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TRANS — A ONE-DIMENSIONAL FØRTRAN IV PROGRAM FOR COMPUTING THE TIME RESPONSE OF FUEL RODS TO A LOADING-UNLOADING ENVIRONMENT

W. E. Stillman

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ORNL-TM-3293

Contract No. W-7405-eng-26

METALS AND CERAMICS DIVISION

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W. E. Stillman

MAY 1971

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LIST OF SYMBOLS

C, D, F, G	Stress equation coefficients
C', D', F', G'	Stress equation coefficients
E	Modulus of elasticity
E_p	Plastic modulus
H'	Equivalent thermal load
K	Secondary creep strain rate
m	Ratio of plastic to elastic modulus
p	Radial pressure
r	Radial distance
T	Temperature
u	Radial displacement
α	Thermal expansion coefficient
ϵ	Strain
ν	Poisson's ratio
σ	Stress
P'	Equivalent plastic strain load

<u>Subscripts</u>

a	Absolute temperature, with T
e	Effective stress, with σ
ec	Effective creep strain, with ϵ
et	Equivalent modified strain, with ϵ
i	Inner surface
o	Outer surface
p	Equivalent plastic strain, with ϵ; used as superscript when ϵ carries another subscript

r, θ, z	Radial, tangential, axial
y	Yield stress, with σ

Superscripts

c	Creep
p	Plastic

TRANS – A ONE-DIMENSIONAL FØRTRAN IV PROGRAM FOR COMPUTING THE TIME RESPONSE OF FUEL RODS TO A LOADING-UNLOADING ENVIRONMENT

W. E. Stillman[1]

ABSTRACT

The TRANS code is designed to compute transient stresses in cylindrical fuel rods. This version considers the response to thermal and pressure loads in one bilinear material with temperature-dependent properties. Plastic and creep strain increments are computed for load or time increments, respectively, and the resulting stresses determined. The stresses can be evaluated for any time in a general load cycle.

INTRODUCTION

The installation and replacement of fuel rods is a significant factor in the total cost of a nuclear reactor. Safety and reliability of operation require periodic replacement of rods at some time prior to their expected time of failure. Predictions of failure are normally accomplished by a mechanical analysis of the rod up to some assumed failing criterion. In the Liquid Metal Fast Breeder Reactor (LMFBR) the loading environment is so severe that current analytical tools are inadequate.

---

[1]Consultant from the University of Tennessee.

A fuel rod is subjected to an external coolant pressure and an internal gas pressure. There is a severe thermal environment, producing a restructuring of the fuel and leading even to liquefaction at the highest operating temperatures. The neutron flux leads to swelling of fuel and cladding as well as embrittlement of the cladding. In the highly stressed and hottest regions the creep strain rate can be quite large. Also, it must be considered that the thermal gradient causes localized variations of the material properties. In addition, a typical load-time history consists of many cycles of loading and unloading, of varying intensity and duration.

TRANS is designed to calculate the stresses and strains in an axisymmetric thick-walled cylinder under varying load conditions. The material properties are considered to vary through the thickness of the wall with temperature and perhaps with time. All materials are considered to be elastic-plastic with linear strain hardening, giving a bilinear stress-strain curve. Load changes, pressure and thermal, are assumed to be applied instantaneously, although the effect of strain rate on material properties is neglected. Creep response is considered to take place at constant stress levels.

The code consists of a main program and a series of subroutines. The subroutines perform auxiliary functions such as computing the material properties at a point, the elastic stress increments due to a loading increment, the creep strain increments over a given time period, and matrix inversion.

This report describes the theoretical basis of the code and describes the input instructions. In the appendices are provided

a FØRTRAN listing of the code, a flow diagram, input data sheets, and a sample output.

MECHANICAL ANALYSIS OF AXISYMMETRIC THICK CYLINDER

Basic Equations

For an axisymmetric thick cylinder in generalized plane strain, the equilibrium equation is, from Mendelson:[2]

$$\frac{d\sigma_r}{dr} + \frac{\sigma_r - \sigma_\theta}{r} = -F_r \ , \tag{1}$$

where F_r is the body force per unit volume.

The strain-displacement relations are:

$$\epsilon_r = \frac{du}{dr} \ , \qquad \epsilon_\theta = \frac{u}{r} \tag{2}$$

with the corresponding compatibility equation:

$$\frac{d\ \epsilon_\theta}{dr} + \frac{\epsilon_\theta - \epsilon_r}{r} = 0 \ . \tag{3}$$

The constitutive equations are:

$$\epsilon_r = \frac{1}{E}\left[\sigma_r - \nu\ (\sigma_\theta + \sigma_z)\right] + \alpha T + \epsilon_r^{\ p} + \epsilon_r^{\ c} \ , \tag{4a}$$

$$\epsilon_\theta = \frac{1}{E}\left[\sigma_\theta - \nu\ (\sigma_r + \sigma_z)\right] + \alpha T + \epsilon_\theta^{\ p} + \epsilon_\theta^{\ c} \ , \tag{4b}$$

$$\epsilon_z = \frac{1}{E}\left[\sigma_z - \nu\ (\sigma_r + \sigma_\theta)\right] + \alpha T + \epsilon_z^{\ p} + \epsilon_z^{\ c} \ . \tag{4c}$$

---

[2]A. Mendelson, Plasticity: Theory and Application, The Macmillan Company, New York, 1968.

The p and c superscripts refer to plastic and creep strain, respectively. Under the assumption of constant volume, or no dilatation:

$$\epsilon_r^{\,p} + \epsilon_\theta^{\,p} + \epsilon_z^{\,p} = 0 \,, \tag{5}$$

$$\epsilon_r^{\,c} + \epsilon_\theta^{\,c} + \epsilon_z^{\,c} = 0 \,. \tag{6}$$

The boundary conditions are:

$$\begin{aligned} &\text{at} \quad r = r_i, \qquad \sigma_r = -p_i \,, \\ &\text{at} \quad r = r_o, \qquad \sigma_r = -p_o \,, \end{aligned} \tag{7}$$

where i denotes the inner surface; o, the outer surface. In addition, the generalized plane strain assumption requires that:

$$\frac{d\epsilon_z}{dr} = 0 \,. \tag{8}$$

Also, if one end of the rod is free, equilibrium on a cut transverse section causes:

$$\int_{r_i}^{r_o} \sigma_z \, r \, dr = \frac{p_i \, r_i^{\,2} - p_o \, r_o^{\,2}}{2} \,. \tag{9}$$

For σ_z, one substitutes from (4c) and solves for ϵ_z in terms of σ_r and σ_θ at a point.

In the process of solution, the strains are substituted from (4) into (3) with the resulting equation:

$$\frac{d}{d_r}\left[\frac{1}{E}\sigma_\theta - \frac{\nu}{E}\sigma_r - \frac{\nu^2}{E}(\sigma_r + \sigma_\theta) - \nu\,\epsilon_z\right.$$

$$\left. + \nu\,\alpha T + \nu\,(-\epsilon_r{}^p - \epsilon_\theta{}^p) + \nu\,(-\epsilon_r{}^c - \epsilon_\theta{}^c) + \alpha T + \epsilon_\theta{}^p + \epsilon_\theta{}^c\right]$$

$$= \frac{1-\nu}{Er}(\sigma_r - \sigma_\theta) + \frac{\epsilon_r{}^p - \epsilon_\theta{}^p}{r} + \frac{\epsilon_r{}^c - \epsilon_\theta{}^c}{r}\,, \tag{10}$$

where the substitution for σ_z from (4c) has been made. This provides two equations, (1) and (10), in two unknowns, σ_r and σ_θ. Note that the $\nu\,\epsilon_z$ term on the left-hand side of (10) vanishes due to (8).

FINITE DIFFERENCE FORMULATION

Choose a number of points along the radius internal to the structure such that the thickness is divided into n (not necessarily equal) intervals. Thus there are n + 1 mesh points. The use of the second order central difference approximation to the derivatives gives the following equations which are equivalent to (1) and (10), respectively.[3]

$$-C_i\,\sigma_{r_i} + D_i\,\sigma_{\theta_i} + F_i\,\sigma_{r_{i-1}} + G_i\,\sigma_{\theta_{i-1}} = 0 \tag{11a}$$

$$-C_i'\,\sigma_{r_i} + D_i'\,\sigma_{\theta_i} - F_i'\,\sigma_{r_{i-1}} - G_i'\,\sigma_{\theta_{i-1}} = H_i' + P_i' \tag{11b}$$

---

[3]D. N. Johnson, Analysis of Elastic-Plastic Stress Distribution in Thick-Wall Cylinders and Spheres Subjected to Internal Pressure and Nuclear Radiation Heating, NASA TN D-271, p. 15 (April 1960).

where

$$C_n = \frac{1}{h_n} + \frac{1}{2r_n}, \quad C_n' = \frac{-\nu_n (1 + \nu_n)}{h_n E_n} - \frac{1 + \nu_n}{2E_n r_n},$$

$$D_n = \frac{1}{2r_n}, \quad D_n' = \frac{1 - \nu_n^2}{h_n E_n} + \frac{1 + \nu_n}{2E_n r_n},$$

$$F_n = \frac{1}{h_n} - \frac{1}{2r_{n-1}}, \quad F_n' = \frac{-\nu_{n-1} (1 + \nu_{n-1})}{h_n E_{n-1}} + \frac{1 + \nu_{n-1}}{2E_{n-1} r_{n-1}}, \tag{12}$$

$$G_n = \frac{1}{2r_{n-1}}, \quad G_n' = \frac{1 - \nu^2_{n-1}}{h_n E_{n-1}} - \frac{1 + \nu_{n-1}}{2E_{n-1} r_{n-1}},$$

$$H_n' = \frac{-(1 + \nu_n)}{h_n} \left[(\alpha T)_n - (\alpha T)_{n-1} \right],$$

$$P_n' = -\left(\frac{1 - \nu_n}{h_n} + \frac{1}{2r_n} \right) \left(\epsilon_\theta^{\,p} \right)_n + \left(\frac{1}{2r_n} + \frac{\nu_n}{h_n} \right) \left(\epsilon_r^{\,p} \right)_n$$

$$+ \left(\frac{1 - \nu_{n-1}}{h_n} - \frac{1}{2r_{n-1}} \right) \left(\epsilon_\theta^{\,p} \right)_{n-1} + \left(\frac{1}{2r_{n-1}} - \frac{\nu}{h_n} \right) \left(\epsilon_r^{\,p} \right)_{n-1}$$

where h_n is the width of the nth increment. In the expression, P_n', each plastic strain term, e.g. $\left(\epsilon_r^{\,p} \right)_n$, is considered to contain the creep strain also.

The boundary conditions are, from (7), that:

$$\sigma_{r_1} = -p_i$$
$$\sigma_{r_{n+1}} = -p_o \tag{13}$$

Equations (11) are written at n points from i = 2 to i = n+1. These, with the two equations (13), give 2(n+1) equations for a corresponding number of unknown stress quantities.

The matrix formulation is:

$$[R] \quad \{\sigma\} = \{B\} , \tag{14}$$

where

$$\{\sigma\} = \{\sigma_{r_1}, \ \sigma_{\theta_1} \ . \ . \ . \ , \ \sigma_{r_{n+1}} \ \sigma_{\theta_{n+1}}\} \tag{15a}$$

and

$$\{B\} = \{-p_i, \ 0, \ H_2' + P_2', \ 0, \ H_3' + P_3' , \ . \ . \ . \ , \tag{15b}$$
$$H_{n+1}' + P_{n+1}' , \ -p_o\} .$$

The R matrix is the matrix of coefficients defined in (12). For a solution [R] is inverted to give:

$$\{\sigma\} = [R]^{-1} \ \{B\}$$

or (16)

$$\{\sigma\} = [A] \ \{B\} .$$

Start by assuming all plastic and creep strains are zero. Thus, all values P_i' are zero. Solve (16) for a beginning set of stresses. These are improved in accuracy by an iterative process to be described. Note that matrix [R] only has to be inverted once for each loading condition defined as a specific thermal environment. This is conducive to a large saving in computer time.

PLASTIC ANALYSIS

Define the equivalent or effective stress at a point in terms of principal stresses as:

$$\sigma_e = \frac{1}{\sqrt{2}} [\sigma_r - \sigma_\theta)^2 + (\sigma_\theta - \sigma_z)^2 + (\sigma_z - \sigma_r)^2]^{1/2} \tag{17}$$

By the von Mises – Hencky distortion energy theory of failure, the material commences to yield when σ_e exceeds σ_y, the yield stress in uniaxial tension.

Define also the equivalent modified total strain:

$$\epsilon_{et} = \frac{\sqrt{2}}{3} [(\epsilon_r' - \epsilon_\theta')^2 + (\epsilon_\theta' - \epsilon_z')^2 + (\epsilon_z' - \epsilon_r')^2]^{1/2} \tag{18}$$

where the modified total strain is, for example,

$$\epsilon_r' = \epsilon_r - \epsilon_r^{\,p} \tag{19}$$

and e_r^p is the total plastic strain prior to the time of loading, including previous creep strain.

By Mendelson,[4] the equivalent plastic strain increment is:

$$\Delta\epsilon_p = \frac{\epsilon_{et} - \frac{2}{3}[(1+\nu)/E]\,\sigma_{e,\,i-1}}{1 + \frac{2}{3}[(1+\nu)/E]\;(d\sigma_e/d\epsilon_p)_{i-1}} \quad , \tag{20}$$

where i-1 refers to conditions at the end of the previous loading increment. This equation is exact for linear strain hardening. For an elastic-perfectly plastic material the strain hardening is zero and (20) becomes:

$$\Delta\epsilon_p = \epsilon_{et} - \frac{2}{3}\,\frac{(1+\nu)}{E}\;\sigma_y \; . \tag{21}$$

In the case of linear straining we have:

$$\frac{d\sigma_e}{d\epsilon_p} = \frac{m\,E}{1-m} \quad , \tag{22}$$

where $m = \frac{E_p}{E}$, the ratio of plastic to elastic modulus.

With this (20) can be written:

$$\Delta\epsilon_p = \frac{\epsilon_{et} - (2/3)[(1+\nu)/E]\;\sigma_{e_{i-1}}}{1 + (2/3)(1+\nu)\left(\frac{m}{1-m}\right)} \quad . \tag{23}$$

---

[4]A. Mendelson, Plasticity: Theory and Application, The Macmillan Company, New York, 1968.

The equivalent plastic strain increment is used to compute plastic strain increments at a point:

$$\Delta\epsilon_r{}^p = \frac{\Delta\epsilon_p}{3\epsilon_{et}} \quad (2\epsilon_r' - \epsilon_\theta' - \epsilon_z') \tag{24a}$$

$$\Delta\epsilon_\theta^p = \frac{\Delta\epsilon_p}{3\epsilon_{et}} \quad (2\epsilon_\theta' - \epsilon_r' - \epsilon_z') \tag{24b}$$

$$\Delta\epsilon_z{}^p = - \Delta\epsilon_r{}^p - \Delta\epsilon_\theta{}^p \ . \tag{24c}$$

Now the initial elastic solution previously discussed produces a set of stresses and strains at each point. If the computed equivalent stress at a point exceeds the yield stress at that point, an inelastic condition exists. In this case the equivalent modified total strain is used in Eq. (20) to obtain the equivalent plastic strain increment. These, in turn, are used to give the plastic strain increments. These are used to compute a new value of P' in the matrix {B} of (15b). The cycle is repeated until convergence is achieved.

LOAD CYCLING

Assume that a solution has been obtained and the state of stress and strain in a structure is known. Now impose some change in loading, either pressure or thermal. Compute a new elastic solution, assuming the quantities P_i' are unchanged from the previous step.

From this, one can obtain new values of effective stress σ_e. Two possibilities emerge.

1. Plastic Loading

If the computed effective stress exceeds the effective stress at the previous stage of loading and if it is above the yield stress at that point, then a plastic stress increment exists. Here an iterative solution is required. The difference is that the initial solution is based on the plastic strains computed in the previous cycle. Thus, P_i' is, in general, nonzero. In the formulation for P_i' replace $\left(\epsilon_\theta{}^p\right)_n$ with $\left(\epsilon_\theta{}^p\right)_n + \left(\Delta\epsilon_\theta{}^p\right)_n$, and likewise for $\left(\epsilon_r{}^p\right)_n$. The method of solution corresponds to that already set forth.

2. Unloading or Elastic Loading

If the computed effective stress is less than the yield stress and/or it is less than that at the preceding stage, an elastic change of state is indicated. It is assumed that unloading from any stress state follows a path parallel to the elastic loading portion. Thus, the response to an incremental unloading of effective stress is indistinguishable from that due to loading below the yield point. This implies that the plastic stress increment vanishes. The plastic strain remains constant. Consequently, no iteration is necessary.

CREEP

It is assumed for the purpose of this program that creep is steady state only, i.e., the material is in the secondary creep range. This implies that at a specific point:

$$\dot{\epsilon} = K \tag{25a}$$

or

$$\Delta\epsilon_{ec} = K\Delta t, \tag{25b}$$

where K is a function of the effective stress and temperature at that point.

The computed value of $\Delta\epsilon_{ec}$ is analogous to the equivalent plastic strain increment $\Delta\epsilon_p$. Therefore,

$$\Delta\epsilon_r{}^c = \frac{\Delta\epsilon_{ec}}{2\sigma_e} \quad (2\sigma_r - \sigma_\theta - \sigma_z) \tag{26a}$$

$$\Delta\epsilon_\theta{}^c = \frac{\Delta\epsilon_{ec}}{2\sigma_e} \quad (2\sigma_\theta - \sigma_r - \sigma_z) \tag{26b}$$

$$\Delta\epsilon_z{}^c = - \Delta\epsilon_r{}^c - \Delta\epsilon_\theta{}^c \tag{26c}$$

The creep strain increments computed in (26) are added to the plastic strains in order to permit computation of P_i' in (12). A one-step solution leads directly to the condition at the end of a time interval Δt.

A commonly used creep relation is of the type:

$$\dot{\epsilon}_{ec} = A \sinh\ (\sigma_e/B)^n \exp(-C/T_a)\ , \tag{27}$$

where A, B, C, and n are arbitrary constants related to the material in question. Over a long period of time $\Delta\epsilon_{ec}$ could become quite significant, lending in turn to a substantial modification in σ_e. One could iterate until (27) is based on the average stress over the time interval, rather than the initial stress. A better course would appear to be a simple dividing of the time period into shorter intervals. This should suffice for most purposes.

