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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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DEVELOPMENT OF A SOLID ROCKET PROPELLANT NONLINEAR VISCOELASTIC CONSTITUTIVE THEORY

Volume II - Appendices

Prepared by:

Aerojet Solid Propulsion Company
Sacramento, California

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Air Force Rocket Propulsion Laboratory
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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.

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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

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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.

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

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.

<u>Equations for isotropic media with strains as the independent variables</u>: 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; <u>but this dependence is to be assumed unless stated otherwise</u>. 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 <u>not</u> 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

$$
\begin{aligned}
I_1 &\equiv \varepsilon_{ii} \\
I_2 &\equiv \varepsilon_{ij}\,\varepsilon_{ij} \\
I_3 &\equiv \varepsilon_{ij}\,\varepsilon_{jm}\,\varepsilon_{mi}
\end{aligned}
\tag{4}
$$

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:

$$
\begin{aligned}
\tilde{I}_2 &\equiv e_{ij}\,e_{ij} \\
\tilde{I}_3 &\equiv e_{ij}\,e_{jm}\,e_{mi}
\end{aligned}
\tag{6}
$$

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

$$
\begin{aligned}
\tilde{I}_2 &= I_2 - \frac{1}{3}\,I_1^2 \\
\tilde{I}_3 &= I_3 - I_1 I_2 + \frac{2}{9}\,I_1^3
\end{aligned}
\tag{8}
$$

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

$$s_{ij} = -\frac{\partial F_e}{\partial \tilde{I}_3} \tilde{I}_2 \delta_{ij} + 2 \frac{\partial F_e}{\partial \tilde{I}_2} e_{ij} + 3 \frac{\partial F_e}{\partial \tilde{I}_3} e_{im} e_{mj} \tag{9}$$

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]; <u>this simplification will be used in all of the following discussion</u> 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.

<u>An elastic free energy function for propellant</u>: 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

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

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:

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

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,

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

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

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,

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

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

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

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

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

$$\frac{\theta}{3} = a_F \frac{\partial q}{\partial I_T} \int_0^t K(\psi - \psi') \frac{dq}{d\tau} d\tau \tag{44a}$$

$$s_{ij} = 2a_F[\int_0^t G(\psi - \psi') \frac{de_{ij}}{d\tau} d\tau + \frac{\partial q}{\partial \tilde{I}_2} e_{ij} \int_0^t K(\psi - \psi') \frac{dq}{d\tau} d\tau] \tag{44b}$$

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 $\tilde{I}_2$.

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

$$\frac{I_1}{3} = \frac{\partial F_s}{\partial \theta} + \frac{1}{9}\frac{\partial Q}{\partial \theta}\int_0^t \Delta B(\psi - \psi')\frac{d(Q/a_G)}{d\tau}\,d\tau \tag{47a}$$

$$e_{ij} = 2\frac{\partial F_s}{\partial \tilde{J}_2}s_{ij} + \frac{1}{2}\int_0^t \Delta J(\psi - \psi')\frac{d(s_{ij}/a_G)}{d\tau}\,d\tau$$

$$+ 2\frac{\partial Q}{\partial \tilde{J}_2}s_{ij}\int_0^t \Delta B(\psi - \psi')\frac{d(Q/a_G)}{d\tau}\,d\tau \tag{47b}$$

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 $\sigma = \sigma(\epsilon)$ 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

$$I_T = \begin{cases} \dfrac{\theta}{3K_e} & : \varepsilon_s < b_s \\[2ex] \dfrac{\theta}{3K_e} + a_s(\varepsilon_s - b_s) & : \varepsilon_s \geq b_s\ ;\ (a_s,\ b_s) \geq 0 \end{cases} \tag{64}$$

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)):

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

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 $\varepsilon_s \geq b_s$:

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

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

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

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:

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

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):

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

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 $\varepsilon_1 < b_s$.

<u>Representation of vacuole dilatation in terms of strains due to externally applied loads (MSS)</u>: 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 $\nu \approx \frac{1}{2}$, 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_1 and the respective initial strains (83):

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

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

$$\varepsilon_{se} = \varepsilon_1 \qquad \text{(shear test)} \qquad (84c)$$

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

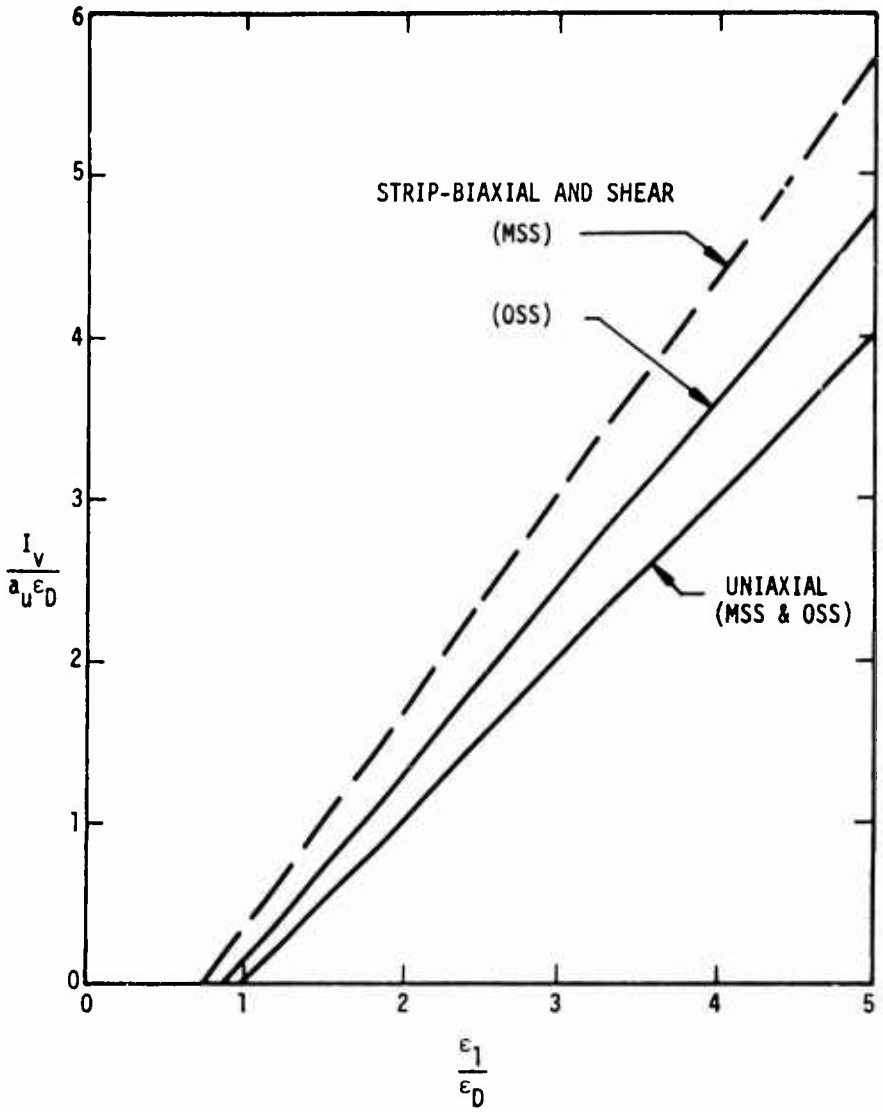

Figure 1. Comparison of Octahedral and Maximum Shear Strain Theories for $a_u << 1$.

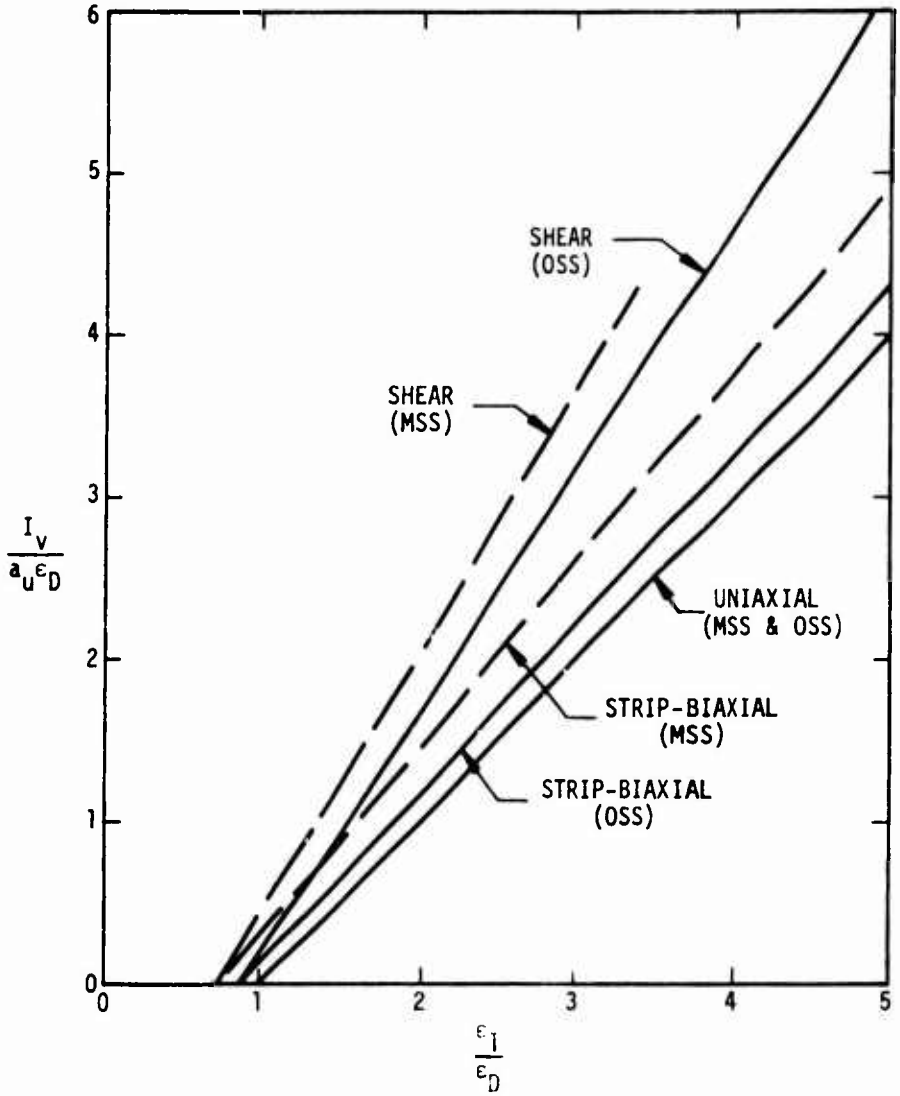

Figure 2. Comparison of Octahedral and Maximum Shear Strain Theories for $a_u = 0.5$.

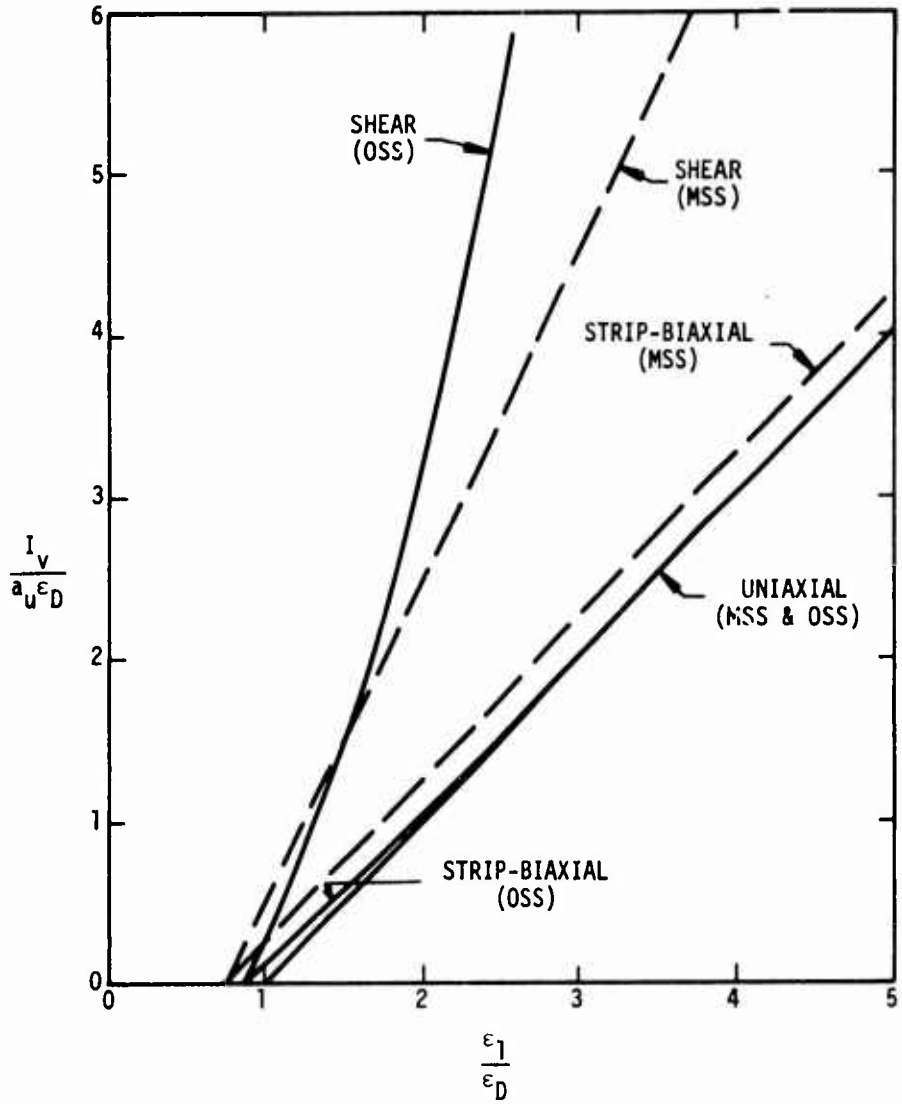

Figure 3. Comparison of Octahedral and Maximum Shear Strain Theories for $a_u = 1$.

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 $dI_v/d\varepsilon_u$ 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 <u>failure time</u>.

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 <u>initially</u> isolated, it is shown in [3] that the crack size at 90 percent of the failure time is only $10^n \times (2a_o)$; 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 <u>stress concentration factor</u>, 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 <u>elastic</u> 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:

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

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:

$$1 = \int_0^{t_i} \frac{dt}{t_{ci}} \tag{96a}$$

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. <u>Without</u> 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" Lebesgue 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 $i^{\underline{th}}$ 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 $i^{\underline{th}}$ 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, $2a_{ai} - 2a_{oi} \approx 2a_{ai}$. <u>Interaction between cracks when $t > t_i$ is allowed</u>.

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

$$\xi_i \equiv \int_0^{t_i} \frac{dt}{a_T} \tag{98b}$$

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 <u>number</u> of cracks, N_c, having g-values between g and g + dg, <u>and</u> 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),

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

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

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

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 <u>undamaged</u> propellant,

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

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 <u>non-decreasing</u> 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

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

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

$$m = m_1(S, a_o)\, f^\alpha \tag{114a}$$

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

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

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.

<u>Elastic specimen</u>: 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

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

where (115)

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

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

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

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.

<u>Creep of a viscoelastic specimen:</u> 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.

<u>Generalizations of the constitutive theory with microcracking</u>: 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:

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

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

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

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

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

where

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

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],

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

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

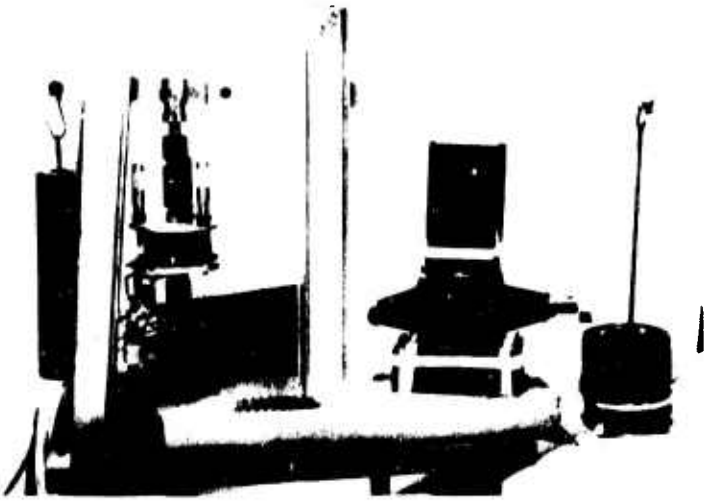

Figure 5. Poker-Chip Assembly used for Tensile tests.

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

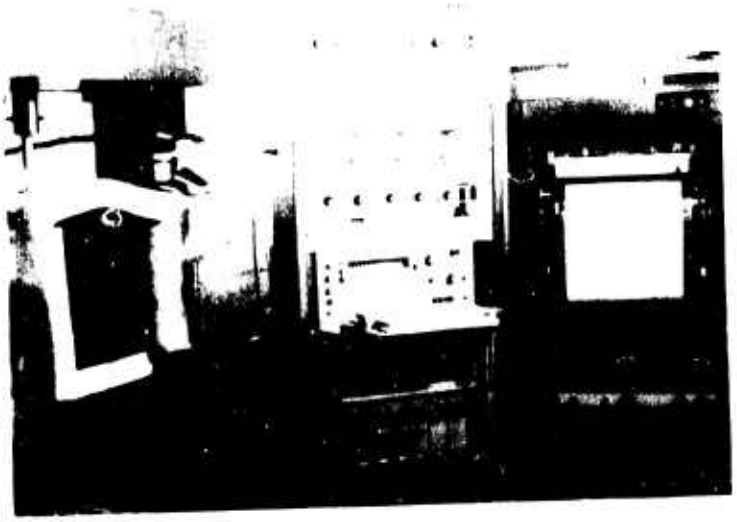

Figure 6. Biaxial Dilatometer Mounted in Instron Test Machine.

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.

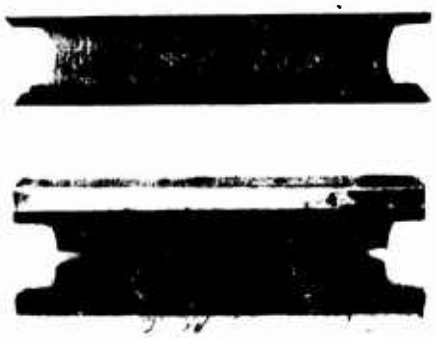

Figure 7. Unfailed and Failed Strip-biaxial Specimen End-Bonded to Aluminum.

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,

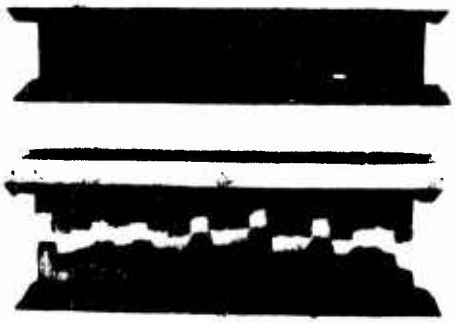

Figure 9. Unfailed and Failed Uniaxial Specimens End-bonded to Aluminum Plates.

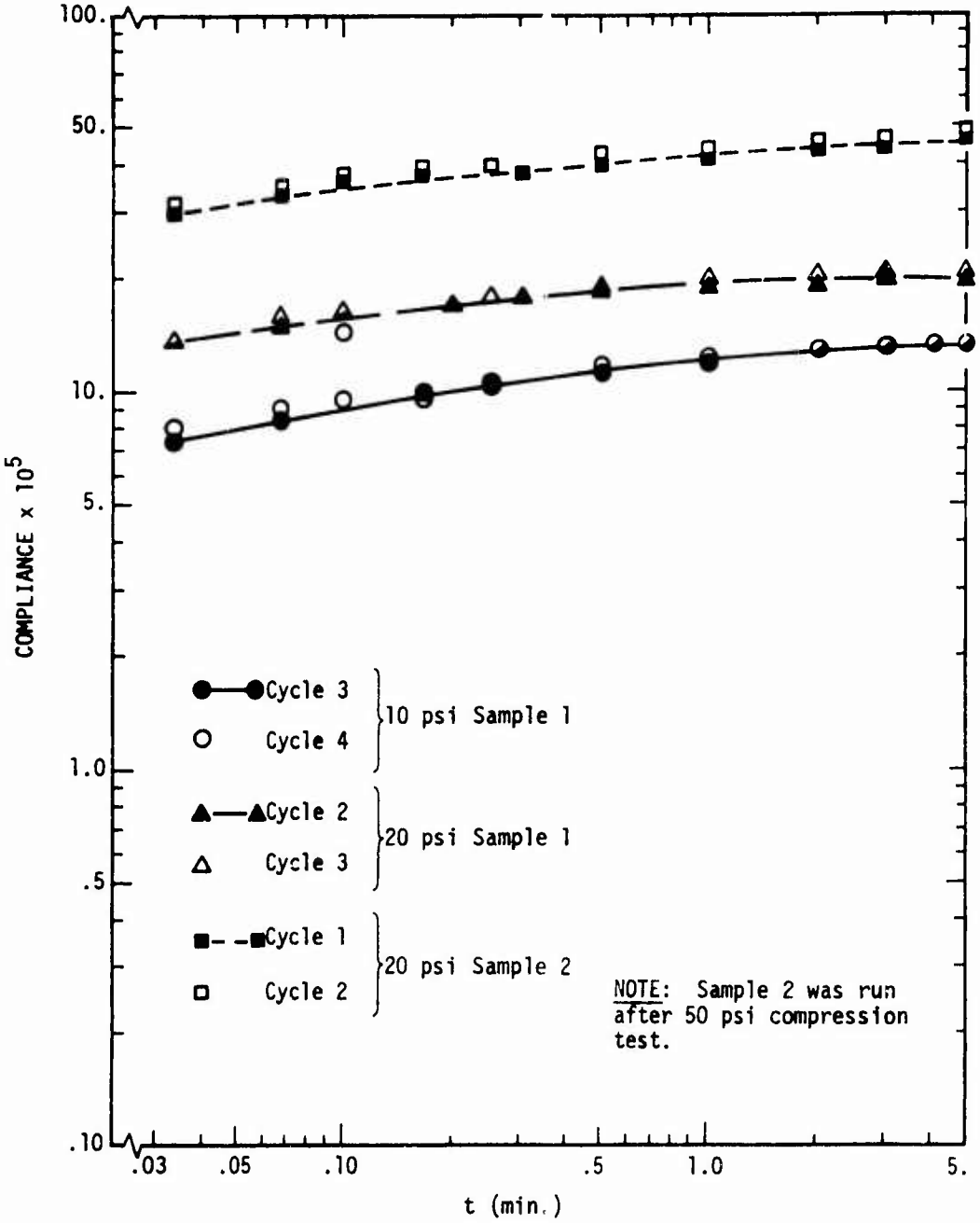

Figure 10. Poker Chip Creep Compliance in Tension.

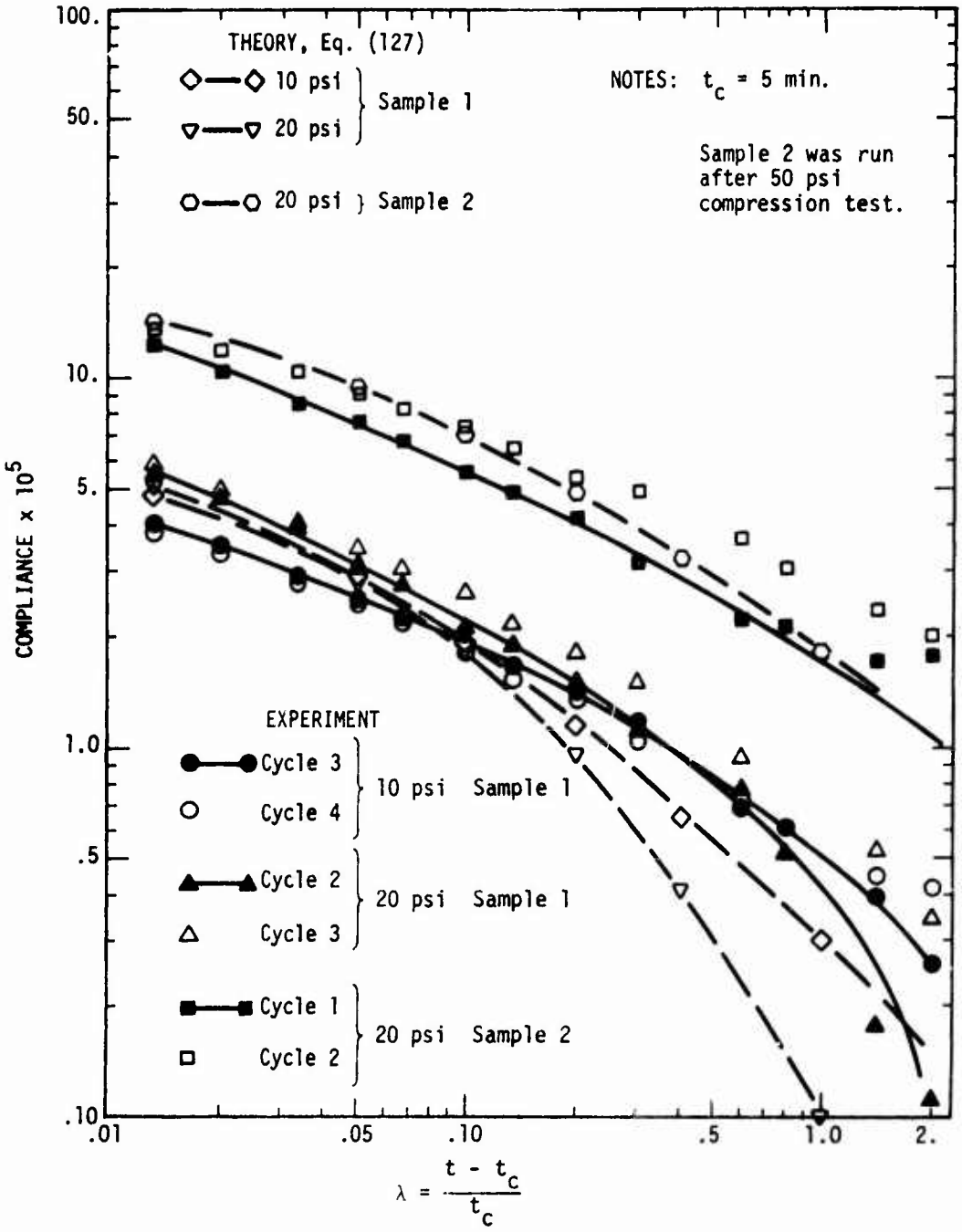

Figure 11. Poker Chip Recovery Compliance in Tension.

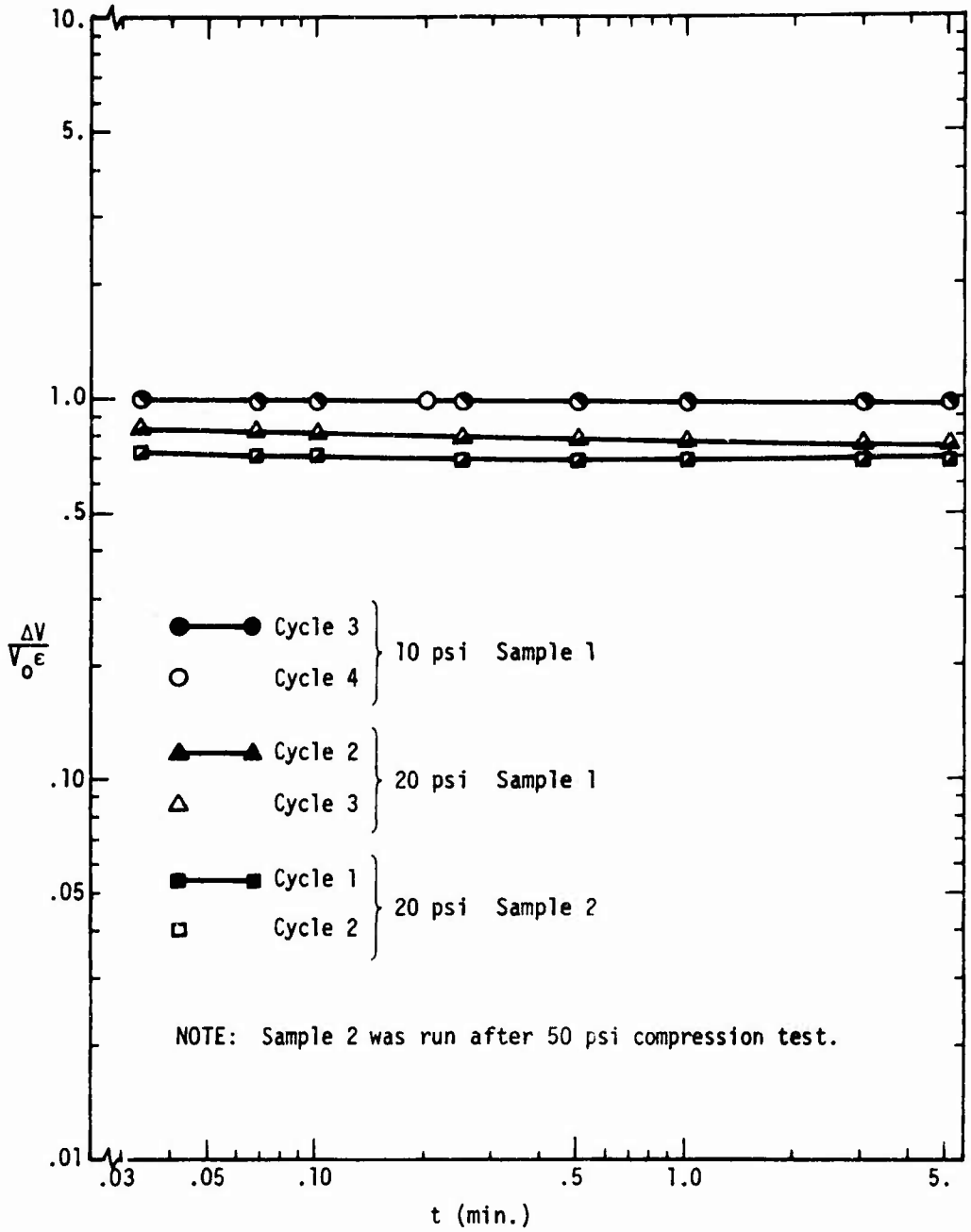

Figure 12. Poker Chip Dilatation in Tension-Creep.

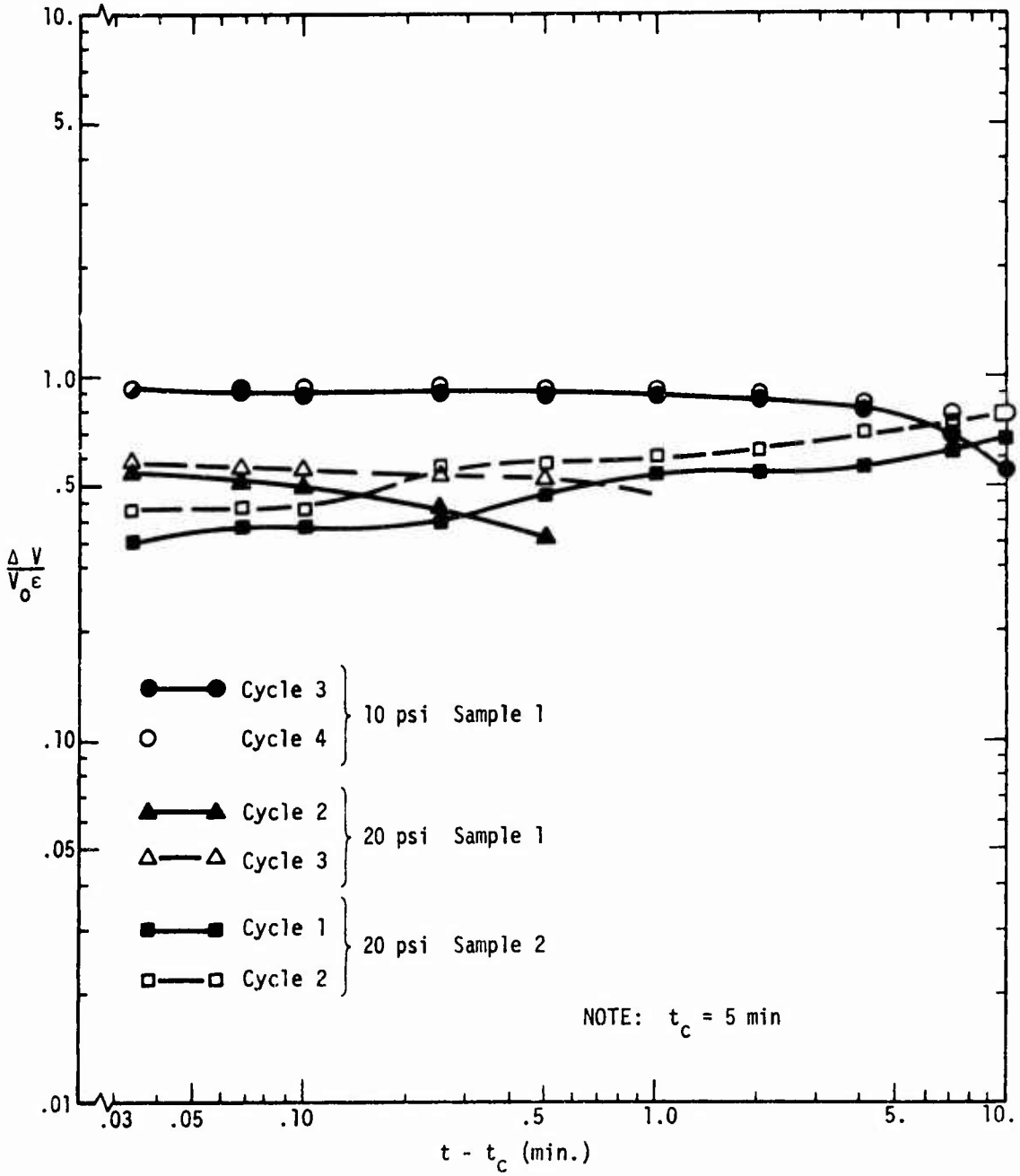

Figure 13. Poker Chip Dilatation in Tension-Recovery.

