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DEVELOPMENT OF A SOLID ROCKET PROPELLANT NONLINEAR VISCOELASTIC CONSTITUTIVE THEORY. VOLUME 2. APPENDICES

Richard J. Farris, et al

Aerojet Solid Propulsion Company

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This program was designed to develop three dimensional nonlinear viscoelastic equations that could describe the stress-strain response of solid propellant materials for complex loading conditions. The approach used was to identify and mathematically model the underlying mechanisms contributing to the constitutive nonlinearity and to then include these effects within the framework of a continuum constitutive theory.

The program was successful in meeting its objectives and some of the program developments and conclusions are as follows. The dominant mechanisms leading to the nonlinear stress-strain response is microstructural damage in the form of the Mullins' stress-softening effect and vacuole dilatation. Reversible nonlinearities were found to be of secondary importance. These effects have been modeled and combined into a constitutive theory that works very well for fitting the distortional stress-strain behavior under complex loading conditions. This theory is a permanent memory constitutive theory and contains irreversible effects of the past history on the current response. Time effects are included through time-dependent structural damage as well as the ordinary viscous energy dissipation. The experimental work consisted of determining the three dimensional strain response due to complex stress histories at temperatures from -65°F to +150°F and superimposed hydrostatic stress-states from 0 to 1000 psi. To handle the large masses of data generated on this contract computerized characterization techniques were developed wherein the equations could be fit to large masses of data.

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10. Computerized Characterization						

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DEVELOPMENT OF A SOLID ROCKET PROPELLANT NONLINEAR VISCOELASTIC CONSTITUTIVE THEORY

Volume II - Appendices

Prepared by:

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FOREWORD

This program was sponsored by the

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The technical effort reported herein was accomplished under Contract F04611-71-C-0046 and covered the period from May 1971 through June 1973. Mr. Norman Walker was the Air Force project engineer at the start of this contract until he left AFRPL. Dr. Randy L. Peeters was the Air Force materials engineer for the remainder of this contract.

The program was completely successful in meeting its objectives. The success of the program was due to the combined efforts of key personnel at two facilities, the Aerojet Solid Propulsion Company and the Texas A&M Research Foundation. The Aerojet team performed an extensive experimental effort, developed computerized characterization techniques, and performed theoretical work in developing constitutive equations which accurately model the multi-axial behavior of composite propellants. The team at the Texas A&M Research Foundation supported the effort by performing theoretical and experimental work to develop mathematical models for characterizing solid propellants under realistic states of strain. The emphasis of their work was to develop simple constitutive equations based on thermodynamic principles for visco-elastic materials having microstructural damage.

The key technical personnel on this program were: Dr. Richard J. Farris who directed the Aerojet effort and coordinated the overall effort as the Program Technical Manager, and Dr. Richard A. Schapery who directed the Texas A&M effort. Mr. Frederick H. Davidson performed all of the experimental work at Aerojet and Mr. Dennis F. Vronay was primarily responsible for the computerized characterization work. Mr. L. E. Lewis and Mr. R. T. Shankle performed the Texas A&M experimental effort which was under the guidance of Mr. Scott Beckwith.

This technical report has been reviewed and is approved.

Dr. Randy L. Peeters (MKPB)
Materials Engineer, AFRPL
Edwards, California

ABSTRACT

This program was designed to develop three dimensional nonlinear viscoelastic equations that could describe the stress-strain response of solid propellant materials for complex loading conditions. The approach used was to identify and mathematically model the underlying mechanisms contributing to the constitutive nonlinearity in these highly filled polymeric materials and to then include these effects within the framework of a continuum constitutive theory. Also considerable theoretical work was done showing how the resulting mathematical representations could be contained within the framework of a thermodynamic theory and viscoelastic fracture mechanics. During the course of this contract considerable experimental as well as theoretical work were performed since the development of the theory was based on modeling observable effects. The experimental work consisted of determining the three dimensional strain response due to complex stress histories at temperatures from -65°F to +150°F and superimposed hydrostatic stress-states from 0 to 1000 psi. In total over 250 experiments were run using uniaxial and biaxial volumetric dilatometers and the stress-strain-strain invariant-time history of each experiment is stored on magnetic tape and can be made available for others to use.

The program was successful in meeting its objectives and some of the program developments and conclusions are as follows. The dominant mechanisms leading to the nonlinear stress-strain response is microstructural damage in the form of the Mullins' stress-softening effect and vacuole dilatation. Reversible nonlinearities such as second order hereditary strain effects were found to be of secondary importance. These effects have been successfully modeled and combined into a relatively simple constitutive theory that works very well for fitting the distortional stress-strain behavior under complex loading conditions. This theory is a permanent memory constitutive theory and contains irreversible effects of the past history on the current response which are not included in the usual fading memory viscoelastic theories. Time effects are included in the permanent memory theory through time-dependent structural damage as well as the ordinary viscous energy dissipation. The bulk effects were also modeled and good agreement could be obtained only when the vacuole gas phase compressibility was included in the constitutive theory which resulted in a mixed stress-invariant-strain invariant representation. To handle the large masses of data generated on this contract computerized characterization techniques were developed wherein the equations could be fit to large masses of data to determine the applicability of the theory. For constant temperature conditions the theory could be fit within a standard deviation of ± 12% of the observed distortional stress data for approximately forty complex experiments using the entire response curve to failure. The overall accuracy dropped when all the temperature data was analyzed together to about ± 15%. The bulk response predictions were poorer and typical deviations were ± 25% nevertheless all of the proper trends were in the predictions and much of these errors were no doubt experimental.

TABLE OF CONTENTS

APPENDIX A - Studies on the Nonlinear Viscoelastic Behavior of Solid Propellant

APPENDIX B - Preprocessor Code NL001

APPENDIX C - Post Processor Code

APPENDIX D - Characterization Code NL002

APPENDIX E - Characterization Code NL003

APPENDIX F - Subprograms

APPENDIX G - Computerized Characterization Procedures for Linear Viscoelastic Materials Using Arbitrary Deformation Histories

APPENDIX H - Samples of Experimental Data

FOREWORD TO APPENDIX A

Appendix A, "Studies on the Nonlinear Viscoelastic Behavior of Solid Propellant," represents the final technical report from Texas A&M University subcontract effort to the Aerojet Solid Propulsion Company. The work at Texas A&M was performed under the direction of Professor R. A. Schapery. The intent of this subcontract was to (1) support the theoretical and experimental efforts being conducted at Aerojet, (2) provide an independent laboratory and technical staff to test and verify constitutive assumptions, (3) study the relation between Farris' non-fading memory constitutive theory and Schapery's thermodynamic theory, and (4) compare the relation, if any, between Farris' model for the Mullins' effect and Knauss' theory for the influence of microstructural cracks on the mechanical response of propellants.

The work performed at Texas A&M not only provided support for the work and representations used at Aerojet but recommended alternate inverse representations using L_p norms in stress rather than strain. In particular, the energy approach used by Schapery was instrumental in suggesting simplified three dimensional representations using only two strain invariants, the dilatation and the octahedral shear strain and bringing out the coupled dependency of dilatation and mean pressure on octahedral shear strain.

APPENDIX A

STUDIES ON THE NONLINEAR VISCOELASTIC BEHAVIOR OF SOLID PROPELLANT

Final Report from
Texas A&M University

By

R. A. Schapery

TABLE OF CONTENTS

		PAGE
I.	INTRODUCTION AND SUMMARY.	1
II.	THEORETICAL INVESTIGATIONS.	3
	A. Constitutive Equations for Elastic Media with Microstructural Damage	3
	B. Constitutive Equations for Viscoelastic Media with Microstructural Damage	12
	C. On Constitutive Equations which are Homogeneous to Degree One	19
	D. The Dilatational Constitutive Equation.	21
	E. Microstructural Damage Theory	33
	F. Thermodynamic Constitutive Equations with Implicit Pressure Dependence	50
	G. Generalization for Finite Strains	50
III.	EXPERIMENTAL INVESTIGATIONS	51
	A. Test Equipment and Procedures	51
	B. Experimental Data and Comparison with Analysis. . .	63
IV.	CONCLUSIONS	88
ACKNOWLEDGMENT.		89
REFERENCES.		90

STUDIES ON THE NONLINEAR VISCOELASTIC BEHAVIOR OF SOLID PROPELLANT

R. A. Schapery

May 1973

I. INTRODUCTION AND SUMMARY

The state-of-the-art of nonlinear viscoelastic characterization of solid propellant existing just prior to the start of this investigation was reviewed in [1]. Although some promising models had been proposed, such as Farris' representation of microstructural damage [2], little experimental verification existed for propellant with vacuole dilatation. The present study was undertaken in cooperation with Aerojet Solid Propulsion Company in order to develop mathematical models for characterizing solid propellant under realistic states of strain. Emphasis of the study at Texas A&M University was on the development of simple constitutive equations for propellant having very large amounts of vacuole dilatation and on the application of viscoelastic fracture mechanics to constitutive theory.

In Section II, constitutive equations based on thermodynamic principles are examined for elastic and viscoelastic media with microstructural damage. These equations provide the framework for establishing some special cases which apply to solid propellant. The role of fracture

mechanics in constitutive theory is brought out using the theory developed in [3].

The experimental investigations described in Section III cover uniaxial, strip biaxial, and poker chip tests. Dilatation was measured in all three modes; a dilatometer was used for the former two tests and changes in circumference were monitored to obtain dilatation in the poker chip test [4]. The strip biaxial and uniaxial data were found to support the proposed constitutive model. Poker chip test results turned out to be of rather limited quantitative use, especially with compressive loading, because of the strong nonlinearities exhibited by the propellant.

II. THEORETICAL INVESTIGATIONS

Three-dimensional constitutive equations for nonlinear media with microstructural damage are developed in this section. Results from thermodynamic theory are used to establish the general form of the equations, while possible measures of damage are examined in the light of viscoelastic fracture mechanics theory. As a means of clearly bringing out certain physical aspects of the problem we first derive equations for damaged elastic media. Viscoelastic equations are then developed. In order to provide a sufficiently general theory for incorporating physical models of microstructural damage and to be able to examine the relative merits of different specific representations, we examine both the case in which stresses are expressed as functions of strains and in which strains are functions of stresses.

For simplicity of notation, infinitesimal strain theory is used in the theoretical development of constitutive equations. However, at the end of Section II we show how the results can be immediately extended to finite strain theory by simply making a change in the notation.

A. Constitutive Equations for Elastic Media with Microstructural Damage

Introductory comments: Consider first a nonlinear elastic body with an arbitrary distribution of cracks with fixed length. Derivation of the overall stress-strain equations can be accomplished by following the same steps used for uncracked bodies. Specifically, by combining the First and Second Laws of Thermodynamics, with strains and temperature being the independent state variables, there results for isothermal processes [5]:

$$\sigma_{ij} = \frac{\partial F_e}{\partial \varepsilon_{ij}} \tag{1}$$

where F_e is the Helmholtz free energy/initial volume ("strain energy"). It is a function of the strains, ε_{ij}, temperature, T, and a set of parameters (β_K, say) which are needed to define the geometry (size, shape, orientation, location) of all cracks. The inverse strain-stress equation for isothermal processes likewise can be derived from thermodynamics by taking stresses and temperature as the independent variables [5]:

$$\varepsilon_{ij} = \frac{\partial F_s}{\partial \sigma_{ij}} \tag{2}$$

where $-F_s$ is the Gibbs free energy per unit initial volume ("complementary strain energy"). The energy F_s is, in general, a function of the stresses, σ_{ij}, temperature, T, and the crack parameters β_K.

Berry [6] has used the one-dimensional form of Eq. (2) to derive the overall Young's modulus, E_e, of a large linear elastic sheet under uniformly applied tensile stress, σ_{11}, and with one crack perpendicular to the external load. He obtained:

$$\varepsilon_{11} = \frac{\partial F_s}{\partial \sigma_{11}} = \frac{\sigma_{11}}{E}\left(1 + \frac{2\pi a^2}{A}\right) \tag{3a}$$

where E is the uncracked Young's modulus, 2a is the constant crack length, and A = sheet length x width. Thus,

$$E_e \equiv \frac{\sigma_{11}}{\varepsilon_{11}} = \left(1 + \frac{2\pi a^2}{A}\right)^{-1} E \tag{3b}$$

If there are N noninteracting cracks of length $2a_K$, instead of one crack, then a^2 in Eq. (3b) is simply replaced by $\sum_{K=1}^{N} a_K^2$ [7]; viz.

$$E_e = (1 + \frac{2\pi}{A} \sum_{K=1}^{N} a_K^2)^{-1} E \qquad (3c)$$

Equations (1) - (3) are obviously valid for moving cracks in an elastic body as long as the velocities are small enough for kinetic energy to be negligible. With this case one must still perform the differentiation in Eqs. (1) and (2) with the parameters β_K (e.g. a_K) held constant.

Predictions of time-dependent crack lengths and more realistic overall properties will be taken up in a later subsection. For now we shall assume the instantaneous values of β_K are known.

Equations for isotropic media with strains as the independent variables: Let us return to Eq. (1) and assume that it is valid regardless of the types of damage (e.g., submicroscopic polymer chain failure, binder cracks, and dewetting) which are characterized by the parameters β_K. For notational simplicity, explicit dependence of free energy on T and β_K will not be shown; but this dependence is to be assumed unless stated otherwise. Also, as noted previously, the partial derivatives with respect to strain are taken while holding damage (viz. β_K) constant. Furthermore, we will assume that the body, with or without damage, is statistically homogeneous and isotropic. (The body is defined to be statistically isotropic if, after the external loads are removed, there are no preferred directions; the response to a new set of loads will be independent of the material's orientation. If, for example, all of the cracks in a body are parallel, it is not statistically isotropic; if, however, cracks and other flaws are sufficiently random in their orientation isotropy can be assumed.)

Under the above assumptions, the free energy will depend on strain at most through any three independent invariants of the strain tensor. If, for example, we use the three invariants

$$I_1 \equiv \varepsilon_{ii}$$

$$I_2 \equiv \varepsilon_{ij}\,\varepsilon_{ij} \tag{4}$$

$$I_3 \equiv \varepsilon_{ij}\,\varepsilon_{jm}\,\varepsilon_{mi}$$

where repeated indices imply summation over the range 1, 2, 3, then Eqs. (1) and (4), together with the use of the chain rule and the assumption $F_e = F_e(I_1, I_2, I_3)$, yield (where δ_{ij} is the Kronecker delta),

$$\sigma_{ij} = \frac{\partial F_e}{\partial I_1}\,\delta_{ij} + 2\,\frac{\partial F_e}{\partial I_2}\,\varepsilon_{ij} + 3\,\frac{\partial F_e}{\partial I_3}\,\varepsilon_{im}\,\varepsilon_{mj} \tag{5}$$

The damage parameters β_K, which are implicitly included in F_e, may depend on the history of the invariants (and their current values), but not directly on the individual components of the strain tensor.

For physical reasons, it is often desirable to use instead the invariant I_1 and the two strain-deviator invariants:

$$\tilde{I}_2 \equiv e_{ij}\,e_{ij}$$

$$\tilde{I}_3 \equiv e_{ij}\,e_{jm}\,e_{mi} \tag{6}$$

where e_{ij} are the deviatoric strains,

$$e_{ij} \equiv \varepsilon_{ij} - \frac{1}{3}\,\delta_{ij}\,I_1 \tag{7}$$

By substituting Eq. (7) into (6) we find

$$\tilde{I}_2 = I_2 - \frac{1}{3}\,I_1^2$$

$$\tilde{I}_3 = I_3 - I_1 I_2 + \frac{2}{9}\,I_1^3 \tag{8}$$

Equation (5) can be transformed to the deviator strains by using definition (7) and by applying the chain rule to the derivatives in (5); with $F_e = F_e(I_1, \tilde{I}_2, \tilde{I}_3)$ we find

$$s_{ij} = -\frac{\partial F_e}{\partial \tilde{I}_3}\tilde{I}_2\,\delta_{ij} + \frac{\partial F_e}{\partial \tilde{I}_2}e_{ij} + 3\frac{\partial F_e}{\partial \tilde{I}_3}e_{im}e_{mj} \tag{9}$$

and

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial I_1} \tag{10}$$

where s_{ij} are the deviatoric stresses,

$$s_{ij} \equiv \sigma_{ij} - \frac{1}{3}\delta_{ij}\theta \tag{11}$$

and θ is the dilatational stress,

$$\theta \equiv \sigma_{ii} \tag{12}$$

Note that when we set $i = j$ in Eq. (9) and sum the three equations ($j = 1, 2, 3$), the resulting equation is identically zero. Therefore, Eq. (9) defines five, rather than six, independent equations. These five equations, together with the dilatational Eq. (10), form a set which is equivalent to the set of six equations defined by Eq. (5). However, they are now separated into relations which express distortion, Eq. (9), and dilatation, Eq. (10).

For many metals and polymers (with or without filler particles), it is often possible to neglect the dependence of mechanical properties on $\tilde{I}_3$ [8]; this simplification will be used in all of the following discussion as present indications are that it is valid for solid propellant. Thus, from Eq. (9) with $F_e = F_e(I_1, \tilde{I}_2)$:

$$s_{ij} = 2 \frac{\partial F_e}{\partial \tilde{I}_2} e_{ij} \tag{13}$$

while the form of dilatational Eq. (10) is unchanged.

An important point is that if dependence on $\tilde{I}_3$ is not neglected, the deviatoric stresses in Eq. (9) are linear with respect to the square of the strain tensor, i.e. $e_{im}\, e_{mj}$. This dependence implies the deviatoric stress tensor is definitely not a homogeneous function to degree one. On the other hand, without $\tilde{I}_3$, Eq. (13) shows that it is at least possible (but not necessary) to select F_e such that the stress tensor satisfies this homogeneity condition.

An elastic free energy function for propellant: In this subsection we shall propose a specific free energy function which will be shown to predict actual nonlinear behavior of dewetted propellant. Specifically, we assume

$$F_e = \int_0^{I_T} K_1 I_T dI_T + \int_0^{\tilde{I}_2} G_2 d\tilde{I}_2 + N_1 N_2 \tag{14a}$$

where

$$I_T \equiv I_1 - 3\alpha\Delta T \tag{14b}$$

and the term $3\alpha\Delta T$ is the volumetric thermal expansion due to temperature change ΔT. Also,

$$K_1 = K_1(I_T) \quad , \quad G_2 = G_2(\tilde{I}_2)$$

$$N_1 = N_1(I_T) \quad , \quad N_2 = N_2(\tilde{I}_2)$$

are four nonlinear material property functions, each of which depends on only one invariant.

Substitute Eq. (14) into (10) and (13); thus

$$\frac{\theta}{3} = K_1 I_T + \frac{dN_1}{dI_T} N_2 \tag{15a}$$

$$s_{ij} = 2(G_2 + N_1 \frac{dN_2}{d\tilde{I}_2}) e_{ij} \tag{15b}$$

In the linear range of behavior, these equations must reduce to

$$\frac{\theta}{3} = K_e I_T \tag{16a}$$

$$s_{ij} = 2 G_e e_{ij} \tag{16b}$$

where K_e and G_e are the linear elastic bulk and shear moduli, respectively. Hence, K_1 and G_2 can be interpreted as the nonlinear generalizations of K_e and G_e, while N_1 and N_2 produce coupling between dilatational and shear phenomena. The product $N_1 N_2$ must be selected such that, at small strains, it is at least of third order in the strains in order that the proper linear limiting case, Eq. (16), is obtained.

Let us now go one step further and assume

$$K_1 = K_e \quad , \quad G_2 = G_e$$
$$N_1 = K_e I_T \tag{17}$$

and

$$N_2 = 0 \qquad \text{for} \quad \tilde{I}_2 < b^2$$
$$N_2 = -a(\sqrt{\tilde{I}_2} - b) \quad \text{for} \quad \tilde{I}_2 \geq b^2 \tag{18}$$

where a and b are non-negative quantities.* Substitution of Eqs. (17) and (18) into (15) yields, for $\tilde{I}_2 \geq b^2$:

$$\frac{\theta}{3} = K_e[I_T - a(\sqrt{\tilde{I}_2} - b)] \tag{19a}$$

---

*If $b = 0$, then the free energy function will be positive definite if and only if

$$a < \sqrt{2G_e/K_e}$$

$$s_{ij} = 2[G_e - \frac{aK_e I_T}{2\sqrt{\tilde{I}_2}}]\, e_{ij} \tag{19b}$$

while the linear relations (16) apply for $\tilde{I}_2 < b^2$.

It is of interest to examine Eq. (19) in some detail as these relations turn out to agree with a large amount of propellant data. First, observe that if G_e, K_e, and a depend at most on constant damage parameters β_K and/or are homogeneous to degree zero in the invariants (through β_K), then the deviatoric constitutive Eq. (19b) is homogeneous to degree one, and, in this regard, it agrees with Farris' observations [9]. However, the dilatational Eq. (19a) is not homogeneous to degree one unless (i) $\tilde{I}_2 < b^2$ and K_e depends on β_K as noted above or (ii) $\tilde{I}_2 >> b^2$ and K_e and a both depend on β_K as noted above.

If the dilatational stress θ is either known or is negligible, Eq. (19a) enables dilatation to be easily predicted; viz., for $\tilde{I}_2 \geq b^2$:

$$I_T \equiv I_1 - 3\alpha\Delta T = \frac{\theta}{3K_e} + a(\sqrt{\tilde{I}_2} - b) \tag{20}$$

The significance of this result in predicting dilatation in three common tests will be discussed in Section II-D.

Consider the simple shear test ($\varepsilon_{12} \neq 0$) in which $\Delta T = 0$ and the propellant is constrained such that all normal strains vanish, which implies $I_T \equiv 0$. Equation (19a) yields, for $\sqrt{\tilde{I}_2} = \sqrt{2}\,|\varepsilon_{12}| \geq b$,

$$\frac{\theta}{3} = -K_e\, a(\sqrt{2}\,|\varepsilon_{12}| - b) \quad . \tag{21}$$

Also, Eq. (19b) yields $\sigma_{11} = \sigma_{22} = \sigma_{33}$, and predicts that the effective shear modulus is G_e. Thus, the shear strain produces compressive normal stresses, which is consistent with experimental results [10]. Moreover, if the propellant is permitted to expand during shearing, Eq. (19b) predicts that the effective shear modulus will be less than that for no dilatation; this result, again, is consistent with propellant data [10].

Let us now return to Eq. (19b) and specialize it to uniaxial loading. Assuming $\varepsilon_{11} >> |I_T|$, we find

$$\sigma_{11} = 3 G_e \varepsilon_{11} [1 - \beta \frac{I_T}{\varepsilon_{11}}] \tag{22}$$

where

$$\beta \equiv \frac{aK_e}{\sqrt{6}\, G_e} \tag{23}$$

As long as

$$1 - \beta \frac{I_1}{\varepsilon_{11}} \approx e^{-\beta I_1/\varepsilon_{11}} \tag{24}$$

predicted stress (22) is the same as that reported by Farris [11], where $\beta \approx 2 - 3$.

We have assumed the quantities K_e, G_e, a, and b are constant insofar as the comparison with experimental data was concerned. The influence of damage parameters β_K on these quantities will be discussed in Section II-E.

It should be pointed out that the relations in Eq. (15), instead of those in Eq. (19), may be needed to characterize propellant subjected to moderate and high pressures. Alternatively, use of the method described in Section II-F together with Eq. (19) may prove to be better.

Equations for isotropic media with stresses as the independent variables: Constitutive equations corresponding to the isotropic version of Eq. (2) are completely analogous to those given in terms of strains. We introduce the dilatational stress invariant

$$\theta \equiv \sigma_{ii} \tag{25a}$$

and the two deviatoric stress invariants

$$\tilde{J}_2 = s_{ij}\, s_{ij} \tag{25b}$$

$$\tilde{J}_3 = s_{ij}\, s_{jm}\, s_{mi} \tag{25c}$$

The deviatoric strains are found to be

$$e_{ij} = -\frac{\partial F_s}{\partial \tilde{J}_3}\tilde{J}_2\,\delta_{ij} + 2\frac{\partial F_s}{\partial \tilde{J}_2}s_{ij} + 3\frac{\partial F_s}{\partial \tilde{J}_3}s_{im}\,s_{mj} \tag{26}$$

and the dilatational strain I_1 is

$$\frac{I_1}{3} = \frac{\partial F_s}{\partial \theta} \tag{27}$$

If F_s is independent of the third stress invariant $\tilde{J}_3$, then Eq. (26) becomes simply

$$e_{ij} = 2\frac{\partial F_s}{\partial \tilde{J}_2}s_{ij} \tag{28}$$

B. Constitutive Equations for Viscoelastic Media with Microstructural Damage

Equations for isotropic media with strains as the independent variables: The above considerations can be generalized to include viscoelastic behavior by drawing upon the irreversible thermodynamic theory in [12]. As before, we will assume that the dependence of material properties on $\tilde{I}_3$ can be neglected. Furthermore, the strain measures $q_1,\ldots,q_6$, in [12]

will be assumed as follows:

$$q_1 = \phi + \varepsilon_{11} \qquad q_4 = \varepsilon_{12}$$
$$q_2 = \phi + \varepsilon_{22} \qquad q_5 = \varepsilon_{23} \tag{29}$$
$$q_3 = \phi + \varepsilon_{33} \qquad q_6 = \varepsilon_{13}$$

where $\phi = \phi(I_T, \tilde{I}_2)$ is a material property which is assumed to vanish in the absence of vacuole dilatation; at small strains, this function must be at least of second order in the strains in order for the measures of strain to reduce to the strains in the linear range of behavior. The significance of ϕ will be seen by examining the resulting constitutive equations.

The use of Eq. (29) in the theory in [12] yields, after much rearrangement,

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial I_T} + a_F \frac{\partial q}{\partial I_T} \int_0^t \Delta K(\psi - \psi') \frac{dq}{d\tau} d\tau \tag{30a}$$

$$s_{ij} = 2 \frac{\partial F_e}{\partial \tilde{I}_2} e_{ij} + 2 a_F \int_0^t \Delta G(\psi - \psi') \frac{de_{ij}}{d\tau} d\tau + 2 a_F \frac{\partial q}{\partial \tilde{I}_2} e_{ij} \int_0^t \Delta K(\psi - \psi') \frac{dq}{d\tau} d\tau \tag{30b}$$

where

$$q = q(I_T, \tilde{I}_2) \equiv 3\phi + I_T \tag{31}$$

is the nonlinear dilatational strain measure which may be a function of both I_T and $\tilde{I}_2$. Also, ΔG and ΔK in these relations are the LVE transient components of the shear and bulk relaxation moduli, respectively. In general, there may be four different nonlinear material property functions

in Eq. (30); viz., F_e, a_F, q (or ϕ), and a_ε, where a_ε appears in the definition of reduced time ψ,

$$\psi = \psi(t) \equiv \int_c^t dt/a_\varepsilon \quad ; \quad \psi' \equiv \psi(\tau) \quad ; \quad a_\varepsilon = a_\varepsilon(I_T, \tilde{I}_2, T) \tag{32}$$

The term in Eq. (30b) involving ΔK gives rise to dependence of deviatoric stress on volume-change history, even when the deviatoric strain is constant.

These same equations could have been derived more directly from the underlying thermodynamic theory, Eq. (19) in [12], without making use of the constitutive equations in [12] in terms of strains ε_{ij} and stresses σ_{ij}. This alternative approach would consist of assuming that

$$q_1 = e_{11}, \ldots, q_6 = e_{13} \tag{33a}$$

and

$$q_7 \equiv q = q(I_T, \tilde{I}_2) \tag{33b}$$

where all seven q_i are treated as independent state variables. The virtual work δW, which is used to derive the constitutive equations, is written in the form,

$$\delta W = s_{ij}\delta e_{ij} + \frac{1}{3}\theta\delta I_T + \lambda\delta_{ij}\delta e_{ij} = \sum_{m=1}^{7} Q_m \delta q_m \tag{34}$$

It is to be noted that $\delta_{ij}e_{ij} = e_{ii} \equiv 0$, and therefore out of the six e_{ij}, only five are actually independent; however, all six can be treated as independent quantities in the virtual work condition (34) as long as the term $\lambda\delta e_{ii}$ is added to the equation (where λ is a Lagrange multiplier).

The main point we want to make here is that constitutive equations

(30) can be viewed as being based on the assumption that the thermodynamic measures of deviatoric strain, $q_1,\ldots,q_6$, are equal to the deviatoric strains themselves, while the thermodynamic measure of dilatation, q_7, is a function of the actual dilatation, I_T, and the deviatoric strains (through $\tilde{I}_2$).

The present constitutive theory (30) can be simplified even further by assuming that when all strains are constant in time (generalized relaxation test) the form of the constitutive nonlinearity is independent of time.

For constant strains applied at $t = 0$, and using the relations

$$\Delta K(\psi) \equiv K(\psi) - K_e \tag{35a}$$

$$\Delta G(\psi) \equiv G(\psi) - G_e \tag{35b}$$

where

$$K_e \equiv K(\infty) \text{ and } G_e \equiv G(\infty) \quad ,$$

we find that Eq. (30) reduces to

$$\frac{\theta}{3} = \left[\frac{\partial F_e}{\partial I_T} - \frac{a_F}{2}\frac{\partial q^2}{\partial I_T} K_e\right] + \frac{a_F}{2}\frac{\partial q^2}{\partial I_T} K(\psi) \tag{36a}$$

$$s_{ij} = \left[2\frac{\partial F_e}{\partial \tilde{I}_2} - 2a_F G_e - a_F \frac{\partial q^2}{\partial \tilde{I}_2} K_e\right] e_{ij} + 2a_F G(\psi) e_{ij} + a_F \frac{\partial q^2}{\partial \tilde{I}_2} K(\psi) e_{ij} \tag{36b}$$

The nonlinear form of Eq. (36) at short times, $\psi \approx 0$, will be different from that long time, $\psi \to \infty$, unless the sums in square brackets vanish; viz.,

$$\frac{\partial F_e}{\partial I_T} = \frac{a_F}{2} \frac{\partial q^2}{\partial I_T} K_e \tag{37}$$

$$2 \frac{\partial F_e}{\partial \tilde{I}_2} = 2a_F G_e + a_F \frac{\partial q^2}{\partial \tilde{I}_2} K_e \tag{38}$$

Define a new function g,

$$g \equiv q^2 + 2 \frac{G_e}{K_e} \tilde{I}_2 \tag{39}$$

and then combine Eqs. (37) and (38) to obtain a single equation for g:

$$\frac{\partial g}{\partial I_T} \frac{\partial F_e}{\partial \tilde{I}_2} - \frac{\partial g}{\partial \tilde{I}_2} \frac{\partial F_e}{\partial I_T} = 0 \quad . \tag{40}$$

This equation is solved by a standard method [13] to yield $g = g(F_e)$. Namely, g is an (almost) arbitrary function of the single quantity, F_e; in the linear range of behavior q must reduce to I_T, which implies g must be such that

$$g = \frac{2}{K_e} F_e \qquad \text{when} \qquad |F_e| << 1 \tag{41}$$

which is the only restriction on the function $g(F_e)$. From Eq. (39),

$$q^2 = g(F_e) - 2 \frac{G_e}{K_e} \tilde{I}_2 \tag{42a}$$

and from Eq. (37),

$$a_F = - \frac{2}{K_e (dg/dF_e)} \tag{42b}$$

and Eq. (36) for constant strains becomes

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial I_T} \frac{K(\psi)}{K_e} \tag{43a}$$

$$s_{ij} = 2a_F[G(\psi) - G_e \frac{K(\psi)}{K_e} + \frac{1}{a_F} \frac{\partial F_e}{\partial \tilde{I}_2} \frac{K(\psi)}{K_e}] \; e_{ij} \tag{43b}$$

and Eq. (30) for transient strains becomes

$$\frac{\theta}{3} = a_F \frac{\partial q}{\partial I_T} \int_o^t K(\psi - \psi') \frac{dq}{d\tau} \, d\tau \tag{44a}$$

$$s_{ij} = 2a_F[\int_o^t G(\psi - \psi') \frac{de_{ij}}{d\tau} \, d\tau + \frac{\partial q}{\partial \tilde{I}_2} e_{ij} \int_o^t K(\psi - \psi') \frac{dq}{d\tau} \, d\tau] \tag{44b}$$

where, in Eqs. (43) and (44), a_F and q are to be expressed in terms of the auxiliary function g, which, in turn, is an arbitrary function of F_e (except for condition (41)).

Thus, the constitutive equations now contain <u>three</u> independent material property functions: F_e, g, and a_ε, each of which may depend on a set of damage parameters, β_K.

As one further simplification, assume

$$K(\psi) = A'G(\psi) \tag{45}$$

where A' is a constant; this behavior was reported in [4] for propellant, as determined from poker-chip tests. Relaxation relations (43) become

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial I_T} \frac{G(\psi)}{G_e} \tag{46a}$$

$$s_{ij} = 2 \frac{\partial F_e}{\partial \tilde{I}_2} \frac{G(\psi)}{G_e} \; e_{ij} \quad . \tag{46b}$$

When Eq. (44) is specialized to a uniaxial relaxation test, and

condition (45) is used, we find that the dilatation is independent of time; this behavior for one propellant was reported by Farris [14]. However, for the PBAN propellant studied on this program, as well as for an 82 wt% CTPB propellant studied at the Naval Ordnance Station [15], some change in volume occurred during relaxation. Equation (44) is sufficiently general to predict such behavior, as long as condition (45) is not invoked.

Finally, attention is called to the fact that Eq. (44) is capable of predicting a history-dependent pressure build-up due to shear straining, even when $I_T = 0$. This behavior is a result of the dependence of q on $\tilde{I}_2$.

Equations for isotropic media with stresses as the independent variables: From the theory in [16] we deduce a set of constitutive equations which are similar to those in Eq. (30); viz.

$$\frac{I_1}{3} = \frac{\partial F_s}{\partial \theta} + \frac{1}{9}\frac{\partial Q}{\partial \theta}\int_o^t \Delta B(\psi - \psi')\frac{d(Q/a_G)}{d\tau}\,d\tau \tag{47a}$$

$$e_{ij} = 2\frac{\partial F_s}{\partial \tilde{J}_2}s_{ij} + \frac{1}{2}\int_o^t \Delta J(\psi - \psi')\frac{d(s_{ij}/a_G)}{d\tau}\,d\tau$$

$$+ 2\frac{\partial Q}{\partial \tilde{J}_2}s_{ij}\int_o^t \Delta B(\psi - \psi')\frac{d(Q/a_G)}{d\tau}\,d\tau \tag{47b}$$

where F_s, Q, and a_G are material functions of the invariants θ and $\tilde{J}_2$. Also ΔB and ΔJ are the transient components of the linear viscoelastic creep compliances in bulk and simple shear, respectively. Special forms of Eq. (47) analogous to those in Eq. (44) can be deduced; but, we shall

not pursue these cases here.

C. On Constitutive Equations which are Homogeneous to Degree One

This subsection is concerned with the following questions: (1) given constitutive equations in which the stress tensor σ_{ij} is expressed as a homogeneous functional to degree one in the strain tensor ε_{ij}, and assuming unique inverse relations exist (i.e., strain tensor is a unique functional of the stress tensor) are they homogeneous to degree one?; and (2) under what conditions do inverse relations exist?

We shall prove first that the answer to question (1) is "yes" and then state a general criterion as the answer to question (2).

Write the given functional constitutive equations as

$$\sigma_{ij} = g_{ij}(\varepsilon_{kl}) \tag{48}$$

where

$$g_{ij}(a\varepsilon_{kl}) = ag_{ij}(\varepsilon_{kl}) \tag{49}$$

with a = constant scalar. We assume unique inverse relations exist, i.e.,

$$\varepsilon_{ij} = f_{ij}(\sigma_{kl}) \tag{50}$$

By definition of f_{ij},

$$\sigma_{ij} = g_{ij}[f_{kl}(\sigma_{mn})] \tag{51}$$

It will now be proved that f_{ij} is homogeneous to degree one in the stresses; viz.

$$f_{ij}(c\sigma_{kl}) = cf_{ij}(\sigma_{kl}) \tag{52}$$

where c = constant scalar. Write Eq. (51) for stresses σ'_{ij},

$$\sigma_{ij}' = g_{ij}[f_{kl}(\sigma_{mn}')] \tag{53a}$$

where

$$\sigma'_{ij} = c\sigma_{ij} \tag{53b}$$

Substitute (53b) into (53a),

$$\sigma_{ij} = \frac{1}{c}\, g_{ij}[f_{kl}(c\sigma_{mn})] \quad . \tag{54}$$

Upon using (49), with $a = 1/c$, we find

$$\sigma_{ij} = g_{ij}[\frac{1}{c}\, f_{kl}(c\sigma_{mn})] \quad . \tag{55}$$

In view of equations (51) and (55), and the uniqueness assumption (i.e., for a given stress tensor, there exists only one strain tensor), we observe,

$$\frac{1}{c}\, f_{kl}(c\sigma_{mn}) = f_{kl}(\sigma_{mn}) \tag{56a}$$

or

$$f_{kl}(c\sigma_{mn}) = cf_{kl}\,(\sigma_{mn}) \tag{56b}$$

which, according to equation (52), completes the proof.

Now, consider the question (2). If the quantities g_{ij}, Eq. (48), are algebraic we can use the well-known result from the theory of coordinate transformations that the inverse relations exist and are unique if [5]:

i. The six functions g_{ij} are single-valued, continuous, and possess continuous first partial derivatives throughout the body of interest.

ii. The Jacobian determinant,

$J \equiv |\partial g_{ij}/\partial \epsilon_{kl}|$, does not vanish at any point in the body.

A simple example for which a unique inverse does not exist is the one-dimensional uniaxial case for which $\sigma = \sigma(\varepsilon)$ has a maximum point at

$\varepsilon = \varepsilon_m$, say; for all strains $\varepsilon \geq \varepsilon_m$, a unique single-valued relation $\varepsilon = \varepsilon(\sigma)$ does not exist.

In the actual case of interest, g_{ij} represents a set of six functionals; i.e., it depends on strain history. However, this set of functionals can be reduced to algebraic functions, which can then be subjected to the above stated conditions for invertability. This reduction is easily accomplished (in principle) by approximating the strain histories by piecewise linear or step functions of time. In this form the original functionals g_{ij} become algebraic functions of the constants defining the approximate strain histories. If, for example, we consider all six strains and let each strain history be represented by ten constants, there will be 60 x 60 terms in the Jacobian determinant.

In view of the last comment, a completely general study of invertability would be impractical. However, significant insight into the problem could be gained by examining simple situations, such as the stress-strain equations defining the behavior of a bar under confining pressure and uniaxial tension.

D. The Dilatational Constitutive Equation

Characterization of the effect of vacuole formation and growth on the relation between dilatational stress, θ, and dilatational strain, I_T, is an important and very difficult part of the overall nonlinear viscoelastic characterization problem. In this section, the so-called dilatational constitutive equation is therefore singled-out for special study. Recall that some forms of this equation for the elastic case,

e.g. Eqs. (10) and (19a), and the viscoelastic case, e.g. Eqs. (30a) and (47a), have already been given.

We first <u>define</u> the vacuole dilatation I_v by the following equation:

$$I_v \equiv I_1 - 3\alpha\Delta T - \frac{\theta}{3K_e} = I_T - \frac{\theta}{3K_e} \tag{57}$$

where K_e = bulk modulus in the unstressed state; voids may exist in this state. (Note that, in the linear elastic range of behavior

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} \tag{58}$$

and therefore $I_v = 0$.) Also by definition, I_v is never negative.

In general, I_v can be expressed as a function of the history of the three <u>stress</u> invariants and temperature <u>or</u> the three <u>strain</u> invariants and temperature. We chose the latter four scalars here, and write

$$I_v = F\{I_T \ , \ \tilde{I}_2 \ , \ \tilde{I}_3 \ , \ T\} \tag{59}$$

Now, substitute Eq. (57) for I_v and find

$$I_T = \frac{\theta}{3K_e} + F\{I_T \ , \ \tilde{I}_2 \ , \ \tilde{I}_3 \ , \ T\} \ . \tag{60}$$

In order to obtain a form which is useful for application to experimental data we solve Eq. (60) for mechanical dilatation:

$$I_T = G\{\frac{\theta}{3K_e} \ , \ \tilde{I}_2 \ , \ \tilde{I}_3 \ , \ T\} \tag{61}$$

where $G\{\}$ is a function of the history of its arguments.

Let us now examine some special cases of Eq. (61). Assume first vacuole formation and growth depends only upon I_T, T, and the maximum shear strain ε_s (instead of $\tilde{I}_2$ and $\tilde{I}_3$ separately); the maximum shear

strain is given by

$$\varepsilon_s = \frac{\varepsilon_1 - \varepsilon_3}{2} \tag{62}$$

where ε_1 and ε_3 are, by definition, the algebraically largest and smallest principal strains, respectively; note that $\varepsilon_s \geq 0$. Equation (61) Becomes

$$I_T = G\left\{\frac{\theta}{3K_e}\ ,\ \varepsilon_s\ ,\ T\right\}\ . \tag{63}$$

A special case of G, which turns out to fit the general form of Farris' uniaxial, constant strain-rate data [11] is the piecewise linear algebraic function

$$I_T = \begin{cases} \dfrac{\theta}{3K_e} & : \varepsilon_s < b_s \\ \dfrac{\theta}{3K_e} + a_s(\varepsilon_s - b_s) & : \varepsilon_s \geq b_s\ ;\ (a_s,\ b_s) \geq 0 \end{cases} \tag{64}$$

where a_s and b_s may be functions of θ, T, and $\dot{\varepsilon}_s$. It is seen that the material is idealized such that vacuoles do not form until the maximum shear strain, ε_s, reaches b_s; thus, large positive values of θ are precluded.

Alternatively, we could, as in Section A, suppose that the constitutive function is independent of $\tilde{I}_3$. For easy reference we record here the special result derived earlier (see Eq. (20)):

$$I_T = \begin{cases} \dfrac{\theta}{3K_e} & : \tilde{I}_2 < b^2 \\ \dfrac{\theta}{3K_e} + a(\sqrt{\tilde{I}_2} - b) & : \tilde{I}_2 \geq b^2 \end{cases} \tag{65}$$

Equations (63) and (64) will be called the <u>maximum shear strain</u>

theory (MSS) while Eq. (61), without dependence on $\tilde{I}_3$, and Eq. (65) will be called the octahedral shear strain theory (OSS) because this strain invariant is proportional to $\sqrt{\tilde{I}_2}$. We now examine the implications of Eq. (64) for the uniaxial, strip-biaxial, and double-lap simple shear tests.

Uniaxial test (MSS): For this test, with or without a confining pressure, the principal strains ε_1, ε_2, and ε_3 are

$$\varepsilon_1 \equiv \varepsilon_u = \text{applied axial strain} \tag{66a}$$

and

$$\varepsilon_2 = \varepsilon_3 \tag{66b}$$

The invariants I_1 and ε_s are

$$I_1 = \varepsilon_u + 2\varepsilon_3 \text{ and } \varepsilon_s = (\varepsilon_u - \varepsilon_3)/2. \tag{67}$$

Substituting Eq. (66) into (64) and solving for ε_3 yields, for $\varepsilon_s \geq b_s$:

$$\varepsilon_3 = \frac{3\alpha\Delta T + \frac{\theta}{3K_e} - a_s b_s - (1 - \frac{a_s}{2})\,\varepsilon_u}{(2 + a_s/2)} \,. \tag{68}$$

Also for $\varepsilon_s \geq b_s$, the dilatation becomes

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} + \frac{3\varepsilon_s}{4+a_s}\left[\varepsilon_u - \frac{4b_s}{3} - \alpha\Delta T - \frac{\theta}{9K_e}\right] \tag{69}$$

When $\varepsilon_s < b_s$, set $a_s = 0$ to obtain the dilatation.

Note that the last term in Eq. (69) is the vacuole dilatation; viz,

$$I_v = \frac{3a_s}{4+a_s}\left[\varepsilon_u - \frac{4b_s}{3} - \alpha\Delta T - \frac{\theta}{9K_e}\right] \tag{70}$$

which applies when the condition

$$\varepsilon_s = \frac{\varepsilon_u - \varepsilon_3}{2} \geq b_s \tag{71a}$$

is satisfied. Upon substitution of ε_3, Eq. (68), into Eq. (71a) we find

$$\varepsilon_u \geq \frac{4b_s}{3} + \alpha\Delta T + \frac{\theta}{9K_e} \tag{71b}$$

which is simply the requirement that the vacuole dilatation be non-negative.

Strip-biaxial test (MSS): The strip is assumed to be clamped in place at the reference temperature, for which $\Delta T = 0$. Further, the grips are assumed to be so rigid that the strain in the length direction, ε_2, is essentially zero for all loading conditions. The principal strains are, therefore

$$\varepsilon_1 \equiv \varepsilon_b = \text{applied strain} \tag{72a}$$

$$\varepsilon_2 = 0 \tag{72b}$$

$$\varepsilon_3 = \text{thickness strain} \tag{72c}$$

The invariants are

$$I_1 = \varepsilon_b + \varepsilon_3 \quad , \quad \varepsilon_s = \frac{\varepsilon_b - \varepsilon_3}{2} \tag{73}$$

The basic dilatational Eq. (64) yields for $\varepsilon_s \geq b_s$:

$$\varepsilon_3 = \frac{3\alpha\Delta T + \frac{\theta}{3K_e} - a_s b_s - (1 - \frac{a_s}{2})\,\varepsilon_b}{(1 + a_s/2)} \tag{74}$$

and

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} + \frac{2a_s}{2+a_s}\left[\varepsilon_b - b_s - \frac{3}{2}\,\alpha\Delta T - \frac{\theta}{6K_e}\right] \tag{75}$$

where the last term is the vacuole dilatation:

$$I_v = \frac{2a_s}{2 + a_s} \left[\varepsilon_b - b_s - \frac{3}{2}\alpha\Delta T - \frac{\theta}{6K_e}\right] \tag{76}$$

which is valid when $\varepsilon_s \geq b_s$; i.e.

$$\varepsilon_b \geq b_s + \frac{3}{2}\alpha\Delta T + \frac{\theta}{6K_e} \tag{77}$$

When Eq. (77) is not satisfied, the vacuole dilatation is given by Eq. (76) with $a_s = 0$.

Simple shear test (MSS): The specimen is assumed to be clamped in position at the reference temperature for which $\Delta T = 0$. It is also assumed that the outer two plates are rigidly fastened together and the specimen is thin with respect to the dimensions in the plane of shearing and is long in the direction of shearing. Under these assumptions, the specimen is in a state of simple shear in the plane of shearing. The principal strains are

$$\varepsilon_1 = \gamma/2 \tag{78a}$$

$$\varepsilon_2 = \text{thickness strain} \tag{78b}$$

$$\varepsilon_3 = -\varepsilon_1 = -\gamma/2 \tag{78c}$$

where

γ = applied shear strain

= shear displacement/specimen dimension normal to displacement.

The invariants I_1 and ε_s become

$$I_1 = \varepsilon_2 \quad \text{and} \quad \varepsilon_s = \gamma/2 \quad . \tag{79}$$

We find the thickness strain (for $\varepsilon_s \geq b_s$) from Eq. (64):

$$\varepsilon_2 = 3\alpha\Delta T + \frac{\theta}{3K_e} + a_s\left(\frac{\gamma}{2} - b_s\right) \tag{80}$$

and, in terms of the maximum principal strain, ε_1:

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} + a_s(\varepsilon_1 - b_s) \quad . \tag{81}$$

where the vacuole dilatation is now

$$I_v = a_s(\varepsilon_1 - b_s) \tag{82}$$

The condition $\varepsilon_s \geq b_s$ is the same as $\varepsilon_1 \geq b_s$; also, set $a_s \equiv 0$ whenever $\varepsilon_1 < b_s$.

Representation of vacuole dilatation in terms of strains due to externally applied loads (MSS): If after clamping, but prior to loading in a test machine, the specimens are subjected to a temperature change, ΔT, and pressurization, $p = -\theta/3$, the strains in this state are:

$$\varepsilon_u = \alpha\Delta T + \frac{\theta}{9K_e} = \alpha\Delta T - \frac{p}{3K_e} \qquad \text{(uniaxial test)} \tag{83a}$$

$$\varepsilon_b = \frac{3}{2}\,\alpha\Delta T + \frac{\theta}{6K_e} = \frac{3}{2}\,\alpha\Delta T - \frac{p}{2K_e} \qquad \text{(biaxial test)} \tag{83b}$$

$$\varepsilon_1 = 0 \qquad \text{(shear test)} \tag{83c}$$

where, for the biaxial and shear tests, we have assumed $\nu = \frac{1}{2}$, which implies the three principal stresses under external pressure, p, are all approximately equal to -p.

If the specimens are now strained in the test machine, the principal strains ε_{ue}, ε_{be}, ε_{se}, say, due to the externally applied load are equal

to the difference between ε_u, and ε_b, and ε_l and the respective initial strains (83):

$$\varepsilon_{ue} = \varepsilon_u - \alpha\Delta T + \frac{p}{3K_e} \qquad \text{(uniaxial test)} \qquad (84a)$$

$$\varepsilon_{be} = \varepsilon_b - \frac{3}{2}\alpha\Delta T + \frac{p}{2K_e} \qquad \text{(biaxial test)} \qquad (84b)$$

$$\varepsilon_{se} = \varepsilon_l \qquad \text{(shear test)} \qquad (84c)$$

Now, θ for the uniaxial test is

$$\theta = -3p + \sigma_u \qquad (85a)$$

and for the biaxial test

$$\theta = -3p + \frac{3\sigma_b}{2} \qquad (85b)$$

where σ_u and σ_b are the stresses applied by the testing machine to the uniaxial and strip-biaxial specimens, respectively.

Upon substituting Eqs. (84) and (85) into Eqs. (70), (76), and (82) we find

$$I_v = \frac{3a_s}{4+a_s}\left[\varepsilon_{ue} - \frac{4}{3}b_s - \frac{\sigma_u}{9K_e}\right] \qquad \text{(uniaxial test)} \qquad (86a)$$

$$I_v = \frac{2a_s}{2+a_s}\left[\varepsilon_{be} - b_s - \frac{\sigma_b}{4K_e}\right] \qquad \text{(biaxial test)} \qquad (86b)$$

$$I_v = a_s[\varepsilon_{se} - b_s] \qquad \text{(shear test)} \qquad (86c)$$

Recall that K_e is the bulk modulus in the unstressed state. Thus, the terms $\sigma_u/9K_e$ and $\sigma_b/4K_e$ are expected to be relatively small, and therefore will be neglected in the remainder of Section D. Analogous terms will be neglected in the OSS theory.

We now turn to the application of Eq. (65) to prediction of dilatation in the three tests. Essentially the same steps as in the MSS theory are followed in predicting vacuole dilatation from the OSS theory; consequently, we shall omit the details of the derivations. The strains ε_{ue}, ε_{be}, and ε_{se} are defined in the same way in both theories.

Uniaxial test (OSS): The vacuole dilatation is found to be

$$I_v = \frac{3a}{\sqrt{6}+a}\left(\varepsilon_{ue} - \sqrt{\frac{2}{3}}\, b\right) \tag{87}$$

when $\varepsilon_{ue} \geq \sqrt{\frac{2}{3}}\, b$; for smaller strains set $a \equiv 0$.

Strip-biaxial test (OSS): The vacuole dilatation is not predicted to be piecewise linear for this test. Instead, for $\varepsilon_{be} \geq b/\sqrt{2}$ it is defined by the quadratic equation,

$$\left(\frac{1}{a^2} - \frac{2}{3}\right) I_v^2 + 2I_v\left(\frac{b}{a} + \varepsilon_{be}\right) I_v + \left(b^2 - 2\varepsilon_{be}^2\right) = 0 \tag{88a}$$

with the positive root being

$$I_v = \frac{ab}{\left(1 - \frac{2a^2}{3}\right)}\left[-1 - \frac{a}{b}\,\varepsilon_{be} + \sqrt{\frac{2}{3}\,a^2 + \frac{2a}{b}\,\varepsilon_{be} + \left(2 - \frac{a^2}{3}\right)\frac{\varepsilon_{be}^2}{b^2}}\ \right] \tag{88b}$$

Simple shear test (OSS): A quadratic relation is also found for the vacuole dilatation in the shear test:

$$\left(\frac{1}{a^2} - \frac{2}{3}\right) I_v^2 + 2\,\frac{b}{a}\, I_v + b^2 - 2\varepsilon_{se}^2 = 0 \tag{89a}$$

The positive root of this equation is

$$I_v = \frac{ab}{\left(1 - \frac{2a^2}{3}\right)}\left[-1 + \sqrt{\frac{2a^2}{3} + \left(2 - \frac{4}{3}\,a^2\right)\frac{\varepsilon_{se}^2}{b^2}}\ \right] \tag{89b}$$

Comparison of MSS and OSS theories: Figures 1-3 illustrate vacuole dilatation predicted by Eqs. (86) and (87)-(89). The quantity a_u

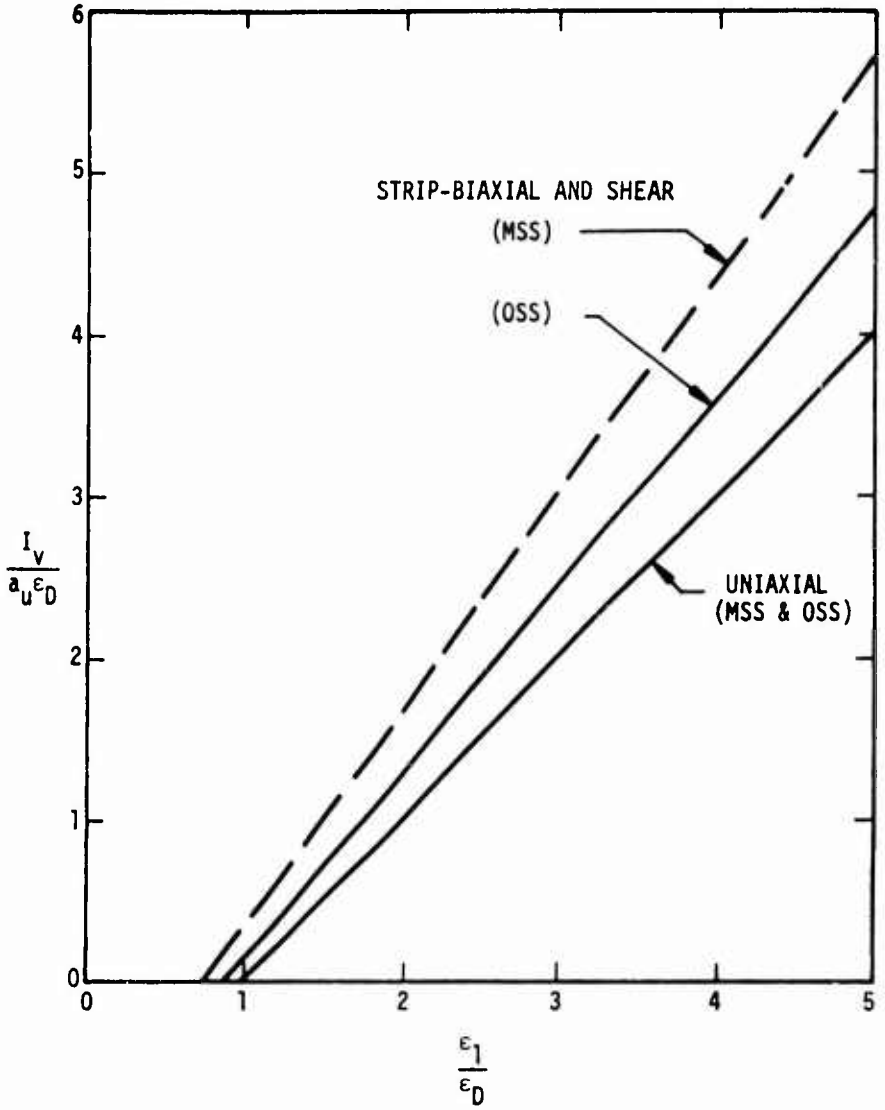

Figure 1. Comparison of Octahedral and Maximum Shear Strain Theories for $a_u << 1$.

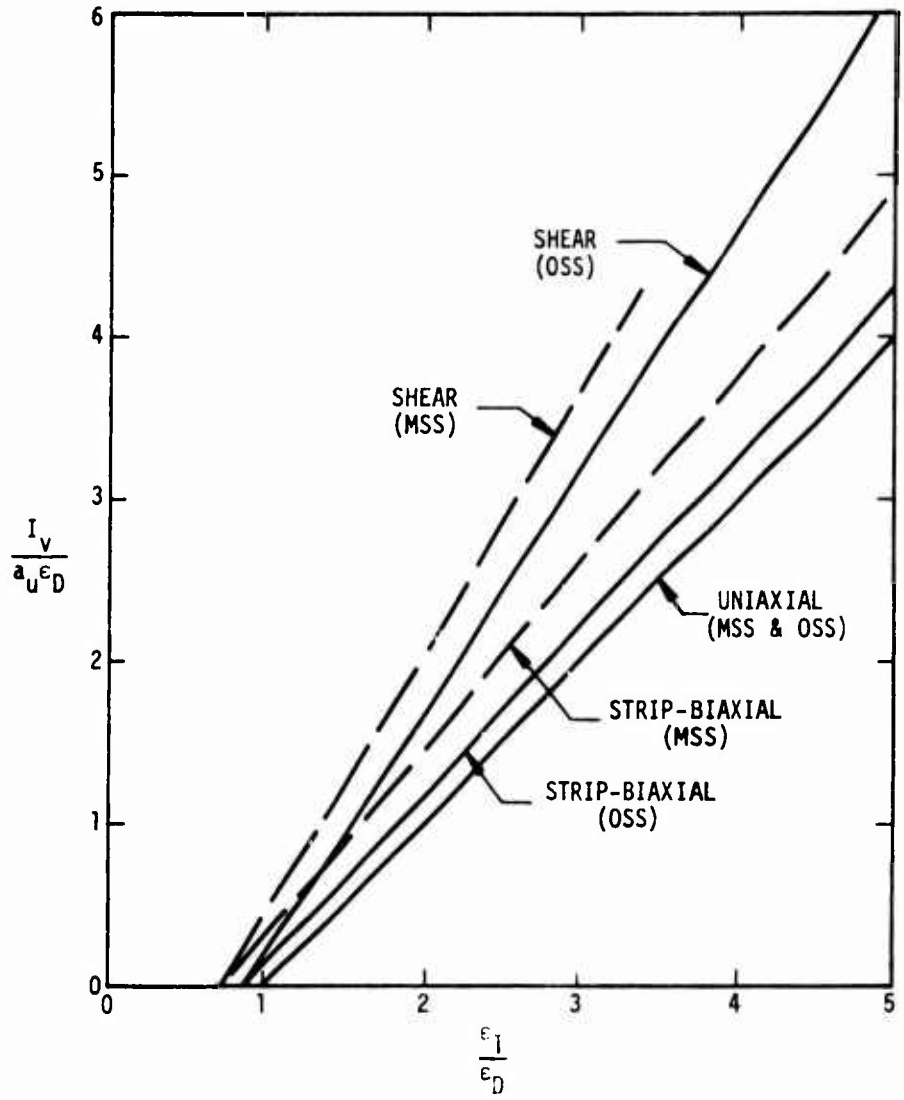

Figure 2. Comparison of Octahedral and Maximum Shear Strain Theories for $a_u = 0.5$.

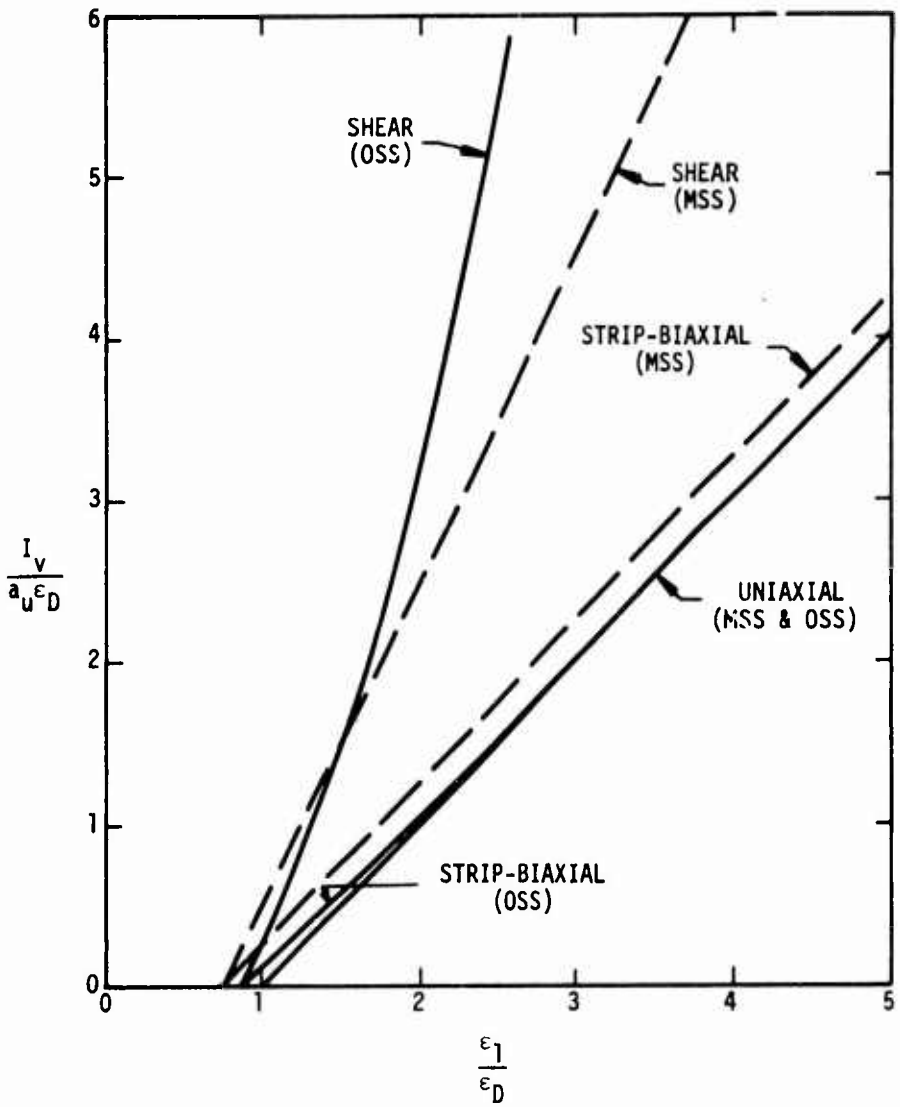

Figure 3. Comparison of Octahedral and Maximum Shear Strain Theories for $a_u = 1$.

is the slope of the dilatation vs. strain line in uniaxial tension; also, ε_D is the value of uniaxial strain at which the dilatation line intersects the strain axis. The same values of a_u and ε_D were used in both theories so that the same vacuole dilatation would be predicted for the uniaxial test. With the normalized variables used in Figs. 1-3, the graphs are independent of ε_D and the predictions in Fig. 1 are independent of a_u as well; the range $0 < a_u \leq 1$ in these figures brackets the range of values a_u observed for solid propellant under constant strain rate.

It is seen that, for given a_u and ε_D, the following inequality is true for each theory:

$$I_v \text{ (uniaxial)} < I_v \text{ (biaxial)} \leq I_v \text{ (shear)} \tag{90}$$

Moreover, except for the shear prediction in Fig. 3, the MSS theory predicts a greater dilatation than the OSS theory in each test. These observations provide a basis for evaluating the relative accuracy of each theory from experimental data. Note that, according to these figures, use of shear and uniaxial data is better for this purpose than biaxial and uniaxial data when a_u is close to unity.

E. Microstructural Damage Theory

In this section the damage parameters and their effect on constitutive equations are examined in the context of viscoelastic fracture mechanics theory. First, however, we shall consider their role in the special dilatational constitutive equations (64) and (65), and in the shear equation (19b) with respect to vacuole dilatation.

Vacuole dilatation: According to Farris' microstructural model for vacuole dilatation [11], the volume fraction of solids about which vacuoles exist is proportional to the slope of the vacuole dilatation vs. uniaxial strain curve; experimental studies showed that this constant of proportionality is approximately unity [11]. Thus, the increase of dilatation with strain when $dI_v/d\varepsilon_u$ = constant is attributed to expansion of the cavities around the particles. With this model as motivation, let us now suppose for the sake of argument that (i) the relative change in damage parameters β_K is small when $dI_v/d\varepsilon_u$ is constant and (ii) this change per cycle remains small in subsequent unloading and loading cycles. We are assuming, in effect, that the major change in β_K occurs during the first loading as the invariant $\tilde{I}_2$ (or ε_s) is increased from zero to its value when $dI_v/d\varepsilon_u$ first becomes constant, and that there is little, if any, rehealing when the speciment is unloaded.

In Farris' model [11] and in the model proposed above it is not actually necessary to assume the microstructural damage is entirely in the form of dewetting. The case in which many (or all) particles have a skin of binder adhering to them is not precluded and, as a result, the term vacuole dilatation, rather then dewetting, is used in this report.

Referring now to the simple constitutive relations Eq. (19) we see that if the above two suppositions are valid then the parameters K_e and G_e are the bulk modulus and shear modulus, respectively, in the range $\tilde{I}_2 < b^2$, after the sample has undergone strains for which $\tilde{I}_2 > b^2$. Some change in these parameters from cycle-to-cycle can be expected as additional damage occurs with each cycle. The bulk modulus K_e will be less than that for the undamaged propellant since the specimen, after being unloaded,

will have a larger void volume fraction than existing in the undamaged propellant; this point is supported by the experimental data in Section III.

The above model can be easily incorporated into viscoelastic constitutive equations. For example, referring to Eq. (44), in which all three material property functions depend on the elastic free energy F_e, we would simply use for F_e the special form in Eq. (14) together with Eqs. (17) and (18).

Microcrack initiation and growth: The state of the propellant at strains for which $dI_v/d\epsilon_u$ is constant is the end result of an extensive amount of micro-flaw growth which occurs within the binder and/or between binder and filler particles. In this subsection we model the initial flaws as cracks and examine the implications of viscoelastic fracture mechanics theory in predicting the dependence of damage parameters on applied loading history. Thus, while the preceding subsection dealt with the final stage of damage, this subsection is concerned with the initial stage. Through a combination of the two models a constitutive theory applicable to all strains is proposed.

In the following theoretical development we assume, for simplicity, that the viscoelastic body is subjected to external uniaxial tensile stress, $\sigma = \sigma(t)$, and that the cracks propagate in only the so-called opening mode. Proposed generalizations to an arbitrary state of applied stress and to other crack propagation modes are given at the end of this subsection.

We suppose that there exists an initial distribution of cracks within the binder and possibly between binder and filler; the size of each crack

is assumed to be defined by a single parameter, $2a_o$, representing the length or diameter of the crack. As the loading on the body is increased from zero a given crack will start to grow when the stress intensity factor* at the tip, N_o, exceeds a certain critical value, N_{or}. This value is identical to that for an elastic continuum whose Young's modulus, E, and Poisson's ratio, ν, are equal to the long-time (rubbery) values E_r and ν_r respectively, for the actual viscoelastic material [3]; thus

$$N_{or} = \sqrt{\frac{\Gamma E_r}{\pi(1 - \nu_r^2)}} \tag{91a}$$

where Γ is the fracture energy. If the stress intensity factor equals or exceeds the value based on initial (glassy) modulus E_g and Poisson's ratio

$$N_{og} = \sqrt{\frac{\Gamma E_g}{\pi(1 - \nu_g^2)}} \tag{91b}$$

then the crack velocity is predicted to be very high, and is limited only by wave action. We shall say the material surrounding a given crack is "failed" if $N_o \geq N_{og}$; the time at which N_{og} is first reached will be called the failure time.

The fracture theory in [3] can be used to predict time-dependent

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*The stress intensity factor is defined in the singular stress distribution near the crack tip,

$$\sigma_y = N_o/\sqrt{x}$$

where σ_y is the stress normal to the crack plane and x is the distance ahead of the tip.

crack size when $N_{or} < N_o < N_{og}$ and failure time for each crack in a propellant specimen under the following assumptions: (i) the rubber binder is linearly viscoelastic; (ii) the Poisson's ratio of the binder is constant (we shall assume $\nu = 1/2$); (iii) all filler particles are rigid relative to the binder; and (iv) the propellant specimen is linearly viscoelastic with crack sizes fixed, and is under a spacewise uniform temperature.

Now the crack velocity, $\dot{a}$, when $N_{or} < N_o < N_{og}$ is governed by the equation [3]

$$D(t_\alpha) = \frac{4\Gamma}{3\pi N_o^2} \tag{92a}$$

with

$$t_\alpha = \alpha/3\dot{a} \tag{92b}$$

and

$$\alpha = \pi^2 N_o^2/\sigma_m^2 I_1^2 \tag{92c}$$

where existing information on rubber indicates that the fracture energy Γ and the stress distribution in the failure zone behind the tip, $\sigma_m I_1$, are constant. The quantity $D(t_\alpha)$ is the creep compliance in uniaxial tension expressed in terms of the "effective time," t_α; also, α is the length of the failure zone behind the tip.

It is further assumed that during <u>most</u> of the time required for local failure, the creep compliance is given by the power law,*

$$D(t) = D_1 (t/a_T)^n \tag{93}$$

where D_1 and n are constants. Also, from the time the body is first loaded, $t = 0$, to the failure time for a given crack we assume the crack is isolated.

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*However, at very short and long times, $D(t) \to E_g^{-1}$ and $D(t) \to E_r^{-1}$, respectively.

That is, the crack is assumed to be so small that the only geometric parameter affecting crack growth is its own instantaneous size, 2a; in support of this point for cracks which are initially isolated, it is shown in [3] that the crack size at 90 percent of the failure time is only 10^n x $(2a_o)$; e.g., if n = 0.3, most of the time required for failure is consumed while the crack doubles in size. The stress intensity factor for the $i^{\underline{th}}$ isolated crack satisfying the assumptions (i) - (iv) listed just above Eq. (92) can be written in the form [3]

$$N_{oi} = \sqrt{a_i}\, f_i\, \sigma \tag{94}$$

where $2a_i$ is the size of the $i^{\underline{th}}$ crack and the coefficient f_i is a measure of state of stress existing in the binder in the neighborhood of the $i^{\underline{th}}$ crack relative to the applied stress; f_i, which will be called a stress concentration factor, is independent of material properties and depends only on the local particle geometry and spacing. According to the theory in [3], Eq. (94) is identical to the stress intensity factor in an elastic binder; thus, in principle, elastic analysis can be used to derive f_i if desired.

We combine Eqs. (92-4) and find the instantaneous size of the $i^{\underline{th}}$ crack at time t:

$$\frac{1}{a_{oi}^{1/n}} - \frac{1}{a_i^{1/n}} = f_i^q \int_o^t \left\{ \frac{3^{(1-n)}\, D_1\, \pi^{(2n+1)}}{4n^n \Gamma\, \sigma_m^{2n}\, I_1^{2n}} \right\}^{1/n} \frac{\sigma}{a_T}^q dt \tag{95a}$$

where the curly bracket in the integrand will be a function of time if chemical aging occurs and/or if there is rehealing (which are accounted for through time-dependent properties). Also,

$$q \equiv 2(1 + \frac{1}{n}) \tag{95b}$$

The failure time of this crack is denoted by t_i, and is obtained by letting $a_i \to \infty$; it can be written in the form of a linear cumulative damage relation:

$$1 = \int_o^{t_i} \frac{dt}{t_{ci}} \tag{96a}$$

where t_{ci} would be the failure time for the $i^{\underline{th}}$ crack if the specimen had been subjected to a timewise constant stress, σ, (applied at $t = 0$) equal to the actual stress at the time t, and had constant material and fracture properties equal to those actually existing at the time t:

$$t_{ci} = (A^{-\frac{1}{n}})(f_i^{-q})(a_{oi}^{-\frac{1}{n}})(M^{-\frac{1}{n}})(\sigma^{-q})a_T \tag{96b}$$

where A is a constant and is the group of terms in curly brackets in Eq. (95a) at a preselected reference state, and M is the ratio of this group at time t to the reference value. Without aging and rehealing M is unity; otherwise $M = M(t)$, and, although not essential, we assume M is the same function for all cracks.

We substitute Eq. (96b) into (96a) and solve for the stress concentration factor required to produce failure at time t_i:

$$f_i = \frac{Ba_{oi}^{-\frac{1}{nq}}}{||\sigma||_{Mq}} \tag{97a}$$

where

$$B \equiv A^{-\frac{1}{nq}} \tag{97b}$$

and $||\sigma||_{Mq}$ is a "weighted" Lebesque norm,

$$||\sigma||_{Mq} \equiv \left\{ \int_0^{t_i} M^{\frac{1}{n}} \sigma^q \frac{dt}{a_T} \right\}^{\frac{1}{q}}$$

$$= \left\{ \int_0^{\xi_i} M^{\frac{1}{n}} \sigma^q \, d\xi \right\}^{\frac{1}{q}} \tag{97c}$$

in which ξ is reduced time,

$$\xi \equiv \int_0^t \frac{dt}{a_T} \tag{97d}$$

Of course, without aging and rehealing we set M = 1 and obtain the Lebesque norm itself in terms of reduced time. Note also that, from Eq. (95b),

$$\frac{1}{nq} = \frac{1}{2(n+1)} = \frac{1}{2} - \frac{1}{q} \tag{97e}$$

Thus, for all cracks in which $f \geq f_i$ failure of the surrounding material has occurred. Cracks with smaller concentration factors have not yet failed. When the time t_i is exceeded for a given crack, the growth will be very rapid until the tips are arrested at filler particles and/or the tips move into a region of low stress concentration. We shall assume that the increase in the i^{th} crack size from the time t_i to the time the crack is arrested, t_{ai}, say (or, at least, until its velocity reduces to a relatively small value) is much larger than $2a_o$, and that the time difference $t_{ai} - t_i$ is negligible compared to t_i. Let us denote the crack size at time t_{ai} as $2a_{ai}$; since $a_{ai} >> a_{oi}$ and in view of the comments immediately following Eq. (93) we conclude that the influence of the i^{th} crack on overall mechanical response is felt approximately at the time t_i, and the magnitude of this influence is directly related to the total growth, $2a_{ai} - 2a_{oi} \simeq 2a_{ai}$. Interaction between cracks when $t > t_i$ is allowed.

Let us now predict the increment in specimen strain that results when the $i^{\underline{th}}$ crack grows to length $2a_{ai}$ at the time t_i. In view of the linearity assumption this increment can be calculated by superposition. Specifically, consider the normal stress distribution that acts across an imaginary surface, where this surface is identical to the fracture surface which is later formed when the crack grows to length $2a_{ai}$. The increment in specimen strain due to actual crack growth is identical to that resulting from a sudden superposition of a pressure distribution at time t_i, whose magnitude is equal to the normal stress distribution existing across the imaginary surface following failure. This pressure is proportional to applied stress σ. Linearity plus dimensional analysis yield the following strain increment for a thermorheologically simple material if the applied stress is constant for $t > t_i$:

$$\varepsilon_i = S_i \, \sigma \, D(\xi - \xi_i) \tag{98a}$$

where ξ is defined in Eq. (97d) and

$$\xi_i \equiv \int_o^{t_i} \frac{dt}{a_T} \tag{98b}$$

Also, $D(\xi)$ is the uniaxial creep compliance of the propellant in terms of reduced time; it should be added that with rigid particles and linearity, dimensional analysis can be used to show that this creep compliance is proportional to the insitu compliance of the binder. The coefficient S_i is a constant.

Extension of Eq. (98) to a time varying stress following time t_{ai} is readily accomplished by superposition as long as further change in crack length is small compared to $2a_{ai}$. Specifically, introduce the

Heaviside unit-step function,

$$H(\xi - \xi_i) \equiv \begin{cases} 1, & \xi > \xi_i \\ 0, & \xi < \xi_i \end{cases} \tag{99}$$

where $\xi_i \equiv \xi(t_i)$. Then the strain is

$$\varepsilon_i = S_i \int_0^{\xi} D(\xi - \xi') \frac{d[H(\xi' - \xi_i)\sigma]}{d\xi'} d\xi' \tag{100}$$

Since the Dirac delta function, δ, is given by

$$\delta(\xi - \xi_i) = \frac{d\, H(\xi - \xi_i)}{d\xi} \tag{101}$$

Eq. (100) can be written explicitly as

$$\varepsilon_i = S_i \sigma_i D(\xi - \xi_i) + S_i \int_{\xi_i}^{\xi} D(\xi - \xi') \frac{d\sigma}{d\xi'} d\xi' \tag{102}$$

where $\sigma_i \equiv \sigma(\xi_i)$.

We now turn to a statistical description of the microcracking problem, and thereby derive a constitutive equation by summing over the strains given by Eq. (102). First, define g_i as

$$g_i \equiv \frac{f_i (a_{oi})^{\frac{1}{nq}}}{B} \tag{103}$$

The stress concentration factor f_i and initial flaw size are random variables which, in turn, imply g_i is a random variable. Likewise, S_i is a random variable. Dropping the subscript (i) we write the expression for the number of cracks, N_c, having g-values between g and g + dg, and S-values between S and S + dS in the form

$$N_c = n(S, g)\, d\, S\, d\, g \tag{104}$$

The distribution function $n = n(S, g)$ can be calculated from a distribution function in terms of the three random variables a_o, f. and S, which will be demonstrated later. Equation (104) will be used in the constitutive theory development.

It is to be noted that g and failure time are directly related through a deterministic relation, which is obtained by combining Eqs. (97a) and (103),

$$g(\xi_f) = \frac{1}{||\sigma||_{Mq}} \equiv \left\{ \int_o^{\xi_f} \frac{1}{M^n}\, \sigma^q d\xi \right\}^{-\frac{1}{q}} \tag{105}$$

where ξ_f is now used as the generic variable representing reduced failure time.

The strain due to all microcracking, ε_m, say, at reduced time ξ, is obtained by multiplying Eq. (100) by (104), replacing ξ_i by ξ_f, and integrating over all possible S-factors ($-\infty < S < \infty$) and all possible g-values corresponding to $0 \leq \xi_f \leq \xi$. There results, finally,

$$\varepsilon_m = \int_o^{\xi} D(\xi - \xi') \frac{d}{d\xi'} \left\{ \sigma \int_{g'}^{\infty} G(g)\, dg \right\} d\xi' \tag{106}$$

where

$$g' \equiv g(\xi') = \left\{ \int_o^{\xi'} \frac{1}{M^n}\, \sigma^q\, d\xi \right\}^{-\frac{1}{q}} \tag{107}$$

and $G = G(g)$ is the following distribution function:

$$G \equiv \int_{-\infty}^{\infty} S\, n(S, g)\, dS \tag{108}$$

In view of the linearity assumption, the total axial strain, ε, is

that due to the externally applied stress acting on undamaged propellant,

$$\varepsilon_u = \int_0^{\xi} D(\xi - \xi') \frac{d\sigma}{d\xi'} d\xi' \tag{109}$$

plus the strain ε_m; viz, from Eqs. (106) and (109),

$$\varepsilon = \int_0^{\xi} D(\xi - \xi') \frac{d}{d\xi'} \left\{ \sigma[1 + \int_{g'}^{\infty} G(g)\, dg] \right\} d\xi' \tag{110}$$

where g' is given by Eq. (107) in terms of a weighted Lebesque norm at time ξ'. In view of Eq. (107), we see $\int_{g'}^{\infty}$ is a non-decreasing function of time (without rehealing).

A distribution function G(g) of particular interest is the power law

$$G = \begin{cases} G_1 g^{-r} & , \quad g \leq g_m \\ 0 & , \quad g > g_m \end{cases} \tag{111}$$

where g_m, G_1, and r are constants; this function will be used later.

Before examining some special cases of Eq. (110) we shall derive the relation between n = n(S, g) in Eq. (104) and the dist-ibution function for stress concentration factor and initial crack size. The distribution function m = m(S, a_o, f) is defined by the condition that N_{fa} is the number of cracks having S-values between S and S + dS, a_o-values between a_o and $a_o + da_o$, and f-values between f and f + df:

$$N_{fa} = m(S, a_o, f)\, dS\, da_o\, df \tag{112}$$

The number of cracks N_c in Eq. (104) is equal to the integral of N_{fa} over the area in the a_o - f plane bounded by the curves g = constant and g + dg = constant, where f and a_o satisfy Eq. (103). After equating N_c

to the area there results

$$n(S, g) = B \int_0^\infty m(S, a_o, Bga_o^{-\frac{1}{nq}}) \, a_o^{-\frac{1}{nq}} \, da_o \qquad (113)$$

As an example, if m is a power law in f,

$$m = m_1(S, a_o) \, f^\alpha \qquad (114a)$$

where α is a constant, we find that n(S, g) is given by a power law in g,

$$n(S, g) = B^{1+\alpha} \, g^\alpha \int_0^\infty m_1(S, a_o) \, a_o^{-\frac{1}{nq}(1+\alpha)} \, da_o \qquad (114b)$$

By substituting this result into Eq. (108) the function G(g) is found to be the power law in Eq. (111) with $r = -\alpha$ and $g_m = \infty$.

We now examine two special cases of Eq. (110) in order to help bring out the physical significance of this constitutive equation.

Elastic specimen: It is assumed that the creep compliance appearing in Eq. (110) is a constant, D, say; but the compliance in the fracture theory is still the power law, Eq. (93). These assumptions are not inconsistent. This point follows from the fact that the effective time t_α in fracture Eq. (92) is typically several decades smaller than that governing the overall mechanical response of the binder [3]; thus, for example, crack growth may be controlled by viscoelastic processes at the same time the binder response is essentially in its long-time elastic response range.

Equation (110) reduces to

$$\epsilon = D\sigma \left\{ 1 + \int_g^\infty G(g) \, dg \right\} \qquad (115)$$

where

$$g = g(\xi) = ||\sigma||_{Mq}^{-1}$$

Equation (115) shows that the microscopic damage is characterized by a single function of the weighted Lebesque norm $||\sigma||_{Mq}$, as in Eq. (110). This result is analogous to that obtained by Farris [2], but the role of stress and strain is reversed.

The power law distribution Eq. (111) reduces this theory to

$$\varepsilon = D\sigma \left\{ 1 + \frac{G_1}{r-1} \left[(||\sigma||_{Mq})^{r-1} - g_m^{1-r} \right] \right\} \tag{116a}$$

when $r \neq 1$, and

$$\varepsilon = D\sigma \left\{ 1 + G_1 \ell n [||\sigma||_{Mq}\, g_m] \right\} \tag{116b}$$

when $r = 1$. Solution (116) is valid for only the range $||\sigma||_{Mq} \geq g_m^{-1}$; when $||\sigma||_{Mq} < g_m^{-1}$ failure has not occured and one must set $G_1 = 0$. If $g_m = \infty$, the integral in Eq. (115) converges only if $r > 1$; for this case Eq. (116a) shows that the strain will be approximately homogeneous to degree one in stress if r is close to unity.