LOAD-TIME RELATIONS

In any load cycling problem we encounter variations in loading with time. The program in use can evaluate an instantaneous load change (elastic-plastic stresses) or a constant load over a period of time (creep). Thus, it is necessary to modify any load-time relationship into a series of vertical and horizontal steps. Here the solid line history is approximated by the dashed line sequence. Should conditions warrant, a line could be approximated by more than one step, as shown in Fig. 1.

For greater utility of this method the step size effect should be investigated. Initial indications were that the size of step is not of paramount importance. However, further study is in order.

ORNL-DWG 70-8380

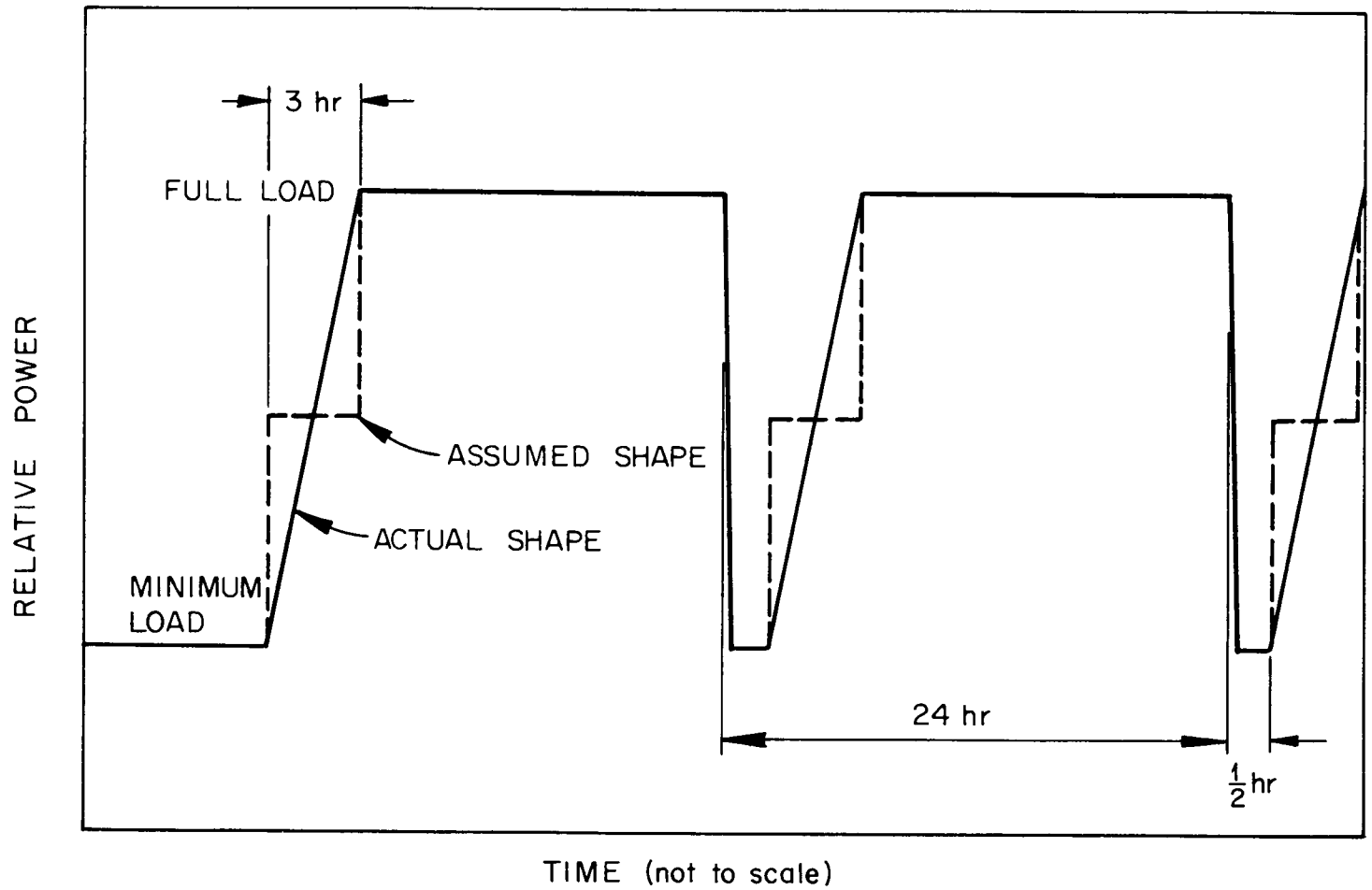

Fig. 1. Power Cycle Shape.

APPENDIX A

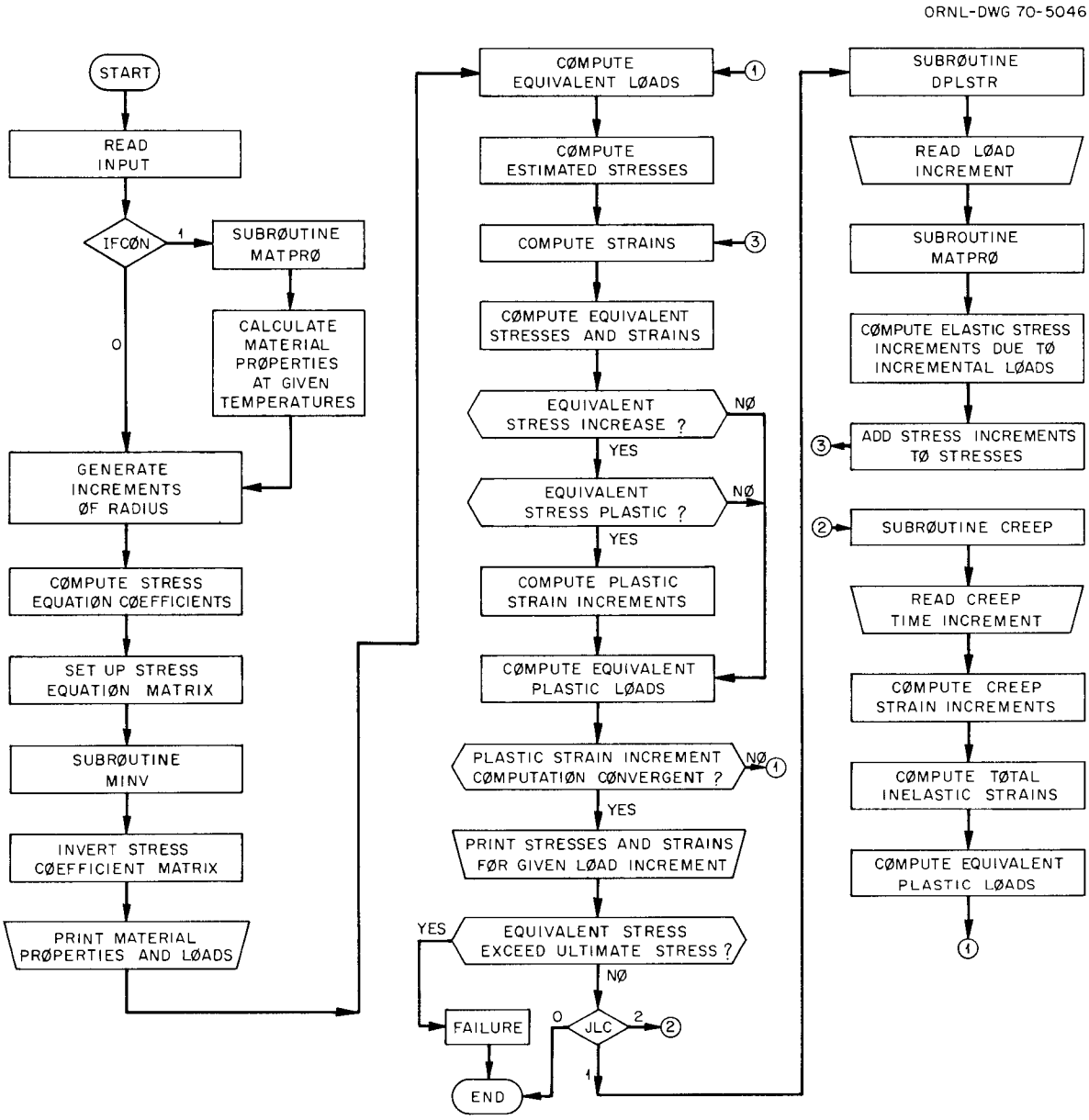

Fig. A-1. Flow Diagram for TRANS Program.

APPENDIX B

INPUT INSTRUCTIONS

Figure B-1 indicates the position of the input variables on the data cards. Figure B-2 is the input data for the sample problem discussed in Appendix D. If the problem consists of more than a simple one-step loading, then LINC = 1. Cards 60 to 80 are used when the additional loading is repetitive; cards 35 to 50 when not. The numbers in Columns 1 through 8 on the data cards have no effect on the calculations, with the exception of card 30, which has a 10-place floating point format. The input variables are defined in the glossary of terms, Appendix C.

ORNL-DWG 70-4464R

650 DATA SHEET

REQUEST ____ JOB TITLE INPUT FØRMAT FØR TRANS PRØGRAM WRITTEN BY ____ DATE ____

1-8	9-16	17-24	25-32	33-40	41-48	49-56	57-64	65-72	73-80
JOB IDEN	TIFICATI	ØN IN CØ	LUMNS 1-	80					
5	NINC	JTEMP	NØFI	IØUT	LINC	IFCØN	IFREP	NCP	
10	RIN	RØUT	SIGRI	SIGRR	TØL	CYCFAC			
15	EMØD	ALPH	PR	PLEM	SY	SU	TEM		
CARD 15	NECESSARY	ØNLY	WHEN	IFCØN=1					
20	TEMPR(I)	,I=1,NR							
CARD 20	NECESSARY	WHEN	JTEMP	EQUALS 1					
25	NØPTS								
30 T(J)	EM(J)	EMP(J)	AL(J)		PØI(J)	SY(J)	SU(J),J=1,NØPTS		
CARDS 25	AND 30	NECESSARY	WHEN	IFCØN IS	NØT EQUAL	TØ 1			
35	JLC								
40	IM	ITEMP							
45	DSIGRI	DSIGRR	DEPI						
50	DTEMP(I)	,I=1,NR							
CARDS 40	TØ 50	NECESSARY	WHEN	JLC=1					
CARD 50	NECESSARY	ØNLY	WHEN	ITEMP=1					
55	IM		TIMINC						
CARD 55	NECESSARY	ØNLY	WHEN	JLC=2					
60	NSTEPS	NØCYC							
65	KLC(J)	KTEMP(J)							
70	DKTEMP(J	,I),I=1,	NR						
75	DKSRI(J)	,DKSRR(J)	,DKEPI(J)						
80	TIMKNC(J)								
CARDS 60	TØ 80	NECESSARY	ØNLY	WHEN	IFREP>0				
CARDS 65	TØ 80	READ IN	FOR	J=1,NSTEPS					
CARDS 70	AND 75	NECESSARY	ØNLY	WHEN	KLC(J)=1				
CARD 70	NECESSARY	ØNLY	WHEN	KTEMP(J)>0					
CARD 80	NECESSARY	ØNLY	WHEN	KLC(J)=2					

Fig. B-1. Input Format for TRANS Program.

ORNL-DWG 70-8722

650 DATA SHEET

REQUEST ____ JOB TITLE SAMPLE PRØBLEM INPUT DATA ____ WRITTEN BY ____ DATE ____

1-8	9-16	17-24	25-32	33-40	41-48	49-56	57-64	65-72	73-80
STAINLESS STEEL	CLAD		PØWER	CYCLING	UP TØ	2 YEARS			
	10	1	2.00	2	1		1		
	.25	.27	2000.	100.	.005				
	650.	645.	640.	635.	630.	625.	620.	615.	610.
	605.	600.							
	5								
21.	28.6	E6 69.	E3	18. E-6	.295	43.	E3 98.	E3	
200.	27.8	E6 85.	E3	18.1 E-6	.305	28.	E3 70.	E3	
400.	25.6	E6 102.	E3	19.2 E-6	.313	22.	E3 73.	E3	
650.	21.3	E6 190.	E3	19.8 E-6	.326	17.5	E3 51.	E3	
800.	18.8	E6 220.	E3	20.3 E-6	.321	16.	E3 27.	E3	
	5	5							
	2								
	84.								
	2								
	84.								
	1	1							
	-350.	-345.	-340.	-335.	-330.	-325.	-320.	-315.	-310.
	-305.	-300.							
	-1000.								
	2								
	2.								
	1	1							
	350.	345.	340.	335.	330.	325.	320.	315.	310.
	305.	300.							
	1000.								

Fig. B-2. Sample Problem Input Data.

APPENDIX C

GLOSSARY OF IMPORTANT VARIABLES IN CODE

Symbol	Dimensions	Definition
AL(I)	$°C^{-1}$	Thermal expansion coefficient input in MATPRØ.
ALPH	$°C^{-1}$	Thermal expansion coefficient for constant properties case.
ALPHA(I)	$°C^{-1}$	Thermal expansion coefficient at nodal point.
BR(I)	lb/sq in.	Equivalent load.
CC(I)	$in.^{-1}$	Stress equation coefficient.
CP(I)	$(lb/in.)^{-1}$	Stress equation coefficient.
C3	in./in.	Axial stress correction factor.
CYCFAC	%	Percent increase of load per load cycle.
DD(I)	$in.^{-1}$	Stress equation coefficient.
DEC(I)	in./in.	Equivalent creep strain increment.
DECR(I)	in./in.	Radial creep strain increment.
DECT(I)	in./in.	Tangential creep strain increment.
DELR	none	Proportionate change of radial plastic strain increment.
DELT	none	Proportionate change of tangential plastic strain increment.
DEP(I)	in./in.	Equivalent plastic strain increment.
DEPI	in./in.	Estimated maximum equivalent plastic strain increment.
DEPR(I)	in./in.	Radial plastic strain increment.

Symbol	Dimensions	Definition
DEPT(I)	in./in.	Tangential plastic strain increment.
DHP(I)	$in.^{-1}$	Equivalent thermal force increment.
DKEPI(I)	in./in.	Estimated maximum equivalent plastic strain increment for ith step in load cycle.
DKTEMP(J,I)	°C	Temperature increment at ith node in jth load step.
DKSRI(I)	lb/sq in.	Internal pressure increment for ith step in load cycle.
DKSRR(I)	lb/sq in.	External pressure increment for ith step in load cycle.
DP(I)	$(lb/in.)^{-1}$	Stress equation coefficient.
DSIGR(I)	lb/sq in.	Elastic radial stress increment.
DSIGRI	lb/sq in.	Internal pressure increment.
DSIGRR	lb/sq in.	External pressure increment.
DSIGT(I)	lb/sq in.	Elastic tangential stress increment.
DSIGZ(I)	lb/sq in.	Elastic axial stress increment.
DSM(I)	lb/sq in.	Elastic incremental stress vector.
DTEMP(I)	°C	Temperature increment.
E(I)	lb/sq in.	Elastic modulus.
EECR	in./in./hr	Equivalent creep strain rate.
EET(I)	in./in.	Equivalent modified total strain.
EM(I)	lb/sq in.	Input elastic modulus for MATPRØ.
EMØD	lb/sq in.	Constant elastic modulus.
EMP(I)	lb/sq in.	Input plastic modulus for MATPRØ.
EP(I)	in./in.	Equivalent plastic strain.

Symbol	Dimensions	Definition
EPL(I)	lb/sq in.	Plastic modulus.
EPR(I)	in./in.	Plastic radial strain.
EPT(I)	in./in.	Plastic tangential strain.
ERP	in./in.	Modified radial strain.
ETP	in./in.	Modified tangential strain.
ETR(I)	in./in.	Radial strain.
ETT(I)	in./in.	Tangential strain
ETZ(I)	in./in.	Axial strain.
FF(I)	$in.^{-1}$	Stress equation coefficient.
FP(I)	$(lb/in.)^{-1}$	Stress equation coefficient.
GG(I)	$in.^{-1}$	Stress equation coefficient.
GP(I)	$(lb/in.)^{-1}$	Stress equation coefficient.
HP(I)	$in.^{-1}$	Equivalent thermal force.
HT(I)	in.	Radial increment.
IFCØN	none	Constant properties indicator. IFCØN = 1. No radial variation in material properties.
IFREP	none	Repetitive load cycle indicator. IFREP = 0. No repetition. IFREP = 1. Load cycle repeated.
IØUT	none	Printout indicator. IØUT = 0. No printout. IØUT = 1. Print everything. IØUT = 2. Print first and last step in iteration on stress. IØUT = 3. Print first and last step in stress iteration at set intervals in load cycles.
IM	none	Cutoff indicator. IM = 1. Cycle continues. IM = 2. This is last step. New job starts with next input.

Symbol	Dimensions	Definition
ITEMP	none	Incremental thermal loading indicator. ITEMP = 1. Incremental thermal loading.
JLC	none	Loading increment – creep indicator. JLC = 1. Incremental loading. JLC = 2. Creep step.
JPR	none	Indicator of interval of cycles output printed.
JTEMP	none	Thermal loading indicator. JTEMP = 1. Thermal loading.
KLC(J)	none	Load type indicator for jth load step. KLC = 1. Load increment. KLC = 2. Creep increment.
KTEMP(J)	none	Thermal loading indicator for jth step. KTEMP = 1. Thermal loading.
LI	none	Loading increment number.
LINC	none	Incremental loading – creep indicator. LINC = 1. Consider more than one step.
NC	none	Load cycle number.
NCP	none	Interval of load cycles for which output is printed.
NINC	none	Number of radial increments.
NIT	none	Stress computation iteration number.
NØCYC	none	Number of cycles considered.
NØFI	none	Maximum number of iterations.
NØFS	none	Number of radial nodes.
NØPTS	none	Number of input data points for MATPRØ.
NR	none	Number of radial nodes.
NS	none	Step number within a cycle.
NSTEPS	none	Number of steps in a load cycle.

