

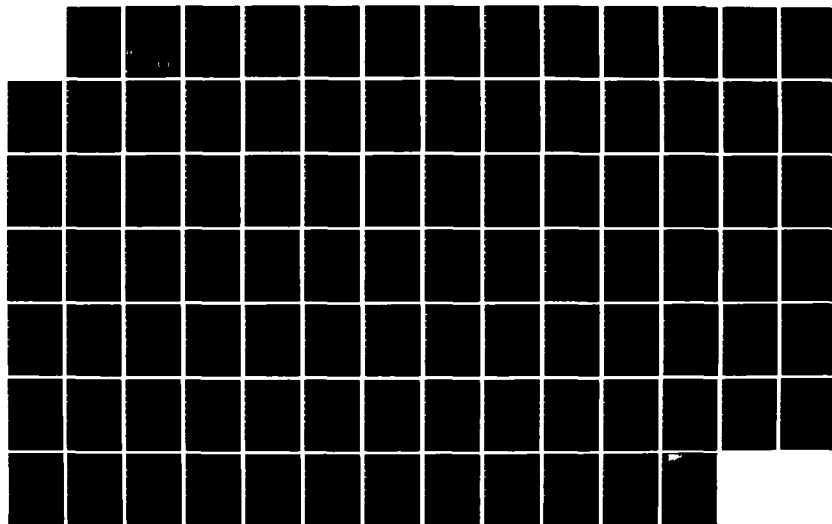
AD-A140 268

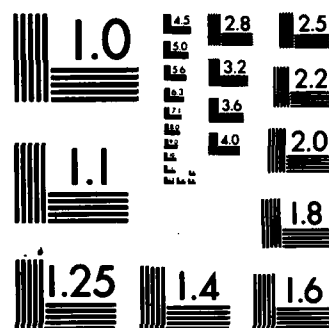
REVISIONS TO THE PETROS 4 SHELL RESPONSE CODE(U) ARMY
ARMAMENT RESEARCH AND DEVELOPMENT CENTER ABERDEEN
PROVIN. N J HUFFINGTON ET AL. FEB 84 ARBRL-TR-02550
SBI-AD-F300 408 F/G 1/2

1/1

UNCLASSIFIED

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A140268

AD-F300408



AD

TECHNICAL REPORT ARBRL-TR-02550

REVISIONS TO THE PETROS 4
SHELL RESPONSE CODE

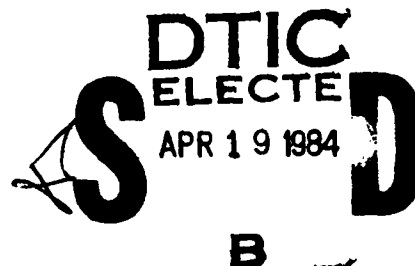
Norris J. Huffington, Jr.
Henry L. Wisniewski

February 1984



US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

Approved for public release; distribution unlimited.



84 04 16 058

DTIC FILE COPY

Destroy this report when it is no longer needed.
Do not return it to the originator.

Additional copies of this report may be obtained
from the National Technical Information Service,
U. S. Department of Commerce, Springfield, Virginia
22161.

The findings in this report are not to be construed as
an official Department of the Army position, unless
so designated by other authorized documents.

*The use of trade names or manufacturers' names in this report
does not constitute endorsement of any commercial product.*

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report ARBRL-TR-02550	2. GOVT ACCESSION NO. AD A140 268	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Revisions to the PETROS 4 Shell Response Code		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Norris J. Huffington, Jr. Henry L. Wisniewski		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Ballistic Research Laboratory, ARDC ATTN: DRSMC-BLV-V(A) Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L1E1102AH43
11. CONTROLLING OFFICE NAME AND ADDRESS US Army AMCCOM, ARDC Ballistic Research Laboratory, ATTN: DRSMC-BLA-S(A) Aberdeen Proving Ground, MD 21005		12. REPORT DATE February 1984
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 93
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
15a. DECLASSIFICATION DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Structural Panels Transverse Shear Deformation Air Blast Surface Traction Effects Elastoplastic Material Finite Difference Method		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The existing PETROS 4 finite deflection elastoplastic structural shell response code was modified to permit analysis of the response of structural panels to nearby high explosive detonations. A modified constitutive formulation involving prescribed through-thickness stresses was introduced. Previously omitted surface traction terms were added to the equations of motion. A recycling option based on a strain equivalence criterion was introduced to inhibit the unrestricted growth of a breathing mode. Additional printer and plotter output features were incorporated into the program.		

TABLE OF CONTENTS

	<i>Page</i>
LIST OF ILLUSTRATIONS	5
I. INTRODUCTION	7
II. DEFICIENCIES OBSERVED IN THE ORIGINAL PETROS 4 PROGRAM.....	8
A. Stress Calculation Inconsistencies.....	9
B. Unstable Growth of D^3	17
C. Constitutive Relation for $ISTRES = 3$	17
D. Effect of Through-Thickness Normal Stresses.....	17
E. Omission of Surface Traction Effects.....	18
F. Reconstitution of Mixed Tensor Stresses	18
G. Plastic Work	18
III. PRESCRIBED VARIATION OF THROUGH-THICKNESS NORMAL STRESS	20
A. Stress Wave Considerations.....	20
B. Modified Constitutive Relation	22
C. Through-Thickness Strain Calculation.....	25
IV. MODIFICATION OF THE D^3 DEGREE-OF-FREEDOM.....	26
A. Modifications to Cartesian Components.....	26
B. Strain Equivalence Criterion.....	27
C. Implementation of the Modification to D^3	29
V. ADDITIONAL MISCELLANEOUS PROGRAM CHANGES	31
A. Addition of Surface Traction Terms.....	31
B. Symmetry of the Contravariant Stress Components.....	31

TABLE OF CONTENTS (cont'd)

	<i>Page</i>
C. Storage of Mixed Tensor Stresses.....	32
D. Additions to Printed Output	32
E. Additions to Plotted Output	38
VI. CONCLUDING REMARKS.....	38
REFERENCES.....	40
NOMENCLATURE.....	41
APPENDIX A.....	55
DISTRIBUTION LIST	85

LIST OF ILLUSTRATIONS

Figure	Page
1 Transient Stress Components for Indicated Options	10
2 Transient Stress Components for Indicated Options	12
3 Transient Stress Components for Indicated Options	13
4 Transient Stress Components for Indicated Options	14
5 Transient Stress Components for Indicated Options	15
6 Growth of Through-Thickness Strain	16
7 Energy Balance Diagram.....	19
8 Stress τ_3 at Gauss Point 4.....	21
9 Simplified Flow Chart Showing Recycling Option	30
10 Sample of Max/Min Stress Output.....	33
11 Sample of Geometric and Stress Output Data	35
12 Sample Printout of Gauss Point Stresses	36
13 Sample Printout of Elastoplastic Activity Matrix	37



Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

I. INTRODUCTION

A recurring problem in vulnerability analysis is the requirement to predict the damage to structural panels produced by the detonation of high explosive charges in close proximity to the target panels. Examples of problems where this requirement arises are (a) the blast effect of shaped charge warheads against lightly armored vehicles and (b) the effect of small caliber high explosive shells which detonate close to aircraft panels. Although both these examples involve additional damaging effects (e.g., the shaped charge jet, and shell casing fragments), this report is concerned only with a rational analysis of the response induced by the air blast, leaving the combined effects of all lethal mechanisms for subsequent consideration.

While the methodology for blast loading prediction is far from satisfactory at present, in the sequel it will be assumed that the blast pressure on the target surface is a known function $p(r, \theta, t)$.^{*} Since we will be concerned with the blast from conventional chemical explosives the pressure will be of high intensity and short duration, resulting in the delivery of a significant impulse to the target. However, the peak pressure will be assumed insufficient to produce spallation from the back side of the target panel, thus excluding consideration of explosives in contact with the target. This is not a serious restriction, since stand-off explosions can produce catastrophic damage to structural panels.

It is now necessary to adopt a structural response analysis tool which has attributes sufficient for adequate modeling of the physical phenomena expected to occur. Specifically the analysis should be capable of treating finite amplitude elastoplastic response of shell structures having a variety of physical edge conditions, which are subjected to transient distributions of surface pressures. It should have flexibility regarding material constitutive representation, including strain hardening and strain-rate dependence. It should also be possible to introduce various material failure models into this analysis and, preferably, to perform some post-failure calculations. Further, since the blast load will initially appear at some interior point on the panel and then spread rapidly to cover the entire panel, the analysis tool should properly account for the propagation of shear waves as well as flexural and membrane waves. Finally, it is desired to avoid a general three-dimensional analysis, if possible, for reasons of computational economy.

Taking the foregoing considerations into account, a variety of available finite element and finite difference computer programs were reviewed and it was decided that the PETROS 4 code^{1,2} provided the best point of departure for meeting these requirements.

^{*} See Nomenclature, p. 41, for definition of symbols.

¹ S. D. Pirotin, L. Morino, E. A. Witmer, and J. W. Leech, "Finite-Difference Analysis for Predicting Large Elastic-Plastic Transient Deformations of Variable-Thickness Kirchhoff, Soft Bonded Thin, and Transverse-Shear Deformable Thicker Shells," US Army Ballistic Research Laboratory Contract Report No. 315, September 1976. AD B013924L

² S. D. Pirotin, B. A. Berg, and E. A. Witmer, "PETROS 4: New Developments and Program Manual for the Finite-Difference Calculation of Large Elastic-Plastic, and/or Viscoelastic Transient Deformations of Multilayer Variable-Thickness (1) Thin Hard-Bonded, (2) Moderately-Thick Hard-Bonded, or (3) Thin Soft-Bonded Shells," US Army Ballistic Research Laboratory Contract Report No. 316, September 1976.

This report is concerned with documentation of the modifications to this code which were required to achieve the desired analysis capability.

II. DEFICIENCIES OBSERVED IN THE ORIGINAL PETROS 4 PROGRAM

The user of the PETROS 4 code has first to choose one of the three versions referred to in the title of Reference 2. For the reasons previously stated the primary attention has been given to the moderately-thick hard-bonded* transverse shear deformable option although occasional use of the thin hard-bonded Kirchhoff shell model has been made for comparison purposes. Another choice to be made is the plasticity theory to be employed, which is selected by the value assigned to the input variable ISTRES, as follows:

ISTRES	Plasticity Theory
0	Mechanical sublayer model ^{3,4,5} , 3-D stress
1	Prandtl-Reuss model, 3-D stress
2	Mechanical sublayer model, $\tau^{3j} = 0$ (j=1,2,3) This option was recommended for the Kirchhoff shell.
3	Mechanical sublayer model, $\tau^{33} = 0$ (This stress component is oriented along the normal to the shell reference surface.)

* The PETROS 4 code can treat shells composed of layers of different materials (although the immediate interest is in applications involving only a single layer).

³ H. F. Bohnenblust, and P. Duwez, "Some Properties of a Mechanical Model of Plasticity," *Journal of Applied Mechanics*, Vol. 15, No. 3, September 1948, pp. 222-225.

⁴ G. N. White, Jr., "Application of the Theory of Perfectly Plastic Solids to Stress Analysis of Strain Hardening Solid," *Graduate Div. of Applied Math., Brown University Tech Report 51*, August 1950.

⁵ J. F. Besseling, "A Theory of Plastic Flow for Anisotropic Hardening in Plastic Deformation of an Initially Isotropic Material," *Report 5410, National Aeronautical Research Institute, Amsterdam, The Netherlands, 1953.*

Another input quality which must be selected is INORML, which controls the manner in which the variable D^3 is calculated. D^3 is the component of the vector $\bar{D}$ in the direction of the normal to the reference surface and $\bar{D}$ represent the three additional degrees-of-freedom of the SHEAR model besides those of the Kirchhoff model at each mesh point. The options for INORML are:

INORML	$\bar{D}$ Calculation
0	The cartesian components of $\bar{D}$ are calculated using three equations of motion
1	D^3 is set to zero after $\bar{D}$ is calculated
2	The incremental change in D^3 is calculated from the incremental strain $\Delta\gamma_j^3$ using the elastoplastic constitutive relations; this corresponds to a thickness change which affects the stresses at the next time step.

A. Stress Calculation Inconsistencies

In order to treat the problem of a blast-loaded structural plate it would appear appropriate to use the SHEAR version of the PETROS 4 code with the options ISTRES = 0, INORML = 0 since these are the most general (least restrictive) choices available. This combination of options has been employed to treat the following physical example:

A square plate of rolled homogeneous steel armor, 0.1905m (7.50 in) by 0.1905m (7.50 in) by 9.53mm (0.375 in) thickness. Young's modulus: 2.068GPa (30×10^6 psi) Poisson's ratio: 0.25. The uniaxial strain-hardening characteristics of this material were represented in the mechanical sublayer model by the following stress-strain coordinates (connected by linear segments):

<u>Coordinate No.</u>	<u>Stress</u>	<u>Strain</u>
1	1.048 GPa (152000 psi)	0.005067
2	1.145 GPa (166000 psi)	0.0135
3	1.248 GPa (181000 psi)	0.0530
4	1.675 GPa (243000 psi)	0.2800

The boundary conditions imposed on all four edges were complete fixity. The plate was loaded by the blast from a 0.907kg (2 pound) spherical pentolite charge detonated 63.5mm (2.5 in) above its midpoint.

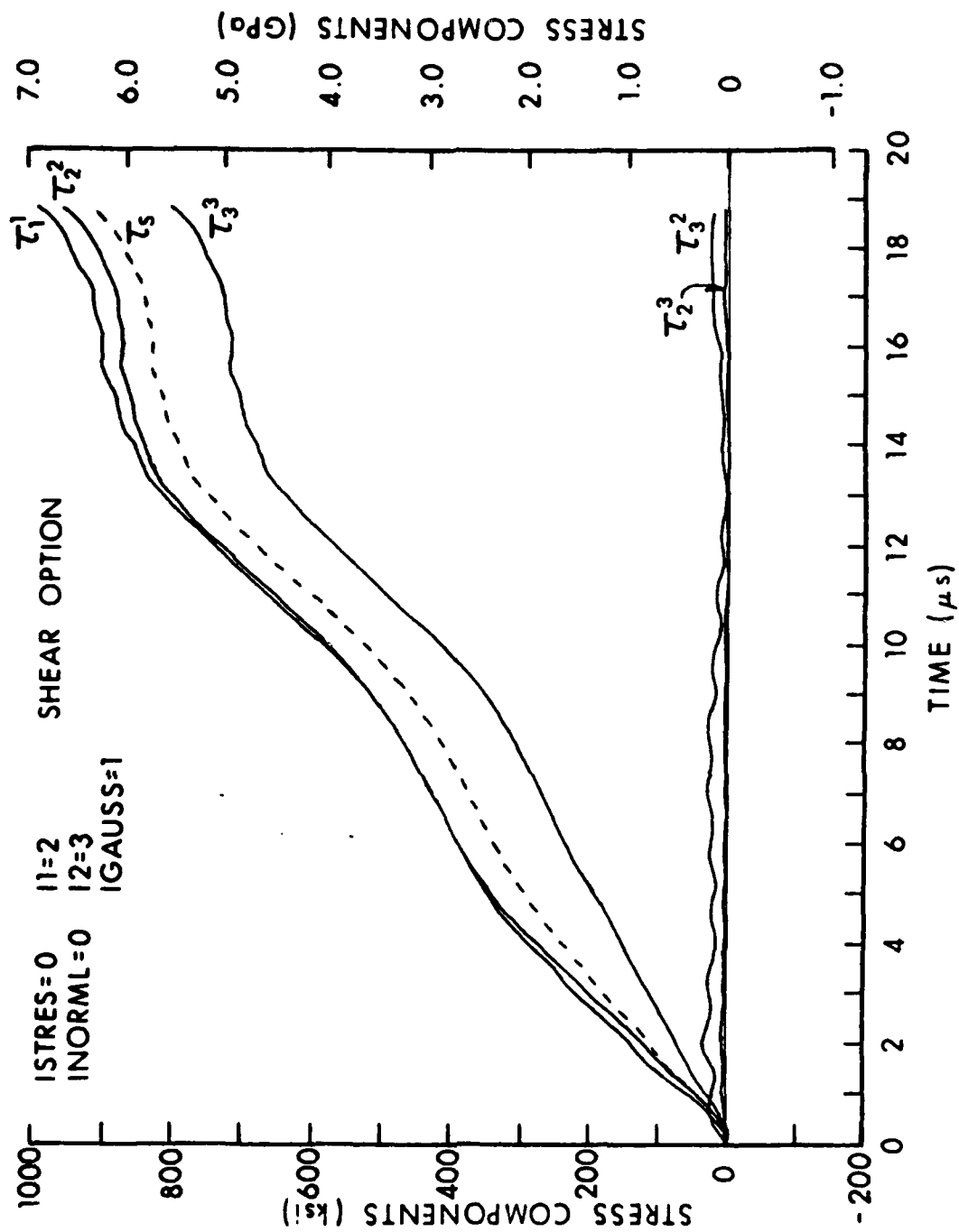


Figure 1. Transient Stress Components for Indicated Options

Results of PETROS 4 calculations of transient stress components using the cited options are shown in Figure 1. The location of these stresses is a point 9.53mm (0.375 in) from the plate midpoint along a line perpendicular to an edge and 0.661mm (0.026 in) above the lower surface. One sees that all three normal stress components have become very large (as has the mean or hydrostatic stress τ_3) by the end of this short run and it may be readily verified that the elastoplastic stress components satisfy the von Mises yield function and the associated flow rule. On the other hand the prescribed blast overpressure at this location jumps to a peak value of 834MPa (120900 psi) and decays exponentially to 621MPa (90000 psi) by the end of the run (while the pressure on the lower surface remains at zero). Consequently, one would expect that the mean value of the through-thickness stress component τ_3 would be negative (compressive) and that any tensile excursion would be small. For this reason it is felt that the normal stresses displayed in Figure 1 are exceedingly suspect.

Before speculating on the cause of this behavior let us compare solutions of the same physical problem obtained by use of other options of the PETROS 4 code. Using the Kirchhoff model with ISTRES = 2, INORML = 0 the distinctly different and more plausible results shown in Figure 2 were derived. Rather than a runaway increase, the normal stresses τ_1 and τ_2 appear to be reaching a maximum at stress levels which armor plate may sustain. However, this Kirchhoff solution has the drawbacks that (1) a two-dimensional constitutive relation is employed ($\tau_3 \equiv 0$) so that the boundary condition on the upper surface cannot be satisfied and (2) the early time solution may be inaccurate since transverse shear deformation is neglected.

Now consider solutions of the same problem derived using the SHEAR model with ISTRES = 3 where the three-dimensional constitutive relation is utilized subject to the constraint $\tau_3 \equiv 0$. For INORML = 0 the predicted stresses are displayed in Figure 3. These stresses appear entirely plausible; however, experience with longer computer runs using this option combination has revealed a tendency to unchecked growth in magnitude of the variable D^3 and the associated through-thickness strain component γ_3^3 . For INORML = 1 the calculated stresses are plotted in Figure 4. These results, while different from the preceding, are also plausible. In this case transverse shear deformation is permitted but the "breathing" deformation mode is inhibited by the non-physical constraint $\gamma_3^3 \equiv 0$. Finally, the solution for INORML = 2 is presented in Figure 5. It had been expected that this option combination would provide the "best" predictions since both shear deformation and "breathing" are permitted. However, in this and all other runs made with this option unstable results, including negative plastic work, were obtained. It must be concluded that there exists an error in either the formulation or the coding for this option.

It is apparent that each option combination leads to a different solution for the stresses. The solutions shown in Figs. 1 and 5 are obviously unsatisfactory. The Kirchhoff shell analysis of Figure 2 is correct within the limitations of classical thin shell theory but a more refined analysis including transverse shear deformation is desired. The differences between the results of Figures 3 and 4 are significant; in sequel these differences will be explained and a more satisfactory formulation derived.

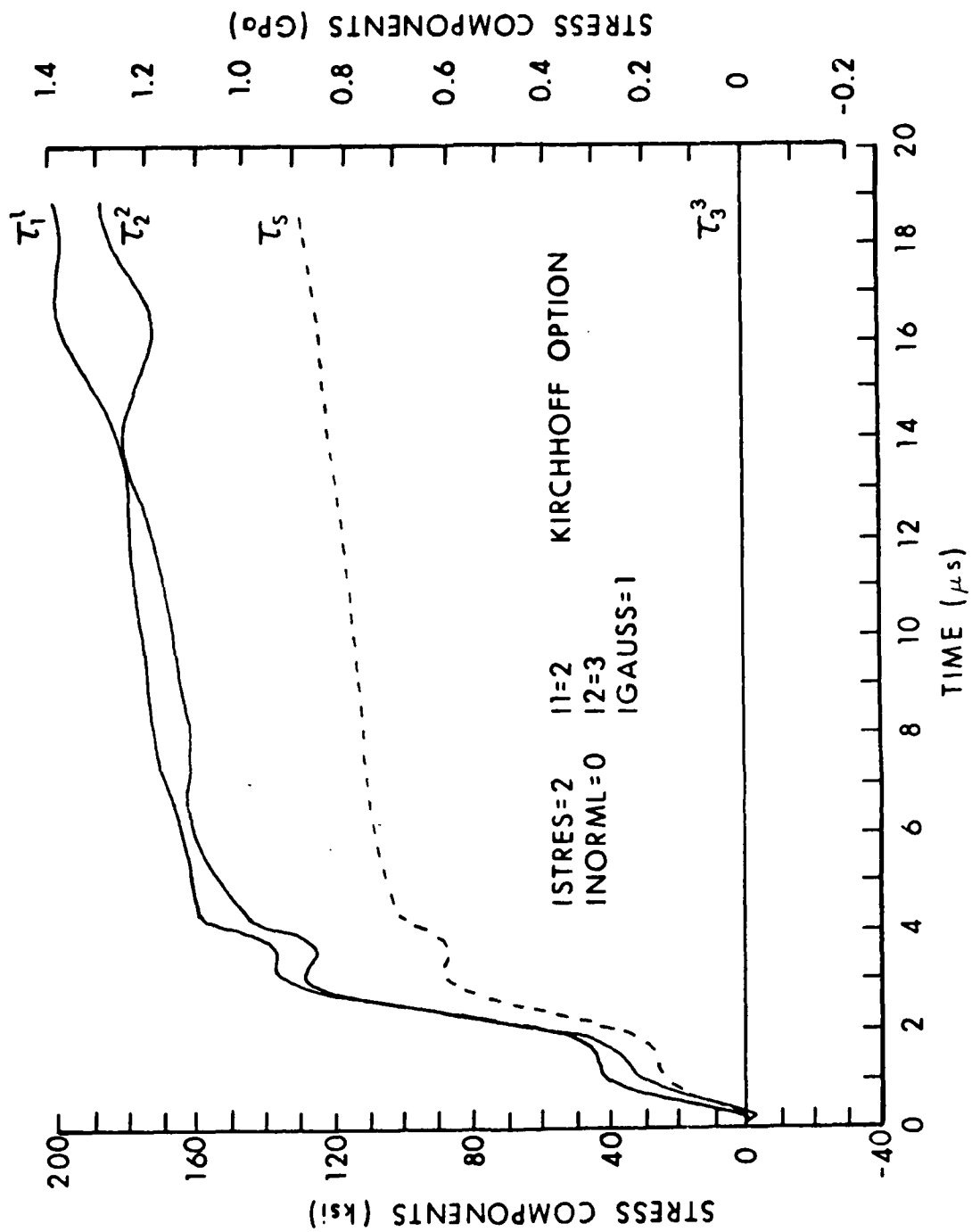


Figure 2. Transient Stress Components for Indicated Options

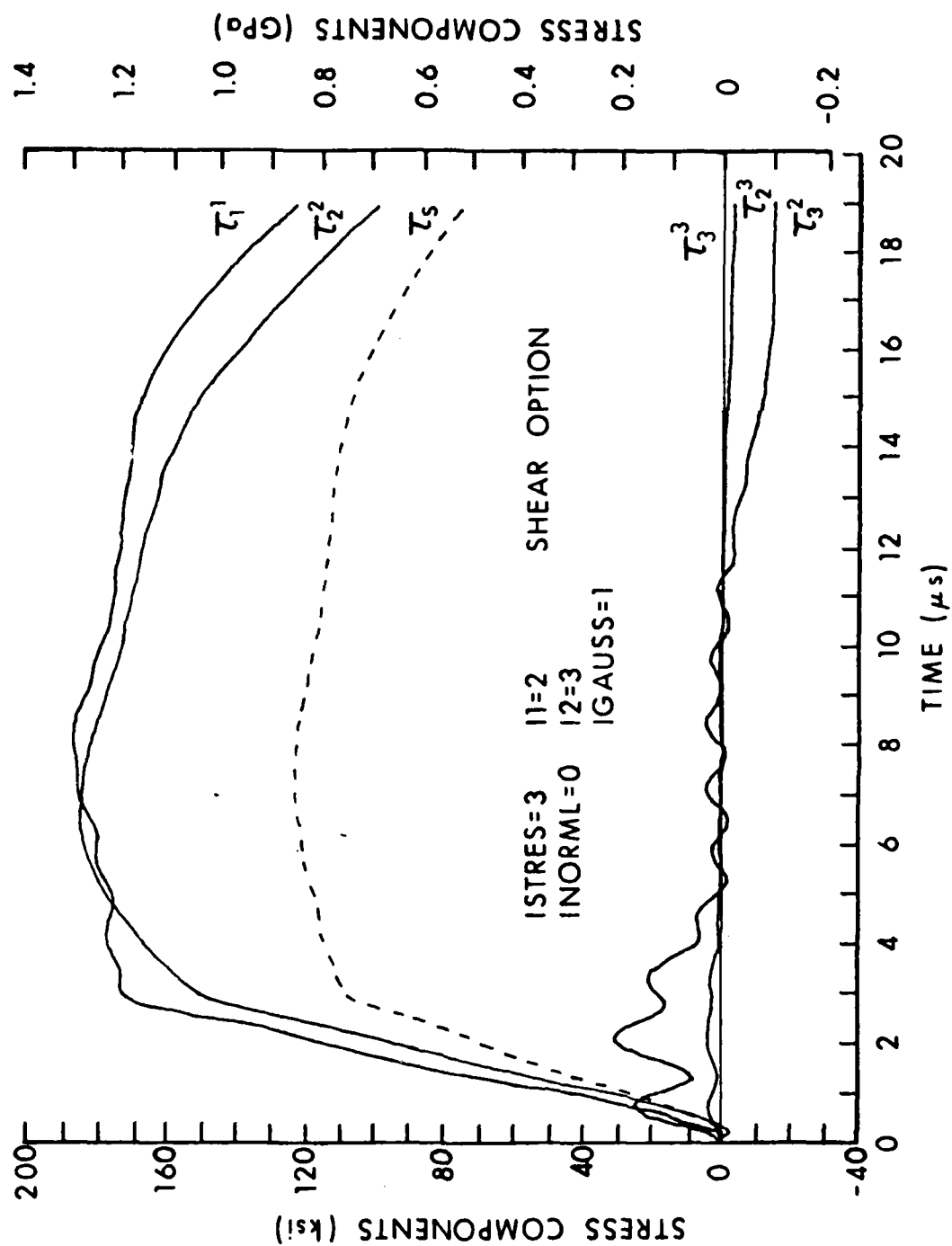


Figure 3. Transient Stress Components for Indicated Options

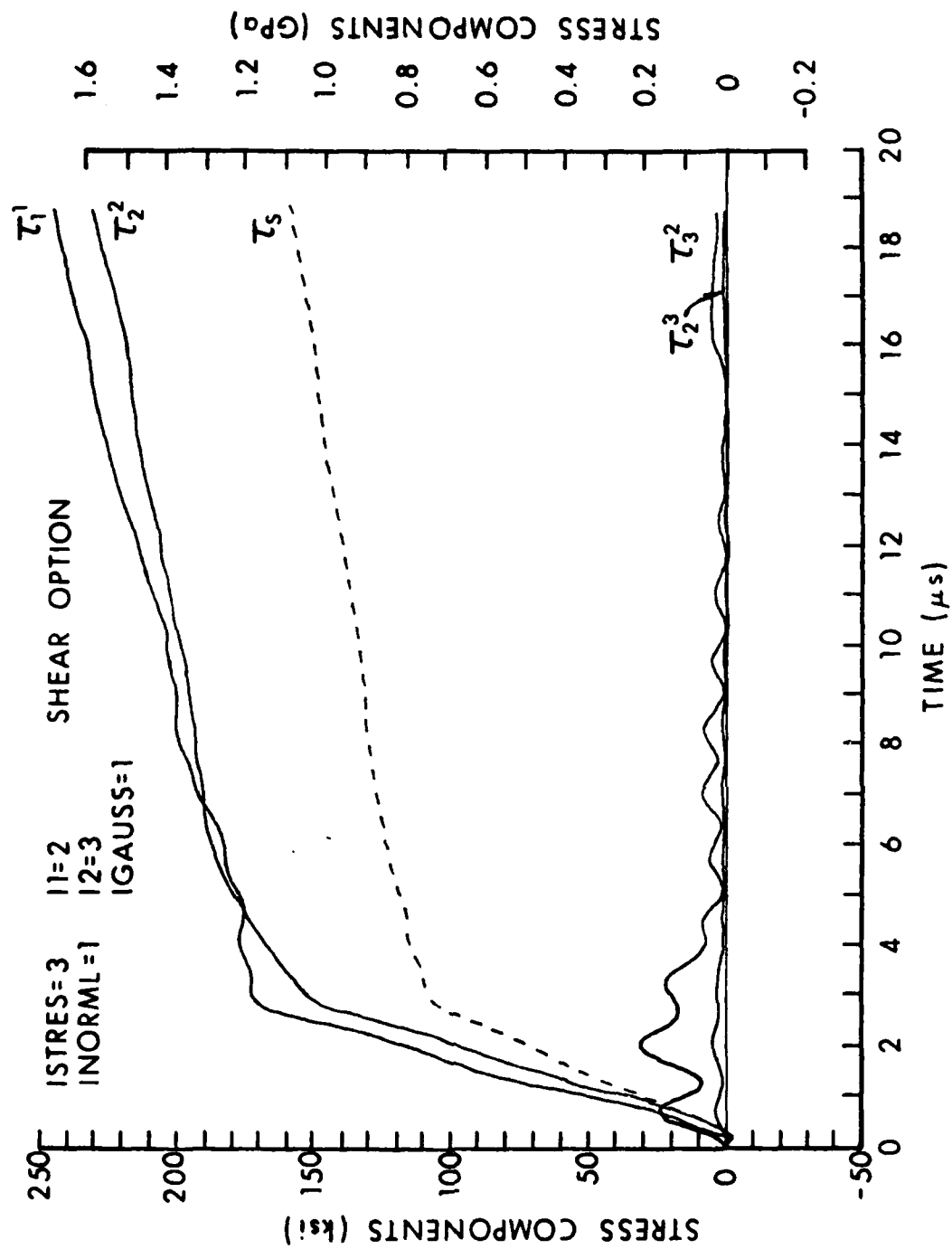


Figure 4. Transient Stress Components for Indicated Options

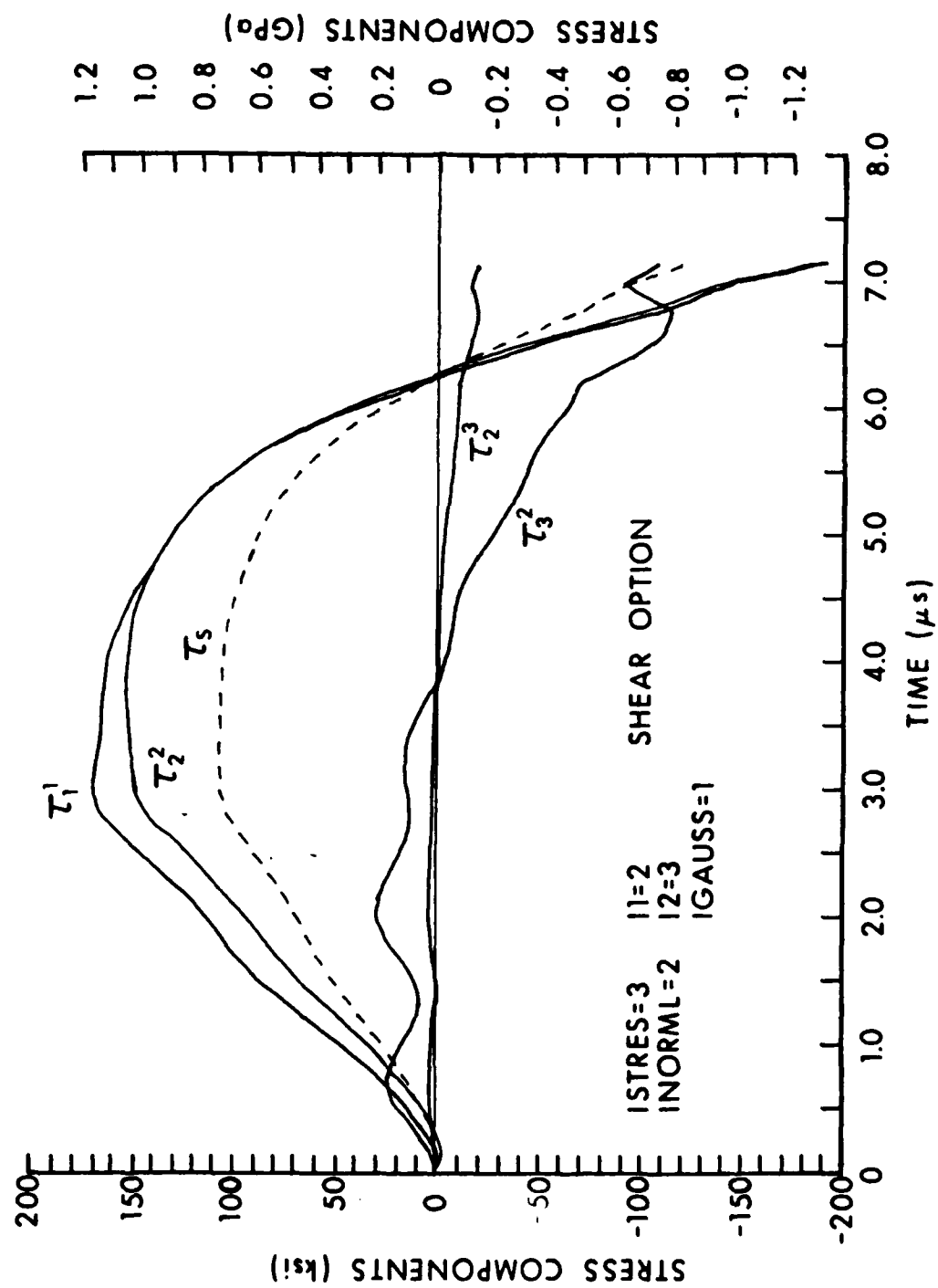


Figure 5. Transient Stress Components for Indicated Options

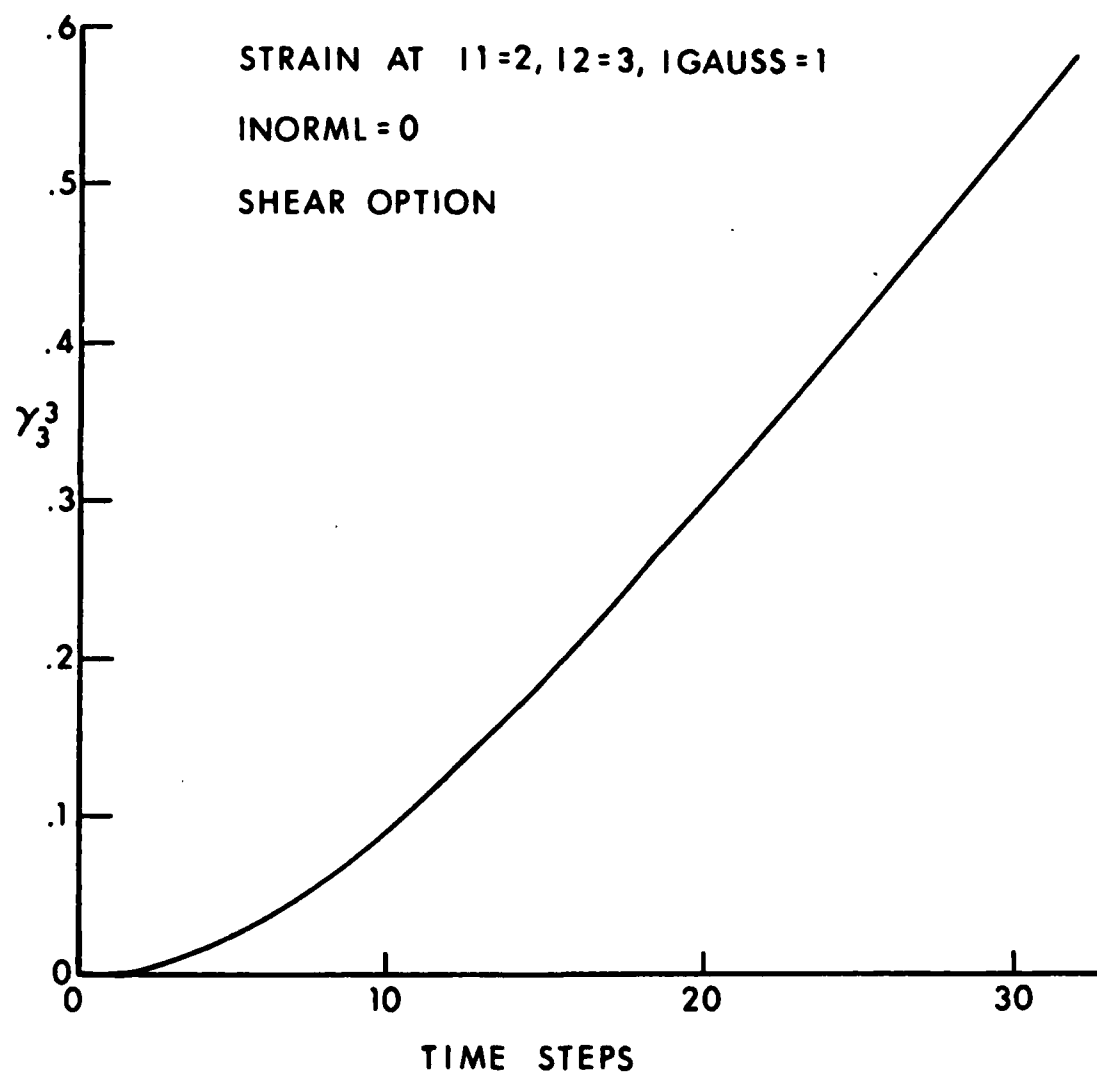


Figure 6. Growth of Through - Thickness Strain

B. Unstable Growth of D^3

As previously noted, the three independent components of the vector $\bar{D}$ represent the additional degrees-of-freedom possessed by the SHEAR option of the PETROS 4 code. With the INORML = 0 option the Cartesian components of $\bar{D}$ are determined by three equations of motion derived using a variational principle. However, it appears that this formulation provides no material stiffness-based restoring force to oppose changes in the magnitude of D^3 , the component of $\bar{D}$ in the direction of the normal to the reference surface. As a consequence solutions using this option tend to exhibit a monotonic growth or decrease in the magnitude of D^3 and of the directly dependent through-thickness strain γ_3^3 , see Figure 6. Corrective measures to circumvent this defect will be presented in Chapter IV.