Creep of a viscoelastic specimen: We set $\sigma = \sigma_c\, H(\xi)$, where σ_c = constant, and use the viscoelastic theory to predict creep compliance with microcracking, $D_c \equiv \varepsilon/\sigma_c$. For simplicity, isothermal behavior ($a_T = 1$) without rehealing and aging ($M = 1$) is assumed and both power laws Eqs. (93) and (111) will be used with $g_m = \infty$.

From Eq. (107),

$$g' = g(t') = \sigma_c^{-1} (t')^{-\frac{1}{q}} \tag{117}$$

where we have set $\xi' = t'$. Equation (110) yields

$$D_c \equiv \frac{\varepsilon}{\sigma_c} = D_1\, t^n \left[1 + \frac{G_1 B}{q} (\sigma_c)^{r-1}\, t^{\frac{r-1}{q}} \right] \tag{118}$$

where the constant B is a Beta function,

$$B \equiv \int_0^1 (1-u)^n \, (u)^{\frac{1}{q}(r-1)-1} \, du \tag{119}$$

For propellant $n \simeq 0.2$, which implies $q \simeq 12$, and therefore if r is close to unity we see $D_c \sim t^n$ and that D_c is nearly independent of stress. The value $r = 1$ is not admissible since $B = \infty$ for this case.

Generalizations of the constitutive theory with microcracking: The above constitutive theory, Eq. (110), is a special case of the nonlinear theory, Eq. (47), based on thermodynamics. Indeed, we may recover the present theory from Eq. (47) by assuming:

$$Q = \theta \tag{120a}$$

$$\frac{\partial F_s}{\partial \theta} = B(\infty)\,\theta/9a_G \tag{120b}$$

$$\frac{\partial F_s}{\partial \bar{J}_2} = J(\infty)/4a_G \tag{120c}$$

$$a_\varepsilon = a_T \tag{120d}$$

$$\frac{1}{a_G} = 1 + \int_{g'}^{\infty} G(g)\, dg \tag{120e}$$

where

$$g' = \left\{ \int_0^{\xi'} M^{\frac{1}{n}} \left| A_1\theta + A_2\sqrt{\bar{J}_2} \right|^q d\xi \right\}^{-\frac{1}{q}} \tag{120f}$$

and A_1 (or A_2) is an arbitrary constant. However, A_2 (or A_1) must satisfy the following relation in order that the three-dimensional theory reduce to uniaxial Eq. (110):

$$A_2 = \sqrt{\frac{3}{2}}\,(1 - A_1) \tag{120g}$$

Clearly, there is a single damage parameter in this representation which reflects the extent of microcracking; it is weighted Lebesque norm $||A_1\theta + A_2\sqrt{J_2}||_{Mq}$ in Eq. (120f). Moreover, if A_1 and A_2 are positive, pressure ($\theta < 0$) is seen to correctly suppress the amount of crack growth.

It should also be recalled that M reflects the effect of aging and/or rehealing. This function is unity in the absence of these effects, but otherwise is given by

$$M = \frac{D_1}{D_{1r}} \frac{\Gamma_r}{\Gamma} \frac{(\sigma_m I_1)_r^{2n}}{(\sigma_m I_1)^{2n}} \tag{121}$$

where subscript r denotes constant quantities corresponding to a preselected reference state; also, recall that D_1 is the coefficient in creep compliance Eq. (93) and that Γ and $(\sigma_m I_1)$ are fracture properties.

The above theory was developed under the assumption that cracks propagate in the opening mode. However, the equations governing fracture in shearing modes are believed to be analogous to the opening mode case [3] and, therefore, we suggest that Eq. (120) may be valid regardless of the crack mode. However, further study is needed to confirm this point or else to determine if the more general theory, Eq. (47), is valid.

It is important to recognize that the three-dimensional theory based on Eq. (47) along with Eq. (120) is identical to linear theory except stresses are multiplied by a scalar factor, $1/a_G$. Hence, the inverse formulation in which the stress tensor is expressed as a functional of the strain tensor likewise will be identical to linear theory except σ_{ij} is replaced by σ_{ij}/a_G. This latter formulation suffers from the fact that the Lebesque norm is expressed in terms of stress invariants rather than strain invariants; consequently, it generally will not be possible to

obtain an explicit representation for stresses in terms of strains and strain invariants.

Let us now consider how the microcracking model can be combined with nonlinear constitutive equations to obtain a theory which is potentially applicable to a wide range of propellant behavior. First, it should be recalled that Eq. (110) is based on the assumption that cracks are (approximately) arrested after rapid growth. As the applied stress is increased one can expect these previously arrested cracks to again propagate, thereby producing significant vacuole dilatation and eventually gross failure. (It should be added that significant dilatation does not necessarily result from the first growth stage when the binder is relatively soft; e.g., when a crack is cut into a sheet of rubber having high ultimate elongation, and the sheet is stretched in a direction normal to the original crack plane, the crack may open so much that it again becomes a sharp crack with its plane parallel to the loading direction [1]. The net change in dilatation for this process is essentially zero.) If it can be assumed that the subsequent propagation obeys the previously developed model, we suggest that all damage may be characterized by the same function a_G, Eq. (120e), except the distribution function G(g) will depend on strain or stress invariants. Moreover, in the high stress range it probably will be necessary to account for nonlinear stress invariant-dependence in Q and in the derivatives of F_s appearing in Eq. (47). Similarly, strain formulation Eq. (30) may apply in the high strain range after the stress tensor is replaced by σ_{ij}/a_G.

F. Thermodynamic Constitutive Equations with Implicit Pressure Dependence

The strain formulation, Eqs. (5) and (30), and special cases, e.g. Eqs. (19) and (44), are based on the assumption that, except for damage parameters, the nonlinearities are defined by strain (rather than stress) invariants. In principle, one can retain the relatively simple forms of the special cases, but yet account for large superposed pressures. Referring to the thermodynamic theory in [17], it is easily shown that the Eqs. (5) and (30), and resulting special cases, may be applied to deformations superposed on the pressurized state. Namely, one interprets the stresses and strains, σ_{ij} and ϵ_{ij}, as values which are added to the values existing in a reference pressure state. All material properties may then depend on this pressure as well as strain invariants. In grain analysis, one could select as reference pressure that in the bore, and then account for its time-dependence just as one does for a spacewise uniform, transient temperature.

G. Generalization for Finite Strains

In all preceding three-dimensional equations make the substitutions [12],

$$\begin{aligned} \epsilon_{ij} &\to E_{ij} \\ \sigma_{ij} &\to \frac{\rho_o}{\rho}\,\tau^{ij} \end{aligned} \tag{122}$$

where the deviatoric components of E_{ij} and τ^{ij} are calculated by using the same definitions as for small strain theory and

E_{ij} = Lagrangian (covariant) strain tensor

τ^{ij} = (contravariant) stress tensor referred to convected coordinates and measured per unit area of the deformed body.

ρ_o, ρ = density in the undeformed and deformed states, respectively.

III. EXPERIMENTAL INVESTIGATIONS

A. Test Equipment and Procedures

Poker chip tests: These tests were made on ANB-3335-1 solid propellant samples furnished by Aerojet Solid Propulsion Company (ASPC). As received, the samples were 4.5 by 4.5 by 0.33 inches. The upper and lower surfaces had been machined to attain the 0.33 in. thickness. Therefore, before attempting to bond these samples to the plattens used for loading, all loose oxidizer particles on the surface of the samples had to be removed; two methods were tried. The first method was to spread Duco cement on the surface of the propellant sample and then press a gauze bandage down firmly onto the cement. After the Duco cement dried for eight hours at room temperature, the gauze along with the cement, and hopefully the loose oxidizer particles, were gently peeled back from the surface of the propellant sample. This procedure was based on previous experience by others, in which it was found to lead to very good bonds. Two initial samples cleaned by the above technique and bonded to the steel plattens turned out to fail under low loads, with gross tearing occurring near the bond line where the material was extremely soft (probably due to the Acetone in Duco cement).

The second method used to remove the loose oxidizer particles was to press down strips of three-inch wide surgical adhesive tape across the surface of the propellant and then peal back gently. All samples used in the mechanical property tests were prepared in this way.

Steel plattens 0.25 in. thick and 4.00 inches in diameter were sand

blasted by a medium grit in order to prepare them for bonding to the sample. The surfaces were then cleaned using Acetone.

Uralane 8615 epoxy compound, a two-part epoxy mixed in approximately equal parts by weight and obtained from Furane Plastics, Los Angeles, California, was used to bond the propellant samples to the plattens. This epoxy is a black material which has a pot life of approximately twenty minutes once the two components are mixed and a complete curing time of about twenty-four hours. The mixed epoxy was placed on both propellant surfaces and spread as thinly as possible to eliminate bubbles. Two steel plattens were fixed in a lathe using centered pull rods which had been screwed into each plate. A poker chip specimen was completed and made ready for curing by placing the propellant coated with epoxy between the two plattens and then mechanically forcing the plattens against the samples. Since the samples would slide out if left alone, several pieces of tape were used to hold the sample centered on the plattens. The bonded sample was allowed to cure for twenty-four hours in this position at room temperature.

The specimen was then turned in a lathe at a very slow speed and excess propellant was trimmed off even with the steel plattens. Completed poker chip specimens were stored in a dry refrigerator maintained at 74°F and containing a desicant to maintain low humidity.

Just before a test, a teflon coated thermocouple girth wire was placed around the outside of the specimen midway between the two plattens, as shown in Fig. 4. One end of the girth wire was stripped and two closely spaced dots of solder were placed on this end of the wire; by

Figure 4. Poker-Chip Specimen Showing Girth Wire, LVDT's, and Micrometers.

inserting a horseshoe-shaped 1/4 in. long x 36 gage wire holder in between these closely spaced solder dots and into the propellant, the girth wire was secured at one end. This wire extended from the tiedown point completely around the circumference of the specimen and came off tangent to the tie-down point to then connect to a lever arm. Horseshoe-shaped portions of bare 36 gage wire were stuck into the propellant over the girth wire at intervals of approximately 0.4 inches, to hold it in position along the mid-plane between the two plattens.

An aluminum plate approximately 1/4 in. thick by 6.5 in. diameter was mounted on top of the upper platten and fastened securely with a nut on the pull rod. This upper plate was designed to accommodate three vertical micrometers at 120 degree spacings. Another aluminum plate of the same size and an S-shaped bracket were mounted securely on the lower side of the lower platten by tightening the nut on the lower pull rod. This lower aluminum plate was designed to accommodate three linear variable differential transformers (LVDT's) aligned with shafts from the three vertical micrometers on the upper plate. These vertical micrometers had a total travel of 0.05 in. which allowed us to make very fine in-place calibrations.

For tension tests the upper pull rod was attached to a universal joint which was in turn attached to a single lever arm loading frame, (see Fig. 5). The lower pull rod was attached to a universal joint which was in turn attached to a slip joint which engages only when the lever arm is loaded. An LVDT was attached to the S-shaped bracket that extends from beneath the lower platten to be in line with the girth wire. The other end

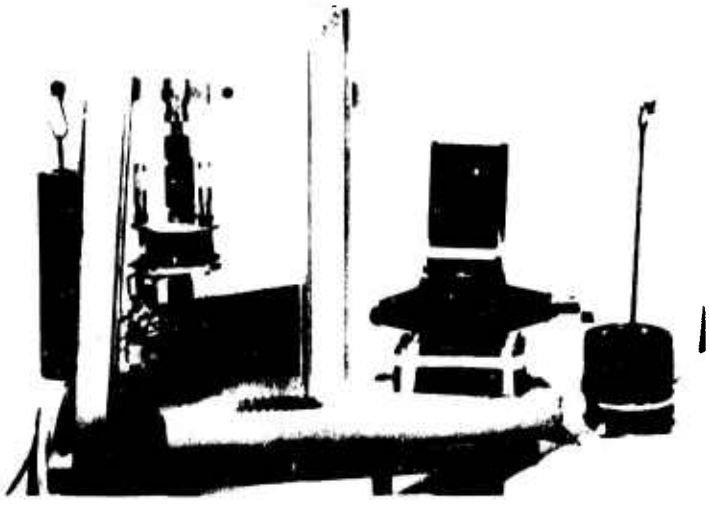

Figure 5. Poker-Chip Assembly used for Tensile tests.

of the LVDT was attached to a Chavetz micrometer which had a total travel of 1.0 in. A modified 4 - 4 1/2 in. hose clamp was attached to the lower platten to support a small L-shaped lever arm. The vertical arm of the lever was connected to the girth wire, while the horizontal arm was connected to a vertical wire extending to a slug within the LVDT mounted on the lower S-shaped bracket. The horizontal girth motion was thus transferred into a vertical motion and magnified by approximately four. With the Chavetz micrometer it was possible to attain an inplace calibration for the girth measurement. To insure that there was no sticking associated with the girth wire or LVDT's, a pulsing vibrator was attached to the frame of the test mechanism.

The three vertical LVDT's spaced 120 degrees apart around the sample were used to measure plate separation and to determine if there was bending in the sample. By averaging the three readings we obtained an overall average strain which, together with the girth measurement, enabled the determination of dilatation. Signals from all four LVDT's were fed into an amplification system that allowed us to obtain high gain settings and to maintain a linear output signal as a function of displacement for a given range.

For testing, the system was loaded to provide 10, 20, 35, and 50 psi average axial stress to the poker chip specimen. Testing was performed at a temperature of 74°F and at a relative humidity of between 34 and 40 percent. All tests were creep and recovery tests with cycles of five minutes creep, ten minutes recovery, and 15 minutes wait between cycles. There were one or two one-minute initial loadings at each load range before the

actual test to insure that the data readings would remain on scale and that the readings were still linear. Five to seven creep and recovery cycles were run for each load range, and only one load range was run per day. Compression tests were also run on poker chip specimens. The only difference in the compression test assembly was that instead of having the upper and lower universal joints attached to the upper and lower pull rods, respectively, heavy steel frames replaced the pull rods; one frame was used to attach the lower platten to the upper universal joint, and another frame connected the upper platten to the lower universal joint.

Strip-biaxial tests: Tests were performed on ANB-3066 and ANB-3335-1 solid propellant obtained from Aerojet Solid Propulsion Company. The biaxial dilatometer used for these tests was obtained from Hill Air Force Base on a loan basis and as received was in unworkable condition as originally manufactured by the CETEC Corporation. The unit was completely dissassembled, and after extensive modification was put into working condition. The dilatometer, shown in Fig. 6, was designed to measure dilatation by two different methods. The first method relied upon direct LVDT measurements of decrease in cross-sectional thickness. The LVDT system consisted of spring loaded probes that slide on the surface of the specimen's sides. Unfortunately the probes were not only insensitive to the small thickness changes but also damaged the surface of the propellant at the point of contact. As a result the LVDT probes were removed entirely, and we relied upon the second method of dilatation measurement. This method was based on state-of-the-art gas dilatometric techniques such as those employed by Farris [11].

The biaxial dilatometer consists of two chambers, a specimen chamber and reference chamber, which are completely separate from each other. The

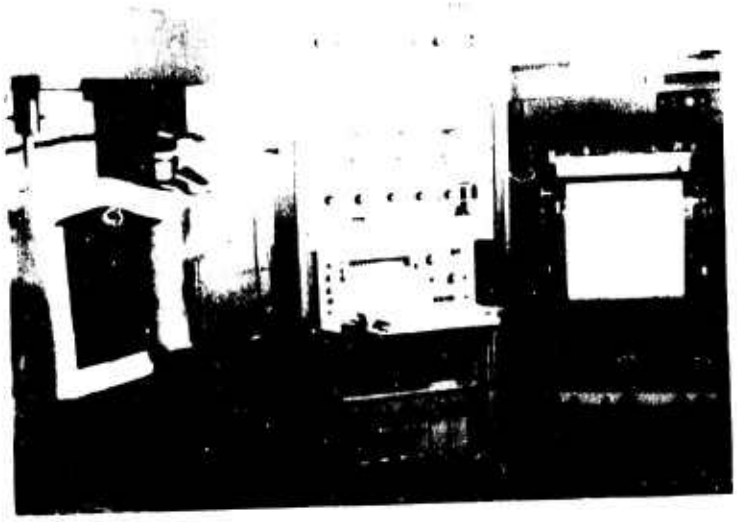

Figure 6. Biaxial Dilatometer Mounted in Instron Test Machine.

dilatometer was configured so that both chambers could be pressurized up to 1000 psi and equalized to the same pressure. Once all the leaks around the dilatometer, plumbing connections, door, shaft, and calibration micrometer were sealed at high pressure, the system was functional. The dilatometer was mounted in an Instron, and an extensometer was mounted to the shaft of the dilatometer to measure sample extension. Unlike other dilatometers which have a compensating shaft that extends from the reference chamber, the dilatometer used in these tests was not equipped with this reference chamber shaft; specimen chamber shaft movement was compensated electronically by coupling the shaft extension with the pressure change due to shaft movement alone.

Before each test, the unit was calibrated for volume change by inserting a precision micrometer shaft into the specimen chamber in increments to simulate a volume change of .00707 in^3 (for the samples used in our tests this corresponds to a volume change of about 0.5 percent). It was possible to resolve volume changes on the order of .01 to .02 percent over a relatively long period, provided the temperature remained constant. To insure constant test conditions, the tests were run in large walk-in chambers which were held to a constant temperature and humidity. The dilatometer and associated plumbing were wrapped thoroughly with insulation material (see Fig. 6) to prevent changes due to the body-heat of people in the room who are running the tests.

The propellant samples furnished by Aerojet were saw-cut into specimens with dimensions of 7.0 by 1.63 by 0.38 inches. Using a circular cutter, each end of each specimen was trimmed to remove the material included within a circular arc with an approximately one-inch radius connecting the two corners

at each end of the specimen, as shown in Fig. 7. The samples were then bonded to aluminum plates using the 8615 epoxy described in the poker-chip section above. The aluminum plates were prepared by first sand blasting the surface to be bonded and then placing masking tape around the plates so that the tape extended approximately 0.25 inches above the surface of the plates. The epoxy was then poured into the cups made by the masking tape to about half full. One 7.0 by 0.38 inch edge of the sample was pushed into the epoxy and against the aluminum plate. Care was taken to create a fillet around the sample as it emerged from the epoxy in order to provide for gripping and a gradual load transfer from the grips. A spacer was placed on each side of the samples to hold the propellant at the center of the aluminum plate while the epoxy cured for twenty-four hours. This process was then repeated for the opposite edge of the sample. After curing, the bonded samples were stored for at least twenty-four hours before testing in constant temperature and humidity walk-in chambers.

A bonded sample was fastened to loading rails and loaded into the dilatometer specimen chamber as shown in Fig. 8. The door was then put in place and bolted down.

If the test was to be run under pressure, the valve connecting the reference and specimen chambers was opened and the system was pressurized to the desired pressure. The valve was then closed to isolate the chambers again while the system stabilized for one to two hours. Just before running the actual test, the two chambers were equalized by opening the connecting valve and then closed to isolate them again. Also, as described above, the unit was calibrated for volume change. In addition, the internal load cell located within the dilatometer was calibrated.

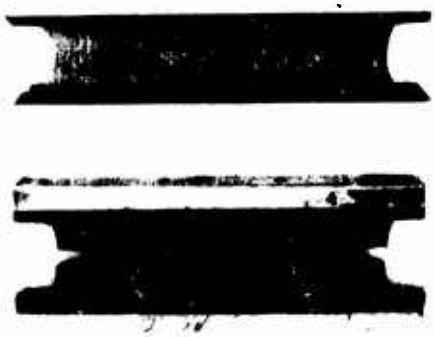

Figure 7. Unfailed and Failed Strip-biaxial Specimen End-Bonded to Aluminum.

Figure 8. Strip-biaxial Specimen Partly Inserted in Dilatometer.

Several types of tests were run including constant strain rate to failure, ramp-relaxation, and cyclic loading and unloading before loading to failure. Sample displacement, volume change, and load were recorded on a light sensitive oscillograph recorder.

Uniaxial tests: These tests were run on AND-3066 and ANB-3335-1 Aerojet propellant using the same biaxial dilatometer used for the strip-biaxial tests. The uniaxial samples were made from the 7.0 by 1.63 by 0.38 inch strip-biaxial specimens. Instead of cutting circular arcs of material away from the ends as was done for the biaxial samples, the rectangular samples were cut completely through to within 0.2 inches of each edge at intervals of 0.37 inches along the length of the sample. The samples were then bonded to the aluminum plates as described for biaxial specimens. This procedure provides nineteen uniaxial samples to be tested at one time, which are shown in Fig. 9.

B. Experimental Data and Comparison with Analysis

Poker-chip tests: Figures 10-13 show compliances and dilatation obtained from tension tests performed on samples Nos. 1 and 2, while Figs. 14-17 show these quantities for compression of sample No. 2. The creep and recovery compliances are defined as follows:

$$D_{pc} \equiv \frac{\varepsilon}{\sigma} \tag{123a}$$

$$D_{pc}^{(r)} \equiv \frac{\varepsilon_r}{\sigma} \tag{123b}$$

where σ is the total axial load divided by platen area, ε is the strain (based on platen separation) during the creep portion of one loading cycle,

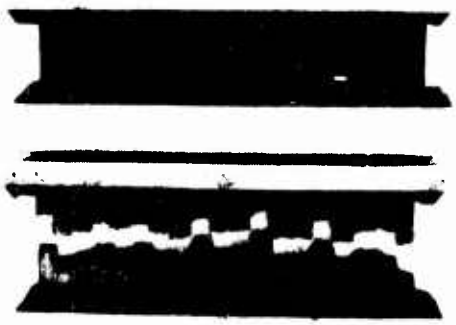

Figure 9. Unfailed and Failed Uniaxial Specimens End-bonded to Aluminum Plates.

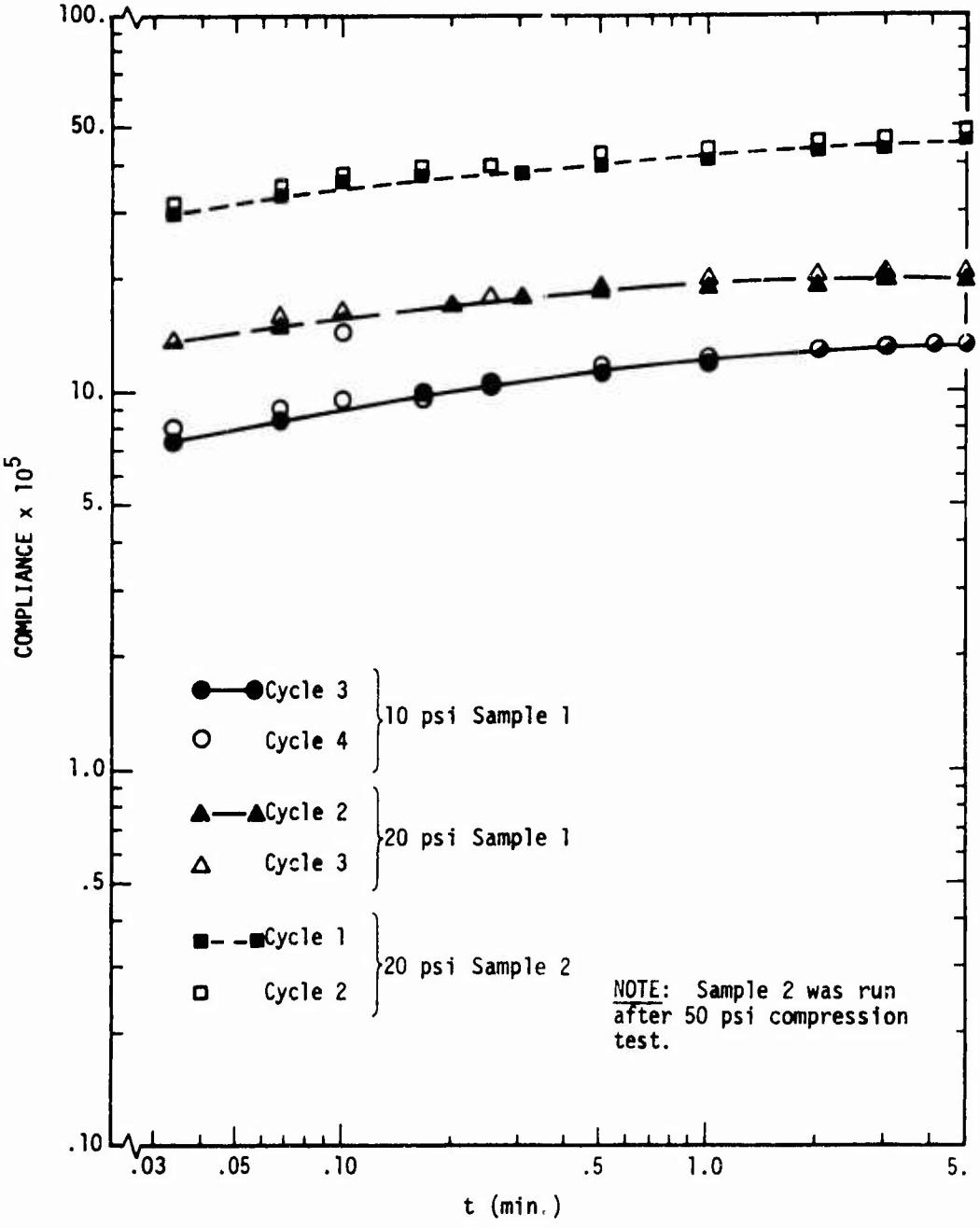

Figure 10. Poker Chip Creep Compliance in Tension.

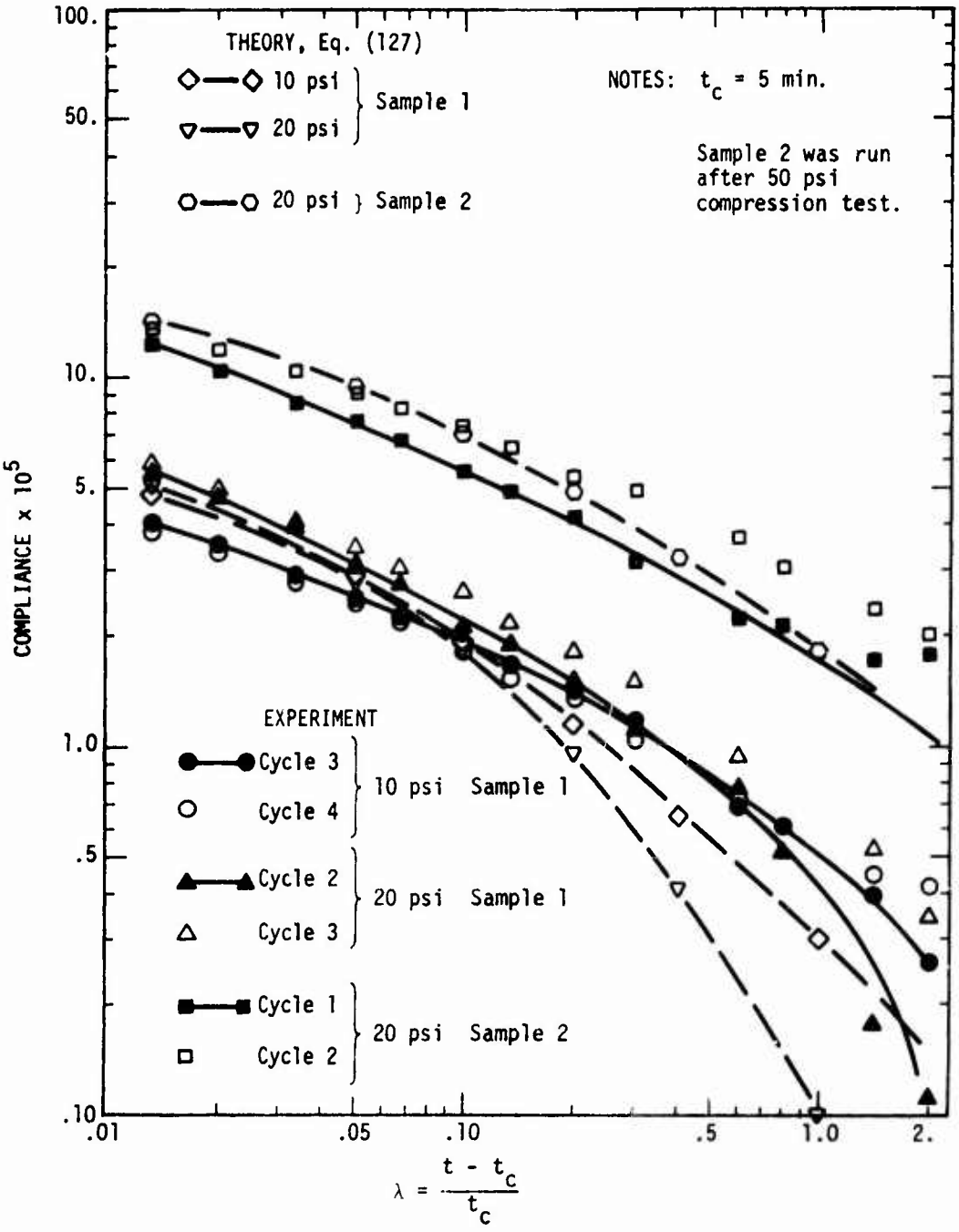

Figure 11. Poker Chip Recovery Compliance in Tension.

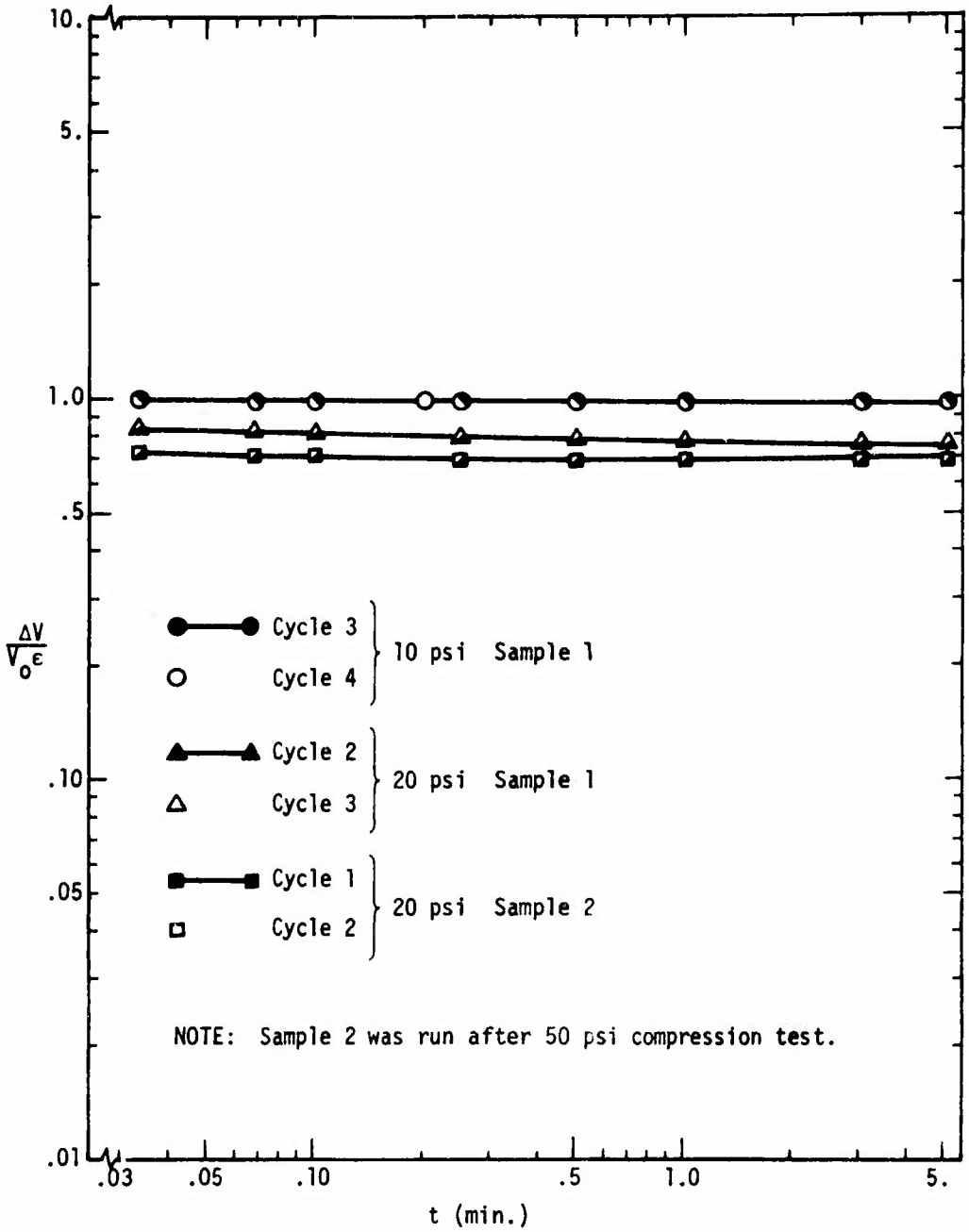

Figure 12. Poker Chip Dilatation in Tension-Creep.

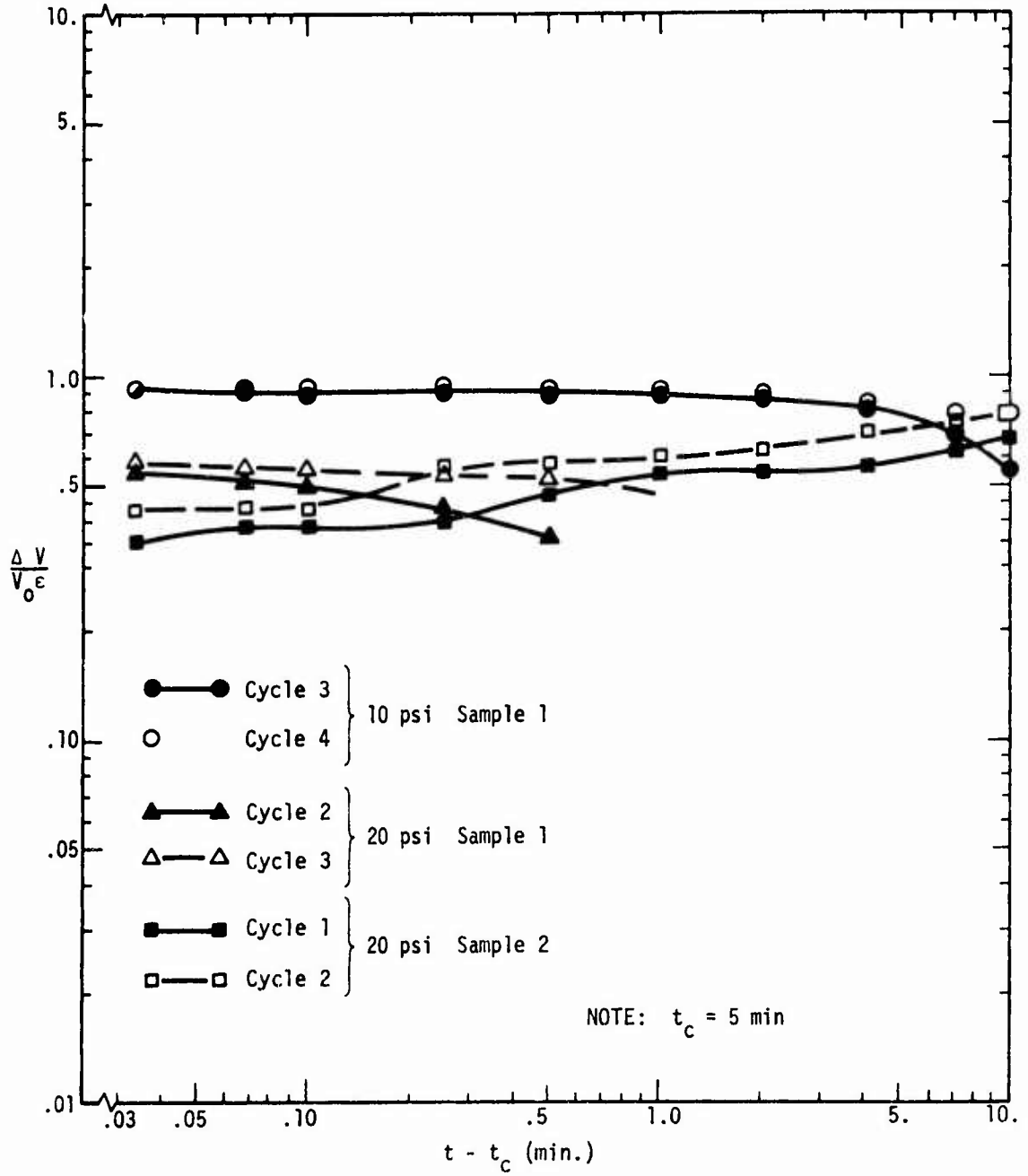

Figure 13. Poker Chip Dilatation in Tension-Recovery.

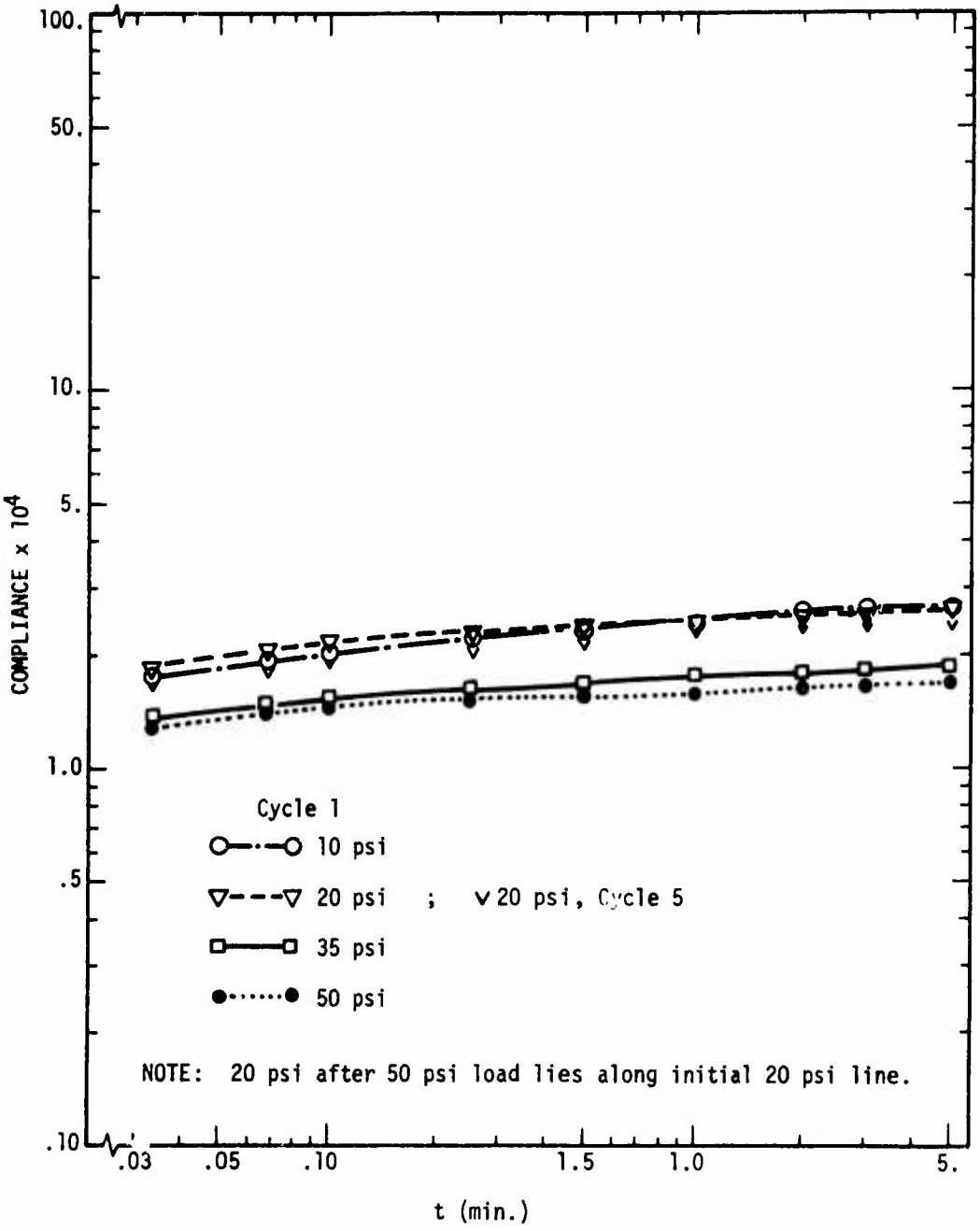

Figure 14. Poker Chip Creep Compliance in Compression.

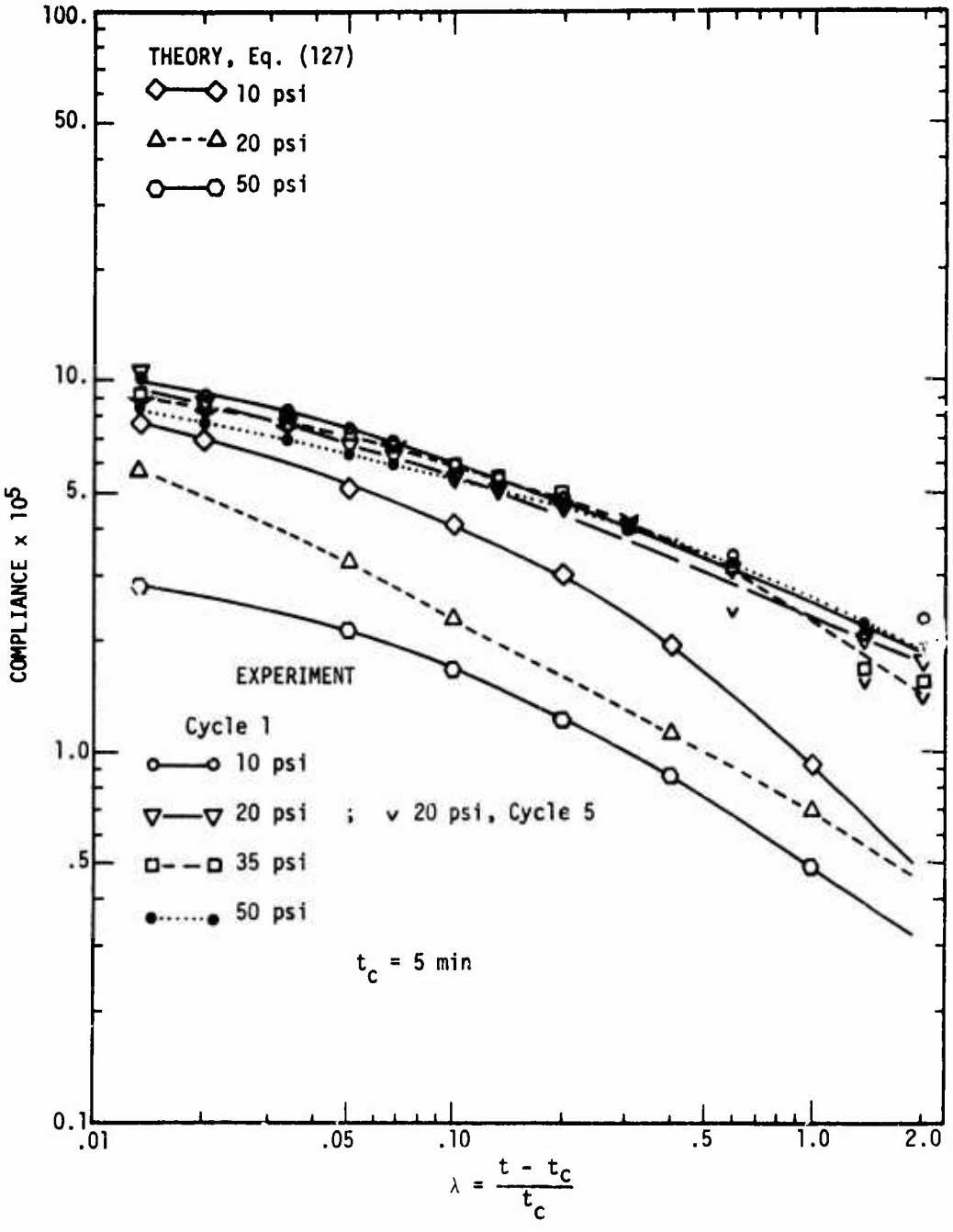

Figure 15. Poker Chip Recovery Compliance in Compression.

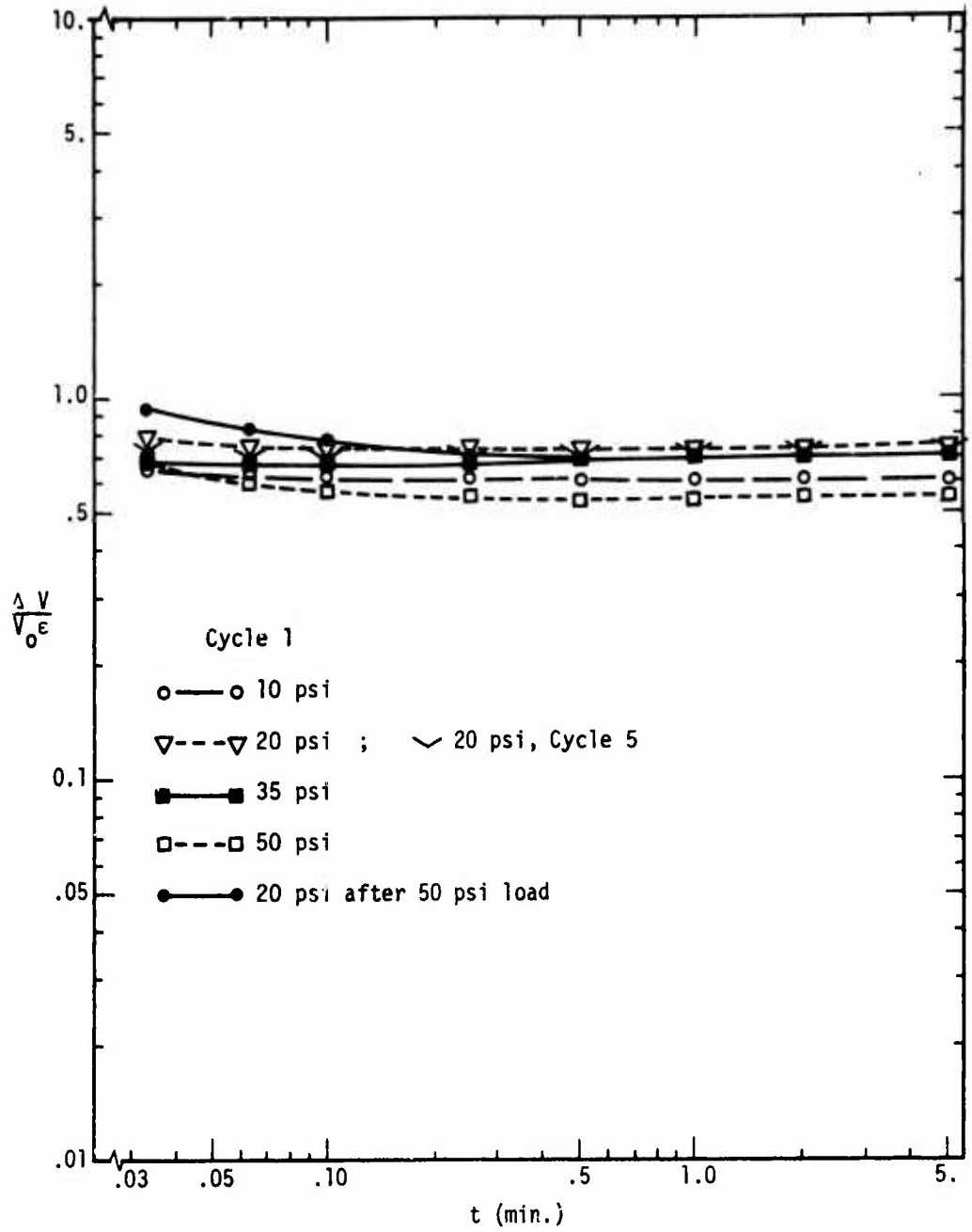

Figure 16. Poker Chip Dilatation in Creep-Compression.

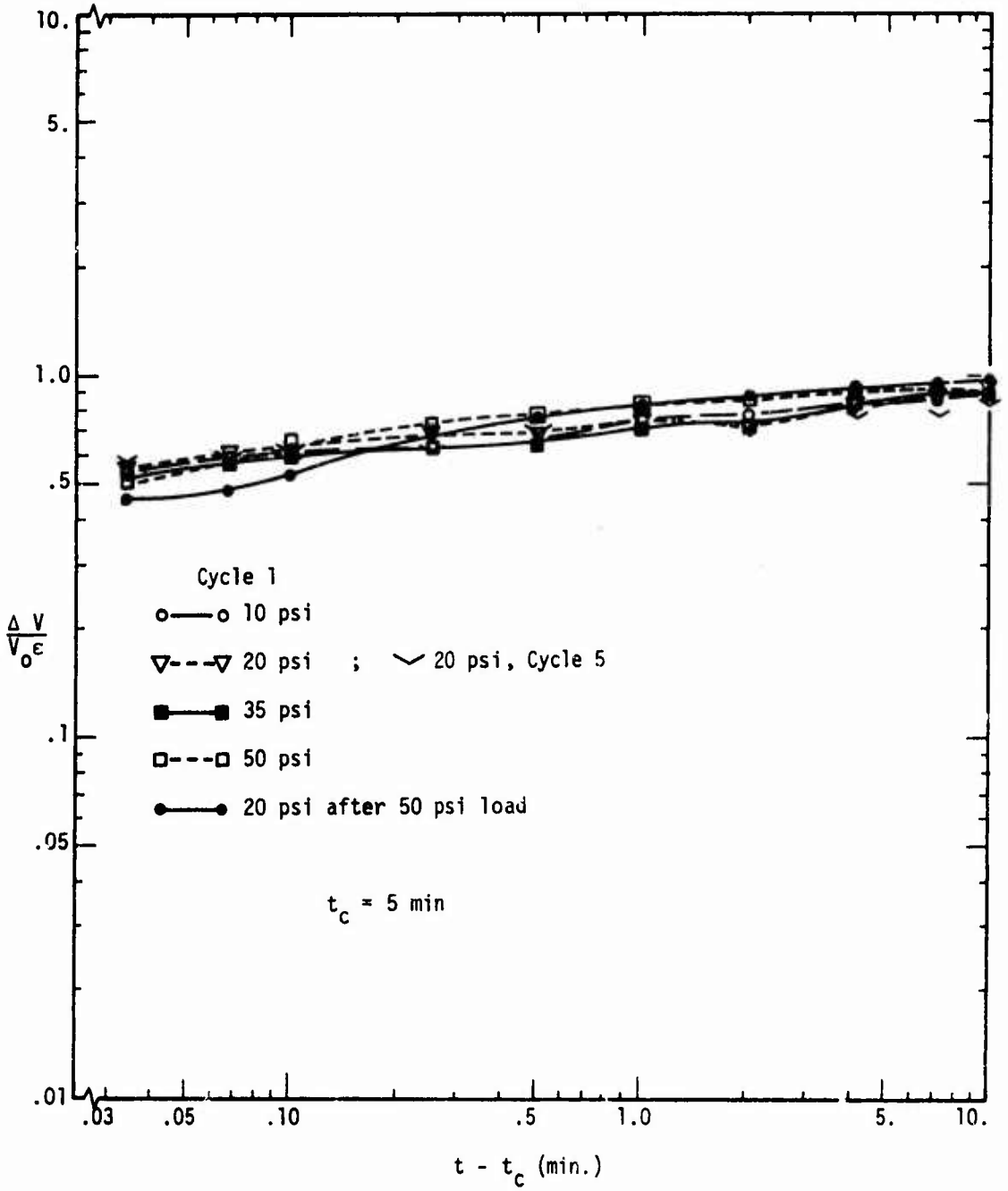

Figure 17. Poker Chip Dilatation in Recovery-Compression.

and ε_r is the recovery strain (which is the strain following load removal). The cycle numbers shown on the graphs represent a loading and unloading sequence, with cycle No. 1 defining the first sequence after the specimen had been loaded once or twice for calibration purposes. Therefore some damage had already been incurred, even before the data labeled cycle No. 1 was obtained. Note, however, that in most cases for each stress level no further significant increase in damage (as measured by changes in compliance and dilatation) appears to have occurred as the sample was cycled.

The dilatation shown in these figures was found using the same procedure described in [4] for earlier work at TAMU; specifically, the following equation was used:

$$\frac{\Delta V}{V_o} = \frac{V_{pl} - V_{para}}{V_o} \tag{124}$$

where

$V_{pl} \equiv$ volume displaced by moving platen

$V_{para} \equiv$ volume swept out by revolving the parabolic area at the periphery around the loading axis.

As an aid in interpreting the compliance and dilatation data, we show in Fig. 18 a graph that enables various property ratios to be deduced from the experimental data. This graph was obtained from a linear quasi-elastic analysis of a compressible poker-chip using the equations in [4]; a condensed version of this graph also appeared in [4]. The following definitions apply:

$E_{pc} \equiv D_{pc}^{-1} \equiv$ effective relaxation modulus of poker chip

$D_u \equiv$ creep compliance under uniaxial loading

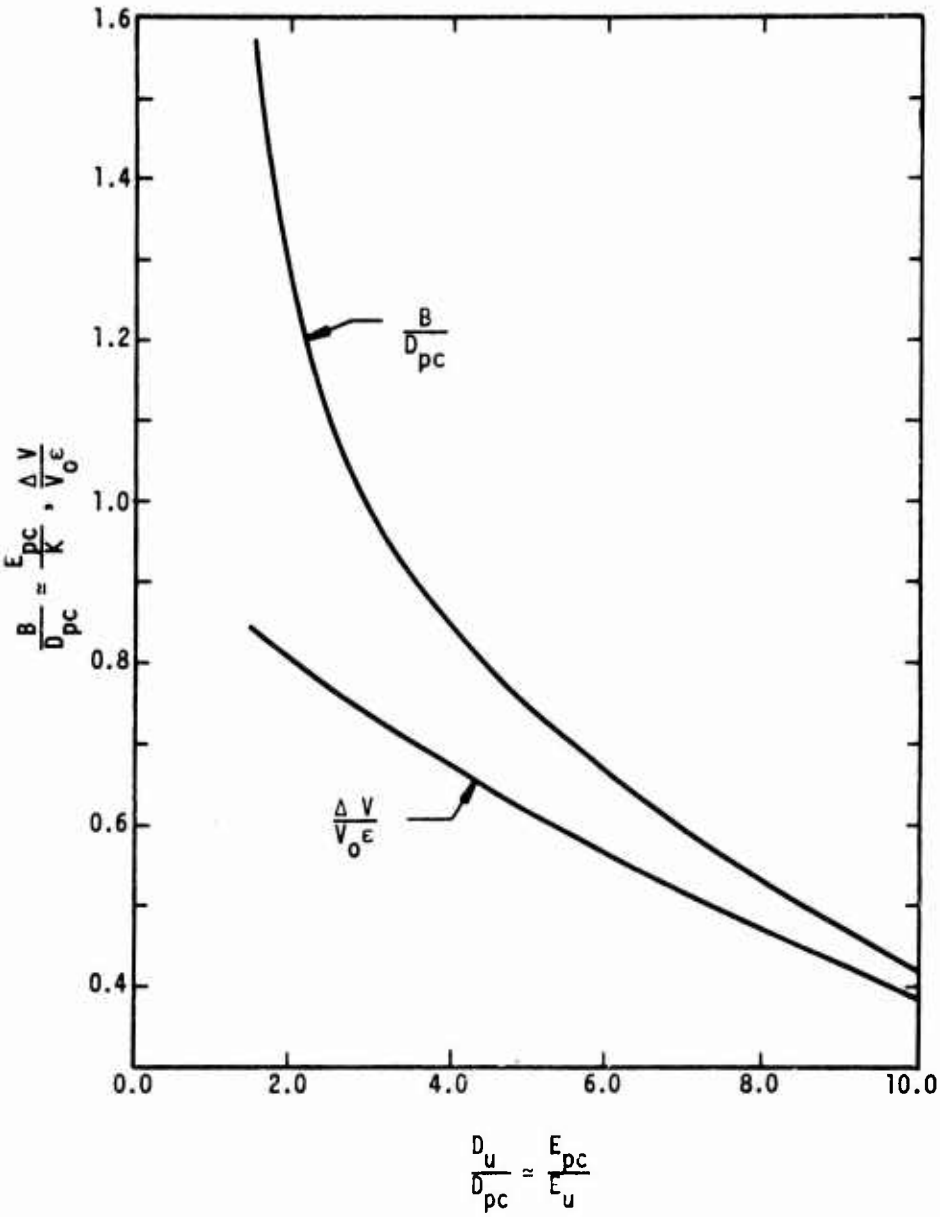

Figure 18. Property Ratios for Poker Chip (Dia/Thickness = 12).

B = bulk creep compliance

K = bulk relaxation modulus ($\simeq B^{-1}$)

E_u = relaxation modulus under uniaxial loading ($\simeq D_u^{-1}$)

In order to illustrate the use of this graph let us consider some of the data in Figs. 10-17. The ratio $\Delta V/V_o\varepsilon$ is reasonably constant in Fig. 12 and, for sample No. 2, has the approximate value of 0.7. Reading across and down from the $\Delta V/V_o\varepsilon$ curve in Fig. 18 we find $D_u/D_{pc} \simeq E_{pc}/E_u = 3.5$. Reading up to the B/D_{pc} curve and over to the ordinate we find $B/D_{pc} \simeq E_{pc}/K \simeq 0.9$.

From the compliance curve in Fig. 10 one can obtain D_{pc} at any time, and therefore calculate the remaining properties in these ratios. For example, at $t = 0.1$ min, $D_{pc}^{-1} \simeq 3000$ psi, and therefore $K \simeq 3300$ psi. This extremely low value predicted for bulk modulus (which is typical of the values obtained from the other data) is probably in error because of non-linear effects. However, it is believed that its order of magnitude is not unreasonable since the specimen probably has a significant void fraction as a result of prior loadings.

An observation of interest is that if $\Delta V/V_o\varepsilon$ is independent of time, as it is in Fig. 12 and in Fig. 16 except at short times, linear theory can be used to show that Poisson's ratio is constant. Now, a composite material consisting of a relatively incompressible viscoelastic binder together with voids and rigid particles can be shown to have a constant Poisson's ratio; this result is easily established by means of the linearity assumption plus dimensional analysis. This latter observation is, of course, consistent with the hypothesis that the poker chip specimens, as tested, contained a

large initial void fraction due to previously induced damage.

A partial check on the microcrack theory in Section II-E is provided by a comparison of creep and recovery data. First of all, consider the following isothermal constitutive equation relating average axial stress applied to the poker-chip, σ, and the axial strain, ε:

$$\varepsilon = \int_0^t D_p(t - t') \frac{d\ P(\sigma)}{dt'} dt' \tag{125}$$

where $P = P(\sigma)$ is a nonlinear function of stress. Also D_p is the linear viscoelastic poker-chip creep compliance. The creep and recovery compliances are predicted to be, respectively,

$$D_{pc}(t) = \frac{P}{\sigma} D_p(t) \tag{126a}$$

$$D_{pc}^{(r)} = \frac{P}{\sigma} [D_p(t) - D_p(t - t_c)] \tag{126b}$$

where t_c is the time at which the load is removed. Combining Eqs. (126a) and (126b) we find

$$D_{pc}^{(r)} = D_{pc}(t) - D_{pc}(t - t_c) \tag{127}$$

Since Eq. (125) with $P = \sigma$ is an exact equation for linear materials, we conclude that the recovery compliance for this special nonlinear theory is related to creep compliance in the same way as in linear theory. Equation (127) has been used to construct the theoretical recovery curves shown in Figs. 11 and 15. Considering the scatter in experimental data, predictions for the tension test are quite good. However, the theory is seen to underpredict recovery compliance in compression; the difference is believed to be due, at least in part, to rubbing between flaw faces which would impede recovery from a compressed state. In both tension and compression

the creep compliance varies appreciably with stress level.

Now, refer to the theory with microcracking. Rigorously, a nonlinear stress analysis of the poker-chip is required to interpret the data because the stresses are not spacewise uniform. However, we will argue that Eq. (110) is approximately valid for the tension tests after replacing D by D_p, if the underlying three-dimensional theory, Eqs. (47) and (120), are themselves correct.

Considering linear theory first, if Poisson's ratio, ν, is constant and the material is linear, the stresses throughout the poker-chip can be shown to be timewise constant during creep and zero during recovery. In tension tests, the thickness-averaged normal stresses are approximately equal and distributed parabolically across the radius (with the maximum occurring at the center), while the thickness-averaged shear stress increases linearly with radius from the center [18]. With this observation in mind, and assuming the stresses in a nonlinear poker-chip are distributed in the same general way, we suggest that the Lebesque norm of stress invariants in Eq. (120f) may be reasonably uniform. On physical grounds it can be argued that A_1 and A_2 are positive; therefore the variation in θ will tend to cancel that of $\sqrt{\tilde{J}}$ since the former invariant is large when the latter one is small and vice-versa. (This cancellation of effects will not occur with compression since both invariants increase algebraically with radius.) If indeed g', and therefore a_G, are essentially independent of radius, the relation between average stress and axial strain will be essentially the same as for linear theory except σ/a_G will replace stress; this can be shown by referring to the thickness-averaged field equations for the poker-chip [19].

Hence, by making the substitution $P \rightarrow \sigma/a_G$ in Eq. (125), the approximate equation with microcracking is obtained. That this equation successfully predicted recovery from creep would seem to imply a_G is essentially independent of time, although it depends on stress in view of the observed stress-dependence of creep compliance. For the power-law distribution function Eq. (111), we find during creep ($0 < t < t_c$):

$$\frac{1}{a_G} = 1 + C_1(\sigma)^{r-1}(t)^{\frac{r-1}{q}} \tag{128}$$

where C_1 is a constant; during recovery a_G^{-1} is given by Eq. (128) with $t = t_c$. For the data in Fig. 10, $n \approx 1/6$, which implies $q \approx 14$. Moreover, we find the stress-dependence of the creep compliance in Fig. 10 can be predicted by neglecting the unity term in Eq. (128) and setting $r \approx 1.8$. Thus, the time-dependence of a_G is relatively weak compared to that of the creep compliance itself. It is of interest to note in passing that the value $r = 2$ is predicted from an approximate distribution function for strain concentration factors derived by Farris [19] for spherical particles.

Strip-biaxial and uniaxial tests: A large number of constant strain rate tests were conducted at room temperature and at approximately -20°F in order to assess the accuracy of simplified constitutive equations in Sections II-A and II-D.

Although most of the tests were conducted on ANB-3335-1 propellant, a study of ANB 3066 at T = -20°F was made early in the program; typical results for stress and dilatation are shown in Fig. 19. The prediction of dilatation was made by first evaluating the constants a_s and b_s in the

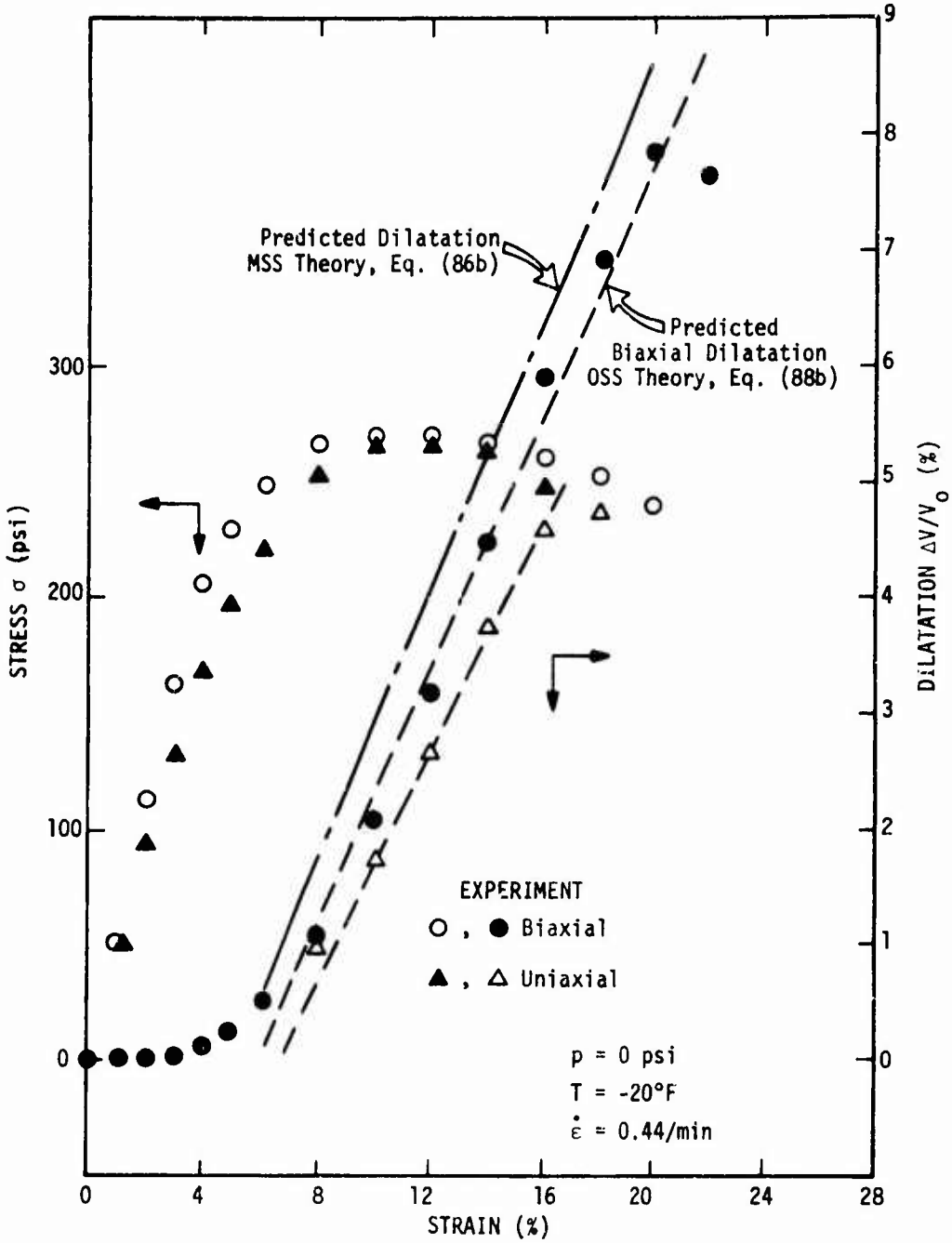

Figure 19. Uniaxial and Strip-Biaxial Data on ANB 3066 Propellant.

MSS theory and a and b in the OSS theory from the uniaxial data. Equations (86b) and (88b) were then used to construct the dilatation for the biaxial test. Obviously, the octahedral strain theory is most accurate for these data. Also, referring to Eq. (32), we find if $\beta \simeq 2$ the stress can be predicted reasonably well.

Similar results were found for ANB 3335-1, as shown in Fig. 20. Again the OSS theory is seen to be better than the MSS theory. Also, for this case $\beta \simeq 2$. Typical room temperature data on this propellant are given in Fig. 21, for which $\beta \simeq 2.5$. The biaxial dilatation data now fall between the OSS and MSS theories. A study of the data obtained on several other specimens revealed that the OSS prediction was generally best, although some of the results were similar to that shown in Fig. 21. In most of these latter cases some of the uniaxial specimens cut from a single strip appeared to fail prematurely, which would account for the OSS prediction being low compared to the biaxial dilatation data.

In order to check the hypothesis that $\tilde{I}_3$ is absent from the dilatational constitutive Eq. (10) (or Eq. (61)), it is not, of course, necessary to use a piecewise linear representation of dilatation. If the term $\theta/3K_e$ is negligible in these equations, then a plot of the actual uniaxial and biaxial data on a graph of I_T vs. $\sqrt{\tilde{I}_2}$ will form a single curve if $\tilde{I}_3$ does not enter the constitutive equation. Figures 22-25 show such plots for 0 psi and 200 psi. Although there is some spread, the theory seems to be quite adequate for correlating the dilatation in the biaxial and uniaxial modes; most of the spread is believed due to premature failure of some uniaxial samples.

It should be added that in view of the relatively large strains involved, we have used invariants based on Lagrangian strains in Figs. 22-25; see

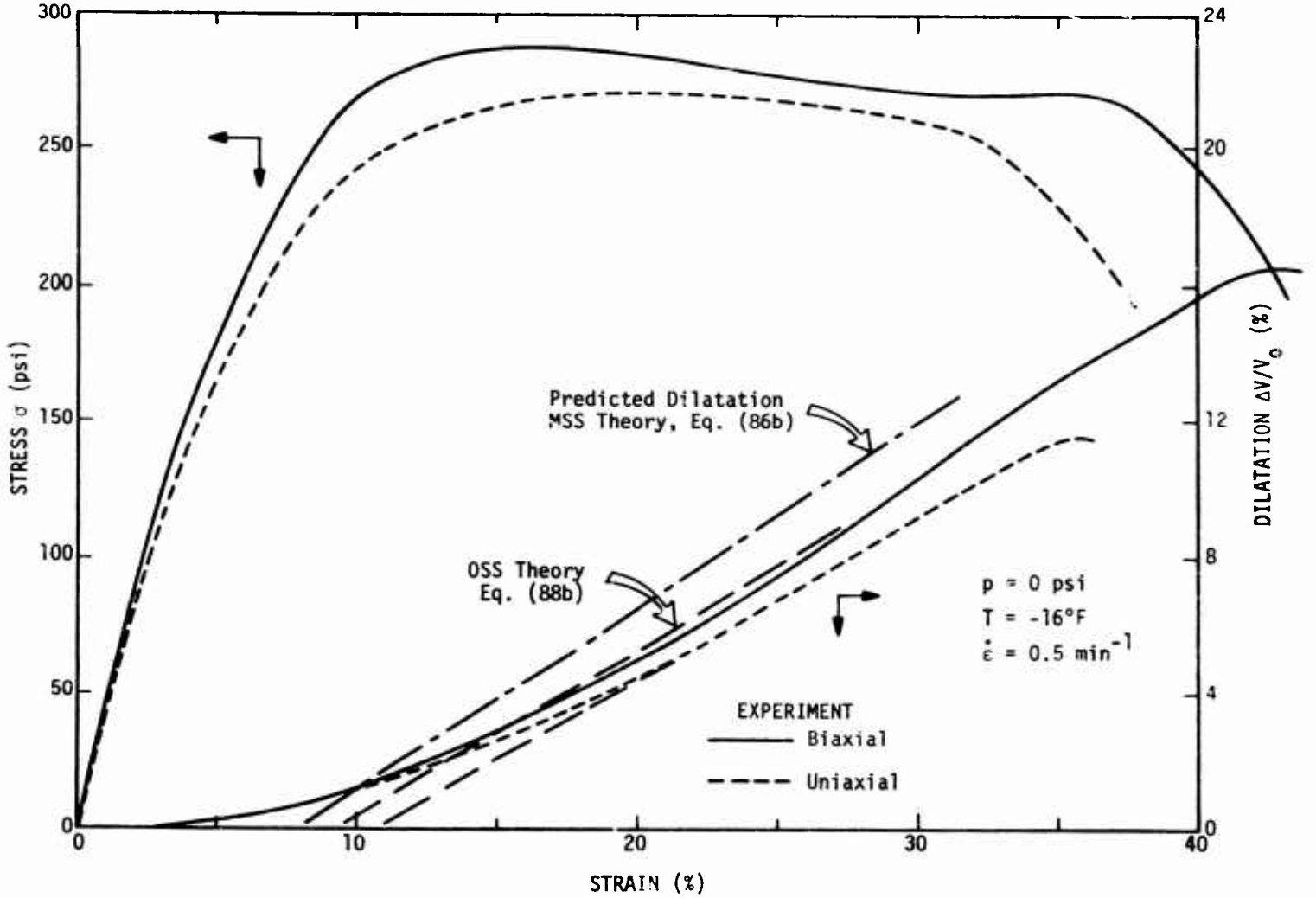

Figure 20. Uniaxial and Strip-Biaxial Data on ANB 3335-1 Propellant.

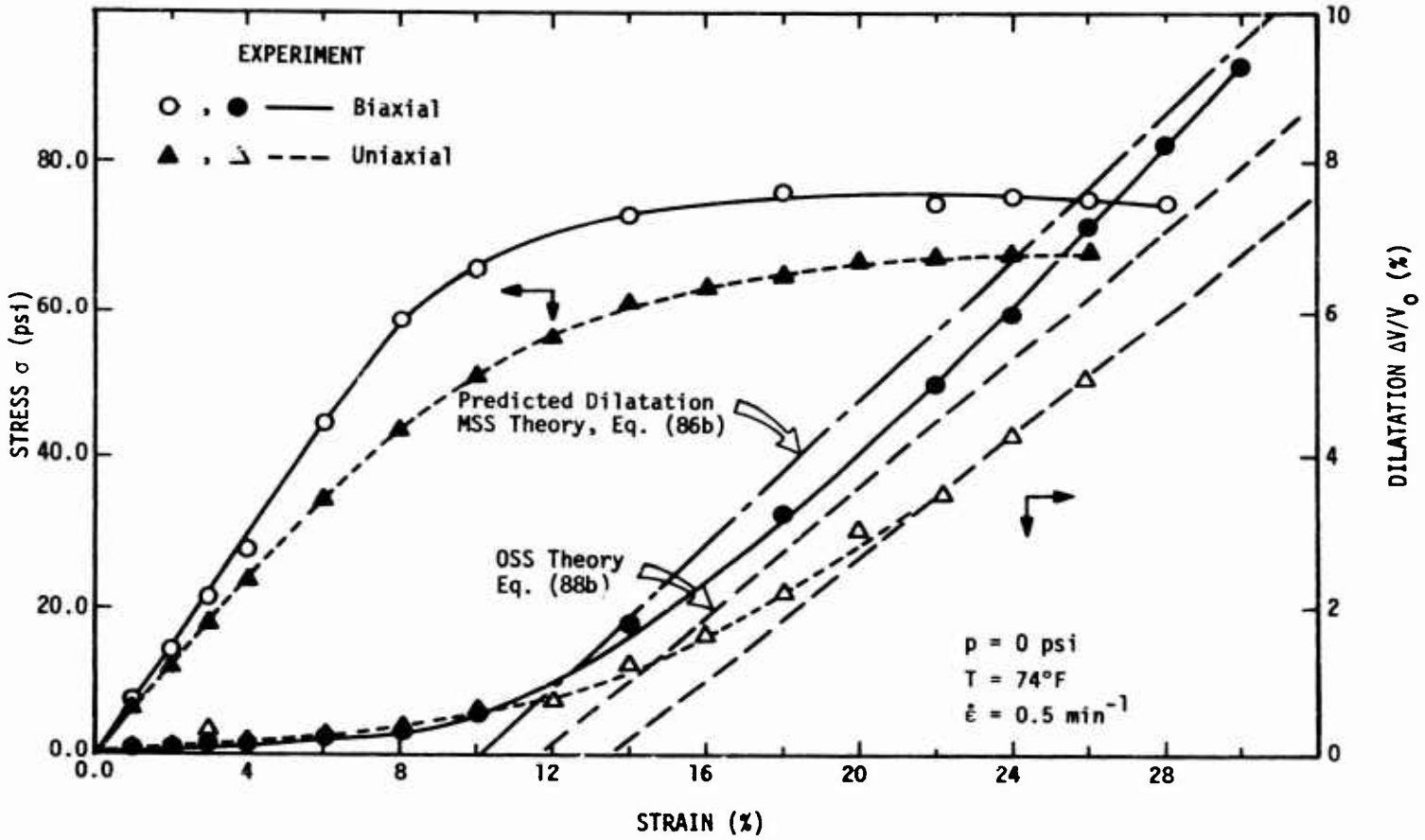

Figure 21. Uniaxial and Strip-Biaxial Data on ANB 3335-1 Propellant.

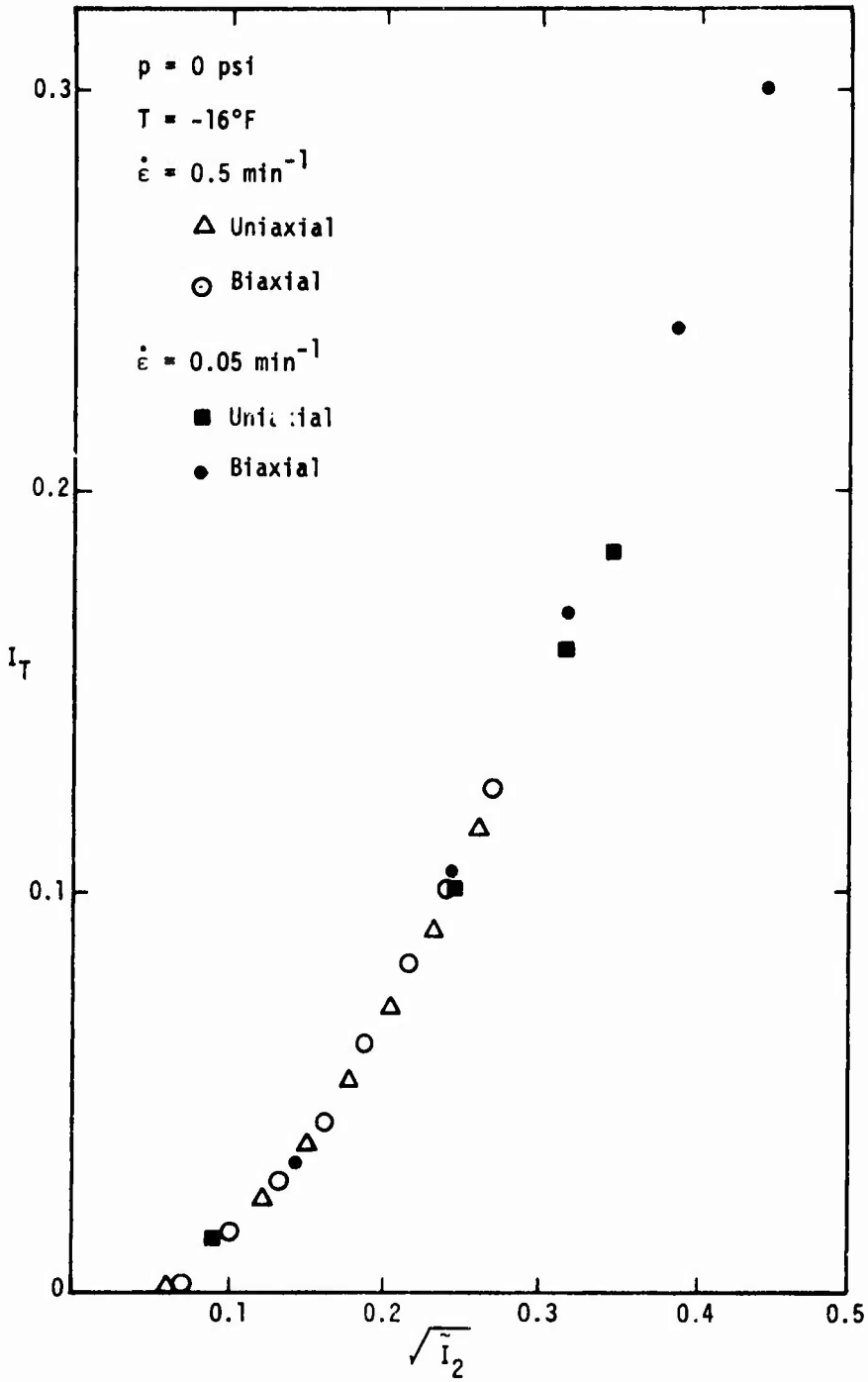

Figure 22. Relation Between First and Second Strain Invariants for Data in Fig. 20.

