.
PLOT TIME =   2.00000 MIRCOSEC.
PLOTTING WILL START WITH       .2000+01    SECONDS LEFT


AXISYMMETRIC CASE ?  YES




MERIDIONAL DISPLACEMENT PRINT OUT ?  YES
CIRCUMFERENTIAL DISPLACEMENT PRINT OUT ?   NO
MERIDIONAL STRESS PRINT OUT ?  YES
CIRCUMFERENTIAL STRESS PRINT OUT ?  YES
SHEAR STRESS PRINT OUT ?   NO
MERIDIONAL STRAIN PRINT OUT ?  YES
CIRCUMFERENTIAL STRAIN PRINT OUT ?  YES
```

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SHEAR STRAIN PRINT OUT ?    NO
RADIAL PRESSURE PRINT OUT ?    NO
MERIDIONAL PRESSURE PRINT OUT ?    NO
CIRCUMFERENTIAL PRESSURE PRINT OUT ?    NO


 STA          R                 RP                PHI

   1     .3000.000+01      .10000000+12      .15707800+01
   2     .3000.000+01      .10000000+12      .15707800+01
   3     .3000.000+01      .10000000+12      .15707800+01
   4     .3000.000+01      .10000000+12      .15707800+01
   5     .3000.000+01      .10000000+12      .15707800+01
   6     .3000.000+01      .10000000+12      .15707800+01
   7     .3000.000+01      .10000000+12      .15707800+01
   8     .3000.000+01      .10000000+12      .15707800+01
   9     .3000.000+01      .10000000+12      .15707800+01
  10     .3000.000+01      .10000000+12      .15707800+01
  11     .3000.000+01      .10000000+12      .15707800+01
  12     .3000.000+01      .10000000+12      .15707800+01
  13     .3000.000+01      .10000000+12      .15707800+01
  14     .3000.000+01      .10000000+12      .15707800+01
  15     .3000.000+01      .10000000+12      .15707800+01
  16     .3000.000+01      .10000000+12      .15707800+01
  17     .3000.000+01      .10000000+12      .15707800+01
  18     .3000.000+01      .10000000+12      .15707800+01
  19     .3000.000+01      .10000000+12      .15707800+01
  20     .3000.000+01      .10000000+12      .15707800+01
  21     .3000.000+01      .10000000+12      .15707800+01
  22     .3000.000+01      .10000000+12      .15707800+01
  23     .3000.000+01      .10000000+12      .15707800+01

T(1) =    .1000+00 INCHES
```

```
THICKNESS DISTRIBUTION

1  1  1    -.500000-01    -.500000-01    -.500000-01    -.500000-01    -.500000-01    -.500000-01
1  7  1    -.500000-01    -.500000-01    -.500000-01    -.500000-01    -.500000-01    -.500000-01
1 13  1    -.500000-01    -.500000-01    -.500000-01    -.500000-01    -.500000-01    -.500000-01
1 19  1    -.500000-01    -.500000-01    -.500000-01
2  1  1     .500000-01     .500000-01     .500000-01     .500000-01     .500000-01     .500000-01
2  7  1     .500000-01     .500000-01     .500000-01     .500000-01     .500000-01     .500000-01
2 13  1     .500000-01     .500000-01     .500000-01     .500000-01     .500000-01     .500000-01
2 19  1     .500000-01     .500000-01     .500000-01
3  1  1     .000000        .000000        .000000        .000000        .000000        .000000
3  7  1     .000000        .000000        .000000        .000000        .000000        .000000
3 13  1     .000000        .000000        .000000        .000000        .000000        .000000
3 19  1     .000000        .000000        .000000
4  1  1     .000000        .000000        .000000        .000000        .000000        .000000
4  7  1     .000000        .000000        .000000        .000000        .000000        .000000
4 13  1     .000000        .000000        .000000        .000000        .000000        .000000
4 19  1     .000000        .000000        .000000

NPLT =   5


   NPW =   4
   NPU =   4
   NPV =   0
   NPEMO =   4
   NPEMI =   4
   NPECO =   4
   NPECI =   4
   NPETO =   0
   NPETI =   0
   NPSMO =   4
   NPSMI =   4
   NPSCO =   4
   NPSCI =   4
   NPSTO =   0
   NPSTI =   0
   NPMM =  0
   NPMC =  0
   NPMT =  0
   NPNM =  0
   NPNC =  0
   NPNT =  0
NL PLOT ARRAY
   1    1    3    1    6    1   11    1    1    1    3    1
   6    1   11    1    1    1    3    1    6    1   11    1
   1    1    3    1    6    1   11    1    1    1    3    1
   6    1   11    1    1    1    3    1    6    1   11    1
   1    1    3    1    6    1   11    1    1    1    3    1
   6    1   11    1    1    1    3    1    6    1   11    1
   1    1    3    1    6    1   11    1
```

```
              SHORE   AXISYMMETRIC  CHECK     ELASTIC PLASTIC
            ELASTIC  PLASTIC    H = 1000000.

        RADIAL DISPLACEMENTS                  TIME =  .0010 MILLISEC.

           X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
    THETA
       .00        .000      -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02
           X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
    THETA
       .00       -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02   -.224-02
           X      .600+01
    THETA
       .00        .000

    MERIDIONAL DISPLACEMENTS                 TIME =  .0010

           X      .150+00    .450+00    .750+00    .105+01    .135+01    .165+01    .195+01    .225+01    .255+01    .285+01
    THETA
       .00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
           X      .315+01    .345+01    .375+01    .405+01    .435+01    .465+01    .495+01    .525+01    .555+01    .585+01
    THETA
       .00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
           X      .615+01
    THETA
       .00        .000

    INNER FIBER MERIDIONAL STRESSES          TIME =  .0010

           X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
    THETA
       .00       -.133-01    .112+05   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04
           X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
    THETA
       .00       -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04    .112+05
           X      .600+01
    THETA
       .00        .123-03
```

```
OUTER FIBER MERIDIONAL STRESSES            TIME =  .0010


          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00          .133-01   -.141+05   -.245+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00         -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.246+04   -.161+05
          X      .600+01
THETA
    .00         -.123-03


INNER FIBER CIRCUMFERENTIAL STRESSES            TIME =  .0010


          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00         -.243-01   -.410+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00         -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.410+04
          X      .600+01
THETA
    .00          .204-01


OUTER FIBER CIRCUMFERENTIAL STRESSES            TIME =  .0010


          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00          .243-01   -.123+05   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00         -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.820+04   -.123+05
          X      .600+01
THETA
    .00         -.214-01


INNER FIBER MERIDIONAL STRAINS            TIME =  .0010
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              X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00           -.598-09    .124-02   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13
              X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00           -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13    .124-02
              X      .600+01
THETA
    .00           -.598-09


OUTER FIBER MERIDIONAL STRAINS            TIME =  .0010


              X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00            .598-09   -.124-02   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13
              X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00           -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.224-13   -.124-02
              X      .600+01
THETA
    .00            .598-09


INNER FIBER CIRCUMFERENTIAL STRAINS            TIME =  .0010


              X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00           -.203-08   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03
              X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00           -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03
              X      .600+01
THETA
    .00            .203-08


OUTER FIBER CIRCUMFERENTIAL STRAINS            TIME =  .0010


              X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00            .203-08   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03   -.746-03
```

```
         X     .300+01   .330+01   .360+01   .390+01   .420+01   .450+01   .480+01   .510+01   .540+01   .570+01
 THETA
     .00      -.746-03  -.746-03  -.746-03  -.746-03  -.746-03  -.746-03  -.746-03  -.746-03  -.746-03  -.746-03
         X     .600+01
 THETA
     .00      -.203-08
```

```
                                        TIME =  .0010 MILLISEC.
DATA AT  X = L/2, THETA = 0 DEGREES

    U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .000       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

        SUBLAYER STRAINS AND STRESSES

     EPP =   -.2239-13   -.2239-13   -.2239-13   -.2239-13   -.2239-13
     EPT =   -.7463-03   -.7463-03   -.7463-03   -.7463-03   -.7463-03
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =   -.2460+04   -.2460+04   -.2460+04   -.2460+04   -.2460+04
      ST =   -.8201+04   -.8201+04   -.8201+04   -.8201+04   -.8201+04
     TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = 0, THETA = 0 DEGREES

    U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .000       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

        SUBLAYER STRAINS AND STRESSES

     EPP =   -.5982-09   -.2991-09    .0000       .2991-09    .5982-09
     EPT =   -.2031-08   -.1016-08    .0000       .1016-08    .2031-08
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =   -.1327-01   -.6636-02    .0000       .6636-02    .1327-01
      ST =   -.2430-01   -.1215-01    .0000       .1215-01    .2430-01
     TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = L/2, THETA = THD/2 DEGREES

    U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .000       .000     -.224-02   -.246+03   -.820+03    .000       .000     -.795-08   -.318-07    .000       .000

        SUBLAYER STRAINS AND STRESSES

     EPP =    .0000       .0000       .0000       .0000       .0000
     EPT =    .0000       .0000       .0000       .0000       .0000
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =    .0000       .0000       .0000       .0000       .0000
      ST =    .0000       .0000       .0000       .0000       .0000
     TTP =    .0000       .0000       .0000       .0000       .0000
```

```
          SHORE   AXISYMMETRIC  CHECK     ELASTIC PLASTIC
        ELASTIC  PLASTIC     H = 1500000.

    RADIAL DISPLACEMENTS                 TIME =  .0500 MILLISEC.

           X     .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00         .000     -.191-01   -.853-01   -.784-01   -.688-01   -.650-01   -.652-01   -.651-01   -.673-01   -.671-01
           X     .300+01   .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00        -.671-01  -.671-01   -.673-01   -.651-01   -.652-01   -.650-01   -.688-01   -.784-01   -.653-01   -.191-01
           X     .600+01
THETA
     .00         .000

MERIDIONAL DISPLACEMENTS                TIME =  .0500

           X     .150+00   .450+00    .750+00    .105+01    .135+01    .165+01    .195+01    .225+01    .255+01    .285+01
THETA
     .00        -.290-01  -.235-01   -.224-01   -.230-01   -.176-01   -.143-01   -.129-01   -.525-02   -.537-02   -.171-02
           X     .315+01   .345+01    .375+01    .405+01    .435+01    .465+01    .495+01    .525+01    .555+01    .565+01
THETA
     .00         .171-02   .537-02    .525-02    .129-01    .140-01    .176-01    .230-01    .224-01    .235-01    .290-01
           X     .615+01
THETA
     .00         .290-01

INNER FIBER MERIDIONAL STRESSES         TIME =  .0500

           X     .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00        -.133+00   .000       .000       .000       .000       .000       .000       .000       .000       .000
           X     .300+01   .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00         .000      .000       .000       .000       .000       .000       .000       .000       .000       .000
           X     .600+01
THETA
     .00        -.333-02
```

```
OUTER FIBER MERIDIONAL STRESSES           TIME =  .0500


          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00         .941-01    .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00         .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .600+01
THETA
     .00        -.512-02


INNER FIBER CIRCUMFERENTIAL STRESSES           TIME =  .0500


          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00        -.179+01    .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00         .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .600+01
THETA
     .00         .175+01


OUTER FIBER CIRCUMFERENTIAL STRESSES           TIME =  .0500


          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00        -.138+01    .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00         .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .600+01
THETA
     .00         .140+01


INNER FIBER MERIDIONAL STRAINS           TIME =  .0500
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```
            X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
      .00          .404-07   -.783-02    .442-01   -.654-03    .149-01    .984-02    .365-02    .213-01    .695-03    .121-01
            X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
      .00          .114-01    .121-01    .895-03    .243-01    .365-02    .984-02    .149-01   -.655-03    .442-01   -.783-02
            X      .600+01
THETA
      .00         -.528-07

OUTER FIBER MERIDIONAL STRAINS             TIME =  .0500

            X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
      .00          .507-07    .445-01   -.370-01   -.348-02    .214-01    .145-01    .319-02    .270-01   -.171-02    .122-01
            X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
      .00          .115-01    .122-01   -.171-02    .270-01    .319-02    .145-01    .214-01   -.348-02   -.370-01    .445-01
            X      .600+01
THETA
      .00         -.426-07

INNER FIBER CIRCUMFERENTIAL STRAINS             TIME =  .0500

            X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
      .00         -.175-06   -.637-02   -.284-01   -.261-01   -.229-01   -.217-01   -.217-01   -.217-01   -.224-01   -.224-01
            X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
      .00         -.224-01   -.224-01   -.224-01   -.217-01   -.217-01   -.217-01   -.229-01   -.261-01   -.284-01   -.637-02
            X      .600+01
THETA
      .00          .175-06

OUTER FIBER CIRCUMFERENTIAL STRAINS             TIME =  .0500

            X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
      .00         -.140-06   -.637-02   -.284-01   -.261-01   -.229-01   -.217-01   -.217-01   -.217-01   -.224-01   -.224-01
```

```
            X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00           -.224-01   -.224-01   -.224-01   -.217-01   -.217-01   -.217-01   -.229-01   -.241-01   -.284-01   -.637-02
            X      .600+01
THETA
    .00            .140-06
```

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                                                TIME =  .2500 MILLISEC.
DATA AT  X = L/2, THETA = 0 DEGREES

     U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

   .000        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

         SUBLAYER STRAINS AND STRESSES

     EPP =     .1213-01    .1216-01    .1219-01    .1221-01    .1224-01
     EPT =    -.2238-01   -.2238-01   -.2238-01   -.2238-01   -.2235-01
     GPT =     .0000       .0000       .0000       .0000       .0000
      SX =     .0000       .0000       .0000       .0000       .0000
      ST =     .0000       .0000       .0000       .0000       .0000
     TTP =     .0000       .0000       .0000       .0000       .0000

DATA AT  X = 0, THETA = 0 DEGREES

     U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

   .000        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

         SUBLAYER STRAINS AND STRESSES

     EPP =     .4045-07    .4301-07    .4556-07    .4812-07    .5068-07
     EPT =    -.1751-06   -.1664-06   -.1578-06   -.1491-06   -.1404-06
     GPT =     .0000       .0000       .0000       .0000       .0000
      SX =    -.1328+00   -.7607-01   -.1936-01    .3735-01    .9406-01
      ST =    -.1791+01   -.1687+01   -.1583+01   -.1480+01   -.1376+01
     TTP =     .0000       .0000       .0000       .0000       .0000

DATA AT  X = L/2, THETA = TH0/2 DEGREES

     U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

   .000        .000     -.671-01       .000        .000        .000        .000        .000        .000        .000        .000

         SUBLAYER STRAINS AND STRESSES

     EPP =     .0000       .0000       .0000       .0000       .0000
     EPT =     .0000       .0000       .0000       .0000       .0000
     GPT =     .0000       .0000       .0000       .0000       .0000
      SX =     .0000       .0000       .0000       .0000       .0000
      ST =     .0000       .0000       .0000       .0000       .0000
     TTP =     .0000       .0000       .0000       .0000       .0000
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           SHORE   AXISYMMETRIC  CHECK    ELASTIC PLASTIC
         ELASTIC  PLASTIC    H = 1800000.

      RADIAL DISPLACEMENTS                    TIME =  .1000 MILLISEC.

            X     .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
    THETA
       .00        .000      .147-02  -.161+00  -.147+00  -.124+00  -.115+00  -.115+00  -.115+00  -.121+00  -.120+00
            X     .300+01   .330+01   .360+01   .390+01   .420+01   .450+01   .480+01   .510+01   .540+01   .570+01
    THETA
       .00      -.120+00  -.120+00  -.121+00  -.115+00  -.115+00  -.115+00  -.124+00  -.117+00  -.161+00   .166-02
            X     .600+01
    THETA
       .00        .000


    MERIDIONAL DISPLACEMENTS                  TIME =  .1000


            X     .150+00   .450+00   .750+00   .105+01   .135+01   .165+01   .195+01   .225+01   .255+01   .285+01
    THETA
       .00      -.659-01  -.510-01  -.510-01  -.544-01  -.414-01  -.329-01  -.313-01  -.118-01  -.130-01  -.415-02
            X     .315+01   .345+01   .375+01   .405+01   .435+01   .465+01   .495+01   .525+01   .555+01   .585+01
    THETA
       .00        .415-02   .130-01   .118-01   .313-01   .329-01   .414-01   .544-01   .510-01   .510-01   .655-01
            X     .615+01
    THETA
       .00        .655-01


    INNER FIBER MERIDIONAL STRESSES           TIME =  .1000


            X     .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
    THETA
       .00      -.343-01   .000      .000      .000      .000      .000      .000      .000      .000      .000
            X     .300+01   .330+01   .360+01   .390+01   .420+01   .450+01   .480+01   .510+01   .540+01   .570+01
    THETA
       .00        .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
            X     .600+01
    THETA
       .00      -.943-02
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OUTER FIBER MERIDIONAL STRESSES           TIME =  .1000


         X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00      -.545-01     .000       .000       .000       .000       .000       .000       .000       .000       .000
         X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
         X      .600+01
THETA
     .00      -.966-02

INNER FIBER CIRCUMFERENTIAL STRESSES           TIME =  .1000


         X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00      -.356+01     .000       .000       .000       .000       .000       .000       .000       .000       .000
         X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
         X      .600+01
THETA
     .00       .355+01

OUTER FIBER CIRCUMFERENTIAL STRESSES           TIME =  .1000


         X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00      -.360+01     .000       .000       .000       .000       .000       .000       .000       .000       .000
         X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
     .00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
         X      .600+01
THETA
     .00       .358+01

INNER FIBER MERIDIONAL STRAINS           TIME =  .1000
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       X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .160+01    .210+01    .240+01    .270+01
THETA
   .00        .103-06    -.431-01   .980-01    -.639-02   .361-01    .227-01    .592-02    .615-01    -.630-03   .295-01

       X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
   .00        .275-01    .295-01    -.629-03   .615-01    .592-02    .227-01    .361-01    -.639-02   .980-01    -.431-01

       X      .600+01
THETA
   .00        -.107-06


OUTER FIBER MERIDIONAL STRAINS          TIME =  .1000


       X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .160+01    .210+01    .240+01    .270+01
THETA
   .00        .102-06    .139+00    -.974-01   -.166-01   .506-01    .341-01    .480-02    .685-01    -.761-02   .298-01

       X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
   .00        .278-01    .298-01    -.761-02   .685-01    .480-02    .341-01    .506-01    -.166-01   -.974-01   .139+00

       X      .600+01
THETA
   .00        -.108-06


INNER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .1000


       X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
   .00        -.355-06   .555-03    -.536-01   -.491-01   -.415-01   -.382-01   -.384-01   -.383-01   -.403-01   -.402-01

       X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .460+01    .510+01    .540+01    .570+01
THETA
   .00        -.401-01   -.402-01   -.403-01   -.393-01   -.384-01   -.352-01   -.415-01   -.491-01   -.536-01   .555-03

       X      .600+01
THETA
   .00        .355-06


OUTER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .1000


       X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
   .00        -.358-06   .555-03    -.536-01   -.491-01   -.415-01   -.342-01   -.364-01   -.383-01   -.403-01   -.402-01
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          X      .300+01   .330+01   .360+01   .390+01   .420+01   .450+01   .480+01   .510+01   .540+01   .570+01
THETA
     .00        -.401-01  -.402-01  -.403-01  -.393-01  -.384-01  -.392-01  -.415-01  -.451-01  -.536-01   .555-03

          X      .600+01
THETA
     .00         .358-06
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                                            TIME =  .1000 MILLISEC.
DATA AT  X = L/2. THETA = 0 DEGREES

    U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  .000        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

          SUBLAYER STRAINS AND STRESSES

     EPP =    .2952-01    .2958-01    .2965-01    .2972-01    .2978-01
     EPT =   -.4016-01   -.4016-01   -.4016-01   -.4016-01   -.4016-01
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =    .0000       .0000       .0000       .0000       .0000
      ST =    .0000       .0000       .0000       .0000       .0000
     TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = 0. THETA = 0 DEGREES

    U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  .000        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

          SUBLAYER STRAINS AND STRESSES

     EPP =    .1033-06    .1031-06    .1029-06    .1026-06    .1024-06
     EPT =   -.3549-06   -.3556-06   -.3564-06   -.3571-06   -.3579-06
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =   -.3432-01   -.3935-01   -.4439-01   -.4942-01   -.5446-01
      ST =   -.3559+01   -.3568+01   -.3577+01   -.3586+01   -.3595+01
     TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = L/2. THETA = TH0/2 DEGREES

    U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  .000        .000      -.120+00      .000        .000        .000        .000        .000        .000        .000        .000

          SUBLAYER STRAINS AND STRESSES

     EPP =    .0000       .0000       .0000       .0000       .0000
     EPT =    .0000       .0000       .0000       .0000       .0000
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =    .0000       .0000       .0000       .0000       .0000
      ST =    .0000       .0000       .0000       .0000       .0000
     TTP =    .0000       .0000       .0000       .0000       .0000
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```
            SHORE   AXISYMMETRIC  CHECK    ELASTIC PLASTIC
          ELASTIC  PLASTIC    R = 1000000.

      RADIAL DISPLACEMENTS                 TIME =  .1500 MILLISEC.

            X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
   THETA
       .00         .000     -.154-01   -.236+00   -.216+00   -.180+00   -.144+00   -.165+00   -.145+00   -.174+00   -.174+00
            X      .300+01   .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
   THETA
       .00        -.174+00  -.174+00   -.174+00   -.165+00   -.165+00   -.164+00   -.180+00   -.216+00   -.236+00   -.154-01
            X      .600+01
   THETA
       .00         .000

   MERIDIONAL DISPLACEMENTS                TIME =  .1500

            X      .150+00   .450+00    .750+00    .105+01    .135+01    .165+01    .195+01    .225+01    .255+01    .285+01
   THETA
       .00        -.994-01  -.811-01   -.795-01   -.858-01   -.652-01   -.518-01   -.497-01   -.184-01   -.207-01   -.658-02
            X      .315+01   .345+01    .375+01    .405+01    .435+01    .465+01    .495+01    .525+01    .555+01    .585+01
   THETA
       .00         .658-02   .207-01    .184-01    .497-01    .518-01    .652-01    .858-01    .795-01    .811-01    .994-01
            X      .615+01
   THETA
       .00         .994-01

   INNER FIBER MERIDIONAL STRESSES         TIME =  .1500

            X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
   THETA
       .00        -.159+00   .000       .000       .000       .000       .000       .000       .000       .000       .000
            X      .300+01   .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
   THETA
       .00         .000      .000       .000       .000       .000       .000       .000       .000       .000       .000
            X      .600+01
   THETA
       .00        -.131-01
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OUTER FIBER MERIDIONAL STRESSES          TIME =  .1500


          X      .000       .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00         .240-01    .000        .000        .000        .000        .000        .000        .000        .000        .000
          X      .300+01    .330+01     .360+01     .390+01     .420+01     .450+01     .480+01     .510+01     .540+01     .570+01
THETA
     .00         .000       .000        .000        .000        .000        .000        .000        .000        .000        .000
          X      .600+01
THETA
     .00        -.149-01

INNER FIBER CIRCUMFERENTIAL STRESSES          TIME =  .1500


          X      .000       .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00        -.560+01    .000        .000        .000        .000        .000        .000        .000        .000        .000
          X      .300+01    .330+01     .360+01     .390+01     .420+01     .450+01     .480+01     .510+01     .540+01     .570+01
THETA
     .00         .000       .000        .000        .000        .000        .000        .000        .000        .000        .000
          X      .600+01
THETA
     .00         .555+01

OUTER FIBER CIRCUMFERENTIAL STRESSES          TIME =  .1500


          X      .000       .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00        -.527+01    .000        .000        .000        .000        .000        .000        .000        .000        .000
          X      .300+01    .330+01     .360+01     .390+01     .420+01     .450+01     .480+01     .510+01     .540+01     .570+01
THETA
     .00         .000       .000        .000        .000        .000        .000        .000        .000        .000        .000
          X      .600+01
THETA
     .00         .527+01

INNER FIBER MERIDIONAL STRAINS          TIME =  .1500
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```
           X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .21 +01    .240+01    .270+01
THETA
    .00          .152-06   -.530-01    .139+00   -.122-01    .573-01    .355-01    .818-02    .986-01   -.215-02    .469-01
           X     .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00          .437-01    .469-01   -.215-02    .986-01    .818-02    .355-01    .573-01   -.122-01    .139+00   -.530-01
           X     .600+01
THETA
    .00         -.168-06


OUTER FIBER MERIDIONAL STRAINS          TIME =  .1500


           X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .21 +01    .240+01    .270+01
THETA
    .00          .160-06    .175+00   -.129+00   -.295-01    .797-01    .539-01    .641-02    .11 +00   -.135-01    .473-01
           X     .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00          .440-01    .473-01   -.135-01    .110+00    .640-02    .539-01    .797-01   -.295-01   -.129+00    .175+00
           X     .600+01
THETA
    .00         -.160-06


INNER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .1500


           X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .21 +01    .240+01    .270+01
THETA
    .00         -.555-06   -.515-02   -.767-01   -.720-01   -.600-01   -.548-01   -.551-01   -.549-01   -.561-01   -.579-01
           X     .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00         -.579-01   -.579-01   -.581-01   -.549-01   -.551-01   -.548-01   -.600-01   -.720-01   -.767-01   -.515-02
           X     .600+01
THETA
    .00          .555-06


OUTER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .1500


           X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .21 +01    .240+01    .270+01
THETA
    .00         -.527-06   -.514-02   -.787-01   -.720-01   -.600-01   -.548-01   -.551-01   -.549-01   -.561-01   -.579-01
```

```
          X       .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00          -.579-01   -.579-01   -.581-01   -.549-01   -.551-01   -.544-01   -.600-01   -.7[illegible]-01   -.747-01   -.515-02

          X       .600+01
THETA
    .00           .527-06
```

```
                                                  TIME =  .1500 MILLISEC.
DATA AT  X = L/2, THETA = 0 DEGREES

    U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  .000        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

         SUBLAYER STRAINS AND STRESSES

    EPP =    .4690-01    .4701-01    .4711-01    .4722-01    .4732-01
    EPT =   -.5795-01   -.5795-01   -.5795-01   -.5795-01   -.5795-01
    GPT =    .0000       .0000       .0000       .0000       .0000
     SX =    .0000       .0000       .0000       .0000       .0000
     ST =    .0000       .0000       .0000       .0000       .0000
    TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = 0, THETA = 0 DEGREES

    U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  .000        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

         SUBLAYER STRAINS AND STRESSES

    EPP =    .1521-06    .1542-06    .1563-06    .1583-06    .1604-06
    EPT =   -.5554-06   -.5484-06   -.5414-06   -.5344-06   -.5273-06
    GPT =    .0000       .0000       .0000       .0000       .0000
     SX =   -.1592+00   -.1134+00   -.6756-01   -.2178-01    .2403-01
     ST =   -.5601+01   -.5518+01   -.5434+01   -.5350+01   -.5266+01
    TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = L/2, THETA = THD/2 DEGREES

    U           V           W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  .000        .000     -.174+00       .000        .000        .000        .000        .000        .000        .000        .000

         SUBLAYER STRAINS AND STRESSES

    EPP =    .0000       .0000       .0000       .0000       .0000
    EPT =    .0000       .0000       .0000       .0000       .0000
    GPT =    .0000       .0000       .0000       .0000       .0000
     SX =    .0000       .0000       .0000       .0000       .0000
     ST =    .0000       .0000       .0000       .0000       .0000
    TTP =    .0000       .0000       .0000       .0000       .0000
```

```
          SHORE    AXISYMMETRIC  CHECK     ELASTIC PLASTIC
       ELASTIC  PLASTIC     H = 1000000.

     RADIAL DISPLACEMENTS                   TIME =  .2000 MILLISEC.

          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
  THETA
     .00         .000      -.257-01   -.312+00   -.285+00   -.236+00   -.214+00   -.215+00   -.215+00   -.220+00   -.227+00
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
  THETA
     .00        -.227+00   -.227+00   -.228+00   -.215+00   -.215+00   -.214+00   -.236+00   -.225+00   -.312+00   -.258-01
          X      .600+01
  THETA
     .00         .000

  MERIDIONAL DISPLACEMENTS                 TIME =  .2000

          X      .150+00    .450+00    .750+00    .105+01    .135+01    .165+01    .195+01    .225+01    .255+01    .285+01
  THETA
     .00        -.134+00   -.111+00   -.118+00   -.117+00   -.891-01   -.708-01   -.680-01   -.249-01   -.284-01   -.901-02
          X      .315+01    .345+01    .375+01    .405+01    .435+01    .465+01    .495+01    .525+01    .555+01    .585+01
  THETA
     .00         .901-02    .284-01    .249-01    .680-01    .708-01    .891-01    .117+00    .118+00    .111+00    .134+00
          X      .615+01
  THETA
     .00         .134+00

  INNER FIBER MERIDIONAL STRESSES          TIME =  .2000

          X      .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
  THETA
     .00        -.244+00    .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
  THETA
     .00         .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
          X      .600+01
  THETA
     .00        -.182-01
```

```
OUTER FIBER MERIDIONAL STRESSES              TIME =  .2000


             X      .000        .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00            .615-01     .000        .000        .000        .000        .000        .000        .000        .000        .000
             X      .300+01     .330+01     .360+01     .390+01     .420+01     .450+01     .480+01     .510+01     .540+01     .570+01
THETA
     .00            .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
             X      .600+01
THETA
     .00           -.209-01


INNER FIBER CIRCUMFERENTIAL STRESSES              TIME =  .2000


             X      .000        .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00           -.760+01     .000        .000        .000        .000        .000        .000        .000        .000        .000
             X      .300+01     .330+01     .360+01     .390+01     .420+01     .450+01     .480+01     .510+01     .540+01     .570+01
THETA
     .00            .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
             X      .600+01
THETA
     .00            .753+01


OUTER FIBER CIRCUMFERENTIAL STRESSES              TIME =  .2000


             X      .000        .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00           -.705+01     .000        .000        .000        .000        .000        .000        .000        .000        .000
             X      .300+01     .330+01     .360+01     .390+01     .420+01     .450+01     .480+01     .510+01     .540+01     .570+01
THETA
     .00            .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
             X      .600+01
THETA
     .00            .706+01


INNER FIBER MERIDIONAL STRAINS              TIME =  .2000
```

```
         X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .21 +01    .240+01    .270+01
THETA
    .00         .204-06   -.642-01    .182+00   -.181-01    .784-01    .483-01    .104-01    .136+00   -.360-02    .643-01
         X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00         .598-01    .643-01   -.368-02    .136+00    .104-01    .483-01    .784-01   -.181-01    .182+00   -.662-01
         X      .600+01
THETA
    .00        -.228-06


OUTER FIBER MERIDIONAL STRAINS          TIME =  .2000


         X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .21 +01    .240+01    .270+01
THETA
    .00         .218-06    .223+00   -.166+00   -.424-01    .109+00    .737-01    .801-02    .152+00   -.194-01    .649-01
         X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .51 +01    .540+01    .570+01
THETA
    .00         .603-01    .649-01   -.194-01    .152+00    .801-02    .737-01    .109+00   -.424-01   -.166+00    .223+00
         X      .600+01
THETA
    .00        -.214-06


INNER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .2000


         X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00        -.753-06   -.858-02   -.104+00   -.949-01   -.785-01   -.714-01   -.718-01   -.715-01   -.760-01   -.757-01
         X      .300+01    .330+01    .360+01    .390+01    .420+01    .450+01    .480+01    .510+01    .540+01    .570+01
THETA
    .00        -.757-01   -.757-01   -.760-01   -.715-01   -.718-01   -.714-01   -.785-01   -.949-01   -.104+00   -.858-02
         X      .600+01
THETA
    .00         .753-06


OUTER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .2000


         X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00        -.706-06   -.858-02   -.104+00   -.949-01   -.785-01   -.714-01   -.718-01   -.715-01   -.760-01   -.757-01
```

```
         X      .300+01   .330+01   .360+01   .390+01   .420+01   .450+01   .480+01   .510+01   .540+01   .570+01
THETA
     .00       -.757-01  -.757-01  -.760-01  -.715-01  -.718-01  -.714-01  -.785-01  -.949-01  -.104+00  -.858-02
         X      .600+01
THETA
     .00        .706-06
```

```
                                             TIME =   .2000 MILLISEC.
DATA AT   X = L/2, THETA = 0 DEGREES

     U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

   .000       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

          SUBLAYER STRAINS AND STRESSES

     EPP =     .6428-01   .6443-01   .6457-01   .6472-01   .6486-01
     EPT =    -.7573-01  -.7573-01  -.7573-01  -.7573-01  -.7573-01
     GPT =     .0000      .0000      .0000      .0000      .0000
      SX =     .0000      .0000      .0000      .0000      .0000
      ST =     .0000      .0000      .0000      .0000      .0000
     TTP =     .0000      .0000      .0000      .0000      .0000

DATA AT   X = 0, THETA = 0 DEGREES

     U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

   .000       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

          SUBLAYER STRAINS AND STRESSES

     EPP =     .2037-06   .2072-06   .2106-06   .2141-06   .2175-06
     EPT =    -.7532-06  -.7415-06  -.7298-06  -.7181-06  -.7064-06
     GPT =     .0000      .0000      .0000      .0000      .0000
      SX =    -.2441+00  -.1677+00  -.9134-01  -.1494-01   .6145-01
      ST =    -.7605+01  -.7465+01  -.7326+01  -.7186+01  -.7046+01
     TTP =     .0000      .0000      .0000      .0000      .0000

DATA AT   X = L/2, THETA = TWO/2 DEGREES

     U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

   .000       .000     -.227+00     .000       .000       .000       .000       .000       .000       .000       .000

          SUBLAYER STRAINS AND STRESSES

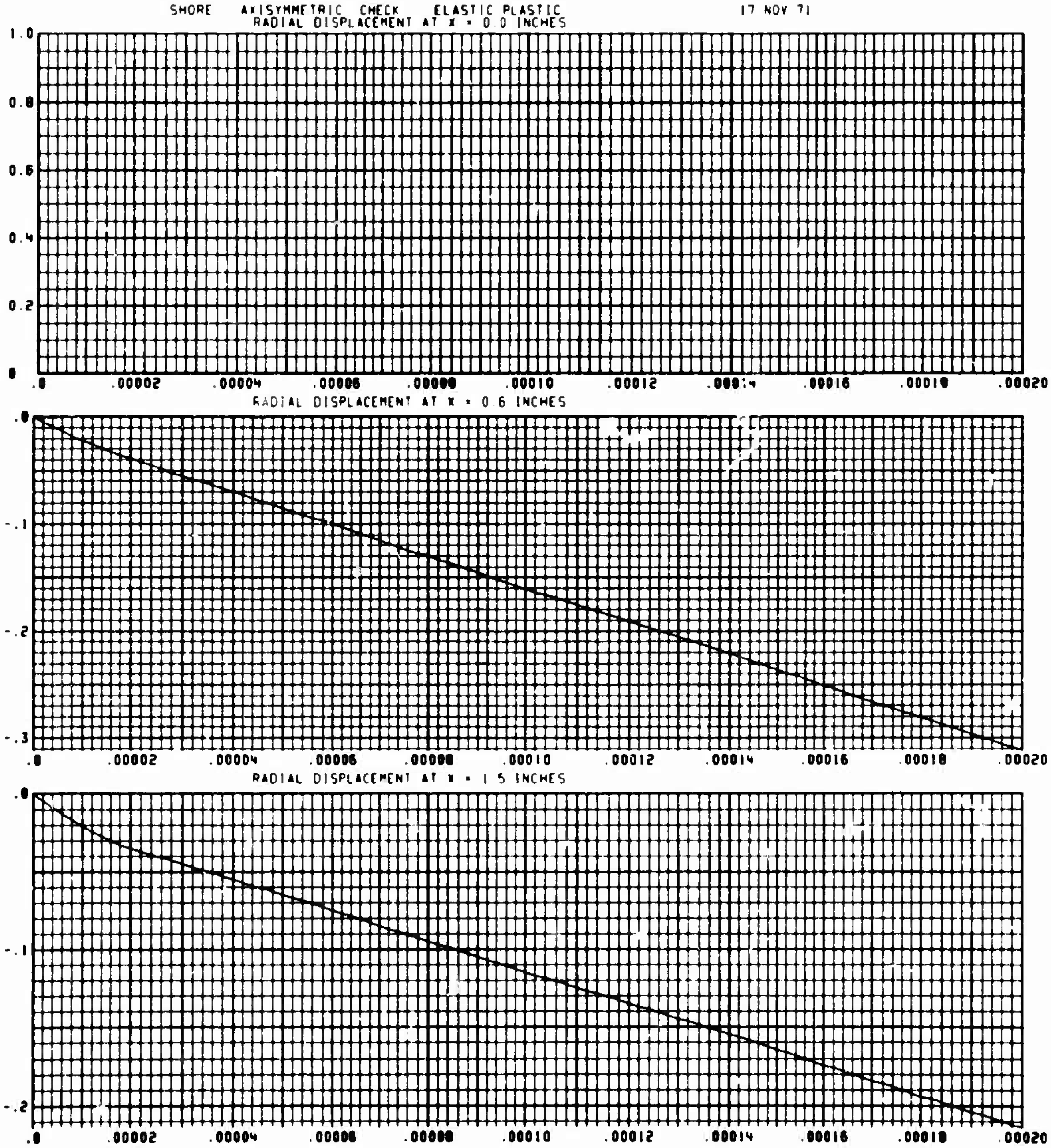
     EPP =     .0000      .0000      .0000      .0000      .0000
     EPT =     .0000      .0000      .0000      .0000      .0000
     GPT =     .0000      .0000      .0000      .0000      .0000
      SX =     .0000      .0000      .0000      .0000      .0000
      ST =     .0000      .0000      .0000      .0000      .0000
     TTP =     .0000      .0000      .0000      .0000      .0000
```

