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CHEMICAL AND PHYSICAL PROPERTIES OF ASPHALT- RUBBER MIXTURES — PHASE III

VOLUME 5

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16. Abstract

This study had the objective of evaluating the effects of temperature on physical properties of asphalt-rubber mixtures. Eight different asphalt-rubber mixtures formulated with two different asphalts and two types of granulated reclaimed rubber at 20 and 25 percent concentrations were studied. These mixtures were comparable to mixtures supplied by two of the major asphalt-rubber producers. These mixtures were tested at three different temperatures - 77F (25C), 39.2F (4C), and -20F (-29C).

Asphalt-rubber mixtures were produced in the Torque-Fork mixer at 375F using a one hour mixing duration. Testing procedures utilized were the Schweyer Rheometer and Force-Ductility. A total of 12 measured or calculated parameters are reported and discussed.

The study concluded that (1) temperature significantly influences physical properties of asphalt-rubber mixtures, (2) that mixtures made with the two rubber types and asphalts studied behave differently at different temperatures.

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1.0 EXPERIMENT DESCRIPTION

1.1 The objective of this experiment was to evaluate the effects of temperature on physical properties of asphalt-rubber mixtures.

1.2 A laboratory investigation was performed which considered asphalt-rubber mixtures formulated with two rubber types, two rubber concentrations and two asphalts. Testing was performed at three different temperatures.

1.2.1 Granulated rubber utilized was produced from two different reclamation processes and materials as follows:

- Ambient grind tread peel crumb (Atlos TPO44)
- Ambient grind high natural rubber content devulcanized crumb (U.S. Rubber Reclaiming GT274)

Each of the two rubber types studied was incorporated into asphalt-rubber mixtures at two concentrations - 20 and 25 percent by weight of total mixture.

1.2.2 The two asphalt types utilized were:

- ARCO AR4000 with 2 percent Califlux GP extender oil
- Sahuaro AR1000

1.2.3 Properties and characteristics of the asphalts and rubbers are contained in the project Summary Report (1).

1.2.4 Testing temperatures were 77F (25C), 39.2F (4C) and -20F (-29C).

1.2.5 Asphalt-rubber mixtures were all prepared using a standard mixing procedure in the Arizona Torque-Fork as described in the project Summary Report (1).

1.3 Materials properties assessed in this study are:

- Apparent viscosity and shear rate sensitivity by the Schweyer Rheometer
- Stress, strain, and creep compliance properties using Force-Ductility

1.3.1 A total of 12 different parameters were evaluated, analyzed and reported. Details of testing procedures and calculations are contained in the project Summary Report (1).

2.0 EXPERIMENTAL DESIGN AND DATA ANALYSIS

2.1 The experiment was designed as a sequentially randomized four factor fixed factorial model with two replications per cell.

2.1.1 The experimental matrix is presented in Figure 1.

2.1.2 This experiment utilized portions of data reported in Volume I, "Effects of Rubber Type, Concentration, and Asphalt" of this investigation. Data utilized from Volume I was at 39.2F (4C) for the mixtures investigated. Testing sequence at 77F (25C) and -20F (-29C) was sequentially randomized - first by temperature and then by mixture type.

2.1.3 The fixed factor model is:

$$Y_{ijklm} = \mu + R_i + Q_j + A_k + T_l + (RQ)_{ij} + (RA)_{ik} + (RT)_{il} + (QA)_{jk} + (QT)_{jl} + (AT)_{kl} + (RQA)_{ijk} + (RAT)_{ikl} + (QAT)_{jkl} + (RQT)_{ijl} + (RQAT)_{ijkl} + \varepsilon_{(ijkl)m}$$

in which:

Y_{ijklm} = Response variable (Schweyer constants, true stress, etc.) for the ith level of rubber type, j^{th} level of rubber concentration, k^{th} level of asphalt, l^{th} level of temperature, and m^{th} replication.