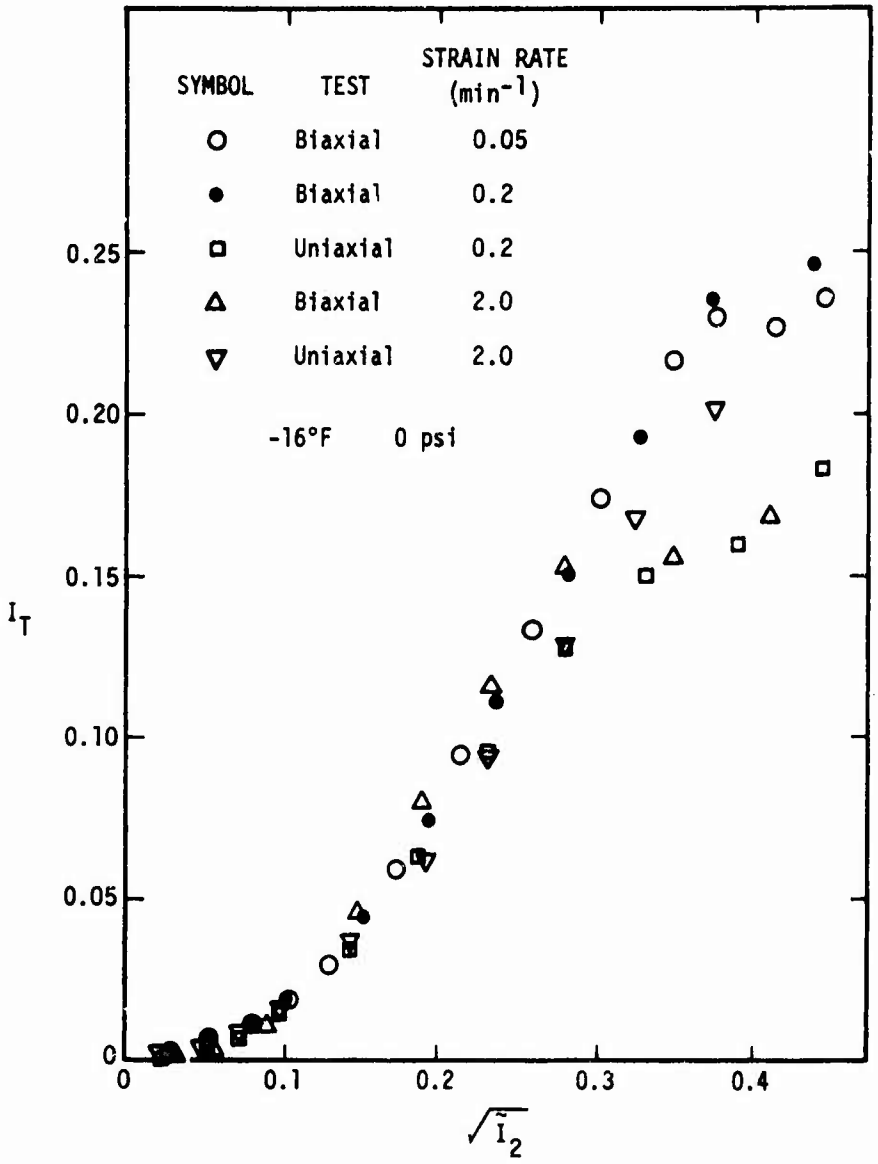

Figure 23. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant

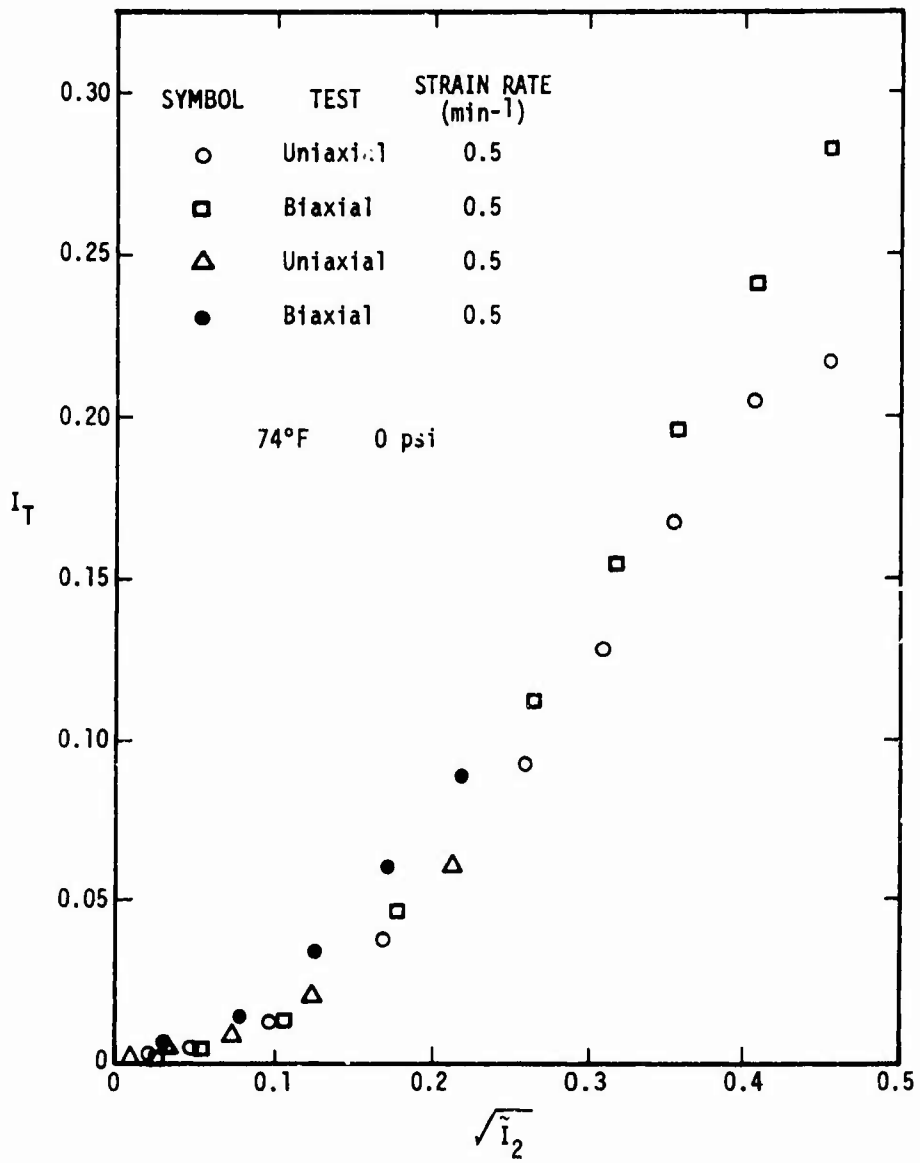

Figure 24. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant

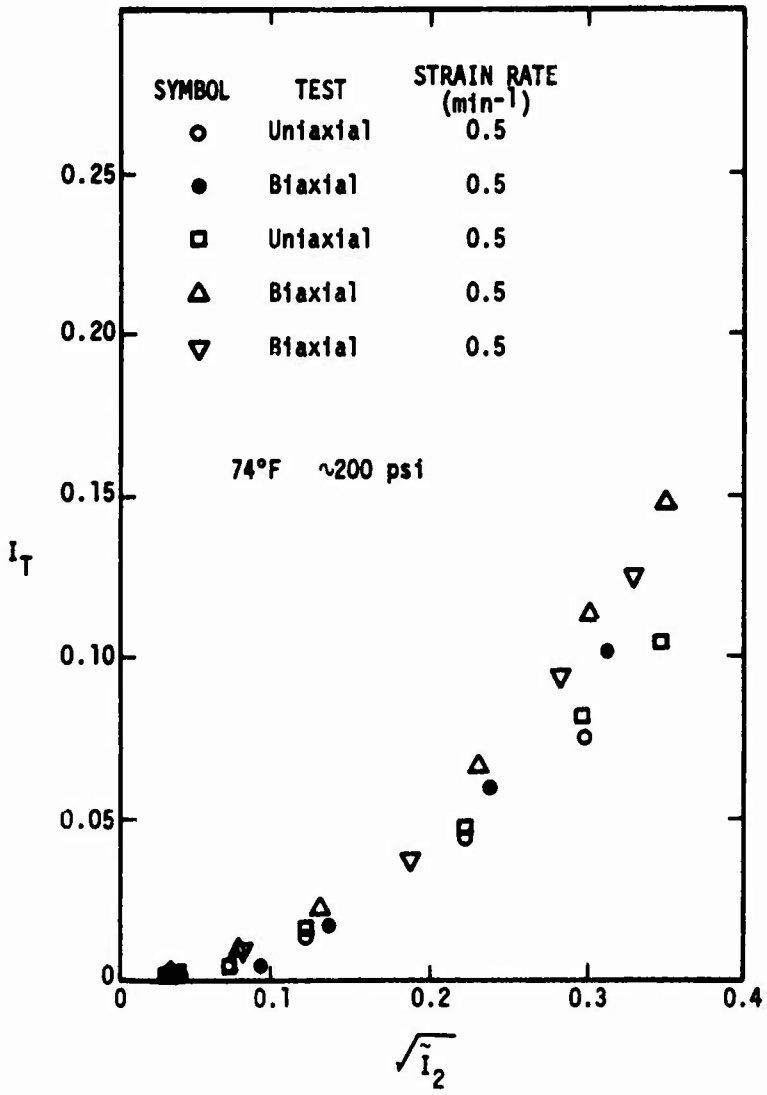

Figure 25. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant.

Section II-G. In particular, with primes denoting deviatoric strains,

$$I_T \equiv E_{ii} - 3\alpha\Delta T \tag{129a}$$

$$\tilde{I}_2 \equiv E_{ij}' E_{ij}' \tag{129b}$$

Note that the invariant defined by Eq. (129a) is not equal to the dilatation, except for small strains.

Finally, it is of interest to compare the value of the modulus ratio in Eq. (23) found from the uniaxial and biaxial stress-strain data with that obtained from the poker chip tests. For the former tests at 74°F we have found that the relation $\beta/a \simeq 5$ holds. Thus,

$$\frac{K_e}{G_e} \simeq 5\sqrt{6} \simeq 12 \tag{130}$$

Referring to Fig. 18, it is found that this result predicts the dilatation-strain ratio

$$\frac{\Delta V}{V_o \epsilon} \simeq 0.69 \tag{131}$$

where the standard linear elastic relation

$$G_e = \frac{3K_e E_u}{9K_e - E_u} \tag{132}$$

has been used; also, corresponding to the notation in Fig. 18, $K_e \equiv K$. The ratio in Eq. (131) is of the correct order of magnitude, based on the poker chip data in Fig. 12.

IV. CONCLUSIONS

Emphasis in this study has been on (i) establishing a simple constitutive theory for propellant at large values of vacuole dilatation, and (ii) the use of viscoelastic fracture mechanics as a means of relating overall mechanical response to fundamental parameters that define the extent of microstructural damage.

Under item (i) we have found the dilatation of strip-biaxial specimens and uniaxial specimens to be essentially equal when referred to equal values of the octahedral shear strain. An implication of this result is that the third deviatoric strain invariant probably can be omitted from the nonlinear constitutive theory without introducing appreciable error. It is shown that dilatation measured on thin simple shear specimens would provide another check of this conclusion; however shear data were not obtained in this study.

In the area (ii) we developed a constitutive theory which is identical to linear viscoelasticity except the stress tensor is multiplied by a scalar function that reflects microstructural damage. This function depends on a weighted Lebesque norm involving stress invariants (rather than strain invariants) and is expressed in terms of temperature-reduced time; the weighting function in the norm reflects one effect of aging and rehealing, if any. The fracture mechanics theory was developed during the latter portion of the program and therefore only a limited check of the theory is given.

ACKNOWLEDGMENT

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APPENDIX B

PREPROCESSOR CODE NL001

1.0 INTRODUCTION

NL001 is a preprocessor for the nonlinear viscoelastic characterization code NL002. It takes the raw test data, consisting of a temperature, strain rate, time step increment, stress and dilatation, and then calculate the following data:

1. Principal strains, shear strain and true stress
2. Strain rates
3. Strain invariants
4. Dilatation, corrected for pressure and temperature
5. Octahedral strain
6. The 10th, 20th, 30th, 40th, 50th, 60th and infinite Lebesque norms

All these data are generated for the same time points as the original data. The generated and raw test data are then assigned a user prescribed identification and written out onto a tape as a single element. This process is then repeated once for each test, with each test being limited to 100 input data points. There is, however, no limit to the number of tests which may be processed in a single run.

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2.0 PROGRAM INSTRUCTIONS

The purpose of this section is to list the basic variables of the NL001 code and provide a set of input instructions for running the program.

2.1 BASIC VARIABLES

Following is a list of the basic program variables of NL001. Each variable is described briefly and labeled as either an input or calculated output variable. All input is also saved as output. Any variable which is not either input or output is merely a working variable used internally, usually for intermediate calculations.

A1, A2	Working variables
BETA	Volumetric expansion coefficient - input
BULK	Bulk modulus - input
C1, C2	Arbitrarily small constants - fixed in program by user. Presently 1.0E-6.
DIL	Dilatation an input - corrected for temperature and pressure for output
DR1, DR2, DR12	Normal and shear calculated strain rates - output
DT	Time step in minutes - input
EOCT	Octahedral strain - output
EPS	Epsilon tester working variable
E_{11}, E_{22}, E_{33}	Normal strains - output
E_{12}	Shear strain - output
INV1	First strain invariant = $E_{11} + E_{22} + E_{33}$ - output
INV2	Second strain invariant = $E_{11} E_{22} + E_{22} E_{33} + E_{33} E_{11}$ - output

INV3	Third strain invariant = E_{11} E_{22} E_{33} - output
KODE	Input control variable: = 1 if a uniaxial test, = 2 if a biaxial test, = 3 if a shear test
KTEMP	Input control variable: = 1 if a constant temperature test = 2 if a variable temperature test
LAST	Input delimiter flagging last input data point. Set blank or zero if not last data point - nonzero if last data point.
MATID	Material identification - input
NAME	Test identification - input
NDP	Number of data points of a specific test
NØRMF	Infinite Lebesque norm - output
NORMi	ith Lebesque norm - output
PRES	Test pressure - input
RATE	Strain rate, observed - input
SP	Working variable
STRESS	Observed stress-input
STRUE	True stress - output
T	Time in minutes - output
TEMP	Test temperature - input

2.2 INPUT INSTRUCTIONS

The following series of cards are read once for each test processed through NL001. The last card of the input deck is always a blank, however there is no blank card between tests. The required input variables for each card appear below with their formats shown in parentheses.

Card 1 (A6, E14.4, 2I5, 5a4, 2E15.6) NAME, PRES, KTEMP, KØDE, MATID, BULK, BETA

Card(s) 2 (5E10.3, I5) TEMP(J), RATE(J), DT(J), STRESS(J), DIL(J), LAST

Here J indicates the Jth data point of this test. Card 2 is repeated once for each data point.

Cards 1 and 2 are repeated once for each test processed.

Card 3 - A blank card indicating that last test has been processed.

2.3 SAMPLE INPUT SHEET

Shown below is a sample input sheet for NL001. It contains the input data for two uniaxial constant temperature tests. The first, U00100 is at ambient pressure while U10105 is run at 100 psig.

2.4 PROGRAM LISTING

The listing of NL001 appears below. Note that it is written specifically for the UNIVAC 1108 computer. Use of this program on any other computer would require substitution of the appropriate statements for the MAKELT and SQUEEZ subroutines.

JOB NUMBER | REPORT TITLE: Sample input NL001 | DATE | PAGE OF

```
100106                    1   1 ANB 3335-1                500000.                  1.8          E-04
150.        0.5           0.09        14.5          0.0
150.        0.5           0.05        21.7          0.10
150.        0.5           0.05        27.0          0.35
150.        0.5           0.05        29.8          0.80
150.        0.5           0.05        30.8          1.50
150.        0.5           0.05        30.9          2.35
150.        0.5           0.05        30.3          3.25
150.        0.5           0.05        29.6          4.20
150.        0.5           0.05        28.3          5.15          11111
110105  100.                1   1 ANB 3335-1                5.0          E+05  1.8          E-04
150.        0.5           0.065       10.2          0.0
150.        0.5           0.05        18.0          0.0006
150.        0.5           0.05        25.4          0.0027
150.        0.5           0.05        32.5          0.06
150.        0.5           0.05        38.8          0.11
150.        0.5           0.05        43.8          0.18
150.        0.5           0.05        47.8          0.27
150.        0.5           0.05        50.7          0.373
150.        0.5           0.05        52.4          0.486
150.        0.5           0.05        53.0          0.602
150.        0.5           0.02        52.8          0.647         11111
                    BLANK    CARD
G-7
```

PLEASE PRINT CLEARLY - USE BLACK PENCIL

LT FOR NL001.NL001 15 JUN 73 00:00:06.92P
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:24(00)
FORTRAN V: ISD VERSION 2.6

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	001643
0000	*DATA	022565
0002	*BLANK	000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	NTRAN
0004	EXIT
0005	NWDU$
0006	NIO2$
0007	NRDU$
0010	NIO1$
0011	NERR2$
0012	CART
0013	SQRT
0014	DSQRT
0015	NEXP8$
0016	NSTOP$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	017571	1F	0001	000362	10L	0001	000030	1266	0001	000467	13L
0001	001012	16L	0001	001177	17L	0001	000077	1726	0001	000025	2L
0001	000170	2346	0000	017600	28F	0001	000250	2606	0001	000325	2766
0000	017555	30F	0001	001630	300I	0000	017643	301F	0001	001177	31L
0001	001204	32L	0001	001416	33L	0001	000502	3306	0001	001423	34L
0001	001124	3746	0001	000125	4L	0001	000220	41L	0001	001227	4226
0001	001260	4376	0001	000231	5L	0001	001436	5066	0001	001450	5136
0001	000467	7L	0000 D	017523	A1	0000 D	017525	A2	0000 R	017657	B
0000 D	017545	BULK	0000 R	017533	C1	0000 R	017534	C2	0000 D	007025	DR
0000 R	000144	DR1	0000 R	000454	DR12	0000 R	000310	DR2	0000 R	000620	DT
0000 R	017552	EPS	0000 R	000764	E11	0000 R	001440	E12	0000 R	001130	E22
0000 I	017537	I	0000 I	017657	IR	0000 D	001604	INV1	0000 D	002114	INV2
0000 I	017535	IPG	0000 I	017540	J	0000 I	017554	K	0000 I	017544	KODE
0000 I	017547	LAST	0000 I	017532	LD	0000 I	017536	LINE	0000 I	017531	LO
0000 I	017505	N	0000 I	017541	NAME	0000 I	017550	NDF	0000 I	017527	NEND
0000 R	003251	NORM10	0000 R	003561	NORM20	0000 R	004171	NORM30	0000 R	004801	NORM50
0000 R	005221	NORM60	0000 I	017553	NOUT	0000 I	017530	NU	0000 R	017542	PRES
0000 R	017551	SP	0000 R	005675	STRESS	0000 R	006041	STRUE	0000 R	006205	T

```
00100     1*   C
00100     2*   C *** PROGRAM NAME = NL001.   A PREPROCESSOR FOR THE NONLINEAR THERMO-
00100     3*   C                             VISCOELASTIC CHARACTERIZATION CODE NL002. -
00100     4*   C
```

```
00100    5*  C***  SPECIAL VERSION TO USE BINARY TAPE WRITES
00100    6*  C
00100    7*  C        EACH TEST IS LIMITED TO A MAXIMUM OF 100 DATA POINTS - NDP.
00100    8*  C         LAST DATA INPUT CARD IS A BLANK.
00100    9*  C         MUST MAKE A SEPERATE RUN FOR EACH MATERIAL.
00100   10*  C
00100   11*  C         BULK     = BULK MODULUS FOR THIS MATERIAL.
00100   12*  C         BETA     = VOLUMETRIC EXPANSION COEFFICIENT.
00100   13*  C         C1, C2   = ARBITRILY SMALL COEFFICIENTS.
00100   14*  C         NU       = BINARY OUTPUT UNIT.
00100   15*  C
00101   16*        DIMENSION     DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00101   17*       1         E11(100), E22(100), E33(100), E12(100), INV1(100),
00101   18*       2         INV2(100), INV3(100), MATID(5), NORME(100), NORM10(100),
00101   19*       3         NORM20(100), NORM30(100), NORM40(100), NORM50(100),
00101   20*       4         NORM60(100), RATE(100), STRESS(100), STRUE(100), T(100),
00101   21*       5         TEMP(100),  EOCT(100)
00103   22*        DIMENSION   IA(1400), B(1400), DA(2200), N(14)
00103   23*  C
00103   24*  C
00104   25*        DOUBLE PRECISION   INV1, INV2, INV3, NORME, NORM10, NORM20,
00104   26*       1       NORM30, NORM40, NORM50, NORM60, A1, A2, EOCT
00105   27*        DOUBLE PRECISION  DA
00105   28*  C
00106   29*        EQUIVALENCE(B(1),IA(1))
00107   30*        DATA IEND/'END'/
00107   31*  C
00107   32*  C          ASSIGN TAPE UNIT SRC.
00111   33*        NU = 1
00112   34*        L0 = 10
00113   35*        L0 = 10
00114   36*        CALL STRAN(NU,10)
00114   37*  C          INITIALIZE ARBITRARY CONSTANTS - USER'S OPTION.
00114   38*  C
00115   39*        C1 = 1.0E-6
00116   40*        C2 = 1.0E-6
00117   41*        IPG = 1
00120   42*        LINE = 0
00121   43*        WRITE(6,24) IPG
00124   44*    2   CONTINUE
00124   45*  C
00124   46*  C          BEGIN NEXT TEST.
00124   47*  C
00124   48*  C               ZERO ALL VARIABLES FOR THIS TEST.
00124   49*  C
00125   50*        DO 100 I=1,100
00130   51*        DIL(I) = 0.0
00131   52*        DR1(I) = 0.0
00132   53*        DR2(I) = 0.0
00133   54*        DR12(I) = 0.0
00134   55*        DT(I) = 0.0
00135   56*        E11(I) = 0.0
00136   57*        E22(I) = 0.0
00137   58*        E33(I) = 0.0
00140   59*        E12(I) = 0.0
00141   60*        EOCT(I) = 0.00
00142   61*        INV1(I) = 0.00
00143   62*        INV2(I) = 0.00
00144   63*        INV3(I) = 0.00
00145   64*        NORME(I) = 0.00
```

```
00146   85*          NORM1J(I) = 0.00
00147   86*          NORM2J(I) = 0.00
00150   87*          NORM3J(I) = 0.00
00151   88*          NORM4J(I) = 0.00
00152   89*          NORM5J(I) = 0.00
00153   90*          NORM6J(I) = 0.00
00154   91*          RATE(I) = 0.0
00155   92*          STRESS(I) = 0.0
00156   93*          STRUE(I) = 0.0
00157   94*          T(I) = 0.0
00160   95*          TEMP(I) = 0.0
00161   96*      100 CONTINUE
00163   97*          J = 2
00164   98*          READ(5,3) NAME, PRES, KTEMP, KODE, (MATID(I),I=1,5), BULK, BETA
00164   99*  C
00164  100*  C                 ALL DONE ?
00164  101*  C
00200  102*          IF(KODE.NE.0) GO TO 4
00202  103*          CALL NTRAN(NU,1,10,MEND,LG)
00203  104*          CALL NTRAN(NU,9)
00204  105*          CALL EXIT
00204  106*  C
00204  107*  C
00205  108*      4   CONTINUE
00206  109*          J = J + 1
00207  110*          READ(5,1)  TEMP(J), RATE(J), DT(J), STRESS(J), DIL(J), LAST
00217  111*          IF(LAST.EQ.0) GO TO 4
00217  112*  C
00221  113*          NOP = J
00222  114*          DT(2) = 20.
00223  115*          TEMP(3) = TEMP(2)
00224  116*          TEMP(1) = TEMP(2)
00224  117*  C
00224  118*  C                 LIST INPUT DATA.
00224  119*  C
00225  120*          WRITE(6,30) NAME,NOP,PRES,KTEMP,KODE,(MATID(I),I=1,5),BULK,BETA
00242  121*      30  FORMAT(1H ,T10,A6,T20,I3,T35,F8.0,T50,I3,T60,I3,T70,5A4,
00242  122*     1       T100,E10.4,T115,E10.4  )
00243  123*          LINE = LINE + 1
00244  124*          IF(LINE.LT.50) GO TO 41
00246  125*          IPG = IPG + 1
00247  126*          WRITE(6,24) IPG
00252  127*          LINE = 0
00253  128*      41  CONTINUE
00253  129*  C           COMPUTE STRAINS AND 2ND INVARIANT BASED ON TYPE OF TEST.
00253  130*  C
00254  131*          GO TO(5,6,7),KODE
00255  132*      5   CONTINUE
00255  133*  C                 UNIAXIAL TEST.
00256  134*          SP = CBRT(1. - PRES/BULK) - 1.0
00257  135*          DO 8 I=2,NOP
00262  136*          DIL(I) = DIL(I)/100. - PRES/BULK
00263  137*          SP = SP + RATE(I)*DT(I)
00264  138*          E11(I) = ( (1.0 + SP)**2 - 1.0) / 2.0
00265  139*          DIL(I) = DIL(I) + C1*E11(I) + BETA*(TEMP(I)-TEMP(I-1))
00266  140*          E22(I) = (((1.0 + DIL(I))/(1.0 + SP)) - 1.0)/2.0
00267  141*          E33(I) = E22(I)
00270  142*      8   CONTINUE
00272  143*          GO TO 10
00272  144*  C
```

```
00272   125*   C
00273   126*    6     CONTINUE
00273   127*   C                    BIAXIAL TEST.
00274   128*         SP = SQRT(1.0 - PRES/BULK) - 1.0
00275   129*         DO 9 I=2,NDP
00300   130*         DIL(I) = DIL(I)/100. - PRES/BULK
00301   131*         SP = SP + RATE(I)*DT(I)
00302   132*         E11(I) = ( (1.0 + SP)**2  -1.0) / 2.
00303   133*         DIL(I) = DIL(I) + C2*E11(I) + BETA*(TEMP(I)-TEMP(I-1))
00304   134*         E22(I) = (( (1.0 + DIL(I))/(1.0 + SP) )**2 -1.0)/2.
00305   135*    9    CONTINUE
00305   136*   C
00305   137*   C              COMPUTE INVARIANTS AND TRUE STRESS FOR UNIAXIAL OR BIAXIAL TESTS.
00305   138*   C
00307   139*    10   CONTINUE
00310   140*         DO 11 I=2,NDP
00313   141*         INV1(I) = E11(I) + E22(I) + E33(I)
00314   142*         INV2(I) = E11(I)*E22(I) + E22(I)*E33(I) + E33(I)*E11(I)
00315   143*         INV3(I) = E11(I)*E22(I)*E33(I)
00316   144*         STRUE(I) = STRESS(I)*SQRT((1.0+2.*E11(I))/(1.0+DIL(I)) )
00316   145*   C
00316   146*   C              COMPUTE THE OCTAHEDRAL STRAIN.
00316   147*   C
00317   148*         EOCT(I) = (E11(I)-E22(I))**2 + (E11(I)-E33(I))**2 + (E33(I)-
00317   149*        1        E22(I))**2
00320   150*         EOCT(I) = DSQRT(EOCT(I))/3.D0
00321   151*    11   CONTINUE
00323   152*         GO TO 13
00323   153*   C
00324   154*    7    CONTINUE
00324   155*   C
00324   156*   C$$$
```

```
00354  185*          NORM20(I) = NORM20(I-1) + (A1**21-A2**21)/ (21*(A1-A2)/DT(I))
00355  186*          NORM30(I) = NORM30(I-1) + (A1**31-A2**31)/ (31*(A1-A2)/DT(I))
00356  187*          NORM40(I) = NORM40(I-1) + (A1**41-A2**41)/ (41*(A1-A2)/DT(I))
00357  188*          NORM50(I) = NORM50(I-1) + (A1**51-A2**51)/ (51*(A1-A2)/DT(I))
00360  189*          NORM60(I) = NORM60(I-1) + (A1**61-A2**61)/ (61*(A1-A2)/DT(I))
00361  190*          GO TO 15
00362  191*    16    CONTINUE
00363  192*          NORM10(I) = NORM10(I-1) + (A1**10)*DT(I)
00364  193*          NORM20(I) = NORM20(I-1) + (A1**20)*DT(I)
00365  194*          NORM30(I) = NORM30(I-1) + (A1**30)*DT(I)
00366  195*          NORM40(I) = NORM40(I-1) + (A1**40)*DT(I)
00367  196*          NORM50(I) = NORM50(I-1) + (A1**50)*DT(I)
00370  197*          NORM60(I) = NORM60(I-1) + (A1**60)*DT(I)
00371  198*    15    CONTINUE
00373  199*          DO 27 I=1, NDP
00376  200*          NORM10(I) = NORM10(I)**(1./10.)
00377  201*          NORM20(I) = NORM20(I)**(1./20.)
00400  202*          NORM30(I) = NORM30(I)**(1./30.)
00401  203*          NORM40(I) = NORM40(I)**(1./40.)
00402  204*          NORM50(I) = NORM50(I)**(1./50.)
00403  205*          NORM60(I) = NORM60(I)**(1./60.)
00404  206*    27    CONTINUE
00404  207*    C
00406  208*    17    CONTINUE
00406  209*    C
00406  210*    C          WRITE OUT THE SINGLE PRECISION/INTEGER RECORD.
00407  211*    31    IF(LQ+1) 300,31,32
00412  212*    32    CONTINUE
00413  213*          NOUT = 12 + 14*NDP
00413  214*    C
00414  215*          IR(1) = NAME
00415  216*          IR(2) = NDP
00416  217*          R(3) = PRES
00417  218*          IR(4) = KTEMP
00420  219*          IR(5) = KODE
00421  220*          DO 19 K=1,5
00424  221*          J = K+5
00425  222*    19    IR(J) = MATID(K)
00427  223*          R(11) = BULK
00430  224*          R(12) = BETA
00431  225*          DO 20 I=1,14
00434  226*    20    N(I) = 12 + (I-1)*NDP
00434  227*    C
00436  228*          DO 21 I=1,NDP
00441  229*          J = N(1)
00442  230*          R(J+I) = TEMP(I)
00443  231*          J = N(2)
00444  232*          R(J+I) = RATE(I)
00445  233*          J = N(3)
00446  234*          R(J+I) = DT(I)
00447  235*          J = N(4)
00450  236*          R(J+I) = STRESS(I)
00451  237*          J = N(5)
00452  238*          R(J+I) = DIL(I)
00453  239*          J = N(6)
00454  240*          R(J+I) = T(I)
00455  241*          J = N(7)
00456  242*          R(J+I) = F11(I)
00457  243*          J = N(8)
00460  244*          R(J+I) = F22(I)
```

```
00461  245*          J = N(9)
00462  246*          B(J+I) = F33(I)
00463  247*          J = N(10)
00464  248*          B(J+I) = F12(I)
00465  249*          J = N(11)
00466  250*          B(J+I) = STRUF(I)
00467  251*          J = N(12)
00470  252*          B(J+I) = DR1(I)
00471  253*          J = N(13)
00472  254*          B(J+I) = DR2(I)
00473  255*          J = N(14)
00474  256*          B(J+I) = DR12(I)
00475  257*    21    CONTINUE
00477  258*              CALL NTRAN(NU,1,NOUT,B,LD)
00477  259*    C
00477  260*    C         WRITE OUT THE DOUBLE PRECISION RECORD.
00477  261*    C
00500  262*     33   IF(LD+1) 300,33,34
00503  263*     34   CONTINUE
00504  264*          NOUT = 10*NDP
00504  265*    C
00505  266*          DO 22 I=1,11
00510  267*     22   N(I) = (I-1)*NDP
00510  268*    C
00512  269*          DO 23 I=1,NDP
00515  270*          J = N(1)
00516  271*          DR(J+I) = INV1(I)
00517  272*          J = N(2)
00520  273*          DR(J+I) = INV2(I)
00521  274*          J = N(3)
00522  275*          DR(J+I) = INV3(I)
00523  276*          J = N(4)
00524  277*          DR(J+I) = NORMF(I)
00525  278*          J = N(5)
00526  279*          DR(J+I) = EOCT(I)
00526  280*    C
00527  281*          IF(KTEMP.EQ.2) GO TO 23
00531  282*          NOUT = 22*NDP
00531  283*    C
00532  284*          J = N(6)
00533  285*          DR(J+I) = NORM10(I)
00534  286*          J = N(7)
00535  287*          DR(J+I) = NORM20(I)
00536  288*          J = N(8)
00537  289*          DR(J+I) = NORM30(I)
00540  290*          J = N(9)
00541  291*          DR(J+I) = NORM40(I)
00542  292*          J = N(10)
00543  293*          DR(J+I) = NORM50(I)
00544  294*          J = N(11)
00545  295*          DR(J+I) = NORM60(I)
00546  296*     23   CONTINUE
00546  297*    C
00550  298*              CALL NTRAN(NU,1,NOUT,DR,LD)
00550  299*    C
00550  300*    C
00551  301*          GO TO 2
00552  302*    300   CONTINUE
00552  303*    C
00552  304*    C           TAPE WRITE ERROR
```

```
00552   305*  C
00553   306*        WRITE(6,301) L0, LD
00557   307*        CALL EXIT
00557   308*  C
00557   309*  C              * * *  F O R M A T  S T A T E M E N T S  * * *
00557   310*  C
00560   311*     1  FORMAT( 5E10.3, I5)
00561   312*     3  FORMAT(A6, E14.4,2I5,5A4, 2E15.6)
0056    313*    24  FORMAT(1H1, T40, 'N L 0 0 1   MASTER TAPE GENERATION SUMMARY',
00562   314*        1      T120,'PAGE',I4.////,T13,'TEST',T20,'NDP',T35,'PRESSURE',T50,
00562   315*        2      'KTEMP',T60,'KODE',T70,'MATERIAL I.D.',T104,'BULK',
00562   316*        3      T11A,'BETA', //)
00563   317*   301  FORMAT(1H1,20(/), T20,'TAPE WRITE ERROR ... LC = ',I5,///,T41,
00563   318*        1      'LD = ', I5 )
00563   319*  C
00564   320*        END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

SINGLE WORD HOLLERITH STRINGS------

```
END    :  0107
```

NAMES------

```
AAS    :  0351
A1     :  0104  0346  0350  0353  0354  0355  0356  0357  0360  0363  0364  0365  0366  0367  0370
A2     :  0104  0347  0350  0353  0354  0355  0356  0357  0360
B      :  0103  0106  0416  0427  0430  0442  0444  0446  0450  0452  0454  0456  0460  0462  0468  0468  0470
          0472  0474  0477
BETA   :  0164  0225  0265  0303  0430
BULK   :  0164  0225  0256  0263  0274  0300  0427
CHRT   :  0256
C1     :  0114  0265
C2     :  0116  0303
DABS   :  0336  0346  0347
DR     :  0103  0105  0516  0520  0522  0524  0526  0533  0535  0537  0541  0543  0545  0550
DTC    :  0101  0130  0207  0262  0265  0266  0300  0303  0304  0316  0452
DMAX1  :  0336
DR1    :  0101  0131  0333  0470
DR12   :  0101  0133  0335  0474
DR2    :  0101  0132  0334  0472
DSQRT  :  0326
DT     :  0101  0134  0207  0222  0263  0301  0332  0333  0334  0335  0353  0354  0355  0356  0357  0360  0363
          0364  0365  0366  0367  0370  0446
FOCT   :  0101  0104  0141  0317  0320  0336  0346  0347  0526
FPS    :  0350  0351
EXIT   :  0204  0557
E11    :  0101  0135  0264  0265  0302  0303  0313  0314  0315  0316  0317  0332  0456
E12    :  0101  0140  0335  0464
E22    :  0101  0136  0266  0267  0304  0313  0314  0315  0317  0334  0460
E33    :  0101  0137  0267  0313  0314  0315  0317  0462
I      :  0125  0130  0131  0132  0133  0134  0135  0136  0137  0140  0141  0142  0143  0144  0145  0146  0147
          0150  0151  0152  0153  0154  0155  0156  0157  0160  0164  0225  0257  0262  0263  0264  0265  0266
          0267  0275  0300  0301  0302  0303  0304  0310  0313  0314  0315  0316  0317  0320  0327  0332  0333
          0334  0335  0336  0343  0346  0347  0353  0354  0355  0356  0357  0360  0363  0364  0365  0366  0367
          0370  0373  0376  0377  0400  0401  0402  0403  0431  0434  0436  0442  0444  0446  0450  0452  0454
          0456  0460  0462  0464  0466  0470  0472  0474  0505  0510  0512  0516  0520  0522  0524  0526  0533
          0535  0537  0541  0543  0545
IB     :  0103  0106  0414  0415  0417  0420  0425
INV1   :  0101  0104  0142  0313  0516
```

```
IW2    :  0101  0104  0143  0314  0526
IW3    :  0101  0104  0144  0315  0522
IPG    :  0117  0121  0246  0247
J      :  0163  0206  0207  0221  0424  0425  0441  0442  0443  0444  0445  0446  0447  0450  0451  0452  0453
          0454  0455  0456  0457  0460  0461  0462  0463  0464  0465  0466  0467  0470  0471  0472  0473  0474
          0515  0516  0517  0520  0521  0522  0523  0524  0525  0526  0532  0533  0534  0535  0536  0537  0540
          0541  0542  0543  0544  0545
K      :  0421  0424  0425
KODE   :  0164  0200  0225  0254  0420
KTEMP  :  0164  0225  0341  0417  0527
LAST   :  0207  0217
LD     :  0113  0500  0550  0563
LIMF   :  0120  0243  0244  0262
LQ     :  0112  0202  0407  0477  0553
MATID  :  0101  0164  0225  0425
N      :  0103  0434  0441  0443  0445  0447  0451  0453  0455  0457  0461  0463  0465  0467  0471  0473  0510
          0515  0517  0521  0523  0525  0533  0534  0536  0540  0542  0544
NAME   :  0164  0225  0414
NAP    :  0221  0225  0257  0275  0310  0327  0343  0373  0413  0415  0434  0436  0504  0510  0512  0531
NEND   :  0107  0202
NORMF  :  0101  0104  0145  0336  0524
NORM10 :  0101  0104  0146  0363  0363  0376  0543
NORM20 :  0101  0104  0147  0364  0364  0377  0535
NORM30 :  0101  0104  0150  0365  0365  0400  0537
NORM40 :  0101  0104  0151  0366  0366  0401  0541
NORM50 :  0101  0104  0152  0367  0367  0402  0543
NORM60 :  0101  0104  0153  0370  0370  0403  0545
NOST   :  0413  0477  0504  0531  0550
NTRAN  :  0114  0202  0203  0407  0550
NU     :  0111  0124  0202  0203  0477  0550
PRES   :  0164  0225  0256  0262  0274  0300  0416
RATF   :  0131  0154  0207  0263  0301  0444
SP     :  0256  0263  0264  0266  0274  0301  0302  0304
START  :  0224  0316
STRESS :  0101  0155  0207  0316  0450
STRUE  :  0101  0156  0316  0466
T      :  0101  0157  0326  0332  0454
TEMP   :  0101  0160  0207  0223  0224  0265  0303  0442

LABELS-----
     1:  0207  0560
     2:  0124  0551
     3:  0164  0561
     4:  0200  0205  0217
     5:  0254  0255
     6:  0254  0273
     7:  0254  0324
     8:  0257  0270
     9:  0275  0305
    10:  0272  0307
    11:  0310  0321
    13:  0323  0325
    14:  0327  0337
    15:  0343  0361  0371
    16:  0351  0362
    17:  0341  0406
    19:  0421  0425
    20:  0431  0434
    21:  0436  0475
    22:  0505  0510
```

```
    23:  0512  0527  0546
    24:  0121  0247  0562
    27:  0373  0404
    30:  0225  0242
    31:  0407
    32:  0407  0412
    33:  0500
    34:  0500  0503
    41:  0244  0253
   100:  0125  0161
   300:  0407  0500  0552
   301:  0553  0563

INTEGER CONSTANTS------
     0:  0120  0200  0217  0252
     1:  0106  0111  0117  0125  0164  0202  0206  0224  0225  0243  0246  0265  0302  0326  0332  0333
         0334  0335  0336  0347  0353  0354  0355  0356  0357  0360  0363  0364  0365  0366  0367  0370
         0373  0407  0414  0421  0431  0434  0436  0441  0477  0500  0505  0510  0512  0515  0550
     2:  0163  0222  0223  0224  0257  0264  0275  0302  0304  0310  0317  0327  0341  0343  0415  0443
         0517  0527
     3:  0223  0416  0445  0521
     4:  0417  0447  0523
     5:  0161  0164  0207  0225  0420  0421  0424  0451  0525
     6:  0121  0225  0247  0453  0532  0553
     7:  0455  0554
     8:  0457  0536
     9:  0203  0461  0540
    10:  0112  0113  0114  0202  0363  0463  0504  0542
    11:  0353  0427  0465  0505  0544
    12:  0413  0430  0434  0467
    13:  0471
    14:  0103  0413  0431  0473
    20:  0364
    21:  0354
    22:  0531
    30:  0365
    31:  0355
    40:  0366
    41:  0356
    50:  0244  0367
    51:  0357
    60:  0370
    61:  0360
   100:  0101  0125
  1400:  0103
  2200:  0103

REAL CONSTANTS------
0.00000000+00:  0130  0131  0132  0133  0134  0135  0136  0137  0140  0154  0155  0156  0157  0160
0.10000000-05:  0115  0116  0351
0.10000000+01:  0256  0264  0266  0274  0302  0304  0316  0376  0377  0400  0401  0402  0403
0.20000000+01:  0264  0266  0302  0304  0316
0.10000000+02:  0376
0.20000000+02:  0222  0326  0377
0.30000000+02:  0400
0.40000000+02:  0401
0.50000000+02:  0402
0.59999999+02:  0403
0.10000000+03:  0262  0300
```

APPENDIX C

POST PROCESSOR CODE

1.0 INTRODUCTION

POST is a postprocessor for the NL001 code. It takes the output of NL001 off the NL001 output tape, and prints selected output in a report format. There is a minimum of two pages of output for each test reported. The first two columns of each page are the data point numbers and time in seconds. Page 1 then contains the three strain invariants, the dilatation $\Delta V/V_0$, corrected for any temperature and pressure effects, and the octahedral strain. Page 2 displays the temperature, calculated strains, and the true stress. In addition to the above, each page has a heading giving material type, bulk modulus and volumetric expansion coefficient, the test type, initial strain rate, pressure, and whether it is a constant or variable temperature test.

The only card input to POST is the last card, a blank, signifying the end of the data. All other input is read directly from the NL001 output data tape.

2.0 PROGRAM INSTRUCTIONS

The purpose of this section is to list the basic variables of the POST code and provide a set of instructions for running the program.

2.1 BASIC VARIABLES

Following is a list of the basic program variables of POST. The names and meaning of variables is compatible with the NL001 code.

BETA	Volumetric expansion coefficient
BULK	Bulk modulus
DUM	Dummy variable
EDØTO	Initial strain rate
ITEMP	Alphanumeric constant/variable temperature header
ITYPE	Alphanumeric uniaxial/biaxial/shear test type header
KØDE	Test type control variable
KTEMP	Temperature control variable
LAST	Last data point delimiter
MATID	Material identification
NAME	Test element identification
NDP	Number of data points in a specific test
PRES	Test pressure, psig
X	An array used to store the various output quantities

2.2 INPUT INSTRUCTIONS

There is no card input for PØST. All input is read from the NL001 data output tape, element by element. The user merely inserts an "ADD" card for each element of the tape he wishes processed by POST. After the last "ADD" card, the user inserts a blank card to terminate execution.

2.3 SAMPLE INPUT SHEET AND OUTPUT

Shown below is a typical input sheet for POST showing the UNIVAC 1108 "ADD" cards and the last (blank) card. In the example shown, two tests are processed U00100 and U10105. Following the sample input sheet is the actual output generated by POST.

2.4 The listing of POST appears below. Note that it is machine independent, except that it expects the input to be in a specific format. This format is exactly that used by the NL001 code.

JOB NUMBER | REPORT TITLE: Sample input - Post | DATE

```
// XQT PØST
// ADD U00100
// ADD U10105
(BLANK CARD)
```

0140-10 (REV 7/68)

PLEASE PRINT CLEARLY - USE BLACK PENCIL

```
@ ELT POST,1,730521, 48361
```

```
000001          C         POST-PROCESSOR FOR NL001.
000002          C
000003          C
000004                DIMENSION MATID(5), X(7,100)
000005                DOUBLE PRECISION ITEMP(2), ITYPE(3)
000006                DATA ITEMP(1)/'CONSTANT'/,ITEMP(2)/'VARIABLE'/,ITYPE(1)/'UNIAXIAL'
000007               1/,ITYPE(2)/'BIAXIAL'/,ITYPE(3)/'SHEAR'/
000008          C
000009          C              NEXT TEST
000010          C
000011           50   CONTINUE
000012                IPG = 0
000013                READ(5,8) NAME, PRES, KTEMP, KODE, (MATID(I),I=1,5),BULK,BETA
000014          C               ALL DONE ?
000015                IF(KODE.EQ.0) CALL EXIT
000016                NDP = 0
000017                IPG = IPG + 1
000018           51   CONTINUE
000019                NDP = NDP + 1
000020                READ(5,9)  X(2,NDP), X(3,NDP), LAST
000021                IF(LAST.EQ.0) GO TO 51
000022                EDOTO = X(3,3)
000023                WRITE(6,1) NAME, NAME, IPG
000024                WRITE(6,2) (MATID(I),I=1,5), ITYPE(KODE)
000025                WRITE(6,3) BULK, EDOTO, BETA, PRES, ITEMP(KTEMP)
000026                WRITE(6,4)
000027                I = 1
000028           52   CONTINUE
000029                READ(5,10)  X(1,I), X(3,I), X(4,I), X(5,I), X(6,I), X(7,I), LAST
000030                I = I+1
000031                IF(LAST.EQ.0) GO TO 52
000032                DO 100 I=2,NDP                                          **-4
000033          C                                                             *NEW
000034          C         CONVERT TIME FROM MINUTES TO SECONDS FOR PRINTOUT    *NEW
000035          C                                                             *NEW
000036                X(1,I) = X(1,I)*60.                                     *NEW
000037                K = I-1
000038                WRITE(6,5) K, (X(J,I),J=1,7)
000039           100  CONTINUE
000040          C
000041          C
000042           53   CONTINUE
000043                READ(5,11) LAST
000044                IF(LAST.EQ.0) GO TO 53
000045          C
000046                IPG = IPG + 1
000047                WRITE(6,1) NAME, NAME, IPG
000048                WRITE(6,2) (MATID(I),I=1,5), ITYPE(KODE)
000049                WRITE(6,3) BULK, EDOTO, BETA, PRES, ITEMP(KTEMP)
000050                WRITE(6,6)
000051          C
000052                I = 0
000053           54   CONTINUE
000054                I = I+1
000055                READ(5,12) X(2,I), X(3,I), X(4,I), DUM, X(5,I), X(6,I), LAST
000056                IF(LAST.EQ.0) GO TO 54
```

```
000057          C
000058          C
000059                DO 200 I=2,NDP
000060                K = I-1
000061                WRITE(6,7) K, (X(J,I),J=1,6)
000062           200  CONTINUE
000063          C
000064          C
000065           55   CONTINUE
000066                READ(5,13)  LAST
000067                IF(LAST.EQ.0) GO TO 55
000068          C
000069          C          GO ON TO NEXT TEST
000070          C
000071                GO TO 50
000072          C
000073          C
000074          C
000075           1    FORMAT(1H1,T40,'S U M M A R Y   O F   T E S T   N O . ', A6,
000076                1       T113,'PAGE  ', A6,' - ', I2, ///, T10,'M A T E R I A L   ',
000077                2       'D A T A', T95, 'T E S T   D A T A', / )
000078           2    FORMAT(1H , T10,'MATERIAL IS ',5A4, T95,'TYPE ... ', A8 )
000079           3    FORMAT(1H , T10,'BULK MODULUS = ', F10.4, T95,'INITIAL STRAIN ',
000080                1       'RATE = ', E10.4, /, T10,'VOLUMETRIC EXPANSION COEFFICIENT'
000081                2       ,' = ', F10.4, T95,'PRESSURE = ', F10.0, ' PSIG',/,T95,
000082                3       'TEMPERATURE IS ', A8 )
000083           4    FORMAT(1H , ///,T10,'DATA', T23,'TIME', T37,'TEMP.', T72,'STRAINS'
000084                1       ,' (CALCULATED)', T117,'TRUE STRESS',/,  T10,'POINT', T23,
000085                2       'SEC.', T37,'DEG.-F', T56,'E11',T71,'E22', T86,'E33', T101,
000086                3       'E12', T117,'(S11 - S22)', // )
000087           5    FORMAT(1H , T10,I4, T20,F10.3, T33,F8.0, T47,4E15.4, T112,E15.4 )
000088           6    FORMAT(1H , ///, T10,'DATA', T23,'TIME', T52,'STRAIN INVARIANTS',
000089                1       T92,'CORRECTED', T112,'OCTAHEDRAL',/, T10,'POINT', T23,
000090                2       'SEC.', T47,'I1', T62,'I2', T77,'I3', T92,'DILATATION',
000091                3       T114,'STRAIN', //)
000092           7    FORMAT(1H , T10,I4, T20,E10.3, T37,3E15.4, T92,E10.4, T112,E10.4 )
000093           8    FORMAT(A6, F14.4, 2I5, 5A4 , 2E15.6)
000094           9    FORMAT(2F10.3,30X,I5)
000095           10   FORMAT(6F12.4, I8)
000096           11   FORMAT(60X,I10)
000097           12   FORMAT(6E12.5, I8)
000098           13   FORMAT(72X, I8)
000099                END

3. IN A                                                                    00:00:03.106

      END OF FILE -- UNIT A

      END CUR,    ISD VERSION 2.12
```

SUMMARY OF TEST NO. U00100 PAGE U00100 - 1

MATERIAL DATA

MATERIAL IS AND 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .5000+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	150.	.0000	.0000	.0000	.0000	.0000
2	.540+01	150.	.4601-01	-.2153-01	-.2153-01	.0000	.1515+02
3	.840+01	150.	.7245-01	-.3224-01	-.3224-01	.0000	.2321+02
4	.114+02	150.	.9951-01	-.4178-01	-.4178-01	.0000	.2951+02
5	.144+02	150.	.1272+00	-.5000-01	-.5000-01	.0000	.3324+02
6	.174+02	150.	.1555+00	-.5677-01	-.5677-01	.0000	.3500+02
7	.204+02	150.	.1845+00	-.6261-01	-.6261-01	.0000	.3574+02
8	.234+02	150.	.2140+00	-.6799-01	-.6799-01	.0000	.3567+02
9	.264+02	150.	.2442+00	-.7295-01	-.7295-01	.0000	.3538+02
10	.294+02	150.	.2750+00	-.7771-01	-.7771-01	.0000	.3496+02

SUMMARY OF TEST NO. U00100 PAGE U00100 - 2

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .5000+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.540+01	.2950-02	-.1518-02	.2133-04	.4601-07	.3184-01
3	.840+01	.7964-02	-.3632-02	.7532-04	.1000-02	.4835-01
4	.114+02	.1595-01	-.6570-02	.1737-03	.3500-02	.6661-01
5	.144+02	.2720-01	-.1022-01	.3180-03	.8000-02	.8353-01
6	.174+02	.4198-01	-.1443-01	.5012-03	.1500-01	.1001+00
7	.204+02	.5924-01	-.1918-01	.7230-03	.2350-01	.1165+00
8	.234+02	.7803-01	-.2448-01	.9893-03	.3250-01	.1329+00
9	.264+02	.9830-01	-.3031-01	.1300-02	.4200-01	.1495+00
10	.294+02	.1196+00	-.3670-01	.1661-02	.5150-01	.1663+00

6 AND U10105

SUMMARY OF TEST P.O. 010105 PAGE 010105 - 1

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .5000+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	150.	-.6668-04	-.6666-04	-.6666-04	.0000	.0000
2	.390+01	150.	.3296-01	-.1580-01	-.1580-01	.0000	.1053+02
3	.690+01	150.	.5808-01	-.2722-01	-.2722-01	.0000	.1804+02
4	.990+01	150.	.8583-01	-.3805-01	-.3805-01	.0000	.2749+02
5	.129+02	150.	.1132+00	-.4832-01	-.4832-01	.0000	.3598+02
6	.159+02	150.	.1412+00	-.5808-01	-.5808-01	.0000	.4392+02
7	.189+02	150.	.1698+00	-.6732-01	-.6732-01	.0000	.5066+02
8	.219+02	150.	.1991+00	-.7609-01	-.7609-01	.0000	.5685+02
9	.249+02	150.	.2289+00	-.8444-01	-.8444-01	.0000	.6111+02
10	.279+02	150.	.2594+00	-.9241-01	-.9241-01	.0000	.6483+02
11	.309+02	150.	.2906+00	-.1001+00	-.1001+00	.0000	.6645+02
12	.321+02	150.	.3032+00	-.1030+00	-.1030+00	.0000	.6671+02

SUMMARY OF TEST NO. U10105 PAGE U10105 - 2

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .5000+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	.1333-07	-.2963-12	-.2000-03	.1054-07
2	.390+01	.1351-02	-.7920-03	.8232-05	-.2000-03	.2299-01
3	.690+01	.4636-02	-.2476-02	.4379-04	-.1399-03	.4068-01
4	.990+01	.9740-02	-.5083-02	.1242-03	.7009-04	.5840-01
5	.129+02	.1655-01	-.8606-02	.2644-03	.4001-03	.7615-01
6	.159+02	.2505-01	-.1303-01	.4762-03	.9001-03	.9384-01
7	.189+02	.3519-01	-.1833-01	.7696-03	.1600-02	.1118+00
8	.219+02	.4690-01	-.2450-01	.1152-02	.2500-02	.1297+00
9	.249+02	.6007-01	-.3153-01	.1632-02	.3530-02	.1477+00
10	.279+02	.7463-01	-.3941-01	.2215-02	.4660-02	.1656+00
11	.309+02	.9047-01	-.4813-01	.2909-02	.5820-02	.1841+00
12	.321+02	.9714-01	-.5186-01	.3218-02	.6270-02	.1915+00

DATA CARDS IGNORED - FIRST IS LISTED BELOW

APPENDIX D

CHARACTERIZATION CODE NL002

1.0 INTRODUCTION

The computer code NL002 is a nonlinear thermoviscoelastic characterization code that accepts pressurized uniaxial, biaxial and shear data from code NL001. Dozens of experiments of this type having arbitrary deformation-temperature time histories can be simultaneously fit to constitutive equations using NL002 which performs both a distortional and bulk characterization as described in the text of this report.

2.0 PROGRAM INSTRUCTIONS

The purpose of this section is to present the basic program variables, their definitions and use in the NL002 code, a sample problem and a listing of the program following the sample problem input sheet.

2.1 BASIC VARIABLES

A	Coefficient in $_e$ A*DIL/EOCT which is a modulus multiplier
AT	Shift function - input
AVGAT	Interpolated value of shift function at a specific arbitrary point
B	Coefficient of t in power law term $(1 + Bt)^P$ - input
BB	Solution vector in regression analysis
BCAL	Calculated value of dilatational stress
BETA	Thermal volumetric expansion coefficient - input
BO	Regression coefficients for bulk term - calculated
BULK	Bulk modulus - input
CO	Regression coefficients for shear term - calculated
D	Slope of shift function vs temperature curve - calculated
DEV	Local percent error

DEV1	Final local error on σ_{11}
DEV2	Final local error on σ_{22}
DI	Working variable
DIL	Corrected dilatation $\Delta V/V_o$ - input
DR1	Calculated strain rate $\dot{E}_{11}$ - input
DR2	Calculated strain rate $\dot{E}_{22}$ - input
DR12	Calculated strain rate $\dot{E}_{12}$ - input
DT	Time step - input
DTR	Reduced time step - calculated
EØCT	Octahedral strain - input
E11, E22, E33	Principal strains - input
E12	Shear strain - input
F	A coefficient defined as $F = e^{[A*DIL/E_{OCT}]}$
G	A coefficient defined as $G = (1 - \frac{E_{OCT}}{NORMF})$
IFF	F coefficient flag; set IFF(I) = 1 to multiply Ith term in regression by the coefficient F
IFG	G coefficient flag; set IFG(I) = 1 to multiply Ith power law term by the coefficient G
IFN	Norm selector; selects up to six norm terms, 10th, 20th, 30th, 40th, 50th, or 60th depending upon whether or not IFN(I) is 1, 2, 3, 4, 5, or 6 respectively.
INT1, INT2, INT12	Hereditary integral terms - calculated
INV1, INV2, INV3	First, second, and third strain invariants respectively - input

IPG	Page counter
KØDE	Test type indicator - input
KTEMP	Constant or variable temperature test indicator - input
LAST	Input data delimiter
LINE	Output line counter
MATID	Material identification - input
NAME	Run title printed at top of each page
NAT	Number of values of shift function vs temperature
NBULKS	Number of terms in series for bulk term regression presently fixed at 14
NDP	
NORM	The Lebesque norms of E_{OCT} - input
NORMF	Infinite norm of E_{OCT} - input
NORMS	Number of norm terms in series for shear term regression - limited to a maximum of 6
NPL	Number of power law terms of the form $(HBt)^P$
NTERMS	Number of terms in series for shear term regression - limited to a maximum of 14.
NTEST	Test number in this run
NTØT	Total number of data points processed in this run, i.e., ΣNDP
N1	First data point used in regression analysis
P	Exponent in power law term $(HBt)^P$
PRES	Test pressure, psig
R	Primary matrix of regression analysis
RATE	Observed strain rate - input

RESID	
RESID1	Interim variable used in calculating standard deviations
RESID2	
SCAL	Calculated value of stress in shear regression
STD	Standard deviation
STRESS	Observed stress
STRN	Interim strain storage variable
STRUE	True stress
SUM	
SUM1	Interim variables used in calculating average error and standard deviation
SUM2	
S1, S2	True stress, STRUE = S1-S2
S1CAL	Calculated values of S1 and S2
S2CAL	
T	Time in minutes
TEMP	Test temperature
TITLE	Test identification - input
TR	Reduced time - calculated
TSHFT	Temperature at which shift function is input
XBAR	Average error
XF, XF1, XF2	Terms in series used for regression analysis
XN	Power to which norm term is raised
XP, XQ	Working variables
Z	Exponent of G coefficient

2.2 PROGRAM INPUT

This section lists the required input for NL002 on a card by card basis. The format for each card is shown in parentheses.

Card 1 (20A4) NAME

Card 2 (2E10.0) A, Z

Card 3 (7I5) IFG(I), I = 1,7

Card 4 (14I5) IFF(I) I = 1, 14

Card 5 (06I5) IFN(I),I = 1,6

Card 6 (6E10.0) XN(Ie) I = 1,6

Card 7 (15) NPL

Card(s) (8E10) (P(I)), I = 1 NPL)

Card(s) 9 (2E10.0, I5) TSMFT(I), AT(I), LAST. Where

LAST = 0 or blank if another TSMFT vs AT pair follows, and

LAST ≠ 0 if this is last pair.

Card(s) 10 "ADD" cards to add elements from NL001 output data tape, as many as desired

Card 11 A blank card to indicate end of data

The above cards are shown on the coding sheet below.

2.3 SAMPLE PROBLEM

Shown below is an input sheet for a simple but typical problem using 13 tests of 77° data, as indicated in the title, Card 1. Card 2 sets A = Z = 1.0. Card 3 indicates that all power law terms are multiplied by G. Card 4 indicates that all terms in the shear term series are to be multiplied by F. Card 5 says to take 6 norm terms, but to use the 10th norm for each

term. Card 6 gives the power to which each norm term indicated on Card 5 is raised. Card 7 indicates how many power law terms to keep; here 3. Card 8 shows that these 3 power law terms of the for $(1 + Bt)^{)}$ are $(1 + t)$, $(1 + 2t)^2$, and $(1 + 3t)^3$. Card 9 shows a constant shift function vs temperature curve. Cards 10 are the elements from tiie NL001 data output tape for the tests of interest. Card 11 is a blank card which indicate the ned of a run.

2.4 PROGRAM LISTING

A complete source listing follows the data input sheet for the above problem.

JOB NUMBER | REPORT TITLE | DATE | PAGE

Sample input NL002

CARD NØ.

NAME (80 COLUMN TITLE FOR THIS RUN)

A Z

IFG(1) IFG(2) IFG(3) IFG(4) IFG(5) IFG(6) IFG(7)

IFF(1) IFF(2) IFF(3) IFF(4) IFF(5) IFF(6) IFF(7) IFF(8) IFF(9) IFF(10) IFF(11) IFF(12) IFF(13) IFF(14)

IFN(1) IFN(2) IFN(3) IFN(4) IFN(5) IFN(6)

XN(1) XN(2) XN(3) XN(4) XN(5) XN(6)

NPL

P(1) B(1) P(2) B(2) P(3) B(3) P(4) B(4)

P(5) B(5) P(6) B(6) P(7) B(7)

TSHFT(1) AT(1)

TSHFT(2) AT(2)

•

•

•

TSHFT(NAT-1) AT(NAT-1)

TSHFT(NAT) AT(NAT) 11111

" ADD EL1

" ADD EL2

•

•

•

" ADD ELAST

LAST CARD = A BLANK

AGCS 0140-10 (REV 7/68)

PLEASE PRINT CLEARLY - USE BLACK PENCIL

JOB NUMBER | REPORT TITLE | DATE | PAGE OF

Sample input NL002

CARD NO.