```
START SC4020 PLOTTING
PLOT 40 CURVES
FINISH PLOTTING

ELAPSED PLOT TIME =  0: 0: 2,484

@FIN


   RUNID:  B24962   ACCOUNT: R14J011008     PROJECT: 604342
DD33015233  D PG UNDERWOOD 5233 205 45511                    C
      LOAD 52344  9/4 SHORE        -1 B24962
B24962   -  PLOT O/P--R=0007, W=0014, BUFFERS=   27
PLT 50    R     14          AA604342      PLOT=2
   TIME: 00:01:23,951    IN: 96     OUT: 0        PAGES:   59
   INITIATION  TIME:   17:44:22-NOV 17,1971    CPU TIME: 00:00:57
   TERMINATION TIME:   17:44:23-NOV 17,1971    I/O TIME: 00:00:26
```



SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

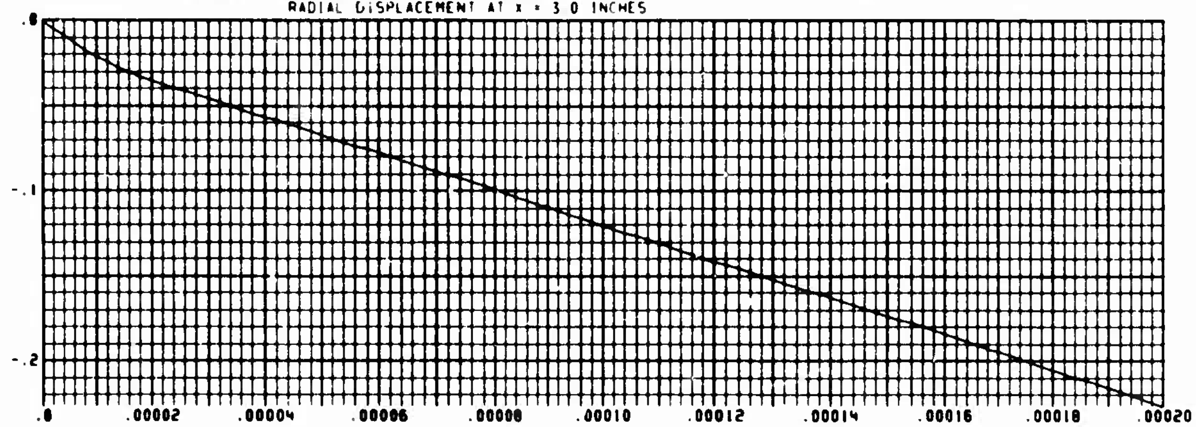
RADIAL DISPLACEMENT AT X = 0.0 INCHES

RADIAL DISPLACEMENT AT X = 0.6 INCHES

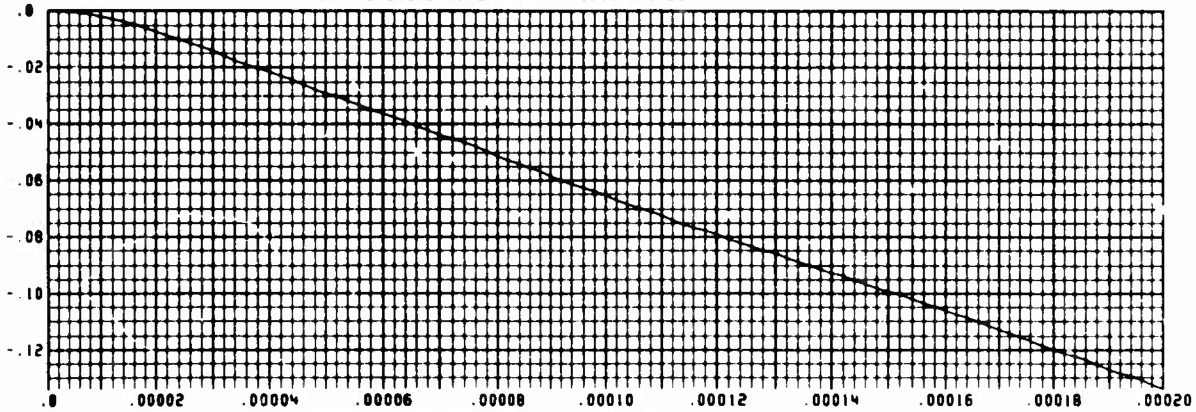
RADIAL DISPLACEMENT AT X = 1.5 INCHES

SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

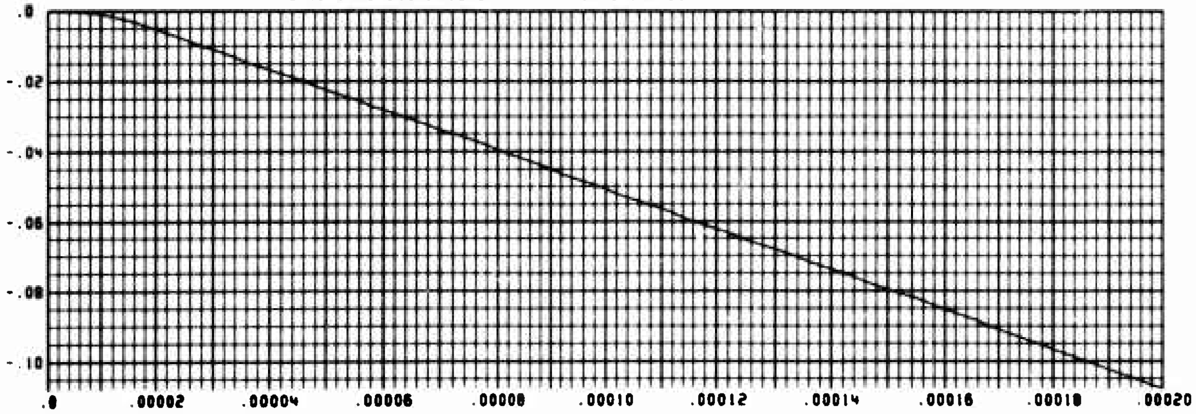
RADIAL DISPLACEMENT AT x = 3.0 INCHES



MERIDIONAL DISPLACEMENT AT x = 0.15 INCHES

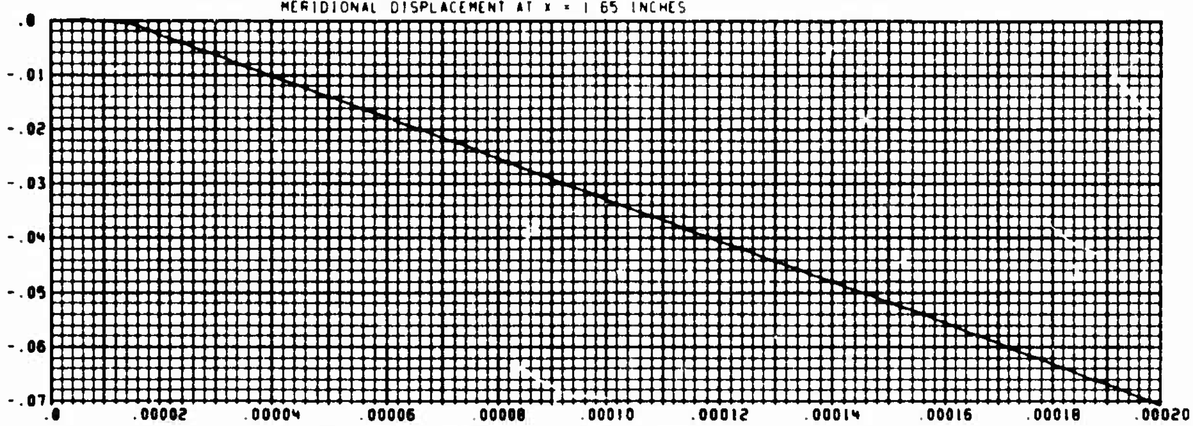


MERIDIONAL DISPLACEMENT AT x = 0.75 INCHES

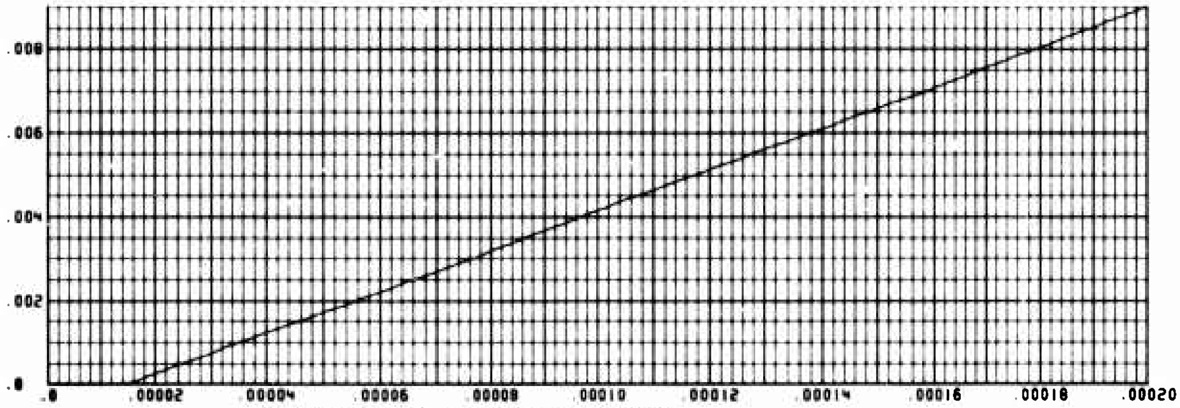


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

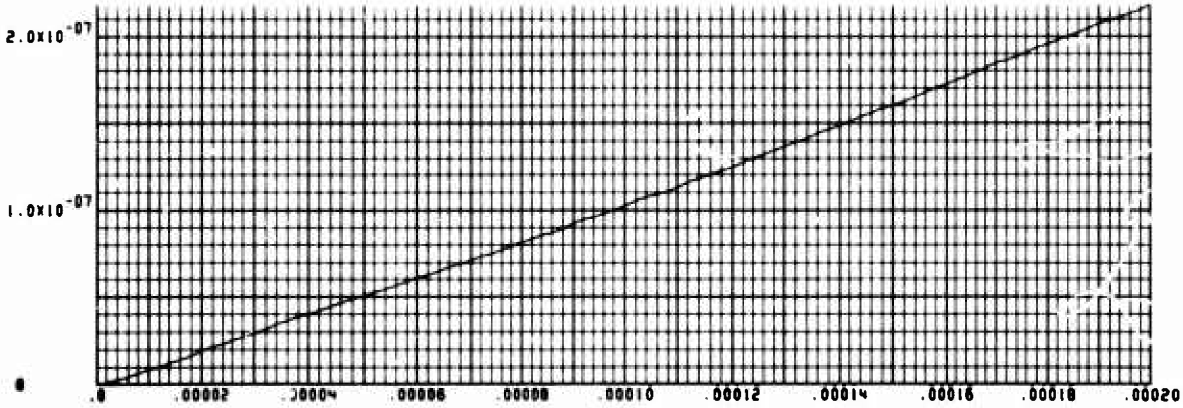
MERIDIONAL DISPLACEMENT AT X = 1.65 INCHES



MERIDIONAL DISPLACEMENT AT X = 3.15 INCHES

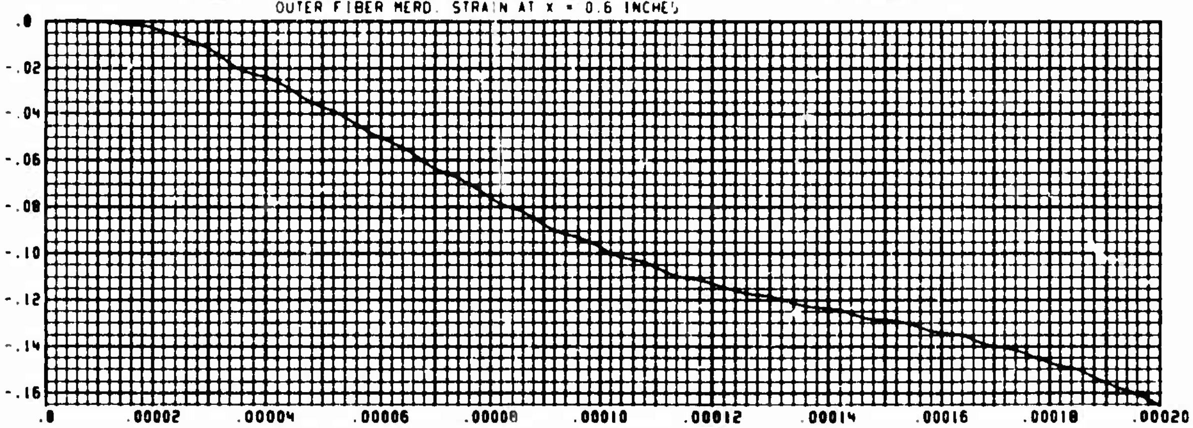


OUTER FIBER MERD. STRAIN AT X = 0.0 INCHES

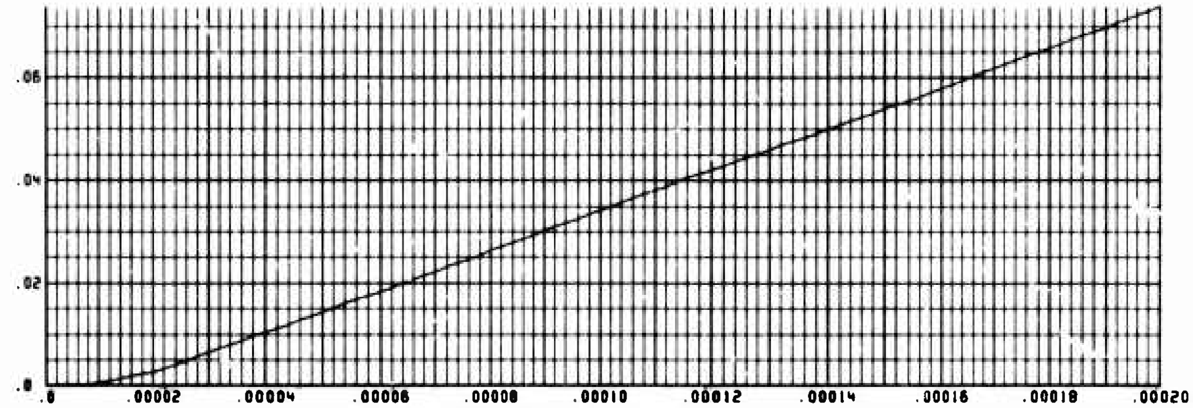


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

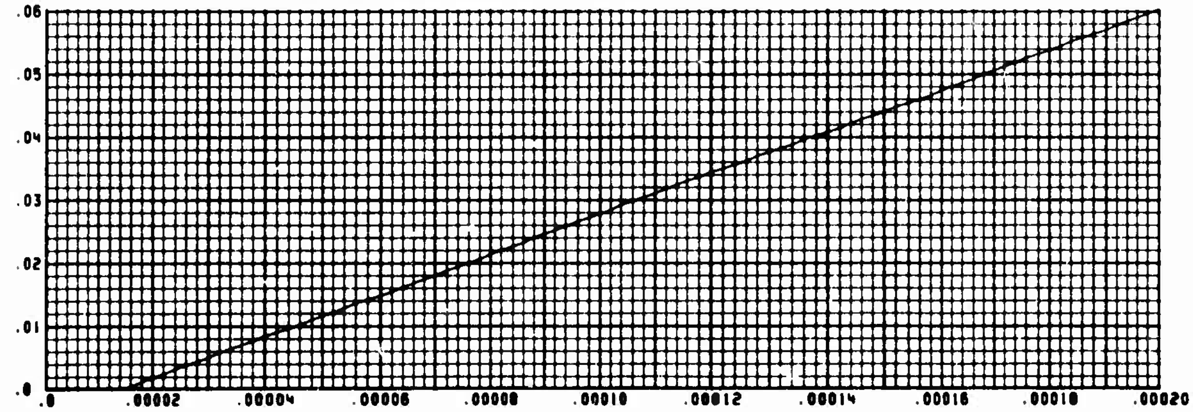
OUTER FIBER MERD. STRAIN AT X = 0.6 INCHES



OUTER FIBER MERD STRAIN AT X = 1.5 INCHES

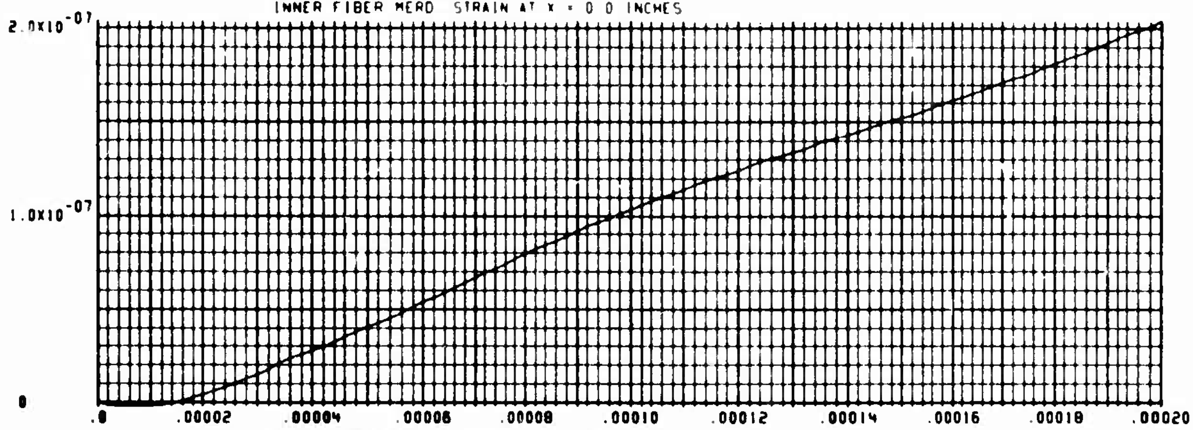


OUTER FIBER MERD STRAIN AT X = 3.0 INCHES

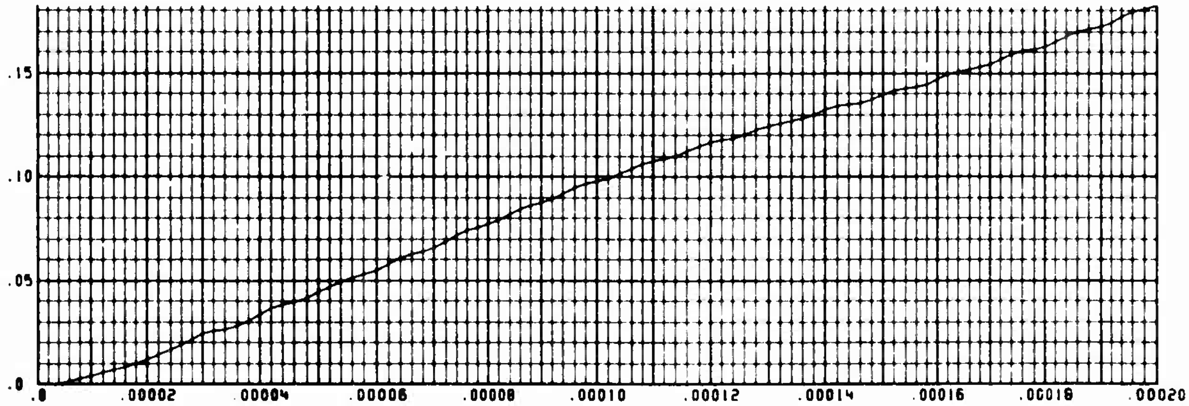


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

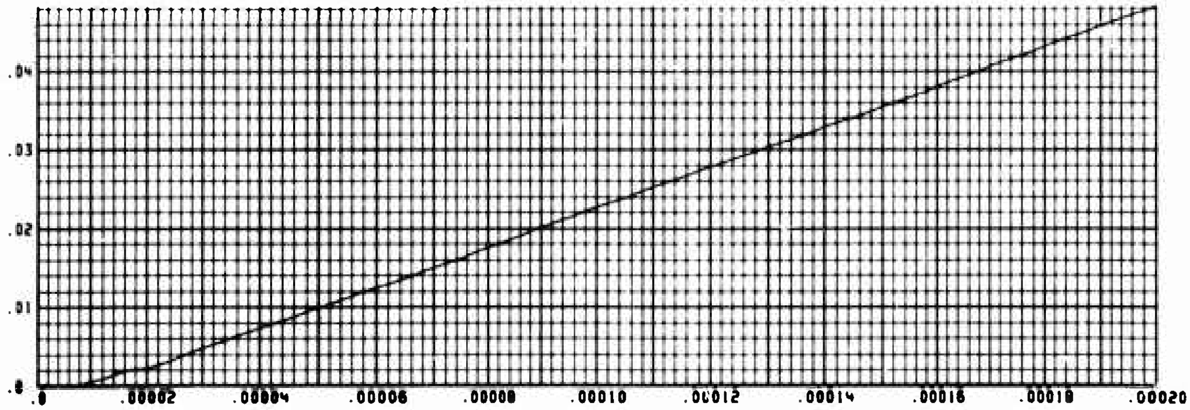
INNER FIBER MERD STRAIN AT x = 0.0 INCHES



INNER FIBER MERD STRAIN AT x = 0.6 INCHES

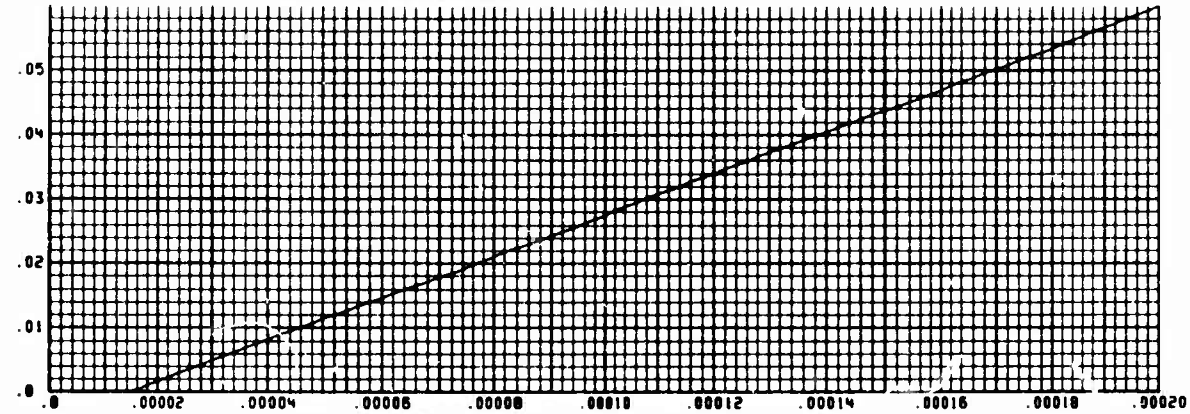


INNER FIBER MERD STRAIN AT x = 1.5 INCHES

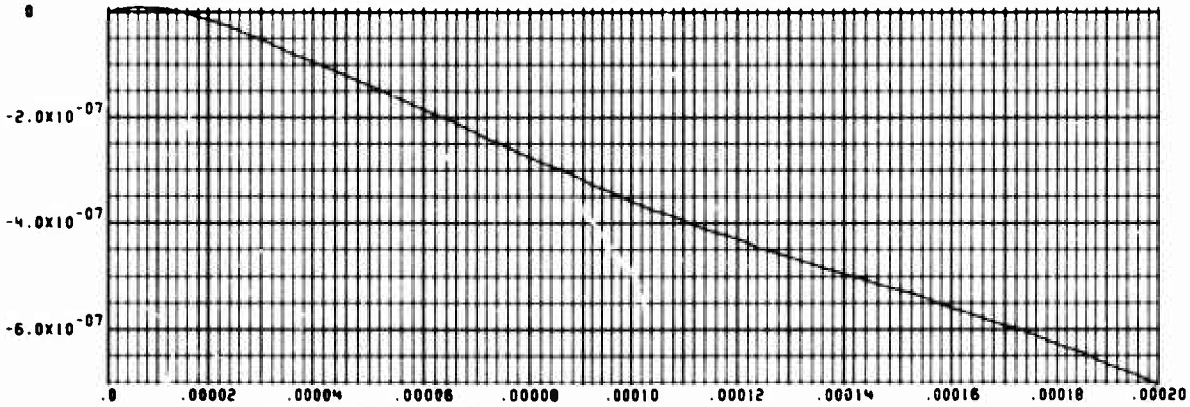


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

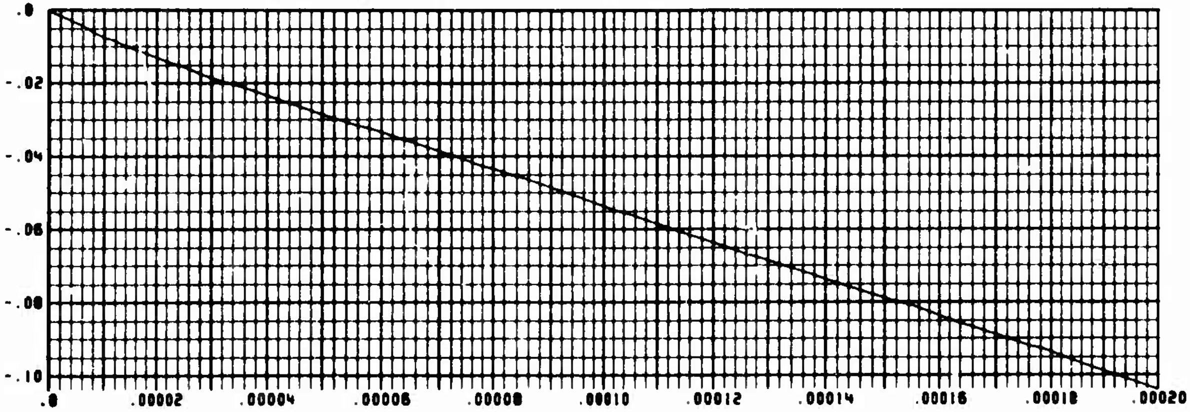
INNER FIBER MERD STRAIN AT x = 3.0 INCHES



OUTER FIBER CIRC. STRAIN AT x = 0.0 INCHES

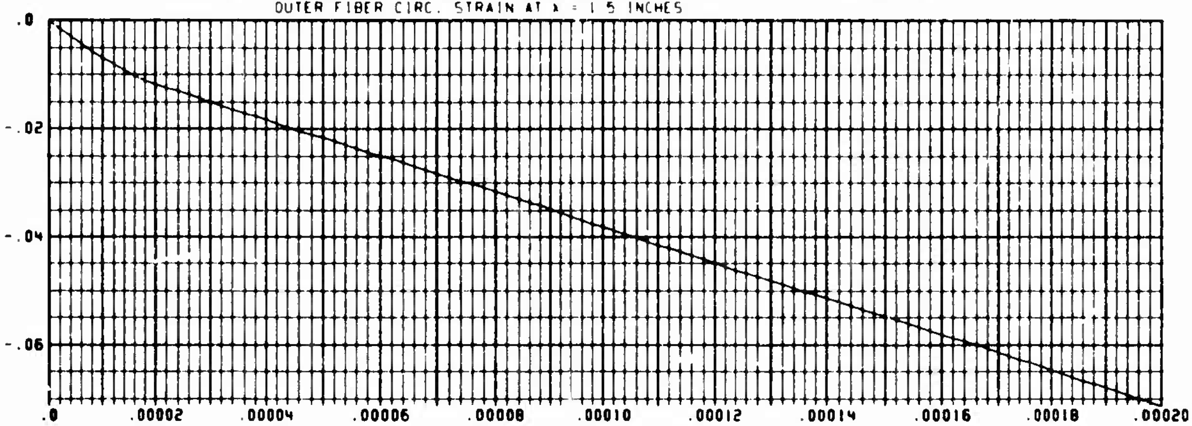


OUTER FIBER CIRC. STRAIN AT x = 0.6 INCHES

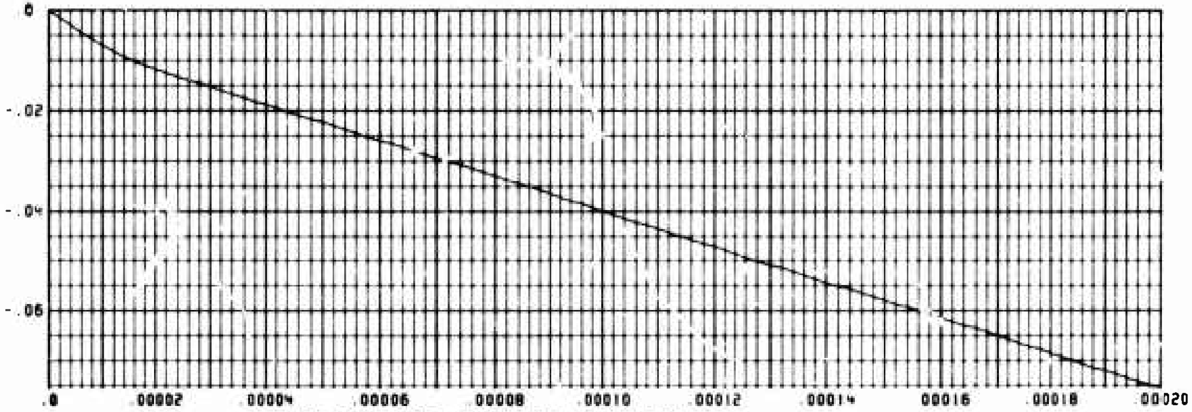


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

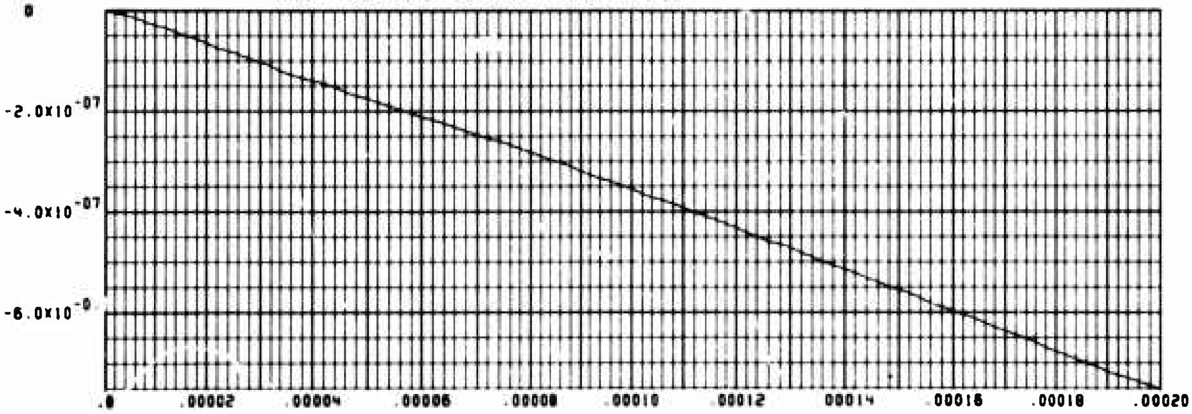
OUTER FIBER CIRC. STRAIN AT X = 1.5 INCHES

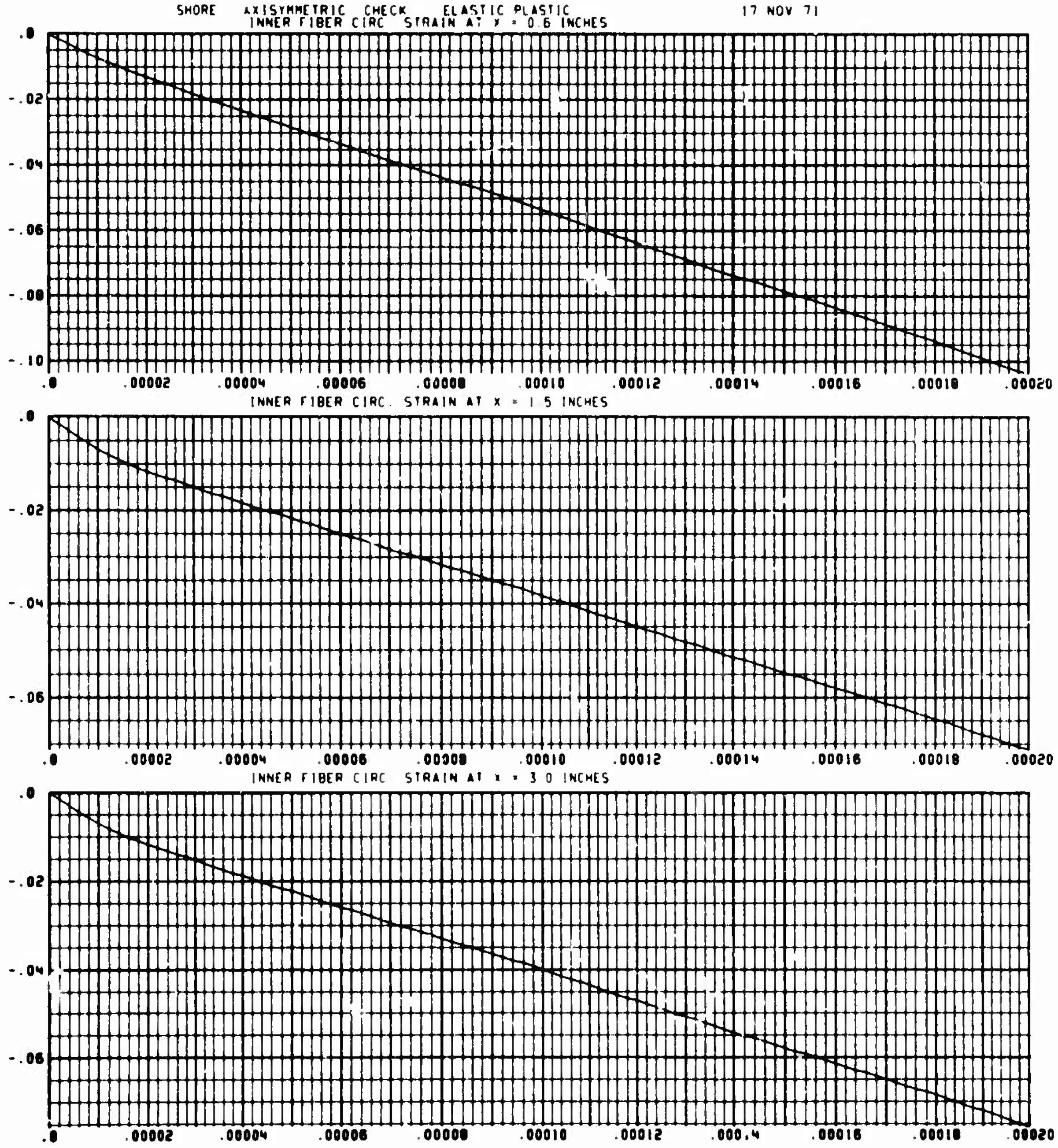


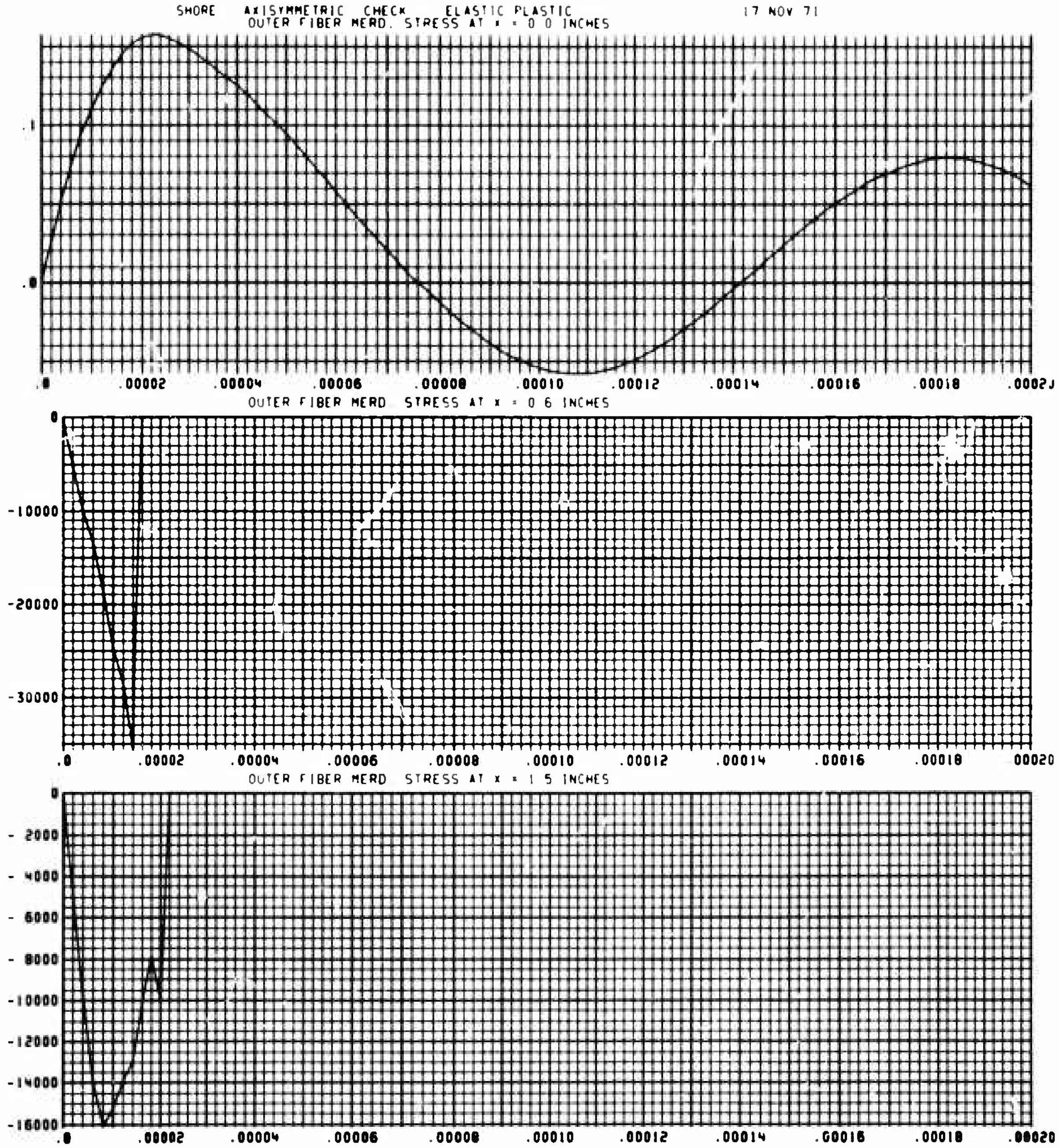
OUTER FIBER CIRC. STRAIN AT X = 3.0 INCHES

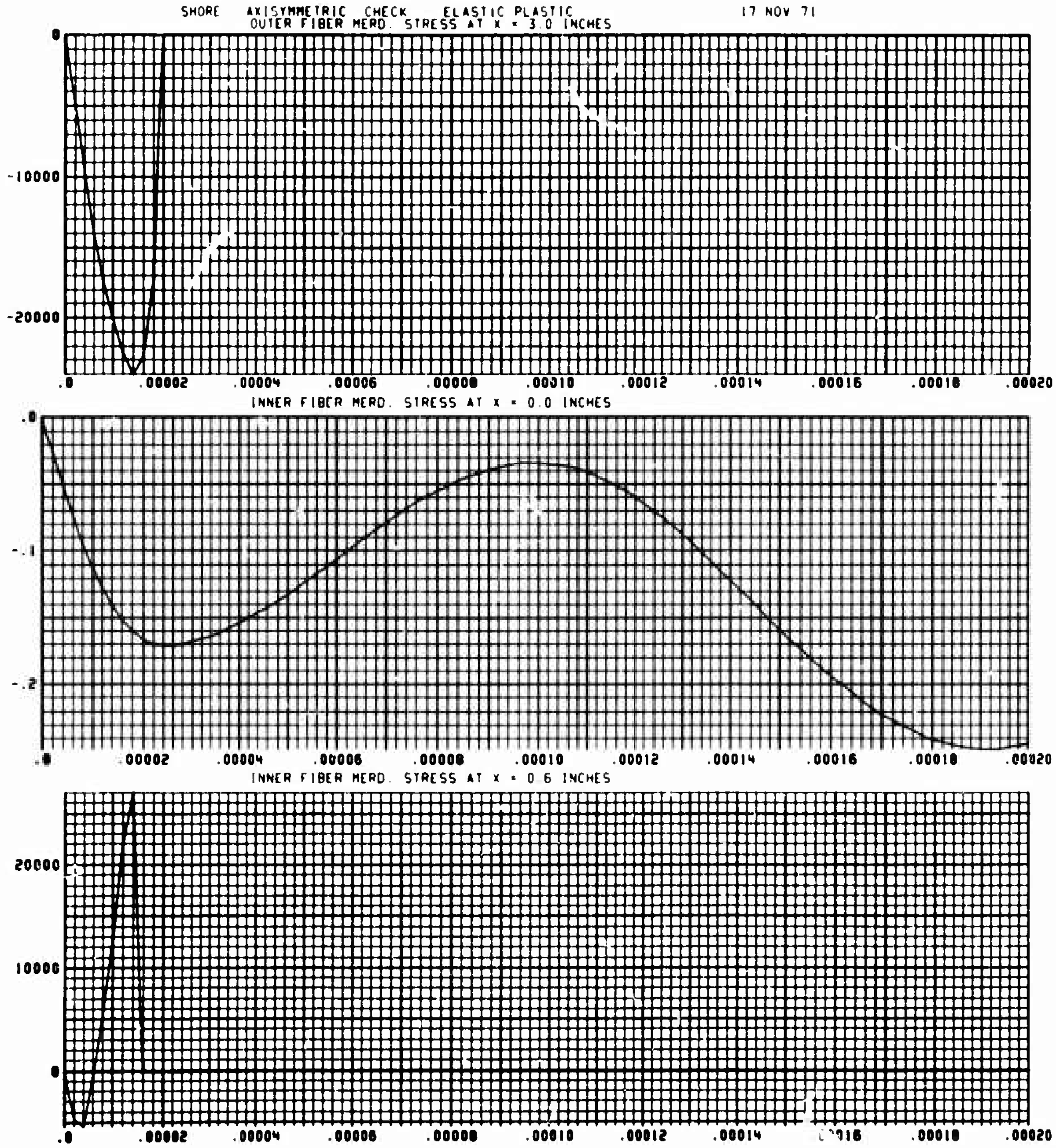


INNER FIBER CIRC. STRAIN AT X = 0.0 INCHES



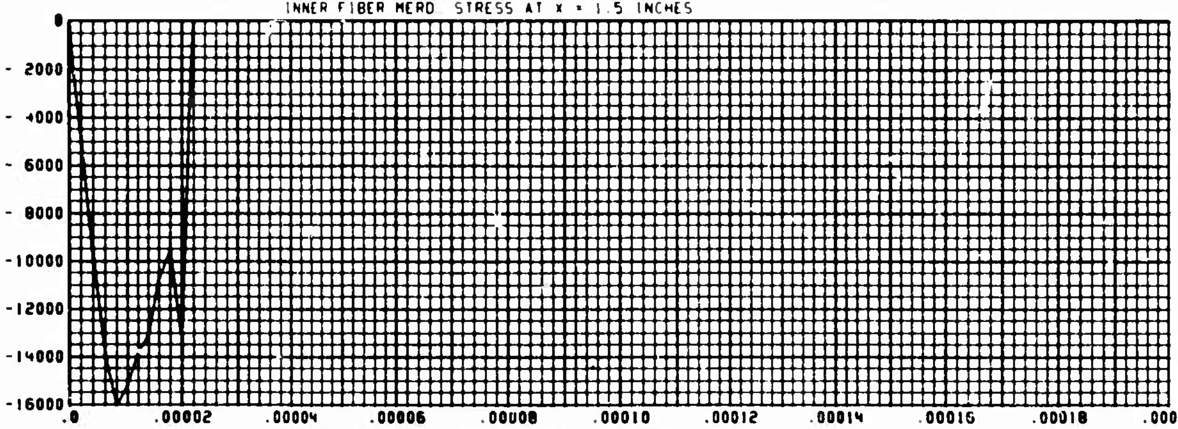

SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC
17 NOV 71
INNER FIBER CIRC. STRAIN AT X = 0.6 INCHES
.0
-.02
-.04
-.06
-.08
-.10
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
INNER FIBER CIRC. STRAIN AT X = 1.5 INCHES
.0
-.02
-.04
-.06
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
INNER FIBER CIRC. STRAIN AT X = 3.0 INCHES
.0
-.02
-.04
-.06
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC
17 NOV 71
OUTER FIBER MERD. STRESS AT x = 0 0 INCHES
.1
.0
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.0002J
OUTER FIBER MERD STRESS AT x = 0 6 INCHES
0
-10000
-20000
-30000
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
OUTER FIBER MERD STRESS AT x = 1 5 INCHES
0
- 2000
- 4000
- 6000
- 8000
-10000
-12000
-14000
-16000
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020

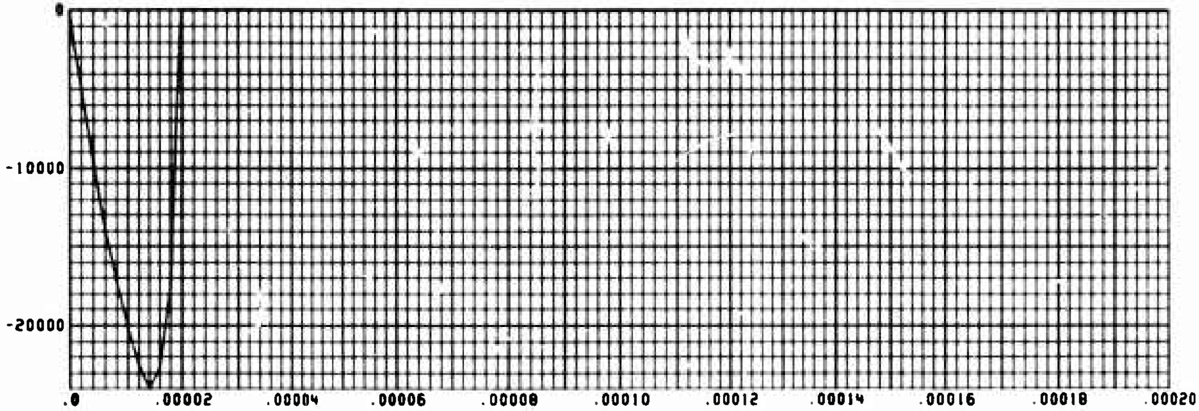

SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC
17 NOV 71
OUTER FIBER MERD. STRESS AT X = 3.0 INCHES
0
-10000
-20000
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
INNER FIBER MERD. STRESS AT X = 0.0 INCHES
.0
-.1
-.2
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
INNER FIBER MERD. STRESS AT X = 0.6 INCHES
20000
10000
0
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020

SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

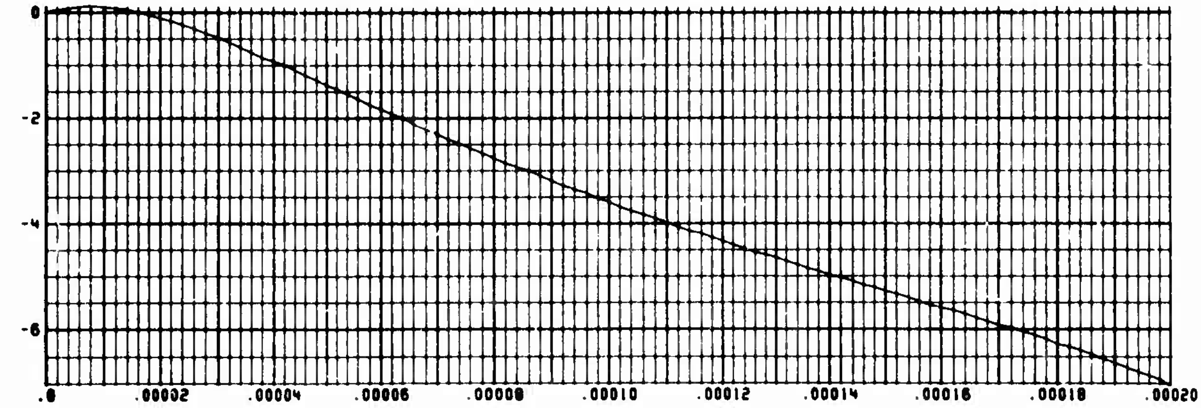
INNER FIBER MERD. STRESS AT X = 1.5 INCHES



INNER FIBER MERD. STRESS AT X = 3.0 INCHES

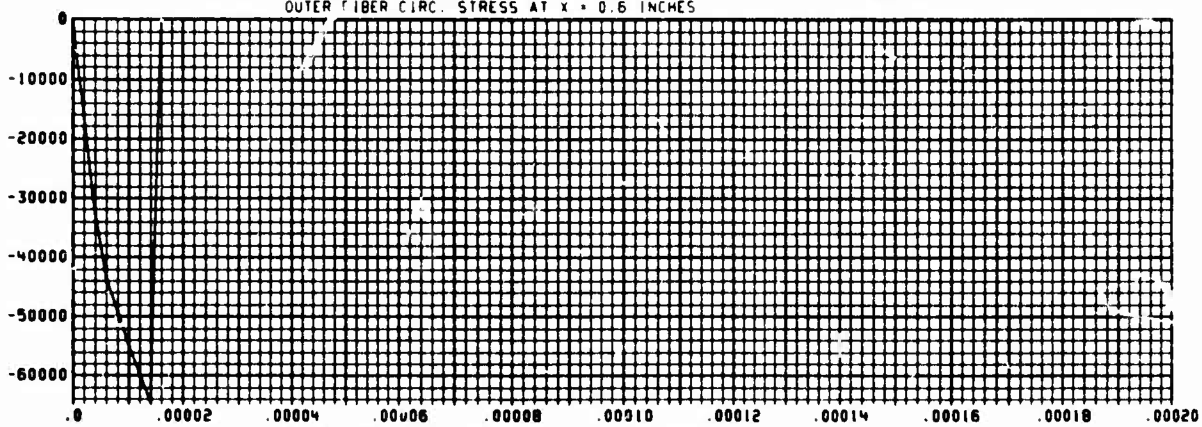


OUTER FIBER CIRC. STRESS AT X = 0.0 INCHES

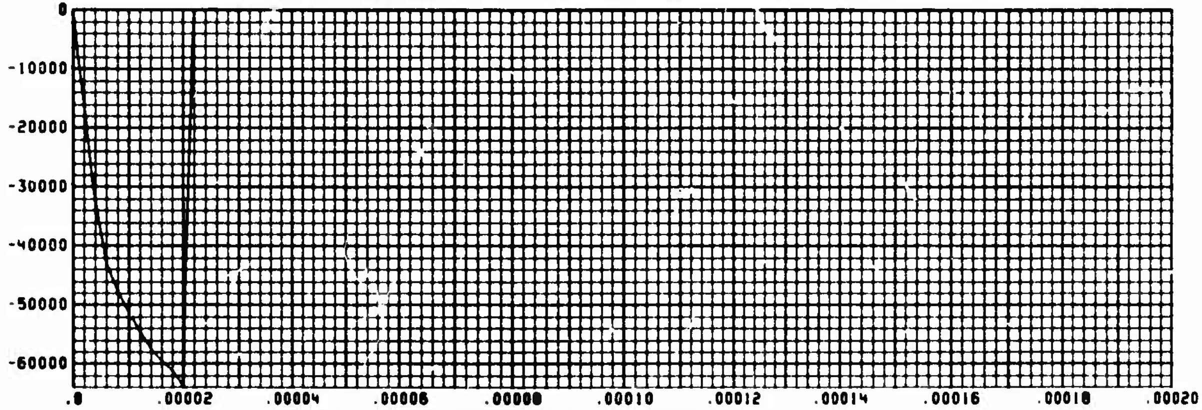


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC 17 NOV 71

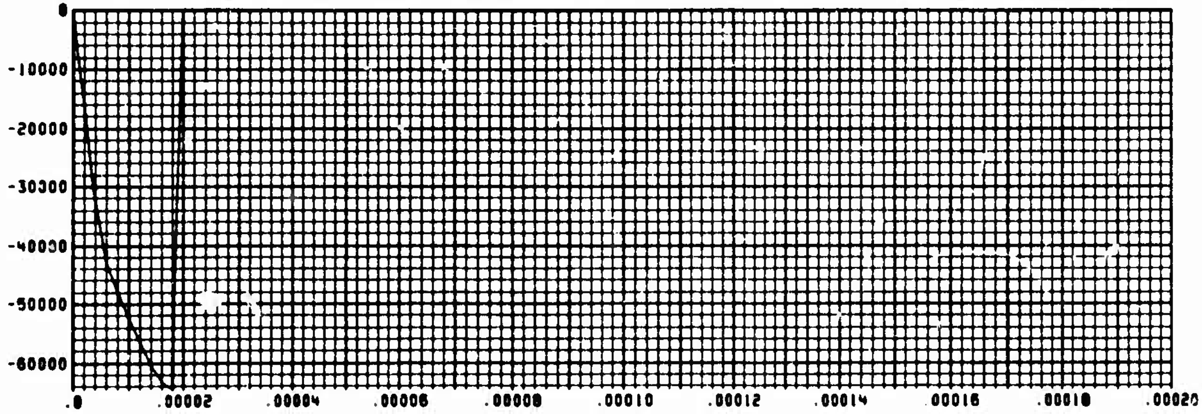
OUTER FIBER CIRC. STRESS AT X = 0.6 INCHES

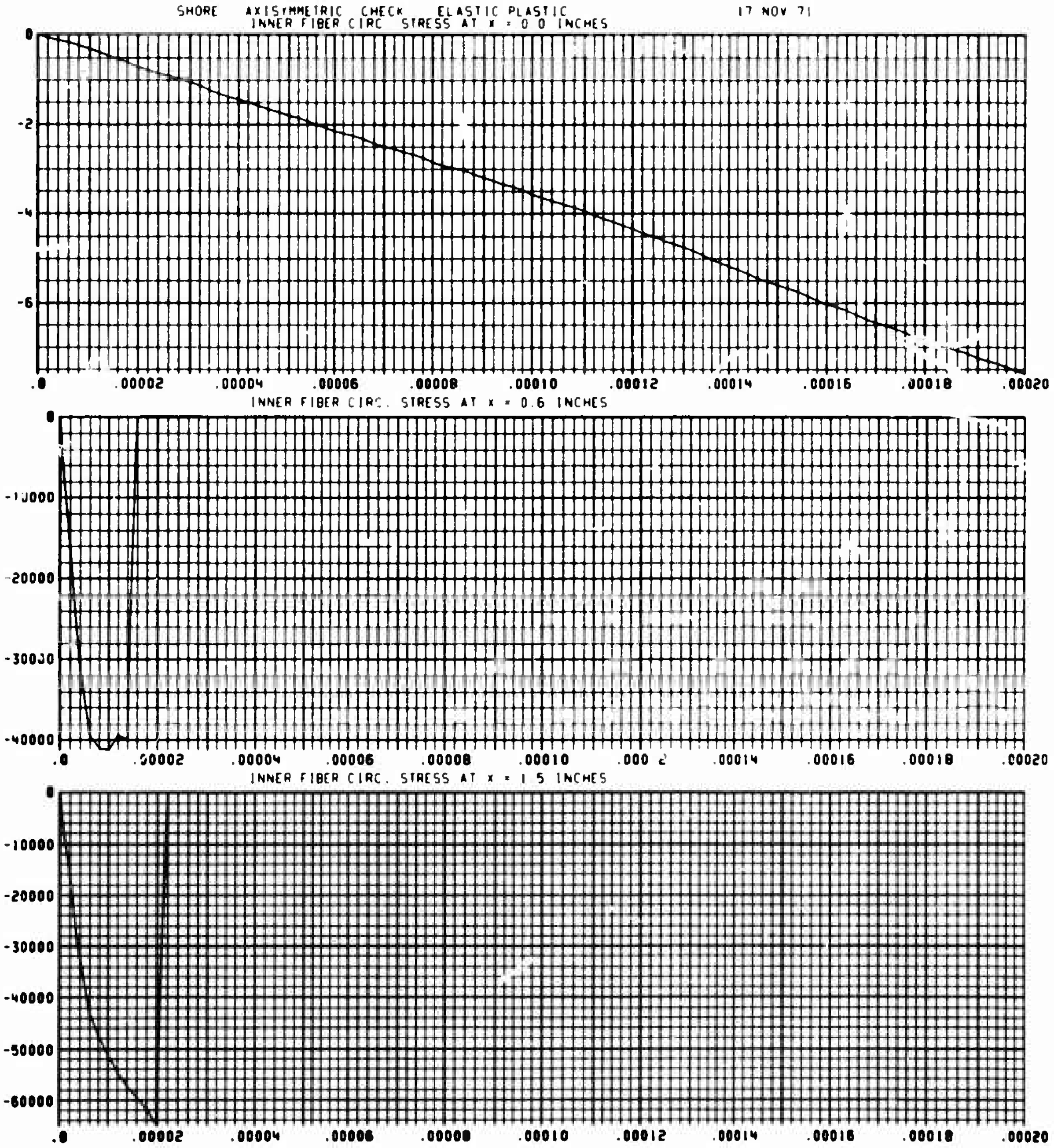


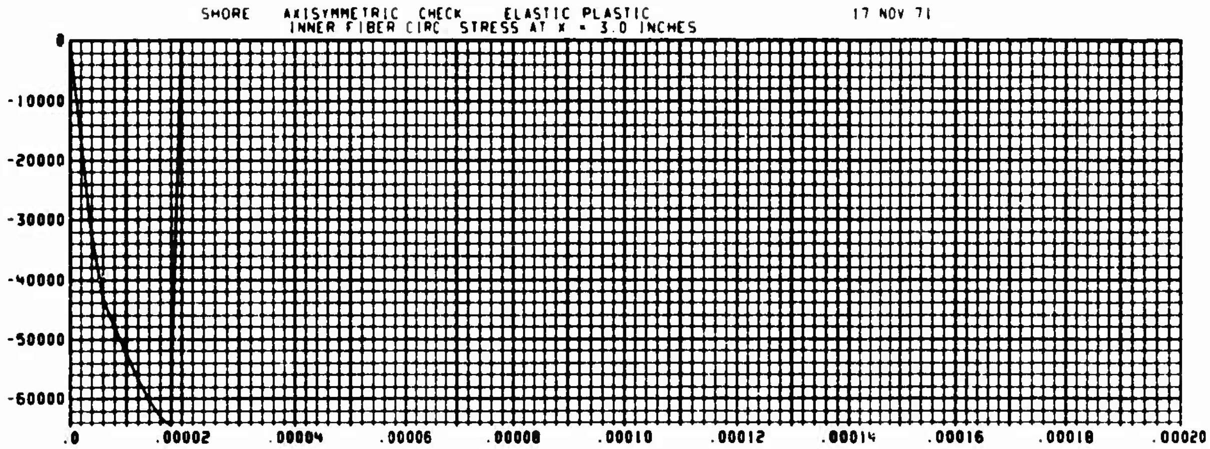
OUTER FIBER CIRC. STRESS AT X = 1.5 INCHES



OUTER FIBER CIRC. STRESS AT X = 3.0 INCHES




SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC
17 NOV 71
INNER FIBER CIRC. STRESS AT x = 0.0 INCHES
0
-2
-4
-6
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
INNER FIBER CIRC. STRESS AT x = 0.6 INCHES
0
-10000
-20000
-30000
-40000
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
INNER FIBER CIRC. STRESS AT x = 1.5 INCHES
0
-10000
-20000
-30000
-40000
-50000
-60000
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020


SHORE AXISYMMETRIC CHECK ELASTIC PLASTIC
17 NOV 71
INNER FIBER CIRC STRESS AT X = 3.0 INCHES
0
-10000
-20000
-30000
-40000
-50000
-60000
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020