Symbol	Dimensions	Definition
PLEM	lb/sq in.	Constant plastic modulus.
PØI(I)	none	Poisson ratio input to MATPRØ.
PP(I)	$in.^{-1}$	Equivalent plastic loading.
PR	none	Constant Poisson ratio.
RAD(I)	in.	Nodal radius.
RIN	in.	Inner radius.
RINC	in.	Increment of radius.
RØUT	in.	Outer radius.
SIGE(I)	lb/sq in.	Equivalent stress.
SIGEM(I)	lb/sq in.	Equivalent stress at previous iteration.
SIGR(I)	lb/sq in.	Radial stress.
SIGRI	lb/sq in.	Inner pressure.
SIGRR	lb/sq in.	Outer pressure.
SIGT(I)	lb/sq in.	Tangential stress.
SIGU(I)	lb/sq in.	Ultimate stress.
SIGY(I)	lb/sq in.	Yield stress.
SIGZ(I)	lb/sq in.	Axial stress.
SMI(I)	lb/sq in.	Computed stress vector.
SU	lb/sq in.	Constant ultimate stress.
SY	lb/sq in.	Constant yield stress
T(I)	°C	Temperature input.
TEM	°C	Temperature input for constant properties case.
TEMP(I)	°C	Average nodal temperature during a load step.
TEMPR(I)	°C	Nodal temperature.

Symbol	Dimensions	Definition
TIME	hr	Total time.
TIMINC	hr	Creep time interval.
TIMKNC(I)	hr	Time interval for ith step in load cycle.
TØL	none	Convergence tolerance on plastic strain increments.
YMU(I)	none	Computed Poisson ratio.

APPENDIX D

SAMPLE PROBLEM

Consider a type 316L stainless steel tube cladding undergoing power cycling. The assumed design and operating conditions are:

Inner radius	0.25 in.
Outer radius	0.27 in.

	Full Load	Minimum Load
Temperature	650 to 600°C	300°C
Inner pressure	2000 psi	1000 psi
Outer pressure	100 psi	100 psi
Time period	168 hr	2 hr

The input format is given in Appendix B, and the output format is given here.

STAINLESS STEEL CLAD POWER CYCLING UP TO 2 YEARS

ELASTIC-PLASTIC ANALYSIS

STA NO	RADIUS (CM)	TEMP (DEG C)	THERMAL EXPANSION COEFF.	ELASTIC MODULUS (ATM)	POISSON'S RATIO	PLASTIC MODULUS	YIELD STRESS	ULTIMATE STRESS
1	0.25000	650.	0.188E-04	0.264E 08	0.31000	0.956E 05	24250.00	71875.00
2	0.25200	645.	0.188E-04	0.265E 08	0.30990	0.954E 05	24325.00	71837.44
3	0.25400	640.	0.188E-04	0.265E 08	0.30980	0.952E 05	24400.00	71799.94
4	0.25600	635.	0.187E-04	0.265E 08	0.30970	0.950E 05	24475.00	71762.44
5	0.25800	630.	0.187E-04	0.265E 08	0.30960	0.948E 05	24550.00	71724.94
6	0.26000	625.	0.187E-04	0.265E 08	0.30950	0.946E 05	24625.00	71687.50
7	0.26200	620.	0.187E-04	0.266E 08	0.30940	0.943E 05	24700.00	71649.94
8	0.26400	615.	0.187E-04	0.266E 08	0.30930	0.941E 05	24775.00	71612.44
9	0.26600	610.	0.187E-04	0.266E 08	0.30920	0.939E 05	24850.00	71574.94
10	0.26800	605.	0.187E-04	0.267E 08	0.30910	0.937E 05	24925.00	71537.44
11	0.27000	600.	0.186E-04	0.267E 08	0.30900	0.935E 05	25000.00	71500.00

INNER PRESSURE 2000.000

OUTER PRESSURE 100.000

ITERATION NUMBER 1

SIGR	SIGT	SIGZ	SIGE	ETR	ETT	ETZ	DEPR	DEPT	PP	DEP
-0.200E 04	0.463E 04	-0.106E 04	0.621E 04	0.599E-02	0.632E-02	0.603E-02	0.0	0.0	0.0	0.0
-0.193E 04	0.851E 04	0.152E 04	0.921E 04	0.586E-02	0.638E-02	0.603E-02	0.0	0.0	0.0	0.0
-0.183E 04	0.124E 05	0.410E 04	0.123E 05	0.574E-02	0.644E-02	0.603E-02	0.0	0.0	0.0	0.0
-0.171E 04	0.162E 05	0.668E 04	0.155E 05	0.562E-02	0.650E-02	0.603E-02	0.0	0.0	0.0	0.0
-0.156E 04	0.200E 05	0.927E 04	0.187E 05	0.550E-02	0.656E-02	0.603E-02	0.0	0.0	0.0	0.0
-0.138E 04	0.238E 05	0.1195 05	0.218E 05	0.538E-02	0.662E-02	0.603E-02	0.0	0.0	0.0	0.0
-0.117E 04	0.275E 05	0.144E 05	0.249E 05	0.527E-02	0.668E-02	0.603E-02	-0.491E-05	0.463E-05	-0.238E-02	0.552E-05
-0.938E 03	0.312E 05	0.170E 05	0.279E 05	0.515E-02	0.673E-02	0.603E-02	-0.925E-04	0.856E-04	-0.419E-01	0.103E-03
-0.682E 03	0.349E 05	0.196E 05	0.310E 05	0.504E-02	0.679E-02	0.603E-02	-0.180E-03	0.164E-03	-0.416E-01	0.199E-03
-0.403E 03	0.386E 05	0.222E 05	0.339E 05	0.493E-02	0.684E-02	0.603E-02	-0.267E-03	0.240E-03	-0.414E-01	0.294E-03
-0.100E 03	0.423E 05	0.248E 05	0.369E 05	0.482E-02	0.689E-02	0.603E-02	-0.353E-03	0.315E-03	-0.412E-01	0.388E-03

NUMBER OF ITERATIONS 16

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.590E-02	0.649E-02	0.606E-02	0.0	0.0	0.357E-03	0.0	0.0
2	0.577E-02	0.656E-02	0.606E-02	0.0	0.0	0.457E-03	0.0	0.0
3	0.565E-02	0.662E-02	0.606E-02	0.0	0.0	0.558E-03	0.0	0.0
4	0.554E-02	0.668E-02	0.606E-02	0.0	0.0	0.659E-03	0.0	0.0
5	0.542E-02	0.673E-02	0.606E-02	0.0	0.0	0.759E-03	0.0	0.0
6	0.527E-02	0.679E-02	0.606E-02	-0.603E-04	0.586E-04	0.878E-03	0.687E-04	-0.298E-01
7	0.509E-02	0.684E-02	0.606E-02	-0.184E-03	0.171E-03	0.102E-02	0.206E-03	-0.590E-01
8	0.490E-02	0.690E-02	0.606E-02	-0.313E-03	0.290E-03	0.116E-02	0.344E-03	-0.593E-01
9	0.472E-02	0.695E-02	0.606E-02	-0.443E-03	0.386E-03	0.130E-02	0.482E-03	-0.594E-01
10	0.453E-02	0.700E-02	0.606E-02	-0.574E-03	0.489E-03	0.144E-02	0.620E-03	-0.594E-01
11	0.435E-02	0.704E-02	0.606E-02	-0.706E-03	0.589E-03	0.158E-02	0.757E-03	-0.593E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.101E 05	0.129E 04	0.108E 05
2	-0.189E 04	0.139E 05	0.388E 04	0.138E 05
3	-0.175E 04	0.177E 05	0.646E 04	0.169E 05
4	-0.158E 04	0.215E 05	0.904E 04	0.200E 05
5	-0.139E 04	0.253E 05	0.116E 05	0.231E 05
6	-0.118E 04	0.273E 05	0.136E 05	0.246E 05
7	-0.959E 03	0.275E 05	0.148E 05	0.247E 05
8	-0.742E 03	0.278E 05	0.158E 05	0.248E 05
9	-0.527E 03	0.280E 05	0.167E 05	0.249E 05
10	-0.313E 03	0.283E 05	0.174E 05	0.250E 05
11	-0.100E 03	0.285E 05	0.181E 05	0.251E 05

TIME INCREMENT 84.00 HOURS

	DECR	DECT
0.8186E-05	-0.5822E-05	0.7895E-05
0.1734E-04	-0.1350E-04	0.1617E-04
0.3754E-04	-0.3069E-04	0.3406E-04
0.8203E-04	-0.6909E-04	0.7284E-04
0.1799E-03	-0.1545E-03	0.1569E-03
0.2396E-03	-0.2103E-03	0.2046E-03
0.1955E-03	-0.1751E-03	0.1628E-03
0.1592E-03	-0.1447E-03	0.1298E-03
0.1293E-03	-0.1188E-03	0.1036E-03
0.1048E-03	-0.9710E-04	0.8265E-04
0.8470E-04	-0.7901E-04	0.6592E-04

TIME 84.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.584E-02	0.660E-02	0.607E-02	-0.582E-05	0.789E-05	0.442E-03	0.0	0.0
2	0.572E-02	0.666E-02	0.607E-02	-0.135E-04	0.162E-04	0.534E-03	0.0	-0.413E-02
3	0.559E-02	0.672E-02	0.607E-02	-0.307E-04	0.341E-04	0.619E-03	0.0	-0.902E-02
4	0.545E-02	0.678E-02	0.607E-02	-0.691E-04	0.728E-04	0.686E-03	0.0	-0.197E-01
5	0.529E-02	0.684E-02	0.607E-02	-0.155E-03	0.157E-03	0.715E-03	0.0	-0.431E-01
6	0.511E-02	0.689E-02	0.607E-02	-0.271E-03	0.263E-03	0.722E-03	0.687E-04	-0.563E-01
7	0.494E-02	0.694E-02	0.607E-02	-0.359E-03	0.334E-03	0.756E-03	0.206E-03	-0.406E-01
8	0.477E-02	0.699E-02	0.607E-02	-0.457E-03	0.410E-03	0.783E-03	0.344E-03	-0.444E-01
9	0.460E-02	0.704E-02	0.607E-02	-0.562E-03	0.490E-03	0.805E-03	0.482E-03	-0.473E-01
10	0.443E-02	0.709E-02	0.607E-02	-0.672E-03	0.572E-03	0.823E-03	0.620E-03	-0.495E-01
11	0.426E-02	0.714E-02	0.607E-02	-0.785E-03	0.655E-03	0.837E-03	0.757E-03	-0.513E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.130E 05	0.243E 04	0.134E 05
2	-0.187E 04	0.166E 05	0.495E 04	0.162E 05
3	-0.171E 04	0.199E 05	0.739E 04	0.188E 05
4	-0.153E 04	0.225E 05	0.963E 04	0.208E 05
5	-0.134E 04	0.237E 05	0.114E 05	0.217E 05
6	-0.114E 04	0.242E 05	0.127E 05	0.220E 05
7	-0.945E 03	0.256E 05	0.141E 05	0.230E 05
8	-0.740E 03	0.267E 05	0.153E 05	0.239E 05
9	-0.530E 03	0.277E 05	0.163E 05	0.246E 05
10	-0.316E 03	0.285E 05	0.173E 05	0.252E 05
11	-0.100E 03	0.292E 05	0.181E 05	0.256E 05

TIME INCREMENT 84.00 HOURS

	DECR	DECT
0.1904E-04	-0.1384E-04	0.1824E-04
0.3745E-04	-0.2927E-04	0.3487E-04
0.6913E-04	-0.5650E-04	0.6275E-04
0.1078E-03	-0.9101E-04	0.9547E-04
0.1144E-03	-0.9961E-04	0.9861E-04
0.9859E-04	-0.8788E-04	0.8265E-04
0.1106E-03	-0.9971E-04	0.9130E-04
0.1162E-03	-0.1057E-03	0.9459E-04
0.1158E-03	-0.1061E-03	0.9315E-04
0.1106E-03	-0.1020E-03	0.8806E-04
0.1021E-03	-0.9464E-04	0.8050E-04

TIME 168.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.580E-02	0.669E-02	0.607E-02	-0.197E-04	0.261E-04	0.500E-03	0.0	0.0
2	0.566E-02	0.675E-02	0.607E-02	-0.428E-04	0.510E-04	0.577E-03	0.0	-0.125E-01
3	0.552E-02	0.680E-02	0.607E-02	-0.872E-04	0.968E-04	0.638E-03	0.0	-0.232E-01
4	0.536E-02	0.686E-02	0.607E-02	-0.160E-03	0.168E-03	0.676E-03	0.0	-0.370E-01
5	0.519E-02	0.692E-02	0.607E-02	-0.254E-03	0.256E-03	0.700E-03	0.0	-0.463E-01
6	0.502E-02	0.697E-02	0.607E-02	-0.358E-03	0.346E-03	0.719E-03	0.687E-04	-0.496E-01
7	0.485E-02	0.702E-02	0.607E-02	-0.459E-03	0.425E-03	0.743E-03	0.206E-03	-0.461E-01
8	0.468E-02	0.707E-02	0.607E-02	-0.563E-03	0.505E-03	0.766E-03	0.344E-03	-0.472E-01
9	0.451E-02	0.712E-02	0.607E-02	-0.668E-03	0.583E-03	0.787E-03	0.482E-03	-0.476E-01
10	0.434E-02	0.716E-02	0.607E-02	-0.774E-03	0.660E-03	0.808E-03	0.620E-03	-0.479E-01
11	0.417E-02	0.721E-02	0.607E-02	-0.880E-03	0.736E-03	0.827E-03	0.757E-03	-0.482E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.151E 05	0.329E 04	0.151E 05
2	-0.185E 04	0.181E 05	0.569E 04	0.175E 05
3	-0.169E 04	0.206E 05	0.789E 04	0.193E 05
4	-0.151E 04	0.222E 05	0.977E 04	0.205E 05
5	-0.132E 04	0.232E 05	0.113E 05	0.213E 05
6	-0.113E 04	0.241E 05	0.126E 05	0.219E 05
7	-0.929E 03	0.251E 05	0.138E 05	0.226E 05
8	-0.728E 03	0.261E 05	0.149E 05	0.234E 05
9	-0.522E 03	0.271E 05	0.159E 05	0.240E 05
10	-0.313E 03	0.280E 05	0.168E 05	0.247E 05
11	-0.100E 03	0.289E 05	0.177E 05	0.253E 05

LOAD INCREMENT 1

INNER PRESSURE -1000.000

OUTER PRESSURE 0.0

STA	RADIUS	TEMP INC
1	0.25000	-350.
2	0.25200	-345.
3	0.25400	-340.
4	0.25600	-335.
5	0.25800	-330.
6	0.26000	-325.
7	0.26200	-320.
8	0.26400	-315.
9	0.26600	-310.
10	0.26800	-305.
11	0.27000	-300.

STA NO	RADIUS (CM)	TEMP (DEG C)	THERMAL EXPANSION COEFF.	ELASTIC MODULUS (ATM)	POISSON'S RATIO	PLASTIC MODULUS	YIELD STRESS	ULTIMATE STRESS
1	0.25000	300.	0.194E-04	0.243E 08	0.31690	0.128E 06	20650.00	66400.00
2	0.25200	300.	0.194E-04	0.244E 08	0.31677	0.128E 06	20695.00	66620.00
3	0.25400	300.	0.194E-04	0.244E 08	0.31664	0.127E 06	20740.00	66840.00
4	0.25600	300.	0.194E-04	0.244E 08	0.31651	0.126E 06	20785.00	67060.00
5	0.25800	300.	0.194E-04	0.245E 08	0.31638	0.125E 06	20830.00	67280.00
6	0.26000	300.	0.193E-04	0.245E 08	0.31625	0.124E 06	20875.00	67500.00
7	0.26200	300.	0.193E-04	0.246E 08	0.31612	0.123E 06	20920.00	67720.00
8	0.26400	300.	0.193E-04	0.246E 08	0.31599	0.122E 06	20965.00	67940.00
9	0.26600	300.	0.193E-04	0.247E 08	0.31586	0.121E 06	21010.00	68160.00
10	0.26800	300.	0.193E-04	0.247E 08	0.31573	0.120E 06	21055.00	68380.00
11	0.27000	300.	0.193E-04	0.247E 08	0.31560	0.120E 06	21100.00	68600.00

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.869E-02	0.987E-02	0.958E-02	-0.197E-04	0.261E-04	0.688E-03	0.0	0.0
2	0.864E-02	0.984E-02	0.948E-02	-0.428E-04	0.510E-04	0.659E-03	0.0	-0.124E-01
3	0.858E-02	0.980E-02	0.939E-02	-0.872E-04	0.968E-04	0.612E-03	0.0	-0.232E-01
4	0.851E-02	0.976E-02	0.929E-02	-0.160E-03	0.168E-03	0.543E-03	0.0	-0.370E-01
5	0.843E-02	0.972E-02	0.919E-02	-0.254E-03	0.256E-03	0.459E-03	0.0	-0.463E-01
6	0.834E-02	0.968E-02	0.910E-02	-0.358E-03	0.346E-03	0.369E-03	0.687E-04	-0.497E-01
7	0.825E-02	0.964E-02	0.900E-02	-0.459E-03	0.425E-03	0.289E-03	0.206E-03	-0.462E-01
8	0.817E-02	0.960E-02	0.890E-02	-0.503E-03	0.505E-03	0.215E-03	0.344E-03	-0.473E-01
9	0.808E-02	0.956E-02	0.881E-02	-0.668E-03	0.583E-03	0.161E-03	0.482E-03	-0.477E-01
10	0.799E-02	0.952E-02	0.871E-02	-0.774E-03	0.660E-03	0.151E-03	0.620E-03	-0.480E-01
11	0.790E-02	0.947E-02	0.861E-02	-0.880E-03	0.736E-03	0.193E-03	0.757E-03	-0.483E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.100E 04	0.200E 05	0.152E 05	0.191E 05
2	-0.835E 03	0.195E 05	0.141E 05	0.183E 05
3	-0.679E 03	0.185E 05	0.128E 05	0.170E 05
4	-0.537E 03	0.166E 05	0.111E 05	0.151E 05
5	-0.414E 03	0.141E 05	0.913E 04	0.128E 05
6	-0.312E 03	0.115E 05	0.690E 04	0.103E 05
7	-0.231E 03	0.911E 04	0.453E 04	0.809E 04
8	-0.169E 03	0.665E 04	0.204E 04	0.603E 04
9	-0.127E 03	0.418E 04	-0.530E 03	0.452E 04
10	-0.104E 03	0.169E 04	-0.317E 04	0.426E 04
11	-0.100E 03	-0.811E 03	-0.587E 04	0.545E 04