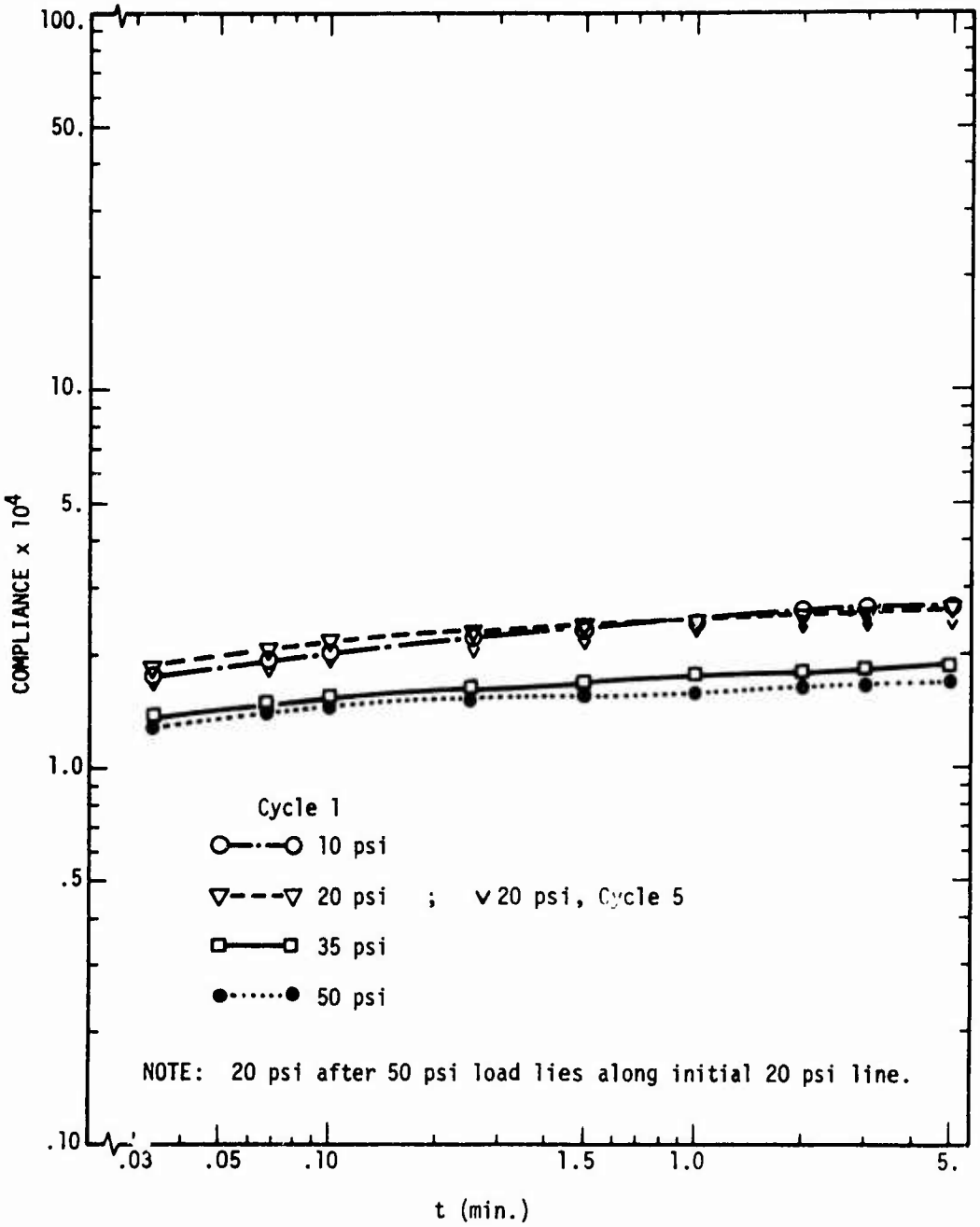

Figure 14. Poker Chip Creep Compliance in Compression.

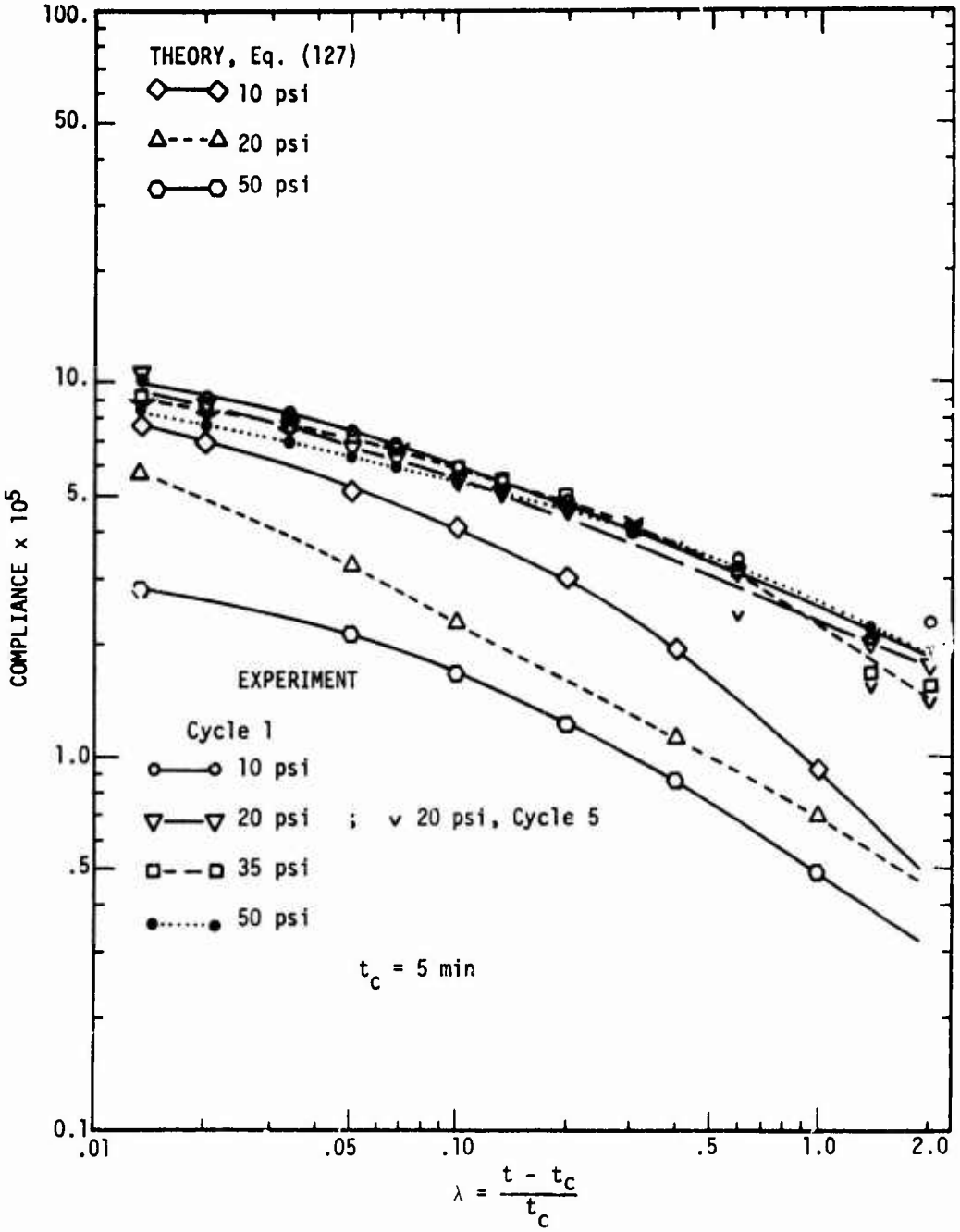

Figure 15. Poker Chip Recovery Compliance in Compression.

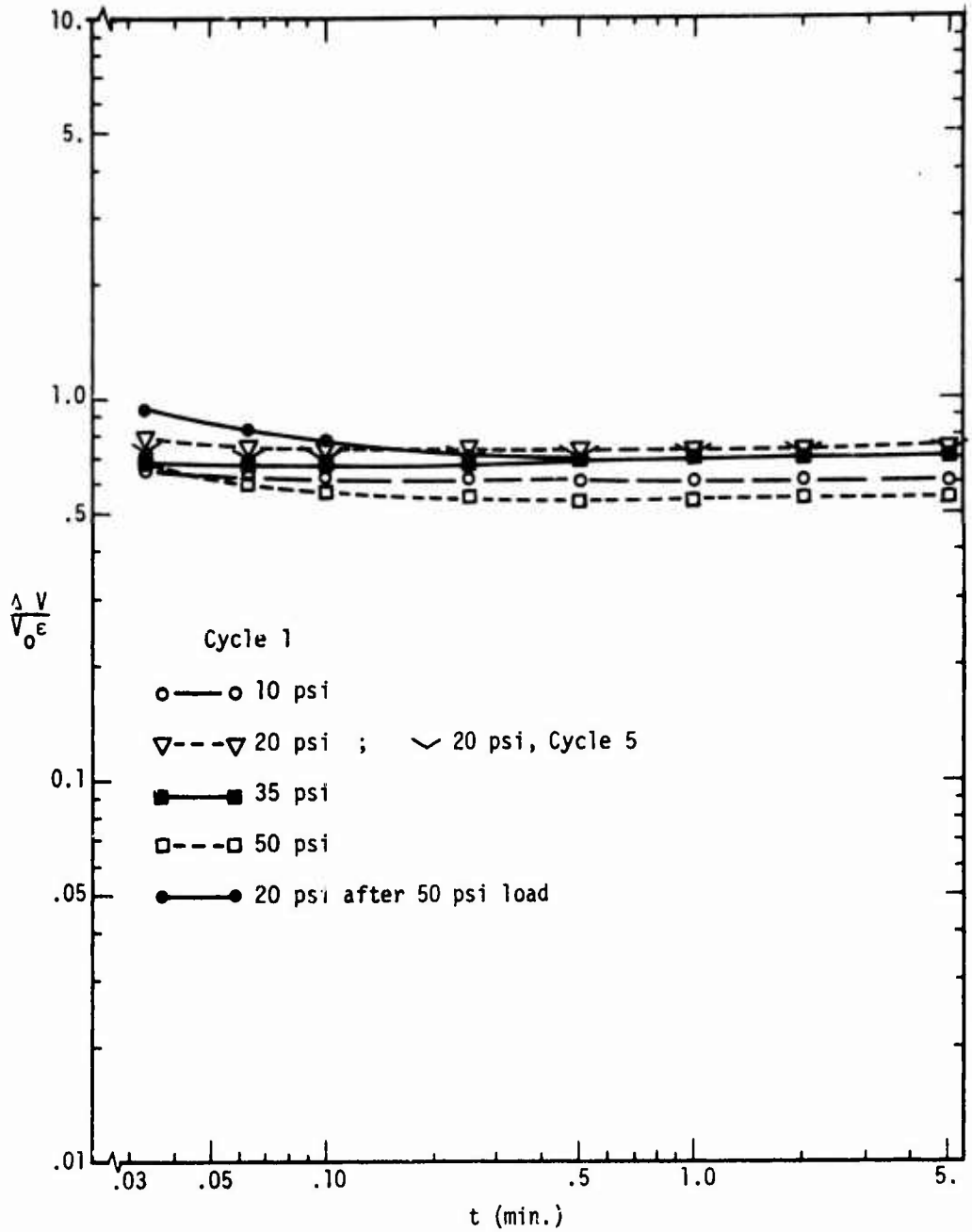

Figure 16. Poker Chip Dilatation in Creep-Compression.

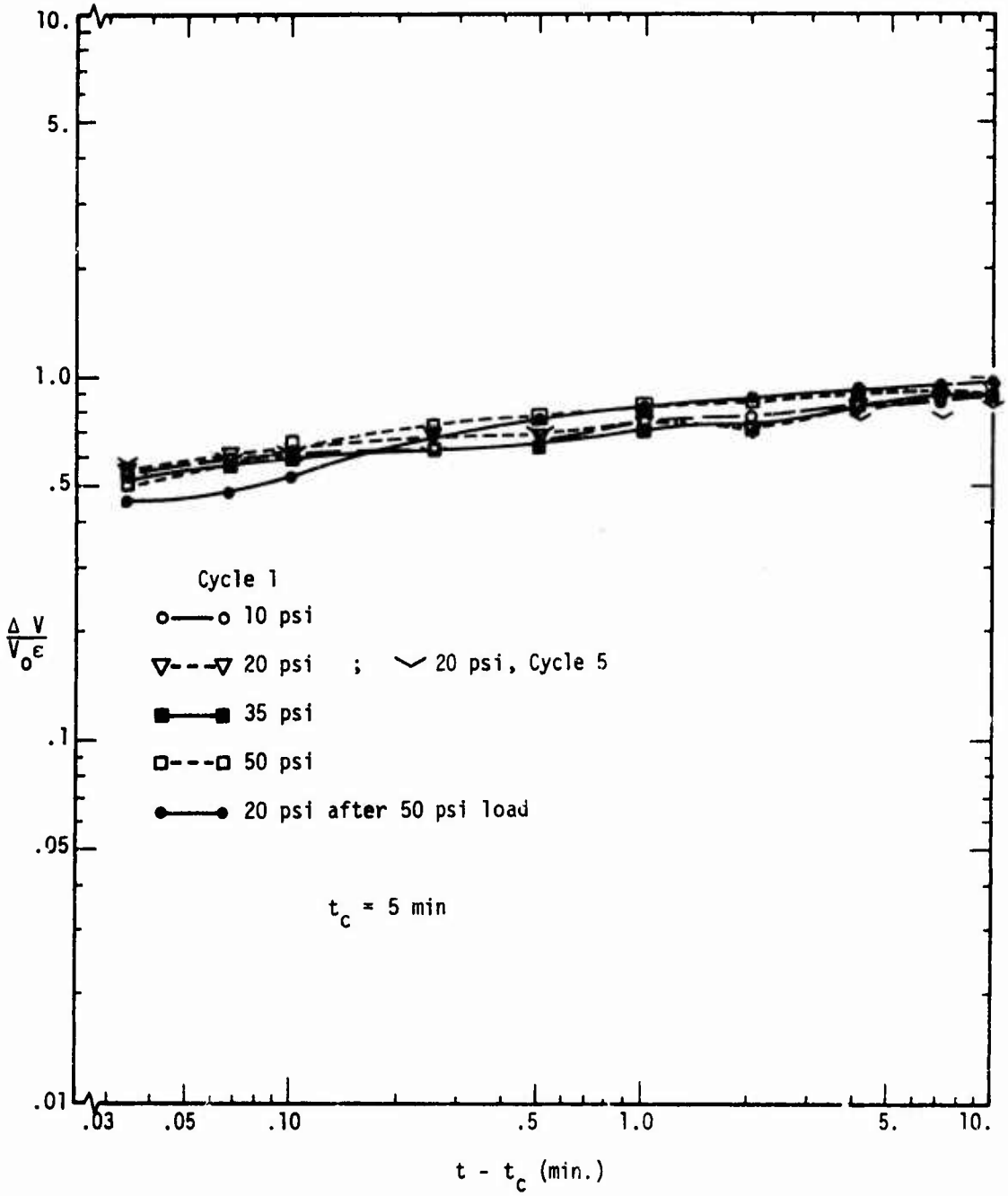

Figure 17. Poker Chip Dilatation in Recovery-Compression.

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:

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

$D_u =$ creep compliance under uniaxial loading

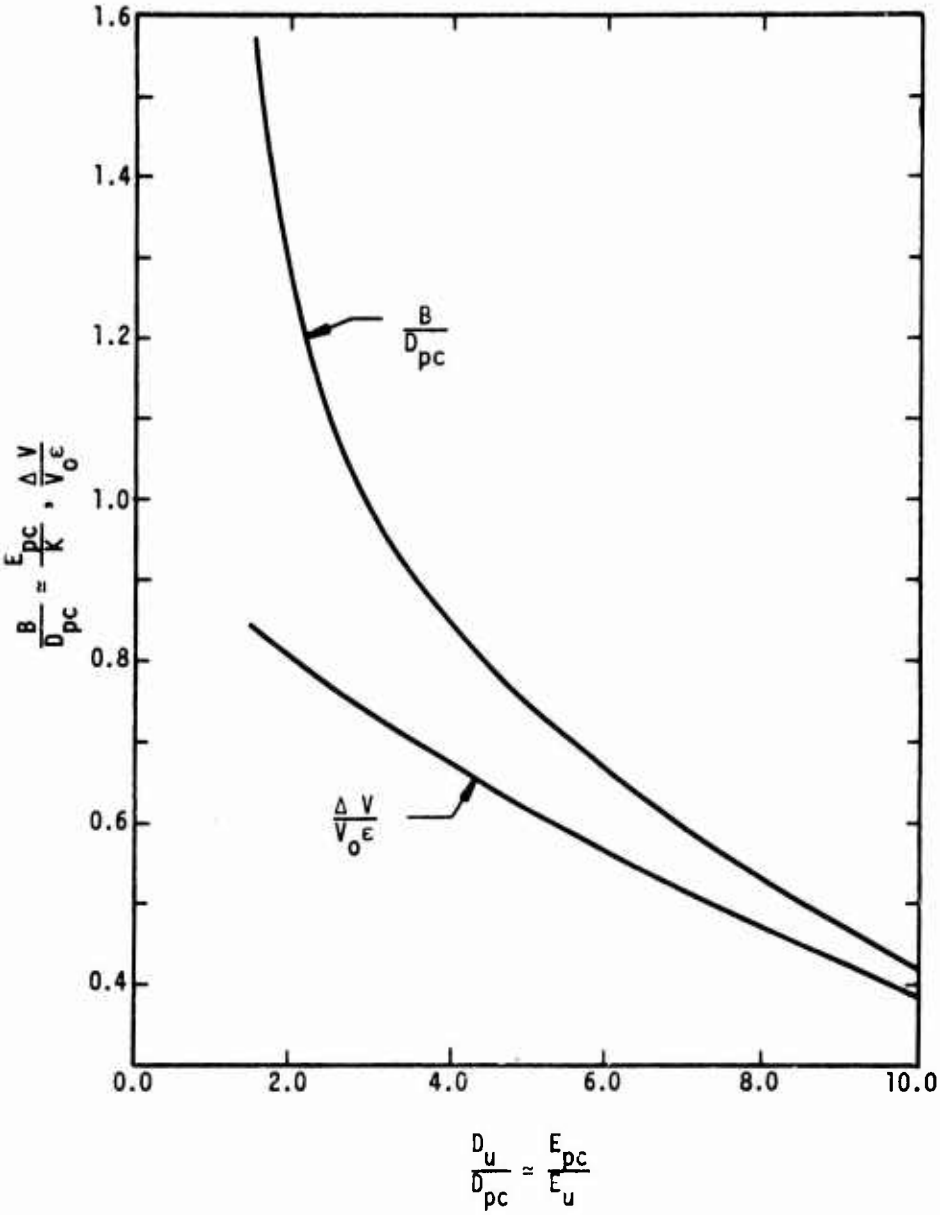

Figure 18. Property Ratios for Poker Chip (Dia/Thickness = 12).

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 <u>linear</u> 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 $\sqrt{J}$ 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

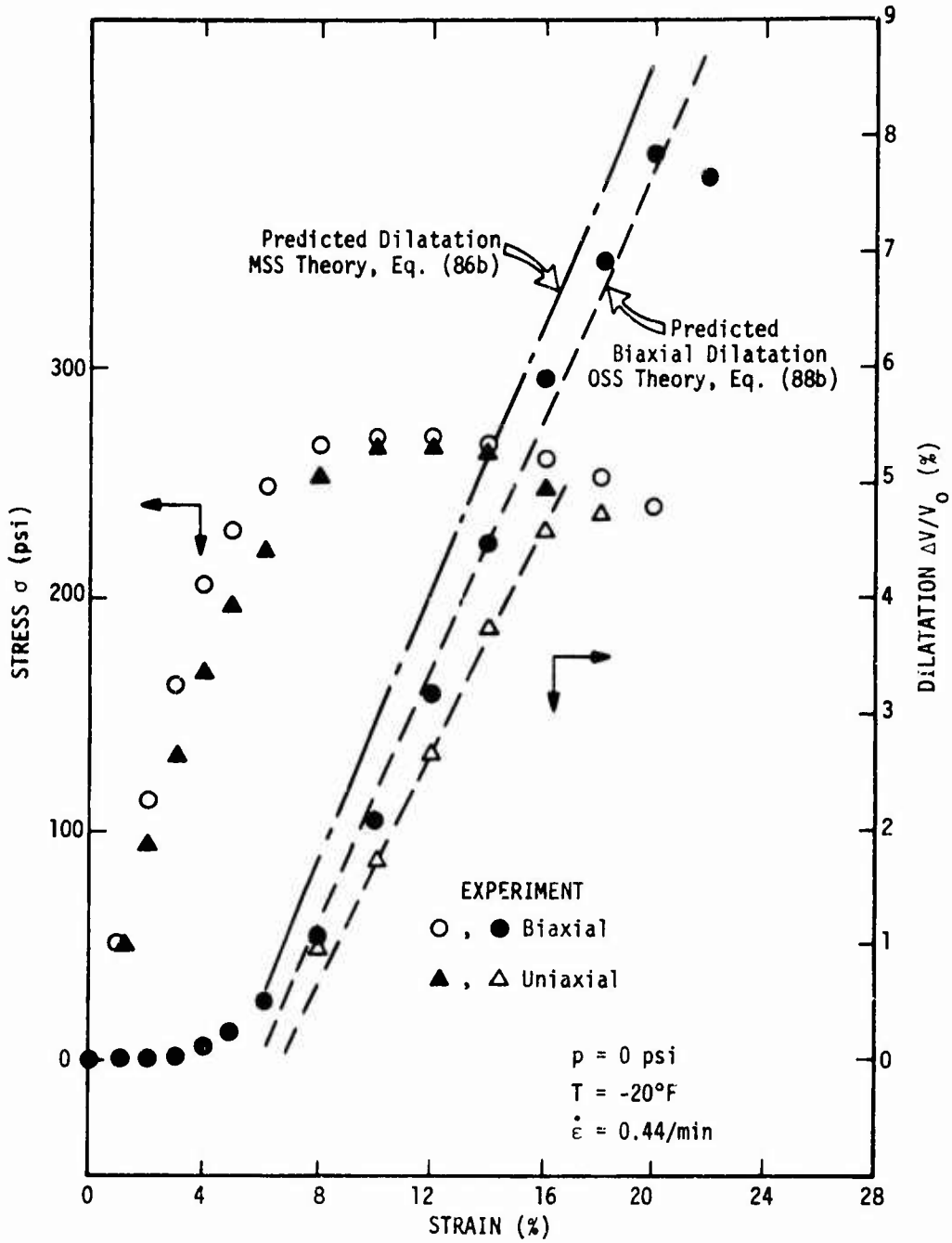

Figure 19. Uniaxial and Strip-Biaxial Data on ANB 3066 Propellant.

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 $\beta \approx 2$ 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 $\beta \approx 2$. Typical room temperature data on this propellant are given in Fig. 21, for which $\beta \approx 2.5$. 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

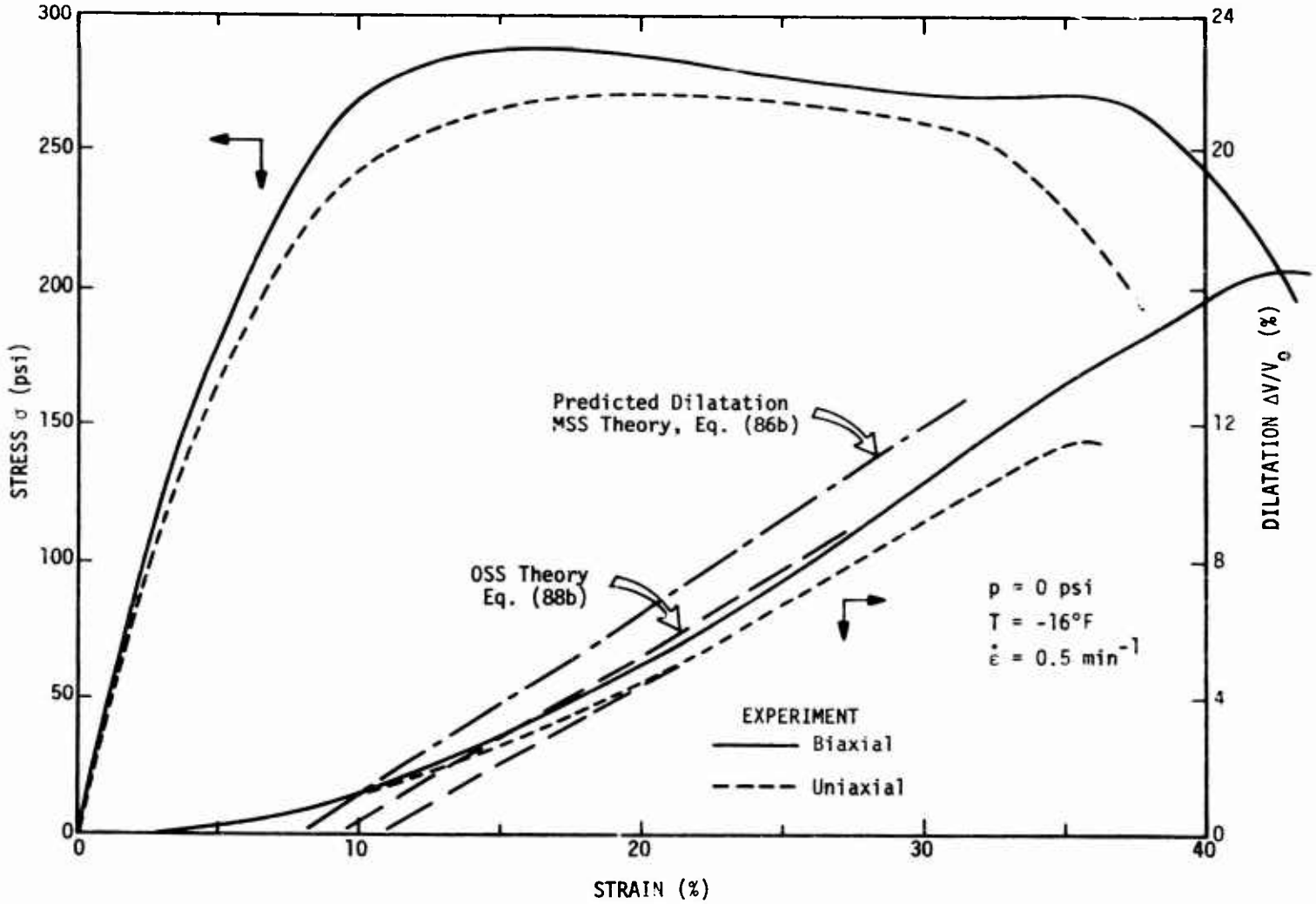

Figure 20. Uniaxial and Strip-Biaxial Data on ANB 3335-1 Propellant.

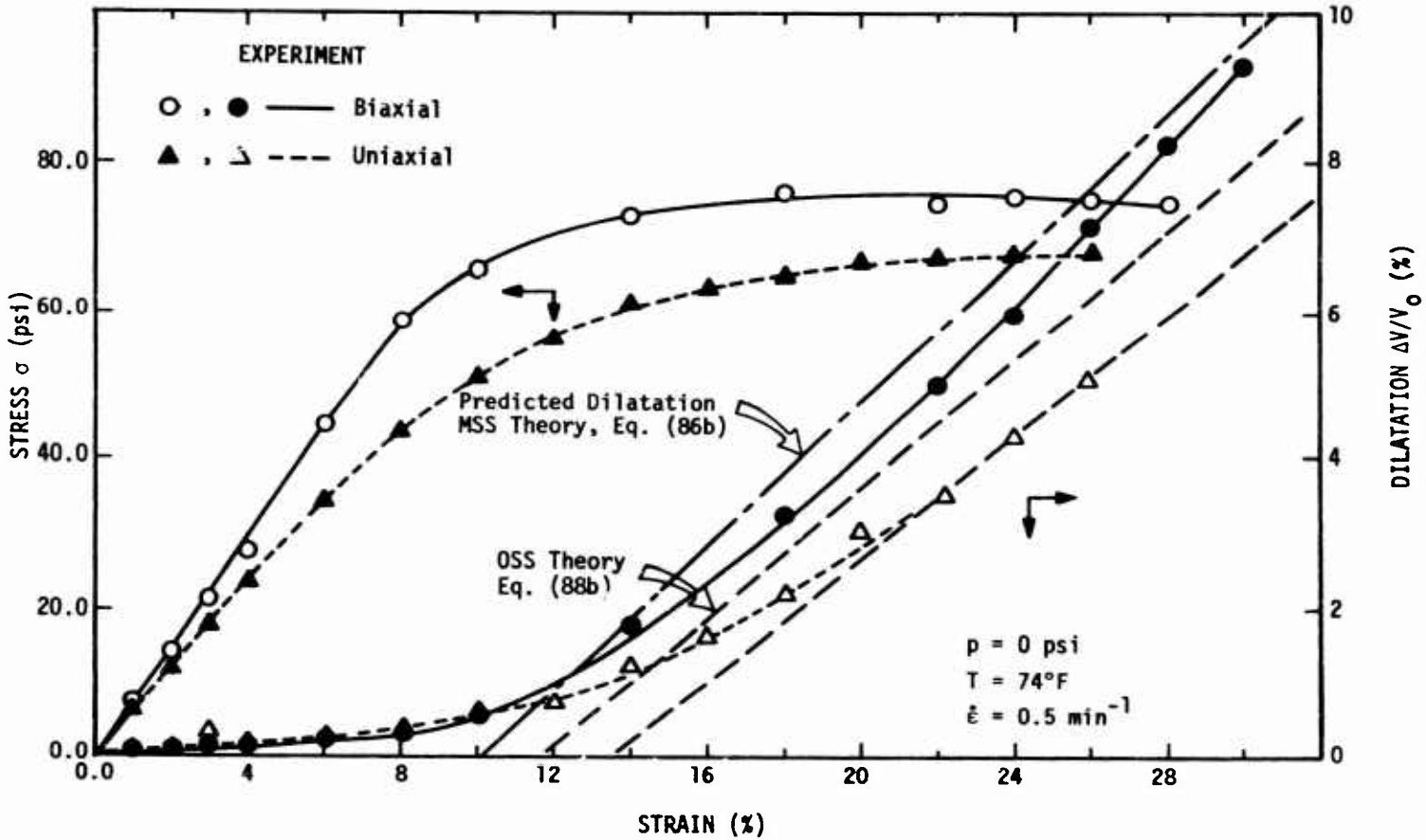

Figure 21. Uniaxial and Strip-Biaxial Data on ANB 3335-1 Propellant.