```
@LOG      DD33015233  D PG UNDERWOOD 5233 205 45511                    0
@DELETE,C SHORE.
@ASG,T SHORE.,T,57495
@ASG,T NUT1.,D4/1792
@USE 31,NUT1
@ASG,T NUT2.,D/5376
@USE 32,NUT2
@ASG,T NUT3.,D/1792
@USE 33,NUT3
@ADD SYS$*ASG$.
@S,PIC
@COPIN SHORE.,TPFS.
@FREE SHORE.
@FOR,S BNDCON,BNDCON,BNDCON
-195,200
      NP(NC+1,J) = NP(NC-1,J)
      NT(NC+1,J) = NT(NC-1,J)
      MP(NC+1,J) = MP(NC-1,J)
      MT(NC+1,J) = MT(NC-1,J)
      NPT(NC+1,J) = -NPT(NC-1,J)
      MPT(NC+1,J) = -MPT(NC-1,J)
@PREP
@MAP,S AMEN,AMENA
@XQT AMENA
     SRI EXPERIMENTS     AFWL-TR-68-56     NONLINEAR
           L/D = 1          A/H = 24       8400 TAPS
   10    18     4     3     0     0     0     0     0     0     1     1
    1     1     1     1     2     1     1     5     1     1
    1     1     1     1     1     1     1     1     0     0     0
  3.0          .1          .25         .25         180.
+10.    +06+10.    +06+4.     +06+45.    +03+45.    +03+26.    +03
                                3
+10.    +06+10.    +06+10.    +06+10.    +06+10.    +06
  .122
+1.     -06+200.   -06+50.    -06  30.
+2.     -06     5
  3.0       +1.      +10   .125      1.57078
   28     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0
    2     1     3     1     4     1     5     1     6     1     7     1
    8     1     9     1    10     1    11     1    11     2    11     3
   11     4    11     5    11     6    11     7    11     8    11     9
   11    10    11    11    11    12    11    13    11    14    11    15
   11    16    11    17    11    18    11    19
001    RADIAL DISPLACEMENT AT X = 0.3 INCHES AND THETA =  0 DEGREES
002    RADIAL DISPLACEMENT AT X = 0.6 INCHES AND THETA =  0 DEGREES
003    RADIAL DISPLACEMENT AT X = 0.9 INCHES AND THETA =  0 DEGREES
004    RADIAL DISPLACEMENT AT X = 1.2 INCHES AND THETA =  0 DEGREES
005    RADIAL DISPLACEMENT AT X = 1.5 INCHES AND THETA =  0 DEGREES
006    RADIAL DISPLACEMENT AT X = 1.8 INCHES AND THETA =  0 DEGREES
007    RADIAL DISPLACEMENT AT X = 2.1 INCHES AND THETA =  0 DEGREES
008    RADIAL DISPLACEMENT AT X = 2.4 INCHES AND THETA =  0 DEGREES
009    RADIAL DISPLACEMENT AT X = 2.7 INCHES AND THETA =  0 DEGREES
010    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =  0 DEGREES
011    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 10 DEGREES
012    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 20 DEGREES
013    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 30 DEGREES
014    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 40 DEGREES
015    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 50 DEGREES
016    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 60 DEGREES
017    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 70 DEGREES
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018    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 80 DEGREES
019    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 90 DEGREES
020    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =100 DEGREES
021    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =110 DEGREES
022    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =120 DEGREES
023    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =130 DEGREES
024    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =140 DEGREES
025    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =150 DEGREES
026    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =160 DEGREES
027    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =170 DEGREES
028    RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =180 DEGREES

@FIN
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     SRI EXPERIMENTS    AFWL-TR-68-56    NONLINEAR
          L/D = 1          A/H = 24      8400 TAPS



                         NONLINEAR KINEMATICS
                               ONE LAYER SHELL


N DELTA X             =   10
N DELTA THETA         =   18
N LAYERS              =    4
BOUNDARY CONDITIONS =      1     1     1     1     2     1     1     5     1     1
IMPULSE  CONDITION  =      3
THERMAL  CONDITION  =      0
LENGTH                 =    3.0000 IN.
DENSITY                =     .1000 LB/CU. IN.
POISSONS RATIOS  X,T =      .2500      .2500
ANGLE DEFINING BOUNDARY =     .1800+03 DEGREES
ELASTIC MODULI               X,T,S =       .100+08       .100+08       .400+07 PSI
YIELD STRESSES               X,T,S =       .450+05       .450+05       .260+05 PSI
FRACTURE STRESSES            XC,XT,TC,TT,S =      .100+08      .100+08      .100+08      .100+08      .100+08 PSI

EFFECTIVE YIELD STRESS  =       .000     PSI
STRAIN HARDENING MODULUS  =       .000     PSI
PLASTICITY FORMULATION  3
THERMAL EXPANSION COEFFS,  X,T =       .000          .000
MAXIMUM IMPULSE =      .12200 PSI-SEC.
WAVE VELOCITY   =     .0000     FT/SEC.
INCIDENCE ANGLE =     .0000     RADIANS


DAMPING COEFFICIENT =     .0000     LBF-SEC/IN**3


DELTA TIME =    1.00000 MICROSEC.(INPUT)
TOTAL TIME =     .20000 MILLISEC.
PRINT TIME =  50.00000 MICRCSEC.
PLOT TIME =   2.00000 MIRCOSEC.
PLOTTING WILL START WITH     30.0000       SECONDS LEFT


MERIDIONAL DISPLACEMENT PRINT OUT ?  YES
CIRCUMFERENTIAL DISPLACEMENT PRINT OUT ?  YES
MERIDIONAL STRESS PRINT OUT ?  YES
CIRCUMFERENTIAL STRESS PRINT OUT ?  YES
SHEAR STRESS PRINT OUT ?  YES
MERIDIONAL STRAIN PRINT OUT ?  YES
CIRCUMFERENTIAL STRAIN PRINT OUT ?  YES
SHEAR STRAIN PRINT OUT ?  YES
RADIAL PRESSURE PRINT OUT ?   NO
MERIDIONAL PRESSURE PRINT OUT ?   NO
CIRCUMFERENTIAL PRESSURE PRINT OUT ?   NO
```

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STA          R               RP              PHI

  1    .30000000+01    .10000000+11    .15707800+01
  2    .30000000+01    .10000000+11    .15707800+01
  3    .30000000+01    .10000000+11    .15707800+01
  4    .30000000+01    .10000000+11    .15707800+01
  5    .30000000+01    .10000000+11    .15707800+01
  6    .30000000+01    .10000000+11    .15707800+01
  7    .30000000+01    .10000000+11    .15707800+01
  8    .30000000+01    .10000000+11    .15707800+01
  9    .30000000+01    .10000000+11    .15707800+01
 10    .30000000+01    .10000000+11    .15707800+01
 11    .30000000+01    .10000000+11    .15707800+01
 12    .30000000+01    .10000000+11    .15707800+01
 13    .30000000+01    .10000000+11    .15707800+01

T(1) =    .1250+00 INCHES
```

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THICKNESS DISTRIBUTION

1  1  1     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  2     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  3     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  4     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  5     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  6     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  7     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  8     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1  9     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 10     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 11     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 12     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 13     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 14     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 15     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 16     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 17     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 18     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  1 19     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  1     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  2     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  3     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  4     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  5     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  6     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  7     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  8     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7  9     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 10     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 11     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 12     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 13     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 14     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 15     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 16     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 17     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 18     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
1  7 19     -.625000-01    -.625000-01    -.625000-01    -.625000-01    -.625000-01
2  1  1      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  2      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  3      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  4      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  5      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  6      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  7      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  8      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1  9      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 10      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 11      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 12      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 13      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 14      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 15      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 16      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
2  1 17      .625000-01     .625000-01     .625000-01     .625000-01     .625000-01     .625000-01
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2  1 18    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  1 19    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  1    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  2    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  3    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  4    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  5    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  6    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  7    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  8    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7  9    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 10    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 11    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 12    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 13    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 14    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 15    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 16    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 17    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 18    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
2  7 19    .625000-01    .625000-01    .625000-01    .625000-01    .625000-01
3  1  1    .000000       .000000       .000000       .000000       .000000       .000000
3  1  2    .000000       .000000       .000000       .000000       .000000       .000000
3  1  3    .000000       .000000       .000000       .000000       .000000       .000000
3  1  4    .000000       .000000       .000000       .000000       .000000       .000000
3  1  5    .000000       .000000       .000000       .000000       .000000       .000000
3  1  6    .000000       .000000       .000000       .000000       .000000       .000000
3  1  7    .000000       .000000       .000000       .000000       .000000       .000000
3  1  8    .000000       .000000       .000000       .000000       .000000       .000000
3  1  9    .000000       .000000       .000000       .000000       .000000       .000000
3  1 10    .000000       .000000       .000000       .000000       .000000       .000000
3  1 11    .000000       .000000       .000000       .000000       .000000       .000000
3  1 12    .000000       .000000       .000000       .000000       .000000       .000000
3  1 13    .000000       .000000       .000000       .000000       .000000       .000000
3  1 14    .000000       .000000       .000000       .000000       .000000       .000000
3  1 15    .000000       .000000       .000000       .000000       .000000       .000000
3  1 16    .000000       .000000       .000000       .000000       .000000       .000000
3  1 17    .000000       .000000       .000000       .000000       .000000       .000000
3  1 18    .000000       .000000       .000000       .000000       .000000       .000000
3  1 19    .000000       .000000       .000000       .000000       .000000       .000000
3  7  1    .000000       .000000       .000000       .000000       .000000
3  7  2    .000000       .000000       .000000       .000000       .000000
3  7  3    .000000       .000000       .000000       .000000       .000000
3  7  4    .000000       .000000       .000000       .000000       .000000
3  7  5    .000000       .000000       .000000       .000000       .000000
3  7  6    .000000       .000000       .000000       .000000       .000000
3  7  7    .000000       .000000       .000000       .000000       .000000
3  7  8    .000000       .000000       .000000       .000000       .000000
3  7  9    .000000       .000000       .000000       .000000       .000000
3  7 10    .000000       .000000       .000000       .000000       .000000
3  7 11    .000000       .000000       .000000       .000000       .000000
3  7 12    .000000       .000000       .000000       .000000       .000000
3  7 13    .000000       .000000       .000000       .000000       .000000
3  7 14    .000000       .000000       .000000       .000000       .000000
3  7 15    .000000       .000000       .000000       .000000       .000000
3  7 16    .000000       .000000       .000000       .000000       .000000
3  7 17    .000000       .000000       .000000       .000000       .000000
3  7 18    .000000       .000000       .000000       .000000       .000000
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  3  7 19    .000000    .000000    .000000    .000000    .000000
  4  1  1    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  2    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  3    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  4    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  5    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  6    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  7    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  8    .000000    .000000    .000000    .000000    .000000    .000000
  4  1  9    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 10    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 11    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 12    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 13    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 14    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 15    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 16    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 17    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 18    .000000    .000000    .000000    .000000    .000000    .000000
  4  1 19    .000000    .000000    .000000    .000000    .000000    .000000
  4  7  1    .000000    .000000    .000000    .000000    .000000
  4  7  2    .000000    .000000    .000000    .000000    .000000
  4  7  3    .000000    .000000    .000000    .000000    .000000
  4  7  4    .000000    .000000    .000000    .000000    .000000
  4  7  5    .000000    .000000    .000000    .000000    .000000
  4  7  6    .000000    .000000    .000000    .000000    .000000
  4  7  7    .000000    .000000    .000000    .000000    .000000
  4  7  8    .000000    .000000    .000000    .000000    .000000
  4  7  9    .000000    .000000    .000000    .000000    .000000
  4  7 10    .000000    .000000    .000000    .000000    .000000
  4  7 11    .000000    .000000    .000000    .000000    .000000
  4  7 12    .000000    .000000    .000000    .000000    .000000
  4  7 13    .000000    .000000    .000000    .000000    .000000
  4  7 14    .000000    .000000    .000000    .000000    .000000
  4  7 15    .000000    .000000    .000000    .000000    .000000
  4  7 16    .000000    .000000    .000000    .000000    .000000
  4  7 17    .000000    .000000    .000000    .000000    .000000
  4  7 18    .000000    .000000    .000000    .000000    .000000
  4  7 19    .000000    .000000    .000000    .000000    .000000

NPLT =  5


    NPW  =  28
    NPU  =   0
    NPV  =   0
    NPEMO  =   0
    NPEMI  =   0
    NPECO  =   0
    NPECI  =   0
    NPETO  =   0
    NPETI  =   0
    NPSMO  =   0
    NPSMI  =   0
    NPSCO  =   0
```

```
        NPSCI  =   0
        NPSTO  =   0
        NPSTI  =   0
        NPMM  =   0
        NPMC  =   0
        NPMT  =   0
        NPNM  =   0
        NPNC  =   0
        NPNT  =   0

    NL PLCT ARRAY
       2      1      3      1      4      1      5      1      6      1      7      1
       9      1      9      1     10      1     11      1     11      2     11      3
      11      4     11      5     11      6     11      7     11      8     11      9
      11     10     11     11     11     12     11     13     11     14     11     15
      11     16     11     17     11     18     11     19
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                SRI EXPERIMENTS     AFWL-TR-68-56     NONLINEAR
                     L/D = 1           A/H = 24       9400 TAPS


           RADIAL DISPLACEMENTS                  TIME =  .0010 MILLISEC.

               X        .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
        THETA
           ,00          .000      -.377-02   -.377-02   -.377-02   -.377-02   -.377-02   -.377-02   -.377-02   -.377-02   -.377-02
         10,00          .000      -.371-02   -.371-02   -.371-02   -.371-02   -.371-02   -.371-02   -.371-02   -.371-02   -.371-02
         20,00          .000      -.354-02   -.354-02   -.354-02   -.354-02   -.354-02   -.354-02   -.354-02   -.354-02   -.354-02
         30,00          .000      -.326-02   -.326-02   -.326-02   -.326-02   -.326-02   -.326-02   -.326-02   -.326-02   -.326-02
         40,00          .000      -.289-02   -.289-02   -.289-02   -.289-02   -.289-02   -.289-02   -.289-02   -.289-02   -.289-02
         50,00          .000      -.242-02   -.242-02   -.242-02   -.242-02   -.242-02   -.242-02   -.242-02   -.242-02   -.242-02
         60,00          .000      -.188-02   -.188-02   -.188-02   -.188-02   -.188-02   -.188-02   -.188-02   -.188-02   -.188-02
         70,00          .000      -.129-02   -.129-02   -.129-02   -.129-02   -.129-02   -.129-02   -.129-02   -.129-02   -.129-02
         80,00          .000      -.654-03   -.654-03   -.654-03   -.654-03   -.654-03   -.654-03   -.654-03   -.654-03   -.654-03
         90,00          .000      -.511-08   -.511-08   -.511-08   -.511-08   -.511-08   -.511-08   -.511-08   -.511-08   -.511-08
        100,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        110,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        120,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        130,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        140,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        150,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        160,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        170,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
        180,00          .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

               X        .300+01
        THETA
           ,00         -.377-02
         10,00         -.371-02
         20,00         -.354-02
         30,00         -.326-02
         40,00         -.289-02
         50,00         -.242-02
         60,00         -.188-02
         70,00         -.129-02
         80,00         -.654-03
         90,00         -.511-08
        100,00          .000
        110,00          .000
        120,00          .000
        130,00          .000
        140,00          .000
        150,00          .000
        160,00          .000
        170,00          .000
        180,00          .000


        MERIDIONAL DISPLACEMENTS                 TIME =  .0010
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          X      .150+00   .450+00   .750+00   .105+01   .135+01   .165+01   .195+01   .225+01   .255+01   .285+01
THETA
     .00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   10,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   20,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   30,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   40,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   50,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   60,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   70,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   80,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   90,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  100,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  110.00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  120,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  130,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  140,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  150,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  160,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  170,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
  180,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000

          X      .315+01
THETA
     .00         .000
   10,00         .000
   20,00         .000
   30,00         .000
   40.00         .000
   50,00         .000
   60.00         .000
   70,00         .000
   80,00         .000
   90,00         .000
  100,00         .000
  110.00         .000
  120,00         .000
  130,00         .000
  140,00         .000
  150,00         .000
  160,00         .000
  170,00         .000
  180,00         .000


CIRCUMFERENTIAL DISPLACEMENTS                    TIME =  ,0010


          X      .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    5,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   15,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   25.00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   35,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   45,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
   55,00         .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
```

```
    65.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
    75.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
    85.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
    95.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   105.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   115.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   125.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   135.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   145.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   155.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   165.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   175.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   185.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

         X       .300+01
 THETA
     5.00        .000
    15.00        .000
    25.00        .000
    35.00        .000
    45.00        .000
    55.00        .000
    65.00        .000
    75.00        .000
    85.00        .000
    95.00        .000
   105.00        .000
   115.00        .000
   125.00        .000
   135.00        .000
   145.00        .000
   155.00        .000
   165.00        .000
   175.00        .000
   185.00        .000


 INNER FIBER MERIDIONAL STRESSES            TIME =   .0010


         X       .000       .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
 THETA
      .00      -.503+05     .248+05    -.328+04    -.328+04    -.328+04    -.328+04    -.328+04    -.328+04    -.328+04    -.328+04
    10.00      -.503+05     .245+05    -.323+04    -.323+04    -.323+04    -.323+04    -.323+04    -.323+04    -.323+04    -.323+04
    20.00      -.501+05     .233+05    -.308+04    -.308+04    -.308+04    -.308+04    -.308+04    -.308+04    -.308+04    -.308+04
    30.00      -.483+05     .215+05    -.284+04    -.284+04    -.284+04    -.284+04    -.284+04    -.284+04    -.284+04    -.284+04
    40.00      -.428+05     .170+05    -.251+04    -.251+04    -.251+04    -.251+04    -.251+04    -.251+04    -.251+04    -.251+04
    50.00      -.359+05     .159+05    -.211+04    -.211+04    -.211+04    -.211+04    -.211+04    -.211+04    -.211+04    -.211+04
    60.00      -.279+05     .124+05    -.164+04    -.164+04    -.164+04    -.164+04    -.164+04    -.164+04    -.164+04    -.164+04
    70.00      -.191+05     .845+04    -.112+04    -.112+04    -.112+04    -.112+04    -.112+04    -.112+04    -.112+04    -.112+04
    80.00      -.969+04     .428+04    -.567+03    -.567+03    -.567+03    -.567+03    -.567+03    -.567+03    -.567+03    -.567+03
    90.00      -.757-01    -.397+03    -.397+03    -.397+03    -.397+03    -.397+03    -.397+03    -.397+03    -.397+03    -.397+03
   100.00        .000      -.311-02    -.311-02    -.311-02    -.311-02    -.311-02    -.311-02    -.311-02    -.311-02    -.311-02
   110.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   120.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   130.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
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 140.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 150.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 160.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 170.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 180.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000

          X   .300+01
THETA
    .00     -.328+04
  10.00     -.323+04
  20.00     -.308+04
  30.00     -.284+04
  40.00     -.251+04
  50.00     -.211+04
  60.00     -.164+04
  70.00     -.112+04
  80.00     -.567+03
  90.00     -.397+03
 100.00     -.311-02
 110.00      .000
 120.00      .000
 130.00      .000
 140.00      .000
 150.00      .000
 160.00      .000
 170.00      .000
 180.00      .000


OUTER FIBER MERIDIONAL STRESSES            TIME =  .0010


          X   .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    .00      .503+05  -.311+05  -.342+04  -.342+04  -.342+04  -.342+04  -.342+04  -.342+04  -.342+04  -.342+04
  10.00      .503+05  -.306+05  -.337+04  -.337+04  -.337+04  -.337+04  -.337+04  -.337+04  -.337+04  -.337+04
  20.00      .501+05  -.292+05  -.321+04  -.321+04  -.321+04  -.321+04  -.321+04  -.321+04  -.321+04  -.321+04
  30.00      .483+05  -.270+05  -.296+04  -.296+04  -.296+04  -.296+04  -.296+04  -.296+04  -.296+04  -.296+04
  40.00      .428+05  -.239+05  -.262+04  -.262+04  -.262+04  -.262+04  -.262+04  -.262+04  -.262+04  -.262+04
  50.00      .359+05  -.200+05  -.220+04  -.220+04  -.220+04  -.220+04  -.220+04  -.220+04  -.220+04  -.220+04
  60.00      .279+05  -.156+05  -.171+04  -.171+04  -.171+04  -.171+04  -.171+04  -.171+04  -.171+04  -.171+04
  70.00      .191+05  -.107+05  -.117+04  -.117+04  -.117+04  -.117+04  -.117+04  -.117+04  -.117+04  -.117+04
  80.00      .969+04  -.543+04  -.592+03  -.592+03  -.592+03  -.592+03  -.592+03  -.592+03  -.592+03  -.592+03
  90.00      .757-01   .398+03   .398+03   .398+03   .398+03   .398+03   .398+03   .398+03   .398+03   .398+03
 100.00      .000      .311-02   .311-02   .311-02   .311-02   .311-02   .311-02   .311-02   .311-02   .311-02
 110.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 120.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 130.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 140.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 150.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 160.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 170.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
 180.00      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000

          X   .300+01
THETA
```

```
      .00     -.342+04
    10.00     -.337+04
    20.00     -.321+04
    30.00     -.296+04
    40.00     -.262+04
    50.00     -.220+04
    60.00     -.171+04
    70.00     -.117+04
    80.00     -.592+03
    90.00      .398+03
   100.00      .311-02
   110.00      .000
   120.00      .000
   130.00      .000
   140.00      .000
   150.00      .000
   160.00      .000
   170.00      .000
   180.00      .000


INNER FIBER CIRCUMFERENTIAL STRESSES          TIME =  .0010


            X      .000       .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
      .00     -.140+05    -.609+04    -.131+05    -.131+05    -.131+05    -.131+05    -.131+05    -.131+05    -.131+05    -.131+05
    10.00     -.138+05    -.600+04    -.129+05    -.129+05    -.129+05    -.129+05    -.129+05    -.129+05    -.129+05    -.129+05
    20.00     -.132+05    -.572+04    -.123+05    -.123+05    -.123+05    -.123+05    -.123+05    -.123+05    -.123+05    -.123+05
    30.00     -.121+05    -.528+04    -.114+05    -.114+05    -.114+05    -.114+05    -.114+05    -.114+05    -.114+05    -.114+05
    40.00     -.107+05    -.447+04    -.100+05    -.100+05    -.100+05    -.100+05    -.100+05    -.100+05    -.100+05    -.100+05
    50.00     -.897+04    -.392+04    -.843+04    -.843+04    -.843+04    -.843+04    -.843+04    -.843+04    -.843+04    -.843+04
    60.00     -.698+04    -.305+04    -.655+04    -.655+04    -.655+04    -.655+04    -.655+04    -.655+04    -.655+04    -.655+04
    70.00     -.477+04    -.209+04    -.448+04    -.448+04    -.448+04    -.448+04    -.448+04    -.448+04    -.448+04    -.448+04
    80.00     -.242+04    -.106+04    -.227+04    -.227+04    -.227+04    -.227+04    -.227+04    -.227+04    -.227+04    -.227+04
    90.00     -.189-01    -.159+04    -.159+04    -.159+04    -.159+04    -.159+04    -.159+04    -.159+04    -.159+04    -.159+04
   100.00      .000       -.124-01    -.124-01    -.124-01    -.124-01    -.124-01    -.124-01    -.124-01    -.124-01    -.124-01
   110.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   120.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   130.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   140.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   150.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   160.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   170.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   180.00      .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