TIME INCREMENT 2.00 HOURS

	DECR	DECT
0.1746E-16	-0.1703E-16	0.1184E-16
0.1159E-16	-0.1119E-16	0.8201E-17
0.6017E-17	-0.5757E-17	0.4392E-17
0.2242E-17	-0.2129E-17	0.1672E-17
0.5628E-18	-0.6236E-18	0.5062E-18
0.1812E-18	-0.1671E-18	0.1444E-18
0.5628E-19	-0.4904E-19	0.4843E-19
0.1908E-19	-0.1429E-19	0.1810E-19
0.8593E-20	-0.3709E-20	0.8568E-20
0.7467E-20	0.1113E-20	0.5838E-20
0.1404E-19	0.8347E-20	0.5600E-20

TIME 170.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.883E-02	0.101E-01	0.909E-02	-0.197E-04	0.261E-04	0.721E-03	0.0	0.0
2	0.875E-02	0.998E-02	0.909E-02	-0.428E-04	0.510E-04	0.677E-03	0.0	-0.124E-01
3	0.867E-02	0.991E-02	0.909E-02	-0.872E-04	0.968E-04	0.619E-03	0.0	-0.232E-01
4	0.857E-02	0.983E-02	0.909E-02	-0.160E-03	0.168E-03	0.541E-03	0.0	-0.370E-01
5	0.846E-02	0.976E-02	0.909E-02	-0.254E-03	0.256E-03	0.453E-03	0.0	-0.463E-01
6	0.835E-02	0.969E-02	0.909E-02	-0.358E-03	0.346E-03	0.367E-03	0.687E-04	-0.497E-01
7	0.823E-02	0.961E-02	0.909E-02	-0.459E-03	0.425E-03	0.295E-03	0.206E-03	-0.462E-01
8	0.811E-02	0.953E-02	0.909E-02	-0.563E-03	0.505E-03	0.235E-03	0.344E-03	-0.473E-01
9	0.799E-02	0.945E-02	0.909E-02	-0.668E-03	0.583E-03	0.199E-03	0.482E-03	-0.477E-01
10	0.787E-02	0.938E-02	0.909E-02	-0.774E-03	0.660E-03	0.199E-03	0.620E-03	-0.480E-01
11	0.775E-02	0.930E-02	0.909E-02	-0.880E-03	0.736E-03	0.233E-03	0.757E-03	-0.483E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.100E 04	0.209E 05	0.362E 04	0.200E 05
2	-0.829E 03	0.201E 05	0.473E 04	0.188E 05
3	-0.670E 03	0.188E 05	0.564E 04	0.172E 05
4	-0.526E 03	0.167E 05	0.625E 04	0.151E 05
5	-0.402E 03	0.142E 05	0.657E 04	0.126E 05
6	-0.300E 03	0.115E 05	0.665E 04	0.102E 05
7	-0.220E 03	0.895E 04	0.663E 04	0.826E 04
8	-0.160E 03	0.639E 04	0.650E 04	0.660E 04
9	-0.120E 03	0.381E 04	0.630E 04	0.561E 04
10	-0.100E 03	0.123E 04	0.605E 04	0.560E 04
11	-0.100E 03	-0.136E 04	0.575E 04	0.657E 04

LOAD INCREMENT 2

INNER PRESSURE 1000.000

OUTER PRESSURE 0.0

STA	RADIUS	TEMP INC
1	0.25000	350.
2	0.25200	345.
3	0.25400	340.
4	0.25600	335.
5	0.25800	330.
6	0.26000	325.
7	0.26200	320.
8	0.26400	315.
9	0.26600	310.
10	0.26800	305.
11	0.27000	300.

STA NO	RADIUS (CM)	TEMP (DEG C)	THERMAL EXPANSION COEFF.	ELASTIC MODULUS (ATM)	POISSON'S RATIO	PLASTIC MODULUS	YIELD STRESS	ULTIMATE STRESS
1	0.25000	650.	0.194E-04	0.243E 08	0.31690	0.128E 06	20650.00	66400.00
2	0.25200	645.	0.194E-04	0.244E 08	0.31677	0.128E 06	20695.00	66620.00
3	0.25400	640.	0.194E-04	0.244E 08	0.31664	0.127E 06	20740.00	66840.00
4	0.25600	635.	0.194E-04	0.244E 08	0.31651	0.126E 06	20785.00	67060.00
5	0.25800	630.	0.194E-04	0.245E 08	0.31638	0.125E 06	20830.00	67280.00
6	0.26000	625.	0.193E-04	0.245E 08	0.31625	0.124E 06	20875.00	67500.00
7	0.26200	620.	0.193E-04	0.246E 08	0.31612	0.123E 06	20920.00	67720.00
8	0.26400	615.	0.193E-04	0.246E 08	0.31599	0.122E 06	20965.00	67940.00
9	0.26600	610.	0.193E-04	0.247E 08	0.31586	0.121E 06	21010.00	68160.00
10	0.26800	605.	0.193E-04	0.247E 08	0.31573	0.120E 06	21055.00	68380.00
11	0.27000	600.	0.193E-04	0.247E 08	0.31560	0.120E 06	21100.00	68600.00

ITERATION NUMBER 1

SIGR	SIGT	SIGZ	SIGE	ETR	ETT	ETZ	DEPR	DEPT	PP	DEP
-0.200E 04	0.159E 05	-0.826E 04	0.217E 05	0.900E-02	0.100E-01	0.868E-02	-0.105E-04	0.380E-04	0.0	0.392E-04
-0.185E 04	0.187E 05	-0.365E 04	0.215E 05	0.884E-02	0.100E-01	0.878E-02	-0.129E-04	0.296E-04	-0.101E-01	0.297E-04
-0.168E 04	0.209E 05	0.778E 03	0.215E 05	0.867E-02	0.101E-01	0.888E-02	-0.153E-04	0.260E-04	-0.225E-01	0.252E-04
-0.149E 04	0.224E 05	0.492E 04	0.214E 05	0.848E-02	0.101E-01	0.897E-02	-0.152E-04	0.207E-04	-0.353E-01	0.215E-04
-0.131E 04	0.233E 05	0.877E 04	0.214E 05	0.828E-02	0.101E-01	0.907E-02	-0.171E-04	0.193E-04	-0.463E-01	0.211E-04
-0.111E 04	0.240E 05	0.124E 05	0.218E 05	0.808E-02	0.101E-01	0.917E-02	-0.294E-04	0.280E-04	-0.548E-01	0.332E-04
-0.918E 03	0.250E 05	0.159E 05	0.228E 05	0.788E-02	0.101E-01	0.927E-02	-0.615E-04	0.503E-04	-0.592E-01	0.655E-04
-0.718E 03	0.259E 05	0.194E 05	0.240E 05	0.767E-02	0.102E-01	0.937E-02	-0.104E-03	0.740E-04	-0.627E-01	0.107E-03
-0.515E 03	0.267E 05	0.227E 05	0.255E 05	0.747E-02	0.102E-01	0.947E-02	-0.156E-03	0.966E-04	-0.644E-01	0.158E-03
-0.309E 03	0.275E 05	0.261E 05	0.271E 05	0.727E-02	0.102E-01	0.957E-02	-0.215E-03	0.116E-03	-0.649E-01	0.215E-03
-0.100E 03	0.283E 05	0.294E 05	0.290E 05	0.707E-02	0.102E-01	0.966E-02	-0.277E-03	0.131E-03	-0.648E-01	0.277E-03

NUMBER OF ITERATIONS 145

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.701E-02	0.118E-01	0.925E-02	-0.170E-02	0.178E-02	0.274E-02	0.199E-02	0.0
2	0.685E-02	0.118E-01	0.925E-02	-0.181E-02	0.186E-02	0.282E-02	0.207E-02	-0.586E-01
3	0.668E-02	0.119E-01	0.925E-02	-0.192E-02	0.194E-02	0.288E-02	0.212E-02	-0.588E-01
4	0.652E-02	0.119E-01	0.925E-02	-0.204E-02	0.201E-02	0.290E-02	0.215E-02	-0.590E-01
5	0.636E-02	0.119E-01	0.925E-02	-0.215E-02	0.209E-02	0.291E-02	0.215E-02	-0.592E-01
6	0.620E-02	0.119E-01	0.925E-02	-0.226E-02	0.216E-02	0.290E-02	0.222E-02	-0.593E-01
7	0.603E-02	0.119E-01	0.925E-02	-0.237E-02	0.223E-02	0.291E-02	0.235E-02	-0.593E-01
8	0.587E-02	0.120E-01	0.925E-02	-0.248E-02	0.230E-02	0.291E-02	0.249E-02	-0.593E-01
9	0.571E-02	0.120E-01	0.925E-02	-0.259E-02	0.237E-02	0.290E-02	0.263E-02	-0.593E-01
10	0.555E-02	0.120E-01	0.925E-02	-0.270E-02	0.244E-02	0.290E-02	0.277E-02	-0.593E-01
11	0.539E-02	0.120E-01	0.925E-02	-0.281E-02	0.250E-02	0.290E-02	0.290E-02	-0.593E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.224E 05	0.947E 04	0.212E 05
2	-0.180E 04	0.227E 05	0.101E 05	0.212E 05
3	-0.161E 04	0.230E 05	0.107E 05	0.213E 05
4	-0.142E 04	0.232E 05	0.112E 05	0.213E 05
5	-0.123E 04	0.234E 05	0.117E 05	0.214E 05
6	-0.104E 04	0.237E 05	0.122E 05	0.214E 05
7	-0.846E 03	0.239E 05	0.126E 05	0.214E 05
8	-0.658E 03	0.241E 05	0.129E 05	0.215E 05
9	-0.471E 03	0.243E 05	0.133E 05	0.215E 05
10	-0.285E 03	0.246E 05	0.136E 05	0.216E 05
11	-0.100E 03	0.248E 05	0.140E 05	0.216E 05

TIME INCREMENT 84.00 HOURS

	DECR	DECT
0.2406E-03	-0.2040E-03	0.2125E-03
0.1951E-03	-0.1672E-03	0.1706E-03
0.1576E-03	-0.1364E-03	0.1365E-03
0.1268E-03	-0.1107E-03	0.1089E-03
0.1017E-03	-0.8947E-04	0.8653E-04
0.8136E-04	-0.7200E-04	0.6981E-04
0.6494E-04	-0.5774E-04	0.5461E-04
0.5170E-04	-0.4615E-04	0.4325E-04
0.4105E-04	-0.3677E-04	0.3418E-04
0.3250E-04	-0.2921E-04	0.2695E-04
0.2567E-04	-0.2314E-04	0.2120E-04

TIME 254.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P* (PP)
1	0.685E-02	0.119E-01	0.925E-02	-0.191E-02	0.199E-02	0.666E-03	0.199E-02	0.0
2	0.671E-02	0.119E-01	0.925E-02	-0.198E-02	0.203E-02	0.699E-03	0.207E-02	-0.400E-01
3	0.656E-02	0.120E-01	0.925E-02	-0.206E-02	0.207E-02	0.727E-03	0.212E-02	-0.435E-01
4	0.641E-02	0.120E-01	0.925E-02	-0.215E-02	0.212E-02	0.748E-03	0.215E-02	-0.465E-01
5	0.626E-02	0.120E-01	0.925E-02	-0.224E-02	0.217E-02	0.766E-03	0.215E-02	-0.490E-01
6	0.611E-02	0.120E-01	0.925E-02	-0.233E-02	0.223E-02	0.779E-03	0.222E-02	-0.510E-01
7	0.595E-02	0.120E-01	0.925E-02	-0.243E-02	0.229E-02	0.790E-03	0.235E-02	-0.527E-01
8	0.580E-02	0.121E-01	0.925E-02	-0.253E-02	0.235E-02	0.798E-03	0.249E-02	-0.540E-01
9	0.564E-02	0.121E-01	0.925E-02	-0.263E-02	0.240E-02	0.805E-03	0.263E-02	-0.550E-01
10	0.549E-02	0.121E-01	0.925E-02	-0.273E-02	0.247E-02	0.810E-03	0.277E-02	-0.559E-01
11	0.534E-02	0.121E-01	0.925E-02	-0.283E-02	0.253E-02	0.814E-03	0.290E-02	-0.566E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.193E 05	0.871E 04	0.184E 05
2	-0.183E 04	0.206E 05	0.951E 04	0.194E 05
3	-0.165E 04	0.217E 05	0.103E 05	0.202E 05
4	-0.146E 04	0.226E 05	0.110E 05	0.208E 05
5	-0.127E 04	0.234E 05	0.116E 05	0.214E 05
6	-0.108E 04	0.241E 05	0.122E 05	0.218E 05
7	-0.884E 03	0.246E 05	0.127E 05	0.221E 05
8	-0.688E 03	0.252E 05	0.132E 05	0.224E 05
9	-0.492E 03	0.256E 05	0.136E 05	0.226E 05
10	-0.296E 03	0.260E 05	0.141E 05	0.228E 05
11	-0.100E 03	0.264E 05	0.144E 05	0.230E 05

TIME INCREMENT 84.00 HOURS

	DECR	DECT
0.9841E-04	-0.8540E-04	0.8505E-04
0.1071E-03	-0.9311E-04	0.9237E-04
0.1101E-03	-0.9604E-04	0.9463E-04
0.1078E-03	-0.9444E-04	0.9231E-04
0.1014E-03	-0.8915E-04	0.8642E-04
0.9217E-04	-0.8131E-04	0.7824E-04
0.8147E-04	-0.7207E-04	0.6893E-04
0.7036E-04	-0.6241E-04	0.5934E-04
0.5960E-04	-0.5299E-04	0.5011E-04
0.4967E-04	-0.4427E-04	0.4164E-04
0.4083E-04	-0.3647E-04	0.3413E-04

TIME 338.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P* (PP)
1	0.677E-02	0.120E-01	0.925E-02	-0.199E-02	0.208E-02	0.661E-03	0.199E-02	0.0
2	0.662E-02	0.120E-01	0.925E-02	-0.207E-02	0.212E-02	0.687E-03	0.207E-02	-0.444E-01
3	0.647E-02	0.120E-01	0.925E-02	-0.216E-02	0.217E-02	0.711E-03	0.212E-02	-0.455E-01
4	0.632E-02	0.120E-01	0.925E-02	-0.224E-02	0.221E-02	0.734E-03	0.215E-02	-0.462E-01
5	0.618E-02	0.121E-01	0.925E-02	-0.233E-02	0.226E-02	0.755E-03	0.215E-02	-0.469E-01
6	0.603E-02	0.121E-01	0.925E-02	-0.241E-02	0.231E-02	0.774E-03	0.222E-02	-0.476E-01
7	0.588E-02	0.121E-01	0.925E-02	-0.250E-02	0.236E-02	0.792E-03	0.235E-02	-0.486E-01
8	0.573E-02	0.121E-01	0.925E-02	-0.259E-02	0.240E-02	0.807E-03	0.249E-02	-0.497E-01
9	0.558E-02	0.121E-01	0.925E-02	-0.268E-02	0.246E-02	0.821E-03	0.263E-02	-0.508E-01
10	0.543E-02	0.122E-01	0.925E-02	-0.278E-02	0.251E-02	0.832E-03	0.277E-02	-0.520E-01
11	0.528E-02	0.122E-01	0.925E-02	-0.287E-02	0.256E-02	0.841E-03	0.290E-02	-0.531E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.191E 05	0.871E 04	0.183E 05
2	-0.183E 04	0.202E 05	0.942E 04	0.191E 05
3	-0.165E 04	0.212E 05	0.101E 05	0.198E 05
4	-0.147E 04	0.221E 05	0.108E 05	0.204E 05
5	-0.128E 04	0.230E 05	0.115E 05	0.211E 05
6	-0.109E 04	0.239E 05	0.121E 05	0.216E 05
7	-0.899E 03	0.247E 05	0.127E 05	0.222E 05
8	-0.702E 03	0.254E 05	0.133E 05	0.226E 05
9	-0.503E 03	0.261E 05	0.138E 05	0.231E 05
10	-0.302E 03	0.267E 05	0.143E 05	0.234E 05
11	-0.100E 03	0.273E 05	0.147E 05	0.237E 05

LOAD INCREMENT 3

INNER PRESSURE -10000.00

OUTER PRESSURE 0.0

STA	RADIUS	TEMP INC
1	0.25000	-350.
2	0.25200	-345.
3	0.25400	-340.
4	0.25600	-335.
5	0.25800	-330.
6	0.26000	-325.
7	0.26200	-320.
8	0.26400	-315.
9	0.26600	-310.
10	0.26800	-305.
11	0.27000	-300.