C. Constitutive Relation for ISTRES = 3

In the course of checking the PETROS 4 code it was discovered that values of the normal components of trial stresses (TR (1, 1) in the code) were being evaluated incorrectly in the STRESS subroutine for the option ISTRES = 3. Specifically, the non-zero value of DGAMMX (3, 3) was being included in the calculation of DGAMMA, which is inappropriate when the stress-strain relation is constrained by the condition $\tau_3^3 \equiv 0$. Also, non-zero values of corrector stress TC (3,3) (as well as TR (3,3) and TM (3,3)) were being used in the calculation of $\bar{\lambda}$ and $(\tau_j^i)_{n+1}$, causing an additional error in the elastoplastic stress evaluation. The fact that later in the cycle τ^{33} was set equal to zero did nothing to remedy the errors introduced into the other component of τ^u . Once this problem was detected, appropriate corrections were readily made to the STRESS subroutine.

D. Effect of Through-Thickness Normal Stresses

For most shell structures subjected to surface loadings the magnitude of the through-thickness normal stress τ_3^3 is negligible in comparison to induced flexural and membrane stresses appearing as the components τ_1^1 and τ_2^2 . However, for the presently contemplated application the blast pressure-induced values of τ_3^3 during the early portion of the loading are of the same order as the other normal stresses and deserve to be taken into account when applying the constitutive relations. This raises the question as to whether such problems can be treated in a rational manner without resorting to a complete three-dimensional analysis. It should be noted that, of the options available with the PETROS 4 code, only the ISTRES = 0 option does not set $\tau_3^3 \equiv 0$. Unfortunately, as shown in Figure 1, solutions obtained using this option predict unreasonably large tensile values of τ_3^3 rather than the compressive stresses which would be expected to result from surface pressure loading. An alternative formulation for incorporating the effects of through-thickness normal stresses will be given in Chapter III.

E. Omission of Surface Traction Effects

In the theoretical formulation report¹ for the PETROS 4 code the effect of surface tractions was embodied in the equations of motion by terms designated $\tilde{E}_{(n)}^k$. Later in the same report it was argued that the terms $\tilde{E}_{(2)}^k$ and $\tilde{E}_{(3)}^k$ could be neglected for thin shells. However in Appendix D of Reference 1, where the equations of motion for the SHEAR (moderately thick shell) equations are presented, the term $\tilde{E}_{(2)}^k$ is retained (as it should be). It was discovered that this term was not included in the finite difference equations of motion in subroutine EQUIL2 of the PETROS 4 code which are used to calculate the components of $\bar{D}$.

F. Reconstitution of Mixed Tensor Stresses

In the cyclic time marching solution procedure employed by the PETROS 4 code the values of the unsymmetric mixed tensor stress components τ_k^j in each sublayer at the previous time step are needed in the calculation of elastoplastic stresses at the current time step. However, in an apparent effort to economize on use of computer memory, the symmetric contravariant stress tensor components τ^{ij} are saved rather than the mixed tensor components. Thus at the previous time step the calculations $\tau^{ij} = G^{ik}\tau_k^j$ are performed and, when stress calculations are resumed at the next cycle, the values of τ_k^j are reconstituted by use of $\tau_k^j = G_{ki}\tau^{ij}$. However, in the interim a new set of metric tensors has been calculated so that the reconstituted values of τ_k^j are not generally identical with the values determined during the previous cycle. In fact, if a significant geometry change has occurred the differences may be appreciable. It is feared that, for long computer runs, these differences may accumulate to cause serious departures from the correct solution.

G. Plastic Work

The PETROS 4 code calculates the total plastic work performed within the boundaries of the structure as one of the ingredients of an energy balance diagram which is useful for detecting numerical instabilities and for determining an appropriate time to terminate the solution. The other ingredients are the total kinetic energy, total elastic strain energy, and the total work done on the structure by external loads. For conservation of energy the sum of the kinetic energy, strain energy, and plastic work should not exceed the external work, except possibly for a small discretization error. However, for the blast loaded panels of current interest the energy balance diagram of Figure 7 is typical. By a process of elimination it has been concluded that the observed discrepancy is due to an error in the plastic work, either in the finite deformation formulation or the coding. Fortunately, the computation of plastic work is an auxiliary calculation which has no effect on the basic solution process.

The next three chapters are devoted to modifications to the PETROS 4 code designed to remedy the foregoing deficiencies.

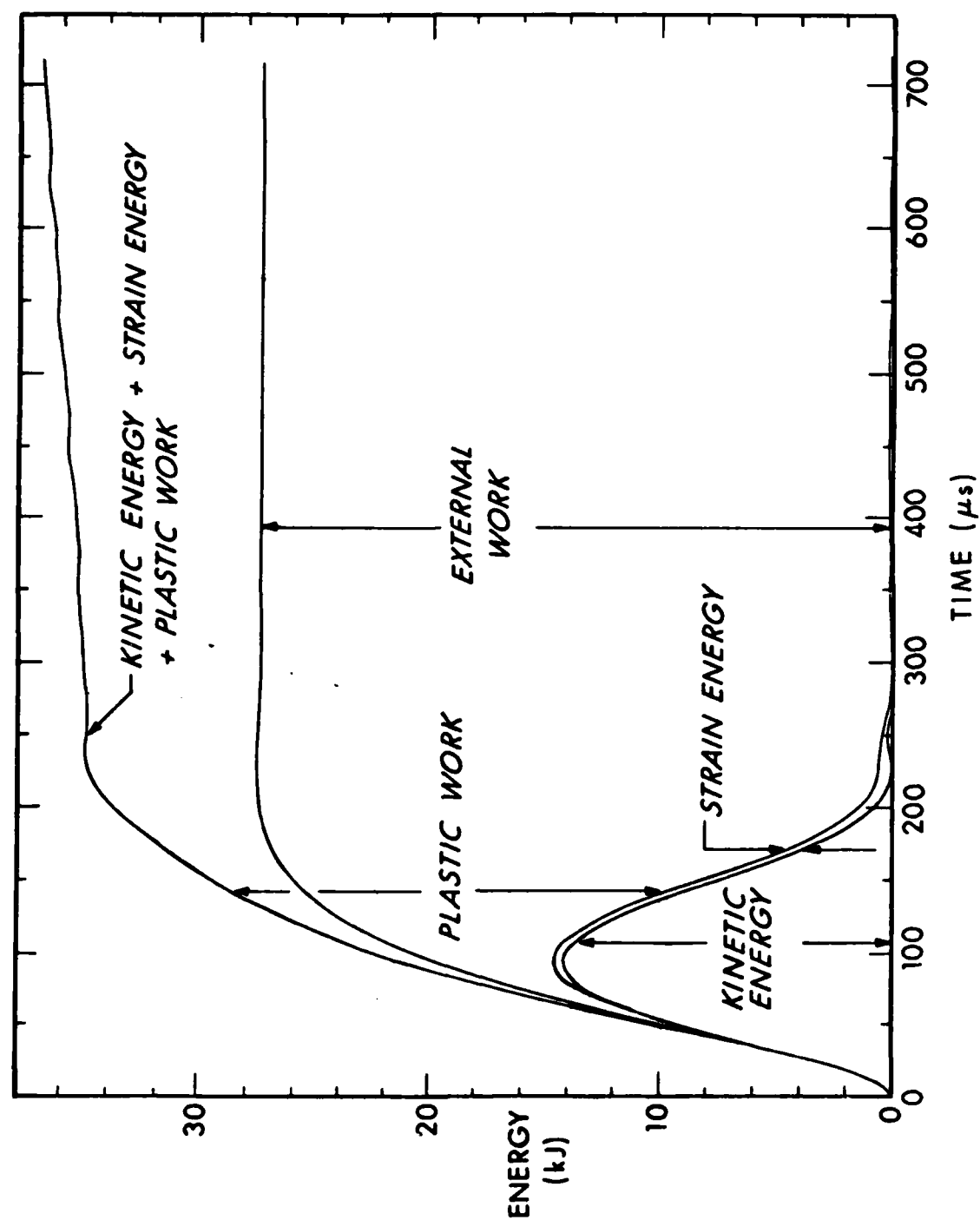


Figure 7. Energy Balance Diagram

III. PRESCRIBED VARIATION OF THROUGH-THICKNESS NORMAL STRESS

The issues raised in Section D of Chapter II concerning the effects of through-thickness normal stresses will now be examined in more detail.

A. Stress Wave Considerations

In order to assess the significance of the τ_3^3 stress component on elastoplastic calculations it is necessary to have some information as to the manner in which this component varies through the shell thickness. Therefore, consideration was given to an idealized one-dimensional problem of elastic stress wave propagation for the through-thickness direction. This is not as restrictive as it may seem. One is not concerned with blast pressures great enough to induce plasticity in the first pass of the stress wave through the thickness or to cause spallation off the far side of the shell because it is known that rupture of the shell will occur for lower blast pressures. The analysis which follows is for only slightly more than two wave passes through a plate and it is known that plasticity is not induced in the plate (due to flexure and stretching) until much later. However, it will be possible to draw conclusions which will also apply during elastoplastic response.

In the idealized problem it was assumed that the upper surface of a plate was subjected to a uniformly distributed blast pressure which jumped to a value p_0 followed by an exponential decay. The lower surface of the plate was assumed stress-free. The solid line in Figure 8 is the traveling wave solution for the through-thickness normal stress at the Gauss point closest to the loaded surface. On the other hand, if one assumes a linear variation of through-thickness stress from $-p(t)$ at the upper surface to zero at the lower surface the stress at each Gauss point can be calculated. In this manner the dashed curve in Figure 8 was obtained (this curve is actually the "variable mean" of the traveling wave solution). Similar results can be obtained at the other Gauss points. The one-dimensional traveling wave analysis is only applicable for a uniform blast pressure which is not the actual distribution for an explosive charge detonated near a plate. Inasmuch as it is desired to avoid a general three-dimensional response analysis it is felt that the linear variation of through-thickness normal stress represents a reasonably satisfactory approximate basis for defining this component of the stress tensor in subsequent calculations; certainly this is better than assuming $\tau_3^3 \equiv 0$.

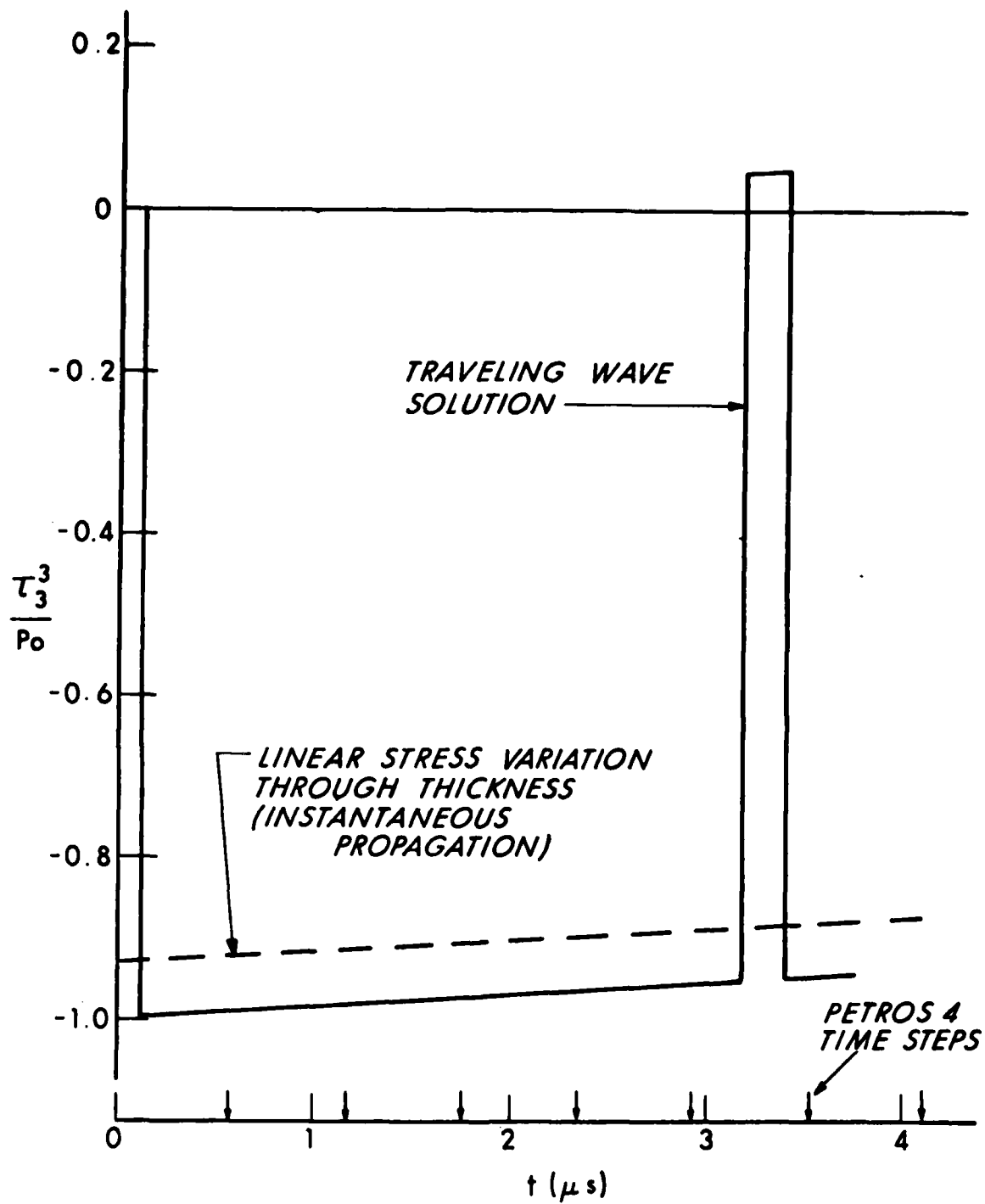


Figure 8. Stress τ_3^3 at Gauss Point 4

B. Modified Constitutive Relation

At the upper surface of the plate (or shell) the boundary conditions* are

$$\tau^{33}(\xi^a, \frac{h}{2}, t) = -G^{33}(\xi^a, \frac{h}{2}, t) p(\xi^a, \frac{h}{2}, t) \quad , \quad \tau^{31} = \tau^{32} = 0 \quad (1)^{**}$$

while on the lower surface ($\zeta = -h/2$) all three stress components vanish. The mixed tensor through-thickness component at the upper surface is given by

$$\begin{aligned} \tau_3^3(\xi^a, \frac{h}{2}, t) &= G_{3j}(\xi^a, \frac{h}{2}, t) \tau^{3j}(\xi^a, \frac{h}{2}, t) \quad \dagger \\ &= G_{33}(\xi^a, \frac{h}{2}, t) \tau^{33}(\xi^a, \frac{h}{2}, t) \\ &= -G_{33}(\xi^a, \frac{h}{2}, t) G^{33}(\xi^a, \frac{h}{2}, t) p(\xi^a, \frac{h}{2}, t) \end{aligned} \quad (2)$$

For the desired linear variation of τ_3^3 between the surface boundary conditions,

$$\tau_3^3(\xi^a, \zeta_g, t) = -G_{33}(\xi^a, \frac{h}{2}, t) G^{33}(\xi^a, \frac{h}{2}, t) p(\xi^a, \frac{h}{2}, t) (\frac{1}{2} + \frac{\zeta_g}{h}) \quad (3)$$

where ζ_g are the locations of the discrete Gauss points.

In the PETROS 4 code the nine incremental stress components are determined from nine strain increments $\Delta\gamma_j^i$ and the known values of the stress components $(\tau_j^i)_n$ at the time t_n prior to the incremental change. When the stress component τ_3^3 is prescribed as shown in equation (3) its value is known at both t_n and t_{n+1} so that

$$\Delta\tau_3^3 = \left(\tau_3^3\right)_{n+1} - \left(\tau_3^3\right)_n \quad (4)$$

is also prescribed. Thus the elastoplastic constitutive problem is shifted to determining eight incremental stress components and an incremental strain component $\Delta\gamma_3^3$ which generally differs from that provided by the ZETA subroutine.

* These are the physical boundary conditions. The displacement model embodied in the PETROS 4 code does not provide for satisfaction of these conditions.

** Superscripts and subscripts range over the integers as follows: greek 1,2; latin 1,2,3.

† The summation convention is employed: terms having a repeated index, once as a subscript and once as a superscript, are to be summed over the range of that index.

The generalized Hooke's law can be rearranged to obtain the following expressions for the trial stress increments:

$$\begin{aligned}\Delta \tau_1^T &= \frac{E}{1-\nu^2}(\Delta \gamma_1^T + \nu \Delta \gamma_2^T) + \frac{\nu}{1-\nu} \Delta \tau_3^T \\ \Delta \tau_2^T &= \frac{E}{1-\nu^2}(\nu \Delta \gamma_1^T + \Delta \gamma_2^T) + \frac{\nu}{1-\nu} \Delta \tau_3^T \\ \Delta \tau_j^T &= \frac{E}{1+\nu} \Delta \gamma_j^T \quad \text{for } i \neq j\end{aligned}\quad (5)$$

The trial stresses at time t_{n+1} are

$$\left(\begin{matrix} T \\ \tau_j^i \end{matrix} \right)_{n+1} = \left(\begin{matrix} T \\ \tau_j^i \end{matrix} \right)_n + \Delta \tau_j^T \quad (6)$$

To determine whether plasticity occurs during the interval $t_{n+1} - t_n = \Delta t$ the values of the trial stresses are substituted in the plastic potential function

$$\phi_{n+1}^T = \left[\tau_j^T \tau_i^T - \frac{1}{3} \left(\tau_m^T \right)^2 - \frac{2}{3} \sigma_Y^2 \right]_{n+1} \quad (7)$$

which may be recognized as the von Mises yield function. If the resulting value of $\phi_{n+1}^T \leq 0$ the stress change is elastic and the trial stresses $(\tau_j^i)^{n+1}$ become the actual stresses $(\tau_j^i)_{n+1}$. For $\phi_{n+1}^T > 0$ plasticity occurs and the total strain increments are composed of

$$\Delta \gamma_j^T = \Delta \gamma_j^e + \Delta \gamma_j^p \quad (8)$$

i.e., elastic and plastic parts. The plastic strain increments are obtained from the flow rule

$$\Delta \gamma_j^p = \frac{\partial \phi_n}{\partial \tau_j^i} \Delta \lambda = \left[2 \left(\tau_j^i \right)_n - \frac{2}{3} \left(\tau_m^T \right)_n \delta_j^i \right] \Delta \lambda \quad (9)$$

where $\Delta \lambda$ is a scalar multiplier. Even in the presence of plasticity the stress increments are related to the elastic strain increments by Hooke's law:

$$\Delta \tau_j^T = \frac{E}{1+\nu} \Delta \gamma_j^e + \left\{ \frac{\nu E}{1-\nu^2} \Delta \gamma_a^e + \frac{\nu}{1-\nu} \Delta \tau_3^T \right\} \delta_j^i \quad (10)$$

Then, substituting

$$\Delta \gamma_j^e = \Delta \gamma_j^T - \Delta \gamma_j^p \quad (11)$$

and the plastic strain increments from equation (9), one obtains

$$\Delta \tau_j^T = \frac{E}{1+\nu} \Delta \tau_j^T - \lambda \left[\begin{matrix} C \\ \tau_j^i \end{matrix} \right]_n \quad (12)$$

where $\Delta \tau_j^T$ is given by equations (5),

$$\left[\frac{C}{\tau_j} \right]_n - \left[\tau_j^i \right]_n - \frac{1}{1-\nu} \left\{ \frac{1-2\nu}{3} \left[\tau_m^m \right]_n + \nu \left[\tau_3^3 \right]_n \right\} \delta_j \quad (13)$$

and $\lambda = \frac{2E\Delta\lambda}{1+\nu}$. Since $\Delta \tau_3^3$ is prescribed it is arbitrary whether $\Delta \tau_3^T$ or $(\Delta \tau_3^3)_n$ is defined as long as equation (12) is satisfied. However, it is preferable to set $\Delta \tau_3^T = \Delta \tau_3^3$, $(\Delta \tau_3^3)_n = 0$ so that when the test for plasticity (equation (7)) is applied, $\left(\frac{T}{\tau_3^3} \right)_{n+1}$ is already known. The stresses at the end of the time interval are

$$\left[\tau_j^i \right]_{n+1} = \left[\tau_j^i \right]_n + \Delta \tau_j^i - \left[\tau_j^i \right]_n + \Delta \tau_j^i - \lambda \left[\frac{C}{\tau_j} \right]_n - \left[\frac{T}{\tau_j} \right]_{n+1} - \lambda \left[\frac{C}{\tau_j} \right]_n \quad (14)$$

In the mechanical sublayer constitutive model each hypothetical sublayer is treated as an elastic, perfectly plastic material having a distinct yield stress. Consequently the condition $\phi_{n+1} = 0$ is imposed in order to determine the parameter λ for each sublayer experiencing plasticity. When the stresses given by equation (14) are subjected to this condition a quadratic equation of the form

$$A\lambda^2 - 2B\lambda + C = 0 \quad (15)$$

results, where

$$\begin{aligned} A &= \left[\frac{C}{\tau_j} \right]_n \left[\frac{C}{\tau_j} \right]_n - \frac{1}{3} \left[\frac{C}{\tau_m^m} \right]_n^2 \\ B &= \left[\frac{T}{\tau_j} \right]_{n+1} \left[\frac{C}{\tau_j} \right]_n - \frac{1}{3} \left[\frac{T}{\tau_m^m} \right]_{n+1} \left[\frac{C}{\tau_r} \right]_n \\ C &= \phi_{n+1} = \left[\frac{T}{\tau_j} \right]_{n+1} \left[\frac{T}{\tau_j} \right]_{n+1} - \frac{1}{3} \left[\frac{T}{\tau_m^m} \right]_{n+1}^2 - \frac{2}{3} \sigma_y^2 \end{aligned} \quad (16)$$

From equation (15),

$$\lambda = \frac{B}{A} - \left\{ \left[\frac{B}{A} \right]^2 - \frac{C}{A} \right\}^{1/2} \quad (17)$$

Once a real, positive value of λ has been obtained the stresses $(\tau_j^i)_{n+1}$ can be calculated by use of equation (14). Huffington⁶ has presented a procedure for dealing with complex

⁶ N. J. Huffington, Jr., "Numerical Analysis of Elastoplastic Stresses," US Army Ballistic Research Laboratory Memorandum Report No. 2006, September 1969. AD 861688.

roots should they arise by subdividing Δt for purposes of stress evaluation only. This procedure was already incorporated in the PETROS 4 code. However, it has been found that under certain circumstances even when a real root λ is obtained without subdividing Δt , inaccurate or oscillatory stresses may result. This difficulty is associated with an excessively large excursion of the trial stress vector $\begin{pmatrix} T \\ \tau \end{pmatrix}$ outside the yield surface in stress space. A technique for coping with this problem devised by Huffington (see Appendix B of Reference 7) has recently been introduced into the PETROS 4 code. It entails calculating an integer L which defines the number of subdivisions of the time step Δt , where

$$L = \text{INT} \left\lceil \text{YLDFAC} \left\lceil \sqrt{(1.5 \phi_{n+1}^T + \sigma_y^2) / \sigma_y^2 - 1} \right\rceil \right\rceil + 1 \quad (18)$$

YLDFAC is a parameter which varies the accuracy of the stress evaluation; it ranges from 0 (no subdivision of Δt) to ∞ (differential subintervals). Normally YLDFAC = 1 is used.

The foregoing formulation, entailing the prescribed linear variation of τ_j^3 through the thickness, has been incorporated in the PETROS 4 code as option ISTRES = 4.

C. Through-Thickness Strain Calculation

The strain increment component $\Delta \gamma_j^3$ may be determined by use of

$$\Delta \gamma_j^3 = \frac{1}{E} \left[\Delta \tau_j^3 - \nu (\Delta \tau_1^1 + \Delta \tau_2^2) \right] + \frac{(1+\nu)}{3E} \left[2\tau_j^3 - \tau_1^1 - \tau_2^2 \right]_n \lambda \quad (19)$$

once λ has been evaluated. If plasticity is occurring at a Gauss point the value of $\Delta \gamma_j^3$ will generally be different for each sublayer. A weighted average $\Delta \gamma_j^3$ for the Gauss point can be obtained through multiplying the sublayer $\Delta \gamma_j^3$ strains by the same weighting factors employed with the mechanical sublayer model and summing. Alternatively, after the total elastoplastic stresses τ_j^1 at a Gauss point have been determined the value of $\Delta \gamma_j^3$ for the Gauss point can be calculated by imposing the condition of plastic incompressibility:

$$\Delta \gamma_j^3 = \frac{\Delta \tau_k^k}{3K} - \Delta \gamma_a^a \quad (20)$$

Generally, a different value of $\Delta \gamma_j^3$ will result for each Gauss point rather than the constant value of $\Delta \gamma_j^3$ through the thickness which the PETROS 4 displacement function admits. In the next chapter a compromise resolution of this discrepancy will be presented.

⁷ J. M. Santiago, H. L. Wisniewski, and N. J. Huffington, Jr., "A User's Manual for the REPSIL Code," US Army Ballistic Research Laboratory Report No. 1744, October 1974.
AD A003176.

IV. MODIFICATION OF THE D^3 DEGREE-OF-FREEDOM

The problem of unstable growth of the variable $D^3(\xi^\alpha, t)$ when the INORML = 0 option is employed was discussed in Chapter II. This variable corresponds to just one of the six degrees-of-freedom which appear in the PETROS 4 displacement function, which has the following forms:

$$\bar{u}(\xi^\alpha, \zeta, t) = \bar{u}_0(\xi^\alpha, t) + \zeta[\bar{N}(\xi^\alpha, t) - \bar{n}(\xi^\alpha, 0)] + \zeta \bar{D}(\xi^\alpha, t) \quad (21a)$$

$$= v^\alpha \bar{A}_\alpha + w \bar{N} + \zeta(\bar{N} - \bar{n}) + \zeta(D^\alpha \bar{A}_\alpha + D^3 \bar{N}) \quad (21b)$$

$$= Y^{(1)k} \bar{i}_k + \zeta N^k \bar{i}_k + \zeta Y^{(2)k} \bar{i}_k - (\bar{r}_0 + \zeta \bar{n}) \quad (21c)$$

The first form is a vectorial one, showing the independent variables upon which these vectors depend. Equation (21b) designates the components of the vector quantities in the directions of the basis vectors $\bar{A}_\alpha$ lying in the deformed reference surface and the normal vector $\bar{N}$ perpendicular to this surface. The third form represents the rectangular cartesian component version of the same displacement function. Note that

$$\bar{D}(\xi^\alpha, t) = D^\alpha \bar{A}_\alpha + D^3 \bar{N} = Y^{(2)k} \bar{i}_k \quad (22)$$

When the strain-displacement relations are applied to the displacement model of equation (21) it is found that $\Delta \gamma_{33}$ and γ_{33} cannot vary with the through-thickness coordinate ζ . This result is of course in direct contradiction to the conclusion regarding the variability of strain components through the thickness reached at the end of the preceding chapter, where these quantities were evaluated using the constitutive relations. Clearly, a generalization of the displacement function to permit modeling the variation of γ_3^3 with ζ would be desirable. However, this would entail an extensive reformulation for the PETROS 4 code with the addition of other degrees-of-freedom and increased storage and computing requirements. Since this is not feasible at present it appears that the best one can do is to modify the value of $D^3(\xi^\alpha, t)$ so that the value of $\Delta \gamma_3^3$ obtained by differentiating the displacement function will agree with some mean value of the $\Delta \gamma_3^3$ strain increments at the ξ^α location which are obtained using the constitutive relations (i.e., equations (19) or (20)).

A. Modifications to Cartesian Components

Consider that the quantities $Y^{(2)j}$ are known at a time t_n and that the EQUIL2 subroutine of PETROS 4 has produced the next set of incremental changes $\Delta Y^{(2)j}$. These incremental changes also satisfy an equation similar to equation (22):

$$\Delta \bar{D} = \Delta D^\alpha \bar{A}_\alpha + \Delta D^3 \bar{N} = \Delta Y^{(2)j} \bar{i}_j \quad (23)$$

After modifications to certain incremental quantities the following equation will apply:

$$\frac{m}{\Delta \bar{D}} = \Delta D^\alpha \bar{A}_\alpha + \Delta D^3 \bar{N} = \Delta Y^{(2)j} \bar{i}_j \quad (24)$$

where the terms with overscript m are modified. Note that the terms involving $\bar{A}_\alpha$ are unmodified, also that $\bar{N}$ depends only on $Y^{(1)j}$ and is unaffected by changes in $\bar{D}$. Taking the inner product of both sides of equations (23) and (24) with the unit vector $\bar{J}$ one obtains:

$$\Delta Y^{(2)j} = \Delta D^\alpha \bar{A}_\alpha \cdot \bar{J} + \Delta D^3 N^j \quad (25)$$

$$\Delta Y^{(2)j} = \Delta D^\alpha \bar{A}_\alpha \cdot \bar{J} + \Delta D^3 N^j \quad (26)$$

Letting

$$\eta(\xi^\alpha, t) = \Delta D^3 - \Delta D^3 \quad (27)$$

and subtracting equation (25) from equation (26) gives

$$\Delta Y^{(2)j} = \Delta Y^{(2)j} + \eta N^j \quad (28)$$

The modified values of the cartesian components of $\bar{D}$ at the next time step are

$$\begin{aligned} (Y^{(2)j})_{n+1} &= (Y^{(2)j})_n + \Delta Y^{(2)j} \\ &= (Y^{(2)j})_n + \Delta Y^{(2)j} + \eta N^j \\ &= (Y^{(2)j})_{n+1} + \eta N^j \end{aligned} \quad (29)$$

Before proceeding further a formulation for η which will produce the desired effect is needed.

B. Strain Equivalence Criterion

The derivation of an expression for determining η requires examination of the non-linear incremental strain-displacement relations employed by PETROS 4. The incremental through-thickness strain $\Delta \gamma_3^3$ is related to the covariant incremental strains by

$$\Delta \gamma_3^3 = \Delta \gamma_{3m} G^{m3} \quad (30)$$

In turn, the covariant strain increment $\Delta \gamma_{33}$ is related to the cartesian components of the basis vector $\bar{G}_3$ and its incremental change by

$$\Delta \gamma_{33} = J_j \Delta J_j - 0.5 \Delta J_j \Delta J_j \quad (31)^*$$

* Since these are cartesian components the summation convention applies even though the repeated indices are superscripts.

For the SHEAR option (only),

$$J_j^i = N^j + Y^{(2)j} \quad (32)$$

$$\Delta J_j^i = \Delta N^j + \Delta Y^{(2)j} \quad (33)$$

Using these relations the effect of the previously cited modifications can readily be traced. As noted before, the surface normal depends only on the reference surface $Y^{(1)j}$ so that modifications to $\bar{D}$ have no effect on N^j or ΔN^j .

When $\Delta Y^{(2)j}$ is modified as indicated by equation (28) the components of the basis vector increment $\Delta \bar{G}_j$ are affected as follows:

$$\begin{aligned} \Delta J_j^i &= \Delta N^j + \Delta Y^{(2)j} + \eta N^j \\ &= \Delta J_j^i + \eta N^j \end{aligned} \quad (34)$$

Similarly,

$$J_j^i = J_j^i + \eta N^j \quad (35)$$

The effect on $\Delta \gamma_{33}$ is, by use of equations (31), (34), and (35),

$$\begin{aligned} \Delta \gamma_{33} &= J_j^i \Delta J_j^i - 0.5 \Delta J_j^i \Delta J_j^i \\ &= (J_j^i + \eta N^j) (\Delta J_j^i + \eta N^j) - 0.5 (\Delta J_j^i + \eta N^j)^2 \\ &= \Delta \gamma_{33} + J_j^i N^j \eta + 0.5 \eta^2 \end{aligned} \quad (36)$$

Solving this quadratic expression for η ,

$$\eta = -J_j^i N^j + \left[(J_j^i N^j)^2 - 2 \left(\Delta \gamma_{33} - \Delta \gamma_{33}^m \right) \right]^{1/2} \quad (37)$$

From equation (30) it follows that

$$\Delta \gamma_{33} = \frac{\Delta \gamma_3^3 - \Delta \gamma_{31} G^{13} - \Delta \gamma_{32} G^{23}}{G^{33}} \quad (38)$$

and a similar form for $\Delta \gamma_{33}^m$. Substituting these into equation (37):

$$\eta = -J_j^i N^j + \left[(J_j^i N^j)^2 - 2 \left(\frac{\Delta \gamma_3^3 - \Delta \gamma_{31} G^{13} - \Delta \gamma_{32} G^{23}}{G^{33}} - \frac{\Delta \gamma_3^3 - \Delta \gamma_{31} G^{13} - \Delta \gamma_{32} G^{23}}{G^{33}} \right) \right]^{1/2} \quad (39)$$

Up to this point no approximations have been made; however, since the quotient involving modified quantities contains several unknowns it is useful to assume

$$G^{33} \approx G^{33}, \Delta\gamma_{31}^m G^{13} + \Delta\gamma_{32}^m G^{23} \approx \Delta\gamma_{31} G^{13} + \Delta\gamma_{32} G^{23}$$

On this basis equation (39) reduces to

$$\eta = -J_3^j N^j + \left[\left(J_3^j N^j \right)^2 - 2 \left(\frac{\Delta\gamma_3^3 - \Delta\gamma_3^3{}^m}{G^{33}} \right) \right]^{1/2} \quad (40)$$

which will provide the proper η to produce the desired value of $\Delta\gamma_3^3{}^m$.