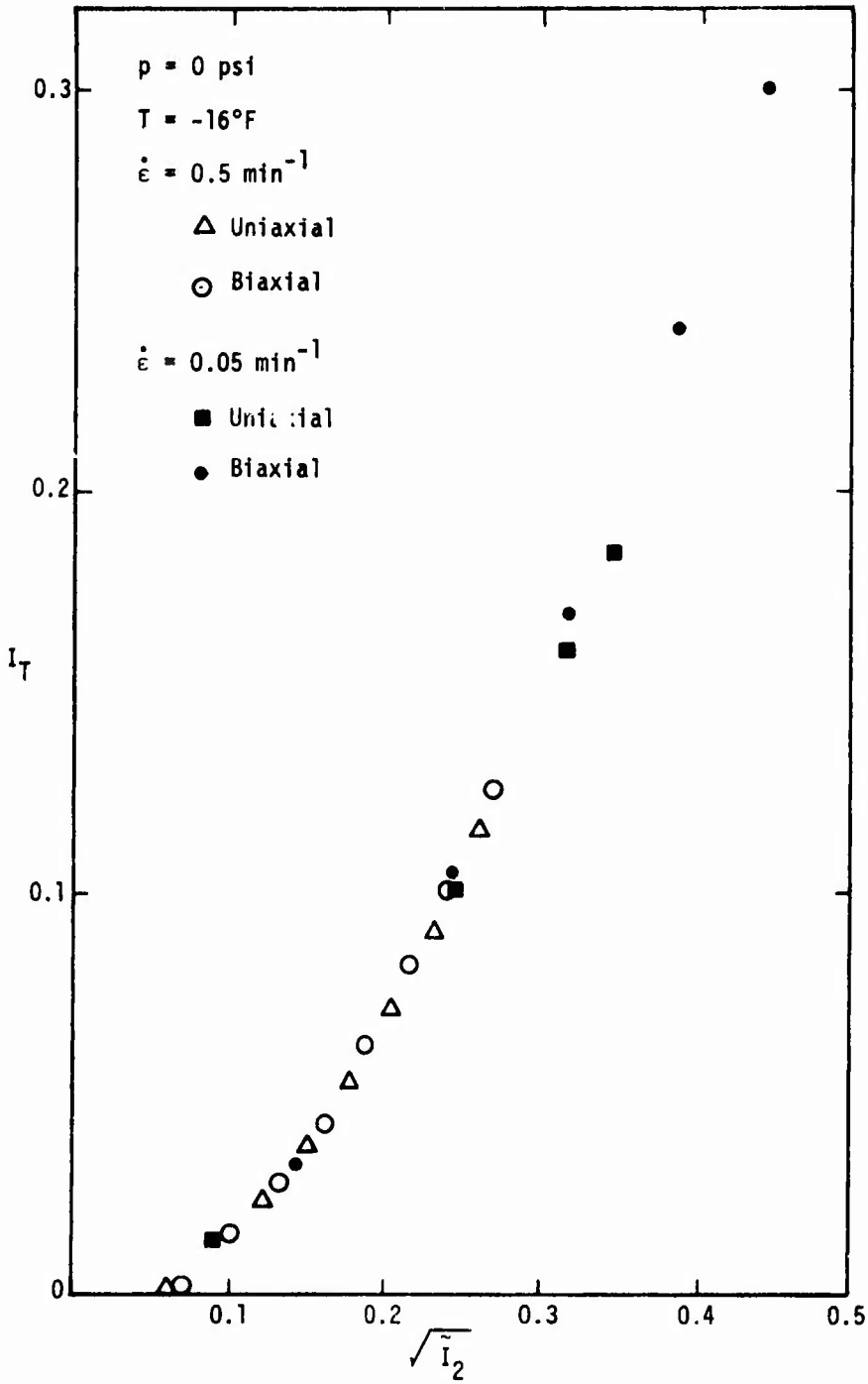

Figure 22. Relation Between First and Second Strain Invariants for Data in Fig. 20.

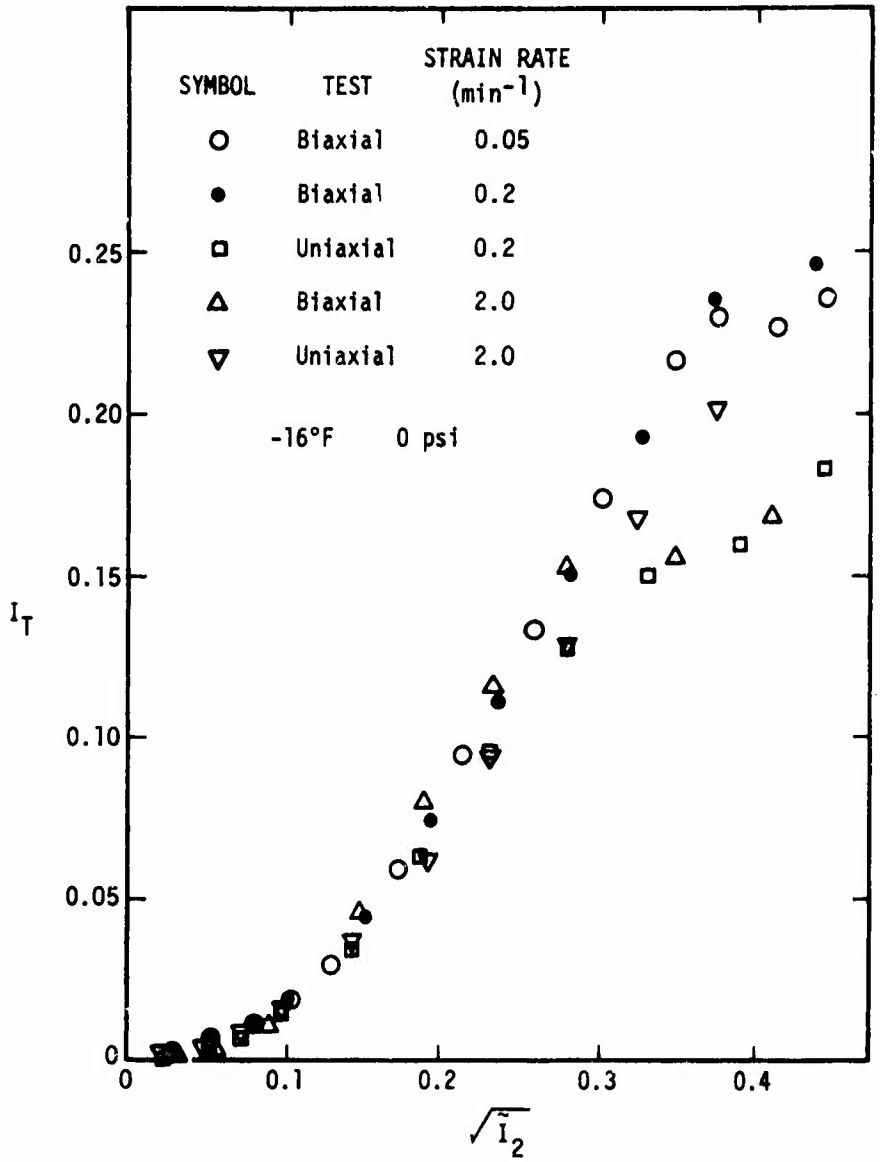

Figure 23. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant

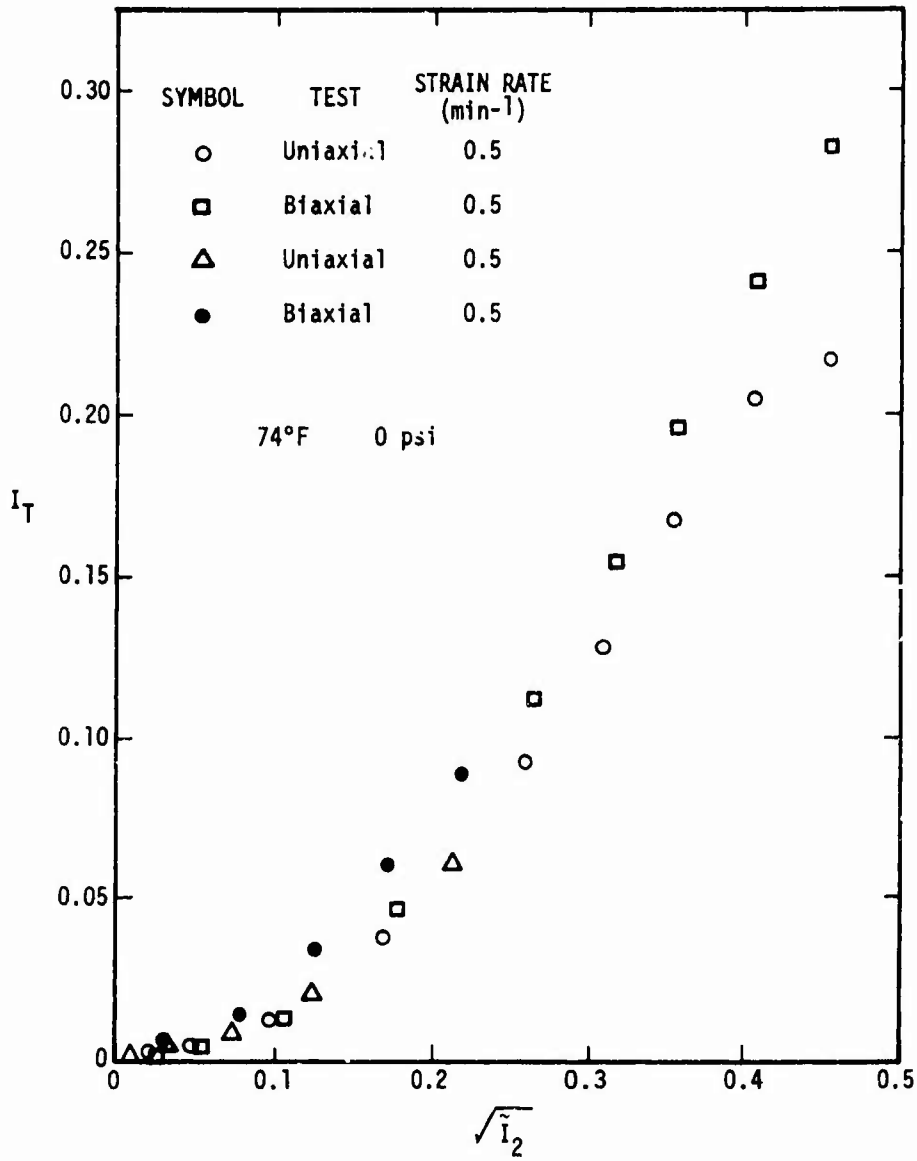

Figure 24. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant

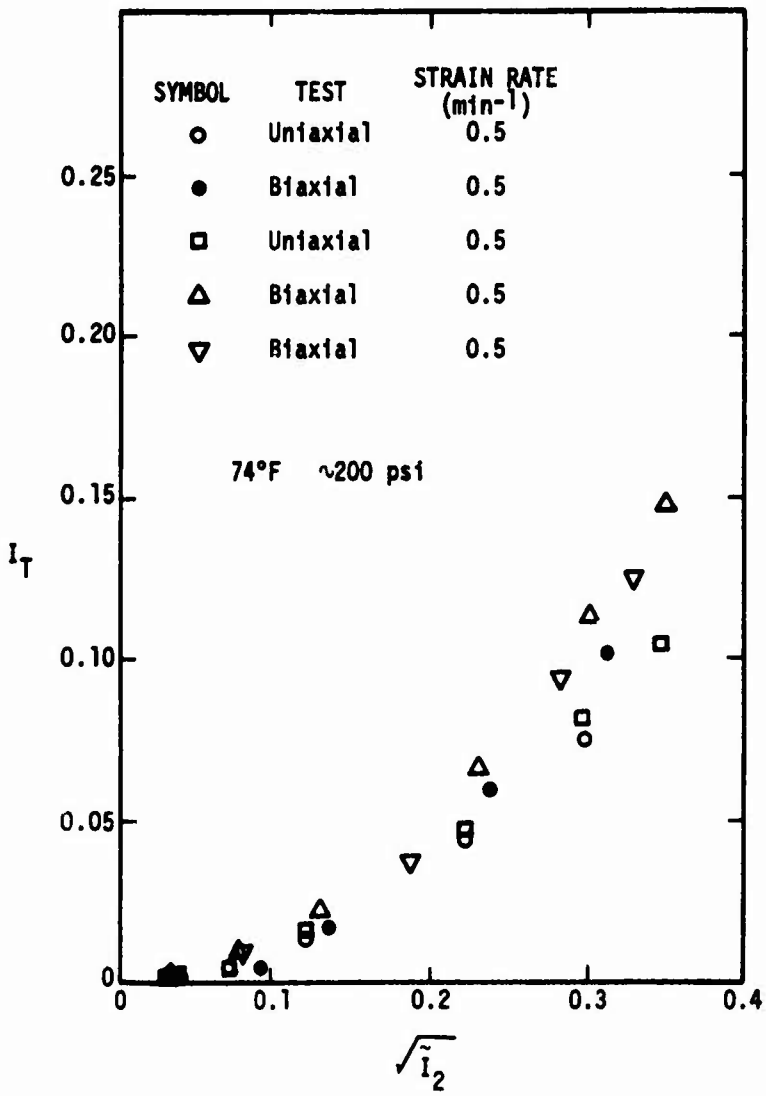

Figure 25. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant.

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 $\beta/a \approx 5$ holds. Thus,

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

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

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

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	DATE	PAGE OF
	Sample input NL001		

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	0.006			
150.	0.5	0.05		25.4	0.027			
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	111111		
BLANK CARD								

PLEASE PRINT CLEARLY - USE BLACK PENCIL

```
                VRONAY,425772,1,100                                                    15 JUN 73   09:24:58   PAGE   18
&T FOR NL001,NL001                                                                     15 JUN 73   00:00:06.928
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   CBRT
        0013   SQRT
        0014   DSQRT
        0015   NEXPB$
        0016   NSTOP$

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

    0000   017571 1F        0001   000362 10L       0001   000030 1266      0001   000467 13L       0001   001117 15L
    0001   001012 16L       0001   001177 17L       0001   000077 1726      0001   000025 2L        0001   001615 23L
    0001   000170 234G      0000   017600 24F       0001   000250 260G      0001   000325 276G      0000   017573 3F
    0000   017555 30F       0001   001630 300I      0000   017643 301F      0001   001177 31L       0001   000367 311G
    0001   001204 32L       0001   001416 33L       0001   000502 330G      0001   001423 34L       0001   000540 344G
    0001   001124 374G      0001   000125 4L        0001   000220 41L       0001   001227 422G      0001   001246 432G
    0001   001260 437G      0001   000231 5L        0001   001436 506G      0001   001450 513G      0001   000306 6L
    0001   000467 7L        0000 D 017523 A1        0000 D 017525 A2        0000 R 017657 B         0000 R 017546 BETA
    0000 D 017545 BULK      0000 R 017533 C1        0000 R 017534 C2        0000 D 007025 DB        0000 R 000000 DIL
    0000 R 300144 DR1       0000 R 000454 DR12      0000 R 000310 DR2       0000 R 000620 DT        0000 D 006515 FOCT
    0000 R 017552 FPS       0000 R 000764 E11       0000 R 001440 E12       0000 R 001130 E22       0000 R 001278 E33
    0000 I 017537 I         0000 I 017657 IB        0000 D 001604 INV1      0000 D 002114 INV2      0000 D 002424 INV3
    0000 I 017535 IPG       0000 I 017540 J         0000 I 017554 K         0000 I 017544 KODE      0000 I 017543 KTEMP
    0000 I 017547 LAST      0000 I 017532 LD        0000 I 017536 LINE      0000 I 017531 LQ        0000 I 002734 MATID
    0000 I 017505 N         0000 I 017541 NAME      0000 I 017550 NDF       0000 I 017527 NEND      0000 D 002741 NORME
    0000 D 003251 NORM10    0000 D 003561 NORM20    0000 D 004071 NORM30    0000 D 004801 NORM40    0000 D 004711 NORM50
    0000 D 005221 NORM60    0000 I 017553 NOUT      0000 I 017530 NU        0000 R 017542 PRES      0000 R 005531 RATE
    0000 R 017551 SP        0000 R 005675 STRESS    0000 R 006041 STRUE     0000 R 006205 T         0000 R 006351 TEMP


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      C***  SPECIAL VERSION TO USE BINARY TAPE WRITES
00100      C
00100      C        EACH TEST IS LIMITED TO A MAXIMUM OF 100 DATA POINTS - NDP.
00100      C         LAST DATA INPUT CARD IS A BLANK.
00100      C         MUST MAKE A SEPERATE RUN FOR EACH MATERIAL.
00100      C
00100      C         BULK      = BULK MODULUS FOR THIS MATERIAL.
00100      C         BETA      = VOLUMETRIC EXPANSION COEFFICIENT.
00100      C         C1, C2    = ARBITRILY SMALL COEFFICIENTS.
00100      C         NU        = BINARY OUTPUT UNIT.
00100      C
00101            DIMENSION     DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00101           1          F11(100), F22(100), F33(100), F12(100), INV1(100),
00101           2          INV2(100), INV3(100), MATID(5), NORMF(100), NORM10(100),
00101           3          NORM20(100), NORM30(100), NORM40(100), NORM50(100),
00101           4          NORM60(100), RATE(100), STRESS(100), STRUF(100), T(100),
00101           5          TEMP(100),  EOCT(100)
00103            DIMENSION   IB(1400), B(1400), DB(2200), N(14)
00103      C
00103      C
00104            DOUBLE PRECISION   INV1, INV2, INV3, NORMF, NORM10, NORM20,
00104           1        NORM30, NORM40, NORM50, NORM60, A1, A2, EOCT
00105            DOUBLE PRECISION  DB
00105      C
00106            EQUIVALENCE(B(1),IB(1))
00107            DATA NEND/'END'/
00107      C
00107      C          ASSIGN TAPE UNIT QBQ.
00111            NU = 1
00112            LQ = 10
00113            LD = 10
00114            CALL NTRAN(NU,10)
00114      C          INITIALIZE ARBITRARY CONSTANTS - USER'S OPTION.
00114      C
00115            C1 = 1.0E-6
00116            C2 = 1.0E-6
00117            IPG = 1
00120            LINE = 0
00121            WRITE(6,24) IPG
00124        2   CONTINUE
00124      C
00124      C          BEGIN NEXT TEST.
00124      C
00124      C               ZERO ALL VARIABLES FOR THIS TEST.
00124      C
00125            DO 100 I=1,100
00130            DIL(I) = 0.0
00131            DR1(I) = 0.0
00132            DR2(I) = 0.0
00133            DR12(I) = 0.0
00134            DT(I) = 0.0
00135            F11(I) = 0.0
00136            F22(I) = 0.0
00137            F33(I) = 0.0
00140            F12(I) = 0.0
00141            EOCT(I) = 0.D0
00142            INV1(I) = 0.D0
00143            INV2(I) = 0.D0
00144            INV3(I) = 0.D0
00145            NORMF(I) = 0.D0
```

```
00146   65*          NORM10(I) = 0.00
00147   66*          NORM20(I) = 0.00
00150   67*          NORM30(I) = 0.00
00151   68*          NORM40(I) = 0.00
00152   69*          NORM50(I) = 0.00
00153   70*          NORM60(I) = 0.00
00154   71*          RATE(I) = 0.0
00155   72*          STRESS(I) = 0.0
00156   73*          STRUE(I) = 0.0
00157   74*          T(I) = 0.0
00160   75*          TEMP(I) = 0.0
00161   76*     100  CONTINUE
00163   77*          J = 2
00164   78*          READ(5,3) NAME, PRES, KTEMP, KODE, (MATID(I),I=1,5), BULK, BETA
00164   79*     C
00164   80*     C              ALL DONE ?
00164   81*     C
00200   82*          IF(KODE.NE.0) GO TO 4
00202   83*          CALL NTRAN(NU,1,10,NEND,LG)
00203   84*          CALL NTRAN(NU,9)
00204   85*          CALL EXIT
00204   86*     C
00204   87*     C
00205   88*       4  CONTINUE
00206   89*          J = J + 1
00207   90*          READ(5,1)  TEMP(J), RATE(J), DT(J), STRESS(J), DIL(J), LAST
00217   91*          IF(LAST.EQ.0) GO TO 4
00217   92*     C
00221   93*          NOP = J
00222   94*          DT(2) = 20.
00223   95*          TEMP(2) = TEMP(3)
00224   96*          TEMP(1) = TEMP(2)
00224   97*     C
00224   98*     C              LIST INPUT DATA.
00224   99*     C
00225  100*          WRITE(6,30) NAME,NOP,PRES,KTEMP,KODE,(MATID(I),I=1,5),BULK,BETA
00242  101*      30  FORMAT(1H ,T10,A6,T20,I3,T35,F8.0,T50,I3,T60,I3,T70,5A4,
00242  102*        1      T100,E10.4,T115,E10.4  )
00243  103*          LINE = LINE + 1
00244  104*          IF(LINE.LT.50) GO TO 41
00246  105*          IPG = IPG + 1
00247  106*          WRITE(6,24) IPG
00252  107*          LINE = 0
00253  108*      41  CONTINUE
00253  109*     C          COMPUTE STRAINS AND 2ND INVARIANT BASED ON TYPE OF TEST.
00253  110*     C
00254  111*          GO TO(5,6,7),KODE
00255  112*       5  CONTINUE
00255  113*     C              UNIAXIAL TEST.
00256  114*          SP = SQRT(1. - PRES/BULK) - 1.0
00257  115*          DO 8 I=2,NOP
00262  116*          DIL(I) = DIL(I)/100. - PRES/BULK
00263  117*          SP = SP + RATE(I)*DT(I)
00264  118*          E11(I) = ( (1.0 + SP)**2 - 1.0) / 2.0
00265  119*          DIL(I) = DIL(I) + C1*E11(I) + BETA*(TEMP(I)-TEMP(I-1))
00266  120*          E22(I) = (((1.0 + DIL(I))/(1.0 + SP)) - 1.0)/2.0
00267  121*          E33(I) = E22(I)
00270  122*       8  CONTINUE
00272  123*          GO TO 10
00272  124*     C
```

```
00272      C
00273    6     CONTINUE
00273      C            BIAXIAL TEST.
00274          SP = SQRT(1.0 - PRES/BULK) - 1.0
00275          DO 9 I=2,NDP
00300          DIL(I) = DIL(I)/100. - PRES/BULK
00301          SP = SP + RATE(I)*DT(I)
00302          E11(I) = ( (1.0 + SP)**2  -1.0) / 2.
00303          DIL(I) = DIL(I) + C2*E11(I) + BETA*(TEMP(I)-TEMP(I-1))
00304          E22(I) = (( (1.0 + DIL(I))/(1.0 + SP) )**2 -1.0)/2.
00305    9     CONTINUE
00305      C
00305      C            COMPUTE INVARIANTS AND TRUE STRESS FOR UNIAXIAL OR BIAXIAL TESTS.
00305      C
00307   10     CONTINUE
00310          DO 11 I=2,NDP
00313          INV1(I) = E11(I) + E22(I) + E33(I)
00314          INV2(I) = E11(I)*E22(I) + E22(I)*E33(I) + E33(I)*E11(I)
00315          INV3(I) = E11(I)*E22(I)*E33(I)
00316          STRUE(I) = STRESS(I)*SQRT((1.0+2.*E11(I))/(1.0+DIL(I)) )
00316      C
00316      C            COMPUTE THE OCTAHEDRAL STRAIN.
00316      C
00317          EOCT(I) = (E11(I)-E22(I))**2 + (E11(I)-E33(I))**2 + (E33(I)-
00317         1             E22(I))**2
00320          EOCT(I) = DSQRT(EOCT(I))/3.D0
00321   11     CONTINUE
00323          GO TO 13
00323      C
00324    7     CONTINUE
00324      C
00324      C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
00324      C                                                                            $
00324      C            ADD SHEAR TEST CALCULATIONS HERE.                               $
00324      C                                                                            $
00324      C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
00324      C
00324      C      INCREMENT TIME  COMPUTE STRAIN RATES AND INFINITE NORM.
00324      C
00325   13     CONTINUE
00326          T(1) = -20.
00327          DO 14 I=2,NDP
00332          T(I) = T(I-1) + DT(I)
00333          DR1(I) = (E11(I) - E11(I-1) )/DT(I)
00334          DR2(I) = (E22(I) - E22(I-1) )/DT(I)
00335          DR12(I) = (E12(I) - E12(I-1) )/DT(I)
00336          NORME(I) = DMAX1(NORME(I-1), DABS(EOCT(I)) )
00337   14     CONTINUE
00337      C
00337      C            IF TEMP IS CONSTANT COMPUTE 10TH THRU 60TH NORMS.
00337      C            IF A VARIABLE TEMP TEST (KTEMP=2) NORMS ARE COMPUTED IN NLOOP.
00337      C
00341          IF(KTEMP.EQ.2) GO TO 17
00341      C
00343          DO 15 I=2,NDP
00346          A1 = DABS(EOCT(I))
00347          A2 = DABS(EOCT(I-1))
00350          EPS = A1-A2
00351          IF(ABS(EPS).LT.1.E-6) GO TO 16
00353          NORM10(I) = NORM10(I-1) + (A1**11-A2**11)/ (11*(A1-A2)/DT(I))
```

```
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) = FOCT(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) LO, LO
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( 5F10.3, 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,////,T10,'TEST',T20,'NDP',T35,'PRESSURE',T50,
00562   315*         2       'KTEMP',T60,'KODE',T70,'MATERIAL I.D.',T104,'BULK',
00562   316*         3       T118,'BETA', //)
00563   317*   301    FORMAT(1H1,20(/), T20,'TAPE WRITE ERROR ... LO = ',I5,///,T41,
00563   318*         1       'LO = ', I5 )
00563   319*   C
00564   320*          END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

```
SINGLE WORD HOLLERITH STRINGS------
END    :   0107

NAMES------
ABS    :   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   0156   0416   0427   0430   0442   0444   0446   0450   0452   0454   0456   0460   0462   0464   0466   0470
           0472   0474   0477
BETA   :   0164   0225   0265   0303   0430
BULK   :   0164   0225   0256   0263   0274   0300   0427
CHRT   :   0256
C1     :   0115   0265
C2     :   0116   0303
DABS   :   0336   0346   0347
DB     :   0103   0105   0516   0520   0522   0524   0526   0533   0535   0537   0541   0543   0545   0550
DIE    :   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  :   0320
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   0333   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
```

```
INV2   :  0101  0104  0143  0314  0520
INV3   :  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
LINE   :  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  0532  0534  0536  0540  0542  0544
NAME   :  0164  0225  0414
NOP    :  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  0353  0363  0376  0533
NORM20 :  0101  0104  0147  0354  0364  0377  0535
NORM30 :  0101  0104  0150  0355  0365  0400  0537
NORM40 :  0101  0104  0151  0356  0366  0401  0541
NORM50 :  0101  0104  0152  0357  0367  0402  0543
NORM60 :  0101  0104  0153  0360  0370  0403  0545
NOUT   :  0413  0477  0504  0531  0550
NTRAN  :  0114  0202  0203  0477  0550
NU     :  0111  0204  0202  0203  0477  0550
PRES   :  0164  0225  0256  0262  0274  0300  0416
RATE   :  0101  0154  0207  0263  0301  0444
SP     :  0256  0263  0264  0266  0274  0301  0302  0304
SQRT   :  0274  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  0203  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:  0101  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	DATE
	Sample input - Post	

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

S 0140-10 (REV 7/68)

PLEASE PRINT CLEARLY - USE BLACK PENCIL

```
Q 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                NOP = 0
000017                IPG = IPG + 1
000018           51   CONTINUE
000019                NOP = NOP + 1
000020                READ(5,9)  X(2,NOP), X(3,NOP), 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,NOP                                          **-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), NUM, 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 = ', F10.4, /, 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,F10.3, T37,3F15.4, T92,F10.4, 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 COR, ISD VERSION 2.12

S U M M A R Y O F T E S T N O . U00100 PAGE U00100 - 3

M A T E R I A L D A T A

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

T E S T D A T A

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	.3436+02

S U M M A R Y O F T E S T N O . U00100 PAGE L00100 - 2

M A T E R I A L D A T A

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

T E S T D A T A

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	.4035-01
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

22 MAY 73 10:50:14 PAGE 5

SUMMARY OF TEST NO. U10105 PAGE U10105 - 1

MATERIAL DATA

MATERIAL IS ANR 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.	.5908-01	-.2722-01	-.2722-01	.0000	.1904+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	.5645+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	.6443+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

S U M M A R Y O F T E S T N O . 010105

M A T E R I A L D A T A

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

T E S T D A T A

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	.1658+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 <u>all</u> 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 the 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 OF

Sample input NL002

CARD NØ.

1	NAME (80 CØLUMN TITLE FØR THIS RUN)													
2	A		Z											
3	IFG(1)	IFG(2)	IFG(3)	IFG(4)	IFG(5)	IFG(6)	IFG(7)							
4	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)
5	IFN(1)	IFN(2)	IFN(3)	IFN(4)	IFN(5)	IFN(6)								
6	XN(1)		XN(2)		XN(3)		XN(4)		XN(5)		XN(6)			
7	NPL													
8	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)			
9	TSHFT(1)		AT(1)											
	TSHFT(2)		AT(2)											
	•		•											
	•		•											
	•		•											
	TSHFT(NAT-1)		AT(NAT-1)											
	TSHFT(NAT)		AT(NAT)		11111									
10	" ADD EL1													
	" ADD EL2													
	•													
	•													
	•													
	" ADD ELAST													
11	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       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                 1111
10     ADD 000300
       ADD 000301
       ADD 000302
       ADD 000303
       ADD 000304
       ADD 000305
       ADD 000306
       ADD 000307
       ADD 000308
       ADD 000309
       ADD 000310
       ADD 000311
       ADD 000312
       ADD 000313
       ADD 000315
11         LAST CARD = A BLANK
```

D-8

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/VO	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	.3426-10
							.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	48.9669	-.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	.4969-07
							.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	.3623-05
							.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	.3578-04
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	.1898-02	.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	.3546-02	.3138-03	.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	.8888-04

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	.2291-08
							.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	.1422-05
							.6146-07	.2635-08	.1392-01	.6294-03	.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	.3064-04
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

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	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	.4384	.1060	60.8359	59.0571	-2.9239	*	.5269+00	.5094-01	.4997-02	.4503-03	.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	.6864-08
							.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	.1299-10	.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	.6144-11
							.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	.8937-05	.8675-07	.7719-09
							.6785-11	.5917-13	.4811-02	.1814-03	.6902-05
77.0000	22.5000	.1188	.0060	36.9356	32.8545	-11.0492	.1662+00	.2258-02	.3076-04	.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	.2830-09	.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	.3211-03	.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/VO	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	.8817-09	.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	.2328-04
							* .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	.1495-02	.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	.1518-02	.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	.8605-03
							* .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	.1879-02
							* .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	.4340-03	.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	.8563-07	.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	.8295-03	.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	.1595-03	.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	.3204-02	.3755-03	.6520-04	
77.0000	1.6940	.2895	.1360	12.7902	12.7658	-.1908	* .1360+00	.1850-01	.2515-02	.3421-03	.2895+00
							* .8382-01	.2427-01	.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	.9887-01	.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/VO	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	.6519-03	.5448-04
							*	.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	.1412-03
							*	.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	.2794-04	

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	SB-EXACT	SB-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	.4403-01
							*	.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	.2107-06	
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	.1586-07	
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	.2355-02	.2669-03
							*	.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
							*	.1558-04	.1220-03	[illegible]	.4861-[illegible]	
77.0000	17.0000	.1442	.0410	9.7882	10.2066	4.2747	*	.4100-01	.1681-02	[illegible]	.2826-05	.1442+00
							*	.2078-01	.2996-02	.4318-03	.5910-03	.5520-03
							*	.3493-04	.2423-03	.9936-03	.1432-0[illegible]	
77.0000	19.0000	.1606	.0520	9.3430	9.2833	-.6382	*	.5300-01	.2704-02	.3406-03	.7112-05	.1606+00
							*	.2579-01	.4181-[illegible]	.6650-03	.8359-02	.3341-02
							*	.6973-04	.4340-03	.3258-04	.3621-0[illegible]	
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	.1970-02
							*	.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	.7333-02	.1425-02	.1418-01	.2755-02
							*	.2011-03	.1035-02	.7558-04	.1468-04	
77.0000	25.0000	.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	[illegible]	[illegible]	

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	.2755-28	.4957-01
							*	.2457-02	.1218-03	.6039-05	.3592-08	.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	.9258-04	.5709-05
							*	.8564-08	.1388-06	.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	.4715-03	.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	.1996-07	
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	.1277+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	.2383-03	.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	1.71580+03
7	-2.02826+04
8	5.11708+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	1.1139	.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	-.6615	.0000	.0000
77.0000	6.4000	.3712	60.9824	60.1922	-1.2958	.0000	-.1830	.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	.2[illegible]7	47.4165	48.3090	1.8823	.0000	-1.0118	.0000	.0000
77.0000	21.0000	.2[illegible]70	47.6337	48.6501	2.1339	.0000	-.7348	.0000	.0000
77.0000	23.0000	.3288	47.7286	49.2544	3.1968	.0000	.2931	.0000	.0000
77.0000	25.0000	.3696	47.0750	49.7747	5.7349	.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