STA NO	RADIUS (CM)	TEMP (DEG C)	THERMAL EXPANSION COEFF.	ELASTIC MODULUS (ATM)	POISSON'S RATIO	PLASTIC MODULUS	YIELD STRESS	ULTIMATE STRESS
1	0.25000	300.	0.194E-04	0.243E 08	0.31690	0.128E 06	20650.00	66400.00
2	0.25200	300.	0.194E-04	0.244E 08	0.31677	0.128E 06	20695.00	66620.00
3	0.25400	300.	0.194E-04	0.244E 08	0.31664	0.127E 06	20740.00	66840.00
4	0.25600	300.	0.194E-04	0.244E 08	0.31651	0.126E 06	20785.00	67060.00
5	0.25800	300.	0.194E-04	0.245E 08	0.31638	0.125E 06	20830.00	67280.00
6	0.26000	300.	0.193E-04	0.245E 08	0.31625	0.124E 06	20875.00	67500.00
7	0.26200	300.	0.193E-04	0.246E 08	0.31612	0.123E 06	20920.00	67720.00
8	0.26400	300.	0.193E-04	0.246E 08	0.31599	0.122E 06	20965.00	67940.00
9	0.26600	300.	0.193E-04	0.247E 08	0.31586	0.121E 06	21010.00	68160.00
10	0.26800	300.	0.193E-04	0.247E 08	0.31573	0.120E 06	21055.00	68380.00
11	0.27000	300.	0.193E-04	0.247E 08	0.31560	0.120E 06	21100.00	68600.00

ITERATION NUMBER 1

SIGR	SIGT	SIGZ	SIGE	ETR	ETT	ETZ	DEPR	DEPT	PP	DEP
-0.100E 04	0.241E 05	0.206E 05	0.235E 05	0.659E-02	0.120E-01	0.967E-02	-0.102E-03	0.626E-04	0.0	0.103E-03
-0.811E 03	0.216E 05	0.178E 05	0.208E 05	0.653E-02	0.119E-01	0.957E-02	-0.232E-05	0.148E-05	-0.799E-02	0.235E-05
-0.645E 03	0.190E 05	0.150E 05	0.180E 05	0.648E-02	0.119E-01	0.947E-02	0.0	0.0	-0.446E-01	0.0
-0.501E 03	0.165E 05	0.122E 05	0.153E 05	0.642E-02	0.118E-01	0.937E-02	0.0	0.0	-0.462E-01	0.0
-0.379E 03	0.139E 05	0.930E 04	0.125E 05	0.636E-02	0.117E-01	0.927E-02	0.0	0.0	-0.469E-01	0.0
-0.279E 03	0.113E 05	0.639E 04	0.101E 05	0.630E-02	0.116E-01	0.917E-02	0.0	0.0	-0.476E-01	0.0
-0.200E 03	0.866E 04	0.342E 04	0.772E 04	0.624E-02	0.116E-01	0.907E-02	0.0	0.0	-0.486E-01	0.0
-0.144E 03	0.597E 04	0.410E 03	0.595E 04	0.617E-02	0.115E-01	0.897E-02	0.0	0.0	-0.497E-01	0.0
-0.108E 03	0.322E 04	-0.264E 04	0.510E 04	0.610E-02	0.114E-01	0.888E-02	0.0	0.0	-0.508E-01	0.0
-0.934E 02	0.428E 03	-0.574E 04	0.592E 04	0.603E-02	0.113E-01	0.878E-02	0.0	0.0	-0.520E-01	0.0
-0.100E 03	-0.242E 04	-0.887E 04	0.787E 04	0.596E-02	0.113E-01	0.868E-02	0.0	0.0	-0.531E-01	0.0

NUMBER OF ITERATIONS 2

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.669E-02	0.122E-01	0.917E-02	-0.209E-02	0.214E-02	0.825E-03	0.209E-02	0.0
2	0.665E-02	0.121E-01	0.917E-02	-0.208E-02	0.212E-02	0.708E-03	0.207E-02	-0.799E-02
3	0.657E-02	0.120E-01	0.917E-02	-0.216E-02	0.217E-02	0.620E-03	0.212E-02	-0.446E-01
4	0.648E-02	0.119E-01	0.917E-02	-0.224E-02	0.221E-02	0.533E-03	0.215E-02	-0.462E-01
5	0.639E-02	0.118E-01	0.917E-02	-0.233E-02	0.226E-02	0.447E-03	0.215E-02	-0.469E-01
6	0.630E-02	0.116E-01	0.917E-02	-0.241E-02	0.231E-02	0.363E-03	0.222E-02	-0.476E-01
7	0.620E-02	0.115E-01	0.917E-02	-0.250E-02	0.236E-02	0.282E-03	0.235E-02	-0.486E-01
8	0.611E-02	0.114E-01	0.917E-02	-0.259E-02	0.240E-02	0.207E-03	0.249E-02	-0.497E-01
9	0.601E-02	0.113E-01	0.917E-02	-0.268E-02	0.246E-02	0.149E-03	0.263E-02	-0.508E-01
10	0.591E-02	0.112E-01	0.917E-02	-0.278E-02	0.251E-02	0.132E-03	0.277E-02	-0.520E-01
11	0.581E-02	0.111E-01	0.917E-02	-0.287E-02	0.256E-02	0.171E-03	0.290E-02	-0.531E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.100E 04	0.222E 05	0.687E 04	0.204E 05
2	-0.818E 03	0.216E 05	0.804E 04	0.196E 05
3	-0.651E 03	0.192E 05	0.766E 04	0.172E 05
4	-0.505E 03	0.166E 05	0.723E 04	0.148E 05
5	-0.384E 03	0.140E 05	0.678E 04	0.125E 05
6	-0.283E 03	0.114E 05	0.629E 04	0.102E 05
7	-0.204E 03	0.877E 04	0.574E 04	0.790E 04
8	-0.146E 03	0.607E 04	0.516E 04	0.582E 04
9	-0.109E 03	0.333E 04	0.455E 04	0.419E 04
10	-0.941E 02	0.532E 03	0.390E 04	0.372E 04
11	-0.100E 03	-0.231E 04	0.322E 04	0.482E 04

TIME INCREMENT 2.00 HOURS

	DECR	DECT
0.3517E-16	-0.2676E-16	0.3315E-16
0.2320E-16	-0.1854E-16	0.2135E-16
0.6720E-17	-0.5484E-17	0.6105E-17
0.1922E-17	-0.1610E-17	0.1715E-17
0.5583E-18	-0.4827E-18	0.4843E-18
0.1657E-18	-0.1490E-18	0.1372E-18
0.5099E-19	-0.4811E-19	0.3868E-19
0.1706E-19	-0.1690E-19	0.1045E-19
0.7171E-20	-0.6939E-20	0.1904E-20
0.5578E-20	-0.3464E-20	-0.2055E-20
0.1008E-19	-0.1152E-20	-0.8099E-20

TIME 340.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.669E-02	0.122E-01	0.917E-02	-0.209E-02	0.214E-02	0.736E-03	0.209E-02	0.0
2	0.666E-02	0.121E-01	0.917E-02	-0.208E-02	0.212E-02	0.706E-03	0.207E-02	-0.799E-02
3	0.657E-02	0.120E-01	0.917E-02	-0.216E-02	0.217E-02	0.620E-03	0.212E-02	-0.446E-01
4	0.649E-02	0.119E-01	0.917E-02	-0.224E-02	0.221E-02	0.533E-03	0.215E-02	-0.462E-01
5	0.639E-02	0.118E-01	0.917E-02	-0.233E-02	0.226E-02	0.447E-03	0.215E-02	-0.469E-01
6	0.630E-02	0.116E-01	0.917E-02	-0.241E-02	0.231E-02	0.363E-03	0.222E-02	-0.476E-01
7	0.620E-02	0.115E-01	0.917E-02	-0.250E-02	0.236E-02	0.282E-03	0.235E-02	-0.486E-01
8	0.611E-02	0.114E-01	0.917E-02	-0.259E-02	0.240E-02	0.207E-03	0.249E-02	-0.497E-01
9	0.601E-02	0.113E-01	0.917E-02	-0.268E-02	0.246E-02	0.149E-03	0.263E-02	-0.508E-01
10	0.591E-02	0.112E-01	0.917E-02	-0.278E-02	0.251E-02	0.132E-03	0.277E-02	-0.520E-01
11	0.581E-02	0.111E-01	0.917E-02	-0.287E-02	0.256E-02	0.171E-03	0.290E-02	-0.531E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.100E 04	0.222E 05	0.687E 04	0.204E 05
2	-0.818E 03	0.216E 05	0.804E 04	0.196E 05
3	-0.651E 03	0.192E 05	0.766E 04	0.172E 05
4	-0.506E 03	0.166E 05	0.723E 04	0.148E 05
5	-0.384E 03	0.140E 05	0.678E 04	0.125E 05
6	-0.283E 03	0.114E 05	0.629E 04	0.102E 05
7	-0.204E 03	0.877E 04	0.574E 04	0.790E 04
8	-0.146E 03	0.607E 04	0.516E 04	0.582E 04
9	-0.109E 03	0.333E 04	0.455E 04	0.418E 04
10	-0.941E 02	0.532E 03	0.390E 04	0.372E 04
11	-0.100E 03	-0.231E 04	0.322E 04	0.482E 04

TIME INCREMENT 2.00 HOURS

	DECR	DECT
0.3558E-16	-0.2755E-16	0.3327E-16
0.2255E-16	-0.1840E-16	0.2049E-16
0.7288E-17	-0.6071E-17	0.6528E-17
0.2030E-17	-0.1723E-17	0.1791E-17
0.5733E-18	-0.4989E-18	0.4941E-18
0.1649E-18	-0.1482E-18	0.1367E-18
0.4886E-19	-0.4581E-19	0.3762E-19
0.1550E-19	-0.1526E-19	0.9970E-20
0.5942E-20	-0.5821E-20	0.1879E-20
0.4190E-20	-0.2559E-20	-0.1593E-20
0.7703E-20	-0.2588E-21	-0.6538E-20

TIME 680.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.238E-02	0.163E-01	0.932E-02	-0.640E-02	0.631E-02	0.737E-03	0.634E-02	0.0
2	0.242E-02	0.162E-01	0.932E-02	-0.631E-02	0.623E-02	0.704E-03	0.630E-02	-0.990E-02
3	0.240E-02	0.160E-01	0.932E-02	-0.632E-02	0.620E-02	0.625E-03	0.633E-02	-0.406E-01
4	0.237E-02	0.158E-01	0.932E-02	-0.635E-02	0.618E-02	0.537E-03	0.635E-02	-0.478E-01
5	0.234E-02	0.157E-01	0.932E-02	-0.638E-02	0.617E-02	0.449E-03	0.635E-02	-0.483E-01
6	0.230E-02	0.155E-01	0.932E-02	-0.641E-02	0.615E-02	0.363E-03	0.640E-02	-0.489E-01
7	0.226E-02	0.153E-01	0.932E-02	-0.644E-02	0.614E-02	0.279E-03	0.653E-02	-0.496E-01
8	0.222E-02	0.152E-01	0.932E-02	-0.648E-02	0.613E-02	0.201E-03	0.665E-02	-0.504E-01
9	0.218E-02	0.150E-01	0.932E-02	-0.652E-02	0.612E-02	0.136E-03	0.676E-02	-0.513E-01
10	0.213E-02	0.148E-01	0.932E-02	-0.656E-02	0.612E-02	0.114E-03	0.687E-02	-0.522E-01
11	0.208E-02	0.147E-01	0.932E-02	-0.661E-02	0.612E-02	0.153E-03	0.698E-02	-0.531E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.100E 04	0.223E 05	0.735E 04	0.204E 05
2	-0.818E 03	0.216E 05	0.861E 04	0.195E 05
3	-0.650E 03	0.194E 05	0.828E 04	0.174E 05
4	-0.504E 03	0.167E 05	0.762E 04	0.149E 05
5	-0.380E 03	0.141E 05	0.696E 04	0.125E 05
6	-0.279E 03	0.114E 05	0.627E 04	0.101E 05
7	-0.200E 03	0.871E 04	0.556E 04	0.782E 04
8	-0.143E 03	0.597E 04	0.484E 04	0.563E 04
9	-0.107E 03	0.320E 04	0.409E 04	0.383E 04
10	-0.931E 02	0.398E 03	0.332E 04	0.320E 04
11	-0.100E 03	-0.245E 04	0.254E 04	0.432E 04

LOAD INCREMENT 9

INNER PRESSURE 1000.000

OUTER PRESSURE 0.0

STA	RADIUS	TEMP INC
1	0.25000	350.
2	0.25200	345.
3	0.25400	340.
4	0.25600	335.
5	0.25800	330.
6	0.26000	325.
7	0.26200	320.
8	0.26400	315.
9	0.26600	310.
10	0.26800	305.
11	0.27000	300.

STA NO	RADIUS (CM)	TEMP (DEG C)	THERMAL EXPANSION COEFF.	ELASTIC MODULUS (ATM)	POISSON'S RATIO	PLASTIC MODULUS	YIELD STRESS	ULTIMATE STRESS
1	0.25000	650.	0.194E-04	0.243E 08	0.31690	0.128E 06	20650.00	66400.00
2	0.25200	645.	0.194E-04	0.244E 08	0.31677	0.128E 06	20695.00	66620.00
3	0.25400	640.	0.194E-04	0.244E 08	0.31664	0.127E 06	20740.00	66840.00
4	0.25600	635.	0.194E-04	0.244E 08	0.31651	0.126E 06	20785.00	67060.00
5	0.25800	630.	0.194E-04	0.245E 08	0.31638	0.125E 06	20830.00	67280.00
6	0.26000	625.	0.193E-04	0.245E 08	0.31625	0.124E 06	20875.00	67500.00
7	0.26200	620.	0.193E-04	0.246E 08	0.31612	0.123E 06	20920.00	67720.00
8	0.26400	615.	0.193E-04	0.246E 08	0.31599	0.122E 06	20965.00	67940.00
9	0.26600	610.	0.193E-04	0.247E 08	0.31586	0.121E 06	21010.00	68160.00
10	0.26800	605.	0.193E-04	0.247E 08	0.31573	0.120E 06	21055.00	68380.00
11	0.27000	600.	0.193E-04	0.247E 08	0.31560	0.120E 06	21100.00	68600.00

ITERATION NUMBER 1

SIGR	SIGT	SIGZ	SIGE	ETR	ETT	ETZ	DEPR	DEPT	PP	DEP
-0.200E 04	0.173E 05	-0.454E 04	0.207E 05	0.256E-02	0.163E-01	0.891E-02	-0.903E-06	0.222E-05	0.0	0.223E-05
-0.184E 04	0.202E 05	0.227E 03	0.211E 05	0.250E-02	0.162E-01	0.901E-02	-0.890E-05	0.155E-04	-0.158E-01	0.156E-04
-0.165E 04	0.215E 05	0.341E 04	0.211E 05	0.239E-02	0.162E-01	0.910E-02	-0.829E-05	0.121E-04	-0.394E-01	0.124E-04
-0.147E 04	0.224E 05	0.629E 04	0.211E 05	0.227E-02	0.161E-01	0.920E-02	-0.722E-05	0.912E-05	-0.467E-01	0.962E-05
-0.128E 04	0.232E 05	0.916E 04	0.213E 05	0.215E-02	0.160E-01	0.930E-02	-0.129E-04	0.142E-04	-0.510E-01	0.157E-04
-0.109E 04	0.240E 05	0.120E 05	0.217E 05	0.203E-02	0.159E-01	0.940E-02	-0.265E-04	0.257E-04	-0.551E-01	0.302E-04
-0.898E 03	0.247E 05	0.149E 05	0.224E 05	0.191E-02	0.159E-01	0.950E-02	-0.483E-04	0.414E-04	-0.587E-01	0.523E-04
-0.702E 03	0.254E 05	0.177E 05	0.233E 05	0.178E-02	0.158E-01	0.960E-02	-0.778E-04	0.592E-04	-0.616E-01	0.813E-04
-0.503E 03	0.261E 05	0.205E 05	0.243E 05	0.166E-02	0.157E-01	0.970E-02	-0.114E-03	0.770E-04	-0.637E-01	0.116E-03
-0.302E 03	0.267E 05	0.233E 05	0.255E 05	0.153E-02	0.157E-01	0.980E-02	-0.156E-03	0.932E-04	-0.651E-01	0.157E-03
-0.100E 03	0.272E 05	0.261E 05	0.268E 05	0.140E-02	0.156E-01	0.989E-02	-0.201E-03	0.107E-03	-0.660E-01	0.201E-03

NUMBER OF ITERATIONS 151

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.561E-03	0.180E-01	0.948E-02	-0.814E-02	0.803E-02	0.276E-02	0.834E-02	0.0
2	0.496E-03	0.180E-01	0.943E-02	-0.815E-02	0.801E-02	0.285E-02	0.839E-02	-0.590E-01
3	0.426E-03	0.179E-01	0.948E-02	-0.817E-02	0.799E-02	0.286E-02	0.844E-02	-0.591E-01
4	0.353E-03	0.178E-01	0.948E-02	-0.820E-02	0.797E-02	0.285E-02	0.845E-02	-0.591E-01
5	0.280E-03	0.178E-01	0.948E-02	-0.822E-02	0.794E-02	0.285E-02	0.844E-02	-0.591E-01
6	0.206E-03	0.177E-01	0.948E-02	-0.825E-02	0.792E-02	0.284E-02	0.849E-02	-0.591E-01
7	0.131E-03	0.176E-01	0.948E-02	-0.828E-02	0.790E-02	0.283E-02	0.860E-02	-0.592E-01
8	0.544E-04	0.175E-01	0.948E-02	-0.830E-02	0.788E-02	0.282E-02	0.871E-02	-0.592E-01
9	-0.227E-04	0.175E-01	0.948E-02	-0.833E-02	0.786E-02	0.281E-02	0.881E-02	-0.592E-01
10	-0.101E-03	0.174E-01	0.948E-02	-0.836E-02	0.784E-02	0.279E-02	0.891E-02	-0.592E-01
11	-0.179E-03	0.173E-01	0.948E-02	-0.839E-02	0.783E-02	0.278E-02	0.900E-02	-0.592E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.225E 05	0.104E 05	0.212E 05
2	-0.180E 04	0.227E 05	0.110E 05	0.212E 05
3	-0.161E 04	0.229E 05	0.113E 05	0.213E 05
4	-0.142E 04	0.232E 05	0.116E 05	0.213E 05
5	-0.123E 04	0.234E 05	0.118E 05	0.214E 05
6	-0.104E 04	0.237E 05	0.120E 05	0.214E 05
7	-0.847E 03	0.239E 05	0.123E 05	0.214E 05
8	-0.658E 03	0.241E 05	0.125E 05	0.215E 05
9	-0.471E 03	0.244E 05	0.127E 05	0.215E 05
10	-0.285E 03	0.246E 05	0.129E 05	0.215E 05
11	-0.100E 03	0.248E 05	0.132E 05	0.216E 05

TIME INCREMENT 42.00 HOURS

	DECR	DECT
0.1203E-03	-0.1048E-03	0.1036E-03
0.9757E-04	-0.8583E-04	0.8309E-04
0.7865E-04	-0.6932E-04	0.6684E-04
0.6321E-04	-0.5574E-04	0.5369E-04
0.5068E-04	-0.4471E-04	0.4302E-04
0.4053E-04	-0.3577E-04	0.3439E-04
0.3233E-04	-0.2855E-04	0.2742E-04
0.2573E-04	-0.2272E-04	0.2181E-04
0.2042E-04	-0.1804E-04	0.1730E-04
0.1616E-04	-0.1428E-04	0.1369E-04
0.1276E-04	-0.1128E-04	0.1080E-04