            X      .300+01
THETA
      .00     -.131+05
    10.00     -.129+05
    20.00     -.123+05
    30.00     -.114+05
    40.00     -.100+05
    50.00     -.843+04
    60.00     -.655+04
    70.00     -.448+04
```

```
      80.00       -.227+04
      90.00       -.159+04
     100.00       -.124-01
     110.00        .000
     120.00        .000
     130.00        .000
     140.00        .000
     150.00        .000
     160.00        .000
     170.00        .000
     180.00        .000


OUTER FIBER CIRCUMFERENTIAL STRESSES            TIME =  .0010


            X      .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
        .00        .140+05   -.216+05   -.137+05   -.137+05   -.137+05   -.137+05   -.137+05   -.137+05   -.137+05   -.137+05
      10.00        .138+05   -.203+05   -.135+05   -.135+05   -.135+05   -.135+05   -.135+05   -.135+05   -.135+05   -.135+05
      20.00        .132+05   -.194+05   -.128+05   -.128+05   -.128+05   -.128+05   -.128+05   -.128+05   -.128+05   -.128+05
      30.00        .121+05   -.178+05   -.118+05   -.118+05   -.118+05   -.118+05   -.118+05   -.118+05   -.118+05   -.118+05
      40.00        .107+05   -.158+05   -.105+05   -.105+05   -.105+05   -.105+05   -.105+05   -.105+05   -.105+05   -.105+05
      50.00        .897+04   -.132+05   -.878+04   -.878+04   -.878+04   -.878+04   -.878+04   -.878+04   -.878+04   -.878+04
      60.00        .698+04   -.103+05   -.683+04   -.683+04   -.683+04   -.683+04   -.683+04   -.683+04   -.683+04   -.683+04
      70.00        .477+04   -.705+04   -.467+04   -.467+04   -.467+04   -.467+04   -.467+04   -.467+04   -.467+04   -.467+04
      80.00        .242+04   -.388+04   -.237+04   -.237+04   -.237+04   -.237+04   -.237+04   -.237+04   -.237+04   -.237+04
      90.00        .189-01    .159+04    .159+04    .159+04    .159+04    .159+04    .159+04    .159+04    .159+04    .159+04
     100.00        .000       .124-01    .124-01    .124-01    .124-01    .124-01    .124-01    .124-01    .124-01    .124-01
     110.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     120.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     130.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     140.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     150.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     160.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     170.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
     180.00        .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

            X      .300+01
THETA
        .00       -.137+05
      10.00       -.135+05
      20.00       -.128+05
      30.00       -.118+05
      40.00       -.105+05
      50.00       -.878+04
      60.00       -.683+04
      70.00       -.467+04
      80.00       -.237+04
      90.00        .159+04
     100.00        .124-01
     110.00        .000
     120.00        .000
     130.00        .000
     140.00        .000
     150.00        .000
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 160.00       .000
 170.00       .000
 180.00       .000


INNER FIBER SHEAR STRESSES                    TIME =  .0010


         X    .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
  10.00       .000     -.131+03   -.295-03   -.295-03   -.295-03   -.295-03   -.295-03   -.295-03   -.295-03   -.341-03
  20.00       .000     -.356+03   -.582-03   -.582-03   -.582-03   -.532-03   -.582-03   -.582-03   -.582-03   -.558-03
  30.00       .000     -.521+03   -.850-03   -.850-03   -.850-03   -.850-03   -.850-03   -.850-03   -.850-03   -.804-03
  40.00       .000     -.649+03   -.109-02   -.109-02   -.109-02   -.109-02   -.109-02   -.109-02   -.109-02   -.112-02
  50.00       .000     -.798+03   -.130-02   -.130-02   -.130-02   -.130-02   -.130-02   -.130-02   -.130-02   -.130-02
  60.00       .000     -.902+03   -.147-02   -.147-02   -.147-02   -.147-02   -.147-02   -.147-02   -.147-02   -.145-02
  70.00       .000     -.978+03   -.160-02   -.160-02   -.160-02   -.160-02   -.160-02   -.160-02   -.160-02   -.160-02
  80.00       .000     -.103+04   -.167-02   -.167-02   -.167-02   -.167-02   -.167-02   -.167-02   -.167-02   -.167-02
  90.00       .000     -.521+03   -.850-03   -.850-03   -.850-03   -.850-03   -.850-03   -.850-03   -.850-03   -.844-03
 100.00       .000     -.407-02   -.664-08   -.664-08   -.664-08   -.664-08   -.664-08   -.664-08   -.664-08   -.660-08
 110.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 120.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 130.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 140.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 150.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 160.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 170.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000
 180.00       .000       .000       .000       .000       .000       .000       .000       .000       .000       .000

         X    .300+01
THETA
    .00       .000
  10.00     -.295-03
  20.00     -.582-03
  30.00     -.850-03
  40.00     -.109-02
  50.00     -.130-02
  60.00     -.147-02
  70.00     -.160-02
  80.00     -.167-02
  90.00     -.850-03
 100.00     -.664-08
 110.00       .000
 120.00       .000
 130.00       .000
 140.00       .000
 150.00       .000
 160.00       .000
 170.00       .000
 180.00       .000


OUTER FIBER SHEAR STRESSES                    TIME =  .0010
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```
          X       .000         .300+00      .600+00      .900+00      .120+01      .150+01      .180+01      .210+01      .240+01      .270+01
THETA
   .00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
 10.00            .000         .131+03      .295-03      .295-03      .295-03      .295-03      .295-03      .295-03      .295-03      .342-03
 20.00            .000         .356+03      .582-03      .582-03      .582-03      .582-03      .582-03      .582-03      .582-03      .559-03
 30.00            .000         .521+03      .850-03      .850-03      .850-03      .850-03      .850-03      .850-03      .850-03      .804-03
 40.00            .000         .649+03      .109-02      .109-02      .109-02      .109-02      .109-02      .109-02      .109-02      .112-02
 50.00            .000         .798+03      .130-02      .130-02      .130-02      .130-02      .130-02      .130-02      .130-02      .130-02
 60.00            .000         .902+03      .147-02      .147-02      .147-02      .147-02      .147-02      .147-02      .147-02      .145-02
 70.00            .000         .978+03      .160-02      .160-02      .160-02      .160-02      .160-02      .160-02      .160-02      .160-02
 80.00            .000         .103+04      .167-02      .167-02      .167-02      .167-02      .167-02      .167-02      .167-02      .167-02
 90.00            .000         .521+03      .850-03      .850-03      .850-03      .850-03      .850-03      .850-03      .850-03      .844-03
100.00            .000         .407-02      .664-08      .664-08      .664-08      .664-08      .664-08      .664-08      .664-08      .660-08
110.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
120.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
130.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
140.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
150.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
160.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
170.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000
180.00            .000         .000         .000         .000         .000         .000         .000         .000         .000         .000

          X       .300+01
THETA
   .00            .000
 10.00            .295-03
 20.00            .581-03
 30.00            .850-03
 40.00            .109-02
 50.00            .130-02
 60.00            .147-02
 70.00            .160-02
 80.00            .167-02
 90.00            .850-03
100.00            .664-08
110.00            .000
120.00            .000
130.00            .000
140.00            .000
150.00            .000
160.00            .000
170.00            .000
180.00            .000


INNER FIBER MERIDIONAL STRAINS               TIME =  .0010


          X       .000         .300+00      .600+00      .900+00      .120+01      .150+01      .180+01      .210+01      .240+01      .270+01
THETA
   .00           -.523-02      .264-02     -.377-12     -.377-12     -.377-12     -.377-12     -.377-12     -.377-12     -.377-12     -.377-12
 10.00           -.515-02      .260-02      .198-10      .198-10      .198-10      .198-10      .198-10      .198-10      .198-10      .401-10
 20.00           -.492-02      .248-02     -.354-12     -.354-12     -.354-12     -.354-12     -.354-12     -.354-12     -.354-12      .401-10
 30.00           -.453-02      .228-02     -.326-12     -.326-12     -.326-12     -.326-12     -.326-12     -.326-12     -.326-12     -.326-12
 40.00           -.401-02      .202-02      .199-10      .199-10      .199-10      .199-10      .199-10      .199-10      .199-10      .199-10
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     50.00      -.336-02   .169-02   .200-10   .200-10   .200-10   .200-10   .200-10   .200-10   .200-10   .402-10
     60.00      -.262-02   .131-02  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12
     70.00      -.179-02   .897-03  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12
     80.00      -.909-03   .455-03   .499-11   .499-11   .499-11   .499-11   .499-11   .499-11   .499-11   .100-10
     90.00      -.710-08   .355-08  -.511-18  -.511-18  -.511-18  -.511-18  -.511-18  -.511-18  -.511-18   .380-16
    100.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    110.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    120.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    130.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    140.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    150.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    160.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    170.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    180.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000

             X   .300+01
  THETA
       .00      -.377-12
     10.00      -.206-10
     20.00      -.812-10
     30.00      -.326-12
     40.00       .199-10
     50.00      -.205-10
     60.00      -.188-12
     70.00      -.129-12
     80.00      -.512-11
     90.00      -.776-16
    100.00       .000
    110.00       .000
    120.00       .000
    130.00       .000
    140.00       .000
    150.00       .000
    160.00       .000
    170.00       .000
    180.00       .000

  OUTER FIBER MERIDIONAL STRAINS              TIME =  .0010

             X   .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
  THETA
       .00       .523-02  -.260-02  -.377-12  -.377-12  -.377-12  -.377-12  -.377-12  -.377-12  -.377-12  -.377-12
     10.00       .515-02  -.256-02  -.206-10  -.206-10  -.206-10  -.206-10  -.206-10  -.206-10  -.206-10  -.408-10
     20.00       .492-02  -.244-02  -.354-12  -.354-12  -.354-12  -.354-12  -.354-12  -.354-12  -.354-12  -.408-10
     30.00       .453-02  -.225-02  -.326-12  -.326-12  -.326-12  -.326-12  -.326-12  -.326-12  -.326-12  -.326-12
     40.00       .401-02  -.199-02  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10
     50.00       .336-02  -.167-02  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10  -.205-10  -.407-10
     60.00       .262-02  -.130-02  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12  -.188-12
     70.00       .179-02  -.892-03  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12  -.129-12
     80.00       .909-03  -.454-03  -.512-11  -.512-11  -.512-11  -.512-11  -.512-11  -.512-11  -.512-11  -.102-10
     90.00       .710-08  -.355-08  -.511-18  -.511-18  -.511-18  -.511-18  -.511-18  -.511-18  -.511-18  -.391-16
    100.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    110.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
    120.00       .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
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130,00       .000      ,000      ,000      .000      .000      .000      .000      ,000      .000      ,000
140,00       .000      ,000      ,000      ,000      .000      ,000      .000      ,000      .000      ,000
150,00       .000      ,000      ,000      ,000      .000      ,000      .000      ,000      .000      ,000
160,00       .000      ,000      ,000      ,000      .000      ,000      .000      ,000      .000      ,000
170,00       .000      ,000      ,000      ,000      .000      ,000      ,000      ,000      ,000      ,000
180,00       .000      ,000      ,000      .000      .000      ,000      .000      ,000      .000      ,000

         X     .300+01
THETA
    ,00      -.377-12
  10,00       .198-10
  20,00       .805-10
  30,00      =.326-12
  40,00      -.205-10
  50,00       .200-10
  60,00      -.188-12
  70,00      -.129-12
  80,00       .499-11
  90,00       .766-16
 100,00       .000
 110,00       .000
 120,00       .000
 130,00       .000
 140,00       .000
 150,00       .000
 160,00       .000
 170,00       .000
 180,00       .000


INNER FIBER CIRCUMFERENTIAL STRAINS            TIME =  ,0010


         X     .000      ,300+00   ,600+00   ,900+00   .120+01   ,150+01   .180+01   ,210+01   ,240+01   ,270+01
THETA
    ,00       .000    -.123=02  -.123-02  -.123=02  -.123-02  -.123-02  -.123-02  -.123-02  -.123-02  -.123-02
  10,00       .000    -.121=02  -.121-02  -.121-02  -.121-.2   -.121-02  -.121-02  -.121-02  -.121-02  -.121-02
  20,00       .000    -.116=02  -.116-02  -.116-02  -.116-02  -.116-02  -.116-02  -.116-02  -.116-02  -.116-02
  30,00       .000    -.106=02  -.106-02  -.106-02  -.106-02  -.106-02  -.106-02  -.106-02  -.106-02  -.106-02
  40,00       .000    -.942=03  -.942-03  -.942-03  -.942-03  -.942-03  -.942-03  -.942-03  -.942-03  -.942-03
  50,00       .000    -.790=03  =.790=03  -.790=03  -.790-03  -.790-03  -.790-03  -.790-03  -.790-03  -.790-03
  60,00       .000    -.614-03  -.614-03  -.614-03  -.614-03  -.614-03  -.614-03  -.614-03  -.614-03  -.614-03
  70,00       .000    -.420=03  -.420-03  -.420-03  -.420-03  -.420-03  -.420-03  -.420-03  -.420-03  -.420-03
  80,00       .000    -.213=03  -.213-03  -.213-03  -.213-03  -.213-03  -.213-03  -.213-03  -.213-03  -.213-03
  90,00       .000    -.149=03  -.149-03  -.149-03  -.149-03  -.149-03  -.149-03  -.149-03  -.149-03  -.149-03
 100,00       .000    -.117=08  -.117-08  -.117-08  -.117-08  -.117-08  -.117-08  -.117-08  -.117-08  -.117-08
 110,00       .000     ,000      ,000      .000      .000      .000      ,000      ,000      .000      ,000
 120,00       .000     ,000      ,000      .000      .000      .000      .000      ,000      .000      ,000
 130,00       .000     ,000      ,000      ,000      .000      .000      ,000      ,000      .000      .000
 140,00       .000     ,000      ,000      ,000      .000      .000      .000      ,000      .000      .000
 150,00       .000     ,000      ,000      ,000      .000      .000      .000      ,000      .000      .000
 160,00       .000     ,000      ,000      ,000      .000      .000      .000      ,000      .000      ,000
 170,00       .000     ,000      .000      ,000      .000      .000      ,000      ,000      ,000      ,000
 180,00       .000     ,000      ,000      .000      .000      ,000      .000      ,000      .000      ,000

         X     .300+01
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THETA
   ,00      -.123-02
 10,00      -.121-02
 20,00      -.116-02
 30,00      -.106-02
 40,00      -.942-03
 50,00      -.790-03
 60,00      -.614-03
 70,00      -.420-03
 80,00      -.213-03
 90,00      -.149-03
100.00      -.117-08
110,00       .000
120,00       .000
130,00       .000
140,00       .000
150,00       .000
160,00       .000
170,00       .000
180,00       .000


OUTER FIBER CIRCUMFERENTIAL STRAINS            TIME =  ,0010


          X    .000      ,300+00    ,600+00    ,900+00    .120+01    ,150+01    ,180+01    ,210+01    ,240+01    ,270+01
THETA
   ,00         .000     -,128-02   -,128-02   -,128-02   -.128-02   -.128-02   -.128-02   -,128-02   -.128-02   -,128-02
 10,00         .000     -,126-02   -,126-02   -,126-02   -.126-02   -,126-02   -,126-02   -,126-02   -,126-02   -,126-02
 20,00         .000     -,120-02   -,120-02   -,120-02   -.120-02   -.120-02   -.120-02   -,120-02   -,120-02   -,120-02
 30,00         .000     -,111-02   -,111-02   -,111-02   -.111-02   -,111-02   -,111-02   -,111-02   -.111-02   -,111-02
 40,00         .000     -,982-03   -,982-03   -,982-03   -.982-03   -,982-03   -,982-03   -,982-03   -.982-03   -,982-03
 50,00         .000     -,824-03   -,824-03   -,824-03   -.824-03   -,824-03   -,824-03   -,824-03   -.824-03   -,824-03
 60,00         .000     -,640-03   -,640-03   -,640-03   -.640-03   -,640-03   -,640-03   -,640-03   -,640-03   -,640-03
 70,00         .000     -,438-03   -,438-03   -,438-03   -.438-03   -,438-03   -.438-03   -,438-03   -,438-03   -,438-03
 80.00         .000     -,222-03   -,222-03   -,222-03   -.222-03   -.222-03   -.222-03   -,222-03   -.222-03   -,222-03
 90,00         .000      ,149-03    ,149-03    .149-03    .149-03    .149-03    .149-03    ,149-03    ,149-03    ,149-03
100.00         .000      ,117-08    ,117-08    .117-08    .117-08    .117-08    .117-08    ,117-08    ,117-08    ,117-08
110,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
120,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
130,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
140,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
150,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
160,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
170,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000
180,00         .000      ,000       ,000       .000       .000       .000       .000       ,000       .000       ,000

          X    .300+01
THETA
   ,00        -.128-02
 10,00        -.126-02
 20,00        -.120-02
 30,00        -.111-02
 40,00        -.982-03
 50,00        -.824-03
 60,00        -.640-03
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   70.00       -.438-03
   80.00       -.222-03
   90.00        .149-03
  100.00        .117-08
  110.00        .000
  120.00        .000
  130.00        .000
  140.00        .000
  150.00        .000
  160.00        .000
  170.00        .000
  180.00        .000


INNER FIBER SHEAR STRAINS                          TIME =  .0010


             X    .000      .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
   10.00          .000     -.226-04    -.369-10    -.369-10    -.369-10    -.369-10    -.369-10    -.369-10    -.369-10    -.427-10
   20.00          .000     -.445-04    -.727-10    -.727-10    -.727-10    -.727-10    -.727-10    -.727-10    -.727-10    -.698-10
   30.00          .000     -.651-04    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09    -.100-09
   40.00          .000     -.837-04    -.137-09    -.137-09    -.137-09    -.137-09    -.137-09    -.137-09    -.137-09    -.140-09
   50.00          .000     -.997-04    -.163-09    -.163-09    -.163-09    -.163-09    -.163-09    -.163-09    -.163-09    -.163-09
   60.00          .000     -.113-03    -.184-09    -.184-09    -.184-09    -.184-09    -.184-09    -.184-09    -.184-09    -.181-09
   70.00          .000     -.122-03    -.200-09    -.200-09    -.200-09    -.200-09    -.200-09    -.200-09    -.200-09    -.200-09
   80.00          .000     -.128-03    -.209-09    -.209-09    -.209-09    -.209-09    -.209-09    -.209-09    -.209-09    -.209-09
   90.00          .000     -.651-04    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09    -.106-09
  100.00          .000     -.509-09    -.831-15    -.831-15    -.831-15    -.831-15    -.831-15    -.831-15    -.831-15    -.825-15
  110.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  120.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  130.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  140.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  150.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  160.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  170.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000
  180.00          .000      .000        .000        .000        .000        .000        .000        .000        .000        .000

             X    .300+01
THETA
     .00          .000
   10.00         -.369-10
   20.00         -.727-10
   30.00         -.106-09
   40.00         -.137-09
   50.00         -.163-09
   60.00         -.184-09
   70.00         -.200-09
   80.00         -.209-09
   90.00         -.106-09
  100.00         -.831-15
  110.00          .000
  120.00          .000
  130.00          .000
  140.00          .000
```

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  150.00        .000
  160.00        .000
  170.00        .000
  180.00        .000


 OUTER FIBER SHEAR STRAINS                    TIME =  .0010


          X     .000        .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
 THETA
     .00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
   10.00        .000        .226-04     .369-10     .369-10     .369-10     .369-10     .369-10     .369-10     .369-10     .427-10
   20.00        .000        .445-04     .727-10     .727-10     .727-10     .727-10     .727-10     .727-10     .727-10     .698-10
   30.00        .000        .651-04     .106-09     .106-09     .106-09     .106-09     .106-09     .106-09     .106-09     .100-09
   40.00        .000        .837-04     .137-09     .137-09     .137-09     .137-09     .137-09     .137-09     .137-09     .140-09
   50.00        .000        .997-04     .163-09     .163-09     .163-09     .163-09     .163-09     .163-09     .163-09     .163-09
   60.00        .000        .113-03     .184-09     .184-09     .184-09     .184-09     .184-09     .184-09     .184-09     .181-09
   70.00        .000        .122-03     .200-09     .200-09     .200-09     .200-09     .200-09     .200-09     .200-09     .200-09
   80.00        .000        .128-03     .209-09     .209-09     .209-09     .209-09     .209-09     .209-09     .209-09     .209-09
   90.00        .000        .651-04     .106-09     .106-09     .106-09     .106-09     .106-09     .106-09     .106-09     .106-09
  100.00        .000        .509-09     .831-15     .831-15     .831-15     .831-15     .831-15     .831-15     .831-15     .825-15
  110.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  120.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  130.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  140.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  150.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  160.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  170.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000
  180.00        .000        .000        .000        .000        .000        .000        .000        .000        .000        .000

          X     .300+01
 THETA
     .00        .000
   10.00        .369-10
   20.00        .727-10
   30.00        .106-09
   40.00        .137-09
   50.00        .163-09
   60.00        .184-09
   70.00        .200-09
   80.00        .209-09
   90.00        .106-09
  100.00        .831-15
  110.00        .000
  120.00        .000
  130.00        .000
  140.00        .000
  150.00        .000
  160.00        .000
  170.00        .000
  180.00        .000
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                                                  TIME =  .0010 MILLISEC.
DATA AT  X = L/2, THETA = 0 DEGREES

    U          V           W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .000       .000      -.371-02   -.412+03   -.165+04    .000       .000      -.178+00   -.714+00    .769-06    .769-06

        SUBLAYER STRAINS AND STRESSES

     EPP =   -.3767-12   -.3767-12   -.3767-12   -.3767-12   -.3767-12
     EPT =   -.1230-02   -.1243-02   -.1256-02   -.1269-02   -.1282-02
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =   -.3279+04   -.3314+04   -.3349+04   -.3384+04   -.3418+04
      ST =   -.1312+05   -.1326+05   -.1340+05   -.1353+05   -.1367+05
     TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = 0, THETA = 0 DEGREES

    U          V           W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .000       .000      -.371-02   -.387+03   -.164+04    .397-07    .397-07   -.717+02   -.186+02    .471+00    .471+00

        SUBLAYER STRAINS AND STRESSES

     EPP =   -.5232-02   -.2616-02    .0000       .2616-02    .5232-02
     EPT =    .0000       .0000       .0000       .0000       .0000
     GPT =    .0000       .0000       .0000       .0000       .0000
      SX =   -.5034+05   -.2791+05    .0000       .2791+05    .5034+05
      ST =   -.1400+05   -.6977+04    .0000       .6977+04    .1400+05
     TTP =    .0000       .0000       .0000       .0000       .0000

DATA AT  X = L/2, THETA = TWO/2 DEGREES

    U          V           W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .000       .000      -.511-08    .645-01    .258+00    .152-12    .152-12    .104+01    .414+01    .221-05    .221-05

        SUBLAYER STRAINS AND STRESSES

     EPP =    .4987-11    .2461-11   -.6542-13   -.2592-11   -.5118-11
     EPT =   -.2126-03   -.2150-03   -.2173-03   -.2196-03   -.2218-03
     GPT =   -.2093-09   -.1047-09    .0000       .1047-09    .2093-09
      SX =   -.5674+03   -.5735+03   -.5795+03   -.5855+03   -.5916+03
      ST =   -.2270+04   -.2294+04   -.2318+04   -.2342+04   -.2366+04
     TTP =   -.1675-02   -.8373-03    .0000       .8373-03    .1675-02
```

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              SPI EXPERIMENTS    AFWL-TR-68-56    NONLINEAR
                     L/D = 1          A/H = 24       8400 TAPS

RADIAL DISPLACEMENTS                        TIME =  .1000 MILLISEC.

          X        .000      .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00           .000     -.542-01   -.101+00   -.119+00   -.120+00   -.119+00   -.123+00   -.129+00   -.131+00   -.128+00
   10.00           .000     -.539-01   -.991-01   -.116+00   -.117+00   -.116+00   -.119+00   -.123+00   -.125+00   -.123+00
   20.00           .000     -.504-01   -.923-01   -.108+00   -.107+00   -.106+00   -.106+00   -.108+00   -.109+00   -.111+00
   30.00           .000     -.429-01   -.800-01   -.931-01   -.921-01   -.903-01   -.883-01   -.868-01   -.875-01   -.916-01
   40.00           .000     -.338-01   -.639-01   -.739-01   -.729-01   -.702-01   -.669-01   -.641-01   -.653-01   -.694-01
   50.00           .000     -.24 -01   -.451-01   -.512-01   -.494-01   -.448-01   -.407-01   -.376-01   -.391-01   -.425-01
   60.00           .000     -.133-01   -.238-01   -.251-01   -.205-01   -.138-01   -.884-02   -.625-02   -.729-02   -.882-02
   70.00           .000     -.295-02   -.238-02    .225-02    .975-02    .174-01    .223-01    .242-01    .241-01    .243-01
   80.00           .000      .634-02    .162-01    .242-01    .351-01    .421-01    .463-01    .483-01    .493-01    .500-01
   90.00           .000      .116-01    .263-01    .389-01    .481-01    .544-01    .584-01    .609-01    .624-01    .634-01
  100.00           .000      .121-01    .262-01    .375-01    .453-01    .502-01    .533-01    .555-01    .571-01    .581-01
  110.00           .000      .854-02    .188-01    .272-01    .334-01    .374-01    .398-01    .415-01    .430-01    .439-01
  120.00           .000      .413-02    .947-02    .142-01    .181-01    .208-01    .225-01    .237-01    .245-01    .249-01
  130.00           .000      .781-03    .182-02    .288-02    .388-02    .477-02    .562-02    .638-02    .681-02    .694-02
  140.00           .000     -.885-03   -.236-02   -.377-02   -.466-02   -.488-02   -.451-02   -.394-02   -.360-02   -.354-02
  150.00           .000     -.14 -02   -.384-02   -.628-02   -.806-02   -.886-02   -.884-02   -.838-02   -.806-02   -.806-02
  160.00           .000     -.157-02   -.440-02   -.744-02   -.988-02   -.112-01   -.116-01   -.113-01   -.108-01   -.107-01
  170.00           .000     -.165-02   -.469-02   -.811-02   -.110-01   -.129-01   -.137-01   -.134-01   -.128-01   -.124-01
  180.00           .000     -.167-02   -.477-02   -.831-02   -.114-01   -.135-01   -.144-01   -.142-01   -.135-01   -.129-01

          X        .300+01
THETA
     .00          -.125+00
   10.00          -.122+00
   20.00          -.112+00
   30.00          -.946-01
   40.00          -.713-01
   50.00          -.437-01
   60.00          -.897-02
   70.00           .247-01
   80.00           .504-01
   90.00           .638-01
  100.00           .584-01
  110.00           .442-01
  120.00           .251-01
  130.00           .700-02
  140.00          -.359-02
  150.00          -.816-02
  160.00          -.107-01
  170.00          -.123-01
  180.00          -.127-01


MERIDIONAL DISPLACEMENTS                       TIME =  .1000

          X      .150+00     .45 +00    .750+00    .105+01    .135+01    .165+01    .195+01    .225+01   [illegible]   .285+01
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THETA
    .00    -.330-02  -.659-02  -.718-02  -.589-02  -.433-02  -.308-02  -.211-02  -.139-02  -.805-03  -.247-03
  10.00    -.303-02  -.625-02  -.680-02  -.551-02  -.407-02  -.291-02  -.205-02  -.132-02  -.729-03  -.228-03
  20.00    -.280-02  -.55 -02  -.597-02  -.482-02  -.363-02  -.266-02  -.188-02  -.127-02  -.730-03  -.256-03
  30.00    -.224-02  -.43 -02  -.475-02  -.374-02  -.274-02  -.198-02  -.136-02  -.862-03  -.451-03  -.127-03
  40.00    -.147-02  -.277-02  -.302-02  -.231-02  -.158-02  -.109-02  -.689-03  -.414-03  -.245-03  -.825-04
  50.00    -.912-03  -.144-02  -.146-02  -.104-02  -.692-03  -.508-03  -.381-03  -.287-03  -.202-03  -.590-04
  60.00    -.465-03  -.778-03  -.677-03  -.441-03  -.468-03  -.554-03  -.570-03  -.516-03  -.379-03  -.130-03
  70.00    -.582-03  -.625-03  -.706-03  -.720-03  -.778-03  -.846-03  -.859-03  -.775-03  -.555-03  -.193-03
  80.00    -.492-03  -.665-03  -.919-03  -.110-02  -.109-02  -.104-02  -.974-03  -.809-03  -.544-03  -.184-03
  90.00    -.491-03  -.919-03  -.131-02  -.154-02  -.153-02  -.136-02  -.114-02  -.871-03  -.550-03  -.192-03
 100.00    -.406-03  -.792-03  -.113-02  -.134-02  -.134-02  -.119-02  -.971-03  -.713-03  -.436-03  -.150-03
 110.00    -.374-03  -.661-03  -.940-03  -.110-02  -.111-02  -.972-03  -.783-03  -.566-03  -.330-03  -.104-03
 120.00    -.280-03  -.489-03  -.654-03  -.723-03  -.685-03  -.572-03  -.440-03  -.301-03  -.177-03  -.500-04
 130.00    -.829-04  -.125-03  -.116-03  -.814-04  -.243-04   .269-04   .702-04   .923-04   .614-04   .254-04
 140.00     .599-04   .15 -03   .236-03   .310-03   .339-03   .346-03   .320-03   .260-03   .175-03   .540-04
 150.00     .154-03   .395-03   .572-03   .679-03   .723-03   .661-03   .555-03   .395-03   .222-03   .664-04
 160.00     .206-03   .547-03   .792-03   .972-03   .105-02   .101-02   .839-03   .592-03   .319-03   .103-03
 170.00     .189-03   .498-03   .744-03   .953-03   .106-02   .107-02   .973-03   .817-03   .561-03   .237-03
 180.00     .190-03   .506-03   .808-03   .105-02   .121-02   .129-02   .131-02   .124-02   .932-03   .353-03

        X   .315+01
THETA
    .00     .247-03
  10.00     .228-03
  20.00     .256-03
  30.00     .127-03
  40.00     .825-04
  50.00     .590-04
  60.00     .130-03
  70.00     .193-03
  80.00     .184-03
  90.00     .192-03
 100.00     .150-03
 110.00     .104-03
 120.00     .500-04
 130.00    -.254-04
 140.00    -.540-04
 150.00    -.664-04
 160.00    -.103-03
 170.00    -.237-03
 180.00    -.353-03


CIRCUMFERENTIAL DISPLACEMENTS                    TIME =  .1000


        X   .000      .30 +00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    .00     .000      .87 -03   .107-02   .138-02   .148-02   .182-02   .208-02   .262-02   .279-02   .259-02
  10.00     .000      .327-02   .368-02   .492-02   .544-02   .647-02   .750-02   .836-02   .874-02   .872-02
  20.00     .000      .611-02   .772-02   .954-02   .109-01   .121-01   .135-01   .148-01   .149-01   .156-01
  30.00     .000      .861-02   .119-01   .146-01   .168-01   .188-01   .198-01   .212-01   .212-01   .224-01
  40.00     .000      .111-01   .158-01   .200-01   .226-01   .257-01   .264-01   .280-01   .284-01   .299-01
  50.00     .000      .128-01   .187-01   .243-01   .277-01   .311-01   .320-01   .334-01   .340-01   .354-01
  60.00     .000      .131-01   .197-01   .256-01   .298-01   .329-01   .334-01   .346-01   .351-01   .363-01
```

```
    70.00       .000       .119-01    .181-01    .231-01    .270-01    .295-01    .296-01    .306-01    .308-01    .316-01
    80.00       .000       .925-02    .140-01    .176-01    .201-01    .220-01    .219-01    .227-01    .226-01    .230-01
    90.00       .000       .597-02    .858-02    .104-01    .115-01    .125-01    .122-01    .126-01    .123-01    .125-01
   100.00       .000       .278-02    .340-02    .389-02    .371-02    .378-02    .308-02    .306-02    .256-02    .278-02
   110.00       .000       .478-03   -.285-03   -.903-03   -.208-02   -.277-02   -.372-02   -.401-02   -.471-02   -.458-02
   120.00       .000      -.834-03   -.224-02   -.355-02   -.535-02   -.649-02   -.761-02   -.809-02   -.878-02   -.877-02
   130.00       .000      -.127-02   -.280-02   -.425-02   -.620-02   -.737-02   -.853-02   -.911-02   -.970-02   -.978-02
   140.00       .000      -.106-02   -.243-02   -.369-02   -.531-02   -.639-02   -.748-02   -.804-02   -.865-02   -.864-02
   150.00       .000      -.791-03   -.178-02   -.267-02   -.393-02   -.481-02   -.578-02   -.625-02   -.685-02   -.688-02
   160.00       .000      -.484-03   -.104-02   -.163-02   -.249-02   -.306-02   -.370-02   -.404-02   -.456-02   -.484-02
   170.00       .000      -.151-03   -.308-03   -.562-03   -.856-03   -.104-02   -.124-02   -.139-02   -.169-02   -.197-02
   180.00       .000       .151-03    .308-03    .562-03    .856-03    .104-02    .124-02    .139-02    .169-02    .197-02

            X   .300+01
  THETA
      .00       .245-02
    10.00       .832-02
    20.00       .147-01
    30.00       .219-01
    40.00       .295-01
    50.00       .352-01
    60.00       .361-01
    70.00       .314-01
    80.00       .229-01
    90.00       .122-01
   100.00       .242-02
   110.00      -.497-02
   120.00      -.909-02
   130.00      -.101-01
   140.00      -.902-02
   150.00      -.734-02
   160.00      -.532-02
   170.00      -.209-02
   180.00       .209-02


  INNER FIBER MERIDIONAL STRESSES              TIME =  .1000


            X   .000       .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
  THETA
      .00       .207+05    .624+04   -.106+05    .587+04   -.291+04   -.230+05   -.176+05    .118+05    .111+05   -.297+05
    10.00       .124+05    .754+04   -.388+04    .107+05    .412+02   -.171+05   -.147+05    .346+04   -.129+04   -.227+05
    20.00       .912+04    .116+05    .117+05    .131+05    .119+04   -.387+04   -.972+04   -.143+05   -.238+05   -.856+04
    30.00      -.377+04    .142+05    .154+05    .189+05    .561+04    .880+04   -.877+04   -.245+05   -.351+05   -.367+04
    40.00      -.127+05    .116+05    .155+05    .101+05    .779+04    .103+05   -.326+04   -.324+05   -.254+05    .768+04
    50.00      -.963+04    .937+04    .143+05    .274+04    .131+05    .985+04   -.451+04   -.303+05   -.107+05    .190+05
    60.00       .207+04    .747+04    .872+04   -.216+04    .370+03   -.381+04   -.155+05   -.220+05    .363+04    .190+05
    70.00       .169+05    .723+04   -.138+04   -.997+04   -.944+04   -.199+05   -.236+05   -.112+05    .850+04    .104+05
    80.00       .259+05    .299+04   -.145+05   -.230+05   -.227+05   -.246+05   -.163+05   -.490+04    .489+04    .552+04
    90.00       .201+05   -.32 +04   -.253+05   -.324+05   -.239+05   -.176+05   -.108+05   -.592+04    .242+03    .603+03
   100.00       .213+05   -.361+04   -.267+05   -.304+05   -.203+05   -.112+05   -.455+03    .215+04    .295+04    .356+04
   110.00       .282+05    .532+03   -.193+05   -.202+05   -.143+05   -.784+04    .290+04    .589+04    .512+04    .419+04
   120.00       .225+05    .326+03   -.853+04   -.705+04   -.505+04   -.163+04    .334+04    .422+04    .484+04    .652+04
   130.00       .343+04    .127+03    .162+04    .324+04    .450+04    .604+04    .612+04    .404+04    .336+04    .483+04
   140.00      -.884+04   -.339+03    .537+04    .854+04    .958+04    .881+04    .555+04    .177+04    .725+03    .125+04
```

```
 150.00    -.976+04   .147+04   .708+04   .930+04   .906+04   .553+04   .114+04  -.432+04  -.557+04  -.347+04
 160.00    -.860+04   .324+04   .771+04   .102+05   .975+04   .496+04   .677+02  -.695+04  -.882+04  -.757+04
 170.00    -.110+05   .124+04   .612+04   .101+05   .107+05   .778+04   .549+04  -.123+04  -.467+04  -.586+04
 180.00    -.112+05   .103+04   .710+04   .109+05   .124+05   .108+05   .996+04   .264+04  -.204+04  -.534+04

          X    .300+01
THETA
    .00    -.485+05
  10.00    -.295+05
  20.00     .126+05
  30.00     .424+05
  40.00     .405+05
  50.00     .267+05
  60.00     .114+05
  70.00     .440+04
  80.00     .327+04
  90.00     .230+03
 100.00     .431+04
 110.00     .387+04
 120.00     .553+04
 130.00     .460+04
 140.00     .274+04
 150.00    -.864+03
 160.00    -.617+04
 170.00    -.625+04
 180.00    -.583+04


OUTER FIBER MERIDIONAL STRESSES          TIME =  .1000


          X    .000      .30 +00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    .00     .246+05   .313+05   .341+05   .111+05   .264+03  -.630+03  -.182+05  -.514+05  -.519+05  -.214+05
  10.00     .172+05   .253+05   .299+05   .932+04   .257+04  -.292+04  -.168+05  -.438+05  -.447+05  -.241+05
  20.00     .123+05   .102+05   .148+05   .642+03   .462+03  -.114+05  -.135+05  -.138+05  -.641+04  -.230+05
  30.00     .122+05  -.473+04   .393+04  -.190+04   .474+03  -.120+05  -.342+04   .113+05   .182+05  -.195+05
  40.00     .936+04  -.123+05  -.804+04  -.195+04  -.583+04  -.119+05  -.294+03   .266+05   .156+05  -.216+05
  50.00     .303+04  -.157+05  -.145+05  -.317+04  -.107+05  -.959+04   .599+04   .322+05   .110+05  -.200+05
  60.00    -.175+05  -.213+05  -.170+05  -.308+04  -.6 6+04   .449+03   .206+05   .330+05   .115+05  -.526+03
  70.00    -.360+05  -.215+05  -.853+04   .466+04   .516+04   .141+05   .251+05   .236+05   .935+04   .157+05
  80.00    -.440+05  -.178+05   .420+04   .157+05   .173+05   .218+05   .213+05   .188+05   .177+05   .245+05
  90.00    -.499+05  -.174+05   .115+05   .248+05   .226+05   .219+05   .210+05   .227+05   .229+05   .284+05
 100.00    -.472+05  -.16 +05   .152+05   .282+05   .267+05   .237+05   .178+05   .180+05   .198+05   .220+05
 110.00    -.437+05  -.197+05   .724+04   .161+05   .196+05   .206+05   .148+05   .141+05   .167+05   .175+05
 120.00    -.405+05  -.187+05  -.256+04   .408+04   .985+04   .117+05   .918+04   .923+04   .911+04   .723+04
 130.00    -.757+04  -.591+04  -.289+04  -.198+04  -.878+03  -.137+04  -.876+03   .644+02  -.130+04  -.356+04
 140.00     .174+05   .735+04   .551+03  -.379+04  -.646+04  -.659+04  -.427+04  -.176+04  -.209+04  -.416+04
 150.00     .317+05   .156+05   .607+04  -.190+04  -.722+04  -.810+04  -.696+04  -.362+04  -.266+04  -.392+04
 160.00     .380+05   .219+05   .106+05   .878+03  -.656+04  -.100+05  -.116+05  -.812+04  -.592+04  -.593+04
 170.00     .377+05   .218+05   .117+05   .240+04  -.550+04  -.943+04  -.114+05  -.664+04  -.428+04  -.433+04
 180.00     .382+05   .223+05   .134+05   .440+04  -.346+04  -.714+04  -.919+04  -.443+04  -.257+04  -.210+04