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W@DLAY.S25772.1.10G                                                    15 JUN 73   14:12:33   PAGE    3
GT FOR.* NL002.FL002                                                   15 JUN 73   00:00:02.552
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  14:12(02)
FORTRAN V:  ISG 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   PAGEL
          0006   BUFFER
          0007   REGR
          0010   NREWS
          0011   NRBWS
          0012   NIO1S
          0013   NIO2S
          0014   NWBUS
          0015   ALOG
          0016   EXP
          0017   NEXPAS
          0020   DSQRT
          0021   DEXP
          0022   NEXP6S
          0023   NWRUS
          0024   NRBUS
          0025   NSTOPS

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

    0000   012071 1F        0001   000567 10L       0001   000374 100L      0001   001772 1006G     0001   002603 1016G
    0001   002603 1016G     0001   002020 1025G     0001   002025 1031G     0001   002075 1060G     0001   002175 1104G
    0001   002220 1120G     0001   002232 1124G     0001   002235 1131G     0001   002256 1142G     0001   002313 1152G
    0001   002335 1172G     0001   002335 1174G     0001   000547 12L       0001   002344 1203G     0001   000071 121G
    0001   002355 1210G     0001   002454 1232G     0001   002502 1241G     0001   002505 1244G     0001   002517 1247G
    0001   002571 1266G     0001   002602 1274G     0001   002602 1276G     0000   012100 13F       0001   002635 1313G
    0001   000052 133G      0001   002700 1331G     0001   002722 1350G     0001   002722 1352G     0001   002735 1362G
    0001   002745 1370G     0001   002745 1372G     0000   012105 14F       0001   002760 1400G     0001   002763 1404G
    0001   000064 141G      0001   003027 1431G     0001   003132 1455G     0001   000076 147G      0001   003165 1476G
    0000   012107 15F       0001   003231 1514G     0001   003253 1537G     0001   003253 1575G     0001   003265 1545G
    0001   000110 155G      0001   003276 1553G     0001   003276 1565G     0001   003310 1563G     0001   003314 1570G
    0001   003324 1577G     0001   000132 166G      0001   000641 18L       0001   001020 19L       0000   012072 2F
    0001   000754 20L       0001   001631 200L      0001   000160 202G      0001   000742 21L       0001   000177 213G
    0001   000214 222G      0001   000270 247G      0001   000302 256G      0001   000353 274G      0001   000225 [illegible]
    0000   012111 30F       0001   000355 300G      0000   012140 31F       0001   000362 310G      0001   001513 310L
    0000   012146 32F       0001   000400 320G      0000   012160 33F       0001   000467 34L       0000   012203 35F
    0001   000427 350G      0000   012074 4F        0000   012214 40F       0001   000524 4[illegible]G     0000   012277 410F
    0001   000537 412G      0000   012245 42F       0001   000604 427G      0001   000627 433G      0000   012257 44F
    0001   000662 444G      0001   000703 451G      0001   000771 470G      0001   001003 475G      0001   001231 50L
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0001  001062 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  003450 575L   0001  003367 586L   0001  003405 587L   0000  012313 588F   0001  002123 600L
0001  002051 605L   0001  001454 626G   0001  001457 632G   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  001620 717G   0000  012556 720F
0000  012600 725F   0001  001673 737G   0000  012276 75F    0001  001736 755G   0001  001760 774G
0001  001766 776G   0001  001341 78L    0001  002535 9L     0000 R 012017 A      0000 R 000000 AT
0000 R 012025 AVGAT 0000 R 012000 A1    0000 R 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 BC    0003 R 000012 BULK
0000 R 000207 CO    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 001144 E11   0003 R 001620 E12
0003 R 001310 E22   0003 R 001654 E33   0000 R 000371 F     0000 R 000535 G     0000 I 012012 I
0000 I 000761 IFF   0000 I 000717 IFG   0000 I 012007 IFLAG 0000 I 000726 IFN   0000 R 012008 INT1
0000 R 012006 INT12 0000 R 012005 INT2  0003 R 002604 INV1  0003 R 003114 INV2  0003 R 003424 INV3
0000 I 012013 IPR   0003 I 000000 ITEST 0000 I 012022 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 012026 M
0003 I 000005 MATID 0000 I 012035 MP7   0000 I 012033 N     0000 I 000734 NAME  0000 I 012016 NAT
0000 I 012051 NBULKS 0003 I 000001 NDP  0000 I 011777 NERD  0003 R 004244 NORM  0003 R 003734 NORMF
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 012105 RATE  0000 R 012042 RESID 0000 R 012055 RESID1 0000 R 012056 RESID2 0000 R 012048 SCAL
0000 R 012050 ST    0000 R 000470 STRESS 0000 R 012046 STRN 0003 R 001744 STRUE  0000 R 012041 SUM
0000 R 012054 SUM1  0000 R 012054 SUM2  0000 R 012061 S1    0000 R 012057 SICAL 0000 R 012062 S2
0000 R 012060 S2CAL 0003 R 001000 T     0003 R 000014 TEMP  0000 R 001373 TR    0000 R 001377 TSHFT
0000 R 011701 WORK1 0000 R 011770 WORK2 0000 R 012047 XBAR  0000 R 001663 XF    0000 R 004373 XF1
0000 R 007103 XF2   0000 R 011753 XN    0000 R 012027 XP    0000 R 012030 XQ    0000 R 012014 Z
```

```
00100    1*   C
00100    2*   C *** PROGRAM NAME = N1002.
00100    3*   C          NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE.
00100    4*   C          BULK      =    BULK MODULUS.
00100    5*   C          BETA      =    VOLUMETRIC EXPANSION COEFFICIENT.
00100    6*   C          EOCT      =    OCTAHEDRAL SHEAR STRAIN
00100    7*   C          IFN       =    NORM SELECTOR, ANY ONE OR COMBINATION OF THE
00100    8*   C                          10TH, 20TH, 30TH, 40TH, 50TH, OR 60TH NORMS.
00100    9*   C                          ENTER A NONZERO VALUE TO INCLUDE THAT NORM.
00100   10*   C          NPL       =    NO. OF POWER LAW TERMS.
00100   11*   C          NMT       =    NO. OF AT VS. TSHFT INPUT DATA POINTS.
00100   12*   C          NDP       =    NO. OF DATA PTS. FOR A SPECIFIC TEST.
00100   13*   C          N1        =    FIRST DATA POINT USED IN THE REGRESSION ANALYSIS.
00100   14*   C
00101   15*          DIMENSION AT(100), B(7), BB(14), BO(14), CO(14), D(100),
00101   16*        1         DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00101   17*        2         E11(100), E22(100), E33(100), E12(100), F(100), G(100),
00101   18*        3         IFF(14), IFG(7), IFN(6), INV1(100), INV2(100),
00101   19*        4         INV3(100), MATID(5), NAME(20), NORM(6,100), NORMF(100),
00101   20*        5         P(7), R(14,14), RATE(100), STRESS(100), STRUE(100),          **-2
00101   21*        6         T(100), TEMP(100), TR(100), TSHFT(100), XF(14,100),
00101   22*        7       XF1(14,100), XF2(14,100), XN(6), EOCT(100)
00101   23*   C
00102   24*          DIMENSION WORK1(7), WORK2(7)                                          *NEW
00103   25*   C                                                                            *NEW
00104   26*          COMMON /INPUT/ ITEST, NDP, PRES, KTEMP, KODE, MATID, BULK, BETA,
00104   27*        1                TEMP, RATE, DT, STRESS, DIL, T, E11, E22, E33, E12,
```

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00104   2*        2              STRUF, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00104   24*       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 DRR.
00113   42*        NU = 1
00113   43*  C
00113   44*  C       DYNAMICALLY ALLOCATE DRUM SPACE.
00113   45*  C
00114   46*            CALL IOUNIT('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
00153   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, D(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) )
```

```
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
```

```
00362          IF(LINE.LE.50) GO TO 34
00364          CALL PAGNL(IPG, NAME )
00365          WRITE(6,33)
00367          LINE = 0
00370     34   CONTINUE
00371          WRITE(6,35) NTEST,ITEST,NDP,KODE,KTEMP,PRES,TEMP(1)
00371     C
00371     C        COMPUTE THE REDUCED TIME, TR.
00371     C
00402          DO 8 I=N1,NDP
00405          IF(I.EQ.N1) GO TO 9
00407  *DIAGNOSTIC.  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00407          IF(TEMP(I).EQ.TEMP(I-1)) GO TO 10
00411      9   DO 11 J=1,NAT
00414          IF(TEMP(I).LT.TSHFT(J)) GO TO 12
00416     11   CONTINUE
00420     12   AVGAT = ( EXP(LOG(AT(J-1)) + D(J)*(TEMP(I) - TSHFT(J-1) )) )
00421     10   TR(I) = TR(I-1)  +  DT(I)/AVGAT
00422      8   CONTINUE
00422     C
00422     C
00422     C        IF TEMP IS CONSTANT READ 10TH THRU 60TH NORMS, OTHERWISE
00422     C        COMPUTE THEM BASED ON THE REDUCED TIME, TR.
00422     C
00424          IF(KTEMP.EQ.2) GO TO 18
00424     C
00424     C
00424     C        IF A CONSTANT TEMP TEST, MULTIPLY THE PTH NORM BY (1/AT)**1/P.
00424     C
00426          DO 60 M=1,6
00431          XP = 1.0/(10*M)
00432          DO 60 I=1,NDP
00435          NORM(M,I) = NORM(M,I)*((1./AVGAT)**XP)
00436     60   CONTINUE
00441          GO TO 19
00442     18   CONTINUE
00442     C
00443          DO 20 M=1,6
00446          XP = 1.0+10.*M
00447          XQ = 10.*M
00450          DO 20 I=N1,NDP
00453          DTR = TR(I) - TR(I-1)
00454          A1 = DABS(INV2(I))
00455          A2 = DABS(INV2(I-1))
00456  *DIAGNOSTIC.  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00456          IF(A1.EQ.A2) GO TO 21
00460          NORM(M,I) = NORM(M,I-1) + (A1**XP-A2**XP)/(XP*(A1-A2)/DTR  )
00461          GO TO 20
00462     21   CONTINUE
00463          NORM(M,I) = NORM(M,I-1) + (A1**XQ)*DTR
00464     20   CONTINUE
00464     C
00467          DO 22 M=1,6
00472          XP = M*10.
00473          XP = 1./XP
00474          DO 22 I=N1,NDP
00477          NORM(M,I) = NORM(M,I)**XP
00500     22   CONTINUE
00500     C
00503     19   CONTINUE
```

```
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) = E22(I)
00512  216*          XF(1,I) = F11(I) - E22(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 = IFN(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, NP1
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 78
00575  259*          INT1 = INT1 - (DR1(K)/(B(M)*A3))*((1. + B(M)*(TR(J)-TR(K)))**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*     78   CONTINUE
00601  265*          INT12= INT12- (DR12(K)/(B(M)*A3))*((1. + B(M)*(TR(J)-TR(K)))**A3
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00601          1          - (1. + B(M)*(TR(J)-TR(K-1)))**A3 )
00602     71   CONTINUE
00604          XF1(N+M,J) = INT1
00605          XF2(N+M,J) = INT2
00606          IF(IFF(MP7).NE.0) XF1(N+M,J) = XF1(N+M,J)*F(J)
00610          IF(IFF(MP7).NE.0) XF2(N+M,J) = XF2(N+M,J)*F(J)
00612          IF(IFG(M).NE.0) XF1(N+M,J) = XF1(N+M,J)*G(J)
00614          IF(IFG(M).NE.0) XF2(N+M,J) = XF2(N+M,J)*G(J)
00616          XF(N+M,J) = XF1(N+M,J) - XF2(N+M,J)
00617     70   CONTINUE
00617    C
00617    C          FORM PRIMARY MATRIX R, AND SOLUTION VECTOR BB.
00617    C
00622          NTERMS = NORMS + NPL + 1
00622    C
00623          DO 300 K=1,NTERMS
00626          DO 300 J=1,NTERMS
00631             DO 310 I=N1,NDP
00634              IF(ABS(STRUE(I)).LT.8.0 ) GO TO 310
00636             R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/STRUE(I)**2
00637             IF(J.GT.1)  GO TO 310
00641             BB(K) = BB(K) + XF(K,I)/STRUE(I)
00642    310      CONTINUE
00644    300   CONTINUE
00644    C
00644    C              SAVE DATA ON SCRATCH DRUMS 11 AND 12.
00644    C
00647             WRITE(11)  NDP, KOFF, PRES
00654             WRITE(11) (DIL(I), E11(I), E12(I),FOCT(I), INV1(I), INV2(I)
00654          1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
00673             WRITE(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
00673    C
00705             WRITE(12)  (STRESS(I), I=1,NDP)
00713             WRITE(12)  (( XF(K,I),K=1,14),I=1,NDP
00713    C
00713    C          GO READ NEXT TEST.
00713    C
00713    C                    ALL DONE ?
00713    C
00724          IF(IFLAG.EQ.2) GO TO 200
00724    C
00726          GO TO 100
00726    C
00727    200   CONTINUE
00730          REWIND 11
00731             REWIND 12
00731    C
00731    C          REGRESSION ANALYSIS FOR SHEAR TERM.
00731    C
00732             CALL REGR(NTERMS, BB, CO, R )
00732    C
00732    C          CALCULATE SHEAR TERM AND RELATIVE AND GLOBAL ERROR.
00732    C
00733          NTOT = 0
00734          SUM = 0.0
00735          RESID = 0.0
00736          DO 600 L=1,NTEST
00741          LINE = 0
00742          CALL PAGNL( IPG, NAME )
00743          WRITE(6,650) L
```

```
00746  326*            READ(11)  NDP, KODE, PRES
00753  327*            READ(11) (DIL(I), E11(I), E12(I),FOCT(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) I
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(6,7 0)(I, CO(I),I=1,NTERMS)
01111  360*        WRITE(6,710) NTOT, XBAR, STD
01111  361*  C
01111  362*  C         NOW HAVE S[illegible]R TERM COEFFICIENTS CO(K).  GO GET BULK TERM
01111  363*  C         COEFFICIENT  BO(K) BY ADDING EXPRESSIONS FOR S11 AND S22.
01111  364*  C
01116  365*        NBULKS = 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),FOCT(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
```

```
C
C
      DO 510 I=N1,NDP
      STRESS(I) = STRUE(I)/2. - PRES
C
C         XF NOW BECOMES SOLUTION MATRIX FOR THE NBULKS TERMS.
C
      XF(1,I) = DIL(I)
      XF(2,I) = DIL(I)**2
      XF(3,I) = DIL(I)**3
      XF(4,I) = DIL(I)**4
       XF(5,I) = FOCT(I)
       XF(6,I) = FOCT(I)**2.
       XF(7,I) = FOCT(I)**3.
       XF(8,I) = FOCT(I)**4.
      XF(9,I) = FOCT(I)*DIL(I)
      XF(10,I) = FOCT(I)**2*DIL(I)
      XF(11,I) = FOCT(I)**2*DIL(I)**2
      XF(12,I) = FOCT(I)*DIL(I)**2
      XF(13,I) = FOCT(I)*DIL(I)**3
      XF(14,I) = FOCT(I)**2*DIL(I)**3
      DO 510 K=1,NTERMS
      STRESS(I) = STRESS(I) - CO(K)*XF1(K,I)/2  - CO(K)*XF2(K,I) /2
  510 CONTINUE
C
C         FORM PRIMARY MATRIX R, AND SOLUTION VECTOR BB.
C
C
      DO 520 K=1,NBULKS
      DO 520 J=1,NBULKS
         DO 530 I=K1,NDP
         IF(ABS(STRESS(I)).LT.0.0 ) GO TO 530
         R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/STRESS(I)**2
         IF(J.GT.1) GO TO 530
         BB(K) = BB(K) + XF(K,I)/STRESS(I)
  530    CONTINUE
  520 CONTINUE
C
         WRITE(12)  (STRESS(I), I=1,NDP)
         WRITE(12)  (( XF(K,I),K=1,14),I=1,NDP)
C
  500 CONTINUE
C
         REWIND 11
         REWIND 12
C
         CALL REGR( NBULKS, BB, BO, R )
C
C         FINAL STRESS AND ERROR CALCULATIONS.
C
      SUM = 0.0
      RESID = 0.0
      DO 550 L=1,NTEST
      LINE = 0
      CALL PAGNL( IPG, NAME )
      WRITE(6,655) L
          READ(11)  NDP, KODE, PRES
          READ(11) (DIL(I), E11(I), E12(I),FOCT(I), INV1(I), INV2(I)
     1 ,INV3(I), STRUE(I), T(I), TEMP(I), I=1,NDP)
          READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
```

```
01360                 READ(12)  (STRESS(I), I=1,NDP)
01366                 READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01377           DO 550 I=N1,NDP
01402           BCAL = 0.0
01403               DO 560 J=1,NBULKS
01406                   BCAL = BCAL + BO(J)*XF(J,I)
01407     560       CONTINUE
01411           DEV = 100*(BCAL - STRESS(I))/STRESS(I)
01412               IF(ABS(STRESS(I)).LT.8.0 ) GO TO 565
01414           SUM = SUM + DEV/100.
01415           RESID = RESID + DEV**2/10.**4
01416     565   CONTINUE
01417            STRN=EOCT(I)
01420           WRITE(6,660)  TEMP(I), T(I), STRN, DIL(I), STRESS(I), BCAL, DEV,
01420          1                (XF(J,I),J=1,NBULKS )
01435           LINE = LINE + 4
01436           IF(LINE.LT.48) GO TO 550
01440           CALL PAGNL( IPG, NAME )
01441           WRITE(6,655) L
01444           LINE = 0
01445     550   CONTINUE
01445     C
01445     C         ERROR SUMMARY AND COEFFICIENTS FOR BULK TERM.
01445     C
01450           XBAR = SUM/NTOT
01451           STD = ((NTOT*RESID-SUM**2)/(NTOT*(NTOT-1)))**0.5
01452           CALL PAGNL(IPG,NAME)
01453           WRITE(6,700)(I, BO(I),I=1,NBULKS)
01462           WRITE(6,710) NTOT, XBAR, STD
01462     C
01467           REWIND 11
01470           REWIND 12
01470     C
01471           SUM1= 0.0
01472           SUM2= 0.0
01473           RESID1= 0.0
01474           RESID2= 0.0
01475           DO 575 L=1,NTEST
01500           LINE=0
01501           CALL PAGNL( IPG, NAME )
01502           WRITE(6,675) L
01505                 READ(11)  NDP, KODE, PRES
01512                 READ(11) (DIL(I), F11(I), F12(I),EOCT(I), INV1(I), INV2(I)
01512          1 ,INV3(I), STRUF(I), T(I), TEMP(I), I=1,NDP)
01531                 READ(11)  (( XF1(K,I), XF2(K,I),K=1,14),I=1,NDP)
01543                 READ(12)  (STRESS(I), I=1,NDP)
01551                 READ(12)  (( XF(K,I),K=1,14),I=1,NDP)
01562           DO 575 I= N1,NDP
01565           S1CAL = 0.0
01566           S2CAL = 0.0
01567               DO 580 K=1,NBULKS
01572               S1CAL = S1CAL + BO(K)*XF(K,I)
01573               S2CAL = S1CAL
01574     580       CONTINUE
01576               DO 585 K=1,NTERMS
01601               S1CAL = S1CAL + CO(K)*XF1(K,I)
01602               S2CAL = S2CAL + CO(K)*XF2(K,I)
01603     585   CONTINUE
01605           S1 = STRUF(I) - PRES
01606           S2 = -PRES
```

```
01607          DEV1 = 100*(S1CAL - S1)/S1
01610          DEV2 = 100*(S2CAL - S2)/S2
01611          IF(ABS(S1).LT.8.) GO TO 586
01613          SUM1 = SUM1 + DEV1/100.
01614          RESID1 = RESID1 + DEV1**2/10.**4
01615     586  IF(ABS(S2).LT.8.) GO TO 587
01617          SUM2 = SUM2 + DEV2/100.
01620          RESID2 = RESID2 + DEV2**2/10.**4
01621     587  CONTINUE
01622          STRN = E11(I)
01622    C
01623          WRITE(6,588) TEMP(I), T(I), STRN, S1, S1CAL, DEV1, S2, S2CAL,
01623         1                DEV2, PRES
01637          LINE = LINE + 2
01640          IF(LINE.LT.48) GO TO 575
01642          CALL PAGNL( IPG, NAME )
01643          WRITE(6,675) L
01646          LINE = 0
01647     575  CONTINUE
01647    C
01652          XBAR = SUM1/NTOT
01653          STD = ((NTOT*RESID1-SUM1**2)/(NTOT*(NTOT-1)))**0.5
01654          CALL PAGNL( IPG, NAME )
01655          WRITE(6,720) XBAR, STD
01661          XBAR = SUM2/NTOT
01662          STD = ((NTOT*RESID2-SUM2**2)/(NTOT*(NTOT-1)))**0.5
01663          WRITE(6,725)  XBAR, STD
01663    C
01663    C          F O R M A T   S T A T E M E N T S
01663    C
01667      1   FORMAT(20A4)
01670      2   FORMAT(8F10.0)
01671      4   FORMAT( 2F10.0, I5)
01672      7   FORMAT( 5F10.3, I5)
01673     13   FORMAT(A6, F14.4, 2I5, 5A4, 2E15.4)
01674     14   FORMAT(1P6F12.4)
01675     15   FORMAT(1P3F20.6)
01676     30   FORMAT(1H , //,20X,'THERE WERE ',I3, ' VALUES OF SHIFT FUNCTION VS
01676         1. TEMPERATURE ...',///,T12,'I',T21,'AT(I)',T34,'TSHFT(I)', // )
01677     31   FORMAT(1H ,10X, I2, T19,1PF10.3, T32, 1PF10.3 )
01700     32   FORMAT(1H ,//,10X,'A = ',F10.3,/,10X,'Z = ', F10.3,///// )
01701     33   FORMAT(1H ,10X,'TEST NO.',5X,'TEST ID',5X,' NDP ',5X,'KODE',5X,
01701         1       'KTEMP',8X,'PRESSURE',8X,'TEMP', //)
01702     35   FORMAT(1H , 10X,I8, 5X,A6, 6X, I5, 5X, I4, 5X, I5, 8X, F8.2, 6X,
01702         1          F6.1  )
01703     40   FORMAT(1H , 20X, 'POWER LAW TERMS, (1 + B*T)** P',//, 10X,
01703         1       'I', 8X,'B(I)',11X,' P(I)', 9X,'IFG(I)', /,
01703         2       7(/,10X,I1,5X,1PF10.3,5X,1PF10.3,7X,I3),///)
01704     42   FORMAT(1H , 10X,' I',10X,'IFF(I)',/,I4(/,10X,I2,10X,I4), /// )
01705     44   FORMAT(1H , 10X, 'I',10X, 'NORM', 12X, 'XN(I)', /,
01705         1       6(/,10X,I1, 11X, I1, '0', 10X, 1PF10.3)  )
01706     75   FORMAT(16I5)
01707    410   FORMAT(1H , 20(/), 40X, 'I N V E R S E   F A I L E D   O N   R O W
01707         1       ', I6
01710    588   FORMAT(1H ,/, 6X, 10F12.4 )
01711    650   FORMAT(1H , 40X,'SUMMARY OF SHEAR TERM FOR TEST NO.',I4,//, T9,
01711         1       'TEMP', T19,'TIME', T26,'E11 OR E12', T39,'DV/V0', T49,
01711         2    'STRUE',T58,'S-CALC',T69,'ERROR',T95,'XF(I),I=1,NTERMS', /  )
01712    655   FORMAT(1H , /,40X,'SUMMARY OF BULK RESULTS FOR TEST NO.',I5,//,T9,
01712         1       'TEMP', T19,'TIME', T26,'STRAIN', T39,'DV/V0', T49,
```