```
1 NL002 SAMPLE PROBLEM USING 77 DEGREE DATA ( 13 TESTS TOTAL )
2 1.0                 1.0
3         1     1     1     1     1     1     1
4         1     1     1     1     1     1     1     1     1     1     1     1     1
5         1     1     1     1     1     1
6 1.                  2.          3.          4.          5.          6.
7         3
8 1.                  1.          2.          2.          3.          3.
9 0.0                 1.0
  77.                 1.0
  100.                1.0         1 1 1 1 1
10 ADD  U00300
   ADD  U00301
   ADD  U00302
   ADD  U00303
   ADD  U00304
   ADD  U00305
   ADD  U00306
   ADD  U00307
   ADD  U00308
   ADD  U00309
   ADD  U00310
   ADD  U00311
   ADD  U00312
   ADD  U00313
   ADD  U00315
11 LAST CARD = A BLANK
```

PLEASE PRINT CLEARLY - USE BLACK PENCIL

NL002 DEMONSTRATION PROBLEM

A = -.100+01
Z = .100+01

POWER LAW TERMS, (1 + B*T)** P

I	B(I)	P(I)	IFG(I)
1	1.000+10	-1.330-01	0
2	1.000+10	-2.660-01	0
3	1.000+10	-4.000-01	0
4	0.000	0.000	0
5	0.000	0.000	0
6	0.000	0.000	0
7	0.000	0.000	0

I	IFF(I)
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1

I	NORM	XN(I)
1	30	2.000+00
2	30	4.000+00
3	30	6.000+00
4	40	8.000+00
5	50	1.000+01
6	60	1.200+01

NL002 DEMONSTRATION PROBLEM

THERE WERE 10 VALUES OF SHIFT FUNCTION VS. TEMPERATURE ...

I	AT(I)	TSHFT(I)
1	1.000+10	-9.000+01
2	1.000+08	-6.500+01
3	1.500+06	-4.000+01
4	6.000+04	-2.000+01
5	3.000+03	0.000
6	2.800+01	4.000+01
7	1.000+00	7.700+01
8	2.500-01	1.000+02
9	3.000-02	1.400+01
10	1.000-02	1.600+02

NL002 DEMONSTRATION PROBLEM

TEST NO.	TEST ID	NDP	KODE	KTEMP	PRESSURE	TEMP
1	U00300	20	1	1	.00	77.0
2	U00301	12	1	1	.00	77.0
3	U00302	16	1	1	.00	77.0
4	U00303	14	1	1	.00	77.0
5	U00304	13	1	1	.00	77.0

NL002 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 1

TEMP	TIME	E11 OR E12	DV/V0	STRIE	S-CALC	ERROR	XF(I),I=1,NTERMS
77.0000	.0700	.0356	.0000	16.5600	17.5426	5.9334	.5250-01 .1084-03 .2239-06 .4625-09 .6730-12 .9674-15 .1380-17 .4034-02 .3175-03 .2535-04
77.0000	.1100	.0565	.0006	26.3671	27.4921	4.2666	.8223-01 .4022-03 .1969-05 .9637-08 .3826-10 .1203-12 .4192-15 .5947-02 .4405-03 .3309-04
77.0000	.1600	.0832	.0020	38.4096	38.9273	1.3479	.1191+00 .1182-02 .1174-04 .1167-06 .8634-09 .6311-11 .4577-13 .8195-02 .5773-03 .4123-04
77.0000	.2100	.1105	.0043	49.2876	48.9665	-.6508	.1557+00 .2556-02 .4208-04 .6926-06 .8648-08 .1067-09 .1305-11 .1033-01 .7014-03 .4829-04
77.0000	.2600	.1384	.0083	57.6174	57.1875	-.7461	.1916+00 .4603-02 .1110-03 .2676-05 .8966-07 .9113-09 .1658-10 .1235-01 .8145-03 .5444-04
77.0000	.3100	.1670	.0139	64.2351	63.3700	-1.3468	.2270+00 .7369-02 .2404-03 .7842-05 .1994-06 .5007-08 .1248-09 .1428-01 .9198-03 .6000-04
77.0000	.3600	.1962	.0210	68.3164	67.5813	-1.0760	.2620+00 .1086-01 .4532-03 .1891-04 .6211-06 .2010-07 .6487-09 .1615-01 .1019-02 .6515-04
77.0000	.4100	.2260	.0295	71.6129	70.2482	-1.9056	.2967+00 .1507-01 .7709-03 .3943-04 .1602-05 .6432-07 .2562-08 .1757-01 .1115-02 .6999-04
77.0000	.4600	.2564	.0388	73.8568	71.9841	-2.5356	.3314+00 .2002-01 .1220-02 .7432-04 .4523-05 .1745-06 .8337-08 .1977-01 .1208-02 .7471-04
77.0000	.5100	.2875	.0487	75.7367	73.4986	-2.9551	.3662+00 .2573-01 .1825-02 .1295-03 .7396-05 .4174-06 .2337-07 .2156-01 .1299-02 .7932-04
77.0000	.5600	.3192	.0595	77.0994	75.3944	-2.2114	.4010+00 .3209-01 .2596-02 .2100-03 .1377-04 .8913-06 .5725-07 .2332-01 .1389-02 .8376-04
77.0000	.6100	.3515	.0702	78.2313	77.6784	-.6815	.4362+00 .3932-01 .3587-02 .3273-03 .2431-04 .1784-05 .1298-06 .2510-01 .1479-02 .8827-04

NL002 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 1

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
77.0000	.6600	.3844	.0815	79.0363	80.1442	1.4017	* .4715+00 .4721-01 .4790-02 .4859-03 .4033-04 * .3306-05 .2689-06 .2686-01 .1568-02 .9264-04 *
77.0000	.7100	.4180	.0925	79.4674	81.8793	3.0351	* .5074+00 .5603-01 .6280-02 .7038-03 .6477-04 * .5886-05 .5311-06 .2865-01 .1657-02 .9711-04 *
77.0000	.7600	.4522	.1045	79.9675	82.2400	2.8418	* .5433+00 .6532-01 .7978-02 .9744-03 .9816-04 * .9767-05 .9643-06 .3041-01 .1744-02 .1013-03 *
77.0000	.8100	.4870	.1160	79.7986	80.5944	.9973	* .5798+00 .7563-01 .1004-01 .1332-02 .1463-03 * .1587-04 .1707-05 .3221-01 .1833-02 .1057-03 *
77.0000	.8600	.5224	.1275	79.4565	78.3800	-1.3549	* .6167+00 .8676-01 .1243-01 .1782-02 .2121-03 * .2492-04 .2906-05 .3401-01 .1922-02 .1101-03 *
77.0000	.9100	.5585	.1390	78.3915	80.4652	2.6453	* .6540+00 .9872-01 .1520-01 .2341-02 .3003-03 * .3804-04 .4781-05 .3582-01 .2011-02 .1144-03 *

NL002 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 2

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
77.0000	.0940	.0238	.0000	13.3055	11.9319	-10.3232	* .3525-01 .3221-04 .2943-07 .2690-10 .1766-13 * .1145-16 .7369-20 .2605-02 .1971-03 .1513-04
77.0000	.2940	.0762	.0020	38.6074	35.2627	-8.6635	* .1094+00 .8794-03 .7080-05 .5701-07 .3559-09 * .2195-11 .1343-13 .6940-02 .4511-03 .2971-04
77.0000	.4940	.1311	.0100	57.0141	53.0847	-6.8921	* .1811+00 .3706-02 .7609-04 .1563-05 .2578-07 * .4202-09 .6795-11 .1071-01 .6486-03 .3978-04
77.0000	.6940	.1886	.0250	66.0687	64.1062	-2.9705	* .2505+00 .8960-02 .3222-03 .1159-04 .3429-06 * .1002-07 .2906-09 .1415-01 .8178-03 .4785-04
77.0000	.8940	.2485	.0450	71.2136	69.4239	-2.5131	* .3190+00 .1668-01 .8782-03 .4625-04 .2038-05 * .8872-07 .3832-08 .1742-01 .9735-03 .5505-04
77.0000	1.0940	.3109	.0670	74.5885	72.3368	-3.0189	* .3882+00 .2701-01 .1858-02 .1334-03 .7941-05 * .4670-06 .2724-07 .2065-01 .1125-02 .6201-04
77.0000	1.2940	.3758	.0900	76.9483	75.6740	-1.6561	* .4585+00 .4008-01 .2546-02 .2138-03 .2375-04 * .1776-05 .1318-06 .2388-01 .1274-02 .6881-04
77.0000	1.4940	.4433	.1140	78.0795	78.3048	.2885	* .5300+00 .5580-01 .5960-02 .6366-03 .5865-04 * .5338-05 .4821-06 .2712-01 .1422-02 .7546-04
77.0000	1.6940	.5132	.1360	77.7305	74.8396	-3.7190	* .6037+00 .7531-01 .9557-02 .1213-02 .1336-03 * .1454-04 .1570-05 .3044-01 .1573-02 .8232-04
7.0000	1.8940	.5856	.1490	77.9423	76.9731	-1.2435	* .6814+00 .1028+00 .1582-01 .2436-02 .3270-03 * .4336-04 .5704-05 .3395-01 .1735-02 .8988-04

NL002 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 3

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
77.0000	.6000	.0304	.0000	11.8450	14.2566	20.3595	.4500-01 .5919-04 .7786-07 .1024-09 .1096-12 .1157-15 .1213-18 .2598-02 .1537-03 .9201-05
77.0000	1.4000	.0724	.0008	28.6645	30.1687	5.2475	.1047+00 .6976-03 .4656-05 .3108-07 .1785-09 .1012-11 .5696-14 .5398-02 .2851-03 .1524-04
77.0000	1.9000	.0995	.0038	38.2524	38.3858	.3487	.1409+00 .1640-02 .1914-04 .2234-06 .2201-08 .2322-10 .2335-12 .6967-02 .3528-03 .1806-04
77.0000	2.4000	.1272	.0078	45.7419	45.2928	-.9819	.1767+00 .3128-02 .5555-04 .9863-06 .1564-07 .2450-09 .3807-11 .8471-02 .4157-03 .2062-04
77.0000	2.9000	.1553	.0140	50.3721	50.6319	.5157	.2118+00 .5167-02 .1266-03 .3101-05 .6876-07 .1506-08 .3272-10 .9893-02 .4730-03 .2285-04
77.0000	3.4000	.1844	.0220	53.5848	54.4690	1.6501	.2464+00 .7763-02 .2459-03 .7790-05 .2258-06 .6465-08 .1837-09 .1126-01 .5268-03 .2490-04
77.0000	3.9000	.2140	.0310	55.9026	56.9820	1.9308	.2808+00 .1095-01 .4298-03 .1687-04 .6111-06 .2187-07 .7768-09 .1260-01 .5789-03 .2687-04
77.0000	4.4000	.2442	.0410	57.5148	58.4730	1.6660	.3152+00 .1471-01 .6915-03 .3251-04 .1522-05 .6146-07 .2835-08 .1392-01 .6284-03 .2875-04
77.0000	4.9000	.2750	.0510	58.8992	59.2272	.5569	.3499+00 .1915-01 .1057-02 .5837-04 .3017-05 .1541-06 .7806-08 .1524-01 .6798-03 .3054-04
77.0000	5.4000	.3064	.0620	59.7700	59.7413	-.0480	.3845+00 .2411-01 .1527-02 .9671-04 .5771-05 .3401-06 .1989-07 .1654-01 .7287-03 .3244-04
77.0000	5.9000	.3385	.0730	60.5083	60.1190	-.6435	.4196+00 .2977-01 .2135-02 .1532-03 .1040-04 .6981-06 .4648-07 .1785-01 .7778-03 .3425-04
77.0000	6.4000	.3712	.0840	60.9824	60.3751	-.9957	.4550+00 .3611-01 .2901-02 .2331-03 .1782-04 .1346-05 .1008-06 .1916-01 .8267-03 .3605-04

NLOG2 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 3

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR		XF(I),I=1,NTERMS			
77.0000	6.9000	.4045	.0950	61.1918	60.2098	-1.5867	*	.4908+00	.4316-01	.3848-02	.3431-03	.2922-04
							*	.2459-05	.2053-06	.2048-01	.8755-03	.3784-04
							*					
77.0000	7.4000	.4284	.1060	60.8359	59.0571	-2.9239	*	.5269+00	.5094-01	.4997-02	.4903-03	.4615-04
							*	.4290-05	.3957-06	.2180-01	.9243-03	.3961-04
							*					

NL002 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 4

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
77.0000	3.0000	.0382	.0000	13.5912	15.3218	12.7330	* .5625-01 .1038-03 .1915-06 .3533-09 .5901-12 * .9734-15 .1593-17 .2622-02 .1252-03 .6042-05
77.0000	5.0000	.0645	.0010	22.9385	23.6464	3.0861	* .9330-01 .4543-03 .2215-05 .1080-07 .4930-10 * .2224-12 .9953-15 .4061-02 .1810-03 .8153-05
77.0000	7.0000	.0913	.0030	31.4903	30.9014	-1.8700	* .1299+00 .1186-02 .1085-04 .9924-07 .8698-09 * .7531-11 .6470-13 .5406-02 .2303-03 .9912-05
77.0000	9.0000	.1188	.0070	38.0259	36.9218	-2.9035	* .1658+00 .2375-02 .3411-04 .4900-06 .6868-03 * .9500-10 .1305-11 .6665-02 .2743-03 .1140-04
77.0000	11.0000	.1470	.0130	41.9296	41.6498	-.6672	* .2009+00 .4056-02 .8218-04 .1665-05 .3338-07 * .6610-09 .1209-10 .7859-02 .3147-03 .1272-04
77.0000	13.0000	.1757	.0215	44.3978	45.0839	1.5455	* .2352+00 .6193-02 .1638-03 .4335-05 .1148-06 * .3005-08 .7800-10 .8990-02 .3517-03 .1388-04
77.0000	15.0000	.2051	.0310	45.7279	47.3950	3.6458	* .2694+00 .8839-02 .2918-03 .9631-05 .3212-06 * .1058-07 .3459-09 .1010-01 .3877-03 .1501-04
77.0000	17.0000	.2351	.0410	46.7034	48.7149	4.3069	* .3037+00 .1203-01 .4797-03 .1913-04 .7769-06 * .3116-07 .1240-08 .1120-01 .4231-03 .1612-04
77.0000	19.0000	.2657	.0520	47.4165	49.3208	4.0161	* .3379+00 .1569-01 .7343-03 .3437-04 .1649-05 * .7820-07 .3679-08 .1229-01 .4574-03 .1718-04
77.0000	21.0000	.2970	.0630	47.6337	49.3848	3.6761	* .3725+00 .1994-01 .1077-02 .5820-04 .3243-05 * .1785-06 .9748-08 .1337-01 .4917-03 .1824-04
77.0000	23.0000	.3288	.0730	47.7286	48.9623	2.5848	* .4079+00 .2498-01 .1546-02 .9572-04 .6140-05 * .3890-06 .2445-07 .1448-01 .5268-03 .1934-04
77.0000	25.5000	.3696	.0860	47.0750	48.1110	2.2008	* .4523+00 .3211-01 .2307-02 .1657-03 .1241-04 * .9185-06 .6743-07 .1586-01 .5696-03 .2065-04

NL002 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 5

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS				
77.0000	5.0000	.0253	.0000	9.2250	9.6941	5.0855	.3750-01	.2975-04	.2360-07	.1873-10	.1391-13
							.1021-16	.7436-20	.1633-02	.7285-04	.3283-05
77.0000	10.0000	.0512	.0000	18.6900	17.6624	-5.4981	.7501-01	.2266-03	.6853-06	.2072-08	.6184-11
							.1799-13	.5229-16	.2979-02	.1212-03	.4978-05
77.0000	14.0000	.0724	.0000	26.2150	23.3534	-10.9159	.1050+00	.6062-03	.3503-05	.2024-07	.1173-09
							.6716-12	.3815-14	.3989-02	.1552-03	.6094-05
77.0000	17.5000	.0913	.0015	31.8399	27.6803	-13.0640	.1306+00	.1138-02	.6937-05	.4675-07	.2719-09
							.6785-11	.5917-13	.4811-02	.1614-03	.6902-05
77.0000	22.5000	.1188	.0060	36.9356	32.8545	-11.0492	.1662+00	.2258-02	.1076-04	.4191-06	.5923-08
							.8269-10	.1145-11	.5913-02	.2153-03	.7906-05
77.0000	27.5000	.1470	.0130	39.5562	36.8625	-6.8098	.2009+00	.3812-02	.7261-04	.1383-05	.2772-07
							.5489-09	.1078-10	.6951-02	.2461-03	.8786-05
77.0000	32.5000	.1757	.0215	41.1772	39.7819	-3.3884	.2352+00	.5826-02	.1450-03	.3609-05	.9560-07
							.2501-08	.6494-10	.7956-02	.2754-03	.9611-05
77.0000	37.5000	.2051	.0310	41.9854	41.6741	-.7416	.2694+00	.8315-02	.2582-03	.8018-05	.2674-06
							.8810-08	.2880-09	.8940-02	.3037-03	.1040-04
77.0000	42.5000	.2351	.0415	42.1775	42.6811	1.1942	.3035+00	.1126-01	.4210-03	.1574-04	.6368-06
							.2546-07	.1010-08	.9907-02	.3711-03	.1115-04
77.0000	47.5000	.2657	.0520	41.9872	42.9317	2.2496	.3379+00	.1476-01	.6503-03	.2864-04	.1375-05
							.6518-07	.3066-08	.1088-01	.3585-03	.1191-04
77.0000	52.5000	.2970	.0620	41.4081	42.5430	2.7406	.3729+00	.1891-01	.9677-03	.4953-04	.2772-05
							.1539-06	.8456-08	.1186-01	.3861-03	.1268-04

NL002 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	1.03097+00
2	-1.16290+03
3	-6.41740+03
4	-5.56108+05
5	1.65255+07
6	-1.53141+08
7	4.71936+08
8	5.15139+03
9	5.31490+04
10	-7.90460+05

THERE WERE 75 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0022

THE STANDARD DEVIATION, STD, WAS .0472

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 1

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,	XF(K),K=1,NBULKS				
77.0000	.0700	.0248	.0000	5.1563	4.6866	-9.1084	* .3561-07	.1268-14	.4517-22	.1608-29	.2476-01
							* .6130-03	.1518-04	.3757-06	.8817-08	.2183-10
							* .7774-18	.3140-16	.1118-23	.2769-25	
77.0000	.1100	.0388	.0006	8.0628	7.2825	-9.6776	* .6001-03	.3601-06	.2161-09	.1296-12	.3879-01
							* .1505-02	.5838-04	.2265-05	.2328-04	.9031-06
							* .5419-09	.1307-07	.8382-11	.3252-12	
77.0000	.1600	.0562	.0020	11.5299	10.0365	-12.9520	* .2000-02	.4000-05	.8001-08	.1600-10	.5624-01
							* .3163-02	.1779-03	.1001-04	.1125-03	.6327-05
							* .1265-07	.2250-06	.4500-09	.2531-10	
77.0000	.2100	.0736	.0043	14.4502	12.2429	-15.2752	* .4300-02	.1849-04	.7951-07	.3419-09	.7358-01
							* .5413-02	.3983-03	.2931-04	.3164-03	.9328-04
							* .1001-06	.1360-05	.5850-08	.4304-09	
77.0000	.2600	.0907	.0083	16.0009	13.8574	-14.4653	* .8300-02	.6889-04	.5718-06	.4746-08	.9065-01
							* .8218-02	.7449-03	.6753-04	.7524-03	.6821-04
							* .5661-06	.6245-05	.5184-07	.4659-08	
77.0000	.3100	.1075	.0139	17.3349	15.3262	-11.5877	* .1390-01	.1932-03	.2686-05	.3733-07	.1075+00
							* .1156-01	.1243-02	.1337-03	.1405-02	.1607-03
							* .2234-05	.2078-04	.2888-06	.3105-07	
77.0000	.3600	.1242	.0210	17.5209	16.6491	-4.9758	* .2100-01	.4410-03	.9261-05	.1945-06	.1242+00
							* .1544-01	.1618-02	.2383-03	.2608-02	.3242-03
							* .6808-05	.5480-04	.1151-05	.1430-06	
77.0000	.4100	.1409	.0295	17.6136	17.4560	-.8947	* .2950-01	.8703-03	.2567-04	.7574-06	.1409+00
							* .1984-01	.2796-02	.3938-03	.4156-02	.5858-03
							* .1727-04	.1226-03	.3617-05	.5095-06	
77.0000	.4600	.1575	.0388	17.4166	17.8126	2.2735	* .3880-01	.1505-02	.5841-04	.2266-05	.1575+00
							* .2482-01	.3909-02	.6158-03	.6112-02	.9625-03
							* .3736-04	.2372-03	.9202-05	.1450-05	
77.0000	.5100	.1743	.0487	17.1190	17.7002	3.3953	* .4870-01	.2372-02	.1155-03	.5625-05	.1743+00
							* .3037-01	.5293-02	.9225-03	.8487-02	.1479-02
							* .7204-04	.4133-03	.2013-04	.3508-05	
77.0000	.5600	.1911	.0595	16.4532	16.7147	1.5891	* .5950-01	.3540-02	.2106-03	.1253-04	.1911+00
							* .3651-01	.6976-02	.1333-02	.1137-01	.2172-02
							* .1293-03	.6765-03	.4025-04	.7691-05	
77.0000	.6100	.2081	.0702	15.5927	15.9823	2.4983	* .7020-01	.4928-02	.3460-03	.2429-04	.2081+00
							* .4331-01	.9014-02	.1876-02	.1461-01	.3040-02
							* .2134-03	.1026-02	.7200-04	.1498-04	

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 1

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,		XF(K),K=1,NBULKS			
77.0000	.6600	.2253	.0815	14.5323	14.8296	2.0457	*	.8150-01	.6642-02	.5414-03	.4412-04	.2253+00
							*	.5075-01	.1143-01	.2575-02	.1836-01	.4136-02
							*	.3371-03	.1496-02	.1220-03	.2747-04	
77.0000	.7100	.2427	.0925	13.5385	14.1404	4.4458	*	.9250-01	.8556-02	.7915-03	.7321-04	.2427+00
							*	.5891-01	.1430-01	.3470-02	.2245-01	.5449-02
							*	.5041-03	.2077-02	.1921-03	.4663-04	
77.0000	.7600	.2602	.1045	12.9984	12.8950	-.7951	*	.1045+00	.1002-01	.1141-02	.1197-03	.2602+00
							*	.6772-01	.1762-01	.4586-02	.2719-01	.7076-02
							*	.7395-03	.2842-02	.2970-03	.7728-04	
77.0000	.8100	.2781	.1160	12.8394	12.2328	-4.7249	*	.1160+00	.1346-01	.1561-02	.1811-03	.2781+00
							*	.7732-01	.2150-01	.5978-02	.3226-01	.8969-02
							*	.1040-02	.3742-02	.8340-03	.1207-03	
77.0000	.8600	.2961	.1275	12.8487	11.7981	-8.1770	*	.1275+00	.1626-01	.2073-02	.2643-03	.2961+00
							*	.8770-01	.2597-01	.7692-02	.3776-01	.1118-01
							*	.1426-02	.4814-02	.6138-03	.1818-03	
77.0000	.9100	.3145	.1390	11.1067	11.7722	5.9920	*	.1390+00	.1932-01	.2686-02	.3733-03	.3145+00
							*	.9889-01	.3110-01	.9780-02	.4371-01	.1375-01
							*	.1911-02	.6076-02	.8446-03	.2656-03	

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 2

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,		XF(K),K=1,NBULKS			
77.0000	.0940	.0166	.0000	4.5721	3.0185	-33.9799	*	.2378-07	.5653-15	.1344-22	.3196-30	.1662-01
							*	.2762-03	.4591-05	.7630-07	.3952-09	.6568-11
							*	.1562-18	.9395-17	.2234-24	.3713-26	
77.0000	.2940	.0516	.0020	12.3845	9.0846	-26.6457	*	.2000-02	.4000-05	.8001-08	.1600-10	.5162-01
							*	.2665-02	.1376-03	.7100-05	.1032-07	.5330-05
							*	.1066-07	.2065-06	.4130-09	.2132-10	
77.0000	.4940	.0856	.0100	16.6468	11.7052	-29.6848	*	.1000-01	.1000-03	.1000-05	.1000-07	.8562-01
							*	.7332-02	.6278-03	.5375-04	.8563-05	.7332-04
							*	.7332-06	.8563-05	.8563-07	.7332-08	
77.0000	.6940	.1187	.0250	16.8756	11.8986	-29.4927	*	.2500-01	.6250-03	.1563-04	.3906-06	.1187+00
							*	.1409-01	.1673-02	.1986-03	.2968-02	.3523-03
							*	.8808-05	.7420-04	.1855-05	.2202-06	
77.0000	.8940	.1515	.0450	16.2704	10.2693	-36.8838	*	.4500-01	.2025-02	.9113-04	.4101-05	.1515+00
							*	.2296-01	.3479-02	.5271-03	.6818-02	.1033-02
							*	.4649-04	.3068-03	.1381-04	.2092-05	
77.0000	1.0940	.1848	.0670	15.5433	9.3508	-39.8403	*	.6700-01	.4489-02	.3008-03	.2015-04	.1848+00
							*	.3414-01	.6309-02	.1166-02	.1238-01	.2288-02
							*	.1533-03	.6295-03	.5558-04	.1027-04	
77.0000	1.2940	.2188	.0900	14.3234	10.4063	-27.3475	*	.9000-01	.8100-02	.7290-03	.6561-04	.2188+00
							*	.4785-01	.1047-01	.2290-02	.1969-01	.4307-02
							*	.3876-03	.1772-02	.1585-03	.3488-04	
77.0000	1.4940	.2535	.1140	12.7935	12.8349	.3237	*	.1140+00	.1300-01	.1482-02	.1689-03	.2535+00
							*	.6425-01	.1629-01	.4128-02	.2890-01	.7325-02
							*	.8350-03	.3294-02	.3755-03	.9520-04	
77.0000	1.6940	.2895	.1360	12.7902	12.7658	-.1908	*	.1360+00	.1850-01	.2515-02	.3421-03	.2895+00
							*	.8382-01	.2497-01	.7026-02	.3937-01	.1140-01
							*	.1550-02	.5355-02	.7283-03	.2108-03	
77.0000	1.8940	.3280	.1490	11.7193	11.6045	-.9794	*	.1490+00	.2220-01	.3308-02	.4929-03	.3280+00
							*	.1076+00	.3528-01	.1157-01	.3797-01	.1603-01
							*	.2388-02	.7281-02	.1085-02	.3558-03	

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 3

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,		XF(K),K=1,NBULKS				
77.0000	.6000	.0212	.0000	3.4066	3.9518	16.0014	*	.3045-07	.9272-15	.2823-22	.8597-30	.2122-01
							*	.4503-03	.9554-05	.2027-06	.6461-09	.1371-10
							*	.4175-18	.1967-16	.5991-24	.1271-25	
77.0000	1.4000	.0494	.0008	8.5344	9.3731	9.8270	*	.8001-03	.6401-06	.5121-09	.4097-12	.4940-01
							*	.2440-02	.1205-03	.5954-05	.3952-04	.1952-05
							*	.1562-08	.3162-07	.2530-10	.1250-11	
77.0000	1.9000	.0665	.0038	11.1785	11.0742	-.9332	*	.3800-02	.1444-04	.5488-07	.2085-09	.6654-01
							*	.4428-02	.2946-03	.1961-04	.2529-03	.1683-04
							*	.6394-07	.9609-06	.3652-08	.2430-09	
77.0000	2.4000	.0836	.0078	12.8845	12.4779	-3.1561	*	.7800-02	.6084-04	.4746-06	.3702-08	.8357-01
							*	.6985-02	.5838-03	.4879-04	.6519-05	.5448-06
							*	.4250-06	.5085-05	.3966-07	.3315-08	
77.0000	2.9000	.1003	.0140	13.2674	13.1560	-.8395	*	.1400-01	.1960-03	.2744-05	.3842-07	.1003+00
							*	.1006-01	.1008-02	.1011-03	.1404-02	.1408-03
							*	.1971-05	.1965-04	.2752-06	.2759-07	
77.0000	3.4000	.1168	.0220	13.1536	13.2421	.6725	*	.2200-01	.4840-03	.1065-04	.2343-06	.1168+00
							*	.1363-01	.1592-02	.1859-03	.2569-02	.3000-03
							*	.6599-05	.5652-04	.1243-05	.1452-06	
77.0000	3.9000	.1332	.0310	12.8918	13.0018	.8536	*	.3100-01	.9610-03	.2979-04	.9235-06	.1332+00
							*	.1775-01	.2365-02	.3151-03	.4170-02	.5503-03
							*	.1706-04	.1280-03	.3969-05	.5299-06	
77.0000	4.4000	.1497	.0410	12.5333	12.2797	-2.0242	*	.4100-01	.1681-02	.6892-04	.2826-05	.1497+00
							*	.2241-01	.3355-02	.5022-03	.6138-02	.9188-03
							*	.3767-04	.2516-03	.1032-04	.1545-05	
77.0000	4.9000	.1664	.0510	12.3391	11.8785	-3.7330	*	.5100-01	.2601-02	.1327-03	.6765-05	.1664+00
							*	.2768-01	.4605-02	.7661-03	.8465-02	.1412-02
							*	.7199-04	.4327-03	.2207-04	.3672-05	
77.0000	5.4000	.1831	.0620	11.9512	11.0948	-7.1659	*	.6200-01	.3844-02	.2383-03	.1478-04	.1831+00
							*	.3351-01	.6135-02	.1123-02	.1135-01	.2079-02
							*	.1288-03	.7037-03	.4363-04	.7987-05	
77.0000	5.9000	.2000	.0730	11.6053	10.7492	-7.3772	*	.7300-01	.5329-02	.3890-03	.2840-04	.2000+00
							*	.3999-01	.7998-02	.1599-02	.1460-01	.2919-02
							*	.2131-03	.1066-02	.7780-04	.1556-04	
77.0000	6.4000	.2171	.0840	11.2165	10.7299	-4.3380	*	.8400-01	.7056-02	.5927-03	.4979-04	.2171+00
							*	.4714-01	.1024-01	.2223-02	.1824-01	.3960-02
							*	.3326-03	.1532-02	.1287-03	.2704-04	

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 3

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,	XF(K),K=1,NBULKS				
77.0000	6.9000	.2345	.0950	10.8652	10.8697	.0417	* .9500-01	.9025-02	.8574-03	.8145-04	.2345+00
							* .5499-01	.1290-01	.3024-02	.2228-01	.5224-02
							* .4963-03	.2116-02	.2011-03	.4715-04	
77.0000	7.4000	.2521	.1060	10.5977	10.9968	3.7663	* .1060+00	.1124-01	.1191-02	.1262-03	.2521+00
							* .6356-01	.1602-01	.4040-02	.2672-01	.6737-02
							* .7141-03	.2833-02	.3003-03	.7570-04	

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 4

TEMP	TIME	STRAIN	DV/V0	SR-EXACT	SR-CALC	ERROR,		XF(K),K=1,NBULKS			
77.0000	3.0000	.0265	.0000	4.0552	5.0581	24.7329	*	.3820-07	.1459-14	.5576-22	.2130-29	.2653-01
							*	.7038-03	.1867-04	.4953-06	.1013-08	.2689-10
							*	.1027-17	.3872-16	.1479-23	.3924-25	
77.0000	5.0000	.0440	.0010	6.9452	8.1303	17.0634	*	.1000-02	.1000-05	.1000-08	.1000-11	.4803-01
							*	.1938-02	.8534-04	.3757-05	.4403-06	.1938-05
							*	.1939-08	.4403-07	.4403-10	.1939-11	
77.0000	7.0000	.0614	.0030	9.4500	10.4819	10.9201	*	.3000-02	.9001-05	.2700-07	.8101-10	.6137-01
							*	.3766-02	.2311-03	.1418-04	.1841-03	.1130-04
							*	.3390-07	.5523-06	.1657-08	.1017-09	
77.0000	9.0000	.0784	.0070	10.9533	11.7555	7.3236	*	.7000-02	.4900-04	.3430-06	.2401-08	.7837-01
							*	.6142-02	.4813-03	.3772-04	.5486-03	.4299-04
							*	.3009-06	.3840-05	.2688-07	.2107-08	
77.0000	11.0000	.0951	.0130	11.2336	12.3294	9.7553	*	.1300-01	.1690-03	.2197-05	.2856-07	.9507-01
							*	.9039-02	.8593-03	.8170-04	.1236-02	.1175-03
							*	.1528-05	.1607-04	.2089-06	.1986-07	
77.0000	13.0000	.1114	.0215	10.9168	11.8146	8.2237	*	.2150-01	.4623-03	.9939-05	.2137-06	.1114+00
							*	.1241-01	.1383-02	.1541-03	.2385-02	.2668-03
							*	.5738-05	.5150-04	.1107-05	.1234-06	
77.0000	15.0000	.1277	.0310	10.2963	10.9879	6.7167	*	.3100-01	.9610-03	.2979-04	.9235-06	.1277+00
							*	.1632-01	.2084-02	.2662-03	.3960-02	.5058-03
							*	.1568-04	.1220-03	.9496-05	.4861-06	
77.0000	17.0000	.1442	.0410	9.7882	10.2066	4.2747	*	.4100-01	.1681-02	.6892-04	.2826-05	.1442+00
							*	.2078-01	.2996-02	.4318-03	.6910-03	.9520-03
							*	.3493-04	.2423-03	.9936-05	.1432-05	
77.0000	19.0000	.1606	.0520	9.3430	9.2833	-.6382	*	.5200-01	.2704-02	.1406-03	.7312-05	.1606+00
							*	.2579-01	.4181-02	.6650-03	.8359-03	.1341-02
							*	.6973-04	.4341-03	.3258-04	.1621-05	
77.0000	21.0000	.1772	.0630	8.8798	9.0207	1.5867	*	.6300-01	.3969-02	.2501-03	.1575-04	.1772+00
							*	.3141-01	.5547-02	.9866-03	.1117-01	.1976-02
							*	.1247-03	.7034-03	.4432-04	.7854-05	
77.0000	23.0000	.1943	.0730	8.6187	9.5277	10.5463	*	.7300-01	.5329-02	.3890-03	.2840-04	.1943+00
							*	.3774-01	.7383-02	.1425-02	.1418-01	.2755-02
							*	.2011-03	.1035-02	.7558-04	.1468-04	
77.0000	25.5000	.2158	.0860	8.0286	10.2103	27.1737	*	.8600-01	.7396-02	.6361-03	.5470-04	.2158+00
							*	.4657-01	.1005-01	.2169-02	.1856-01	.4005-02
							*	.3445-03	.1596-02	.1371-03	.6663-04	

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 5

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,		XF(K),K=1,NBULKS				
77.0000	5.0000	.0177	.0000	2.9174	3.2312	10.7586	*	.2531-07	.6407-15	.1622-22	.4105-30	.1768-01
							*	.3126-03	.5528-05	.9774-07	.4476-09	.7913-11
							*	.2003-18	.1133-16	.2868-24	.5070-26	
77.0000	10.0000	.0354	.0000	6.1043	6.9370	13.6406	*	.5125-07	.2627-14	.1346-21	.6899-29	.3538-01
							*	.1252-02	.4430-04	.1567-05	.1813-08	.6416-10
							*	.3288-17	.9294-16	.4763-23	.1685-24	
77.0000	14.0000	.0496	.0000	8.6663	9.9104	14.3564	*	.7245-07	.5249-14	.3805-21	.2756-28	.4957-01
							*	.2457-02	.1218-03	.6039-05	.3592-06	.1780-09
							*	.1290-16	.2602-15	.1885-22	.9346-24	
77.0000	17.5000	.0617	.0015	10.3741	11.4332	10.2090	*	.1500-02	.2250-05	.3376-08	.5064-11	.6169-01
							*	.3906-02	.2348-03	.1448-04	.8258-06	.5709-05
							*	.8564-08	.1348-06	.2082-09	.1285-10	
77.0000	22.5000	.0786	.0060	11.3358	12.3636	9.0673	*	.6000-02	.3600-04	.2160-06	.1296-08	.7858-01
							*	.6175-02	.4852-03	.3813-04	.4715-05	.3705-04
							*	.2223-06	.2829-05	.1697-07	.1334-08	
77.0000	27.5000	.0951	.0130	11.1245	12.3294	10.8310	*	.1300-01	.1690-03	.2197-05	.2856-07	.9502-01
							*	.9039-02	.8593-03	.8170-04	.1236-02	.1175-03
							*	.1528-05	.1607-04	.2089-06	.1906-07	
77.0000	32.5000	.1114	.0215	10.5983	11.8146	11.4764	*	.2150-01	.4623-03	.9939-05	.2137-06	.1114+00
							*	.1241-01	.1383-02	.1541-03	.2395-02	.2669-03
							*	.5738-05	.5150-04	.1107-05	.1234-06	
77.0000	37.5000	.1277	.0310	9.9059	10.9479	10.9223	*	.3100-01	.9610-03	.2979-04	.9235-06	.1222+00
							*	.1632-01	.2084-02	.2662-03	.3960-02	.5058-03
							*	.1568-04	.1228-03	.3806-05	.4861-06	
77.0000	42.5000	.1441	.0415	9.1349	9.8693	8.0390	*	.4150-01	.1722-02	.7147-04	.2966-05	.1441+00
							*	.2075-01	.2990-02	.4307-03	.5978-02	.8612-03
							*	.3574-04	.2481-03	.1030-04	.1483-05	
77.0000	47.5000	.1606	.0520	8.4518	9.2833	9.8393	*	.5200-01	.2704-02	.1406-03	.7312-05	.1606+00
							*	.2579-01	.4141-02	.6650-03	.8350-02	.1341-02
							*	.6973-04	.4342-03	.2258-04	.3626-05	
77.0000	52.5000	.1774	.0620	7.8439	9.4181	20.0686	*	.6300-01	.3844-02	.2363-03	.1478-04	.1774+00
							*	.3148-01	.5585-02	.9908-03	.1100-01	.1952-02
							*	.1210-03	.6820-03	.4228-04	.7502-05	

NL002 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	-2.57459+02
2	3.38865+04
3	5.94925+05
4	-4.14762+06
5	1.58470+02
6	1.715A0+03
7	-2.02826+04
8	5.1170A+04
9	-1.81813+04
10	2.16925+05
11	-1.47137+06
12	-6.37019+05
13	4.24863+06
14	6.05113+05

THERE WERE 75 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0128

THE STANDARD DEVIATION, STD, WAS .1134

NL002 DEMONSTRATION PROBLEM

TEST NO. 1: FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRESSURE
77.0000	.0700	.0356	16.5600	16.5816	.1307	.0000	-.9609	.0000	.0000
77.0000	.1100	.0565	26.3671	26.1493	-.8260	.0000	-1.3428	.0000	.0000
77.0000	.1600	.0832	38.4096	37.1751	-3.2140	.0000	-1.7522	.0000	.0000
77.0000	.2100	.1105	49.2876	46.9200	-4.8038	.0000	-2.0469	.0000	.0000
77.0000	.2600	.1384	57.6174	55.0589	-4.4404	.0000	-2.1286	.0000	.0000
77.0000	.3100	.1670	64.2351	61.7938	-3.8005	.0000	-1.5761	.0000	.0000
77.0000	.3600	.1962	68.3164	67.0771	-1.8141	.0000	-.5043	.0000	.0000
77.0000	.4100	.2260	71.6129	70.7730	-1.1728	.0000	.5247	.0000	.0000
77.0000	.4600	.2564	73.8568	73.3164	-.7317	.0000	1.3323	.0000	.0000
77.0000	.5100	.2875	75.7367	75.1989	-.7101	.0000	1.7003	.0000	.0000
77.0000	.5600	.3192	77.0994	76.5084	-.7686	.0000	1.7139	.0000	.0000
77.0000	.6100	.3515	78.2113	78.3344	.1574	.0000	.6560	.0000	.0000
77.0000	.6600	.3844	79.0363	79.8876	1.0770	.0000	-.2567	.0000	.0000
77.0000	.7100	.4180	79.4674	81.2752	2.2749	.0000	-.6041	.0000	.0000
77.0000	.7600	.4522	79.9675	81.0004	1.2917	.0000	-1.2396	.0000	.0000
77.0000	.8100	.4870	79.7986	79.5899	-.2616	.0000	-1.0046	.0000	.0000
77.0000	.8600	.5224	79.4565	77.8677	-1.9997	.0000	-.5124	.0000	.0000
77.0000	.9100	.5585	78.3915	80.0938	2.1716	.0000	-.3713	.0000	.0000

NL002 DEMONSTRATION PROBLEM

TEST NO. 2, FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRESSURE
77.0000	.0940	.0236	13.3055	11.0651	-16.8378	.0000	-.8668	.0000	.0000
77.0000	.2940	.0762	38.6074	33.6351	-12.8792	.0000	-1.6276	.0000	.0000
77.0000	.4940	.1311	57.0141	50.1078	-12.1133	.0000	-2.9768	.0000	.0000
77.0000	.6940	.1886	66.0687	60.1104	-9.0184	.0000	-3.9958	.0000	.0000
77.0000	.8940	.2485	71.2136	64.3176	-9.6836	.0000	-5.1063	.0000	.0000
77.0000	1.0940	.3109	74.5885	67.2702	-9.8117	.0000	-5.0666	.0000	.0000
77.0000	1.2940	.3758	76.9483	72.3941	-5.9186	.0000	-3.2799	.0000	.0000
77.0000	1.4940	.4433	78.0795	78.2336	.1973	.0000	-.0712	.0000	.0000
77.0000	1.6940	.5132	77.7305	76.2606	-1.8909	.0000	1.4210	.0000	.0000
77.0000	1.8940	.5856	77.9423	77.3429	-.7690	.0000	.3698	.0000	.0000

NL002 DEMONSTRATION PROBLEM

TEST NO. 3. FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRESSURE
77.0000	.6000	.0304	11.8450	13.5959	14.7818	.0000	-.6607	.0000	.0000
77.0000	1.4000	.0724	28.6645	30.2553	5.5496	.0000	.0866	.0000	.0000
77.0000	1.9000	.0995	38.2524	38.2148	-.0984	.0000	-.1710	.0000	.0000
77.0000	2.4000	.1272	45.7419	45.1107	-1.3800	.0000	-.1821	.0000	.0000
77.0000	2.9000	.1555	50.3721	50.3906	.0368	.0000	-.2413	.0000	.0000
77.0000	3.4000	.1844	53.5448	54.1153	.9902	.0000	-.3536	.0000	.0000
77.0000	3.9000	.2140	55.9026	56.5523	1.1622	.0000	-.4296	.0000	.0000
77.0000	4.4000	.2442	57.5148	57.7402	.3919	.0000	-.7328	.0000	.0000
77.0000	4.9000	.2750	58.8992	58.6026	-.5036	.0000	-.6246	.0000	.0000
77.0000	5.4000	.3064	59.7700	58.8992	-1.4569	.0000	-.8421	.0000	.0000
77.0000	5.9000	.3385	60.5083	59.4575	-1.7366	.0000	-.6614	.0000	.0000
77.0000	6.4000	.3712	60.9824	60.1922	-1.2958	.0000	-.1838	.0000	.0000
77.0000	6.9000	.4045	61.1818	60.7003	-.7869	.0000	.4905	.0000	.0000
77.0000	7.4000	.4384	60.8359	60.3456	-.8058	.0000	1.2885	.0000	.0000

NL002 DEMONSTRATION PROBLEM

TEST NO. 4. FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRESSURE
77.0000	3.0000	.0382	13.5912	15.4595	13.7460	.0000	.1377	.0000	.0000
77.0000	5.0000	.0645	22.9385	24.4776	6.7094	.0000	.8311	.0000	.0000
77.0000	7.0000	.0913	31.4903	32.2278	2.3420	.0000	1.3264	.0000	.0000
77.0000	9.0000	.1188	38.0259	38.2760	.6578	.0000	1.3542	.0000	.0000
77.0000	11.0000	.1470	41.9296	42.8856	2.2800	.0000	1.2358	.0000	.0000
77.0000	13.0000	.1757	44.3978	45.6386	2.7949	.0000	.5547	.0000	.0000
77.0000	15.0000	.2051	45.7279	47.2530	3.3353	.0000	-.1420	.0000	.0000
77.0000	17.0000	.2351	46.7034	48.1276	3.0493	.0000	-.5873	.0000	.0000
77.0000	19.0000	.2657	47.4165	48.3090	1.8823	.0000	-1.0118	.0000	.0000
77.0000	21.0000	.2970	47.6337	48.6501	2.1339	.0000	-.7348	.0000	.0000
77.0000	23.0000	.3288	47.7286	49.2544	3.1968	.0000	.2991	.0000	.0000
77.0000	25.0000	.3606	47.8750	49.7747	3.9349	.0000	1.6637	.0000	.0000

NL002 DEMONSTRATION PROBLEM

TEST NO. 5, FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRESSURE
77.0000	5.0000	.0253	9.2250	9.7734	5.9451	.0000	.0793	.0000	.0000
77.0000	10.0000	.0512	18.6900	19.0089	1.7061	.0000	1.3465	.0000	.0000
77.0000	14.0000	.0724	26.2150	26.0284	-.7120	.0000	2.6750	.0000	.0000
77.0000	17.5000	.0913	31.8399	30.8192	-3.2057	.0000	3.1389	.0000	.0000
77.0000	22.5000	.1188	36.9356	35.9229	-2.7418	.0000	3.0684	.0000	.0000
77.0000	27.5000	.1470	39.5562	39.4143	-.3589	.0000	2.5517	.0000	.0000
77.0000	32.5000	.1757	41.1772	41.6959	1.2596	.0000	1.9139	.0000	.0000
77.0000	37.5000	.2051	41.9854	42.9117	2.2062	.0000	1.2376	.0000	.0000
77.0000	42.5000	.2351	42.1775	43.1637	2.3382	.0000	.4825	.0000	.0000
77.0000	47.5000	.2657	41.9872	43.2910	3.1054	.0000	.3593	.0000	.0000
77.0000	52.5000	.2970	41.4081	43.5497	5.1719	.0000	1.0067	.0000	.0000

NL002 DEMONSTRATION PROBLEM

FOR THE STRESS SIGMA-11, ...

XBAR = -.0025 AND STD = .0477

FOR THE STRESS SIGMA-22, ...

XBAR = .0000 AND STD = .0000

DATA CARDS IGNORED - FIRST IS LISTED BELOW

GT FOR:* NL002.NL002 15 JUN 73 00:00:02.552
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 14:12(02)
FORTRAN V: ISA VERSION 2.6

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	003566
0000	*DATA	012731
0002	*BLANK	000000
0003	INPUT	007034

EXTERNAL REFERENCES (BLOCK, NAME)

0004	IOUNIT
0005	PARAL
0006	BUFFER
0007	REAR
0010	NREWS
0011	NBKUS
0012	NIO1S
0013	NIO2S
0014	NERUS
0015	ALOG
0016	EXP
0017	NEXPAS
0020	DSQRT
0021	DEXP
0022	NEXP6S
0023	NARUS
0024	NRWUS
0025	NSTOPS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	012071	1F	0001	000567	18L	0001	000574	100L	0001	001772	1006G
0001	002003	1016G	0001	002020	1025G	0001	002025	1031G	0001	002035	1060G
0001	002220	1120G	0001	002232	1124G	0001	002235	1131G	0001	002256	1142G
0001	002335	1172G	0001	002335	1174G	0001	000547	12L	0001	002348	1203G
0001	002355	1210G	0001	002454	1232G	0001	002502	1241G	0001	002505	1244G
0001	002571	1266G	0001	002602	1274G	0001	002602	1276G	0000	012100	13F
0001	000052	133G	0001	002700	1331G	0001	002722	1350G	0001	002722	1352G
0001	002745	1370G	0001	002745	1372G	0000	012105	14F	0001	002760	1400G
0001	000064	141G	0001	003027	1431G	0001	003132	1455G	0001	000076	147G
0000	012107	15F	0001	003231	1514G	0001	003253	1533G	0001	003253	1535G
0001	000110	155G	0001	003276	1553G	0001	003276	1565G	0001	003310	1563G
0001	003324	1577G	0001	000132	166G	0001	000641	18L	0001	001020	19L
0001	000754	20L	0001	001631	200L	0001	000160	202G	0001	000742	21L
0001	000214	222G	0001	000270	247G	0001	000302	256G	0001	000353	274G
0000	012111	30F	0001	000355	300G	0000	012140	31F	0001	000362	310G
0000	012146	32F	0001	000400	320G	0000	012160	33F	0001	000467	34L
0001	000427	350G	0000	012074	4F	0000	012214	40F	0001	000524	417G
0001	000537	412G	0000	012245	42F	0001	000604	427G	0001	000627	433G
0001	000662	444G	0001	000702	451G	0001	000771	470G	0001	001003	475G

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0001  001662 506G    0001  001143 526G    0001  002541 530L    0001  001170 536G    0001  001223 55L
0001  003055 550L    0001  001242 556G    0001  001255 562G    0001  003011 565L    0001  001275 571G
0001  003430 575L    0001  003367 586L    0001  003405 587L    0000  012313 588F    0001  002123 600L
0001  002051 605L    0001  001454 624G    0001  001457 627G    0001  001471 632G    0001  001133 65L
0000  012316 650F    0000  012356 655F    0001  001553 656G    0000  012417 660F    0000  012431 675F
0001  001575 675G    0001  001575 677G    0000  012076 7F      0000  012477 700F    0001  001607 707G
0001  001372 71L     0000  012522 710F    0001  001620 715G    0001  001630 717G    0000  012556 720F
0000  012600 725F    0001  001673 737G    0000  012276 75F     0001  001736 755G    0001  001760 774G
0001  001764 776G    0001  001341 78L     0001  000535 9L      0000 R 012017 A       0000 R 000000 AT
0000  012065 AVGAT   0000 D 012000 A1      0000 D 012002 A2      0000 R 012026 A3      0000 R 000144 B
0000 R 000153 B4      0000 R 012052 BCAL    0003 R 000013 BETA    0000 R 000171 BG      0003 R 000012 BULK
0000 R 000207 CJ      0000 R 000225 D       0000 R 012045 DEV     0000 R 012063 DEV1    0000 R 012064 DEV2
0000 R 012024 DI      0003 R 000634 DIL     0003 R 002130 DR1     0003 R 002440 DR12    0003 R 002274 DR2
0003 R 000324 DT      0000 R 012031 DTR     0003 R 006524 EOCT    0003 R 001164 E11     0003 R 001620 E12
0003 R 001310 E22     0003 R 001454 E33     0000 R 000371 F       0000 R 000535 G       0000 I 012013 I
0000 I 000761 IFF     0000 I 000717 IFG     0000 I 012007 IFLAG   0000 I 000726 IFN     0000 R 012008 INT1
0000 R 012006 INT2    0000 R 012005 INT3    0003 D 002604 INV1    0003 D 003110 INV2    0003 D 003420 INV3
0000 I 012010 IPO     0003 I 000000 ITEST   0000 I 012027 J       0000 I 012022 K       0003 I 000000 KODE
0003 I 000003 KTEMP   0000 I 012043 L       0000 I 012017 LAST    0000 I 012021 LINE    0000 I 012036 M
0003 I 000005 MATID   0000 I 012035 MB7     0000 I 012033 N       0000 I 000734 NAME    0000 I 012016 NAT
0000 I 012051 NBULKS  0003 I 000001 NDP     0000 I 011777 NEND    0003 D 004248 NORM    0003 D 003738 NORME
0000 I 012032 NORMS   0000 I 012015 NPL     0000 I 012037 NTERMS  0000 I 012020 NTEST   0000 I 012040 NTOT
0000 I 012011 NU      0000 I 012024 N1      0000 R 000760 P       0003 R 000002 PRES    0000 R 000767 R
0000 R 000165 RATE    0000 R 012042 RESID   0000 R 012055 RESID1  0000 R 012056 RESID2  0000 R 012048 SCAL
0000 R 012050 ST      0003 R 000470 STRESS  0000 R 012046 STRN    0003 R 001744 STRUE   0000 R 012041 SUM
0000 R 012054 SUM1    0000 R 012053 SUM2    0000 R 012061 S1      0000 R 012062 S1CAL   0000 R 012063 S2
0000 R 012060 S2CAL   0003 R 001000 T       0003 R 000014 TEMP    0000 R 001273 TR      0000 R 001432 TSHFT
0000 R 011761 WORK1   0000 R 011770 WORK2   0000 R 012047 XBAR    0000 R 001663 XF      0000 R 004373 XF1
0000 R 007163 XF2     0000 R 011753 XN      0000 R 012027 XP      0000 R 012030 XQ      0000 R 012014 Z
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```
00100     1*    C
00100     2*    C *** PROGRAM NAME = NL002.
00100     3*    C     NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE.
00100     4*    C
00100     5*    C     BULK      =   BULK MODULUS.
00100     6*    C     BETA      =   VOLUMETRIC EXPANSION COEFFICIENT.
00100     7*    C     EOCT      =   OCTAHEDRAL SHEAR STRAIN
00100     8*    C     IFN       =   NORM SELECTOR, ANY ONE OR COMBINATION OF THE
00100     9*    C                     10TH, 20TH, 30TH, 40TH, 50TH, OR 60TH NORMS.
00100    10*    C                     ENTER A NON-ZERO VALUE TO INCLUDE THAT NORM.
00100    11*    C     NPL       =   NO. OF PRONY LAW TERMS.
00100    12*    C     NAT       =   NO. OF AT VS. TSHFT INPUT DATA POINTS.
00100    13*    C     NTERMS    =   NO. OF DATA PTS. FOR A SPECIFIC TEST.
00100    14*    C     N1        =   FIRST DATA POINT USED IN THE REGRESSION ANALYSIS.
00100    15*    C
00101    16*          DIMENSION AT(100), B(7), BB(14), BO(14), CO(14), D(100),
00101    17*         1          DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00101    18*         2          E11(100), E22(100), E33(100), E12(100), F(100), G(100),
00101    19*         3          IFF(14), IFG(7), IFN(6), INV1(100), INV2(100),
00101    20*         4          INV3(100), MATID(5), NAME(20), NORM(6,100), NORME(100),
00101    21*         5          P(7), R(14,14), RATE(100), STRESS(100), STRUE(100),          **-2
00101    22*         6          T(100), TEMP(100), TR(100), TSHFT(100), XF(14,100),
00101    23*         7        XF1(14,100), XF2(14,100), XN(6), FOCT(100)
00101    24*    C
00102    25*          DIMENSION WORK1(7), WORK2(7)                                          *NEW
00103    26*    C                                                                           *NEW
00104    27*          COMMON /INPUT/ ITEST, NDP, PRES, KTEMP, KODE, MATID, BULK, BETA,
00104    28*         1               TEMP, RATE, DT, STRESS, DIL, T, E11, E22, E33, E12,
```

```
00104   29*          2              STRUE, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00104   29*          3              NORM, FOCT
00104   30*    C
00105   31*          DATA NEND/'END'/
00105   32*    C
00105   33*    C
00107   34*          DOUBLE PRECISION  A1, A2, INV1, INV2, INV3, NORMF, NORM, FOCT
00107   35*    C
00110   36*          REAL     INT1, INT2, INT12
00110   37*    C
00111   38*          IFLAG = 0
00112   39*          IPG = 0
00112   40*    C
00112   41*    C          ASSIGN TAPE UNIT ORR.
00113   42*          NU = 1
00113   43*    C
00113   44*    C       DYNAMICALLY ALLOCATE DRUM SPACE.
00113   45*    C
00114   46*              CALL ICOUNT('DRUM',11,,75,WORK1)
00115   47*              CALL IOUNIT('DRUM',12,,25,WORK2)
00115   48*    C
00115   49*    C
00116   50*          REWIND NU
00116   51*    C
00116   52*    C
00116   53*    C
00117   54*          READ(5,1) (NAME(I),I=1,20 )
00125   55*          READ(5,2) A,Z
00131   56*          READ(5,75) (IFG(I),I=1,7)
00137   57*          READ(5,75) (IFF(I),I=1,14)
00137   58*    C
00137   59*    C          INPUT NORM SELECTOR AND EXPONENTS.
00137   60*    C
00145   61*          READ(5,75) (IFN(I),I=1,6)
00153   62*          READ(5,2)(XN(I),I=1,6)
00153   63*    C
00163   64*    C          INPUT POWER LAW EXPONENTS AND COEFFICIENTS.
00161   65*          READ(5,75)     NPL
00164   66*          READ(5,2)( P(I), C(I), I=1,NPL   )
00164   67*    C
00173   68*          CALL PAGNL(IPG, NAME)
00174   69*          WRITE(6,32) A,Z
00200   70*          WRITE(6,40)(I, P(I),  P(I), IFG(I), I=1,7)
00211   71*          WRITE(6,42)( I, IFF(I),I=1,14)
00220   72*          WRITE(6,44)( I, IFN(I), XN(I),I=1,6)
00220   73*    C
00220   74*    C          INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE, TSHFT, COLD TO HOT.
00220   75*    C
00230   76*          NAT = 0
00231   77*      3   NAT = NAT + 1
00232   78*          READ(5,4)  TSHFT(NAT),  AT(NAT), LAST
00237   79*          IF(LAST.EQ.0) GO TO 3
00241   80*          CALL PAGNL(IPG, NAME)
00242   81*          WRITE(6,30)  NAT
00245   82*          WRITE(6,31)(I, AT(I), TSHFT(I), I=1,NAT)
00245   83*    C
00245   84*    C          COMPUTE   SLOPE, D, AT EACH INPUT POINT.
00245   85*    C
00255   86*          DO 5 I=2,NAT
00260   87*          D(I) = (LOG(AT(I)) - LOG(AT(I-1)) )/( TSHFT(I) - TSHFT(I-1) )
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```
00261    84*     5    CONTINUE
00263    89*          D(1) = D(2)
00263    90*    C
00264    91*          NTEST = 0
00265    92*          REWIND 11
00266    93*          REWIND 12
00267    94*          LINE = 0
00270    95*          CALL PAGNL(IPG, NAME)
00271    96*          WRITE(6,33)
00273    97*          DO 110 I=1,14
00276    98*          RR(I) = 0.0
00277    99*          DO 105 K=1,100
00302   100*          XF1(I,K) = 0.0
00303   101*          XF2(I,K) = 0.0
00304   102*          XF(I,K) = 0.0
00305   103*   105    CONTINUE
00307   104*          DO 110 J=1,14
00312   105*          R(I,J) = 0.0
00313   106*   110    CONTINUE
00313   107*    C
00313   108*    C          BEGIN NEXT TEST.
00313   109*    C
00316   110*    100    CONTINUE
00316   111*    C
00316   112*    C          ZERO ALL VARIABLES.
00316   113*    C
00317   114*          DO 107 I=1,100
00322   115*          DIL(I) = 0.0
00323   116*          DR1(I) = 0.0
00324   117*          DR2(I) = 0.0
00325   118*          DR12(I) = 0.0
00326   119*          DT(I) = 0.0
00327   120*          E11(I) = 0.0
00330   121*          E22(I) = 0.0
00331   122*          E33(I) = 0.0
00332   123*          E12(I) = 0.0
00333   124*          F(I) = 0.0
00334   125*          G(I) = 0.0
00335   126*          INV1(I) = 0.000
00336   127*          INV2(I) = 0.000
00337   128*          INV3(I) = 0.000
00340   129*          NORMF(I) = 0.000
00341   130*          RATE(I) = 0.0
00342   131*          STRESS(I) = 0.0
00343   132*          STRUE(I) = 0.0
00344   133*          T(I) = 0.0
00345   134*          TEMP(I) = 0.0
00346   135*          TR(I) = 0.0
00347   136*          DO 107 K=1,6
00352   137*          NORM(K,I) = 0.000
00353   138*    107   CONTINUE
00353   139*    C
00353   140*    C          INPUT RAW DATA FOR THIS TEST.
00353   141*    C
00356   142*          CALL BUFFER (NU, IFLAG)
00356   143*    C
00356   144*    C
00357   145*          NTEST = NTEST + 1
00360   146*          N1 = 3
00361   147*          LINE = LINE + 1
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00362   148*          IF(LINE.LE.50) GO TO 34
00364   149*          CALL PAGNL(IPG, NAME )
00365   150*          WRITE(6,33)
00367   151*          LINE = 0
00370   152*     34   CONTINUE
00371   153*          WRITE(6,35) NTEST,ITEST,NDP,KODE,KTEMP,PREF,TEMP(1)
00371   154*     C
00371   155*     C         COMPUTE THE REDUCED TIME, TR.
00371   156*     C
00402   157*          DO 8 I=N1,NDP
00405   158*          IF(I.EQ.N1) GO TO 9
00407   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00407   159*          IF(TEMP(I).EQ.TEMP(I-1)) GO TO 10
00411   160*     9    DO 11 J=1,NAT
00414   161*          IF(TEMP(I).LT.TSHFT(J)) GO TO 12
00416   162*     11   CONTINUE
00420   163*     12   AVGAT = ( EXP(LOG(AT(J-1)) + D(J)*(TEMP(I) - TSHFT(J-1) )) )
00421   164*     10   TR(I) = TR(I-1)  +  DT(I)/AVGAT
00422   165*     8    CONTINUE
00422   166*     C
00422   167*     C
00422   168*     C         IF TEMP IS CONSTANT READ 10TH THRU 60TH NORMS, OTHERWISE
00422   169*     C         COMPUTE THEM BASED ON THE REDUCED TIME, TR.
00422   170*     C
00424   171*          IF(KTEMP.EQ.2) GO TO 18
00424   172*     C
00424   173*     C
00424   174*     C         IF A CONSTANT TEMP TEST, MULTIPLY THE PTH NORM BY (1/AT)**1/P.
00424   175*     C
00426   176*          DO 60 M=1,6
00431   177*          XP = 1.0/(10*M)
00432   178*          DO 60 I=1,NDP
00435   179*          NORM(M,I) = NORM(M,I)*((1./AVGAT)**XP)
00436   180*     60   CONTINUE
00441   181*          GO TO 19
00442   182*     18   CONTINUE
00442   183*     C
00443   184*          DO 20 M=1,6
00446   185*          XP = 1.0+10.*M
00447   186*          XC = 10.*M
00450   187*          DO 20 I=N1,NDP
00453   188*          DTR = TR(I) - TR(I-1)
00454   189*          A1 = DABS(INV2(I))
00455   190*          A2 = DABS(INV2(I-1))
00456   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00456   191*          IF(A1.EQ.A2) GO TO 21
00460   192*          NORM(M,I) = NORM(M,I-1) + (A1**XP-A2**XP)/(XP*(A1-A2)/DTR  )
00461   193*          GO TO 20
00462   194*     21   CONTINUE
00463   195*          NORM(M,I) = NORM(M,I-1) + (A1**XC)*DTR
00464   196*     20   CONTINUE
00464   197*     C
00467   198*          DO 22 M=1,6
00472   199*          XP = M*10.
00473   200*          XP = 1./XP
00474   201*          DO 22 I=N1,NDP
00477   202*          NORM(M,I) = NORM(M,I)**XP
00500   203*     22   CONTINUE
00500   204*     C
00503   205*     19   CONTINUE
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00503   206*  C
00503   207*  C          FORM CONSTITUTIVE EQUATIONS FOR THIS TEST.
00503   208*  C
00503   209*  C
00503   210*  C          COMPUTE THE FACTORS F, G, AND XF(1,I).
00503   211*  C
00504   212*          F(I) = 0.0
00505   213*          DO 65 I=N1,NDP
00510   214*          XF1(1,I) = F11(I)
00511   215*          XF2(1,I) = F22(I)
00512   216*          XF(1,I) = F11(I) - F22(I)
00513   217*          G(I) = (1.0 - DABS(INV2(I))/NORMF(I)  ) **Z
00514   218*          F(I) = DEXP(A*INV3(I)/(DSQRT(DABS(INV2(I)))))
00515   219*          IF(IFF(1).EQ.0) GO TO 65
00517   220*          XF1(1,I) = XF1(1,I)*F(I)
00520   221*          XF2(1,I) = XF2(1,I)*F(I)
00521   222*          XF(1,I) = XF(1,I)*F(I)
00522   223*    65    CONTINUE
00522   224*  C
00522   225*  C          COMPUTE THE NORM TERMS.
00522   226*  C
00524   227*          NORMS = 0
00524   228*  C
00525   229*          DO 50 K=1,6
00530   230*          M = IFF(K)
00531   231*          IF(M.EQ.0) GO TO 50
00533   232*          NORMS = NORMS + 1
00534   233*          N = NORMS + 1
00535   234*          DO 55 J=N1,NDP
00540   235*          DI = ( DABS(INV2(J))/NORM(M,J) )**XN(K)
00541   236*          XF1(N,J) = XF1(1,J)*DI
00542   237*          XF2(N,J) = XF2(1,J)*DI
00543   238*          XF(N,J) = XF(1,J)*DI
00544   239*          IF(IFF(M).EQ.0) GO TO 55
00546   240*          XF1(N,J) = XF1(N,J)*F(J)
00547   241*          XF2(N,J) = XF2(N,J)*F(J)
00550   242*          XF(N,J) = XF(N,J)*F(J)
00551   243*    55    CONTINUE
00551   244*  C
00553   245*    50    CONTINUE
00553   246*  C
00553   247*  C
00553   248*  C          COMPUTE THE POWER LAW (INTEGRALS) TERMS.
00553   249*  C
00555   250*          DO 70 M=1, NPI
00560   251*          MP7 = M + 7
00561   252*          DO 70 J=N1,NDP
00564   253*          A3 = P(M) + 1.
00565   254*          INT1 = 0.0
00566   255*          INT2 = 0.0
00567   256*          INT12 = 0.0
00570   257*          DO 71 K=N1,J
00573   258*          IF(KONF.EQ.3) GO TO 7A
00575   259*          INT1 = INT1 - (DR1(K)/(B(M)*A3))*((1. + B(M)*(TR(J)-TR(K-1))**A3
00575   260*         1              - (1. + B(M)*(TR(J)-TR(K-1)))**A3 )
00576   261*          INT2 = INT2 - (DR2(K)/(B(M)*A3))*((1. + B(M)*(TR(J)-TR(K)))**A3
00576   262*         1              - (1. + B(M)*(TR(J)-TR(K-1)))**A3 )
00577   263*          GO TO 71
00600   264*    7A    CONTINUE
00601   265*          INT12= INT12- (DR12(K)/(B(M)*A3))*((1. + B(M)*(TR(J)-TR(K)))**A3
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00601  266*          1         - (1. + B(M)*(TR(J)-TR(K-1)))**A3 )
00602  267*     71   CONTINUE
00604  268*          XF1(N+M,J) = INT1
00605  269*          XF2(N+M,J) = INT2
00608  270*          IF(IFF(MP7).NE.0) XF1(N+M,J) = XF1(N+M,J)*F(J)
00610  271*          IF(IFF(MP7).NE.0) XF2(N+M,J) = XF2(N+M,J)*F(J)
00612  272*          IF(IFG(M).NE.0) XF1(N+M,J) = XF1(N+M,J)*G(J)
00614  273*          IF(IFG(M).NE.0) XF2(N+M,J) = XF2(N+M,J)*G(J)
00616  274*          XF(N+M,J) = XF1(N+M,J) - XF2(N+M,J)
00617  275*     70   CONTINUE
00617  276*     C
00617  277*     C         FORM PRIMARY MATRIX R, AND SOLUTION VECTOR RR.
00617  278*     C
00622  279*          NTERMS = NORMS + NPL + 1
00622  280*     C
00623  281*          DO 300 K=1,NTERMS
00626  282*          DO 300 J=1,NTERMS
00631  283*              DO 310 I=1,NDP
00634  284*               IF(ABS(STRUF(I)).LT.R.0 ) GO TO 310
00636  285*              R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/STRUE(I)**2
00637  286*              IF(J.GT.1)  GO TO 310
00641  287*              RR(K) = RR(K) + XF(K,I)/STRUF(I)
00642  288*     310      CONTINUE
00644  289*     300  CONTINUE
00644  290*     C
00644  291*     C              SAVE DATA ON SCRATCH DRUMS 11 AND 12.
00644  292*     C
00647  293*              WRITE(11)  NDP, KOEF, PRES
00654  294*              WRITE(11) (OIL(I), E11(I), E12(I),FOCT(I), INV1(I), INV2(I)
00654  295*         1 ,INV3(I), STRUF(I), T(I), TEMP(I), I=1,NDP)
00673  296*              WRITE(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
00673  297*     C
00705  298*              WRITE(12)  (STRESS(I), I=1,NDP)
00713  299*              WRITE(12)  (( XF(K,I),K=1,14),I=1,NDP
00713  300*     C
00713  301*     C          GO READ NEXT TEST.
00713  302*     C
00713  303*     C                    ALL DONE ?
00713  304*     C
00724  305*          IF(IFLAG.EQ.2) GO TO 200
00724  306*     C
00726  307*          GO TO 100
00726  308*     C
00727  309*     200  CONTINUE
00730  310*          REWIND 11
00731  311*              REWIND 12
00731  312*     C
00731  313*     C         REGRESSION ANALYSIS FOR SHEAR TERM.
00731  314*     C
00732  315*              CALL REGR(NTERMS, RR, CO, R )
00732  316*     C
00732  317*     C         CALCULATE SHEAR TERM AND RELATIVE AND GLOBAL ERROR.
00732  318*     C
00733  319*          NTOT = 0
00734  320*          SUM = 0.0
00735  321*          RESID = 0.0
00736  322*          DO 600 L=1,NTEST
00741  323*          LINE = 0
00742  324*          CALL PAGNL( IPG, NAME )
00743  325*          WRITE(6,650) L
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00746  326*            READ(11)  NDP, KODE, PRES
00753  327*            READ(11) (DIL(I), E11(I), E12(I),FACT(I), INV1(I), INV2(I)
00753  328*       1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
00772  329*            READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01004  330*            READ(12)  (STRESS(I), I=1,NDP)
01012  331*            READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01023  332*       NTOT = NTOT + NDP
01024  333*       DO 600 I=N1,NDP
01027  334*       SCAL = 0.0
01030  335*            DO 610 J=1,NTERMS
01033  336*            SCAL = SCAL + CO(J)*XF(J,I)
01034  337*  610       CONTINUE
01036  338*       DEV = 100*(SCAL - STRUE(I))/STRUE(I)
01037  339*            IF(ABS(STRUE(I)).LT.8.0 ) GO TO 605
01041  340*       SUM = SUM + DEV/100.
01042  341*       RESID = RESID + DEV**2/10.**4
01043  342*  605  CONTINUE
01044  343*       STRN = E11(I)
01045  344*       IF(KODE.EQ.3)  STRN = E12(I)
01047  345*       WRITE(6,660)  TEMP(I), T(I), STRN, DIL(I), STRUE(I), SCAL, DEV,
01047  346*      1              (XF(J,I),J=1,NTERMS)
01064  347*       LINE = LINE + 4
01065  348*       IF(LINE.LT.48) GO TO 600
01067  349*       CALL PAGNL(IPG, NAME)
01070  350*       WRITE(6,650) (
01073  351*       LINE = 0
01074  352*  600  CONTINUE
01074  353*  C
01074  354*  C         ERROR SUMMARY AND COEFFICIENTS.
01074  355*  C
01077  356*       XBAR = SUM/NTOT
01100  357*       STD = ((NTOT*RESID-SUM**2)/(NTOT*(NTOT-1)))**0.5
01101  358*       CALL PAGNL( IPG, NAME )
01102  359*       WRITE(6,700)(I, CO(I),I=1,NTERMS)
01111  360*       WRITE(6,710) NTOT, XBAR, STD
01111  361*  C
01111  362*  C         NOW HAVE S.. FOR TERM COEFFICIENTS CO(K).  GO GET RULK TERM
01111  363*  C         COEFFICIENT  BO(K) BY ADDING EXPRESSIONS FOR S11 AND S22.
01111  364*  C
01116  365*       NRULKS = 14
01116  366*  C         ZERO R AND BB
01116  367*  C
01117  368*       DO 505 K=1,14
01122  369*       BB(K) = 0.0
01123  370*       DO 506 I=1,100
01126  371*  506  XF(K,I) = 0.0
01126  372*  C
01130  373*       DO 505 J=1,14
01133  374*       R(K,J) = 0.0
01134  375*  505  CONTINUE
01137  376*            REWIND 11
01140  377*            REWIND 12
01141  378*       DO 500 L=1,NTEST
01144  379*            READ(11)  NDP, KODE, PRES
01151  380*            READ(11) (DIL(I), E11(I), E12(I),FACT(I), INV1(I), INV2(I)
01151  381*       1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
01170  382*            READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01170  383*  C
01202  384*       DO 501 I=1,100
01205  385*  501  STRESS(I) = 0.0
```

```
01205  386*  C
01206  387*  C
01207  388*        DO 510 I=N1,NDP
01212  389*        STRESS(I) = STRUE(I)/2. - PRES
01212  390*  C
01212  391*  C          XF NOW BECOMES SOLUTION MATRIX FOR THE NAULKS TERMS.
01212  392*  C
01213  393*        XF(1,I) = DIL(I)
01214  394*        XF(2,I) = DIL(I)**2
01215  395*        XF(3,I) = DIL(I)**3
01216  396*        XF(4,I) = DIL(I)**4
01217  397*         XF(5,I) = FOCT(I)
01220  398*         XF(6,I) = FOCT(I)**2.
01221  399*         XF(7,I) = FOCT(I)**3.
01222  400*         XF(8,I) = FOCT(I)**4.
01223  401*        XF(9,I) = FOCT(I)*DIL(I)
01224  402*        XF(10,I) = FOCT(I)**2*DIL(I)
01225  403*        XF(11,I) = FOCT(I)**2*DIL(I)**2
01226  404*        XF(12,I) = FOCT(I)*DIL(I)**2
01227  405*        XF(13,I) = FOCT(I)*DIL(I)**3
01230  406*        XF(14,I) = FOCT(I)**2*DIL(I)**3
01231  407*        DO 510 K=1,NTERMS
01234  408*        STRESS(I) = STRESS(I) - CO(K)*XF1(K,I)/2  - CO(K)*XF2(K,I) /2
01235  409*   510  CONTINUE
01235  410*  C
01235  411*  C          FORM PRIMARY MATRIX R, AND SOLUTION VECTOR BB.
01235  412*  C
01235  413*  C
01240  414*        DO 520 K=1,NAULKS
01243  415*        DO 520 J=1,NAULKS
01246  416*            DO 530 I=N1,NDP
01251  417*            IF(ABS(STRESS(I)).LT.F.0 ) GO TO 530
01252  418*            R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/STRESS(I)**2
01254  419*            IF(J.GT.1) GO TO 530
01256  420*            BB(K) = BB(K) + XF(K,I)/STRESS(I)
01257  421*   530      CONTINUE
01261  422*   520  CONTINUE
01261  423*  C
01264  424*            WRITE(12)  (STRESS(I), I=1,NDP)
01272  425*            WRITE(12)  (( XF(K,I),K=1,14),I=1,NDP)
01272  426*  C
01303  427*   500  CONTINUE
01303  428*  C
01305  429*            REWIND 11
01306  430*            REWIND 12
01306  431*  C
01307  432*            CALL REGR( NAULKS, BB, BO, R )
01307  433*  C
01307  434*  C          FINAL STRESS AND ERROR CALCULATIONS.
01307  435*  C
01310  436*        SUM = 0.0
01311  437*        RESID = 0.0
01312  438*        DO 550 L=1,NTEST
01315  439*        LTHE = 0
01316  440*        CALL PAGE( IPG, NAME )
01317  441*        WRITE(6,655) L
01322  442*            READ(11)  NDP, KODE, PRES
01327  443*            READ(11) (DIL(I), F11(I), E12(I),FOCT(I), INV1(I), INV2(I)
01327  444*     1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
01346  445*            READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
```

```
01360  446*              READ(12)  (STRESS(I), I=1,NDP)
01366  447*              READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01377  448*          DO 550 I=1,NDP
01402  449*          RCAL = 0.0
01403  450*              DO 560 J=1,NBULKS
01406  451*              RCAL = RCAL + RO(J)*XF(J,I)
01407  452*   560        CONTINUE
01411  453*          DEV = 100*(RCAL - STRESS(I))/STRESS(I)
01412  454*              IF(ABS(STRESS(I)).LT.P.0 ) GO TO 565
01414  455*          SUM = SUM + DEV/100.
01415  456*          RESID = RESID + DEV**2/10.**4
01416  457*   565    CONTINUE
01417  458*           STRNEOCT(I)
01420  459*          WRITE(6,660)  TEMP(I), T(I), STRN, DIL(I), STRESS(I), RCAL, DEV,
01420  460*         1                  (XF(J,I),J=1,NBULKS )
01435  461*          LINE = LINE + 4
01436  462*          IF(LINE.LT.48) GO TO 550
01440  463*          CALL PAGE( IPG, NAME )
01441  464*          WRITE(6,655) I
01444  465*          LINE = 0
01445  466*   550    CONTINUE
01445  467*   C
01445  468*   C          ERROR SUMMARY AND COEFFICIENTS FOR BULK TERM.
01445  469*   C
01450  470*          XBAR = SUM/NTOT
01451  471*          STD = ((NTOT*RESID-SUM**2)/(NTOT*(NTOT-1)))**0.5
01452  472*          CALL PAGE(IPG,NAME)
01453  473*          WRITE(6,700)(I, RO(I),I=1,NBULKS)
01462  474*          WRITE(6,710) NTOT, XBAR, STD
01462  475*   C
01467  476*          REWIND 11
01470  477*          REWIND 12
01470  478*   C
01471  479*          SUM1= 0.0
01472  480*          SUM2= 0.0
01473  481*          RESID1= 0.0
01474  482*          RESID2= 0.0
01475  483*          DO 575 L=1,NTEST
01500  484*          LINE=0
01501  485*          CALL PAGE( IPG, NAME )
01502  486*          WRITE(6,675) L
01505  487*              READ(11)  NDP, KODE, PRES
01512  488*              READ(11) (DIL(I), F11(I), F12(I),EOCT(I), INV1(I), INV2(I)
01512  489*         1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
01531  490*              READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01543  491*              READ(12)  (STRESS(I), I=1,NDP)
01551  492*              READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01562  493*          DO 575 I= N1,NDP
01565  494*          S1CAL = 0.0
01566  495*          S2CAL = 0.0
01567  496*              DO 580 K=1,NBULKS
01572  497*              S1CAL = S1CAL + RO(K)*XF(K,I)
01573  498*              S2CAL = S1CAL
01574  499*   580        CONTINUE
01576  500*              DO 585 K=1,NTERMS
01601  501*              S1CAL = S1CAL + CO(K)*XF1(K,I)
01602  502*              S2CAL = S2CAL + CO(K)*XF2(K,I)
01603  503*   585    CONTINUE
01605  504*          S1 = STRUE(I) - PRES
01606  505*          S2 = -PRES
```

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01607  506*          DEV1 = 100*(S1CAL - S1)/S1
01610  507*          DEV2 = 100*(S2CAL - S2)/S2
01611  508*          IF(ABS(S1).LT.8.) GO TO 586
01613  509*          SUM1 = SUM1 + DEV1/100.
01614  510*          RESID1 = RESID1 + DEV1**2/10.**4
01615  511*    586   IF(ABS(S2).LT.8.) GO TO 587
01617  512*          SUM2 = SUM2 + DEV2/100.
01620  513*          RESID2 = RESID2 + DEV2**2/10.**4
01621  514*    587   CONTINUE
01622  515*          STRN = E11(I)
01622  516*    C
01623  517*          WRITE(6,588) TEMP(I), T(I), STRN, S1, S1CAL, DEV1, S2, S2CAL,
01623  518*         1             DEV2, PHFS
01637  519*          LINE = LINE + 2
01640  520*          IF(LINE.LT.48) GO TO 575
01642  521*          CALL PAGNL( IPG, NAME )
01643  522*          WRITE(6,675) L
01646  523*          LINE = 0
01647  524*    575   CONTINUE
01647  525*    C
01652  526*          XBAR = SUM1/NTOT
01653  527*          STD = ((NTOT*RESID1-SUM1**2)/(NTOT*(NTOT-1)))**0.5
01654  528*          CALL PAGNL( IPG, NAME )
01655  529*          WRITE(6,720) XBAR, STD
01661  530*          XBAR = SUM2/NTOT
01662  531*          STD = ((NTOT*RESID2-SUM2**2)/(NTOT*(NTOT-1)))**0.5
01663  532*          WRITE(6,725)  XBAR, STD
01663  533*    C
01663  534*    C         F O R M A T   S T A T E M E N T S
01663  535*    C
01667  536*      1   FORMAT(20A4)
01670  537*      2   FORMAT(8F10.0)
01671  538*      4   FORMAT( 2E10.0, I5)
01672  539*      7   FORMAT( 5F10.3, I5)
01673  540*     13   FORMAT(A6, F14.4, 2I5, 5A4, 2E15.6)
01674  541*     14   FORMAT(1P6E12.4)
01675  542*     15   FORMAT(1P3E20.6)
01676  543*     30   FORMAT(1H , //,20X,'THESE WERE ',I3, ' VALUES OF SHIFT FUNCTION VS
01676  544*    1, ' TEMPERATURE ...',///,T12,'I',T21,'AT(I)',T34,'TSHFT(I)', // )
01677  545*     31   FORMAT(1H ,10X, I2, T15,1PE10.3, T32, 1PE10.3 )
01700  546*     32   FORMAT(1H ,//,10X,'A = ',F10.3,/,10X,'Z = ', F10.3,///// )
01701  547*     33   FORMAT(1H ,10X,'TEST NO.',5X,'TEST ID',5X,' NBR ',5X,'MODE',5X,
01701  548*    1       'XTEMP',8X,'PRESSURE',8X,'TEMP', ///)
01702  549*     35   FORMAT(1H , 10X,I8, 5X,A6, 6X, I5, 5X, I4, 5X, I5, 8X, F8.2, 8X,
01702  550*    1       F6.1  )
01703  551*     40   FORMAT(1H , 20X, 'POWER LAW TERMS, (1 + A*T)** P',,//, 10X,
01703  552*    1       'I', 8X,'A(I)',11X,' P(I)', 9X,'IFG(I)', /,
01703  553*    2       7(/,10X,I1,5X,1PE10.3,5X,1PE10.3,7X,I3),///)
01704  554*     42   FORMAT(1H , 10X,' I',10X,'IFF(I)',/,I4(/,10X,I2,10X,I4), /// )
01705  555*     44   FORMAT(1H , 10X, 'I',10X, 'NORM', 12X, 'XN(I)', /,
01705  556*    1       6(/,10X,I1, 11X, I1, '0', 10X, 1PE10.3)  )
01706  557*     75   FORMAT(16I5)
01707  558*    410   FORMAT(1H , 20(/), 40X, 'I N V E R S E  F A I L E D  O N  R O W
01707  559*    1       ', I6 )
01710  560*    588   FORMAT(1H ,/, 6X, 10E12.4 )
01711  561*    650   FORMAT(1H , 40X,'SUMMARY OF SHEAR TERM FOR TEST NO.',I4,//, T9,
01711  562*    1       'TEMP', T19,'TIME', T26,'E11 OR E12', T39,'DV/V0', T49,
01711  563*    2   'STRUE',T58,'S-CALC',T69,'ERROR',T85,'XF(I),I=1,NTERMS', / )
01712  564*    655   FORMAT(1H , /,40X,'SUMMARY OF BULK RESULTS FOR TEST NO.',I5,//,T9,
01712  565*    1       'TEMP', T19,'TIME', T25,'STRAIN', T39,'DV/V0', T49,
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01712   566*          2      'SR-EXACT',T60,'SR-CALC',  T70,'ERROR','T95,'XF(K),K=1,NPULKS'
01712   567*          3      , / )
01713   568*     660  FORMAT(1H ,//,5X, 7F10.4,T80,'*', 5F10.4,2(/,T80,'*',5F10.4)  )
01714   569*     675  FORMAT(1H ,//,40X,'TEST NO. ',I4,',  F I N A L   S U M M A R Y',//,
01714   570*          1      T15,'TEMP',T27,'TIME',T38,'STRAIN',T51,'S11',T61,'S11-CALC',
01714   571*          2      T73,'ERROR',T87,'S22',T97,'S22-CALC',T111,'ERROR',T122,
01714   572*          3   'PRESSURE', / )
01715   573*     700  FORMAT(1H, 3(/), 30X,'REGRESSION COEFFICIENTS ...',//, 12X,'I',
01715   574*          1      26X, 'CO(I)',//,15(11X,I2,22X,1PE12.5,/), 10(/))
01716   575*     710  FORMAT(1H ,10X,'THERE WERE',I6,'  EXPERIMENTAL TEST POINTS', ///,
01716   576*          1       10X,'THE AVERAGE DEVIATION, XBAR, WAS ', F10.4, ///, 10X,
01716   577*          2       'THE STANDARD DEVIATION, STD, WAS ', F10.4  )
01717   578*     720  FORMAT(1H ,5(/),20X,'FOR THE STRESS SIGMA-11, ...',////,20X,
01717   579*          1      'XBAR = ',F10.4,5X,'AND STD = ', F10.4, //)
01720   580*     725  FORMAT(1H , 5(/), 20X,'FOR THE STRESS SIGMA-22, ...',////,20X,
01720   581*          1      'XBAR = ', F10.4, 5X, 'AND STD = ', F10.4 )
01720   582*  C
01721   583*          END
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* CROSS REFERENCE BY SEQUENCE NUMBER *

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SINGLE WORD HOLLERITH STRINGS------
DRUM  :   0114   0115
END   :   0105

NAMES------
A     :   0125   0174   0514
ABS   :   0634   01037  01251  01412  01611  01615
AT    :   0101   0232   0245   0260   0420
AVGAT :   0420   0421   0435
A1    :   0107   0454   0456   0460   0463
A2    :   0107   0455   0456   0460
A3    :   0564   0575   0576   0601
B     :   0101   0164   0200   0575   0576   0601
BB    :   0101   0276   0641   0732   01122  01256  01307
BCAL  :  01402  01406  01411  01420
BETA  :   0104
BO    :   0101   01307  01406  01453  01572
BUFFER:   0356
BULK  :   0104
CC    :   0101   0732   01033  01102  01234  01601  01602
D     :   0101   0260   0263   0420
DABS  :   0454   0455   0513   0514   0540
DEV   :  01036  01041  01042  01047  01411  01414  01415  01420
DEV1  :  01607  01613  01614  01623
DEV2  :  01610  01617  01620  01623
DEXP  :   0514
DI    :   0540   0541   0542   0543
DIL   :   0101   0104   0322   0654   0753   01047  01151  01213  01214  01215  01216  01223  01224  01225  01226  01227  01230
          01327  01420  01512
DR1   :   0101   0104   0323   0575
DR12  :   0101   0104   0325   0601
DR2   :   0101   0104   0324   0576
DSQRT :   0514
DT    :   0101   0104   0326   0421
DTR   :   0453   0460   0463
EQCT  :   0101   0104   0107   0654   0753   01151  01217  01220  01221  01222  01223  01224  01225  01226  01227  01230  01327
          01417  01512
EXP   :   0420
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F11    : 0101  0104  0327  0510  0512  0654  0753  01044 01151 01327 01512 01622
F12    : 0101  0104  0332  0654  0753  01045 01151 01327 01512
E22    : 0101  0104  0230  0511  0512
E33    : 0101  0104  0331
F      : 0101  0333  0504  0514  0517  0520  0621  0546  0547  0550  0606  0610
G      : 0101  0334  0513  0612  0614
I      : 0117  0131  0137  0145  0153  0164  0200  0211  0220  0245  0255  0260  0273  0276  0302  0307  0308
         0312  0317  0322  0323  0324  0325  0326  0327  0330  0331  0332  0333  0334  0335  0336  0337  0340
         0341  0342  0343  0344  0345  0346  0352  0402  0405  0407  0414  0420  0421  0432  0435  0450  0453
         0454  0455  0460  0463  0474  0477  0505  0510  0511  0512  0513  0514  0517  0520  0521  0631  0634
         0636  0641  0654  0673  0705  0713  0753  0772  01004 01012 01024 01033 01036 01037 01044 01045 01047
         01102 01123 01126 01151 01170 01202 01205 01207 01212 01213 01214 01215 01216 01217 01220 01221 01222
         01223 01224 01225 01226 01227 01230 01234 01246 01251 01255 01256 01266 01272 01327 01346 01360 01366
         01377 01406 01411 01412 01417 01420 01453 01512 01531 01543 01551 01562 01572 01601 01602 01605 01622
         01623
IFF    : 0101  0137  0211  0515  0544  0606  0610
IFG    : 0101  0131  0200  0612  0614
IFLAG  : 0111  0356  0724
IFN    : 0101  0145  0220  0530
INPUT  : 0104
INT1   : 0110  0505  0575  0604
INT12  : 0110  0567  0601
INT2   : 0110  0566  0576  0605
INV1   : 0101  0104  0107  0335  0654  0753  01151 01327 01512
INV2   : 0101  0104  0107  0336  0454  0455  0513  0514  0540  0654  0753  01151 01327 01512
INV3   : 0101  0104  0107  0337  0514  0654  0753  01151 01327 01512
IOUNIT : 0114  0115
IPG    : 0112  0173  0241  0270  0364  0742  01067 01101 01316 01440 01452 01501 01642 01654
ITEST  : 0104  0371
J      : 0307  0312  0411  0414  0420  0535  0540  0541  0542  0543  0546  0547  0550  0561  0570  0575  0576
         0601  0604  0505  0606  0610  0612  0614  0616  0626  0636  0637  01030 01033 01047 01130 01131 01242
         01253 01254 01403 01406 01420
K      : 0277  0302  0303  0304  0347  0352  0525  0530  0540  0570  0575  0576  0601  0623  0626  0641  0673
         0713  0772  01012 01117 01122 01126 01133 01170 01231 01234 01240 01253 01256 01272 01346 01366 01551
         01561 01567 01572 01576 01601 01602
KODE   : 0104  0371  0573  0647  0746  01045 01144 01322 01505
KTEMP  : 0104  0371  0424
L      : 0736  0743  01070 01141 01312 01317 01441 01475 01502 01643
LAST   : 0232  0237
LINE   : 0267  0361  0362  0367  0741  01064 01065 01073 01435 01436 01444 01500 01637 01640 01645
LOG    : 0260  0420
M      : 0420  0431  0435  0443  0446  0447  0460  0463  0467  0472  0477  0530  0531  0540  0555  0560  0564
         0575  0576  0601  0604  0605  0606  0610  0612  0614  0616
MATID  : 0101  0104
MP7    : 0560  0606  0610
N      : 0534  0541  0542  0543  0544  0546  0547  0550  0604  0605  0606  0610  0612  0614  0616
NAME   : 0101  0117  0173  0241  0270  0364  0742  01067 01101 01316 01440 01452 01501 01642 01654
NAT    : 0230  0231  0232  0242  0245  0255  0411
NBULKS : 01116 01240 01243 01307 01403 01420 01453 01567
NDP    : 0104  0371  0402  0432  0450  0474  0505  0535  0561  0631  0647  0654  0673  0705  0713  0746  0753
         0772  01004 01012 01023 01024 01144 01151 01170 01207 01246 01264 01272 01322 01327 01346 01360 01366
         01377 01505 01512 01531 01543 01551 01562
NEND   : 0105
NORM   : 0101  0104  0107  0352  0435  0460  0463  0477  0540
NORMF  : 0101  0104  0107  0340  0513
NORMS  : 0524  0533  0534  0622
NPL    : 0161  0164  0555  0622
NTERMS : 0622  0623  0626  0732  01030 01047 01102 01231 01576
NTEST  : 0264  0357  0371  0736  01141 01312 01475
NTOT   : 0733  01023 01077 01100 01111 01450 01451 01462 01652 01653 01661 01662
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```
FU      :  0113  0116  0456
M1      :  0366  0402  0405  0450  0474  0505  0535  0561  0570  0631  01024 01207 01246 01377 01562
P       :  0101  0164  0200  0564
PAGAL   :  0173  0241  0270  0364  0742  01067 01101 01316 01440 01452 01501 01642 01654
PRES    :  0104  0371  0647  0746  01144 01212 01322 01505 01605 01606 01623
R       :  0101  0312  0536  0732  01133 01253 01307
RATE    :  0101  0104  0341
REGR    :  0732  01307
RESID   :  0735  01042 01100 01311 01415 01451
RESID1  :  01473 01614 01653
RESID2  :  01474 01620 01662
SCAL    :  01027 01033 01036 01047
STD     :  01100 01111 01451 01462 01653 01655 01662 01663
STRESS  :  0101  0104  0342  0765  01094 01205 01212 01234 01251 01253 01256 01264 01360 01411 01412 01420 01583
STRN    :  01644 01646 01647 01417 01420 01622 01623
STRUE   :  0101  0104  0343  0634  0636  0641  0654  0753  01036 01037 01047 01151 01212 01327 01512 01605
SUM     :  0734  01041 01077 01100 01310 01414 01450 01451
SUM1    :  01471 01613 01652 01653
SUM2    :  01472 01617 01661 01662
S1      :  01605 01607 01611 01623
S1CAL   :  01565 01572 01573 01601 01607 01623
S2      :  01606 01610 01615 01623
S2CAL   :  01566 01573 01602 01610 01623
T       :  0101  0104  0344  0654  0753  01047 01151 01327 01420 01512 01623
TEMP    :  0101  0104  0345  0371  0407  0414  0420  0654  0753  01047 01151 01327 01420 01512 01623
TR      :  0101  0346  0421  0453  0575  0576  0601
TSHFT   :  0101  0232  0245  0260  0414  0420
WORK1   :  0103  0114
WORK2   :  0103  0115
XBAR    :  01077 01111 01450 01462 01652 01655 01661 01663
XF      :  0101  0304  0512  0521  0543  0550  0616  0636  0641  0713  01012 01033 01047 01126 01213 01214 01215
           01216 01217 01220 01221 01222 01223 01224 01225 01226 01227 01230 01253 01256 01272 01366 01406 01420
           01551 01572
XF1     :  0101  0302  0510  0517  0541  0546  0604  0606  0612  0616  0673  0772  01170  01234 01346 01531 01601
XF2     :  0101  0303  0511  0520  0542  0547  0605  0610  0614  0616  0673  0772  01170  01234 01346 01531 01602
XN      :  0101  0153  0220  0540
XP      :  0431  0435  0446  0460  0472  0473  0477
XQ      :  0447  0463
Z       :  0125  0174  0513

LABELS
      1:  0117  01667
      2:  0125  0153  0164  01670
      3:  0231  0237
      4:  0232  01671
      5:  0255  0261
      7:  01672
      8:  0402  0422
      9:  0405  0411
     10:  0407  0421
     11:  0411  0416
     12:  0414  0420
     13:  01673
     14:  01674
     15:  01675
     18:  0424  0442
     19:  0441  0503
     20:  0443  0458  0461  0464
     21:  0456  0462
     22:  0467  0474  0500
```

```
   30:   0242  01676
   31:   0245  01677
   32:   0174  01700
   33:   0271   0365  01701
   34:   0362   0370
   35:   0371  01702
   40:   0208  01703
   42:   0211  01704
   44:   0226  01705
   50:   0525   0541   0553
   55:   0535   0544   0551
   60:   0426   0432   0436
   65:   0505   0515   0522
   70:   0555   0561   0617
   71:   0570   0577   0602
   75:   0131   0137   0145   0161  01706
   78:   0573   0600
  100:   0316   0726
  105:   0277   0305
  107:   0317   0347   0353
  110:   0273   0307   0313
  200:   0724   0727
  300:   0623   0626   0644
  310:   0631   0634   0637   0642
  410:  01707
  500:  01141  01303
  501:  01202  01205
  505:  01117  01130  01134
  506:  01123  01126
  510:  01207  01231  01235
  520:  01240  01243  01261
  530:  01246  01251  01254  01267
  550:  01312  01377  01436  01445
  560:  01403  01407
  565:  01412  01416
  575:  01476  01562  01640  01647
  580:  01567  01574
  585:  01576  01603
  586:  01611  01615
  587:  01615  01621
  588:  01623  01710
  600:   0736  01024  01065  01074
  605:  01037  01043
  610:  01030  01034
  650:   0743  01070  01711
  655:  01317  01441  01712
  660:  01047  01420  01713
  675:  01502  01643  01714
  700:  01102  01453  01715
  710:  01111  01462  01716
  720:  01655  01717
  725:  01663  01720

INTEGER CONSTANTS-----
     0:   0111   0112   0230   0237   0264   0267   0367   0515   0524   0531   0544   0606   0610   0612   0614   0733
          0741  01073  01315  01444  01500  01646
     1:   0113   0117   0131   0137   0145   0153   0164   0200   0211   0220   0231   0245   0260   0263   0273   0277
          0307   0317   0347   0357   0361   0371   0407   0411   0420   0421   0426   0432   0443   0453   0455   0460
          0463   0467   0504   0510   0511   0512   0515   0517   0520   0521   0525   0533   0534   0541   0542   0543
          0555   0575   0576   0601   0622   0623   0626   0637   0654   0673   0705   0713   0736   0753   0772  01004
```

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```
                01012  01030  01047  01100  01102  01117  01123  01130  01141  01151  01170  01202  01213  01231  01240  01243
                01254  01264  01272  01312  01327  01346  01360  01366  01403  01420  01451  01453  01475  01512  01531  01543
                01551  01567  01576  01653  01662
            2:  0255   0263   0424   0636   0729   01042  01100  01214  01224  01225  01226  01230  01234  01253  01415  01451
                01614  01620  01637  01653  01662
            3:  0360   0573   01045  01215  01227  01230
            4:  01042  01064  01216  01415  01435  01614  01620
            5:  0101   0117   0125   0131   0137   0145   0153   0161   0164   0232   01217
            6:  0101   0145   0153   0174   0200   0211   0220   0242   0245   0271   0347   0365   0371   0426   0443   0467
                0525   0743   01047  01070  01102  01111  01220  01317  01420  01441  01453  01462  01502  01625  01643  01655
                01663
            7:  0101   0103   0131   0200   0560   01221
            8:  01222
            9:  01223
           10:  0431   01224
           11:  0114   0265   0647   0654   0673   0730   0746   0753   0772   01137  01144  01151  01170  01225  01305  01322
                01327  01346  01467  01505  01512  01631
           12:  0115   0266   0705   0713   0731   01004  01012  01140  01226  01264  01272  01306  01360  01366  01470  01543
                01551
           13:  01227
           14:  0101   0137   0211   0273   0307   0673   0713   0772   01012  01116  01117  01130  01170  01230  01272  01346
                01366  01531  01551
           20:  0101   0117
           48:  01065  01436  01640
           50:  0362
          100:  0101   0277   0317   01036  01123  01202  01411  01607  01610

REAL CONSTANTS------
0.0000000E+00:  0276   0302   0303   0304   0312   0322   0323   0324   0325   0326   0327   0330   0331   0332   0333   0334
                0341   0342   0343   0344   0345   0346   0504   0565   0566   0567   0734   0735   01027  01122  01126  01133
                01205  01310  01311  01402  01471  01472  01473  01474  01565  01566
0.2500000E+00:  0115
0.5000000E+00:  01100  01451  01653  01662
0.7500000E+00:  0114
0.1000000E+01:  0431   0435   0446   0473   0513   0544   0575   0576   0601
0.2000000E+01:  01212  01220
0.3000000E+01:  01221
0.4000000E+01:  01222
0.8000000E+01:  0634   01037  01251  01412  01611  01615
0.1000000E+02:  0446   0447   0472   01042  01415  01614  01620
0.1000000E+03:  01041  01414  01613  01617

DOUBLE PRECISION CONSTANTS------
0.0000000E+00:  0335   0336   0337   0340   0352
```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 2 *DIAGNOSTIC* MESSAGE(S)

NL002		SYMBOLIC	15 JUN 73	13:44(01)	0	00213314	14	583 (DELETED)
NL002	CORE	RELOCATABLE	15 JUN 73	13:44(01)	0	00233256	14	235 (DELETED)
					1	00241610	36	1

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APPENDIX E

CHARACTERIZATION CODE NL003

1.0 INTRODUCTION

The computer code NL003 is identical in input and operation as NL002 and performs the identical distortional characterization. NL003 differs from NL002 in the bulk characterization. In this code the dilatation is expressed in terms of the mean pressure and the octahedral shear strain as discussed in the text of this report.

Since the code operation is identical only a sample problem and the listing is provided in this appendix.

NL003 DEMONSTRATION PROBLEM

A = -.100+01
Z = .100+01

POWER LAW TERMS, (1 + B*T)** P

I	B(I)	P(I)	IFG(I)
1	1.000+10	-1.330-01	0
2	1.000+10	-2.660-01	0
3	1.000+10	-4.000-01	0
4	0.000	0.000	0
5	0.000	0.000	0
6	0.000	0.000	0
7	0.000	0.000	0

I	IFF(I)
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1

I	NORM	XN(I)
1	30	2.000+00
2	30	4.000+00
3	30	6.000+00
4	40	8.000+00
5	50	1.000+01
6	60	1.200+01

NL003 DEMONSTRATION PROBLEM

THERE WERE 10 VALUES OF SHIFT FUNCTION VS. TEMPERATURE ...