C. Implementation of the Modification to D^3

The normal sequence of calculations in the PETROS 4 code is indicated in the simplified flow chart of Figure 9 by solid lines. Beginning at subroutine EQUIL2, where values of $\Delta Y^{(2)j}$ and $(Y^{(2)j})_{n+1}$ are determined, the calculations proceed through subroutines GEOMET, STRAIN, and ZETA during which the unmodified geometric quantities N^j , ΔN^j , J_k^j , ΔJ_k^j , G_k^j , G^k , $\Delta\gamma_k^j$ and $\Delta\gamma_k^j{}^*$ are computed. In subroutine ZETA there is a call for subroutine STRESS where the elastoplastic stress calculations are made, after which there would normally be a return to subroutine ZETA for calculation of force and moment resultants at t_{n+1} . However, to implement the desired modification to D^3 the following changes have been incorporated into PETROS 4.

Once the elastoplastic stress increments and stresses $(\tau_k^j)_{n+1}$ have been determined in subroutine STRESS, equation (19) is used to calculate the strain increment $\Delta\gamma_3^3$ for each sublayer. The Gauss point values of $\Delta\gamma_3^3$ are then determined using the mechanical sublayer coefficients. After returning to subroutine ZETA a Gaussian mean value of $\Delta\gamma_3^3$ through the thickness is computed which is then introduced into equation (40) as $\Delta\gamma_3^3{}^m$, thus completing the information necessary to evaluate η . The program then branches back to a point near the end of subroutine EQUIL2 (see dotted path on Figure 9) where $\Delta Y^{(2)j}$ and $(Y^{(2)j})_{n+1}$ are calculated using equations (28) and (29). The program then proceeds forward, calculating modified values of J_k^j , ΔJ_k^j , G_k^j , G^k , $\Delta\gamma_k^j$, and $\Delta\gamma_k^j{}^*$. Clearly, the foregoing procedure could be continued iteratively to cause the difference $\Delta\gamma_3^3 - \Delta\gamma_3^3{}^m$

* While $\Delta\gamma_{33}$ is independent of ζ the use of equation (30) introduces a very slight variation of $\Delta\gamma_3^3$ with ζ . To avoid ambiguity a through-thickness Gaussian average value of $\Delta\gamma_3^3$ is calculated for use in equation (40). A similarly averaged value of G^{33} is also calculated for this purpose.

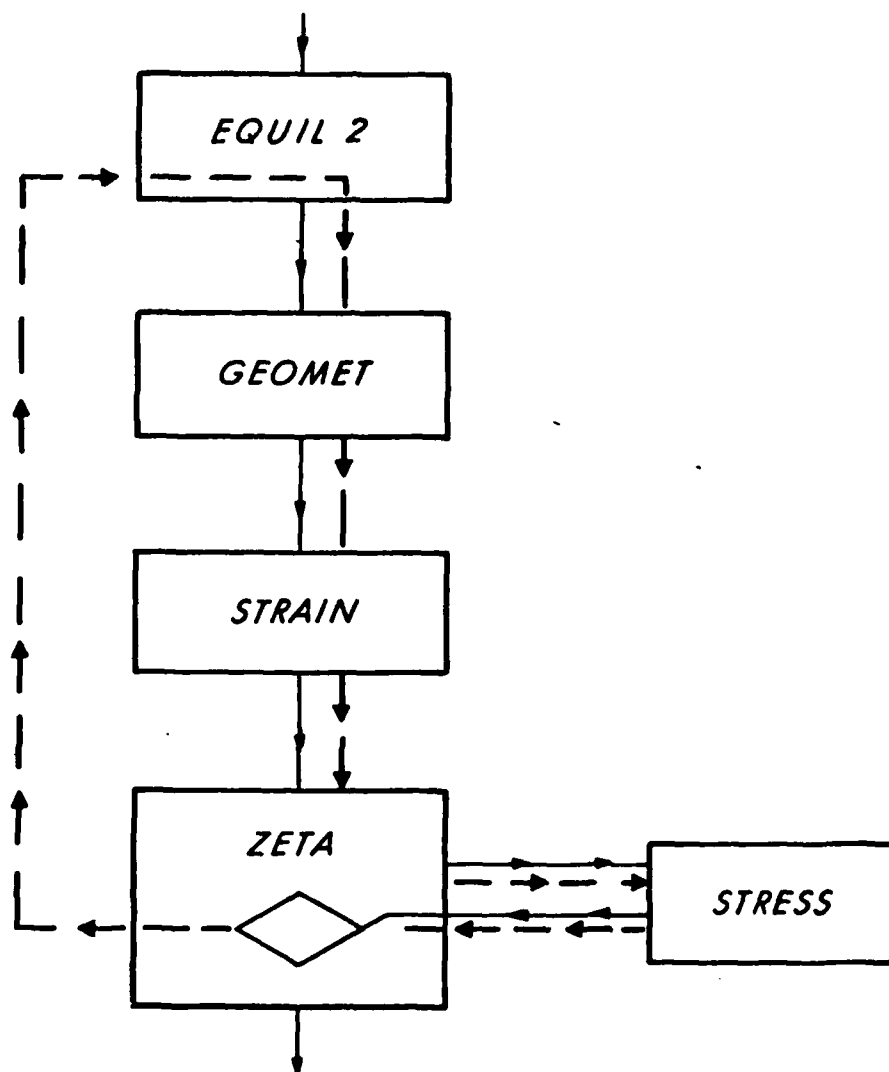


Figure 9. Simplified Flow Chart Showing Recycling Option

to be less than or equal to some small quantity. However, experience has shown that a single recycling back to EQUIL2 for the cited modification is sufficient to control the growth of D^3 and provide the desired compromise value of γ_3^3 . This single recycling step per time step has been incorporated in PETROS 4 as option INORML = 3.

V. ADDITIONAL MISCELLANEOUS PROGRAM CHANGES

A. Addition of Surface Traction Terms

The omission of surface traction terms in the PETROS 4 code was discussed in Section E of Chapter II. These terms were introduced in a general manner by equation (2.71b) of the theoretical formulation report.¹ The specific relations needed to compute values of these quantities are:²

$$\bar{E}_{(1)}^k = - \left[\sqrt{G} G^{3i} J_i^k p \right]_{-h/2}^{h/2} \quad (41)$$

$$\bar{E}_{(2)}^k = \bar{E}_{(3)}^k = - \left[\sqrt{G} G^{3i} J_i^k \zeta p \right]_{-h/2}^{h/2} \quad (42)$$

The evaluation of these expressions has been introduced into the PETROS 4 code through subroutine SFORCE. The finite difference equations of motion in subroutines EQUIL and EQUIL2 were modified to incorporate the values of $\bar{E}_{(1)}^k$ and $\bar{E}_{(2)}^k$, respectively.

It was hoped that the addition of the surface traction terms would eliminate the need for the one-step recycling option. Such was not found to be true and both modifications are required for a satisfactory solution, at least when the ISTRES = 4, INORML = 3 option combination is employed.

B. Symmetry of the Contravariant Stress Components

From equilibrium considerations the contravariant stress tensor τ^{ij} must be symmetric (in the absence of couple stresses) which permits the storing of six rather than nine quantities at all locations where values of this tensor must be saved for use at the next time step. However, the calculations in the STRESS subroutine which provide values of τ^{ij} do not satisfy this requirement exactly. This was true even before the introduction of the ISTRES = 4 option, for which the problem is aggravated since the prescribed value of τ_3^3 generally differs from that which would be calculated using the symmetric $\Delta\gamma_{kl}$ strain increment tensor. After the elastoplastic stresses τ_k^j have been determined and the relation $\tau^{ij} = G^{ik} \tau_k^j$ employed the resulting stresses τ^{ij} are generally not equal to τ^{ji} for $i \neq j$.

¹ I am indebted to my colleague, Dr. J. M. Santiago, Jr., for providing the formulation of these expressions.

In the original version of PETROS 4 this problem was dealt with by selecting τ^{12} , τ^{13} , and τ^{23} as the correct off-diagonal terms and equating τ^{21} , τ^{31} , and τ^{32} to these quantities, respectively. It was felt that this procedure could bias the problem solution so the program was modified to calculate all nine components τ^{ij} and then average the respective symmetrically off-diagonal components; i.e.,

$$\bar{\tau}^{ij} = \bar{\tau}^{ji} = (\tau^{ij} + \tau^{ji})/2 \quad \text{for } i \neq j \quad (43)$$

This modification was found to have a slight but not entirely negligible effect upon lengthy solutions.

C. Storage of Mixed Tensor Stresses

The problems associated with the reconstitution of the τ_k^j sublayer stresses each time step as is done in the original version of PETROS 4 were discussed in Section F of Chapter II. A revised version of this code has been developed in which the τ_k^j stresses are saved for use at the next time step rather than the τ^k stresses. This version requires a 14% increase in computer memory but features a 14% reduction in running time for a representative length run. The revised version is preferred because (a) computer memory is not critical today and any reduction in running time is appreciated, (b) the cumulative deviations from the true solution associated with reconstituting the τ_k^j are circumvented, and (c) this version provides flexibility for future applications involving material failure. The required changes to the code are primarily confined to subroutine STRESS, which is listed in the Appendix.

D. Additions to Printed Output

The format for listing input data on cards for the original version of the PETROS 4 code is presented on pp. 110-129 of the user's manual². In sequel, information is provided concerning modifications or additions to input data controlling various options for printed output.

A useful feature which has been added is a listing at the end of a run of the maximum and minimum values of each mixed tensor stress component along with the locations and times at which these extreme values occur. The format for this output is illustrated in Figure 10. For some applications this may provide all the desired information but, if not, it directs attention to critical locations where a re-run can provide detailed printed and plotted output. Card 5 enters the values of fifteen variables in format (15I5). The first of these variables is MAUXIL, which controls the printing of the max/min values: 0 = no print, 1 = print.

```

MAXIMJM MIXED TENSOR STRESSES

TIME= .197938E-03 ITIME= 337 I1= 2 I2= 5 GAUSS PT. 2 TAU(1,1)= .20002618E+06
TIME= .233531E-02 ITIME= 3975 I1=20 I2=16 GAUSS PT. 2 TAU(1,2)= .30704287E+06
TIME= .192524E-02 ITIME= 3277 I1=20 I2=12 GAUSS PT. 4 TAU(1,3)= .93637187E+05
TIME= .233531E-02 ITIME= 3975 I1=16 I2=20 GAUSS PT. 2 TAU(2,1)= .30704287E+06
TIME= .197988E-03 ITIME= 337 I1= 5 I2= 2 GAUSS PT. 2 TAU(2,2)= .20002618E+06
TIME= .192524E-02 ITIME= 3277 I1=12 I2=20 GAUSS PT. 4 TAU(2,3)= .93637187E+05
TIME= .169783E-03 ITIME= 239 I1= 7 I2= 5 GAUSS PT. 4 TAU(3,1)= .32815313E+05
TIME= .169783E-03 ITIME= 239 I1= 5 I2= 7 GAUSS PT. 4 TAU(3,2)= .32815313E+05
TIME= .164324E-02 ITIME= 2797 I1= 3 I2= 3 GAUSS PT. 4 TAU(3,3)= .16607912E+02

MINIMJM MIXED TENSOR STRESSES

TIME= .229125E-04 ITIME= 39 I1= 2 I2= 2 GAUSS PT. 4 TAU(1,1)= -.28573178E+06
TIME= .220606E-02 ITIME= 3755 I1=20 I2=16 GAUSS PT. 1 TAU(1,2)= -.27961387E+06
TIME= .159683E-02 ITIME= 2718 I1=20 I2= 2 GAUSS PT. 1 TAU(1,3)= -.13696105E+06
TIME= .220606E-02 ITIME= 3755 I1=16 I2=20 GAUSS PT. 1 TAU(2,1)= -.27961387E+06
TIME= .229125E-04 ITIME= 39 I1= 2 I2= 2 GAUSS PT. 4 TAU(2,2)= -.28573178E+06
TIME= .159683E-02 ITIME= 2718 I1= 2 I2=20 GAUSS PT. 1 TAU(2,3)= -.13696105E+06
TIME= .159624E-02 ITIME= 2717 I1=20 I2= 2 GAUSS PT. 1 TAU(3,1)= -.34152247E+05
TIME= .159624E-02 ITIME= 2717 I1= 2 I2=20 GAUSS PT. 1 TAU(3,2)= -.34152247E+05
TIME= .152750E-04 ITIME= 26 I1= 2 I2= 2 GAUSS PT. 4 TAU(3,3)= -.21151544E+06

```

Figure 10. Sample of Max/Min Stress Output

The PETROS 4 code controls the printing of groups of output data through the entries on card 6a, which contains the variables

KF,IOUT(K) (K-1,KF) Format (1615)

KF = number of print options available (currently = 14) and IOUT(K) is the cyclic frequency at which the K^{th} print option is to be printed. To avoid the printing of the K^{th} option, set IOUT(K) to an integer greater than the final time step = ITIMEF. The first eleven print options have not been changed.

Print option K=12 has been modified to provide a rather extensive output of geometric and stress variables which is useful for code checking. This information, a portion of which is illustrated in Figure 11, is provided at mesh location (IS₁,IS₂) the coordinates of which are entered on card 27b in format (215). At each Gauss point the following geometric data are listed:

$$J_k^j \equiv \text{GBASE}(J,K), \Delta J_k^j \equiv \text{DGBASE}(J,K), G_k \equiv G(J,K), G \equiv \text{GTYPE}, \\ G^k \equiv \text{GG}(J,K), \Delta \gamma_k \equiv \text{DGAM}(J,K), \text{ and } \Delta \gamma_k^j \equiv \text{DGAMMX}(J,K).$$

This is followed by a row of printing which gives the pressures $p(\xi^a, t_n) \equiv P(11,12)$, $p(\xi^a, t_{n+1}) \equiv PPL(11,12)$ and the value of G^{33} on the loaded surface. Next, the code lists for each sublayer associated with the Gauss point the arrays of

$(\tau_k^j)_n \equiv \text{TN}(J,K)$ and $\tau_k^j{}_{n+1} \equiv \text{TR}(J,K)$. The value of $C \equiv \text{CZ}$ is then printed as well as $\sigma_Y^2 \equiv \text{SIGMSQ}$. If $C \leq 0$ the stress increment in the sublayer is elastic and $(\tau_k^j)_{n+1} \equiv \text{TR}(J,K)$. For $C > 0$ the stress change is elastoplastic and the following information is printed: $A \equiv \text{AZ}$, $B \equiv \text{BZ}$, and the discriminant $B^2 - AC \equiv \text{DISCR}$. This is

followed by $\tau_k^j{}_n \equiv \text{TC}(J,K)$, $\lambda = \text{HLAMDA}$ and $\tau_k^j{}_{n+1} \equiv \text{TM}(J,K)$. Regardless of whether the stress state is elastic or plastic the code then prints "(REVISED)DGAMMX(3,3) = ." This is the sublayer strain increment $\Delta \gamma_3^3$ consistent with the constitutive relations which is determined by use of equation (19). The corresponding value of $\Delta \gamma_3^3$ obtained by use of the strain-displacement relations is printed with the rest of such quantities in the DGAMMX(J,K) array for the Gauss point. When the preceding material has been printed for all sublayers at one Gauss point the corresponding material is listed for all the other Gauss points at the selected mesh point.

At the end of this output group the value of $\Delta \gamma_3^3 \equiv \text{AGAM33}$ is printed.

Print option K=13 has been added which provides the array of total Gauss point mixed tensor stresses TAUF(J,K), a sample of which is shown in Figure 12. The frequency of output of this array is controlled by the value assigned to IOUT(13) on card 6a. The location(s) at which these stresses are printed are determined by entries on two cards: on card 27c the value of NUM (= number of points at which mixed tensor stresses are to be printed (and plotted)) in format (15) and on card 27d the values of coordinate pairs $\text{IPS}_1(1), \text{IPS}_2(1)$ in format (215) for $I = 1, \text{NUM}$.

```

TIME, 35 TIME= .20562500E-04 11= 3 12= 4 IGAUSS= 1
SUBROUTINE ZETA
GBASE(1,1)= .37893251895738E+00 GBASE(1,2)= -.413256987744E-03 GBASE(1,3)= .35550497437237E-02
GBASE(2,1)= -.360067057460506E-03 GBASE(2,2)= .40110469810599E+00 GBASE(2,3)= .775469468757733E-02
GBASE(3,1)= -.869704612229633E-02 GBASE(3,2)= -.17738543504857E-01 GBASE(3,3)= .997215493648903E+00
UGBASE(1,1)= .109700035526450E-03 UGBASE(1,2)= -.10088335294948E-04 UGBASE(1,3)= .320614335387140E-03
UGBASE(2,1)= -.352052696718141E-04 UGBASE(2,2)= .695762027705736E-04 UGBASE(2,3)= .695859400429576E-03
UGBASE(3,1)= -.806974886417549E-03 UGBASE(3,2)= -.165142814188526E-02 UGBASE(3,3)= .148983139703584E-04
C(1,1)= .143603218756590E+00 C(1,2)= -.274631947023525E-03 C(1,3)= .256931207027375E-03
C(2,1)= -.274631947023525E-03 C(2,2)= .160455244345924E+00 C(2,3)= .621220124778138E-03
C(3,1)= .256931207027375E-03 C(3,2)= .621220124778138E-03 C(3,3)= .94482403583486E+00
CTYPE= .434922515244921E+02
CG(1,1)= .696365818140230E+01 CG(1,2)= .118895414151621E-01 CG(1,3)= -.180540539655156E-02
CG(2,1)= .118895414151621E-01 CG(2,2)= .621332652360197E+01 CG(2,3)= -.388247825648656E-02
CG(3,1)= -.180540539655156E-02 CG(3,2)= .388247825648656E-02 CG(3,3)= .100520073317927E+01
UGAM(1,1)= .426833672033370E-04 UGAM(1,2)= -.103586723556792E-04 UGAM(1,3)= .708412576162949E-05
UGAM(2,1)= -.103586723556792E-04 UGAM(2,2)= .330992722892061E-04 UGAM(2,3)= .174118638177484E-04
UGAM(3,1)= .708412576162949E-05 UGAM(3,2)= .174118638177484E-04 UGAM(3,3)= .147795106023350E-04
UGAMMX(1,1)= .296957176747182E-03 UGAMMX(1,2)= -.71752351970449E-04 UGAMMX(1,3)= .493117582772549E-04
UGAMMX(2,1)= -.71752351970449E-04 UGAMMX(2,2)= .235465406514481E-03 UGAMMX(2,3)= .108212467043010E-03
UGAMMX(3,1)= .493117582772549E-04 UGAMMX(3,2)= .108212467043010E-03 UGAMMX(3,3)= .147763738242392E-04
P(1,1)= .165449061751486E+06 P(1,1,1)= .161464111607328E+06 SURFACE CG(3,3)= .100520073317927E+01
SUBROUTINE STRESS
ISP= 1
TN(1,1)= .135630384408410E+02 TN(1,2)= -.205973615010952E+05 TN(1,3)= .199573980166363E+05
TN(2,1)= -.183428640377496E+05 TN(2,2)= .116939574041466E+06 TN(2,3)= .429011455632432E+05
TN(3,1)= .285565307072260E+04 TN(3,2)= .688918368105165E+04 TN(3,3)= -.115820941288514E+05
TR(1,1)= .147240795731694E+06 TR(1,2)= -.222791951385260E+05 TR(1,3)= .211178298512595E+05
TR(2,1)= -.198398093672534E+05 TR(2,2)= .126455658221882E+06 TR(2,3)= .454373752595638E+05
TR(3,1)= .302168753489503E+04 TR(3,2)= .729682268944645E+04 TR(3,3)= -.112706943061650E+05
* * * ISB= 1 L= 1 LC= 1 L2= .112706943061650E+05 SIGMSQ= .231640000000000E+11
AZ= .60895211412449411E+10 AZ= .987751093967023E+10 LISQ= .897632223346856E+20
TC(1,1)= .910444120134951E+05 TC(1,2)= -.205973615010952E+05 TC(1,3)= .199573980166363E+05
TC(2,1)= -.205973615010952E+05 TC(2,2)= .723536011465513E+05 TC(2,3)= .429011455632432E+05
TC(3,1)= .199573980166363E+05 TC(3,2)= .429011455632432E+05 TC(3,3)= 0.
MLAPCA= .480366781850871E-01
TM(1,1)= .142006880490751E+06 TM(1,2)= -.210837426975426E+05 TM(1,3)= .199595687650763E+05
TM(2,1)= -.210837426975426E+05 TM(2,2)= .122256495563181E+06 TM(2,3)= .429475352805667E+05
TM(3,1)= .199595687650763E+05 TM(3,2)= .429475352805667E+05 TM(3,3)= -.112706943061650E+05
(REVISED) DGAMMX(3,3)= -.376152435240412E-03
SUBROUTINE STRESS
ISP= 2
TN(1,1)= .135630384408410E+02 TN(1,2)= -.205973615010952E+05 TN(1,3)= .199573980166363E+05
TN(2,1)= -.183428640377496E+05 TN(2,2)= .116939574041466E+06 TN(2,3)= .429011455632432E+05
TN(3,1)= .285565307072260E+04 TN(3,2)= .688918368105165E+04 TN(3,3)= -.115820941288514E+05
TR(1,1)= .147240795731694E+06 TR(1,2)= -.222791951385260E+05 TR(1,3)= .211178298512595E+05
TR(2,1)= -.198398093672534E+05 TR(2,2)= .126455658221882E+06 TR(2,3)= .454373752595638E+05
TR(3,1)= .302168753489503E+04 TR(3,2)= .729682268944645E+04 TR(3,3)= -.112706943061650E+05
* * * ISB= 2 L= 1 LC= 1 L2= -.923271177036889E+11 SIGMSQ= .164025000000000E+12
(REVISED) DGAMMX(3,3)= -.187267242611658E-03
SUBROUTINE STRESS
ISP= 3
TN(1,1)= .135630384408410E+02 TN(1,2)= -.205973615010952E+05 TN(1,3)= .199573980166363E+05
TN(2,1)= -.183428640377496E+05 TN(2,2)= .116939574041466E+06 TN(2,3)= .429011455632432E+05
TN(3,1)= .285565307072260E+04 TN(3,2)= .688918368105165E+04 TN(3,3)= -.115820941288514E+05
TR(1,1)= .147240795731694E+06 TR(1,2)= -.222791951385260E+05 TR(1,3)= .211178298512595E+05
TR(2,1)= -.198398093672534E+05 TR(2,2)= .126455658221882E+06 TR(2,3)= .454373752595638E+05
TR(3,1)= .302168753489503E+04 TR(3,2)= .729682268944645E+04 TR(3,3)= -.112706943061650E+05
* * * ISB= 3 L= 1 LC= 1 L2= -.156249111770375E+13 SIGMSQ= .236852699499997E+13
(REVISED) DGAMMX(3,3)= -.187267242611658E-03
SUBROUTINE STRESS
ISP= 4
TN(1,1)= .135630384408410E+02 TN(1,2)= -.205973615010952E+05 TN(1,3)= .199573980166363E+05
TN(2,1)= -.183428640377496E+05 TN(2,2)= .116939574041466E+06 TN(2,3)= .429011455632432E+05
TN(3,1)= .285565307072260E+04 TN(3,2)= .688918368105165E+04 TN(3,3)= -.115820941288514E+05
TR(1,1)= .147240795731694E+06 TR(1,2)= -.222791951385260E+05 TR(1,3)= .211178298512595E+05
TR(2,1)= -.198398093672534E+05 TR(2,2)= .126455658221882E+06 TR(2,3)= .454373752595638E+05
TR(3,1)= .302168753489503E+04 TR(3,2)= .729682268944645E+04 TR(3,3)= -.112706943061650E+05
* * * ISB= 4 L= 1 LC= 1 L2= -.981387711770375E+13 SIGMSQ= .147456000000000E+14
(REVISED) DGAMMX(3,3)= -.187267242611658E-03
TIME, 35 TIME= .20562500E-04 11= 3 12= 4 IGAUSS= 2
SUBROUTINE ZETA
GBASE(1,1)= .378205310921024E+00 GBASE(1,2)= -.186990377125572E-03 GBASE(1,3)= .357545760510226E-02
GBASE(2,1)= -.186990377125572E-03 GBASE(2,2)= .400946626384346E+00 GBASE(2,3)= .779267737706874E-02
SUBROUTINE STRESS
ISP= 4
TN(1,1)= -.148107553084206E+06 TN(1,2)= .195886776111032E+05 TN(1,3)= .258255223114955E+05
TN(2,1)= .174518329476193E+05 TN(2,2)= -.130142462352690E+06 TN(2,3)= .541003399135265E+05
TN(3,1)= .368981010467346E+04 TN(3,2)= .468264981549050E+04 TN(3,3)= -.155230328352574E+06
TR(1,1)= .1558249460305899E+06 TR(1,2)= .216656511782414E+05 TR(1,3)= .273367214570208E+05
TR(2,1)= .193028894416050E+05 TR(2,2)= -.135240157478074E+06 TR(2,3)= .568215478303290E+05
TR(3,1)= .390655411819357E+04 TR(3,2)= .9102138018738775E+04 TR(3,3)= -.151056756959810E+06
* * * ISB= 4 L= 1 LC= 1 L2= -.982608.14351544E+11 SIGMSQ= .147456000000000E+14
(REVISED) DGAMMX(3,3)= .258758683316771E-03
ACAM(1,1)= .17587413767404E-04

```

Figure 11. Sample of Geometric and Stress Output Data

```

TIME = .293750E-03  ITIME = 500  I1 = 2  I2 = 3  GAUSS PT. = 1  TAUSPH = 328.0
MIXED TENSOR STRESSES
TAUF(1,1) = -34615.2  TAUF(1,2) = .0  TAUF(1,3) = -.0
TAUF(2,1) = .0  TAUF(2,2) = 35544.7  TAUF(2,3) = 4127.1
TAUF(3,1) = .0  TAUF(3,2) = 1343.4  TAUF(3,3) = .5
TIME = .293750E-03  ITIME = 500  I1 = 2  I2 = 3  GAUSS PT. = 2  TAUSPH = 35448.2
MIXED TENSOR STRESSES
TAUF(1,1) = -14415.4  TAUF(1,2) = .0  TAUF(1,3) = -.0
TAUF(2,1) = .0  TAUF(2,2) = 126257.6  TAUF(2,3) = -672.1
TAUF(3,1) = .0  TAUF(3,2) = 513.4  TAUF(3,3) = 7.0
TIME = .293750E-03  ITIME = 500  I1 = 2  I2 = 3  GAUSS PT. = 3  TAUSPH = 32231.5
MIXED TENSOR STRESSES
TAUF(1,1) = 155164.7  TAUF(1,2) = -.0  TAUF(1,3) = .0
TAUF(2,1) = -.0  TAUF(2,2) = -38483.2  TAUF(2,3) = -6263.7
TAUF(3,1) = -.0  TAUF(3,2) = -1243.8  TAUF(3,3) = 5.0
TIME = .293750E-03  ITIME = 500  I1 = 2  I2 = 3  GAUSS PT. = 4  TAUSPH = 5609.5
MIXED TENSOR STRESSES
TAUF(1,1) = 100779.0  TAUF(1,2) = -.0  TAUF(1,3) = -.0
TAUF(2,1) = -.0  TAUF(2,2) = -83361.0  TAUF(2,3) = -10016.4
TAUF(3,1) = -.0  TAUF(3,2) = -1341.3  TAUF(3,3) = 7.0

```

Figure 12. Sample Printout of Gauss Point Stresses

TIME= .293750E-03 ITIME= 500
 SUBDIVISIONS OF TIME INCREMENT IN STRESS

LMAT(I1,I2 1) LAYER 1 GAUSS PT. 1 SUBLAYER 1																					
I1	I2=	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2		0	0	2	2	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
3		0	2	2	2	3	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0
4		0	2	2	2	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
5		0	2	3	2	2	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0
6		0	0	2	0	2	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
7		0	2	2	2	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
8		0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
9		0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13. Sample Printout of Elastoplastic Activity Matrix

Print option K=14 provides the matrix of integer values L discussed in Section B of Chapter III (see Figure 13). These integers indicate the level of elastoplastic activity currently taking place at each mesh location: zero indicates elastic behavior, one signifies normal plastic behavior, and any integer ≥ 2 specifies rapid plastic flow requiring the code to subdivide the time step into L equal substeps for purposes of stress evaluation. The code will provide an L matrix for each sublayer at each Gauss point at time intervals determined by the value assigned to IOUT(14).

E. Additions to Plotted Output

The PETROS 4 program had already been altered to couple with the REPSIL plotting program (Appendix D of Reference 7). With this plotting package one obtains isometric plots of the deformed shell surface at selected time intervals, two dimensional plots of displacement vs time, load vs time, and surface strains vs time as well as an energy balance diagram. The plot of pressure loading vs time is generated for mesh location (IP₁, IP₂), the coordinates of which are entered on card 27a in format (215).

The following plotted output has been added:

1. The cartesian components of $\bar{D}$, i.e., $Y^{(2)k}$ are plotted vs time at the same mesh location already selected for $Y^{(1)k}$.
2. Mixed tensor stress components τ_k^j vs time (see Figures 1-5) are plotted for each Gauss point through the thickness for the mesh point location selected for print option K=13.
3. Also, for the same location, a plot of the through-thickness strain component γ_3^j vs time has been added.

VI. CONCLUDING REMARKS

The modifications to the PETROS 4 code discussed in the foregoing text have resulted in an improved version which is suitable for use even in rather exceptional applications such as those cited in the Introduction, where the hydrostatic component of stress is a significant fraction of the largest principal stress. The concept of prescribed through-thickness normal stress is considered to be a novel approximate procedure for taking account of this stress component in elastoplastic stress evaluations. The problem of unstable growth of through-thickness strain γ_3^j has been successfully circumvented with the introduction of the INORML = 3 (recycling) option. It is believed that the SHEAR option with the ISTRES = 4, INORML = 3 combination will satisfactorily treat the elastoplastic response of panels subjected to blast from nearby explosive charges and serve as a point-of-departure for studies of panel rupture.

The difficulty with the $ISTRES = 0$, $INORML = 0$ combination cited in Chapter II persists and is not alleviated by the addition of surface traction terms and use of recycling. In retrospect, it is concluded that the $ISTRES = 0$ option will not, in general, give a satisfactory representation for stresses in thin and moderately thick shells since there is nothing in the basic PETROS 4 formulation to enforce the stress boundary conditions on the two shell surfaces (or more significantly, at the Gauss points closest to the surfaces). By contrast the $ISTRES = 4$ option does satisfy the surface boundary condition on the normal stress and by use of a constrained three-dimensional constitutive formulation provides elastoplastic stresses which appear to be realistic.

The $INORML = 2$ option was intended to take account of an average thickness change by modifying the $Y^{(2)j}$ variables at the next time step. While the problem with this option (shown in Figure 5) was not resolved the subject appears moot since the new $INORML = 3$ option takes account of $\Delta\gamma_j^3$ changes in the current time step. One remaining issue which deserves further study is correction or improvement of the formulation for the plastic work.

The cited modifications to the PETROS 4 program have affected only a few subroutines of this rather lengthy code; a listing of these revised subroutines is provided in the Appendix. Consideration was given to inclusion of an application of the modified PETROS 4 code in this report but, owing to the complexity of such results, it is preferred to present these as a separate document.

REFERENCES

1. S. D. Pirotin, L. Morino, E. A. Witmer, and J. W. Leech, "Finite-Difference Analysis for Predicting Large Elastic-Plastic Transient Deformations of Variable-Thickness Kirchhoff, Soft Bonded Thin, and Transverse-Shear Deformable Thicker Shells," US Army Ballistic Research Laboratory Contract Report No. 315, September 1976. AD B 015924L
2. S. D. Pirotin, B. A. Berg, and E. A. Witmer, "PETROS 4: New Developments and Program Manual for the Finite-Difference Calculation of Large Elastic-Plastic, and/or Viscoelastic Transient Deformations of Multilayer Variable-Thickness (1) Thin Hard-Bonded, (2) Moderately-Thick Hard-Bonded, or (3) Thin Soft-Bonded Shells," US Army Ballistic Research Laboratory Contract Report No. 316, September 1976. AD B 014255L
3. H. F. Bohnenblust, and P. Duwez, "Some Properties of a Mechanical Model of Plasticity," *Journal of Applied Mechanics*, Vol. 15, No. 3, September 1948, pp. 222-225.
4. G. N. White, Jr., "Application of the Theory of Perfectly Plastic Solids to Stress Analysis of Strain Hardening Solid," Graduate Div. of Applied Math., Brown University Tech Report 51, August 1950.
5. J. F. Besseling, "A Theory of Plastic Flow for Anisotropic Hardening in Plastic Deformation of an Initially Isotropic Material," Report 5410, National Aeronautical Research Institute, Amsterdam, The Netherlands, 1953.
6. N. J. Huffington, Jr., "Numerical Analysis of Elastoplastic Stresses," US Army Ballistic Research Laboratory Memorandum Report No. 2006, September 1969. AD 861688
7. J. M. Santiago, H. L. Wisniewski, and N. J. Huffington, Jr., "A User's Manual for the REPSIL Code," US Army Ballistic Research Laboratory Report No. 1744, October 1974. AD A 003176.