          X    .300+01
THETA
    .00     .942+04
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```
  10.00      -.963+04
  20.00      -.380+05
  30.00      -.514+05
  40.00      -.431+05
  50.00      -.225+05
  60.00       .817+04
  70.00       .244+05
  80.00       .307+05
  90.00       .319+05
 100.00       .230+05
 110.00       .168+05
 120.00       .775+04
 130.00      -.367+04
 140.00      -.577+04
 150.00      -.587+04
 160.00      -.685+04
 170.00      -.508+04
 180.00      -.296+04

INNER FIBER CIRCUMFERENTIAL STRESSES          TIME =  .1000

          X      .000      .30 +00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    .00       -.782+04  -.631+04  -.214+05   .163+05   .203+05   .879+04   .514+04   .164+05   .205+05   .866+04
  10.00       -.464+04   .263+04  -.940+04   .221+05   .270+05   .114+05   .893+04   .107+05   .128+05   .924+04
  20.00       -.280+04   .521+04   .573+04   .313+05   .255+05   .102+05   .536+04   .313+04   .226+04   .837+04
  30.00       -.489+04   .41 +04   .123+05   .368+05   .275+05   .148+05   .558+04   .140+04  -.309+04   .827+03
  40.00       -.565+04   .39 +04   .135+05   .317+05   .259+05   .175+05   .157+05   .114+05   .124+05   .109+05
  50.00       -.289+04   .156+04   .126+05   .261+05   .219+05   .145+05   .186+05   .152+05   .187+05   .178+05
  60.00        .249+04  -.739+03   .373+04   .116+05   .942+04  -.311+04   .230+04   .522+04   .933+04   .448+04
  70.00        .967+04  -.27 +04  -.675+04  -.290+04  -.677+04  -.146+05  -.100+05  -.271+04  -.256+04  -.118+05
  80.00        .142+05  -.716+04  -.173+05  -.162+05  -.163+05  -.199+05  -.164+05  -.112+05  -.114+05  -.160+05
  90.00        .150+05  -.127+05  -.244+05  -.204+05  -.139+05  -.158+05  -.134+05  -.114+05  -.104+05  -.103+05
 100.00        .164+05  -.162+05  -.239+05  -.197+05  -.138+05  -.155+05  -.986+04  -.901+04  -.830+04  -.571+04
 110.00        .165+05  -.112+05  -.130+05  -.743+04  -.470+04  -.426+04   .192+04   .334+04   .346+04   .351+04
 120.00        .957+04  -.744+04  -.221+04   .239+04   .386+04   .504+04   .867+04   .921+04   .121+05   .122+05
 130.00        .147+04  -.149+04   .459+04   .937+04   .132+05   .180+05   .212+05   .221+05   .255+05   .237+05
 140.00       -.220+04   .312+04   .662+04   .983+04   .156+05   .178+05   .200+05   .214+05   .220+05   .241+05
 150.00       -.243+04   .192+04   .315+04   .356+04   .506+04   .510+04   .623+04   .812+04   .940+04   .973+04
 160.00       -.215+04   .154+04   .179+04  -.164+04  -.2 6+04  -.181+04   .176+04   .363+04   .410+04   .236+04
 170.00       -.274+04   .117+04   .336+02  -.346+04  -.186+04  -.980+03   .483+04   .776+04   .649+04   .332+04
 180.00       -.281+04   .442+03  -.223+04  -.305+04  -.123+04  -.626+03   .412+04   .904+04   .642+04   .352+04

          X      .300+01
THETA
    .00       -.133+05
  10.00       -.166+04
  20.00        .560+04
  30.00        .656+04
  40.00        .912+04
  50.00        .129+05
  60.00        .154+04
  70.00       -.130+05
  80.00       -.142+05
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    90.00      -.120+05
   100.00      -.544+04
   110.00       .372+04
   120.00       .123+05
   130.00       .223+05
   140.00       .227+05
   150.00       .885+04
   160.00       .258+04
   170.00       .278+04
   180.00       .100+04


OUTER FIBER CIRCUMFERENTIAL STRESSES        TIME =  .100


          X     .000      .30 +00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
     .00       .191+05   .227+05   .495+04   .229+05   .247+05   .112+05  -.831+04  -.263+05  -.247+05   .150+04
   10.00       .155+05   .186+05   .421+04   .222+05   .308+05   .942+04  -.486+04  -.183+05  -.151+05  -.177+04
   20.00       .112+05   .146+05   .775+04   .199+05   .256+05   .553+04  -.302+04   .196+04   .690+04  -.187+04
   30.00       .889+04   .808+04   .148+05   .192+05   .219+05   .998+04   .860+04   .186+05   .223+05  -.436+02
   40.00       .642+04  -.127+03   .531+04   .120+05   .834+04   .144+04   .608+04   .209+05   .164+05  -.615+04
   50.00       .311+04  -.627+04  -.306+04   .594+04  -.448+03  -.323+04   .313+04   .155+05   .488+04  -.161+05
   60.00      -.408+04  -.894+04  -.302+04   .956+04   .105+05   .810+04   .171+05   .257+05   .158+05   .445+04
   70.00      -.115+05  -.909+04   .365+04   .193+05   .190+05   .168+05   .246+05   .231+05   .141+05   .193+05
   80.00      -.174+05  -.988+04   .784+04   .230+05   .246+05   .191+05   .252+05   .202+05   .180+05   .177+05
   90.00      -.221+05  -.11 +05   .865+04   .232+05   .259+05   .193+05   .212+05   .209+05   .191+05   .216+05
  100.00      -.232+05  -.118+05   .863+04   .259+05   .276+05   .216+05   .188+05   .185+05   .178+05   .209+05
  110.00      -.220+05  -.165+05  -.193+04   .100+05   .145+05   .151+05   .167+05   .173+05   .203+05   .228+05
  120.00      -.172+05  -.186+05  -.976+04  -.431+04   .916+02   .269+04   .528+04   .587+04   .826+04   .626+04
  130.00      -.434+04  -.11 +05  -.120+05  -.130+05  -.147+05  -.136+05  -.121+05  -.118+05  -.946+04  -.116+05
  140.00       .435+04  -.615+02  -.681+04  -.117+05  -.112+05  -.111+05  -.813+04  -.543+04  -.493+04  -.350+04
  150.00       .793+04   .438+04  -.681+03  -.459+04  -.516+04  -.432+04  -.148+04   .261+04   .383+04   .233+04
  160.00       .949+04   .602+04   .184+04  -.538+04  -.792+04  -.735+04  -.274+04   .180+04   .529+04   .773+03
  170.00       .945+04   .632+04   .111+04  -.668+04  -.819+04  -.869+04  -.354+04   .211+04   .577+04   .362+04
  180.00       .958+04   .581+04  -.924+03  -.558+04  -.733+04  -.878+04  -.542+04   .265+04   .507+04   .456+04

          X     .300+01
THETA
     .00       .178+05
   10.00       .636+04
   20.00      -.114+05
   30.00      -.195+05
   40.00      -.176+05
   50.00      -.167+05
   60.00       .815+04
   70.00       .244+05
   80.00       .203+05
   90.00       .264+05
  100.00       .199+05
  110.00       .233+05
  120.00       .843+04
  130.00      -.109+05
  140.00      -.601+04
  150.00      -.404+03
  160.00      -.102+02
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 170.00         .370+04
 180.00         .273+04


INNER FIBER SHEAR STRESSES                    TIME =  .1000


          X       .000        .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
      .00        .295+02    -.884+02    -.491+03    -.411+03    -.559+03    -.710+03    -.643+03    -.218+03     .186+03     .234+03
    10.00        .173+05     .122+05     .278+03     .842+03     .254+04     .291+04    -.220+03    -.470+03     .334+04     .421+04
    20.00        .147+05     .21 +05     .544+04     .549+04     .789+04     .644+04     .442+04     .112+04     .482+04     .434+04
    30.00        .187+05     .213+05     .154+05     .126+05     .162+05     .148+05     .116+05     .589+04     .636+04     .279+04
    40.00        .181+05     .221+05     .193+05     .173+05     .179+05     .183+05     .155+05     .110+05     .947+04     .342+04
    50.00        .171+05     .202+05     .174+05     .162+05     .154+05     .137+05     .163+05     .118+05     .865+04     .312+04
    60.00        .157+05     .175+05     .161+05     .140+05     .142+05     .125+05     .128+05     .936+04     .623+04     .237+04
    70.00        .113+05     .143+05     .150+05     .165+05     .149+05     .129+05     .950+04     .729+04     .492+04     .252+04
    80.00        .541+04     .127+05     .126+05     .145+05     .131+05     .787+04     .500+04     .400+04     .272+04     .204+04
    90.00       -.209+04     .105+05     .920+04     .111+05     .738+04     .418+04     .183+04     .138+04     .510+03     .684+03
   100.00       -.741+04     .831+04     .457+04     .588+04     .239+04     .369+04     .685+03    -.187+02    -.213+03     .191+01
   110.00       -.112+05     .536+04     .400+04     .326+04    -.143+03    -.276+04    -.280+04    -.203+04    -.584+03    -.115+03
   120.00       -.103+05     .436+04     .209+04    -.287+04    -.537+04    -.532+04    -.400+04    -.278+04    -.906+03    -.203+03
   130.00       -.993+04    -.493+04    -.517+04    -.876+04    -.967+04    -.794+04    -.621+04    -.425+04    -.211+04    -.987+03
   140.00       -.112+05    -.107+05    -.101+05    -.125+05    -.124+05    -.998+04    -.799+04    -.576+04    -.307+04    -.178+04
   150.00       -.843+04    -.109+05    -.103+05    -.113+05    -.1 8+05    -.881+04    -.696+04    -.551+04    -.322+04    -.253+04
   160.00       -.625+04    -.817+04    -.798+04    -.900+04    -.847+04    -.694+04    -.549+04    -.468+04    -.354+04    -.354+04
   170.00       -.403+04    -.417+04    -.447+04    -.531+04    -.458+04    -.331+04    -.237+04    -.218+04    -.227+04    -.234+04
   180.00       -.625+02    -.596+01    -.143+02    -.213+02    -.238+02    -.159+02    -.273+01    -.251+01    -.489+01    -.211+01

          X       .300+01
THETA
      .00       -.135+03
    10.00        .233+03
    20.00        .102+04
    30.00        .169+04
    40.00        .144+04
    50.00        .797+03
    60.00        .403+02
    70.00       -.135+03
    80.00       -.592+02
    90.00        .624+02
   100.00        .111+03
   110.00        .917+02
   120.00        .393+02
   130.00        .113+02
   140.00        .375+01
   150.00        .155+01
   160.00        .160+01
   170.00        .281+01
   180.00        .216+01


OUTER FIBER SHEAR STRESSES                    TIME =  .1000
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             X      .000       .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
   .00              .557+01   -.128+03   -.367+03   -.379+03   -.569+03   -.716+03   -.642+03   -.198+03    .935+02    .234+03
 10.00              .474+04    .110+05    .996+04    .109+05    .898+04    .936+04    .134+05    .925+04   -.377+04   -.106+05
 20.00              .997+04    .174+05    .156+05    .181+05    .158+05    .182+05    .226+05    .125+05   -.212+04   -.110+05
 30.00              .170+05    .183+05    .198+05    .196+05    .194+05    .236+05    .248+05    .122+05    .314+04   -.204+04
 40.00              .174+05    .192+05    .204+05    .209+05    .227+05    .247+05    .221+05    .127+05    .990+04    .784+04
 50.00              .167+05    .206+05    .202+05    .197+05    .243+05    .219+05    .198+05    .127+05    .139+05    .113+05
 60.00              .155+05    .204+05    .199+05    .184+05    .175+05    .127+05    .126+05    .106+05    .150+05    .110+05
 70.00              .123+05    .17 +05    .147+05    .130+05    .812+04    .331+04    .718+03    .595+04    .995+04    .726+04
 80.00              .794+04    .114+05    .984+04    .666+04    .276+04   -.175+04   -.377+04    .138+03    .230+04    .147+04
 90.00              .280+03    .806+04    .413+04    .674+03   -.527+04   -.746+04   -.839+04   -.557+04   -.406+04   -.258+04
100.00             -.764+04   -.203+04   -.260+04   -.657+03   -.343+04   -.417+04   -.577+04   -.399+04   -.302+04   -.147+04
110.00             -.127+05   -.115+05   -.132+05   -.129+05   -.104+05   -.695+04   -.697+04   -.524+04   -.301+04   -.140+04
120.00             -.161+05   -.208+05   -.252+05   -.240+05   -.197+05   -.136+05   -.867+04   -.637+04   -.382+04   -.182+04
130.00             -.145+05   -.247+05   -.252+05   -.250+05   -.232+05   -.158+05   -.102+05   -.655+04   -.361+04   -.190+04
140.00             -.117+05   -.21 +05   -.225+05   -.239+05   -.208+05   -.150+05   -.105+05   -.694+04   -.375+04   -.239+04
150.00             -.897+04   -.151+05   -.160+05   -.175+05   -.161+05   -.127+05   -.918+04   -.620+04   -.321+04   -.248+04
160.00             -.665+04   -.101+05   -.111+05   -.132+05   -.128+05   -.109+05   -.758+04   -.498+04   -.293+04   -.284+04
170.00             -.427+04   -.503+04   -.602+04   -.761+04   -.721+04   -.567+04   -.370+04   -.226+04   -.164+04   -.168+04
180.00             -.625+01   -.598+01   -.143+02   -.213+02   -.238+02   -.159+02   -.273+01   -.251+01   -.481+01   -.210+01

             X      .300+01
THETA
   .00             -.234+03
 10.00              .669+02
 20.00              .892+03
 30.00              .103+04
 40.00              .105+04
 50.00              .593+03
 60.00              .365+02
 70.00             -.139+03
 80.00             -.113+03
 90.00              .751+02
100.00              .115+03
110.00              .916+02
120.00              .475+02
130.00              .164+02
140.00              .373+01
150.00              .155+01
160.00              .160+01
170.00              .285+01
180.00              .215+01


INNER FIBER MERIDIONAL STRAINS            TIME =  .1000


             X      .000       .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
   .00             -.972-01    .854-02    .231-01    .171-01    .644-02    .719-03    .187-02    .552-02    .545-02    .142-02
 10.00             -.950-01    .691-02    .230-01    .163-01    .594-02    .911-03    .200-02    .450-02    .393-02    .158-02
 20.00             -.866-01    .677-02    .214-01    .151-01    .466-02    .182-02    .226-02    .210-02    .105-02    .216-02
 30.00             -.742-01    .630-02    .187-01    .133-01    .393-02    .266-02    .177-02    .132-03   -.962-03    .190-02
 40.00             -.564-01    .392-02    .154-01    .101-01    .370-02    .199-02    .113-02   -.191-02   -.142-02    .183-02
 50.00             -.390-01    .317-02    .114-01    .700-02    .311-02    .389-03   -.252-03   -.285-02   -.960-03    .201-02
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    60.00      -.224-01   .253-02   .694-02   .495-02   .154-02  -.127-02  -.164-02  -.233-02   .130-03   .179-02
    70.00      -.752-02   .243-02   .264-02   .216-02   .247-03  -.189-02  -.211-02  -.106-02   .914-03   .134-02
    80.00       .565-02   .235-02  -.244-03  -.767-03  -.967-03  -.161-02  -.122-02  -.210-03   .775-03   .951-03
    90.00       .131-01   .152-02  -.167-02  -.250-02  -.164-02  -.830-03  -.264-03   .170-03   .749-03   .770-03
   100.00       .141-01   .11 -02  -.214-02  -.270-02  -.172-02  -.732-03   .201-03   .440-03   .503-03   .499-03
   110.00       .937-02   .704-03  -.167-02  -.186-02  -.131-02  -.677-03   .242-03   .506-03   .426-03   .331-03
   120.00       .387-02   .266-03  -.798-03  -.764-03  -.602-03  -.289-03   .118-03   .166-03   .124-03   .281-03
   130.00       .532-03 [illegible]  .472-04   .898-04   .121-03   .153-03   .829-04  -.149-03  -.310-03  -.174-03
   140.00      -.927-03  -.112-03   .372-03   .608-03   .568-03   .435-03   .558-04  -.358-03  -.476-03  -.478-03
   150.00      -.915-03   .991-04   .629-03   .841-03   .780-03   .425-03  -.419-04  -.635-03  -.792-03  -.590-03
   160.00      -.905-03   .285-03   .726-03   .106-02   .103-02   .541-03  -.373-04  -.786-03  -.109-02  -.832-03
   170.00      -.103-02   .95 -04   .611-03   .109-02   .111-02   .802-03   .428-03  -.317-03  -.969-03  -.127-02
   180.00      -.105-02   .916-04   .765-03   .117-02   .127-02   .110-02   .893-03   .376-04  -.109-02  -.219-02

           X    .300+01
THETA
      .00      -.163-02
    10.00      -.463-04
    20.00       .356-02
    30.00       .504-02
    40.00       .383-02
    50.00       .206-02
    60.00       .103-02
    70.00       .764-03
    80.00       .661-03
    90.00       .768-03
   100.00       .567-03
   110.00       .294-03
   120.00       .103-03
   130.00      -.245-03
   140.00      -.293-03
   150.00      -.303-03
   160.00      -.685-03
   170.00      -.175-02
   180.00      -.261-02


OUTER FIBER MEDIDIONAL STRAINS              TIME =  .1000


           X    .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
      .00       .533-01  -.241-02  -.154-01  -.744-02   .393-02   .767-02   .487-02  -.556-03  -.154-02   .239-02
    10.00       .547-01  -.318-02  -.158-01  -.688-02   .365-02   .681-02   .393-02   .437-03   .199-04   .178-02
    20.00       .514-01  -.309-02  -.155-01  -.678-02   .329-02   .467-02   .295-02   .197-02   .257-02   .104-02
    30.00       .448-01  -.198-02  -.146-01  -.623-02   .280-02   .239-02   .243-02   .319-02   .376-02   .400-03
    40.00       .375-01  -.112-02  -.126-01  -.509-02   .116-02   .138-02   .167-02   .376-02   .262-02  -.630-03
    50.00       .277-01  -.835-03  -.944-02  -.410-02  -.665-03   .106-02   .124-02   .349-02   .160-02  -.100-02
    60.00       .146-01  -.146-02  -.579-02  -.329-02  -.133-02   .109-02   .170-02   .270-02   .800-03  -.119-03
    70.00       .671-03  -.246-02  -.300-02  -.180-02   .389-04   .187-02   .216-02   .162-02   .557-03   .108-02
    80.00      -.119-01  -.259-02  -.289-03   .600-03   .173-02   .230-02   .179-02   .133-02   .100-02   .145-02
    90.00      -.193-01  -.253-02   .118-02   .229-02   .240-02   .225-02   .182-02   .168-02   .141-02   .162-02
   100.00      -.194-01  -.175-02   .166-02   .231-02   .220-02   .189-02   .135-02   .132-02   .137-02   .141-02
   110.00      -.143-01  -.164-02   .772-03   .136-02   .160-02   .168-02   .106-02   .975-03   .116-02   .118-02
   120.00      -.761-02  -.141-02  -.125-04   .515-03   .982-03   .110-02   .786-03   .777-03   .705-03   .567-03
   130.00      -.164-02  -.315-03   .302-04   .154-03   .279-03   .203-03   .216-03   .302-03   .106-03  -.661-04
```

```
 140.00       .163-02    .737-03    .225-03   -.865-04   -.367-03   -.381-03   -.224-03   -.404-04   -.858-04   -.328-03
 150.00       .297-02    .155-02    .624-03   -.755-04   -.593-03   -.702-03   -.660-03   -.427-03   -.361-03   -.450-03
 160.00       .356-02    .204-02    .101-02    .222-03   -.458-03   -.818-03   -.109-02   -.857-03   -.724-03   -.613-03
 170.00       .355-02    .203-02    .115-02    .407-03   -.346-03   -.726-03   -.105-02   -.716-03   -.733-03   -.891-03
 180.00       .358-02    .208-02    .137-02    .579-03   -.163-03   -.494-03   -.784-03   -.509-03   -.950-03   -.167-02

          X   .300+01
THETA
    .00       .513-02
  10.00       .308-02
  20.00      =.143-03
  30.00      =.335-02
  40.00      =.273-02
  50.00      =.127-02
  60.00       .458-03
  70.00       .181-02
  80.00       .178-02
  90.00       .179-02
 100.00       .144-02
 110.00       .110-02
 120.00       .564-03
 130.00      =.939-04
 140.00      =.426-03
 150.00      =.577-03
 160.00      =.685-03
 170.00      =.140-02
 180.00      =.209-02


INNER FIBER CIRCUMFERENTIAL STRAINS          TIME =  .1000


          X   .000       .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00       .700-24   -.147-01   -.288-01   -.333-01   -.330-01   -.313-01   -.313-01   -.305-01   -.304-01   -.309-01
  10.00       .227-04   -.125-01   -.269-01   -.307-01   -.300-01   -.283-01   -.275-01   -.279-01   -.280-01   -.277-01
  20.00       .163-03   -.105-01   -.218-01   -.257-01   -.241-01   -.232-01   -.226-01   -.222-01   -.230-01   -.223-01
  30.00       .255-03   -.915-02   -.176-01   -.201-01   -.184-01   -.162-01   -.165-01   -.156-01   -.166-01   -.165-01
  40.00       .325-03   -.634-02   -.129-01   -.131-01   -.118-01   -.664-02   -.811-02   -.709-02   -.662-02   -.730-02
  50.00       .461-03   -.44 -02   -.853-02   -.740-02   -.491-02   -.252-02   -.719-03   -.284-03   -.415-03   -.123-02
  60.00       .519-03   -.366-02   -.553-02   -.480-02   -.145-02   -.752-04    .670-03    .107-02    .643-03   -.270-04
  70.00       .455-03   -.33 -02   -.389-02   -.381-02   -.218-02   -.112-02   -.415-03    .104-04   -.466-03   -.144-02
  80.00       .317-03   -.354-02   -.391-02   -.370-02   -.355-02   -.247-02   -.123-02   -.998-03   -.127-02   -.173-02
  90.00       .171-03   -.331-02   -.359-02   -.362-02   -.367-02   -.338-02   -.271-02   -.270-02   -.279-02   -.281-02
 100.00       .664-04   -.284-02   -.257-02   -.165-02   -.135-02   -.130-02   -.974-03   -.954-03   -.904-03   -.660-03
 110.00       .154-04   -.162-02   -.931-03   -.228-03   -.112-03   -.230-03    .120-03    .187-03    .218-03    .247-03
 120.00       .870-06   -.61 -03   -.818-05    .416-03    .512-03    .544-03    .783-03    .885-03    .125-02    .120-02
 130.00       .483-06   -.153-03    .419-03    .856-03    .120-02    .165-02    .196-02    .211-02    .249-02    .242-02
 140.00       .105-05    .32 -03    .528-03    .749-03    .132-02    .156-02    .186-02    .210-02    .219-02    .238-02
 150.00       .592-06    .156-03    .139-03    .124-03    .279-03    .372-03    .594-03    .920-03    .108-02    .106-02
 160.00       .325-06    .731-04   -.133-04   -.420-03   -.450-03   -.305-03    .175-03    .537-03    .644-03    .455-03
 170.00       .135-06    .855-04   -.150-03   -.598-03   -.453-03   -.292-03    .345-03    .807-03    .140-02    .149-02
 180.00       .421-25    .185-04   -.400-03   -.577-03   -.434-03   -.334-03    .163-03    .838-03    .211-02    .330-02

          X   .300+01
THETA
```

```
       .00          -.312-01
     10.00          -.261-01
     20.00          -.235-01
     30.00          -.164-01
     40.00          -.759-02
     50.00          -.129-02
     60.00          -.111-03
     70.00          -.141-02
     80.00          -.150-02
     90.00          -.297-02
    100.00          -.652-03
    110.00           .275-03
    120.00           .145-02
    130.00           .249-02
    140.00           .220-02
    150.00           .939-03
    160.00           .413-03
    170.00           .222-02
    180.00           .375-02


OUTER FIBER CIRCUMFERENTIAL STRAINS               TIME =  .1000


           X        .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
       .00          .700-24  -.148-01  -.300-01  -.356-01  -.356-01  -.341-01  -.348-01  -.356-01  -.356-01  -.345-01
     10.00          .229-04  -.14 -01  -.291-01  -.332-01  -.326-01  -.309-01  -.307-01  -.319-01  -.321-01  -.310-01
     20.00          .103-03  -.121-01  -.240-01  -.280-01  -.261-01  -.253-01  -.247-01  -.240-01  -.247-01  -.246-01
     30.00          .265-03  -.964-02  -.190-01  -.218-01  -.198-01  -.178-01  -.175-01  -.163-01  -.166-01  -.174-01
     40.00          .325-03  -.647-02  -.139-01  -.143-01  -.133-01  -.105-01  -.980-02  -.823-02  -.783-02  -.885-02
     50.00          .461-03  -.467-02  -.942-02  -.862-02  -.691-02  -.462-02  -.281-02  -.210-02  -.258-02  -.388-02
     60.00          .519-03  -.351-02  -.551-02  -.528-02  -.193-02  -.622-04   .107-02   .158-02   .113-02   .297-03
     70.00          .456-03  -.29 -02  -.274-02  -.243-02  -.167-03   .157-02   .256-02   .257-02   .206-02   .158-02
     80.00          .317-03  -.192-02  -.335-03   .944-03   .154-02   .265-02   .358-02   .363-02   .355-02   .320-02
     90.00          .171-03  -.135-02   .635-03   .227-02   .284-02   .333-02   .437-02   .473-02   .480-02   .488-02
    100.00          .664-04  -.122-02   .339-03   .190-02   .219-02   .197-02   .212-02   .217-02   .234-02   .261-02
    110.00          .154-04  -.14 -02  -.374-03   .602-03   .956-03   .991-03   .130-02   .138-02   .161-02   .184-02
    120.00          .870-06  -.132-02  -.912-03  -.533-03  -.237-03  -.229-04   .299-03   .356-03   .598-03   .445-03
    130.00          .483-06  -.956-03  -.119-02  -.135-02  -.145-02  -.132-02  -.119-02  -.118-02  -.913-03  -.107-02
    140.00          .165-05  -.19 -03  -.694-03  -.107-02  -.954-03  -.947-03  -.706-03  -.499-03  -.441-03  -.246-03
    150.00          .592-06   .227-04  -.220-03  -.412-03  -.336-03  -.229-03   .265-04   .352-03   .450-03   .331-03
    160.00          .326-06   .547-04  -.803-04  -.560-03  -.628-03  -.485-03   .155-04   .383-03   .677-03   .226-03
    170.00          .135-06   .858-04  -.182-03  -.728-03  -.681-03  -.633-03  -.688-04   .377-03   .102-02   .115-02
    180.00          .421-25   .237-04  -.428-03  -.668-03  -.647-03  -.700-03  -.312-03   .376-03   .178-02   .316-02

           X        .300+01
THETA
       .00          -.335-01
     10.00          -.310-01
     20.00          -.262-01
     30.00          -.163-01
     40.00          -.936-02
     50.00          -.387-02
     60.00           .450-03
     70.00           .165-02
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```
    80.00          .346-02
    90.00          .472-02
   100.00          .260-02
   110.00          .191-02
   120.00          .454-03
   130.00         -.100-02
   140.00         -.457-03
   150.00          .103-03
   160.00          .170-03
   170.00          .194-02
   180.00          .368-02


INNER FIBER SHEAR STRAINS                    TIME =  .100


             X     .000      .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
      .00        -.416-04   -.145-03   -.106-03   -.417-04   -.405-04   -.748-04   -.811-04   -.300-04    .231-04    .295-04
    10.00         .645-02    .114-02    .411-03    .963-03    .107-02    .698-03    .305-03    .234-03    .628-03    .633-03
    20.00         .138-01    .268-02    .140-02    .238-02    .227-02    .191-02    .114-02    .613-03    .927-03    .696-03
    30.00         .195-01    .528-02    .302-02    .401-02    .377-02    .278-02    .206-02    .120-02    .112-02    .520-03
    40.00         .246-01    .812-02    .485-02    .542-02    .499-02    .335-02    .233-02    .160-02    .126-02    .447-03
    50.00         .294-01    .103-01    .633-02    .636-02    .543-02    .349-02    .210-02    .151-02    .108-02    .391-03
    60.00         .313-01    .115-01    .702-02    .681-02    .548-02    .315-02    .164-02    .117-02    .779-03    .296-03
    70.00         .293-01    .116-01    .686-02    .652-02    .528-02    .261-02    .119-02    .912-03    .615-03    .316-03
    80.00         .244-01    .103-01    .584-02    .511-02    .417-02    .186-02    .625-03    .500-03    .339-03    .255-03
    90.00         .179-01    .81 -02    .448-02    .345-02    .273-02    .120-02    .324-03    .215-03    .867-04    .955-04
   100.00         .111-01    .552-02    .302-02    .198-02    .134-02    .507-03    .856-04   -.234-05   -.267-04    .239-06
   110.00         .533-02    .29 -02    .142-02    .527-03   -.178-04   -.345-03   -.351-03   -.253-03   -.731-04   -.144-04
   120.00         .128-02    .835-03    .261-03   -.359-03   -.672-03   -.664-03   -.500-03   -.334-03   -.896-04   -.117-04
   130.00        -.943-03   -.616-03   -.647-03   -.110-02   -.121-02   -.993-03   -.777-03   -.532-03   -.260-03   -.113-03
   140.00        -.140-02   -.136-02   -.127-02   -.156-02   -.155-02   -.125-02   -.999-03   -.720-03   -.384-03   -.223-03
   150.00        -.105-02   -.137-02   -.125-02   -.141-02   -.135-02   -.110-02   -.870-03   -.689-03   -.402-03   -.316-03
   160.00        -.782-03   -.102-02   -.997-03   -.113-02   -.106-02   -.867-03   -.687-03   -.585-03   -.457-03   -.445-03
   170.00        -.504-03   -.522-03   -.559-03   -.664-03   -.573-03   -.414-03   -.296-03   -.273-03   -.316-03   -.320-03
   180.00        -.763-07   -.746-06   -.178-05   -.266-05   -.297-05   -.199-05   -.341-06   -.314-06   -.534-06   -.226-06

             X     .300+01
THETA
      .00        -.295-04
    10.00         .759-05
    20.00         .111-03
    30.00         .168-03
    40.00         .141-03
    50.00         .741-04
    60.00         .456-05
    70.00        -.169-04
    80.00        -.740-05
    90.00         .780-05
   100.00         .138-04
   110.00         .115-04
   120.00         .595-05
   130.00         .205-05
   140.00         .469-06
   150.00         .195-06
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```
  160.00       .200-06
  170.00       .387-06
  180.00       .225-06

OUTER FIBER SHEAR STRAINS                 TIME =  .100

          X     .000     .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
     .00     -.415-04  -.145-03  -.106-03  -.417-04  -.4 5-04  -.748-04  -.811-04  -.30 -04   .231-04   .295-04
   10.00      .683-02   .289-02   .199-02   .191-02   .146-02   .173-02   .206-02   .145-02  -.270-03  -.121-02
   20.00      .147-01   .676-02   .394-02   .360-02   .279-02   .315-02   .345-02   .204-02   .561-04  -.121-02
   30.00      .237-01   .114-01   .662-02   .536-02   .431-02   .395-02   .374-02   .201-02   .736-03  -.719-04
   40.00      .262-01   .158-01   .973-02   .726-02   .597-02   .449-02   .317-02   .183-02   .132-02   .100-02
   50.00      .313-01   .191-01   .125-01   .919-02   .724-02   .482-02   .251-02   .159-02   .174-02   .141-02
   60.00      .333-01   .21 -01   .141-01   .106-01   .757-02   .415-02   .168-02   .133-02   .188-02   .138-02
   70.00      .312-01   .205-01   .138-01   .101-01   .657-02   .268-02   .998-03   .127-02   .153-02   .919-03
   80.00      .261-01   .166-01   .120-01   .743-02   .451-02   .153-02   .632-03   .990-03   .837-03   .431-03
   90.00      .191-01   .107-01   .594-02   .373-02   .225-02   .631-03   .156-03   .407-03   .271-03   .127-03
  100.00      .117-01   .433-02   .145-02   .631-03   .350-03  -.269-03  -.424-03  -.177-03  -.597-04  -.387-04
  110.00      .570-02  -.34 -03  -.165-02  -.161-02  -.129-02  -.112-02  -.871-03  -.654-03  -.377-03  -.175-03
  120.00      .135-02  -.26 -02  -.315-02  -.299-02  -.246-02  -.171-02  -.108-02  -.796-03  -.476-03  -.228-03
  130.00     -.101-02  -.311-02  -.339-02  -.344-02  -.290-02  -.197-02  -.127-02  -.819-03  -.451-03  -.237-03
  140.00     -.149-02  -.263-02  -.281-02  -.298-02  -.259-02  -.187-02  -.132-02  -.867-03  -.469-03  -.299-03
  150.00     -.112-02  -.188-02  -.200-02  -.218-02  -.2 1-02  -.159-02  -.115-02  -.775-03  -.401-03  -.310-03
  160.00     -.933-03  -.126-02  -.139-02  -.145-02  -.160-02  -.133-02  -.948-03  -.622-03  -.366-03  -.354-03
  170.00     -.537-03  -.629-03  -.752-03  -.952-03  -.9 2-03  -.709-03  -.463-03  -.283-03  -.228-03  -.236-03
  180.00     -.783-07  -.745-06  -.179-05  -.266-05  -.297-05  -.199-05  -.341-06  -.314-06  -.534-06  -.226-06

          X     .300+01
THETA
     .00     -.295-04
   10.00      .758-05
   20.00      .111-03
   30.00      .169-03
   40.00      .141-03
   50.00      .741-04
   60.00      .453-05
   70.00     -.169-04
   80.00     -.733-05
   90.00      .759-05
  100.00      .139-04
  110.00      .115-04
  120.00      .594-05
  130.00      .204-05
  140.00      .465-06
  150.00      .194-06
  160.00      .200-06
  170.00      .367-06
  180.00      .226-06
```

```
                                          TIME =  .1000 MILLISEC.
DATA AT  X = L/2, THETA =   DEGREES

     U          V          W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  -.551-02   -.138-02   -.117+00    -.522+03    .236+04     .713+03     .713+03    -.617+01     .398+01     .769+01     .769+01

          SUBLAYER STRAINS AND STRESSES

      EPP =    .4443-02    .5815-02    .5107-02    .4559- 2    .3931-02
      EPT =   -.3299-01   -.3364-01   -.3430-01   -.3496- 1   -.3561-01
      GPT =   -.4048-04   -.4 48-04   -.4048-04   -.4048- 4   -.4048-04
       SX =   -.2996+04   -.4622+04   -.7602+04   -.7224+ 4    .2639+03
       ST =    .2027+05    .1329+05    .1157+05    .1572+ 5    .2474+05
      TTP =   -.5586+03   -.5517+03   -.5556+03   -.5698+ 3   -.5888+03

DATA AT  X = 0, THETA =   DEGREES

     U          V          W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

   .303-02    .233-02   -.539-01     .147+04    -.620+03     .171+04     .171+04     .445+02     .173+02     .951+00     .951+00

          SUBLAYER STRAINS AND STRESSES

      EPP =   -.9725-01   -.5961-01   -.2197-01    .1567- 1    .5330-01
      EPT =    .7001-24    .7 01-24    .7001-24    .7001-24    .7001-24
      GPT =   -.4164-04   -.4164-04   -.4164-04   -.4164- 4   -.4164-04
       SX =    .2070+05    .1176+05    .5530+04    .3978+ 5    .2460+05
       ST =   -.7616+04   -.1 05+05   -.1133+05    .2208+ 5    .1914+05
      TTP =    .2951+02    .4649+01   -.5577+02   -.7158+ 2    .5587+01

DATA AT  X = L/2, THETA = THE/2 DEGREES

     U          V          W           NX          NT          NXT         NTX         MX          MT          MXT         MTX

  -.720-03    .231-01    .481-01     .149+03     .797+03     .495+03     .495+03     .638+02     .588+02    -.139+02    -.139+02

          SUBLAYER STRAINS AND STRESSES

      EPP =   -.9670-03   -.2939-03    .3793-03    .1052- 2    .1726-02
      EPT =   -.3552-02   -.2276-02   -.1024-02    .2696- 3    .1543-02
      GPT =    .4168-02    .4254- 2    .4341-02    .4427- 2    .4513-02
       SX =   -.2266+05   -.1174+05   -.9372+03    .8984+ 4    .1726+05
       ST =   -.1630+05   -.5290+ 4    .5900+04    .1617+ 5    .2463+05
      TTP =    .1312+05    .1297+05    .1109+05    .7546+ 4    .2756+04
```

```
          SPI EXPERIMENTS     AFWL-TR-66-56     NONLINEAR
              L/D = 1            A/H = 24       8400 TAPS

RADIAL DISPLACEMENTS                     TIME =  .2000 MILLISEC.