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01712   566*          2        'SR-EXACT',T60,'SR-CALC', T70,'ERROR','T95,'XF(K),K=1,NBULKS'
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',T39,'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
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

```
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   0041   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
EGCT   :   0101   0104   0107   0654   0753  01151  01217  01220  01221  01222  01223  01224  01225  01226  01227  01230  01327
          01417  01512
EXP    :   0420
```

```
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  0330  0511  0512
E33   :  0101  0104  0331
F     :  0101  0333  0504  0514  0517  0520  0521  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  0303  0304
         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  01253  01256  01264  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  0565  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  0605  0606  0610  0612  0614  0616  0626  0636  0637  01030  01033  01047  01130  01133  01243
        01253  01254  01403  01406  01420
K     :  0277  0302  0303  0304  0347  0352  0525  0530  0540  0570  0575  0576  0601  0623  0636  0641  0673
         0713  0772  01012  01117  01122  01125  01133  01170  01231  01234  01240  01253  01256  01272  01346  01366  01531
        01551  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  [illegible]  01435  01436  01444  01500  01637  01640  01646
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
```

```
MU     :  0113  0116  0356
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  01004 01205 01212 01234 01251 01253 01256 01264 01360 01411 01412 01420 01543
STRN   :  01044 01045 01047 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  0450  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:   0200  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   0724  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  01623  01643  01655
          01663
     7:   0101   0103   0131   0200   0560  01221
     6:  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  01531
    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------
0.00000000+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
0.25000000+00:   0115
0.50000000+00:  01100  01451  01653  01662
0.75000000+00:   0114
0.10000000+01:   0431   0435   0446   0473   0513   0564   0575   0576   0601
0.20000000+01:  01212  01220
0.30000000+01:  01221
0.40000000+01:  01222
0.80000000+01:   0634  01037  01251  01412  01611  01615
0.10000000+02:   0446   0447   0472  01042  01415  01614  01620
0.10000000+03:  01041  01414  01613  01617

DOUBLE PRECISION CONSTANTS------
0.00000000+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   CODE     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

NLOO3 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	.3175-03	.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	.1891-05	.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	.2022-01	.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,NTEPVS				
.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	.1332-02	.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	.1144-03
							*				

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	.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	.2948+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	.8597-05	.2383-06
							* .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	.2289-04	.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	.5088-04	.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	.1236-02	.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	.3760-01	.3493-02	.3244-03	.2438-04
							* .1809-05	.1332-06	.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	.8626-04
							* .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				
							*	.4833+00	.5750-01	.6955-02	.8813-03	.8313-04
.7700+02	.6600+00	.3844+00	.4540-01	.9496+02	.1047+03	.1028+02	*	.8114-05	.7857-06	.2758-01	.1613-02	.9553-04
							*					
							*	.5204+00	.6952-01	.9459-02	.1287-02	.1437-03
.7700+02	.7100+00	.4180+00	.5100-01	.9516+02	.1169+03	.2280+02	*	.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	.6739-12
							.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	.9844-08	.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	.4469-04	.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	.4505+01	.1896+00	.4556-02	.1099-03	.2651-05	.4911-07
							.8984-09	.1631-10	.1227-01	.8133-03	.5468-04
.7700+02	.2600+00	.1350+00	.2250-02	.6101+02	.6795+02	.1137+02	.1896+00	.4395-02	.1023-03	.2380-05	.4299-07
							.7693-09	.1369-10	.1205-01	.7757-03	.4967-04
.7700+02	.2700+00	.1350+00	.2[illegible]00-02	.5696+02	.6209+02	.9003+01	.1896+00	.4244-02	.9536-04	.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	.3507-04
.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	.3029-04
.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	.9266-04	.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	.6989-04
							*				
.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	.3316-04
							* .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	.5446-06	.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/VO	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	.5501-13
							.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	.8045-05	.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	.1899+00	-.6298-03	.1128+03	.8613+02	-.2365+02	.2627+00	.1174-01	.5283-03	.2378-04	.8387-06
							.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	.6736-01	.8452-02	.1326-02	.1518-03
							.1715-04	.1923-05	.2807-01	.1647-02	.9795-04
.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	.4848-03
							.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	E11 OR E12	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	.3468-13
							*	.2541-16	.1847-19	.3011-02	.2478-03	.2070-04
							*					
.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	.3786-14	.6896-02	.4998-03	.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	.4894-05
							*	.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	.2835-04
							*	.2193-05	.1684-06	.2344-01	.1412-02	.8620-04
							*					
.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	.3486-01	.1984-02	.1144-03
							*					
.7700+02	.8800+00	.5358+00	-.1239-02	.1836+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/VO	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	.3983-03	.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	.1501+03	.1912+04	.2373+05	.9065-01
							*	.8218-02	.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	*	.1238+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	.3862-01
							*	.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	.7868-01	-.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	.1456-01	
.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	.1762-01	.4586-02	.2846+00	.7407-01
							*	.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	.8408-01
							*	.2338-01	.3289+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	.1822+03	.2460+04	.3321+05	.3145+00
							*	.9889-01	.3110-01	.9780-02	.3569+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	.8670-02	.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	.4959-04	.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	-.[illegible]6+05	.5817+06	.1782+00
							* .3177-01	.5662-02	.1[illegible]09-02	.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	.7893+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	DIL	DIL-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	-.3742+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	EGCT	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	.8995+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	-.6449+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	.3881-01	.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	.3877-01	.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	.3853-01	.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	.3845-01	.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	.3840-01	.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	.3817-01	.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	.3751-01	.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	.1697-02	.1585-03	

ALOO3 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	.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	.4541-01	.4557-02
							* .4573-03	.2055-01	.2062-02	.2070-03	
.7700+02	[illegible]	.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	.5089-02	.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	.7965-02	.1591-02	.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,NBULKS				
.7700+02	.5000-01	.1768-01	-.4923+03	-.1000-02	-.1034-02	.3390+01	* -.4923+03	.2424+06	-.1193+09	.5874+11	.1768-01
							* .3124-03	.5522-05	.9761-07	.1286-07	.2273-05
							* .4018-07	.9359-06	.1654-07	.2924-08	
.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	.2739-07	.9685-05
							* .3425-06	.2121-05	.7501-07	.2653-08	
.7700+02	.1500+00	.5309-01	-.4804+03	-.8999-03	-.8597-03	-.4472+01	* -.4804+03	.2308+06	-.1109+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	.5796+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	-.4998-03	-.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	.2323-02	.4603-03
							* .9120-04	.2725-04	.5398-05	.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	.2720-02	.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	.8072-03
							* .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	.3288-09	.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	DIL	DIL-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	.8732+12	.3446+00
							*	.1188+00	.4094-01	.1411-01	.2184-04	.7526-05
							*	.2594-05	.1384-08	.4768-09	.1643-09	
.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	.2379-09	

NL003 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	6.73311-06
2	1.30469-08
3	8.23299-12
4	-3.49580-16
5	7.55943-03
6	-4.72075-02
7	1.10045-01
8	-5.12728-02
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

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                VRONAY,425772,1,100                                    15 JUN 73   13:44:49   PAGE    3
GI FOR,* NL003,NL003                                                   15 JUN 73   00:00:02.524
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  13:44(n.)
FORTRAN V:  ISD VERSION 2.6

    MAIN PROGRAM

    STORAGE USED (BLOCK, NAME, LENGTH)

          0001   *CODE    003175
          0000   *DATA    012720
          0002   *BLANK   000000
          0003   INPUT    007034

    EXTERNAL REFERENCES (BLOCK, NAME)

          0004   IOUNIT
          0005   PAGNL
          0006   BUFFER
          0007   REGR
          0010   NREW$
          0011   NRDU$
          0012   NIO1$
          0013   NIO2$
          0014   NWDU$
          0015   ALOG
          0016   EXP
          0017   NEXPA$
          0020   DSQRT
          0021   DEXP
          0022   NEXP6$
          0023   NWBU$
          0024   NRBU$
          0025   NSTOP$

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

    0000   012057 1F        0001   000567 10L       0001   000374 100L      0001   001772 1006G     0001   002003 1014G
    0001   [illegible] 1016G    0001   002020 1026G     0001   002023 1031G     0001   002075 1060G     0001   002177 1104G
    0001   002232 1120G     0001   002234 1124G     0001   002237 1131G     0001   002260 1142G     0001   002315 1153G
    0001   002337 1172G     0001   002337 1174G     0001   000547 12L       0001   002346 1203G     0001   000031 121G
    0001   002362 1210G     0001   002375 1214G     0001   002512 1242G     0001   002515 1245G     0001   002527 1250G
    0001   002606 1271G     0001   002617 1277G     0000   012066 13F       0001   002617 1301G     0001   002652 1316G
    0001   000052 133G      0001   002715 1334G     0001   002737 1353G     0001   002737 1355G     0001   002751 1365G
    0001   002762 1373G     0001   002762 1375G     0000   012073 14F       0001   002775 1403G     0001   003000 1407G
    0001   000064 141G      0001   003051 1436G     0001   003154 1462G     0001   000076 147G      0000   012075 15F
    0001   000110 155G      0001   000132 166G      0001   000641 18L       0001   001020 19L       0000   012060 2F
    0001   000754 20L       0001   001631 200L      0001   000160 202G      0001   000742 21L       0001   000177 213G
    0001   000214 222G      0001   000270 247G      0001   000302 256G      0001   000353 274G      0001   000225 3L
    0000   012077 30F       0001   000355 300G      0000   012126 31F       0001   000362 310G      0001   001513 310L
    0000   012134 32F       0001   000400 320G      0000   012146 33F       0001   000467 34L       0000   012171 35F
    0001   000427 350G      0000   012062 4F        0000   012202 40F       0001   000524 403G      0000   012265 410F
    0001   000537 412G      0000   012233 42F       0001   000604 427G      0001   000627 433G      0000   012245 44F
    0001   000652 444G      0001   000703 451G      0001   000771 470G      0001   001063 475G      0001   001231 50L
    0001   001062 506G      0001   001143 526G      0001   002556 530L      0001   001170 536G      0001   001223 55L
    0001   003077 550L      0001   001242 556G      0001   001255 562G      0001   003033 565L      0001   001275 571G
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0000   012301 585F    0001   002123 600L    0001   002051 605L    0001   001454 624G    0001   001557 627G
0001   001471 632G    0001   001133 65L     0000   012304 656F    0000   012344 655F    0001   001553 656G
0000   012404 660F    0000   012416 675F    0001   001575 675G    0001   001575 677G    0000   012064 7F
0000   012464 700F    0001   001607 707G    0001   001372 71L     0000   012507 710F    0001   001620 715G
0001   001620 717G    0000   012543 720F    0000   012565 725F    0001   001673 737G    0000   012264 75F
0001   001736 755G    0001   001760 774G    0001   001760 776G    0001   001341 79L     0001   000535 5L
0000 R 012013 A       0000 R 000016 AT      0000 R 012025 AVGAT   0000 R 012000 A1      0000 D 012002 A2
0000 R 012036 A3      0000 R 000162 B       0000 R 000171 BB      0000 R 012052 BCAL    0003 R 000013 BETA
0000 R 000207 BO      0003 R 000012 BULK    0000 R 000225 CO      0000 R 000243 D       0000 R 012045 DEV
0000 R 012034 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 001144 E11     0003 R 001620 E12
0003 R 001310 F22     0003 R 001454 F33     0000 R 000407 F       0000 R 000553 G       0000 I 012012 I
0000 I 000717 IFF     0000 I 000735 IFG     0000 I 012007 IFLAG   0000 I 000744 IFN     0000 R 012004 INT1
0000 R 012006 INT12   0000 R 012005 INT2    0003 D 002604 INV1    0003 D 003114 INV2    0003 D 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 012026 M
0003 I 000005 MATID   0000 I 012035 MP7     0000 I 012033 N       0000 I 000752 NAME    0000 I 012016 NAT
0000 I 012051 NBULKS  0003 I 000001 NDP     0000 I 011777 NEND    0003 D 004244 NORM    0003 D 003734 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 000776 P       0003 R 000002 PRES    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 000014 TEMP
0000 R 001311 TR      0000 R 001455 TSHFT   0000 R 000000 WORK1   0000 R 000007 WORK2   0000 R 012047 XRAP
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      C
00100      C *** PROGRAM NAME = NL003.
00100      C          NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE.
00100      C
00100      C     THIS CODE IS SIMILAR TO THE NL002 CODE EXCEPT THAT THE SERIES
00100      C     EXPANSION FOR THE BULK TERM EXPRESSES DILATATION
00100      C     AND THERE IS NO FINAL ERROR SUMMARY FOR S11 AND S22.
00100      C
00100      C          BULK      =    BULK MODULUS.
00100      C          BETA      =    VOLUMETRIC EXPANSION COEFFICIENT.
00100      C          EOCT      =    OCTAHEDRAL SHEAR STRAIN
00100      C          IFN       =    NORM SELECTOR, ANY ONE OR COMBINATION OF THE
00100      C                         10TH, 20TH, 30TH, 40TH, 50TH, OR 60TH NORMS.
00100      C                         ENTER A NONZERO VALUE TO INCLUDE THAT NORM .
00100      C          NPL       =    NO. OF POWER LAW TERMS.
00100      C          NAT       =    NO. OF AT VS. TSHFT INPUT DATA POINTS.
00100      C          NDP       =    NO. OF DATA PTS. FOR A SPECIFIC TEST.
00100      C          N1        =    FIRST DATA POINT USED IN THE REGRESSION ANALYSIS.
00100      C
00101            DIMENSION WORK1(7), WORK2(7)                                    *NEW
00101      C                                                                     *NEW
00103             DIMENSION AT(100), B(7), BB(14), BO(14), CO(14), D(100),
00103           1          DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00103           2          E11(100), E22(100), E33(100), E12(100), E(100), G(100),
00103           3          IFF(14), IFG(7), IFN(6), INV1(100), INV2(100),
00103           4          INV3(100), MATID(5), NAME(20), NORM(6,100), NORME(100),
00103           5          P(7), R(14,14), RATE(100), STRESS(100), STRUE(100),
00103           6          T(100), TEMP(100), TR(100), TSHFT(100), XF(14,100),
00103           7        XF1(14,100), XF2(14,100), XN(6), EOCT(100)
00103      C
00104            COMMON /INPUT/ ITEST, NDP, PRES, KTEMP, KODE, MATID, BULK, BETA,
```

```
00104          1                TEMP, RATE, DT, STRESS, DIL, T, E11, E22, E33, E12,
00104          2                STRUE, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00104          3                NORM, FOCT
00104    C
00105          DATA NEND/'END'/
00105    C
00107          DOUBLE PRECISION   A1, A2, INV1, INV2, INV3, NORMF, NORM, FOCT
00107    C
00107    C
00110          REAL     INT1, INT2, INT12
00110    C
00110    C                                                                    *NEW
00110    C        DYNAMICALLY ALLOCATE DRUM SPACE.                            *NEW
00110    C                                                                    *NEW
00111              CALL IOUNIT('DRUM',11,.75,WORK1)                          *NEW
00112              CALL IOUNIT('DRUM',12,.25,WORK2)                          *NEW
00112    C                                                                    *NEW
00112    C                                                                    *NEW
00113          IFLAG = 0
00114          IPG = 0
00114    C
00114    C          ASSIGN TAPE UNIT 9BQ.
00115          NU = 1
00116          REWIND NU
00116    C
00116    C
00116    C
00117          READ(5,1) (NAME(I),I=1,20  )
00125          READ(5,2) A,Z
00131          READ(5,75) (IFG(I),I=1,7)
00137          READ(5,75) (IFF(I),I=1,14)
00137    C
00137    C          INPUT NORM SELECTOR AND EXPONENTS.
00137    C
00145          READ(5,75) (IFN(I),I=1,6)
00153          READ(5,2)(XN(I),I=1,6)
00153    C
00153    C          INPUT POWER LAW EXPONENTS AND COEFFICIENTS.
00161          READ(5,75)      NPL
00164          READ(5,2)( P(I), B(I), I=1,NPL    )
00164    C
00173          CALL PAGNL(IPG, NAME)
00174          WRITE(6,32) A,Z
00200          WRITE(6,40)(I, B(I),  P(I), IFG(I), I=1,7)
00211          WRITE(6,42)( I, IFF(I),I=1,14)
00220          WRITE(6,44)( I, IFN(I), XN(I),I=1,6)
00220    C
00220    C          INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE, TSHFT, COLD TO HOT.
00220    C
00230          NAT = 0
00231      3   NAT = NAT + 1
00232          READ(5,4)  TSHFT(NAT),  AT(NAT), LAST
00237          IF(LAST.EQ.0) GO TO 3
00241          CALL PAGNL(IPG, NAME)
00242          WRITE(6,30)  NAT
00245          WRITE(6,31)(I, AT(I), TSHFT(I), I=1,NAT)
00245    C
00245    C          COMPUTE   SLOPE, n, AT EACH INPUT POINT.
00245    C
00255          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
00266   96*          NTEST = 0
00265   97*          REWIND 11
00266   98*          REWIND 12
00267   99*          LTNF = 0
00270  100*          CALL PAGNL(IPG, NAME)
00271  101*          WRITE(6,33)
00273  102*          DO 110 I=1,14
00276  103*          RR(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
00312  111*    110   CONTINUE
00312  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*          DR1(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
```

```
00361          LINE = LINE + 1
00362          IF(LINE.LE.50) GO TO 34
00364          CALL PAGNL(IPG, NAME )
00365          WRITE(6,33)
00367          LINE = 0
00370     34   CONTINUE
00371          WRITE(6,35) NTEST,ITEST,NDP,KODE,KTEMP,PRES,TEMP(1)
00371     C
00371     C        COMPUTE THE REDUCED TIME, TR.
00371     C
00402          DO 8 I=N1,NDP
00405          IF(I.EQ.N1) GO TO 9
00407 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00407          IF(TEMP(I).EQ.TEMP(I-1)) GO TO 10
00411      9   DO 11 J=1,NAT
00414          IF(TEMP(I).LT.TSHFT(J)) GO TO 12
00416     11   CONTINUE
00420     12   AVGAT = ( EXP(LOG(AT(J-1)) + D(J)*(TEMP(I) - TSHFT(J-1) )) )
00421     10   TR(I) = TR(I-1)  +  DT(I)/AVGAT
00422      8   CONTINUE
00422     C
00422     C
00422     C        IF TEMP IS CONSTANT READ 10TH THRU 60TH NORMS, OTHERWISE
00422     C        COMPUTE THEM BASED ON THE REDUCED TIME, TR.
00422     C
00424          IF(KTEMP.EQ.2) GO TO 18
00424     C
00424     C
00424     C        IF A CONSTANT TEMP TEST, MULTIPLY THE PTH NOTM BY (1/AT)**1/P.
00424     C
00426          DO 60 M=1,6
00431          XP = 1.0/(10*M)
00432          DO 60 I=1,NDP
00435          NORM(M,I) = NORM(M,I)*((1./AVGAT)**XP)
00436     60   CONTINUE
00441          GO TO 19
00442     18   CONTINUE
00442     C
00443          DO 20 M=1,6
00446          XP = 1.0+10.*M
00447          XQ = 10.*M
00450          DO 20 I=N1,NDP
00453          DTR = TR(I) - TR(I-1)
00454          A1 = DABS(INV2(I))
00455          A2 = DABS(INV2(I-1))
00456 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00456          IF(A1.EQ.A2) GO TO 21
00460          NORM(M,I) = NORM(M,I-1) + (A1**XP-A2**XP)/(XP*(A1-A2)/DTR  )
00461          GO TO 20
00462     21   CONTINUE
00463          NORM(M,I) = NORM(M,I-1) + (A1**XQ)*DTR
00464     20   CONTINUE
00464     C
00467          DO 22 M=1,6
00472          XP = M*10.
00473          XP = 1./XP
00474          DO 22 I=N1,NDP
00477          NORM(M,I) = NORM(M,I)**XP
00500     22   CONTINUE
00500     C
```

```
00503   19  CONTINUE
00503   C
00503   C        FORM CONSTITUTIVE EQUATIONS FOR THIS TEST.
00503   C
00503   C
00503   C        COMPUTE THE FACTORS F, G, AND XF(1,I).
00503   C
00504           F(1) = 0.0
00505           DO 65 I=N1,NDP
00510           XF1(1,I) = F11(I)
00511           XF2(1,I) = E22(I)
00512           XF(1,I) = F11(I) - F22(I)
00513           G(I) = (1.0 - DABS(INV2(I))/NORMF(I)  ) **Z
00514           F(I) = DEXP(A*INV3(I)/(DSQRT(DABS(INV2(I)))))
00515           IF(IFF(1).EQ.0) GO TO 65
00517           XF1(1,I) = XF1(1,I)*F(I)
00520           XF2(1,I) = XF2(1,I)*F(I)
00521           XF(1,I) = XF(1,I)*F(I)
00522   65  CONTINUE
00522   C
00522   C        COMPUTE THE NORM TERMS.
00522   C
00524           NORMS = 0
00524   C
00525           DO 50 K=1,6
00530           M = IFN(K)
00531           IF(M.EQ.0) GO TO 50
00533           NORMS = NORMS + 1
00534           N = NORMS + 1
00535           DO 55 J=N1,NDP
00540           DI = ( DABS(INV2(J))/NORM(M,J) )**N(K)
00541           XF1(N,J) = XF1(1,J)*DI
00542           XF2(N,J) = XF2(1,J)*DI
00543           XF(N,J) = XF(1,J)*DI
00544           IF(IFF(N).EQ.0) GO TO 55
00546           XF1(N,J) = XF1(N,J)*F(J)
00547           XF2(N,J) = XF2(N,J)*F(J)
00550           XF(N,J) = XF(N,J)*F(J)
00551   55  CONTINUE
00551   C
00553   50  CONTINUE
00553   C
00553   C
00553   C        COMPUTE THE POWER LAW (INTEGRALS) TERMS.
00553   C
00555           DO 70 M=1, NPL
00560           MP7 = M + 7
00561           DO 70 J=N1,NDP
00564           A3 = P(M) + 1.
00565           INT1 = 0.0
00566           INT2 = 0.0
00567           INT12 = 0.0
00570           DO 71 K=N1,J
00573           IF(MODE.EQ.3) GO TO 78
00575           INT1 = INT1 - (DR1(K)/(P(M)*A3))*((1. + P(M)*(TR(J)-TR(K)))**A3
00575          1          - (1. + P(M *(TR(J)-TR(K-1)))**A3 )
00576           INT2 = INT2 - (DR2(K)/(P(M)*A3))*((1. + P(M)*(TR(J)-TR(K)))**A3
00576          1          - (1. + P(M)*(TR(J)-TR(K-1)))**A3 )
00577           GO TO 71
00600   78  CONTINUE
```

```
00601   270*          INT12= INT12- (DP12(K)/(R(M)*A3))*((1. + R(M)*(TR(J)-TR(M)))**A3
00601   271*        1          - (1. + R(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 R, AND SOLUTION VECTOR RR.
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.R.0 ) GO TO 310
00636   290*              R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/STRUE(I)**2
00637   291*              IF(J.GT.1)  GO TO 310
00641   292*              RR(K) = RR(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
00675   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, RR, 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(6,650) L
00746   331*             READ(11)  NDP, KODE, PRES
00753   332*             READ(11) (DIL(I), F11(I), F12(I),FOCT(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=1,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(NCASE.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 PAGEL(IPG, NAME)
01070   355*        WRITE(6,650) 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 PAGEL( IPG, NAME )
01102   364*        WRITE(6,700)(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 GET 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 R AND RR
01116   372*   C
01117   373*        DO 505 K=1,14
01122   374*        RR(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*        R(K,J) = 0.0
01134   380*   505  CONTINUE
01137   381*             REWIND 11
01140   382*             REWIND 12
01141   383*        DO 509 L=1,NTEST
01144   384*             READ(11)  NDP, KODE, PRES
01151   385*             READ(11) (DIL(I), F11(I), F12(I),FOCT(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      501  STRESS(I) = 0.0
01205      C
01205      C
01207           DO 510 I=N1,NDP
01212           STRESS(I) = STRUE(I)/2. - PRES
01213           DO 515 K=1,NTERMS
01216           STRESS(I) = STRESS(I) - CO(K)*XF1(K,I)/2  - CO(K)*XF2(K,I) /2
01217      515  CONTINUE
01217      C
01217      C          XF NOW BECOMES SOLUTION MATRIX FOR THE NBULKS TERMS.
01217      C
01221           XF(1,I) = STRESS(I)
01222           XF(2,I) = STRESS(I)**2
01223           XF(3,I) = STRESS(I)**3
01224           XF(4,I) = STRESS(I)**4
01225           XF(5,I) = FOCT(I)
01226           XF(6,I) = FOCT(I)**2
01227           XF(7,I) = FOCT(I)**3
01230           XF(8,I) = FOCT(I)**4
01231           XF(9,I) = (EXP(.01*STRESS(I)))*FOCT(I)
01232           XF(10,I) = (EXP(.01*STRESS(I)))*FOCT(I)**2
01233           XF(11,I) = (EXP(.01*STRESS(I)))*FOCT(I)**3
01234           XF(12,I) = (EXP(.02*STRESS(I)))*FOCT(I)
01235           XF(13,I) = (EXP(.02*STRESS(I)))*FOCT(I)**2
01236           XF(14,I) = (EXP(.02*STRESS(I)))*FOCT(I)**3
01237      510  CONTINUE
01237      C
01237      C          FORM PRIMARY MATRIX R, AND SOLUTION VECTOR RR.
01237      C
01237      C
01241           DO 520 K=1,NBULKS
01244           DO 520 J=1,NBULKS
01247              DO 530 I=N1,NDP
01252              IF(ABS(STRESS(I)).LT.0.0 ) GO TO 530
01254           IF(ABS(DIL(I)).LT.3.E-4) GO TO 530
01256           R(K,J) = R(K,J) + XF(K,I)*XF(J,I)/DIL(I)**2
01257              IF(J.GT.1) GO TO 530
01261           RR(K) = RR(K) + XF(K,I)/DIL(I)
01262      530      CONTINUE
01264      520  CONTINUE
01264      C
01267              WRITE(12)  (STRESS(I), I=1,NDP)
01275              WRITE(12)  (( XF(K,I),K=1,14),I=1,NDP)
01275      C
01306      500  CONTINUE
01306      C
01310              REWIND 11
01311              REWIND 12
01311      C
01312              CALL REGR( NBULKS, RR, RO, R )
01312      C
01312      C          FINAL STRESS AND ERROR CALCULATIONS.
01312      C
01313           SUM = 0.0
01314           RESID = 0.0
01315           DO 550 L=1,NTEST
01320           LINE = 0
01321           CALL PAGHL( IPG, NAME )
01322           WRITE(6,655) L
01325              READ(11)  NDP, 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( 5F10.3, I5)
01500   491*   13   FORMAT(A6, E14.4, 2I5, 5A4, 2F15.4)
01501   492*   14   FORMAT(1P6F12.4)
01502   493*   15   FORMAT(1P3F20.6)
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,'KODE',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,I1,5X,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,I1, 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*    588  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,'E1 OR E12', T39,'DV/V0', T49,
01516   514*        2    'STRUE',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,'SB-CALC',T49,'DIL',T60,
01517   517*        2        'DIL-CALC.',T70,'ERROR',T95,'XF(K),K=1,NBULKS',/)
01520   518*    660  FORMAT(1H ,/,5X,7E10.4,T80,'*',5F10.4,2(/,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 ...',//,  'X','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 ', F10.4, ///, 10X,
01523   527*        2         'THE STANDARD DEVIATION, STD, WAS ', F10.4  )
01524   528*    720  FORMAT(1H ,5(/),20X,'FOR THE STRESS SIGMA-11, ...',///,20X,
01524   529*        1        'XBAR = ',F10.4,5X,'AND STD = ', F10.4, //)
01525   530*    725  FORMAT(1H , 5(/), 20X,'FOR THE STRESS SIGMA-22, ...',///,20X,
01525   531*        1        'XBAR = ', F10.4, 5X, 'AND STD = ', F10.4 )
01525   532*  C
01526   533*        END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

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SINGLE WORD HOLLERITH STRINGS------
DRUM  :   0111   0112
END   :   0105

NAMES------
A     :   0125   0174   0514
ABS   :   0634  01037  01252  01254  01415  01417
AT    :   0103   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     :   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
DTR   :   0453   0460   0463
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ECCT  :  0103  0104  0107  0654  0753  01151 01225 01226 01227 01230 01231 01232 01233 01234 01235 01236 01332
         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  0303  0304
         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  0452
         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 01216 01221 01222 01223 01224 01225 01226 01227
         01230 01231 01232 01233 01234 01235 01236 01247 01252 01254 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 01120 01123 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  0565  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
NBULKS:  01116 01241 01244 01312 01406 01425 01460
NOP   :  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 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
```

```
LTOT  :  0733  01023  01077  01100  01111  01455  01456  01467
TD    :  0115  0116   0356
T1    :  0360  0402   0405   0450   0474   0505   0535   0561   0570   0631   01024  01207  01247  01402
F     :  0103  0164   0200   0364
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
REGR  :  0732  01312
RESID :  0736  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  01233  01236  01235
         01236  01252  01267  01363  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   0245   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
XN    :  0103   0153   0220   0549
XP    :  0431   0435   0446   0460   0472   0473   0477
XU    :  0447   0463
Z     :  0125   0174   0513

LABELS-------
     1:  0117  01474
     2:  0125  0153   0164  01475
     3:  0231  0237
     4:  0232  01476
     5:  0251  0261
     7:  01[illegible]
     8:  04[illegible]  0422
     9:  0400  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  01513
   78:  0573  0600
  100:  0316  0726
  105:  0277  0305
  107:  0317  1347  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
  506:  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  0544  0606  0610  0612  0614  0733
        0741  01073  01320  01451
    1:  0115  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  0452  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  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  01222  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  0347
        0525  0743  01047  01070  01102  01111  01226  01322  01425  01446  01460  01467
    7:  0101  0103  0131  0200  0563  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.

```
                VRONAY,4/5/,2,1,100                                                  15 JUN 73   09:24:58   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  000000


   EXTERNAL REFERENCES (BLOCK, NAME)

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


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

    0000   000001 1F        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
```

```
                    VRONAY,4,5772,1,100                                          15 JUN 73   09:24:50   PAGE    4
@I FOR REGR,REGR                                                                 15 JUN 73   00:00:00.833
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  09:24(00)
FORTRAN V:  ISO VERSION 2.6

   SUBROUTINE REGR       ENTRY POINT 000257

   STORAGE USED (BLOCK, NAME, LENGTH)

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


   EXTERNAL REFERENCES (BLOCK, NAME)

         0003   PAGNL
         0004   EXIT
         0005   N*DUS
         0006   NIO2S
         0007   NERR3S


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

    0001   000016 111G      0001   000025 116G      0001   000047 125G      0001   000070 134G      0001   000077 142G
    0001   000121 151G      0001   000167 175G      0001   000173 201G      0001   000215 210G      0001   000222 215G
    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
00101     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 = ', 1PF12.4 )
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)
00114    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.D0) GO TO 400
00132   28*          R(K,K) = 1.D0
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.D0
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 FAGNL(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.D0
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   NIOZS
        0005   NIOIS
        0006   NERR3S


   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 = ', E10.0, ' PSIG',/,T95,
 00134    27*        3       'TEMPERATURE IS ', A8 )
 00134    28*   C
 00135    29*         RETURN
```



```
 00136    30*         END
```

* CROSS REFERENCE BY SEQUENCE NUMBER *

```
                VPCNAY,425772,1,100                                                    15 JUN 73   09:24:58   PAGE    9
 LT FOR BUFFER,BUFFER                                                                  15 JUN 73   00:00:03.165
 DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  09:24(00)
 FORTRAN V:  ISD VERSION 2.5

   SUBROUTINE BUFFER    ENTRY POINT 000465

   STORAGE USED (BLOCK, NAME, LENGTH)

         0001   *CODE   000507
         0000   *DATA   013353
         0002   *BLANK  000000
         0003   INPUT   007034


   EXTERNAL REFERENCES (BLOCK, NAME)

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


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

    0000   010505 1F        0001   000044 10L       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 99GL      0000 R 010531 B         0003 R 000013 BETA
    0003 R 000012 BULK      0000 D 000000 DB        0003 R 000634 DIL       0003 R 002130 DR1       0003 R 002440 DR12
    0003 R 002274 DR2       0003 R 000324 DT        0003 D 006524 EOCT      0003 R 001144 E11       0003 R 001620 E12
    0003 R 001310 F22       0003 R 001454 F33       0000 I 010504 I         0000 I 010531 IB        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 LQ        0003 I 000005 MATID
    0000 I 010477 MTEST     0000 I 010460 N         0003 I 000001 NDP       0000 I 010476 NEND      0003 D 004244 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 B(1400), IB(1400), DB(2200), N(14)
00104     8*         DIMENSION      DIL(100), DR1(100), DR2(100), DR12(100), DT(100),
00104     9*        1               E11(100), F22(100), F33(100), F12(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 DB, 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, F22, E33, E12,
```

```
00106          2                STRUE, DR1, DR2, DR12, INV1, INV2, INV3, NORMF,
00106          3                NORM, FOCT
00106    C
00107          EQUIVALENCE ( R(1), IR(1) )
00107    C
00110          DATA NEND/'END'/
00110    C
00112          IF(IFLAG.EQ.1) GO TO 10
00114     50   CONTINUE
00115          READ(5,1) MTEST
00120          IF(MTEST.EQ.NEND) GO TO 200
00120    C
00120    C
00122              CALL NTRAN(NU,4,MTEST,1400,R,LD)
00123              CALL NTRAN(NU,2,2200,DR,LD)
00123    C
00123    C
00124          IF(IFLAG.EQ.1) RETURN
00126     10   IF(LD+1) 999,10,20
00131     20   CONTINUE
00131    C
00131    C         LOAD SINGLE PRECISION/INTEGER ARRAYS.
00131    C
00132          ITEST = IR(1)
00133          NDP = IR(2)
00134          PRES = R(3)
00135          KTEMP = IR(4)
00136          KODE = IR(5)
00137          DO 21 K=1,5
00142          J = K+5
00143     21   MATID(K) = IR(J)
00145          BULK = R(11)
00146          BETA = R(12)
00146    C
00147          DO 22 I=1,14
00152     22   N(I) = 12 + (I-1)*NDP
00152    C
00154          DO 100 I=1,NDP
00157          J = N(1)
00160          TEMP(I)    = R(J+I)
00161          J = N(2)
00162          RATE(I)    = R(J+I)
00163          J = N(3)
00164          DT(I)      = R(J+I)
00165          J = N(4)
00166          STRESS(I) = R(J+I)
00167          J = N(5)
00170          DTL(I)     = R(J+I)
00171          J = N(6)
00172          T(I) =        R(J+I)
00173          J = N(7)
00174          E11(I)     = R(J+I)
00175          J = N(8)
00176          E22(I)     = R(J+I)
00177          J = N(9)
00200          E33(I)     = R(J+I)
00201          J = N(10)
00202          E12(I)     = R(J+I)
00203          J = N(11)
00204          STRUE(I)   = R(J+I)
```

```
00205          J = N(12)
00206          DR1(I)     = B(J+I)
00207          J = N(13)
00210          DR2(I)     = B(J+I)
00211          J = N(14)
00212          DR12(I)    = B(J+I)
00213      100 CONTINUE
00213    C
00213    C          LOAD DOUBLE PRECISION ARRAYS.
00213    C
00215          DO 23 I=1,11
00220       23 N(I) = (I-1)*NDP
00220    C
00222          DO 110 I=1,NDP
00225          J = N(1)
00226          INV1(I) = DB(J+I)
00227          J = N(2)
00230          INV2(I) = DB(J+I)
00231          J = N(3)
00232          INV3(I) = DB(J+I)
00233          J = N(4)
00234          NORMF(I)= DB(J+I)
00235          J = N(5)
00236          FCCT(I) = DB(J+I)
00237          IF(KTEMP.EQ.2) GO TO 110
00241          J = N(6)
00242          NORM(1,I) = DB(J+I)
00243          J = N(7)
00244          NORM(2,I) = DB(J+I)
00245          J = N(8)
00246          NORM(3,I) = DB(J+I)
00247          J = N(9)
00250          NORM(4,I) = DB(J+I)
00251          J = N(10)
00252          NORM(5,I) = DB(J+I)
00253          J = N(11)
00254          NORM(6,I) = DB(J+I)
00255      110 CONTINUE
00255    C
00257          IFLAG = 1
00260          GO TO 50
00260    C
00260    C          ALL DONE.  RETURN WITH LAST TEST AND DO NOT REENTER.
00260    C
00261      200 CONTINUE
00262          IFLAG = 2
00263          RETURN
00263    C
00264      999 CONTINUE
00265          WRITE(6,2) LQ, LD
00271          CALL EXIT
00271    C
00272        1 FORMAT(A6)
00273        2 FORMAT(1H1, 10(/),30X,'T A P E   E R R O R . . .',//,
00273         1        T60,'LQ = ', I5,//,T60,'LD = ', I5,///,'JOB TERMINATED',/)
00273    C
00274          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
CH     :  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
CT     :  0104  0106  0164
EOCT   :  0104  0105  0106  0236
EXIT   :  0271
E11    :  0104  0106  0174
E12    :  0104  0106  0202
E22    :  0104  0106  0176
E33    :  0104  0106  0200
I      :  0147  0152  0154  0160  0162  0164  0166  0170  0172  0174  0176  0200  0202  0204  0206  0210  0212
          0215  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  :  0166  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
```

```
                    VRONAY,[illegible]5772,1,100                                    15 JUN 73   09:[illegible]   PAGE   1[illegible]

 ET FOR POST,POST                                                                   15 JUN 73   00:00:05.439
 DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73  09:[illegible](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   NPF$
          0010   NWDU$
          0011   NIO2$
          0012   NSTOP$


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

     0001   000115 100L      0001   000042 125G      0001   000147 156G      0001   000221 200L      0000   000020 4F
     0000   000070 5F        0001   000006 50L       0000   000101 6F        0000   000145 7F        0003 R 000013 BETA
     0003 R 000012 BULK      0003 R 000634 DIL       0003 R 002130 DR1       0003 R 002440 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 F33       0000 I 000016 I         0000 I 000013 IFLAG     0003 D 002604 INV1      0003 D 003114 INV2
     0003 D 003424 INV3      0000 I 000014 IPG       0000 D 000000 ITEMP     0003 I 000000 ITEST     0000 D 000004 ITYPE
     0000 I 000017 K         0003 I 000004 KODE      0003 I 000003 KTEMP     0000 I 000015 LINE      0003 I 000005 MATID
     0003 I 000001 NDP       0003 D 004244 NORM      0003 D 003734 NORMF     0000 I 000012 NU        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
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), F33(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,NDP
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,NDP
00160   53*         K = I-1
00161   54*         WRITE(6,7) K, T(I), INV1(I), INV2(I), INV3(I), DIL(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,F15.4 )
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    78*        3       T114,'STRAIN', //)
00210    79*    7    FORMAT(1H , T10,I4, T20,F10.3, T37,3F15.4, T92,F10.4, T112,F10.4 )
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
F22   :   0101   0104   0130
F33   :   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
STRUE :   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