NOMENCLATURE

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
	$\bar{A}_\alpha$	Deformed reference surface base vectors
A(LA,LB)		Covariant components of metric tensor of deformed reference surface
ABSCIS (IGAUSS,NGAUSL)		Location of IGAUSSth of the N Gaussian stations in a particular layer; interval is -1 to +1.
ACC(J,I1,I2)	$\ddot{Y}^{(1)j}$	Acceleration components
ALPHA		Coefficient of linear thermal expansion
AGAM33	$\Delta \gamma_3^m$	Gaussian average of SGAM33
ANUM		Status of material (in FMAT)
AVEG33	G^{33}	Gaussian average G^{33}
AVIS (ILAYER)		Viscoelastic coefficient of ILAYER
AZ	A	Coefficient in quadratic equation
B(LA,LB)		Covariant components of deformed reference surface curvature tensor
BM(LA,LB)		Mixed curvature tensor components of deformed reference surface
BSTIV(ILAYER)		Elastic modulus coefficient of ILAYER
BZ	B	Coefficient in quadratic equation
CAPQ1(LA,I1,I2) CAPQ2(LA,I1,I2) CAPQ3(LA,I1,I2)		Generalized force resultant tensor
CAP2Q1(LA,I1,I2) CAP2Q2(LA,I1,I2) CAP2Q3(LA,I1,I2)		Generalized force in EQUIL2
COEFF(ISB)		Weighting factors of the mechanical sublayer model

<u>FORTTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
CONST		Strain-rate sensitivity parameter
CS(J,LA)		See ZETA 158-163
CX(I,J)		See ZETA 358-375
CZ	C, ϕ_{n+1}^T	Coefficient in quadratic equation
C1		Viscous damping parameter
	$\bar{D}(\xi^\alpha, t)$	Non-Kirchhoff displacement field
	D^α, D^3	Tangential and normal components of $\bar{D}$ in basis $\bar{G}_i$
D(J,I1,I2)	$\Delta Y^{(1)j}$	Incremental change in $Y^{(1)j}$
DA(LA,LB)		Incremental change in the covariant components of the metric tensor associated with the deformed midsurface of the shell
DB(LA,LB)		Incremental change in the corresponding curvature tensor
DD(I,LA)	$\frac{\partial \Delta Y^{(1)j}}{\partial \xi^\alpha}$	
DD2(J,LA)	$\frac{\partial \Delta Y^{(2)j}}{\partial \xi^\alpha}$	
DEL		See ZETA 146,156
DELBAR	η	See ZETA 409
DELNOR		See EQUIL2 174
DELSN1		See EQUIL2 176,180
DELSN2		See EQUIL2 177,181
DELSN3		See EQUIL2 178,182
DELTA(I,J)	δ_j^i	Kronecker delta

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
DELTAP		Previous time increment
DELTAT	Δt	Time increment
DGAM(I,J)	$\Delta \gamma_{ij}$	Covariant components of strain increment
DGAMAT		See STRESS 263
DGAMA3		Average $\Delta \gamma_3^3$
DGAMMA		See STRESS 94, 95, 96
DGAMMX(I,J)	$\Delta \gamma^j_i$	Mixed components of the incremental strain tensor
DGAM33	$\Delta \gamma_3^3$	Mixed component of incremental strain tensor at Gauss point
DGBASE(I,J)	ΔJ^j_i	Cartesian components of base vector increment
DGTEMP		See STRESS 93
DGM33	$\Delta \gamma_3^3$	Gaussian average $\Delta \gamma_3^3$
DGOG		See ZETA 408
DISCR		Discriminant of quadratic equation
DJR		Saved value of D from previous time step
DN(J)	ΔN^j	Incremental change in component of surface normal
DTAU33		See STRESS 123
DTEMP		Temperature increment
DTM(I,J)		Incremental change in stress
DUM		Intermediate variable
DX1		Increment in ξ^1 coordinate
DX2		Increment in ξ^2 coordinate

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
DZ(I)	$\frac{\partial z}{\partial \xi^a}, \frac{\partial z}{\partial \zeta}$	
DZA1(I1,I2)	$\frac{\partial z^{(A)}}{\partial \xi^1}$	
DZA2(I1,I2)	$\frac{\partial z^{(A)}}{\partial \xi^2}$	
DZB1(I1,I2)	$\frac{\partial z^{(B)}}{\partial \xi^1}$	
DZB2(I1,I2)	$\frac{\partial z^{(B)}}{\partial \xi^2}$	
D2(J,I1,I2)	$\Delta Y^{(2)j}$	Incremental change in $Y^{(2)j}$
D33S		See ZETA 297
EE	E	Young's modulus
EEP		See STRESS 102
EL		Number of subdivisions of time step
EPSL1(I1,I2)		Normal strain components on lower surface
EPSL2(I1,I2)		
EPSU1(I1,I2)		Normal strain components on upper surface
EPSU2(I1,I2)		
ES	E	Young's modulus
ETERM1		See STRESS 195
ETERM2		See STRESS 196
E1(J,I1,I2)	$\bar{E}_{(1)}^j$	Surface force term for EQUIL
E2(J,I1,I2)	$\bar{E}_{(2)}^j$	Surface force term for EQUIL2
FACTOR		Coefficient of strain-rate sensitivity
FMAS11(I1,I2)		Generalized masses
FMAS22(I1,I2)		
FMAS23(I1,I2)		

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
FMAT		Material status array
FORCES(J)		Component of externally-applied force per unit area in j-direction
FORCEZ(J)		Convenient grouping of force components
	$\bar{G}_3$	Covariant basis vector component of deformed shell in direction of normal
G(I,J)	G_{ij}	Covariant components of the metric tensor of the deformed surface
GAMMAL(I1,I2)		Shear strain component on lower surface
GAMMAU(I1,I2)		Shear strain component on upper surface
GBASE(I,J)	J_i^j	Cartesian components of the base vector $\bar{G}_i$ in j-direction
GBTN	$J_3^j N^j$	See ZETA 225
GG(I,J)	G^{ij}	Contravariant components of the metric tensor of the deformed surface
GTYPE	G	Metric determinant
HLAMDA	λ	Plasticity parameter
HM(LA,J)		Contravariant components of the relative moment-resultant tensor
HM1(LA,I1,I2) HM2(LA,I1,I2)		Storage of components of HM
HN(LA,J)		Contravariant components of the relative stress-resultant tensor
HNU	ν	Poisson's ratio
HNUP		See STRESS 104,105
HNUPP		See STRESS 103,106

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
HTERM		See STRESS 241
	$\bar{i}_k$	Cartesian unit vector in k-direction
I		Component index
ICOUNT		Output control counter
IC1 IC2		Mesh indices selected by user at which specific output is desired
IFRACT		Failure model selector
IGAUSS	IGAUSS	Gauss point index
IGMAX(I,J)		Gauss point index where maximum value of stress component occurs
IGMIN(I,J)		Gauss point index where minimum value of stress component occurs
IGO		Selector for calculation or output of max/min stresses
III		Output control index
IJ		Number of components
ILAYER		Layer index
INORML	INORML	Control number for options regarding $\gamma^{(2)}$ modification
IOUT(K)		Printout indicator
IPLAST(I1,I2)		Plasticity indicator
IPS1(I) IPS2(I)		Coordinates of locations at which output of Gauss point mixed tensor stresses is desired
IRY1,IRY2, IRY3,IRY4		Indices corresponding to the limits of the complete finite difference grid
ISB		Sublayer index
ISTRES	ISTRES	Plasticity model control

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
ISTREZ		Plasticity model control
ISUBL		Sublayer index
IS1(I) IS2(I)		Coordinates of locations at which output of geometric and stress variables is desired (IOUT(12))
ITIM(I,J)		Time cycle of maximum value of stress component
ITIME		Current cycle number
ITIMEF		Final cycle number
ITIMEP		ITIME-1
ITIMM(I,J)		Time cycle of minimum value of stress component
IV		Component index
IZ		Gauss layer counter
IZZ		Upper/lower surface selector
I1	I1	Mesh point index
I1M		I1-1
I1MAX(I,J)		I1 location where maximum value of stress component occurs
I1MIN(I,J)		I1 location where minimum value of stress component occurs
I1P		I1 + 1
I2	I2	Mesh point index
I2M		I2-1
I2MAX(I,J)		I2 location where maximum value of stress component occurs
I2MIN(I,J)		I2 location where minimum value of stress component occurs

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
I2P		I2+1
J		Component index
JD1		Number of stress memory locations in ξ^1 -direction
JD2		Number of stress memory locations in ξ^2 -direction
JD3		Number of stress memory locations in ξ -direction
JV		Component index
	K	Bulk modulus = $E/(3(1-2\nu))$
K		Component index
K1,K2,K3,K4		Boundary condition control indices on the four boundary lines
KF		Number of print options available
L	L	Number of subdivisions of time increment
LA,LB		Component indices
LC		Counter for time increment subdivision
LEN		See STRESS 73
LI1I2		Input to LMAT
LL		Index of mesh points for IOUT(13)
LMAT(I1,I2,IZ)		Plasticity activity arrays
LS		Component index
LZ		See STRESS 444
MAX		Integer controlling output heading
MAUXIL		Controls max/min stress output
MIN		Integer controlling output heading

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
MPHYS		PHYSIC control variable
MTEMPE		Index for temperature effects
	$\bar{N}$	Deformed reference surface normal
	$\bar{n}$	Undeformed reference surface normal
NGAUSL		Number of Gauss stations in layer
NGAUSS(ILAYER)		Number of Gauss stations in layer = ILAYER
NLAYER		Number of layers
NMESH1		Number of meshes in ξ^1 -direction
NMESH2		Number of meshes in ξ^2 -direction
NSBL		Number of sublayers
NSUBL(ILAYER)		Number of sublayers in i-th layer
NUM		Number of mesh points at which IOUT(13) is desired
P(I1,I2)	p	Pressure
	p_0	Peak value of pressure
PAR		See ZETA 304
PARSQ		See ZETA 305
PARSQZ		See ZETA 376
PGAM33	γ_3^3	See ZETA 413
PPL(I1,I2)		Pressure at next time step
PRSQD1		See ZETA 319
PRSQD2		See ZETA 320
PRSQD3		See ZETA 321
PRSQZZ		See ZETA 343

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
QCZ		Logical variable for time step subdivision
QIRCH		Logical variable for Kirchhoff shell theory
QM		Logical variable for max/min stress calculation
QPRINT(20)		Printout indicator
QQQ2,QQQ3,QQQ4		Logical variables used in STRESS for defining coefficients of constitutive functions
QQ1,QQ2		Logical variables used in EQUIL to avoid calculations at boundary points
Q11		Logical variable for maximum or minimum stress selection
QSHEAR		Logical variable for SHEAR option
QSTRES		Logical variable for stress erasure
	$\bar{r}_o$	Undeformed shell reference surface position vector
SGAM33		See ZETA 398
SIGMA(ISB)		Uniaxial yield stress of the ISBth sublayer
	σ_Y	Static uniaxial yield stress of the material
SIGN		± 1 .
SN(J,I1,I2)	N^j	Components of the surface normal
SQRG	$\sqrt{G}$	$\sqrt{G}$
STRESL(J,I1,I2) STRESP(LA,I1,I2) STRESQ(LA,I1,I2)		Generalized forces calculated in ZETA
SUMG		See ZETA 396
SURFGG		G^{33} at shell surface
TAU(I,J)	τ^{ij}	Contravariant stress components at Gauss points

<u>FORTTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
	C	
TAUC	τ_m^m	Trace of the corrector stress tensor
TAUF(I,J)	τ_j^i	Mixed tensor stress components at Gauss points
TAUM	$(\tau_m^m)_{n+1}$	Trace of the new mixed stress tensor
TAUMAX(I,J)		Maximum value of the stress component
TAUMIN(I,J)		Minimum value of the stress component
TAUP(LZ,I,J)		Storage of TAUF stresses
TAUSPH		Hydrostatic stress
TAUSPL(LL,IGAUSS)		Storage of TAUSPH
TAUSUM		See ZETA 400
	T	
TAUT	τ_m^m	Trace of the trial stress tensor
TAU11(I1,I2,Iz)		Storage of mixed tensor sublayer stresses
TAU12(I1,I2,Iz)		
TAU13(I1,I2,Iz)		
TAU21(I1,I2,Iz)		
TAU22(I1,I2,Iz)		
TAU23(I1,I2,Iz)		
TAU31(I1,I2,Iz)		
TAU32(I1,I2,Iz)		
TAU33(I1,I2,Iz)		
	C	
TC(I,J)	τ_j^i	Mixed tensor corrector stress components
THIC		See ZETA 201
THICKN	h	Shell thickness
THICKZ		See ZETA 200
THIKZ		See ZETA 151
TIM(I,J)		Time of maximum value of stress component

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
TIME	t, t_n	Time
TIMM		Time of minimum value of stress component
TM(I,J)	$(\tau_j^i)_{n+1}$	New mixed tensor sublayer stresses
TN(I,J)	$(\tau_j^i)_n$	Previous mixed tensor sublayer stresses
TR(I,J)	τ $(\tau_j^i)_{n+1}$	Trial mixed tensor sublayer stresses
T33		See STRESS 121
T33PL		See STRESS 122
	$\bar{u}$	Displacement field vector
	$\bar{u}_0$	Displacement vector of points on the reference surface
	v^α, w	Components of $\bar{u}_0$ in surface -normal directions
WEIGHT (IGAUSS,NGAUSL)		Gaussian weighting factors
Y(J,I1,I2)	$Y^{(1)j}$	Rectangular cartesian coordinates of mesh point (I1,I2)
YLDFAC	YLDFAC	Factor controlling subdivision of time step
YY(J,LA)	$\frac{\partial Y^{(1)j}}{\partial \xi^\alpha}$	
YYU(J,LA)	$Y^{(1)\alpha j}$	
YY2(J,LA)	$\frac{\partial Y^{(2)j}}{\partial \xi^\alpha}$	
Y2(J,I1,I2)	$Y^{(2)j}$	Rectangular cartesian components of $\bar{D}$
Y2DOT2(J,I1,I2)		Acceleration of $Y^{(2)j}$
Y3ACEL(J)		Rectangular cartesian components of $\ddot{N}$

<u>FORTRAN NAME</u>	<u>TEXT SYMBOL</u>	<u>DESCRIPTION</u>
Z	ζ	Distance from reference surface
	ζ_g	Distance of Gauss point from reference surface
ZA(I1,I2)		ζ location of interface of upper and middle layer
ZB(I1,I2)		ζ location at interface of lower and middle layer
ZCEN		See ZETA 152
ZCENTR		Value of ζ at the center of a given layer
ZZ		Displacement field parameter
ZZCEN		See ZETA 155
	γ_{33}	Covariant strain component in through-thickness direction
	ξ^a	Curvilinear coordinates of particles on the reference surface
	$\overset{T}{\Delta \tau}_j^i$	Mixed tensor trial stress increment
	ϕ_n	Yield function
	$()_n$	Quantity evaluated at t_n
	$()_{n+1}$	Quantity evaluated at t_{n+1}
	$()^{(m)}$	Modified quantity
	INT []	Integer part of []

APPENDIX A

Listing of Significantly Affected Subroutines

APPENDIX A

Listing of Significantly Affected Subroutines

C	SUBROUTINE AUXIL(INDEXX)	AUXIL 1
C		AUXIL 2
C	IMPLICIT LOGICAL(Q)	AUXIL 3
C		AUXIL 4
C	COMMON /CARTE/ YTEST,YNEW,YSAVE	AUXIL 5
	COMMON /CARTEL/ Y(3,20,20),D(3,20,20),Y2(3,20,20),D2(3,20,20)	AUXIL 6
	LEVEL 2,Y,D,Y2,D2	AUXIL 7
C		AUXIL 8
	COMMON /CTIME/ AUX(20),TIME,DELTAT,TIMEF,ITIME,ITIMEF,IAUX(20),	AUXIL 9
	• IOUT(20),QPRINT(20)	AUXIL 10
	COMMON /CTIMEL/ IPLAST(20,20),P(20,20),PPL(20,20)	AUXIL 11
	LEVEL 2,IPLAST,P,PPL	AUXIL 12
C		AUXIL 13
	COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,NZ,N1M,N2M,AUXIL 14	AUXIL 15
	• N1M,N2M,I1,I2,I2,I1ZERO,I2ZERO,IRY1,IRY2,IRY3,IRY4,ISTR1,ISTR2,AUXIL 16	AUXIL 17
	• ISTR3,ISTR4,IC1,IC2,ID1,ID2,IP1,IP2,IS1,IS2,K1,K2,K3,K4,KRUN,AUXIL 18	AUXIL 19
	• KZSTOP,KYTEST,IDIR,I1TEST,I2TEST,KINITL	AUXIL 20
C		AUXIL 21
	COMMON /QLOGIC/ QAUX(20),QZETA,QSTRES,QPLAST,QSENS1,QEQUIL,	AUXIL 22
	• QDIAGN,QINGEO,QINVEL,QLOAD,QMATPR,QTHIKL,QTEMP,QSPTEM,QAUX11,	AUXIL 23
	• QAUX12,QSPLOA,QIMPUL,QSHARP,QPESO,QIRCH,QSHEAR	AUXIL 24
C		AUXIL 25
	COMMON /FRAC/ TAUF(3,3),TAUSPH,NUM,IPS1(10),IPS2(10)	AUXIL 26
C		AUXIL 27
	II=INDEXX	AUXIL 28
	IF(INDEXX .GE. 4) II=4	AUXIL 29
	IF(INDEXX .EQ. 11) II=5	AUXIL 30
	GOTO(1001,1002,1003,1004,1005),II	AUXIL 31
C		AUXIL 32
	1001 IF(II.EQ.IC1.AND.I2.EQ.IC2) CALL PRINT(1)	AUXIL 33
C		AUXIL 34
	RETURN	AUXIL 35
C		AUXIL 36
	1002 CALL PRINT(2)	AUXIL 37
	403 FORMAT(215,3E15,6)	AUXIL 38
	III=ITIME/IOUT(9)*IOUT(9)-ITIME	AUXIL 39
	IF(III.NE.0.AND..NOT.QPRINT(9)) GO TO 409	AUXIL 40
	WRITE(NWRITE,401) ITIME	AUXIL 41
	401 FORMAT(///9X,"CIRCUMFERENTIAL POSITIONS AT ITIME=","15//"	AUXIL 42
	• 2X,"X","Y1",13X,"Y2",13X,"Y3")	AUXIL 43
	IF(.NOT.QIRCH) WRITE(NWRITE,4011)	AUXIL 44
	4011 FORMAT("•",64X,"Y2(1)",10X,"Y2(2)",10X,"Y2(3)")	AUXIL 45
	DO 402 I1=ISTR1,ISTR3	AUXIL 46
	WRITE(NWRITE,403) I1,IC2,Y(1,I1,IC2),Y(2,I1,IC2),Y(3,I1,IC2)	AUXIL 47
	IF (QIRCH) GO TO 402	AUXIL 48
	WRITE(NWRITE,1403) Y2(1,I1,IC2),Y2(2,I1,IC2),Y2(3,I1,IC2)	AUXIL 49
	1403 FORMAT("•",59X,3E15,6)	AUXIL 50
	402 CONTINUE	AUXIL 51
C		AUXIL 52
	WRITE(NWRITE,411) ITIME	AUXIL 53
	411 FORMAT(///12X,"CROWN POSITIONS AT ITIME=","15//"	AUXIL 54
	• 8X,"Y1",13X,"Y2",13X,"Y3")	AUXIL 55
	IF(.NOT.QIRCH) WRITE(NWRITE,4011)	AUXIL 56
	DO 412 I2=ISTR2,ISTR4	AUXIL 57
	WRITE(NWRITE,403) IC1,I2,Y(1,IC1,I2),Y(2,IC1,I2),Y(3,IC1,I2)	AUXIL 58
	IF (QIRCH) GO TO 412	AUXIL 59
	WRITE(NWRITE,1403) Y2(1,IC1,I2),Y2(2,IC1,I2),Y2(3,IC1,I2)	AUXIL 60
	412 CONTINUE	AUXIL 61
	409 CONTINUE	

C	III=ITIME/IOUT(10)*IOUT(10)-ITIME	AUXIL 52
	IF (III.NE.0.AND..NOT.QPRINT(10)) GO TO 429	AUXIL 53
C		AUXIL 54
	WRITE(NWRITE,466)ITIME,TIME,IC1,IC2,Y(1,IC1,IC2),Y(2,IC1,IC2),	AUXIL 55
	• Y(3,IC1,IC2)	AUXIL 56
	466 FORMAT(" ITIME=",I5," TIME=",E13.6/" POSITION OF DESIRED POINT	AUXIL 57
	• (I1="I2=",I2="I2.") IS Y(1)=",E13.6," Y(2)=",E13.6,	AUXIL 58
	•" Y(3)=",E13.6)	AUXIL 59
	IF (QIRCH) GO TO 429	AUXIL 60
	WRITE(NWRITE,1466) Y2(1,IC1,IC2),Y2(2,IC1,IC2),Y2(3,IC1,IC2)	AUXIL 61
	1466 FORMAT(48X,"Y2(1)=",E13.6," Y2(2)=",E13.6," Y2(3)=",E13.6)	AUXIL 62
	429 CONTINUE	AUXIL 63
C		AUXIL 64
	RETURN	AUXIL 65
C		AUXIL 66
C		AUXIL 67
	1003 IF (I1.EQ.IC1.AND.I2.EQ.IC2) CALL PRINT(3)	AUXIL 68
	RETURN	AUXIL 69
	1004 IF (I1.EQ.IS1 .AND. I2.EQ.IS2) CALL PRINT(INDEXX)	AUXIL 70
	RETURN	AUXIL 71
C	MIXED TENSOR STRESSES CHECK	AUXIL 72
	1005 III=ITIME/IOUT(13)*IOUT(13)-ITIME	AUXIL 73
	IF (III.NE.0 .AND. .NOT. QPRINT(13))GOTO 1020	AUXIL 74
	DO 1010 L=1,NUM	AUXIL 75
	IF (I1.EQ.IPS1(L) .AND. I2.EQ.IPS2(L))GOTO 1015	AUXIL 76
	1010 CONTINUE	AUXIL 77
	GOTO 1020	AUXIL 78
	1015 CALL PRINT (INDEXX)	AUXIL 79
	1020 RETURN	AUXIL 80
	END	AUXIL 81

	SUBROUTINE EQUIL	EQUIL 1
C		EQUIL 2
C		EQUIL 3
C	EVALUATE THE DISPLACEMENT INCREMENTS AND FROM THEM EVALUATE THE	EQUIL 4
C	NEW POSITIONS	EQUIL 5
C		EQUIL 6
C	IMPLICIT LOGICAL(Q)	EQUIL 7
C		EQUIL 8
C	COMMON /CARTE/ YTEST,YNEW,YSAVE	EQUIL 9
	COMMON /CARTEL/ Y(3,20,20),D(3,20,20),Y2(3,20,20),D2(3,20,20)	EQUIL 10
	LEVEL 2,Y,D,Y2,D2	EQUIL 11
C		EQUIL 12
	COMMON /CTIME/ AUX(20),TIME,DELTAT,TIMEF,ITIME,ITIMEF,IAUX(20),	EQUIL 13
	* IOUT(20),QPRINT(20)	EQUIL 14
	COMMON /CTIMEL/ IPLAST(20,20),P(20,20),PPL(20,20)	EQUIL 15
	LEVEL 2,IPLAST,P,PPL	EQUIL 16
C		EQUIL 17
	COMMON /CTIMER/ ITIMEC,ITIMER,DELTAP,DELX,OMR,UNH,MEE	EQUIL 18
	* ,TKEEP,MTHIK,QFINIS,QFINO,YSTART,YSTART,YDOTF	EQUIL 19
	* ,ES,OSTIV(4),NSTIV(4)	EQUIL 20
C		EQUIL 21
	COMMON /DAMP/ MDAMP,DAMPF,DFACT,TDAMP,TOTKP,C1	EQUIL 22
C		EQUIL 23
	COMMON /FORCB/ FORCEZ(3)	EQUIL 24
C		EQUIL 25
	COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,NZ,N1M,N2M,	EQUIL 26
	* N1MM,N2MM,I1,I2,IZ,I1ZERO,I2ZERO,IRY1,IRY2,IRY3,IRY4,ISTR1,ISTR2,	EQUIL 27
	* ISTR3,ISTR4,IC1,IC2,ID1,ID2,IP1,IP2,IS1,IS2,K1,K2,K3,K4,KRUN,	EQUIL 28
	* KZSTOP,KYTEST,IOIR,I1TEST,I2TEST,KTNITL	EQUIL 29
C		EQUIL 30
	COMMON /PUSH/ FORCES(3),VELOC(3),RATIO,RATIOM,DX1,DX2,TEMP,DTFMP,	EQUIL 31
	* FSPACE,TSFACE,FINCNO,FSTOP,TSTOP,THCOEF	EQUIL 32
	COMMON /PUSHL/ SQRA1(20,20),SQRA2(20,20),FMAS11(20,20),	EQUIL 33
	* FMAS22(20,20),FMAS23(20,20),FMAS33(20,20)	EQUIL 34
	LEVEL 2,SQRA1,SQRA2,FMAS11,FMAS22,FMAS23,FMAS33	EQUIL 35
C		EQUIL 36
	COMMON /QBCOND/ Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q11,Q12,Q13,Q14,Q15	EQUIL 37
	* ,QFREE1,QFREE2,QFREE3,QFREE4,QFCORN,QQ1,QQ2	EQUIL 38
	* TRAC1,QTRAC2,QTRAC3,QTRAC4	EQUIL 39
C		EQUIL 40
	COMMON /SURNOM/ SNPR(3)	EQUIL 41
	COMMON /SURNOL/ SN(3,20,20)	EQUIL 42
	LEVEL 2,SN	EQUIL 43
C		EQUIL 44
	COMMON /S2/ STRESE(3)	EQUIL 45
	COMMON /S2L/ STRESL(3,20,20),STRESQ(2,20,20),STRESP(2,20,20)	EQUIL 46
	LEVEL 2,STRESL,STRESQ,STRESP	EQUIL 47
C		EQUIL 48
	COMMON /TNCOMP/ HM1(2,20,20),HM2(2,20,20),CAPQ1(2,20,20),	EQUIL 49
	* CAPQ2(2,20,20),CAPQ3(2,20,20),CAPQ4(2,20,20),	EQUIL 50
	* CAPQ5(2,20,20),CAPQ6(2,20,20)	EQUIL 51
	LEVEL 2,HM1,HM2,CAPQ1,CAPQ2,CAPQ3,CAPQ4,CAPQ5,CAPQ6	EQUIL 52
C		EQUIL 53
	COMMON /VELS/ Y3ACEL(3),Y3DOT(3),Y3ACPO(4,3)	EQUIL 54
	COMMON /VELSL/ VELO(3,20,20),ACC(3,20,20)	EQUIL 55
	LEVEL 2,VELO,ACC	EQUIL 56
C		EQUIL 57
	COMMON /SURFOR/ E1(3,20,20),E2(3,20,20)	EQUIL 58
	LEVEL 2,E1,E2	EQUIL 59
C		EQUIL 60
C		EQUIL 61
	TFPMY=DELTAT/DELTAP	EQUIL 62
C		EQUIL 63
	QQ1=I1.EQ.IRY1.OR.I1.EQ.IRY3	EQUIL 64
	QQ2=I2.EQ.IRY2.OR.I2.EQ.IRY4	EQUIL 65
C		EQUIL 66
	I1P=I1+1	EQUIL 67
	I1M=I1-1	EQUIL 68
	I2P=I2+1	EQUIL 69
	I2M=I2-1	EQUIL 70
C		EQUIL 71
	L1=ISIGN(1,N1-2*I1)	EQUIL 72
	L2=ISIGN(1,N2-2*I2)	EQUIL 73
C		EQUIL 74
	TFPM=1./FMAS11(I1,I2)	EQUIL 75
	TERM2=DELTAT*DELTAT	EQUIL 76
	DO 29P J=1,3	EQUIL 77
C		EQUIL 78

C	DISPLACEMENTS FOR VISCOUS DAMPING	EQUIL 79
	DJR=DIJ.11.12)	EQUIL 80
C		EQUIL 81
C	NEXT STATEMENTS AVOID IMPERFECTIONS DUE TO ROUND-OFF ERRORS	EQUIL 82
C		EQUIL 83
	IF(K1.EQ.7.AND.J.EQ.1) GO TO 298	EQUIL 84
	IF(K2.EQ.7.AND.J.EQ.2) GO TO 298	EQUIL 85
	IF(K1.EQ.5.AND.I1.EQ.2.AND.J.EQ.1) GO TO 298	EQUIL 86
	IF(K2.EQ.5.AND.I2.EQ.2.AND.J.EQ.2) GO TO 298	EQUIL 87
	IF(K3.EQ.5.AND.I1.EQ.N1M.AND.J.EQ.1) GO TO 298	EQUIL 88
	IF(K4.EQ.5.AND.I2.EQ.N2M.AND.J.EQ.2) GO TO 298	EQUIL 89
	IF(K1.EQ.6.AND.J.EQ.1) GO TO 298	EQUIL 90
	IF(K2.EQ.6.AND.J.EQ.2) GO TO 298	EQUIL 91
C	DERIV=0.	EQUIL 92
C		EQUIL 93
	DX=DX1	EQUIL 94
	DXFACT=.5/DX	EQUIL 95
C		EQUIL 96
	IF(QQ1) GO TO 111	EQUIL 97
C		EQUIL 98
	GO TO (102,104,106). J	EQUIL 99
102	DERIV=DERIV+DXFACT*(CAPQ1(1,I1P,I2)-CAPQ1(1,I1M,I2))	EQUIL 100
	GO TO 119	EQUIL 101
104	DERIV=DERIV+DXFACT*(CAPQ2(1,I1P,I2)-CAPQ2(1,I1M,I2))	EQUIL 102
	GO TO 119	EQUIL 103
106	DERIV=DERIV+DXFACT*(CAPQ3(1,I1P,I2)-CAPQ3(1,I1M,I2))	EQUIL 104
	GO TO 119	EQUIL 105
C		EQUIL 106
C		EQUIL 107
	111 DUM=DXFACT*L1	EQUIL 108
	GO TO (112,114,116). J	EQUIL 109
112	DERIV=DERIV+DUM*(-3.*CAPQ1(1,I1,I2)+4.*CAPQ1(1,I1+L1,I2)-CAPQ1(1,I1+2*L1,I2))	EQUIL 110
	GO TO 119	EQUIL 111
114	DERIV=DERIV+DUM*(-3.*CAPQ2(1,I1,I2)+4.*CAPQ2(1,I1+L1,I2)-CAPQ2(1,I1+2*L1,I2))	EQUIL 112
	GO TO 119	EQUIL 113
116	DERIV=DERIV+DUM*(-3.*CAPQ3(1,I1,I2)+4.*CAPQ3(1,I1+L1,I2)-CAPQ3(1,I1+2*L1,I2))	EQUIL 114
	GO TO 119	EQUIL 115
119	CONTINUE	EQUIL 116
C		EQUIL 117
C		EQUIL 118
C		EQUIL 119
	DX=DX2	EQUIL 120
	DXFACT=.5/DX	EQUIL 121
C		EQUIL 122
	IF(QQ2) GO TO 131	EQUIL 123
C		EQUIL 124
	GO TO (122,124,126). J	EQUIL 125
122	DERIV=DERIV+DXFACT*(CAPQ1(2,I1,I2P)-CAPQ1(2,I1,I2M))	EQUIL 126
	GO TO 139	EQUIL 127
124	DERIV=DERIV+DXFACT*(CAPQ2(2,I1,I2P)-CAPQ2(2,I1,I2M))	EQUIL 128
	GO TO 139	EQUIL 129
126	DERIV=DERIV+DXFACT*(CAPQ3(2,I1,I2P)-CAPQ3(2,I1,I2M))	EQUIL 130
	GO TO 139	EQUIL 131
C		EQUIL 132
C		EQUIL 133
	131 DUM=DXFACT*L2	EQUIL 134
	GO TO (132,134,136). J	EQUIL 135
132	DERIV=DERIV+DUM*(-3.*CAPQ1(2,I1,I2)+4.*CAPQ1(2,I1+I2+L2)-CAPQ1(2,I1+2*L2,I2))	EQUIL 136
	GO TO 139	EQUIL 137
134	DERIV=DERIV+DUM*(-3.*CAPQ2(2,I1,I2)+4.*CAPQ2(2,I1+I2+L2)-CAPQ2(2,I1+2*L2,I2))	EQUIL 138
	GO TO 139	EQUIL 139
136	DERIV=DERIV+DUM*(-3.*CAPQ3(2,I1,I2)+4.*CAPQ3(2,I1+I2+L2)-CAPQ3(2,I1+2*L2,I2))	EQUIL 140
	GO TO 139	EQUIL 141
139	CONTINUE	EQUIL 142
C		EQUIL 143
C		EQUIL 144
	DERIV=DERIV+FORCEZ(J)	EQUIL 145
	ACC(J,I1,I2)=(DERIV+FI(J,I1,I2))*TFRM	EQUIL 146
	D(J,I1,I2)=D(J,I1,I2)+TERM1*ACC(J,I1,I2)+TERM2	EQUIL 147
	V(J,I1,I2)=V(J,I1,I2)+D(J,I1,I2)	EQUIL 148
C	VISCOUS DAMPING C1	EQUIL 149
	IF(TDAMP.EQ.0.0)GOTO 298	EQUIL 150
	D(J,I1,I2)=D(J,I1,I2)-(D(J,I1,I2)+DJR)*C1	EQUIL 151
298	CONTINUE	EQUIL 152
	RETURN	EQUIL 153
	END	EQUIL 154
		EQUIL 155
		EQUIL 156
		EQUIL 157
		EQUIL 158
		EQUIL 159

	SUBROUTINE EQUIL2	EQUIL2 1
C		EQUIL2 2
C		EQUIL2 3
C	EVALUATE MIDSURFACE GEOMETRIC QUANTITIES (BASE VECTORS, SURFACE	EQUIL2 4
C	NORMAL, METRIC TENSOR, CURVATURE TENSOR, ETC.)	EQUIL2 5
C		EQUIL2 6
	IMPLICIT LOGICAL (Q)	EQUIL2 7
C		EQUIL2 8
	COMMON /CARTE/ YTEST,YNEW,YSAVE	EQUIL2 9
	COMMON /CARTEL/ Y(3,20,20),D(3,20,20),Y2(3,20,20),D2(3,20,20)	EQUIL210
	LEVEL 2,Y,D,Y2,D2	EQUIL211
C		EQUIL212
	COMMON /CTIME/ AUX(20),TIME,DELTAT,TIMEF,ITIME,ITIMEF,IAUX(20),	EQUIL213
	• IOUT(20),QPRINT(20)	EQUIL214
	COMMON /CTIME/ IPLAST(20,20),P(20,20),PPL(20,20)	EQUIL215
	LEVEL 2,IPLAST,P,PPL	EQUIL216
C		EQUIL217
	COMMON/CTIMER/ITIMEC,ITIMER,DELTAP,DELX,QMP,UNM,HEE	EQUIL218
	• ,TKFEP,MTHIK,QFINIS,QFINP,TSTART,YSTART,YOOTF	EQUIL219
	• ,ES,RSTIV(4),NSTIV(4)	EQUIL220
C		EQUIL221
	COMMON /OPTERM/ MDISPL(4),MDISDR(4,3),PERID(4,3),DISPL(4,3),QDISP3	EQUIL222
	COMMON /OPTERL/ PRSCRR(3,20,20)	EQUIL223
	LEVEL 2,PRSCRR	EQUIL224
C		EQUIL225
	COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,NZ,N1M,N2M,	EQUIL226
	• N1NM,N2NM,I1,I2,I2,I1ZERO,I2ZERO,IRY1,IRY2,IRY3,IRY4,ISTR1,ISTR2,	EQUIL227
	• ISTR3,ISTR4,IC1,IC2,ID1,ID2,IP1,IP2,IS1,IS2,K1,K2,K3,K4,KRUN,	EQUIL228
	• KZSTOP,KYTEST,IDIR,I1TEST,I2TEST,KINITL	EQUIL229
C		EQUIL230
	COMMON /OPTION/ MAUXIL,MINGEO,MINVEL,MLOAD,MMATPR,MSPLOA,	EQUIL231
	• MSPTEM,MTEMPE,MTHIKL,MIMPUL,ISTRES,INORML,ISTREZ	EQUIL232
C		EQUIL233
	COMMON /POLEGH/ SNPOLF(4,3),VELPOL(4,3),NUMS(4),NPL,LOCPOL(4),QPOLE	EQUIL234
	• ,DYPOLF(4,3),YPOLE(4,3),D2POLE(4,3),Y2POLE(4,3),JPOLE(4)	EQUIL235
	• ,QPOLET	EQUIL236
C		EQUIL237
	COMMON /PUSH/ FORCES(3),VELOC(3),RATIO,RATION,OX1,OX2,TEMP,DTEMP,	EQUIL238
	• FSPACE,TSPACE,FINCND,FSTOP,TSTOP,THCOEF	EQUIL239
	COMMON /PUSH/ SQRTAT(20,20),SQRAZ(20,20),FMAS11(20,20),	EQUIL240
	• FMAS22(20,20),FMAS23(20,20),FMAS33(20,20)	EQUIL241
	LEVEL 2,SQRTAT,SQRAZ,FMAS11,FMAS22,FMAS23,FMAS33	EQUIL242
C		EQUIL243
	COMMON /QRCOND/ Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q11,Q12,Q13,Q14,Q15	EQUIL244
	• ,QFREE1,QFREE2,QFREE3,QFREE4,QFCORN,QQ1,QQ2	EQUIL245
	• TRAC1,QTRAC2,QTRAC3,QTRAC4	EQUIL246
C		EQUIL247
	COMMON /SURNOM/ SNPR(3)	EQUIL248
	COMMON /SURNOL/ SN(3,20,20)	EQUIL249
	LEVEL 2,SN	EQUIL250
C		EQUIL251
	COMMON /S2/ STRESF(3)	EQUIL252
	COMMON /S2L/ STRESL(3,20,20),STRESQ(2,20,20),STRESP(2,20,20)	EQUIL253
	LEVEL 2,STRESL,STRESQ,STRESP	EQUIL254
C		EQUIL255
	COMMON /TENCOM/ YY(3,2),YYY(3,2,2),A(3,3),B(3,3),AA(3,3),BB(3,3),	EQUIL256
	• RM(3,3),DA(3,3),DR(3,3),G(3,3),GR(3,3),DN(3),DN(3,2),DDO(3,2,2),	EQUIL257
	• DGAM(3,3),DGAMX(3,3),HN(3,3),HQ(2),TAU(3,3),TAUSRL(3,3)	EQUIL258
	• ,DD2(3,2),DDO2(3,2,2),YY2(3,2),YYY2(3,2,2),YYU(3,2),DPM(3,3)	EQUIL259
C		EQUIL260
C		EQUIL261
	COMMON /TNCOMP/ HM1(2,20,20),HM2(2,20,20),CAPQ1(2,20,20),	EQUIL262