μ = Effect of overall mean

R_i = Effect of rubber type

Q_j = Effect of rubber concentration

A_k = Effect of asphalt type

T_l = Effect of temperature

ASPHALT

RUBBER CONCENTRATION

RUBBER TYPE

TEMPERATURE

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%						
	25%						
AR1000	20%						
	25%						

Figure 1 Experiment Test Matrix

$$\left.\begin{array}{l}(RQ)_{ij}\\(RA)_{ik}\\(RT)_{il}\\(QA)_{jk}\\(QT)_{jl}\\(AT)_{kl}\end{array}\right\} = \text{Second order interactions}$$

$$\left.\begin{array}{l}(RQA)_{ijk}\\(RAT)_{ikl}\\(QAT)_{jkl}\\(RQT)_{ijl}\end{array}\right\} = \text{Third order interactions}$$

$$(RQAT)_{ijkl} = \text{Fourth order interaction}$$

$$\varepsilon_{(ijkl)m} = \text{Experimental error}$$

2.1.4 Degrees of freedom for the analysis are as follows:

Source	Degrees of Freedom
R_i	1
Q_j	1
A_k	1
T_l	2
$(RQ)_{ij}$	1
$(RA)_{ik}$	1
$(RT)_{il}$	2
$(QA)_{jk}$	1
$(QT)_{jl}$	2
$(AT)_{kl}$	2
$(RQA)_{ijk}$	1
$(RAT)_{ikl}$	2
$(QAT)_{jkl}$	2
$(RQT)_{ijl}$	2
$(RQAT)_{ijkl}$	2
Error	24
Total	47

2.1.5 Prior to analysis, homogeneity of variance was tested by the Foster and Burr q-test (2). Appropriate data transformations were used when necessary to comply with variance homogeneity constraints required for analysis of variance.

2.2 Levels of Independent Variables

2.2.1 Rubber at two levels:

- TP044
- GT274

2.2.2 Rubber quantities at two levels, 20 and 25 percent by weight of the asphalt-rubber mixture.

2.2.3 Asphalt at two levels:

- AR4000 + 2 percent extender oil
- AR1000

2.2.4 Temperature at three levels:

- 77F (25C)
- 39.2F (4C)
- -20F (-29C)

3.0 RESULTS AND DISCUSSIONS

3.1 Schweyer Rheometer Constant, F-tube.

3.1.1 Measured rheometer constants using the F-tube are tabulated in Appendix A in Table A-1 and plotted in Figures A1 and A2.

3.1.2 Measured data did not require transformation to provide for variance homogeneity for analysis.

3.1.3 The ANOVA summary for rheometer constant, F-tube, is tabulated in Table A-2.

3.1.3.1 Rubber type is a significant effect at the 0.05 level but not at the 0.01. Temperature is significant at the 0.01 level. All other main effects and interactions are not significant at the 0.05 level.

3.1.4 Analysis indicates that rubber type and temperature influence the shear susceptibility constant in the F-tube. Average results at 77F are 0.42 for TPO44 rubber and 0.51 for GT274, at 39.2F are 0.79 for TPO44 and 1.10 for GT274, and at -20F, 0.24 for TPO44 and 0.28 for GT274. These results indicate that at 39.2F, the asphalt-rubber mixtures tested are close to being Newtonian, while at 77 and -20F, materials tested are pseudoplastic.

3.2 Schweyer Rheometer Apparent Viscosity ($\eta_{0.05}$) F-tube

3.2.1 Measured apparent viscosity data using the F-tube are tabulated in Appendix B in Table B-1 and plotted in Figures B1 and B2.

3.2.2 In order to satisfy variance homogeneity requirements, logarithmic transformations of the data were required prior to analysis. Log transformed data are tabulated in Appendix B in Table B-2.

3.2.3 The ANOVA summary for log apparent viscosity, F-tube is tabulated in Table B-3.

3.2.3.1 Rubber concentration is a significant effect at the 0.05 level but not at the 0.01. Temperature and the rubber-temperature interaction are significant at the 0.01 level. All other main effects and interactions are not significant at the 0.05 level.