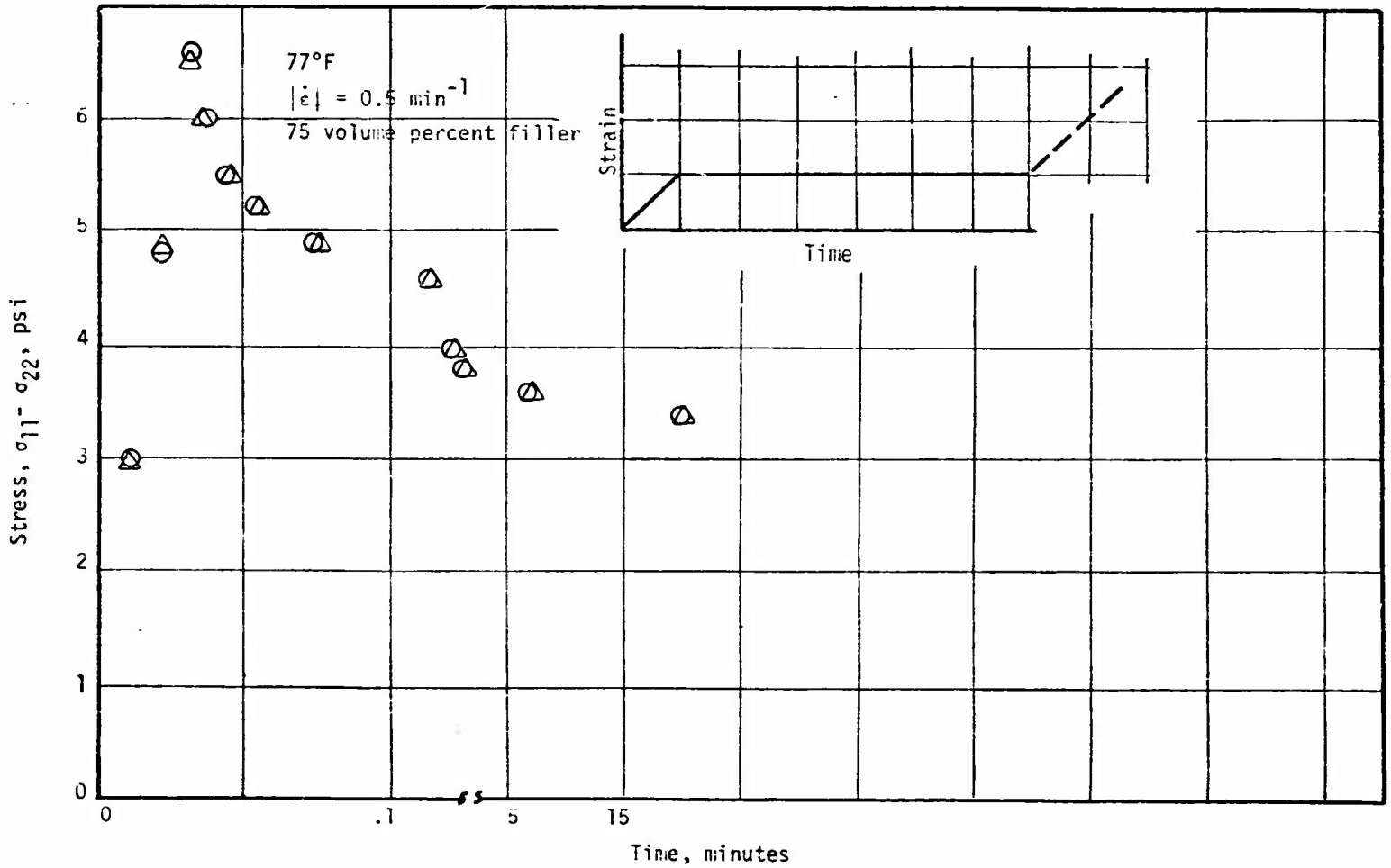

Figure 1

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

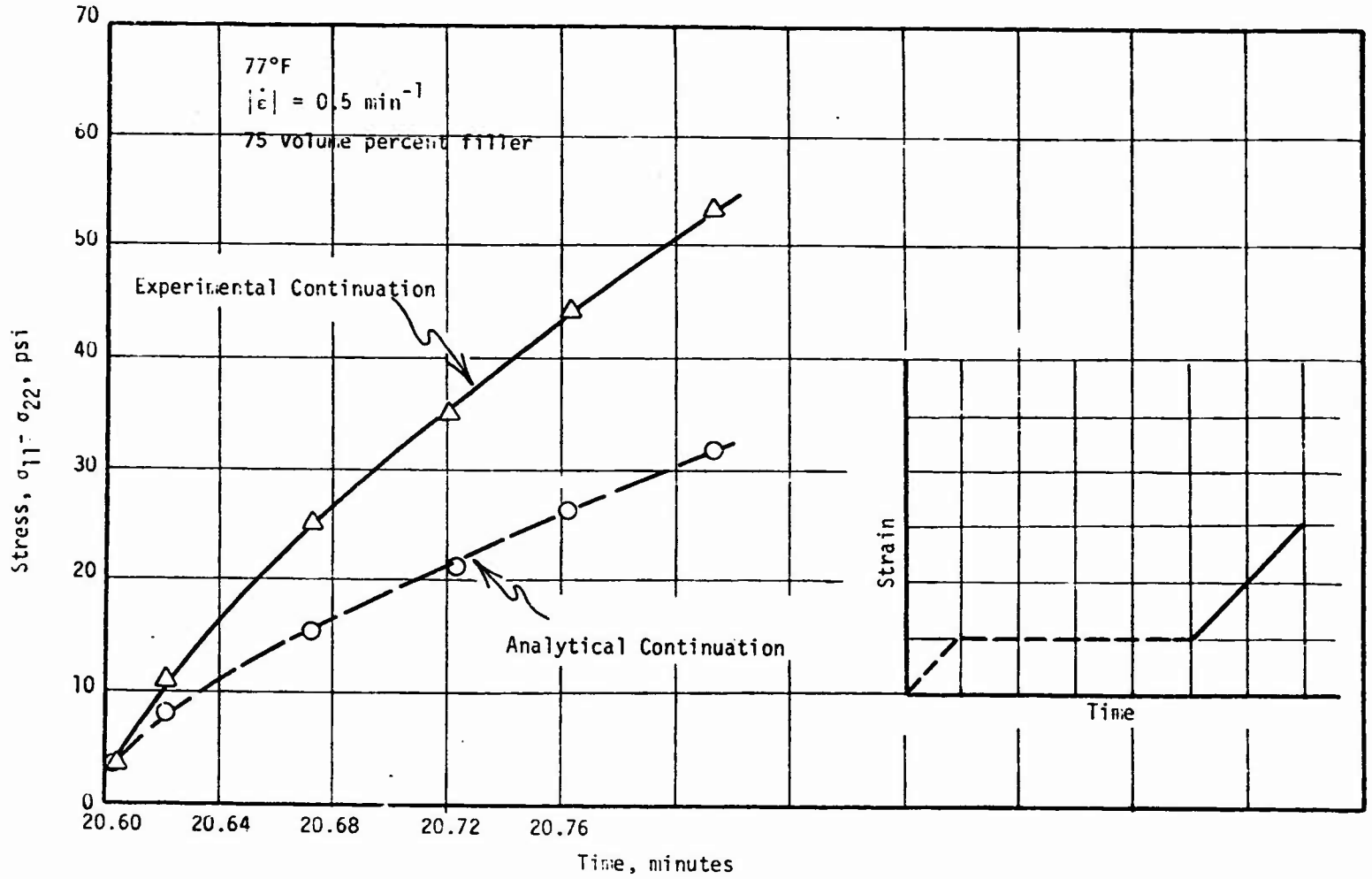

Figure 2

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

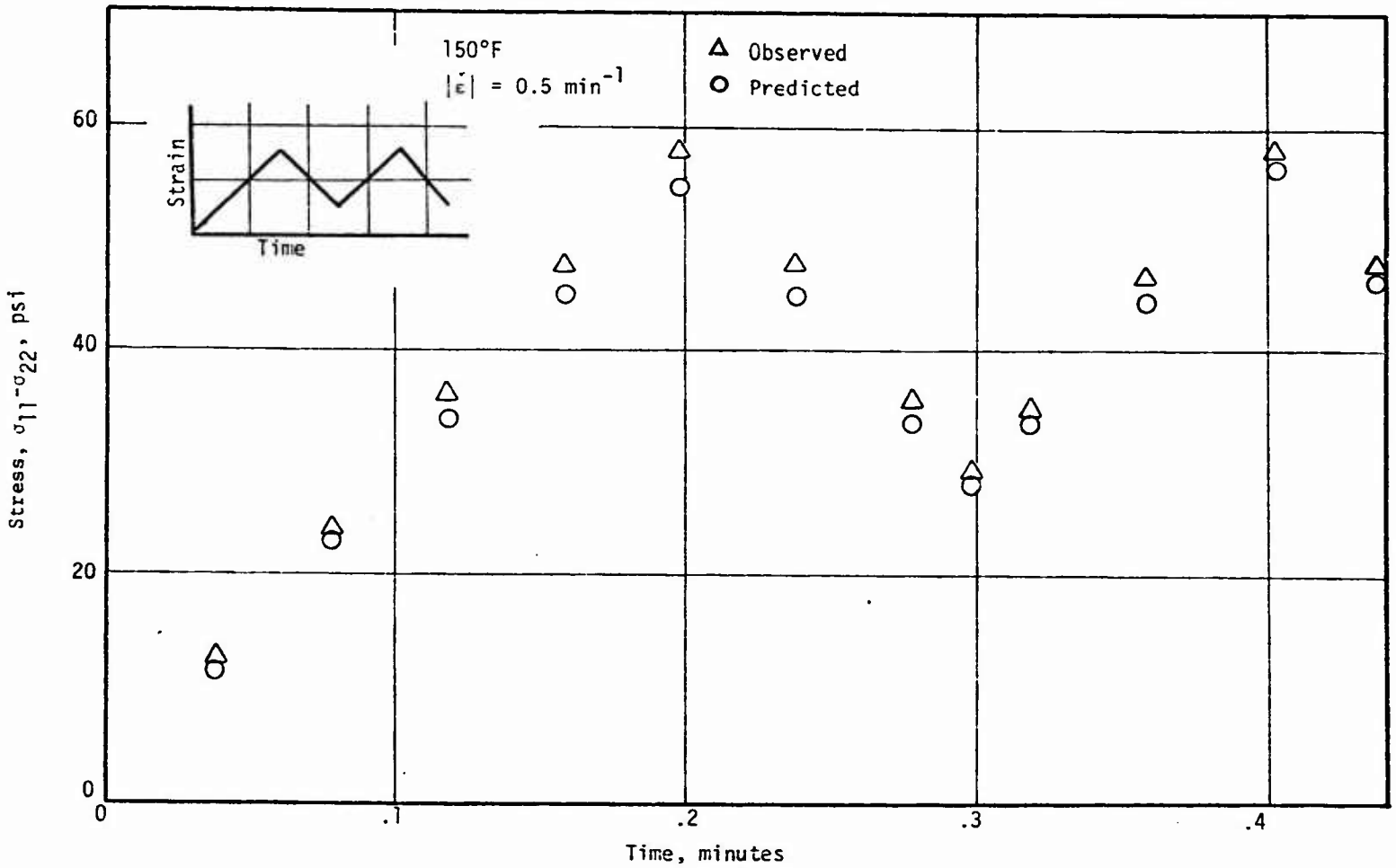

Figure 3

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

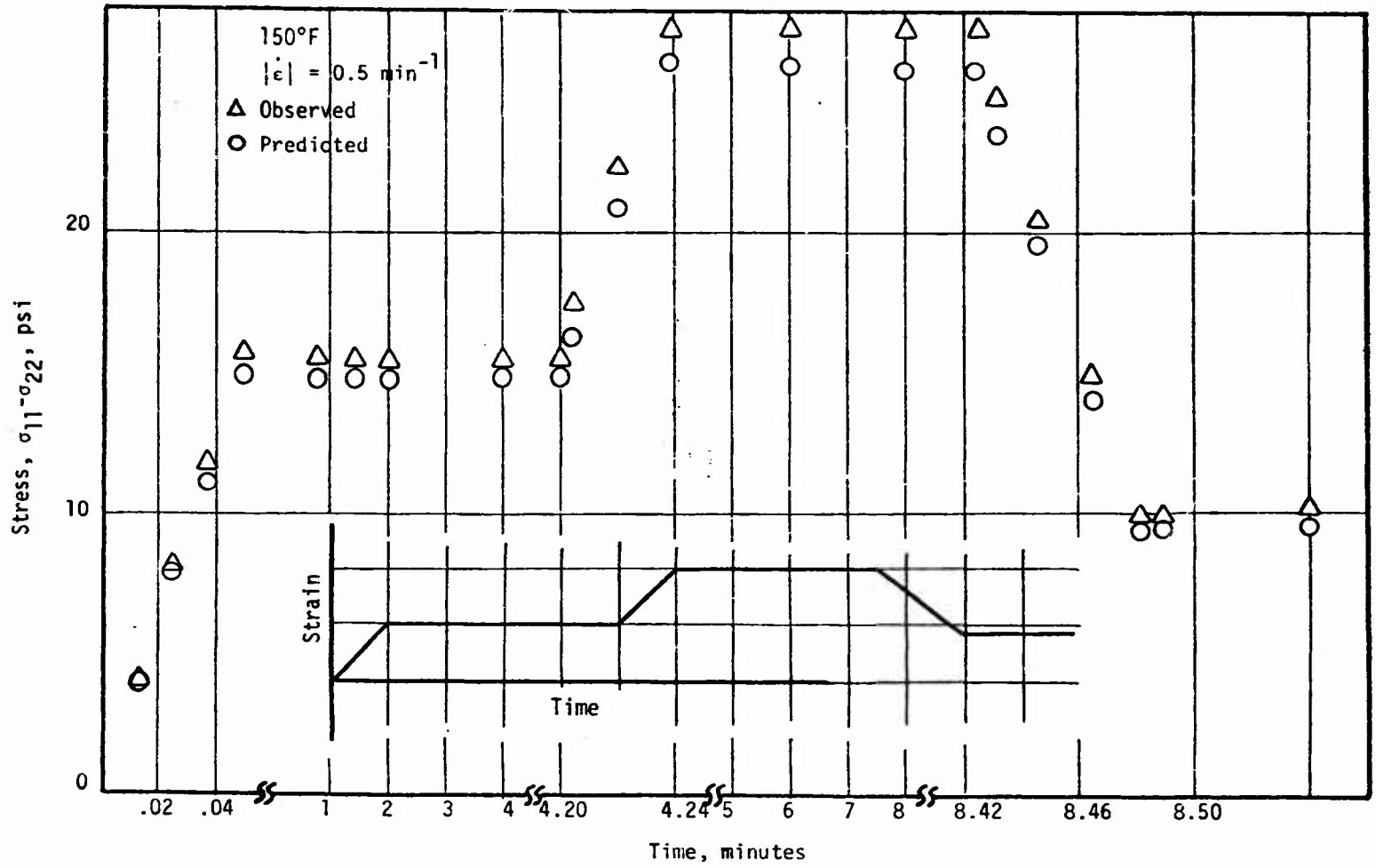

Figure 4

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

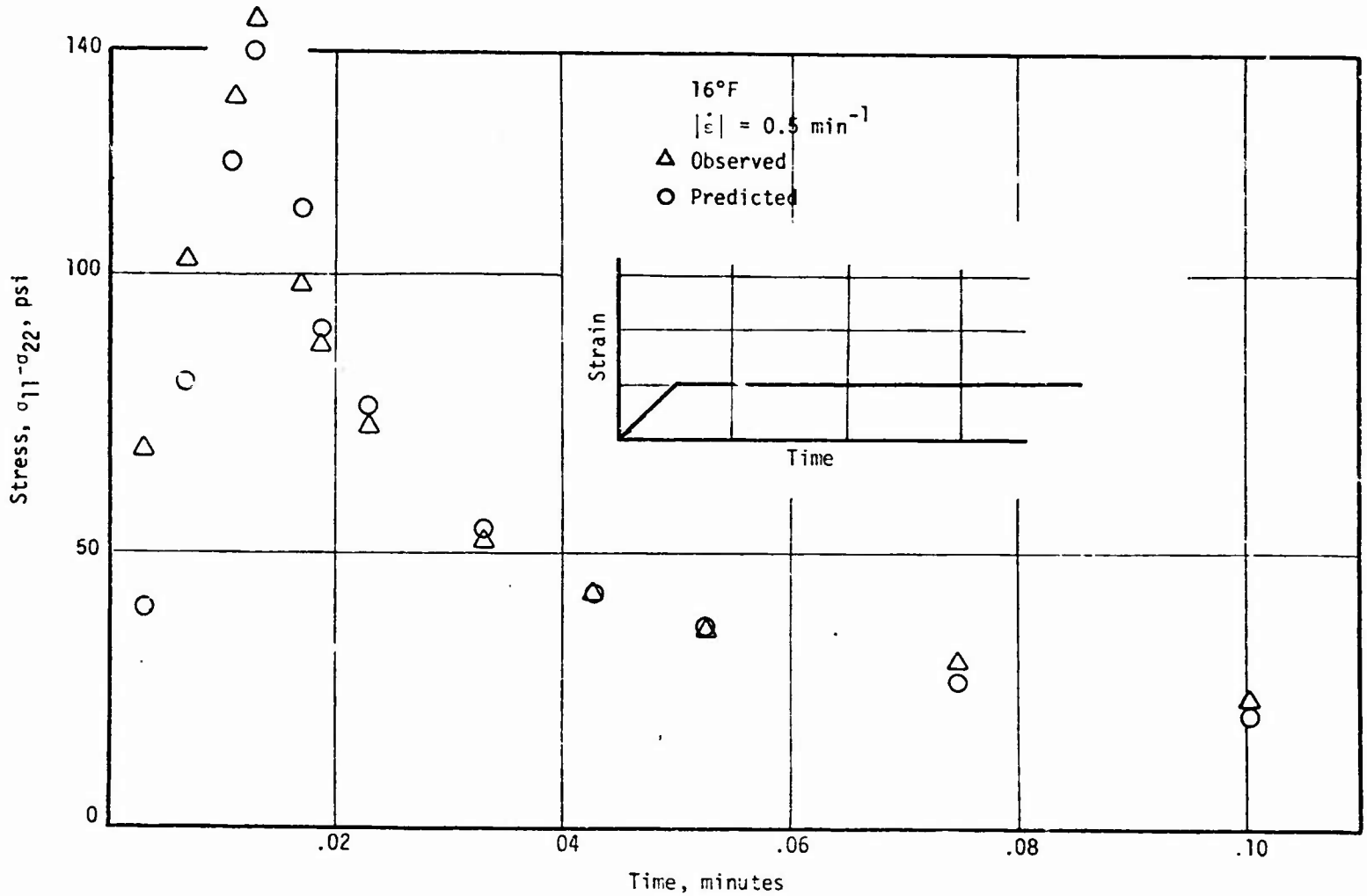

Figure 5

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

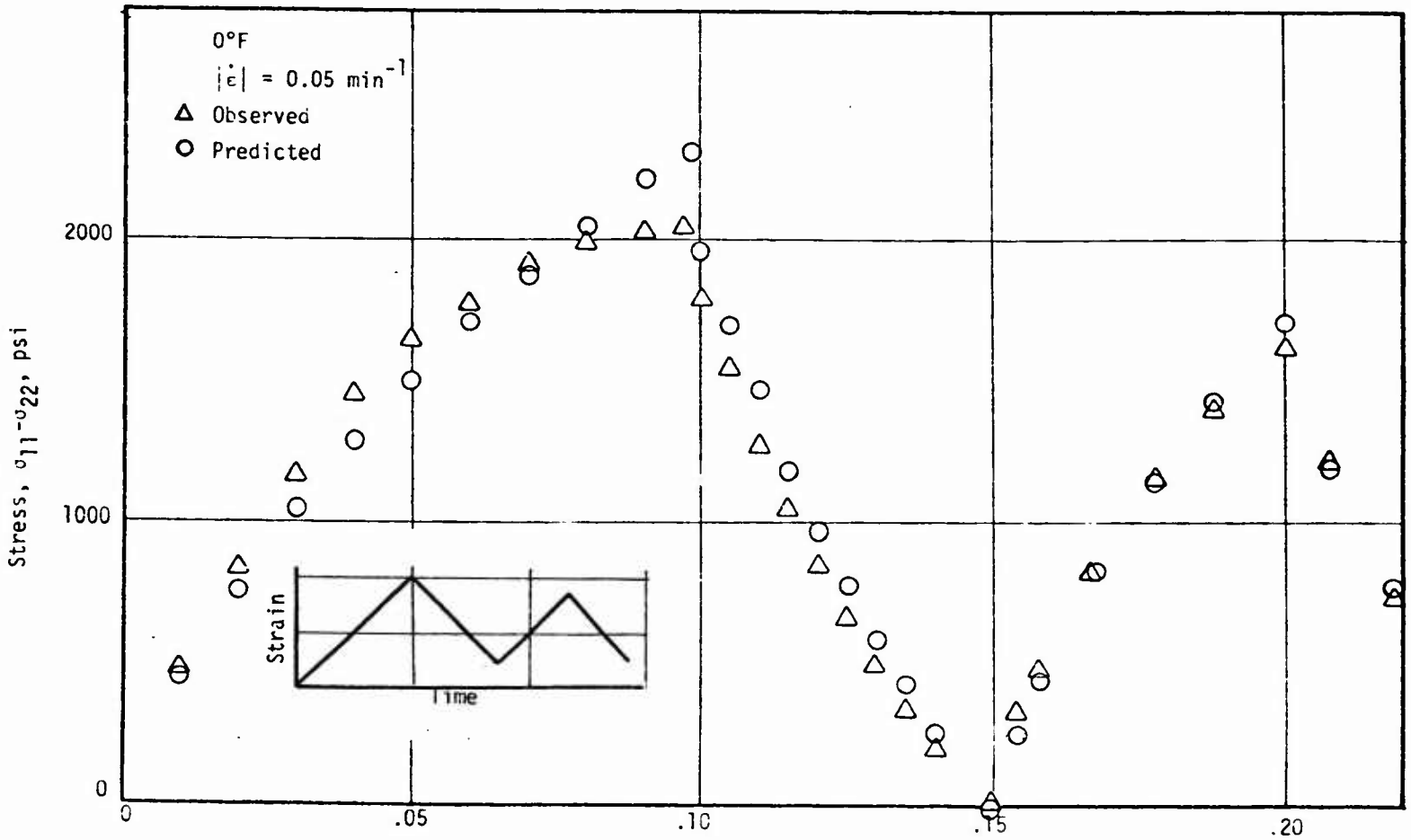

Figure 6

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

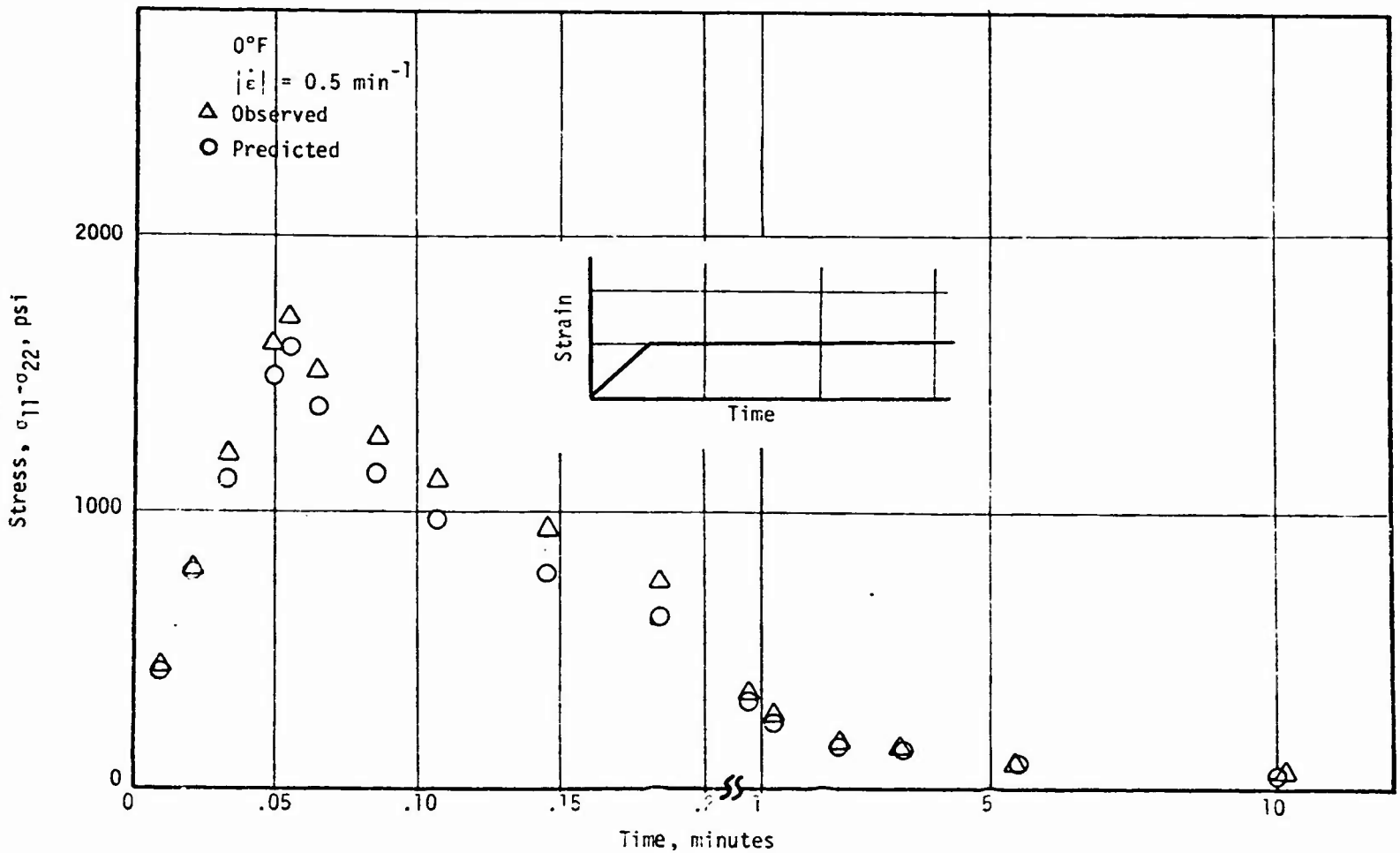

Figure 7

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

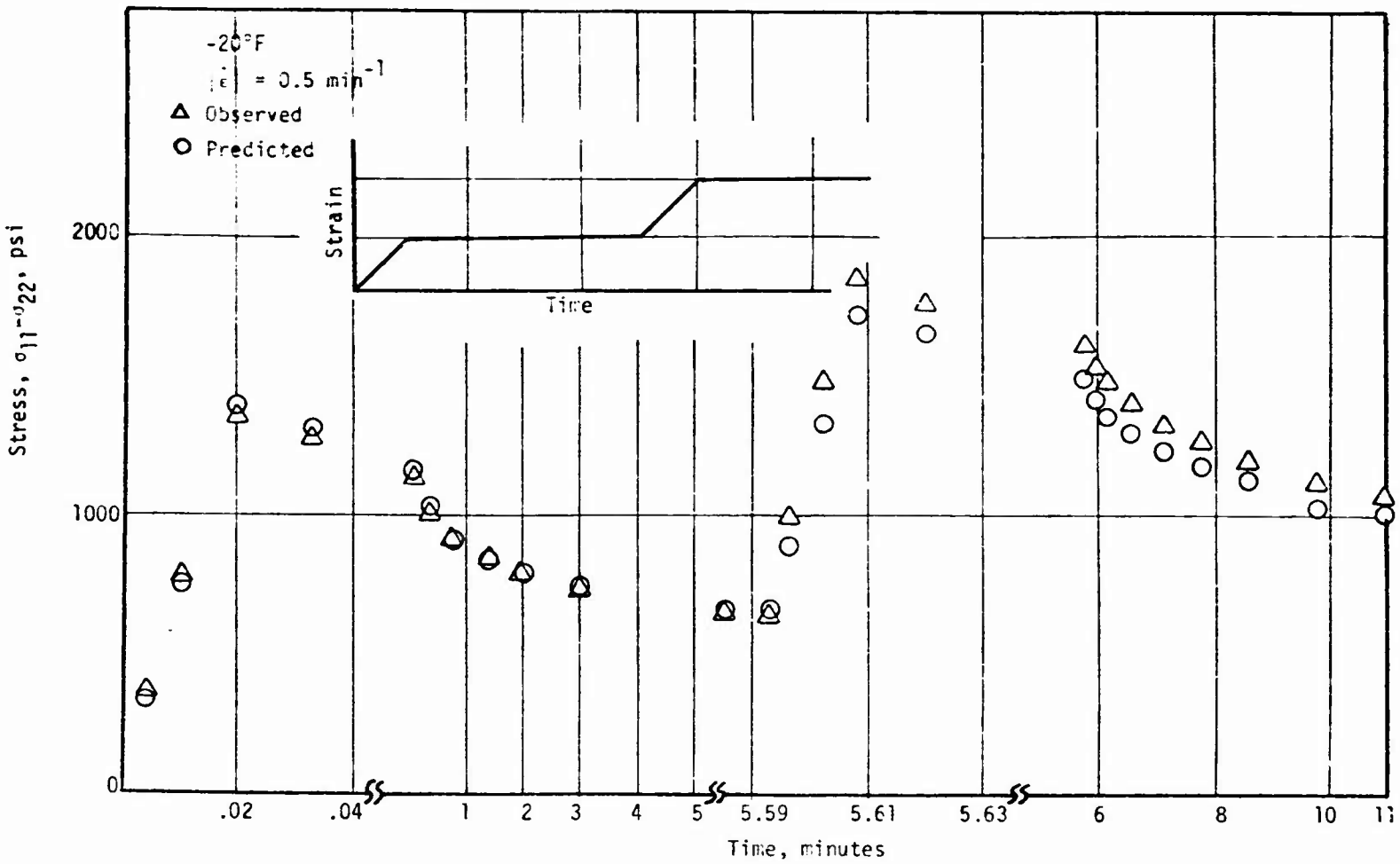

Figure 8

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

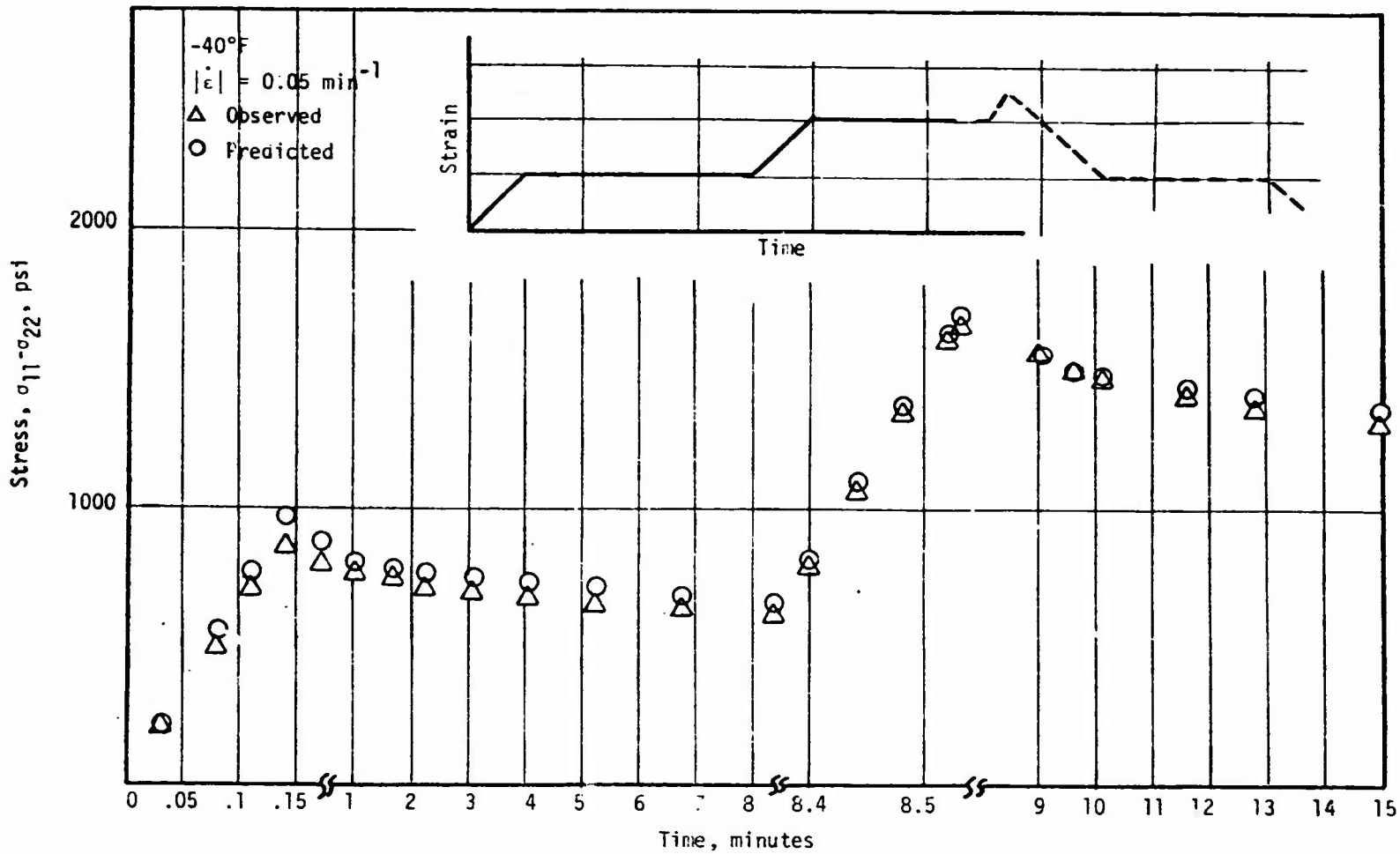

Figure 9

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

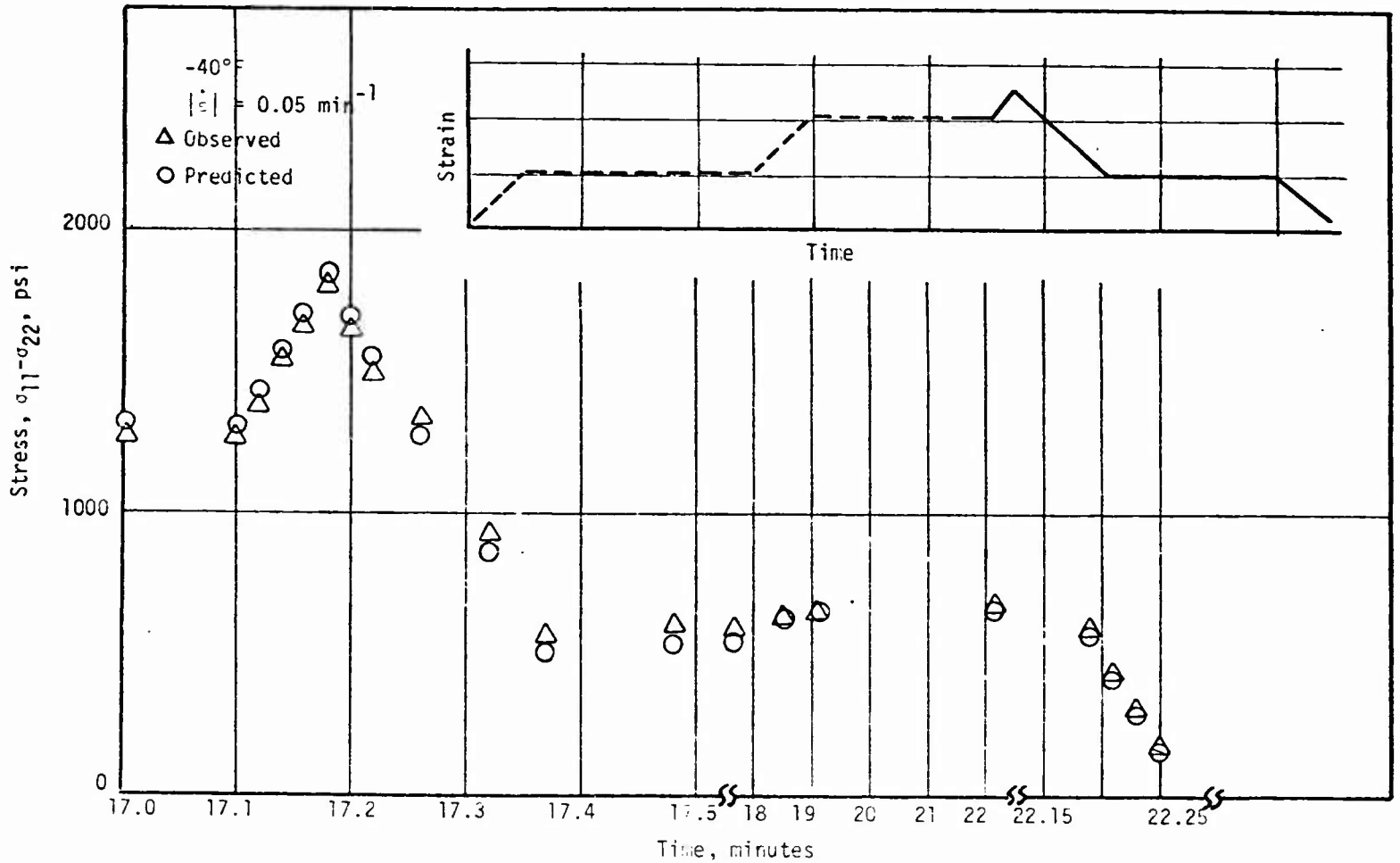

Figure 10

COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS
AND EXPERIMENTAL DATA FOR SOLITHANE 113