	* CAPQ2(2,20,20),CAPQ3(2,20,20),CAPQ01(2,20,20),	EQUIL263
	* CAP2Q2(2,20,20),CAP2Q3(2,20,20)	EQUIL264
	LEVEL 2,MM1,MM2,CAPQ1,CAPQ2,CAPQ3,CAP2Q1,CAP2Q2,CAP2Q3	EQUIL265
C	COMMON /VELS/ Y3ACEL(3),Y3DOT(3),Y3ACPO(4,3)	EQUIL266
	COMMON /VELSL/ VELO(3,20,20),ACC(3,20,20)	EQUIL267
	LEVEL 2,VELO,ACC	EQUIL268
C	COMMON /ZACCEL/ SNDOT2(3,20,20),Y2DOT2(3,20,20)	EQUIL270
	LEVEL 2,SNDOT2,Y2DOT2	EQUIL271
C	COMMON /DELC/ ICOUNT	EQUIL272
	COMMON /DEL/ DELBAR(20,20)	EQUIL273
	LEVEL 2,DELRAR	EQUIL274
	COMMON /SURFOR/ E1(3,20,20),E2(3,20,20)	EQUIL275
	LEVEL 2,E1,E2	EQUIL276
	TERMT=DELTAT/DELTAP	EQUIL277
	Q01=I1.EQ.IRY1.OR.I1.EQ.IRY3	EQUIL278
	Q02=I2.EQ.IRY2.OR.I2.EQ.IRY4	EQUIL279
	I1P=I1-1	EQUIL290
	I2P=I2-1	EQUIL291
	I1M=I1-1	EQUIL292
	I2M=I2-1	EQUIL293
	L1=ISTGN(1,N1-2*I1)	EQUIL294
	L2=ISTGN(1,N2-2*I2)	EQUIL295
	TERMT2=DELTAT*DELTAT	EQUIL296
	IF(ICOUNT.EQ.0)GOTO 400	EQUIL297
	CALL NACEL	EQUIL298
	DO 298 J=1,3	EQUIL299
C	NO Y2 STRAIN ON G9 SLIDING-CLAMPED EDGE IN MOISDR(K,J)=1 DIRECTION	EQUIL299
C	IF(Q01.AND.I1.EQ.IRY1.AND.K1.EQ.9.AND.MOISDR(1,J).EQ.1) GO TO 390	EQUIL299
	IF(Q01.AND.I1.EQ.IRY1.AND.K3.EQ.9.AND.MOISDR(3,J).EQ.1) GO TO 390	EQUIL299
	IF(Q02.AND.I2.EQ.IRY2.AND.K2.EQ.9.AND.MOISDR(2,J).EQ.1) GO TO 390	EQUIL299
	IF(Q02.AND.I2.EQ.IRY4.AND.K4.EQ.9.AND.MOISDR(4,J).EQ.1) GO TO 390	EQUIL299
C	TO AVOID ROUNDOFF IMPERFECTIONS	EQUIL299
C	IF (K1.EQ.7.AND.J.EQ.1) GO TO 390	EQUIL100
	IF (K2.EQ.7.AND.J.EQ.2) GO TO 390	EQUIL101
	IF (K1.EQ.5.AND.I1.EQ.2.AND.J.EQ.1) GO TO 390	EQUIL102
	IF (K2.EQ.5.AND.I2.EQ.2.AND.J.EQ.2) GO TO 390	EQUIL103
	IF (K3.EQ.5.AND.I1.EQ.N1M.AND.J.EQ.1) GO TO 390	EQUIL104
	IF (K4.EQ.5.AND.I2.EQ.N2M.AND.J.EQ.2) GO TO 390	EQUIL105
	IF (K1.EQ.6.AND.J.EQ.1) GO TO 390	EQUIL106
	IF (K2.EQ.6.AND.J.EQ.2) GO TO 390	EQUIL107
C	DFRIV=0.	EQUIL108
C	DX=DX1	EQUIL109
	DXFACT=.5/DX	EQUIL110
C	IF(Q01) GO TO 130	EQUIL111
C	GO TO (120,124,126), J	EQUIL112
	120 DERIV=DERIV+DXFACT*(CAP2Q1(1,I1P,I2)-CAP2Q1(1,I1M,I2))	EQUIL113
	GO TO 140	EQUIL114
	124 DERIV=DFRIV+DXFACT*(CAP2Q2(1,I1P,I2)-CAP2Q2(1,I1M,I2))	EQUIL115
	GO TO 140	EQUIL116
	126 DERIV=DERIV+DXFACT*(CAP2Q3(1,I1P,I2)-CAP2Q3(1,I1M,I2))	EQUIL117
	GO TO 140	EQUIL118
C	170 OIJM=DXFACT*L1	EQUIL119
	GO TO (132,134,136), J	EQUIL120
	132 DFRIV=DERIV-DUM*(-3.*CAP2Q1(1,I1,I2)+4.*CAP2Q1(1,I1+L1,I2)-CAP2Q1	EQUIL121
	* 1,I1+2*L1,I2))	EQUIL122
		EQUIL123
		EQUIL124
		EQUIL125
		EQUIL126
		EQUIL127
		EQUIL128

```

      GO TO 140
134 DERIV=DERIV+DUM*(-3.*CAP2Q2(1.I1.I2)+4.*CAP2Q2(1.I1+L1.I2)-CAP2Q2
    * 1.I1+2*L1.I2))
      GO TO 140
136 DERIV=DERIV+DUM*(-3.*CAP2Q3(1.I1.I2)+4.*CAP2Q3(1.I1+L1.I2)-CAP2Q3
    * 1.I1+2*L1.I2))
140 CONTINUE
C
C
C      DX=DX2
      DXFACT=.5/DX
C
      IF(QQ2) GO TO 151
C
      GO TO (142,144,146).J
142 DERIV=DERIV+DXFACT*(CAP2Q1(2.I1.I2P)-CAP2Q1(2.I1.I2M))
      GO TO 160
144 DERIV=DERIV+DXFACT*(CAP2Q2(2.I1.I2P)-CAP2Q2(2.I1.I2M))
      GO TO 160
146 DERIV=DERIV+DXFACT*(CAP2Q3(2.I1.I2P)-CAP2Q3(2.I1.I2M))
      GO TO 160
C
C
151 DUM=DXFACT*L2
      GO TO (152,154,156).J
152 DERIV=DERIV+DUM*(-3.*CAP2Q1(2.I1.I2)+4.*CAP2Q1(2.I1.I2+L2)-CAP2Q1
    * 2.I1.I2+2*L2))
      GO TO 160
154 DERIV=DERIV+DUM*(-3.*CAP2Q2(2.I1.I2)+4.*CAP2Q2(2.I1.I2+L2)-CAP2Q2
    * 2.I1.I2+2*L2))
      GO TO 160
156 DERIV=DERIV+DUM*(-3.*CAP2Q3(2.I1.I2)+4.*CAP2Q3(2.I1.I2+L2)-CAP2Q3
    * 2.I1.I2+2*L2))
160 CONTINUE
C
      Y2DOT2(J,I1,I2)=(DERIV+E2(J,I1,I2)-STRESL(J,I1,I2)-FMAS23(I1,I2)
    * *Y3ACEL(J))/FMAS22(I1,I2)
C
      D2(J,I1,I2)=D2(J,I1,I2)+TERM1+TERM2*Y2DOT2(J,I1,I2)
      Y2(J,I1,I2)=Y2(J,I1,I2)+D2(J,I1,I2)
300 CONTINUE
298 CONTINUE
C
      TAKE OUT NORMAL COMPONENT WHEN IT IS DESIRED TO BE ZERO
      IF(INORML.NE.1) GO TO 300
      DELNOR=SN(1.I1.I2)*D2(1.I1.I2)+SN(2.I1.I2)*D2(2.I1.I2)
    * *SN(3.I1.I2)*D2(3.I1.I2)
      DELSN1=DELNOR*SN(1.I1.I2)
      DELSN2=DELNOR*SN(2.I1.I2)
      DELSN3=DELNOR*SN(3.I1.I2)
      GOTO 410
400 DELSN1=-DELSN1*(1.I1.I2)*SN(1.I1.I2)
      DELSN2=-DELSN2*(1.I1.I2)*SN(2.I1.I2)
      DELSN3=-DELSN3*(1.I1.I2)*SN(3.I1.I2)
410 D2(1.I1.I2)=D2(1.I1.I2)-DELSN1
      D2(2.I1.I2)=D2(2.I1.I2)-DELSN2
      D2(3.I1.I2)=D2(3.I1.I2)-DELSN3
      Y2DOT2(1.I1.I2)=Y2DOT2(1.I1.I2)-TERM2*DELSN1
      Y2DOT2(2.I1.I2)=Y2DOT2(2.I1.I2)-TERM2*DELSN2
      Y2DOT2(3.I1.I2)=Y2DOT2(3.I1.I2)-TERM2*DELSN3
      Y2(1.I1.I2)=Y2(1.I1.I2)-DELSN1
      Y2(2.I1.I2)=Y2(2.I1.I2)-DELSN2
      Y2(3.I1.I2)=Y2(3.I1.I2)-DELSN3
300 CONTINUE
      RETURN
      END

```

EQUIL129
 EQUIL130
 EQUIL131
 EQUIL132
 EQUIL133
 EQUIL134
 EQUIL135
 EQUIL136
 EQUIL137
 EQUIL138
 EQUIL139
 EQUIL140
 EQUIL141
 EQUIL142
 EQUIL143
 EQUIL144
 EQUIL145
 EQUIL146
 EQUIL147
 EQUIL148
 EQUIL149
 EQUIL150
 EQUIL151
 EQUIL152
 EQUIL153
 EQUIL154
 EQUIL155
 EQUIL156
 EQUIL157
 EQUIL158
 EQUIL159
 EQUIL160
 EQUIL161
 EQUIL162
 EQUIL163
 EQUIL164
 EQUIL165
 EQUIL166
 EQUIL167
 EQUIL168
 EQUIL169
 EQUIL170
 EQUIL171
 EQUIL172
 EQUIL173
 EQUIL174
 EQUIL175
 EQUIL176
 EQUIL177
 EQUIL178
 EQUIL179
 EQUIL180
 EQUIL181
 EQUIL182
 EQUIL183
 EQUIL184
 EQUIL185
 EQUIL186
 EQUIL187
 EQUIL188
 EQUIL189
 EQUIL190
 EQUIL191
 EQUIL192
 EQUIL193
 EQUIL194

```

SUBROUTINE PRINT(INDEX)
IMPLICIT LOGICAL(I)
C
COMMON /ALLENE/ TOTAL,TOTKIN,TOTELA,TOTPLA,TOTWEX,TOTTEM,INFRGY
* .TOTVIS,TOTF1,TOTE2,ECHECK
* .DTM(3,3),SQRG,SQRA,SIGMSQ,AZ,RZ,CZ
C
COMMON /CARTE/ YTEST,YNEW,YSAVE
COMMON /CARTEL/ Y(3,20,20),O(3,20,20),Y2(3,20,20),O2(3,20,20)
LEVEL 2,Y,O,Y2,O2
C
COMMON /CTIME/ AUX(20),TIME,DELTAT,TIMEF,ITIME,ITIMFF,IAUX(20),
* IOUT(20),QPRINT(20)
COMMON /CTIMEL/ IPLAST(20,20),P(20,20),PPL(20,20)
LEVEL 2,IPLAST,P,PPL
C
COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,NZ,N1M,N2M,
* N1NM,N2NM,I1,I2,I3,I1ZERO,I2ZERO,I3Y1,I3Y2,I3Y3,I3Y4,ISTR1,ISTR2,
* ISTR3,ISTR4,IC1,IC2,IO1,IO2,IP1,IP2,IS1,IS2,K1,K2,K3,K4,KRUN,
* KZSTOP,KYTEST,IOIR,I1TEST,I2TEST,KINITL
C
COMMON /PHYSCH/ EE,MNU,ALPHA,CONST,EXPON,FACTOR,RATE,RHO,
* MLAMDA,COEFF(5),SIGMA(5),TM(3,3),TC(3,3),DELTA(3,3)
C
COMMON /POLEGH/SNPOLE(4,3),VELPOL(4,3),NUMS(4),NPL,LOCPOL(4),QPOLE
* .DYPOLE(4,3),YPOLE(4,3),O2POLE(4,3),Y2POLE(4,3),JPOLE(4)
* .QPOLET
C
COMMON /QBCOND/Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q11,Q12,Q13,Q14,Q15
* .QFREE1,QFREE2,QFREE3,QFREE4,QFCORN,QQ1,QQ2
* TRAC1,QTRAC2,QTRAC3,QTRAC4
C
COMMON /QLOGIC/ QAUX(20),QZETA,QSTRFS,QPLAST,QSENS1,QEGUIL,
* QDIAGN,QINGEO,QINVEL,QLOAD,QMATPR,QTHIKL,QTEMP,QSPTEM,QAUX11,
* QAUX12,QSPLQA,QIMPUL,QSHARP,QRESO,QIRCH,QSHEAR
C
COMMON /SURNOM/ SNPR(1)
COMMON /SURNOL/ SN(3,20,20)
LEVEL 2,SN
C
COMMON /S2/ STRESE(3)
COMMON /S2L/ STRESL(3,20,20),STRESQ(2,20,20),STRESP(2,20,20)
LEVEL 2,STRESL,STRESQ,STRESP
C
COMMON /TENCOM/ YY(3,2),YYY(3,2,2),A(3,3),R(3,3),AA(3,3),RR(3,3),
* RM(3,3),OA(3,3),OR(3,3),G(3,3),GG(3,3),ON(3),OO(3,2),ODD(3,2,2),
* DGAM(3,3),DGAMMX(3,3),MN(3,3),MQ(2),TAU(3,3),TAUSPL(3,3)
* .DD2(3,2),DDO2(3,2,2),YY2(3,2),YYY2(3,2,2),YYU(3,2),DBM(3,3)
C
COMMON /THKNS/ Z,ZZ,7CENTR,THICKN,ARSCIS(4,6),WEIGHT(4,6),
* NGAUSS(4),IGAUSS,NLAYER,ILAYER,NSURL(4),ISUBL
C
COMMON /TNCOMP/ HM1(2,20,20),HM2(2,20,20),CAPQ1(2,20,20),
* CAPQ2(2,20,20),CAPQ3(2,20,20),CAPQ01(2,20,20),
* CAPQ02(2,20,20),CAPQ03(2,20,20)
LEVEL 2,HM1,HM2,CAPQ1,CAPQ2,CAPQ3,CAPQ01,CAPQ02,CAPQ03
C
COMMON /STPOUT/ ISR,L,LC,NISCR,TP(3,3),TN(3,3)
C
COMMON /GPRINT/ GTYPE,GRASE(3,3),DGRASE(3,3)
C
COMMON /THREE/ AGAM33

```

```

PRINT 1
PRINT 2
PRINT 3
PRINT 4
PRINT 5
PRINT 6
PRINT 7
PRINT 8
PRINT 9
PRINT 10
PRINT 11
PRINT 12
PRINT 13
PRINT 14
PRINT 15
PRINT 16
PRINT 17
PRINT 18
PRINT 19
PRINT 20
PRINT 21
PRINT 22
PRINT 23
PRINT 24
PRINT 25
PRINT 26
PRINT 27
PRINT 28
PRINT 29
PRINT 30
PRINT 31
PRINT 32
PRINT 33
PRINT 34
PRINT 35
PRINT 36
PRINT 37
PRINT 38
PRINT 39
PRINT 40
PRINT 41
PRINT 42
PRINT 43
PRINT 44
PRINT 45
PRINT 46
PRINT 47
PRINT 48
PRINT 49
PRINT 50
PRINT 51
PRINT 52
PRINT 53
PRINT 54
PRINT 55
PRINT 56
PRINT 57
PRINT 58
PRINT 59
PRINT 60
PRINT 61
PRINT 62

```

```

COMMON /FRAC/ TAUF(3,3),TAUSPH,NUM,IPS1(10),IPS2(10) PRINT 63
C COMMON /MATRIX/ YLDFAC,ANUM PRINT 64
COMMON /MATRIX/ LMAT(20,20,16),FMAT(6,20,20) PRINT 65
LEVEL 2,LMAT,FMAT PRINT 66
C PRINT 67
PRINT 68
IF (ITIME .EQ. -1) RETURN PRINT 69
II=INDEXX PRINT 70
IF (INDEXX .GE. 4) II=4 PRINT 71
GOTO(1000,2000,3000,4000),II PRINT 72
C PRINT 73
C PRINT 74
C POSITION AND TIME PRINT 75
C PRINT 76
1000 III=ITIME/IOUT(1)*IOUT(1)-ITIME PRINT 77
IF (III.NE.0.AND..NOT.QPRINT(1)) GO TO 701 PRINT 78
WRITE(NWRITE,1001)I1,I2,ITIME PRINT 79
1001 FORMAT("I1=","I5," I2=","I5," ITIME=","I5/") PRINT 80
701 CONTINUE PRINT 81
C PRINT 82
C FIRST AND SECOND Y'S DERIVATIVES PRINT 83
C FIRST AND SECOND OY'S DERIVATIVES PRINT 84
III=ITIME/IOUT(2)*IOUT(2)-ITIME PRINT 85
IF (III.NE.0.AND..NOT.QPRINT(2)) GO TO 702 PRINT 86
WRITE(NWRITE,100) PRINT 87
100 FORMAT(/,9X,"FIRST PARTIAL DERIVATIVE OF Y",20X,"SECOND PARTIAL DEPRINT 88
RIVATIVE OF Y"/,12X,"YY(J,1)",8X,"YY(J,2)",19X,"YYY(J,1,1)",5X, PRINT 89
"YYY(J,1,2)",5X,"YYY(J,2,2)"/) PRINT 90
WRITE(NWRITE,102) YY(1,1),YY(1,2),YYY(1,1,1),YYY(1,1,2),YYY(1,2,2)PRINT 91
WRITE(NWRITE,102) YY(2,1),YY(2,2),YYY(2,1,1),YYY(2,1,2),YYY(2,2,2)PRINT 92
WRITE(NWRITE,102) YY(3,1),YY(3,2),YYY(3,1,1),YYY(3,1,2),YYY(3,2,2)PRINT 93
102 FORMAT(7X,2E15.6,12X,3E15.6) PRINT 94
WRITE(NWRITE,103) PRINT 95
103 FORMAT(/,6X,"FIRST PARTIAL DERIVATIVE OF DELTA Y",14X,"SECOND PARTPRINT 96
IAL DERIVATIVE OF DELTA Y"/,12X,"DD(J,1)",8X,"DD(J,2)",19X,"DDD(J, PRINT 97
"1,1)",5X,"DDD(J,1,2)",5X,"DDD(J,2,2)"/) PRINT 98
WRITE(NWRITE,102) DD(1,1),DD(1,2),DDD(1,1,1),DDD(1,1,2),DDD(1,2,2)PRINT 99
WRITE(NWRITE,102) DD(2,1),DD(2,2),DDD(2,1,1),DDD(2,1,2),DDD(2,2,2)PRINT 100
WRITE(NWRITE,102) DD(3,1),DD(3,2),DDD(3,1,1),DDD(3,1,2),DDD(3,2,2)PRINT 101
IF (QIRCH) GO TO 5101 PRINT 102
WRITE(NWRITE,5100) PRINT 103
5100 FORMAT(/,9X,"FIRST PARTIAL DERIVATIVE OF Y2",19X,"SECOND PARTIAL DPRINT 104
ERIVATIVE OF Y2"/,12X,"YY2(J,1)",7X,"YY2(J,2)",18X,"YYY2(J,1,1)",PRINT 105
"4X,"YYY2(J,1,2)",4X,"YYY2(J,2,2)"/) PRINT 106
WRITE(NWRITE,102) YY2(1,1),YY2(1,2),YYY2(1,1,1),YYY2(1,1,2),YYY2(1,2,2)PRINT 107
"2,2) PRINT 108
WRITE(NWRITE,102) YY2(2,1),YY2(2,2),YYY2(2,1,1),YYY2(2,1,2),YYY2(2,2,2)PRINT 109
"2,2) PRINT 110
WRITE(NWRITE,102) YY2(3,1),YY2(3,2),YYY2(3,1,1),YYY2(3,1,2),YYY2(3,2,2)PRINT 111
"2,2) PRINT 112
WRITE(NWRITE,5103) PRINT 113
5103 FORMAT(/,5X,"FIRST PARTIAL DERIVATIVE OF DELTA Y2",14X,"SECOND PARTPRINT 114
IAL DERIVATIVE OF DELTA Y2"/,12X,"DD2(J,1)",7X,"DD2(J,2)",18X,"DDDPRINT 115
"2(J,1,1)",4X,"DDD2(J,1,2)",4X,"DDD2(J,2,2)"/) PRINT 116
WRITE(NWRITE,102) DD2(1,1),DD2(1,2),DDD2(1,1,1),DDD2(1,1,2),DDD2(1,2,2)PRINT 117
"2,2) PRINT 118
WRITE(NWRITE,102) DD2(2,1),DD2(2,2),DDD2(2,1,1),DDD2(2,1,2),DDD2(2,2,2)PRINT 119
"2,2) PRINT 120
WRITE(NWRITE,102) DD2(3,1),DD2(3,2),DDD2(3,1,1),DDD2(3,1,2),DDD2(3,2,2)PRINT 121
"2,2) PRINT 122
5101 CONTINUE PRINT 123
702 CONTINUE PRINT 124
C PRINT 125
C FIRST AND SECOND METRIC TENSORS PRINT 125
C FIRST AND SECOND METRIC TENSORS INCRFMENTS PRINT 127
C PRINT 128
III=ITIME/IOUT(3)*IOUT(3)-ITIME PRINT 129
IF (III.NE.0.AND..NOT.QPRINT(3)) GO TO 703 PRINT 130
WRITE(NWRITE,106) PRINT 131
106 FORMAT(/,14X,"FIRST METRIC TENSOR",29X,"SECOND METRIC TENSOR"/) PRINT 132
WRITE(NWRITE,907) A(1,1),A(1,2),B(1,1),B(1,2) PRINT 133
907 FORMAT(2X,"A(1,1)=",F13.6," A(1,2)=",E13.6,4X,"B(1,1)=",E13.6, PRINT 134
" B(1,2)=",E13.6) PRINT 135
WRITE(NWRITE,908) A(2,1),A(2,2),B(2,1),B(2,2) PRINT 136
908 FORMAT(2X,"A(2,1)=",E13.6," A(2,2)=",E13.6,4X,"B(2,1)=",E13.6, PRINT 137
" B(2,2)=",E13.6) PRINT 138
WRITE(NWRITE,109) PRINT 139
109 FORMAT(/,9X,"FIRST METRIC TENSOR INCREMENT",19X,"SECOND METRIC TENPRINT 140
SOR INCREMENT"/) PRINT 141
WRITE(NWRITE,909) DA(1,1),DA(1,2),DB(1,1),DB(1,2) PRINT 142
909 FORMAT(" DA(1,1)=",E13.6," DA(1,2)=",E13.6," DB(1,1)=",E13.6,PRINT 143

```

```

      *H DR(1,2)="E13.6)                                PRINT144
      WRITE(NWRITE,910) DA(2,1),DA(2,2),DB(2,1),DR(2,2) PRINT145
910 FORMAT(" DA(2,1)=",E13.6," DA(2,2)=",E13.6," DB(2,1)=",E13.6,PRINT146
      *H DR(2,2)="E13.6)                                PRINT147
703 CONTINUE                                           PRINT148
C                                                       PRINT149
C STRESS RESULTANT                                     PRINT150
C                                                       PRINT151
C III=ITIME/IOUT(5)*IOUT(5)-ITIME                     PRINT152
C IF(III.NE.0.AND..NOT.QPRINT(5)) GO TO 705           PRINT153
C WRITE(NWRITE,11A)                                     PRINT154
118 FORMAT("// CONTRAVARIANT COMPONENTS OF THE RELATIVE STRESS-RESULTANT TENSOR") PRINT155
C *H TENSOR")                                           PRINT156
C WRITE(NWRITE,917) MN(1,1),MN(1,2),MN(1,3)           PRINT157
917 FORMAT(1X,MN(1,1)="E13.6," MN(1,2)="E13.6," MN(1,3)="E13.6) PRINT158
C WRITE(NWRITE,918) MN(2,1),MN(2,2),MN(2,3)           PRINT159
918 FORMAT(1X,MN(2,1)="E13.6," MN(2,2)="E13.6," MN(2,3)="E13.6) PRINT160
705 CONTINUE                                           PRINT161
C RETURN                                                PRINT162
C                                                       PRINT163
C                                                       PRINT164
C RESULTANTS                                           PRINT165
C                                                       PRINT166
2000 IF (ITIME.EQ.0) RETURN                             PRINT167
C III=ITIME/IOUT(6)*IOUT(6)-ITIME                     PRINT168
C IF(III.NE.0.AND..NOT.QPRINT(6)) GO TO 706           PRINT169
C ITIMEP=ITIME-1                                       PRINT170
C TIMEP=ITIMEP*DELTA T                                PRINT171
C                                                       PRINT172
C WRITE TIME AND ITIME AT PRECEDING STEP              PRINT173
C                                                       PRINT174
C WRITE(NWRITE,2) TIMEP,ITIMEP                         PRINT175
C WRITE(NWRITE,920)                                     PRINT176
920 FORMAT("//36X,"TENSOR DEFINED IN "29X,"CONTRAVARIANT COMPONENTS OF THE"//33X," THE PETROS & REPORT",36X,"RELATIVE MOMENT RESULTANT TENSOR"//3X,"I1 I2",32X,"Q(LA,J,I1,I2)",45X,"M(LA,LB,I1,I2)",1) PRINT177
C *H I2")                                               PRINT178
C DO 12R I1=1,N1                                       PRINT179
C DO 12R I2=1,N2                                       PRINT180
C WRITE(NWRITE,921) I1,I2,CAPQ1(1,I1,I2),CAPQ2(1,I1,I2),CAPQ3(1,I1,I2),MM1(1,I1,I2),MM2(1,I1,I2),MM3(1,I1,I2) PRINT181
921 FORMAT(2I5," CAPQ(1,1)=",E13.6," CAPQ(1,2)=",E13.6," CAPQ(1,3)=",E13.6," MM1=",E13.6," MM2=",E13.6," MM3=",E13.6) PRINT182
C WRITE(NWRITE,922) CAPQ1(2,I1,I2),CAPQ2(2,I1,I2),CAPQ3(2,I1,I2),MM1(2,I1,I2),MM2(2,I1,I2),MM3(2,I1,I2) PRINT183
922 FORMAT(13X,"CAPQ(2,1)=",E13.6," CAPQ(2,2)=",E13.6," CAPQ(2,3)=",E13.6," MM1=",E13.6," MM2=",E13.6," MM3=",E13.6) PRINT184
C IF (QIRCH) GO TO 12R                                  PRINT185
C WRITE(NWRITE,A21) I1,I2,CAP2Q1(1,I1,I2),CAP2Q2(1,I1,I2),CAP2Q3(1,I1,I2),STRES1(1,I1,I2),STRES2(1,I1,I2),STRES3(1,I1,I2) PRINT186
A21 FORMAT(2I5," CAP2Q(1,1)=",E13.6," CAP2Q(1,2)=",E13.6," CAP2Q(1,3)=",E13.6," STRES1=",E13.6," STRES2=",E13.6," STRES3=",E13.6) PRINT187
C WRITE(NWRITE,A22) CAP2Q1(2,I1,I2),CAP2Q2(2,I1,I2),CAP2Q3(2,I1,I2),STRES1(2,I1,I2),STRES2(2,I1,I2),STRES3(2,I1,I2) PRINT188
A22 FORMAT(12X,"CAP2Q(2,1)=",E13.6," CAP2Q(2,2)=",E13.6," CAP2Q(2,3)=",E13.6," STRES1=",E13.6," STRES2=",E13.6," STRES3=",E13.6) PRINT189
C WRITE(NWRITE,A23) I1,I2,STRESL(1,I1,I2),STRESL(2,I1,I2),STRESL(3,I1,I2) PRINT190
A23 FORMAT(2I5," STRESL(1)=",E13.6," STRESL(2)=",E13.6," STRESL(3)=",E13.6) PRINT191
128 CONTINUE                                           PRINT192
706 CONTINUE                                           PRINT193
C                                                       PRINT194
C NORMAL                                               PRINT195
C                                                       PRINT196
C III=ITIME/IOUT(7)*IOUT(7)-ITIME                     PRINT197
C IF(III.NE.0.AND..NOT.QPRINT(7)) GO TO 707           PRINT198
C ITIMEP=ITIME-1                                       PRINT199
C TIMEP=ITIMEP*DELTA T                                PRINT200
C                                                       PRINT201
C WRITE TIME AND ITIME AT PRECEDING STEP              PRINT202
C                                                       PRINT203
C WRITE(NWRITE,2) TIMEP,ITIMEP                         PRINT204
C WRITE(NWRITE,1002)                                    PRINT205
1002 FORMAT("//17X,"COMPONENTS OF THE SURFACE NORMAL"//3X,"I1 I2",6X,"SN(1)",10X,"SN(2)",10X,"SN(3)"/) PRINT206
C DO 1007 I1=1,N1                                       PRINT207
C DO 1007 I2=1,N2                                       PRINT208

```

```

WRITE(NWRITE,1003) I1,I2, SN(1,I1,I2),SN(2,I1,I2),SN(3,I1,I2) PRINT222
1003 FORMAT(2I5,3E15,6) PRINT223
1007 CONTINUE PRINT224
IF(.NOT.QR) GO TO 707 PRINT225
DO 1010 I=1,NPL PRINT226
K=LOCPOL(I) PRINT227
1010 WRITE(NWRITE,1020) K, SNPOLE(K,1),SNPOLE(K,2),SNPOLE(K,3) PRINT228
1020 FORMAT(" POLE ON"/" SIDE",I2," =",3E15,6) PRINT229
707 CONTINUE PRINT230
C PRINT231
C POSITIONS AND INCREMENTS PRINT232
C PRINT233
III=ITIME/IOUT(8)*IOUT(8)-ITIME PRINT234
IF(III.NE.0.AND..NOT.QPRINT(A)) GO TO 70A PRINT235
WRITE(NWRITE,2) TIME,ITIME PRINT236
2 FORMAT("1",AX,"TIME=",E13,6,AX" ITIME=",I5/) PRINT237
WRITE(NWRITE,3) PRINT238
3 FORMAT(/48X,"CARTESIAN COORDINATES"/30X,"POSITION",37X,"CHANGE IN" PRINT239
" POSITION"/3X,"I1 I2",6X,"Y1",13X,"Y2",13X,"Y3",18X,"D1",13X,"DPRINT240
"2",13X,"D3",12X,"P",10X,"IPLAST"/) PRINT241
WRITE(NWRITE,4)((I1,I2,Y(1,I1,I2),Y(2,I1,I2),Y(3,I1,I2),D(1,I1,I2) PRINT242
" D(2,I1,I2),D(3,I1,I2),P(I1,I2),IPLAST(I1,I2), PRINT243
" I2=IRY2,IRY4),I1=IRY1,IPY3) PRINT244
4 FORMAT(2I5,3E15,6," "4E15,6,3X,I5) PRINT245
IF (QIRCH) GO TO 100A PRINT246
WRITE(NWRITE,1053) PRINT247
1053 FORMAT(///52X,"Y2 COORDINATES "///30X,"POSITION",37X,"CHANGE IN" PRINT248
" POSITION"/3X,"I1 I2",6X,"Y2(1)",10X,"Y2(2)",10X,"Y2(3)",15X, PRINT249
"02(1)",10X,"02(2)",10X,"02(3) IPLAST"/) PRINT250
WRITE(NWRITE,5)((I1,I2,Y2(1,I1,I2),Y2(2,I1,I2),Y2(3,I1,I2),D2(1,I1,I2) PRINT251
" I2=IRY2,IRY4),I1= PRINT252
" IRY1,IPY3) PRINT253
5 FORMAT(2I5,3E15,6," "3E15,6,3X,I5) PRINT254
100A CONTINUE PRINT255
IF(NPL.EQ.0) GO TO 929 PRINT256
DO 927 I=1,NPL PRINT257
K=LOCPOL(I) PRINT258
WRITE(NWRITE,928)K,YPOLE(K,1),YPOLE(K,2),YPOLE(K,3),DYPOL(K,1), PRINT259
" DYPOL(K,2),DYPOL(K,3) PRINT260
928 FORMAT("0POLE ON SIDE",I2," HAS POSITION AND INCREMENTS ="/ PRINT261
" 10X,3E15,6," "3E15,6) PRINT262
IF (QIRCH) GO TO 927 PRINT263
WRITE(NWRITE,1928)K,Y2POLE(K,1),Y2POLE(K,2),Y2POLE(K,3),D2POLE(K,1),Y2POLE(K,2),D2POLE(K,3) PRINT264
" 1,D2POLE(K,2),D2POLE(K,3) PRINT265
1928 FORMAT(" POLE ON SIDE",I2," Y2 POSITION AND INCREMENTS ="/ PRINT266
" 10X,3E15,6," "3E15,6) PRINT267
927 CONTINUE PRINT268
929 WRITE(NWRITE,930) PRINT269
930 FORMAT(/22X,"* IPLAST GREATER THAN ZERO INDICATES PLASTICITY AT TPRINT270
" IS TIME STEP") PRINT271
708 CONTINUE PRINT272
C PRINT273
C WRITE LMATRIX PRINT274
C III=ITIME/IOUT(14)*IOUT(14)-ITIME PRINT275
IF(III.NE.0.AND..NOT.QPRINT(14))GOTO 730 PRINT276
WRITE(NWRITE,711) TIME,ITIME PRINT277
I2=0 PRINT278
DO 710 ILAYER=1,NLAYER PRINT279
NGAUSS=NGAUSS(ILAYER) PRINT280
DO 710 IGAUSS=1,NGAUSS PRINT281
NSBL=NSURL(ILAYER) PRINT282
DO 710 ISB=1,NSBL PRINT283
I2=I2+1 PRINT284
WRITE(NWRITE,715) ILAYER,ILAYER,IGAUSS,ISB,(I2,I2=IRY2,IRY4) PRINT285
DO 710 I1=IRY1,IRY3 PRINT286
WRITE(NWRITE,720) I1,(LMAT(I1,I2,I2),I2=IRY2,IRY4) PRINT287
710 CONTINUE PRINT288
711 FORMAT("1",AX,"TIME=",E13,6,AX," ITIME=",I5/ PRINT289
"AX,"SUBDIVISIONS OF TIME INCREMENT IN STRESS"/) PRINT290
715 FORMAT(//20X,"LMAT(I1,I2,I2," LAYER",I2," GAUSS PT.",I2, PRINT291
" SUBLAYER",I2// " I1 I2=",40I3/) PRINT292
720 FORMAT(" "14,5X,40I3) PRINT293
C WRITE FMAT PRINT294
C 730 III=ITIME/IOUT(15)*IOUT(15)-ITIME PRINT295
IF(III.NE.0.AND..NOT.QPRINT(15))GOTO 740 PRINT296
WRITE(NWRITE,740) TIME,ITIME PRINT297
DO 735 ILAYER=1,NLAYER PRINT298
NGAUSS=NGAUSS(ILAYER) PRINT299
DO 735 IGAUSS=1,NGAUSS PRINT300