I	AT(I)	TSHFT(I)
1	1.000+10	-9.000+01
2	1.000+08	-6.500+01
3	1.500+06	-4.000+01
4	6.000+04	-2.000+01
5	3.000+03	0.000
6	2.800+01	4.000+01
7	1.000+00	7.700+01
8	2.500-01	1.000+02
9	3.000-02	1.400+01
10	1.000-02	1.600+02

NLOOP3 DEMONSTRATION PROBLEM

TEST NO.	TEST ID	NDP	KODE	KTEMP	PRESSURE	TEMP
1	U00300	20	1	1	.00	77.0
2	U10300	16	1	1	50.00	77.0
3	U10305	25	1	1	100.00	77.0
4	U10322	14	1	1	500.00	77.0
5	U10326	16	1	1	1000.00	77.0

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 1

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
.7700+02	.7000-01	.3561-01	.3561-07	.1656+02	.1936+02	.1089+02	* .5200-01 .1084-03 .2239-06 .4625-09 .6730-12 * .9674-15 .1380-17 .4034-02 .3175-07 .2535-04
.7700+02	.1100+00	.5651-01	.6001-03	.2637+02	.2595+02	-.1588+01	* .8223-01 .4022-03 .1969-05 .9637-08 .3426-10 * .1203-12 .4192-15 .5947-02 .4405-03 .3309-04
.7700+02	.1600+00	.8320-01	.2000-02	.3841+02	.3924+02	.2158+01	* .1191+00 .1182-02 .1174-04 .1167-06 .8634-09 * .6311-11 .4577-13 .8195-02 .5773-03 .4123-04
.7700+02	.2100+00	.1105+00	.4300-02	.4929+02	.5543+02	.1246+02	* .1557+00 .2556-02 .4208-04 .6926-06 .8648-08 * .1067-09 .1305-11 .1033-01 .7014-03 .4829-04
.7700+02	.2600+00	.1384+00	.8300-02	.5762+02	.7043+02	.2224+02	* .1916+00 .4603-02 .1110-03 .2676-05 .4969-07 * .9113-09 .1658-10 .1235-01 .8145-03 .5444-04
.7700+02	.3100+00	.1670+00	.1390-01	.6424+02	.8110+02	.2626+02	* .2270+00 .7369-02 .2404-03 .7842-05 .1994-06 * .5007-08 .1248-09 .1428-01 .9198-03 .6000-04
.7700+02	.3600+00	.1962+00	.2100-01	.6932+02	.8624+02	.2624+02	* .2620+00 .1086-01 .4532-03 .1891-04 .6211-06 * .2015-07 .6487-09 .1615-01 .1019-02 .6515-04
.7700+02	.4100+00	.2260+00	.2950-01	.7161+02	.8671+02	.2109+02	* .2967+00 .1507-01 .7709-03 .3943-04 .1602-05 * .6432-07 .2562-08 .1797-01 .1115-02 .6999-04
.7700+02	.4600+00	.2564+00	.3880-01	.7386+02	.8456+02	.1449+02	* .3314+00 .2082-01 .1220-02 .7432-04 .3623-05 * .1745-06 .8337-08 .1977-01 .1208-02 .7471-04
.7700+02	.5100+00	.2875+00	.4870-01	.7574+02	.8197+02	.8231+01	* .3662+00 .2573-01 .1825-02 .1295-03 .7396-05 * .4174-06 .2337-07 .2156-01 .1299-02 .7932-04
.7700+02	.5600+00	.3192+00	.5950-01	.7710+02	.8061+02	.4556+01	* .4010+00 .3209-01 .2596-02 .2100-03 .1377-04 * .8913-06 .5725-07 .2332-01 .1389-02 .8376-04
.7700+02	.6100+00	.3515+00	.7020-01	.7821+02	.8182+02	.4614+01	* .4362+00 .3932-01 .3587-02 .3273-03 .2431-04 * .1784-05 .1298-06 .2510-01 .1479-02 .8827-04

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 1

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
.7700+02	.6600+00	.3844+00	.8150-01	.7904+02	.8484+02	.7345+01	* .4715+00 .4721-01 .8790-02 .4859-03 .4033-04 * .3306-05 .2689-06 .2686-01 .1568-02 .9264-04 *
.7700+02	.7100+00	.4180+00	.9250-01	.7947+02	.8961+02	.1276+02	* .5074+00 .5603-01 .6280-02 .7038-03 .6477-04 * .5888-05 .5311-06 .2865-01 .1657-02 .9711-04 *
.7700+02	.7600+00	.4522+00	.1045+00	.7997+02	.9195+02	.1498+02	* .5433+00 .6532-01 .7978-02 .9744-03 .9816-04 * .9767-05 .9643-06 .3041-01 .1744-02 .1013-03 *
.7700+02	.8100+00	.4870+00	.1160+00	.7980+02	.9234+02	.1572+02	* .5798+00 .7563-01 .1004-01 .1352-02 .1463-03 * .1587-04 .1707-05 .3221-01 .1833-02 .1057-03 *
.7700+02	.8600+00	.5224+00	.1275+00	.7946+02	.8702+02	.9514+01	* .6167+00 .8676-01 .1243-01 .1782-02 .2121-03 * .2492-04 .2306-05 .3401-01 .1922-02 .1101-03 *
.7700+02	.9100+00	.5585+00	.1390+00	.7839+02	.7330+02	-.6495+01	* .6540+00 .9872-01 .1520-01 .2341-02 .3003-03 * .3804-04 .4741-05 .3582-01 .2011-02 .1184-03 *

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 2

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XE(I),I=1,NTERMS
.7700+02	.6000-01	.3042-01	-.9997-04	.1597+02	.1667+02	.4411+01	* .4500-01 .6902-04 .1059-06 .1624-09 .1738-12 * .1836-15 .1925-18 .3529-02 .2835-03 .2311-04 *
.7700+02	.1100+00	.5648-01	.3001-03	.2048+02	.2603+02	-.8597+01	* .8232-01 .4040-03 .1984-05 .9743-08 .3474-10 * .1224-12 .4277-15 .5955-02 .4412-03 .3315-04 *
.7700+02	.1600+00	.8316-01	.1100-02	.4210+02	.3957+02	-.6002+01	* .1195+00 .1196-02 .1199-04 .1202-06 .8975-09 * .6618-11 .4842-13 .8223-02 .5795-03 .4141-04 *
.7700+02	.2100+00	.1105+00	.2600-02	.5242+02	.5607+02	.6964+01	* .1564+00 .2605-02 .4351-04 .7267-06 .9205-08 * .1152-09 .1429-11 .1038-01 .7053-03 .4858-04 *
.7700+02	.2600+00	.1384+00	.4900-02	.6290+02	.7153+02	.1372+02	* .1930+00 .4760-02 .1178-03 .2917-05 .5556-07 * .1045-08 .1051-10 .1245-01 .8221-03 .5501-04 *
.7700+02	.3100+00	.1670+00	.7900-02	.7110+02	.8218+02	.1559+02	* .2295+00 .7769-02 .2644-03 .8997-05 .3383-06 * .6237-08 .1619-09 .1445-01 .9325-03 .6095-04 *
.7700+02	.3600+00	.1962+00	.1170-01	.7743+02	.8634+02	.1152+02	* .2657+00 .1170-01 .5187-03 .2299-04 .8014-06 * .2759-07 .9425-09 .1641-01 .1038-02 .6647-04 *
.7700+02	.4100+00	.2260+00	.1640-01	.8247+02	.8524+02	.3363+01	* .3018+00 .1659-01 .9158-03 .5058-04 .2242-05 * .9735-07 .4195-08 .1831-01 .1138-02 .7165-04 *
.7700+02	.4600+00	.2564+00	.2170-01	.8640+02	.8216+02	-.4908+01	* .3378+00 .2251-01 .1514-02 .1019-03 .5475-05 * .2907-06 .1572-07 .2015-01 .1256-02 .7664-04 *
.7700+02	.5100+00	.2875+00	.2750-01	.8976+02	.8078+02	-.1000+02	* .3739+00 .2948-01 .2350-02 .1874-03 .1202-04 * .7613-06 .4785-07 .2205-01 .1332-02 .8147-04 *
.7700+02	.5600+00	.3192+00	.3340-01	.9192+02	.8405+02	-.8552+01	* .4101+00 .3740-01 .3493-02 .3244-03 .2438-04 * .1809-05 .1372-06 .2390-01 .1426-02 .8623-04 *
.7700+02	.6100+00	.3515+00	.3940-01	.9408+02	.9264+02	-.1526+01	* .4466+00 .4692-01 .5004-02 .5335-03 .4626-04 * .3961-05 .3366-06 .2574-01 .1520-02 .9091-04 *

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 2

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS				
.7700+02	.6600+00	.3844+00	.4540-01	.9496+02	.1047+03	.1028+02	* .4833+00	.5750-01	.6955-02	.8813-03	.8313-04
							* .8114-05	.7857-06	.2758-01	.1613-02	.9553-04
							*				
.7700+02	.7100+00	.4180+00	.5100-01	.9516+02	.1169+03	.2280+02	* .5204+00	.6952-01	.9459-02	.1287-02	.1437-03
							* .1584-04	.1732-05	.2944-01	.1706-02	.1002-03
							*				

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 3

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
.7700+02	.7000-01	.3554-01	-.2000-03	.1760+02	.1836+02	.4364+01	* .5250-01 .1004-03 .2241-06 .4630-09 .6736-12 * .9691-15 .1383-17 .4034-02 .3174-03 .2535-04
.7700+02	.1100+00	.5644-01	.5644-07	.2848+02	.2610+02	-.8378+01	* .8241-01 .4057-03 .1998-05 .9848-08 .3521-10 * .1244-12 .4361-15 .5963-02 .4418-03 .3320-04
.7700+02	.1600+00	.8313-01	.5001-03	.4232+02	.3976+02	-.6055+01	* .1197+00 .1205-02 .1215-04 .1225-06 .9192-09 * .6815-11 .5013-13 .8240-02 .5808-03 .4151-04
.7700+02	.2100+00	.1104+00	.1200-02	.5632+02	.5660+02	.4978+00	* .1570+00 .2685-02 .4449-04 .7552-06 .9672-09 * .1224-09 .1536-11 .1042-01 .7085-03 .4883-04
.7700+02	.2540+00	.1350+00	.2300-02	.6754+02	.7058+02	.4508+01	* .1896+00 .4556-02 .1099-03 .2651-05 .4911-07 * .8984-09 .1671-10 .1227-01 .8137-03 .5468-04
.7700+02	.2600+00	.1350+00	.2350-02	.6101+02	.6795+02	.1137+02	* .1896+00 .4395-02 .1023-03 .2380-05 .4290-07 * .7693-09 .1369-10 .1205-01 .7757-03 .4967-04
.7700+02	.2700+00	.1350+00	.2400-02	.5696+02	.6209+02	.9003+01	* .1896+00 .4244-02 .9526-04 .2143-05 .3822-07 * .6775-09 .1197-10 .1183-01 .7442-03 .4632-04
.7700+02	.2900+00	.1350+00	.2100-02	.5325+02	.5513+02	.3540+01	* .1897+00 .4092-02 .8819-04 .1905-05 .3374-07 * .5956-09 .1049-10 .1152-01 .7033-03 .4230-04
.7700+02	.3600+00	.1350+00	.2000-02	.4841+02	.4536+02	-.6290+01	* .1897+00 .3835-02 .7784-04 .1580-05 .2784-07 * .4899-09 .8616-11 .1086-01 .6231-03 .3907-04
.7700+02	.4500+00	.1350+00	.1900-02	.4571+02	.4224+02	-.7585+01	* .1897+00 .3693-02 .7217-04 .1410-05 .2483-07 * .4370-09 .7687-11 .1036-01 .5660-03 .3629-04
.7700+02	.6500+00	.1350+00	.1800-02	.4278+02	.4389+02	.2590+01	* .1898+00 .3533-02 .6600-04 .1233-05 .2171-07 * .3821-09 .6724-11 .9692-02 .4951-03 .2475-04
.7700+02	.6600+00	.1406+00	.1900-02	.5813+02	.5331+02	-.8287+01	* .1973+00 .4267-02 .8266-04 .2012-05 .4121-07 * .8428-09 .1722-10 .1041-01 .5689-03 .3247-04

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 3

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS				
.7700+02	.6800+00	.1520+00	.2900-02	.7070+02	.6796+02	-.3867+01	* .2119+00	.5896-02	.1648-03	.4606-05	.1152-06
							* .2760-08	.6396-10	.1152-01	.6557-03	.3921-04
							*				
.7700+02	.7100+00	.1692+00	.4100-02	.8082+02	.8066+02	-.1938+00	* .2340+00	.8281-02	.2947-03	.1048-04	.2951-06
							* .8128-08	.2218-09	.1303-01	.7605-03	.4650-04
							*				
.7700+02	.7600+00	.1965+00	.6400-02	.9190+02	.8955+02	-.2553+01	* .2708+00	.1256-01	.5868-03	.2741-04	.1007-05
							* .3655-07	.1316-08	.1532-01	.9064-03	.5573-04
							*				
.7700+02	.8100+00	.2283+00	.9300-02	.1004+03	.9050+02	-.9890+01	* .3075+00	.1790-01	.1051-02	.6171-04	.2874-05
							* .1322-06	.6034-08	.1747-01	.1034-02	.6326-04
							*				
.7700+02	.8600+00	.2588+00	.1270-01	.1075+03	.8932+02	-.1690+02	* .3442+00	.2440-01	.1748-02	.1252-03	.7165-05
							* .4051-06	.2272-07	.1953-01	.1152-02	.6980-04
							*				
.7700+02	.9100+00	.2899+00	.1640-01	.1131+03	.9114+02	-.1940+02	* .3809+00	.3213-01	.2745-02	.2344-03	.1610-04
							* .1093-05	.7356-07	.2154-01	.1263-02	.7597-04
							*				
.7700+02	.9600+00	.3217+00	.2050-01	.1175+03	.9884+02	-.1589+02	* .4177+00	.4113-01	.4108-02	.4103-03	.3916-04
							* .2647-05	.2096-06	.2351-01	.1369-02	.8163-04
							*				
.7700+02	.1010+01	.3540+00	.2450-01	.1211+03	.1128+03	-.6892+01	* .4546+00	.5154-01	.5938-02	.6841-03	.6410-04
							* .5931-05	.5486-06	.2545-01	.1472-02	.8707-04
							*				
.7700+02	.1060+01	.3870+00	.2860-01	.1238+03	.1287+03	.3930+01	* .4918+00	.6336-01	.8312-02	.1091-02	.1169-03
							* .1238-04	.1300-05	.2738-01	.1573-02	.9228-04
							*				
.7700+02	.1110+01	.4206+00	.3260-01	.1259+03	.1410+03	.1198+02	* .5292+00	.7669-01	.1134-01	.1678-02	.2036-03
							* .2441-04	.2904-05	.2929-01	.1672-02	.9734-04
							*				
.7700+02	.1160+01	.4549+00	.3600-01	.1263+03	.1454+03	.1519+02	* .5670+00	.9180-01	.1520-01	.2518-02	.3835-03
							* .4629-04	.6189-05	.3121-01	.1770-02	.1024-03
							*				

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 4

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	X**(I),I=1,NTERMS
.7700+02	.5000-01	.2497-01	-.1000-02	.1640+02	.1494+02	-.8931+01	.3749-01 .4045-04 .4365-07 .4710-10 .5081-13 .2571-16 .1873-19 .3012-02 .2479-03 .2071-04
.7700+02	.1000+00	.5090-01	-.9599-03	.3256+02	.2397+02	-.2638+02	.7496-01 .3082-03 .1268-05 .5216-08 .1548-10 .4539-13 .1320-15 .5493-02 .4123-03 .3139-04
.7700+02	.1500+00	.7745-01	-.8999-03	.4946+02	.3688+02	-.2544+02	.1124+00 .1008-02 .9045-05 .8118-07 .5800-09 .3548-11 .2313-13 .7808-02 .5553-03 .4005-04
.7700+02	.2500+00	.1324+00	-.7499-03	.8326+02	.7011+02	-.1578+02	.1875+00 .4450-02 .1060-03 .2526-05 .4615-07 .8327-09 .1491-10 .1217-01 .8086-03 .5447-04
.7700+02	.3500+00	.1869+00	-.6298-03	.1128+03	.8613+02	-.2365+02	.2627+00 .1174-01 .5283-03 .2378-04 .8587-06 .2922-07 .1010-08 .1631-01 .1037-02 .6682-04
.7700+02	.4500+00	.2499+00	-.4998-03	.1378+03	.8164+02	-.4076+02	.3381+00 .2404-01 .1728-02 .1242-03 .7112-05 .4023-06 .2957-07 .2031-01 .1250-02 .7793-04
.7700+02	.5500+00	.3124+00	-.3997-03	.1555+03	.9544+02	-.3864+02	.4139+00 .4232-01 .4395-02 .4564-03 .3824-04 .3165-05 .2599-06 .2422-01 .1452-02 .8923-04
.7700+02	.6500+00	.3774+00	-.3096-03	.1676+03	.1381+03	-.1759+02	.4899+00 .6776-01 .9452-02 .1326-02 .1518-03 .1715-04 .1923-05 .2807-01 .1647-02 .9705-04
.7700+02	.7000+00	.4108+00	-.2796-03	.1714+03	.1553+03	-.9436+01	.5281+00 .8263-01 .1323-01 .2118-02 .2777-03 .3597-04 .4623-05 .2997-01 .1743-02 .1027-03
.7700+02	.7500+00	.4449+00	-.2496-03	.1739+03	.1617+03	-.7050+01	.5664+00 .9978-01 .1804-01 .3261-02 .4868-03 .7120-04 .1037-04 .3186-01 .1837-02 .1073-03
.7700+02	.8000+00	.4795+00	-.2195-03	.1757+03	.1621+03	-.7712+01	.6048+00 .1189+00 .2405-01 .4864-02 .8125-03 .1341-03 .2194-04 .3374-01 .1929-02 .1118-03
.7700+02	.8500+00	.5148+00	-.2095-03	.1745+03	.1721+03	-.1394+01	.6433+00 .1400+00 .3144-01 .7061-02 .1314-02 .2417-03 .4408-04 .3562-01 .2021-02 .1162-03

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 5

TEMP	TIME	EII OR EI2	DV/V0	STRUE	S-CALC	ERROR	XF(I),I=1,NTERMS
.7700+02	.5000-01	.2463-01	-.2000-02	.1230+02	.1493+02	.2134+02	* .3748-01 .4034-04 .4343-07 .4676-10 .5068-13 * .2541-16 .1847-19 .3011-02 .2478-05 .2070-08
.7700+02	.1300+00	.6640-01	-.1980-02	.4262+02	.3114+02	-.2692+02	* .9744-01 .6648-03 .4541-05 .3102-07 .1555-09 * .7704-12 .3746-14 .6896-02 .4908-03 .3674-04
.7700+02	.2300+00	.1209+00	-.1920-02	.7696+02	.6389+02	-.1698+02	* .1725+00 .3504-02 .7143-04 .1456-05 .2263-07 * .3475-09 .5293-11 .1132-01 .7604-03 .5179-04
.7700+02	.3300+00	.1778+00	-.1830-02	.1107+03	.8523+02	-.2302+02	* .2476+00 .9940-02 .4016-03 .1622-04 .5117-06 * .1594-07 .4929-09 .1549-01 .9927-03 .6846-04
.7700+02	.4300+00	.2373+00	-.1760-02	.1386+03	.8237+02	-.4055+02	* .3230+00 .2118-01 .1404-02 .9300-04 .6894-05 * .2544-06 .1312-07 .1952-01 .1208-02 .7578-04
.7700+02	.5300+00	.2993+00	-.1600-02	.1582+03	.8973+02	-.4327+02	* .3986+00 .3822-01 .3719-02 .3619-03 .3835-04 * .2193-05 .1684-06 .2344-01 .1812-02 .1620-04
.7700+02	.6300+00	.3637+00	-.1480-02	.1716+03	.1296+03	-.2448+02	* .4746+00 .6189-01 .8229-02 .1094-02 .1184-03 * .1266-04 .1342-05 .2729-01 .1608-02 .9601-04
.7700+02	.6800+00	.3969+00	-.1420-02	.1769+03	.1500+03	-.1520+02	* .5127+00 .7642-01 .1165-01 .1775-02 .2211-03 * .2721-04 .3322-05 .2920-01 .1704-02 .1008-03
.7700+02	.7300+00	.4307+00	-.1370-02	.1902+03	.1607+03	-.1085+02	* .5509+00 .9282-01 .1603-01 .2769-02 .3927-03 * .5501-04 .7646-05 .3110-01 .1799-02 .1054-03
.7700+02	.7800+00	.4651+00	-.1320-02	.1821+03	.1621+03	-.1100+02	* .5892+00 .1112+00 .2155-01 .4180-02 .6683-03 * .1055-03 .1654-04 .3298-01 .1892-02 .1099-03
.7700+02	.8300+00	.5002+00	-.1269-02	.1840+03	.1664+03	-.9542+01	* .6277+00 .1315+00 .2838-01 .6139-02 .1095-02 * .1933-03 .3386-04 .3686-01 .1984-02 .1184-03
.7700+02	.8800+00	.5358+00	-.1239-02	.1936+03	.1888+03	.2806+01	* .6662+00 .1538+00 .3671-01 .8761-02 .1737-02 * .3401-03 .6607-04 .3673-01 .2075-02 .1188-03

NL003 DEMONSTRATION PROBLEM
SUMMARY OF SHEAR TERM FOR TEST NO. 5

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR		XF(I),I=1,NTERMS				
.7700+02	.9300+00	.5721+00	-.1219-02	.1817+03	.2141+03	.1781+02	*	.7049+00	.1781+00	.4670-01	.1224-01	.2674-02
							*	.5771-03	.1235-03	.3859-01	.2165-02	.1231-03
							*					
.7700+02	.9700+00	.6016+00	-.1209-02	.1767+03	.1623+03	-.8180+01	*	.7359+00	.1991+00	.5603-01	.1577-01	.3706-02
							*	.8605-03	.1982-03	.4008-01	.2237-02	.1265-03
							*					

NL003 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	6.28058+03
2	2.63588+04
3	-7.50470+05
4	8.93190+06
5	-6.32645+07
6	2.21092+08
7	-3.00840+08
8	-2.80744+05
9	3.80980+06
10	-1.64232+07

THERE WERE 91 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0221

THE STANDARD DEVIATION, STD, WAS .1485

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 1

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC. ERROR		XF(K),K=1,NBULKS				
.7700+02	.7000-01	.2476-01	.5010+01	.3561-07	-.1350-03	-.3792+06	* .5010+01	.2510+02	.1258+03	.6300+03	.2476-01
							* .6130-03	.1518-04	.3757-06	.2603-01	.6445-03
							* .1596-04	.2737-01	.6776-03	.1678-04	
.7700+02	.1100+00	.3879-01	.8187+01	.6001-03	.5389-03	-.1019+02	* .8187+01	.6702+02	.5487+03	.4492+04	.3879-01
							* .1505-02	.5038-04	.2265-05	.4210-01	.1633-02
							* .6336-04	.4570-01	.1773-02	.6877-04	
.7700+02	.1600+00	.5624-01	.1112+02	.2000-02	.2331-02	.1653+02	* .1112+02	.1236+03	.1374+04	.1528+05	.5624-01
							* .3163-02	.1779-03	.1001-04	.6286-01	.3535-02
							* .1988-03	.7025-01	.3951-02	.2222-03	
.7700+02	.2100+00	.7358-01	.1253+02	.4300-02	.5222-02	.2145+02	* .1253+02	.1571+03	.1968+04	.2467+05	.7358-01
							* .5413-02	.3993-03	.2931-04	.8340-01	.6136-02
							* .4515-03	.9453-01	.6955-02	.5118-03	
.7700+02	.2600+00	.9065-01	.1241+02	.8300-02	.9060-02	.9151+01	* .1241+02	.1561+03	.1912+04	.2373+05	.9065-01
							* .8218-03	.7449-03	.6753-04	.1026+00	.9304-02
							* .8434-03	.1162+00	.1053-01	.9548-03	
.7700+02	.3100+00	.1075+00	.1205+02	.1390-01	.1384-01	-.4678+00	* .1205+02	.1453+03	.1752+04	.2112+05	.1075+00
							* .1156-01	.1243-02	.1337-03	.1213+00	.1304-01
							* .1402-02	.1368+00	.1471-01	.1582-02	
.7700+02	.3600+00	.1242+00	.1155+02	.2100-01	.1952-01	-.7045+01	* .1155+02	.1335+03	.1542+04	.1781+05	.1242+00
							* .1544-01	.1918-02	.2383-03	.1395+00	.1733-01
							* .2153-02	.1565+00	.1945-01	.2417-02	
.7700+02	.4100+00	.1409+00	.1180+02	.2950-01	.2644-01	-.1037+02	* .1180+02	.1391+03	.1641+04	.1936+05	.1409+00
							* .1984-01	.2796-02	.3938-03	.1585+00	.2233-01
							* .3146-02	.1784+00	.2512-01	.3539-02	
.7700+02	.4600+00	.1575+00	.1238+02	.3880-01	.3471-01	-.1054+02	* .1230+02	.1533+03	.1897+04	.2349+05	.1575+00
							* .2482-01	.3909-02	.6158-03	.1783+00	.2809-01
							* .4424-02	.2018+00	.3179-01	.5008-02	
.7700+02	.5100+00	.1743+00	.1310+02	.4870-01	.4442-01	-.8792+01	* .1310+02	.1715+03	.2247+04	.2943+05	.1743+00
							* .3037-01	.5293-02	.9225-03	.1987+00	.3462-01
							* .6034-02	.2265+00	.3947-01	.6879-02	
.7700+02	.5600+00	.1911+00	.1330+02	.5950-01	.5513-01	-.7337+01	* .1330+02	.1770+03	.2355+04	.3133+05	.1911+00
							* .3651-01	.6976-02	.1333-02	.2183+00	.4171-01
							* .7969-02	.2493+00	.4764-01	.9103-02	
.7700+02	.6100+00	.2081+00	.1288+02	.7020-01	.6670-01	-.4989+01	* .1288+02	.1660+03	.2138+04	.2754+05	.2081+00
							* .4331-01	.9014-02	.1876-02	.2367+00	.4927-01
							* .1025-01	.2693+00	.5604-01	.1166-01	

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 1

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC.	ERROR		XF(K),K=1,NBULKS			
.7700+02	.6600+00	.2253+00	.1176+02	.8150-01	.7968-01	-.3458+01	*	.1176+02	.1383+03	.1626+04	.1911+05	.2253+00
							*	.5075-01	.1143-01	.2575-02	.2534+00	.5708-01
							*	.1286-01	.2850+00	.6420-01	.1446-01	
.7700+02	.7100+00	.2427+00	.1004+02	.9250-01	.9105-01	-.1572+01	*	.1004+02	.1008+03	.1012+04	.1015+05	.2427+00
							*	.5891-01	.1430-01	.3470-02	.2683+00	.6513-01
							*	.1581-01	.2967+00	.7201-01	.1748-01	
.7700+02	.7600+00	.2602+00	.8963+01	.1045+00	.1052+00	.6578+00	*	.8963+01	.8053+02	.7200+03	.6453+04	.2602+00
							*	.6772-01	.1752-01	.4586-02	.2986+00	.7807-01
							*	.1927-01	.3113+00	.8101-01	.2108-01	
.7700+02	.8100+00	.2781+00	.8389+01	.1160+00	.1215+00	.4739+01	*	.8389+01	.7037+02	.5903+03	.4952+04	.2781+00
							*	.7732-01	.2150-01	.5978-02	.3024+00	.8808-01
							*	.2338-01	.3249+00	.9144-01	.2543-01	
.7700+02	.8600+00	.2961+00	.9657+01	.1275+00	.1429+00	.1211+02	*	.9657+01	.9325+02	.9005+03	.8696+04	.2961+00
							*	.8770-01	.2597-01	.7692-02	.3262+00	.9659-01
							*	.2861-01	.3592+00	.1064+00	.3151-01	
.7700+02	.9100+00	.3145+00	.1350+02	.1390+00	.1730+00	.2447+02	*	.1350+02	.1882+03	.2620+04	.3321+05	.3145+00
							*	.9889-01	.3110-01	.9780-02	.3509+00	.1132+00
							*	.3559-01	.4119+00	.1295+00	.4074-01	

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 2

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K),K=1,NBULKS				
.7700+02	.6000-01	.2122-01	-.4475+02	-.9997-04	-.1852-03	.8527+02	* -.4475+02	.2002+04	-.8961+05	.4010+07	.2122-01
							* .4502-03	.9553-05	.2027-06	.1356-01	.2878-03
							* .6107-05	.8670-03	.1840-03	.3904-05	
.7700+02	.1100+00	.3884-01	-.4052+02	.3001-03	.2852-03	-.4935+01	* -.4052+02	.1642+04	-.6651+05	.2695+07	.3884-01
							* .1508-02	.5858-04	.2275-05	.2590-01	.1006-02
							* .3906-04	.1727-01	.6708-03	.2605-04	
.7700+02	.1600+00	.5642-01	-.3676+02	.1100-02	.1217-02	.1060+02	* -.3676+02	.1351+04	-.4967+05	.1826+07	.5642-01
							* .3183-02	.1796-03	.1013-04	.3906-01	.2204-02
							* .1243-03	.2705-01	.1526-02	.8608-04	
.7700+02	.2100+00	.7391-01	-.3557+02	.2600-02	.2631-02	.1176+01	* -.3557+02	.1265+04	-.4502+05	.1601+07	.7391-01
							* .5463-02	.4038-03	.2985-04	.5179-01	.3828-02
							* .2829-03	.3629-01	.2682-02	.1982-03	
.7700+02	.2600+00	.9134-01	-.3444+02	.4900-02	.4601-02	-.6103+01	* -.3444+02	.1186+04	-.4083+05	.1406+07	.9134-01
							* .8342-02	.7620-03	.6959-04	.6473-01	.5912-02
							* .5400-03	.4587-01	.4190-02	.3827-03	
.7700+02	.3100+00	.1087+00	-.3363+02	.7900-02	.7160-02	-.9373+01	* -.3363+02	.1131+04	-.3804+05	.1279+07	.1087+00
							* .1182-01	.1285-02	.1397-03	.7767-01	.8445-02
							* .9182-03	.5549-01	.6033-02	.6559-03	
.7700+02	.3600+00	.1261+00	-.3244+02	.1170-01	.1043-01	-.1082+02	* -.3244+02	.1052+04	-.3413+05	.1107+07	.1261+00
							* .1590-01	.2004-02	.2527-03	.9116-01	.1149-01
							* .1449-02	.6590-01	.8309-02	.1048-02	
.7700+02	.4100+00	.1434+00	-.3067+02	.1640-01	.1459-01	-.1105+02	* -.3067+02	.9407+03	-.2885+05	.8849+06	.1434+00
							* .2057-01	.2949-02	.4230-03	.1055+00	.1513-01
							* .2170-02	.7766-01	.1114-01	.1597-02	
.7700+02	.4600+00	.1608+00	-.2885+02	.2170-01	.1968-01	-.9300+01	* -.2885+02	.8323+03	-.2401+05	.6927+06	.1608+00
							* .2585-01	.4156-02	.6683-03	.1205+00	.1937-01
							* .3115-02	.9029-01	.1452-01	.2334-02	
.7700+02	.5100+00	.1782+00	-.2762+02	.2750-01	.2561-01	-.6880+01	* -.2762+02	.7627+03	-.2106+05	.5817+06	.1782+00
							* .3177-01	.5662-02	.1009-02	.1352+00	.2410-01
							* .4296-02	.1026+00	.1829-01	.3259-02	
.7700+02	.5600+00	.1959+00	-.2808+02	.3340-01	.3184-01	-.4669+01	* -.2808+02	.7883+03	-.2213+05	.6215+06	.1959+00
							* .3836-01	.7513-02	.1471-02	.1479+00	.2897-01
							* .5674-02	.1117+00	.2188-01	.4285-02	
.7700+02	.6100+00	.2137+00	-.2996+02	.3940-01	.3815-01	-.3161+01	* -.2996+02	.8976+03	-.2689+05	.8057+06	.2137+00
							* .4565-01	.9752-02	.2084-02	.1583+00	.3383-01
							* .7228-02	.1173+00	.2507-01	.5356-02	

BLOCK DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 2

TEMP	TIME	EOCT	SR-CALC	OIL	OIL-CALC.	ERROR		XF(K),K=1,NBULKS			
.7700+02	.6600+00	.2316+00	-.3350+02	.4540-01	.4410-01	-.2871+01	*	-.3350+02	.1122+04	-.3760+05	.1260+07	.2316+00
							*	.5366-01	.1243-01	.2879-02	.1657+00	.3838-01
							*	.8891-02	.1185+00	.2746-01	.6360-02	
.7700+02	.7100+00	.2499+00	-.3747+02	.5100-01	.5022-01	-.1533+01	*	-.3742+02	.1400+04	-.5238+05	.1960+07	.2499+00
							*	.6245-01	.1561-01	.3900-02	.1719+00	.4296-01
							*	.1074-01	.1182+00	.2955-01	.7385-02	

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 3

TEMP	TIME	EXCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K),K=1,NBULKS				
.7700+02	.7000-01	.2476-01	-.9405+02	-.2000-03	-.2993-03	.4969+02	* -.9405+02	.8985+04	-.8319+06	.7824+08	.2476-01
							* .6129-03	.1517-04	.3756-06	.9666-02	.2393-03
							* .5924-05	.3774-02	.9343-04	.2317-05	
.7700+02	.1100+00	.3888-01	-.9029+02	.5644-07	-.3334-04	-.5917+05	* -.9029+02	.8152+04	-.7360+06	.6645+08	.3888-01
							* .1512-02	.5978-04	.2285-05	.1576-01	.6128-03
							* .2383-04	.6390-02	.2484-03	.9660-05	
.7700+02	.1600+00	.5652-01	-.8640+02	.5001-03	.4808-03	-.3855+01	* -.8640+02	.7464+04	-.6448+06	.5572+08	.5652-01
							* .3195-02	.1906-03	.1021-04	.2382-01	.1347-02
							* .7612-04	.1004-01	.5676-03	.3208-04	
.7700+02	.2100+00	.7419-01	-.8330+02	.1200-02	.1252-02	.4288+01	* -.8330+02	.6939+04	-.5781+06	.4815+08	.7419-01
							* .5504-02	.4083-03	.3029-04	.3225-01	.2393-02
							* .1775-03	.1402-01	.1040-02	.7717-04	
.7700+02	.2540+00	.8970-01	-.8125+02	.2300-02	.2175-02	-.5429+01	* -.8125+02	.6601+04	-.5363+06	.4358+08	.8970-01
							* .8046-02	.7218-03	.6475-04	.5881-01	.3571-02
							* .3203-03	.1766-01	.1585-02	.1421-03	
.7700+02	.2600+00	.8971-01	-.8390+02	.2250-02	.2087-02	-.7234+01	* -.8390+02	.7039+04	-.5906+06	.4955+08	.8971-01
							* .8048-02	.7220-03	.6478-04	.5877-01	.3478-02
							* .3120-03	.1675-01	.1503-02	.1348-03	
.7700+02	.2700+00	.8972-01	-.8453+02	.2200-02	.2067-02	-.6035+01	* -.8453+02	.7146+04	-.6041+06	.5106+08	.8972-01
							* .8050-02	.7223-03	.6481-04	.5853-01	.3457-02
							* .3102-03	.1654-01	.1484-02	.1332-03	
.7700+02	.2900+00	.8974-01	-.8475+02	.2100-02	.2062-02	-.1832+01	* -.8475+02	.7182+04	-.6087+06	.5158+08	.8974-01
							* .8054-02	.7228-03	.6487-04	.5845-01	.3451-02
							* .3097-03	.1648-01	.1479-02	.1327-03	
.7700+02	.3600+00	.8976-01	-.8492+02	.2000-02	.2057-02	.2867+01	* -.8492+02	.7211+04	-.6123+06	.5198+08	.8976-01
							* .8058-02	.7233-03	.6493-04	.5840-01	.3447-02
							* .3094-03	.1643-01	.1474-02	.1324-03	
.7700+02	.4500+00	.8979-01	-.8553+02	.1900-02	.2039-02	.7301+01	* -.8553+02	.7316+04	-.6257+06	.5352+08	.8979-01
							* .8061-02	.7238-03	.6499-04	.5817-01	.3427-02
							* .3077-03	.1623-01	.1457-02	.1308-03	
.7700+02	.6500+00	.8981-01	-.8730+02	.1800-02	.1984-02	.1021+02	* -.8730+02	.7621+04	-.6653+06	.5808+08	.8981-01
							* .8065-02	.7243-03	.6505-04	.5751-01	.3369-02
							* .3025-03	.1567-01	.1407-02	.1264-03	
.7700+02	.6600+00	.9337-01	-.8183+02	.1900-02	.2394-02	.2599+02	* -.8183+02	.6606+04	-.5479+06	.4484+08	.9337-01
							* .8719-02	.8141-03	.7601-04	.4120-01	.3847-02
							* .3592-03	.1817-01	.1695-02	.1585-03	

BLOCK DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 3

TEMP	TIME	STRAIN	SR-CALC	DIL	DIL-CALC. ERROR		XF(K),K=1,NBULKS			
.7700+02	.6800+00	.1004+00	-.7929+02	.2900-02	.2995-02	.3267+01	* -.7929+02	.6287+04	-.4985+06	.3953+08	.1004+00
							* .1007-01	.1011-02	.1014-03	.8541-01	.8557-02
							* .4573-03	.2055-01	.2062-02	.2070-03	
.7700+02	.7100+00	.1109+00	-.7761+02	.4100-02	.3952-02	-.3603+01	* -.7761+02	.6024+04	-.4675+06	.3628+08	.1109+00
							* .1230-01	.1365-02	.1514-03	.5104-01	.5662-02
							* .6280-03	.2349-01	.2606-02	.2890-03	
.7700+02	.7600+00	.1286+00	-.7496+02	.6400-02	.5924-02	-.7435+01	* -.7496+02	.5619+04	-.4212+06	.3158+08	.1286+00
							* .1653-01	.2125-02	.2733-03	.6076-01	.7811-02
							* .1004-02	.2871-01	.3691-02	.4746-03	
.7700+02	.8100+00	.1462+00	-.7178+02	.9300-02	.8504-02	-.8564+01	* -.7178+02	.5153+04	-.3699+06	.2655+08	.1462+00
							* .2139-01	.3127-02	.4573-03	.7134-01	.1043-01
							* .1526-02	.3450-01	.5045-02	.7442-03	
.7700+02	.8600+00	.1640+00	-.6877+02	.1270-01	.1174-01	-.7586+01	* -.6877+02	.4729+04	-.3252+06	.2236+08	.1640+00
							* .2688-01	.4408-02	.7227-03	.8243-01	.1351-01
							* .2216-02	.4144-01	.6794-02	.1114-02	
.7700+02	.9100+00	.1818+00	-.6712+02	.1640-01	.1546-01	-.5729+01	* -.6712+02	.4506+04	-.3024+06	.2030+08	.1818+00
							* .3305-01	.6007-02	.1092-02	.9291-01	.1689-01
							* .3070-02	.4748-01	.8631-02	.1569-02	
.7700+02	.9600+00	.1997+00	-.6757+02	.2050-01	.1937-01	-.5528+01	* -.6757+02	.4566+04	-.3085+06	.2085+08	.1997+00
							* .3988-01	.7565-02	.1561-02	.1016+00	.2029-01
							* .4053-02	.5170-01	.1032-01	.2062-02	
.7700+02	.1010+01	.2178+00	-.7006+02	.2450-01	.2323-01	-.5191+01	* -.7006+02	.4909+04	-.3439+06	.2410+08	.2178+00
							* .4745-01	.1074-01	.2252-02	.1081+00	.2355-01
							* .5130-02	.5365-01	.1169-01	.2546-02	
.7700+02	.1060+01	.2361+00	-.7368+02	.2860-01	.2710-01	-.5261+01	* -.7368+02	.5429+04	-.4000+06	.2947+08	.2361+00
							* .5575-01	.1316-01	.3109-02	.1130+00	.2669-01
							* .6301-02	.5410-01	.1277-01	.3016-02	
.7700+02	.1110+01	.2546+00	-.7671+02	.3260-01	.3151-01	-.3334+01	* -.7671+02	.5985+04	-.4515+06	.3463+08	.2546+00
							* .6483-01	.1651-01	.4204-02	.1182+00	.3011-01
							* .7466-02	.5490-01	.1398-01	.3559-02	
.7700+02	.1160+01	.2734+00	-.7837+02	.3600-01	.3698-01	.2718+01	* -.7837+02	.6142+04	-.4813+06	.3772+08	.2734+00
							* .7476-01	.2044-01	.5590-02	.1249+00	.3415-01
							* .9337-02	.5704-01	.1560-01	.4264-02	

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 4

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K),K=1,NRULES				
.7700+02	.5000-01	.1768-01	-.4923+03	-.1000-02	-.1034-02	.3390+01	* -.4923+03	.2424+06	-.1193+09	.5878+11	.176B-01
							* .3124-03	.5522-05	.9761-07	.12B6-0?	.2273-05
							* .4018-07	.9359-06	.1654-07	.2924-0B	
.7700+02	.1000+00	.3536-01	-.4861+03	-.9599-03	-.9366-03	-.2428+01	* -.4861+03	.2363+06	-.1148+09	.5582+11	.3536-01
							* .1251-02	.4422-04	.1564-05	.2739-0?	.9685-05
							* .3425-06	.2121-05	.7501-07	.2653-0B	
.7700+02	.1500+00	.5309-01	-.4804+03	-.8999-03	-.8597-03	-.4472+01	* -.4804+03	.2308+06	-.1106+09	.5325+11	.5309-01
							* .2818-02	.1496-03	.7942-05	.4352-03	.2310-04
							* .1227-05	.3568-05	.1894-06	.1006-07	
.7700+02	.2500+00	.8872-01	-.4711+03	-.7499-03	-.7494-03	-.6189-01	* -.4711+03	.2219+06	-.1045+09	.4924+11	.8872-01
							* .7870-02	.6982-03	.6194-04	.7984-03	.7083-04
							* .6284-05	.7186-05	.6375-06	.5656-07	
.7700+02	.3500+00	.1247+00	-.4611+03	-.6298-03	-.6663-03	.5766+01	* -.4611+03	.2126+06	-.9801+08	.4519+11	.1247+00
							* .1555-01	.1939-02	.2418-03	.1240-02	.1547-03
							* .1929-04	.1233-04	.1539-05	.1918-06	
.7700+02	.4500+00	.1611+00	-.4489+03	-.4999-03	-.5669-03	.1344+02	* -.4489+03	.2015+06	-.9047+08	.4061+11	.1611+00
							* .2597-01	.4184-02	.6743-03	.1810-02	.2916-03
							* .4699-04	.2072-04	.3275-05	.5277-06	
.7700+02	.5500+00	.1961+00	-.4446+03	-.3897-03	-.4288-03	.1004+02	* -.4446+03	.1977+06	-.8788+08	.3907+11	.1981+00
							* .3925-01	.7777-02	.1541-02	.2333-02	.4603-03
							* .9120-04	.2725-04	.5388-05	.1069-05	
.7700+02	.6500+00	.2357+00	-.4506+03	-.3096-03	-.2550-03	-.1765+02	* -.4506+03	.2031+06	-.9150+08	.4123+11	.2357+00
							* .5556-01	.1310-01	.3087-02	.2603-02	.6135-03
							* .1446-03	.2874-04	.6774-05	.1597-05	
.7700+02	.7000+00	.2548+00	-.4540+03	-.2796-03	-.1408-03	-.4965+02	* -.4540+03	.2061+06	-.9354+08	.4247+11	.2548+00
							* .6491-01	.1654-01	.4213-02	.2730-02	.6931-03
							* .1766-03	.2905-04	.7401-05	.1885-05	
.7700+02	.7500+00	.2740+00	-.4552+03	-.2496-03	.1030-04	-.1041+03	* -.4552+03	.2072+06	-.9434+08	.4294+11	.2740+00
							* .7507-01	.2057-01	.5636-02	.2889-02	.7915-03
							* .2169-03	.3046-04	.8345-05	.2286-05	
.7700+02	.8000+00	.2934+00	-.4553+03	-.2195-03	.2025-03	-.1922+03	* -.4553+03	.2073+06	-.9436+08	.4296+11	.2934+00
							* .8608-01	.2526-01	.7410-02	.3092-02	.9072-03
							* .2662-03	.3259-04	.9561-05	.2805-05	
.7700+02	.8500+00	.3130+00	-.4593+03	-.2095-03	.3949-03	-.2885+03	* -.4593+03	.2110+06	-.9691+08	.4451+11	.3130+00
							* .9796-01	.3066-01	.9597-02	.3168-02	.9914-03
							* .3103-03	.3206-04	.1003-04	.3140-05	

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 5

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K),K=1,NBULKS				
.7700+02	.5000-01	.1767-01	-.9923+03	-.2000-02	-.2098-02	.4900+01	* -.9923+03	.9846+06	-.9769+09	.9694+12	.1767-01
							* .3122-03	.5517-05	.9748-07	.8668-06	.1532-07
							* .2706-09	.4252-10	.7514-12	.1328-13	
.7700+02	.1300+00	.4599-01	-.9804+03	-.1980-02	-.1883-02	-.4873+01	* -.9804+03	.9611+06	-.9423+09	.9238+12	.4599-01
							* .2115-02	.9726-04	.4473-05	.2541-05	.1168-06
							* .5373-08	.1404-09	.6455-11	.2968-12	
.7700+02	.2300+00	.8157-01	-.9705+03	-.1920-02	-.1721-02	-.1034+02	* -.9705+03	.9418+06	-.9140+09	.8870+12	.8157-01
							* .6653-02	.5427-03	.4427-04	.4975-05	.4058-06
							* .3310-07	.3035-09	.2475-10	.2019-11	
.7700+02	.3300+00	.1175+00	-.9594+03	-.1830-02	-.1612-02	-.1192+02	* -.9594+03	.9205+06	-.8831+09	.8473+12	.1175+00
							* .1380-01	.1621-02	.1904-03	.8002-05	.9400-06
							* .1104-06	.5451-09	.6404-10	.7523-11	
.7700+02	.4300+00	.1538+00	-.9463+03	-.1760-02	-.1526-02	-.1326+02	* -.9463+03	.8955+06	-.8474+09	.8018+12	.1538+00
							* .2366-01	.3639-02	.5597-03	.1195-04	.1838-05
							* .2827-06	.9282-09	.1428-09	.2196-10	
.7700+02	.5300+00	.1907+00	-.9395+03	-.1600-02	-.1487-02	-.7022+01	* -.9395+03	.8827+06	-.8293+09	.7791+12	.1907+00
							* .3635-01	.6930-02	.1321-02	.1585-04	.3022-05
							* .5761-06	.1318-08	.2512-09	.4790-10	
.7700+02	.6300+00	.2281+00	-.9440+03	-.1480-02	-.1495-02	.1010+01	* -.9440+03	.8911+06	-.8412+09	.7941+12	.2281+00
							* .5203-01	.1187-01	.2707-02	.1813-04	.4136-05
							* .9435-06	.1442-08	.2288-09	.7500-10	
.7700+02	.6800+00	.2471+00	-.9474+03	-.1420-02	-.1493-02	.5154+01	* -.9474+03	.8975+06	-.8503+09	.8056+12	.2471+00
							* .6104-01	.1508-01	.3726-02	.1898-04	.4691-05
							* .1159-05	.1459-08	.3604-09	.8905-10	
.7700+02	.7300+00	.2662+00	-.9493+03	-.1370-02	-.1472-02	.7464+01	* -.9493+03	.9013+06	-.8556+09	.8123+12	.2662+00
							* .7087-01	.1887-01	.5023-02	.2006-04	.5339-05
							* .1421-05	.1511-08	.4023-09	.1071-09	
.7700+02	.7800+00	.2855+00	-.9496+03	-.1320-02	-.1427-02	.8148+01	* -.9496+03	.9017+06	-.8563+09	.8131+12	.2855+00
							* .8153-01	.2328-01	.6647-02	.2146-04	.6127-05
							* .1750-05	.1613-08	.4605-09	.1315-09	
.7700+02	.8300+00	.3050+00	-.9506+03	-.1269-02	-.1369-02	.7869+01	* -.9506+03	.9037+06	-.8591+09	.8166+12	.3050+00
							* .9305-01	.2838-01	.8659-02	.2269-04	.6922-05
							* .2111-05	.1688-08	.5149-09	.1571-09	
.7700+02	.8800+00	.3247+00	-.9578+03	-.1239-02	-.1326-02	.6991+01	* -.9578+03	.9173+06	-.8785+09	.8414+12	.3247+00
							* .1055+00	.3425-01	.1112-01	.2249-04	.7305-05
							* .2372-05	.1658-08	.5060-09	.1643-09	

NL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 5

TEMP	TIME	EXCT	SR-CALC	OIL	OIL-CALC. ERROR	XF(K),K=1,NBULKS				
.7700+02	.9300+00	.3446+00	-.9667+03	-.1219-02	-.1272-02 .4318+01	* -.9667+03	.9344+06	-.9033+09	.8772+12	.3446+00
						* .1188+00	.4004-01	.1411-01	.2184-04	.7526-05
						* .2594-05	.1384-08	.4768-09	.1643-08	
.7700+02	.9700+00	.3607+00	-.9550+03	-.1209-02	-.1102-02 -.8891+01	* -.9550+03	.9121+06	-.8711+09	.8319+12	.3607+00
						* .1301+00	.4693-01	.1693-01	.2568-04	.9262-05
						* .3341-05	.1828-08	.6593-09	.2379-08	

NL003 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	6.73311-06
2	1.30469-08
3	8.23299-12
4	-3.49560-16
5	7.55943-03
6	-4.72075-02
7	1.10045-01
8	-5.12720-02
9	1.57065-02
10	3.61805-02
11	2.68790+00
12	-5.81638-02
13	1.20213+00
14	-1.59303+00

THERE WERE 91 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0063

THE STANDARD DEVIATION, STD, WAS .0793

DATA CARDS IGNORED - FIRST IS LISTED BELOW

SI FOR,* NL003.NL003 15 JUN 73 00:00:02.524
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 13:44(0.)
FORTRAN V: ISD VERSION 2.6

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	003175
0000	*DATA	012720
0002	*BLANK	003000
0003	INPUT	007034

EXTERNAL REFERENCES (BLOCK, NAME)

0004	ICUNIT
0005	PANIL
0006	BUFFER
0007	REAR
0010	NREAS
0011	NRBUS
0012	NIO1S
0013	NIO2S
0014	NWBUS
0015	ALOG
0016	EXP
0017	NEXPAS
0020	DSQRT
0021	DEXP
0022	NEXPDS
0023	NWBUS
0024	NRBUS
0025	NSTOPS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	012057	1F	0001	000567	10L	0001	000374	100L	0001	001772	10056
0001	002021	10166	0001	002020	10256	0001	002023	10316	0001	002075	10606
0001	002232	11206	0001	002234	11246	0001	002237	11316	0001	002260	11426
0001	002337	11726	0001	002337	11746	0001	000547	12L	0001	002346	12036
0001	002362	12106	0001	002375	12146	0001	002512	12426	0001	002515	12456
0001	002606	12716	0001	002617	12776	0000	012066	13F	0001	002617	13016
0001	000052	133G	0001	002715	13346	0001	002737	13536	0001	002737	13556
0001	002762	13736	0001	002762	13756	0000	012073	14F	0001	002775	14036
0001	000064	141G	0001	003051	14366	0001	003154	14626	0001	000076	147G
0001	000110	155G	0001	000132	1666	0001	000641	18L	0001	001020	19L
0001	000754	20L	0001	001631	200L	0001	000160	202G	0001	000742	21L
0001	000214	222G	0001	000270	247G	0001	000302	256G	0001	000363	274G
0000	012077	30F	0001	000355	3006	0000	012126	31F	0001	000362	3106
0000	012134	32F	0001	000400	3206	0000	012146	33F	0001	000467	34L
0001	000427	350G	0000	012062	4F	0000	012202	40F	0001	000528	403G
0001	000537	412G	0000	012233	42F	0001	000604	427G	0001	000627	433G
0001	000652	444G	0001	000703	451G	0001	000771	470G	0001	001063	475G
0001	001062	5066	0001	001143	5266	0001	002556	530L	0001	001170	5346
0001	003077	550L	0001	001242	5566	0001	001255	5626	0001	003033	565L

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                VRDLAY,825272.1.100                                    15 JUN 79   13:58:42   PAGE    8

     0000   012301 586F      0001   002123 600L      0001   002051 605L      0001   001454 6285      0001   001357 6276
     0001   001471 632G      0001   001133 65L       0000   012304 656F      0000   012366 655F      0001   001557 6566
     0000   012404 660F      0000   012416 675F      0001   001575 6756      0001   001575 6776      0000   012065 7F
     0000   012464 700F      0001   001697 7076      0001   001372 71L       0000   012507 710F      0001   001620 7156
     0001   001620 7176      0000   012543 720F      0000   012565 725F      0001   001673 7376      0000   012264 75F
     0001   001736 7556      0001   001740 7746      0001   001740 7766      0001   001341 79L       0001   000595 9L
     0000 R 012013 A         0000 R 000016 AT        0000 R 012025 AVGAT     0000 R 012000 A1        0000 R 012002 A2
     0000 R 012026 A3        0000 R 000162 B         0000 R 000171 BB        0000 R 012052 BCAL      0003 R 000013 BETA
     0000 R 000207 B0        0003 R 000012 BULK      0000 R 000225 CO        0000 R 000243 D         0000 R 012045 DEV
     0000 R 012034 D1        0003 R 000639 DIL       0003 R 002130 DR1       0003 R 002440 DR12      0003 R 002274 DR2
     0003 R 000324 DT        0000 R 012031 DTR       0003 R 006524 EOCT      0003 R 001144 E11       0003 R 001620 E12
     0003 R 001310 E22       0003 R 001454 E33       0000 R 000407 F         0000 R 000553 G         0000 I 012012 I
     0000 I 000717 IEF       0000 I 000735 IFG       0000 I 012007 IFLAG     0000 I 000744 IFN       0000 R 012004 INT1
     0000 R 012006 INT10     0000 R 012005 INT2      0003 R 002604 INV1      0003 R 003114 INV2      0003 R 003424 INV3
     0000 I 012010 IPG       0003 I 000000 ITEST     0000 I 012023 J         0000 I 012022 K         0003 I 000004 KODE
     0003 I 000003 KTEMP     0000 I 012043 L         0000 I 012017 LAST      0000 I 012021 LINE      0000 I 012024 M
     0003 I 000005 MATID     0000 I 012035 MP7       0000 I 012033 N         0000 I 000752 NAME      0000 I 012016 NAT
     0000 I 012051 NBLKS     0003 I 000001 NDP       0000 I 011777 NEND      0003 R 004264 NORM      0003 R 003734 NORME
     0003 I 012032 NORMS     0000 I 012015 NPL       0000 I 012037 NTEPMS    0000 I 012040 NTEST     0000 I 012041 NTOT
     0000 I 012011 NU        0000 I 012014 N1        0000 R 000776 P         0003 R 000002 PPFS      0000 R 001005 R
     0003 R 000160 RATE      0000 R 012042 RESID     0000 R 012044 SCAL      0000 R 012050 STD       0003 R 000470 STRESS
     0000 R 012046 STRN      0003 R 001764 STRUE     0000 R 012041 SUM       0003 R 001000 T         0003 R 000010 TEMP
     0000 R 001311 TR        0000 R 001455 TSHET     0000 R 000000 WORK1     0000 R 000007 WORK2     0000 R 012007 XP4P
     0000 R 001621 XF        0000 R 004411 XF1       0000 R 007201 XF2       0000 R 011771 XN        0000 R 012027 XP
     0000 R 012030 XQ        0000 R 012014 Z

00100     1*  C
00100     2*  C *** PROGRAM NAME = NL003.
00100     3*  C          NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE.
00100     4*  C
00100     5*  C     THIS CODE IS SIMILAR TO THE NL002 CODE EXCEPT THAT THE SERIES
00100     6*  C     EXPANSION FOR THE BULK TERM EXPRESSES DILATATION
00100     7*  C     AND THERE IS NO FINAL ERROR SUMMARY FOR S11 AND S22.
00100     8*  C
00100     9*  C          BULK      =    BULK MODULUS.
00100    10*  C          BETA      =    VOLUMETRIC EXPANSION COEFFICIENT.
00100    11*  C          EOCT      =    OCTAHEDRAL SHEAR STRAIN
00100    12*  C          IEN       =    NORM SELECTOR, ANY ONE OR COMBINATION OF THE
00100    13*  C                         10TH, 20TH, 30TH, 40TH, 50TH, OR 60TH NORMS,
00100    14*  C                         ENTER A NONZERO VALUE TO INCLUDE THAT NORM .
00100    15*  C          NPL       =    NO. OF POWER LAW TERMS.
00100    16*  C          NAT       =    NO. OF AT VS. TSHET INPUT DATA POINTS.
00100    17*  C          NDP       =    NO. OF DATA PTS. FOR A SPECIFIC TEST.
00100    18*  C          N1        =    FIRST DATA POINT USED IN THE REGRESSION ANALYSIS.
00100    19*  C
00101    20*       DIMENSION WORK1(7), WORK2(7)                                        *NEW
00101    21*  C                                                                        *NEW
00103    22*        DIMENSION AT(100), B(7), BB(14), BO(14), CO(14), D(100),
00103    23*       1          DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00103    24*       2          E11(100), E22(100), E33(100), E12(100), E(100), G(100),
00103    25*       3          IEF(14), IFG(7), IFN(6), INV1(100), INV2(100),
00103    26*       4          INV3(100), MATID(5), NAME(20), NORM(6,100), NORME(100),
00103    27*       5          P(7), R(14,14), RATE(100), STRESS(100), STRUE(100),
00103    28*       6          T(100), TEMP(100), TR(100), TSHET(100), XF(14,100),
00103    29*       7        XF1(14,100), XF2(14,100), XN(6), EOCT(100)
00103    30*  C
00104    31*        COMMON /INPUT/ ITEST, KDP, PLOG, KTEMP, KODE, MATID, BULK, BETA,
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00104   32*         1               TEMP, RATE, DT, STRESS, DIL, T, E11, E22, E33, E12,
00104   33*         2               STRUE, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00104   34*         3               NORM, FOCT
00104   35*   C
00105   36*         DATA BEND/'END'/
00105   37*   C
00107   38*         DOUBLE PRECISION   A1, A2, INV1, INV2, INV3, NORMF, NORM, FOCT
00107   39*   C
00107   40*   C
00110   41*         REAL     INT1, INT2, TA,I2
00110   42*   C
00110   43*   C                                                                    *NEW
00110   44*   C     DYNAMICALLY ALLOCATE DRUM SPACE.                               *NEW
00110   45*   C                                                                    *NEW
00111   46*           CALL IOUNIT('DRUM',.11,.75,WORK1)                            *NEW
00112   47*           CALL IOUNIT('DRUM',.12,.25,WORK2)                            *NEW
00112   48*   C                                                                    *NEW
00112   49*   C                                                                    *NEW
00112   50*         IELAG = 0
00114   51*         IPG = 0
00114   52*   C
00114   53*   C           ASSIGN TAPE UNIT PRG.
00115   54*         NU = 1
00116   55*         REWIND NU
00116   56*   C
00116   57*   C
00116   58*   C
00117   59*         READ(5,1) (NAME(I),I=1,20  )
00125   60*         READ(5,2) A,Z
00131   61*         READ(5,75) (IPG(I),I=1,7)
00137   62*         READ(5,75) (IFF(I),I=1,14)
00137   63*   C
00137   64*   C           INPUT NORM SELECTOR AND EXPONENTS.
00137   65*   C
00145   66*         READ(5,75) (IFN(I),I=1,6)
00153   67*         READ(5,2)(XN(I),I=1,6)
00153   68*   C
00153   69*   C           INPUT POWER LAW EXPONENTS AND COEFFICIENTS.
00161   70*         READ(5,75)     NPL
00164   71*         READ(5,2)( P(I), B(I), I=1,NPL   )
00164   72*   C
00173   73*         CALL PAGNL(IPG, NAME)
00174   74*         WRITE(6,32) A,Z
00200   75*         WRITE(6,40)(I, P(I),  B(I), IPG(I), I=1,7)
00211   76*         WRITE(6,42)( I, IFF(I),I=1,14)
00227   77*         WRITE(6,44)( I, IFN(I), XN(I),I=1,6)
00220   78*   C
00220   79*   C           INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE, TSHFT, COLD TO HOT.
00220   80*   C
00230   81*         NAT = 0
00231   82*    3    NAT = NAT + 1
00232   83*         READ(5,4)  TSHFT(NAT),  AT(NAT), LAST
00237   84*         IF(LAST.EQ.0) GO TO 3
00241   85*         CALL PAGNL(IPG, NAME)
00242   86*         WRITE(6,30)  NAT
00245   87*         WRITE(6,31)(I, AT(I), TSHFT(I), I=1,NAT)
00245   88*   C
00245   89*   C           COMPUTE   SLOPE, D, AT EACH INPUT POINT.
00245   90*   C
00255   91*         DO 5 I=2,NAT
```

```
00260    92*          D(I) = (LOG(AT(I)) - LOG(AT(I-1)) )/( TSHFT(I) - TSHFT(I-1) )
00261    93*     5    CONTINUE
00263    94*          D(1) = D(2)
00263    95*    C
00268    96*          NTEST = 0
00265    97*          REWIND 11
00266    98*          REWIND 12
00267    99*          LINF = 0
00270   100*          CALL PARNL(IPG, NAME)
00271   101*          WRITE(6,33)
00273   102*          DO 110 I=1,14
00276   103*          BB(I) = 0.0
00277   104*          DO 105 K=1,100
00302   105*          XF1(I,K) = 0.0
00303   106*          XF2(I,K) = 0.0
00304   107*          XF(I,K) = 0.0
00305   108*   105    CONTINUE
00307   109*          DO 110 J=1,14
00312   110*          R(I,J) = 0.0
00313   111*   110    CONTINUE
00313   112*    C
00313   113*    C          BEGIN NEXT TEST.
00313   114*    C
00316   115*   100    CONTINUE
00316   116*    C
00316   117*    C          ZERO ALL VARIABLES.
00316   118*    C
00317   119*          DO 107 I=1,100
00322   120*          DT1(I) = 0.0
00323   121*          DR1(I) = 0.0
00324   122*          DR2(I) = 0.0
00325   123*          DR12(I) = 0.0
00326   124*          DT(I) = 0.0
00327   125*          E11(I) = 0.0
00330   126*          E22(I) = 0.0
00331   127*          E33(I) = 0.0
00332   128*          E12(I) = 0.0
00333   129*          F(I) = 0.0
00334   130*          G(I) = 0.0
00335   131*          INV1(I) = 0.000
00336   132*          INV2(I) = 0.000
00337   133*          INV3(I) = 0.000
00340   134*          NORMF(I) = 0.000
00341   135*          RATE(I) = 0.0
00342   136*          STRESS(I) = 0.0
00343   137*          STRUE(I) = 0.0
00344   138*          T(I) = 0.0
00345   139*          TEMP(I) = 0.0
00346   140*          TR(I) = 0.0
00347   141*          DO 107 K=1,6
00352   142*          NORM(K,I) = 0.000
00353   143*   107    CONTINUE
00353   144*    C
00353   145*    C          INPUT RAW DATA FOR THIS TEST.
00353   146*    C
00356   147*          CALL BUFFER (NU, IFLAG)
00356   148*    C
00356   149*    C
00357   150*          NTEST = NTEST + 1
00360   151*          N1 = 3
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00361   152*          LINE = LINE + 1
00362   153*          IF(LINE.LE.50) GO TO 34
00364   154*          CALL PAGE(IPG, NAME )
00365   155*          WRITE(6,33)
00367   156*          LINE = 0
00370   157*    34    CONTINUE
00371   158*          WRITE(6,35) NTEST,ITEST,NDP,KODE,KTEMP,PRES,TEMP(1)
00371   159*    C
00371   160*    C          COMPUTE THE REDUCED TIME, TR.
00371   161*    C
00402   162*          DO 8 I=N1,NDP
00405   163*          IF(I.EQ.N1) GO TO 9
00407  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00407   164*          IF(TEMP(I).EQ.TEMP(I-1)) GO TO 10
00411   165*    9     DO 11 J=1,NAT
00414   166*          IF(TEMP(I).LT.TSHFT(J)) GO TO 12
00416   167*    11    CONTINUE
00420   168*    12    AVGAT = ( EXP(LOG(AT(J-1)) + D(J)*(TEMP(I) - TSHFT(J-1) )) )
00421   169*    10    TR(I) = TR(I-1)  +  DT(I)/AVGAT
00422   170*    8     CONTINUE
00422   171*    C
00422   172*    C
00422   173*    C          IF TEMP IS CONSTANT READ 10TH THRU 60TH NORMS, OTHERWISE
00422   174*    C          COMPUTE THEM BASED ON THE REDUCED TIME, TR.
00422   175*    C
00424   176*          IF(KTEMP.EQ.2) GO TO 18
00424   177*    C
00424   178*    C
00424   179*    C          IF A CONSTANT TEMP TEST, MULTIPLY THE PTH NORM BY (1/AT)**1/P.
00424   180*    C
00426   181*          DO 60 M=1,6
00431   182*          XP = 1.0/(10*M)
00432   183*          DO 60 I=1,NDP
00435   184*          NORM(M,I) = NORM(M,I)*((I./AVGAT)**XP)
00436   185*    60    CONTINUE
00441   186*          GO TO 19
00442   187*    18    CONTINUE
00442   188*    C
00443   189*          DO 20 M=1,6
00446   190*          XP = 1.0+10.*M
00447   191*          XQ = 10.*M
00450   192*          DO 20 I=N1,NDP
00453   193*          DTR = TR(I) - TR(I-1)
00454   194*          A1 = DABS(INV2(I))
00455   195*          A2 = DABS(INV2(I-1))
00456  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00456   196*          IF(A1.EQ.A2) GO TO 21
00460   197*          NORM(M,I) = NORM(M,I-1) + (A1**XP-A2**YP)/(XP*(A1-A2)/DTR  )
00461   198*          GO TO 20
00462   199*    21    CONTINUE
00463   200*          NORM(M,I) = NORM(M,I-1) + (A1**XQ)*DTR
00464   201*    20    CONTINUE
00464   202*    C
00467   203*          DO 22 M=1,6
00472   204*          XP = M*10.
00473   205*          XP = 1./XP
00474   206*          DO 22 I=N1,NDP
00477   207*          NORM(M,I) = NORM(M,I)**XP
00500   208*    22    CONTINUE
00500   209*    C
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00503   210*    19   CONTINUE
00503   211*  C
00503   212*  C          FORM CONSTITUTIVE EQUATIONS FOR THIS TEST.
00503   213*  C
00503   214*  C
00503   215*  C          COMPUTE THE FACTORS F, G, AND XF(1,I).
00503   216*  C
00504   217*          F(1) = 0.0
00505   218*          DO 65 I=M1,NDP
00510   219*          XF1(1,I) = F11(I)
00511   220*          XF2(1,I) = F22(I)
00512   221*          XF(1,I) = F11(I) - F22(I)
00513   222*          G(I) = (1.0 - DABS(INV2(I))/NORV2(I)  ) **Z
00514   223*          F(I) = DEXP(A*INV3(I)/(DSQRT(DABS(INV2(I)))))
00515   224*          IF(IFF(I).EQ.0) GO TO 65
00517   225*          XF1(1,I) = XF1(1,I)*F(I)
00520   226*          XF2(1,I) = XF2(1,I)*F(I)
00521   227*          XF(1,I) = XF(1,I)*F(I)
00522   228*    65    CONTINUE
00522   229*  C
00522   230*  C          COMPUTE THE NORM TERMS.
00522   231*  C
00524   232*          NORMS = 0
00524   233*  C
00525   234*          DO 50 K=1,6
00530   235*          M = IPP(K)
00531   236*          IF(M.EQ.0) GO TO 50
00533   237*          NORMS = NORMS + 1
00534   238*          N = NORMS + 1
00535   239*          DO 55 J=M1,NDP
00540   240*          DI = ( DABS(INV2(J))/NORM(M,J) )**EN(K)
00541   241*          XF1(N,J) = XF1(1,J)*DI
00542   242*          XF2(N,J) = XF2(1,J)*DI
00543   243*          XF(N,J) = XF(1,J)*DI
00544   244*          IF(IFF(J).EQ.0) GO TO 55
00546   245*          XF1(N,J) = XF1(N,J)*F(J)
00547   246*          XF2(N,J) = XF2(N,J)*F(J)
00550   247*          XF(N,J) = XF(N,J)*F(J)
00551   248*    55    CONTINUE
00551   249*  C
00553   250*    50    CONTINUE
00553   251*  C
00553   252*  C
00553   253*  C          COMPUTE THE POWER LAW (INTEGRALS) TERMS.
00553   254*  C
00555   255*          DO 70 M=1, NPL
00560   256*          MP7 = M + 7
00561   257*          DO 70 J=M1,NDP
00564   258*          A3 = P(M) + 1.
00565   259*          INT1 = 0.0
00566   260*          INT2 = 0.0
00567   261*          INT12 = 0.0
00570   262*          DO 71 K=M1,J
00573   263*          IF(NDP.EQ.3) GO TO 72
00575   264*          INT1 = INT1 + (DRT(K)/(P(M)*A3))*((1. + P(M)*(TR(J)-TR(K)))**A3
00575   265*         1          - (1. + P(M)*(TR(J)-TR(K-1)))**A3 )
00576   266*          INT2 = INT2 + (DR2(K)/(P(M)*A3))*((1. + P(M)*(TR(J)-TR(K)))**A3
00576   267*         1          - (1. + P(M)*(TR(J)-TR(K-1)))**A3 )
00577   268*          GO TO 71
00600   269*    72    CONTINUE
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00601  270*          INT12= INT12- (DP12(K)/(B(M)*A3))*((1. + B(M)*(TR(J)-TR(M)))**A3
00601  271*         1          - (1. + B(M)*(TR(J)-TR(K-1)))**A3 )
00602  272*     71   CONTINUE
00604  273*          XF1(N+M,J) = INT1
00605  274*          XF2(N+M,J) = INT2
00606  275*          IF(IFF(MP7).NE.0) XF1(N+M,J) = XF1(N+M,J)*F(J)
00610  276*          IF(IFF(MP7).NE.0) XF2(N+M,J) = XF2(N+M,J)*F(J)
00612  277*          IF(IFG(M).NE.0) XF1(N+M,J) = XF1(N+M,J)*G(J)
00614  278*          IF(IFG(M).NE.0) XF2(N+M,J) = XF2(N+M,J)*G(J)
00616  279*          XF(N+M,J) = XF1(N+M,J) - XF2(N+M,J)
00617  280*     70   CONTINUE
00617  281*     C
00617  282*     C          FORM PRIMARY MATRIX B, AND SOLUTION VECTOR BB.
00617  283*     C
00622  284*          NTERMS = NORMS + NPL + 1
00622  285*     C
00623  286*          DO 300 K=1,NTERMS
00626  287*          DO 300 J=1, TERMS
00631  288*              DO 310 I=1,NDP
00634  289*               IF(ABS(STRUE(I)).LT.A.0 ) GO TO 310
00635  290*              B(K,J) = B(K,J) + XF(K,I)*XF(J,I)/STRUE(I)**2
00637  291*              IF(J.GT.1)  GO TO 310
00641  292*              BB(K) = BB(K) + XF(K,I)/STRUE(I)
00642  293*     310      CONTINUE
00644  294*     300  CONTINUE
00644  295*     C
00644  296*     C               SAVE DATA ON SCRATCH DRUMS 11 AND 12.
00644  297*     C
00647  298*              WRITE(11)  NDP, KODE, PRES
00654  299*              WRITE(11) (DIL(I), E11(I), E12(I),EOCT(I), INV1(I), INV2(I)
00654  300*         1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
00673  301*              WRITE(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
00673  302*     C
00715  303*              WRITE(12)  (STRESS(I), I=1,NDP)
00713  304*              WRITE(12)  (( XF(K,I),K=1,14),I=1,NDP)
00713  305*     C
00713  306*     C          GO READ NEXT TEST.
00713  307*     C
00713  308*     C                    ALL DONE ?
00713  309*     C
00724  310*          IF(IFLAG.EQ.2) GO TO 200
00724  311*     C
00726  312*          GO TO 100
00726  313*     C
00727  314*     200  CONTINUE
00730  315*          REWIND 11
00731  316*              REWIND 12
00731  317*     C
00731  318*     C          REGRESSION ANALYSIS FOR SHEAR TERM.
00731  319*     C
00732  320*              CALL REGR(NTERMS, BB, CO, R )
00732  321*     C
00732  322*     C          CALCULATE SHEAR TERM AND RELATIVE AND GLOBAL ERROR.
00732  323*     C
00733  324*          NTOT = 0
00734  325*          SUM = 0.0
00735  326*          RESID = 0.0
00736  327*          DO 600 L=1,NTEST
00741  328*          LINE = 0
00742  329*          CALL PAGNE ( IPG, NAME )
```

```
00743   330*          WRITE(6,659) L
00746   331*               READ(11)  NDP, KODE, PRES
00753   332*               READ(11) (DIL(I), F11(I), F12(I),FACT(I), INV1(I), INV2(I)
00753   333*     1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
00772   334*               READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01004   335*               READ(12)  (STRESS(I), I=1,NDP)
01012   336*               READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01023   337*          NTOT = NTOT + NDP
01024   338*          DO 600 I=NJ,NDP
01027   339*          SCAL = 0.0
01030   340*              DO 610 J=1,NTERMS
01033   341*              SCAL = SCAL + CO(J)*XF(J,I)
01034   342*     610      CONTINUE
01036   343*          DEV = 100.*(SCAL - STRUE(I))/STRUE(I)
01037   344*               IF(ABS(STRUE(I)).LT.A.0 ) GO TO 605
01041   345*          SUM = SUM + DEV/100.
01042   346*          RESID = RESID + DEV**2/10.**4
01043   347*     605  CONTINUE
01044   348*          STRN = F11(I)
01045   349*          IF(NCOF.EQ.3)  STRN = F12(I)
01047   350*          WRITE(6,660)  TEMP(I), T(I), STRN, DIL(I), STRUE(I), SCAL, DEV,
01047   351*         1              (XF(J,I),J=1,NTERMS)
01064   352*          LINE = LINE + 4
01065   353*          IF(LINE.LT.42) GO TO 600
01067   354*          CALL PAGHL(IPG, NAME)
01070   355*          WRITE(6,658) L
01072   356*          LINE = 0
01074   357*     600  CONTINUE
01074   358*     C
01074   359*     C         ERROR SUMMARY AND COEFFICIENTS.
01074   360*     C
01077   361*          XBAR = SUM/NTOT
01100   362*          STD = ((NTOT*RESID-SUM**2)/(NTOT*(NTOT-1)))**0.5
01101   363*          CALL PAGHL( IPG, NAME )
01102   364*          WRITE(6,709)(I, CO(I),I=1,NTERMS)
01111   365*          WRITE(6,710) NTOT, XBAR, STD
01111   366*     C
01111   367*     C         NOW HAVE SHEAR TERM COEFFICIENTS CO(K).  GO SET BULK TERM
01111   368*     C         COEFFICIENTS DO(K) BY ADDING EXPRESSIONS FOR S11 AND S22.
01111   369*     C
01116   370*          NBULKS = 14
01116   371*     C         ZERO B AND BB
01116   372*     C
01117   373*          DO 505 K=1,14
01122   374*          BB(K) = 0.0
01123   375*          DO 506 I=1,100
01126   376*     506  XF(K,I) = 0.0
01126   377*     C
01130   378*          DO 505 J=1,14
01133   379*          B(K,J) = 0.0
01134   380*     505  CONTINUE
01137   381*               REWIND 11
01140   382*               REWIND 12
01141   383*          DO 500 L=1,NTEST
01144   384*               READ(11)  NDP, KODE, PRES
01151   385*               READ(11) (DIL(I), F11(I), F12(I),FACT(I), INV1(I), INV2(I)
01151   386*         1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
01170   387*               READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01170   388*     C
01202   389*          DO 501 I=1,100
```

```
01205   390*     501  STRESS(I) = 0.0
01205   391*  C
01205   392*  C
01207   393*        DO 510 I=N1,NNP
01212   394*        STRESS(I) = STRUE(I)/2. - PRES
01213   395*        DO 515 K=1,MTERMS
01216   396*        STRESS(I) = STRESS(I) - CO(K)*XF1(K,I)/2  - CO(K)*XF2(K,I) /2
01217   397*   515  CONTINUE
01217   398*  C
01217   399*  C          XF NOW RECOMES SOLUTION MATRIX FOR THE NNULKS TERMS.
01217   400*  C
01221   401*        XF(1,I) = STRESS(I)
01222   402*        XF(2,I) = STRESS(I)**2
01223   403*        XF(3,I) = STRESS(I)**3
01224   404*        XF(4,I) = STRESS(I)**4
01225   405*        XF(5,I) = FOCT(I)
01226   406*        XF(6,I) = FOCT(I)**2
01227   407*        XF(7,I) = FOCT(I)**3
01230   408*        XF(8,I) = FOCT(I)**4
01231   409*        XF(9,I) = (EXP(.01*STRESS(I)))*FOCT(I)
01232   410*        XF(10,I) = (EXP(.01*STRESS(I)))*FOCT(I)**2
01233   411*        XF(11,I) = (EXP(.01*STRESS(I)))*FOCT(I)**3
01234   412*        XF(12,I) = (EXP(.02*STRESS(I)))*FOCT(I)
01235   413*        XF(13,I) = (EXP(.02*STRESS(I)))*FOCT(I)**2
01236   414*        XF(14,I) = (EXP(.02*STRESS(I)))*FOCT(I)**3
01237   415*   516  CONTINUE
01237   416*  C
01237   417*  C          FORM PRIMARY MATRIX R. AND SOLUTION VECTOR RR.
01237   418*  C
01237   419*  C
01241   420*        DO 520 K=1,NNULKS
01244   421*        DO 52U J=1,NNULKS
01247   422*           DO 530 I=N1,NNP
01252   423*           IF(ABS(STRESS(I)).LT.A.0 ) GO TO 530
01254   424*        IF(ABS(DIL(I)).LT.3.E-4) GO TO 53%
01254   425*        R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/DIL(I)**2
01257   426*           IF(J.GT.I) GO TO 530
01261   427*        RR(K) = RR(K) + XF(K,I)/DIL(I)
01262   428*   53n     CONTINUE
01264   429*   520  CONTINUE
01264   430*  C
01267   431*           WRITE(12)  (STRESS(I), I=1,NNP)
01275   432*           WRITE(12)  (( XF(K,I),K=1,14),I=1,NNP)
01275   433*  C
01306   434*   500  CONTINUE
01306   435*  C
01310   436*           REWIND 11
01311   437*           REWIND 12
01311   438*  C
01312   439*           CALL RFOR( NNULKS, RR, RO, 0 )
01312   440*  C
01312   441*  C          FINAL STRESS AND ERROR CALCULATIONS.
01312   442*  C
01313   443*        SUM = 0.0
01314   444*        RESID = 0.0
01315   445*        DO 55n I=1,NTEST
01320   446*        LINE = 0
01321   447*        CALL PAGHL( IPG, NAME )
01322   448*        WRITE(6,655) I
01325   449*           READ(11)  NNP, KOFF, PRES
```

```
01332  450*            READ(11) (DIL(I), F11(I), F12(I),EOCT(I), INV1(I), INV2(I)
01332  451*           1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
01351  452*            READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01363  453*            READ(12)  (STRESS(I), I=1,NDP)
01371  454*            READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01402  455*          DO 550 I=N1,NDP
01405  456*          RCAL = 0.0
01406  457*              DO 560 J=1,NBULKS
01411  458*              RCAL = RCAL + RO(J)*XF(J,I)
01412  459*     560      CONTINUE
01414  460*          DEV = 100*(RCAL-DIL(I))/DIL(I)
01415  461*              IF(ABS(STRESS(I)).LT.8.0 ) GO TO 565
01417  462*          IF(ABS(DIL(I)).LT.3.E-4) GO TO 565
01421  463*          SUM = SUM + DEV/100.
01422  464*          RESID = RESID + DEV**2/10.**4
01423  465*     565  CONTINUE
01424  466*           STRN=EOCT(I)
01425  467*          WRITE(6,660) TEMP(I), T(I), STRN, STRESS(I), DIL(I), RCAL, DEV,
01425  468*         1              (XF(J,I),J=1,NBULKS )
01442  469*          LINE = LINE + 4
01443  470*          IF(LINE.LT.48) GO TO 550
01445  471*          CALL PAGNL( IPG, NAME )
01446  472*          WRITE(6,655) L
01451  473*          LINE = 0
01452  474*     550  CONTINUE
01452  475*     C
01452  476*     C         ERROR SUMMARY AND COEFFICIENTS FOR BULK TERM.
01452  477*     C
01455  478*          XBAR = SUM/NTOT
01456  479*          STD = ((NTOT*RESID-SUM**2)/(NTOT*(NTOT-1)))**0.5
01457  480*          CALL PAGNL(IPG,NAME)
01460  481*          WRITE(6,700)(I, RO(I),I=1,NBULKS)
01467  482*          WRITE(6,710) NTOT, XBAR, STD
01467  483*     C
01467  484*     C
01467  485*     C         F O R M A T   S T A T E M E N T S
01467  486*     C
01474  487*       1   FORMAT(20A4)
01475  488*       2   FORMAT(8E10.0)
01476  489*       4   FORMAT( 2F10.0, I5)
01477  490*       7   FORMAT( 5E10.3, I5)
01500  491*      13   FORMAT(A6, E14.4, 2I5, 5A4, 2F15.4)
01501  492*      14   FORMAT(1P6E12.4)
01502  493*      15   FORMAT(1P3E20.6)
01503  494*      30   FORMAT(1H , //,20X,'THERE WERE ',I3, ' VALUES OF SHIFT FUNCTION VS
01503  495*     1. TEMPERATURE ...',///,T12,'I',T21,'AT(I)',T34,'TSHFT(I)', // )
01504  496*      31   FORMAT(1H ,10X, I2, T19,1PE10.3, T32, 1PE10.3 )
01505  497*      32   FORMAT(1H ,//,10X,'A = ',E10.3,/,10X,'B = ', E10.3,///// )
01506  498*      33   FORMAT(1H ,10X,'TEST NO.',5X,'TEST ID',5X,' NDP ',5X,'MODE',5X,
01506  499*     1       'KTEMP',8X,'PRESSURE',8X,'TEMP', //)
01507  500*      35   FORMAT(1H , 10X,I8, 5X,A6, 6X, I5, 5X, I4, 5X, I5, 8X, F8.2, 8X,
01507  501*     1         F6.1  )
01510  502*      40   FORMAT(1H , 20X, 'POWER LAW TERMS, (1 + B*T)** P',//, 10X,
01510  503*     1       'I', 8X,'B(I)',11X,' P(I)', 9X,'IFG(I)', /,
01510  504*     2       7(/,10X,I3,5X,1PE10.3,5X,1PE10.3,7X,I3),///)
01511  505*      42   FORMAT(1H , 10X,' I',10X,'IFF(I)',/,14(/,10X,I2,10X,I4), /// )
01512  506*      44   FORMAT(1H , 10X, 'I',10X, 'NORM', 12X, 'XN(I)', /,
01512  507*     1       6(/,10X,I3, 11X, I1, '0', 10X, 1PE10.3)  )
01513  508*      75   FORMAT(16I5)
01514  509*      410  FORMAT(1H , 20(/), 40X, 'I N V E R S E  F A I L E D  O N  R O W
```

```
01514   510*          1       *, I6  )
01515   511*     58A  FORMAT(1H ,/, 6X, 10F12.4 )
01516   512*     650  FORMAT(1H , 40X,*SUMMARY OF SHEAR TERM FOR TEST NO.*,I8,//, T9,
01516   513*          1       *TEMP*, T19,*TIME*, T26,*E(I) OR F12*, T39,*DV/V0*, T49,
01516   514*          2   *STRIE*,T58,*S-CALC*,T69,*ERROR*,T95,*XF(I),I=1,NTERMS*, /  )
01517   515*     655  FORMAT(1H , /,40X,*SUMMARY OF BULK RESULTS FOR TEST NO.*,I5,//,T9,
01517   516*          1       *TEMP*,T19,*TIME*,T26,*EOCT*,T39,*SR-CALC*,T49,*OIL*,T60,
01517   517*          2       *OIL-CALC*,T70,*ERROR*,T95,*XF(K),K=1,*NBULKS*,/)
01520   518*     660  FORMAT(1H ,/,5X,7E10.4,T80,'*',5E10.4,2(/,T80,'*',5E10.4)  )
01521   519*     675  FORMAT(1H ,/,40X,*TEST NO. *,I4,*,  F I N A L   S U M M A R Y*,//,
01521   520*          1       T15,*TEMP*,T27,*TIME*,T38,*STRAIN*,T51,*S11*,T61,*S11-CALC*,
01521   521*          2       T73,*ERROR*,T87,*S22*,T97,*S22-CALC*,T111,*ERROR*,T122,
01521   522*          3   *PRESSURE*, / )
01522   523*     700  FORMAT(1H, 3(/), 30X,*REGRESSION COEFFICIENTS ...*,///,  1X,*I*,
01522   524*          1       26X, *CO(I)*,//,15(11X,I2,22X,1PE12.5,/), 10(/))
01523   525*     710  FORMAT(1H ,10X,*THERE WERE*,I6,*  EXPERIMENTAL TEST POINTS*, ///,
01523   526*          1       10X,*THE AVERAGE DEVIATION, XBAR, WAS *, E10.4, ///, 10X,
01523   527*          2       *THE STANDARD DEVIATION, STD, WAS *, E10.4  )
01524   528*     720  FORMAT(1H ,5(/),20X,*FOR THE STRESS SIGMA-11, ...*,///,20X,
01524   529*          1       *XBAR = *,E10.4,5X,*AND STD = *, E10.4, //)
01525   530*     725  FORMAT(1H , 5(/), 20X,*FOR THE STRESS SIGMA-22, ...*,///,20X,
01525   531*          1       *XBAR = *, E10.4, 5X, *AND STD = *, E10.4 )
01525   532*     C
01526   533*          END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