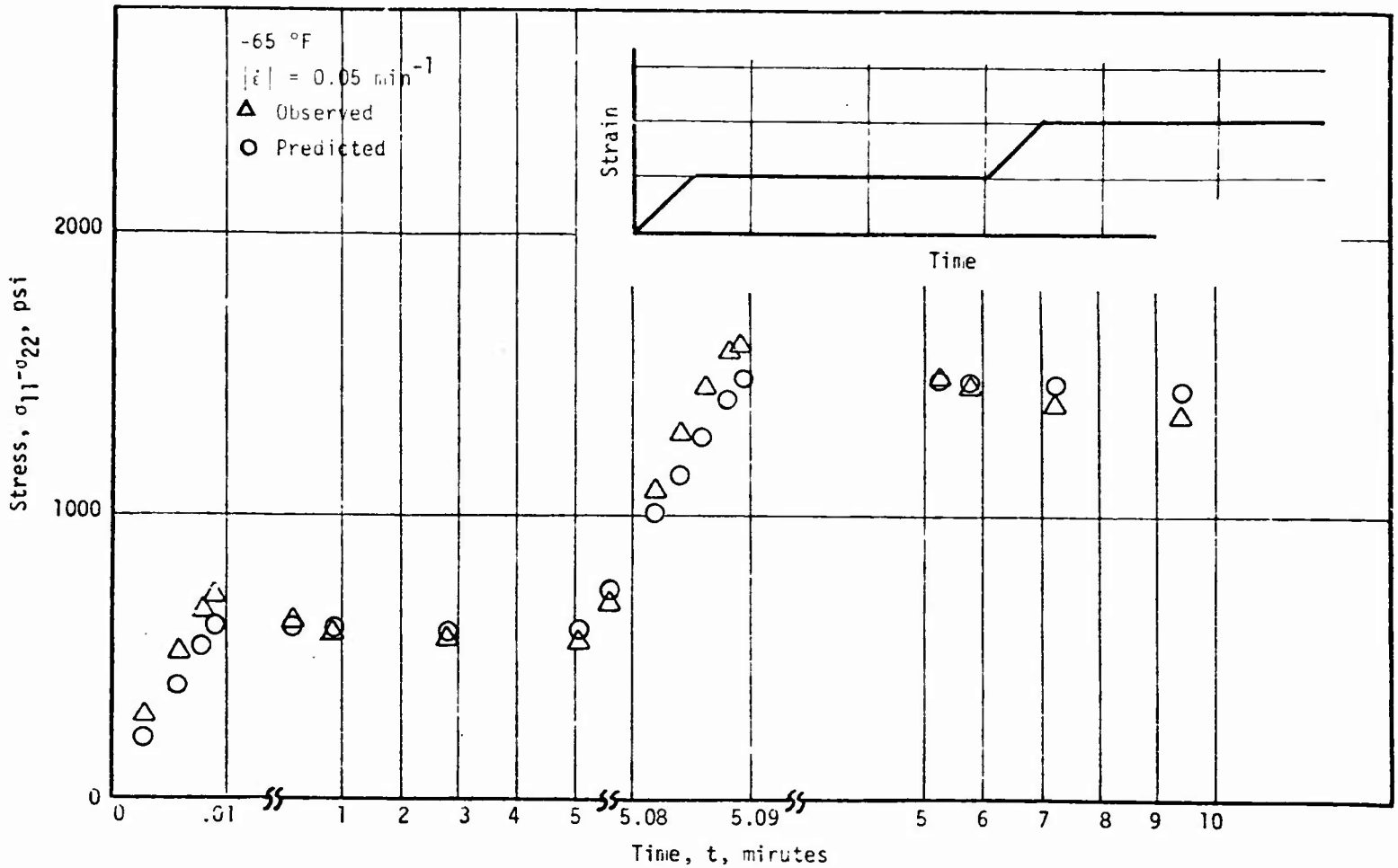

Figure 11

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

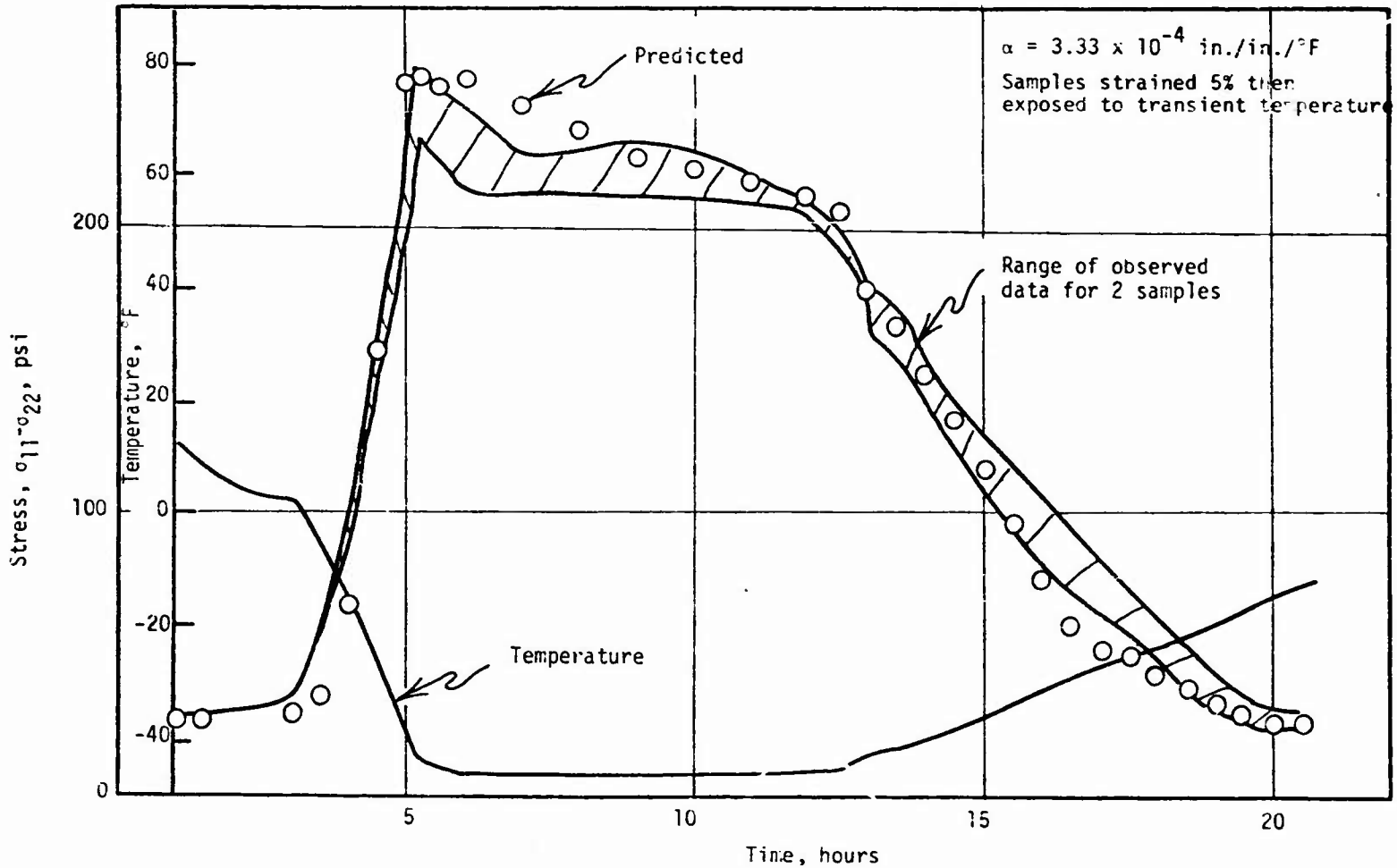

Figure 12

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 OF

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	KØNE			
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)

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JOB NUMBER	REPORT TITLE	DATE	PAGE
	SAMPLE INPUT - LINVIS		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	.0032	13.8	0.0

AGCS 0140-10 (REV 7/60)

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

CARD NO.

7	150.	1.25	.016	21.0	0.03
			.02	28.9	0.17
				34.0	0.48
				36.7	1.02
				37.6	1.75
				37.7	2.60
				37.3	3.55
				36.7	4.52
			.04	35.0	6.6
	150.	1.25	.04	32.5	8.5

AGCS 8140-10 (REV 7/68)

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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

LINEAR VISCOELASTIC CHARACTERIZATION CODE

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

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 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)	TNV1(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

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

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	.3400+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

[illegible] C H A R A C T E R I Z A T I O N C O D E PAGE 5

LINVIS SAMPLE PROBLEM

REGRESSION ANALYSIS PRIMARY MATRIX

COLUMN 1	.114964-02	.101666-02	.642704-04	.646343-06
COLUMN 2	.101666-02	.902272-03	.591399-04	.595012-06
COLUMN 3	.642704-04	.591399-04	.668985-05	.681803-07
COLUMN 4	.646343-06	.595012-06	.681803-07	.695302-09

LINVIS SAMPLE PROBLEM

REGRESSION ANALYSIS X BY Y COLUMN VECTOR

.143482+00	.128707+00	.987670-02	.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	.584468+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

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	STRAIN1	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	.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	.80941-04	
150.00000	.24000+00	.12000+00	.60000-02	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

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	.20808-01	.21936-03	
150.00000	.48000-01	.60000-01	.30000-03	24.40	21.00	16.18	.95687-01	.93506-01	.21194-01	.21421-03	
150.00000	.68000-01	.85000-01	.17000-02	29.13	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	.17510-03	
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	.22800+00	.28500+00	.66000-01	43.85	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 PAGE 10

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)
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 PAGE 11

LINVIS SAMPLE PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	.13006+02
2	.75592+02
3	.97660+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

C     LINEAR VISCOELASTIC CHARACTERIZATION CODE WITH DILATATION FOR
C     DEVIATORIC STRESSES USING MODIFIED POWER SERIES OR PRONY SERIES
C     AT        =    VECTOR OF SHIFT FUNCTION VALUES ASSOCIATED WITH TTEM
C     AVGAT     =    VALUE OF SHIFT FUNCTION FOR A SPECIFIC TIME.
C     B         =    CONSTANT IN THE POWER SERIES TERM (1+BT)**NN, OR THE
C                    EXPONENT IN THE PRONY SERIES TERM  EXP(-BT).
C     BB        =    A COLUMN VECTOR IN THE REGRESSION EQUATION.
C     BETA      =    VOLUMETRIC EXPANSION COEFFICIENT.
C     CO        =    REGRESSION COEFFICIENTS.
C     D         =    INTERPOLATION SLOPE FOR SHIFT FUNCTION, AT.
C     DEV       =    PERCENT DEVIATION BETWEEN EXPERIMENTAL AND CALCULATE
C     DEVRAT    =    DEFINED AS   D(E11-E22)/DT.
C     DT        =    DELTA TIME BETWEEN EXPERIMENTAL INPUT POINTS.
C     E1, E2    =    STRAINS E11 AND E22 RESPECTIVELY.
C     F         =    FRONT FACTOR TO INCLUDE TEMPERATURE DEPENDENCE OF MO
C                    TO CORRECT FOR TRUE STRESS.
C     G         =    INVERSE MATRIX.
C     I2        =    SET TO 1 IF IT IS DESIRED TO INCLUDE A LINEAR ELASTI
C                    IN THE SERIES CHARACTERIZATION.
C     I3        =    NUMBER OF TERMS OF TME POWER OR PRONY SERIES.
C     I4        =    I2 + I3
C     I6        =    NTEMP
C     INV1      =    FIRST STRAIN INVARIANT, EKK = E11+E22+E33 = DV/V.
C     INV2      =    SECOND STRAIN INVARIANT (NOT USED THIS CODE).
C     JL        =    TOTAL NUMBER OF OUTPUT POINTS EQUALS TOTAL NUMBER OF
C                    EXPERIMENTAL INPUT POINTS.
C     KEL       =    NUMBER OF EXPERIMENTAL INPUT DATA POINTS FROM A PART
C                    TEST, MAXIMUM = 50.
C     KODE      =    TYPE OF TEST INPUT DATA:    0 FOR UNIAXIAL
C                                                1 FOR SHEAR
C                                                2 FOR BIAXIAL STRIP ( E33
C     LLL       =    CHARACTERIZATION CODE    = 0 FOR POWER SERIES (1+B*T)
C                                             = 1 FOR PRONY SERIES EXP(-B*
C     NN        =    EXPONENT IN THE POWER SERIES TERM  (1+BT)**NN.
C     NEXP      =    NUMBER OF EXPERIMENTAL INPUT DATA POINTS FROM THIS T
C     NTEMP     =    NUMBER OF INPUT SHIFT FUNCTION/TEMPERATURE DATA POIN
C                    MAXIMUM IS 20.
C     NTESTS    =    TOTAL NUMBER OF TESTS INPUT FOR THIS RUN, MAXIMUM =
C     RATE      =    INCREMENTAL STRAIN RATE.
C     SIG1      =    MEASURED VALUES OF STRESS INPUT FOR ALL TESTS, MAXIM
C     STD       =    STANDARD DEVIATION
C     STRN1     =    STRAIN EPSILON-11.
C     T         =    EXPERIMENTAL INPUT TIME POINTS, 50 MAXIMUM.
C     TEM       =    TEMPERATURE.
C     TEMP      =    TEMPERATURE FOR INPUT DATA.
C     TIME      =    TIME, CALCULATED OUTPUT POINTS, 600 MAXIMUM.
C     TITLE     =    80 COLUMN IDENTIFICATION
C     TR        =    REDUCED TIME, DEFINED AS DT/AT.
C     TTEMP     =    VECTOR OF TEMPERATURE VALUES CORRESPONDING TO INPUT
C                    OF THE SHIFT FUNCTION AT.
C     V         =     MATRIX GENERATED FOR REGRESSION ANALYSIS.
C     VOLUME    =    DILATATION, SAME AS INV1.
C     X         =    EQUATION VARIABLES FOR A PARTICULAR TEST.
C     XBAR      =    AVERAGE DEVIATION
C     XF        =    COLLECTION OF VARIABLES FOR ALL TESTS, THE UNION OF
C                    TME X SETS.
```

```
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), F2(50),  F(50),  G(15,15),   A 610
     2          INV1(50),  INV2(50),  KODE(50),  NEXP(50),  NN(14),       A 620
     3          RATE(50),  SIG1(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 POLER 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 (8E10.0)                                                     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,I3,2X, 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,'XC',I1,'1'), // )      A1040
   19 FORMAT (1H ,1X,F9.5, 3F10.5, 3F10.2, 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 , 6(/),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=NTEMP                                                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)   EN(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), EN(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          TIME(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
```

```
      Y(K)=0.                                                           A1770
      E1(K)=0.                                                          A1780
      TEMP(K)=0.                                                        A1790
      INV2(K)=0.0                                                       A1800
      INV1(K)=0.                                                        A1810
      DT(K)=0.                                                          A1820
      TR(K)=0.                                                          A1830
      E2(K)=0.                                                          A1840
      DEVRAT(K)=0.                                                      A1850
      F(K)=0.                                                           A1860
      AVGAT(K)=0.          BR:16:45   PAGE   22                         A1870
      DO 33 J=1,15                                                      A1880
      X(J,K)=0.D0                                                       A1890
   33 CONTINUE                                                          A1900
      READ (5,3)  NEXP(NT), KODE(NT)                                    A1910
      KFL=NEXP(NT)+1                                                    A1920
      IPG=IPG+1                                                         A1930
      WRITE (6,16)  IPG, (TITLE(I),I=1,20)                              A1940
      IF (KODE(NT).EQ.0) WRITE (6,13)   NT, KFL                         A1950
      IF (KODE(NT).EQ.1) WRITE (6,14)   NT, KFL                         A1960
      IF (KODE(NT).EQ.2) WRITE (6,15)   NT, KFL                         A1970
      WRITE (6,11)                                                      A1980
      DO 34 K=2,KFL                                                     A1990
      M=K-1                                                             A2000
      READ (5,4)        TEMP(K), RATE(K), DT(K), Y(K), INV1(K)          A2010
      WRITE (6,12)  M, TEMP(M), RATE(M), DT(M), Y(M), INV1(M)           A2020
   34 CONTINUE                                                          A2030
      WRITE (6,12)  K, TEMP(K), RATE(K), DT(K), Y(K), INV1(K)           A2040
C                                                                       A2050
      DO 35 K=2,KFL                                                     A2060
      INV1(K)=INV1(K)/100.                                              A2070
      T(K)=T(K-1)+DT(K)                                                 A2080
      INV1(K)=INV1(K)+BETA*(TEMP(K)-TEMP(2) )                           A2090
      E1(K)=E1(K-1)+RATE(K)*DT(K)                                       A2100
      E2(K)=0.5*(INV1(K) - E1(K) )                                      A2110
      IF (KODE(NT).EQ.1) E2(K)=0.0                                      A2120
      IF (KODE(NT).EQ.2) E2(K)=2.*E2(K)                                 A2130
      DEVRAT(K)=RATE(K)-(E2(K)-E2(K-1) )/DT(K)                          A2140
   35 CONTINUE                                                          A2150
C                                                                       A2160
C          INTERPOLATE FOR SHIFT FUNCTION AND COMPUTE REDUCED TIME.     A2170
C                                                                       A2180
      DO 41 K=2,KFL                                                     A2190
      IF (K.EQ.2) GO TO 36                                              A2200
      EPS=ABS(TEMP(K))-ABS(TEMP(K-1))                                   A2210
      EPS=ABS(EPS)                                                      A2220
      IF (EPS.LT.1.E-1) GO TO 39                                        A2230
   36 DO 37 J=1,I6                                                      A2240
      IF (TEMP(K).LT.TTEMP(J)) GO TO 38                                 A2250
   37 CONTINUE                                                          A2260
   38 AVGAT(K)=(EXP(LOG(AT(J-1))+D(J)*(TEMP(K)-TTEMP(J-1))) )           A2270
      GO TO 40                                                          A2280
   39 AVGAT(K)=AVGAT(K-1)                                               A2290
   40 TR(K)=TR(K-1)+DT(K)/AVGAT(K)                                      A2300
      F(K)=((TEMP(K)+459.4)/540.)*((1.+INV1(K))/(1.+E1(K)))             A2310
      X(1,K)=(E1(K)-E2(K))*F(K)                                         A2320
   41 CONTINUE                                                          A2330
      IF (LLL.EQ.1) GO TO 44                                            A2340
C                                                                       A2350
C          COMPUTE POWER SERIES TERMS.                                  A2360
```

```
C
      DO 43 M=1,I3
      DO 43 J=2,KFL
      A3=NN(M)+1.
      INT=0.
      DO 42 K=2,J
      INT=INT-(DEVRAT(K)/(B(M)*A3))*((1.+B(M)*(TR(J)-TR(K)))**A3-      (1
     1.+B(M)*(TR(J)-TR(K-1)))**A3)*AVGAT(K)
   42 CONTINUE
      X(I2+M,J)=INT*F(J)
   43 CONTINUE          BA2460
      GO TO 47
C
C         COMPUTE PRONY SERIES TERMS.
C
   44 DO 46 M=1,I3
      DO 46 J=2,KFL
      INT=0.D0
      DO 45 K=2,J
      INT=INT+((AVGAT(K)*DEVRAT(K))/B(M))*(DEXP(-B(M)*(TR(J)-TR(K)))-
     1DEXP(-B(M)* (TR(J)-TR(K-1))))
   45 CONTINUE
      X(I2+M,J)=INT*F(J)
   46 CONTINUE
C
C              LOAD LOCAL VECTORS INTO GLOBAL VECTORS.
C
   47 CONTINUE
      DO 48 K=1,KFL
      STR1(JL+K)=F1(K)
      SIG1(JL+K)=Y(K)
      TIME(JL+K)=T(K)
      VOLUME(JL+K)=INV1(K)
      TEMP(JL+K)=TEMP(K)
      DO 48 M=1,I4
      XF(M,JL+K)=X(M,K)
   48 CONTINUE
      JL=JL+KFL
   49 CONTINUE
      II=I4
C
C         REGRESSION ANALYSIS.
C
      DO 51 K=1,II          B780
      DO 51 J=1,II
      SA=0.
      DO 50 I=1,JI
      IF (SIG1(I).LT.1.) GO TO 50
      SA=SA+XF(K,I)*XF(J,I)/SIG1(I)**2.
   50 CONTINUE
      V(K,J)=SA
   51 CONTINUE
      DO 53 K=1,II
      BB(K)=0.
      DO 52 I=1,JI
      IF (SIG1(I).LT.1.) GO TO 52
      BB(K)=BB(K)+XF(K,I)*SIG1(I)/SIG1(I)**2.
   52 CONTINUE
   53 CONTINUE
      DO 54 I=1,II
```

```
      DO 54 J=1,II                                                      A2970
   54 G(I,J)=V(I,J)                                                     A2980
      IPG=IPG+1                                                         A2990
      WRITE (6,16)  IPG, (TITLE(I),I=1,20)                              A3000
      WRITE (6,22)                                                      A3010
      DO 55 J=1,II                                                      A3020
   55 WRITE (6,8)  J, (V(I,J),I=1,II)                                   A3030
      IPG=IPG+1                                                         A3040
      WRITE (6,16)  IPG, (TITLE(I),I=1,20)                              A3050
      WRITE (6,23) (BB(J),J=1,II)                                       A3060
C                                                                       A3070
C        COMPUTE INVERSE.                                               A3080
C                                                                       A3090
      N1=II                                                             A3100
      NCE=0                                                             A3110
      DO 59 K=1,N1                                                      A3120
      COM=G(K,K)          B                                             A3130
      IF (COM.EQ.0.0  ) GO TO 60                                        A3140
      G(K,K)=1.                                                         A3150
      DO 56 J=1,N1                                                      A3160
   56 G(K,J)=G(K,J)/COM                                                 A3170
      DO 59 I=1,N1                                                      A3180
      IF (I-K) 57,59,57                                                 A3190
   57 COM=G(I,K)                                                        A3200
      G(I,K)=0.0                                                        A3210
      DO 58 J=1,N1                                                      A3220
   58 G(I,J)=G(I,J)-COM*G(K,J)                                          A3230
   59 CONTINUE                                                          A3240
      GO TO 61                                                          A3250
   60 NCE=K                                                             A3260
      IPG=IPG+1                                                         A3270
      WRITE (6,16)  IPG, (TITLE(I),I=1,20)                              A3280
      WRITE (6,21)   NCE                                                A3290
      CALL  EXIT                                                        A3300
   61 CONTINUE                                                          A3310
      IPG=IPG+1                                                         A3320
      WRITE (6,16)  IPG, (TITLE(I),I=1,20)                              A3330
      WRITE (6,24)                                                      A3340
      DO 62 J=1, N1                                                     A3350
      WRITE (6,8)  J, (G(I,J),I=1,N1)                                   A3360
   62 CONTINUE                                                          A3370
C                                                                       A3380
C        COMPUTE REGRESSION COEFFICIENTS.                               A3390
C                                                                       A3400
      DO 63 K=1,II                                                      A3410
      CO(K)=0.                                                          A3420
      DO 63 I=1,II                                                      A3430
      CO(K)=CO(K)+G(K,I)*BB(I)                                          A3440
   63 CONTINUE                                                          A3450
      N=1                                                               A3460
      KFL=NEXP(N)+1                                                     A3470
      IPG=IPG+1                                                         A3480
      WRITE (6,16)  IPG, (TITLE(I),I=1,20)                              A3490
      IF (KODE(N).EQ.0) WRITE (6,13)   N, KFL                           A3500
      IF (KODE(N).EQ.1) WRITE (6,14)   N, KFL                           A3510
      IF (KODE(N).EQ.2) WRITE (6,15)   N, KFL                           A3520
      WRITE (6,18) (I,I=1,5)                                            A3530
C                                                                       A3540
C        CALCULATE STRESS AT INPUT POINTS.                              A3550
C                                                                       A3560
```

```
000357          LINE=-3                                                    A3570
000358          SUM=0.                                                     A3580
000359          RESID=0.                                                   A3590
000360          M=0                                                        A3600
000361          DO 67 I=1,JL                                               A3610
000362          M=M+1                                                      A3620
000363          IF (M.LE.KFL) GO TO 64                                     A3630
000364          N=N+1                                                      A3640
000365          KFL=NEXP(N)+1                                              A3650
000366          LINE=50                                                    A3660
000367          M=1                                                        A3670
000368     64   CONTINUE                                                   A3680
000369          LINE=LINE+3                                                A3690
000370          IF (LINE.LT.33) GO TO 65                                   A3700
000371          IPG=IPG+1                                                  A3710
000372          LINE=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) (KN, KN=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)  TEN(I), TIME(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          RESID=RESID+DEV**2./10.**4.                                A3860
000387          SUM=SUM+DEV/100.                                           A3870
000388     67   CONTINUE                                                   A3880
000389          XBAR=SUM/JL                                                A3890
000390          STD=((JL*RESID-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, XBAR, 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.

S U M M A R Y O F T E S T N O . U00600

M A T E R I A L D A T A

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

T E S T D A T A

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	.609+01	0.	.7642-01	-.3292-01	-.3292-01	.0000	.1265+03
5	.960+01	0.	.1129+00	-.4435-01	-.4435-01	.0000	.1668+03
6	.126+02	0.	.1506+00	-.5378-01	-.5378-01	.0000	.1899+03
7	.156+02	0.	.1894+00	-.6140-01	-.6140-01	.0000	.2036+03
8	.186+02	0.	.2293+00	-.6736-01	-.6736-01	.0000	.2115+03
9	.216+02	0.	.2703+00	-.7219-01	-.7219-01	.0000	.2168+03
10	.246+02	0.	.3124+00	-.7598-01	-.7598-01	.0000	.2207+03
11	.276+02	0.	.3557+00	-.7957-01	-.7957-01	.0000	.2233+03
12	.306+02	0.	.4001+00	-.8262-01	-.8262-01	.0000	.2244+03
13	.336+02	0.	.4456+00	-.8551-01	-.8551-01	.0000	.2241+03
14	.366+02	0.	.4922+00	-.8792-01	-.8792-01	.0000	.2223+03
15	.396+02	0.	.5400+00	-.9160-01	-.9160-01	.0000	.2126+03

SUMMARY OF TEST NO. U00600

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	.2348+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

S U M M A R Y O F T E S T N O . U00601

M A T E R I A L D A T A

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

T E S T D A T A

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	.2306+03
16	.402+02	0.	.5497+00	-.8658-01	-.8658-01	.0000	.2317+03

SUMMARY OF TEST NO. U00601

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	.9476-02
3	.240+01	.1059-02	-.5386-03	.4625-05	.2716-07	.1895-01
4	.420+01	.4156-02	-.1624-02	.2307-04	.1000-02	.3296-01
5	.720+01	.1292-01	-.4664-02	.1046-03	.4000-02	.5600-01
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

S U M M A R Y O F T E S T N O . U00602

M A T E R I A L D A T A

MATERIAL IS AND 3375-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

T E S T D A T A

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	.600+01	0.	.2006+00	-.7717-01	-.7717-01	.0000	.1503+03
6	.780+01	0.	.2407+00	-.8837-01	-.8837-01	.0000	.1904+03
7	.900+01	0.	.2619+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.	.3898+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

SUMMARY OF TEST NO. U00602

MATERIAL DATA

MATERIAL IS ANR 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	.6897-03	.1616-06	.1070+00
5	.600+01	.4623-01	-.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	. 377-01	.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

@ AND U00605

SUMMARY OF TEST NO. U00605

MATERIAL DATA

MATERIAL ID ANR 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

TEST DATA

TYPE ... UNIAXIAL
INITIAL STRAIN RATE = .3300+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	-.3278-02	-.3278-02	.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 ANR 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	.2337-07	.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	.8395-01
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	.2930+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. 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	-.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	.1943+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	.684+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	.1531+03
31	.936+02	0.	.3374+00	-.7462-01	-.7462-01	.0000	.1949+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.	.3992+00	-.7905-01	-.7905-01	.0000	.2512+03
35	.101+03	0.	.4447+00	-.8204-01	-.8204-01	.0000	.2590+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	.2518+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

M A T E R I A L D A T A

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

T E S T D A T A

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	.430+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	.4774-01	-.1363-01	.4394-03	.2200-01	.9794-01
17	.318+02	.7310-01	-.1962-01	.6983-03	.3600-01	.1195+00
18	.348+02	.1020+00	-.2633-01	.1006-02	.5200-01	.1409+00
19	.394+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	.1738+00
22	.414+02	.1541+00	-.3739-01	.1520-02	.8200-01	.1738+00
23	.438+02	.1545+00	-.3730-01	.1512-02	.8250-01	.1737+00
24	.468+02	.1549+00	-.3721-01	.1504-02	.8300-01	.1736+00
25	.504+02	.1549+00	-.3721-01	.1504-02	.8300-01	.1736+00
26	.564+02	.1553+00	-.3712-01	.1495-02	.8350-01	.1735+00
27	.684+02	.1556+00	-.3703-01	.1487-02	.8400-01	.1734+00
28	.908+02	.1561+00	-.3694-01	.1479-02	.8450-01	.1733+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	.3229+00	-.7562-01	.3481-02	.1710+00	.2713+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

E ADD U00607

SUMMARY OF TEST NO. 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	.560+00	0.	.4028-02	-.2002-02	-.2002-02	.0000	.1807+02
3	.160+00	0.	.1078-01	-.5303-02	-.5303-02	.0000	.3942+02
4	.276+01	0.	.3129-01	-.1495-01	-.1495-01	.0000	.8183+02
5	.576+01	0.	.6639-01	-.2928-01	-.2928-01	.0000	.1804+03
6	.876+01	0.	.1026+00	-.4136-01	-.4136-01	.0000	.1838+03
7	.118+02	0.	.1379+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	.2541+03
12	.220+02	0.	.2521+00	-.6949-01	-.6949-01	.0000	.2717+03
13	.232+02	0.	.2358+00	-.6721-01	-.6721-01	.0000	.2721+02
14	.258+02	0.	.2196+00	-.6446-01	-.6446-01	.0000	.5046+02
15	.282+02	0.	.1957+00	-.6043-01	-.6043-01	.0000	.7243+02
16	.293+02	0.	.1767+00	-.5238-01	-.5238-01	.0000	.8584+02
17	.302+02	0.	.1189+00	-.4317-01	-.4317-01	.0000	.9318+02
18	.328+02	0.	.1189+00	-.4317-01	-.4317-01	.0000	.9931+02
19	.358+02	0.	.1189+00	-.4317-01	-.4317-01	.0000	.1324+02
20	.392+02	0.	.1189+00	-.4331-01	-.4331-01	.0000	.1455+02
21	.398+02	0.	.1189+00	-.4380-01	-.4380-01	.0000	.1766+02
22	.448+02	0.	.1189+00	-.4380-01	-.4380-01	.0000	.1987+02
23	.779+02	0.	.1189+00	-.4384-01	-.4384-01	.0000	.1988+02
24	.784+02	0.	.1281+00	-.4426-01	-.4426-01	.0000	.2880+02
25	.790+02	0.	.1716+00	-.4669-01	-.4669-01	.0000	.3563+02
26	.808+02	0.	.1888+00	-.5159-01	-.5159-01	.0000	.5883+02
27	.838+02	0.	.2533+00	-.5925-01	-.5925-01	.0000	.7307+02
28	.868+02	0.	.2333+00	-.6587-01	-.6587-01	.0000	.1112+03
29	.898+02	0.	.2745+00	-.7294-01	-.7294-01	.0000	.1633+03
30	.928+02	0.	.3167+00	-.7787-01	-.7787-01	.0000	.2153+03
31	.952+02	0.	.3601+00	-.8217-01	-.8217-01	.0000	.2382+03
32	.988+02	0.	.4046+00	-.8589-01	-.8589-01	.0000	.2485+03
33	.102+03	0.	.4502+00	-.8906-01	-.8906-01	.0000	.2551+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 AISI 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	.2843-02
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	.1420+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	.5187-01	-.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	.2869-03	.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	.1460-02	.6300-01	.1678+00
30	.928+02	.1610+00	-.4326-01	.1921-02	.7900-01	.1960+00
31	.958+02	.1957+00	-.5243-01	.2431-02	.9600-01	.2285+00
32	.988+02	.2328+00	-.6212-01	.2985-02	.1140+00	.2712+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