```

```

WRITE(NWRITE,745) ILAYER,IGAUSS,(I2,I2=ISTR2,ISTR4)
DO 735 I1=ISTR1,ISTR3
WRITE(NWRITE,750) I1,(FMAT(IGAUSS,I1,I2),I2=ISTR2,ISTR4)
735 CONTINUE
740 FORMAT(' ',8X,'TIME=' ,E13.6,8X,' ITIME=' ,I5/)
745 FORMAT('//20X,'FMAT(I1,I2,' ,I2,') GAUSS PT. ',I2,
*// ' I1 I2=' ,40I3)
740 FORMAT(' ',I4,6X,40A3)
740 CONTINUE
RETURN
C
C STRESSES
C
3000 IF (ITIME.EQ.0) RETURN
III=ITIME/IOUT(4)*IOUT(4)-ITIME
IF(III.NE.0.AND..NOT.QPRINT(4)) GO TO 3003
IF(ILAYER.EQ.1.AND.IGAUSS.EQ.1 .AND. ISUBL.EQ.1) WRITE(NWRITE,932)
932 FORMAT('1',I4X,"CONTRAVARIANT COMPONENTS OF THE STRESS TENSOR"//
* LAYER GAUSS STATION SUBLAYER TAUSBL(I,1) TAUSRL(I,2)
* AUSRL(I,3)"/)
WRITE(NWRITE,1933) ILAYER,IGAUSS,ISURL
1933 FORMAT(2X,I2,8X,I2,11X,I2)
WRITE(NWRITE,1934) ((TAUSRL(I,J),J=1,3),I=1,3)
1934 FORMAT(34X,3E15.6)
NSBL=NSUBL(ILAYER)
IF(ISURL.EQ.NSBL) WRITE(NWRITE,3007) ILAYER,IGAUSS,
* ((TAU(I,J),J=1,3),I=1,3)
3002 FORMAT('1' CONTRAVARIANT COMP. OF THE STRESS TENSOR. TAU(I,J). FOR
* LAYER",I2,". GAUSS STAT.",I2," ="/(85X,3E15.6))
3003 RETURN
C
4000 IF (ITIME .EQ. 0) RETURN
IF (INDEXX .EQ. 1) GOTO 8300
III=ITIME/IOUT(12)*IOUT(12)-ITIME
IF(III.NE.0 .AND. .NOT.QPRINT(12)) GOTO 4010
II=(INDEXX-3)
GOTO(4100,5000,6000,7000,8000,8100,A200),II
C
4100 WRITE(NWRITE,4001) ISB
4001 FORMAT(' SURROUTINE STRESS'// ISB=' ,I3,/)
WRITE(NWRITE,4002) ((TN(J,I),I=1,3),J=1,3)
4002 FORMAT(' TN(1,1)=' ,E22.15,' TN(1,2)=' ,E22.15,' TN(1,3)=' ,E22.15/
* TN(2,1)=' ,E22.15,' TN(2,2)=' ,E22.15,' TN(2,3)=' ,E22.15/
* TN(3,1)=' ,E22.15,' TN(3,2)=' ,E22.15,' TN(3,3)=' ,E22.15)
4010 RETURN
C
5000 WRITE(NWRITE,5005) ((TR(J,I),I=1,3),J=1,3)
5005 FORMAT(' TR(1,1)=' ,E22.15,' TR(1,2)=' ,E22.15,' TR(1,3)=' ,E22.15/
* TR(2,1)=' ,E22.15,' TR(2,2)=' ,E22.15,' TR(2,3)=' ,E22.15/
* TR(3,1)=' ,E22.15,' TR(3,2)=' ,E22.15,' TR(3,3)=' ,E22.15)
WRITE(NWRITE,5006) ISB,L,LC,CZ,SIGMSQ
5006 FORMAT(' *** ISB=' ,I3,' L=' ,I3,' LC=' ,I3,' CZ=' ,E22.15,' SIGMSQ=' ,E22.15)
RETURN
C
6000 WRITE(NWRITE,6005) AZ,RZ,DISCR
6005 FORMAT(' AZ=' ,E22.15,' BZ=' ,E22.15,' DISCR=' ,E22.15)
WRITE(NWRITE,6006) ((TC(J,I),I=1,3),J=1,3)
6006 FORMAT(' TC(1,1)=' ,E22.15,' TC(1,2)=' ,E22.15,' TC(1,3)=' ,E22.15/
* TC(2,1)=' ,E22.15,' TC(2,2)=' ,E22.15,' TC(2,3)=' ,E22.15/
* TC(3,1)=' ,E22.15,' TC(3,2)=' ,E22.15,' TC(3,3)=' ,E22.15)
RETURN
C
7000 WRITE(NWRITE,7001) HLAMDA
7001 FORMAT(' HLAMDA=' ,E22.15)
WRITE(NWRITE,7006) ((TM(J,I),I=1,3),J=1,3)
7006 FORMAT(' TM(1,1)=' ,E22.15,' TM(1,2)=' ,E22.15,' TM(1,3)=' ,E22.15/
* TM(2,1)=' ,E22.15,' TM(2,2)=' ,E22.15,' TM(2,3)=' ,E22.15/
* TM(3,1)=' ,E22.15,' TM(3,2)=' ,E22.15,' TM(3,3)=' ,E22.15)
RETURN
C
A000 WRITE(NWRITE,A001) ITIME,TIME,IGAUSS,I1,I2
A001 FORMAT(' ITIME=' ,I4,' TIME=' ,E15.8,' IGAUSS=' ,I4,' I1=' ,I4,' I2=' ,I4)
* I4)
WRITE(NWRITE,A002)
A002 FORMAT(' SURROUTINE ZETA')
WRITE(NWRITE,A003) ((GBASE(J,I),I=1,3),J=1,3)
A003 FORMAT(' GRASF(1,1)=' ,E22.15,' GRASF(1,2)=' ,E22.15,' GRASF(1,3)=' ,E22.15,

```

```

*E22.15/
* GBASE(2.1)=.E22.15. GRASF(2.2)=.F22.15. GRASE(2.3)=.E22.15/PRINT379
* GBASE(3.1)=.E22.15. GRASE(3.2)=.E22.15. GBASE(3.3)=.E22.15/PRINT390
WRITE(NWRITE,R004) ((DGRASE(J,I),I=1,3),J=1,3) PRINT391
R004 FORMAT(' DGRASE(1.1)=.F22.15. DGRASE(1.2)=.E22.15. DGRASE(1.3)PRINT392
*E22.15/
* DGRASE(2.1)=.E22.15. DGBASE(2.2)=.E22.15. DGRASE(2.3)=.E22.15/PRINT393
*15/
* DGRASE(3.1)=.E22.15. DGRASE(3.2)=.E22.15. DGRASE(3.3)=.F22.15/PRINT394
*15) PRINT395
WRITE(NWRITE,R005) ((G(J,I),I=1,3),J=1,3) PRINT396
R005 FORMAT(' G(1.1)=.E22.15. G(1.2)=.E22.15. G(1.3)=.E22.15/ PRINT397
* G(2.1)=.E22.15. G(2.2)=.E22.15. G(2.3)=.E22.15/ PRINT398
* G(3.1)=.E22.15. G(3.2)=.E22.15. G(3.3)=.E22.15) PRINT399
WRITE(NWRITE,R006) GTYPE PRINT400
R006 FORMAT(' GTYPE=.E22.15) PRINT401
WRITE(NWRITE,R007) ((GG(J,I),I=1,3),J=1,3) PRINT402
R007 FORMAT(' GG(1.1)=.E22.15. GG(1.2)=.E22.15. GG(1.3)=.E22.15/ PRINT403
* GG(2.1)=.E22.15. GG(2.2)=.E22.15. GG(2.3)=.E22.15/ PRINT404
* GG(3.1)=.E22.15. GG(3.2)=.E22.15. GG(3.3)=.E22.15) PRINT405
WRITE(NWRITE,R008) ((DGAM(J,I),I=1,3),J=1,3) PRINT406
R008 FORMAT(' DGAM(1.1)=.E22.15. DGAM(1.2)=.E22.15. DGAM(1.3)=.E22.15/PRINT407
*15/
* DGAM(2.1)=.E22.15. DGAM(2.2)=.E22.15. DGAM(2.3)=.E22.15/ PRINT408
* DGAM(3.1)=.E22.15. DGAM(3.2)=.E22.15. DGAM(3.3)=.E22.15) PRINT409
WRITE(NWRITE,R009) ((DGAMMX(J,I),I=1,3),J=1,3) PRINT410
R009 FORMAT(' DGAMMX(1.1)=.E22.15. DGAMMX(1.2)=.E22.15. DGAMMX(1.3)PRINT411
*E22.15/
* DGAMMX(2.1)=.E22.15. DGAMMX(2.2)=.E22.15. DGAMMX(2.3)=.E22.15/PRINT412
*15/
* DGAMMX(3.1)=.E22.15. DGAMMX(3.2)=.E22.15. DGAMMX(3.3)=.F22.15/PRINT413
*15) PRINT414
RETURN PRINT415
C PRINT416
R100 WRITE(NWRITE,R101) DGAMMX(3.3) PRINT417
R101 FORMAT(' (REVISED) DGAMMX(3.3)=.E22.15) PRINT418
RETURN PRINT419
C PRINT420
C MIXED TENSOR STRESSES PRINT421
C PRINT422
R100 WRITE(NWRITE,R120) TIME,ITIME,I1,I2,IGAUSS,TAUSPH PRINT423
WRITE(NWRITE,R125) ((TAUF(K,J),J=1,3),K=1,3) PRINT424
RETURN PRINT425
C PRINT426
R120 FORMAT(' TIME=.E15.6,3X,ITIME=.I5. I1=.I3. I2=.I3. PRINT427
* GAUSS PT. =.I3. TAUSPH =.F10.1) PRINT428
R125 FORMAT(54X,MIXED TENSOR STRESSES/ PRINT429
*39X, TAUF(1.1)=.F10.1. TAUF(1.2)=.F10.1. TAUF(1.3)=.F10.1/ PRINT430
*39X, TAUF(2.1)=.F10.1. TAUF(2.2)=.F10.1. TAUF(2.3)=.F10.1/ PRINT431
*39X, TAUF(3.1)=.F10.1. TAUF(3.2)=.F10.1. TAUF(3.3)=.F10.1) PRINT432
END PRINT433

```

```

SUBROUTINE MAXMIN(TAU,IGD)
IMPLICIT LOGICAL (L)
C
COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,N3,N1M,N2M,MAXMIN 1
* N1MM,N2MM,I1,I2,I3,I1ZERO,I2ZERO,IRY1,IRY2,IRY3,IRY4,ISTR1,ISTR2,MAXMIN 2
* ISTR3,ISTR4,IC1,IC2,IC3,IC4,IP1,IP2,IS1,IS2,K1,K2,K3,K4,KRUN,MAXMIN 3
* K2STOP,KYTEST,IWIN,I1TEST,I2TEST,KINITL
MAXMIN 4
C
COMMON /THNS/ Z,ZZ,ZCENTR,THICKN,ABSLIS(6,6),WEIGHT(6,6),MAXMIN 5
* NGAUSS(4),IGAUSS,NLAYER,ILAYER,NSUBL(4),ISUBL
MAXMIN 6
C
COMMON /TIME/ TAUX(20),TIME,DELTA,TIMEF,ITIME,ITIMEF,TAUX(20),MAXMIN 7
* IOUT(20),DPRINT(20)
MAXMIN 8
COMMON /CTIME/ IPLAST(20,20),P(20,20),PPL(20,20)
MAXMIN 9
LEVEL 2,IPLAST,P,PPL
MAXMIN 10
C
DIMENSION TAU(3,3),TAUMAX(3,3),TAUMIN(3,3),I1MAX(3,3),I1MIN(3,3),MAXMIN 11
* I2MAX(3,3),I2MIN(3,3),IGMAX(3,3),IGMIN(3,3),ITIME(3,3),TIME(3,3)
MAXMIN 12
* ,ITIMM(3,3),TIMM(3,3)
MAXMIN 13
C
DATA OM,FALSE,/,MAX/, 'MAX',/,MIN/, 'MIN',/
MAXMIN 14
C
GOTO(5,35),IGD
MAXMIN 15
C
5 IF(IGD)GOTO 20
MAXMIN 16
DO 10 I=1,3
MAXMIN 17
DO 10 J=1,3
MAXMIN 18
TAUMAX(I,J)=0.0
MAXMIN 19
TAUMIN(I,J)=0.0
MAXMIN 20
I1MAX(I,J)=0
MAXMIN 21
I1MIN(I,J)=0
MAXMIN 22
I2MAX(I,J)=0
MAXMIN 23
I2MIN(I,J)=0
MAXMIN 24
IGMIN(I,J)=0
MAXMIN 25
IGMAX(I,J)=0
MAXMIN 26
10 CONTINUE
MAXMIN 27
OM=.TRUE.
MAXMIN 28
C
20 DO 30 I=1,3
MAXMIN 29
DO 30 J=1,3
MAXMIN 30
G11=TAU(I,J),GT, TAUMAX(I,J)
MAXMIN 31
IF(.NOT. G11)GOTO 25
MAXMIN 32
TAUMAX(I,J)=TAU(I,J)
MAXMIN 33
I1MAX(I,J)=I1
MAXMIN 34
I2MAX(I,J)=I2
MAXMIN 35
ITIME(I,J)=ITIME
MAXMIN 36
TIME(I,J)=TIME
MAXMIN 37
IGMAX(I,J)=IGAUSS
MAXMIN 38
25 G11=TAU(I,J),LT, TAUMIN(I,J)
MAXMIN 39
IF(.NOT. G11)GOTO 30
MAXMIN 40
TAUMIN(I,J)=TAU(I,J)
MAXMIN 41
I1MIN(I,J)=I1
MAXMIN 42
I2MIN(I,J)=I2
MAXMIN 43
ITIMM(I,J)=ITIME
MAXMIN 44
TIMM(I,J)=TIME
MAXMIN 45
IGMIN(I,J)=IGAUSS
MAXMIN 46
30 CONTINUE
MAXMIN 47
RETURN
MAXMIN 48
C
35 WRITE(NWRITE,100) MAX
MAXMIN 49
DO 45 I=1,3
MAXMIN 50
DO 45 J=1,3
MAXMIN 51
WRITE(NWRITE,110) TIME(I,J),ITIME(I,J),I1MAX(I,J),I2MAX(I,J)
MAXMIN 52
* ,IGMAX(I,J),I,J,TAUMAX(I,J)
MAXMIN 53
45 CONTINUE
MAXMIN 54
C
WRITE(NWRITE,100) MIN
MAXMIN 55
DO 50 I=1,3
MAXMIN 56
DO 50 J=1,3
MAXMIN 57
WRITE(NWRITE,110) TIMM(I,J),ITIMM(I,J),I1MIN(I,J),I2MIN(I,J)
MAXMIN 58
* ,IGMIN(I,J),I,J,TAUMIN(I,J)
MAXMIN 59
50 CONTINUE
MAXMIN 60
RETURN
MAXMIN 61
C
100 FORMAT(' ',A4,'[UM MIXED TENSOR STRESSES']
MAXMIN 62
110 FORMAT(' TIME=',E13.6,' ITIME=',E13.6,' I1=',I2,' I2=',I2,
MAXMIN 63
* ' GAUSS PT.',I2,' TAUF(',I1,',',I1,',',I1,',',E14.3)
MAXMIN 64
END
MAXMIN 65

```

	SURROUTINE SFORCE (CS,THICKN,YY,YY2,I1,I2,SURF66)	SFORCE 1
	SURFACE FORCES (ONLY FOR SHEAR OPTION)	SFORCE 2
C	COMMON /CARTE/ YTEST,YNEW,YSAVE	SFORCE 3
	COMMON /CARTEL/ Y(3,20,20),D(3,20,20),Y2(3,20,20),D2(3,20,20)	SFORCE 4
	LEVEL 2,Y,D,Y2,D2	SFORCE 5
C	COMMON /PUSH/ FORCES(7),VELOC(3),RATIO,RATION,DX1,DX2,TEMP,OTEMP,	SFORCE 6
	• FSPACE,TSPACE,FINCND,FSTOP,TSTOP,THCOEF	SFORCE 7
	COMMON /PUSHL/ SQRAT(20,20),SQRAZ(20,20),FMA911(20,20),	SFORCE 8
	• FMA522(20,20),FMA523(20,20),FMA533(20,20)	SFORCE 9
	LEVEL 2,SQRAT,SQRAZ,FMA511,FMA522,FMA523,FMA533	SFORCE 10
C	COMMON /SURNOM/ SNPR(3)	SFORCE 11
	COMMON /SURNOL/ SN(3,20,20)	SFORCE 12
	LEVEL 2,SN	SFORCE 13
C	COMMON /SUPFOR/ E1(3,20,20),F2(3,20,20)	SFORCE 14
	LEVEL 2,E1,E2	SFORCE 15
C	DIMENSION DZ(3),CS(3,7),GBASE(3,7),G(3,3),GG(3,3),YY(3,2),YY2(3,2)	SFORCE 16
	• SUME(3)	SFORCE 17
C	DO 3 J=1,3	SFORCE 18
	E1(J,I1,I2)=0.0	SFORCE 19
	E2(J,I1,I2)=0.0	SFORCE 20
	3 CONTINUE	SFORCE 21
C	DO 50 IZZ=1,2	SFORCE 22
	ZZ=0	SFORCE 23
	CALL EPRASE (DZ,3)	SFORCE 24
	DZ(3)=1.0	SFORCE 25
	GOTO (25,30),IZZ	SFORCE 26
25	ZZ=-.5*THICKN	SFORCE 27
	SIGN=1.0	SFORCE 28
	CALL LOADL	SFORCE 29
	GOTO 34	SFORCE 30
10	ZZ=.5*THICKN	SFORCE 31
	SIGN=-1.0	SFORCE 32
	CALL LOAD	SFORCE 33
14	DO 35 J=1,3	SFORCE 34
	GRASE(1,J)=YY(J,1)-ZZ*CS(J,1)	SFORCE 35
	GRASE(2,J)=YY(J,2)-ZZ*CS(J,2)	SFORCE 36
	GRASE(3,J)=SN(J,I1,I2)	SFORCE 37
C	GRASE(1,J)=GRASE(1,J)+DZ(1)*Y2(J,I1,I2)+ZZ*YY2(J,1)	SFORCE 38
	GRASE(2,J)=GRASE(2,J)+DZ(2)*Y2(J,I1,I2)+ZZ*YY2(J,2)	SFORCE 39
	GRASE(3,J)=GRASE(3,J)+DZ(3)*Y2(J,I1,I2)	SFORCE 40
35	CONTINUE	SFORCE 41
	G(1,1)=GBASE(1,1)*GRASE(1,1)+GBASE(1,2)*GRASE(1,2)	SFORCE 42
	• GRASE(1,3)*GBASE(1,3)	SFORCE 43
	G(1,2)=GBASE(1,1)*GRASE(2,1)+GBASE(1,2)*GRASE(2,2)	SFORCE 44
	• GRASE(1,3)*GBASE(2,3)	SFORCE 45
	G(1,3)=GBASE(1,1)*GRASE(3,1)+GBASE(1,2)*GRASE(3,2)	SFORCE 46
	• GRASE(1,3)*GBASE(3,3)	SFORCE 47
	G(2,1)=G(1,2)	SFORCE 48
	G(2,2)=GBASE(2,1)*GRASE(2,1)+GBASE(2,2)*GRASE(2,2)	SFORCE 49
	• GRASE(2,3)*GBASE(2,3)	SFORCE 50
	G(2,3)=GBASE(2,1)*GRASE(3,1)+GBASE(2,2)*GRASE(3,2)	SFORCE 51
	• GRASE(2,3)*GBASE(3,3)	SFORCE 52
	G(3,1)=G(1,3)	SFORCE 53
	G(3,2)=G(2,3)	SFORCE 54
	G(3,3)=GBASE(3,1)*GRASE(3,1)+GBASE(3,2)*GRASE(3,2)	SFORCE 55

•	GBASE(3,3)*GBASE(3,1)	SFORCE63
G	GTYP	SFORCE64
GTYP	=G(1,1)*(G(2,2)*G(3,3)-G(2,3)**2)+G(1,2)*(G(1,3)*G(2,3)-	SFORCE65
•	G(1,2)*G(3,3)+G(1,3)*(G(1,2)*G(2,3)-G(1,3)*G(2,2))	SFORCE66
SQR	=SQRT(GTYP)	SFORCE67
GTYP	=1./GTYP	SFORCE68
GG(1,1)	=(G(2,2)*G(3,3)-G(2,3)**2)*GTYP	SFORCE69
GG(1,2)	=(G(1,3)*G(2,3)-G(1,2)*G(3,3))*GTYP	SFORCE70
GG(2,1)	=GG(1,2)	SFORCE71
GG(1,3)	=(G(1,2)*G(2,3)-G(1,3)*G(2,2))*GTYP	SFORCE72
GG(3,1)	=GG(1,3)	SFORCE73
GG(2,2)	=(G(1,1)*G(3,3)-G(1,3)**2)*GTYP	SFORCE74
GG(2,3)	=(G(1,2)*G(1,3)-G(1,1)*G(3,2))*GTYP	SFORCE75
GG(3,2)	=GG(2,3)	SFORCE76
GG(3,3)	=(G(1,1)*G(2,2)-G(1,2)**2)*GTYP	SFORCE77
IF(IZ7	.EQ. 2) SURFGG=GG(3,3)	SFORCE78
CALL	ERASE(SUME,3)	SFORCE79
DO 40	K=1,3	SFORCE80
DO 40	I=1,3	SFORCE81
SUME(K)	=SUME(K)+GG(3,I)*GBASE(I,K)	SFORCE82
40	CONTINUE	SFORCE83
DO 45	J=1,3	SFORCE84
IF(SN(J,I1,I2)	.EQ. 0,0)GOTO 45	SFORCE85
PRESS	=(FORCES(J)/SN(J,I1,I2))	SFORCE86
TEMP	=SQRG*SUME(J)*PRESS	SFORCE87
E1(J,I1,I2)	=E1(J,I1,I2)+SIGN*TEMP	SFORCE88
E2(J,I1,I2)	=E2(J,I1,I2)+SIGN*72*TEMP	SFORCE89
45	CONTINUE	SFORCE90
50	CONTINUE	SFORCE91
RETURN		SFORCE92
END		SFORCE93

	SUBROUTINE STRESS (JD1,JD2,JD3,TAU11,TAU12,TAU13,	STRESS 1
	• TAU21,TAU22,TAU23,TAU31,TAU32,TAU33)	STRESS 2
C		STRESS 3
C	EVALUATE STRESS INCREMENTS AND STRESSES	STRESS 4
C		STRESS 5
	IMPLICIT LOGICAL(G)	STRESS 6
C		STRESS 7
	COMMON/ ALLENE /TOTAL,TOTKIN,TCTELA,TOTPLA,TOTWEX,TOTTEM,INERGY	STRESS 8
	• ,TOTVIS,TOTEL,TOTE2 ,ECHECK	STRESS 9
	• ,DTM(3,3),SQRG,SQRA,SIGMSQ,AZ,BZ,CZ	STRESS10
C		STRESS11
	COMMON /CTIME/ AUX(20),TIME,DELTAT,TIMEF,ITIME,ITIMEF,IAUX(20),	STRESS12
	• IOUT(20),CPRINT(20)	STRESS13
	COMMON /CTIME/ IPLAST(20,20),P(20,20),PPL(20,20)	STRESS14
	LEVEL 2,IPLAST,P,PPL	STRESS15
C		STRESS16
	COMMON/CTIMER/ITIMEC,ITIMER,DELTAP,DELX,OMR,UNH,HEE	STRESS17
	• ,TKEEP,MTHIK,CFINIS,QFINP,TSTART,YSTART,YOUTF	STRESS18
	• ,ES,BSTIV(4),NSTIV(4)	STRESS19
C		STRESS20
	COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,N3,N1P,N2P,	STRESS21
	• N1M,N2M,11,12,13,11ZERO,12ZERO,1RY1,1RY2,1RY3,1RY4,1STR1,1STR2,	STRESS22
	• 1STR3,1STR4,1C1,1C2,1C3,1C4,1P1,1P2,1S1,1S2,K1,K2,K3,K4,KRUN,	STRESS23
	• KZSTOP,KYTEST,1DIR,1LTEST,1ZTEST,KINITL	STRESS24
C		STRESS25
	COMMON /OPTION/ MAUXIL,MINGED,MINVEL,MLOAD,MPTPR,MSPLGA,	STRESS26
	• MSPTEP,MTEMPE,MTHIKL,MIMPUL,ISTRES,INCRPL,ISTREZ	STRESS27
	COMMON /OPTFRA/ IFRACT,GFRACT	STRESS28
	COMMON /MAII/ NCCNT,NWRITE,NTRAIN,WRITE,NDEL,P,ETAD1,ETAC2,NSTRN	STRESS29
	• ,FACTDP,MQ,FACTDN,NQ,FKIN	STRESS30
C		STRESS31
	COMMON /PHYSCH/ EE,MNU,ALPHA,CONST,EXPON,FACTOR,RATE,RHC,	STRESS32
	• HLAMDA,COEFF(5),SIGMA(5),TP(3,3),TC(3,3),DELTA(3,3)	STRESS33
C		STRESS34
	COMMON /PUSH/ FORCES(3),VELCC(3),RATIO,RATIOX,CX1,CX2,TEMP,CTEMP,	STRESS35
	• FSPACE,TSPACE,FINCND,FSTOP,TSTOP,THCOEF	STRESS36
	COMMON /PUSHL/ SCRAT(20,20),SQRAZ(20,20),FMAS11(20,20),	STRESS37
	• FMAS22(20,20),FMAS23(20,20),FMAS33(20,20)	STRESS38
	LEVEL 2,SCRAT,SCRAZ,FMAS11,FMAS22,FMAS23,FMAS33	STRESS39
C		STRESS40
	COMMON /CLOGIC/ GAUX(20),GZETA,GSTRES,CPLAST,USENS1,CECUIL,	STRESS41
	• QDIAGN,GINGED,GINVEL,CLOAC,QMATPR,QTHIKL,QTEMPE,QSPTEP,CAUX11,	STRESS42
	• GAUX12,CSPLDA,CIMPUL,CSHARP,CPESD,CIRCH,CSHEAR	STRESS43
C		STRESS44
	COMMON /TENCOM/ YY(3,2),YY1(3,2,2),A(3,3),G(3,3),AA(3,3),BB(3,3),	STRESS45
	• BM(3,3),DA(3,3),GB(3,3),G(3,3),GG(3,3),DN(3),CC(3,2),CCC(3,2,2),	STRESS46
	• DGAM(3,3),DGAMX(3,3),PA(3,3),MQ(2),TAU(3,3),TAUSBL(3,3)	STRESS47
	• ,DD2(3,2),DD2(3,2,2),YY2(3,2),YY2(3,2,2),YYL(3,2),DBM(3,3)	STRESS48
C		STRESS49
	COMMON /THKNS/ Z,ZZ,ZCENTR,THICKN,ABSCIS(6,6),WEIGHT(6,6),	STRESS50
	• NGAUSS(4),IGAUSS,NLAYER,ILAYER,NSUBL(4),ISUBL	STRESS51
	COMMON /DNE/ DGAM33	STRESS52
	COMMON /GG/ SURFGG	STRESS53
C		STRESS54
	COMMON /DELC/ ICCUNT	STRESS55
C		STRESS56
	COMMON /STROUT/ ISB,L,LC,DISCR,TR(3,3),TN(3,3)	STRESS57
C		STRESS58
	COMMON /FRAC/ TAU(3,3),TAUSPH,NUM,IPS1(10),IPS2(10)	STRESS59
C		STRESS60
	COMMON /STRPLG/ TAUP(6,3,3), TAUSPL(16,6)	STRESS61
	COMMON /MATRIX/ YLDFAC,ANUP	STRESS62
	COMMON /MATRIL/ LMAT(20,20,16),FMAT(6,20,20)	STRESS63
	LEVEL 2,LMAT,FMAT	STRESS64
C		STRESS65
C		STRESS66
	DIMENSION TAU11(JD1,JD2,JD3),TAU12(JD1,JD2,JD3),TAU13(JD1,JD2,JD3)	STRESS67
	• ,TAU21(JD1,JD2,JD3),TAU22(JD1,JD2,JD3),TAU23(JD1,JD2,JD3)	STRESS68
	• ,TAU31(JD1,JD2,JD3),TAU32(JD1,JD2,JD3),TAU33(JD1,JD2,JD3)	STRESS69
C		STRESS70
C		STRESS71
	IF (QSTRES) GO TO 20	STRESS72
	LEN=JD1*JD2*JD3	STRESS73
	CALL ERASE(TAU11,LEN)	STRESS74
	CALL ERASE(TAU12,LEN)	STRESS75
	CALL ERASE(TAU13,LEN)	STRESS76
	CALL ERASE(TAU21,LEN)	STRESS77
	CALL ERASE(TAU22,LEN)	STRESS78
	CALL ERASE(TAU23,LEN)	STRESS79
	CALL ERASE(TAU31,LEN)	STRESS80

CALL ERASE(TAU32,LEN)	STRESS81
CALL ERASE(TAU33,LEN)	STRESS82
GSTRES=.TRUE.	STRESS83
C	STRESS84
20 CONTINUE	STRESS85
QQQ2=.FALSE.	STRESS86
QQQ3=.FALSE.	STRESS87
QQQ4=.FALSE.	STRESS88
IF (1STREZ.EQ.2) QQC2=.TRUE.	STRESS89
IF (1STREZ.EQ.2.CR.1STREZ.EQ.3) QQQ3=.TRUE.	STRESS90
IF(1STREZ.EQ.4)QQQ4=.TRUE.	STRESS91
C	STRESS92
DGTEMP=-(1.+HNU)*ALPHA*DGTEPP/HNU	STRESS93
OGAMPA=CGAMMX(1,1)+OGAMMX(2,2)+OGAMMX(3,3)+DGTEMP*3.	STRESS94
IF(CQQ3 .OR. QCC4) OGAMPA=CGAMMX(1,1)+CGAMMX(2,2)+UGTEMP*3.	STRESS95
IF(HNU .EQ. 0.5) OGAMMA=3.*(DGTEPP+ALPHA*DGTEMP)	STRESS96
IF(HNU .EQ. 0.5) HNUP=HNU/3.	STRESS97
C	STRESS98
ES=EE	STRESS99
IF (BSTIV(ILAYER).NE.0.) CALL ESTIFF	STRES100
FACTOR=1.	STRES101
EPP=ES/(1.+HNU)	STRES102
HNUPP=1./3.	STRES103
IF(HNU .NE. 0.5) HNUP=HNU/(1.-2.*HNU)	STRES104
IF(CQQ3 .OR. QCC4) HNUP=HNU/(1.-HNU)	STRES105
IF(CQQ3 .OR. QCC4) HNUPP=(1.-2.*HNU)/(3.*(1.-HNU))	STRES106
C	STRES107
IF(CONST.NE.0.) CALL SENSIT	STRES108
C	STRES109
CALL ERASE(TAU,9)	STRES110
CGAM33=0.0	STRES111
NSBL=NSUBL(ILAYER)	STRES112
C	STRES113
C	STRES114
CALL ERASE(DTM,9)	STRES115
CALL ERASE(TAUF,9)	STRES116
C	STRES117
THE FOLLOWING T33,T33PL CALCULATION IS ONLY VALID FOR INITIALLY	STRES118
C	STRES119
CONSTANT THICKNESS PLATE	STRES120
C	STRES121
IF(.NOT. QQQ4)GOTO 25	STRES122
T33=-P(1,12)*SURFGG*(1.+2.*Z/THICKN)/2.	STRES123
T33PL=-PPL(1,12)*SURFGG*(1.+2.*Z/THICKN)/2.	STRES124
DTAU33=G(3,3)*(T33PL-T33)	STRES125
25 CONTINUE	STRES126
IF(ICOUNT .EQ. C)GOTO 1010	STRES127
IF(11.EQ.151 .AND. 12.EQ.152)GOTO 1000	STRES128
GOTO 1010	STRES129
1000 III=ITIME/ICUT(12)*ICUT(12)-ITIME	STRES130
IF(III .NE. 0 .AND. .NOT.GPRINT(12))GOTO 1010	STRES131
WRITE(6,1007) P(1,12),PPL(1,12),SURFGG	STRES132
1007 FORMAT(' P(1,12)=',E22.15,' PPL(1,12)=',E22.15,	STRES133
* ' SURFACE GG(3,3)=',E22.15)	STRES134
1010 CONTINUE	STRES135
C	STRES136
DETERMINE STRESSES FOR EACH SUBLAYER	STRES137
DO 250 ISB=1,NSBL	STRES138
QCZ=.FALSE.	STRES139
L1112=0	STRES140
L=1	STRES141
EL=1.	STRES142
SIG*SQ=SIGMA(ISB)*SIGMA(ISR)*FACTOR*FACTOR	STRES143
IZ=IZ+1	STRES144
C	STRES145
CALL ERASE(TN,9)	STRES146
TN(1,1)=TAU11(11,12,12)	STRES147
TN(1,2)=TAU12(11,12,12)	STRES148
TN(2,1)=TAU21(11,12,12)	STRES149
TN(2,2)=TAU22(11,12,12)	STRES150
IF(CQQ2)GOTO 3050	STRES151
TN(1,3)=TAU13(11,12,12)	STRES152
TN(2,3)=TAU23(11,12,12)	STRES153
TN(3,1)=TAU31(11,12,12)	STRES154
TN(3,2)=TAU32(11,12,12)	STRES155
IF(CQQ3)GOTO 3050	STRES156
TN(3,3)=TAU33(11,12,12)	STRES157
IF(ETIME.GT.1 .AND. TN(3,3).EQ.0.0)T33=0.0	STRES158
IF(CQQ4)TN(3,3)=T33	STRES159
3050 CONTINUE	
C	
C	
CALCULATE - TN(I,J) AT EACH SUBLAYER AND SUM	

```

C      DTM(1,1)=DTM(1,1)-TN(1,1)*CCEFF(158)      STRES160
C      DTM(1,2)=DTM(1,2)-TN(1,2)*CCEFF(158)      STRES161
C      DTM(1,3)=DTM(1,3)-TN(1,3)*CCEFF(158)      STRES162
C      DTM(2,1)=DTM(2,1)-TN(2,1)*CCEFF(158)      STRES163
C      DTM(2,2)=DTM(2,2)-TN(2,2)*CCEFF(158)      STRES164
C      IF (GOC2) GO TO 5050      STRES165
C      DTM(1,3)=DTM(1,3)-TN(1,3)*CCEFF(158)      STRES166
C      DTM(2,3)=DTM(2,3)-TN(2,3)*CCEFF(158)      STRES167
C      DTM(3,1)=DTM(3,1)-TN(3,1)*CCEFF(158)      STRES168
C      DTM(3,2)=DTM(3,2)-TN(3,2)*CCEFF(158)      STRES169
C      DTM(3,3)=DTM(3,3)-TN(3,3)*CCEFF(158)      STRES170
5050 CONTINUE      STRES171
C      TM(LA,LB) ARE THE MIXED INITIAL STRESSES FOR THIS PARTICULAR SUBLA      STRES172
C      YER      STRES173
C      SUBDIVIDED TIME STEP STARTS HERE, IF REQUIRED      STRES174
C      45 CONTINUE      STRES175
C      TM(1,1)=TN(1,1)      STRES176
C      TM(1,2)=TN(1,2)      STRES177
C      TM(1,3)=TN(1,3)      STRES178
C      TM(2,1)=TN(2,1)      STRES179
C      TM(2,2)=TN(2,2)      STRES180
C      TM(2,3)=TN(2,3)      STRES181
C      TM(3,1)=TN(3,1)      STRES182
C      TM(3,2)=TN(3,2)      STRES183
C      TM(3,3)=TN(3,3)      STRES184
C      TAU=TM(1,1)+TM(2,2)+TM(3,3)      STRES185
C      LC=1      STRES186
C      IF (ICOUNT .EQ. 1) CALL AUXIL(4)      STRES187
C      CALCULATE MIXED TRIAL ELASTIC STRESSES TR(LA,LB)      STRES188
C      50 CONTINUE      STRES189
C      MLAMDA=C.      STRES190
C      CALL ERASE(TR,4)      STRES191
C      ETERM1=EEP/EL      STRES192
C      ETERM2=MNUP*DGAMMA*ETERM1      STRES193
C      TR(1,1)=TM(1,1)+ETERM1*CGAMPX(1,1)+ETERM2      STRES194
C      TR(1,2)=TM(1,2)+ETERM1*CGAMPX(1,2)      STRES195
C      TR(2,1)=TM(2,1)+ETERM1*CGAMPX(2,1)      STRES196
C      TR(2,2)=TM(2,2)+ETERM1*CGAMPX(2,2)+ETERM2      STRES197
C      IF (GOC2) GO TO 6050      STRES198
C      TR(1,3)=TM(1,3)+ETERM1*CGAMPX(1,3)      STRES199
C      TR(2,3)=TM(2,3)+ETERM1*CGAMPX(2,3)      STRES200
C      TR(3,1)=TM(3,1)+ETERM1*CGAMPX(3,1)      STRES201
C      TR(3,2)=TM(3,2)+ETERM1*CGAMPX(3,2)      STRES202
C      IF (GOC3) GO TO 6050      STRES203
C      TR(3,3)=TM(3,3)+ETERM1*CGAMPX(3,3)+ETERM2      STRES204
C      IF (.NOT. GOC4) GO TO 6050      STRES205
C      TR(1,1)=TR(1,1)+MNUP*DTAU33/EL      STRES206
C      TR(2,2)=TR(2,2)+MNUP*DTAU33/EL      STRES207
C      TR(3,3)=TR(3,3)+DTAU33/EL      STRES208
C      6050 CONTINUE      STRES209
C      TAU=TR(1,1)+TR(2,2)+TR(3,3)      STRES210
C      YIELD PHI      STRES211
C      CZ=TR(1,1)+TR(1,1)+2.*(TR(1,2)+TR(2,1)+TR(1,3)+TR(3,1)      STRES212
C      +TR(2,3)+TR(3,2))+TR(2,2)+TR(2,2)+TR(3,3)+TR(3,3)      STRES213
C      *-(TAU**2+2.*SIGMSQ)/3.      STRES214
C      IF (LC .GT. LC) GO TO 55      STRES215
C      IF (ICOUNT .EQ. 1) CALL AUXIL(5)      STRES216
C      TEST YIELD CONDITION      STRES217
C      55 IF (CZ .LT. 0 .AND. LC .EQ. LC) GO TO 220      STRES218
C      IF (CZ .LT. 0.) GO TO 121      STRES219
C      IF (GOC7) GO TO 60      STRES220
C      L=INT(VLDFAC*(SQRT((1.5*CZ+SIGMSQ)/SIGMSQ)-1.0))+1      STRES221
C      EL=L      STRES222
C      QCZ=.TRUE.      STRES223
C      IF (LC .GT. 1) GO TO 50      STRES224
C      60 CONTINUE      STRES225
C      PLASTIC BEHAVIOR      STRES226
C      MIXED CORRECTOR 3 DIMENSIONAL STRESSES TC(LA,LB) ARE INITIAL      STRES227
C      DEVIATORIC STRESS (FOR THIS INCREMENT OR SUB-INCREMENT) BASED ON      STRES228
C      TM(LA,LB)      STRES229
C      STRES230
C      STRES231
C      STRES232
C      STRES233
C      STRES234
C      STRES235
C      STRES236
C      STRES237
C      STRES238
C      STRES239
C      STRES240