SINGLE WORD HOLLERITH STRINGS------

```
DNUM  :  0111,  0112
END   :  0105
```

NAMES------

```
A     :  0125  0174  0614
AAS   :  0634  01037  01252  01254  01416  01417
AT    :  0103  0232  0245  0260  0420
AVGAT :  0425  0421  0435
A1    :  0107  0454  0456  0460  0463
A2    :  0107  0455  0456  0460
A3    :  0564  0575  0576  0601
B     :  0103  0164  0200  0575  0576  0601
BB    :  0103  0276  0641  0732  01122  01261  01312
BCAL  :  01405  01411  01414  01425
BETA  :  0104
BO    :  0103  01312  01411  01460
BUFFER:  0356
BULK  :  0104
CO    :  0103  0732  01033  01102  01216
D     :  0103  0260  0263  0420
DABS  :  0454  0455  0513  0514  0540
DEV   :  01036  01041  01042  01047  01414  01421  01422  01425
DEXP  :  0514
DI    :  0540  0541  0542  0543
DIL   :  0103  0104  0322  0654  0753  01047  01151  01254  01256  01261  01332  01414  01417  01425
DR1   :  0103  0104  0323  0575
DR12  :  0103  0104  0325  0601
DR2   :  0103  0104  0324  0576
DSORT :  0514
DT    :  0103  0104  0326  0421
DTH   :  0453  0460  0463
```

```
EOCT  :  0103  0104  0107  0654  0753  01151 01225 01226 01227 01230 01231 01232 01233 01234 01235 01236 01359
         01424
EXP   :  0420  01231 01232 01233 01234 01235 01236
E11   :  0103  0104  0327  0510  0512  0654  0753  01044 01151 01332
E12   :  0103  0104  0332  0654  0753  01045 01151 01332
E22   :  0103  0104  0330  0511  0512
E33   :  0103  0104  0331
F     :  0103  0333  0504  0514  0517  0520  0521  0546  0547  0550  0606  0610
G     :  0103  0334  0513  0612  0614
I     :  0117  0131  0137  0145  0153  0164  0200  0211  0220  0245  0255  0260  0273  0276  0302  0307  0308
         0312  0317  0322  0323  0324  0325  0326  0327  0330  0331  0332  0333  0334  0335  0336  0337  0340
         0341  0342  0343  0344  0345  0346  0352  0402  0405  0407  0414  0420  0421  0432  0435  0450  0453
         0454  0455  0460  0463  0476  0477  0505  0510  0511  0512  0513  0514  0517  0520  0521  0631  0634
         0636  0641  0654  0673  0705  0713  0753  0772  01004 01012 01024 01033 01036 01037 01040 01045 01047
         01102 01123 01126 01151 01170 01202 01205 01207 01212 01216 01221 01222 01223 01224 01225 01226 01227
         01230 01231 01232 01233 01234 01235 01236 01247 01252 01256 01256 01261 01267 01275 01332 01351 01363
         01371 01402 01411 01414 01415 01417 01424 01425 01460
IFF   :  0103  0137  0211  0515  0544  0606  0610
IFG   :  0103  0131  0200  0612  0614
IFLAG :  0113  0256  0724
IFN   :  0103  0145  0220  0530
INPUT :  0104
INT1  :  0110  0565  0575  0604
INT12 :  0110  0567  0581
INT2  :  0110  0566  0576  0605
INV1  :  0103  0104  0107  0335  0654  0753  01151 01332
INV2  :  0103  0104  0107  0336  0654  0655  0513  0514  0540  0654  0753  01151 01332
INV3  :  0103  0104  0107  0337  0514  0654  0753  01151 01332
IOUNIT:  0111  0112
IPG   :  0114  0173  0241  0270  0364  0742  01067 01101 01321 01445 01457
ITEST :  0104  0371
J     :  0307  0312  0411  0414  0420  0535  0540  0541  0542  0543  0546  0547  0550  0561  0570  0575  0576
         0601  0604  0605  0606  0610  0612  0614  0616  0626  0636  0637  01030 01033 01047 01170 01177 01208
         01256 01257 01406 01411 01425
K     :  0277  0302  0303  0304  0347  0352  0525  0530  0540  0570  0575  0576  0601  0623  0636  0641  0673
         0713  0772  01012 01117 01122 01126 01133 01170 01213 01216 01241 01256 01261 01275 01351 01371
KODE  :  0104  0371  0573  0647  0746  01045 01144 01325
KTEYP :  0104  0371  0424
L     :  0736  0743  01070 01141 01315 01322 01446
LAST  :  0232  0237
LINE  :  0267  0361  0362  0367  0741  01064 01065 01073 01320 01442 01443 01451
LOG   :  0260  0420
M     :  0426  0431  0435  0443  0446  0447  0460  0463  0467  0473  0477  0530  0531  0540  0555  0563  0568
         0575  0576  0601  0604  0605  0606  0610  0612  0614  0616
MATID :  0103  0104
MP7   :  0560  0606  0610
N     :  0534  0541  0542  0543  0544  0546  0547  0550  0604  0605  0606  0610  0612  0614  0616
NAME  :  0103  0117  0173  0241  0270  0364  0742  01067 01101 01321 01445 01457
NAT   :  0230  0231  0232  0242  0245  0255  0411
NNULNS:  01116 01241 01244 01312 01406 01425 01460
NOP   :  0104  0371  0402  0432  0450  0474  0505  0535  0561  0631  0647  0658  0673  0705  0713  0746  0753
         0772  01004 01012 01023 01024 01144 01151 01170 01207 01247 01267 01275 01325 01332 01351 01363 01371
         01402
NEND  :  0105
NORM  :  0103  0104  0107  0352  0435  0460  0463  0477  0540
NORMF :  0103  0104  0107  0340  0513
NORMS :  0524  0533  0534  0622
NPL   :  0161  0164  0555  0622
NTERMS:  0622  0623  0626  0732  01030 01047 01102 01213
NTEST :  0264  0557  0571  0736  01141 01315
```

```
ATOT  :  0733  01023  01077  01100  01111  01455  01456  01467
FD    :  0115  0116  0356
F1    :  0350  0402  0405  0450  0474  0505  0535  0561  0570  0631  01024  01207  01247  01402
F     :  0103  0164  0200  0348
PAGAL :  0173  0241  0270  0364  0742  01067  01101  01321  01445  01457
PRES  :  0104  0371  0647  0746  01144  01212  01325
R     :  0103  0312  0636  0732  01133  01256  01312
RATE  :  0103  0104  0341
RERR  :  0732  01312
RESID :  0735  01042  01100  01314  01422  01456
SCAL  :  01027  01033  01036  01047
STD   :  01100  01111  01456  01467
STRESS:  0103  0104  0342  0765  01004  01205  01212  01216  01221  01222  01223  01224  01231  01232  01245  01246  01255
         01256  01252  01267  01345  01415  01425
STRN  :  01044  01045  01047  01424  01425
STULE :  0103  0104  0343  0634  0636  0641  0654  0753  01036  01037  01047  01151  01212  01332
SUM   :  0734  01041  01077  01100  01313  01421  01455  01456
T     :  0103  0104  0344  0654  0753  01047  01151  01332  01425
TEMP  :  0103  0104  0345  0371  0407  0414  0420  0654  0753  01047  01151  01332  01425
TR    :  0103  0346  0421  0453  0475  0576  0601
TSHFT :  0103  0232  0645  0260  0414  0420
WORK1 :  0101  0111
WORK2 :  0101  0112
XMAP  :  01077  01111  01455  01467
XF    :  0103  0304  0512  0521  0543  0550  0616  0636  0641  0713  01012  01033  01047  01126  01221  01222  01223
         01224  01225  01226  01227  01230  01231  01232  01233  01234  01235  01236  01256  01261  01275  01371  01411  01425
XF1   :  0103  0302  0510  0517  0541  0546  0604  0606  0612  0616  0673  0772  01170  01216  01351
XF2   :  0103  0303  0511  0520  0542  0547  0605  0610  0614  0616  0673  0772  01170  01216  01351
XR    :  0103  0153  0220  0540
XP    :  0431  0435  0446  0460  0472  0473  0477
X..   :  0447  0463
Z     :  0125  0174  0513

LABELS-----
     1:  0117  01474
     2:  0125  0153  0164  01475
     3:  0231  0237
     4:  0232  01476
     5:  0261
     7:  01
     8:  04  0422
     9:  040  0411
    10:  0402  0421
    11:  0411  0416
    12:  0414  0420
    13:  01500
    14:  01501
    15:  01502
    18:  0424  0442
    19:  0441  0503
    20:  0443  0450  0461  0464
    21:  0456  0462
    22:  0467  0474  0500
    30:  0242  01503
    31:  0245  01504
    32:  0174  01505
    33:  0271  0365  01506
    34:  0362  0370
    35:  0371  01507
    40:  0200  01510
```

```
   42:   0211  01511
   44:   0220  01512
   50:   0525   0531   0553
   55:   0535   0544   0551
   60:   0426   0432   0436
   65:   0505   0515   0522
   70:   0555   0561   0617
   71:   0570   0577   0602
   75:   0131   0137   0145   0161   01514
   78:   0573   0600
  100:   0316   0726
  105:   0277   0305
  107:   0317   0347   0353
  110:   0273   0307   0313
  200:   0724   0727
  300:   0623   0626   0644
  310:   0631   0634   0637   0642
  410:  01514
  500:  01141  01306
  501:  01202  01205
  505:  01117  01130  01134
  508:  01123  01126
  510:  01207  01237
  515:  01213  01217
  520:  01241  01244  01264
  530:  01247  01252  01254  01257  01262
  550:  01315  01402  01443  01452
  560:  01406  01412
  565:  01415  01417  01423
  580:  01515
  600:   0736  01024  01065  01074
  605:  01037  01043
  610:  01030  01034
  650:   0743  01070  01516
  655:  01322  01446  01517
  660:  01047  01425  01520
  675:  01521
  700:  01102  01460  01522
  710:  01111  01467  01523
  720:  01524
  725:  01525

INTEGER CONSTANTS----------
    0:   0113   0114   0230   0237   0264   0267   0367   0515   0524   0531   0588   0606   0610   0612   0618   0733
         0741  01073  01320  01451
    1:   0115   0117   0131   0137   0145   0153   0164   0200   0211   0220   0231   0285   0260   0263   0273   0277
         0307   0317   0347   0357   0361   0371   0407   0411   0420   0421   0426   0439   0443   0455   0460   0462
         0463   0467   0504   0510   0511   0512   0515   0517   0520   0521   0525   0533   0534   0541   0582   0587
         0555   0575   0576   0601   0622   0623   0626   0637   0654   0673   0705   0713   0736   0752   0772  01008
        01012  01030  01047  01100  01102  01117  01123  01130  01141  01151  01170  01202  01213  01221  01241  01244
        01257  01267  01275  01315  01332  01351  01363  01371  01406  01425  01456  01460
    2:   0255   0263   0424   0636   0724  01042  01100  01216  01322  01226  01232  01235  01256  01422  01456
    3:   0360   0573  01045  01223  01227  01233  01236
    4:  01042  01064  01224  01230  01422  01442
    5:   0103   0117   0125   0131   0137   0145   0153   0161   0164   0232  01225
    6:   0103   0145   0153   0174   0200   0211   0220   0242   0245   0271   0347   0365   0371   0426   0443   0447
         0525   0743  01047  01070  01102  01111  01226  01322  01425  01446  01460  01467
    7:   0101   0103   0131   0200   0560  01227
    8:  01230
    9:  01231
```

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APPENDIX F

SUBPROGRAMS

1.0 INTRODUCTION

This appendix lists the additional subprograms called for in codes NL001, NL002, NL003, POST, and LINVIS. These routines are used for page counting, headings and matrix inversion and are common to these codes. Since these subroutines need no input from the user only the listings are presented.

```
                    VRQLAY:4/5/.2.1.100                                  15 JUN 73   09:24:59    PAGE     2

 LI FOR PAGNL,PAGNL                                                      15 JUN 73   00:00:00.044
 DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  09:24(00)
 FORTRAN V:  ISD VERSION 2.6

    SUBROUTINE PAGNL     ENTRY POINT 000035

    STORAGE USED (BLOCK, NAME, LENGTH)

          0001   *CODE   000047
          0000   *DATA   000045
          0002   *BLANK  003000

    EXTERNAL REFERENCES (BLOCK, NAME)

          0003   NWRU$
          0004   NIO2$
          0005   NIO1$
          0006   NERR3$

    STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0000   000001 IF        0001   000020 1126       0000   000027 2F       0000 I 000000 I


 00100      1*   C
 00101      2*         SUBROUTINE PAGNL(IPG, TITLE)
 00101      3*   C
 00101      4*   C        SUBROUTINE PULLS UP A NEW PAGE FOR NL002, INCREMENTS AND NUMBERS
 00101      5*   C        IT, SKIPS TWO LINES THEN WRITES AN 80 COLUMN TITLE IN THE CENTER
 00101      6*   C        OF THE PAGE.
 00101      7*   C
 00103      8*         DIMENSION TITLE(20)
 00104      9*         IPG = IPG + 1
 00105     10*         WRITE(6,1)  IPG
 00110     11*         WRITE(6,2) (TITLE(I),I=1,20 )
 00110     12*   C
 00116     13*    1    FORMAT(1H1, ' N O N L I N E A R   T H E R M O V I S C O E L A S T
 00116     14*        1I C   C H A R A C T E R I Z A T I O N   C O D E', T120, 'PAGE',
 00116     15*        2I4, // )
 00117     16*    2    FORMAT(1H , 30X, 20A4 )
 00117     17*   C
 00120     18*         RETURN
 00121     19*         END

                                        * CROSS REFERENCE BY SEQUENCE NUMBER *

 NAMES------
 I      :   0110
 IPG    :   0101   0104   0105
 PAGNL  :   0101
 TITLE  :   0101   0103   0110
```

```
                    WORKAY.4A.5772.1.100                                  15 JUN 73   09:24:50   PAGE    1

GI FOR REGR,REGR                                                          15 JUN 73   00:00:00.33
OPTE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  09:24(00)
FORTRAN V:  ISD VERSION 2.0

    SUBROUTINE REGR      ENTRY POINT 000257

    STORAGE USED (BLOCK, NAME, LENGTH)

          0001   *CODE   000300
          0000   *DATA   000774
          0002   *BLANK  000000


    EXTERNAL REFERENCES (BLOCK, NAME)

          0003   PAUSE
          0004   EXIT
          0005   NUMOUT
          0006   NIO2S
          0007   NERR3S


    STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001   000616 1116      0001   000625 1166      0001   000647 1256      0001   000670 1346      0001   000677 1426
     0001   000121 1516      0001   000167 1756      0001   000173 2016      0001   000215 2106      0001   000222 2156
     0000   000707 300F      0001   000127 350L      0001   000141 400L      0000   000715 410F      0001   000163 500L
     0000 D 000000 BB        0000 D 000034 CO        0000 D 000700 COM       0000 I 000702 I         0000 I 000705 IPG
     0000 I 000704 J         0000 I 000703 K         0000 I 000706 NAME      0000 D 000070 R


00100     1*    C
00100     2*          SUBROUTINE REGR( NTERMS, BBS, COS, RS )
00101     3*    C
00101     4*    C         PREMULTIPLIES THE VECTOR BB BY R INVERSE TO FORM THE
00101     5*    C         REGRESSION COEFFICIENTS CO.
00101     6*    C
00103     7*          DIMENSION     BB(14), CO(14), R(14,14)
00104     8*          DIMENSION     BBS(14), COS(14), RS(14,14)
00105     9*          DOUBLE PRECISION  BB, CO, R, COM
00106    10*      300 FORMAT(1H , //, 40X, 'COM = ', 1PE12.4 )
00107    11*      410 FORMAT(1H , 20(/), 40X, 'I N V E R S E   F A I L E D   O N   R O W
00107    12*         1       ', I6  )
00107    13*    C
00107    14*    C     LOAD INTO DOUBLE PRECISION ARRAYS FOR INVERSION.
00107    15*    C
00110    16*          DO 100 I=1,14
00113    17*          BB(I) = BBS(I)
00116    18*          CO(I) = COS(I)
00115    19*          DO 100 K=1,14
00120    20*          R(I,K) = RS(I,K)
00121    21*      100 CONTINUE
00121    22*    C
00121    23*    C         INVERT R.
00121    24*    C
```

```
00124    25*          DO 350 K=1,NTERMS
00127    26*          COM = R(K,K)
00130   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00130    27*          IF(COM.EQ.0.00) GO TO 400
00132    28*          R(K,K) = 1.00
00133    29*              DO 360 J=1,NTERMS
00136    30*              R(K,J) = R(K,J)/COM
00137    31*   360        CONTINUE
00137    32*     C
00141    33*          DO 350 I=1,NTERMS
00144    34*          IF(I.EQ.K) GO TO 350
00146    35*          COM = R(I,K)
00147    36*          R(I,K) = 0.00
00150    37*              DO 370 J=1,NTERMS
00153    38*              R(I,J) = R(I,J) - COM*R(K,J)
00154    39*   370        CONTINUE
00156    40*   350    CONTINUE
00161    41*          GO TO 500
00162    42*   400    CONTINUE
00162    43*     C
00162    44*     C         INVERSE FAILS.
00162    45*     C
00163    46*          CALL PAGNL(IPG, NAME)
00164    47*          WRITE(6,410) K
00167    48*          WRITE(6,300) COM
00172    49*          CALL EXIT
00172    50*     C
00173    51*    500   CONTINUE
00173    52*     C
00173    53*     C         COMPUTE THE REGRESSION COEFFICIENTS CO(I).
00173    54*     C
00174    55*          DO 510 K=1,NTERMS
00177    56*          CO(K) = 0.00
00200    57*          DO 510 I=1,NTERMS
00203    58*          CO(K) = CO(K) + R(K,I)*BB(I)
00204    59*   510    CONTINUE
00204    60*     C
00204    61*     C
00204    62*     C    LOAD RESULTS INTO SINGLE PRECISION ARRAYS AND RETURN
00204    63*     C
00207    64*          DO 200 I=1,14
00212    65*          BBS(I) = BB(I)
00213    66*          COS(I) = CO(I)
00214    67*          DO 200 K=1,14
00217    68*          RS(I,K) = R(I,K)
00220    69*   200    CONTINUE
00223    70*          RETURN
00223    71*     C
00224    72*          END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

```
NAMES-----
  BB   :  0103  0105  0113  0203  0212
  BBS  :  0101  0104  0113  0212
  CO   :  0103  0105  0114  0177  0203  0213
  COM  :  0105  0127  0130  0136  0146  0153  0167
  COS  :  0101  0104  0114  0213
  EXIT :  0172
```



```
  I    :  0110  0113  0114  0120  0141  0144  0146  0147  0153  0200  0203  0207  0212  0213  0217
  IPG  :  0163
  J    :  0133  0136 *0150  0153
  K    :  0115  0120  0124  0127  0132  0136  0144  0146  0147  0153  0164  0174  0177  0203  0214  0217
```

GI FOR PGPOST,PGPOST 15 JUN 73 00:00:02.220
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:24(00)
FORTRAN V: ISD VERSION 2.6

SUBROUTINE PGPOST ENTRY POINT 000074

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000123
0000	*DATA	000132
0002	*BLANK	000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	NWDUS
0004	NIWES
0005	NIOIS
0006	NERRS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 000001 1F 0001 000040 1166 0000 000034 2F 0000 000045 3F 0000 I 000000 I

```
00100     1*  C
00101     2*        SUBROUTINE PGPOST(IPG,LINE,KODE,KTEMP,ITEST,ITYPE,ITEMP,BULK,
00101     3*       1                  BETA, MATID, RATE, PRES )
00101     4*  C
00101     5*  C         PAGE HEADING FOR POST PROCESSOR.
00101     6*  C
00103     7*        DIMENSION MATID(5), ITYPE(3), RATE(100), ITEMP(2)
00103     8*  C
00104     9*        DOUBLE PRECISION ITEMP, ITYPE
00104    10*  C
00104    11*  C
00105    12*        IPG = IPG + 1
00106    13*        LINE = 0
00106    14*  C
00107    15*        WRITE(6,1) ITEST,ITEST, IPG
00114    16*        WRITE(6,2) (MATID(I),I=1,5), ITYPE(KODE)
00123    17*        WRITE(6,3) BULK, RATE(3), BETA, PRES, ITEMP(KTEMP)
00123    18*  C
00123    19*  C
00132    20*    1   FORMAT(1H1,T40,'S U M M A R Y  O F  T E S T  N O . ',A6,
00132    21*       1       T113,'PAGE ',A6,' - ',I2, ///, T10,'M A T E R I A L  ',
00132    22*       2       'D A T A', T95, 'T E S T  D A T A', / )
00133    23*    2   FORMAT(1H , T10,'MATERIAL IS ',5A4, T95,'TYPE ... ', A8 )
00134    24*    3   FORMAT(1H , T10,'BULK MODULUS = ', E10.4, T95,'INITIAL STRAIN ',
00134    25*       1       'RATE = ', F10.4, /, T10,'VOLUMETRIC EXPANSION COEFFICIENT'
00134    26*       2       ,' = ', E10.4, T95,'PRESSURE = ', F10.0, ' PSIG',/,T95,
00134    27*       3       'TEMPERATURE IS ', A8 )
00134    28*  C
00135    29*        RETURN
```



```
00136    30*        END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

GT FOR BUFFER,BUFFER 15 JUN 73 09:24:58
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:24:00)
FORTRAN V: ISD VERSION 2.0

SUBROUTINE BUFFER ENTRY POINT 000465

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000507
0002	*DATA	013352
0002	*BLANK	000000
0003	INPUT	007034

EXTERNAL REFERENCES (BLOCK, NAME)

0004	NTRAN
0005	EXIT
0006	NERR0$
0007	NIO2$
0010	NWDU$
0011	NERR3$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	010505 IF	0001	000044 IOL	0001	000421 110L	0001	000067 140G	0001	000106 150G		
0001	000120 155G	0000	010506 2F	0001	000051 20L	0001	000430 200L	0001	000251 216G		
0001	000264 223G	0001	000004 50L	0001	000435 95GL	0000 R	010531 R	0003 R	000013 BETA		
0003 R	000012 BULK	0000 D	000000 DR	0003 R	000634 DIL	0003 R	002130 DR1	0003 R	002480 DR12		
0003 R	002274 DR2	0003 R	000324 DT	0003 D	006524 EOCT	0003 R	001144 E11	0003 R	001620 E12		
0003 R	001310 E22	0003 R	001454 E33	0000 I	010504 I	0000 I	010531 IA	0003 D	002604 INV1		
0003 D	003114 INV2	0003 D	003424 INV3	0003 I	000000 ITEST	0000 I	010503 J	0000 I	010502 K		
0003 I	000004 KODE	0003 I	000003 KTEMP	0000 I	010501 LD	0000 I	010500 LO	0003 I	000005 MATID		
0000 I	010477 MTEST	0000 I	010460 N	0003 I	000001 NDP	0000 I	010476 NEND	0003 D	006244 NORM		
0003 D	003734 NORMF	0003 R	000002 PRES	0003 R	000160 RATE	0003 R	000470 STRESS	0003 R	001764 STRUE		
0003 R	001000 T	0003 R	000014 TEMP								

```
00100     1*    C
00101     2*          SUBROUTINE BUFFER (NU,IFLAG)
00101     3*    C
00101     4*    C         SUBROUTINE BUFFERS BINARY TAPE INPUT.
00101     5*    C         ASSUMES NU001 OUTPUT SEQUENCE ON TAPE.
00101     6*    C
00103     7*          DIMENSION A(1400), IA(1400), DR(2200), N(14)
00104     8*          DIMENSION     DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00104     9*         1              E11(100), E22(100), E33(100), E12(100), EOCT(100),
00104    10*         2              INV1(100), INV2(100), INV3(100), MATID(5),
00104    11*         3              NORM(6,100), NORMF(100), RATE(100), STRESS(100),
00104    12*         4              STRUE(100), T(100), TEMP(100)
00105    13*          DOUBLE PRECISION DR, INV1, INV2, INV3, EOCT, NORM, NORMF
00105    14*    C
00106    15*          COMMON /INPUT/ ITEST, NDP, PRES, KTEMP, KODE, MATID, BULK, BETA,
00106    16*         1               TEMP, RATE, DT, STRESS, DIL, T, E11, E22, E33, E12,
```

```
00106  17*        2                STRUE, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00106  18*        3                NORM, FOCT
00106  19*   C
00107  20*        EQUIVALENCE ( A(1), IA(1) )
00107  21*   C
00110  22*        DATA NEND/'END'/
00110  23*   C
00112  24*        IF(IFLAG.EQ.1) GO TO 10
00114  25*    50  CONTINUE
00115  26*        READ(5,1) MTEST
00120  27*        IF(MTEST.EQ.NEND) GO TO 200
00120  28*   C
00120  29*   C
00122  30*            CALL NTRAN(NU,4,MTEST,1400,0,0)
00123  31*            CALL NTRAN(NU,2,2200,DR,LD)
00123  32*   C
00123  33*   C
00124  34*        IF(IFLAG.EQ.1) RETURN
00126  35*    10  IF(LD+1) 999,10,20
00131  36*    20  CONTINUE
00131  37*   C
00131  38*   C        LOAD SINGLE PRECISION/INTEGER ARRAYS.
00131  39*   C
00132  40*        ITEST = IA(1)
00133  41*        NDP = IA(2)
00134  42*        PRES = A(3)
00135  43*        KTEMP = IA(4)
00136  44*        KODE = IA(5)
00137  45*        DO 21 K=1,5
00142  46*        J = K+5
00143  47*    21  MATID(K) = IA(J)
00145  48*        BULK = A(11)
00146  49*        BETA = A(12)
00146  50*   C
00147  51*        DO 22 I=1,14
00152  52*    22  N(I) = 12 + (I-1)*NDP
00152  53*   C
00154  54*        DO 100 I=1,NDP
00157  55*        J = N(1)
00160  56*        TEMP(I)   = A(J+I)
00161  57*        J = N(2)
00162  58*        RATE(I)   = A(J+I)
00163  59*        J = N(3)
00164  60*        DT(I)     = A(J+I)
00165  61*        J = N(4)
00166  62*        STRESS(I) = A(J+I)
00167  63*        J = N(5)
00170  64*        DTL(I)    = A(J+I)
00171  65*        J = N(6)
00172  66*        T(I) =      A(J+I)
00173  67*        J = N(7)
00174  68*        E11(I)    = A(J+I)
00175  69*        J = N(8)
00176  70*        E22(I)    = A(J+I)
00177  71*        J = N(9)
00200  72*        E33(I)    = A(J+I)
00201  73*        J = N(10)
00202  74*        E12(I)    = A(J+I)
00203  75*        J = N(11)
00204  76*        STRUE(I)  = A(J+I)
```

```
00205   77*         J = N(12)
00206   78*         DR1(I)    = B(J+I)
00207   79*         J = N(13)
00210   80*         DR2(I)    = B(J+I)
00211   81*         J = N(14)
00212   82*         DR12(I)   = B(J+I)
00213   83*  100  CONTINUE
00213   84*  C
00213   85*  C          LOAD DOUBLE PRECISION ARRAYS.
00213   86*  C
00215   87*         DO 23 I=1,11
00220   88*   23    N(I) = (I-1)*NDP
00220   89*  C
00222   90*         DO 110 I=1,NDP
00225   91*         J = N(1)
00226   92*         INV1(I) = DP(J+I)
00227   93*         J = N(2)
00230   94*         INV2(I) = DP(J+I)
00231   95*         J = N(3)
00232   96*         INV3(I) = DP(J+I)
00233   97*         J = N(4)
00234   98*         NORME(I)= DP(J+I)
00235   99*         J = N(5)
00236  100*         FCCT(I) = DP(J+I)
00237  101*         IF(KTEMP.EQ.2) GO TO 110
00241  102*         J = N(6)
00242  103*         NORM(1,I) = DP(J+I)
00243  104*         J = N(7)
00244  105*         NORM(2,I) = DP(J+I)
00245  106*         J = N(8)
00246  107*         NORM(3,I) = DP(J+I)
00247  108*         J = N(9)
00250  109*         NORM(4,I) = DP(J+I)
00251  110*         J = N(10)
00252  111*         NORM(5,I) = DP(J+I)
00253  112*         J = N(11)
00254  113*         NORM(6,I) = DP(J+I)
00255  114*  110  CONTINUE
00255  115*  C
00257  116*         IFLAG = 1
00260  117*         GO TO 50
00260  118*  C
00260  119*  C          ALL DONE.  RETURN WITH LAST TEST AND DO NOT REENTER.
00260  120*  C
00261  121*  200  CONTINUE
00262  122*         IFLAG = 2
00263  123*         RETURN
00263  124*  C
00264  125*  999  CONTINUE
00265  126*         WRITE(6,2) LQ, LD
00271  127*         CALL EXIT
00271  128*  C
00272  129*    1    FORMAT(A6)
00273  130*    2    FORMAT(1H1, 10(/),30X,'T A P E   E R R O R . . .'///,
00273  131*   1          T60,'LQ = ', I5,///,T60,'LD = ', I5,////,'JOB TERMINATED',/)
00273  132*  C
00274  133*         END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

SINGLE WORD HOLLERITH STRINGS------
END : 0110

NAMES------
B : 0103 0107 0122 0134 0145 0146 0160 0162 0164 0166 0170 0172 0174 0176 0200 0202 0204
0206 0210 0212
BETA : 0106 0146
BUFFER: 0101
BULK : 0106 0145
CM : 0103 0105 0123 0226 0230 0232 0234 0236 0242 0244 0246 0250 0252 0254
DIL : 0104 0106 0170
DR1 : 0104 0106 0206
DR12 : 0104 0106 0212
DR2 : 0104 0106 0210
DT : 0104 0106 0164
EOCT : 0104 0105 0106 0236
EXIT : 0271
F11 : 0104 0106 0174
F12 : 0104 0106 0202
F22 : 0104 0106 0176
F33 : 0104 0106 0200
I : 0147 0152 0154 0160 0162 0164 0166 0170 0172 0174 0176 0200 0202 0204 0206 0210 0212
0216 0220 0222 0226 0230 0232 0234 0236 0242 0244 0246 0250 0252 0254
IB : 0103 0107 0132 0133 0135 0136 0143
IFLAG : 0101 0112 0124 0257 0262
INPUT : 0106
INV1 : 0104 0105 0106 0226
INV2 : 0104 0105 0106 0230
INV3 : 0104 0105 0106 0232
ITEST : 0106 0132
J : 0142 0143 0157 0160 0161 0162 0163 0164 0165 0166 0167 0170 0171 0172 0173 0174 0175
0176 0177 0200 0201 0202 0203 0204 0205 0206 0207 0210 0211 0212 0225 0226 0227 0230
0231 0232 0233 0234 0235 0236 0241 0242 0243 0244 0245 0246 0247 0250 0251 0252 0253
0254
K : 0137 0142 0143
KODE : 0106 0136
KTEMP : 0106 0135 0237
LD : 0123 0126 0265
LU : 0122 0265
MATID : 0104 0106 0143
MTEST : 0115 0120 0122
N : 0103 0152 0157 0161 0163 0165 0167 0171 0173 0175 0177 0201 0203 0205 0207 0211 0220
0225 0227 0231 0233 0235 0241 0243 0245 0247 0251 0253
NOP : 0106 0133 0152 0154 0220 0222
NEND : 0110 0120
NORM : 0104 0105 0106 0242 0244 0246 0250 0252 0254
NORMF : 0104 0105 0106 0234
NTRAN : 0122 0123
NU : 0101 0122 0123
PRES : 0106 0134
RATE : 0104 0106 0162
STRESS: 0104 0106 0166
STRUE : 0104 0106 0204
T : 0104 0106 0172
TEMP : 0104 0106 0160

LABELS------
1: 0115 0272
2: 0265 0273

ET FOR POST,POST 15 JUN 73 00:00:05.439
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:34:00
FORTRAN V: ISD VERSION 2.6

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000235
0000	*DATA	000160
0002	*BLANK	000000
0003	INPUT	007034

EXTERNAL REFERENCES (BLOCK, NAME)

0004	BUFFER
0005	PGPOST
0006	EXIT
0007	NPEW$
0010	NWDU$
0011	NIO2$
0012	NSTOP$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000115 130L	0001	000042 1256	0001	000147 1566	0001	000221 200L
0000	000070 5F	0001	000006 50L	0000	000101 6F	0003	R 000145 7F
0003	R 000012 BULK	0003	R 000634 DIL	0003	R 002130 DR1	0003	R 002460 DR12
0003	R 000324 DT	0003	D 006524 EOCT	0003	R 001144 E11	0003	R 001620 E12
0003	R 001454 E33	0000	I 000016 I	0000	I 000013 IFLAG	0003	D 002604 INV1
0003	D 003424 INV3	0000	I 000014 IPG	0000	D 000000 ITEMP	0003	I 000000 ITEST
0000	I 000017 K	0003	I 000004 KODE	0003	I 000003 KTEMP	0000	I 000015 LINE
0003	I 000001 NDP	0003	D 004244 NORM	0003	D 003734 NORMF	0000	I 000012 NU
0003	R 000160 RATE	0003	R 000470 STRESS	0003	R 001764 STRUE	0003	R 001000 T

```
00100     1*  C
00100     2*  C        POST-PROCESSOR FOR NL001.
00100     3*  C
00100     4*  C
00101     5*        DIMENSION    DIL(100), DR1(100), DR2(100), DR12(100), DT,100),
00101     6*       1             E11(100), E22(100), E33(100), E12(100), EOCT(100),
00101     7*       2             INV1(100), INV2(100), INV3(100), MATID(5),
00101     8*       3             NORM(6,100), NORMF(100), RATE(100), STRESS(100),
00101     9*       4             STRUE(100), T(100), TEMP(100), ITEMP(2), ITYPE(3)
00101    10*  C
00103    11*       DOUBLE PRECISION INV1, INV2, INV3, EOCT, NORM, NORMF, ITEMP, ITYPE
00103    12*  C
00104    13*       COMMON /INPUT/ ITEST, NDP, PRES, KTEMP, KODE, MATID, BULK, BETA,
00104    14*      1               TEMP, RATE, DT, STRESS, DIL, T, E11, E22, E33, E12,
00104    15*      2               STRUE, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00104    16*      3               NORM, EOCT
00104    17*  C
```

```
00104   18*  C
00105   19*        DATA ITEMP(1)/'CONSTANT'/,ITEMP(2)/'VARIABLE'/,ITYPE(1)/'UNIAXIAL'
00105   20*       1/,ITYPE(2)/'BIAXIAL'/,ITYPE(3)/'SHEAR'/
00113   21*        NU = 1
00114   22*        IFLAG = 0
00115   23*        REWIND NU
00115   24*  C
00115   25*  C               NEXT TEST
00115   26*  C
00116   27*   50   CONTINUE
00117   28*        IPG = 0
00117   29*  C
00120   30*            CALL BUFFER(NU,IFLAG)
00120   31*  C
00121   32*            CALL PGPOST(IPG, LINE, KODE, KTEMP, ITEST, ITYPE, ITEMP, BULK,
00121   33*       1                BETA, MATID, RATE, PRES )
00122   34*        WRITE(6,4)
00122   35*  C
00124   36*        DO 100 I=2,NOP
00127   37*        K = I-1
00130   38*        WRITE(6,5) K, T(I), TEMP(I), E11(I), E22(I), E33(I), E12(I),
00130   39*       1           STRUE(I)
00142   40*        LINE = LINE + 1
00143   41*        IF(LINE.LT.44) GO TO 100
00143   42*  C
00145   43*            CALL PGPOST(IPG, LINE, KODE, KTEMP, ITEST, ITYPE, ITEMP, BULK,
00145   44*       1                BETA, MATID, RATE, PRES )
00146   45*        WRITE(6,4)
00150   46*   100  CONTINUE
00150   47*  C
00152   48*            CALL PGPOST(IPG, LINE, KODE, KTEMP, ITEST, ITYPE, ITEMP, BULK,
00152   49*       1                BETA, MATID, RATE, PRES )
00153   50*        WRITE(6,6)
00153   51*  C
00155   52*        DO 200 I=2,NOP
00160   53*        K = I-1
00161   54*        WRITE(6,7) K, T(I), INV1(I), INV2(I), INV3(I), DII(I), EOCT(I)
00172   55*        LINE = LINE + 1
00173   56*        IF(LINE.LT.44) GO TO 200
00173   57*  C
00175   58*            CALL PGPOST(IPG, LINE, KODE, KTEMP, ITEST, ITYPE, ITEMP, BULK,
00175   59*       1                BETA, MATID, RATE, PRES )
00176   60*        WRITE(6,6)
00200   61*   200  CONTINUE
00200   62*  C
00200   63*  C               ALL DONE ?
00200   64*  C
00202   65*        IF(IFLAG.EQ.2) CALL EXIT
00202   66*  C          GO ON TO NEXT TEST
00202   67*  C
00204   68*        GO TO 50
00204   69*  C
00205   70*    4   FORMAT(1H , ///,T10,'DATA', T23,'TIME', T37,'TEMP.', T72,'STRAINS'
00205   71*       1       ,' (CALCULATED)', T117,'TRUE STRESS'//,  T10,'POINT', T23,
00205   72*       2       'MIN.', T37,'DEG.-F', T56,'E11',T71,'E22', T86,'E33', T101,
00205   73*       3       'E12', T117,'(S11 - S22)', // )
00206   74*    5   FORMAT(1H , T10,I4, T20,E10.3, T33,F8.0, T47,4E15.4, T112,E15.4 )
00207   75*    6   FORMAT(1H , ///, T10,'DATA', T23,'TIME', T52,'STRAIN INVARIANTS',
00207   76*       1       T92,'CORRECTED', T112,'OCTAHEDRAL',//, T10,'POINT', T23,
00207   77*       2       'MIN.', T47,'I1', T62,'I2', T77,'I3', T92,'DILATATION',
```


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```
00207   7a*          3      T114,'STRAIN', //)
00210   79*     7    FORMAT(1H , T10,I4, T20,F10.3, T37,3F15.4, T92,E10.4, T112,E10.4 )
00211   80*          END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

HOLLERITH STRINGS > 1 WORD------

CONSTANT	:	0105				
VARIABLE	:	0105				
UNIAXIAL	:	0105				
BIAXIAL	:	0105				

SINGLE WORD HOLLERITH STRINGS------

SHEAR	:	0105				

NAMES------

BETA	:	0104	0121	0145	0152	0175
BUFFER	:	0120				
BULK	:	0104	0121	0145	0152	0175
DIL	:	0101	0104	0161		
DR1	:	0101	0104			
DR12	:	0101	0104			
DR2	:	0101	0104			
DT	:	0101	0104			
FOCT	:	0101	0103	0104	0161	
EXIT	:	0202				
E11	:	0101	0104	0130		
E12	:	0101	0104	0130		
E22	:	0101	0104	0130		
E33	:	0101	0104	0130		
I	:	0124	0127	0130	0155	0160	0161
IFLAG	:	0114	0120	0202		
INPUT	:	0104				
INV1	:	0101	0103	0104	0161	
INV2	:	0101	0103	0104	0161	
INV3	:	0101	0103	0104	0161	
IPG	:	0117	0121	0145	0152	0175
ITEMP	:	0101	0103	0105	0121	0145	0152	0175
ITEST	:	0104	0121	0145	0152	0175
ITYPE	:	0101	0103	0105	0121	0145	0152	0175
K	:	0127	0130	0160	0161	
KODE	:	0104	0121	0145	0152	0175
KTEMP	:	0104	0121	0145	0152	0175
LINE	:	0121	0142	0143	0145	0152	0172	0173	0175
MATID	:	0101	0104	0121	0145	0152	0175
NDP	:	0104	0124	0155		
NORM	:	0101	0103	0104		
NORMF	:	0101	0103	0104		
NU	:	0113	0115	0120		
PGPOST	:	0121	0145	0152	0175	
PRES	:	0104	0121	0145	0152	0175
RATE	:	0101	0104	0121	0145	0152	0175
STRESS	:	0101	0104			
STRUF	:	0101	0104	0130		
T	:	0101	0104	0130	0161	
TEMP	:	0101	0104	0130		

LABELS------

4	:	0122	0146	0205

APPENDIX G

COMPUTERIZED CHARACTERIZATION PROCEDURES FOR LINEAR VISCOELASTIC MATERIALS USING ARBITRARY DEFORMATION HISTORIES

By

Richard J. Farris

1.0 INTRODUCTION

The purpose of this appendix is to provide an improved means of linear viscoelastic characterization. The computer code presented in this appendix was the first code developed on this contract and formed the basis for the nonlinear characterization codes. The code calculates the best fit distortional stress-strain relation for mixed uniaxial, biaxial and shear tests having complex deformation histories including transient temperature histories. The representation used is

$$\sigma^{(D)}(t) = \int_0^t G(t'-\xi')\dot{\varepsilon}^{(D)}(\xi)d\xi \tag{1}$$

where $\sigma^{(D)}$ = distortional stress

$\varepsilon^{(D)}$ = distortional strain

Thermal effects are included in that the distortional strain depends upon thermal dilatation and the reduced time, $t'-\xi'$, depends upon temperature in the usual manner

$$t'-\xi' = \int_\xi^t d\tau/A_T(\tau) \tag{2}$$

The kernel function G(t) can be represented as either a Prony series or as a power law series depending upon users preference.

In the Prony series representation the kernel function becomes

$$G(t) = A_1 + \sum_{i=2}^{M} A_i e^{-\beta_i t} \tag{3}$$

and in the power law representation the kernel function is

$$G(t) = A_1 + \sum_{i=2}^{M} A_2(1 + \beta_i t)^{N_i} \tag{4}$$

The code requires as input parameters the time-temperature shift function and a family of exponents β_i, $i \leq 15$, for the Prony series representation. The code then computes the best fit linear coefficients A_i based on a relative regression analysis as discussed in the text of this report. Once having determined the coefficients the program can be used to calculate the response to any history of interest.

There are many advantages to this type of characterization method some of which are given below.

- All of the data obtained on a material can be used in the characterization.
- The method can provide the best approximation to any complex history.
- Provides the best fit to all of the data not just a relaxation test.
- Provides direct comparisons between observed and predicted data.
- The method is much more accurate than usual methods and provides statistical information regarding accuracy and variability.
- Eliminates the need for special tests and test equipment, such as stress-relaxometers, since characterization can be carried out from any experiment.
- It provides a practical method for linear and nonlinear viscoelastic characterization.

As an example of the application of the method the following figures are included. Figure 1 demonstrates the excellent results obtained when a five term Prony series is fit to a ramp loaded stress-relaxation experiment for a composite propellant. From this experiment, one might get the misleading impression that linear viscoelasticity was a good approximation to propellant response. Figure 2 shows the linear viscoelastic analytical continuation (based on the fit from Figure 1) compared to the experimental results when straining is again commenced. Obviously the material is not linearly viscoelastic. The remaining figures illustrate the excellent fit obtained in Solethane 113, an unfilled rubber, on a series of experiments using complex histories at temperatures from -65°F to +150°F. The last figure shows a comparison of predicted transient thermoviscoelastic stress response for Solethane 113 with experimental results. The Solethane characterization was carried out using 15 Prony series terms and the predictions were within $\pm$ 10% for one standard deviation demonstrating that linear viscoelasticity is an excellent approximation to the behavior of this unfilled polymer.

COMPARISON OF LINEAR VISCOELASTIC PREDICTION AND FIRST STRESS-RELAXATION FOR A COMPOSITE SOLID PROPELLANT

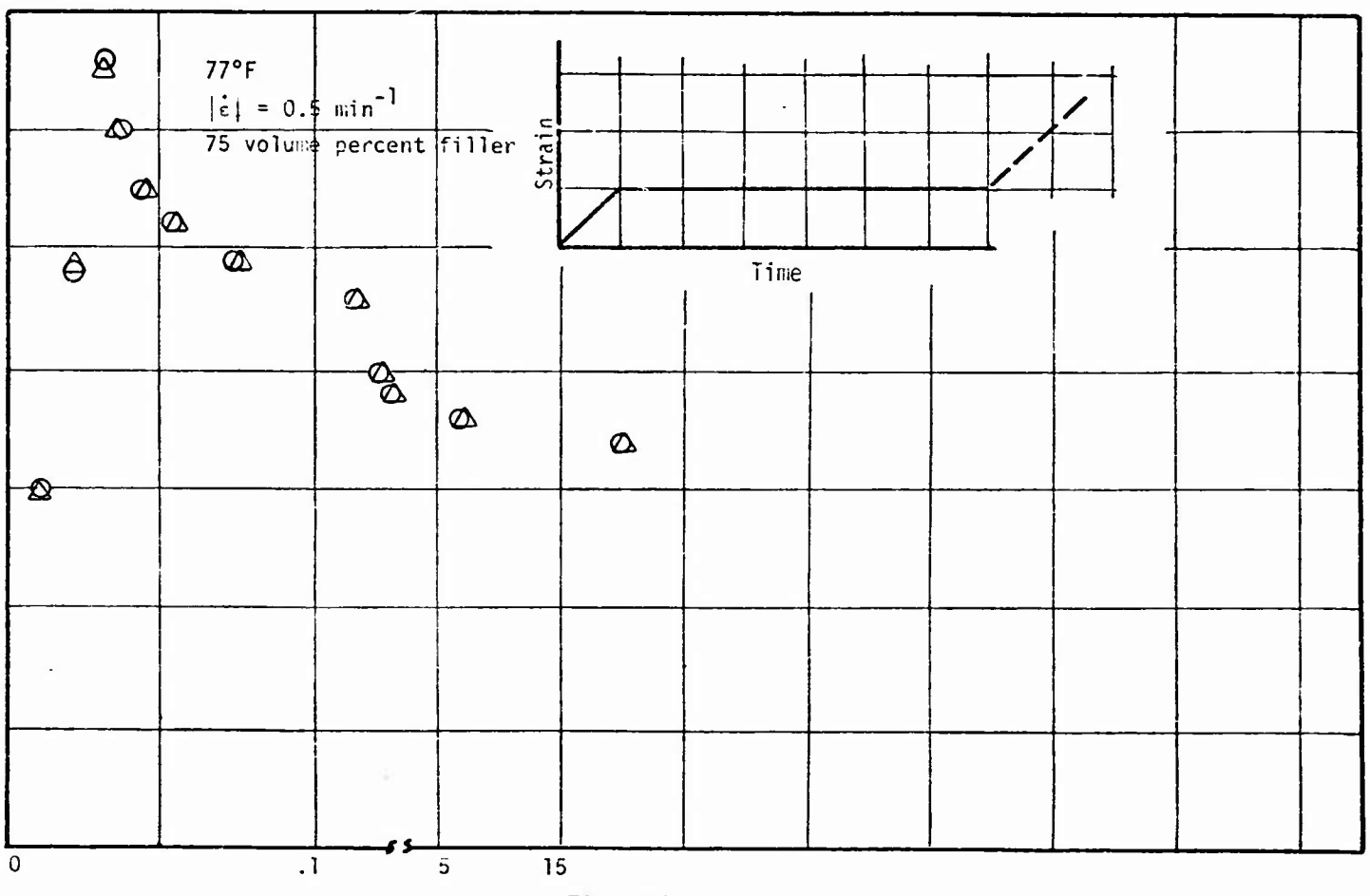

Figure 1

COMPARISON OF EXPERIMENTAL AND ANALYTICAL EXTENSIONS USING CHARACTERIZATION FROM FIRST RELAXATION FOR THE COMPOSITE SOLID PROPELLANT

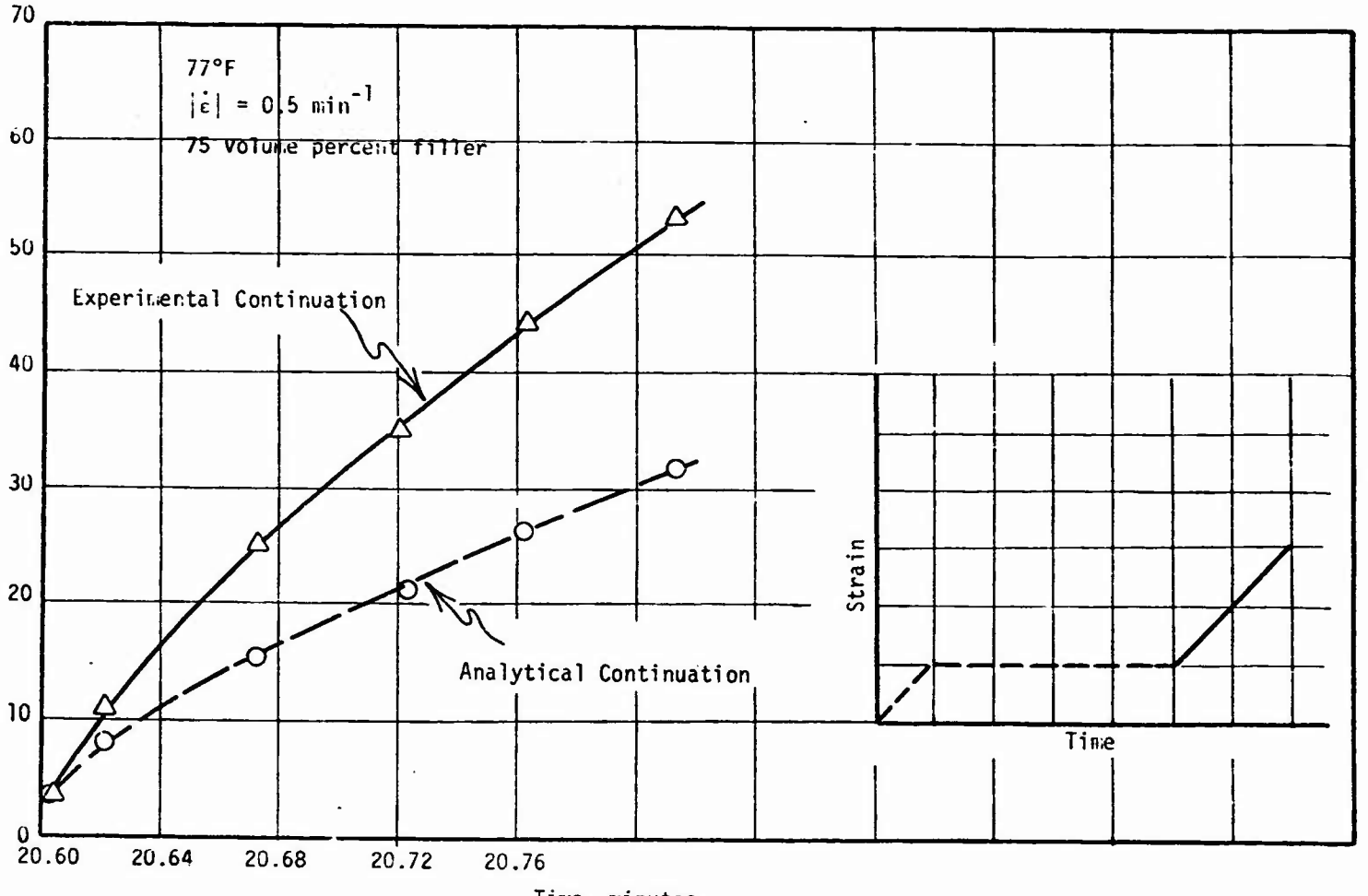

Figure 2

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

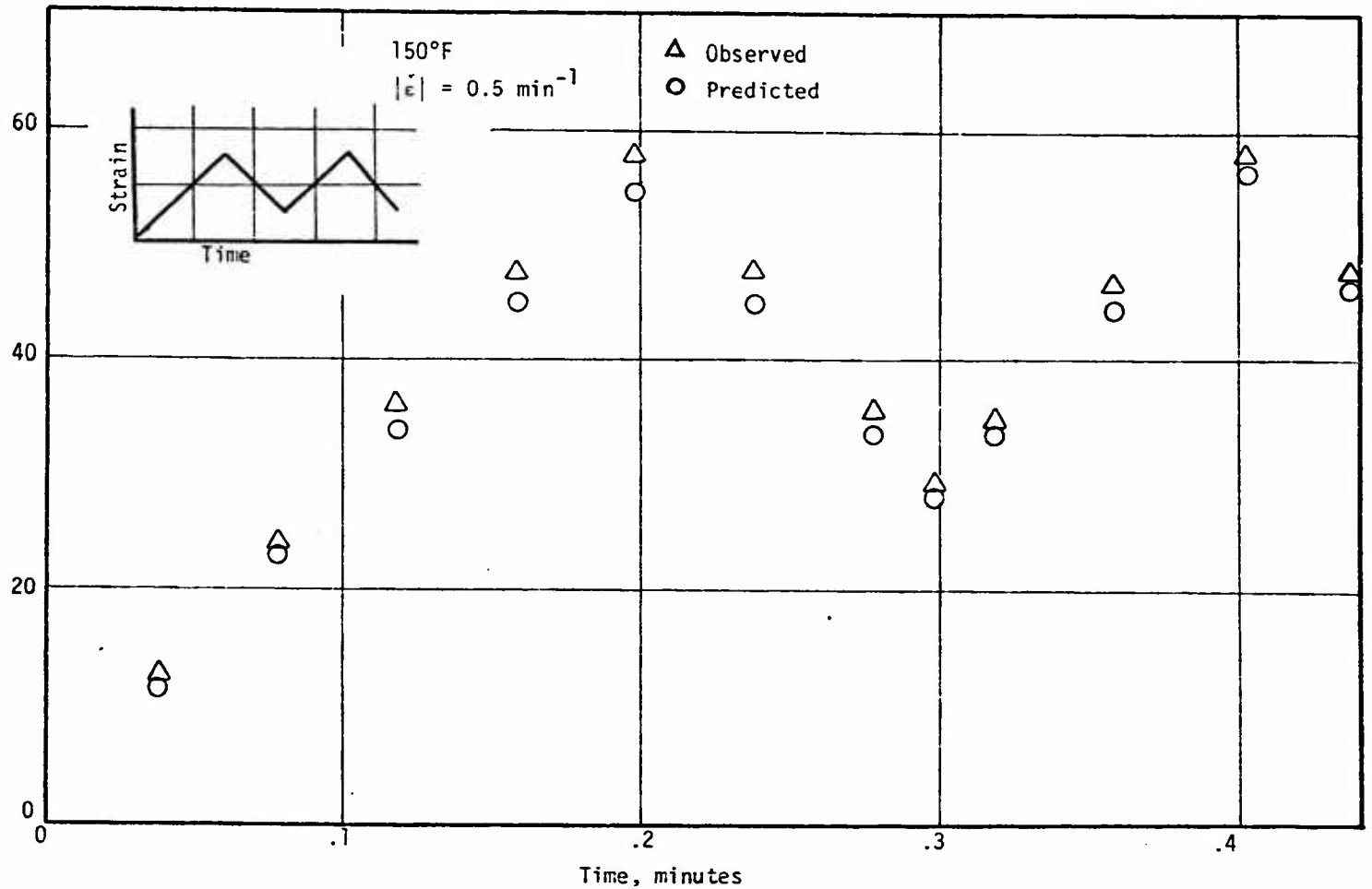

Figure 3

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

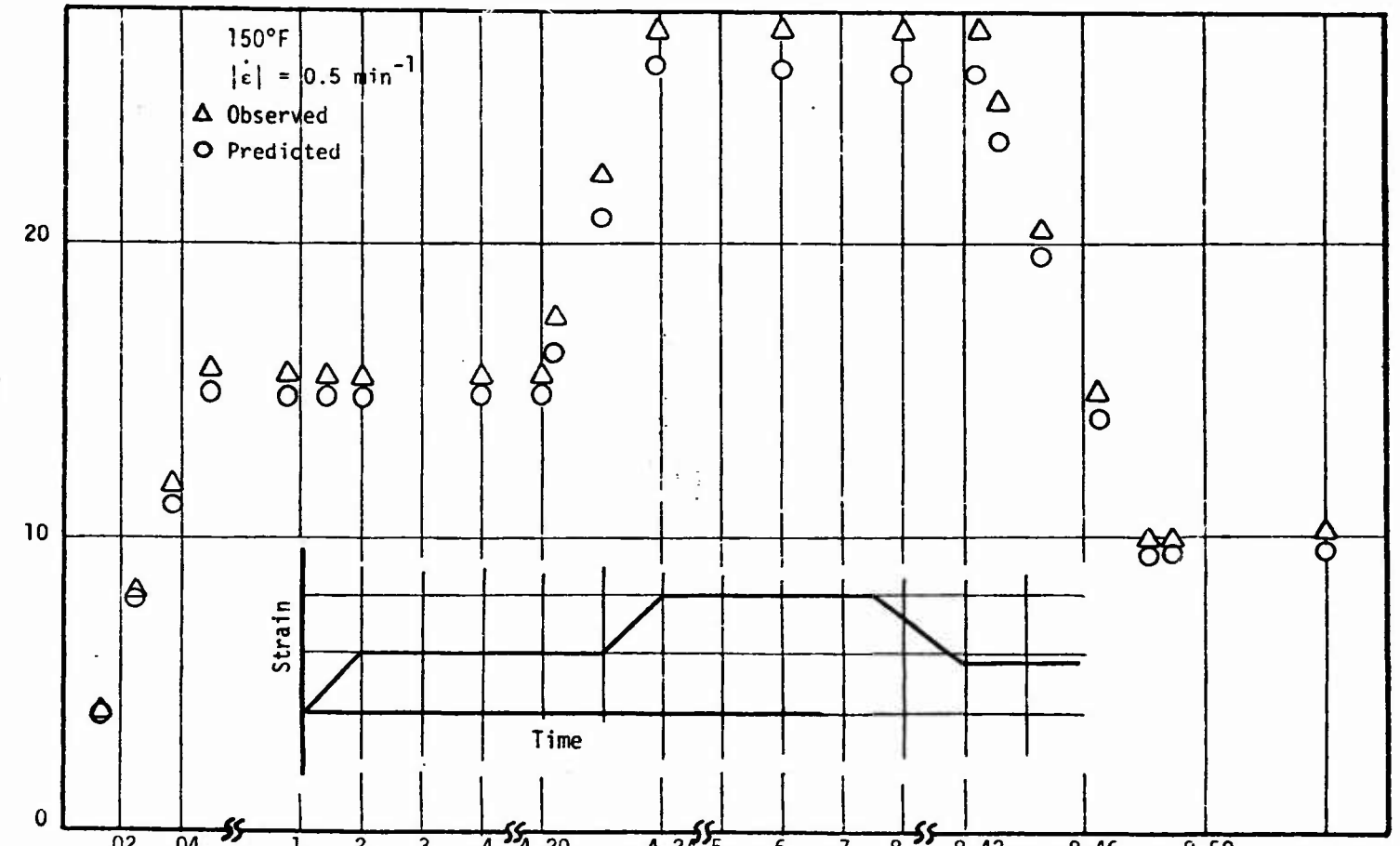

Figure 4

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

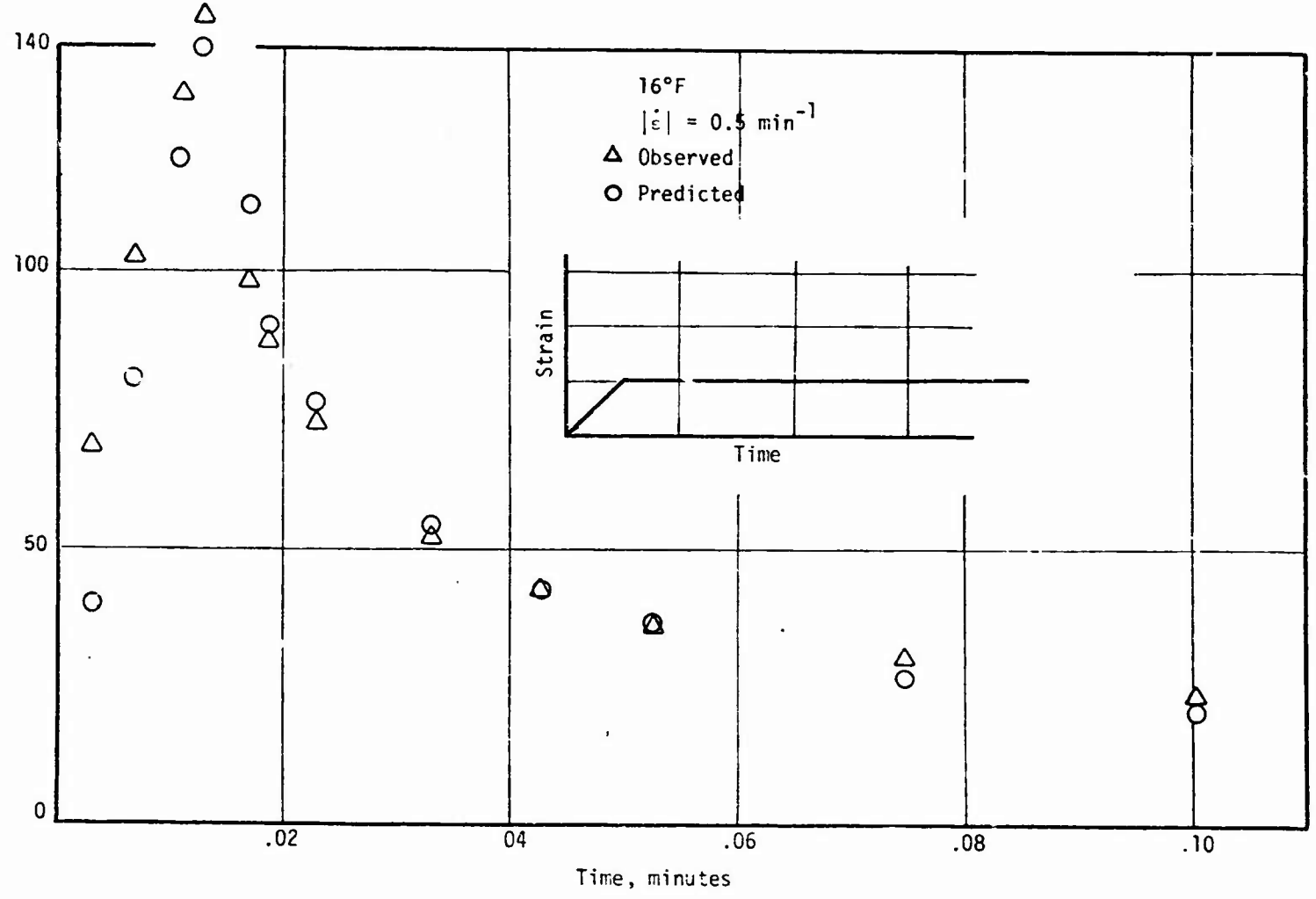

Figure 5

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

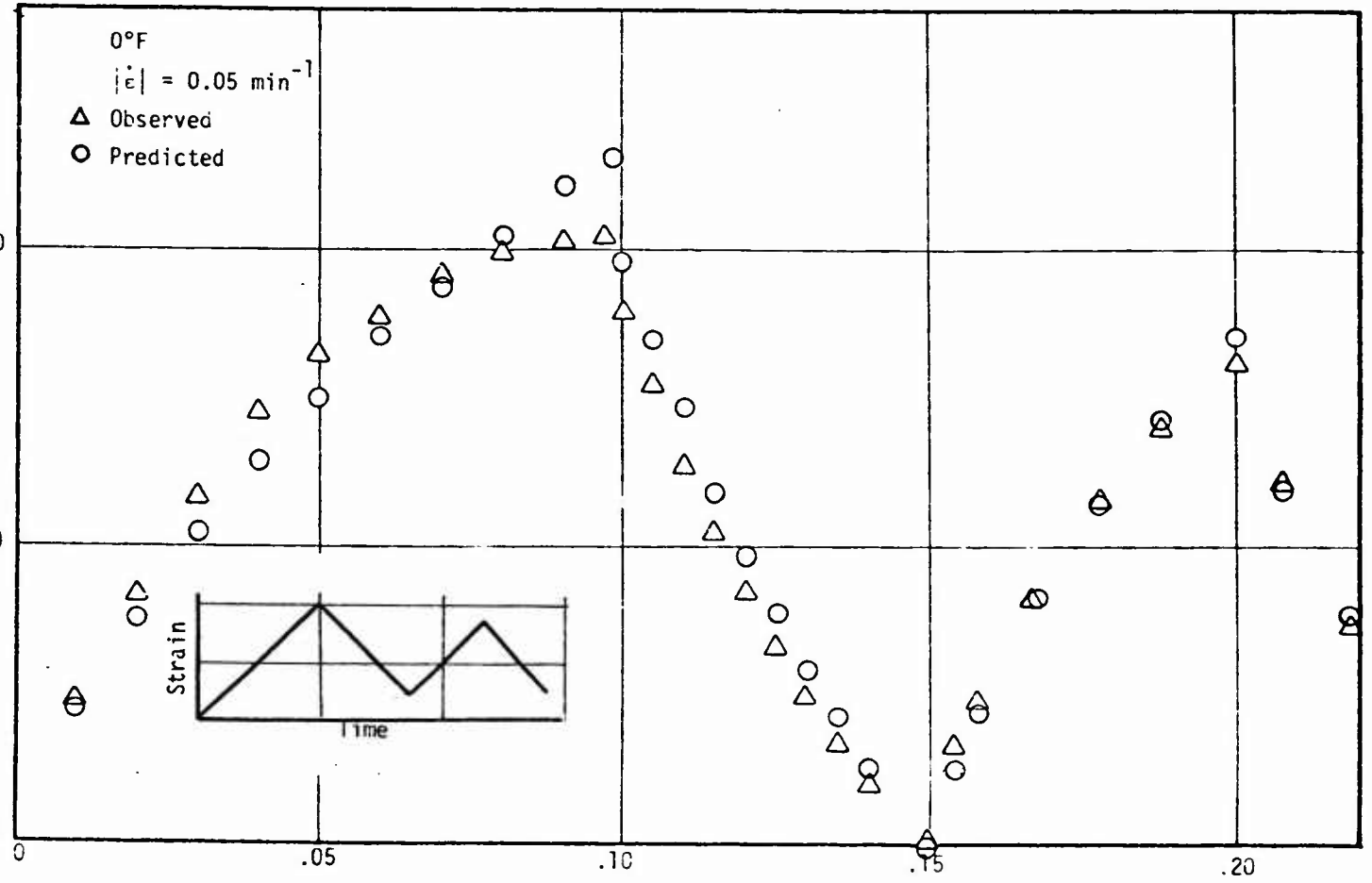

Figure 6

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

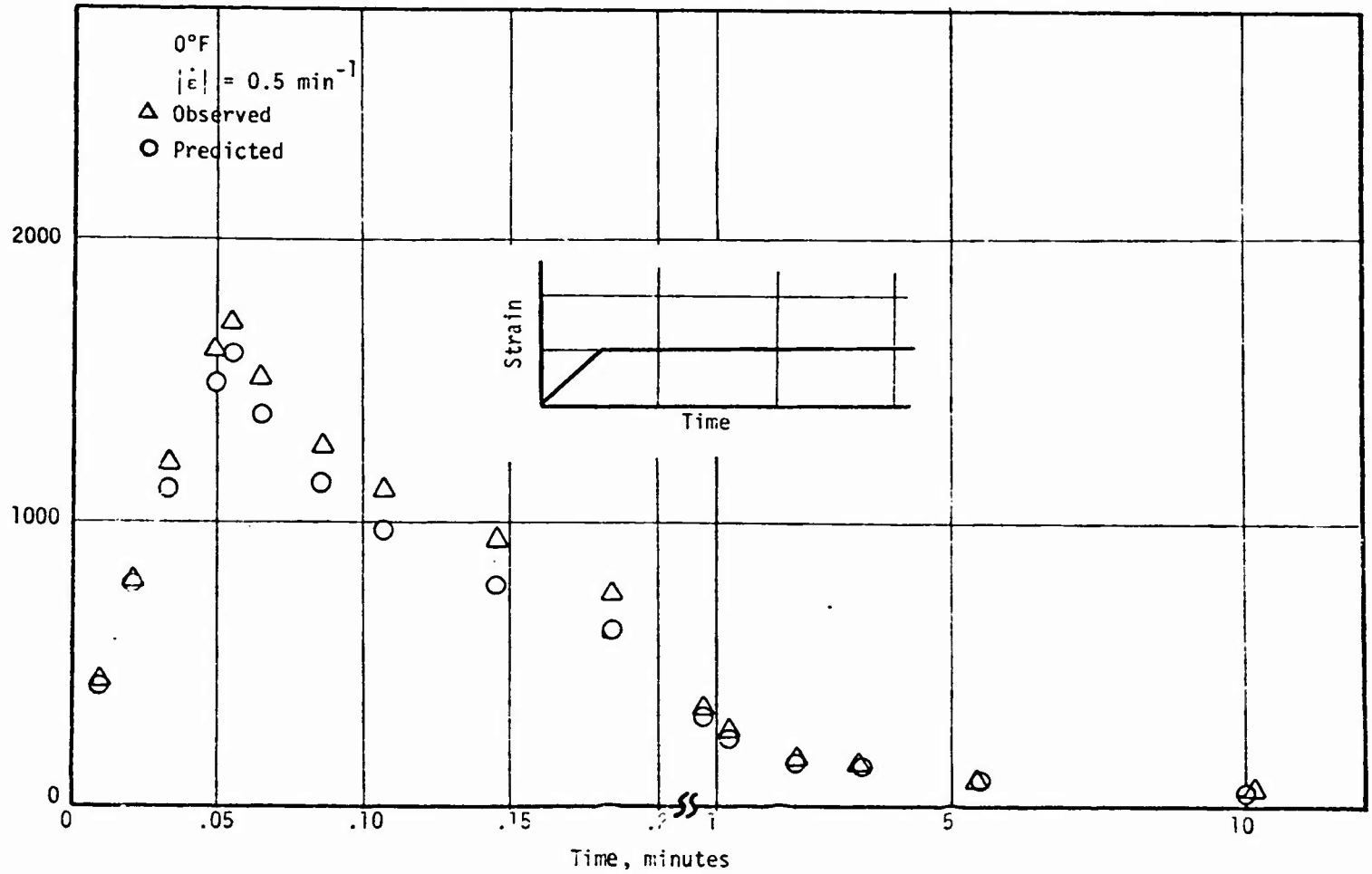

Figure 7

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

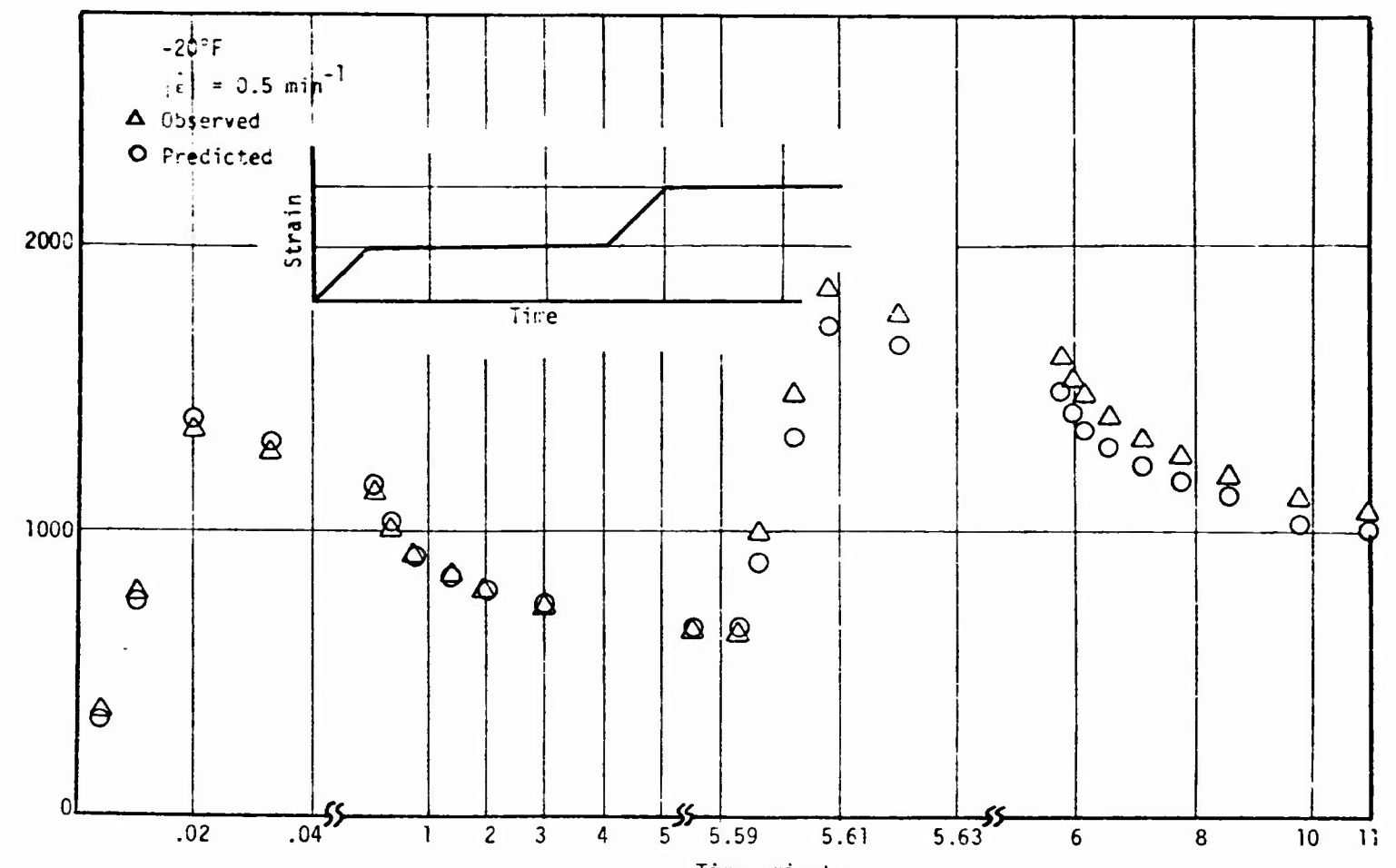

Figure 8

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

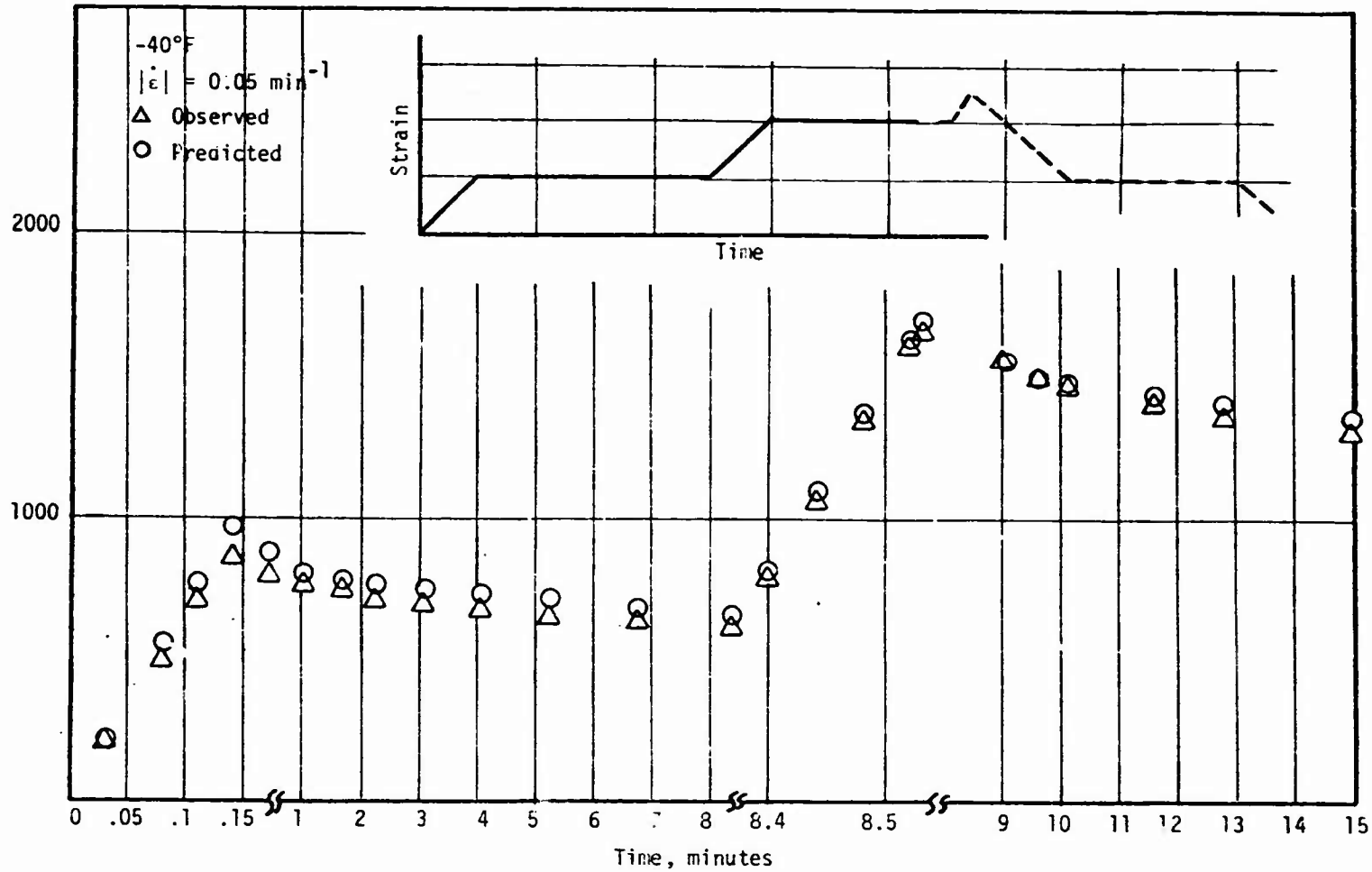

Figure 9

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

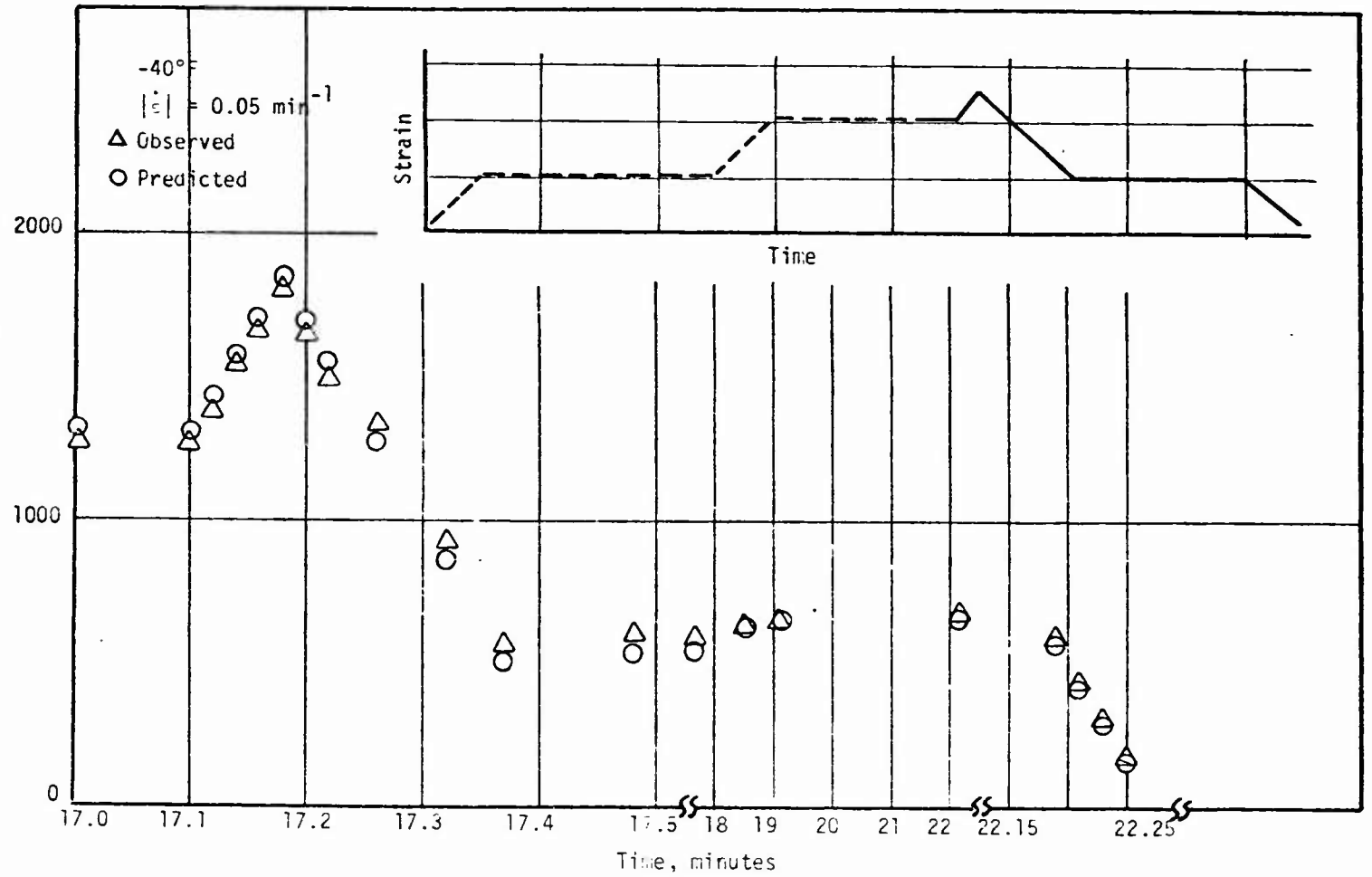

Figure 10

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

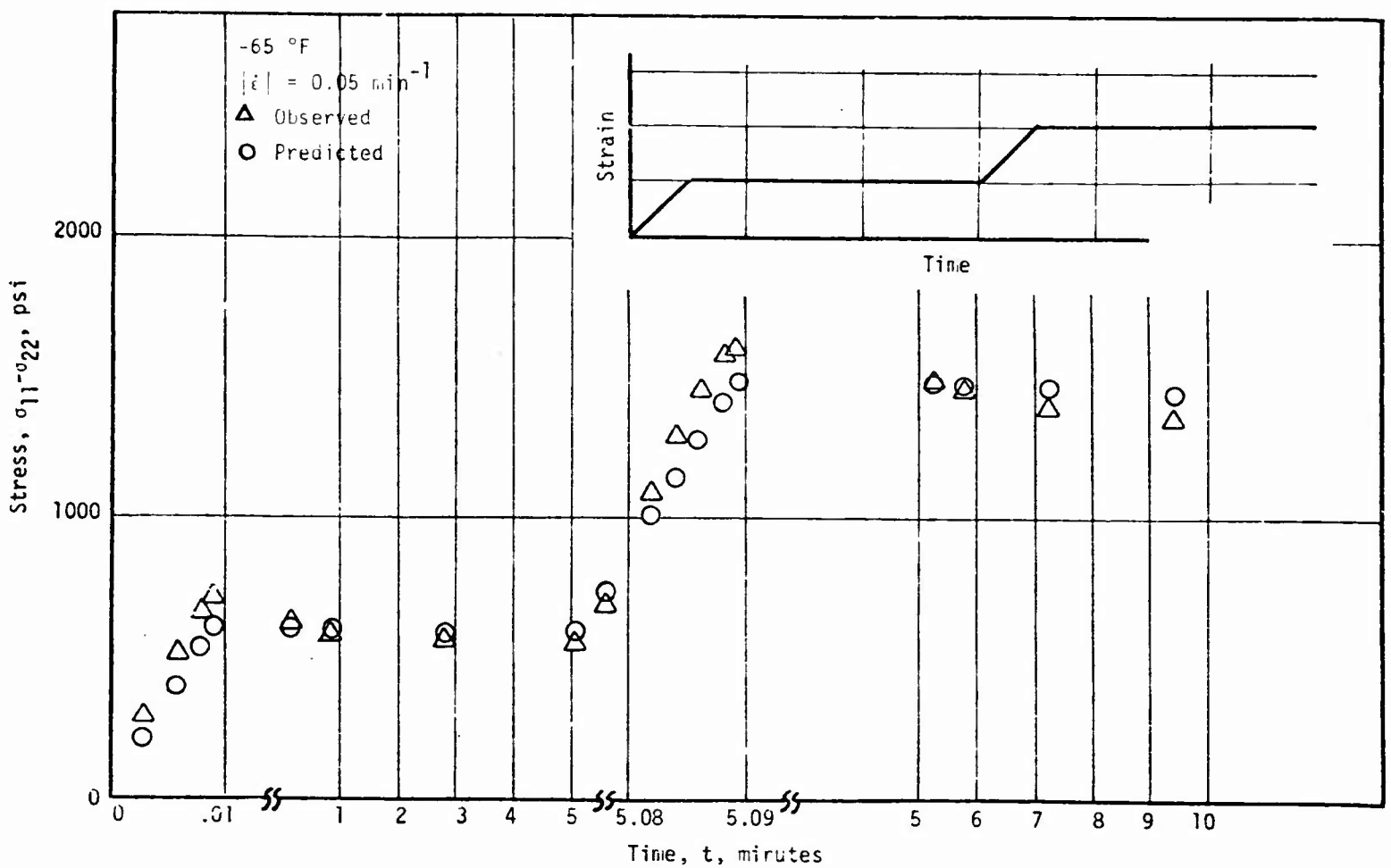

Figure 11

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS AND EXPERIMENTAL DATA
FOR THERMOVISCOELASTIC EXPERIMENT ON SOLITHANE 113

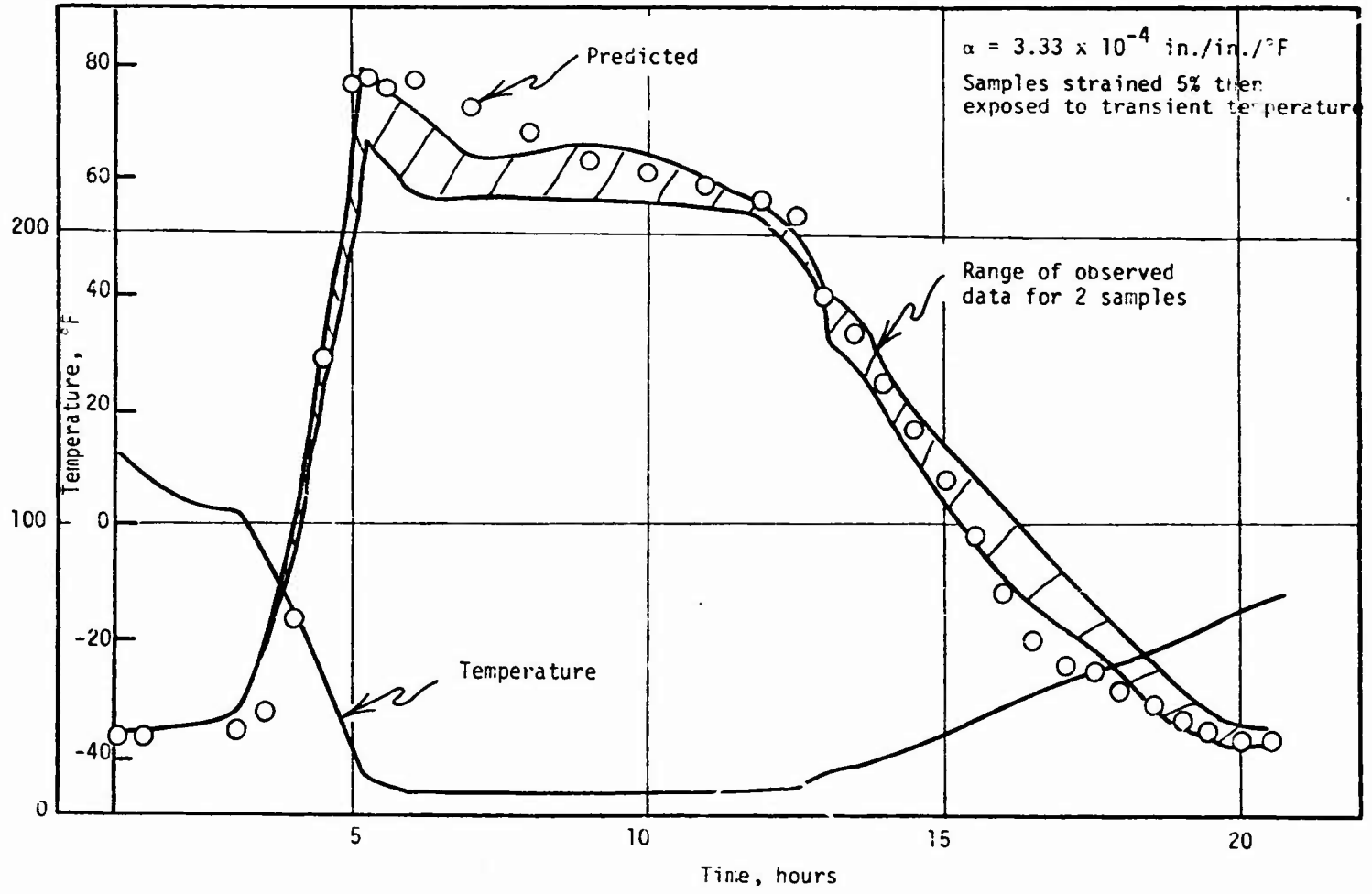

Figure 12

2.0 PROGRAM INSTRUCTIONS

This section presents a description of the basic variables of the LINVIS linear viscoelastic characterization code. It includes a data sheet showing the input variables and formats, a sample problem and a listing of the program.

2.1 BASIC VARIABLES

AT	Vector of shift function - input
AVGAT	Average value of AT - calculated
B	Constant in the power series term $(1 + Bt)^{NN}$ or the exponent in the prony series term e^{-Bt} - input
BB	Column vector in regression equation
BETA	Volumetric expansion coefficient - input
CO	Regression coefficients - calculated
D	Slope of shift function - calculated
DEV	Percent error between calculated and observed stress
DEVRAT	Deviation strain rate - calculated
DT	Time increment - input
E1, E2	Principal normal strains - calculated
F	Working variable
G	Inverse matrix
I2	Set to 1 to include a linear elastic term in the series characterization otherwise leave blank or zero - input
I3	Number of power or prony series terms - input
I4	I2 + I3 - calculated

I6	Equal to NTEMP - Calculated
INV1	First strain invariant - input
JL	Total number of input data points - calculated
KFL	Number of input data points in a particular test - calculated
KODE	Test type: = 0 for uniaxial; = 1 for shear; = 2 for biaxial stop - input
LLL	Characterization type: = 0 for power series; = 1 for prony series - input
NN	Exponent in the power series term $(1 + Bt)^{NN}$ - input
NEXP	Number of data points for this test - input
NTEMP	Number of shift function vs temperature pairs - input, 20 max.
NTESTS	Number of tests for this run - input
RATE	Incremental strain rate - input
SIG1	Working array to store all stress input
STD	Standard deviation - calculated
STRN1	Same as SIG1 except for strain - calculated
T	Time - calculated
TEM	Same as SIG1 except for temperature - calculated
TEMP	Temperature at a data point - input
TIME	Output time - calculated
TITLE	80 column alphanumeric identification - input
TR	Reduced time - calculated
TTEMP	Shift function input temperature - input
V	Working matrix
VOLUME	Same as SIG 1 except for INV1 - calculated

X	Dummy array
XBAR	Average error - calculated
XF	Union of the X sets
Y	Observed stress - input
YCAL	Calculated stress - output

2.2 DATA INPUT

The input variable required by LINVIS are shown below, card by card, with the format shown in parentheses.

Card 1 (20A4) TITLE

Card 2 (E10.0) BETA

Card 3 (5I5) I2, I3, LLL, NTESTS, NTEMP

Card(s) 4 (2E10.0) NN, B

Card(s) 5 (2E10.0) TTEMP, AT

Card 6 (2I5) NEXP, KØDE

Card(s) 7 (5E10.0) TEMP, RATE, DT, Y, INV1

Cards 1 through 5 are read only once per run.

Cards 6 and 7 are repeated for each test.

The above cards are shown on the data sheet below.

2.3 Shown below are the sample input sheets for a typical problem. By referring to the master data sheet, above, the input is self explanatory. The output sheets for this sample problem follow the data sheets.

2.4 PROGRAM LISTING

A complete source listing follows the sample problem output.

JOB NUMBER | REPORT TITLE: SAMPLE INPUT - LINVIS | DATE | PAGE

CARD NØ.

①	TITLE					
②	BETA					
③	I2 | I3	LLL | NTESTS	NTEMP			
④	NN(1)	B(1)				
	NN(2)	B(2)				
	•	•				
	•	•				
	•	•				
	NN(I3)	B(I3)				
⑤	TTEMP(1)	AT(1)				
	TTEMP(2)	AT(2)				
	•	•				
	•	•				
	•	•				
	TTEMP(NTEMP)	AT(NTEMP)				
⑥	NEXP | KODE					
⑦	TEMP(2)	RATE(2)	DT(2)	Y(2)	INV1(2)	
	TEMP(3)	RATE(3)	DT(3)	Y(3)	INV1(3)	
	•	•	•	•	•	
	•	•	•	•	•	
	•	•	•	•	•	
	TEMP(KFL)	RATE(KFL)	DT(KFL)	Y(KFL)	INV1(KFL)	

AGCS 0163-10 (REV 7/68)

PLEASE PRINT CLEARLY - USE BLACK PENCIL

JOB NUMBER | REPORT TITLE: Sample INPUT – LINVIS | DATE | PAGE 1 of 2

CARD NO.