TIME 722.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.474E-03	0.181E-01	0.948E-02	-0.825E-02	0.814E-02	0.717E-03	0.834E-02	0.0
2	0.420E-03	0.180E-01	0.948E-02	-0.824E-02	0.810E-02	0.733E-03	0.839E-02	-0.497E-01
3	0.358E-03	0.180E-01	0.948E-02	-0.824E-02	0.806E-02	0.746E-03	0.844E-02	-0.515E-01
4	0.294E-03	0.179E-01	0.948E-02	-0.825E-02	0.802E-02	0.757E-03	0.845E-02	-0.529E-01
5	0.227E-03	0.178E-01	0.948E-02	-0.827E-02	0.799E-02	0.765E-03	0.844E-02	-0.541E-01
6	0.158E-03	0.177E-01	0.948E-02	-0.829E-02	0.796E-02	0.772E-03	0.849E-02	-0.551E-01
7	0.868E-04	0.177E-01	0.948E-02	-0.830E-02	0.793E-02	0.777E-03	0.860E-02	-0.559E-01
8	0.143E-04	0.176E-01	0.948E-02	-0.833E-02	0.790E-02	0.782E-03	0.871E-02	-0.565E-01
9	-0.597E-04	0.175E-01	0.948E-02	-0.835E-02	0.788E-02	0.785E-03	0.881E-02	-0.570E-01
10	-0.135E-03	0.175E-01	0.948E-02	-0.838E-02	0.786E-02	0.787E-03	0.891E-02	-0.575E-01
11	-0.212E-03	0.174E-01	0.948E-02	-0.840E-02	0.784E-02	0.789E-03	0.900E-02	-0.578E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.209E 05	0.996E 04	0.198E 05
2	-0.182E 04	0.217E 05	0.107E 05	0.203E 05
3	-0.163E 04	0.223E 05	0.111E 05	0.207E 05
4	-0.144E 04	0.229E 05	0.115E 05	0.211E 05
5	-0.125E 04	0.234E 05	0.118E 05	0.214E 05
6	-0.106E 04	0.238E 05	0.121E 05	0.216E 05
7	-0.865E 03	0.243E 05	0.124E 05	0.218E 05
8	-0.673E 03	0.246E 05	0.127E 05	0.219E 05
9	-0.482E 03	0.250E 05	0.129E 05	0.221E 05
10	-0.291E 03	0.253E 05	0.132E 05	0.222E 05
11	-0.100E 03	0.256E 05	0.134E 05	0.223E 05

TIME INCREMENT 42.00 HOURS

	DECR	DECT
0.7766E-04	-0.6823E-04	0.6624E-04
0.7277E-04	-0.6433E-04	0.6162E-04
0.6599E-04	-0.5832E-04	0.5589E-04
0.5837E-04	-0.5153E-04	0.4950E-04
0.5059E-04	-0.4463E-04	0.4294E-04
0.4310E-04	-0.3800E-04	0.3660E-04
0.3617E-04	-0.3188E-04	0.3074E-04
0.2999E-04	-0.2642E-04	0.2549E-04
0.2459E-04	-0.2166E-04	0.2090E-04
0.1997E-04	-0.1760E-04	0.1698E-04
0.1609E-04	-0.1418E-04	0.1368E-04

TIME 764.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.417E-03	0.181E-01	0.948E-02	-0.832E-02	0.820E-02	0.696E-03	0.834E-02	0.0
2	0.366E-03	0.181E-01	0.948E-02	-0.830E-02	0.816E-02	0.715E-03	0.839E-02	-0.480E-01
3	0.308E-03	0.180E-01	0.948E-02	-0.830E-02	0.811E-02	0.733E-03	0.844E-02	-0.491E-01
4	0.247E-03	0.179E-01	0.948E-02	-0.831E-02	0.807E-02	0.748E-03	0.845E-02	-0.501E-01
5	0.184E-03	0.178E-01	0.948E-02	-0.831E-02	0.803E-02	0.762E-03	0.844E-02	-0.512E-01
6	0.119E-03	0.178E-01	0.948E-02	-0.832E-02	0.799E-02	0.774E-03	0.849E-02	-0.522E-01
7	0.514E-04	0.177E-01	0.948E-02	-0.834E-02	0.796E-02	0.783E-03	0.860E-02	-0.532E-01
8	-0.179E-04	0.176E-01	0.948E-02	-0.835E-02	0.793E-02	0.791E-03	0.871E-02	-0.541E-01
9	-0.891E-04	0.176E-01	0.948E-02	-0.837E-02	0.790E-02	0.798E-03	0.881E-02	-0.549E-01
10	-0.162E-03	0.175E-01	0.948E-02	-0.839E-02	0.787E-02	0.804E-03	0.891E-02	-0.556E-01
11	-0.236E-03	0.174E-01	0.948E-02	-0.842E-02	0.785E-02	0.808E-03	0.900E-02	-0.563E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.202E 05	0.973E 04	0.193E 05
2	-0.182E 04	0.211E 05	0.105E 05	0.198E 05
3	-0.164E 04	0.219E 05	0.109E 05	0.204E 05
4	-0.145E 04	0.226E 05	0.113E 05	0.208E 05
5	-0.126E 04	0.233E 05	0.117E 05	0.213E 05
6	-0.107E 04	0.239E 05	0.121E 05	0.216E 05
7	-0.878E 03	0.244E 05	0.124E 05	0.219E 05
8	-0.684E 03	0.249E 05	0.128E 05	0.222E 05
9	-0.490E 03	0.254E 05	0.131E 05	0.224E 05
10	-0.295E 03	0.258E 05	0.134E 05	0.226E 05
11	-0.100E 03	0.262E 05	0.137E 05	0.228E 05

TIME INCREMENT 42.00 HOURS

	DECR	EECT
0.6431E-04	-0.5670E-04	0.5463E-04
0.5192E-04	-0.5488E-04	0.5227E-04
0.5835E-04	-0.5167E-04	0.4931E-04
0.5376E-04	-0.4770E-04	0.4569E-04
0.4899E-04	-0.4325E-04	0.4155E-04
0.4367E-04	-0.3850E-04	0.3710E-04
0.3824E-04	-0.3368E-04	0.3252E-04
0.3293E-04	-0.2898E-04	0.2803E-04
0.2792E-04	-0.2456E-04	0.2378E-04
0.2333E-04	-0.2052E-04	0.1989E-04
0.1926E-04	-0.1692E-04	0.1641E-04

TIME 806.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.368E-03	0.182E-01	0.948E-02	-0.837E-02	0.826E-02	0.683E-03	0.834E-02	0.0
2	0.317E-03	0.181E-01	0.948E-02	-0.836E-02	0.821E-02	0.704E-03	0.839E-02	-0.474E-01
3	0.261E-03	0.180E-01	0.948E-02	-0.835E-02	0.816E-02	0.724E-03	0.844E-02	-0.480E-01
4	0.203E-03	0.180E-01	0.948E-02	-0.835E-02	0.811E-02	0.742E-03	0.845E-02	-0.486E-01
5	0.143E-03	0.179E-01	0.948E-02	-0.836E-02	0.807E-02	0.758E-03	0.844E-02	-0.494E-01
6	0.802E-04	0.178E-01	0.948E-02	-0.836E-02	0.803E-02	0.773E-03	0.849E-02	-0.502E-01
7	0.157E-04	0.177E-01	0.948E-02	-0.837E-02	0.799E-02	0.786E-03	0.860E-02	-0.511E-01
8	-0.508E-04	0.177E-01	0.948E-02	-0.838E-02	0.796E-02	0.798E-03	0.871E-02	-0.520E-01
9	-0.119E-03	0.176E-01	0.948E-02	-0.840E-02	0.792E-02	0.808E-03	0.881E-02	-0.529E-01
10	-0.190E-03	0.175E-01	0.948E-02	-0.841E-02	0.789E-02	0.816E-03	0.891E-02	-0.538E-01
11	-0.262E-03	0.175E-01	0.948E-02	-0.843E-02	0.787E-02	0.823E-03	0.900E-02	-0.546E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.198E 05	0.959E 04	0.189E 05
2	-0.182E 04	0.207E 05	0.103E 05	0.195E 05
3	-0.164E 04	0.216E 05	0.108E 05	0.201E 05
4	-0.146E 04	0.224E 05	0.113E 05	0.207E 05
5	-0.127E 04	0.231E 05	0.117E 05	0.212E 05
6	-0.109E 04	0.239E 05	0.121E 05	0.216E 05
7	-0.887E 03	0.245E 05	0.125E 05	0.220E 05
8	-0.692E 03	0.251E 05	0.128E 05	0.224E 05
9	-0.496E 03	0.257E 05	0.132E 05	0.227E 05
10	-0.298E 03	0.262E 05	0.135E 05	0.230E 05
11	-0.100E 03	0.267E 05	0.138E 05	0.232E 05

TIME INCREMENT 42.00 HOURS

	DECR	EECT
0.5739E-04	-0.5070E-04	0.4884E-04
0.5587E-04	-0.4959E-04	0.4708E-04
0.5359E-04	-0.4751E-04	0.4522E-04
0.5073E-04	-0.4489E-04	0.4291E-04
0.4736E-04	-0.4183E-04	0.4015E-04
0.4354E-04	-0.3840E-04	0.3698E-04
0.3938E-04	-0.3468E-04	0.3350E-04
0.3502E-04	-0.3080E-04	0.2983E-04
0.3061E-04	-0.2689E-04	0.2611E-04
0.2632E-04	-0.2310E-04	0.2246E-04
0.2227E-04	-0.1954E-04	0.1903E-04

TIME 848.00 HOURS

NUMBER OF ITERATIONS 1

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.322E-03	0.182E-01	0.948E-02	-0.842E-02	0.831E-02	0.675E-03	0.834E-02	0.0
2	0.272E-03	0.181E-01	0.948E-02	-0.841E-02	0.826E-02	0.696E-03	0.839E-02	-0.470E-01
3	0.218E-03	0.181E-01	0.948E-02	-0.840E-02	0.821E-02	0.717E-03	0.844E-02	-0.474E-01
4	0.161E-03	0.180E-01	0.948E-02	-0.840E-02	0.816E-02	0.737E-03	0.845E-02	-0.478E-01
5	0.102E-03	0.179E-01	0.948E-02	-0.840E-02	0.811E-02	0.755E-03	0.844E-02	-0.483E-01
6	0.421E-04	0.178E-01	0.948E-02	-0.840E-02	0.807E-02	0.772E-03	0.849E-02	-0.489E-01
7	-0.201E-04	0.178E-01	0.948E-02	-0.840E-02	0.802E-02	0.788E-03	0.860E-02	-0.496E-01
8	-0.842E-04	0.177E-01	0.948E-02	-0.841E-02	0.799E-02	0.802E-03	0.871E-02	-0.504E-01
9	-0.150E-03	0.176E-01	0.948E-02	-0.842E-02	0.795E-02	0.815E-03	0.881E-02	-0.513E-01
10	-0.218E-03	0.176E-01	0.948E-02	-0.844E-02	0.792E-02	0.826E-03	0.891E-02	-0.522E-01
11	-0.288E-03	0.175E-01	0.948E-02	-0.845E-02	0.789E-02	0.835E-03	0.900E-02	-0.531E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.200E 04	0.196E 05	0.949E 04	0.187E 05
2	-0.183E 04	0.205E 05	0.102E 05	0.193E 05
3	-0.165E 04	0.213E 05	0.107E 05	0.199E 05
4	-0.146E 04	0.222E 05	0.112E 05	0.205E 05
5	-0.128E 04	0.230E 05	0.116E 05	0.211E 05
6	-0.109E 04	0.238E 05	0.121E 05	0.216E 05
7	-0.894E 03	0.246E 05	0.125E 05	0.221E 05
8	-0.698E 03	0.253E 05	0.129E 05	0.225E 05
9	-0.500E 03	0.259E 05	0.133E 05	0.229E 05
10	-0.301E 03	0.265E 05	0.136E 05	0.232E 05
11	-0.100E 03	0.271E 05	0.140E 05	0.236E 05

LOAD INCREMENT 9

INNER PRESSURE -1000.000

OUTER PRESSURE 0.0

STA	RADIUS	TEMP INC
1	0.25000	-350.
2	0.25200	-345.
3	0.25400	-340.
4	0.25600	-335.
5	0.25800	-330.
6	0.26000	-325.
7	0.26200	-320.
8	0.26400	-315.
9	0.26600	-310.
10	0.26800	-305.
11	0.27000	-300.

STA NO	RADIUS (CM)	TEMP (DEG C)	THERMAL EXPANSION COEFF.	ELASTIC MODULUS (ATM)	POISSON'S RATIO	PLASTIC MODULUS	YIELD STRESS	ULTIMATE STRESS
1	0.25000	300.	0.194E-04	0.243E 08	0.31690	0.128E 06	20650.00	66400.00
2	0.25200	300.	0.194E-04	0.244E 08	0.31677	0.128E 06	20695.00	66620.00
3	0.25400	300.	0.194E-04	0.244E 08	0.31664	0.127E 06	20740.00	66840.00
4	0.25600	300.	0.194E-04	0.244E 08	0.31651	0.126E 06	20785.00	67060.00
5	0.25800	300.	0.194E-04	0.245E 08	0.31638	0.125E 06	20830.00	67280.00
6	0.26000	300.	0.193E-04	0.245E 08	0.31625	0.124E 06	20875.00	67500.00
7	0.26200	300.	0.193E-04	0.246E 08	0.31612	0.123E 06	20920.00	67720.00
8	0.26400	300.	0.193E-04	0.246E 08	0.31599	0.122E 06	20965.00	67940.00
9	0.26600	300.	0.193E-04	0.247E 08	0.31586	0.121E 06	21010.00	68160.00
10	0.26800	300.	0.193E-04	0.247E 08	0.31573	0.120E 06	21055.00	68380.00
11	0.27000	300.	0.193E-04	0.247E 08	0.31560	0.120E 06	21100.00	68600.00

ITERATION NUMBER 1

SIGR	SIGT	SIGZ	SIGE	ETR	ETT	ETZ	DEPR	DEPT	PP	DEP
-0.100E 04	0.245E 05	0.214E 05	0.241E 05	0.144E-03	0.183E-01	0.989E-02	-0.123E-03	0.733E-04	0.0	0.123E-03
-0.808E 03	0.219E 05	0.186E 05	0.212E 05	0.187E-03	0.181E-01	0.980E-02	-0.187E-04	0.116E-04	-0.995E-02	0.189E-04
-0.640E 03	0.192E 05	0.156E 05	0.183E 05	0.223E-03	0.179E-01	0.970E-02	0.0	0.0	-0.405E-01	0.0
-0.495E 03	0.166E 05	0.125E 05	0.155E 05	0.256E-03	0.177E-01	0.960E-02	0.0	0.0	-0.478E-01	0.0
-0.373E 03	0.139E 05	0.945E 04	0.127E 05	0.285E-03	0.176E-01	0.950E-02	0.0	0.0	-0.483E-01	0.0
-0.273E 03	0.113E 05	0.634E 04	0.100E 05	0.312E-03	0.174E-01	0.940E-02	0.0	0.0	-0.489E-01	0.0
-0.196E 03	0.855E 04	0.320E 04	0.764E 04	0.334E-03	0.172E-01	0.930E-02	0.0	0.0	-0.496E-01	0.0
-0.140E 03	0.582E 04	0.366E 02	0.587E 04	0.353E-03	0.171E-01	0.920E-02	0.0	0.0	-0.504E-01	0.0
-0.105E 03	0.305E 04	-0.316E 04	0.537E 04	0.369E-03	0.169E-01	0.910E-02	0.0	0.0	-0.513E-01	0.0
-0.920E 02	0.246E 03	-0.638E 04	0.646E 04	0.382E-03	0.168E-01	0.901E-02	0.0	0.0	-0.522E-01	0.0
-0.100E 03	-0.260E 04	-0.962E 04	0.855E 04	0.391E-03	0.166E-01	0.891E-02	0.0	0.0	-0.531E-01	0.0

NUMBER OF ITERATIONS 2

STA NO	TOTAL RADIAL STRAIN (ETR)	TOTAL TANGENTIAL STRAIN (ETT)	TOTAL AXIAL STRAIN (ETZ)	PLASTIC RADIAL STRAIN (EPR)	PLASTIC TANGENTIAL STRAIN (EPT)	ELASTIC STRAIN (EET)	PLASTIC STRAIN (EP)	P' (PP)
1	0.233E-03	0.184E-01	0.940E-02	-0.855E-02	0.838E-02	0.844E-03	0.847E-02	0.0
2	0.300E-03	0.182E-01	0.940E-02	-0.843E-02	0.827E-02	0.721E-03	0.841E-02	-0.995E-02
3	0.315E-03	0.180E-01	0.940E-02	-0.840E-02	0.821E-02	0.625E-03	0.844E-02	-0.405E-01
4	0.317E-03	0.178E-01	0.940E-02	-0.840E-02	0.816E-02	0.537E-03	0.845E-02	-0.478E-01
5	0.315E-03	0.176E-01	0.940E-02	-0.840E-02	0.811E-02	0.449E-03	0.844E-02	-0.483E-01
6	0.310E-03	0.174E-01	0.940E-02	-0.840E-02	0.807E-02	0.363E-03	0.849E-02	-0.489E-01
7	0.302E-03	0.172E-01	0.940E-02	-0.840E-02	0.802E-02	0.279E-03	0.860E-02	-0.496E-01
8	0.290E-03	0.170E-01	0.940E-02	-0.841E-02	0.799E-02	0.201E-03	0.871E-02	-0.504E-01
9	0.275E-03	0.168E-01	0.940E-02	-0.842E-02	0.795E-02	0.136E-03	0.881E-02	-0.513E-01
10	0.256E-03	0.166E-01	0.940E-02	-0.844E-02	0.792E-02	0.113E-03	0.891E-02	-0.522E-01
11	0.235E-03	0.165E-01	0.940E-02	-0.845E-02	0.789E-02	0.152E-03	0.900E-02	-0.531E-01