```

HTERM=HNUPP*TAUM	STRES241
CALL ERASE(TC,9)	STRES242
TC(1,1)=TM(1,1)-HTERM	STRES243
IF(IGQ04) TC(1,1)=TC(1,1)-HNUPP*TM(3,3)	STRES244
TC(1,2)=TM(1,2)	STRES245
TC(2,1)=TM(2,1)	STRES246
TC(2,2)=TM(2,2)-HTERM	STRES247
IF(IGQ04) TC(2,2)=TC(2,2)-HNUPP*TM(3,3)	STRES248
IF (IGQ02) GO TO 7050	STRES249
TC(1,3)=TM(1,3)	STRES250
TC(2,3)=TM(2,3)	STRES251
TC(3,1)=TM(3,1)	STRES252
TC(3,2)=TM(3,2)	STRES253
IF(IGQ03 .OR. IGQ04)GOTO 7050	STRES254
TC(3,3)=TM(3,3)-HTERM	STRES255
7050 CONTINUE	STRES256
TAUC=TC(1,1)+TC(2,2)+TC(3,3)	STRES257
C	STRES258
IF (ISTRES .NE.1) GO TO 70	STRES259
C TANGENT APPROACH	STRES260
TAUM3=TAUM/3.	STRES261
HLAMDA=0.	STRES262
DGAMAT=DGAMMA/3.-ALPHA*OTEMP	STRES263
DO 65 LA=1,3	STRES264
DO 65 LB=1,3	STRES265
65 HLAMDA=HLAMDA+(TM(LA,LB)-TAUM3*DELTA(LA,LB))	STRES266
* (DGAMMA*(LB,LA)-DGAMAT*DELTA(LB,LA))	STRES267
HLAMDA=HLAMDA*EEP*1.5/(SIGMSQ*EI.)	STRES268
IF (HLAMDA) 150,150,121	STRES269
70 CONTINUE	STRES270
C COMPUTE AND CHECK VALUES OF AZ,BZ AND DISCRIMINANT	STRES271
C	STRES272
AZ=TC(1,1)*TC(1,1)+2.*(TC(1,2)*TC(2,1)+TC(1,3)*TC(3,1)	STRES273
+TC(2,3)*TC(3,2))+TC(2,2)*TC(2,2)+TC(3,3)*TC(3,3)-(TAUC**2)/3.	STRES274
BZ=TC(1,1)*TR(1,1)+TC(1,2)*TR(2,1)+TC(1,3)*TR(3,1)	STRES275
+TC(2,1)*TR(1,2)+TC(2,2)*TR(2,2)+TC(2,3)*TR(3,2)	STRES276
+TC(3,1)*TR(1,3)+TC(3,2)*TR(2,3)+TC(3,3)*TR(3,3)-TAUC*TAUT/3.	STRES277
DISCR=BZ*BZ-AZ*CZ	STRES278
IF(L .GT. L11I2) L11I2=L	STRES279
IF(ICOUNT .EQ. 1)CALL AUXIL(6)	STRES280
C	STRES281
C TEST AZ	STRES282
C IF AZ IS NEGATIVE - PRINT ERROR MESSAGE	STRES283
C IF AZ IS ZERO - SUB-INCREMENT	STRES284
C IF AZ IS POSITIVE - CONTINUE	STRES285
C	STRES286
IF(AZ) 80,150,100	STRES287
80 WRITE(NWRITE,7C)	STRES288
90 FORMAT(1H ,4X,14HAA NEGATIVE AT)	STRES289
GO TO 180	STRES290
C	STRES291
C TEST DISCRIMINANT	STRES292
C	STRES293
C IF DISCR IS NEGATIVE - SUB-INCREMENT	STRES294
C OTHERWISE CONTINUE	STRES295
100 IF(DISCR.LT.0.) GO TO 150	STRES296
C	STRES297
C TEST BZ	STRES298
C	STRES299
C IF BZ IS NEGATIVE OR ZERO - SUB-INCREMENT	STRES300
C OTHERWISE CONTINUE	STRES301
C	STRES302
IF(BZ.LE.0.)GOTO 150	STRES303
C COMPUTE HLAMDA AND ELASTOPLASTIC STRESSES	STRES304
HLAMD2= BZ*SQRT(DISCR)	STRES305
HLAMDA=CZ/HLAMD2	STRES306
121 CONTINUE	STRES307
TM(1,1)=TR(1,1)-HLAMDA*TC(1,1)	STRES308
TM(1,2)=TR(1,2)-HLAMDA*TC(1,2)	STRES309
TM(2,1)=TR(2,1)-HLAMDA*TC(2,1)	STRES310
TM(2,2)=TR(2,2)-HLAMDA*TC(2,2)	STRES311
IF (IGQ02) GO TO 8050	STRES312
TM(1,3)=TR(1,3)-HLAMDA*TC(1,3)	STRES313
TM(2,3)=TR(2,3)-HLAMDA*TC(2,3)	STRES314
TM(3,1)=TR(3,1)-HLAMDA*TC(3,1)	STRES315
TM(3,2)=TR(3,2)-HLAMDA*TC(3,2)	STRES316
IF(IGQ03)GOTO 8050	STRES317
TM(3,3)=TR(3,3)-HLAMDA*TC(3,3)	STRES318
IF(IGQ04) TM(3,3)=TR(3,3)	STRES319
8050 CONTINUE	STRES320

```

TAUM=TP(1,1)+TM(2,2)*TP(3,3)
IF(IICOUNT.EQ.1)CALL AUXIL(7)
CHECK THE SUB-INCREMENT NUMBER
STRESS321
STRESS322
STRESS323
C
C
C
IF(LC.EG.L)GOTO 210
LC=LC+1
GO TO 50
STRESS324
STRESS325
STRESS326
STRESS327
C
C
C
PAKE SUB-INCREMENTS SMALLER
STRESS328
STRESS329
STRESS330
C
150 L=L+1
EL=L
STRESS331
STRESS332
C
C
CHECK MAXIMUM NUMBER OF ALLOWABLE SUB-INCREMENTS
STRESS333
STRESS334
C
IF(L-100) 45,45,160
WRITE(INWRITE,17C)
STRESS335
STRESS336
170 FORMAT(1H ,4X,36MSTRESS CALCULATION UNSATISFACTORY AT )
STRESS337
180 WRITE(INWRITE,190) TIME,11,12,I,LAYER,ISB,L,LC
STRESS338
STRESS339
190 FORMAT(1H ,9X,9MTIME STEP,16,5X,3HI1=,12,5X,3HI2=,12,5X,6MLAYER=,1
STRESS340
*2,9MSUBLAYER=,12,5X,2HL=,13,5X,3MLC=,13)
STRESS341
WRITE(INWRITE,200) AZ,BZ,CZ,DISCR,
STRESS342
* ((TM(IV,JV),JV=1,3),IV=1,3),((TR(IV,JV),
STRESS343
* JV=1,3),IV=1,3),((TC(IV,JV),JV=1,3),IV=1,3))
STRESS344
200 FORMAT(10X,"AZ " =",E15.6,10X,"BZ " =",E15.6,10X,"CZ " =",E15.6,5
STRESS345
*,10X,"DISCR " =",E15.6
STRESS346
*/10X,"FIXED INITIAL STRESSES",16X,"= TM " =",3E15.6/56X,3E15.6/
STRESS347
*56X,3E15.6/10X,"MIXED TRIAL ELASTIC STRESSES",10X,"= TR " =,
STRESS348
*3E15.6/56X,3E15.6/56X,3E15.6/10X,"MIXED CORRECTOR 3-DIMENSIONAL ST
STRESS349
*RESSES= TC " =",3E15.6/56X,3E15.6/56X,3E15.6)
STRESS350
CALL DIAGNO(5)
STRESS351
C
C
C
HAVE REACHED PLASTIC SOLUTION
STRESS352
STRESS353
C
210 CONTINUE
IPLAST(11,12)=IPLAST(11,12)+1
STRESS354
STRESS355
GO TO 222
STRESS356
STRESS357
C
220 CONTINUE
STRESS358
STRESS359
C
C
ELASTIC TM EQUALS TRIAL TR PER SUBLAYER
STRESS360
STRESS361
C
TM(1,1)=TR(1,1)
STRESS362
TM(1,2)=TR(1,2)
STRESS363
TM(2,1)=TR(2,1)
STRESS364
TM(2,2)=TR(2,2)
STRESS365
IF (QQQ2) GO TO 9050
STRESS366
TM(1,3)=TR(1,3)
STRESS367
TM(2,3)=TR(2,3)
STRESS368
TM(3,1)=TR(3,1)
STRESS369
TM(3,2)=TR(3,2)
STRESS370
TM(3,3)=TR(3,3)
STRESS371
9050 CONTINUE
STRESS372
C
222 CONTINUE
STRESS373
STRESS374
CGAMPMX(3,3)=(TM(3,3)-TN(3,3))-MMU*((TM(1,1)-TN(1,1))*(TM(2,2)-TN(
STRESS375
*2,2))) / ES + (L * MMU) * (2 * TN(3,3) - TN(1,1) - TN(2,2)) * MLAMCA / (3 * ES)
STRESS376
IF(IICOUNT.EQ.1)CALL AUXIL(7)
STRESS377
C
C
STORE MIXED TENSOR SUBLAYER STRESSES
STRESS378
STRESS379
IF(IICOUNT.EQ.0)GOTO 2500
STRESS380
C
TAU11(11,12,12)=TM(1,1)
STRESS381
STRESS382
TAU12(11,12,12)=TM(1,2)
STRESS383
TAU21(11,12,12)=TM(2,1)
STRESS384
TAU22(11,12,12)=TM(2,2)
STRESS385
IF(QQQ2)GOTO 2500
STRESS386
TAU13(11,12,12)=TM(1,3)
STRESS387
TAU23(11,12,12)=TM(2,3)
STRESS388
TAU31(11,12,12)=TM(3,1)
STRESS389
TAU32(11,12,12)=TM(3,2)
STRESS390
IF(QQQ3)GOTO 2500
STRESS391
TAU33(11,12,12)=TM(3,3)
STRESS392
2500 CONTINUE
STRESS393
C
C
C
CALCULATE TOTAL MIXED TENSOR STRESSES FROM SUBLAYER STRESSES
STRESS394
STRESS395
LMAT(11,12,12)=LI112
STRESS396
TAUF(1,1)=TAUF(1,1)+COEFF(ISB)*TM(1,1)
STRESS397
TAUF(1,2)=TAUF(1,2)+COEFF(ISB)*TM(1,2)
STRESS398

```

```

      TAU(2,1)=TAUF(2,1)*COEFF(ISB)*TM(2,1)
      TAU(2,2)=TAUF(2,2)*COEFF(ISB)*TM(2,2)
      IF(QQQ2)GOTO 2501
      TAU(1,3)=TAUF(1,3)*COEFF(ISB)*TM(1,3)
      TAU(3,1)=TAUF(3,1)*COEFF(ISB)*TM(3,1)
      TAU(2,3)=TAUF(2,3)*COEFF(ISB)*TM(2,3)
      TAU(3,2)=TAUF(3,2)*COEFF(ISB)*TM(3,2)
      IF(QQQ3)GOTO 2501
      TAU(3,3)=TAUF(3,3)*COEFF(ISB)*TM(3,3)
2501 CONTINUE
      CGAM33=CGAM33+COEFF(ISB)*DGAMMX(3,3)
      ISUBL=ISB
      IF(ICOUNT.EQ.1)CALL AUXIL(3)
C
C 250 CONTINUE
C      CONTRAVARIANT TOTAL STRESSES
      TAU(1,1)=TAUF(1,1)*GG(1,1)+TAUF(1,2)*GG(2,1)+TAUF(1,3)*GG(3,1)
      TAU(1,2)=TAUF(1,1)*GG(1,2)+TAUF(1,2)*GG(2,2)+TAUF(1,3)*GG(3,2)
      TAU(2,1)=TAUF(2,1)*GG(1,1)+TAUF(2,2)*GG(2,1)+TAUF(2,3)*GG(3,1)
      TAU(2,2)=TAUF(2,1)*GG(1,2)+TAUF(2,2)*GG(2,2)+TAUF(2,3)*GG(3,2)
      TAU(1,2)=.5*(TAU(1,2)+TAU(2,1))
      TAU(2,1)=TAU(1,2)
      IF(QQQ2)GOTO 2600
      TAU(1,3)=TAUF(1,1)*GG(1,3)+TAUF(1,2)*GG(2,3)+TAUF(1,3)*GG(3,3)
      TAU(3,1)=TAUF(3,1)*GG(1,1)+TAUF(3,2)*GG(2,1)+TAUF(3,3)*GG(3,1)
      TAU(2,3)=TAUF(2,1)*GG(1,3)+TAUF(2,2)*GG(2,3)+TAUF(2,3)*GG(3,3)
      TAU(3,2)=TAUF(3,1)*GG(1,2)+TAUF(3,2)*GG(2,2)+TAUF(3,3)*GG(3,2)
      TAU(3,3)=TAUF(3,1)*GG(1,3)+TAUF(3,2)*GG(2,3)+TAUF(3,3)*GG(3,3)
      TAU(1,3)=.5*(TAU(1,3)+TAU(3,1))
      TAU(3,1)=TAU(1,3)
      TAU(2,3)=.5*(TAU(2,3)+TAU(3,2))
      TAU(3,2)=TAU(2,3)
2600 CONTINUE
      IF(ICOUNT.EQ.1)GOTO 270
      ANUM=1/F
      IF(IPLAST(11,12).GT.0) ANUM=1/M
      TAUSPM=(TAUF(1,1)+TAUF(2,2)+TAUF(3,3))/3.0
      IF(MAUXIL.EQ.1)CALL MAXMIN(TAUF,1)
      CALL AUXIL(11)
      DO 260 LL=1,NUP
      IF(LL.NE.1)PS1(LL)GOTO 260
      IF(LL.NE.2)PS2(LL)GOTO 260
      TAUSPL(LL,IGAUS)=TAUSPM
      LZ=IGAUS+NGAUS(ILAYER)*(LL-1)*[LAYER
      DO 255 I=1,3
      DO 255 J=1,3
      TAUPL(LZ,I,J)=TAUF(I,J)
255 CONTINUE
260 CONTINUE
C
C      FMAT(IGAUS,11,12)=ANUM
270 CONTINUE
C      CALCULATE CHANCE IN TM PER GAUSS STATION AS TP - TN
C
      DTM(1,1)=DTM(1,1)+TAU(1,1)*G(1,1)+TAU(1,2)*G(2,1)+TAU(1,3)*G(3,1)
      DTM(1,2)=DTM(1,2)+TAU(1,1)*G(1,2)+TAU(1,2)*G(2,2)+TAU(1,3)*G(3,2)
      DTM(2,1)=DTM(2,1)+TAU(2,1)*G(1,1)+TAU(2,2)*G(2,1)+TAU(2,3)*G(3,1)
      DTM(2,2)=DTM(2,2)+TAU(2,1)*G(1,2)+TAU(2,2)*G(2,2)+TAU(2,3)*G(3,2)
      IF(QQQ2)GO TO 9070
      DTM(1,3)=DTM(1,3)+TAU(1,1)*G(1,3)+TAU(1,2)*G(2,3)+TAU(1,3)*G(3,3)
      DTM(2,3)=DTM(2,3)+TAU(2,1)*G(1,3)+TAU(2,2)*G(2,3)+TAU(2,3)*G(3,3)
      DTM(3,1)=DTM(3,1)+TAU(3,1)*G(1,1)+TAU(3,2)*G(2,1)+TAU(3,3)*G(3,1)
      DTM(3,2)=DTM(3,2)+TAU(3,1)*G(1,2)+TAU(3,2)*G(2,2)+TAU(3,3)*G(3,2)
      DTM(3,3)=DTM(3,3)+TAU(3,1)*G(1,3)+TAU(3,2)*G(2,3)+TAU(3,3)*G(3,3)
9070 CONTINUE
      RETURN
      END

```

STRES401
 STRES402
 STRES403
 STRES404
 STRES405
 STRES406
 STRES407
 STRES408
 STRES409
 STRES410
 STRES411
 STRES412
 STRES413
 STRES414
 STRES415
 STRES416
 STRES417
 STRES418
 STRES419
 STRES420
 STRES421
 STRES422
 STRES423
 STRES424
 STRES425
 STRES426
 STRES427
 STRES428
 STRES429
 STRES430
 STRES431
 STRES432
 STRES433
 STRES434
 STRES435
 STRES436
 STRES437
 STRES438
 STRES439
 STRES440
 STRES441
 STRES442
 STRES443
 STRES444
 STRES445
 STRES446
 STRES447
 STRES448
 STRES449
 STRES450
 STRES451
 STRES452
 STRES453
 STRES454
 STRES455
 STRES456
 STRES457
 STRES458
 STRES459
 STRES460
 STRES461
 STRES462
 STRES463
 STRES464
 STRES465
 STRES466
 STRES467

C	SUBROUTINE ZETA	ZETA	1
C	EVALUATE STRESSES THROUGH THE THICKNESS AND EVALUATE	ZETA	2
C	CONTRAVARIANT COMPONENTS OF THE RELATIVE MOMENT RESULTANT TENSOR	ZETA	3
C	AND OF THE RELATIVE STRESS RESULTANT TENSOR	ZETA	4
C	IMPLICIT LOGICAL(Q)	ZETA	5
C	COMMON/ ALLENE /TOTAL,TOTKIN,TOTELA,TOTPLA,TOTWEX,TOTTEM,ENERGY	ZETA	6
	* ,TOTVIS,TOTE1,TOTE2,EHECK	ZETA	7
	* ,DTM(3,3),SORG,SGRA,SIGMSG,AZ,BZ,CZ	ZETA	8
C	COMMON /APTRAC/ KSPOTS,KT(4),KDIR(4,3),MMTYPE(4),MTTYPE(4),KSPOT,	ZETA	9
	* KSIDE,STIFN(4,3),TORQK(4)	ZETA	10
	COMMON /APTRAL/ TA1(3,80),TA2(3,80),HM1(80),HM2(80)	ZETA	11
	LEVEL 2,TA1,TA2,HM1,HM2	ZETA	12
C	COMMON /CARTE/ YTEST,YNEW,YSAVE	ZETA	13
	COMMON /CARTEL/ Y(3,20,20),G(3,20,20),Y2(3,20,20),D2(3,20,20)	ZETA	14
	LEVEL 2,Y,G,Y2,D2	ZETA	15
C	COMMON /CTIME/ AUX(20),TIME,DELTAT,TIMEF,ITIME,ITIMEF,IAUX(20),	ZETA	16
	* IQUT(20),QPRINT(20)	ZETA	17
	COMMON /CTIME/ IPLAST(20,20),PI(20,20),PPL(20,20)	ZETA	18
	LEVEL 2,IPLAST,P,PPL	ZETA	19
C	COMMON/CTHKN/ ZA(20,20),ZB(20,20),DZA1(20,20),DZA2(20,20),	ZETA	20
	* DZB1(20,20),DZB2(20,20),HBAR(80)	ZETA	21
	LEVEL 2,ZA,ZB,DZA1,DZA2,DZB1,DZB2,HBAR	ZETA	22
C	COMMON /INDEX/ NREAD,NWRITE,NPUNCH,NMESH1,NMESH2,N1,N2,NZ,N1P,N2P,	ZETA	23
	* N1PM,N2PM,I1,I2,I3,I1ZERO,I2ZERO,IRY1,IRY2,IKY3,IKY4,ISTR1,ISTR2,	ZETA	24
	* ISTR3,ISTR4,IC1,IC2,IC1,IC2,IP1,IP2,IS1,IS2,K1,K2,K3,K4,KRON,	ZETA	25
	* KZSTOP,KYTEST,ICIR,I1TEST,I2TEST,KINITL	ZETA	26
C	COMMON /NEW1/ GCISP,MDISP,IST1,IST2,IST3,IST4,QTRAC,*TRAC,	ZETA	27
	* TAUMAX,TAUMIN,GAMMAX,GAMMIN,ELMAX,ELMIN,I1MAX,I2MAX,IGAMAS,	ZETA	28
	* ILAMAS,I1MINS,I2MINS,IGAMIS,ILAMIS,I1MAXX,I2MAXX,I2MAXX,I1PINX,	ZETA	29
	* I2PINX,I2MINX,I1PMAX,I2PMAX,I2PMAX,I1PMIN,I2PMIN,I2PMIN,I1I(20),	ZETA	30
	* QTRACT,QTRACT,I1PHY(20),MPHY	ZETA	31
C	COMMON /OPTION/ MAUXIL,PINGEO,MINVEL,MLOAD,MMATPR,MSPLCA,	ZETA	32
	* MSPTEM,MTEPE,MTHICK,PIMPUL,ISTRES,INCRML,ISTREZ	ZETA	33
C	COMMON /PHYSN/ EE,MNU,ALPHA,CONST,EXPCN,FACTOR,RATE,KMG,	ZETA	34
	* HLPDA,COEFF(5),SIGMA(5),IP(3,3),TC(3,3),DELTA(3,3)	ZETA	35
C	COMMON /PUSH/ FORCES(3),VELCC(3),RATIO,RATION,CX1,CX2,TEMP,CTEMP,	ZETA	36
	* FSPACE,TSPACE,FINCNO,FSTOP,TSTOP,THCUEF	ZETA	37
	COMMON /PUSHL/ SCRAT(20,20),SGRAZ(20,20),FMAS11(20,20),	ZETA	38
	* FMAS22(20,20),FMAS23(20,20),FMAS33(20,20)	ZETA	39
	LEVEL 2,SGRAT,SGRAZ,FMAS11,FMAS22,FMAS23,FMAS33	ZETA	40
C	COMMON /GLOGIC/ GAUX(20),QZETA,QSTRES,CPLAST,QSENS1,QEGUL,	ZETA	41
	* QDIAGN,QINGEO,QINVEL,CLQAC,QMATPR,CTHICK,QTEPE,GSPTEM,GAUX11,	ZETA	42
	* GAUX12,GSPLOA,QIMPUL,GSHARP,QPESD,QIRCH,QSHEAR	ZETA	43
C	COMMON /SURNOM/ SNPR(3)	ZETA	44
	COMMON /SURNOL/ SN(3,20,20)	ZETA	45
	LEVEL 2,SN	ZETA	46
C	COMMON /SZ/ STRESL(3)	ZETA	47
	COMMON /SZL/ STRESL(3,20,20),STRESG(2,20,20),STRESP(2,20,20)	ZETA	48
	LEVEL 2,STRESL,STRESG,STRESP	ZETA	49
C	COMMON /TENCOM/ YY(3,2),YYY(3,2,2),A(3,3),B(3,3),AA(3,3),BB(3,3),	ZETA	50
	* BM(3,3),DA(3,3),DB(3,3),G(3,3),GG(3,3),DN(3,3),CC(3,2,2),	ZETA	51
	* DGAM(3,3),DGAMPX(3,3),HM(3,3),HC(2),TAU(3,3),TALSBL(3,3)	ZETA	52
	* ,DD2(3,2),DD2(3,2,2),YY2(3,2),YYY2(3,2,2),YYU(3,2),DBM(3,3)	ZETA	53
C	COMMON /THKNS/ Z,ZZ,ZCENTR,THICKN,ABSCIS(6,6),WEIGHT(6,6),	ZETA	54
	* NGAUSS(4),IGAUSS,NLAYER,ILAYER,NSUBL(4),ISUBL	ZETA	55
C	COMMON /TNCMP/ HM1(2,20,20),HM2(2,20,20),CAPQ1(2,20,20),	ZETA	56
	* CAPQ2(2,20,20),CAPQ3(2,20,20),CAP2G1(2,20,20),	ZETA	57
	* CAP2Q2(2,20,20),CAP2Q3(2,20,20)	ZETA	58
	LEVEL 2,HM1,HM2,CAPQ1,CAPQ2,CAPQ3,CAP2G1,CAP2Q2,CAP2Q3	ZETA	59
C	COMMON /VARTHK/ VTHIK(4,20,20),CENTRV(4,20,20)	ZETA	60
	LEVEL 2,VTHIK,CENTRV	ZETA	61

C	COMMON /VIS1/ IVIS,AVIS(4),GVIS(4),DSTR11,DSTR12,DSTR13,DSTR21,	ZETA 81
	* DSTR22,DSTR23,DSTR31,DSTR32,DSTR33	ZETA 82
	COMMON /VISL/ VSTR11(4,20,20),VSTR12(4,20,20),VSTR13(4,20,20),	ZETA 83
	* VSTR22(4,20,20),VSTR23(4,20,20)	ZETA 84
	LEVEL 2,VSTR11,VSTR12,VSTR13,VSTR22,VSTR23	ZETA 85
C	COMMON /STRINT/ EPSL1(20,20),EPSL2(20,20),GAMMAL(20,20),	ZETA 86
	* EPSU1(20,20),EPSU2(20,20),GAMMAU(20,20)	ZETA 87
	LEVEL 2,EPSL1,EPSL2,GAMMAL,EPSU1,EPSU2,GAMMAU	ZETA 88
	COMMON /MA11/ NCONT,NRITE,NTRAIN,NRITE,NCPL,ETAD1,ETAC2,NSTRN	ZETA 89
	* ,FACTDM,MQ,FACTDN,NQ,FKIN	ZETA 90
	COMMON /CNE/ OGAM33	ZETA 91
	COMMON /THREE/ AGAM33	ZETA 92
	COMMON /TEMP/ PGAM33	ZETA 93
C	COMMON /DELC/ ICOUNT	ZETA 94
	COMMON /DEL/ DELBAR(20,20)	ZETA 95
	LEVEL 2,DELBAR	ZETA 96
	COMMON /GG/SURFGG	ZETA 97
	COMMON /GPRINT/ GTYPE,GBASE(3,3),GDBASE(3,3)	ZETA 98
C	COMMON /FRAC/ TAU(3,3),TAUSPH,NUM,IPSL(10),IPSL(10)	ZETA 99
C	DIMENSION DZ(3),CS(3,2),CX(3,3),MM(2,2)	ZETA 100
C	PAR=0.	ZETA 101
C	FOR ORTHOGONAL COORDINATES, TO REDUCE ERROR	ZETA 102
C	IF (K1.NE.7.AND.K2.NE.7) GO TO 10	ZETA 103
	DA(1,2)=0.	ZETA 104
	DA(2,1)=C.	ZETA 105
	DB(1,2)=0.	ZETA 106
	DB(2,1)=0.	ZETA 107
10	CONTINUE	ZETA 108
	CALL ERASE(MM,4)	ZETA 109
	STRESL(1,1,12)=0.	ZETA 110
	STRESL(2,1,12)=0.	ZETA 111
	STRESL(3,1,12)=0.	ZETA 112
	CAPC1(1,1,12)=0.	ZETA 113
	CAPC1(2,1,12)=0.	ZETA 114
	CAPC2(1,1,12)=0.	ZETA 115
	CAPC2(2,1,12)=0.	ZETA 116
	CAPC3(1,1,12)=0.	ZETA 117
	CAPC3(2,1,12)=0.	ZETA 118
	CAP2C1(1,1,12)=0.	ZETA 119
	CAP2C1(2,1,12)=0.	ZETA 120
	CAP2C2(1,1,12)=0.	ZETA 121
	CAP2C2(2,1,12)=0.	ZETA 122
	CAP2C3(1,1,12)=0.	ZETA 123
	CAP2C3(2,1,12)=0.	ZETA 124
	STRESP(1,1,12)=0.	ZETA 125
	STRESP(2,1,12)=0.	ZETA 126
	STRESQ(1,1,12)=0.	ZETA 127
	STRESQ(2,1,12)=0.	ZETA 128
	DZ(1)=0.	ZETA 129
	DZ(2)=0.	ZETA 130
	DZ(3)=0.	ZETA 131
	ZZ=0.	ZETA 132
	DB(3,3)=C.	ZETA 133
	IPLAST(11,12)=0	ZETA 134
C	*IC-SURFACE OFFSET	ZETA 135
C	FOR KIRCHHOFF OR SHEAR SHELL CONSIDER DEL=0 SINCE, FROM THICKLA,	ZETA 136
C	THE POINT Z=0 IS THE HALF THICKNESS OF THE SHELL AND IS NOT WEIGHTED	ZETA 137
C	VARIATION IN THE DENSITY	ZETA 138
	DEL=0.0	ZETA 139
	IF (QIRCH .OR. CSMEAR) GO TO 2205	ZETA 140
	THICKZ=C.	ZETA 141
	DO 2204 I LAYER =1,3	ZETA 142
	CALL THICKLA(I)	ZETA 143
2204	THICKZ=THICKZ+THICKN	ZETA 144
	ZCEN=THICKZ*.5	ZETA 145
	I LAYER=1	ZETA 146
	CALL THICKLA(I)	ZETA 147
	ZZCEN=THICKN-ZB(11,12)	ZETA 148
	DEL=ZCEN-ZZCEN	ZETA 149
2205	CONTINUE	ZETA 150
	CS(1,1)=BM(1,1)*YY(1,1)+BM(2,1)*YY(1,2)	ZETA 151
	CS(1,2)=BM(1,2)*YY(1,1)+BM(2,2)*YY(1,2)	ZETA 152
	CS(2,1)=BM(1,1)*YY(2,1)+BM(2,1)*YY(2,2)	ZETA 153
	CS(2,2)=BM(1,2)*YY(2,1)+BM(2,2)*YY(2,2)	ZETA 154
	CS(3,1)=BM(1,1)*YY(3,1)+BM(2,1)*YY(3,2)	ZETA 155
		ZETA 156
		ZETA 157
		ZETA 158
		ZETA 159
		ZETA 160
		ZETA 161
		ZETA 162