```
1  LINVIS SAMPLE PROBLEM
2    1.8E-04
3    1   3     1   2                 9
4                .01
                 1.0
                 100.
5  -65.          1.0       E+08
   -40.          1.5       E+06
   -20.          6.0       E+04
   0.            3.0       E+03
   40.           2.8       E+01
   77.           1.0       E+00
   100.          2.5       E-01
   140.          3.0       E-02
   160.          1.0       E-02
6    9   0
7  150.          .5        .09       14.5      0.0
                           .05       21.7      0.1
                                     27.       0.35
                                     29.8      0.80
                                     30.8      1.50
                                     30.9      2.35
                                     30.3      3.25
                                     29.6      4.20
   150.          .5        .05       28.3      5.15
6    11  0
7  150.          1.26      .032      13.8      0.0
```

AGCS 0140-10 (REV 7/68)

PLEASE PRINT CLEARLY - USE BLACK PENCIL

JOB NUMBER | REPORT TITLE: SAMPLE INPUT - LINVIS | DATE | PAGE 2 - 2

CARD NO.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

| | | |

L I N E A R V I S C O E L A S T I C C H A R A C T E R I Z A T I O N C O D E

LINVIS SAMPLE PROBLEM

BETA = .1800-03

THIS IS A PRONY SERIES CHARACTERIZATION

THE FOLLOWING IS A LIST OF THE EXPONENTS, B(I), FOR THE GENERAL PRONY SERIES TERM EXP(-B*T) ...

I	B(I)
1	.1000-01
2	.1000+01
3	.1000+03

LINVIS SAMPLE PROBLEM

INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE, TTEMP ...

I	AT(I)	TTEMP(I)
1	.1000+09	-.6500+02
2	.1500+07	-.4000+02
3	.6000+05	-.2000+02
4	.3000+04	.0000
5	.2800+02	.4000+02
6	.1000+01	.7700+02
7	.2500+00	.1000+03
8	.3000-01	.1400+02
9	.1000-01	.1600+03

LINEAR VISCOELASTIC CHARACTERIZATION CODE PAGE 3

LINVIS SAMPLE PROBLEM

TEST NO. 1 10 INPUT DATA POINTS

DATA IS FROM A U N I A X I A L TEST

I	TEMP(I)	RATE(I)	DT(I)	Y(I)	INV1(I)
1	.0000	.0000	.0000	.0000	.0000
2	.1500+03	.5000+00	.9000-01	.1450+02	.0000
3	.1500+03	.5000+00	.5000-01	.2170+02	.1000+00
4	.1500+03	.5000+00	.5000-01	.2700+02	.3500+00
5	.1500+03	.5000+00	.5000-01	.2980+02	.8000+00
6	.1500+03	.5000+00	.5000-01	.3080+02	.1500+01
7	.1500+03	.5000+00	.5000-01	.3090+02	.2350+01
8	.1500+03	.5000+00	.5000-01	.3030+02	.3250+01
9	.1500+03	.5000+00	.5000-01	.2960+02	.4200+01
10	.1500+03	.5000+00	.5000-01	.2830+02	.5150+01

LINEAR VISCOELASTIC CHARACTERIZATION CODE PAGE 8

LINVIS SAMPLE PROBLEM

TEST NO. 2 12 INPUT DATA POINTS

DATA IS FROM A UNIAXIAL TEST

I	TEMP(I)	RATE(I)	DT(I)	Y(I)	TNV1(I)
1	.0000	.0000	.0000	.0000	.0000
2	.1500+03	.1250+01	.3200-01	.1380+02	.0000
3	.1500+03	.1250+01	.1600-01	.2100+02	.3000-01
4	.1500+03	.1250+01	.2000-01	.2890+02	.1700+00
5	.1500+03	.1250+01	.2000-01	.3600+02	.4800+00
6	.1500+03	.1250+01	.2000-01	.3670+02	.1020+01
7	.1500+03	.1250+01	.2000-01	.3760+02	.1750+01
8	.1500+03	.1250+01	.2000-01	.3770+02	.2600+01
9	.1500+03	.1250+01	.2000-01	.3730+02	.3550+01
10	.1500+03	.1250+01	.2000-01	.3670+02	.4520+01
11	.1500+03	.1250+01	.4000-01	.3500+02	.6600+01
12	.1500+03	.1250+01	.4000-01	.3250+02	.8500+01

LEWIS SAMPLE PROBLEM

REGRESSION ANALYSIS PRIMARY MATRIX

COLUMN 1	.114964-02	.101666-02	.642704-04	.646343-06
COLUMN 2	.101666-02	.902272-03	.591309-04	.595012-06
COLUMN 3	.642704-04	.591309-04	.668985-05	.681803-07
COLUMN 4	.646343-06	.595012-06	.681803-07	.695302-09

L I N E A R V I S C O E L A S T I C C H A R A C T E R I Z A T I O N C O D E PAGE 6

LINVIS SAMPLE PROBLEM

REGRESSION ANALYSIS X BY Y COLUMN VECTOR

.143462+00 .128707+00 .907670-02 .995743-04

LINVIS SAMPLE PROBLEM

REGRESSION ANALYSIS INVERSE MATRIX

COLUMN 1	.729859+06	-.886369+06	.127120+08	-.116647+10
COLUMN 2	-.886369+06	.108056+07	-.162164+08	.148942+10
COLUMN 3	.127120+08	-.162164+08	.606891+09	-.574503+11
COLUMN 4	-.116647+10	.148942+10	-.574503+11	.588468+13

L I N E A R V I S C O E L A S T I C C H A R A C T E R I Z A T I O N C O D E PAGE 8

LINVIS SAMPLE PROBLEM

TEST NO. 1 10 INPUT DATA POINTS

DATA IS FROM A U N I A X I A L TEST

TEMP	TIME	STRN1	VOLUME	SIGCAL	SIG1	DEV	XF(1)	XF(2)	XF(3)	XF(4)	XF(5)
.00000	.00+00	.00000	.00000	.00	.00	-.00	.00000	.00000	.00000	.00000	
150.00000	.90000-01	.45000-01	.00000	13.67	14.50	-5.72	.72895-01	.69935-01	.87303-02	.87324-04	
150.00000	.14000+00	.70000-01	.10000-02	16.46	21.70	-24.16	.11033+00	.10344+00	.84241-02	.84231-04	
150.00000	.19000+00	.95000-01	.35000-02	18.89	27.00	-30.02	.14557+00	.13327+00	.80957-02	.80981-04	
150.00000	.24000+00	.12000+00	.80000-02	21.04	29.80	-29.41	.17876+00	.16003+00	.77222-02	.77200-04	
150.00000	.29000+00	.14500+00	.15000-01	22.91	30.80	-25.62	.21008+00	.18372+00	.73369-02	.73343-04	
150.00000	.34000+00	.17000+00	.23500-01	24.69	30.90	-20.09	.24014+00	.20516+00	.70796-02	.70790-04	
150.00000	.39000+00	.19500+00	.32500-01	26.43	30.30	-12.76	.26936+00	.22489+00	.69388-02	.69383-04	
150.00000	.44000+00	.22000+00	.42000-01	28.07	29.60	-5.18	.29783+00	.24308+00	.68072-02	.68067-04	
150.00000	.49000+00	.24500+00	.51500-01	29.64	28.30	4.72	.32573+00	.25998+00	.67308-02	.67308-04	

LINEAR VISCOELASTIC CHARACTERIZATION CODE PAGE 9

LINVIS SAMPLE PROBLEM

TEST NO. 2 12 INPUT DATA POINTS

DATA IS FROM A U N I A X I A L TEST

TEMP	TIME	STRN1	VOLUME	SIGCAL	SIG1	DEV	XF(1)	XF(2)	XF(3)	XF(4)	XF(5)
.00000	.00000	.00000	.00000	.00	.00	.00	.00000	.00000	.00000	.00000	
150.00000	.32000-01	.40000-01	.00000	13.41	13.80	-2.79	.65107-01	.64150-01	.20908-01	.21936-03	
150.00000	.48000-01	.60000-01	.30000-03	24.40	21.00	16.18	.95687-01	.93506-01	.21104-01	.21421-03	
150.00000	.68000-01	.85000-01	.17000-02	28.13	28.90	-.80	.13195+00	.12766+00	.20679-01	.20669-03	
150.00000	.88000-01	.11000+00	.48000-02	31.85	34.00	-6.32	.16611+00	.15945+00	.19872-01	.19798-03	
150.00000	.10800+00	.13500+00	.10200-01	33.98	36.70	-7.40	.19827+00	.18853+00	.18952-01	.18843-03	
150.00000	.12800+00	.16000+00	.17500-01	35.64	37.60	-5.22	.22891+00	.21558+00	.18159-01	.18063-03	
150.00000	.14800+00	.18500+00	.26000-01	37.17	37.70	-1.41	.25844+00	.24107+00	.17578-01	.17519-03	
150.00000	.16800+00	.21000+00	.35500-01	38.84	37.30	4.12	.28707+00	.26524+00	.17101-01	.17050-03	
150.00000	.18800+00	.23500+00	.45200-01	40.41	36.70	10.10	.31508+00	.28838+00	.16826-01	.16810-03	
150.00000	.20800+00	.26000+00	.66000-01	43.05	35.00	25.28	.36933+00	.33175+00	.16306-01	.16301-03	

L I N E A R V I S C O E L A S T I C C H A R A C T E R I Z A T I O N C O D E

LINVIS SAMPLE PROBLEM

TEST NO. 2 . 12 INPUT DATA POINTS

DATA IS FROM A U N I A X I A L TEST

TEMP	TIME	STRN1	VOLUME	SIGCAL	SIG1	DEV	XE(1)	XE(2)	XE(3)	XE(4)	XE(5)
150.00000	.26800+00	.33500+00	.85000-01	47.39	32.50	45.83	.42191+00	.37215+00	.16187-01	.16193-03	

L I N E A R V I S C O E L A S T I C C H A R A C T E R I Z A T I O N C O D E

LINVIS SAMPLE PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	.13006+02
2	.75592+02
3	.97668+04
4	-.89129+06

THERE WERE 22 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, X P A R , WAS -.0314

THE STANDARD DEVIATION, S T D , WAS .1785

DATA CARDS IGNORED - FIRST IS LISTED BELOW

```
* ELT LINVIS,1,730521, 39540

000001      C     LINEAR VISCOELASTIC CHARACTERIZATION CODE WITH DILATATION FOR      A  10
000002      C     DEVIATORIC STRESSES USING MODIFIED POWER SERIES OR PRONY SERIES    A  20
000003      C     AT          =    VECTOR OF SHIFT FUNCTION VALUES ASSOCIATED WITH ITEM  A  30
000004      C     AVGAT       =    VALUE OF SHIFT FUNCTION FOR A SPECIFIC TIME.       A  40
000005      C     B           =    CONSTANT IN THE POWER SERIES TERM (1+BT)**NN, OR THE  A  50
000006      C                      EXPONENT IN THE PRONY SERIES TERM  EXP(-BT).       A  60
000007      C     BB          =    B COLUMN VECTOR IN THE REGRESSION EQUATION.        A  70
000008      C     BETA        =    VOLUMETRIC EXPANSION COEFFICIENT.                  A  80
000009      C     CO          =    REGRESSION COEFFICIENTS.                           A  90
000010      C     D           =    INTERPOLATION SLOPE FOR SHIFT FUNCTION, AT.        A 100
000011      C     DEV         =    PERCENT DEVIATION BETWEEN EXPERIMENTAL AND CALCULATE  A 110
000012      C     DEVDAT      =    DEFINED AS   D(E11-E22)/DT.                        A 120
000013      C     DT          =    DELTA TIME BETWEEN EXPERIMENTAL INPUT POINTS.      A 130
000014      C     E1, E2      =    STRAINS E11 AND E22 RESPECTIVELY.                  A 140
000015      C     F           =    FRONT FACTOR TO INCLUDE TEMPERATURE DEPENDENCE OF MO  A 150
000016      C                      TO CORRECT FOR TRUE STRESS.                        A 160
000017      C     G           =    INVERSE MATRIX.                                    A 170
000018      C     I2          =    SET TO 1 IF IT IS DESIRED TO INCLUDE A LINEAR ELASTI  A 180
000019      C                      IN THE SERIES CHARACTERIZATION.                    A 190
000020      C     I3          =    NUMBER OF TERMS OF THE POWER OR PRONY SERIES.      A 200
000021      C     I4          =    I2 + I3                                            A 210
000022      C     I6          =    NTEMP                                              A 220
000023      C     INV1        =    FIRST STRAIN INVARIANT, EKK = E11+E22+E33 = DV/V.  A 230
000024      C     INV2        =    SECOND STRAIN INVARIANT (NOT USED THIS CODE).      A 240
000025      C     JL          =    TOTAL NUMBER OF OUTPUT POINTS EQUALS TOTAL NUMBER OF  A 250
000026      C                      EXPERIMENTAL INPUT POINTS.                         A 260
000027      C     KEL         =    NUMBER OF EXPERIMENTAL INPUT DATA POINTS FROM A PART  A 270
000028      C                      TEST, MAXIMUM = 50.                                A 280
000029      C     KODE        =    TYPE OF TEST INPUT DATA:   0 FOR UNIAXIAL          A 290
000030      C                                                 1 FOR SHEAR           A 300
000031      C                                                 2 FOR BIAXIAL STRIP ( E33  A 310
000032      C     LLL         =    CHARACTERIZATION CODE   = 0 FOR POWER SERIES (1+B*T)  A 320
000033      C                                                = 1 FOR PRONY SERIES EXP(-B*  A 330
000034      C     NN          =    EXPONENT IN THE POWER SERIES TERM  (1+BT)**NN.     A 340
000035      C     NEXP        =    NUMBER OF EXPERIMENTAL INPUT DATA POINTS FROM THIS T  A 350
000036      C     NTEMP       =    NUMBER OF INPUT SHIFT FUNCTION/TEMPERATURE DATA POIN  A 360
000037      C                      MAXIMUM IS 20.                                     A 370
000038      C     NTESTS      =    TOTAL NUMBER OF TESTS INPUT FOR THIS RUN, MAXIMUM =  A 380
000039      C     RATE        =    INCREMENTAL STRAIN RATE.                           A 390
000040      C     SIG1        =    MEASURED VALUES OF STRESS INPUT FOR ALL TESTS, MAXIM  A 400
000041      C     STD         =    STANDARD DEVIATION                                 A 410
000042      C     STR1        =    STRAIN EPSILON-11.                                 A 420
000043      C     T           =    EXPERIMENTAL INPUT TIME POINTS, 50 MAXIMUM.        A 430
000044      C     TEM         =    TEMPERATURE.                                       A 440
000045      C     TEMP        =    TEMPERATURE FOR INPUT DATA.                        A 450
000046      C     TIME        =    TIME, CALCULATED OUTPUT POINTS, 600 MAXIMUM.       A 460
000047      C     TITLE       =    80 COLUMN IDENTIFICATION                           A 470
000048      C     TR          =    REDUCED TIME, DEFINED AS DT/AT.                    A 480
000049      C     TTEMP       =    VECTOR OF TEMPERATURE VALUES CORRESPONDING TO INPUT  A 490
000050      C                      OF THE SHIFT FUNCTION AT.                          A 500
000051      C     V           =    MATRIX GENERATED FOR REGRESSION ANALYSIS.          A 510
000052      C     VOLUME      =    DILATATION, SAME AS INV1.                          A 520
000053      C     X           =    EQUATION VARIABLES FOR A PARTICULAR TEST.          A 530
000054      C     XBAR        =    AVERAGE DEVIATION                                  A 540
000055      C     XE          =    COLLECTION OF VARIABLES FOR ALL TESTS, THE UNION OF  A 550
000056      C                      THE X SETS.                                        A 560
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      C     Y         =    OBSERVED STRESS INPUT FOR A PARTICULAR TEST, MAXIMUM  A 570
      C     YCAL      =    CALCULATED STRESS CORRESPONDING TO AN EXPERIMENTAL I  A 580
      C                    DATA POINT.                                          A 590
      DIMENSION     AT(20), AVGAT(50),  B(14), BB(15),  CO(15),  D(20),        A 600
     1         DEVRAT(50), DT(50),  E1(50), E2(50),  F(50),  G(15,15),         A 610
     2         INV1(50),   INV2(50),  KODE(50),  NEXP(50),  NN(14),            A 620
     3         RATE(50),  STG1(600),  STRN1(600),  T(50),  TEM(600),           A 630
     4         TEMP(50),  TIME(600),  TITLE(20),  TR(50),  TTEMP(20),          A 640
     5         V(15,15),  VOLUME(600),  X(15,50),  XF(15,600),  Y(50)          A 650
      DOUBLE PRECISION INT,X,XF                                                 A 660
       REAL NN ,INV1                                                            A 670
      C                                                                         A 680
      C     * * *  F O R M A T  S T A T E M E N T S  * * *                       A 690
      C                                                                         A 700
      C                                                                         A 710
    1  FORMAT (1H ,40X,'THIS IS A POWER LAW CHARACTERIZATION', //////,10X,      A 720
     1 'THE FOLLOWING IS A LIST OF THE CONSTANTS, B(I), AND EXPONENTS, N        A 730
     2(I), FOR THE GENERAL POLES SERIES TERM  (1 + B*T)**NN ...', /////         A 740
     3,10X,'  I  ', 20X, '  B(I)  ',20X,    '  NN(I) ', // )                   A 750
    2  FORMAT (1H ,40X,'THIS IS A PRONY SERIES CHARACTERIZATION',//////,10      A 760
     1X,'THE FOLLOWING IS A LIST OF THE EXPONENTS, B(I), FOR THE GENERAL        A 770
     2 PRONY SERIES TERM  EXP(-B*T) ...', //////,10X,'  I  ', 20X,'   B(I      A 780
     3)', // )                                                                  A 790
    3  FORMAT (16I5)                                                           A 800
    4  FORMAT (8E10.8)                                                         A 810
    5  FORMAT (1H ,10X, I5, 20X, F10.4 )                                       A 820
    6  FORMAT (20A4)                                                           A 830
    7  FORMAT (1H , 7X, I5, 2(20X, F10.4)  )                                   A 840
    8  FORMAT (1H , 10X, 'COLUMN',I4,/, 3(20X, 5E20.6,/), // )                 A 850
    9  FORMAT (1H ,//////,10X,'INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE,      A 860
     1TTEMP ...', ///,10X,'  I  ',20X,'   AT(I)  ',18X,'  TTEMP(I)  ',//       A 870
     2)                                                                         A 880
   10  FORMAT (1H ,5(/), 50X, 'BETA = ', E10.4, / )                            A 890
   11  FORMAT (1H ,10X,'  I  ',T20,'TEMP(I)',T40,'RATE(I)',T70,'DT(I)',        A 900
     1 T90, 'Y(I)', T100, 'INV1(I)', // )                                       A 910
   12  FORMAT (1H ,10X,I5,2X, 5(10X, F10.4) )                                  A 920
   13  FORMAT (1H , 10X,'TEST NO. ', I2, 30X, I4, ' INPUT DATA POINTS', /       A 930
     1/,  40X,'DATA IS FROM A   U N I A X I A L   TEST', //)                    A 940
   14  FORMAT (1H , 10X,'TEST NO. ', I2, 30X, I4, ' INPUT DATA POINTS', /       A 950
     1/,  40X,'DATA IS FROM A   S H E A R   TEST', //)                          A 960
   15  FORMAT (1H , 10X,'TEST NO. ', I2, 30X, I4, ' INPUT DATA POINTS', /       A 970
     1/,  40X,'DATA IS FROM A   B I A X I A L   S T R I P   TEST', // )         A 980
   16  FORMAT (1H1,'L I N E A R   V I S C O E L A S T I C  C H A R A C T       A 990
     1 E R I Z A T I O N  C O D E',T120,'PAGE',I4,//,30X,20A4, ///)            A1000
   17  FORMAT (1H ,///,30X,'REGRESSION COEFFICIENTS ...',//,12X,'I',26X,       A1010
     1      'CO(I)',//,15(11X,I2,22X,E12.5,/), 10(/)  )                       A1020
   18  FORMAT (1H ,///,5X,'TEMP',6X,'TIME',5X,'STRN1',4X,'VOLUME',6X,          A1030
     1    'SIGCAL',5X,'SIG1',7X,'DEV',5(5X,'XF(',I1,')'), // )                A1040
   19  FORMAT (1H ,1X,F9.5, 3F10.5, 3E10.2, 5E10.5,2(/,71X,5E10.5), / )        A1050
   20  FORMAT (1H , 10X,'THERE WERE',I5,'  EXPERIMENTAL TEST POINTS',///,       A1060
     1     10X,'THE AVERAGE DEVIATION,   X B A R ,  WAS ', F10.4, ///,10      A1070
     2X,'THE STANDARD DEVIATION,   S T D ,  WAS ', F10.4   )                  A1080
   21  FORMAT (1H ,10(/),30X,76('*'),//,50X,'INVERSE FAILED ON ROW',I4,        A1090
     1       //,30X,76('*'), 10(/),50X,'PROGRAM TERMINATED'  )                A1100
   22  FORMAT (1H , 5(/),30X,'REGRESSION ANALYSIS PRIMARY MATRIX', /// )        A1110
   23  FORMAT (1H ,30X,'REGRESSION ANALYSIS X BY Y COLUMN VECTOR',//,           A1120
     1       3(10X,5E20.6,/)  )                                               A1130
   24  FORMAT (1H ,30X,'REGRESSION ANALYSIS INVERSE MATRIX',///)                A1140
      C                                                                         A1150
       READ (5,6) (TITLE(I),I=1,20)                                            A1160
```

```
000117                READ (5,4)      BETA                                    A1170
000118                READ (5,3)      I2, I3, LLL, NTESTS, NTEMP              A1180
000119                I4=I2+I3                                                A1190
000120                I6=.TEMP                                                A1200
000121                IPG=1                                                   A1210
000122                WRITE (6,16)  IPG,  (TITLE(I),I=1,20)                   A1220
000123                WRITE (6,10)    BETA                                    A1230
000124                IF (LLL.EQ.0) WRITE (6,1)                               A1240
000125                IF (LLL.EQ.1) WRITE (6,2)                               A1250
000126          C                                                             A1260
000127          C         TABULATE CONSTANTS AND/OR EXPONENTS FOR THE SERIES.  A1270
000128          C                                                             A1280
000129                DO 25 I=1,I3                                            A1290
000130                READ (5,4)   BB(I), B(I)                                A1300
000131           25   CONTINUE                                                A1310
000132                IF (LLL) 26,27,26                                       A1320
000133           26   WRITE (6,5) (I, B(I), I=1,I3)                           A1330
000134                GO TO 28                                                A1340
000135           27   WRITE (6,7) ( I, B(I), BB(I), I=1,I3 )                  A1350
000136           28   CONTINUE                                                A1360
000137          C                                                             A1370
000138          C         TABULATE SHIFT FUNCTION VS. TEMPERATURE ORDERED COLD TO HOT.  A1380
000139          C                                                             A1390
000140                IPG=IPG+1                                               A1400
000141                WRITE (6,16)  IPG,  (TITLE(I),I=1,20)                   A1410
000142                WRITE (6,9)                                             A1420
000143                DO 29 I=1, NTEMP                                        A1430
000144                READ (5,4)   TTEMP(I), AT(I)                            A1440
000145                WRITE (6,7)   I, AT(I), TTEMP(I)                        A1450
000146           29   CONTINUE                                                A1460
000147          C                                                             A1470
000148          C         COMPUTE SLOPE OF SHIFT FUNCTION CURVE AT EACH INPUT POINT.  A1480
000149          C                                                             A1490
000150                DO 30 J=2, NTEMP                                        A1500
000151                D(J)=(LOG(AT(J))-LOG(AT(J-1)))/(TTEMP(J)-TTEMP(J-1) )   A1510
000152           30   CONTINUE                                                A1520
000153          C                                                             A1530
000154          C         ZERO ALL VARIABLES.                                 A1540
000155          C                                                             A1550
000156                DO 31 J=1,15                                            A1560
000157                DO 31 K=1,600                                           A1570
000158                XF(J,K)=0.D0                                            A1580
000159           31   CONTINUE                                                A1590
000160                DO 32 K=1,600                                           A1600
000161                STRL1(K)=0.                                             A1610
000162                SIGI(K)=0.                                              A1620
000163                TIXL(K)=0.                                              A1630
000164                VOLUME(K)=0.                                            A1640
000165                TEM(K)=0.                                               A1650
000166           32   CONTINUE                                                A1660
000167          C                                                             A1670
000168          C         LOAD EXPERIMENTAL DATA                              A1680
000169          C                                                             A1690
000170                JL=0                                                    A1700
000171                DO 49 NT=1, NTESTS                                      A1710
000172          C                                                             A1720
000173          C         ZERO LOCAL STORAGE VECTORS.                         A1730
000174          C                                                             A1740
000175                DO 33 K=1,50                                            A1750
000176                T(K)=0.                                                 A1760
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000177                Y(K)=0.                                                A1770
000178                E1(K)=0.                                               A1780
000179                TEMP(K)=0.                                             A1790
000180                INV2(K)=0.0                                            A1800
000181                INV1(K)=0.                                             A1810
000182                DT(K)=0.                                               A1820
000183                TR(K)=0.                                               A1830
000184                E2(K)=0.                                               A1840
000185                DEVSAT(K)=0.                                           A1850
000186                E(K)=0.                                                A1860
000187                AVGAT(K)=0.          RR:16:45   PAGE   22             A1870
000188                DO 33 J=1,15                                           A1880
000189                X(J,K)=0.00                                            A1890
000190          33    CONTINUE                                               A1900
000191                READ (5,3)  NEXP(NT), KODE(NT)                         A1910
000192                KEL=NEXP(NT)+1                                         A1920
000193                IPG=IPG+1                                              A1930
000194                WRITE (6,16)  IPG, (TITLE(I),I=1,20)                   A1940
000195                IF (KODE(NT).EQ.0) WRITE (6,13)   NT, KEL              A1950
000196                IF (KODE(NT).EQ.1) WRITE (6,14)   NT, KEL              A1960
000197                IF (KODE(NT).EQ.2) WRITE (6,15)   NT, KEL              A1970
000198                WRITE (6,11)                                           A1980
000199                DO 34 K=2,KEL                                          A1990
000200                M=K-1                                                  A2000
000201                READ (5,4)        TEMP(K), RATE(K), DT(K), Y(K), INV1(K)  A2010
000202                WRITE (6,12)  M, TEMP(M), RATE(M), DT(M), Y(M), INV1(M)  A2020
000203          34    CONTINUE                                               A2030
000204                WRITE (6,12)  K, TEMP(K), RATE(K), DT(K), Y(K), INV1(K)  A2040
000205          C                                                            A2050
000206                DO 35 K=2,KEL                                          A2060
000207                INV1(K)=INV1(K)/100.                                   A2070
000208                T(K)=T(K-1)+DT(K)                                      A2080
000209                INV1(K)=INV1(K)+BETA*(TEMP(K)-TEMP(2) )                A2090
000210                E1(K)=E1(K-1)+RATE(K)*DT(K)                            A2100
000211                E2(K)=0.5*(INV1(K) - E1(K) )                           A2110
000212                IF (KODE(NT).EQ.1) E2(K)=0.0                           A2120
000213                IF (KODE(NT).EQ.2) E2(K)=2.*E2(K)                      A2130
000214                DEVSAT(K)=RATE(K)-(E2(K)-E2(K-1) )/DT(K)               A2140
000215          35    CONTINUE                                               A2150
000216          C                                                            A2160
000217          C         INTERPOLATE FOR SHIFT FUNCTION AND COMPUTE REDUCED TIME.  A2170
000218          C                                                            A2180
000219                DO 41 K=2,KEL                                          A2190
000220                IF (K.EQ.2) GO TO 36                                   A2200
000221                EPS=ABS(TEMP(K))-ABS(TEMP(K-1))                        A2210
000222                EPS=ABS(EPS)                                           A2220
000223                IF (EPS.LT.1.E-1) GO TO 39                             A2230
000224          36    DO 37 J=1,16                                           A2240
000225                IF (TEMP(K).LT.TTEMP(J)) GO TO 38                      A2250
000226          37    CONTINUE                                               A2260
000227          38    AVGAT(K)=(EXP(LOG(AT(J-1))+D(J)*(TEMP(K)-TTEMP(J-1))) )  A2270
000228                GO TO 40                                               A2280
000229          39    AVGAT(K)=AVGAT(K-1)                                    A2290
000230          40    TR(K)=TR(K-1)+DT(K)/AVGAT(K)                           A2300
000231                E(K)=((TEMP(K)+459.4)/540.)*((1.+INV1(K))/(1.+E1(K)))  A2310
000232                X(1,K)=(E1(K)-E2(K))*E(K)                              A2320
000233          41    CONTINUE                                               A2330
000234                IF (LLL.EQ.1) GO TO 44                                 A2340
000235          C                                                            A2350
000236          C         COMPUTE POWER SERIES TERMS.                        A2360
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000237      C                                                                 A2370
000238            DO 43 M=1,I3                                                A2380
000239            DO 43 J=2,KEL                                               A2390
000240            A3=AN(M)+1.                                                 A2400
000241            INT=0.                                                      A2410
000242            DO 42 K=2,J                                                 A2420
000243            INT=INT-(DEVPAT(K)/(B(M)*A3))*((1.+B(M)*(TR(J)-TR(K)))**A3-     (1  A2430
000244           1.+B(M)*(TR(J)-TR(K-1)))**A3)*AVGAT(K)                       A2440
000245      42    CONTINUE                                                    A2450
000246            X(I2+M,J)=INT*F(J)                                          A2460
000247      43    CONTINUE            BA2460                                  A2470
000248            GO TO 47                                                    A2480
000249      C                                                                 A2490
000250      C         COMPUTE PRONY SERIES TERMS.                             A2500
000251      C                                                                 A2510
000252      44    DO 46 M=1,I3                                                A2520
000253            DO 46 J=2,KEL                                               A2530
000254            INT=0.D0                                                    A2540
000255            DO 45 K=2,J                                                 A2550
000256            INT=INT+((AVGAT(K)*DEVPAT(K))/B(M))*(DEXP(-B(M)*(TR(J)-TR(K)))-  A2560
000257           1DEXP(-B(M)*(TR(J)-TR(K-1))))                                A2570
000258      45    CONTINUE                                                    A2580
000259            X(I2+M,J)=INT*F(J)                                          A2590
000260      46    CONTINUE                                                    A2600
000261      C                                                                 A2610
000262      C               LOAD LOCAL VECTORS INTO GLOBAL VECTORS.           A2620
000263      C                                                                 A2630
000264      47    CONTINUE                                                    A2640
000265            DO 48 K=1,KEL                                               A2650
000266            STR1(JL+K)=F1(K)                                            A2660
000267            SIG1(JL+K)=Y(K)                                             A2670
000268            TIM1(JL+K)=T(K)                                             A2680
000269            VOLUME(JL+K)=TRV1(K)                                        A2690
000270            TEMP(JL+K)=TEMP(K)                                          A2700
000271            DO 48 M=1,I4                                                A2710
000272            XF(M,JL+K)=X(M,K)                                           A2720
000273      48    CONTINUE                                                    A2730
000274            JL=JL+KEL                                                   A2740
000275      49    CONTINUE                                                    A2750
000276            II=I4                                                       A2760
000277      C                                                                 A2770
000278      C         REGRESSION ANALYSIS.                                    A2780
000279      C                                                                 A2790
000280            DO 51 K=1,II          B780                                  A2800
000281            DO 51 J=1,II                                                A2810
000282            SA=0.                                                       A2820
000283            DO 50 I=1,JI                                                A2830
000284            IF (SIG1(I).LT.1.) GO TO 50                                 A2840
000285            SA=SA+XF(K,I)*XF(J,I)/SIG1(I)**2.                           A2850
000286      50    CONTINUE                                                    A2860
000287            V(K,J)=SA                                                   A2870
000288      51    CONTINUE                                                    A2880
000289            DO 53 K=1,II                                                A2890
000290            BR(K)=0.                                                    A2900
000291            DO 52 I=1,JI                                                A2910
000292            IF (SIG1(I).LT.1.) GO TO 52                                 A2920
000293            BR(K)=BR(K)+XF(K,I)*SIG1(I)/SIG1(I)**2.                     A2930
000294      52    CONTINUE                                                    A2940
000295      53    CONTINUE                                                    A2950
000296            DO 54 I=1,II                                                A2960
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000297              DO 54 J=1,II                                          A2970
000298        54    G(I,J)=V(I,J)                                         A2980
000299              IPG=IPG+1                                             A2990
000300              WRITE (6,16)  IPG, (TITLE(I),I=1,20)                  A3000
000301              WRITE (6,22)                                          A3010
000302              DO 55 J=1,II                                          A3020
000303        55    WRITE (6,8)  J, (V(I,J),I=1,II)                       A3030
000304              IPG=IPG+1                                             A3040
000305              WRITE (6,16)  IPG, (TITLE(I),I=1,20)                  A3050
000306              WRITE (6,23) (BB(J),J=1,II)                           A3060
000307        C                                                           A3070
000308        C         COMPUTE INVERSE.                                  A3080
000309        C                                                           A3090
000310              N1=II                                                 A3100
000311              NCE=0                                                 A3110
000312              DO 59 K=1,N1                                          A3120
000313              COM=G(K,K)                                            A3130
000314              IF (COM.EQ.0.0 ) GO TO 60                             A3140
000315              G(K,K)=1.                                             A3150
000316              DO 56 J=1,N1                                          A3160
000317        56    G(K,J)=G(K,J)/COM                                     A3170
000318              DO 59 I=1,N1                                          A3180
000319              IF (I-K) 57,59,57                                     A3190
000320        57    COM=G(I,K)                                            A3200
000321              G(I,K)=0.0                                            A3210
000322              DO 58 J=1,N1                                          A3220
000323        58    G(I,J)=G(I,J)-COM*G(K,J)                              A3230
000324        59    CONTINUE                                              A3240
000325              GO TO 61                                              A3250
000326        60    NCE=K                                                 A3260
000327              IPG=IPG+1                                             A3270
000328              WRITE (6,16)  IPG, (TITLE(I),I=1,20)                  A3280
000329              WRITE (6,21)  NCE                                     A3290
000330              CALL EXIT                                             A3300
000331        61    CONTINUE                                              A3310
000332              IPG=IPG+1                                             A3320
000333              WRITE (6,16)  IPG, (TITLE(I),I=1,20)                  A3330
000334              WRITE (6,24)                                          A3340
000335              DO 62 J=1, N1                                         A3350
000336              WRITE (6,8)  J, (G(I,J),I=1,N1)                       A3360
000337        62    CONTINUE                                              A3370
000338        C                                                           A3380
000339        C         COMPUTE REGRESSION COEFFICIENTS.                  A3390
000340        C                                                           A3400
000341              DO 63 K=1,II                                          A3410
000342              CO(K)=0.                                              A3420
000343              DO 63 I=1,II                                          A3430
000344              CO(K)=CO(K)+G(K,I)*BB(I)                              A3440
000345        63    CONTINUE                                              A3450
000346              N=1                                                   A3460
000347              KFL=NEXP(N)+1                                         A3470
000348              IPG=IPG+1                                             A3480
000349              WRITE (6,16)  IPG, (TITLE(I),I=1,20)                  A3490
000350              IF (KODE(N).EQ.0) WRITE (6,13)   N, KFL               A3500
000351              IF (KODE(N).EQ.1) WRITE (6,14)   N, KFL               A3510
000352              IF (KODE(N).EQ.2) WRITE (6,15)   N, KFL               A3520
000353              WRITE (6,18) (I,I=1,5)                                A3530
000354        C                                                           A3540
000355        C         CALCULATE STRESS AT INPUT POINTS.                 A3550
000356        C                                                           A3560
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000357                LIN=-3                                                A3570
000358                SUM=0.                                                A3580
000359                PESID=0.                                              A3590
000360                N=0                                                   A3600
000361                DO 67 I=1,JL                                          A3610
000362                N=N+1                                                 A3620
000363                IF (N.LE.KFL) GO TO 64                                A3630
000364                N=N+1                                                 A3640
000365                KFL=NEXP(N)+1                                         A3650
000366                LIN=50                                                A3660
000367                N=1                                                   A3670
000368          64    CONTINUE                                              A3680
000369                LIN=LIN+3                                             A3690
000370                IF (LIN.LT.33) GO TO 65                               A3700
000371                IPG=IPG+1                                             A3710
000372                LIN=0                                                 A3720
000373                WRITE (6,16)  IPG, (TITLE(L),L=1,20)                  A3730
000374                IF (KODE(N).EQ.0) WRITE (6,13)   N, KFL               A3740
000375                IF (KODE(N).EQ.1) WRITE (6,14)   N, KFL               A3750
000376                IF (KODE(N).EQ.2) WRITE (6,15)   N, KFL               A3760
000377                 WRITE (6,18) (K1, K1=1,5)                            A3770
000378          65    CONTINUE                                              A3780
000379                YCAL=0.0                                              A3790
000380                DO 66 J=1,II                                          A3800
000381          66    YCAL=YCAL+CO(J)*XF(J,I)                               A3810
000382                DEV=100.*(YCAL-SIG1(I))/SIG1(I)                       A3820
000383                WRITE (6,19)  TS(I), TYPE(I),STRN1(I),VOLUME(I),YCAL,SIG1(I),DEV,  A3830
000384               1    (XF(J,I),J=1,II)                                  A3840
000385                IF (SIG1(I).LT.1.) GO TO 67                           A3850
000386                PESID=PESID+DEV**2./10.**4.                           A3860
000387                SUM=SUM+DEV/100.                                      A3870
000388          67    CONTINUE                                              A3880
000389                XMEAN=SUM/JL                                          A3890
000390                STD=((JL*PESID-SUM**2.)/(JL*(JL-1)))**0.5             A3900
000391                IPG=IPG+1                                             A3910
000392                WRITE (6,16)  IPG, (TITLE(I),I=1,20)                  A3920
000393                 WRITE (6,17) ( I, CO(I), I=1,II)                     A3930
000394                WRITE (6,20)   JL, XMEAN, STD                         A3940
000395                STOP                                                  A3950
000396          C                                                           A3951
000397          C                                                           A3952
000398                END                                                   A3960-
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APPENDIX H

SAMPLES OF EXPERIMENTAL DATA

This appendix lists some of the experimental data obtained on ANB-3335-1 propellant at 0°F. These data are from "pressurized" uniaxial and biaxial experiments. In total over 250 experiments of the type illustrated were performed on this propellant at temperatures from -65°F to +150°F and pressures from atmospheric to 1000 psi. After processing the raw data through the Preprocessor Code NL001, calculated stress-strain-invariant histories are stored on magnetic tape. The experimental data listed in this appendix represents only a partial listing of the calculated information from each experiment. These listings were obtained using the Post Processor Code.

These data are illustrated in this appendix to demonstrate the type of experimental data obtained and used on this contract. Arrangements can be made to obtain a copy of the complete magnetic tape data file for those who are interested in testing theory against real data.

SUMMARY OF TEST NO. U00600 PAGE U00600 - 1

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.180+01	0.	.2030-01	-.9852-02	-.9852-02	.0000	.4080+02
3	.360+01	0.	.4101-01	-.1884-01	-.1884-01	.0000	.7590+02
4	.540+01	0.	.7642-01	-.3292-01	-.3292-01	.0000	.1265+03
5	.720+01	0.	.1129+00	-.4435-01	-.4435-01	.0000	.1668+03
6	.900+01	0.	.1506+00	-.5378-01	-.5378-01	.0000	.1999+03
7	.108+02	0.	.1894+00	-.6140-01	-.6140-01	.0000	.2036+03
8	.126+02	0.	.2293+00	-.6736-01	-.6736-01	.0000	.2115+03
9	.144+02	0.	.2703+00	-.7219-01	-.7219-01	.0000	.2168+03
10	.162+02	0.	.3124+00	-.7598-01	-.7598-01	.0000	.2207+03
11	.180+02	0.	.3557+00	-.7957-01	-.7957-01	.0000	.2233+03
12	.198+02	0.	.4001+00	-.8262-01	-.8262-01	.0000	.2244+03
13	.216+02	0.	.4456+00	-.8551-01	-.8551-01	.0000	.2241+03
14	.234+02	0.	.4922+00	-.8792-01	-.8792-01	.0000	.2223+03
15	.252+02	0.	.5400+00	-.9160-01	-.9160-01	.0000	.2126+03

MATERIAL DATA

MATERIAL IS AMR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.180+01	.5981-03	-.3030-03	.1971-05	.2030-07	.1421-01
3	.360+01	.3323-02	-.1190-02	.1456-04	.1000-02	.2821-01
4	.660+01	.1057-01	-.3948-02	.8283-04	.3000-02	.5154-01
5	.960+01	.2425-01	-.9051-02	.2221-03	.9000-02	.7415-01
6	.126+02	.4303-01	-.1331-01	.4356-03	.1800-01	.9636-01
7	.156+02	.6657-01	-.1949-01	.7140-03	.3000-01	.1182+00
8	.186+02	.9455-01	-.2635-01	.1040-02	.4500-01	.1398+00
9	.216+02	.1259+00	-.3381-01	.1400-02	.6200-01	.1614+00
10	.246+02	.1605+00	-.4170-01	.1804-02	.8100-01	.1831+00
11	.276+02	.1965+00	-.5028-01	.2252-02	.1000+00	.2052+00
12	.306+02	.2340+00	-.5928-01	.2731-02	.1200+00	.2276+00
13	.336+02	.2746+00	-.6990-01	.3258-02	.1400+00	.2504+00
14	.366+02	.3164+00	-.7882-01	.3805-02	.1610+00	.2735+00
15	.396+02	.3568+00	-.9053-01	.4530-02	.1780+00	.2977+00

6 ADD U00601

SUMMARY OF TEST NO. U00601 PAGE U00601 - 1

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.120+01	0.	.1349-01	-.6611-02	-.6611-02	.0000	.2534+02
3	.240+01	0.	.2716-01	-.1305-01	-.1305-01	.0000	.5955+02
4	.420+01	0.	.4800-01	-.2192-01	-.2192-01	.0000	.1015+03
5	.720+01	0.	.8363-01	-.3536-01	-.3536-01	.0000	.1596+03
6	.102+02	0.	.1204+00	-.4619-01	-.4619-01	.0000	.1839+03
7	.132+02	0.	.1583+00	-.5421-01	-.5421-01	.0000	.2133+03
8	.162+02	0.	.1973+00	-.6050-01	-.6050-01	.0000	.2237+03
9	.192+02	0.	.2374+00	-.6563-01	-.6563-01	.0000	.2306+03
10	.222+02	0.	.2786+00	-.6968-01	-.6968-01	.0000	.2348+03
11	.252+02	0.	.3210+00	-.7312-01	-.7312-01	.0000	.2380+03
12	.282+02	0.	.3645+00	-.7639-01	-.7639-01	.0000	.2404+03
13	.312+02	0.	.4091+00	-.7913-01	-.7913-01	.0000	.2417+03
14	.342+02	0.	.4548+00	-.8137-01	-.8137-01	.0000	.2415+03
15	.372+02	0.	.5017+00	-.8386-01	-.8386-01	.0000	.2386+03
16	.402+02	0.	.5497+00	-.8658-01	-.8658-01	.0000	.2317+03

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.120+01	.2670-03	-.1347-03	.5896-06	.1349-07	.9876-02
3	.240+01	.1059-02	-.5386-03	.4625-05	.2716-07	.1885-01
4	.420+01	.4156-02	-.1624-02	.2307-04	.1000-02	.3296-01
5	.720+01	.1292-01	-.4664-02	.1046-03	.4000-02	.5606-01
6	.102+02	.2801-01	-.8988-02	.2568-03	.1100-01	.7852-01
7	.132+02	.4984-01	-.1422-01	.4651-03	.2300-01	.1002+00
8	.162+02	.7625-01	-.2021-01	.7221-03	.3800-01	.1215+00
9	.192+02	.1061+00	-.2685-01	.1022-02	.5500-01	.1428+00
10	.222+02	.1393+00	-.3397-01	.1353-02	.7400-01	.1642+00
11	.252+02	.1747+00	-.4160-01	.1716-02	.9400-01	.1858+00
12	.282+02	.2117+00	-.4985-01	.2127-02	.1140+00	.2078+00
13	.312+02	.2508+00	-.5848-01	.2562-02	.1350+00	.2301+00
14	.342+02	.2921+00	-.6740-01	.3012-02	.1570+00	.2528+00
15	.372+02	.3340+00	-.7711-01	.3528-02	.1780+00	.2760+00
16	.402+02	.3765+00	-.8768-01	.4121-02	.1980+00	.2999+00

@ ADD U00602

SUMMARY OF TEST NO. U00602

MATERIAL DATA

MATERIAL IS AND 3375-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .1670+01
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.420+01	0.	.1237+00	-.5233-01	-.5233-01	.0000	.3574+02
3	.480+01	0.	.1425+00	-.5893-01	-.5893-01	.0000	.6802+02
4	.540+01	0.	.1616+00	-.6533-01	-.6533-01	.0000	.1001+03
5	.660+01	0.	.2006+00	-.7717-01	-.7717-01	.0000	.1503+03
6	.780+01	0.	.2407+00	-.8837-01	-.8837-01	.0000	.1964+03
7	.900+01	0.	.2819+00	-.9856-01	-.9856-01	.0000	.2371+03
8	.102+02	0.	.3242+00	-.1074+00	-.1074+00	.0000	.2673+03
9	.120+02	0.	.3888+00	-.1196+00	-.1196+00	.0000	.2940+03
10	.150+02	0.	.5047+00	-.1356+00	-.1356+00	.0000	.3236+03
11	.180+02	0.	.6265+00	-.1482+00	-.1482+00	.0000	.3462+03
12	.210+02	0.	.7553+00	-.1624+00	-.1624+00	.0000	.3615+03
13	.240+02	0.	.8911+00	-.1679+00	-.1679+00	.0000	.3724+03
14	.270+02	0.	.1034+01	-.1760+00	-.1760+00	.0000	.3831+03
15	.300+02	0.	.1184+01	-.1831+00	-.1831+00	.0000	.3880+03
16	.330+02	0.	.1340+01	-.1893+00	-.1893+00	.0000	.3866+03
17	.360+02	0.	.1504+01	-.1956+00	-.1956+00	.0000	.3772+03

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .1670+01
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.420+01	.1907-01	-.1021-01	.3389-03	.1237-06	.8300-01
3	.480+01	.2467-01	-.1332-01	.4949-03	.1425-06	.9857-01
4	.540+01	.3093-01	-.1685-01	.6997-03	.1616-06	.1070+00
5	.600+01	.3623-01	-.2500-01	.1195-02	.1000-02	.1300+00
6	.780+01	.6393-01	-.3472-01	.1879-02	.2000-02	.1551+00
7	.900+01	.8475-01	-.4585-01	.2738-02	.4000-02	.1793+00
8	.102+02	.1093+00	-.5912-01	.3743-02	.8000-02	.2035+00
9	.120+02	.1506+00	-.7891-01	.5572-02	.1500-01	.2501+00
10	.150+02	.2334+00	-.1195+00	.9283-02	.3300-01	.3018+00
11	.180+02	.3300+00	-.1638+00	.1377-01	.5600-01	.3652+00
12	.210+02	.4306+00	-.2189+00	.1991-01	.7000-01	.4326+00
13	.240+02	.5554+00	-.2710+00	.2511-01	.1080+00	.4992+00
14	.270+02	.6819+00	-.3329+00	.3202-01	.1350+00	.5703+00
15	.300+02	.8174+00	-.3999+00	.3968-01	.1630+00	.6443+00
16	.330+02	.9616+00	-.4717+00	.4805-01	.1920+00	.7211+00
17	.360+02	.1113+01	-.5500+00	.5752-01	.2190+00	.8012+00

9 AND U00605

SUMMARY OF TEST NO. U00605 PAGE U00605 - 1

MATERIAL DATA

MATERIAL ID. ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .1000+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.120+01	0.	.6622-02	-.3279-02	-.3279-02	.0000	.2215+02
3	.420+01	0.	.2337-01	-.1129-01	-.1129-01	.0000	.5422+02
4	.660+01	0.	.3696-01	-.1703-01	-.1703-01	.0000	.7768+02
5	.102+02	0.	.5767-01	-.2561-01	-.2561-01	.0000	.1097+03
6	.162+02	0.	.9307-01	-.3861-01	-.3861-01	.0000	.1532+03
7	.222+02	0.	.1296+00	-.4861-01	-.4861-01	.0000	.1817+03
8	.282+02	0.	.1671+00	-.5675-01	-.5675-01	.0000	.1975+03
9	.342+02	0.	.2058+00	-.6317-01	-.6317-01	.0000	.2052+03
10	.402+02	0.	.2455+00	-.6801-01	-.6801-01	.0000	.2128+03
11	.462+02	0.	.2864+00	-.7180-01	-.7180-01	.0000	.2178+03
12	.522+02	0.	.3283+00	-.7540-01	-.7540-01	.0000	.2200+03
13	.582+02	0.	.3713+00	-.7844-01	-.7844-01	.0000	.2227+03
14	.642+02	0.	.4154+00	-.8133-01	-.8133-01	.0000	.2237+03
15	.702+02	0.	.4606+00	-.8336-01	-.8336-01	.0000	.2248+03
16	.762+02	0.	.5069+00	-.8741-01	-.8741-01	.0000	.2225+03
17	.822+02	0.	.5543+00	-.8990-01	-.8990-01	.0000	.2182+03
18	.882+02	0.	.6028+00	-.9195-01	-.9195-01	.0000	.2091+03

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .3300+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.120+01	.6505-04	-.3267-04	.7117-07	.6622-08	.4667-02
3	.420+01	.7884-03	-.4001-03	.2978-05	.2737-07	.1634-01
4	.660+01	.2805-02	-.9689-03	.1072-04	.1000-02	.2545-01
5	.102+02	.6447-02	-.2298-02	.3784-04	.2000-02	.3926-01
6	.162+02	.1585-01	-.5696-02	.1387-03	.5000-02	.6207-01
7	.222+02	.3233-01	-.1023-01	.3062-03	.1300-01	.8385-01
8	.282+02	.5363-01	-.1575-01	.5382-03	.2400-01	.1055+00
9	.342+02	.7945-01	-.2201-01	.8211-03	.3800-01	.1268+00
10	.402+02	.1095+00	-.2877-01	.1136-02	.5500-01	.1478+00
11	.462+02	.1428+00	-.3597-01	.1477-02	.7400-01	.1685+00
12	.522+02	.1775+00	-.4383-01	.1867-02	.9300-01	.1903+00
13	.582+02	.2144+00	-.5210-01	.2285-02	.1130+00	.2120+00
14	.642+02	.2528+00	-.6096-01	.2748-02	.1330+00	.2342+00
15	.702+02	.2939+00	-.6985-01	.3201-02	.1550+00	.2564+00
16	.762+02	.3321+00	-.9098-01	.3874-02	.1710+00	.2802+00
17	.822+02	.3745+00	-.9158-01	.4480-02	.1910+00	.3037+00
18	.882+02	.4189+00	-.1024+00	.5096-02	.2120+00	.3275+00

@ ADD U00606

SUMMARY OF TEST NO. U00606

MATERIAL DATA

MATERIAL IS ANR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .4700+00
PRESSURE = 0. PSI
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.600+00	0.	.6722-02	-.3328-02	-.3328-02	.0000	.7020+02
3	.180+01	0.	.2030-01	-.8872-02	-.8872-02	.0000	.6420+02
4	.480+01	0.	.5504-01	-.2306-01	-.2306-01	.0000	.1272+03
5	.600+01	0.	.8002-01	-.3345-01	-.3345-01	.0000	.1648+03
6	.720+01	0.	.8002-01	-.3345-01	-.3345-01	.0000	.1343+03
7	.760+01	0.	.8002-01	-.3345-01	-.3345-01	.0000	.1074+03
8	.840+01	0.	.8002-01	-.3345-01	-.3345-01	.0000	.9562+02
9	.960+01	0.	.8002-01	-.3345-01	-.3345-01	.0000	.8165+02
10	.114+02	0.	.8002-01	-.3345-01	-.3345-01	.0000	.7198+02
11	.144+02	0.	.8002-01	-.3345-01	-.3345-01	.0000	.6231+02
12	.228+02	0.	.8002-01	-.3298-01	-.3298-01	.0000	.5047+02
13	.234+02	0.	.8726-01	-.3541-01	-.3541-01	.0000	.1058+03
14	.246+02	0.	.1019+00	-.4017-01	-.4017-01	.0000	.1617+03
15	.258+02	0.	.1167+00	-.4437-01	-.4437-01	.0000	.1800+03
16	.288+02	0.	.1544+00	-.5334-01	-.5334-01	.0000	.2229+03
17	.318+02	0.	.1933+00	-.6010-01	-.6010-01	.0000	.2372+03
18	.348+02	0.	.2333+00	-.6567-01	-.6567-01	.0000	.2488+03
19	.378+02	0.	.2971+00	-.7193-01	-.7193-01	.0000	.2520+03
20	.396+02	0.	.2971+00	-.7193-01	-.7193-01	.0000	.2307+03
21	.402+02	0.	.2971+00	-.7173-01	-.7173-01	.0000	.1983+03
22	.414+02	0.	.2971+00	-.7153-01	-.7153-01	.0000	.1651+03
23	.438+02	0.	.2971+00	-.7133-01	-.7133-01	.0000	.1383+03
24	.468+02	0.	.2971+00	-.7114-01	-.7114-01	.0000	.1213+03
25	.504+02	0.	.2971+00	-.7114-01	-.7114-01	.0000	.1104+03
26	.564+02	0.	.2971+00	-.7094-01	-.7094-01	.0000	.9987+02
27	.648+02	0.	.2971+00	-.7074-01	-.7074-01	.0000	.8732+02
28	.858+02	0.	.2971+00	-.7054-01	-.7054-01	.0000	.7638+02
29	.912+02	0.	.3031+00	-.7095-01	-.7095-01	.0000	.6965+02
30	.924+02	0.	.3201+00	-.7290-01	-.7290-01	.0000	.6531+02
31	.936+02	0.	.3374+00	-.7462-01	-.7462-01	.0000	.1940+03
32	.948+02	0.	.3548+00	-.7592-01	-.7592-01	.0000	.2222+03
33	.960+02	0.	.3724+00	-.7719-01	-.7719-01	.0000	.2375+03
34	.978+02	0.	.3902+00	-.7905-01	-.7905-01	.0000	.2512+03
35	.101+03	0.	.4447+00	-.8204-01	-.8204-01	.0000	.2500+03
36	.104+03	0.	.4913+00	-.8417-01	-.8417-01	.0000	.2602+03
37	.107+03	0.	.5390+00	-.8620-01	-.8620-01	.0000	.2574+03
38	.110+03	0.	.5879+00	-.8882-01	-.8882-01	.0000	.2514+03
39	.113+03	0.	.6378+00	-.9166-01	-.9166-01	.0000	.2433+03
40	.115+03	0.	.6684+00	-.9441-01	-.9441-01	.0000	.2347+03

MATERIAL DATA

MATERIAL IS ANB 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RAT .6700+00
PRESSURE = .0 PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.600+00	.6703-04	-.3367-04	.7444-07	.6722-08	.4738-02
3	.180+01	.2559-02	-.2915-03	.1598-05	.2000-02	.1375-01
4	.480+01	.8909-02	-.2007-02	.2928-04	.5000-02	.3682-01
5	.690+01	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
6	.720+01	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
7	.780+01	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
8	.840+01	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
9	.960+01	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
10	.114+02	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
11	.144+02	.1312-01	-.4234-02	.8952-04	.5000-02	.5348-01
12	.228+02	.1405-01	-.4191-02	.8705-04	.6000-02	.5327-01
13	.234+02	.1644-01	-.4926-02	.1094-03	.7000-02	.5783-01
14	.246+02	.2152-01	-.6571-02	.1644-03	.9000-02	.6696-01
15	.258+02	.2792-01	-.8384-02	.2297-03	.1200-01	.7591-01
16	.268+02	.3774-01	-.1363-01	.4394-03	.2200-01	.9764-01
17	.318+02	.7310-01	-.1962-01	.6983-03	.3600-01	.1195+00
18	.348+02	.1020+00	-.2633-01	.1006-02	.5200-01	.1400+00
19	.396+02	.1533+00	-.3757-01	.1537-02	.8100-01	.1740+00
20	.396+02	.1533+00	-.3757-01	.1537-02	.8100-01	.1740+00
21	.402+02	.1537+00	-.3748-01	.1529-02	.8150-01	.1736+00
22	.414+02	.1541+00	-.3739-01	.1520-02	.8200-01	.1732+00
23	.438+02	.1545+00	-.3730-01	.1512-02	.8250-01	.1727+00
24	.468+02	.1549+00	-.3721-01	.1504-02	.8300-01	.1726+00
25	.504+02	.1549+00	-.3721-01	.1504-02	.8300-01	.1726+00
26	.564+02	.1553+00	-.3712-01	.1495-02	.8350-01	.1725+00
27	.684+02	.1556+00	-.3703-01	.1487-02	.8400-01	.1724+00
28	.908+02	.1561+00	-.3694-01	.1479-02	.8450-01	.1723+00
29	.912+02	.1612+00	-.3797-01	.1526-02	.8750-01	.1763+00
30	.924+02	.1743+00	-.4136-01	.1701-02	.9400-01	.1853+00
31	.936+02	.1882+00	-.4478-01	.1878-02	.1010+00	.1942+00
32	.948+02	.2030+00	-.4811-01	.2045-02	.1090+00	.2031+00
33	.960+02	.2180+00	-.5154-01	.2219-02	.1170+00	.2120+00
34	.978+02	.2411+00	-.5686-01	.2495-02	.1290+00	.2254+00
35	.101+03	.2806+00	-.6623-01	.2993-02	.1490+00	.2483+00
36	.104+03	.3329+00	-.7562-01	.3481-02	.1710+00	.2717+00
37	.107+03	.3666+00	-.8550-01	.4005-02	.1930+00	.2947+00
38	.110+03	.4102+00	-.9654-01	.4638-02	.2130+00	.3190+00
39	.113+03	.4545+00	-.1085+00	.5358-02	.2320+00	.3436+00
40	.115+03	.4795+00	-.1173+00	.5957-02	.2400+00	.3596+00

H-11

E ADD U00607

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.[illegible]+00	0.	.4028-02	-.2002-02	-.2002-02	.0000	.1807+02
3	.[illegible]+00	0.	.1078-01	-.5303-02	-.5303-02	.0000	.[illegible]+02
4	.275+01	0.	.3129-01	-.1495-01	-.1495-01	.0000	.[illegible]+02
5	.576+01	0.	.6639-01	-.2928-01	-.2928-01	.0000	.[illegible]+03
6	.876+01	0.	.1026+00	-.4136-01	-.4136-01	.0000	.[illegible]+03
7	.118+02	0.	.1378+00	-.5141-01	-.5141-01	.0000	.2089+03
8	.148+02	0.	.1784+00	-.5873-01	-.5873-01	.0000	.2229+03
9	.178+02	0.	.2130+00	-.6502-01	-.6502-01	.0000	.2317+03
10	.211+02	0.	.2637+00	-.7114-01	-.7114-01	.0000	.2377+03
11	.218+02	0.	.2603+00	-.7041-01	-.7041-01	.0000	.[illegible]+03
12	.220+02	0.	.2631+00	-.6949-01	-.6949-01	.0000	.2417+03
13	.[illegible]+02	0.	.2358+00	-.6721-01	-.6721-01	.0000	.[illegible]+02
14	.[illegible]+02	0.	.2196+00	-.6446-01	-.6446-01	.0000	.[illegible]+02
15	.[illegible]+02	0.	.[illegible]+00	-.6043-01	-.6043-01	.0000	.[illegible]+02
16	.[illegible]+02	0.	.[illegible]+00	-.5238-01	-.5238-01	.0000	.[illegible]+02
17	.[illegible]+02	0.	.1189+00	-.4317-01	-.4317-01	.0000	.[illegible]+01
18	.[illegible]+02	0.	.1189+00	-.4317-01	-.4317-01	.0000	.[illegible]+01
19	.[illegible]+02	0.	.1189+00	-.4317-01	-.4317-01	.0000	.1324+02
20	.[illegible]+02	0.	.1189+00	-.4331-01	-.4331-01	.0000	.1355+02
21	.[illegible]+02	0.	.1189+00	-.4340-01	-.4340-01	.0000	.1766+02
22	.[illegible]+02	0.	.1189+00	-.4340-01	-.4340-01	.0000	.1987+02
23	.779+02	0.	.1189+00	-.4384-01	-.4384-01	.0000	.1998+02
24	.[illegible]+02	0.	.1281+00	-.4426-01	-.4426-01	.0000	.2000+02
25	.790+02	0.	.1716+00	-.4669-01	-.4669-01	.0000	.2563+02
26	.[illegible]+02	0.	.[illegible]+00	-.5159-01	-.5159-01	.0000	.[illegible]+02
27	.[illegible]+02	0.	.[illegible]+00	-.[illegible]-01	-.5925-01	.0000	.[illegible]+03
28	.[illegible]+02	0.	.2333+00	-.[illegible]-01	-.[illegible]-01	.0000	.[illegible]+03
29	.[illegible]+02	0.	.2745+00	-.7204-01	-.7204-01	.0000	.[illegible]+03
30	.[illegible]+02	0.	.3167+00	-.7797-01	-.7797-01	.0000	.3153+03
31	.[illegible]+02	0.	.3601+00	-.8217-01	-.8217-01	.0000	.[illegible]+03
32	.944+02	0.	.4046+00	-.8589-01	-.8589-01	.0000	.[illegible]+03
33	.102+03	0.	.4502+00	-.8906-01	-.8906-01	.0000	.[illegible]+03
34	.105+03	0.	.4969+00	-.9208-01	-.9208-01	.0000	.2565+03
35	.108+03	0.	.5448+00	-.9462-01	-.9462-01	.0000	.2550+03
36	.111+03	0.	.5938+00	-.9738-01	-.9738-01	.0000	.2507+03
37	.113+03	0.	.6237+00	-.9877-01	-.9877-01	.0000	.2447+03

MATERIAL DATA

MATERIAL IS AMS 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.360+00	.2417-04	-.1212-04	.1614-07	.4028-08	.2883-02
3	.960+00	.1712-03	-.9619-04	.3031-06	.1078-07	.7580-02
4	.276+01	.1396-02	-.7122-03	.6994-05	.3129-07	.2180-01
5	.576+01	.7835-02	-.3030-02	.5690-04	.2000-02	.4510-01
6	.876+01	.1988-01	-.6777-02	.1756-03	.7000-02	.6787-01
7	.118+02	.3712-01	-.1175-01	.3699-03	.1500-01	.9020-01
8	.148+02	.6054-01	-.1751-01	.6153-03	.2800-01	.1118+00
9	.178+02	.8754-01	-.2418-01	.9274-03	.4200-01	.1335+00
10	.211+02	.1214+00	-.3245-01	.1334-02	.6000-01	.1578+00
11	.214+02	.1195+00	-.3170-01	.1291-02	.5950-01	.1556+00
12	.220+02	.1131+00	-.3021-01	.1217-02	.5600-01	.1516+00
13	.232+02	.1013+00	-.2717-01	.1065-02	.5000-01	.1428+00
14	.244+02	.9067-01	-.2415-01	.9124-03	.4500-01	.1336+00
15	.262+02	.7482-01	-.2000-01	.7146-03	.3700-01	.1207+00
16	.292+02	.5167-01	-.1367-01	.4300-03	.2600-01	.9857-01
17	.322+02	.3255-01	-.8402-02	.2216-03	.1650-01	.7640-01
18	.328+02	.3255-01	-.8402-02	.2216-03	.1650-01	.7640-01
19	.340+02	.3255-01	-.8402-02	.2216-03	.1650-01	.7640-01
20	.358+02	.3228-01	-.8422-02	.2230-03	.1620-01	.7646-01
21	.388+02	.3210-01	-.8436-02	.2239-03	.1600-01	.7650-01
22	.448+02	.3210-01	-.8436-02	.2239-03	.1600-01	.7650-01
23	.779+02	.3121-01	-.8503-02	.2286-03	.1500-01	.7672-01
24	.784+02	.3439-01	-.9125-02	.2498-03	.1700-01	.7966-01
25	.790+02	.3826-01	-.1011-01	.2868-03	.1900-01	.8406-01
26	.808+02	.5124-01	-.1327-01	.4111-03	.2600-01	.9712-01
27	.838+02	.7480-01	-.1940-01	.6787-03	.3900-01	.1191+00
28	.868+02	.1016+00	-.2640-01	.1012-02	.5150-01	.1410+00
29	.898+02	.1286+00	-.3472-01	.1360-02	.6300-01	.1638+00
30	.928+02	.1610+00	-.4326-01	.1921-02	.7900-01	.1860+00
31	.958+02	.1957+00	-.5243-01	.2431-02	.9600-01	.2085+00
32	.988+02	.2328+00	-.6212-01	.2985-02	.1140+00	.2312+00
33	.102+03	.2721+00	-.7226-01	.3571-02	.1330+00	.2542+00
34	.105+03	.3128+00	-.8304-01	.4214-02	.1520+00	.2777+00
35	.108+03	.3556+00	-.9414-01	.4877-02	.1720+00	.3014+00
36	.111+03	.3990+00	-.1062+00	.5630-02	.1910+00	.3258+00
37	.113+03	.4262+00	-.1135+00	.6085-02	.2030+00	.3406+00

@ ADD U00608

MATERIAL DATA

MATERIAL = AM1 355-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

INITIAL STRAIN RATE =
PRESSURE = 0. PSIA
TEMPERATURE = 530. R

DATA POINT	TIME SEC	DT DEG-F	STRAINS (E11, E22, E33, E12) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.600+00	0.	-.3722-02	-.3328-02	-.3328-02	.0000	.2617+02
3	.180+01	0.	-.9938-02	-.9452-02	-.9452-02	.0000	.5815+02
4	.480+01	0.	.6504-01	-.2472-01	-.2472-01	.0000	.1204+03
5	.780+01	0.	.9089-01	-.3776-01	-.3776-01	.0000	.1763+03
6	.108+02	0.	.1274+00	-.4801-01	-.4801-01	.0000	.2015+03
7	.138+02	0.	.1660+00	-.5615-01	-.5615-01	.0000	.2178+03
8	.150+02	0.	.1870+00	-.5971-01	-.5971-01	.0000	.2222+03
9	.156+02	0.	.1870+00	-.5967-01	-.5967-01	.0000	.2219+03
10	.162+02	0.	.1870+00	-.5963-01	-.5963-01	.0000	.2210+03
11	.168+02	0.	.1870+00	-.5959-01	-.5959-01	.0000	.2197+03
12	.180+02	0.	.1870+00	-.5954-01	-.5954-01	.0000	.2183+03
13	.198+02	0.	.1870+00	-.5937-01	-.5937-01	.0000	.2113+03
14	.228+02	0.	.1870+00	-.5924-01	-.5924-01	.0000	.2002+03
15	.288+02	0.	.1870+00	-.5916-01	-.5916-01	.0000	.1852+03
16	.408+02	0.	.1870+00	-.5916-01	-.5916-01	.0000	.1710+03
17	.534+02	0.	.1870+00	-.5937-01	-.5937-01	.0000	.1654+03
18	.588+02	0.	.1949+00	-.6060-01	-.6060-01	.0000	.1681+03
19	.582+02	0.	.2108+00	-.6365-01	-.6365-01	.0000	.1825+03
20	.594+02	0.	.2268+00	-.6581-01	-.6581-01	.0000	.1984+03
21	.576+02	0.	.2431+00	-.6845-01	-.6845-01	.0000	.2205+03
22	.606+02	0.	.2845+00	-.6989-01	-.6989-01	.0000	.2377+03
23	.654+02	0.	.3374+00	-.7462-01	-.7462-01	.0000	.2644+03
24	.648+02	0.	.3374+00	-.7462-01	-.7462-01	.0000	.2121+03
25	.618+02	0.	.3374+00	-.7450-01	-.7450-01	.0000	.1726+03
26	.672+02	0.	.3374+00	-.7442-01	-.7442-01	.0000	.1554+03
27	.690+02	0.	.3374+00	-.7431-01	-.7431-01	.0000	.1565+03
28	.720+02	0.	.3374+00	-.7423-01	-.7423-01	.0000	.1646+03
29	.942+02	0.	.3374+00	-.7423-01	-.7423-01	.0000	.1813+03
30	.942+02	0.	.3443+00	-.7464-01	-.7464-01	.0000	.1940+03
31	.960+02	0.	.3618+00	-.7632-01	-.7632-01	.0000	.1980+03
32	.978+02	0.	.3884+00	-.7820-01	-.7820-01	.0000	.2014+03
33	.996+02	0.	.4154+00	-.8022-01	-.8022-01	.0000	.2041+03
34	.103+03	0.	.4613+00	-.8297-01	-.8297-01	.0000	.2082+03
35	.106+03	0.	.5083+00	-.8541-01	-.8541-01	.0000	.2126+03
36	.109+0	0.	.5565+00	-.8792-01	-.8792-01	.0000	.2457+03
37	.112+03	0.	.6057+00	-.9081-01	-.9081-01	.0000	.2586+03

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MATERIAL DATA

MATERIAL IS AMR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.600+00	.6703-04	-.3367-04	.7444-07	.6722-08	.4778-02
3	.180+01	.5981-03	-.3030-03	.1971-05	.2030-07	.1421-01
4	.480+01	.5587-02	-.2110-02	.3364-04	.1500-02	.3760-01
5	.780+01	.1537-01	-.5439-02	.1296-03	.5000-02	.6065-01
6	.108+02	.3185-01	-.9973-02	.2947-03	.1300-01	.8291-01
7	.138+02	.5368-01	-.1549-01	.5232-03	.2450-01	.1047+00
8	.154+02	.6758-01	-.1877-01	.6668-03	.3220-01	.1163+00
9	.156+02	.6767-01	-.1876-01	.6658-03	.3230-01	.1163+00
10	.162+02	.6776-01	-.1875-01	.6648-03	.3240-01	.1163+00
11	.168+02	.6784-01	-.1874-01	.6640-03	.3250-01	.1162+00
12	.180+02	.6793-01	-.1873-01	.6630-03	.3260-01	.1162+00
13	.198+02	.6827-01	-.1868-01	.6592-03	.3300-01	.1161+00
14	.228+02	.6853-01	-.1865-01	.6564-03	.3330-01	.1161+00
15	.288+02	.6870-01	-.1863-01	.6545-03	.3350-01	.1160+00
16	.408+02	.6870-01	-.1863-01	.6545-03	.3350-01	.1160+00
17	.534+02	.6827-01	-.1868-01	.6592-03	.3300-01	.1161+00
18	.540+02	.7360-01	-.1995-01	.7158-03	.3600-01	.1204+00
19	.552+02	.8347-01	-.2278-01	.8541-03	.4050-01	.1294+00
20	.564+02	.9523-01	-.2553-01	.9824-03	.4700-01	.1390+00
21	.576+02	.1122+00	-.2754-01	.1041-02	.5950-01	.1454+00
22	.606+02	.1447+00	-.3488-01	.1390-02	.7750-01	.1671+00
23	.648+02	.1882+00	-.4478-01	.1878-02	.1010+00	.1942+00
24	.648+02	.1882+00	-.4478-01	.1878-02	.1010+00	.1942+00
25	.660+02	.1884+00	-.4472-01	.1873-02	.1013+00	.1942+00
26	.672+02	.1885+00	-.4468-01	.1869-02	.1015+00	.1941+00
27	.696+02	.1888+00	-.4462-01	.1863-02	.1018+00	.1941+00
28	.756+02	.1889+00	-.4458-01	.1859-02	.1020+00	.1940+00
29	.948+02	.1889+00	-.4458-01	.1859-02	.1020+00	.1940+00
30	.948+02	.1951+00	-.4583-01	.1918-02	.1055+00	.1975+00
31	.960+02	.2092+00	-.4940-01	.2107-02	.1125+00	.2065+00
32	.978+02	.2320+00	-.5464-01	.2376-02	.1245+00	.2200+00
33	.996+02	.2550+00	-.6022-01	.2673-02	.1360+00	.2337+00
34	.103+03	.2954+00	-.6967-01	.3176-02	.1565+00	.2566+00
35	.106+03	.3375+00	-.7954-01	.3708-02	.1775+00	.2795+00
36	.109+03	.3806+00	-.9012-01	.4301-02	.1980+00	.3038+00
37	.112+03	.4241+00	-.1018+00	.4995-02	.2170+00	.3283+00

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 50. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.3333-04	-.3333-04	-.3333-04	.0000	.0000
2	.120+01	0.	.1346-01	-.6645-02	-.6645-02	.0000	.8458+02
3	.240+01	0.	.2712-01	-.1308-01	-.1308-01	.0000	.1701+03
4	.420+01	0.	.4796-01	-.2195-01	-.2195-01	.0000	.1172+03
5	.720+01	0.	.8360-01	-.3562-01	-.3562-01	.0000	.1780+03
6	.102+02	0.	.1203+00	-.4712-01	-.4712-01	.0000	.2229+03
7	.132+02	0.	.1582+00	-.5598-01	-.5598-01	.0000	.2610+03
8	.162+02	0.	.1972+00	-.6329-01	-.6329-01	.0000	.2616+03
9	.192+02	0.	.2373+00	-.6936-01	-.6936-01	.0000	.2731+03
10	.222+02	0.	.2786+00	-.7451-01	-.7451-01	.0000	.2787+03
11	.252+02	0.	.3210+00	-.7920-01	-.7920-01	.0000	.2863+03
12	.282+02	0.	.3644+00	-.8327-01	-.8327-01	.0000	.2901+03
13	.312+02	0.	.4090+00	-.8694-01	-.8694-01	.0000	.2926+03
14	.342+02	0.	.4548+00	-.9045-01	-.9045-01	.0000	.2935+03
15	.372+02	0.	.5016+00	-.9413-01	-.9413-01	.0000	.2905+03
16	.402+02	0.	.5496+00	-.1004+00	-.1004+00	.0000	.2868+03