          X      .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
   .00           .000      -.55 -01  -.101+00  -.114+00  -.109+00  -.105+00  -.101+00  -.100+00  -.983-01  -.985-01
 10.00           .000      -.54 -01  -.990-01  -.112+00  -.108+00  -.102+00  -.100+00  -.100+00  -.990-01  -.988-01
 20.00           .000      -.50 -01  -.909-01  -.105+00  -.101+00  -.954-01  -.934-01  -.943-01  -.948-01  -.929-01
 30.00           .000      -.419-01  -.786-01  -.909-01  -.880-01  -.829-01  -.802-01  -.818-01  -.836-01  -.827-01
 40.00           .000      -.316-01  -.608-01  -.713-01  -.705-01  -.667-01  -.641-01  -.651-01  -.676-01  -.678-01
 50.00           .000      -.213-01  -.415-01  -.493-01  -.499-01  -.476-01  -.461-01  -.462-01  -.480-01  -.491-01
 60.00           .000      -.113-01  -.231-01  -.279-01  -.276-01  -.255-01  -.247-01  -.246-01  -.259-01  -.270-01
 70.00           .000      -.333-02  -.632-02  -.688-02  -.466-02  -.216-02  -.121-02  -.147-02  -.252-02  -.324-02
 80.00           .000       .385-02   .766-02   .109-01   .142-01   .168-01   .178-01   .176-01   .169-01   .164-01
 90.00           .000       .782-02   .151-01   .203-01   .242-01   .270-01   .283-01   .283-01   .280-01   .277-01
100.00           .000       .786-02   .146-01   .190-01   .222-01   .244-01   .255-01   .258-01   .259-01   .257-01
110.00           .000       .531-02   .999-02   .131-01   .153-01   .170-01   .181-01   .189-01   .192-01   .192-01
120.00           .000       .20 -02   .364-02   .457-02   .537-02   .658-02   .799-02   .926-02   .101-01   .103-01
130.00           .000       .181-03  -.582-03  -.176-02  -.229-02  -.154-02  -.204-03   .122-02   .208-02   .231-02
140.00           .000      -.393-03  -.188-02  -.373-02  -.475-02  -.436-02  -.344-02  -.242-02  -.176-02  -.157-02
150.00           .000      -.295-03  -.813-03  -.146-02  -.163-02  -.655-03   .228-03   .142-02   .254-02   .323-02
160.00           .000       .623-03   .206-02   .359-02   .525-02   .731-02   .943-02   .115-01   .135-01   .149-01
170.00           .000       .181-02   .512-02   .869-02   .123-01   .159-01   .194-01   .227-01   .259-01   .283-01
180.00           .000       .226-02   .627-02   .107-01   .153-01   .201-01   .248-01   .294-01   .337-01   .372-01

          X      .300+01
THETA
   .00          -.102+00
 10.00          -.100+00
 20.00          -.923-01
 30.00          -.816-01
 40.00          -.669-01
 50.00          -.486-01
 60.00          -.270-01
 70.00          -.328-02
 80.00           .164-01
 90.00           .277-01
100.00           .256-01
110.00           .190-01
120.00           .102-01
130.00           .230-02
140.00          -.149-02
150.00           .361-02
160.00           .155-01
170.00           .291-01
180.00           .385-01


MERIDIONAL DISPLACEMENTS                 TIME =  .2000


          X      .150+00   .45 +00   .750+00   .105+01   .135+01   .165+01   .195+01   .225+01   .255+01   .285+01
```

```
THETA
    .00        -.377-02   -.801-02   -.905-02   -.809-02   -.686-02   -.558-02   -.423-02   -.292-02   -.149-02   -.128-03
  10.00        -.345-02   -.741-02   -.836-02   -.743-02   -.625-02   -.511-02   -.399-02   -.284-02   -.162-02   -.437-03
  20.00        -.312-02   -.616-02   -.686-02   -.586-02   -.482-02   -.387-02   -.293-02   -.201-02   -.113-02   -.364-03
  30.00        -.243-02   -.465-02   -.519-02   -.431-02   -.339-02   -.266-02   -.193-02   -.130-02   -.708-03   -.201-03
  40.00        -.161-02   -.293-02   -.330-02   -.269-02   -.201-02   -.152-02   -.108-02   -.717-03   -.406-03   -.114-03
  50.00        -.103-02   -.156-02   -.165-02   -.118-02   -.759-03   -.506-03   -.369-03   -.245-03   -.120-03   -.270-04
  60.00        -.695-03   -.672-03   -.449-03    .181-04    .294-03    .433-03    .442-03    .375-03    .277-03    .114-03
  70.00        -.521-03   -.202-03    .744-04    .452-03    .732-03    .869-03    .843-03    .682-03    .447-03    .159-03
  80.00        -.239-03    .234-03    .546-03    .825-03    .112-02    .122-02    .112-02    .891-03    .561-03    .199-03
  90.00        -.134-03    .271-03    .580-03    .775-03    .100-02    .109-02    .999-03    .767-03    .480-03    .171-03
 100.00        -.631-04    .282-03    .597-03    .789-03    .918-03    .923-03    .812-03    .613-03    .374-03    .120-03
 110.00        -.752-04    .189-03    .383-03    .497-03    .544-03    .535-03    .463-03    .330-03    .190-03    .587-04
 120.00        -.191-04    .162-03    .304-03    .398-03    .444-03    .447-03    .388-03    .274-03    .145-03    .471-04
 130.00        -.313-04    .78 -05    .505-04    .126-03    .191-03    .217-03    .201-03    .164-03    .110-03    .312-04
 140.00        -.112-03   -.22 -03   -.274-03   -.251-03   -.200-03   -.107-03   -.465-04    .127-04    .121-04    .339-05
 150.00        -.874-04   -.248-03   -.321-03   -.290-03   -.226-03   -.112-03   -.345-04    .363-04    .533-04    .311-04
 160.00        -.121-03   -.301-03   -.382-03   -.398-03   -.383-03   -.314-03   -.238-03   -.170-03   -.100-03   -.358-04
 170.00        -.197-03   -.474-03   -.634-03   -.695-03   -.685-03   -.597-03   -.486-03   -.295-03   -.138-03   -.999-05
 180.00        -.197-03   -.452-03   -.592-03   -.630-03   -.584-03   -.488-03   -.348-03   -.142-03   -.669-04    .237-04

          X     .315+01
THETA
    .00         .123-03
  10.00         .437-03
  20.00         .364-03
  30.00         .201-03
  40.00         .114-03
  50.00         .270-04
  60.00        -.114-03
  70.00        -.159-03
  80.00        -.197-03
  90.00        -.171-03
 100.00        -.123-03
 110.00        -.587-04
 120.00        -.471-04
 130.00        -.312-04
 140.00        -.339-05
 150.00        -.311-04
 160.00         .353-04
 170.00         .997-05
 180.00        -.237-04


CIRCUMFERENTIAL DISPLACEMENTS                             TIME =  .2000


          X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00         .000       .923-03    .955-03    .832-03    .438-03    .208-03   -.245-04   -.114-03   -.442-03   -.583-03
  10.00         .000       .32 -02    .306-02    .332-02    .236-02    .215-02    .173-02    .125-02    .466-03    .960-05
  20.00         .000       .567-02    .633-02    .700-02    .639-02    .590-02    .534-02    .490-02    .373-02    .346-02
  30.00         .000       .772-02    .987-02    .111-01    .110-01    .110-01    .979-02    .966-02    .542-02    .835-02
  40.00         .000       .979-02    .130-01    .156-01    .161-01    .169-01    .154-01    .156-01    .149-01    .150-01
  50.00         .000       .112-01    .154-01    .192-01    .2 8-01    .223-01    .215-01    .216-01    .211-01    .214-01
  60.00         .000       .116-01    .164-01    .207-01    .235-01    .253-01    .248-01    .252-01    .248-01    .254-01
```

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  70.00       .000      .105-01   .155-01   .195-01   .225-01   .244-01   .243-01   .249-01   .249-01   .255-01
  80.00       .000      .845-02   .128-01   .160-01   .184-01   .204-01   .207-01   .217-01   .220-01   .227-01
  90.00       .000      .598-02   .916-02   .116-01   .131-01   .151-01   .156-01   .169-01   .173-01   .180-01
 100.00       .000      .388-02   .585-02   .766-02   .861-02   .105-01   .111-01   .125-01   .129-01   .138-01
 110.00       .000      .246-02   .372-02   .505-02   .552-02   .719-02   .772-02   .927-02   .959-02   .105-01
 120.00       .000      .176-02   .279-02   .389-02   .421-02   .573-02   .623-02   .779-02   .810-02   .889-02
 130.00       .000      .148-02   .268-02   .377-02   .426-02   .587-02   .633-02   .777-02   .803-02   .886-02
 140.00       .000      .134-02   .276-02   .401-02   .484-02   .638-02   .692-02   .822-02   .859-02   .940-02
 150.00       .000      .126-02   .261-02   .398-02   .491-02   .620-02   .687-02   .795-02   .834-02   .907-02
 160.00       .000      .937-03   .197-02   .296-02   .382-02   .475-02   .528-02   .619-02   .633-02   .689-02
 170.00       .000      .35 -03   .740-03   .111-02   .147-02   .177-02   .200-02   .232-02   .228-02   .264-02
 180.00       .000     -.35 -03  -.740-03  -.111-02  -.147-02  -.177-02  -.200-02  -.232-02  -.228-02  -.264-02

          X   .300+01
THETA
    .00      -.497-03
  10.00      -.157-03
  20.00       .280-02
  30.00       .769-02
  40.00       .144-01
  50.00       .203-01
  60.00       .249-01
  70.00       .251-01
  80.00       .224-01
  90.00       .177-01
 100.00       .135-01
 110.00       .103-01
 120.00       .872-02
 130.00       .859-02
 140.00       .913-02
 150.00       .787-02
 160.00       .657-02
 170.00       .241-02
 180.00      -.241-02


INNER FIBER MERIDIONAL STRESSES              TIME =  .2000


          X   .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    .00      -.433+05  -.173+05   .809+04  -.654+04  -.216+05  -.217+05  -.955+03  -.321+04  -.213+05  -.307+05
  10.00      -.232+05  -.165+05  -.182+04   .281+04  -.132+05  -.186+05  -.111+05  -.130+04  -.117+05  -.174+05
  20.00      -.144+05  -.167+04   .102+04   .191+05   .724+04  -.167+05  -.236+05  -.246+04   .117+05  -.169+05
  30.00      -.754+04   .603+03   .103+05   .195+05   .113+05  -.126+05  -.360+05  -.869+04   .185+05  -.817+04
  40.00       .915+04  -.487+04  -.109+04   .600+04   .121+05  -.555+04  -.314+05  -.137+05   .109+05   .287+04
  50.00       .195+05  -.840+04  -.856+04  -.603+04   .823+04   .458+04  -.152+05  -.152+05   .249+04   .692+04
  60.00       .137+05  -.522+04  -.563+04  -.361+04   .152+04   .878+03  -.701+04  -.141+05  -.403+04   .644+03
  70.00       .482+04  -.327+04  -.161+04  -.190+04  -.401+04  -.110+05  -.152+05  -.151+05  -.877+04  -.851+04
  80.00      -.803+04  -.305+04  -.408+04  -.570+04  -.944+04  -.192+05  -.187+05  -.168+05  -.144+05  -.133+05
  90.00      -.140+05  -.597+04  -.919+04  -.794+04  -.813+04  -.183+05  -.211+05  -.180+05  -.166+05  -.159+05
 100.00      -.125+05  -.554+04  -.693+04  -.342+04  -.650+04  -.121+05  -.120+05  -.997+04  -.121+05  -.937+04
 110.00       .741+03   .883+03  -.542+04  -.475+04  -.504+04  -.638+04  -.769+04  -.805+04  -.852+04  -.648+04
 120.00       .983+04   .279+04  -.855+02   .240+04   .483+04   .205+04  -.156+04  -.512+04  -.587+04  -.351+04
 130.00      -.171+04  -.606+04  -.698+03   .744+04   .130+05   .610+04   .383+04  -.153+04  -.219+04   .276+03
 140.00      -.904+04  -.125+05  -.425+04   .669+04   .143+05   .978+04   .710+04   .412+04   .275+04   .542+04
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```
   150.00      -.397+04   -.742+04   -.384+04    .448+04    .106+05    .775+04    .712+04    .590+04    .311+04    .307+04
   160.00       .364+04   -.117+04   -.329+04   -.701+03    .326+04    .297+04    .403+04    .373+04    .264+04    .121+04
   170.00       .123+05   -.101+03   -.578+04   -.452+04   -.158+04   -.610+03    .242+04    .265+04    .125+04   -.123+04
   180.00       .193+05    .251+04   -.394+04   -.278+04   -.344+03   -.952+03    .204+03    .252+03   -.255+04   -.918+04

          X     .330+01
 THETA
      .00      -.203+05
    10.00      -.103+05
    20.00      -.159+05
    30.00      -.143+05
    40.00      -.830+04
    50.00      -.510+04
    60.00      -.834+04
    70.00      -.137+05
    80.00      -.171+05
    90.00      -.175+05
   100.00      -.731+04
   110.00      -.192+04
   120.00       .112+04
   130.00       .272+04
   140.00       .612+04
   150.00      -.685+03
   160.00      -.275+04
   170.00      -.792+03
   180.00      -.260+04


 OUTER FIBER MERIDIONAL STRESSES               TIME =  .2000


          X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
 THETA
      .00       .320+05   -.997+04   -.305+05   -.123+05    .105+04   -.279+04   -.149+05    .476+03    .281+05    .385+05
    10.00       .113+05   -.546+04   -.202+05   -.189+05   -.423+04   -.439+04   -.871+04   -.138+05    .329+04    .220+05
    20.00       .433+04   -.127+05   -.257+04   -.208+05   -.164+05    .187+03    .890+04   -.107+05   -.244+05    .297+04
    30.00      -.343+04   -.109+05   -.815+04   -.183+05   -.156+05    .749+04    .257+05   -.208+04   -.329+05   -.908+04
    40.00      -.199+05   -.984+04   -.253+04   -.875+04   -.179+05   -.122+04    .234+05    .548+04   -.241+05   -.162+05
    50.00      -.141+05   -.628+04    .516+04    .538+04   -.104+05   -.923+04    .799+04    .741+04   -.113+05   -.176+05
    60.00       .682+04    .178+04    .974+04    .103+05    .785+03   -.386+04    .691+03    .480+04   -.776+04   -.166+05
    70.00       .252+05    .155+05    .153+05    .119+05    .500+04   -.117+04   -.558+01    .922+03   -.108+05   -.135+05
    80.00       .427+05    .293+05    .200+05    .104+05    .289+04    .457+03   -.144+04   -.542+04   -.993+04   -.104+05
    90.00       .437+05    .319+05    .227+05    .116+05    .370+04    .554+04    .246+04   -.476+04   -.665+04   -.620+04
   100.00       .432+05    .276+05    .223+05    .134+05    .916+04    .698+04    .122+04   -.440+04   -.366+04   -.551+04
   110.00       .309+05    .163+05    .163+05    .758+04    .334+04    .196+04    .173+04   -.919+02   -.454+03   -.183+04
   120.00       .140+05    .825+04    .643+04   -.103+04   -.571+04   -.501+04   -.264+04   -.294+03    .568+03   -.165+03
   130.00       .408+04    .444+04    .415+03   -.532+04   -.854+04   -.633+04   -.327+04    .185+04    .203+04   -.130+04
   140.00      -.832+04   -.179+04   -.411+04   -.795+04   -.919+04   -.323+04   -.254+03    .249+04    .198+04   -.161+04
   150.00      -.221+05   -.617+04   -.486+04   -.603+04   -.756+04   -.134+04    .718+03    .250+04    .311+04    .249+03
   160.00      -.350+05   -.136+05   -.495+04   -.297+04   -.310+04    .124+04    .311+04    .488+04    .766+04    .927+04
   170.00      -.476+05   -.215+05   -.763+04   -.147+04    .191+04    .680+04    .843+04    .128+05    .179+05    .228+05
   180.00      -.501+05   -.223+05   -.783+04   -.103+04    .362+04    .939+04    .145+05    .200+05    .256+05    .312+05

          X     .300+01
 THETA
      .00       .349+05
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```
   10.00          .304+05
   20.00          .155+05
   30.00          .143+05
   40.00          .683+04
   50.00         -.460+03
   60.00         -.101+05
   70.00         -.983+04
   80.00         -.565+04
   90.00         -.375+04
  100.00         -.419+04
  110.00         -.595+04
  120.00         -.405+04
  130.00         -.330+04
  140.00         -.441+03
  150.00          .257+04
  160.00          .133+05
  170.00          .232+05
  180.00          .313+05


INNER FIBER CIRCUMFERENTIAL STRESSES          TIME =  .2000


           X      .000       .300+00     .600+00     .900+00     .120+01     .150+01     .180+01     .210+01     .240+01     .270+01
THETA
     .00       -.155+05    -.985+04    -.152+05     .454+04     .419+04    -.808+04    -.117+05    -.195+05    -.313+05    -.325+05
   10.00       -.121+05    -.164+04    -.165+05     .128+05     .122+05     .311+04    -.175+04    -.604+04    -.116+05    -.978+04
   20.00       -.649+04    -.378+04    -.915+04     .241+05     .225+05     .598+04    -.100+04    -.867+03     .248+04    -.299+04
   30.00       -.454+04    -.293+04     .728+04     .294+05     .195+05     .160+04    -.106+05    -.782+04    -.353+04    -.686+04
   40.00       -.577+03    -.182+04     .413+04     .210+05     .158+05    -.130+04    -.100+05    -.116+05    -.377+04    -.560+04
   50.00        .424+04    -.247+04     .658+03     .604+04     .269+04    -.720+04    -.454+04    -.864+04    -.692+04    -.377+04
   60.00        .673+04    -.197+04    -.236+04    -.997+03    -.890+04    -.204+05    -.108+05    -.985+04    -.877+04    -.519+04
   70.00        .733+04    -.474+04    -.916+04    -.120+05    -.216+05    -.304+05    -.239+05    -.171+05    -.129+05    -.146+05
   80.00        .941+04    -.553+04    -.141+05    -.201+05    -.248+05    -.300+05    -.295+05    -.231+05    -.185+05    -.182+05
   90.00        .237+04    -.897+04    -.199+05    -.178+05    -.196+05    -.205+05    -.192+05    -.120+05    -.108+05    -.112+05
  100.00        .221+04    -.697+04    -.155+05    -.159+05    -.172+05    -.183+05    -.129+05    -.782+04    -.753+04    -.517+04
  110.00        .743+04    -.526+04    -.991+04    -.112+05    -.131+05    -.113+05    -.839+04    -.452+04    -.460+04    -.379+04
  120.00        .647+04    -.133+04     .972+02     .632+03     .156+04     .212+04     .472+04     .677+04     .696+04     .588+04
  130.00        .245+03    -.337+04     .280+04     .594+04     .971+04     .124+05     .143+05     .143+05     .154+05     .159+05
  140.00       -.349+04    -.548+04    -.293+03     .491+04     .114+05     .119+05     .172+05     .185+05     .238+05     .261+05
  150.00       -.267+04    -.244+04    -.222+04     .402+03     .742+04     .694+04     .147+05     .159+05     .159+05     .140+05
  160.00        .107+03    -.356+04    -.545+04    -.499+04    -.977+03    -.579+02     .555+04     .113+05     .119+05     .132+05
  170.00        .320+04    -.665+04    -.117+05    -.137+05    -.122+05    -.123+05    -.528+04     .163+04     .319+04     .833+04
  180.00        .465+04    -.699+04    -.130+05    -.157+05    -.177+05    -.186+05    -.170+05    -.123+05    -.176+05    -.133+05

           X      .300+01
THETA
     .00       -.203+05
   10.00        .313+04
   20.00       -.291+04
   30.00       -.129+05
   40.00       -.135+05
   50.00       -.125+05
   60.00       -.335+04
   70.00       -.145+05
   80.00       -.165+05
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   90.00      -.102+05
  100.00      -.512+04
  110.00      -.347+04
  120.00       .560+04
  130.00       .130+05
  140.00       .229+05
  150.00       .133+05
  160.00       .121+05
  170.00       .623+04
  180.00      -.206+05


OUTER FIBER CIRCUMFERENTIAL STRESSES          TIME =  .200


          X      .000      .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00       .904+04    .902+04   -.203+05    .151+05    .236+05    .118+05   -.165+04    .417+04    .227+05    .241+05
   10.00       .515+04    .826+04   -.191+05    .771+04    .219+05    .405+04   -.733+04   -.114+05   -.897+03    .158+05
   20.00       .181+04    .26 +04   -.379+04    .502+04    .991+04    .351+04   -.512+04   -.147+05   -.127+05    .318+04
   30.00       .706+03   -.29 +03   -.651+03    .176+04    .704+04    .103+05    .689+04   -.595+04   -.201+05   -.124+05
   40.00      -.547+04    .21 +04    .650+04    .502+04   -.977+03   -.132+04    .578+04   -.202+04   -.166+05   -.171+05
   50.00      -.884+04    .362+04    .106+05    .797+04   -.318+04   -.121+05   -.615+04   -.752+04   -.148+05   -.173+05
   60.00      -.667+04    .33 +04    .92 +04    .868+04   -.366+04   -.182+05   -.151+05   -.802+04   -.110+05   -.126+05
   70.00      -.291+04    .182+04    .773+04    .448+04   -.924+04   -.188+05   -.130+05   -.310+04   -.415+04    .272+04
   80.00       .285+04    .243+04    .329+04   -.385+04   -.135+05   -.178+05   -.111+05   -.578+04   -.373+04   -.221+04
   90.00       .525+04    .38 +04    .384+04    .228+04   -.665+04   -.408+04   -.333+03   -.100+04   -.393+04   -.365+04
  100.00       .547+04    .615+04    .327+04    .217+04    .553+03    .128+04    .296+03    .237+04    .158+04    .248+04
  110.00       .768+02    .867+03    .404+04    .394+04    .694+03    .259+04    .469+04    .706+04    .601+04    .552+04
  120.00      -.295+04   -.278+04   -.152+04   -.320+04   -.496+04   -.584+04   -.270+04    .354+03    .364+04    .305+04
  130.00      -.889+03   -.167+04   -.225+04   -.606+04   -.669+04   -.376+04   -.230+04    .263+03   -.226+04   -.148+04
  140.00      -.503+03   -.278+04   -.522+04   -.834+04   -.820+04   -.404+04    .979+01    .111+04    .266+04    .184+04
  150.00      -.153+04   -.521+04   -.991+04   -.123+05   -.121+05   -.935+04   -.420+04   -.950+03    .138+04    .263+04
  160.00      -.544+04   -.815+04   -.721+04   -.654+04   -.410+04   -.364+04    .782+03    .461+04    .613+04    .756+04
  170.00      -.113+05   -.909+04   -.442+04   -.286+03    .491+04    .721+04    .963+04    .111+05    .124+05    .115+05
  180.00      -.132+05   -.976+04   -.469+04    .141+04    .879+04    .109+05    .151+05    .183+05    .223+05    .215+05

          X      .300+01
THETA
     .00       .189+05
   10.00       .151+05
   20.00       .105+05
   30.00      -.329+04
   40.00      -.832+04
   50.00      -.122+05
   60.00      -.849+04
   70.00       .499+04
   80.00       .257+03
   90.00       .416+04
  100.00       .552+03
  110.00       .299+04
  120.00       .239+04
  130.00      -.408+04
  140.00       .437+04
  150.00       .773+04
  160.00       .884+04
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 170.00      .109+05
 180.00      .202+05


INNER FIBER SHEAR STRESSES               TIME =  .2000


          X     .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
    .00       .154+03   .136+03  -.194+03   .176+03  -.105+03  -.357+03  -.129+03  -.184+03  -.259+03  -.949+02
  10.00       .187+05   .954+04  -.784+03   .247+03  -.115+04  -.812+02   .608+03  -.270+03  -.413+04  -.557+04
  20.00       .144+05   .15 +05  -.985+02  -.185+04  -.248+04  -.118+04  -.172+04  -.265+04  -.404+04  -.591+04
  30.00       .131+05   .939+04   .406+04  -.189+04  -.380+03  -.231+04  -.472+04  -.628+04  -.367+04  -.295+04
  40.00       .690+04   .473+04   .291+04  -.247+02  -. 86+03  -.104+04  -.449+04  -.568+04  -.186+04  -.166+03
  50.00       .292+04   .31 +04   .438+03  -.618+03  -.128+04  -.212+04   .949+03  -.213+03   .451+03   .545+03
  60.00       .263+04   .325+04   .141+04   .158+04   .301+03   .473+03   .288+04   .195+04   .187+04   .849+03
  70.00       .309+04   .404+04   .484+04   .666+04   .539+04   .500+04   .411+04   .380+04   .309+04   .128+04
  80.00       .455+04   .744+04   .921+04   .112+05   .104+05   .650+04   .593+04   .579+04   .440+04   .190+04
  90.00       .755+04   .116+05   .125+05   .133+05   .111+05   .922+04   .738+04   .698+04   .495+04   .259+04
 100.00       .142+05   .163+05   .133+05   .133+05   .128+05   .145+05   .968+04   .838+04   .557+04   .324+04
 110.00       .170+05   .215+05   .191+05   .171+05   .169+05   .134+05   .103+05   .925+04   .606+04   .351+04
 120.00       .197+05   .259+05   .222+05   .153+05   .143+05   .126+05   .112+05   .997+04   .613+04   .354+04
 130.00       .250+05   .212+05   .171+05   .151+05   .133+05   .117+05   .112+05   .103+05   .631+04   .322+04
 140.00       .233+05   .172+05   .142+05   .136+05   .125+05   .122+05   .114+05   .102+05   .639+04   .274+04
 150.00       .193+05   .142+05   .119+05   .913+04   .115+05   .105+05   .949+04   .797+04   .513+04   .195+04
 160.00       .145+05   .963+04   .792+04   .614+04   .697+04   .574+04   .560+04   .424+04   .281+04   .658+03
 170.00       .725+04   .505+04   .407+04   .299+04   .278+04   .174+04   .224+04   .131+04   .105+04   .270+03
 180.00      -.151+02  -.107+03  -.249+03  -.394+03  -.530+03  -.639+03  -.697+03  -.689+03  -.553+03  -.188+03

          X     .300+01
THETA
    .00      -.171+03
  10.00      -.337+03
  20.00      -.631+02
  30.00       .181+03
  40.00       .743+02
  50.00       .127+03
  60.00       .117+03
  70.00       .823+02
  80.00       .401+02
  90.00      -.215+02
 100.00      -.410+02
 110.00      -.501+02
 120.00      -.261+02
 130.00       .297+02
 140.00      -.941+01
 150.00      -.155+03
 160.00      -.266+03
 170.00      -.181+03
 180.00       .189+03


OUTER FIBER SHEAR STRESSES               TIME =  .2000
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         X       .000       .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00        .127+03    .972+02   -.156+03    .208+03   -.118+03   -.364+03   -.128+03   -.163+03    .452+02    .921+02
   10.00        .764+04    .11 +05    .368+04   -.114+04   -.181+04   -.643+03   -.289+04   -.746+04   -.628+04   -.196+04
   20.00        .897+04    .122+05    .485+04   -.230+03   -.336+04   -.162+04   -.380+04   -.111+05   -.105+05   -.252+04
   30.00        .103+05    .889+04    .407+04   -.468+04   -.946+04   -.741+04   -.481+04   -.112+05   -.121+05   -.640+04
   40.00        .677+04    .503+04   -.243+03   -.894+04   -.136+05   -.115+05   -.480+04   -.345+04   -.543+04   -.486+04
   50.00        .311+04   -.167+04   -.568+04   -.994+04   -.967+04   -.104+05   -.553+03    .341+04    .779+03   -.248+04
   60.00        .677+04   -.735+04   -.915+04   -.757+04   -.560+04   -.484+04    .137+04    .287+04    .353+04    .385+03
   70.00        .915+04   -.959+04   -.103+05   -.171+04    .280+04    .286+04    .173+04    .115+03    .277+04    .210+04
   80.00        .103+05   -.639+03   -.647+03    .571+04    .937+04    .721+04    .298+04    .113+02    .214+04    .702+03
   90.00        .133+05    .132+05    .126+05    .102+05    .101+05    .675+04    .975+03    .126+04    .110+04   -.387+03
  100.00        .141+05    .212+05    .220+05    .173+05    .143+05    .140+05    .912+04    .876+04    .508+04    .256+04
  110.00        .190+05    .238+05    .246+05    .239+05    .224+05    .209+05    .143+05    .126+05    .835+04    .454+04
  120.00        .223+05    .254+05    .257+05    .259+05    .258+05    .250+05    .181+05    .128+05    .802+04    .464+04
  130.00        .255+05    .258+05    .260+05    .258+05    .256+05    .258+05    .189+05    .141+05    .654+04    .380+04
  140.00        .255+05    .25 +05    .259+05    .256+05    .255+05    .259+05    .211+05    .176+05    .119+05    .602+04
  150.00        .235+05    .257+05    .255+05    .235+05    .214+05    .212+05    .179+05    .167+05    .118+05    .596+04
  160.00        .179+05    .20 +05    .217+05    .197+05    .184+05    .148+05    .135+05    .113+05    .892+04    .419+04
  170.00        .755+04    .123+05    .134+05    .129+05    .124+05    .107+05    .999+04    .832+04    .684+04    .341+04
  180.00       -.101+02   -.107+03   -.249+03   -.394+03   -.530+03   -.547+03   -.553+03   -.482+03   -.346+03   -.780+02

         X       .300+01
THETA
     .00       -.855+02
   10.00       -.634+03
   20.00       -.482+03
   30.00       -.463+03
   40.00       -.315+03
   50.00       -.775+02
   60.00        .113+03
   70.00        .791+02
   80.00       -.139+02
   90.00       -.881+01
  100.00       -.353+02
  110.00       -.501+02
  120.00       -.193+02
  130.00        .343+02
  140.00       -.905+01
  150.00       -.163+03
  160.00       -.275+03
  170.00       -.154+03
  180.00        .770+02


INNER FIBER MERIDIONAL STRAINS              TIME =  .2000


         X       .000       .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
     .00       -.102+00    .627-02    .241-01    .162-01    .498-02    .128-02    .396-02    .491-02    .345-02    .242-02
   10.00       -.980-01    .674-02    .234-01    .158-01    .499-02    .970-03    .263-02    .445-02    .35 -02    .292-02
   20.00       -.902-01    .767-02    .207-01    .153-01    .534-02    .640-03    .103-02    .338-02    .46 -02    .170-02
   30.00       -.742-01    .483-02    .165-01    .136-01    .470-02    .849-03   -.547-03    .180-02    .42 -02    .164-02
   40.00       -.544-01    .242-02    .140-01    .996-02    .439-02    .682-03   -.104-02    .190-03    .262-02    .176-02
   50.00       -.361-01    .15 -02    .940-02    .663-02    .341-02    .404-03   -.748-03   -.745-03    .10 -02    .135-02
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   60.00     -.206-01   .126-02   .565-02   .512-02   .212-02  -.372-03  -.469-03  -.116-02  -.183-03   .214-03
   70.00     -.770-02   .144-02   .265-02   .322-02   .116-02  -.608-03  -.920-03  -.105-02  -.553-03  -.486-03
   80.00      .401-02   .17 -02   .720-03   .106-02   .569-03  -.606-03  -.113-02  -.110-02  -.975-03  -.870-03
   90.00      .101-01   .132-02  -.171-03  -.118-03   .777-04  -.781-03  -.115-02  -.102-02  -.941-03  -.856-03
  100.00      .105-01   .679-03  -.372-03  -.996-04  -.258-03  -.744-03  -.873-03  -.802-03  -.102-02  -.808-03
  110.00      .690-02   .591-03  -.357-03  -.217-03  -.176-03  -.354-03  -.559-03  -.692-03  -.737-03  -.553-03
  120.00      .267-02   .372-03  -.110-04   .234-03   .449-03   .152-03  -.274-03  -.707-03  -.619-03  -.563-03
  130.00      .491-04  -.522-03  -.140-03   .708-03   .111-02   .499-03   .249-04  -.512-03  -.611-03  -.434-03
  140.00     -.129-02  -.111-02  -.414-03   .668-03   .115-02   .681-03   .279-03  -.512-04  -.321-03  -.110-03
  150.00     -.990-03  -.688-03  -.328-03   .439-03   .870-03   .601-03   .344-03   .192-03  -.232-03  -.289-03
  160.00      .604-04  -.277-04  -.193-03   .546-04   .350-03   .298-03   .265-03   .127-03  -.113-03  -.297-03
  170.00      .120-02   .156-03  -.286-03  -.121-03   .146-03   .225-03   .374-03   .566-03   .167-04  -.623-03
  180.00      .182-02   .426-03  -.689-04   .114-03   .409-03   .369-03   .446-03   .708-03  -.276-03  -.118-02

           X  .300+01
 THETA
     .00      .530-02
   10.00      .472-02
   20.00      .153-02
   30.00     -.154-03
   40.00     -.505-03
   50.00     -.492-03
   60.00     -.768-03
   70.00     -.100-02
   80.00     -.129-02
   90.00     -.106-02
  100.00     -.603-03
  110.00     -.113-03
  120.00     -.163-03
  130.00     -.187-03
  140.00     -.130-03
  150.00     -.737-03
  160.00     -.676-03
  170.00     -.111-02
  180.00     -.198-02


 OUTER FIBER MEDIDIONAL STRAINS          TIME =  .2000


           X  .000      .30 +00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
 THETA
     .00      .513-01  -.62 -02  -.213-01  -.958-02   .357-02   .744-02   .503-02   .388-02   .606-02   .669-02
   10.00      .521-01  -.599-02  -.203-01  -.934-02   .319-02   .680-02   .480-02   .326-02   .463-02   .498-02
   20.00      .483-01  -.508-02  -.169-01  -.855-02   .2 0-02   .588-02   .524-02   .270-02   .129-02   .344-02
   30.00      .421-01  -.239-02  -.155-01  -.743-02   .157-02   .424-02   .539-02   .247-02  -.277-03   .175-02
   40.00      .334-01  -.876-03  -.121-01  -.560-02   .176-03   .248-02   .404-02   .224-02  -.522-03   .182-03
   50.00      .232-01  -.145-03  -.782-02  -.329-02  -.570-03   .132-02   .167-02   .158-02  -.143-03  -.726-03
   60.00      .122-01   .546-03  -.341-02  -.193-02  -.259-03   .132-02   .526-03   .726-03  -.455-03  -.130-02
   70.00      .155-02   .971-03  -.727-03  -.659-03   .784-03   .156-02   .748-03   .111-04  -.101-02  -.143-02
   80.00     -.467-02   .174-02   .154-02   .948-03   .150-02   .149-02   .521-03  -.444-03  -.122-02  -.154-02
   90.00     -.116-01   .209-02   .270-02   .167-02   .158-02   .140-02   .560-03  -.522-03  -.969-03  -.121-02
  100.00     -.113-01   .225-02   .283-02   .155-02   .121-02   .611-03   .144-03  -.522-03  -.575-03  -.882-03
  110.00     -.784-02   .146-02   .183-02   .105-02   .538-03   .326-03   .870-04  -.186-03  -.196-03  -.321-03
  120.00     -.290-02   .878-03   .980-03   .407-03  -.131-03  -.104-03  -.988-04  -.383-04  -.342-04  -.927-04
  130.00     -.453-03   .782-03   .439-03  -.197-03  -.67 -03  -.303-03  -.110-03   .281-03   .259-03  -.931-04
```

```
 140.00    -.199-03   .409-03   .880-04  -.486-03  -.806-03  -.569-04   .141-03   .456-03   .320-03   .527-04
 150.00    -.172-03  -.377-03  -.149-03  -.228-03  -.439-03   .171-03   .193-03   .297-03   .356-03   .144-03
 160.00    -.167-02  -.116-02  -.315-03  -.134-03  -.207-03   .215-03   .291-03   .373-03   .613-03   .738-03
 170.00    -.383-02  -.192-02  -.653-03  -.140-03   .683-04   .500-03   .493-03   .824-03   .112-02   .150-02
 180.00    -.445-02  -.201-02  -.666-03  -.138-03   .143-03   .524-03   .723-03   .882-03   .949-03   .185-02

        X     .300+01
THETA
    .00    -.357-02
  10.00     .111-02
  20.00     .333-02
  30.00     .283-02
  40.00     .203-02
  50.00     .853-03
  60.00    -.750-03
  70.00    -.112-02
  80.00    -.135-02
  90.00    -.122-02
 100.00    -.100-02
 110.00    -.670-03
 120.00    -.465-03
 130.00    -.229-03
 140.00     .847-04
 150.00     .322-03
 160.00     .115-02
 170.00     .124-02
 180.00     .167-02


INNER FIBER CIRCUMFERENTIAL STRAINS           TIME =  .2000


        X     .000      .300+00   .600+00   .900+00   .120+01   .150+01   .160+01   .210+01   .240+01   .270+01
THETA
    .00     .956-24  -.144-01  -.292-01  -.341-01  -.341-01  -.331-01  -.334-01  -.338-01  -.347-01  -.352-01
  10.00     .251-04  -.131-01  -.277-01  -.315-01  -.311-01  -.291-01  -.287-01  -.295-01  -.302-01  -.304-01
  20.00     .105-03  -.111-01  -.230-01  -.264-01  -.245-01  -.233-01  -.228-01  -.229-01  -.239-01  -.234-01
  30.00     .192-03  -.952-02  -.180-01  -.209-01  -.193-01  -.169-01  -.174-01  -.171-01  -.177-01  -.171-01
  40.00     .289-03  -.65 -02  -.135-01  -.141-01  -.129-01  -.101-01  -.998-02  -.963-02  -.915-02  -.884-02
  50.00     .405-03  -.436-02  -.915-02  -.919-02  -.679-02  -.456-02  -.276-02  -.304-02  -.331-02  -.308-02
  60.00     .459-03  -.337-02  -.578-02  -.602-02  -.331-02  -.192-02  -.849-03  -.632-03  -.777-03  -.540-03
  70.00     .394-03  -.324-02  -.412-02  -.493-02  -.379-02  -.292-02  -.201-02  -.134-02  -.106-02  -.125-02
  80.00     .264-03  -.323-02  -.385-02  -.453-02  -.474-02  -.361-02  -.248-02  -.189-02  -.149-02  -.149-02
  90.00     .145-03  -.287-02  -.354-02  -.397-02  -.463-02  -.384-02  -.303-02  -.246-02  -.241-02  -.248-02
 100.00     .691-04  -.187-02  -.223-02  -.194-02  -.214-02  -.156-02  -.996-03  -.533-03  -.451-03  -.282-03
 110.00     .305-04  -.104-02  -.966-03  -.987-03  -.119-02  -.975-03  -.647-03  -.251-03  -.247-03  -.217-03
 120.00     .134-04  -.27 -03   .119-04  -.311-04   .249-04   .160-03   .511-03   .874-03   .101-02   .857-03
 130.00     .619-05  -.186-03   .298-03   .230-03   .566-03   .104-02   .134-02   .147-02   .181-02   .176-02
 140.00     .281-05  -.236-03   .597-04   .179-03   .777-03   .944-03   .155-02   .175-02   .231-02   .247-02
 150.00     .180-05  -.566-04  -.126-03  -.732-04   .478-03   .500-03   .130-02   .144-02   .196-02   .210-02
 160.00     .130-05  -.327-03  -.463-03  -.481-03  -.179-03  -.800-04   .454-03   .962-03   .126-02   .150-02
 170.00     .437-06  -.662-03  -.102-02  -.125-02  -.118-02  -.120-02  -.588-03  -.576-03   .176-03   .660-03
 180.00    -.401-24  -.762-03  -.120-02  -.150-02  -.177-02  -.183-02  -.171-02  -.191-02  -.865-03  -.155-02

        X     .300+01
THETA
```

```
    .00       -.351-01
  10.00       -.312-01
  20.00       -.244-01
  30.00       -.169-01
  40.00       -.854-02
  50.00       -.302-02
  60.00       -.107-03
  70.00       -.111-02
  80.00       -.123-02
  90.00       -.234-02
 100.00       -.329-03
 110.00       -.297-03
 120.00        .885-03
 130.00        .155-02
 140.00        .254-02
 150.00        .237-02
 160.00        .142-02
 170.00        .119-02
 180.00       -.461-03


OUTER FIBER CIRCUMFERENTIAL STRAINS            TIME =  .2000


            X      .000      .30 +00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00          .956-24   -.152-01   -.309-01   -.356-01   -.353-01   -.340-01   -.342-01   -.339-01   -.342-01   -.349-01
  10.00          .251-04   -.143-01   -.302-01   -.339-01   -.333-01   -.314-01   -.312-01   -.320-01   -.323-01   -.332-01
  20.00          .105-03   -.128-01   -.246-01   -.289-01   -.273-01   -.258-01   -.255-01   -.257-01   -.267-01   -.251-01
  30.00          .192-03   -.103-01   -.202-01   -.232-01   -.209-01   -.182-01   -.184-01   -.186-01   -.197-01   -.189-01
  40.00          .283-03   -.632-02   -.139-01   -.149-01   -.139-01   -.110-01   -.104-01   -.102-01   -.101-01   -.101-01
  50.00          .406-03   -.392-02   -.854-02   -.853-02   -.719-02   -.551-02   -.379-02   -.379-02   -.399-02   -.406-02
  60.00          .459-03   -.287-02   -.495-02   -.371 02   -.335-02   -.225-02   -.158-02   -.108-02   -.107-02   -.101-02
  70.00          .394-03   -.273-02   -.292-02   -.357-02   -.2 2-02   -.987-03   -.237-05    .519-03    .746-03    .648-03
  80.00          .264-03   -.193-02   -.107-02   -.981-03   -.1 3-02    .640-04    .112-02    .164-02    .207-02    .208-02
  90.00          .145-03   -.127-02   -.217-03    .544-03    .4 8-03    .160-02    .265-02    .322-02    .324-02    .321-02
 100.00          .691-04   -.856-03   -.622-03   -.139-03   -.122-03    .269-03    .685-03    .111-02    .130-02    .145-02
 110.00           [illegible]-04   -.807-03   -.339-03   -.353-05   -.817-04    .942-04    .379-03    .708-03    .612-03    .598-03
 120.00          .134-04   -.10 -02   -.103-02   -.113-02   -.111-02   -.985-03   -.505-03    .427-04    .350-03    .309-03
 130.00          .617-05   -.778-03   -.104-02   -.177-02   -.180-02   -.136-02   -.918-03   -.534-03   -.276-03   -.115-03
 140.00          .281-05   -.554-03   -.101-02   -.173-02   -.172-02   -.190-02   -.155-02   -.162-02   -.135-02   -.144-02
 150.00          .180-05   -.436-03   -.961-03   -.135-02   -.123-02   -.164-02   -.124-02   -.144-02   -.106-02   -.105-02
 160.00          .130-05   -.475-03   -.597-03   -.579-03   -.333-03   -.395-03    .473-06    .339-03    .421-03    .524-03
 170.00          .437-06   -.371-03   -.251-03    .804-05    .443-03    .551-03    .117-02    .116-02    .194-02    .235-02
 180.00         -.401-24   -.41 -03   -.273-03    .167-03    .788-03    .174-02    .298-02    .377-02    .592-02    .620-02

            X      .300+01

THETA
    .00         -.365-01
  10.00         -.341-01
  20.00         -.255-01
  30.00         -.184-01
  40.00         -.967-02
  50.00         -.399-02
  60.00         -.759-03
  70.00          .764-03
```

```
   80.00        .237-02
   90.00        .331-02
  100.00        .139-02
  110.00        .448-03
  120.00        .339-03
  130.00       -.325-03
  140.00       -.147-02
  150.00       -.762-03
  160.00        .544-03
  170.00        .275-02
  180.00        .775-02


INNER FIBER SHEAR STRAINS                    TIME =  .200


          X     .000      .300+00   .600+00   .900+00   .120+01   .150+01   .180+01   .210+01   .240+01   .270+01
THETA
     .00     -.221-04  -.117-03  -.792-04   .317-04   .163-04  -.308-04  -.168-04  -.256-04  -.337-04  -.144-04
   10.00      .479-02   .805-03   .279-03   .889-03   .612-03   .524-03   .408-03   .259-03  -.306-03  -.814-03
   20.00      .140-01   .192-02   .712-03   .146-02   .978-03   .704-03   .371-03   .142-03  -.181-03  -.629-03
   30.00      .169-01   .379-02   .159-02   .220-02   .169-02   .633-03   .162-04  -.304-03  -.163-03  -.198-03
   40.00      .232-01   .595-02   .281-02   .325-02   .270-02   .939-03  -.168-03  -.339-03  -.158-03  -.149-05
   50.00      .276-01   .812-02   .421-02   .426-02   .335-02   .152-02   .173-03   .935-05   .576-04   .683-04
   60.00      .294-01   .969-02   .519-02   .501-02   .374-02   .164-02   .394-03   .244-03   .234-03   .106-03
   70.00      .273-01   .102-01   .559-02   .528-02   .410-02   .163-02   .514-03   .474-03   .386-03   .159-03
   80.00      .223-01   .96 -02   .542-02   .470-02   .382-02   .169-02   .741-03   .724-03   .549-03   .238-03
   90.00      .165-01   .823-02   .489-02   .373-02   .320-02   .183-02   .102-02   .914-03   .635-03   .334-03
  100.00      .114-01   .652-02   .411-02   .291-02   .264-02   .185-02   .121-02   .105-02   .697-03   .405-03
  110.00      .759-02   .492-02   .331-02   .225-02   .211-02   .188-02   .129-02   .116-02   .758-03   .438-03
  120.00      .502-02   .367-02   .277-02   .184-02   .178-02   .158-02   .140-02   .126-02   .789-03   .456-03
  130.00      .343-02   .265-02   .214-02   .137-02   .152-02   .146-02   .140-02   .129-02   .793-03   .413-03
  140.00      .230-02   .215-02   .177-02   .119-02   .157-02   .152-02   .143-02   .127-02   .799-03   .342-03
  150.00      .184-02   .177-02   .149-02   .114-02   .143-02   .132-02   .119-02   .996-03   .652-03   .235-03
  160.00      .157-02   .12 -02   .990-03   .768-03   .871-03   .718-03   .700-03   .509-03   .321-03   .743-04
  170.00      .907-03   .631-03   .508-03   .373-03   .348-03   .217-03   .280-03   .913-04   .285-04  -.805-04
  180.00     -.163-05  -.134-04  -.311-04  -.492-04  -.663-04  -.799-04  -.872-04  -.864-04  -.691-04  -.235-04

          X     .300+01
THETA
     .00      .144-04
   10.00      .309-04
   20.00     -.124-04
   30.00     -.187-04
   40.00     -.295-04
   50.00     -.971-05
   60.00      .141-04
   70.00      .103-04
   80.00      .502-05
   90.00     -.270-05
  100.00     -.513-05
  110.00     -.625-05
  120.00     -.247-05
  130.00      .429-05
  140.00     -.104-05
  150.00     -.205-04
```

```
 160.00        -.345-04
 170.00        -.229-04
 180.00         .235-04


OUTER FIBER SHEAR STRAINS                        TIME =  .200


          X     .000       .300+00    .600+00    .900+00    .120+01    .150+01    .180+01    .210+01    .240+01    .270+01
THETA
    .00      -.221-04   -.117-03   -.792-04    .317-04    .163-04   -.308-04   -.168-04   -.258-04   -.337-04   -.144-04
  10.00       .723-02    .291-02    .120-02    .395-03    .110-03    .455-03    .195-04   -.641-03   -.402-03    .336-03
  20.00       .149-01    .620-02    .259-02    .130-02    .386-03    .672-03    .147-03   -.909-03   -.682-03   -.106-04
  30.00       .201-01    .102-01    .465-02    .233-02    .693-03    .255-03    .397-04   -.907-03   -.107-02   -.617-03
  40.00       .247-01    .139-01    .720-02    .353-02    .143-02    .745-04   -.188-03   -.686-04   -.599-03   -.587-03
  50.00       .294-01    .164-01    .924-02    .549-02    .299-02    .781-03   -.429-04    .433-03    .966-04   -.310-03
  60.00       .317-01    .175-01    .105-01    .732-02    .454-02    .160-02    .210-03    .358-03    .441-03    .481-04
  70.00       .290-01    .172-01    .106-01    .783-02    .506-02    .186-02    .493-03    .543-03    .635-03    .274-03
  80.00       .239-01    .145-01    .903-02    .651-02    .447-02    .192-02    .908-03    .974-03    .816-03    .335-03
  90.00       .175-01    .102-01    .605-02    .420-02    .331-02    .188-02    .122-02    .126-02    .916-03    .401-03
 100.00       .121-01    .582-02    .343-02    .232-02    .224-02    .174-02    .144-02    .142-02    .953-03    .465-03
 110.00       .807-02    .299-02    .177-02    .120-02    .157-02    .168-02    .166-02    .158-02    .104-02    .567-03
 120.00       .535-02    .173-02    .960-03    .534-03    .116-02    .154-02    .169-02    .160-02    .100-02    .580-03
 130.00       .364-02    .170-02    .109-02    .537-03    .110-02    .131-02    .136-02    .131-02    .817-03    .475-03
 140.00       .245-02    .225-02    .206-02    .147-02    .176-02    .159-02    .143-02    .137-02    .100-02    .542-03
 150.00       .195-02    .269-02    .288-02    .246-02    .242-02    .200-02    .174-02    .155-02    .121-02    .620-03
 160.00       .167-02    .250-02    .271-02    .247-02    .230-02    .185-02    .169-02    .142-02    .112-02    .524-03
 170.00       .965-03    .154-02    .167-02    .161-02    .155-02    .135-02    .132-02    .109-02    .959-03    .475-03
 180.00      -.189-05   -.134-04   -.311-04   -.492-04   -.663-04   -.799-04   -.872-04   -.864-04   -.691-04   -.235-04

          X     .300+01
THETA
    .00       .144-04
  10.00       .309-04
  20.00      -.124-04
  30.00      -.187-04
  40.00      -.295-04
  50.00      -.970-05
  60.00       .141-04
  70.00       .103-04
  80.00       .502-05
  90.00      -.270-05
 100.00      -.513-05
 110.00      -.427-05
 120.00      -.247-05
 130.00       .427-05
 140.00      -.104-05
 150.00      -.204-04
 160.00      -.345-04
 170.00      -.223-04
 180.00       .235-04
```

```
                                        TIME =  .2000 MILLISEC.
DATA AT  X = L/2, THETA =   DEGREES

     U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

 -.743-02   -.832-03   -.106+00   -.177+04    .882+03   -.192+03   -.192+03    .216+01    .116+02   -.154+01   -.154+01

          SUBLAYER STRAINS AND STRESSES

     EPP =    .4977-02    .4624-02    .4272-02    .3919-02    .3567-02
     EPT =   -.3413-01   -.3442-01   -.3472-01   -.3501-01   -.3530-01
     GPT =    .1628-04    .1628-04    .1628-04    .1628-04    .1628-04
      SX =   -.2159+05   -.1960+05   -.1855+05   -.1418+05    .1046+04
      ST =    .4170+04    .1322+04    .4709+04    .1347+05    .2365+05
     TTP =   -.1045+03   -.9766+02   -.1017+03   -.1157+03   -.1180+03

DATA AT  X = 0, THETA =   DEGREES

     U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .345-02    .258-02   -.541-01   -.195+04   -.183+04    .155+04    .155+04    .358+02    .156+02    .461+01    .461+01

          SUBLAYER STRAINS AND STRESSES

     EPP =   -.1015+00   -.6334-01   -.2514-01    .1307-01    .5127-01
     EPT =    .9559-24    .9559-24    .9559-24    .9559-24    .9559-24
     GPT =   -.2210-04   -.2210-04   -.2210-04   -.2210-04   -.2210-04
      SX =   -.4329+05   -.2894+05   -.2825+05    .1203+05    .3202+05
      ST =   -.1546+05   -.2 00+05   -.1997+05    .1514+05    .9037+04
     TTP =    .1539+03    .1610+03    .1006+03    .8476+02    .1291+03

DATA AT  X = L/2, THETA = THO/2 DEGREES

     U          V          W          NX         NT         NXT        NTX        MX         MT         MXT        MTX

  .452-03    .195-01    .242-01    .142+03   -.136+04    .133+04    .133+04    .210+02    .265+02   -.327+01   -.327+01

          SUBLAYER STRAINS AND STRESSES

     EPP =    .8636-03    .8 20-03    .1035-02    .1269-02    .1502-02
     EPT =   -.4736-02   -.3810-02   -.2885-02   -.1959-02   -.1033-02
     GPT =    .3822-02    .3984-02    .4145-02    .4307-02    .4468-02
      SX =   -.9440+04   -.4138+04    .1045+04    .5349+04    .2893+04
      ST =   -.2493+05   -.1671+05   -.1241+05   -.7023+04   -.1350+05
     TTP =    .1036+05    .1 81+05    .9528+04    .6585+04    .9375+04
```

```
START SC4020 PLOTTING
PLOT 28 CURVES
FINISH PLOTTING

ELAPSED PLOT TIME =  0:  : 1.567


●FIN


    RUNID:  B92994   ACCOUNT: 814JU11.08     PROJECT: 604342

BR8X0C5231  A PG UNDERWOOD 5231 2 P 45511                        0

        LCAD 6J639  9/4 SHOREN       -1 B92994

B92994    -  PLOT O/P--M=0 00, H=0010, BUFFERS=   19

PLT 50      R      10           AA604342      PLOT94

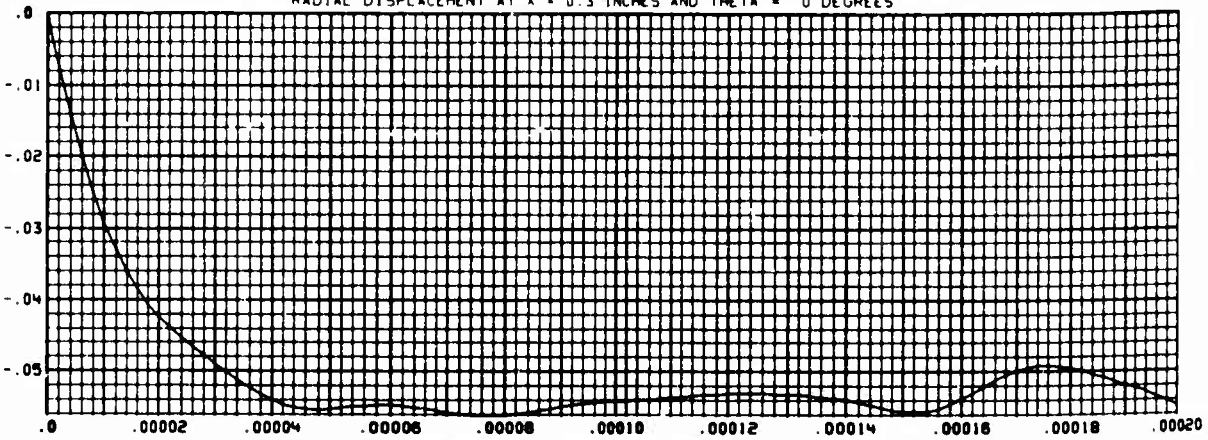
    TIME: 00:06:30.34      IN: 138     OUT: 0        PAGES:   98

    INITIATION  TIME:   19:41:42-AUG 23,1971    CPU TIME: 00:06:03

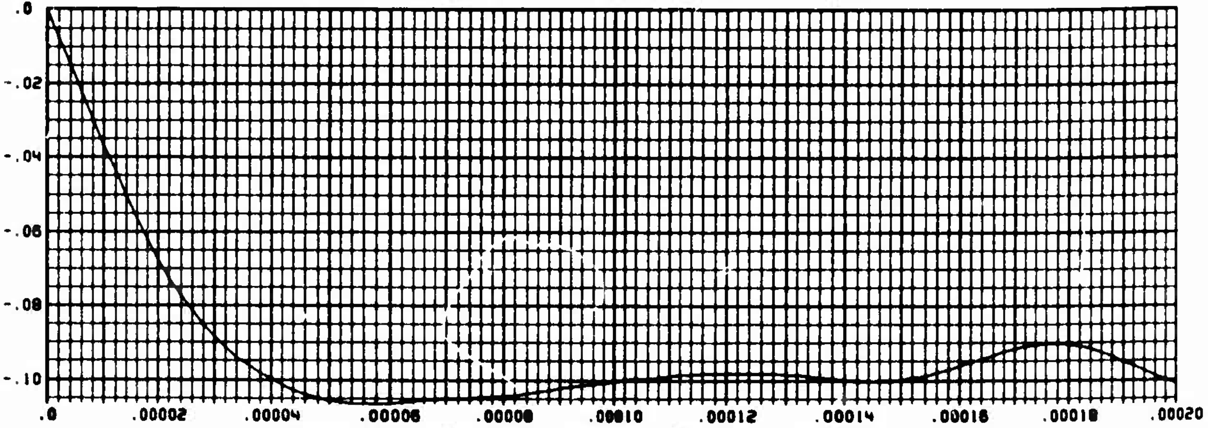
    TERMINATION TIME:   2 :01:40-AUG 23,1971    I/C TIME: 00:00:27
```