CS(3,2)=BM(1,2)*YY(3,1)+BM(2,2)*YY(3,2)	ZETA 163
CALL ERASE (MN,9)	ZETA 164
MM1(1,1,12)=0.0	ZETA 165
MM1(2,1,12)=0.0	ZETA 166
MM2(1,1,12)=0.0	ZETA 167
MM2(2,1,12)=0.0	ZETA 168
IZ=0	ZETA 169
IF(IICOUNT.EQ.1) CALL ENERGY(2,1.0)	ZETA 170
IF(INORPL.EQ.2) DGAMA3=0.	ZETA 171
IF(INORPL.EQ.2) THICKZ=0.	ZETA 172
DGM33=0.0	ZETA 173
SUMG=0.0	ZETA 174
THIC=0.0	ZETA 175
SGAM33=0.0	ZETA 176
C CALCULATIONS FOR ALL LAYERS	ZETA 177
DO 169 ILAYER=1,NLAYER	ZETA 178
ISTREZ=ISTRES	ZETA 179
IF (GIRCH) GO TO 63	ZETA 180
IF (NLAYER.EQ.1) GO TO 61	ZETA 181
IF(ILAYER=2) 60,61,62	ZETA 182
60 ZZ=ZB(1,12)	ZETA 183
DZ(1)=CZB1(1,12)	ZETA 184
DZ(2)=CZB2(1,12)	ZETA 185
DZ(3)=0.	ZETA 186
GO TO 63	ZETA 187
61 CONTINUE	ZETA 188
IF(.NOT.GIRCH.AND..NOT.GSHEAR.AND.ISTRES.EQ.2) ISTREZ=3	ZETA 189
DZ(1)=0.	ZETA 190
DZ(2)=0.	ZETA 191
DZ(3)=1.	ZETA 192
GO TO 63	ZETA 193
62 ZZ=ZA(1,12)	ZETA 194
DZ(1)=CZA1(1,12)	ZETA 195
DZ(2)=CZA2(1,12)	ZETA 196
DZ(3)=0.	ZETA 197
63 CONTINUE	ZETA 198
CALL THICKLA(1)	ZETA 199
IF(INORPL.EQ.2) THICKZ=THICKZ+THICKN	ZETA 200
THIC=THIC+THICKN	ZETA 201
NGAUSL=NGAUSS(ILAYER)	ZETA 202
C SURFACE TRAXON	ZETA 203
CALL SFORCE (CS,THICKN,YY,YY2,1,12,SURFGG)	ZETA 204
C CALCULATIONS FOR EACH GAUSS POINT	ZETA 205
DO 169 IGAUSS=1,NGAUSL	ZETA 206
C Z AS MEASURED FROM MID-SURFACE	ZETA 207
Z=.5*THICKN*ABSCIS(IGAUSS,NGAUSL)+ZCENTR	ZETA 208
C Z AS MEASURED FROM REFERENCE SURFACE	ZETA 209
Z=Z+DEL	ZETA 210
IF (ILAYER.EQ.2,CR.(.NOT.GIRCH.AND.NLAYER.EQ.1)) ZZ=Z	ZETA 211
IF (GSHEAR) ZZ=Z	ZETA 212
IF (MTEPPE .NE. 0) CALL TEPPER	ZETA 213
IF (MTEPPE .NE. 0 .OR. IGAUSS.EQ.1) CALL MATPRO	ZETA 214
IF(MTEPPE.NE.0 .OR. IGAUSS.EQ.1) CALL ENERGY(6,1.0)	ZETA 215
GBTN=0.0	ZETA 216
C CALCULATIONS FOR ALL COMPONENTS	ZETA 217
DO 9 J=1,3	ZETA 218
GBASE(3,J)=SN(J,1,12)	ZETA 219
IF(.NOT.GSHEAR.AND.INORPL.EQ.2) GBASE(3,J)=GBASE(3,J)+Y2(J,1,12)	ZETA 220
IF (GIRCH) GO TO 9891	ZETA 221
IF(.NOT.GSHEAR.AND.INORPL.EQ.2) GO TO 9891	ZETA 222
GBASE(3,J)=GBASE(3,J)+CZ(3)*Y2(J,1,12)	ZETA 223
9891 CONTINUE	ZETA 224
GBTN=GBTN+GBASE(3,J)*SN(J,1,12)	ZETA 225
GBASE(1,J)=YY(J,1)-Z*CS(J,1)	ZETA 226
GBASE(2,J)=YY(J,2)-Z*CS(J,2)	ZETA 227
IF(GIRCH) GO TO 9	ZETA 228
GBASE(1,J)=GBASE(1,J)+CZ(1)*Y2(J,1,12)+ZZ*YY2(J,1)	ZETA 229
GBASE(2,J)=GBASE(2,J)+CZ(2)*Y2(J,1,12)+ZZ*YY2(J,2)	ZETA 230
4 CONTINUE	ZETA 231
CALL ERASE(0GBASE,4)	ZETA 232
0GBASE(3,1)=0N(1)	ZETA 233
0GBASE(3,2)=0N(2)	ZETA 234
0GBASE(3,3)=0N(3)	ZETA 235
IF(GIRCH) GO TO 886	ZETA 236
0GBASE(3,1)=0GBASE(3,1)+DZ(3)*DZ(1,1,12)	ZETA 237
0GBASE(3,2)=0GBASE(3,2)+DZ(3)*DZ(2,1,12)	ZETA 238
0GBASE(3,3)=0GBASE(3,3)+DZ(3)*DZ(3,1,12)	ZETA 239
886 CONTINUE	ZETA 240

```

      DD 888 LA=1,2
      DD 888 K=1,3
      DD 887 LS=1,2
887 DGBASE(LA,K)=DGBASE(LA,K)+(CELTA(LS,LA)-Z*BH(LS,LA))*DD(K,LS)-
      * Z*DBH(LS,LA)*(YY(K,LS)-DD(K,LS))
      IF (QIRCH) GO TO 888
      DGBASE(LA,K)=DGBASE(LA,K)+Z*DDZ(K,LA)+CZ(LA)*DZ(K,I1,I2)
888 CONTINUE
      G(1,1)=GBASE(1,1)*GBASE(1,1)+GBASE(1,2)*GBASE(1,2)
      * GBASE(1,3)*GBASE(1,3)
      G(1,2)=GBASE(1,1)*GBASE(2,1)+GBASE(1,2)*GBASE(2,2)
      * GBASE(1,3)*GBASE(2,3)
      G(1,3)=GBASE(1,1)*GBASE(3,1)+GBASE(1,2)*GBASE(3,2)
      * GBASE(1,3)*GBASE(3,3)
      G(2,1)=G(1,2)
      G(2,2)=GBASE(2,1)*GBASE(2,1)+GBASE(2,2)*GBASE(2,2)
      * GBASE(2,3)*GBASE(2,3)
      G(2,3)=GBASE(2,1)*GBASE(3,1)+GBASE(2,2)*GBASE(3,2)
      * GBASE(2,3)*GBASE(3,3)
      G(3,1)=G(1,3)
      G(3,2)=G(2,3)
      G(3,3)=GBASE(3,1)*GBASE(3,1)+GBASE(3,2)*GBASE(3,2)
      * GBASE(3,3)*GBASE(3,3)
      CALL ERASE(DGAM,9)
      IJ=3
      IF (QIRCH) IJ=2
      DD 102 I=1,IJ
      DD 102 J=1,IJ
      DD 102 K=1,3
102 DGAM(I,J)=CGAM(I,J)+.5*(GBASE(I,K)*DGBASE(J,K)+GBASE(J,K)*DGBASE(I,K)-
      * CGAM(I,K)*CGAM(J,K)+DGBASE(I,K)*DGBASE(J,K))
      C
      G=CTYPE
      CTYPE=G(1,1)*G(2,2)+G(3,3)-G(2,3)*2+G(1,2)*G(1,3)+G(2,3)-
      * G(1,2)*G(3,3)+G(1,3)*G(1,2)+G(2,3)-G(1,3)*G(2,2)
      SQRG=SQRT(CTYPE)
      CTYPE=1./CTYPE
      GG(1,1)=(G(2,2)*G(3,3)-G(2,3)*2)*CTYPE
      GG(1,2)=(G(1,3)*G(2,3)-G(1,2)*G(3,3))*CTYPE
      GG(2,1)=GG(1,2)
      GG(1,3)=(G(1,2)*G(2,3)-G(1,3)*G(2,2))*CTYPE
      GG(3,1)=GG(1,3)
      GG(2,2)=(G(1,1)*G(3,3)-G(1,3)*2)*CTYPE
      GG(2,3)=(G(1,2)*G(1,3)-G(1,1)*G(3,2))*CTYPE
      GG(3,2)=GG(2,3)
      GG(3,3)=(G(1,1)*G(2,2)-G(1,2)*2)*CTYPE
      C
      C
      DGAMMX(1,1)=DGAM(1,1)*GG(1,1)+DGAM(1,2)*GG(2,1)+DGAM(1,3)*GG(3,1)
      DGAMMX(1,2)=DGAM(2,1)*GG(1,1)+DGAM(2,2)*GG(2,1)+DGAM(2,3)*GG(3,1)
      DGAMMX(1,3)=DGAM(3,1)*GG(1,1)+DGAM(3,2)*GG(2,1)+DGAM(3,3)*GG(3,1)
      DGAMMX(2,1)=DGAM(1,1)*GG(1,2)+DGAM(1,2)*GG(2,2)+DGAM(1,3)*GG(3,2)
      DGAMMX(2,2)=DGAM(2,1)*GG(1,2)+DGAM(2,2)*GG(2,2)+DGAM(2,3)*GG(3,2)
      DGAMMX(2,3)=DGAM(3,1)*GG(1,2)+DGAM(3,2)*GG(2,2)+DGAM(3,3)*GG(3,2)
      DGAMMX(3,1)=DGAM(1,1)*GG(1,3)+DGAM(1,2)*GG(2,3)+DGAM(1,3)*GG(3,3)
      DGAMMX(3,2)=DGAM(2,1)*GG(1,3)+DGAM(2,2)*GG(2,3)+DGAM(2,3)*GG(3,3)
      DGAMMX(3,3)=DGAM(3,1)*GG(1,3)+DGAM(3,2)*GG(2,3)+DGAM(3,3)*GG(3,3)
      D33S=DGAMMX(3,3)
      IF (ICOUNT.EQ.1) CALL AUXIL(R)
      C
      THIS IS A CALL TO SUBROUTINE VISCUS
      IF (AVIS(ILAYER).NE.0) CALL DMTAU(3,C)
      C
      THIS IS A CALL TO SUBROUTINE STRESS
      CALL DMTAU(2,C)
      IF (MPHYS.NE.0 .AND. ICOUNT.EQ.1) CALL PHYSIC(2)
      PAR=THICKN*.5*WEIGHT(I GAUSS,NGAUSL)
      PARSC=PAR*SCRG
      MN(1,1)=MN(1,1)+PARSC*(TAU(1,1)*GBASE(1,1)+TAU(1,2)*GBASE(2,1)
      * TAU(1,3)*GBASE(3,1))
      MN(1,2)=MN(1,2)+PARSC*(TAU(1,1)*GBASE(1,2)+TAU(1,2)*GBASE(2,2)
      * TAU(1,3)*GBASE(3,2))
      MN(1,3)=MN(1,3)+PARSC*(TAU(1,1)*GBASE(1,3)+TAU(1,2)*GBASE(2,3)
      * TAU(1,3)*GBASE(3,3))
      MN(2,1)=MN(2,1)+PARSC*(TAU(2,1)*GBASE(1,1)+TAU(2,2)*GBASE(2,1)
      * TAU(2,3)*GBASE(3,1))
      MN(2,2)=MN(2,2)+PARSC*(TAU(2,1)*GBASE(1,2)+TAU(2,2)*GBASE(2,2)
      * TAU(2,3)*GBASE(3,2))
      MN(2,3)=MN(2,3)+PARSC*(TAU(2,1)*GBASE(1,3)+TAU(2,2)*GBASE(2,3)
      * TAU(2,3)*GBASE(3,3))
      IF (QIRCH) GO TO 2165
      PRSQD1=PARSC*DZ(1)
      PRSQD2=PARSC*DZ(2)
      ZETA 241
      ZETA 242
      ZETA 243
      ZETA 244
      ZETA 245
      ZETA 246
      ZETA 247
      ZETA 248
      ZETA 249
      ZETA 250
      ZETA 251
      ZETA 252
      ZETA 253
      ZETA 254
      ZETA 255
      ZETA 256
      ZETA 257
      ZETA 258
      ZETA 259
      ZETA 260
      ZETA 261
      ZETA 262
      ZETA 263
      ZETA 264
      ZETA 265
      ZETA 266
      ZETA 267
      ZETA 268
      ZETA 269
      ZETA 270
      ZETA 271
      ZETA 272
      ZETA 273
      ZETA 274
      ZETA 275
      ZETA 276
      ZETA 277
      ZETA 278
      ZETA 279
      ZETA 280
      ZETA 281
      ZETA 282
      ZETA 283
      ZETA 284
      ZETA 285
      ZETA 286
      ZETA 287
      ZETA 288
      ZETA 289
      ZETA 290
      ZETA 291
      ZETA 292
      ZETA 293
      ZETA 294
      ZETA 295
      ZETA 296
      ZETA 297
      ZETA 298
      ZETA 299
      ZETA 300
      ZETA 301
      ZETA 302
      ZETA 303
      ZETA 304
      ZETA 305
      ZETA 306
      ZETA 307
      ZETA 308
      ZETA 309
      ZETA 310
      ZETA 311
      ZETA 312
      ZETA 313
      ZETA 314
      ZETA 315
      ZETA 316
      ZETA 317
      ZETA 318
      ZETA 319
      ZETA 320

```

PRSQD3=PARSC*DZ(3)	ZETA 321
STRESL(1,1,12)=STRESL(1,1,12)+	ZETA 322
* PRSQD1*	ZETA 323
* (TAU(1,1)*GBASE(1,1)+TAU(1,2)*GBASE(2,1)+TAU(1,3)*GBASE(3,1))*	ZETA 324
* PRSQD2*	ZETA 325
* (TAU(2,1)*GBASE(1,1)+TAU(2,2)*GBASE(2,1)+TAU(2,3)*GBASE(3,1))*	ZETA 326
* PRSQD3*	ZETA 327
* (TAU(3,1)*GBASE(1,1)+TAU(3,2)*GBASE(2,1)+TAU(3,3)*GBASE(3,1))	ZETA 328
STRESL(2,1,12)=STRESL(2,1,12)+	ZETA 329
* PRSQD1*	ZETA 330
* (TAU(1,1)*GBASE(1,2)+TAU(1,2)*GBASE(2,2)+TAU(1,3)*GBASE(3,2))*	ZETA 331
* PRSQD2*	ZETA 332
* (TAU(2,1)*GBASE(1,2)+TAU(2,2)*GBASE(2,2)+TAU(2,3)*GBASE(3,2))*	ZETA 333
* PRSQD3*	ZETA 334
* (TAU(3,1)*GBASE(1,2)+TAU(3,2)*GBASE(2,2)+TAU(3,3)*GBASE(3,2))	ZETA 335
STRESL(3,1,12)=STRESL(3,1,12)+	ZETA 336
* PRSQD1*	ZETA 337
* (TAU(1,1)*GBASE(1,3)+TAU(1,2)*GBASE(2,3)+TAU(1,3)*GBASE(3,3))*	ZETA 338
* PRSQD2*	ZETA 339
* (TAU(2,1)*GBASE(1,3)+TAU(2,2)*GBASE(2,3)+TAU(2,3)*GBASE(3,3))*	ZETA 340
* PRSQD3*	ZETA 341
* (TAU(3,1)*GBASE(1,3)+TAU(3,2)*GBASE(2,3)+TAU(3,3)*GBASE(3,3))	ZETA 342
PRSQZZ=PARSC*ZZ	ZETA 343
CAP2Q1(1,1,12)=CAP2Q1(1,1,12)+PRSQZZ*(TAU(1,1)*GBASE(1,1)	ZETA 344
* +TAU(1,2)*GBASE(2,1)+TAU(1,3)*GBASE(3,1))	ZETA 345
CAP2Q1(2,1,12)=CAP2Q1(2,1,12)+PRSQZZ*(TAU(2,1)*GBASE(1,1)	ZETA 346
* +TAU(2,2)*GBASE(2,1)+TAU(2,3)*GBASE(3,1))	ZETA 347
CAP2Q2(1,1,12)=CAP2Q2(1,1,12)+PRSQZZ*(TAU(1,1)*GBASE(1,2)	ZETA 348
* +TAU(1,2)*GBASE(2,2)+TAU(1,3)*GBASE(3,2))	ZETA 349
CAP2Q2(2,1,12)=CAP2Q2(2,1,12)+PRSQZZ*(TAU(2,1)*GBASE(1,2)	ZETA 350
* +TAU(2,2)*GBASE(2,2)+TAU(2,3)*GBASE(3,2))	ZETA 351
CAP2Q3(1,1,12)=CAP2Q3(1,1,12)+PRSQZZ*(TAU(1,1)*GBASE(1,3)	ZETA 352
* +TAU(1,2)*GBASE(2,3)+TAU(1,3)*GBASE(3,3))	ZETA 353
CAP2Q3(2,1,12)=CAP2Q3(2,1,12)+PRSQZZ*(TAU(2,1)*GBASE(1,3)	ZETA 354
* +TAU(2,2)*GBASE(2,3)+TAU(2,3)*GBASE(3,3))	ZETA 355
2165 CONTINUE	ZETA 356
IF (OSHEAR) GO TO 2059	ZETA 357
CX(1,1)=GBASE(1,1)*YYU(1,1)+GBASE(1,2)*YYU(2,1)	ZETA 358
* +GBASE(1,3)*YYU(3,1)	ZETA 359
CX(1,2)=GBASE(2,1)*YYU(1,1)+GBASE(2,2)*YYU(2,1)	ZETA 360
* +GBASE(2,3)*YYU(3,1)	ZETA 361
CX(1,3)=GBASE(3,1)*YYU(1,1)+GBASE(3,2)*YYU(2,1)	ZETA 362
* +GBASE(3,3)*YYU(3,1)	ZETA 363
CX(2,1)=GBASE(1,1)*YYU(1,2)+GBASE(1,2)*YYU(2,2)	ZETA 364
* +GBASE(1,3)*YYU(3,2)	ZETA 365
CX(2,2)=GBASE(2,1)*YYU(1,2)+GBASE(2,2)*YYU(2,2)	ZETA 366
* +GBASE(2,3)*YYU(3,2)	ZETA 367
CX(2,3)=GBASE(3,1)*YYU(1,2)+GBASE(3,2)*YYU(2,2)	ZETA 368
* +GBASE(3,3)*YYU(3,2)	ZETA 369
CX(3,1)=GBASE(1,1)*SN(1,1,12)+GBASE(1,2)*SN(2,1,12)	ZETA 370
* +GBASE(1,3)*SN(3,1,12)	ZETA 371
CX(3,2)=GBASE(2,1)*SN(1,1,12)+GBASE(2,2)*SN(2,1,12)	ZETA 372
* +GBASE(2,3)*SN(3,1,12)	ZETA 373
CX(3,3)=GBASE(3,1)*SN(1,1,12)+GBASE(3,2)*SN(2,1,12)	ZETA 374
* +GBASE(3,3)*SN(3,1,12)	ZETA 375
PARSQZ=PARSC*Z	ZETA 376
HM(1,1)=HM(1,1)+PARSQZ*(TAU(1,1)*CX(1,1)+TAU(1,2)*CX(1,2)	ZETA 377
* +TAU(1,3)*CX(1,3))	ZETA 378
HM(1,2)=HM(1,2)+PARSQZ*(TAU(1,1)*CX(2,1)+TAU(1,2)*CX(2,2)	ZETA 379
* +TAU(1,3)*CX(2,3))	ZETA 380
HM(2,1)=HM(2,1)+PARSQZ*(TAU(2,1)*CX(1,1)+TAU(2,2)*CX(1,2)	ZETA 381
* +TAU(2,3)*CX(1,3))	ZETA 382
HM(2,2)=HM(2,2)+PARSQZ*(TAU(2,1)*CX(2,1)+TAU(2,2)*CX(2,2)	ZETA 383
* +TAU(2,3)*CX(2,3))	ZETA 384
C	ZETA 385
STRESP(1,1,12)=STRESP(1,1,12)+PARSQ*(TAU(3,1)*CX(1,1)	ZETA 386
* +TAU(3,2)*CX(1,2)+TAU(3,3)*CX(1,3))	ZETA 387
STRESP(2,1,12)=STRESP(2,1,12)+PARSQ*(TAU(3,1)*CX(2,1)	ZETA 388
* +TAU(3,2)*CX(2,2)+TAU(3,3)*CX(2,3))	ZETA 389
STRESQ(1,1,12)=STRESQ(1,1,12)+PARSQZ*(TAU(1,1)*CX(3,1)	ZETA 390
* +TAU(1,2)*CX(3,2)+TAU(1,3)*CX(3,3))	ZETA 391
STRESQ(2,1,12)=STRESQ(2,1,12)+PARSQZ*(TAU(2,1)*CX(3,1)	ZETA 392
* +TAU(2,2)*CX(3,2)+TAU(2,3)*CX(3,3))	ZETA 393
2059 CONTINUE	ZETA 394
DGM33=DGM33+D335*PAR	ZETA 395
SUMG=SUMG+GG(3,3)*PAR	ZETA 396
IF (ICOUNT .EQ. 1) CALL ENERGY(3,PAR)	ZETA 397
SGAM33=SGAM33+DGM33*PAR	ZETA 398
IF (INORPL.NE.2) GO TO 169	ZETA 399
TAUSUM=DTM(1,1)+DTM(2,2)+DTM(3,3)	ZETA 400

OGAMA3=OGAMA3+(((1.-2.*HNU)/EE)*TAUSUM	ZETA 401
* -DGAMMX(1,1)-DGAMMX(2,2)+3.*ALPHA*DTEMP)*PAR	ZETA 402
169 CONTINUE	ZETA 403
OGM33=OGM33/THIC	ZETA 404
AVEG33=SUMG/THIC	ZETA 405
AGAM33=SGAM33/THIC	ZETA 406
IF(ICOUNT.EQ.1)GOTO 180	ZETA 407
DGOG=2.0*(OGM33-AGAM33)/AVEG33	ZETA 408
DELBAR(1,1,2)=-GBTN+SQR(GBTN**2-DGOG)	ZETA 409
180 CONTINUE	ZETA 410
C SURFACE STRAINS FOR PLOTTING	ZETA 411
IF(ICOUNT.EQ.1)GOTO 190	ZETA 412
IF(I1.EQ.I51.AND.I2.EQ.I52) PGAM33=PGAM33+AGAM33	ZETA 413
IF(ICOUNT.EQ.1) CALL AUXIL(10)	ZETA 414
EPSL1(1,1,2)=EPSL1(1,1,2)+0.5*(DA(1,1)+THIC*DB(1,1))	ZETA 415
EPSL2(1,1,2)=EPSL2(1,1,2)+0.5*(DA(2,2)+THIC*DB(2,2))	ZETA 416
GAMMAL(1,1,2)=GAMMAL(1,1,2)+0.5*(DA(1,2)+THIC*DB(1,2))	ZETA 417
EPSU1(1,1,2)=EPSU1(1,1,2)+0.5*(DA(1,1)-THIC*DB(1,1))	ZETA 418
EPSU2(1,1,2)=EPSU2(1,1,2)+0.5*(DA(2,2)-THIC*DB(2,2))	ZETA 419
GAMMAU(1,1,2)=GAMMAU(1,1,2)+0.5*(DA(1,2)-THIC*DB(1,2))	ZETA 420
190 CONTINUE	ZETA 421
IF(INORPL.NE.2) GO TO 200	ZETA 422
C AVERAGING AT EACH POINT	ZETA 423
OGAMA3=OGAMA3/THICKZ	ZETA 424
C SETTING Y2 AND D2	ZETA 425
IF(CIRCH)GO TO 450	ZETA 426
D2(1,1,1,2)=D2(1,1,1,2)+OGAMA3*SN(1,1,1,2)	ZETA 427
D2(2,1,1,2)=D2(2,1,1,2)+OGAMA3*SN(2,1,1,2)	ZETA 428
D2(3,1,1,2)=D2(3,1,1,2)+OGAMA3*SN(3,1,1,2)	ZETA 429
450 Y2(1,1,1,2)=Y2(1,1,1,2)+OGAMA3*SN(1,1,1,2)	ZETA 430
Y2(2,1,1,2)=Y2(2,1,1,2)+OGAMA3*SN(2,1,1,2)	ZETA 431
Y2(3,1,1,2)=Y2(3,1,1,2)+OGAMA3*SN(3,1,1,2)	ZETA 432
200 HM1(1,1,1,2)=HM(1,1)	ZETA 433
HM1(2,1,1,2)=HM(1,2)	ZETA 434
HM2(1,1,1,2)=HM(2,1)	ZETA 435
HM2(2,1,1,2)=HM(2,2)	ZETA 436
C	ZETA 437
C ASSUMING ORTHOGONAL COORDINATES, TO REDUCE ERROR	ZETA 438
C	ZETA 439
IF(K1.NE.7.AND.K2.NE.7) RETURN	ZETA 440
HM1(2,1,1,2)=0.	ZETA 441
HM2(1,1,1,2)=0.	ZETA 442
RETURN	ZETA 443
END	ZETA 444

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
12	Administrator Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314	1	Commander US Army Concepts Analysis Agency 8120 Woodmont Avenue Bethesda, MD 20014
1	Director Defense Advanced Rsch Projects Agency 1400 Wilson Boulevard Arlington, VA 22209	1	Deputy Chief of Staff for Intelligence USA-Europe ATTN: Tech Sec APO, NY 09131
1	Office of Deputy Under-Sec of Defense for Res & Eng (ET) ATTN: Mr. J. Persh Staff Spec for Materi- als & Structures Room 3D1089, The Pentagon Washington, DC 20301	1	Commander in Chief US Army Europe & Seventh Army ATTN: AEURRIC APO, NY 09403
2	Fed Emergency Management Agency ATTN: Mr. M. Pachuta RF-SR, Tech Lib Washington, DC 20472	1	Commandant US Army Command and Gen Staff College ATTN: Archives Ft Leavenworth, KS 66027
6	Director Defense Nuclear Agency ATTN: STSI/Archives DDST/Dr. Oswald SPAS,SPSS,SPTD, RATN Washington, DC 20305	1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333
1	HQDA (DAMA-AR-A) Washington, DC 20310	1	Commander Armament R&D Center US Army AMCCOM ATTN: DRSMC-TDC(D) Dr. D. Gyorog Dover, NJ 07801
1	HQDA (DAMA-WSM) Washington, DC 20310	1	Commander US Army Materiel Development and Readiness Command ATTN: DRCCP 5001 Eisenhower Avenue Alexandria, VA 22333
1	HQDA (DACS-BMZ-A) Washington, DC 20310		

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	Commander Armament R&D Center USA AMCCOM ATTN: DRSMC-TSS(D) Dover, NJ 07801	2	Director US Army BMD Advanced Technology Center ATTN: CRDABH-X, CRDABH-S P.O. Box 1500 Huntsville, AL 35807
1	Commander US Army Armament, Munitions and Chemical Command ATTN: DRSMC-LEP-L(R) Rock Island, IL 61299	1	Commander US Army BMD Systems Command ATTN: BMDSC-TFN, N.J. Hurst P.O. Box 1500 Huntsville, AL 35807
3	Commander US Army Armament, Munitions and Chemical Command ATTN: DRSMC-LEP-L(R) DRCPM ARGADS(R) DRSMC-RDF(R) Rock Island, IL 61299	2	Chief of Engineers ATTN: DAEN-MCE-D DAEN-RDM Washington, DC 20314
1	Director Benet Weapons Laboratory Armament R&D Center ATTN: DRSMC-LCB-TL(D) Watervliet, NY 12189	3	Commander US Army Aviation Research and Development Command ATTN: DRDAV-E DRCPM-ASE DRDAV-DI 4300 Goodfellow Boulevard St. Louis, MO 63120
1	Director Institute for Defense Analyses ATTN: Library 1801 Beauregard Street Alexandria, VA 22311	1	Director US Army Air Mobility Research & Development Laboratory Ames Research Center Moffett Field, CA 94035
2	Dep Chief of Staff for Operations & Plans ATTN: Technical Lib Dir, Chem & Nuclear Operations Department of the Army Washington, DC 20310	1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMA-ST 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Missile Command ATTN: DRSMI-R Redstone Arsenal, AL 35898	1	Commander US Army Missile Command ATTN: DRSMI-YDL Redstone Arsenal, AL 35898

DISTRIBUTION LIST

<u>No. of</u> <u>Copies</u>	<u>Organization</u>	<u>No. of</u> <u>Copies</u>	<u>Organization</u>
4	Director Applied Technology Lab US Army Research & Technology Laboratory (AVRADCOM) ATTN: DAVDL-EU-VAT, Mr. Merritt DAVDL-PP, Mr. Morrow DAVDL-ATL DAVDL-RM Fort Eustis, VA 23604	1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703
1	Commander US Army Troop Support & Aviation Materiel Readiness Command ATTN: DRSTG-G Sys Anal Ofc 4300 Goodfellow Boulevard St. Louis, MO 63120	2	Commander US Army Harry Diamond Lab ATTN: DELHD-TA-L DELHD-RBA/J. Rosado 2800 Powder Mill Road Adelphi, MD 20783
2	Commander US Army Communications Research 1 and Development Command ATTN: DRSEL-ATDD DRDCO-PPA-SA Fort Monmouth, NJ 07703	3	Commander US Army Harry Diamond Lab ATTN: Mr. J. Gaul Mr. J. Gwaltney Mr. R. J. Bostak 2800 Powder Mill Rd Adelphi, MD 20783
1	Commander US Army Engineer Waterways Exp Station ATTN: Tech Lib P.O. Box 631 Vicksburg, MS 39181	1	Commander US Army Missile Command ATTN: DRCPM-MDET-PA Redstone Arsenal, AL 35898
1	Commander US Army Eng Center Fort Belvoir, VA 22060	1	Commander US Army Mobility Equipment R&D Cmd ATTN: DRDME-WC Fort Belvoir, VA 22060
1	Commander US Army Missile Command ATTN: DRSMI-CM Redstone Arsenal, AL 35898	1	Commander US Army Research Office P.O. Box 12211 Research Triangle Pk, NC 27709

DISTRIBUTION LIST

<u>No. of</u> <u>Copies</u>	<u>Organization</u>	<u>No. of</u> <u>Copies</u>	<u>Organization</u>
1	Commander US Army Nuclear & Chem Agcy ATTN: Tech Lib 7500 Backlick Rd, Bldg 2073 Springfield, VA 22150	1	Director US Army TRADOC Systems Analysis Activity ATTN: ATAA-SL White Sands Missile Range NM 88002
1	Commander US Army Natick Research and Development Lab ATTN: DRDNA, Dr. Seiling Natick, MA 01760	1	Commander US Army Training & Doctrine Command ATTN: DCST-TDD Fort Monroe, VA 23651
1	Commander US Army Tank Automotive Command ATTN: DRSTA-TSL Warren, MI 48090	1	Commander US Army Combat Development Experimentation Command ATTN: CSCG Ln Ofc Ford Ord, CA 93941
2	Commander US Army Tank Automotive Command ATTN: DRSTA-UL DRSTA-RWL Warren, MI 48090	1	Commander US Army Forces Command ATTN: AVN SEC Fort McPherson, GA 30330
1	President US Army Aviation Test Bd Fort Rucker, AL 36360	1	Commandant US Army Air Defense Center ATTN: Air Defense Agency Fort Bliss, TX 79916
1	Commander US Army Logistics Management Center Fort Lee, VA 23801	1	Commandant US Army Armor School ATTN: Armor Agency Fort Knox, KY 40121
4	Commander US Army Materials and Mechanics Research Ctr ATTN: DRXMR-RD Tech Lib (J. Mescall) (R. Shea) (S.C. Chou) Watertown, MA 02172	1	Commandant US Army Aviation School Fort Rucker, AL 36360
		1	Commandant US Army Field Artillery Sch ATTN: Field Artillery Agency Fort Sill, OK 73503

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	Commandant US Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905	10	Commander Naval Air Systems Command ATTN: Air-5204 (2 cys) Air-605 (3 cys) Air 530 Air-095A Air-53603B Air-330 Air-350 Washington, DC 20360
1	Commandant US Army Transportation School Fort Eustis, VA 23604	3	Commander Naval Sea Systems Command ATTN: SEA-62R, Mr. Sieve SEA-62Y SEA-9961 Washington, DC 20360
1	Commander US Army Combined Arms Combat Dev Activity Ft Leavenworth, KS 66027	1	Commander Naval Air Development Ctr, Johnsville ATTN: SAED, Code 5033 Warminster, PA 18974
1	Commander US Army Air Defense Human Research Unit ATTN: ATHRD Fort Bliss, TX 79916	4	Commander Naval Surface Weapons Ctr ATTN: Code DG-13 Code G-10 Lib Br, DX-21 Dr. W. Soper Dahlgren, VA 22448
1	Commander US Army Agency for Aviation Safety Fort Rucker, AL 36360	5	Commander Naval Surface Weapons Ctr ATTN: Code 040, Code N- Code 433, Code N- Code WX21/Tech Lib Silver Spring, Md 20910
3	Chief of Naval Operations ATTN: NOP-05 NOP-34 NOP-96C2 Department of the Navy Washington, DC 20350	1	Commander US Army Missile Command ATTN: DRCPM-HA Redstone Arsenal, AL 35898
1	Chief of Naval Material ATTN: MAT-03D15 Dept of Navy Washington, DC 20350		
1	Commander US Army Missile Command ATTN: DRCPM-HA Redstone Arsenal, AL 35898		

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
8	Commander Naval Weapons Center ATTN: Code 338, Code 3831, Code 3835, Code 39104 Code 3431, Tech Lib Code 31804, M. Keith Code 533, Tech Lib Code 6031, Dr. Stronge China Lake, CA 93555	1	Commander Naval Weapons Eval Facility ATTN: Doc Control Kirtland AFB, NM 87117
1	Commander David W. Taylor Naval Ship R&D Center ATTN: Lib Div, Code 522 Bethesda, MD 20084	1	Commander Naval Ammunition Depot ATTN: RD-3 Crane, IN 47522
1	Commander Naval Research Lab ATTN: CODE 2027, Tech Lib Washington, DC 20375	2	Commander Naval Research Lab ATTN: Code 6003 Code 8443 Washington, DC 20375
6	Officer-in-Charge (Code L31) Civil Engineering Lab Naval Construction Btn Ctr ATTN: Dr. W. A. Shaw John Crawford Technical Library Stan Takahashi R. J. Odello W. A. Keenan Port Hueneme, CA 93041	5	Commandant US Marine Corps ATTN: Code AAP Code AAW-1 Code AAW-5 Code APW-52 Code APW-71 Washington, DC 20380
1	Office of Naval Research ATTN: N. Perrone 800 N. Quincy Street Arlington, VA 22217	1	Director Development Center, MCDEC Quantico, VA 22134
1	Superintendent Naval Postgraduate School ATTN: Code 57, Prof Ball Monterey, CA 93940	4	AFWL/SUL AFWL/PG AFSWC/TEEM AFSWC/TESPO Kirtland AFB, NM 87117
		1	HQ USAF (AFSCAGF)/SDOA Andrews AFB, MD 20334
		3	HQ AFSC (SDZ, SDDE, DLAW)/SDOA Andrews AFB, MD 20334

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
3	US Army Field Office /SDOA HQ USAF Systems Command ATTN: SDNE DDAB, SDW Andrews AFB, MD 20334	1	Director Lawrence Livermore Lab Tech Info Div P.O. Box 808 Livermore, CA 94550
1	ADTC (SES) Eglin AFB, FL 32542	2	Director Los Alamos Scientific Lab ATTN: Doc Control P.O. Box 1663 Los Alamos, NM 87544
2	AFATL (DRLRV, J. R. Rutland) (DLYV) Eglin AFB, FL 32542	1	Director NASA Scientific and Tech Info Facility P.O. Box 8757 BaltWash Intern'l Airport, MD 21240
1	USAFTAWC (OA) Eglin AFB, FL 32542		
1	TAC Langley AFB, VA 23365		
1	AFAPL (SFH) Wright-Patterson AFB, OH 45433	1	AFFDL (FBE, Dr. Bader) Wright-Patterson AFB, OH 45433
1	AFFDL (FES) Wright-Patterson AFB, OH 45433	2	Director National Aeronautics and Space Administration Langley Research Center ATTN: MS 246E, L. Bement MS 249, J. Ward Hampton, VA 23665
1	AFFDL (FER) Wright-Patterson AFB, OH 45433		
1	AFFDL (FEN) Wright-Patterson AFB, OH 45433	1	Director National Aeronautics & Space Administration Lewis Research Center 2100 Brookpark Road, MS 77-5 Cleveland, OH 44135
1	AFFDL (FDTR, Dr. Janik) Wright-Patterson AFB, OH 45433		
1	ASD/XROT, G. B. Bennett Wright-Patterson AFB, OH 45433		
1	AFML (LLN, Dr. Nicholas) Wright-Patterson AFB, OH 45433	1	Bell Helicopter Textron ATTN: Mr. Nile Fischer P.O. Box 482 Fort Worth, TX 76101
1	ASD/ENFTV, Mr. J. Wallick Wright-Patterson AFB, OH 45433		

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	The Boeing Company Vertol Division ATTN: Dave Harding P.O. Box 16858 Philadelphia, PA 19142	2	University of Delaware Dept of Mech & Aerospace Engineering ATTN: Prof. J. R. Vinson Prof. M. Taya Newark, DE 19711
1	Fairchild Industries Fairchild Republic Div ATTN: D. Watson Farmingdale, LI, NY 11735	1	Florida Atlantic Univ Dept of Ocean Eng ATTN: Prof. K. Stevens Boca Raton, FL 33432
1	KETRON Company Thor Division 696 Fairmount Avenue Baltimore, MD 21204	1	J.G. Eng Res Associates 3831 Menlo Drive Baltimore, MD 21215
2	Falcon Research and Development Company ATTN: Levelle Mahood Arthur Stein 109 Inverness Drive, E Englewood, CO 80112	1	Mass Inst Of Tech Aerolastic & Structures Research Laboratory ATTN: Dr. E. A. Witmer 77 Massachusetts Avenue Cambridge, MA 02139
1	General Electric Company Military Engine Products Division ATTN: E. L.. Richardson Building 2406A 1000 Western Avenue West Lynn, MA 01905	1	ASD (XRM) Wright-Patterson AFB, OH 45433
1	Kaman Tempo ATTN: E. Bryant 715 Shamrock Rd Suite UL-1 Bel Air, MD 21014	1	Texas A&M University Dept Aerospace Eng ATTN: Dr. W. Haisler College Station, TX 77843
1	Hughes Aircraft Co. ATTN: Security Officer Centinela and Teale Sts Bldg 6, MS E-125 Culver City, CA 90230	1	Weidlinger Associates Consulting Eng ATTN: M. L. Baron 110 East 59th Street New York, NY 10022
2	Director Sandia National Labs ATTN: Info Dist Div Dr. W. Von Riesmann Albuquerque, NM 87115	2	Virginia Polytechnic Inst & State Univ Dept of Eng Mech ATTN: Prof D. Frederick Prof C. W. Smith Blacksburg, VA 24061

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Georgia Inst of Tech School of Civil Eng ATTN: Prof S. N. Atluri Atlanta, GA 30332	1	United Aircraft Corp Sikorsky Aircraft Div ATTN: S. O. Karma Stratford, CT 06602
1	Brown University Div of Eng ATTN: Prof. P. Symonds Providence, RI 02912	1	New Mexico Inst of Minning and Technology TERA Group Socorro, NM 87801
1	University of Dayton Res Inst ATTN: Dr. S. Bless Dayton, OH 45469	1	Southwest Research Inst ATTN: W. Baker 8500 Culebra Road San Antonio, TX 78228
1	University of Washington Dept of Aeronautics and Astronautics ATTN: Prof. I. M. Fyfe Seattle, WA 98105	<u>ABERDEEN PROVING GROUND</u>	
1	LTV Aerospace Corp Vought Systems Division ATTN: D. M. Reedy Unit 2 54244 P.O. Box 5907 Dallas, TX 75222	Dir, USAMSAA ATTN: DRXSY-D DRXSY-MP, H. Cohen	
1	Meredith Engineering 33170 Glen Valley Drive Farmington Hills, MI 48018	Cdr, USATECOM ATTN: DRSTE-TO-F	
1	Aeronautical Research Associates of Princeton, Inc. ATTN: Dr. J. W. Leech P.O. Box 2229 50 Washington Road Princeton, NJ 08540	Cdr, CRDC, AMCCOM ATTN: DRSMC-ACW DRSMC-CLB-PA DRSMC-CLN DRSMC-CLJ-L	
1	Rockwell International Los Angeles Aircraft Div ATTN: R. L. Moonan Mail Code AB75 International Airport Los Angeles, CA 90009		

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number _____
2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.) _____

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.) _____

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: _____

Telephone Number: _____

Organization Address: _____

----- FOLD HERE -----

Director
US Army Ballistic Research Laboratory
ATTN: DRSMC-BLA-S (A)
Aberdeen Proving Ground, MD 21005



NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

OFFICIAL BUSINESS

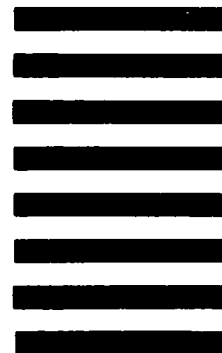
PENALTY FOR PRIVATE USE, \$300

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO 12062 WASHINGTON, DC

POSTAGE WILL BE PAID BY DEPARTMENT OF THE ARMY

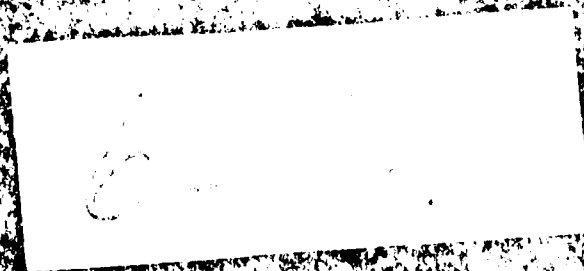
Director
US Army Ballistic Research Laboratory
ATTN: DRSMC-BLA-S (A)
Aberdeen Proving Ground, MD 21005



----- FOLD HERE -----

END

FILMED



DTIC