STA NO	RADIAL STRESS (SIGR)	TANGENTIAL STRESS (SIGT)	AXIAL STRESS (SIGZ)	EQUIV STRESS (SIGE)
1	-0.100E 04	0.223E 05	0.735E 04	0.204E 05
2	-0.818E 03	0.216E 05	0.861E 04	0.195E 05
3	-0.650E 03	0.194E 05	0.830E 04	0.174E 05
4	-0.504E 03	0.167E 05	0.764E 04	0.149E 05
5	-0.380E 03	0.141E 05	0.697E 04	0.125E 05
6	-0.279E 03	0.114E 05	0.627E 04	0.101E 05
7	-0.200E 03	0.871E 04	0.556E 04	0.782E 04
8	-0.143E 03	0.597E 04	0.483E 04	0.563E 04
9	-0.107E 03	0.320E 04	0.408E 04	0.382E 04
10	-0.932E 02	0.399E 03	0.330E 04	0.318E 04
11	-0.100E 03	-0.244E 04	0.251E 04	0.429E 04

APPENDIX E

```
**FTN,G,L,E,P.
C      PROGRAM TRANS
       DIMENSION  CP(30),
      1DP(30),FP(30),GP(30),                    SIGEM(30),AS(3600) ,BR(60),
      2 P1(30),P2(30),P3(30),P4(30),        ETR(30),ETT(30),
      3  EET(30),EP(30),          ETZ(30),                  LV(60),MV(60),
      4  DEP(30) ,DEPR(30),DEPT(30),PP(30),EPR(30),EPT(30)
       DIMENSION WORDS(20),SMI(60),SMT(60),DTEMP(30),DHP(30),DPP(30)
       COMMON/A/NR,NOFS,NOFI,NC,XMU,LI,TIME,KM,NC,NS,IFREP,IPR
       COMMON/B/RS(60,60),DSIGR(30),DSIGT(30),DSIGZ(30),ALPHA(30),HT(30),
      1RAD(30),E(30),TEMP(30),HP(30),YMU(30),ZMU(30),EPL(30),SIGY(30),
      2SIGU(30),SHF(30)
       COMMON /C/ SIGR(30),SIGT(30),SIGZ(30),SIGE(30),DECR(30),DECT(30),
      XDEC(30)
       COMMON /D/ IM     ,ITEMP     ,DSIGRI     ,DSIGRR     ,NI,DEPI,CYCFAC
       COMMON  /E  /  CC(30),DD(30),FF(30),GG(30),TEMPR(30)
       COMMON /F/  KLC(20),KTEMP(20),DKTEMP(20,30),DKSRI(20),DKSRR(20),
      1DKEPI(20),TIMKNC(20)
  500 FORMAT(8X,9I8)
  510 FORMAT(8X,9F8.0)
  520 FORMAT(8X,9E8.0)
  530 FORMAT(20A4)
  100 DO 10 I=1,30
       CC(I)=0.0
       DD(I)=0.0
       FF(I)=0.0
       GG(I)=0.0
       HT(I)=0.0
       RAD(I)=0.0
       CP(I)=0.0
       DP(I)=0.0
       FP(I)=0.0
       GP(I)=0.0
       PF(I)=0.0
       SIGR(I)=0.0
       SIGT(I)=0.0
       SIGZ(I)=0.0
       SIGE(I)=0.0
       TEMP(I)=0.0
       ETR(I)=0.0
       ETT(I)=0.0
       EET(I)=0.0
       EP(I)=0.0
       ALPHA(I)=0.0
       ETZ(I)=0.0
       YMU(I)=0.0
       SIGEM(I)=0.0
       DECR(I)=0.0
       DECT(I)=0.0
       SHF(I)=1.0
   10 CONTINUE
       LI=0
       MD = 1
        TIME=0.0
       IERR=0
       KF=0
       KM=1
```

```
      IM=1
      JLC=0
      IPR=1
      JPR=0
      NC=0
      NS=0
      READ 530,WORDS
      PRINT 531,WORDS
  531 FORMAT  (1H1,20A4)
      READ 500,NINC,JTEMP,NOFI,IOUT,LINC,      IFCON,IFREP,NCP
      READ 510,RIN,ROUT,SIGRI,SIGRR,TOL,CYCFAC
      IF (IFCON.EQ.1) READ 520, EMOD,ALPH,PR,PLEM,SY,SU,TEM
      NR=NINC+1
      NCFS=NR
      IF (JTEMP.NE.1) GO TO 5
      READ 510,(TEMPR(I),I=1,NR)
      DO 15 I=1,NR
      TEMP(I)= .5 *TEMPR(I)
   15 CONTINUE
    5 IF (IFCON.NE.1)  GO TO 6
      DO 17  I=1,NR
      TEMP(I) = TEM
      TEMPR(I) = TEM
   17 CONTINUE
      GO TO 18
    6 CALL MATPRO
   18 RINC=(ROUT-RIN)/FLOAT(NINC)
      DO 20 I=1,NR
                          RI=FLOAT(I-1)
   20 RAD(I)=RIN+RI*RINC
                 DO 3 I=2,NOFS
                                    HT(I)=RAD(I)-RAD(I-1)
    3 CONTINUE
      HT(1)=HT(2)
      DO 1 J=1,NOFS
      IF (IFCON.NE.1)  GO TO 4
                 E(J)=EMOD
      YMU(J)=PR
      ALPHA(J)=ALPH
      EPL(J)=PLEM
      SIGY(J)=SY
      SIGU(J)=SU
    4 IF(J.EQ.1)GOTO 1
C
C     COMPUTE STRESS EQUATION COEFFICIENTS
C
      CC(J)=1./HT(J)+1./(2.*RAD(J))
                                        DD(J)=1./(2.*RAD(J))
      IF(RAD(J-1).GT.0.)GOTO 180
                                    FF(J)=1./HT(J)
      GO TO 190
  180 FF(J)=1./HT(J)-1./(2.*RAD(J-1))
  190 IF(RAD(J-1).GT.0.)GOTO 201
      GG(J)=0.
      GO TO 211
  201 GG(J)=1./(2.*RAD(J-1))
  211 CP(J)=-YMU(J)/(HT(J)*E(J))-YMU(J)**2/(HT(J)*E(J))-(1.+YMU(J))/
```

```
     1(2.*E(J)*RAD(J))
      CP(J)=1./(HT(J)*E(J))-YMU(J)**2/(HT(J)*E(J))+(1.+YMU(J))/
     1(2.*E(J)*RAD(J))
      IF(RAD(J-1).GT.0.)GOTO 221
      FP(J)=-YMU(J)/(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))
      GO TO 231
  221 FP(J)=-YMU(J)/(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))+(1.+YMU(J))/
     1(2.*E(J-1)*RAD(J-1))
  231 IF(RAD(J-1).GT.0.)GOTO 241
      GP(J)=1./(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))
      GO TO 251
  241 GP(J)=1./(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))-(1.+YMU(J))/
     1(2.*E(J-1)*RAD(J-1))
  251 HP(J)=-(1.+YMU(J))/HT(J)*(ALPHA(J)*TEMPR(J)-ALPHA(J-1)*TEMPR(J-1))
      PP(J)=0
    1 CONTINUE
C
C  SET UP STRESS EQUATION MATRIX
C
      DO 24 I=1,3600
   24 AS(I)=0.0
      NO=2*NOFS
      DO 25 I=1,60
      BR(I)=0.0
      DO 25 J=1,60
   25 RS(I,J)=0.0
      RS(1,1)=1.0
                        IF (RAD(1).EQ.0.) RS(1,2)=-1.0
      DO 26 J=2,NOFS
                              JK=2*(J-1)
      LK=JK+1
      RS(JK,JK-1) = -FF(J)
                                    RS(JK,JK) = -GG(J)
      RS(JK,JK+1) =  CC(J)
                                    RS(JK,JK+2)    = -DD(J)
      RS(LK,LK-2) = -FP(J)
                                    RS(LK,LK-1) = -GP(J)
      RS(LK,LK)   =  CP(J)
                                    RS(LK,LK+1) =  DP(J)
   26 CONTINUE
      RS(NO,NO-1) = 1.0
      J=1
                     NK=0
  271 DO 273  K=1,NO
      NK=NK+1
  273 AS(NK)=RS(K,J)
      IF  (J.EQ.NO)  GO TO 274
      J=J+1
      GO TO 271
  274 CONTINUE
C
C  INVERT STRESS EQUATION MATRIX
C
      CALL MINV (AS,NO,D,LV,MV)
      J=1
                     NK=0
  275 DO 276 K=1,NO
```

```
      NK=NK+1
  276 RS(K,J)=AS(NK)
      IF  (J.EQ.NQ)  GO TO 278
      J=J+1
      GO TO 275
  278 PRINT 5070
      PRINT 5000
                                        DO 300 IC=1,NOFS
      PRINT 5010,IC,RAD(IC),TEMPR(IC),ALPHA(IC),E(IC),YMU(IC),EPL(IC),
     XSIGY(IC),SIGU(IC)
  300 CONTINUE
      PRINT 5090,SIGRI,SIGRR
 5090 FORMAT (1H0,14HINNER PRESSURE,F12.3/1H0,14HOUTER PRESSURE,F12.3)
   62 DO 63 IP=1,NOFS
      EF(IP)=0.0
      EPR(IP)=0.0
      EPT(IP)=0.0
      DEPR(IP)=0.0
      DEPT(IP)=0.0
      ETR(IP)=0.
      ETT(IP)=0.0
      DEF(IP)=0.0
   63 CONTINUE
C
C  COMMENCE ITERATION FOR INELASTIC STRESSES
C
  301            DO 501 NIT=1,NOFI
      NK=0
      ERP=0.0
      ETP=0.0
      EZP=0.0
      IF (NIT.EQ.1.AND.JLC.EQ.1)  GO TO 350
  304 DO 305 I=1,NQ
  305 SMI(I)=0.0
  307 DO 310 J=2,NOFS
                                JK=2*J-1
  310 BR(JK)=HP(J)+PP(J)
      BR(1)=-SIGRI
                            BR(NQ)=-SIGRR
C
C  SOLVE FOR ESTIMATED STRESSES
C
      DO 330 I=1,NQ
                                DO 320 J=1,NQ
  320 SMI(I)=      RS(I,J)*BP(J)+SMI(I)
  330 CONTINUE
      DO 340 I=1,NOFS
      IT=2*I
      IR=IT-1
      SIGR(I)=SMI(IR)
                              SIGT(I)=SMI(IT)
  340 CONTINUE
      DO 39  I=1,NOFS
   29 CONTINUE
            SIGZ(I)=YMU(I) *(SIGT(I)+SIGR(I))-E(I)*ALPHA(I)*TEMPR(I)+
     1E(I)*(EPR(I)+EPT(I)+DEPR(I)+DEPT(I))
   39 CONTINUE
```

```
      XC3=0.0
      XC4=0.
                DO 35 I=2,NOFS
                                XC2=(E(I)+E(I-1))/4.*(RAD(I)**2-
     1RAD(I-1)**2)
                        XC4=XC4+XC2
      XC1=(SIGZ(I)+SIGZ(I-1))/4.*(RAD(I)**2-RAD(I-1)**2)
   35 XC3=XC3+XC1
                        C3=(XC3-(SIGRI*RAD(1)**2)/2.)/XC4
      DO 37 I=1,NOFS
   37 SIGZ(I)=SIGZ(I)-C3*E(I)
  350                           DO 30 I=1,NOFS
      ETR(I)=(1./E(I))*(SIGR(I)-YMU(I)*(SIGT(I)+SIGZ(I)))+ALPHA(I)*
     1TEMPR(I)+EPR(I)+DEPR(I)
                        ETT(I)=(1./E(I))*(SIGT(I)-YMU(I)*(SIGR(I)+SIGZ(I)))+
     1ALPHA(I)*TEMPR(I)+EPT(I)+DEPT(I)
                                ETZ(I)=(1./E(I))*(SIGZ(I)-YMU(I)*(SIGR(I)+
     1SIGT(I)))+ALPHA(I)*TEMPR(I)-EPR(I)-EPT(I)-DEPR(I)-DEPT(I)
C
C  COMPUTE EQUIVALENT STRESSES
C
      PRA=((SIGR(I)-SIGT(I))**2+(SIGR(I)-SIGZ(I))**2+(SIGT(I)-SIGZ(I))
     1**2)
            SIGE(I)=(1./1.4142)*SQRT(PRA)
      ERP=ETR(I)-EPR(I)
                                ETP=ETT(I)-EPT(I)
                                                        EZP=ETZ(I)+EPR(I)+EPT(I)
   33 STA=(ERP-ETP)**2+(ETP-EZP)**2+(EZP-ERP)**2
      EET(I)=(1.41421/3.)*SQRT(STA)
      IF (JLC.EQ.2)  GO TO 30
      IF (ABS(SIGEM(I)).GT.ABS(SIGE(I)).OR.ABS(SIGE(I)).LT.
     x(SHF(I)*SIGY(I)))   GO TO 270
      EPRX=DEPR(I)
                        EPTX=DEPT(I)
      EF=2.*(1.+YMU(I))/(3.*E(I))
      EG = E(I)*EPL(I)/(E(I)-EPL(I))
      IF (LI.EQ.0)  SIGEM(I)=SIGY(I)
      IF (ABS(SIGEM(I)).LT. (SHF(I)*SIGY(I)))   SIGEM(I)=SHF(I)*SIGY(I)
      IF (MO.EQ.3)  GO TO 34
C
C  GET PLASTIC STRAIN INCREMENTS
C
      DEP(I) = (EET(I)-EF*SIGEM(I))/(1.+EF*EG)
   34 DEPR(I)=DEP(I)/(3.*EET(I))*(2.*ERP   -ETP   -EZP)
      DEPT(I)=DEP(I)/(3.*EET(I))*(2.*ETP   -ERP   -EZP)
      DELR=(EPRX-DEPR(I))/DEPR(I)
                                DELT=(EPTX-DEPT(I))/DEPT(I)
      IF(ABS(DELR).GT.TOL )NK=NK+1
                                IF(ABS(DELT).GT.TOL )NK=NK+1
  270 IF(I.EQ.1)GOTO 30
                        Q1=1./HT(I)
                                Q2=1./(2.*RAD(I))
      C3=YMU(I)*Q1
      C4=0.
                        IF(RAD(I-1).EQ.0.)GOTO 280
      C4=1./(2.*RAD(I-1))
      P1(I)=-Q1-Q2+Q3
```

```
      P2(I)= Q2+C3
      P3(I)= Q1-C4-C3
      P4(I)= Q4-Q3
  280 EP(I)=  P1(I)     *(EPT(I)+DEPT(I))+ P2(I) *(EPR(I)+DEPR(I))
     1+  P3(I)    *(EPT(I-1)+DEPT(I-1))+P4(I)  *(EPR(I-1)+DEPR(I-1))
   30 CONTINUE
      IF (MD.NE.2.OR.DEPI    .LT..0001)  GO TO 290
      DPM=DEP(1)
      DO 282 J=2,NOFS
  282 IF (DEP(J).GT.DPM)  DPM=DEP(J)
      IF (DPM.LT..0001) GO TO 290
      DO 285 I=1,NOFS
  285 DEP(I)=DEP(I)*DEPI    /DPM
      MD=3
      GO TO 350
  290             IF(NK.LE.1)GOTO 503
      IF (IOUT.GE.2.AND.NIT.GT.1)  GO TO 501
      PRINT 1058,NIT
 1058 FORMAT (1H0,//17H  ITERATION NUMBER,I3)
      PRINT 1060
 1060 FORMAT (1H0,3X,4HSIGR,8X,4HSIGT,8X,4HSIGZ,8X,4HSIGE,8X,3HETR,9X,
     X3HETT,9X,3HETZ,9X,4HDEPR,8X,4HDEPT,9X,2HPP,9X,3HDEP)
      DO 40 I=1,NOFS
   40 PRINT 1070,SIGR(I),SIGT(I),SIGZ(I),SIGE(I),ETR(I),ETT(I),ETZ(I),
     1DEPR(I),DEPT(I),PP(I),DEP(I)
  501 CONTINUE
  503 DO 71 I=1,NOFS
                                                    SIGEM(I)=SIGE(I)
      IF (SIGE(I) .GT. SIGY(I))  SHF(I)=SIGE(I)/SIGY(I)
   71 CONTINUE
      IF(IOUT.LT.1)GOTO 250
      IF (IPR.EQ.0)  GO TO 205
  204 PRINT 5002, NIT
 5002 FORMAT (1H0,20HNUMBER OF ITERATIONS,I5)
      PRINT 5020
  205 IF (NS.EQ.NSTEPS)  JPR=JPR+1
  206 NIT=1
                                        DO 210 ID=1,NOFS
      EPR(ID)=EPR(ID)+DEPR(ID)
      EPT(ID)=EPT(ID)+DEPT(ID)
      EP (ID)=EP (ID)+DEP (ID)
      IF (IPR.EQ.0)  GO TO 209
  208 PRINT 5030,ID,ETR(ID),ETT(ID),ETZ(ID),EPR(ID),EPT(ID),EET(ID),
     1EP(ID),PP(ID)
  209 DEPR(ID)=0.0
      DEPT(ID)=0.0
  210 CONTINUE
      IF (IPR.EQ.1)  PRINT 5040
                                        DO 220 ID=1,NOFS
      IF (SIGE(ID).LT.SIGU(ID))  GO TO 215
      IERR=1
      KF=ID
  215 IF (IPR.EQ.0)  GO TO 220
      PRINT 5030,ID,SIGR(ID),SIGT(ID),SIGZ(ID),SIGE(ID)
  220 CONTINUE
 5000 FORMAT(1H0,43X,7HTHERMAL,8X,7HELASTIC,23X,7HPLASTIC/4X,3HSTA,
```

```