SRI EXPER.'IENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

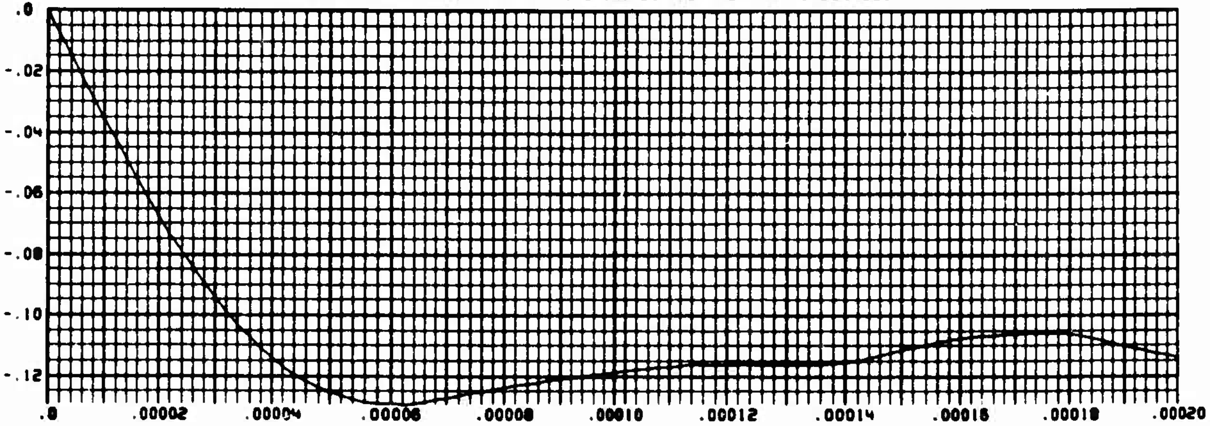
RADIAL DISPLACEMENT AT x = 0.3 INCHES AND THETA = 0 DEGREES

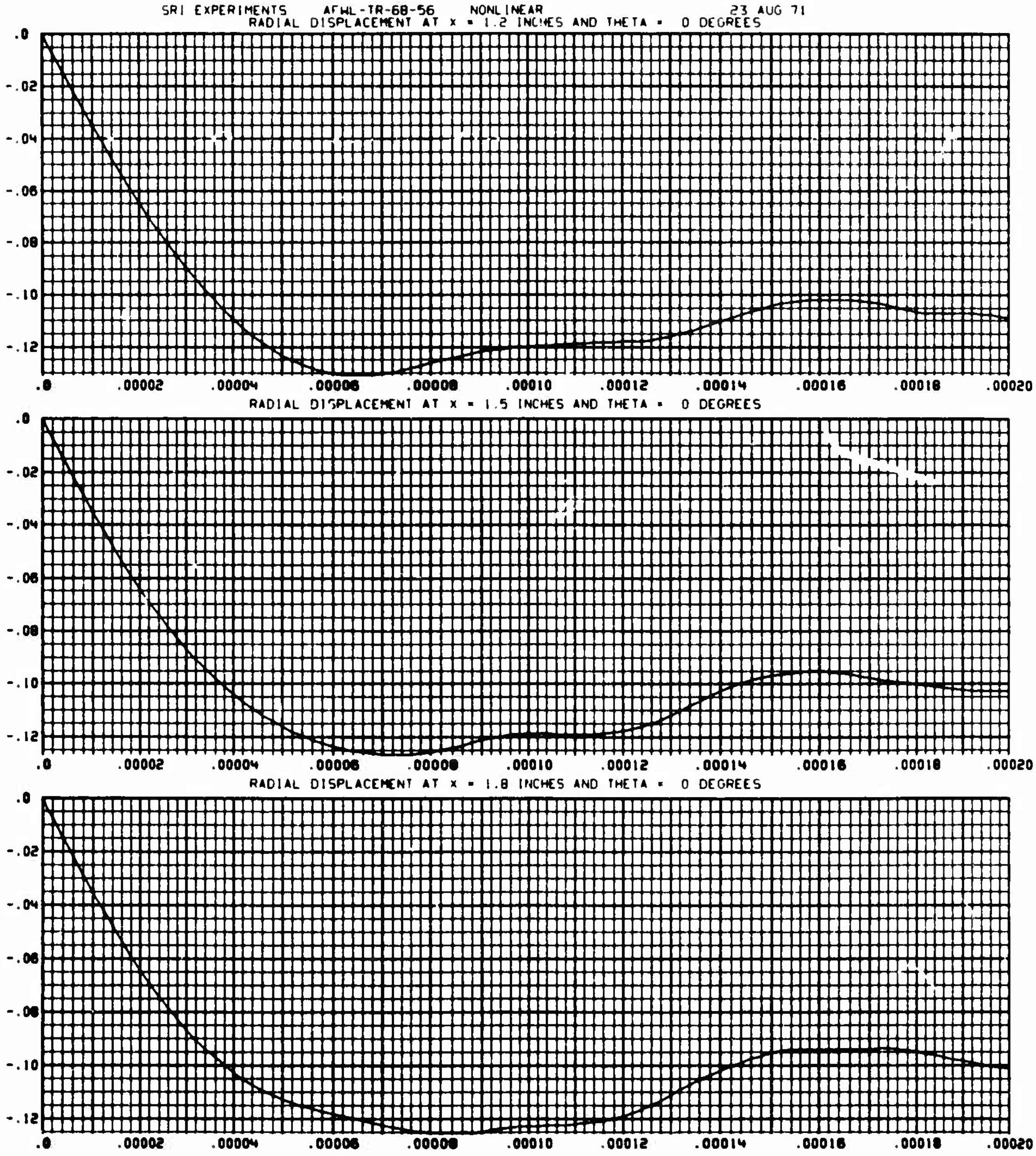


RADIAL DISPLACEMENT AT x = 0.6 INCHES AND THETA = 0 DEGREES



RADIAL DISPLACEMENT AT x = 0.9 INCHES AND THETA = 0 DEGREES





SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

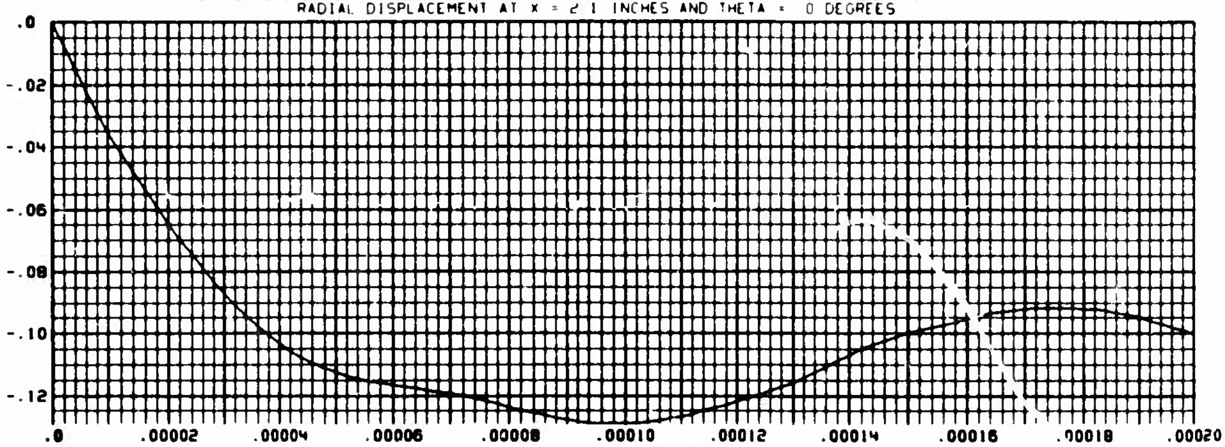
RADIAL DISPLACEMENT AT x = 1.2 INCHES AND THETA = 0 DEGREES

RADIAL DISPLACEMENT AT x = 1.5 INCHES AND THETA = 0 DEGREES

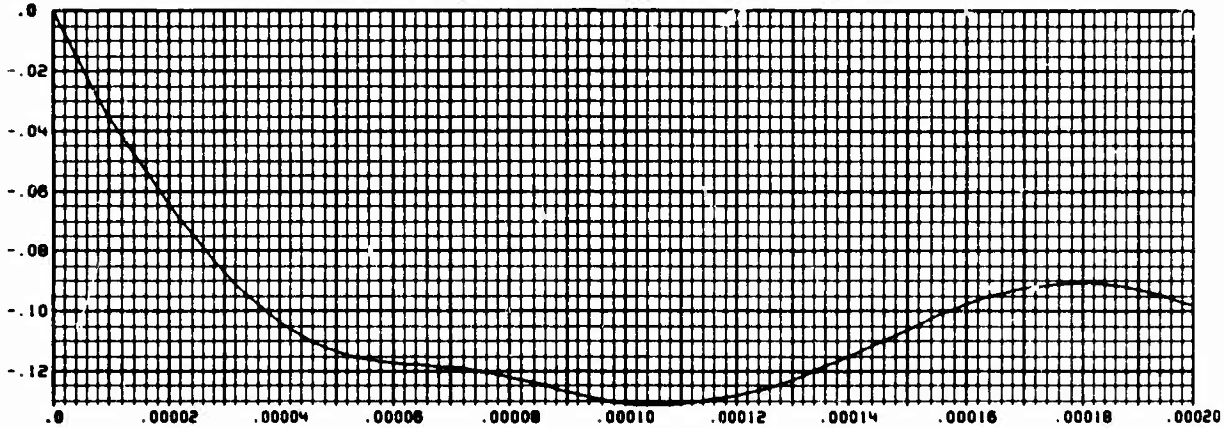
RADIAL DISPLACEMENT AT x = 1.8 INCHES AND THETA = 0 DEGREES

SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

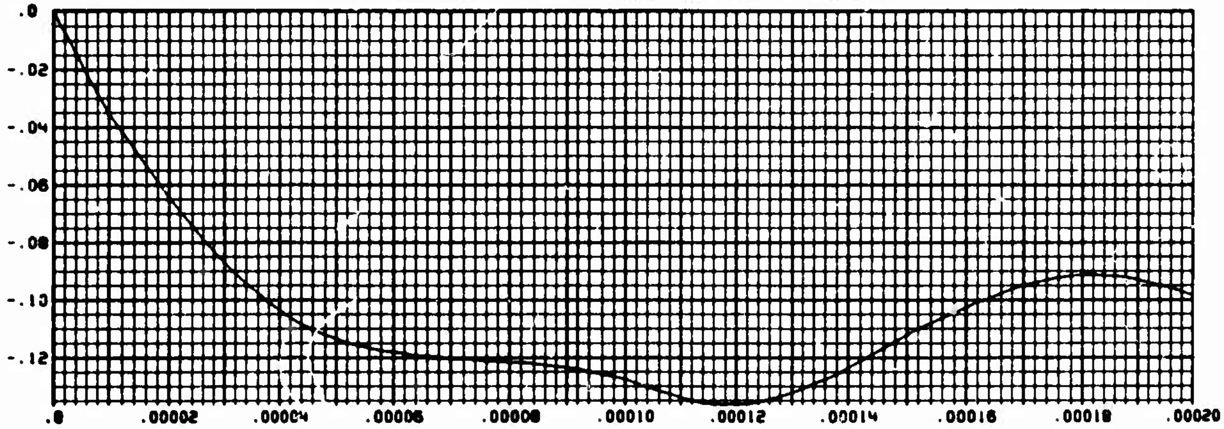
RADIAL DISPLACEMENT AT X = 2.1 INCHES AND THETA = 0 DEGREES

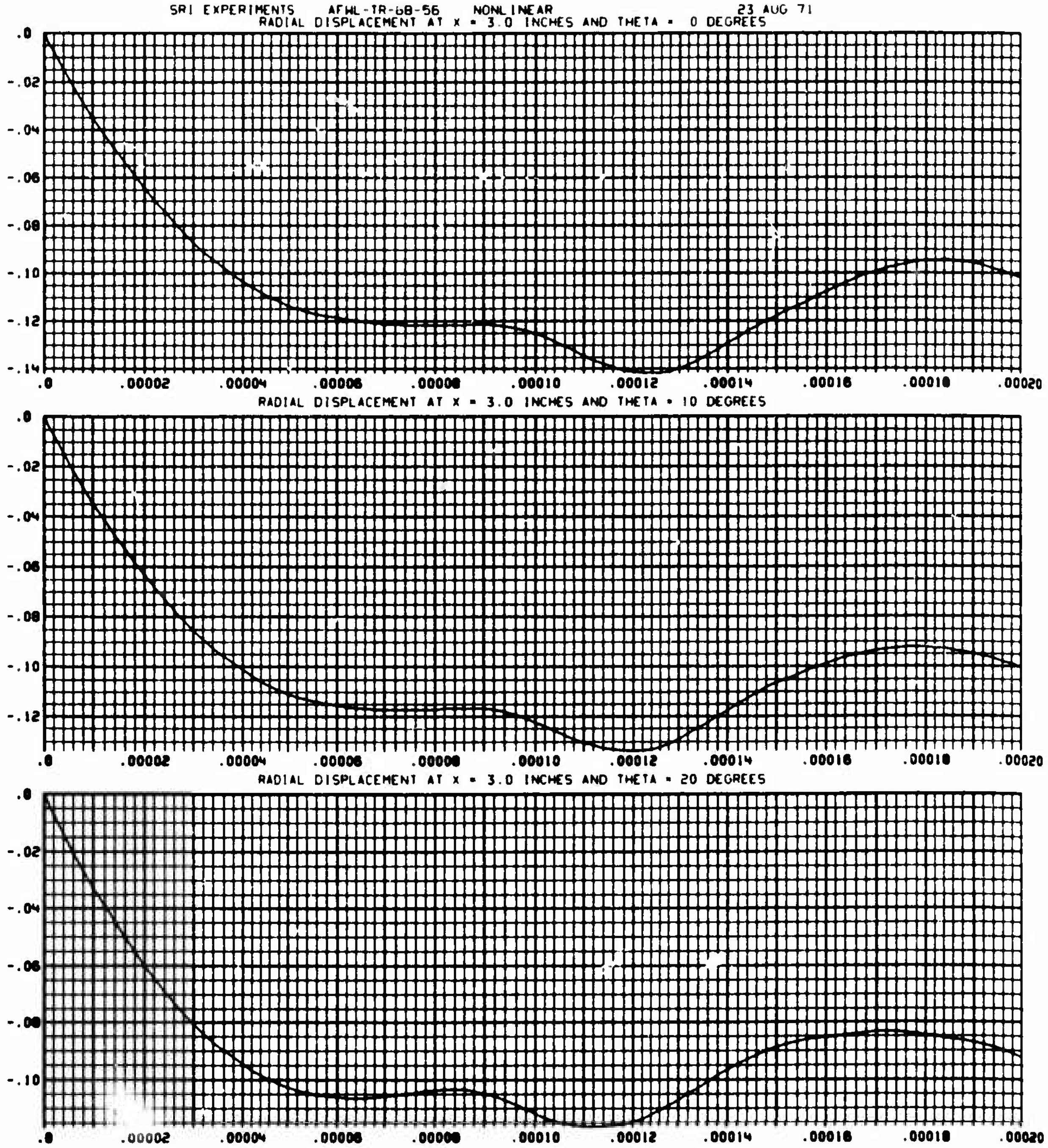


RADIAL DISPLACEMENT AT X = 2.4 INCHES AND THETA = 0 DEGREES



RADIAL DISPLACEMENT AT X = 2.7 INCHES AND THETA = 0 DEGREES





SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

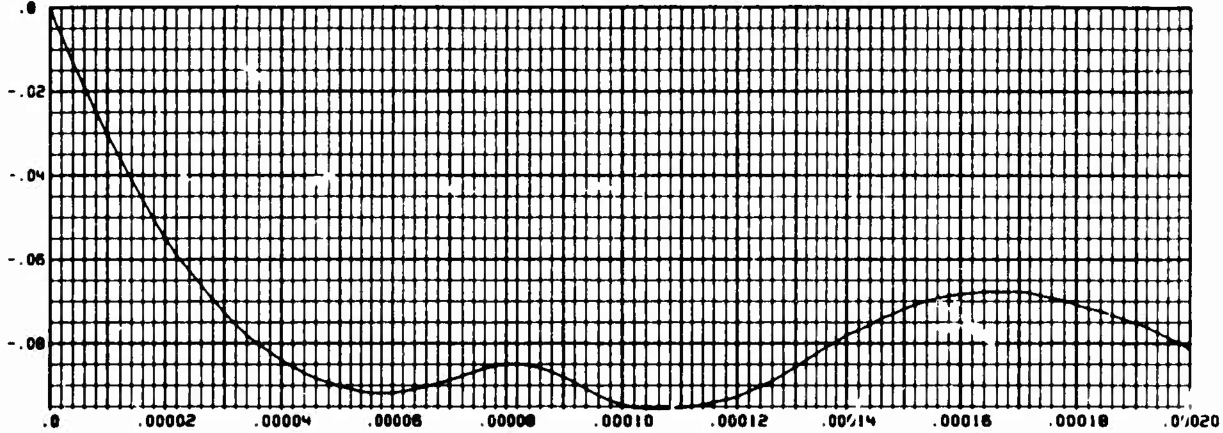
RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 0 DEGREES

RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 10 DEGREES

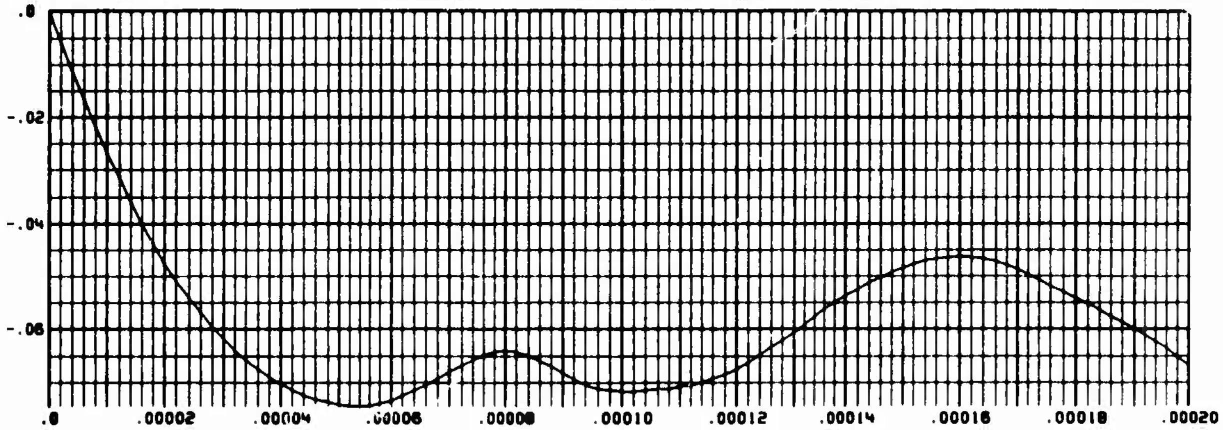
RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 20 DEGREES

SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

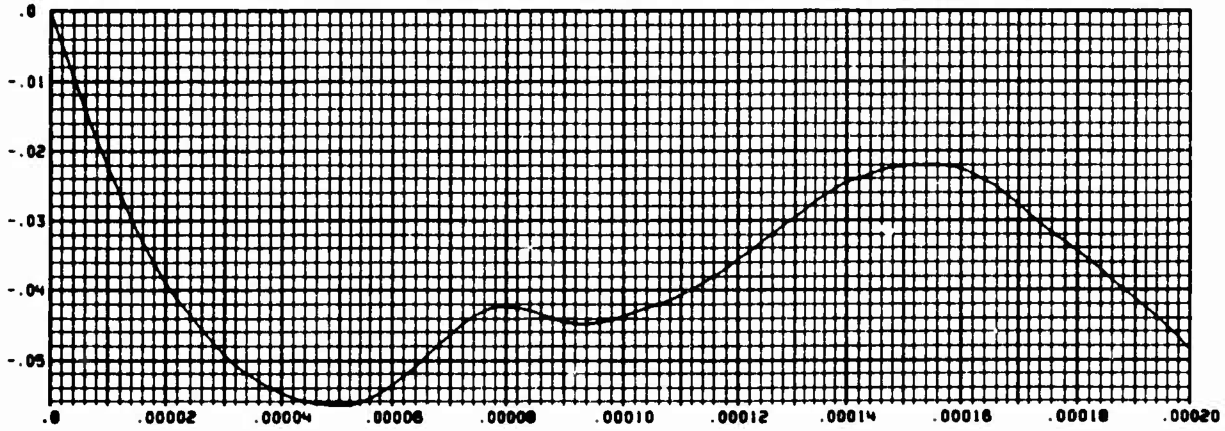
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA = 30 DEGREES



RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA = 40 DEGREES

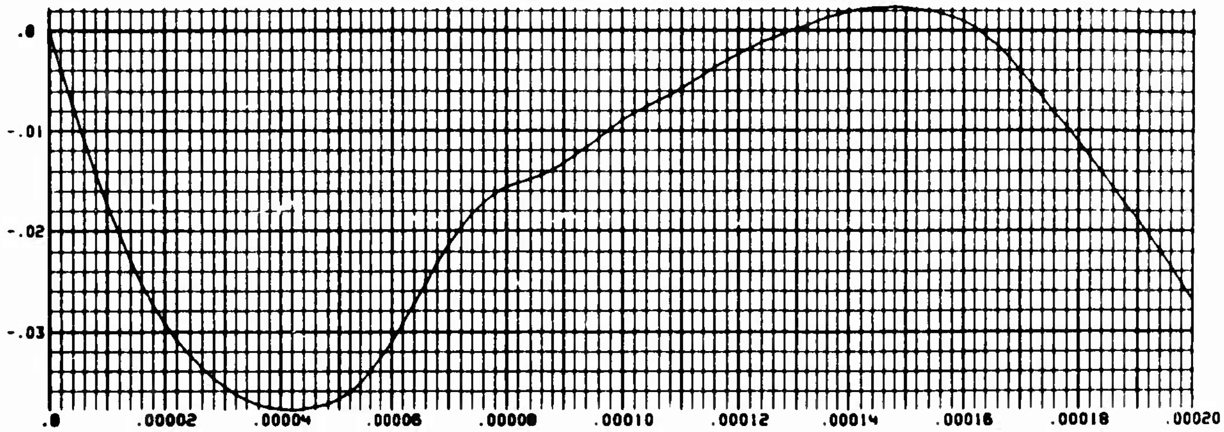


RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA = 50 DEGREES

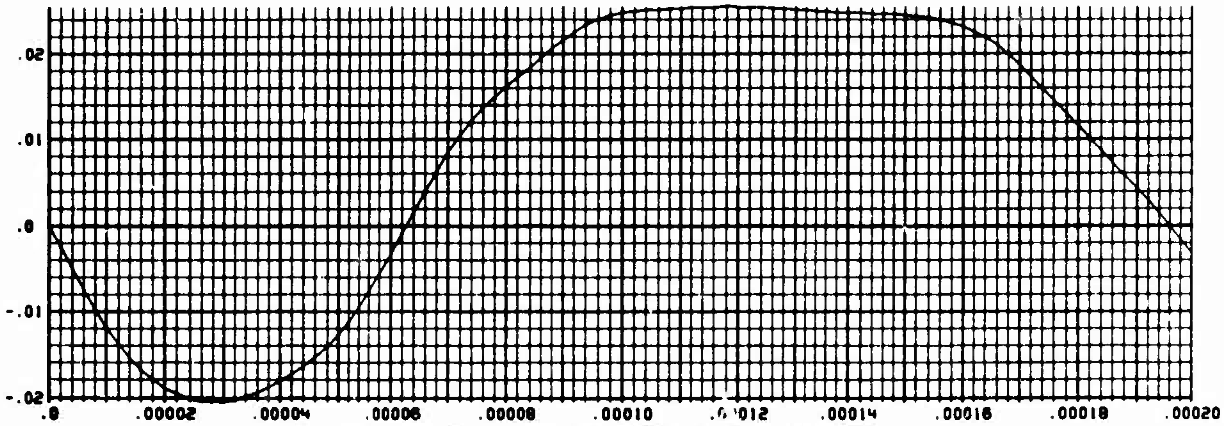


SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

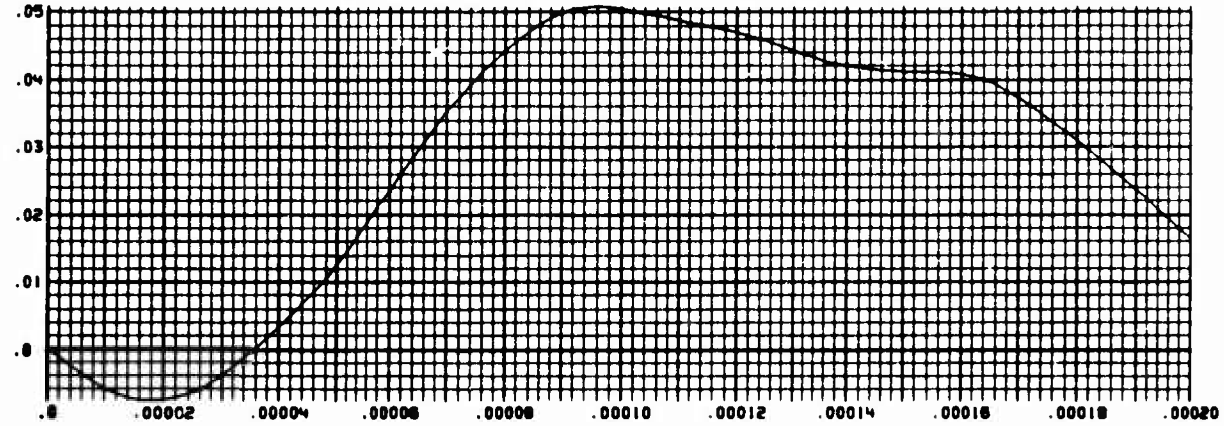
RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 60 DEGREES



RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 70 DEGREES

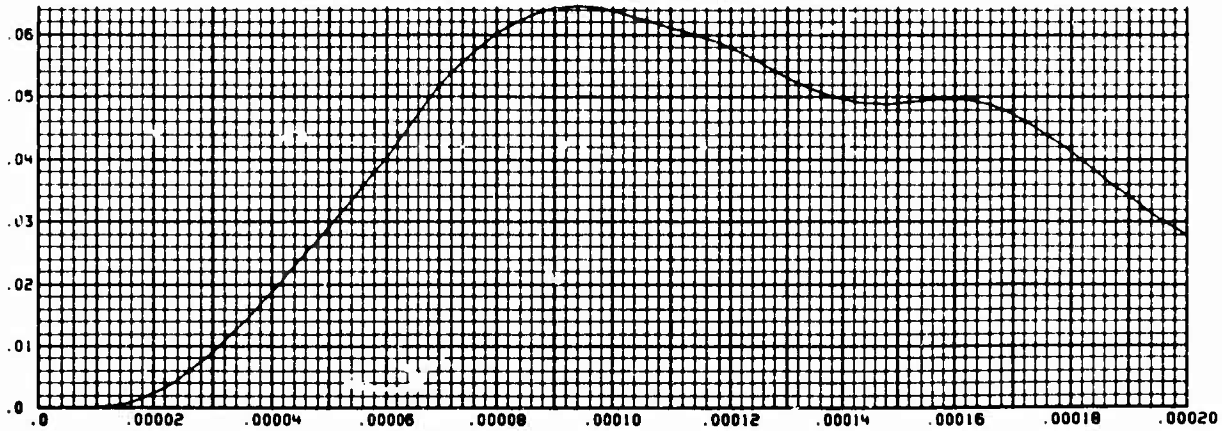


RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 80 DEGREES

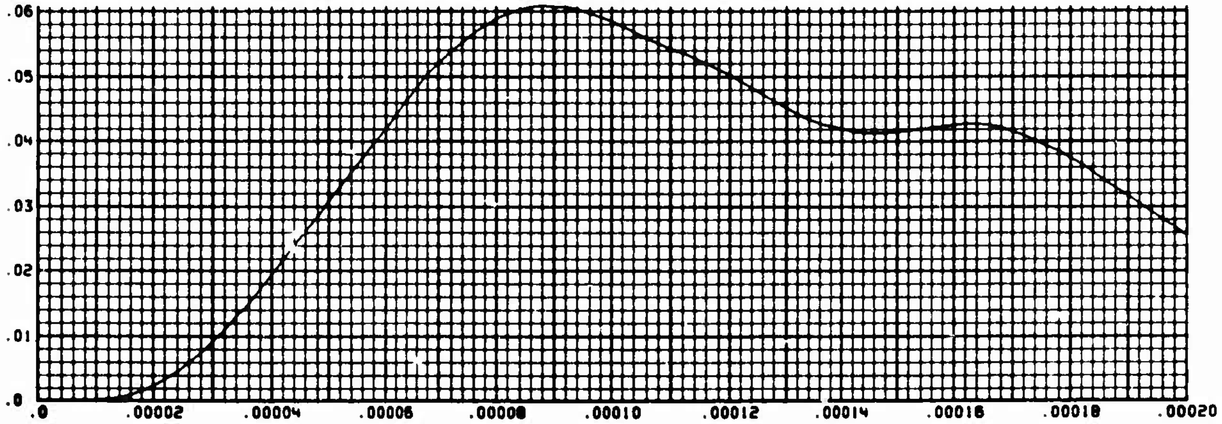


SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

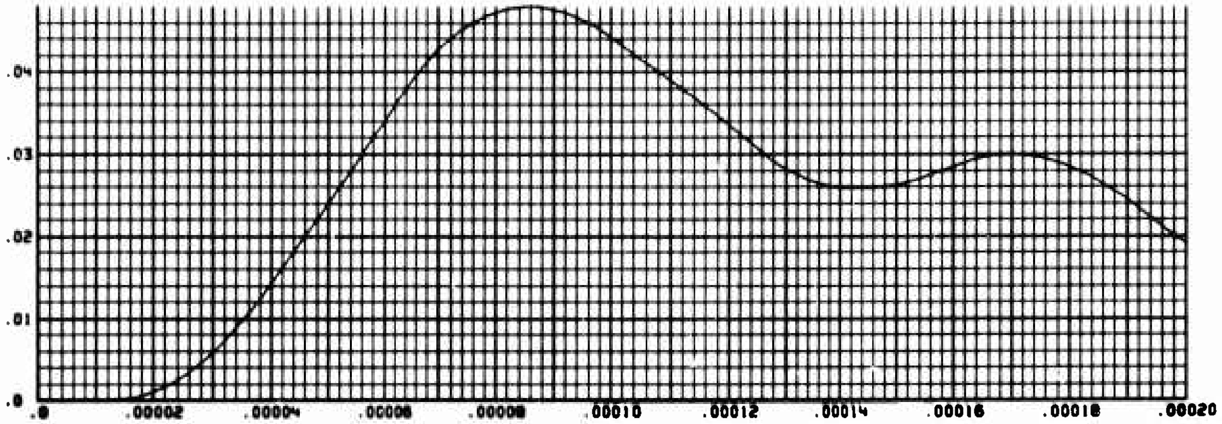
RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA = 90 DEGREES



RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =100 DEGREES

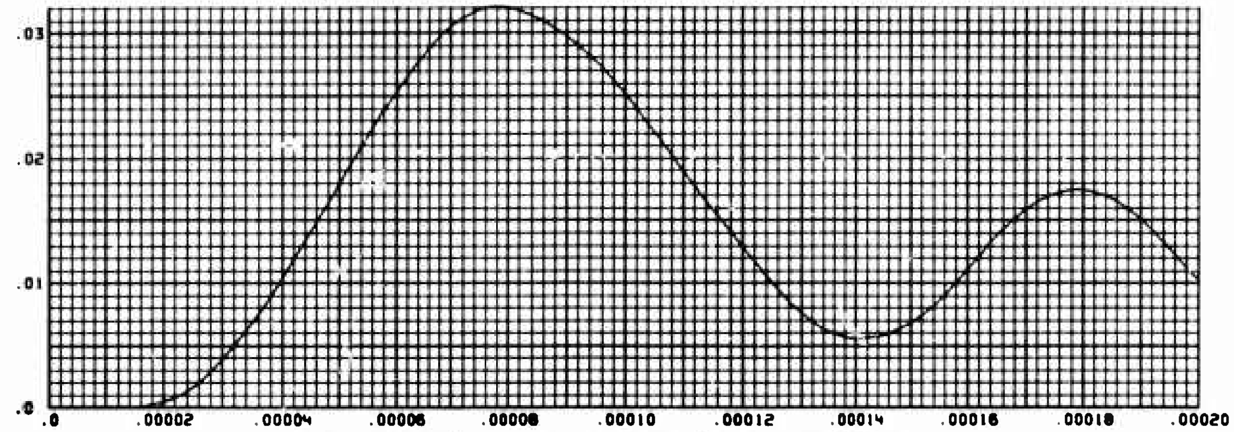


RADIAL DISPLACEMENT AT X = 3.0 INCHES AND THETA =110 DEGREES

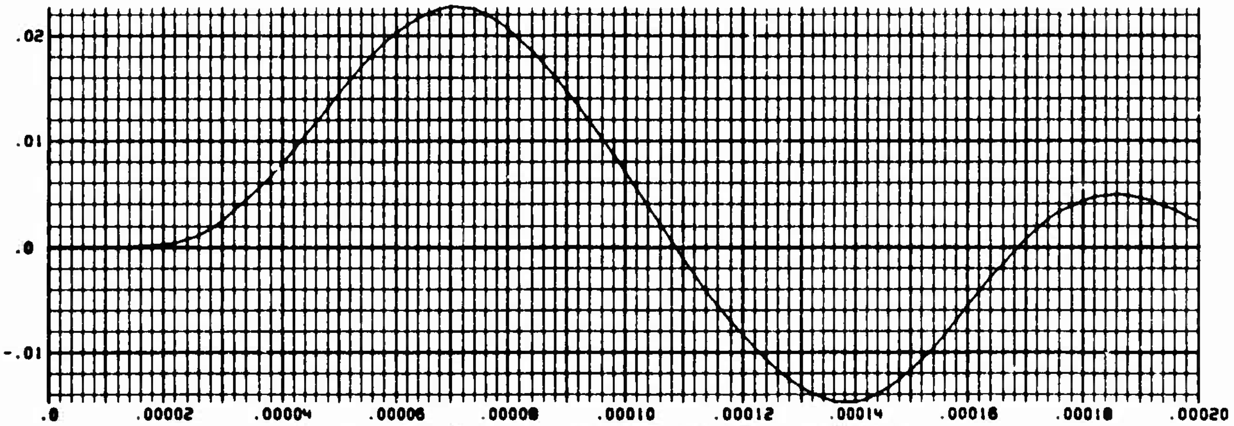


SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71

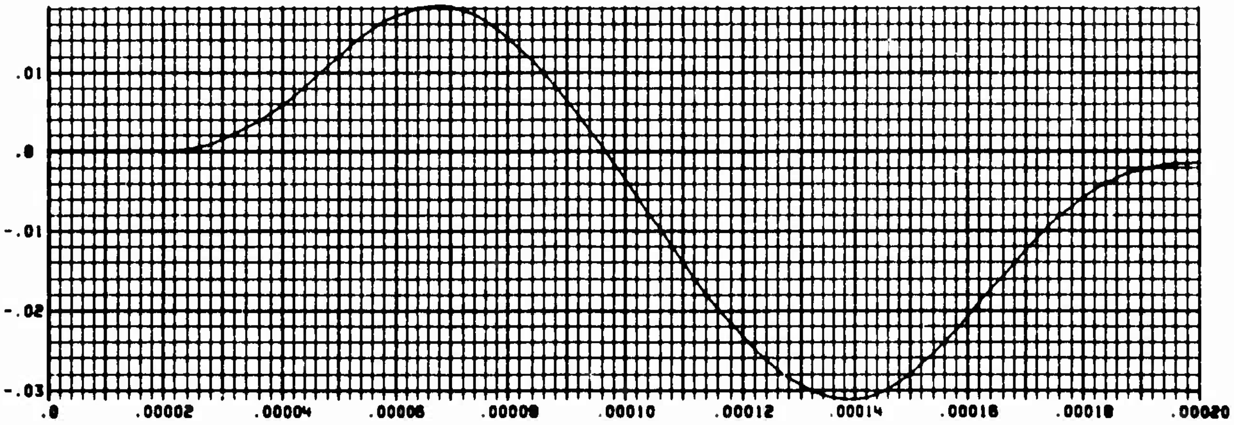
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =120 DEGREES

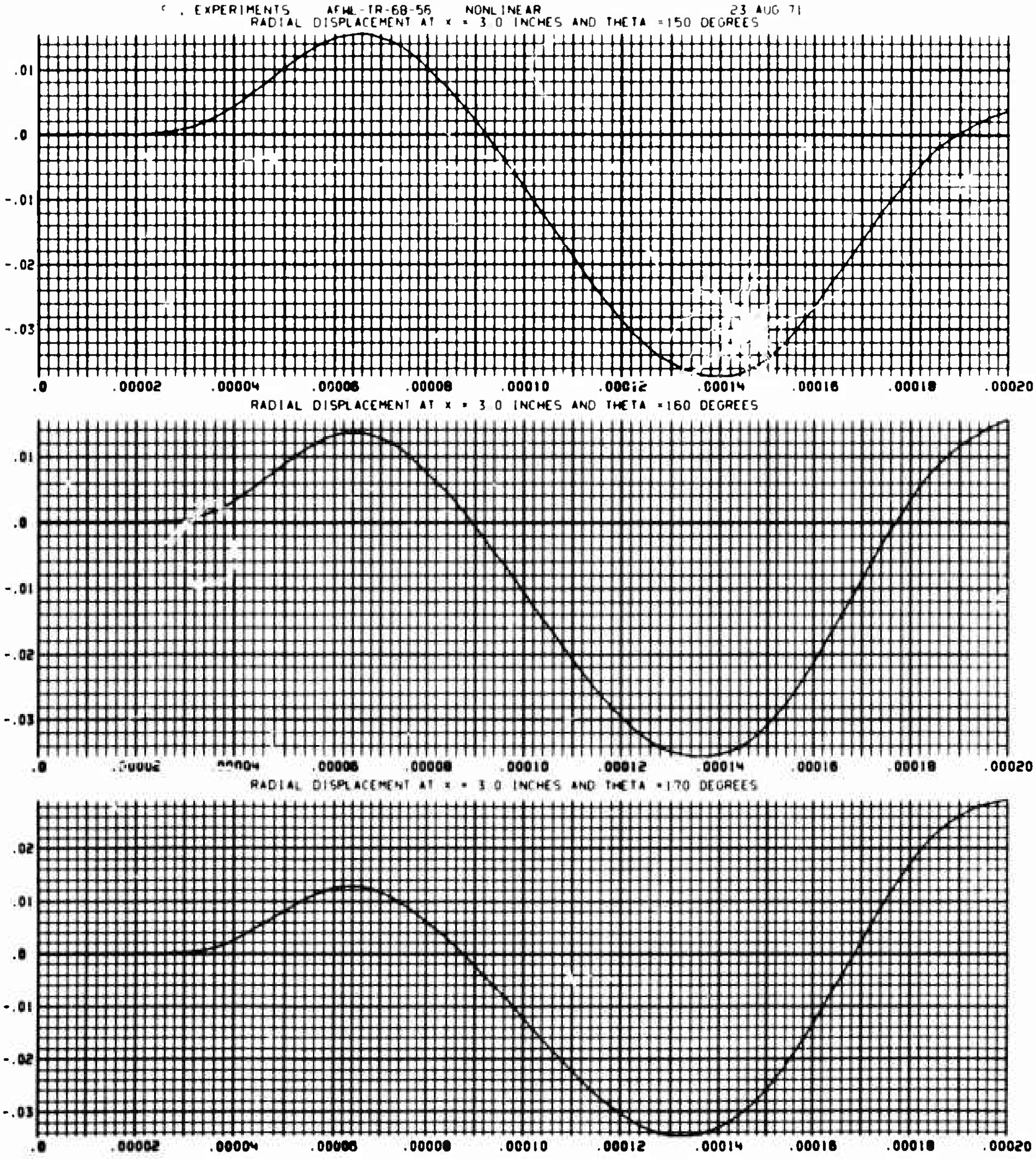


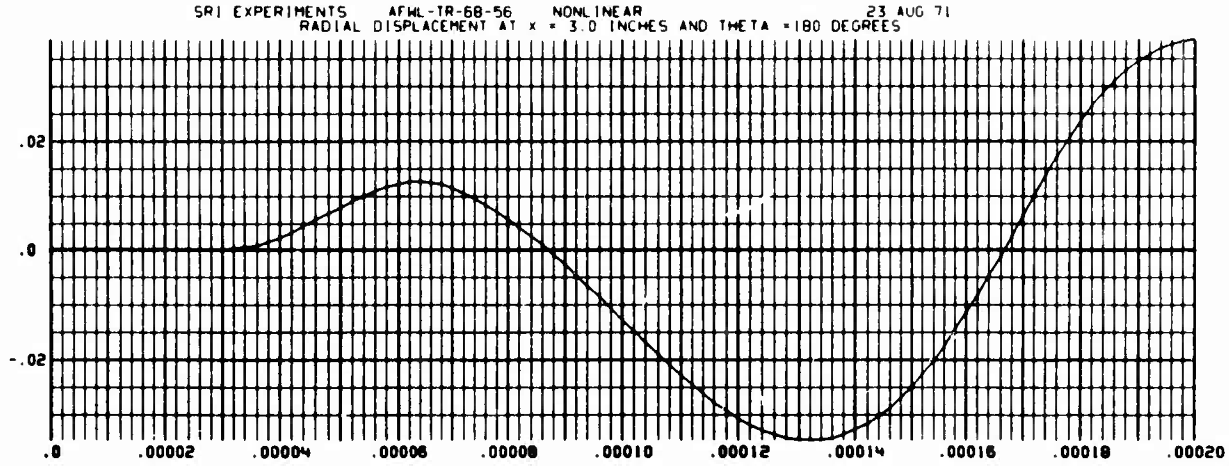
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =130 DEGREES



RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =140 DEGREES




. EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =150 DEGREES
.01
.0
-.01
-.02
-.03
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =160 DEGREES
.01
.0
-.01
-.02
-.03
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =170 DEGREES
.02
.01
.0
-.01
-.02
-.03
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020


SRI EXPERIMENTS AFWL-TR-68-56 NONLINEAR 23 AUG 71
RADIAL DISPLACEMENT AT x = 3.0 INCHES AND THETA =180 DEGREES
.02
.0
-.02
.0
.00002
.00004
.00006
.00008
.00010
.00012
.00014
.00016
.00018
.00020

Section 5
REFERENCES

1. National Aeronautics and Space Administration, An Improved First-Approximation Theory for Thin Shells, by J. L. Sanders, Jr., NASA Technical Report R-24, 1959
2. "Nonlinear Theories for Thin Shells," by J. L. Sanders, Jr., Quarterly of Appl. Math., Vol. XXI, No. 1, 1963, pp 21-36
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4. Kaman Nuclear, CYLINDER, A Computer Program for the Inelastic Dynamic Response of Orthotropic Cylindrical Shells, by R. H. Franke, KN-67-533(R), Sept 26, 1967
5. -----, Further Results in the Inelastic Dynamic Analysis of Cylinderical Shells, by W. F. Hubka, KN-67-452(R), Sept 8, 1967.
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14. Ostrowski, Solution of Equations & Systems of Equations, Academic Press Inc., London, 1960, Appendix D

9

INTERDEPARTMENTAL COMMUNICATION

TO SHORE Users DEPT./ORGN. BLDG./ZONE PLANT/FAC. DATE 2/19/73

FROM Philip Underwood DEPT./ORGN. 52-33 BLDG./ZONE 205 PLANT/FAC. 2 EXT. 45511

SUBJECT: Supplement I - User's Guide to the SHORE Code [1]

Introduction

This supplement to reference [1] is to provide additional information to users of the SHORE code with regard to recent changes and added capability. The changes and additions are: 1) more points through the thickness for two-layered shells in the plastic regime, 2) three-dimensional snapshot plots of all computed response quantities, and 3) temperature-history forcing functions with material properties a function of temperature.

First there is a brief discussion of the new features and then the changes in the input data are presented. Items 1 and 2 are available on the file PGU*SHØREG. and items 1, 2 and 3 are all available on the file PGU*SHØREF. Please note all old input decks will work with the new versions of the code.

Discussion

The new formulation for two layered shells was implemented because many shells of interest have a very thick outer layer as compared with the inner layer. So now for the inner layer the stresses are still computed at three equally spaced stations (two sublayers) through the thickness. For the outer layer the stresses are now computed at five equally spaced stations (four sublayers) through the thickness. Hopefully, this increase in the number of stations through the thickness will increase the accuracy of the integrations performed to determine the resultants for cases involving two layered shells.

The three-dimensional plotting capability is provided by an LMSC developed package, DRAW3D [2]. The set up for using DRAW3D is done in subroutine THREEP which is called at the times the snapshots are desired. The capabilities of DRAW3D are quite versatile, but in THREEP the calling statement for DRAW3D has been specified for only one viewing angle. Also only the radial displacement plot has the accompanying minimum and maximum cross-sections. Anyway if the user wants to change the three-dimensional plotting it can be done by reading the instructions for DRAW3D [2]. This report is available from computer operations. Also both NDT and NDP must be greater than zero to get a three-dimensional plot and if you try to plot a function with all zeros you will get a blank frame.

The thermal history terms, which are a huge addition to the code, are described below.

The strain in the shell is composed of two components, one the kinematic (strains due to shell deformation) and two the thermal (fictitious strains due to thermal expansion or contraction). The kinematic strain is denoted as

$$\epsilon_{k,i} = \epsilon_i + zK_i$$

where i takes on the values ϕ, θ, $\phi\theta$. These are equations (2.1-2) in reference [1]. The thermal strain is denoted as

$$\epsilon_{T,i} = \alpha_i(T - T_o)$$

where i takes on the values ϕ and θ, α is the coefficient of thermal expansion, T_o is the reference temperature and T is the current temperature. It should be noted that T is a function of ϕ,θ,z and t (the shell coordinates and time) so that,

$$T = T(\phi,\theta,z,t).$$

The total strain becomes for ϕ,θ and $\phi\theta$ coordinates

$$e_\phi = \epsilon_\phi + zK_\phi + \alpha_\phi\ (T - T_o)$$

$$e_\theta = \epsilon_\theta + zK_\theta + \alpha_\theta\ (T - T_o)$$

$$e_{\phi\theta} = \epsilon_{\phi\theta} + zK_{\phi\theta}$$

In terms of stresses we have

$$\sigma_\phi = \frac{E_\phi}{\mu}\,\epsilon_{k,\phi} + \nu_\theta\,\frac{E_\theta}{\mu}\,\epsilon_{k,\theta} - \left(\frac{E_\phi}{\mu}\,\alpha_\phi + \nu_\theta\,\frac{E_\theta}{\mu}\,\alpha_\theta\right)(T - T_o)$$

$$\sigma_\theta = \frac{E_\theta}{\mu} \epsilon_{k,\theta} + \nu_\phi \frac{E_\phi}{\mu} \epsilon_{k,\phi} - \left(\frac{E_\theta}{\mu} \alpha_\theta + \nu_\phi \frac{E_\phi}{\mu} \alpha_\phi \right) (T - T_o)$$

$$\sigma_{\phi\theta} = 2G \; e_{\phi\theta}$$

where $\mu = 1 - \nu_\phi \nu_\theta$. (Note that these are equations 2.1-3) of reference [1] and equations (2.1-3a&b) are incorrect in reference [1].)

Briefly and simply, if the temperature increases with time we have positive thermal strain which produces a negative stress (compression). When the equilibrium equations are solved the compressive thermal stresses must be relieved by kinematic motion, hence the shell vibrates about some new equilibrium position that corresponds to a balancing of the stresses in the equilibrium equations. The code output for strain includes only the kinematic portion (i.e., what would be measured by a strain gage) and the output for stress includes both the kinematic and thermal stresses as these are the actual stresses in the shell.

The computational sequence is identical with that developed for the beam equations used in TBEAM and TBEAM2 [3]. First in the input data one can specify all the shell material properties as a function of temperature through a tabular input. The data can be specified for eight different temperatures. Additionally the temperatures as a function of ϕ, θ and z can be specified for eight different times, t, through the standard matrix read.

During the response calculations the temperature for the time and spatial location are determined by a table lookup procedure using linear interpolation between the input data points. From this temperature value the shell material properties are then determined by table lookup. At this point the thermal terms in the strains and stresses, as outlined above, can be computed and then the response calculations proceed with the additional thermal terms.

The temperature matrices are stored on a disc and only the values currently needed are pulled into core. The material properties array is stored in core so only a few additional storage locations are required for the thermal excitation terms.

Input Data Instruction Changes

Cards 1 and 2

a) As before two heading cards are read.

b) As before the first card appears on the time-history plots.

c) Now the first 48 spaces on the second card appear on the three-dimensional plots.

d) As before both cards appear on the printed output.

Card 3

The meaning and use of ITEMP is different, now:

a) ITEMP = 0 no thermal terms considered

b) $0 < \text{ITEMP} \leq 8$ then ITEMP indicates the number of times at which the temperature matrices are going to be input (i.e., if your temperature-history is describable by four time points, ITEMP = 4).

Card 16 (E10.3, I5, 5X, E10.3, I5)

Where now PLT, NPLT, SPLT, NPSP are read.

PLT - plotting time intervals ~ secs.
NPLT - 0 no time-history plots
5 miniature plots only
7 full and miniature
8 full only
SPLT - spatial plotting intervals ~ secs.
NPSP - 0 no spatial plots
> 0 spatial plots

NDT and NDP must both be greater than zero.

Cards 23

If ITEMP = 0 no cards are read

If ITEMP > 0 the following cards are read in 8E10.3 format:

a) TEMB(8) - temperature values which correspond to the material properties below; the temperature values must be in increasing steps.

b) NUPD(8) - values of NUP corresponding to above temperatures
c) NUTD(8) - values of NUT corresponding to above temperatures
d) EXD(8) - values of EX corresponding to above temperatures
e) ETD(8) - values of ET corresponding to above temperatures
f) GGD(8) - values of GG corresponding to above temperatures
g) S1D(8) - values of S1 corresponding to above temperatures
h) S2D(8) - values of S2 corresponding to above temperatures
i) S12D(8) - values of S12 corresponding to above temperatures
j) ALPHXD(8) - values of ALPHAX corresponding to above temperatures
k) ALPHTD(8) - values of ALPHAT corresponding to above temperatures
l) SZD(8) - values of SZ corresponding to above temperatures
m) HD(8) - values of H corresponding to above temperatures
n) S1CD(8) - values of S1C corresponding to above temperatures
o) S1TD(8) - values of S1T corresponding to above temperatures
p) S2CD(8) - values of S2C corresponding to above temperatures
q) S2TD(8) - values of S2T corresponding to above temperatures
r) S12SD(8) - values of S12S corresponding to above temperatures

If NSL = 2 (i.e., a two layered shell cards aa-qq are also read, for the outer shell layer).

aa) NUTAD(8) - values of NUTA corresponding to above temperatures
bb) NUPAD(8) - values of NUPA corresponding to above temperatures
cc) EXAD(8) - values of EXA corresponding to above temperatures
dd) ETAD(8) - values of ETA corresponding to above temperatures
ee) GGAD(8) - values of GGA corresponding to above temperatures
ff) S1AD(8) - values of S1A corresponding to above temperatures
gg) S2AD(8) - values of S2A corresponding to above temperatures
hh) S12AD(8) - values of S12A corresponding to above temperatures
ii) ALFXAD(8) - values of ALPHAXA corresponding to above temperatures
jj) ALFTAD(8) - values of ALPHATA corresponding to above temperatures
kk) SZAD(8) - values of SZA corresponding to above temperatures
ll) HAD(8) - values of HA corresponding to above temperatures
mm) S1ACD(8) - values of S1AC corresponding to above temperatures
nn) S1ATD(8) - values of S1AT corresponding to above temperatures
oo) S2ACD(8) - values of S2AC corresponding to above temperatures

pp) S2ATD(8) - values of S2AT corresponding to above temperatures
qq) S12ASD(8) - values of S12AS corresponding to above temperatures

End of cards for the outer shell layer

s) TIMT(8) - time values which correspond to the temperature arrays below. The time values must be in increasing steps. A zero time and temperature array must be included. If you want a step change in temperature, zero time must correspond to temperatures before heating and then at time = DT input the temperatures after heating. The number of values of TIMT input must equal ITEMP.

t) TXTL(I,J,L) ~ matrix format

The above temperature array is read for each time input in TIMT.

I = 1, NDP+1+NFREE , ϕ coordinate
J = 1, NDT+1 , θ coordinate
L = 1, NLAYS+1 (L = 1 is the inner fiber), thickness

Cards 30 (12I5) NLSP - Spatial Plot Array

If NPSP > 0 two new cards (right after cards 29) are read.

Where if NLSP(I) = 0 no plot is made
or NLSP(I) = 1 a plot is made

where the NLSP array corresponds to

NLSP(1) - radial displacement*
NLSP(2) - meridional displacement
NLSP(3) - circumferential displacement
NLSP(4) - outer fiber merd. strain
NLSP(5) - inner fiber merd. strain
NLSP(6) - outer fiber circ. strain
NLSP(7) - inner fiber circ. strain
NLSP(8) - outer fiber shear strain
NLSP(9) - inner fiber shear strain
NLSP(10) - outer fiber merd. stress
NLSP(11) - inner fiber merd. stress

---

*For the radial displacement you will get 3 plots (includes max and min cross-sections); all others are just 1 plot.

NLSP(12) - outer fiber circ. stress
NLSP(13) - inner fiber circ. stress
NLSP(14) - outer fiber shear stress
NLSP(15) - inner fiber shear stress
NLSP(16) - merd. moment resultant
NLSP(17) - circ. moment resultant
NLSP(18) - shear moment resultant
NLSP(19) - merd. stress resultant
NLSP(20) - circ. stress resultant
NLSP(21) - shear stress resultant
NLSP(22) - radial pressure
NLSP(23) - merd. pressure
NLSP(24) - circ. pressure

Don't forget the @FIN card at the end.

References

[1] User's Guide to the SHORE Code, by Philip Underwood, LMSC-D244589, 30 Jan 1973

[2] User Instructions for DRAW3D An Orthographic Projective Plotting Subprogram, Computer Program 2R2061, by Rod Kure, LMSC-B-70-67-48

[3] User's Guide to TBEAM and TBEAM2, by Philip Underwood, LMSC-D279064, Nov 1972

5-11

INTERDEPARTMENTAL COMMUNICATION

TO SHORE Users
DEPT./ORGN.
BLDG./ZONE
PLANT/FAC.
DATE 11 Oct. 1973

FROM Philip Underwood
DEPT./ORGN. 52-33
BLDG./ZONE 205
PLANT/FAC. 2
EXT. 45511

SUBJECT: SUPPLEMENT II - USER'S GUIDE TO THE SHORE CODE [1]

This supplement is to provide formal documentation of the restart capability that has been added to the SHORE code. The production version of the SHORE code is available on the file PGU*SHOREH.

The main new feature is the restart capability. Other changes include details of the plotting for better use of storage, that should not really affect the user and slight changes in the nonlinear formulation of the equilibrium equations. This later item should only produce very slight changes in answers; if you observe major changes in answers please notify me. The date of the last revision is now printed out on the first page of the output. If the code revision date changes it would be advisable to obtain a new listing.

The input data is identical to that described in [1] and [2] except for two changes in Card 15 which are necessary if you want to restart.

<u>Card 15 (5E10.3, I5)</u> DT, TT, PRINT, ESPT, START, NRST

```
DT     - integration time step (sec)
TT     -  total time (the time span for this run) (sec)
PRINT  - printing time intervals (sec)
ESPT   - time left in run before plotting will start
START  - the time at which this run begins (sec)
NRST   - restart flag  =  -1 starts from a restart tape
                           0  nothing
                           1 writes a restart tape
                           2 starts from a restart tape and
                             writes a restart tape
```

If you are going to write a restart tape it is wise to include the two following @MSG cards just before @XQT.

```
@MSG   NØTE TAPE TØ BE ASSIGNED DURING RUN
@MSG,I NØTE TAPE TØ BE ASSIGNED DURING RUN
```

If you are starting from a restart tape you must read in the input data deck with the appropriate changes in Card 15. Also the following control cards are needed,

```
@ASG,T RESTART., 16N, XXXXX
@USE 16, RESTART.
```

where XXXXX is the tape number of the restart tape previously generated.

NOTE: All tapes are 9 track.

Form LAC 201

From one run to another you can change the following input data:

1) Anything on CARDS 1 & 2 (heading)
2) Anything on CARD 5 (print out flags)
3) LMD on CARD 6
4) Anything on CARD 9 (fracture stresses)
5) Anything on CARD 12 (fracture stresses)
6) Anything on CARD 15 except DT (DO NOT CHANGE DT)!
7) Anything on CARD 16 (plotting times and flags)
8) Anything on CARD 22 pressure data*
9) Anything on CARDS 23 temperature data*
10) Any of the plotting data on CARDS 28, 29 or 30.

*Avoid a discontinuity between runs, but you can add information for greater times that may occur after a restart.

Finally, the restart tape will only be written if the job is successfully completed up to the start of the plotting operations, i.e. all the shell response calculations are completed.

REFERENCES:

[1] User's Guide to the SHORE Code, by Philip Underwood, LMSC-D244589, 30 Jan 1973

[2] Supplement I - User's Guide to the SHORE Code, 19 Feb 1973

INTERDEPARTMENTAL COMMUNICATION

TO SHORE Users DEPT./ORGN. BLDG./ZONE PLANT/FAC. DATE 12 Dec. 1973

FROM P. G. Underwood DEPT./ORGN. 52-33 BLDG./ZONE 205 PLANT/FAC. 2 EXT. 45511

SUBJECT: SUPPLEMENT III - USER'S GUIDE TO THE SHORE CODE [1] (A Status Report)

Introduction

This supplement is to serve many purposes: 1) provide documentation on plane strain and stress ring analyses with the SHORE code and improved estimates of time steps, 2) a status report on what areas of the code have been studied this year, 3) a report on areas that still need work and 4) a discussion keeping the code up to date and a better system for eliminating errors in the code. Hopefully the items discussed under 2 and 3 will spark some interest in users as the developer would like to farm out some development work in hopes that some fresh ideas will help some old problems.

Discussion

Ring Analyses

If the two-dimensional version of SHORE is used for ring analyses (i.e. NDT=0 and IAX=-1) one may set the input data up to do either a plane strain or plane stress analysis. The plane strain analysis would be representative of the midpoint behavior of a long shell loaded uniformly along the length. The plane stress analysis is representative of what is physically thought of as a ring (i.e. a very short free ended shell). It should be noted that the ring version of SHORE, SHORER, that is occasionally used is a plane stress analysis. The following input procedures should be followed for plane strain or stress.

A) Plane Strain

GG (shear modulus) = 0.0
S12 (shear yield) >>> S1 & S2

B) Plane Stress

GG (shear modulus) = 0.0
EX (ϕ-direction modulus) = 0.0
NUP (ϕ-direction Poisson's ratio) = 0.0
S1 (ϕ-direction yield stress) >>> S2
S12 (shear yield) >>> S2

Also to obtain the correct meridional strains for the plane stress case, some changes in subroutine STRESS are necessary.

1) The statement DEPP = DEPP1 + ZZ*(...   ), which is located two statements after 357 CONTINUE, should be deleted and right after DEPT is calculated the statement DEPP = -NUTB*DEPT should be added.

Form LAC 201

2) Right after CALL INELST add

```
        SPT = 0.0
        STS = 1.0
        STS = SIGN(STS,DEPT)
        IF (L.EQ.1) EPP(II,JJ,1) + -NUTB*EPT(II,JJ,1)
            -(.5-NUTB)*(EPT(II,JJ,1) - STS*S2B*RETB)
        IF (L.EQ.NLP) EPP(II.JJ.2 = -NUTB*EPT(II,JJ,2)
            -(.5-NUTB)*(EPT(II.JJ,2) - STS*S2B*RETP)
```

(If you are not interested in meridional strains there is no need to make the changes outlined in 1 and 2 above).

Time Step Calculations

In reference 2 more accurate expressions for computing the time step for stabile time integration are given. These expressions will eventually be placed in the SHORE code but until they are the user may want to check the time selected against the better expressions that are given below.

$$\Delta t_e \le \left[\left(\frac{C}{\Delta s}\right)^2 + \left(\frac{C_s}{R\Delta\theta}\right)^2\right]^{-1/2} \quad , \quad (\Delta s < R\Delta\theta)$$

and

$$\Delta t_f \le \frac{\sqrt{3}}{hc}\left[\frac{1}{\Delta s^2} + \frac{1}{(R\Delta\theta)^2}\right]^{-1}$$

where Δt_e is based on extensional frequencies and Δt_f is based on flexural frequencies; Δt_e is usually smaller than Δt_f and the smaller Δt must be used.

Also; h = thickness

$C^2 = Eg/\rho(1-\nu^2)$

and $C_s^2 = Eg/\rho(1+\nu)$

Status

Status may not be the correct word for this section but somehow I wish to convey to the user a couple of things that are considered to be deficiencies in the code and several areas of study that would add to the usefulness of the code are discussed.

Deficiencies

Two areas that have not been treated adequately are the spatial grid and the boundary conditions for nonlinear problems.

The spatial grid problem pertains to the fact that all the stresses are needed at the same pivotal point to solve the plasticity problem. As pointed out in the manual the grid is just shifted so all the stresses are computed at the same pivotal point. This shift reduces the accuracy of the shear expressions. Indeed if one put a torsional load on the end of the shell the SHORE code would not obtain a very correct answer; the result would resemble the case of an axial end load shown in reference 3. By averaging the derivatives in a certain manner this problem can be minimized to some extent; this has been done in the present SHORE and hopefully even better in a newer version of the code now being checked out. As a sidelight the nonlinear kinematic terms are also affected by the manner in which the derivatives are obtained. During the past year the nonlinear portion of the code was completely rewritten and to the best of my knowledge at this point in time is as accurate as can be considering the grid and shell equations used in the code. One interesting approach to this problem somewhat follows the method used in multi-dimensional wave propagation (references 4 and 5). Here one would use u, v, w and w′ as independent variables with u, v, and w′ at the corners of a quadrilateral grid with w at the geometric center. This of course implies a rotary inertia term to obtain the w′ and this may involve smaller time steps than are now required. Anyway, the spatial grid problem has been briefly outlined, I am still working on it, and the user should be very careful of problems involving direct inplane shear such as applied torsion.

Now, on to boundary conditions; as many of you are aware the boundary condition solution fails to converge for large nonlinearities. This same problem also occurred in the beam codes and was solved by including the nonlinear term in the initial guess for the displacement at the boundary. When the same approach was tried in the SHORE code two problems occurred. One is that shells are complicated compared to beams and second, the beam code uses total displacements and the shell code uses displacement increments. The nonlinear problem is much easier to solve with total displacements so a new version of SHORE based on total displacements is being checked out. When it is running satisfactorily the addition of the nonlinear terms into the boundary conditions will again be tried and hopefully the problem of boundary condition convergence will be cleared up.

Neglected Study Areas

Various areas that would add to the SHORE code are briefly discussed. Hopefully the user may have some interest in these areas and can contribute to the evolution of the code.

Storage - A more efficient use of core would increase the size of problems that could be studied and probably reduce costs for small problems that do not require large core storage.

Plasticity and Fracture - The plasticity theory used should be improved to more accurately represent actual stress-strain relationships. Preliminary studies along the lines of references 6 and 7 have proven interesting and someone may be interested in continuing them. Reference 8 provides a significant step in evaluating engineering plasticity and it also provides many areas for continuing work. Work in fracture is wide open to anyone with ideas.

Segmented Shells - Once a boundary condition technique that is "fool proof", at least to some extent, is available a natural extension is to segmented shells. This would enable the study of discontinuity stresses at the junction of various shell geometries.

Time Step - A criteria for the critical time step for nonlinear equations is needed to eliminate the need for running problems with very small time steps just to ensure stability.

Rings and Stringers - A provision for analyzing ring and stringer stiffened shells would be valuable.

Dynamic Relaxation - This techniques provides a way to obtain static solutions from a code that uses an explicit central difference time integration scheme. Some ground work has been done but there are still many unanswered questions before this technique will be useful as a production analysis method.

Code Updating

In the future new versions of the code will be announced on the print out of the current production version of the code. The new version will be described and the file name given. The old and new version of the code will be available simultaneously for approximately one month. If for any reason the user wants the old version it will be their responsible to make their own file for it. After a new version is announced I would appreciate it if users would start using it for non rush jobs (if there are such jobs at Lockheed). If no difficulties are encountered start using the new version for everything.

Over the years I have learned that it is impossible to write a large computer code without including errors. To help me eliminated errors as fast as possible call me if the error needs urgent repair. Otherwise send me the run with the error and I will try to repair the code. Actually in either case if you send me the run with the error via the computer courier it is a great help. Secondly, if there are parts of the code the user feels are useless let me know and if there are things that would be more useful let me know. Hopefully, I can increase the useful and cut out the useless.

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