SUMMARY OF TEST NO. 000608 [illegible]

MA[illegible]

MATERIAL [illegible]
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TE[illegible]

TYPE [illegible]
INITIAL STRAIN RATE = [illegible]
PRESSURE = [illegible]
TEMPERATURE [illegible]

DATA POINT	TIME SEC.	[illegible] DEG.-F	STRAINS (CALCULATED) E11	E22	E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.600+00	0.	[illegible]	-.3328-02	-.3328-02	.0000	.2617+02
3	.180+01	0.	.2030-01	-.9852-02	-.9852-02	.0000	.5815+02
4	.480+01	0.	.5504-01	-.2472-01	-.2472-01	.0000	.1200+03
5	.780+01	0.	.9089-01	-.3776-01	-.3776-01	.0000	.1702+03
6	.108+02	0.	.1279+00	-.4801-01	-.4801-01	.0000	.2015+03
7	.138+02	0.	.1660+00	-.5615-01	-.5615-01	.0000	.2178+03
8	.154+02	0.	.1870+00	-.5971-01	-.5971-01	.0000	.2227+03
9	.156+02	0.	.1870+00	-.5967-01	-.5967-01	.0000	.2019+03
10	.162+02	0.	.1870+00	-.5963-01	-.5963-01	.0000	.1650+03
11	.168+02	0.	.1870+00	-.5959-01	-.5959-01	.0000	.1477+03
12	.180+02	0.	.1870+00	-.5954-01	-.5954-01	.0000	.1292+03
13	.198+02	0.	.1870+00	-.5937-01	-.5937-01	.0000	.1119+03
14	.228+02	0.	.1870+00	-.5924-01	-.5924-01	.0000	.9802+02
15	.288+02	0.	.1870+00	-.5916-01	-.5916-01	.0000	.8532+02
16	.408+02	0.	.1870+00	-.5916-01	-.5916-01	.0000	.7149+02
17	.534+02	0.	.1870+00	-.5937-01	-.5937-01	.0000	.6574+02
18	.580+02	0.	.1949+00	-.6060-01	-.6060-01	.0000	[illegible]
19	.552+02	0.	.2108+00	-.6365-01	-.6365-01	.0000	.1625+03
20	.564+02	0.	.2268+00	-.6581-01	-.6581-01	.0000	.1968+03
21	.576+02	0.	.2431+00	-.6545-01	-.6545-01	.0000	.2250+03
22	.606+02	0.	.2845+00	-.6989-01	-.6989-01	.0000	.2377+03
23	.6[illegible]+02	0.	.3374+00	-.7462-01	-.7462-01	.0000	[illegible]
24	.6[illegible]+02	0.	.3374+00	-.7462-01	-.7462-01	.0000	.2121+03
25	.6[illegible]+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	.69[illegible]+02	0.	.3374+00	-.7431-01	-.7431-01	.0000	.1356+03
28	.75[illegible]+02	0.	.3374+00	-.7423-01	-.7423-01	.0000	.1146+03
29	.943+02	0.	.3374+00	-.7423-01	-.7423-01	.0000	.9123+02
30	.942+02	0.	.3443+00	-.7464-01	-.7464-01	.0000	.1149+03
31	.960+02	0.	.3618+00	-.7632-01	-.7632-01	.0000	.1680+03
32	.974+02	0.	.3884+00	-.7820-01	-.7820-01	.0000	.2175+03
33	.996+02	0.	.4154+00	-.8022-01	-.8022-01	.0000	.2367+03
34	.103+03	0.	.4613+00	-.8297-01	-.8297-01	.0000	[illegible]
35	.106+03	0.	.5083+00	-.8541-01	-.8541-01	.0000	[illegible]
36	.109+0[illegible]	0.	.5565+00	-.8792-01	-.8792-01	.0000	.2457+03
37	.112+03	0.	.6057+00	-.9081-01	-.9081-01	.0000	.2386+03

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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 = 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	.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	.6759-01	-.1877-01	.6668-03	.3220-01	.1163+00
9	.156+02	.6767-01	-.1876-01	.6659-03	.3230-01	.1163+00
10	.162+02	.6776-01	-.1875-01	.6649-03	.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	.643+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	.943+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	.979+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	.2798+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

S U M M A R Y O F T E S T N O . U10600

M A T E R I A L D A T A

MATERIAL IS ANB 3335-1
BULK MODULUS = .5000+06
VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

T E S T D A T A

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	.8450+02
3	.240+01	0.	.2712-01	-.1308-01	-.1308-01	.0000	.7701+02
4	.420+01	0.	.4796-01	-.2195-01	-.2195-01	.0000	.1172+03
5	.720+01	0.	.8360-01	-.3562-01	-.3562-01	.0000	.1790+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	.2410+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	.2797+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 ANR 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	.5941-06	-.0000-04	.9875-02
3	.240+01	.9586-03	-.5386-03	.4643-05	-.0007-04	.1895-01
4	.420+01	.4056-02	-.1624-02	.2312-04	.0000-03	.3296-01
5	.720+01	.1235-01	-.4687-02	.1061-03	.3000-02	.5620-01
6	.102+02	.2611-01	-.9121-02	.2672-03	.0000-02	.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

G ADD 010601

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	-.3394-02	-.3394-02	.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	.9093+02
5	.600+01	0.	.6917-01	-.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	.162+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	.2855+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	.3656+03
24	.438+02	0.	.3158+00	-.8593-01	-.8593-01	.0000	.3277+03
25	.450+02	0.	.3158+00	-.8632-01	-.8632-01	.0000	.3307+03
26	.468+02	0.	.3158+00	-.8663-01	-.8663-01	.0000	.1937+03
27	.492+02	0.	.3158+00	-.8683-01	-.8683-01	.0000	.1766+03
28	.552+02	0.	.3158+00	-.8749-01	-.8749-01	.0000	.1616+03
29	.758+02	0.	.3158+00	-.8828-01	-.8828-01	.0000	.1667+03
30	.762+02	0.	.3209+00	-.8858-01	-.8858-01	.0000	.1777+03
31	.774+02	0.	.3382+00	-.9074-01	-.9074-01	.0000	.1993+03
32	.786+02	0.	.3556+00	-.9285-01	-.9285-01	.0000	[illegible]
33	.798+02	0.	.3732+00	-.9373-01	-.9373-01	.0000	[illegible]
34	.810+02	0.	.3910+00	-.9444-01	-.9444-01	.0000	[illegible]
35	[illegible]	0.	.4181+00	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	[illegible]	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	[illegible]	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39	[illegible]	0.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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MATERIAL DATA

MATERIAL IS AN9 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	.1834-02	-.8346-03	.8708-05	.2000-03	.2360-01
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	-.8642-02	.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	.8129-01
16	.288+02	.3187-01	-.1190-01	.3922-03	.9600-02	.8932-01
17	.300+02	.3899-01	-.1432-01	.5042-03	.1230-01	.9941-01
18	.318+02	.5118-01	-.1826-01	.6970-03	.1730-01	.1129+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	.5880-01	.1882+00
24	.438+02	.1439+00	-.4688-01	.2331-02	.5780-01	.1884+00
25	.450+02	.1431+00	-.4706-01	.2353-02	.5680-01	.1885+00
26	.468+02	.1425+00	-.4721-01	.2370-02	.5600-01	.1887+00
27	.492+02	.1421+00	-.4730-01	.2381-02	.5550-01	.1888+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	.8880-01	.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

SUMMARY OF TEST NO. U10602

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+02
3	.156+01	0.	.1750-01	-.8627-02	-.8627-02	.0000	.5596+02
4	.276+01	0.	.3123-01	-.1501-01	-.1501-01	.0000	.8556+02
5	.396+01	0.	.5021-01	-.2683-01	-.2683-01	.0000	.1365+03
6	.516+01	0.	.9520-01	-.3999-01	-.3999-01	.0000	.1993+03
7	.112+02	0.	.1323+00	-.5147-01	-.5147-01	.0000	.2430+03
8	.142+02	0.	.1705+00	-.6099-01	-.6099-01	.0000	.2666+03
9	.172+02	0.	.2009+00	-.6913-01	-.6913-01	.0000	.2801+03
10	.202+02	0.	.2504+00	-.7602-01	-.7602-01	.0000	.3005+03
11	.232+02	0.	.2920+00	-.8214-01	-.8214-01	.0000	.3092+03
12	.262+02	0.	.3347+00	-.8794-01	-.8794-01	.0000	.3180+03
13	.292+02	0.	.3261+00	-.8735-01	-.8735-01	.0000	.3159+03
14	.322+02	0.	.3089+00	-.8654-01	-.8654-01	.0000	.3426+03
15	.352+02	0.	.2920+00	-.8492-01	-.8492-01	.0000	.3120+03
16	.382+02	0.	.2504+00	-.8010-01	-.8010-01	.0000	.2726+02
17	.376+02	0.	.1783+00	-.6652-01	-.6652-01	.0000	.2782+02
18	.400+02	0.	.1475+00	-.5894-01	-.5894-01	.0000	.1136+02
19	.406+02	0.	.1551+00	-.6109-01	-.6109-01	.0000	.3826+02
20	.412+02	0.	.1705+00	-.6487-01	-.6487-01	.0000	.5652+02
21	.442+02	0.	.2019+00	-.7218-01	-.7218-01	.0000	.8708+02
22	.472+02	0.	.2422+00	-.7984-01	-.7984-01	.0000	.1208+03
23	.502+02	0.	.2836+00	-.8549-01	-.8549-01	.0000	.1597+03
24	.532+02	0.	.3261+00	-.9046-01	-.9046-01	.0000	.2230+03
25	.562+02	0.	.3697+00	-.9518-01	-.9518-01	.0000	.2935+03
26	.592+02	0.	.4144+00	-.9966-01	-.9966-01	.0000	.3223+03
27	.622+02	0.	.4603+00	-.1043+00	-.1043+00	.0000	.3348+03
28	.652+02	0.	.5073+00	-.1090+00	-.1090+00	.0000	.3392+03
29	.682+02	0.	.5554+00	-.1136+00	-.1136+00	.0000	.3359+03
30	.700+02	0.	.5848+00	-.1168+00	-.1168+00	.0000	.3286+03

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SUMMARY OF TEST NO. U10602

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	-.2063-12	-.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	.8667-01
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	.1539+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	.268+02	.1514+00	-.4933-01	.2488-02	.6080-01	.1989+00
14	.280+02	.1358+00	-.4598-01	.2314-02	.5180-01	.1868+00
15	.292+02	.1221+00	-.4238-01	.2106-02	.4480-01	.1777+00
16	.322+02	.9018-01	-.3369-01	.1606-02	.2880-01	.1558+00
17	.376+02	.4529-01	-.1930-01	.7090-03	.9800-02	.1154+00
18	.400+02	.2959-01	-.1391-01	.5124-03	.3800-02	.9730-01
19	.406+02	.3294-01	-.1522-01	.5789-03	.4800-02	.1019+00
20	.418+02	.4060-01	-.1792-01	.7177-03	.7800-02	.1110+00
21	.442+02	.5757-01	-.2394-01	.1052-02	.1380-01	.1292+00
22	.472+02	.8251-01	-.3230-01	.1544-02	.2380-01	.1518+00
23	.502+02	.1126+00	-.4118-01	.2073-02	.3780-01	.1740+00
24	.532+02	.1451+00	-.5081-01	.2668-02	.5280-01	.1964+00
25	.562+02	.1793+00	-.6131-01	.3348-02	.6780-01	.2191+00
26	.592+02	.2151+00	-.7267-01	.4116-02	.8280-01	.2423+00
27	.622+02	.2517+00	-.8513-01	.5006-02	.9680-01	.2661+00
28	.652+02	.2892+00	-.9874-01	.6032-02	.1098+00	.2905+00
29	.682+02	.3282+00	-.1133+00	.7166-02	.1228+00	.3154+00
30	.700+02	.3511+00	-.1230+00	.7981-02	.1288+00	.3307+00

_G ADD U10603

M A T E R I A L D A T A

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

T E S T D A T A

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	.960+00	0.	.1071-01	-.5369-02	-.5369-02	.0000	.3942+02
3	.216+01	0.	.2234-01	-.1104-01	-.1104-01	.0000	.5633+02
4	.336+01	0.	.3915-01	-.1805-01	-.1805-01	.0000	.9337+02
5	.576+01	0.	.6632-01	-.2901-01	-.2901-01	.0000	.1876+03
6	.576+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	.112+02	0.	.1263+00	-.5012-01	-.5012-01	.0000	.1807+03
9	.124+02	0.	.1263+00	-.5021-01	-.5021-01	.0000	.1979+03
10	.142+02	0.	.1263+00	-.5035-01	-.5035-01	.0000	.1227+03
11	.172+02	0.	.1263+00	-.5052-01	-.5052-01	.0000	.1060+03
12	.232+02	0.	.1263+00	-.5066-01	-.5066-01	.0000	.9260+02
13	.317+02	0.	.1263+00	-.5088-01	-.5088-01	.0000	.8260+02
14	.322+02	0.	.1323+00	-.5258-01	-.5258-01	.0000	.1345+03
15	.334+02	0.	.1475+00	-.5675-01	-.5675-01	.0000	.2073+03
16	.346+02	0.	.1620+00	-.6060-01	-.6060-01	.0000	.2493+03
17	.364+02	0.	.1862+00	-.6601-01	-.6601-01	.0000	.2672+03
18	.388+02	0.	.2179+00	-.7238-01	-.7238-01	.0000	.2841+03
19	.418+02	0.	.2586+00	-.7893-01	-.7893-01	.0000	.2963+03
20	.448+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	.1352+03
25	.520+02	0.	.2954+00	-.8858-01	-.8858-01	.0000	.5657+02
26	.568+02	0.	.2619+00	-.8451-01	-.8451-01	.0000	.6703+02
27	.574+02	0.	.2211+00	-.7791-01	-.7791-01	.0000	.8175+02
28	.580+02	0.	.2211+00	-.7791-01	-.7791-01	.0000	.8721+02
29	.592+02	0.	.2211+00	-.7795-01	-.7795-01	.0000	.5948+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	.682+02	0.	.2211+00	-.7854-01	-.7854-01	.0000	.5969+02
33	.748+02	0.	.2211+00	-.7883-01	-.7883-01	.0000	.6004+02
34	.808+02	0.	.2211+00	-.7908-01	-.7908-01	.0000	.6004+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	.1054-07
2	.960+00	-.2885-04	-.8618-04	.3088-06	-.2000-03	.7580-02
3	.216+01	.6590-03	-.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	.2498-01	-.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	.544+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	.2839+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 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	.120+01	0.	.1342-01	-.6678-02	-.6678-02	.0000	.2230+02
3	.240+01	0.	.2709-01	-.1312-01	-.1312-01	.0000	.5442+02
4	.360+01	0.	.4094-01	-.1934-01	-.1934-01	.0000	.8009+02
5	.600+01	0.	.6917-01	-.3099-01	-.3099-01	.0000	.1269+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	.2999+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 ANR 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	.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	.2042-01
5	.480+01	.7169-02	-.3327-02	.6644-04	.0001-03	.4722-01
6	.930+01	.1730-01	-.7357-02	.2050-03	.3400-02	.7051-01
7	.120+02	.3202-01	-.1277-01	.4392-03	.8200-02	.9750-01
8	.150+02	.5070-01	-.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

@ ADD U10605

SUMMARY OF TEST NO. U10605

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.	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.	.3538-02	-.4121-02	-.4121-02	.0000	.2520+02
3	.222+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	.822+01	0.	.6586-01	-.4161-01	-.4161-01	.0000	.1910+03
6	.112+02	0.	.1330+00	-.5455-01	-.5455-01	.0000	.2427+03
7	.142+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	-.9540-01	.0000	.3405+03
11	.262+02	0.	.3355+00	-.1038+00	-.1038+00	.0000	.3283+03
12	.292+02	0.	.3793+00	-.1117+00	-.1117+00	.0000	.3371+03
13	.322+02	0.	.4243+00	-.1192+00	-.1192+00	.0000	.3447+03
14	.352+02	0.	.4704+00	-.1264+00	-.1264+00	.0000	.3496+03
15	.382+02	0.	.5177+00	-.1334+00	-.1334+00	.0000	.3529+03
16	.412+02	0.	.5660+00	-.1401+00	-.1401+00	.0000	.3518+03

SUMMARY OF TEST NO. U10605

MATERIAL DATA

MATERIAL IS AND 7336-1
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	.4119-01
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	.1119+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

M A T E R I A L D A T A

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

T E S T D A T A

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	.2819+02
[illegible]	.180+01	0.	.2017-01	-.9984-02	-.9984-02	.0000	.5611+02
[illegible]	.300+01	0.	.3392-01	-.1622-01	-.1622-01	.0000	.8611+02
[illegible]	.600+01	0.	.6910-01	-.3082-01	-.3082-01	.0000	.1667+03
[illegible]	.900+01	0.	.1054+00	-.4388-01	-.4388-01	.0000	.2284+03
[illegible]	.120+02	0.	.1828+00	-.5533-01	-.5533-01	.0000	.2755+03
[illegible]	.150+02	0.	.1814+00	-.6530-01	-.6530-01	.0000	.3014+03
9	.180+02	0.	.2210+00	-.7381-01	-.7381-01	.0000	.3335+03
[illegible]	.210+02	0.	.2618+00	-.8189-01	-.8189-01	.0000	.3510+03
12	.216+02	0.	.2618+00	-.8173-01	-.8173-01	.0000	.3076+03
13	.228+02	0.	.2618+00	-.8234-01	-.8234-01	.0000	.2577+03
14	.246+02	0.	.2618+00	-.8294-01	-.8294-01	.0000	.2311+03
15	.276+02	0.	.2618+00	-.8355-01	-.8355-01	.0000	.2106+03
16	.336+02	0.	.2618+00	-.8436-01	-.8436-01	.0000	.1901+03
17	.456+02	0.	.2618+00	-.8529-01	-.8529-01	.0000	.1732+03
18	.636+02	0.	.2618+00	-.8610-01	-.8610-01	.0000	.1612+03
19	.813+02	0.	.2618+00	-.8667-01	-.8667-01	.0000	.1527+03
20	.816+02	0.	.2660+00	-.8698-01	-.8698-01	.0000	.1873+03
21	[illegible]	0.	.2826+00	-.8909-01	-.8909-01	.0000	.2554+03
22	.846+02	0.	.3080+00	-.9256-01	-.9256-01	.0000	.3347+03
23	.864+02	0.	.3337+00	-.9603-01	-.9603-01	.0000	.3603+03
24	.882+02	0.	.3599+00	-.9944-01	-.9944-01	.0000	.3762+03
25	.906+02	0.	.3954+00	-.1038+00	-.1038+00	.0000	.3886+03
26	.937+02	0.	.4426+00	-.1096+00	-.1096+00	.0000	.3965+03
27	.949+02	0.	.4426+00	-.1099+00	-.1099+00	.0000	.3563+03
28	.969+02	0.	.4426+00	-.1107+00	-.1107+00	.0000	.3709+03
29	.972+02	0.	.4426+00	-.1115+00	-.1115+00	.0000	.2858+03
30	.996+02	0.	.4426+00	-.1123+00	-.1123+00	.0000	.2611+03
31	.108+03	0.	.4426+00	-.1134+00	-.1134+00	.0000	.2412+03
32	.118+03	0.	.4426+00	-.1142+00	-.1142+00	.0000	.2100+03
33	.136+03	0.	.4426+00	-.1163+00	-.1163+00	.0000	.2073+03
34	.151+03	0.	.4426+00	-.1172+00	-.1172+00	.0000	.1969+03
35	.152+03	0.	.4537+00	-.1175+00	-.1175+00	.0000	.2418+03
36	.153+03	0.	.4723+00	-.1189+00	-.1189+00	.0000	.2935+03
37	.156+03	0.	.5196+00	-.1227+00	-.1227+00	.0000	.3765+03
	.159+03	0.	.5680+00	-.1272+00	-.1272+00	.0000	.3962+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	.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	.1764-01	-.7325-02	.2029-03	.3800-02	.7037-01
7	.120+02	.3217-01	-.1274-01	.4372-03	.8800-02	.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	.1739-02	.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	.9201-01	-.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	.3559-02	.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	.2228+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	.6262-02	.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

[illegible] TEST [illegible]

MATERIAL DATA

[illegible] 3336-1
[illegible] = .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	.166+02	0.	.2027+00	-.7004-01	-.7004-01	.0000	.3381+03
10	.169+02	0.	.2027+00	-.7012-01	-.7012-01	.0000	.2936+03
11	.175+02	0.	.2027+00	-.7038-01	-.7038-01	.0000	.2596+03
12	.187+02	0.	.2027+00	-.7076-01	-.7076-01	.0000	.2291+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	.409+02	0.	.2027+00	-.7286-01	-.7286-01	.0000	.1543+03
17	.685+02	0.	.2027+00	-.7383-01	-.7383-01	.0000	.1380+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	.3913+02
22	.739+02	0.	.1790+00	-.6957-01	-.6957-01	.0000	.7795+02
23	.763+02	0.	.2106+00	-.7661-01	-.7661-01	.0000	.1709+03
24	.781+02	0.	.2348+00	-.8091-01	-.8091-01	.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	.4069+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

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SUMMARY OF TEST NO. U10607

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	.3594-01	-.1427-01	.5116-03	.8400-02	.9866-01
8	.157+02	.5611-01	-.2116-01	.8652-03	.1710-01	.1217+00
9	.166+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	.6150-01	-.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	.8464-03	.5100-02	.1168+00
20	.721+02	.3037-01	-.1561-01	.6129-03	.1600-02	.1030+00
21	.727+02	.3315-01	-.1706-01	.6945-03	.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	.1488+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	.3990-01	.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

SUMMARY OF TEST NO. U1060B

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	.324+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	.704+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.	.2569+00	-.8178-01	-.8178-01	.0000	.3505+03
10	.212+02	0.	.2487+00	-.8101-01	-.8101-01	.0000	.3135+03
11	.230+02	0.	.2243+00	-.7808-01	-.7808-01	.0000	.1206+03
12	.254+02	0.	.1924+00	-.7221-01	-.7221-01	.0000	.6802+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	.330+02	0.	.1744+00	-.6800-01	-.6800-01	.0000	.6840+02
18	.500+02	0.	.1744+00	-.6834-01	-.6834-01	.0000	.6631+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	.693+02	0.	.2776+00	-.9297-01	-.9297-01	.0000	.3317+03
24	.710+02	0.	.2944+00	-.9560-01	-.9560-01	.0000	.3533+03
25	.740+02	0.	.3372+00	-.9791-01	-.9791-01	.0000	.3793+03
26	.769+02	0.	.3785+00	-.1034+00	-.1034+00	.0000	.3917+03
27	.776+02	0.	.3785+00	-.1039+00	-.1039+00	.0000	.3273+03
28	.789+02	0.	.3785+00	-.1044+00	-.1044+00	.0000	.2925+03
29	.806+02	0.	.3785+00	-.1050+00	-.1050+00	.0000	.2681+03
30	.830+02	0.	.3785+00	-.1056+00	-.1056+00	.0000	.2476+03
31	.860+02	0.	.3785+00	-.1061+00	-.1061+00	.0000	.2335+03
32	.920+02	0.	.3785+00	-.1069+00	-.1069+00	.0000	.2101+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	.2989+03
35	.103+03	0.	.3990+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 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	-.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	-.9994-04	.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	-.3372-01	.1632-02	.2540-01	.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	.1181+00
14	.278+02	.3870-01	-.1905-01	.8021-03	.3800-02	.1142+00
15	.296+02	.3861-01	-.1906-01	.8031-03	.3700-02	.1132+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	.1132+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	.1229+00
21	.650+02	.5696-01	-.2692-01	.1279-02	.8200-02	.1366+00
22	.680+02	.8308-01	-.3569-01	.1919-02	.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	.1839+00
25	.740+02	.1414+00	-.5645-01	.3233-02	.4060-01	.2051+00
26	.768+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	.798+02	.1696+00	-.6913-01	.4126-02	.4870-01	.2276+00
29	.806+02	.1685+00	-.6944-01	.4171-02	.4720-01	.2279+00
30	.830+02	.1673+00	-.6977-01	.4219-02	.4560-01	.2282+00
31	.860+02	.1663+00	-.6983-01	.4258-02	.4430-01	.2284+00
32	.920+02	.1648+00	-.6985-01	.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	.2679+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 3335-1
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	.5923+02
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	.3074+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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M A T E R I A L D A T A

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

T E S T D A T A

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	.3512-09
2	.600+00	-.9331-03	-.3336-04	.8555-07	-.1000-02	.4336-02
3	.300+01	.6469-03	-.8416-03	.9218-05	-.1000-02	.2369-01
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	.2337+00
13	.324+02	.1835+00	-.8905-01	.6317-02	.3020-01	.2588+00
14	.354+02	.2146+00	-.1055+00	.7891-02	.3460-01	.2838+00

@ ADD H00601

SUMMARY OF TEST NO. R00601

MATERIAL DATA

MATERIAL IS ANH 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	.8477+02
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	.4586+02
9	.252+02	0.	.3406-01	-.3123-01	.0000	.0000	.3719+02
10	.402+02	0.	.3406-01	-.3133-01	.0000	.0000	.3306+02
11	.414+02	0.	.3962-01	-.3615-01	.0000	.0000	.7785+02
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	.468+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	.6405+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	-.1044+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	.1239+03
33	.124+03	0.	.2156+00	-.1020+00	.0000	.0000	.1089+03
34	.136+03	0.	.2156+00	-.1015+00	.0000	.0000	.9608+02
35	.166+03	0.	.2156+00	-.1009+00	.0000	.0000	.8216+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	.2469+03
41	.175+03	0.	.3301+00	-.1196+00	.0000	.0000	.2523+03
42	.178+03	0.	.3031+00	-.1236+00	.0000	.0000	.2525+03
43	.181+03	0.	.4282+00	-.1278+00	.0000	.0000	.2425+03

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SUMMARY OF TEST NO. 800601 PAGE 800601 - 2

MATERIAL DATA

MATERIAL IS AND 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.	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	.5452-02
3	.180+01	.8863-03	-.3941-03	.0000	.1000-03	.1622-01
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	.2800-02	.5631-01
14	.462+02	.2190-01	-.7239-02	.0000	.7400-02	.7023-01
15	.468+02	.2300-01	-.7132-02	.0000	.8700-02	.6980-01
16	.480+02	.2385-01	-.7051-02	.0000	.9700-02	.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	.568+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	.1338+00
29	.110+03	.1104+00	-.2268-01	.0000	.6300-01	.1335+00
30	.112+03	.1112+00	-.2251-01	.0000	.6410-01	.1332+00
31	.114+03	.1121+00	-.2232-01	.0000	.6530-01	.1329+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	.7830-01	.1440+00
38	.170+03	.1521+00	-.2909-01	.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

SUMMARY OF TEST NO. B00602

MATERIAL DATA

MATERIAL IS ANU 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	.130+01	0.	.1553-01	-.1506-01	.0000	.0000	.8468+02
3	.258+01	0.	.2923-01	-.2761-01	.0000	.0000	.9230+02
4	.378+01	0.	.4310-01	-.3940-01	.0000	.0000	.1178+03
5	.558+01	0.	.6425-01	-.5552-01	.0000	.0000	.1635+03
6	.678+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	.1[illegible]+03
11	.146+02	0.	.1004+00	-.7406-01	.0000	.0000	.1046+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	.6987+02
15	.666+02	0.	.1056+00	-.7576-01	.0000	.0000	.1060+03
16	.698+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	.2225+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	.1937+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	.9404+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	.1090+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	.2483+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	.2480+03
37	.152+03	0.	.4391+00	-.1350+00	.0000	.0000	.2444+03

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SUMMARY OF TEST NO. B00602 PAGE B00602 - 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 = 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	.1249-01
3	.258+01	.1614-02	-.8069-03	.0000	.2922-07	.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	.858+01	.2247-01	-.7824-02	.0000	.6800-02	.7299-01
8	.918+01	.2449-01	-.7622-02	.0000	.9200-02	.7221-01
9	.104+02	.2533-01	-.7537-02	.0000	.1020-01	.7188-01
10	.122+02	.2592-01	-.7478-02	.0000	.1090-01	.7166-01
11	.146+02	.2634-01	-.7436-02	.0000	.1140-01	.7149-01
12	.206+02	.2693-01	-.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	.8361-01
17	.710+02	.4587-01	-.1212-01	.0000	.2140-01	.9246-01
18	.722+02	.5569-01	-.1426-01	.0000	.2700-01	.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

& ADD B00603

SUMMARY OF TEST NO. P00603

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	-.2605-01	.0000	.0000	.6375+02
4	.376+01	0.	.3959-01	-.3641-01	.0000	.0000	.8725+02
5	.148+02	0.	.6758-01	-.5786-01	.0000	.0000	.1354+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	.1999+03
9	.388+02	0.	.1866+00	-.1044+00	.0000	.0000	.2055+03
10	.448+02	0.	.2181+00	-.1096+00	.0000	.0000	.2096+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	.2178+03

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SUMMARY OF TEST NO. B00603

MATERIAL DATA

MATERIAL IS ANH 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 B00604

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SUMMARY OF TEST NO. B00604

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	-.1951-01	.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. B10601

MATERIAL DATA

MATERIAL IS AMA 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	.1637+03
4	.600+01	0.	.6903-01	-.6013-01	.0000	.0000	.2154+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	.904+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	.8319+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	.634+02	0.	.1428+00	-.1046+00	.0000	.0000	.1897+03
23	.753+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	.1602+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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SUMMARY OF TEST NO. B10601

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 = 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	.2373-01
3	.444+01	.8559-02	-.2330-02	.0000	-.9995-04	.3947-01
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	.5601-01
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	.8200-02	.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	.1545+00
31	.120+03	.1028+00	-.3432-01	.0000	.3360-01	.1588+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

S ADD B10602

SUMMARY OF TEST NO. B10602

MATERIAL DATA

MATERIAL IS ANH 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	-.5436-01	.0000	.0000	.1546+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	.3315+03
7	.155+02	0.	.1875+00	-.1247+00	.0000	.0000	.3641+03
8	.185+02	0.	.2274+00	-.1378+00	.0000	.0000	.3809+03
9	.209+02	0.	.2600+00	-.1472+00	.0000	.0000	.3913+03
10	.239+02	0.	.3019+00	-.1581+00	.0000	.0000	.3997+03
11	.269+02	0.	.3449+00	-.1690+00	.0000	.0000	.4015+03

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SUMMARY OF TEST NO. B10602

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	.1170-03
2	.228+01	.7345-03	-.6321-03	.0000	-.5000-03	.2057-01
3	.528+01	.6171-02	-.3285-02	.0000	-.4999-03	.4685-01
4	.648+01	.9548-02	-.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 B10603

S U M M A R Y O F T E S T N O . R10603

M A T E R I A L D A T A

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

T E S T D A T A

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.	.5451-01	-.4907-01	.0000	.0000	.1981+03
5	.760+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 ANR 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. B10604

MATERIAL DATA

MATERIAL IS ANG 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.	.5398-01	-.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	.6547+03
10	.246+02	0.	.3112+00	-.1875+00	.0000	.0000	.6575+03

SUMMARY OF TEST NO. P10604

MATERIAL DATA

MATERIAL IS ANR 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	.4714-03
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 U00700

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