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MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 50. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.1000-03	.3333-08	-.3704-13	-.1000-03	.0000
2	.120+01	.1670-03	-.1347-03	.5041-06	-.0000-04	.9875-02
3	.240+01	.9586-03	-.5386-03	.4643-05	-.0007-04	.1885-01
4	.420+01	.4056-02	-.1624-02	.2312-04	.0000-03	.3256-01
5	.720+01	.1235-01	-.4687-02	.1061-03	.3000-02	.5620-01
6	.102+02	.2611-01	-.9121-02	.2672-03	.8000-02	.7894-01
7	.132+02	.4626-01	-.1458-01	.4959-03	.1890-01	.1010+00
8	.162+02	.7065-01	-.2096-01	.7899-03	.3140-01	.1228+00
9	.192+02	.9862-01	-.2811-01	.1142-02	.4590-01	.1446+00
10	.222+02	.1296+00	-.3596-01	.1547-02	.6190-01	.1665+00
11	.252+02	.1626+00	-.4457-01	.2013-02	.7840-01	.1886+00
12	.282+02	.1979+00	-.5376-01	.2527-02	.9500-01	.2110+00
13	.312+02	.2352+00	-.6357-01	.3092-02	.1139+00	.2338+00
14	.342+02	.2739+00	-.7408-01	.3720-02	.1319+00	.2570+00
15	.372+02	.3134+00	-.8558-01	.4445-02	.1489+00	.2808+00
16	.402+02	.3468+00	-.1003+00	.5541-02	.1579+00	.3068+00

E ADD U10601

SUMMARY OF TEST NO. U10601 PAGE U10601 - 1

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.6668-04	-.6666-04	-.6666-04	.0000	.0000
2	.600+00	0.	.6655-02	-.3304-02	-.3304-02	.0000	.2920+02
3	.120+01	0.	.2023-01	-.9918-02	-.9918-02	.0000	.6227+02
4	.360+01	0.	.3399-01	-.1608-01	-.1608-01	.0000	.9007+02
5	.600+01	0.	.6017-01	-.3052-01	-.3052-01	.0000	.1556+03
6	.900+01	0.	.1055+00	-.4323-01	-.4323-01	.0000	.2066+03
7	.984+01	0.	.1158+00	-.4650-01	-.4650-01	.0000	.2234+03
8	.102+02	0.	.1158+00	-.4650-01	-.4650-01	.0000	.1814+03
9	.108+02	0.	.1158+00	-.4664-01	-.4664-01	.0000	.1527+03
10	.120+02	0.	.1158+00	-.4673-01	-.4673-01	.0000	.1295+03
11	.138+02	0.	.1158+00	-.4677-01	-.4677-01	.0000	.1129+03
12	.156+02	0.	.1158+00	-.4682-01	-.4682-01	.0000	.1040+03
13	.210+02	0.	.1158+00	-.4686-01	-.4686-01	.0000	.8857+02
14	.270+02	0.	.1158+00	-.4686-01	-.4686-01	.0000	.8078+02
15	.276+02	0.	.1233+00	-.4913-01	-.4913-01	.0000	.1460+03
16	.288+02	0.	.1384+00	-.5324-01	-.5324-01	.0000	.2137+03
17	.300+02	0.	.1536+00	-.5730-01	-.5730-01	.0000	.2843+03
18	.318+02	0.	.1768+00	-.6280-01	-.6280-01	.0000	.2655+03
19	.336+02	0.	.2004+00	-.6790-01	-.6790-01	.0000	.2855+03
20	.360+02	0.	.2324+00	-.7354-01	-.7354-01	.0000	.2954+03
21	.390+02	0.	.2735+00	-.7980-01	-.7980-01	.0000	.3066+03
22	.420+02	0.	.3158+00	-.8538-01	-.8538-01	.0000	.3140+03
23	.426+02	0.	.3158+00	-.8554-01	-.8554-01	.0000	.3056+03
24	.438+02	0.	.3158+00	-.8593-01	-.8593-01	.0000	.2977+03
25	.450+02	0.	.3158+00	-.8632-01	-.8632-01	.0000	.2907+03
26	.468+02	0.	.3158+00	-.8663-01	-.8663-01	.0000	.2837+03
27	.492+02	0.	.3158+00	-.8683-01	-.8683-01	.0000	.2766+03
28	.552+02	0.	.3158+00	-.8749-01	-.8749-01	.0000	.2616+03
29	.558+02	0.	.3158+00	-.8828-01	-.8828-01	.0000	.2567+03
30	.762+02	0.	.3209+00	-.8858-01	-.8858-01	.0000	.2477+03
31	.774+02	0.	.3382+00	-.9034-01	-.9034-01	.0000	.2333+03
32	.786+02	0.	.3556+00	-.9205-01	-.9205-01	.0000	.2191+03
33	.798+02	0.	.3732+00	-.9373-01	-.9373-01	.0000	.2049+03
34	.810+02	0.	.3910+00	-.9544-01	-.9544-01	.0000	.1907+03
35	.822+02	0.	.4181+00	-.9802-01	-.9802-01	.0000	.1766+03
36	.840+02	0.	.4454+00	-.1007+00	-.1007+00	.0000	.1625+03
37	.876+02	0.	.4731+00	-.1034+00	-.1034+00	.0000	.1484+03
38	.114+03	0.	.4986+00	-.1059+00	-.1059+00	.0000	.1343+03
39	.118+03	0.	.5087+00	-.1069+00	-.1069+00	.0000	.1202+03

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MATERIAL DATA

MATERIAL IS ANB 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	.1333-07	-.2963-12	-.2000-03	.1054-07
2	.600+00	-.1330-03	-.3366-04	.7667-07	-.2000-03	.4737-02
3	.180+01	.3981-03	-.3030-03	.1990-05	-.2000-03	.1421-01
4	.300+01	.1838-02	-.8346-03	.8708-05	.2000-03	.2760-01
5	.600+01	.8126-02	-.3291-02	.6445-04	.1800-02	.4700-01
6	.900+01	.1903-01	-.7250-02	.1971-03	.5300-02	.7010-01
7	.984+01	.2284-01	-.8611-02	.2505-03	.6600-02	.7653-01
8	.102+02	.2284-01	-.8611-02	.2505-03	.6600-02	.7653-01
9	.102+02	.2257-01	-.8630-02	.2519-03	.6300-02	.7656-01
10	.120+02	.2230-01	-.8602-02	.2529-03	.6100-02	.7664-01
11	.138+02	.2230-01	-.8649-02	.2534-03	.6000-02	.7666-01
12	.156+02	.2221-01	-.8655-02	.2539-03	.5900-02	.7668-01
13	.210+02	.2212-01	-.8661-02	.2544-03	.5800-02	.7670-01
14	.270+02	.2212-01	-.8661-02	.2544-03	.5900-02	.7670-01
15	.276+02	.2504-01	-.9702-02	.2976-03	.6800-02	.8126-01
16	.288+02	.3187-01	-.1190-01	.3922-03	.9600-02	.9972-01
17	.300+02	.3899-01	-.1432-01	.5042-03	.1230-01	.9941-01
18	.318+02	.5118-01	-.1826-01	.6970-03	.1730-01	.1139+00
19	.336+02	.6456-01	-.2260-01	.9236-03	.2280-01	.1265+00
20	.360+02	.8535-01	-.2978-01	.1257-02	.3230-01	.1442+00
21	.390+02	.1139+00	-.3729-01	.1742-02	.4530-01	.1666+00
22	.420+02	.1450+00	-.4663-01	.2302-02	.5920-01	.1851+00
23	.426+02	.1447+00	-.4670-01	.2310-02	.5980-01	.1892+00
24	.438+02	.1439+00	-.4688-01	.2331-02	.5780-01	.1894+00
25	.450+02	.1431+00	-.4706-01	.2353-02	.5680-01	.1895+00
26	.468+02	.1425+00	-.4721-01	.2370-02	.5600-01	.1897+00
27	.492+02	.1421+00	-.4730-01	.2381-02	.5550-01	.1898+00
28	.552+02	.1408+00	-.4760-01	.2417-02	.5380-01	.1901+00
29	.750+02	.1392+00	-.4796-01	.2461-02	.5180-01	.1905+00
30	.762+02	.1437+00	-.4901-01	.2519-02	.5430-01	.1930+00
31	.774+02	.1575+00	-.5294-01	.2760-02	.6080-01	.2020+00
32	.786+02	.1715+00	-.5700-01	.3013-02	.6730-01	.2110+00
33	.798+02	.1858+00	-.6118-01	.3279-02	.7380-01	.2201+00
34	.810+02	.1999+00	-.6560-01	.3571-02	.7980-01	.2294+00
35	.828+02	.2216+00	-.7249-01	.4035-02	.8980-01	.2434+00
36	.846+02	.2438+00	-.7968-01	.4530-02	.9780-01	.2575+00
37	.876+02	.2800+00	-.9315-01	.5537-02	.1098+00	.2820+00
38	.906+02	.3191+00	-.1070+00	.6576-02	.1238+00	.3065+00
39	.936+02	.3588+00	-.1222+00	.7783-02	.1363+00	.3317+00

- ADD 010602

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.6668-04	-.6666-04	-.6666-04	.0000	.0000
2	.360+00	0.	.3961-02	-.2068-02	-.2068-02	.0000	.1707+03
3	.156+01	0.	.1750-01	-.8627-02	-.8627-02	.0000	.5596+03
4	.276+01	0.	.3123-01	-.1501-01	-.1501-01	.0000	.8556+03
5	.516+01	0.	.5021-01	-.2683-01	-.2683-01	.0000	.1365+04
6	.916+01	0.	.9520-01	-.3999-01	-.3999-01	.0000	.1903+04
7	.112+02	0.	.1323+00	-.5147-01	-.5147-01	.0000	.2430+04
8	.142+02	0.	.1705+00	-.6099-01	-.6099-01	.0000	.2866+04
9	.172+02	0.	.2009+00	-.6913-01	-.6913-01	.0000	.3201+04
10	.202+02	0.	.2504+00	-.7602-01	-.7602-01	.0000	.3805+04
11	.232+02	0.	.2920+00	-.8214-01	-.8214-01	.0000	.3902+04
12	.262+02	0.	.3347+00	-.8794-01	-.8794-01	.0000	.3180+04
13	.268+02	0.	.3261+00	-.8735-01	-.8735-01	.0000	.2158+04
14	.280+02	0.	.3089+00	-.8654-01	-.8654-01	.0000	.1426+04
15	.292+02	0.	.2920+00	-.8492-01	-.8492-01	.0000	.1120+04
16	.322+02	0.	.2504+00	-.8010-01	-.8010-01	.0000	.7126+03
17	.376+02	0.	.1783+00	-.6652-01	-.6652-01	.0000	.2782+03
18	.400+02	0.	.1475+00	-.5894-01	-.5894-01	.0000	.1136+03
19	.406+02	0.	.1551+00	-.6109-01	-.6109-01	.0000	.3826+03
20	.418+02	0.	.1705+00	-.6487-01	-.6487-01	.0000	.5652+03
21	.442+02	0.	.2019+00	-.7218-01	-.7218-01	.0000	.8708+03
22	.472+02	0.	.2422+00	-.7984-01	-.7984-01	.0000	.1208+04
23	.502+02	0.	.2836+00	-.8549-01	-.8549-01	.0000	.1597+04
24	.532+02	0.	.3261+00	-.9046-01	-.9046-01	.0000	.2230+04
25	.562+02	0.	.3697+00	-.9518-01	-.9518-01	.0000	.2935+04
26	.592+02	0.	.4144+00	-.9966-01	-.9966-01	.0000	.3223+04
27	.622+02	0.	.4603+00	-.1043+00	-.1043+00	.0000	.3348+04
28	.652+02	0.	.5073+00	-.1090+00	-.1090+00	.0000	.3392+04
29	.682+02	0.	.5554+00	-.1136+00	-.1136+00	.0000	.3356+04
30	.700+02	0.	.5848+00	-.1168+00	-.1168+00	.0000	.3286+04

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MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	.1333-07	-.2963-12	-.2000-03	.1054-07
2	.360+00	-.1758-03	-.1211-04	.1695-07	-.2000-03	.2842-02
3	.156+01	.2500-03	-.2276-03	.1303-05	-.2000-03	.1232-01
4	.276+01	.1106-02	-.7123-03	.7040-05	-.2000-03	.2180-01
5	.516+01	.5545-02	-.2457-02	.4263-04	.8001-03	.4056-01
6	.816+01	.1523-01	-.6014-02	.1522-03	.3800-02	.6373-01
7	.112+02	.2930-01	-.1097-01	.3505-03	.8800-02	.8663-01
8	.142+02	.4857-01	-.1708-01	.6343-03	.1680-01	.1091+00
9	.172+02	.7163-01	-.2424-01	.1003-02	.2680-01	.1315+00
10	.202+02	.9834-01	-.3229-01	.1447-02	.3880-01	.1536+00
11	.232+02	.1277+00	-.4122-01	.1970-02	.5180-01	.1764+00
12	.262+02	.1568+00	-.5113-01	.2589-02	.6480-01	.1992+00
13	.292+02	.1914+00	-.6233-01	.3488-02	.8080-01	.2286+00
14	.322+02	.2350+00	-.7598-01	.4814-02	.1008+00	.2664+00
15	.352+02	.2921+00	-.9238-01	.6706-02	.1248+00	.3177+00
16	.382+02	.3618-01	-.1136+00	.9306-02	.1568+00	.3858+00
17	.412+02	.4529-01	-.1330-01	.1290-03	.1980-02	.4730+00
18	.442+02	.5658-01	-.1581-01	.1824-03	.2480-02	.5730-01
19	.472+02	.6984-01	-.1852-01	.2478-03	.3080-02	.6930-01
20	.502+02	.8560-01	-.2192-01	.3337-03	.3880-02	.8330-01
21	.532+02	.1035+00	-.2594-01	.4452-03	.4880-02	.9930-01
22	.562+02	.1241+00	-.3080-01	.5894-03	.6080-02	.1172+00
23	.592+02	.1486+00	-.3668-01	.7777-03	.7580-02	.1372+00
24	.622+02	.1781+00	-.4378-01	.1027-02	.9480-02	.1612+00
25	.652+02	.2139+00	-.5232-01	.1360-02	.1188-01	.1912+00
26	.682+02	.2577+00	-.6263-01	.1806-02	.1488-01	.2292+00
27	.712+02	.3116+00	-.7513-01	.2400-02	.1868-01	.2772+00
28	.742+02	.3781+00	-.9033-01	.3195-02	.2348-01	.3372+00
29	.772+02	.4599+00	-.1088+00	.4260-02	.2948-01	.4112+00
30	.802+02	.5599+00	-.1312+00	.5680-02	.3708-01	.5032+00

_C ADD_U10603

MATERIAL DATA

MATERIAL IS ANB 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.6668-04	-.6666-04	-.6666-04	.0000	.0000
2	.900+00	0.	.1071-01	-.5369-02	-.5369-02	.0000	.3942+02
3	.216+01	0.	.2434-01	-.1104-01	-.1104-01	.0000	.5633+02
4	.336+01	0.	.3815-01	-.1805-01	-.1805-01	.0000	.9337+02
5	.476+01	0.	.6632-01	-.2901-01	-.2901-01	.0000	.1376+03
6	.676+01	0.	.1025+00	-.4279-01	-.4279-01	.0000	.1972+03
7	.107+02	0.	.1263+00	-.4999-01	-.4999-01	.0000	.2264+03
8	.113+02	0.	.1263+00	-.5012-01	-.5012-01	.0000	.1807+03
9	.124+02	0.	.1263+00	-.5021-01	-.5021-01	.0000	.1439+03
10	.142+02	0.	.1263+00	-.5035-01	-.5035-01	.0000	.1227+03
11	.170+02	0.	.1263+00	-.5052-01	-.5052-01	.0000	.1068+03
12	.230+02	0.	.1263+00	-.5066-01	-.5066-01	.0000	.9260+02
13	.317+02	0.	.1263+00	-.5078-01	-.5078-01	.0000	.8260+02
14	.422+02	0.	.1323+00	-.5258-01	-.5258-01	.0000	.1345+03
15	.434+02	0.	.1475+00	-.5675-01	-.5675-01	.0000	.2077+03
16	.446+02	0.	.1628+00	-.6060-01	-.6060-01	.0000	.2603+03
17	.464+02	0.	.1862+00	-.6601-01	-.6601-01	.0000	.2672+03
18	.498+02	0.	.2179+00	-.7238-01	-.7238-01	.0000	.2841+03
19	.618+02	0.	.2586+00	-.7893-01	-.7893-01	.0000	.2963+03
20	.998+02	0.	.3004+00	-.8514-01	-.8514-01	.0000	.3062+03
21	.492+02	0.	.3495+00	-.9250-01	-.9250-01	.0000	.3145+03
22	.484+02	0.	.3469+00	-.9245-01	-.9245-01	.0000	.2780+03
23	.493+02	0.	.3302+00	-.9208-01	-.9208-01	.0000	.2016+03
24	.502+02	0.	.3209+00	-.9093-01	-.9093-01	.0000	.1359+03
25	.520+02	0.	.2954+00	-.8858-01	-.8858-01	.0000	.9657+02
26	.566+02	0.	.2619+00	-.8451-01	-.8451-01	.0000	.6703+02
27	.574+02	0.	.2211+00	-.7791-01	-.7791-01	.0000	.4175+02
28	.586+02	0.	.2211+00	-.7791-01	-.7791-01	.0000	.4771+02
29	.542+02	0.	.2211+00	-.7795-01	-.7795-01	.0000	.5348+02
30	.610+02	0.	.2211+00	-.7799-01	-.7799-01	.0000	.5606+02
31	.634+02	0.	.2211+00	-.7816-01	-.7816-01	.0000	.5727+02
32	.680+02	0.	.2211+00	-.7858-01	-.7858-01	.0000	.5869+02
33	.748+02	0.	.2211+00	-.7883-01	-.7883-01	.0000	.5998+02
34	.808+02	0.	.2211+00	-.7908-01	-.7908-01	.0000	.6094+02
35	.814+02	0.	.2292+00	-.8067-01	-.8067-01	.0000	.9040+02
36	.826+02	0.	.2455+00	-.8363-01	-.8363-01	.0000	.1017+03
37	.844+02	0.	.2702+00	-.8735-01	-.8735-01	.0000	.1275+03
38	.874+02	0.	.3123+00	-.9224-01	-.9224-01	.0000	.1750+03
39	.904+02	0.	.3556+00	-.9683-01	-.9683-01	.0000	.2433+03
40	.934+02	0.	.4000+00	-.1013+00	-.1013+00	.0000	.2983+03
41	.964+02	0.	.4455+00	-.1059+00	-.1059+00	.0000	.3210+03
42	.994+02	0.	.4921+00	-.1102+00	-.1102+00	.0000	.3307+03
43	.102+03	0.	.5399+00	-.1145+00	-.1145+00	.0000	.3337+03
44	.105+03	0.	.5887+00	-.1192+00	-.1192+00	.0000	.3257+03

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MATERIAL DATA

MATERIAL IS AMR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	.1333-07	-.2963-12	-.2000-03	.1058-07
2	.960+00	-.2885-04	-.8618-04	.3088-06	-.2000-03	.7580-02
3	.216+01	.6500-03	-.4363-03	.3414-05	-.2000-03	.1706-01
4	.336+01	.2054-02	-.1052-02	.1243-04	.3815-07	.2650-01
5	.576+01	.6695-02	-.3065-02	.5894-04	.8001-03	.4532-01
6	.876+01	.1694-01	-.6944-02	.1878-03	.3800-02	.6851-01
7	.107+02	.2632-01	-.1013-01	.3156-03	.7300-02	.8310-01
8	.112+02	.2605-01	-.1015-01	.3173-03	.7000-02	.8316-01
9	.124+02	.2587-01	-.1016-01	.3184-03	.6800-02	.8321-01
10	.142+02	.2561-01	-.1018-01	.3201-03	.6500-02	.8327-01
11	.172+02	.2525-01	-.1021-01	.3224-03	.6100-02	.8335-01
12	.232+02	.2469-01	-.1023-01	.3241-03	.5800-02	.8342-01
13	.317+02	.2453-01	-.1026-01	.3270-03	.5300-02	.8352-01
14	.322+02	.2715-01	-.1115-01	.3658-03	.6300-02	.8716-01
15	.334+02	.3307-01	-.1352-01	.4749-03	.8800-02	.9627-01
16	.346+02	.4160-01	-.1606-01	.5980-03	.1180-01	.1053+00
17	.364+02	.5413-01	-.2022-01	.8111-03	.1680-01	.1186+00
18	.388+02	.7315-01	-.2630-01	.1142-02	.2480-01	.1368+00
19	.418+02	.1007+00	-.3460-01	.1611-02	.3730-01	.1591+00
20	.448+02	.1301+00	-.4391-01	.2178-02	.4980-01	.1818+00
21	.482+02	.1645+00	-.5610-01	.2990-02	.6230-01	.2084+00
22	.484+02	.1620+00	-.5559-01	.2965-02	.6080-01	.2071+00
23	.490+02	.1540+00	-.5380-01	.2867-02	.5630-01	.2029+00
24	.502+02	.1390+00	-.5009-01	.2654-02	.4930-01	.1941+00
25	.520+02	.1182+00	-.4448-01	.2317-02	.3780-01	.1810+00
26	.548+02	.9290-01	-.3712-01	.1870-02	.2580-01	.1633+00
27	.574+02	.6530-01	-.2839-01	.1342-02	.1380-01	.1410+00
28	.580+02	.6530-01	-.2839-01	.1342-02	.1380-01	.1410+00
29	.592+02	.6521-01	-.2840-01	.1344-02	.1370-01	.1410+00
30	.610+02	.6513-01	-.2841-01	.1345-02	.1360-01	.1410+00
31	.634+02	.6480-01	-.2846-01	.1351-02	.1320-01	.1411+00
32	.688+02	.6405-01	-.2856-01	.1364-02	.1230-01	.1413+00
33	.748+02	.6347-01	-.2865-01	.1374-02	.1160-01	.1414+00
34	.808+02	.6297-01	-.2872-01	.1383-02	.1100-01	.1415+00
35	.814+02	.6785-01	-.3047-01	.1491-02	.1280-01	.1461+00
36	.826+02	.7820-01	-.3406-01	.1717-02	.1680-01	.1551+00
37	.844+02	.9550-01	-.3958-01	.2062-02	.2430-01	.1686+00
38	.874+02	.1279+00	-.4911-01	.2657-02	.3950-01	.1907+00
39	.904+02	.1619+00	-.5949-01	.3334-02	.5480-01	.2133+00
40	.934+02	.1974+00	-.7078-01	.4105-02	.6980-01	.2363+00
41	.964+02	.2336+00	-.8316-01	.4999-02	.8380-01	.2599+00
42	.994+02	.2718+00	-.9628-01	.5971-02	.9830-01	.2838+00
43	.102+03	.3108+00	-.1105+00	.7082-02	.1118+00	.3085+00
44	.105+03	.3503+00	-.1262+00	.8367-02	.1238+00	.3337+00

MATERIAL DATA

MATERIAL IS AMR 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.6668-04	-.6666-04	-.6666-04	.0000	.0000
2	.120+01	0.	.1342-01	-.6678-02	-.6678-02	.0000	.2250+02
3	.240+01	0.	.2709-01	-.1312-01	-.1312-01	.0000	.5842+02
4	.360+01	0.	.4094-01	-.1934-01	-.1934-01	.0000	.9000+02
5	.600+01	0.	.6917-01	-.3099-01	-.3099-01	.0000	.1569+03
6	.900+01	0.	.1055+00	-.4409-01	-.4409-01	.0000	.1813+03
7	.120+02	0.	.1429+00	-.5544-01	-.5544-01	.0000	.2217+03
8	.150+02	0.	.1815+00	-.6533-01	-.6533-01	.0000	.2480+03
9	.180+02	0.	.2211+00	-.7300-01	-.7300-01	.0000	.2656+03
10	.210+02	0.	.2619+00	-.7980-01	-.7980-01	.0000	.2776+03
11	.240+02	0.	.3038+00	-.8614-01	-.8614-01	.0000	.2871+03
12	.270+02	0.	.3469+00	-.9180-01	-.9180-01	.0000	.2942+03
13	.300+02	0.	.3910+00	-.9713-01	-.9713-01	.0000	.2996+03
14	.330+02	0.	.4363+00	-.1021+00	-.1021+00	.0000	.3042+03
15	.360+02	0.	.4827+00	-.1067+00	-.1067+00	.0000	.3084+03

MATERIAL DATA

MATERIAL IS ANB 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 100. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	.1333-07	-.2963-12	-.2000-03	.1054-07
2	.120+01	.6698-04	-.1347-03	.5985-06	-.2000-03	.9475-02
3	.240+01	.8586-03	-.5386-03	.4660-05	-.2000-03	.1965-01
4	.360+01	.2258-02	-.1209-02	.1531-04	-.9996-04	.2842-01
5	.480+01	.7169-02	-.3327-02	.6644-04	.0001-03	.4722-01
6	.600+01	.1730-01	-.7357-02	.2050-03	.3400-02	.7051-01
7	.120+02	.3202-01	-.1277-01	.4392-03	.8209-02	.9750-01
8	.150+02	.5079-01	-.1944-01	.7744-03	.1490-01	.1163+00
9	.180+02	.7512-01	-.2695-01	.1178-02	.2560-01	.1386+00
10	.210+02	.1021+00	-.3547-01	.1672-02	.3720-01	.1611+00
11	.240+02	.1316+00	-.4492-01	.2254-02	.4950-01	.1838+00
12	.270+02	.1633+00	-.5526-01	.2923-02	.6250-01	.2068+00
13	.300+02	.1968+00	-.6653-01	.3689-02	.7560-01	.2301+00
14	.330+02	.2322+00	-.7864-01	.4545-02	.8910-01	.2538+00
15	.360+02	.2693+00	-.9161-01	.5494-02	.1028+00	.2778+00

G ADD U10605

MATERIAL DATA

MATERIAL IS AIR 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.1333-03	-.1333-03	-.1333-03	.0000	.0000
2	.720+00	0.	.3038-02	-.4121-02	-.4121-02	.0000	.2520+02
3	.232+01	0.	.2896-01	-.1223-01	-.1223-01	.0000	.6047+02
4	.522+01	0.	.6985-01	-.2753-01	-.2753-01	.0000	.1270+03
5	.932+01	0.	.1586-01	-.4161-01	-.4161-01	.0000	.1910+03
6	.112+02	0.	.1330+00	-.5455-01	-.5455-01	.0000	.2427+03
7	.182+02	0.	.1712+00	-.6618-01	-.6618-01	.0000	.2808+03
8	.172+02	0.	.2106+00	-.7678-01	-.7678-01	.0000	.3074+03
9	.202+02	0.	.2511+00	-.8651-01	-.8651-01	.0000	.3263+03
10	.232+02	0.	.2927+00	-.9540-01	-.9540- 1	.0000	.3405+03
11	.262+02	0.	.3355+00	-.1038+00	-.1038+00	.0000	.3483+03
12	.292+02	0.	.3793+00	-.1117+00	-.1117+00	.0000	.3571+03
13	.322+02	0.	.4243+00	-.1192+00	-.1192+00	.0000	.3647+03
14	.352+02	0.	.4704+00	-.1264+00	-.1264+00	.0000	.3706+03
15	.382+02	0.	.5177+00	-.1334+00	-.1334+00	.0000	.3759+03
16	.412+02	0.	.5660+00	-.1401+00	-.1401+00	.0000	.3818+03

MATERIAL DATA

MATERIAL IS AMR 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.4000-03	.5334-07	-.2371-11	-.4000-03	.0000
2	.720+00	-.3036-03	-.4844-04	.1348-06	-.4000-03	.5685-02
3	.222+01	.5069-03	-.4609-03	.3732-05	-.4000-03	.1753-01
4	.522+01	.4793-02	-.2537-02	.4535-04	-.8994-04	.4116-01
5	.622+01	.1263-01	-.6246-02	.1660-03	.9001-03	.6480-01
6	.112+02	.2389-01	-.1153-01	.3957-03	.2400-02	.8841-01
7	.142+02	.3869-01	-.1929-01	.7500-03	.5300-02	.1110+00
8	.172+02	.5707-01	-.2645-01	.1241-02	.9100-02	.1356+00
9	.202+02	.7810-01	-.3596-01	.1879-02	.1360-01	.1592+00
10	.232+02	.1019+00	-.4675-01	.2664-02	.1890-01	.1830+00
11	.262+02	.1220+00	-.5885-01	.3612-02	.2440-01	.2071+00
12	.292+02	.1560+00	-.7225-01	.4730-02	.3000-01	.2315+00
13	.322+02	.1860+00	-.8693-01	.6026-02	.3560-01	.2562+00
14	.352+02	.2177+00	-.1029+00	.7515-02	.4100-01	.2813+00
15	.382+02	.2509+00	-.1203+00	.9209-02	.4610-01	.3069+00
16	.412+02	.2859+00	-.1389+00	.1111-01	.5110-01	.3329+00

6 ADD U10606

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.1333-03	-.1333-03	-.1333-03	.0000	.0000
2	.600+00	0.	.6588-02	-.3461-02	-.3461-02	.0000	.2812+02
	.180+01	0.	.2017-01	-.9984-02	-.9984-02	.0000	.5611+02
	.300+01	0.	.3392-01	-.1682-01	-.1682-01	.0000	.8611+02
	.600+01	0.	.6910-01	-.3082-01	-.3082-01	.0000	.1663+03
	.900+01	0.	.1054+00	-.4388-01	-.4388-01	.0000	.2284+03
	.120+02	0.	.1428+00	-.5533-01	-.5533-01	.0000	.2755+03
	.150+02	0.	.1814+00	-.6530-01	-.6530-01	.0000	.3094+03
9	.180+02	0.	.2210+00	-.7381-01	-.7381-01	.0000	.3335+03
	.210+02	0.	.2613+00	-.8109-01	-.8109-01	.0000	.3510+03
	.216+02	0.	.2618+00	-.8173-01	-.8173-01	.0000	.3537+03
	.228+02	0.	.2618+00	-.8234-01	-.8234-01	.0000	.3577+03
	.246+02	0.	.2618+00	-.8294-01	-.8294-01	.0000	.3711+03
14	.276+02	0.	.2618+00	-.8355-01	-.8355-01	.0000	.3106+03
15	.336+02	0.	.2618+00	-.8436-01	-.8436-01	.0000	.1901+03
16	.456+02	0.	.2618+00	-.8529-01	-.8529-01	.0000	.1732+03
17	.636+02	0.	.2618+00	-.8610-01	-.8610-01	.0000	.1612+03
18	.813+02	0.	.2618+00	-.8667-01	-.8667-01	.0000	.1527+03
19	.816+02	0.	.2660+00	-.8698-01	-.8698-01	.0000	.1873+03
20	.836+02	0.	.2826+00	-.8909-01	-.8909-01	.0000	.2554+03
21	.846+02	0.	.3080+00	-.9256-01	-.9256-01	.0000	.3307+03
22	.864+02	0.	.3337+00	-.9603-01	-.9603-01	.0000	.3603+03
23	.882+02	0.	.3599+00	-.9944-01	-.9944-01	.0000	.3762+03
24	.906+02	0.	.3954+00	-.1038+00	-.1038+00	.0000	.3886+03
25	.937+02	0.	.4426+00	-.1096+00	-.1096+00	.0000	.3965+03
26	.948+02	0.	.4426+00	-.1099+00	-.1099+00	.0000	.3962+03
27	.960+02	0.	.4426+00	-.1107+00	-.1107+00	.0000	.3908+03
28	.972+02	0.	.4426+00	-.1115+00	-.1115+00	.0000	.3858+03
29	.984+02	0.	.4426+00	-.1123+00	-.1123+00	.0000	.3811+03
30	.108+03	0.	.4426+00	-.1134+00	-.1134+00	.0000	.3812+03
31	.118+03	0.	.4426+00	-.1149+00	-.1149+00	.0000	.3909+03
32	.136+03	0.	.4426+00	-.1163+00	-.1163+00	.0000	.3973+03
33	.151+03	0.	.4426+00	-.1172+00	-.1172+00	.0000	.4069+03
34	.152+03	0.	.4537+00	-.1175+00	-.1175+00	.0000	.3918+03
35	.153+03	0.	.4723+00	-.1180+00	-.1180+00	.0000	.3935+03
36	.156+03	0.	.5196+00	-.1227+00	-.1227+00	.0000	.3765+03
37	.159+03	0.	.5680+00	-.1272+00	-.1272+00	.0000	.3962+03

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MATERIAL DATA

MATERIAL IS AMR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.0000-03	.5334-07	-.2371-11	-.4000-03	.0000
2	.600+00	-.3330-03	-.3362-04	.7890-07	-.4000-03	.4737-02
3	.180+01	.1980-03	-.3030-03	.2010-05	-.4000-03	.1421-01
4	.300+01	.1489-02	-.8373-03	.8022-05	-.1500-03	.2364-01
5	.600+01	.7458-02	-.3310-02	.6565-04	.1100-02	.4710-01
6	.900+01	.1768-01	-.7325-02	.2029-03	.3800-02	.7037-01
7	.120+02	.3217-01	-.1274-01	.4372-03	.8000-02	.9341-01
8	.150+02	.5077-01	-.1942-01	.7735-03	.1490-01	.1163+00
9	.180+02	.7342-01	-.2718-01	.1204-02	.2360-01	.1390+00
10	.210+02	.9886-01	-.3603-01	.1730-02	.3320-01	.1618+00
11	.216+02	.9837-01	-.3612-01	.1749-02	.3260-01	.1620+00
12	.228+02	.9716-01	-.3634-01	.1775-02	.3110-01	.1622+00
13	.246+02	.9594-01	-.3655-01	.1801-02	.2960-01	.1625+00
14	.276+02	.9473-01	-.3677-01	.1828-02	.2810-01	.1628+00
15	.336+02	.9311-01	-.3706-01	.1863-02	.2610-01	.1632+00
16	.456+02	.9124-01	-.3739-01	.1905-02	.2380-01	.1636+00
17	.636+02	.8962-01	-.3768-01	.1941-02	.2180-01	.1640+00
18	.813+02	.8849-01	-.3787-01	.1967-02	.2040-01	.1643+00
19	.816+02	.8201-01	-.3870-01	.2012-02	.2240-01	.1664+00
20	.828+02	.1045+00	-.4242-01	.2243-02	.2820-01	.1752+00
21	.846+02	.1229+00	-.4845-01	.2638-02	.3590-01	.1888+00
22	.864+02	.1417+00	-.5488-01	.3078-02	.4330-01	.2026+00
23	.882+02	.1610+00	-.6169-01	.3558-02	.5060-01	.2165+00
24	.906+02	.1878+00	-.7131-01	.4260-02	.6040-01	.2353+00
25	.937+02	.2235+00	-.8499-01	.5313-02	.7220-01	.2603+00
26	.942+02	.2288+00	-.8523-01	.5348-02	.7120-01	.2605+00
27	.954+02	.2213+00	-.8574-01	.5423-02	.6910-01	.2608+00
28	.972+02	.2197+00	-.8627-01	.5502-02	.6690-01	.2612+00
29	.996+02	.2181+00	-.8677-01	.5578-02	.6480-01	.2616+00
30	.106+03	.2158+00	-.8754-01	.5694-02	.6160-01	.2621+00
31	.118+03	.2128+00	-.8852-01	.5845-02	.5750-01	.2628+00
32	.136+03	.2100+00	-.8945-01	.5990-02	.5360-01	.2635+00
33	.151+03	.2083+00	-.9000-01	.6077-02	.5130-01	.2639+00
34	.152+03	.2188+00	-.9280-01	.6282-02	.5660-01	.2693+00
35	.153+03	.2344+00	-.9820-01	.6681-02	.6280-01	.2787+00
36	.156+03	.2742+00	-.1124+00	.7821-02	.7760-01	.3028+00
37	.159+03	.3135+00	-.1283+00	.9194-02	.8960-01	.3277+00

6 ADD U10607

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MATERIAL DATA

POISSON'S RATIO = .3336-1
ELASTIC MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.1333-03	-.1333-03	-.1333-03	.0000	.0000
2	.720+00	0.	.7938-02	-.4121-02	-.4121-02	.0000	.3831+02
3	.192+01	0.	.2153-01	-.1063-01	-.1063-01	.0000	.6844+02
4	.372+01	0.	.4226-01	-.1990-01	-.1990-01	.0000	.1156+03
5	.672+01	0.	.7771-01	-.3433-01	-.3433-01	.0000	.1902+03
6	.972+01	0.	.1143+00	-.4705-01	-.4705-01	.0000	.2544+03
7	.127+02	0.	.1520+00	-.5802-01	-.5802-01	.0000	.3001+03
8	.157+02	0.	.1908+00	-.6734-01	-.6734-01	.0000	.3310+03
9	.187+02	0.	.2027+00	-.7004-01	-.7004-01	.0000	.3381+03
10	.169+02	0.	.2027+00	-.7012-01	-.7012-01	.0000	.3936+03
11	.175+02	0.	.2027+00	-.7038-01	-.7038-01	.0000	.3958+03
12	.187+02	0.	.2027+00	-.7076-01	-.7076-01	.0000	.2201+03
13	.205+02	0.	.2027+00	-.7114-01	-.7114-01	.0000	.2057+03
14	.235+02	0.	.2027+00	-.7164-01	-.7164-01	.0000	.1882+03
15	.289+02	0.	.2027+00	-.7211-01	-.7211-01	.0000	.1718+03
16	.307+02	0.	.2027+00	-.7286-01	-.7286-01	.0000	.1543+03
17	.565+02	0.	.2027+00	-.7383-01	-.7383-01	.0000	.1300+03
18	.691+02	0.	.1947+00	-.7239-01	-.7239-01	.0000	.8216+02
19	.703+02	0.	.1790+00	-.6876-01	-.6876-01	.0000	.5231+02
20	.721+02	0.	.1558+00	-.6272-01	-.6272-01	.0000	.1144+02
21	.727+02	0.	.1635+00	-.6517-01	-.6517-01	.0000	.7017+02
22	.739+02	0.	.1790+00	-.6957-01	-.6957-01	.0000	.2795+02
23	.763+02	0.	.2106+00	-.7661-01	-.7661-01	.0000	.1754+03
24	.781+02	0.	.2348+00	-.8001-01	-.8001-01	.0000	.2646+03
25	.793+02	0.	.2511+00	-.8381-01	-.8381-01	.0000	.3155+03
26	.805+02	0.	.2676+00	-.8654-01	-.8654-01	.0000	.3476+03
27	.817+02	0.	.2843+00	-.8925-01	-.8925-01	.0000	.3642+03
28	.847+02	0.	.3268+00	-.9567-01	-.9567-01	.0000	.3884+03
29	.877+02	0.	.3705+00	-.1018+00	-.1018+00	.0000	.4003+03
30	.907+02	0.	.4152+00	-.1074+00	-.1074+00	.0000	.4065+03
31	.937+02	0.	.4611+00	-.1128+00	-.1128+00	.0000	.4108+03
32	.955+02	0.	.4892+00	-.1159+00	-.1159+00	.0000	.4113+03

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.4000-03	.5334-07	-.2371-11	-.4000-03	.0000
2	.720+00	-.3036-03	-.4844-04	.1348-06	-.4000-03	.5685-02
3	.192+01	-.2799-03	-.3447-03	.2432-05	-.4000-03	.1516-01
4	.372+01	.2456-02	-.1286-02	.1674-04	-.4096-04	.2931-01
5	.672+01	.9049-02	-.4157-02	.9160-04	.1100-02	.5282-01
6	.972+01	.2018-01	-.8541-02	.2530-03	.4100-02	.7605-01
7	.127+02	.3504-01	-.1427-01	.5116-03	.8400-02	.9855-01
8	.157+02	.5611-01	-.2116-01	.8652-03	.1710-01	.1217+00
9	.186+02	.6258-01	-.2348-01	.9941-03	.1940-01	.1295+00
10	.169+02	.6241-01	-.2350-01	.9965-03	.1920-01	.1286+00
11	.175+02	.6180-01	-.2357-01	.1004-02	.1860-01	.1287+00
12	.187+02	.6114-01	-.2367-01	.1015-02	.1770-01	.1288+00
13	.205+02	.6038-01	-.2377-01	.1025-02	.1680-01	.1291+00
14	.235+02	.5937-01	-.2390-01	.1040-02	.1560-01	.1293+00
15	.289+02	.5844-01	-.2403-01	.1054-02	.1450-01	.1295+00
16	.409+02	.5692-01	-.2422-01	.1076-02	.1270-01	.1298+00
17	.685+02	.5498-01	-.2447-01	.1105-02	.1040-01	.1303+00
18	.691+02	.4996-01	-.2295-01	.1020-02	.8100-02	.1256+00
19	.703+02	.4151-01	-.1989-01	.8468-03	.5100-02	.1168+00
20	.721+02	.3037-01	-.1561-01	.6128-03	.1600-02	.1038+00
21	.727+02	.3315-01	-.1706-01	.6845-03	.1800-02	.1078+00
22	.739+02	.3988-01	-.2007-01	.8666-03	.3200-02	.1172+00
23	.763+02	.5740-01	-.2640-01	.1236-02	.6500-02	.1354+00
24	.781+02	.7297-01	-.3144-01	.1537-02	.1610-01	.1498+00
25	.793+02	.8349-01	-.3507-01	.1764-02	.2020-01	.1579+00
26	.805+02	.9455-01	-.3883-01	.2004-02	.2460-01	.1670+00
27	.817+02	.1058+00	-.4279-01	.2265-02	.2890-01	.1761+00
28	.847+02	.1355+00	-.5339-01	.2992-02	.3960-01	.1982+00
29	.877+02	.1669+00	-.6507-01	.3840-02	.5080-01	.2226+00
30	.907+02	.2005+00	-.7765-01	.4788-02	.6240-01	.2464+00
31	.937+02	.2356+00	-.9128-01	.5863-02	.7380-01	.2705+00
32	.955+02	.2575+00	-.9994-01	.6568-02	.8060-01	.2852+00

MATERIAL DATA

MATERIAL IS AND 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.1333-03	-.1333-03	-.1333-03	.0000	.0000
2	.240+00	0.	.9289-02	-.4779-02	-.4779-02	.0000	.3028+02
3	.624+01	0.	.3670-01	-.1759-01	-.1759-01	.0000	.8601+02
4	.504+01	0.	.5772-01	-.2663-01	-.2663-01	.0000	.1320+03
5	.384+01	0.	.9366-01	-.4045-01	-.4045-01	.0000	.2025+03
6	.110+02	0.	.1307+00	-.5273-01	-.5273-01	.0000	.2611+03
7	.140+02	0.	.1689+00	-.6318-01	-.6318-01	.0000	.3026+03
8	.170+02	0.	.2082+00	-.7224-01	-.7224-01	.0000	.3302+03
9	.206+02	0.	.2560+00	-.8178-01	-.8178-01	.0000	.3505+03
10	.212+02	0.	.2487+00	-.8101-01	-.8101-01	.0000	.2138+03
11	.230+02	0.	.2243+00	-.7808-01	-.7809-01	.0000	.1206+03
12	.254+02	0.	.1924+00	-.7221-01	-.7221-01	.0000	.6803+02
13	.268+02	0.	.1744+00	-.6770-01	-.6770-01	.0000	.4985+02
14	.278+02	0.	.1744+00	-.6783-01	-.6783-01	.0000	.5706+02
15	.296+02	0.	.1744+00	-.6787-01	-.6787-01	.0000	.6401+02
16	.320+02	0.	.1744+00	-.6791-01	-.6791-01	.0000	.6724+02
17	.380+02	0.	.1744+00	-.6800-01	-.6800-01	.0000	.6840+02
18	.500+02	0.	.1744+00	-.6834-01	-.6834-01	.0000	.6611+02
19	.622+02	0.	.1744+00	-.6851-01	-.6851-01	.0000	.6380+02
20	.632+02	0.	.1884+00	-.7235-01	-.7235-01	.0000	.1206+03
21	.650+02	0.	.2122+00	-.7763-01	-.7763-01	.0000	.1830+03
22	.680+02	0.	.2528+00	-.8484-01	-.8484-01	.0000	.2800+03
23	.690+02	0.	.2776+00	-.9207-01	-.9207-01	.0000	.3317+03
24	.710+02	0.	.2544+00	-.9560-01	-.9560-01	.0000	.3534+03
25	.740+02	0.	.3372+00	-.9791-01	-.9791-01	.0000	.3793+03
26	.760+02	0.	.3785+00	-.1034+00	-.1034+00	.0000	.3917+03
27	.776+02	0.	.3785+00	-.1039+00	-.1039+00	.0000	.3973+03
28	.788+02	0.	.3785+00	-.1044+00	-.1044+00	.0000	.3995+03
29	.806+02	0.	.3785+00	-.1050+00	-.1050+00	.0000	.3981+03
30	.830+02	0.	.3785+00	-.1056+00	-.1056+00	.0000	.3976+03
31	.860+02	0.	.3785+00	-.1061+00	-.1061+00	.0000	.3935+03
32	.920+02	0.	.3785+00	-.1069+00	-.1069+00	.0000	.3101+03
33	.101+03	0.	.3785+00	-.1076+00	-.1076+00	.0000	.2040+03
34	.102+03	0.	.3811+00	-.1076+00	-.1076+00	.0000	.2288+03
35	.103+03	0.	.3890+00	-.1091+00	-.1091+00	.0000	.3038+03
36	.105+03	0.	.4262+00	-.1119+00	-.1119+00	.0000	.3668+03
37	.106+03	0.	.4537+00	-.1146+00	-.1146+00	.0000	.3935+03
38	.109+03	0.	.4911+00	-.1184+00	-.1184+00	.0000	.4047+03
39	.112+03	0.	.5388+00	-.1234+00	-.1234+00	.0000	.4067+03
40	.115+03	0.	.5877+00	-.1289+00	-.1289+00	.0000	.3975+03

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MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.4000-03	.5334-07	-.2371-11	-.4000-03	.0000
2	.840+00	-.2680-03	-.6595-04	.2122-06	-.4000-03	.6632-02
3	.324+01	.1518-02	-.9815-03	.1135-04	-.4000-03	.2556-01
4	.504+01	.4466-02	-.2365-02	.4093-04	-.3994-04	.3976-01
5	.904+01	.1277-01	-.5941-02	.1532-03	.1500-02	.6322-01
6	.110+02	.2527-01	-.1101-01	.3635-03	.4700-02	.8648-01
7	.140+02	.4256-01	-.1735-01	.6742-03	.1050-01	.1094+00
8	.170+02	.6375-01	-.2487-01	.1087-02	.1820-01	.1322+00
9	.206+02	.9331-01	-.3533-01	.1718-02	.2910-01	.1596+00
10	.212+02	.9664-01	-.3672-01	.1838-02	.3540-01	.1554+00
11	.230+02	.6810-01	-.2892-01	.1367-02	.1560-01	.1425+00
12	.254+02	.4795-01	-.2257-01	.1003-02	.6800-02	.1247+00
13	.268+02	.3896-01	-.1902-01	.7990-03	.4100-02	.1141+00
14	.278+02	.3470-01	-.1905-01	.8021-03	.3900-02	.1142+00
15	.296+02	.3861-01	-.1905-01	.8031-03	.3700-02	.1142+00
16	.320+02	.3853-01	-.1907-01	.8041-03	.3600-02	.1142+00
17	.380+02	.3836-01	-.1909-01	.8061-03	.3400-02	.1142+00
18	.500+02	.3767-01	-.1916-01	.8143-03	.2600-02	.1144+00
19	.622+02	.3732-01	-.1920-01	.8184-03	.2200-02	.1145+00
20	.632+02	.4372-01	-.2203-01	.9864-03	.3600-02	.1326+00
21	.650+02	.5696-01	-.2692-01	.1270-02	.8200-02	.1566+00
22	.680+02	.8308-01	-.3569-01	.1819-02	.1880-01	.1591+00
23	.698+02	.9160-01	-.4298-01	.2400-02	.1520-01	.1747+00
24	.710+02	.1032+00	-.4715-01	.2691-02	.1950-01	.1836+00
25	.740+02	.1414+00	-.5645-01	.3233-02	.4060-01	.2051+00
26	.769+02	.1716+00	-.6759-01	.4049-02	.5130-01	.2272+00
27	.776+02	.1707+00	-.6784-01	.4084-02	.5010-01	.2278+00
28	.788+02	.1696+00	-.6813-01	.4126-02	.4870-01	.2276+00
29	.806+02	.1685+00	-.6844-01	.4171-02	.4720-01	.2276+00
30	.830+02	.1673+00	-.6877-01	.4219-02	.4560-01	.2282+00
31	.860+02	.1663+00	-.6903-01	.4258-02	.4430-01	.2284+00
32	.920+02	.1648+00	-.6945-01	.4319-02	.4230-01	.2288+00
33	.101+03	.1632+00	-.6987-01	.4383-02	.4020-01	.2291+00
34	.102+03	.1658+00	-.7046-01	.4416-02	.4170-01	.2304+00
35	.103+03	.1808+00	-.7516-01	.4750-02	.4830-01	.2396+00
36	.105+03	.2024+00	-.8285-01	.5336-02	.5640-01	.2536+00
37	.106+03	.2246+00	-.9085-01	.5957-02	.6460-01	.2678+00
38	.109+03	.2544+00	-.1022+00	.6880-02	.7460-01	.2873+00
39	.112+03	.2920+00	-.1177+00	.8203-02	.8570-01	.3122+00
40	.115+03	.3298+00	-.1349+00	.9768-02	.9460-01	.3378+00

MATERIAL DATA

MATERIAL IS ANB 3336-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 500. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.3334-03	-.3334-03	-.3334-03	.0000	.0000
2	.600+00	0.	.6387-02	-.3660-02	-.3660-02	.0000	.3323+02
3	.300+01	0.	.3372-01	-.1653-01	-.1653-01	.0000	.1692+03
4	.540+01	0.	.6176-01	-.2862-01	-.2862-01	.0000	.1648+03
5	.840+01	0.	.9783-01	-.4269-01	-.4269-01	.0000	.2231+03
6	.114+02	0.	.1350+00	-.5558-01	-.5558-01	.0000	.2874+03
7	.144+02	0.	.1733+00	-.6746-01	-.6746-01	.0000	.3776+03
8	.174+02	0.	.2128+00	-.7830-01	-.7830-01	.0000	.4260+03
9	.204+02	0.	.2533+00	-.8814-01	-.8814-01	.0000	.4626+03
10	.234+02	0.	.2950+00	-.9725-01	-.9725-01	.0000	.4905+03
11	.264+02	0.	.3378+00	-.1058+00	-.1058+00	.0000	.5125+03
12	.294+02	0.	.3817+00	-.1139+00	-.1139+00	.0000	.5272+03
13	.324+02	0.	.4268+00	-.1217+00	-.1217+00	.0000	.5379+03
14	.354+02	0.	.4730+00	-.1292+00	-.1292+00	.0000	.5445+03

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MATERIAL DATA

MATERIAL TS ANR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .4700+00
PRESSURE = 500. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.1000-02	.3334-06	-.3705-10	-.1000-02	.3512-08
2	.600+00	-.9331-03	-.3336-04	.8555-07	-.1000-02	.4336-02
3	.300+01	.6469-03	-.8416-03	.9218-05	-.1000-02	.2368-01
4	.540+01	.4530-02	-.2716-02	.5058-04	-.6999-03	.4261-01
5	.840+01	.1245-01	-.6531-02	.1783-03	.1001-03	.6625-01
6	.114+02	.2387-01	-.1192-01	.4171-03	.1700-02	.8985-01
7	.144+02	.3842-01	-.1884-01	.7888-03	.3900-02	.1135+00
8	.174+02	.5619-01	-.2719-01	.1304-02	.7000-02	.1372+00
9	.204+02	.7707-01	-.3689-01	.1968-02	.1110-01	.1610+00
10	.234+02	.1005+00	-.4792-01	.2790-02	.1570-01	.1846+00
11	.264+02	.1263+00	-.6028-01	.3780-02	.2060-01	.2081+00
12	.294+02	.1539+00	-.7400-01	.4954-02	.2540-01	.2317+00
13	.324+02	.1835+00	-.8905-01	.6317-02	.3020-01	.2558+00
14	.354+02	.2146+00	-.1055+00	.7891-02	.3460-01	.2838+00

H-35

@ ADD H00601

MATERIAL DATA

MATERIAL IS ANS 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.600+00	0.	.6722-02	-.6633-02	.0000	.0000	.2517+02
3	.180+01	0.	.2030-01	-.1941-01	.0000	.0000	.6936+02
4	.300+01	0.	.3406-01	-.3170-01	.0000	.0000	.1085+03
5	.360+01	0.	.3406-01	-.3161-01	.0000	.0000	.1047+03
6	.480+01	0.	.3406-01	-.3142-01	.0000	.0000	.6923+02
7	.720+01	0.	.3406-01	-.3133-01	.0000	.0000	.5476+02
8	.138+02	0.	.3406-01	-.3123-01	.0000	.0000	.8506+02
9	.252+02	0.	.3406-01	-.3123-01	.0000	.0000	.1719+03
10	.409+02	0.	.3406-01	-.3133-01	.0000	.0000	.1306+03
11	.414+02	0.	.3062-01	-.3615-01	.0000	.0000	.1786+03
12	.426+02	0.	.5763-01	-.4753-01	.0000	.0000	.1367+03
13	.444+02	0.	.7898-01	-.6276-01	.0000	.0000	.2003+03
14	.462+02	0.	.9673-01	-.7483-01	.0000	.0000	.2318+03
15	.469+02	0.	.9673-01	-.7373-01	.0000	.0000	.1827+03
16	.480+02	0.	.9673-01	-.7289-01	.0000	.0000	.1480+03
17	.498+02	0.	.9673-01	-.7238-01	.0000	.0000	.1261+03
18	.528+02	0.	.9673-01	-.7179-01	.0000	.0000	.1086+03
19	.588+02	0.	.9673-01	-.7119-01	.0000	.0000	.9123+02
20	.708+02	0.	.9673-01	-.7077-01	.0000	.0000	.7818+02
21	.100+03	0.	.9673-01	-.7043-01	.0000	.0000	.6805+02
22	.101+03	0.	.1019+00	-.7367-01	.0000	.0000	.1068+03
23	.101+03	0.	.1092+00	-.7750-01	.0000	.0000	.1425+03
24	.103+03	0.	.1241+00	-.8407-01	.0000	.0000	.1976+03
25	.104+03	0.	.1468+00	-.9192-01	.0000	.0000	.2334+03
26	.106+03	0.	.1698+00	-.9788-01	.0000	.0000	.2431+03
27	.108+03	0.	.1933+00	-.1026+00	.0000	.0000	.2471+03
28	.110+03	0.	.2156+00	-.1060+00	.0000	.0000	.2507+03
29	.110+03	0.	.2156+00	-.1052+00	.0000	.0000	.2031+03
30	.112+03	0.	.2156+00	-.1040+00	.0000	.0000	.1740+03
31	.114+03	0.	.2156+00	-.1035+00	.0000	.0000	.1460+03
32	.118+03	0.	.2156+00	-.1026+00	.0000	.0000	.1236+03
33	.124+03	0.	.2156+00	-.1020+00	.0000	.0000	.1008+03
34	.136+03	0.	.2156+00	-.1015+00	.0000	.0000	.8608+02
35	.166+03	0.	.2156+00	-.1009+00	.0000	.0000	.7216+02
36	.167+03	0.	.2220+00	-.1021+00	.0000	.0000	.1137+03
37	.168+03	0.	.2382+00	-.1062+00	.0000	.0000	.1673+03
38	.170+03	0.	.2628+00	-.1107+00	.0000	.0000	.2189+03
39	.172+03	0.	.2879+00	-.1146+00	.0000	.0000	.2427+03
40	.173+03	0.	.3133+00	-.1172+00	.0000	.0000	.2460+03
41	.175+03	0.	.3381+00	-.1196+00	.0000	.0000	.2527+03
42	.178+03	0.	.3831+00	-.1236+00	.0000	.0000	.2525+03
43	.181+03	0.	.4282+00	-.1278+00	.0000	.0000	.2425+03

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MATERIAL DATA

MATERIAL IS AMS 3345-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.600+00	.8917-04	-.4459-04	.0000	.6722-08	.5852-02
3	.180+01	.8863-03	-.3941-03	.0000	.1000-03	.1632-01
4	.300+01	.2360-02	-.1080-02	.0000	.2000-03	.2695-01
5	.360+01	.2453-02	-.1077-02	.0000	.3000-03	.2682-01
6	.480+01	.2641-02	-.1070-02	.0000	.5000-03	.2674-01
7	.780+01	.2734-02	-.1067-02	.0000	.6000-03	.2670-01
8	.138+02	.2828-02	-.1064-02	.0000	.7000-03	.2666-01
9	.258+02	.2828-02	-.1064-02	.0000	.7000-03	.2666-01
10	.409+02	.2734-02	-.1067-02	.0000	.6000-03	.2670-01
11	.414+02	.3464-02	-.1432-02	.0000	.6000-03	.3094-01
12	.426+02	.6098-02	-.2549-02	.0000	.1000-02	.4132-01
13	.444+02	.1222-01	-.4706-02	.0000	.2000-02	.5671-01
14	.462+02	.2100-01	-.7239-02	.0000	.3400-02	.7023-01
15	.468+02	.2300-01	-.7132-02	.0000	.3700-02	.6980-01
16	.480+02	.2385-01	-.7051-02	.0000	.3700-02	.6948-01
17	.498+02	.2436-01	-.7001-02	.0000	.1030-01	.6928-01
18	.528+02	.2495-01	-.6944-02	.0000	.1100-01	.6905-01
19	.558+02	.2554-01	-.6887-02	.0000	.1170-01	.6882-01
20	.708+02	.2597-01	-.6846-02	.0000	.1220-01	.6866-01
21	.100+03	.2631-01	-.6813-02	.0000	.1260-01	.6853-01
22	.101+03	.2820-01	-.7505-02	.0000	.1310-01	.7197-01
23	.101+03	.3174-01	-.8466-02	.0000	.1470-01	.7660-01
24	.103+03	.4005-01	-.1044-01	.0000	.1900-01	.8552-01
25	.104+03	.5486-01	-.1349-01	.0000	.2750-01	.9830-01
26	.106+03	.7197-01	-.1662-01	.0000	.3900-01	.1106+00
27	.108+03	.9071-01	-.1983-01	.0000	.4980-01	.1227+00
28	.110+03	.1096+00	-.2284-01	.0000	.6200-01	.1334+00
29	.110+03	.1104+00	-.2268-01	.0000	.6300-01	.1336+00
30	.112+03	.1112+00	-.2251-01	.0000	.6410-01	.1332+00
31	.114+03	.1121+00	-.2232-01	.0000	.6530-01	.1326+00
32	.118+03	.1130+00	-.2212-01	.0000	.6650-01	.1326+00
33	.124+03	.1136+00	-.2199-01	.0000	.6730-01	.1324+00
34	.136+03	.1141+00	-.2188-01	.0000	.6800-01	.1322+00
35	.166+03	.1147+00	-.2175-01	.0000	.6880-01	.1320+00
36	.167+03	.1199+00	-.2266-01	.0000	.7200-01	.1353+00
37	.168+03	.1320+00	-.2530-01	.0000	.7930-01	.1440+00
38	.170+03	.1521+00	-.2999-01	.0000	.8990-01	.1566+00
39	.172+03	.1732+00	-.3300-01	.0000	.1020+00	.1693+00
40	.173+03	.1961+00	-.3670-01	.0000	.1160+00	.1817+00
41	.175+03	.2195+00	-.4055-01	.0000	.1300+00	.1943+00
42	.178+03	.2594+00	-.4737-01	.0000	.1530+00	.2157+00
43	.181+03	.3003+00	-.5472-01	.0000	.1755+00	.2378+00

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MATERIAL DATA

MATERIAL IS ANN 3345-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.130+01	0.	.1553-01	-.1506-01	.0000	.0000	.8468+02
3	.258+01	0.	.2923-01	-.2761-01	.0000	.0000	.1230+03
4	.378+01	0.	.4310-01	-.3940-01	.0000	.0000	.1578+03
5	.498+01	0.	.6425-01	-.5552-01	.0000	.0000	.1635+03
6	.618+01	0.	.7858-01	-.6505-01	.0000	.0000	.1912+03
7	.858+01	0.	.1004+00	-.7793-01	.0000	.0000	.2162+03
8	.918+01	0.	.1004+00	-.7591-01	.0000	.0000	.2051+03
9	.104+02	0.	.1004+00	-.7507-01	.0000	.0000	.1917+03
10	.122+02	0.	.1004+00	-.7448-01	.0000	.0000	.1866+03
11	.146+02	0.	.1004+00	-.7406-01	.0000	.0000	.1846+03
12	.206+02	0.	.1004+00	-.7347-01	.0000	.0000	.8823+02
13	.326+02	0.	.1004+00	-.7297-01	.0000	.0000	.7840+02
14	.682+02	0.	.1004+00	-.7271-01	.0000	.0000	.6907+02
15	.866+02	0.	.1056+00	-.7576-01	.0000	.0000	.1060+03
16	.898+02	0.	.1204+00	-.8329-01	.0000	.0000	.1657+03
17	.710+02	0.	.1354+00	-.8953-01	.0000	.0000	.2015+03
18	.722+02	0.	.1506+00	-.9471-01	.0000	.0000	.2229+03
19	.740+02	0.	.1737+00	-.1016+00	.0000	.0000	.2361+03
20	.748+02	0.	.1854+00	-.1040+00	.0000	.0000	.2405+03
21	.752+02	0.	.1854+00	-.1034+00	.0000	.0000	.2156+03
22	.758+02	0.	.1854+00	-.1028+00	.0000	.0000	.1987+03
23	.770+02	0.	.1854+00	-.1020+00	.0000	.0000	.1638+03
24	.800+02	0.	.1854+00	-.1012+00	.0000	.0000	.1340+03
25	.860+02	0.	.1854+00	-.1003+00	.0000	.0000	.1121+03
26	.980+02	0.	.1854+00	-.9957-01	.0000	.0000	.9484+02
27	.116+03	0.	.1854+00	-.9919-01	.0000	.0000	.8462+02
28	.134+03	0.	.1854+00	-.9881-01	.0000	.0000	.7774+02
29	.135+03	0.	.1917+00	-.1012+00	.0000	.0000	.1000+03
30	.136+03	0.	.2076+00	-.1057+00	.0000	.0000	.1701+03
31	.137+03	0.	.2236+00	-.1098+00	.0000	.0000	.2054+03
32	.139+03	0.	.2400+00	-.1146+00	.0000	.0000	.2361+03
33	.141+03	0.	.2728+00	-.1185+00	.0000	.0000	.2883+03
34	.144+03	0.	.3150+00	-.1248+00	.0000	.0000	.2537+03
35	.147+03	0.	.3583+00	-.1274+00	.0000	.0000	.2538+03
36	.150+03	0.	.4028+00	-.1319+00	.0000	.0000	.2800+03
37	.152+03	0.	.4391+00	-.1350+00	.0000	.0000	.2844+03

MATERIAL DATA

MATERIAL IS AN1 3345-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.138+01	.4678-03	-.2339-03	.0000	.1553-07	.1349-01
3	.258+01	.1614-02	-.8069-03	.0000	.2022-07	.2321-01
4	.378+01	.3697-02	-.1698-02	.0000	.3000-03	.3369-01
5	.558+01	.8735-02	-.3567-02	.0000	.1600-02	.4854-01
6	.678+01	.1353-01	-.5111-02	.0000	.3300-02	.5872-01
7	.458+01	.2247-01	-.7824-02	.0000	.6800-02	.7296-01
8	.918+01	.2449-01	-.7622-02	.0000	.8200-02	.7221-01
9	.104+02	.2533-01	-.7537-02	.0000	.1020-01	.7188-01
10	.122+02	.2582-01	-.7478-02	.0000	.1090-01	.7166-01
11	.146+02	.2636-01	-.7436-02	.0000	.1140-01	.7146-01
12	.206+02	.2683-01	-.7377-02	.0000	.1210-01	.7127-01
13	.326+02	.2743-01	-.7326-02	.0000	.1270-01	.7107-01
14	.682+02	.2769-01	-.7300-02	.0000	.1300-01	.7097-01
15	.686+02	.2979-01	-.7997-02	.0000	.1370-01	.7435-01
16	.698+02	.3710-01	-.1003-01	.0000	.1690-01	.8761-01
17	.710+02	.4587-01	-.1212-01	.0000	.2140-01	.9246-01
18	.722+02	.5569-01	-.1426-01	.0000	.2720-01	.1010+00
19	.740+02	.7215-01	-.1765-01	.0000	.3620-01	.1137+00
20	.749+02	.8145-01	-.1928-01	.0000	.4200-01	.1197+00
21	.752+02	.8206-01	-.1917-01	.0000	.4280-01	.1195+00
22	.758+02	.8267-01	-.1906-01	.0000	.4360-01	.1193+00
23	.770+02	.8343-01	-.1892-01	.0000	.4460-01	.1190+00
24	.800+02	.8427-01	-.1876-01	.0000	.4570-01	.1187+00
25	.860+02	.8511-01	-.1861-01	.0000	.4680-01	.1184+00
26	.980+02	.8587-01	-.1847-01	.0000	.4780-01	.1181+00
27	.116+03	.8626-01	-.1839-01	.0000	.4830-01	.1180+00
28	.134+03	.8664-01	-.1832-01	.0000	.4880-01	.1178+00
29	.135+03	.9057-01	-.1940-01	.0000	.5050-01	.1215+00
30	.136+03	.1019+00	-.2194-01	.0000	.5640-01	.1301+00
31	.137+03	.1138+00	-.2456-01	.0000	.6270-01	.1387+00
32	.139+03	.1334+00	-.2843-01	.0000	.7380-01	.1513+00
33	.141+03	.1543+00	-.3231-01	.0000	.8600-01	.1638+00
34	.144+03	.1902+00	-.3930-01	.0000	.1060+00	.1850+00
35	.147+03	.2309+00	-.4566-01	.0000	.1310+00	.2056+00
36	.150+03	.2709+00	-.5311-01	.0000	.1530+00	.2274+00
37	.152+03	.3042+00	-.5928-01	.0000	.1710+00	.2451+00

C ADD R00603

SUMMARY OF TEST NO. P00603 PAGE P00603 - 1

MATERIAL DATA

MATERIAL IS ANN 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .2660+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.456+01	0.	.2042-01	-.1962-01	.0000	.0000	.8501+02
3	.636+01	0.	.2859-01	-.2695-01	.0000	.0000	.6375+02
4	.876+01	0.	.3959-01	-.3641-01	.0000	.0000	.8725+02
5	.148+02	0.	.6758-01	-.5786-01	.0000	.0000	.1554+03
6	.208+02	0.	.9627-01	-.7534-01	.0000	.0000	.1763+03
7	.268+02	0.	.1257+00	-.8835-01	.0000	.0000	.1932+03
8	.328+02	0.	.1558+00	-.9729-01	.0000	.0000	.1980+03
9	.388+02	0.	.1866+00	-.1044+00	.0000	.0000	.2055+03
10	.448+02	0.	.2181+00	-.1096+00	.0000	.0000	.2066+03
11	.508+02	0.	.2504+00	-.1143+00	.0000	.0000	.2114+03
12	.568+02	0.	.2833+00	-.1180+00	.0000	.0000	.2142+03
13	.628+02	0.	.3169+00	-.1216+00	.0000	.0000	.2158+03
14	.688+02	0.	.3513+00	-.1247+00	.0000	.0000	.2172+03
15	.748+02	0.	.3864+00	-.1276+00	.0000	.0000	.2186+03
16	.808+02	0.	.4221+00	-.1305+00	.0000	.0000	.2174+03

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MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .2660+00
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.456+01	.8013-03	-.4006-03	.0000	.2042-07	.1635-01
3	.636+01	.1641-02	-.7707-03	.0000	.1000-03	.2268-01
4	.876+01	.3183-02	-.1441-02	.0000	.3000-03	.3103-01
5	.148+02	.9721-02	-.3910-02	.0000	.1900-02	.5126-01
6	.208+02	.2093-01	-.7253-02	.0000	.6400-02	.7023-01
7	.268+02	.3732-01	-.1110-01	.0000	.1500-01	.8782-01
8	.328+02	.5850-01	-.1516-01	.0000	.2780-01	.1042+00
9	.388+02	.8217-01	-.1949-01	.0000	.4230-01	.1204+00
10	.448+02	.1085+00	-.2390-01	.0000	.5900-01	.1362+00
11	.508+02	.1361+00	-.2861-01	.0000	.7600-01	.1523+00
12	.568+02	.1653+00	-.3343-01	.0000	.9400-01	.1684+00
13	.628+02	.1953+00	-.3854-01	.0000	.1120+00	.1849+00
14	.688+02	.2266+00	-.4380-01	.0000	.1305+00	.2015+00
15	.748+02	.2587+00	-.4931-01	.0000	.1490+00	.2185+00
16	.808+02	.2917+00	-.5507-01	.0000	.1675+00	.2358+00

@ ADD R00604

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SUMMARY OF TEST NO. B00604 PAGE B00604 - 1

MATERIAL DATA

MATERIAL IS ANA 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700-01
PRESSURE = 0. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.180+02	0.	.2030-01	-.1051-01	.0000	.0000	.2856+02
3	.360+02	0.	.3406-01	-.3189-01	.0000	.0000	.4754+02
4	.480+02	0.	.5504-01	-.4913-01	.0000	.0000	.7705+02
5	.780+02	0.	.9089-01	-.7361-01	.0000	.0000	.1226+03
6	.108+03	0.	.1279+00	-.9157-01	.0000	.0000	.1481+03
7	.138+03	0.	.1660+00	-.1035+00	.0000	.0000	.1571+03
8	.168+03	0.	.2052+00	-.1120+00	.0000	.0000	.1637+03
9	.198+03	0.	.2455+00	-.1186+00	.0000	.0000	.1679+03
10	.228+03	0.	.2870+00	-.1239+00	.0000	.0000	.1714+03
11	.258+03	0.	.3296+00	-.1287+00	.0000	.0000	.1742+03
12	.288+03	0.	.3733+00	-.1332+00	.0000	.0000	.1764+03

SUMMARY OF TEST NO. R10601 PAGE R10601 - 1

MATERIAL DATA

MATERIAL IS AMS 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.2000-03	-.2000-03	.0000	.0000	.0000
2	.264+01	0.	.2971-01	-.2842-01	.0000	.0000	.9677+02
3	.444+01	0.	.5060-01	-.4604-01	.0000	.0000	.1677+03
4	.600+01	0.	.6903-01	-.6013-01	.0000	.0000	.2158+03
5	.624+01	0.	.6903-01	-.6004-01	.0000	.0000	.2005+03
6	.684+01	0.	.6903-01	-.6004-01	.0000	.0000	.1760+03
7	.804+01	0.	.6903-01	-.5995-01	.0000	.0000	.1525+03
8	.984+01	0.	.6903-01	-.5995-01	.0000	.0000	.1344+03
9	.128+02	0.	.6903-01	-.5995-01	.0000	.0000	.1154+03
10	.188+02	0.	.6903-01	-.6004-01	.0000	.0000	.1045+03
11	.308+02	0.	.6903-01	-.6013-01	.0000	.0000	.9065+02
12	.460+02	0.	.6903-01	-.6022-01	.0000	.0000	.8318+02
13	.464+02	0.	.7476-01	-.6452-01	.0000	.0000	.1415+03
14	.476+02	0.	.8922-01	-.7469-01	.0000	.0000	.2213+03
15	.488+02	0.	.1039+00	-.8409-01	.0000	.0000	.2777+03
16	.506+02	0.	.1261+00	-.9681-01	.0000	.0000	.3237+03
17	.520+02	0.	.1428+00	-.1046+00	.0000	.0000	.3433+03
18	.524+02	0.	.1428+00	-.1041+00	.0000	.0000	.3062+03
19	.536+02	0.	.1428+00	-.1040+00	.0000	.0000	.2619+03
20	.554+02	0.	.1428+00	-.1041+00	.0000	.0000	.2325+03
21	.578+02	0.	.1428+00	-.1043+00	.0000	.0000	.2122+03
22	.638+02	0.	.1428+00	-.1046+00	.0000	.0000	.1897+03
23	.758+02	0.	.1428+00	-.1052+00	.0000	.0000	.1706+03
24	.938+02	0.	.1428+00	-.1057+00	.0000	.0000	.1601+03
25	.112+03	0.	.1428+00	-.1059+00	.0000	.0000	.1662+03
26	.113+03	0.	.1480+00	-.1088+00	.0000	.0000	.2020+03
27	.114+03	0.	.1642+00	-.1158+00	.0000	.0000	.2967+03
28	.115+03	0.	.1876+00	-.1248+00	.0000	.0000	.3572+03
29	.117+03	0.	.2113+00	-.1324+00	.0000	.0000	.3810+03
30	.119+03	0.	.2355+00	-.1388+00	.0000	.0000	.3906+03
31	.120+03	0.	.2437+00	-.1409+00	.0000	.0000	.3935+03
32	.120+03	0.	.2519+00	-.1427+00	.0000	.0000	.3950+03
33	.121+03	0.	.2684+00	-.1465+00	.0000	.0000	.3946+03
34	.123+03	0.	.2935+00	-.1524+00	.0000	.0000	.3970+03
35	.126+03	0.	.3276+00	-.1601+00	.0000	.0000	.3997+03

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MATERIAL DATA

MATERIAL IS ANS 3345-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 200. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.4000-03	.4000-07	.0000	-.4000-03	.9428-08
2	.264+01	.1289-02	-.8443-03	.0000	-.4000-03	.2777-01
3	.444+01	.8559-02	-.2330-02	.0000	-.9995-04	.3847-01
4	.600+01	.8902-02	-.4151-02	.0000	.6001-03	.5277-01
5	.624+01	.8990-02	-.4145-02	.0000	.7001-03	.5274-01
6	.684+01	.8990-02	-.4145-02	.0000	.7001-03	.5274-01
7	.804+01	.9078-02	-.4139-02	.0000	.8001-03	.5270-01
8	.984+01	.9078-02	-.4139-02	.0000	.8001-03	.5270-01
9	.128+02	.9078-02	-.4139-02	.0000	.8001-03	.5270-01
10	.188+02	.8990-02	-.4145-02	.0000	.7001-03	.5274-01
11	.308+02	.8902-02	-.4151-02	.0000	.6001-03	.5277-01
12	.460+02	.8814-02	-.4157-02	.0000	.5001-03	.5281-01
13	.464+02	.1025-01	-.4823-02	.0000	.6001-03	.5661-01
14	.476+02	.1453-01	-.6664-02	.0000	.1200-02	.6700-01
15	.488+02	.1977-01	-.8733-02	.0000	.2300-02	.7687-01
16	.506+02	.2934-01	-.1221-01	.0000	.4900-02	.9128-01
17	.520+02	.3811-01	-.1494-01	.0000	.8200-02	.1014+00
18	.524+02	.3866-01	-.1486-01	.0000	.8900-02	.1012+00
19	.536+02	.3874-01	-.1485-01	.0000	.8900-02	.1012+00
20	.554+02	.3866-01	-.1486-01	.0000	.8900-02	.1012+00
21	.578+02	.3850-01	-.1488-01	.0000	.8700-02	.1012+00
22	.638+02	.3811-01	-.1494-01	.0000	.8300-02	.1014+00
23	.758+02	.3756-01	-.1502-01	.0000	.7500-02	.1016+00
24	.938+02	.3709-01	-.1508-01	.0000	.6900-02	.1018+00
25	.112+03	.3686-01	-.1512-01	.0000	.6600-02	.1019+00
26	.112+03	.4002-01	-.1620-01	.0000	.7600-02	.1056+00
27	.114+03	.4839-01	-.1902-01	.0000	.1030-01	.1145+00
28	.115+03	.6275-01	-.2341-01	.0000	.1580-01	.1294+00
29	.117+03	.7893-01	-.2798-01	.0000	.2270-01	.1416+00
30	.119+03	.9667-01	-.3270-01	.0000	.3080-01	.1505+00
31	.120+03	.1028+00	-.3432-01	.0000	.3360-01	.1538+00
32	.120+03	.1092+00	-.3594-01	.0000	.3660-01	.1631+00
33	.121+03	.1218+00	-.3933-01	.0000	.4230-01	.1718+00
34	.123+03	.1411+00	-.4474-01	.0000	.5030-01	.1851+00
35	.126+03	.1675+00	-.5245-01	.0000	.6080-01	.2030+00

& ADD R10602

SUMMARY OF TEST NO. B10602 PAGE B10602 - 1

MATERIAL DATA

MATERIAL IS ANN 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 250. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.2500-03	-.2500-03	.0000	.0000	.0000
2	.228+01	0.	.2553-01	-.2476-01	.0000	.0000	.6768+02
3	.528+01	0.	.6043-01	-.5836-01	.0000	.0000	.1586+03
4	.648+01	0.	.7471-01	-.6517-01	.0000	.0000	.1951+03
5	.948+01	0.	.1112+00	-.8973-01	.0000	.0000	.2762+03
6	.125+02	0.	.1488+00	-.1093+00	.0000	.0000	.3715+03
7	.155+02	0.	.1875+00	-.1247+00	.0000	.0000	.4641+03
8	.185+02	0.	.2274+00	-.1378+00	.0000	.0000	.5505+03
9	.209+02	0.	.2600+00	-.1472+00	.0000	.0000	.6013+03
10	.239+02	0.	.3019+00	-.1581+00	.0000	.0000	.6997+03
11	.269+02	0.	.3449+00	-.1690+00	.0000	.0000	.7816+03

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MATERIAL DATA

MATERIAL IS AN: 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 250. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.5000-03	.6250-07	.0000	-.5000-03	.1179-03
2	.228+01	.7485-03	-.6321-03	.0000	-.5000-03	.2057-01
3	.528+01	.6171-02	-.3285-02	.0000	-.4999-03	.4685-01
4	.648+01	.9568-02	-.4869-02	.0000	-.1999-03	.5715-01
5	.948+01	.2146-01	-.9977-02	.0000	.1500-02	.8218-01
6	.125+02	.3953-01	-.1625-01	.0000	.7000-02	.1058+00
7	.155+02	.6280-01	-.2338-01	.0000	.1590-01	.1283+00
8	.185+02	.8952-01	-.3134-01	.0000	.2650-01	.1506+00
9	.209+02	.1128+00	-.3828-01	.0000	.3560-01	.1688+00
10	.239+02	.1438+00	-.4773-01	.0000	.4720-01	.1908+00
11	.269+02	.1759+00	-.5827-01	.0000	.5770-01	.2138+00

G ADD R10603

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 500. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.5000-03	-.5000-03	.0000	.0000	.0000
2	.120+01	0.	.1298-01	-.1363-01	.0000	.0000	.5371+02
3	.300+01	0.	.3354-01	-.3237-01	.0000	.0000	.1302+03
4	.480+01	0.	.5851-01	-.4907-01	.0000	.0000	.1981+03
5	.780+01	0.	.9035-01	-.7644-01	.0000	.0000	.2999+03
6	.108+02	0.	.1273+00	-.9948-01	.0000	.0000	.3804+03
7	.138+02	0.	.1654+00	-.1193+00	.0000	.0000	.4415+03
8	.168+02	0.	.2046+00	-.1364+00	.0000	.0000	.4731+03
9	.192+02	0.	.2368+00	-.1488+00	.0000	.0000	.4916+03
10	.198+02	0.	.2449+00	-.1517+00	.0000	.0000	.4946+03
11	.216+02	0.	.2697+00	-.1604+00	.0000	.0000	.5012+03

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MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 500. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.1000-02	.2500-06	.0000	-.1000-02	.2357-03
2	.120+01	-.6456-03	-.1765-03	.0000	-.1000-02	.1097-01
3	.300+01	.1172-02	-.1086-02	.0000	-.1000-02	.2691-01
4	.480+01	.4637-02	-.2719-02	.0000	-.7999-03	.4263-01
5	.760+01	.1391-01	-.6906-02	.0000	.1001-03	.6817-01
6	.108+02	.2783-01	-.1266-01	.0000	.2500-02	.9282-01
7	.138+02	.4609-01	-.1973-01	.0000	.6600-02	.1167+00
8	.168+02	.6819-01	-.2791-01	.0000	.1230-01	.1401+00
9	.192+02	.8800-01	-.3523-01	.0000	.1740-01	.1588+00
10	.198+02	.9327-01	-.3715-01	.0000	.1880-01	.1634+00
11	.216+02	.1093+00	-.4326-01	.0000	.2250-01	.1775+00

G ADD B10604

SUMMARY OF TEST NO. P10604 PAGE P10604 - 1

MATERIAL DATA

MATERIAL IS ANC 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 1000. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.1000-02	-.1000-02	.0000	.0000	.0000
2	.480+01	0.	.6398-01	-.5053-01	.0000	.0000	.1991+03
3	.660+01	0.	.7534-01	-.6704-01	.0000	.0000	.2706+03
4	.840+01	0.	.9711-01	-.8265-01	.0000	.0000	.3390+03
5	.114+02	0.	.1343+00	-.1066+00	.0000	.0000	.4350+03
6	.144+02	0.	.1726+00	-.1281+00	.0000	.0000	.5189+03
7	.174+02	0.	.2120+00	-.1477+00	.0000	.0000	.5783+03
8	.204+02	0.	.2525+00	-.1653+00	.0000	.0000	.6260+03
9	.234+02	0.	.2942+00	-.1814+00	.0000	.0000	.6587+03
10	.246+02	0.	.3112+00	-.1875+00	.0000	.0000	.6675+03

SUMMARY OF TEST NO. P10604 PAGE P10604 - 2

MATERIAL DATA

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL
INITIAL STRAIN RATE = .6700+00
PRESSURE = 1000. PSIG
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-02	.1000-05	.0000	-.2000-02	.8714-03
2	.480+01	.3457-02	-.2728-02	.0000	-.2000-02	.4267-01
3	.660+01	.8303-02	-.5051-02	.0000	-.1800-02	.5816-01
4	.840+01	.1445-01	-.8026-02	.0000	-.1600-02	.7346-01
5	.114+02	.2764-01	-.1432-01	.0000	-.9999-03	.9857-01
6	.144+02	.4443-01	-.2211-01	.0000	.2002-03	.1232+00
7	.174+02	.6431-01	-.3130-01	.0000	.1700-02	.1476+00
8	.204+02	.8727-01	-.4173-01	.0000	.3800-02	.1718+00
9	.234+02	.1128+00	-.5337-01	.0000	.6000-02	.1960+00
10	.246+02	.1236+00	-.5835-01	.0000	.6900-02	.2057+00

@ ADD 000700

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