      17X,6HRADIUS,
      29X,4HTEMP,11X,9HEXPANSION,6X,7HMODULUS,8X,9HPOISSON'S,6X,7HMODULUS
      3,        9X,5HYIELD,9X,8HULTIMATE/4X,2HNO,
      48X,4H(CM),11X,7H(DEG C),8X,6HCOEFF.,9X,5H(PSI),10X,5HRATIO,24X,6HS
      5TRESS, 9X,6HSTRESS)
 5010 FORMAT(1H ,I5,5X,F10.5,5X,F10.1,5X,E10.3,5X,E10.3,5X,F10.5,E15.3,
     X2F15.2)
 5020 FORMAT(1H0,10X,5HTOTAL,10X,5HTOTAL,10X,5HTOTAL,10X,7HPLASTIC,8X,
     17HPLASTIC,/1X,3HSTA,7X,6HRADIAL,9X,10HTANGENTIAL,5X,5HAXIAL,10X,
     26HRADIAL,9X,10HTANGENTIAL,5X,7HELASTIC,8X,7HPLASTIC,/1X,2HNO,
     38X,7(6HSTRAIN,9X),2HP',/1X,10X,5H(ETR),10X,5H(ETT),10X,5H(ETZ),
     410X,5H(EPR),10X,5H(EPT),10X,5H(EET),10X,4H(EP),11X,4H(PP))
 5030 FORMAT(1H ,I5,5X,7(E10.3,5X),E10.3)
 5040 FORMAT(1H0,3HSTA,7X,6HRADIAL,9X,10HTANGENTIAL,5X,5HAXIAL,10X,
     15HEQUIV./1X,2HNO,8X,4(6HSTRESS,9X),/1X,10X,6H(SIGR),9X,6H(SIGT),
     29X,6H(SIGZ),9X,6H(SIGF))
 1070 FORMAT(1H ,11(E10.3,2X))
 5060 FORMAT(1H ,I3,7X,F10.5)
 5070 FORMAT(1H0,24HELASTIC-PLASTIC ANALYSIS)
      IF (IERR.EQ.1)  GO TO 700
  250 IF (LINC.NE.1.OR.IM     .EQ.2)  GO TO 900
      IF (IFREP.LT.1)  GO TO 260
      IF (NS.GE.1.OR.NC.GE.1)  GO TO 292
      READ 500,NSTEPS,NOCYC
      DO 258 J=1,NSTEPS
      READ 500,KLC(J),KTEMP(J)
      IF (KLC(J).EQ.2)  GO TO 254
      IF (KTEMP(J).GT.0) READ 510, (DKTEMP(J,I),I=1,NR)
      READ 510, DKSRI(J),DKSRR(J),DKEPI(J)
      GO TO 258
 254  READ 520,TIMKNC(J)
 258  CONTINUE
      GO TO 292
 260  READ 500,JLC
      GO TO 298
 292  NS=NS+1
      IF (NS.LE.NSTEPS)  GO TO 297
      NS=1
      NC=NC+1
      IF (NC.GT.NOCYC)  GO TO 900
      IF (IOUT.LE.2) GO TO 295
      IF (NC.EQ. (JPR*NCP) .OR .NC.EQ.1)  GO TO 294
      IPR=0
      GO TO 297
 294  IPR=1
 295  PRINT 5080,NC
 5080 FORMAT (1H1,11H LOAD CYCLE,I5)
 297  JLC=KLC(NS)
 298  IF (JLC.EQ.2) GO TO 800
      IF (JLC.NE.1)  GO TO 900
C
C  INCREMENTAL ELASTIC STRAIN ROUTINE
C
  587 CALL DPLSTR
  595 DO 600 I=1,NOFS
      SIGR(I)=SIGR(I)+DSIGR(I)
      SIGT(I)=SIGT(I)+DSIGT(I)


      SIGZ(I)=SIGZ(I)+DSIGZ(I)
  600 CONTINUE
      SIGRI=SIGRI+DSIGRI
      SIGRR=SIGRR+DSIGRR
      MC = 2
 650  GO TO 301
  700 PRINT 6000, RAD(KF)
      GO TO 900
C
C  CREEP STRAIN INCREMENT ROUTINE
C
 800  CALL CREEP
      DO 820 K=1,NOFS
      EPR(K)=EPR(K)+DECR(K)
 820  EPT(K)=EPT(K)+DECT(K)
      DO 830 I=2,NOFS
      PP(I)=P1(I)*EPT(I)+P2(I)*EPR(I)+P3(I)*EPT(I-1)+P4(I)*EPR(I-1)
 830  CONTINUE
 850  GO TO 304
 900  GO TO 100
 6000 FORMAT(1H0,7HFAILURE/28H SIGE EXCEEDS SIGU AT RADIUS ,F10.4)
      END
```

```
C     SUBROUTINE TO COMPUTE MATERIAL PROPERTIES
C
      SUBROUTINE MATPRO
      COMMON/A/NR,NOFS,NOFI,NC,XMU,LI,TIME,KM,NC,NS,IFREP,IPR
      COMMON/B/RS(60,60),DSIGR(30),DSIGT(30),DSIGZ(30),ALPHA(30),HT(30),
     1RAD(30),E(30),TEMP(30),HP(30),YMU(30),ZMU(30),EPL(30),SIGY(30),
     2SIGU(30),SHF(30)
      DIMENSION T(50),EM(50),AL(50),POI(50),EMP(50),SY(50),SU(50)
      IF (KM.EQ.2)  GO TO 30
      DO 10 I=1,50
      T(I)=0.0
      EM(I)=0.0
      AL(I)=0.0
      POI(I)=0.0
   10 CONTINUE
      READ 100, NOPTS
      READ 120, (T(J),EM(J),EMP(J),AL(J),POI(J),SY  (J),SU  (J),
     XJ=1,NOPTS)
   30 DO 50 I=1,NOFS
      DO 50 J=1,NOPTS
      IF (TEMP(I).LT.T(J).OR.TEMP(I).GT.T(J+1)) GO TO 50
      PF = (TEMP(I)-T(J))/(T(J+1)-T(J))
      E(I)=EM(J)+PF*(EM(J+1)-EM(J))
      ALPHA(I)=AL(J)+PF*(AL(J+1)-AL(J))
      YMU(I)=POI(J)+PF*(POI(J+1)-POI(J))
      EPL(I)=EMP(J)+PF*(EMP(J+1)-EMP(J))
      SIGY(I)=SY(J)+PF*(SY(J+1)-SY(J))
      SIGU(I)=SU(J)+PF*(SU(J+1)-SU(J))
   50 CONTINUE
      KM=2
      RETURN
  100 FORMAT (8X,3I8)
  120 FORMAT (7F10.4)
      END
```

```
C     ROUTINE TO COMPUTE ELASTIC STRESSES DUE TO INCREMENTAL LOADS
C
      SUBROUTINE DPLSTR                                                 15
      DIMENSION        BR(60),DSM(60),DTEMP(60),DHP(30),
     1CP(30),DP(30),FP(30),GP(30),LV(60),MV(60),AS(3600)
      COMMON/A/NR,NOFS,NCFI,NO,XMU,LI,TIME,KM,NC,NS,IFREP,IPR
      COMMON/B/RS(60,60),DSIGR(30),DSIGT(30),DSIGZ(30),ALPHA(30),HT(30),   30
     1RAD(30),F(30),TEMP(30),HP(30),YMU(30),ZMU(30),EPL(30),SIGY(30),
     2SIGU(30),SHF(30)
      COMMON /D/ IM    ,ITEMP    ,DSIGRI    ,DSIGRR    ,NI,DEPI,CYCFAC
      COMMON  /E  /  CC(30),DD(30),FF(30),GG(30),TEMPR(30)
      COMMON /F/  KLC(20),KTEMP(20),DKTEMP(20,30),DKSRI(20),DKSRR(20),
     1DKEPI(20),TIMKNC(20)
      DO 3 I=1,60
    3 DTEMP(I)=0.
      LI=LI+1
      IF (IPR.EQ.0)  GO TO 4
      PRINT 5080,LI
 4    IF (IFREP.LT.1) GO TO 10
      DSIGRI=DKSRI(NS)
      DSIGRR=DKSRR(NS)
      IF (IFREP.EQ.1)  GO TO 5
      DSIGRI=DSIGRI*NC*CYCFAC
      DSIGRR=DSIGRR*NC*CYCFAC
 5    DEPI=DKEPI(NS)
      ITEMP=KTEMP(NS)
      IF (ITEMP.NE.1) GO TO 20
      DO 6 I=1,NR
      DTEMP(I)=DKTEMP(NS,I)
 6    CONTINUE
      GO TO 12
 10   READ 500,IM,ITEMP
      READ 510, DSIGRI    ,DSIGRR    ,DEPI
      IF (ITEMP    .NE.1)  GO TO 20
      READ 510,(DTEMP(I),I=1,NR)
 12   IF (IPR.EQ.0) GO TO 22
      PRINT 5000
      DO 15 IC=1,NR
      PRINT 5010,IC,RAD(IC),DTEMP(IC)
   15 CONTINUE
 20   PRINT 5090,DSIGRI,DSIGRR
 22   KM=2
      DO 30 I=1,30
      DSIGR(I)=0.0
      DSIGT(I)=0.0
      DSIGZ(I)=0.0
      DHP(I)=0.0
   30 CONTINUE
      DO 40 I=1,60
      BR(I)=0.0
      DSM(I)=0.0
   40 CONTINUE
      XC3=0.0
      XC4=0.0
      IF (ITEMP    .NE.1)  GO TO 55
      DO 45 J=1,NOFS
```

```
      TEMP(J)=TEMPR(J)+DTEMP(J)*0.5
      TEMPR(J) = TEMPR(J) + DTEMP(J)
   45 CONTINUE
      CALL MATPRO
      DO 260 J=2,NOFS
  211 CP(J)=-YMU(J)/(HT(J)*E(J))-YMU(J)**2/(HT(J)*E(J))-(1.+YMU(J))/
     1(2.*E(J)*RAD(J))
      DP(J)=1./(HT(J)*E(J))-YMU(J)**2/(HT(J)*E(J))+(1.+YMU(J))/
     1(2.*E(J)*RAD(J))
      IF(RAD(J-1).GT.0.)GOTO 221
      FP(J)=-YMU(J)/(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))
      GO TO 231
  221 FP(J)=-YMU(J)/(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))+(1.+YMU(J))/
     1(2.*E(J-1)*RAD(J-1))
  231 IF(RAD(J-1).GT.0.)GOTO 241
      GP(J)=1./(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))
      GO TO 251
  241 GP(J)=1./(HT(J)*E(J-1))-YMU(J)**2/(HT(J)*E(J-1))-(1.+YMU(J))/
     1(2.*E(J-1)*RAD(J-1))
  251 HP(J)=-(1.+YMU(J))/HT(J)*(ALPHA(J)*TEMPR(J)-ALPHA(J-1)*TEMPR(J-1))
  260 CONTINUE
C
C  SET UP STRESS EQUATION MATRIX
C
      DO 24 I=1,3600
   24 AS(I)=0.0
      DO 25 I=1,60
      DO 25 J=1,60
   25 RS(I,J)=0.0
      RS(1,1)=1.0
                        IF (RAD(1).EQ.0.) RS(1,2)=-1.0
      DO 26 J=2,NOFS
                        JK=2*(J-1)
      LK=JK+1
      RS(JK,JK-1) = -FF(J)
                        RS(JK,JK) = -GG(J)
      RS(JK,JK+1) =  CC(J)
                        RS(JK,JK+2)   = -DD(J)
      RS(LK,LK-2) = -FP(J)
                        RS(LK,LK-1) = -GP(J)
      RS(LK,LK)   =  CP(J)
                        RS(LK,LK+1) =  DP(J)
   26 CONTINUE
      RS(NQ,NQ-1) = 1.0
      J=1
                        NK=0
  271 DO 273  K=1,NQ
      NK=NK+1
  273 AS(NK)=RS(K,J)
      IF  (J.EQ.NQ)  GO TO 274
      J=J+1
      GO TO 271
  274 CONTINUE
C
C  INVERT STRESS EQUATION MATRIX
C
      CALL MINV (AS,NQ,D,LV,MV)
```

```
      J=1
                    NK=0
  275 DO 276 K=1,NO
      NK=NK+1
  276 RS(K,J)=AS(NK)
      IF  (J.EQ.NO)  GO TO 278
      J=J+1
      GO TO 275
  278 IF (IPR.EQ.0)  GO TO 310
      PRINT 5020
                                        DO 300 IC=1,NOFS
      SYM = SIGY(IC)*SHF(IC)
      PRINT 5030,IC,RAD(IC),TEMPR(IC),ALPHA(IC),E(IC),YMU(IC),EPL(IC),
     XSYM,  SIGU(IC)
  300 CONTINUE
  310 DO 50 J=1,NOFS
      DHP(J)=-(1.+YMU(J))/HT(J) *(ALPHA(J)*DTEMP(J)-
     1ALPHA(J-1)*DTEMP(J-1))
      IF (J.EQ.1) GO TO 50
      JK=2*J-1
      BR(JK)=DHP(J)
   50 CONTINUE
   55 BR(I)=-DSIGRI
                          BR(NO)=-DSIGRR
      DO 70 I=1,NO
                         DO 60 J=1,NO
   60 DSM(I)=RS(I,J)*BR(J)+DSM(I)
   70 CONTINUE
      DO 80 I=1,NOFS
                          IT=2*I
                                        IR=IT-1
      DSIGR(I)=DSM(IR)
                          DSIGT(I)=DSM(IT)
   80 CONTINUE
      DO 100 I=1,NOFS
      DSIGZ(I)=YMU(I)*(DSIGT(I)+DSIGR(I))-E(I)*ALPHA(I)*DTEMP(I)
  100 CONTINUE
      DO 110 I=2,NOFS
      XC2=(E(I)+E(I-1))/4.*(RAD(I)**2-RAD(I-1)**2)
                                                        XC4=XC4+XC2
      XC1=(DSIGZ(I)+DSIGZ(I-1))/4.*(RAD(I)**2-RAD(I-1)**2)
      XC3=XC3+XC1
  110 CONTINUE
      C3=(XC3-(DSIGRI     *RAD(1)**2)/2.)/XC4
      DO 120 I=1,NOFS
  120 DSIGZ(I)=DSIGZ(I)-C3*E(I)
 5000 FORMAT(1H0/                                4X,3HSTA,7X,6HRADIUS,
     19X,8HTEMP INC)
 5010 FORMAT(1H ,I5,5X,F10.5,5X,F10.0,5X,E10.3,5X,F10.3,5X,F10.5)
 5080 FORMAT (1H1,14HLOAD INCREMENT,I4)
 5090 FORMAT (1H0,14HINNER PRESSURE,F12.3/1H0,14HOUTER PRESSURE,F12.3)
      RETURN
  500 FORMAT(8X,3I8)
  510 FORMAT(8X,9F8.0)
 5020 FORMAT(1H0,43X,7HTHERMAL,8X,7HELASTIC,23X,7HPLASTIC/4X,3HSTA,
     17X,6HRADIUS,
     29X,4HTEMP,11X,9HEXPANSION,6X,7HMODULUS,8X,9HPOISSON'S,6X,7HMODULUS

     3,        9X,5HYIELD,9X,8HULTIMATE/4X,2HNO,
     48X,4H(CM),11X,7H(DEG C),8X,6HCOEFF.,9X,5H(ATM),10X,5HRATIO,24X,6HS
     5TRESS, 9X,6HSTRESS)
 5030 FORMAT(1H ,I5,5X,F10.5,5X,F10.0,5X,E10.3,5X,E10.3,5X,F10.5,E15.3,
     X2F15.2)
      END
```

```
C     ROUTINE TO COMPUTE CREEP STRAINS
C
      SUBROUTINE CREEP
      COMMON/A/NR,NOFS,NOFT,NO,XMU,LI,TIME,KM,NC,NS,IFREP,IPR
      COMMON /C/ SIGR(30),SIGT(30),SIGZ(30),SIGE(30),DECR(30),DECT(30),
     xCEC(30)
      COMMON /D/ IM     ,ITEMP     ,DSIGRI     ,DSIGRR     ,NI,DEPI,CYCFAC
      COMMON  /E  /  CC(30),DD(30),FF(30),GG(30),TEMPR(30)
      COMMON /F/  KLC(20),KTEMP(20),DKTEMP(20,30),DKSRI(20),DKSRR(20),
     1DKEPI(20),TIMKNC(20)
      IM=1
      IF (IFREP.LT.1)  GO TO 20
      TIMINC=TIMKNC(NS)
      GO TO 30
 20   READ 300,IM,MX,TIMINC
 30   DO 100 I=1,30
      DECR(I)=0.0
      DECT(I)=0.0
      CEC (I)=0.0
 100  CONTINUE
      DO 200 I=1,NOFS
      ARGS=SIGE(I)
      ARGT=TEMPR(I)
      CALL ECRS(ARGS,ARGT,EECR)
      DEC(I)=EECR*TIMINC
      DECR(I)=DEC(I)*(2.*SIGR(I)-SIGT(I)-SIGZ(I))*0.5/SIGE(I)
      DECT(I)=DEC(I)*(2.*SIGT(I)-SIGR(I)-SIGZ(I))*0.5/SIGE(I)
 200  CONTINUE
 300  FORMAT (8X,2I8,E10.4)
      TIME=TIME+TIMINC
      IF (IPR.EQ.0)  GO TO 500
      PRINT 400,TIMINC
 400  FORMAT (1H1,14HTIME INCREMENT,F13.5,2X,5HHOURS)
      PRINT 420
 420  FORMAT(1H0,20X,4HDECR,10X,4HDECT)
      PRINT 440, (DEC(I),DECR(I),DECT(I),I=1,NOFS)
 440  FORMAT (3E14.4)
      PRINT 460,TIME
 460  FORMAT (1H0,6X,4HTIME,F10.2,2X,5HHOURS)
 500  RETURN
      END
```

```
C     ROUTINE TO COMPUTE CREEP STRAIN RATE FOR ZIRCALOY    ADAMS FORMULA
C
      SUBROUTINE ECRS (ARGS,ARGT,EECR)
      TEMP=ARGT+273.
      IF (TEMP.GT.873) GO TO 30
      EECR=0.0
      GO TO 200
 30   IF (TEMP.GT. 1135.)  GO TO 50
      K2 = 0.02765 * EXP(5414./TEMP)
      SR = 196.3 * EXP(7766./(1.987*TEMP))
      GO TO 100
 50   K2 = 15.411 * EXP(-1739./TEMP)
      SR = .455 * EXP(21400./(1.987*TEMP))
100   EECR = 60. * (ARGS/SR)**K2
200   RETURN
      END
```

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