3.2.4 Analysis indicates that rubber concentration, temperature, and the rubber type-temperature interaction influence apparent viscosity. Average results at 77F are 0.64 x 10^6 Pa-s for 20 percent rubber and 0.92 x 10^6 Pa-s for 25 percent, at 39.2F are 83.7 x 10^6 Pa-s for 20 percent and 400.0 x 10^6 Pa-s for 25 percent, and at -20F, 99.6 x 10^6 Pa-s for 20 percent and 97.1 x 10^6 Pa-s for 25 percent. For 20 percent rubber mixtures, as temperature decreases, apparent viscosity increases as noted in Figure B1. For 25 percent rubber at 39.2F, the average result of 400 x 10^6 Pa-s may be misleading due to a very high observation (2500 x 10^6 Pa-s) for TPO44 rubber which may be an outlying value. This value may be the cause of the indicated rubber concentration effect and the rubber type-temperature interaction.

3.3 Force-Ductility Load at Failure

3.3.1 Measured force ductility load at failure data are tabulated in Appendix C in Table C-1. Three measurements were obtained for each matrix cell replicate.

3.3.2 Analyzed load at failure data are tabulated in Table C-2 and plotted in Figures C1 and C2. Each entry in Table C-2 is the mean of three measurements from Table C-1.

3.3.3 The ANOVA summary for force ductility load at failure is tabulated in Table C-3.

3.3.3.1 Rubber type, temperature, and the rubber-temperature interaction are significant effects at the 0.01 level. All other main effects and interactions are not significant at the 0.05 level.

3.3.4 Analysis indicates that rubber type, temperature, and the rubber-temperature interaction influence load at failure. Average results at 77F are .67 pounds for TPO44 rubber and .55 pounds for GT274, at 39.2F, 17.9 pounds for TPO44 and 15.5 pounds for GT274, and at -20F, 45.8 pounds for TPO44 and 71.6 pounds for GT274. The effect of temperature is that as temperature decreases, load at failure increases. Loads at failure at either 77 or 39.2F are approximately the same for TPO44 and GT274 rubber, but at -20F, average load at failure for GT274 is higher than for TPO44 (71.6 pounds for GT274 compared to 45.8 pounds for TPO44). These trends can be seen in Figures C-1 and C-2. This tends to indicate that mixtures containing GT274 rubber get stronger at low temperatures than mixtures containing TPO44 rubber.

3.4 Force-Ductility Elongation at Failure

3.4.1 Measured force ductility elongation at failure data are tabulated in Appendix D in Table D-1. Three measurements were obtained for each matrix cell replicate.

3.4.2 Reduced elongation at failure data are tabulated in Table D2 and plotted in Figures D1 and D2. Each entry in Table D-2 is the mean of three values from Table D-1.

3.4.3 In order to satisfy variance homogeneity requirements, square root $\sqrt{\ }$ log transformations of the data were required. Analyzed data are tabulated in Table D-3.

3.4.4 The ANOVA summary for elongation at failure is tabulated in Table D-4.

3.4.4.1 Rubber type, rubber concentration, temperature, the rubber type-temperature interaction, and the concentration-rubber type-temperature interaction, and the four-way interaction are significant effects at the 0.01 level. The concentration-temperature interaction is significant at the 0.05 level but not at the 0.01. Asphalt and other interactions are not significant at the 0.05 level.

3.4.5 Analysis indicates that rubber type, rubber concentration, temperature, and several interactions influence elongation at failure results. Lowest elongation at failure results were at -20F (overall average of 16.3 mm). For TPO44 mixtures, elongations at failure at 39.2F were greater than at 77F, which is contrary to the manner in which asphalt cement would behave. For TPO44 rubber, average result was 108 mm at 77F compared to 206 mm at 39.2F. These reduced elongations at 77F may be due to quick specimen necking into a thin thread which was noted during testing at 77F which did not occur to as great an extent at 39.2F.

For GT274 mixtures with 20 percent rubber, average elongations at failure were 453 mm at 77F and 416 mm at 39.2F, and for 25 percent rubber 366 mm at 77F and 396 mm at 39.2F. The noted increase in elongations at failure for TPO44 rubber between 77 and 39.2 are not noted with 20 percent GT274 rubber mixtures, but are for the 25 percent GT274 mixtures, however, not to as great an extent. This limited data tends to indicate that larger rubber particles and increasing rubber concentrations will tend to decrease elongations at failure at 77F when compared to results at 39.2F.

3.5 Force-Ductility Engineering Stress at Failure

3.5.1 Calculated engineering stress at failure data are tabulated in Appendix E in Table E-1. Three determinations were obtained for each matrix cell replication.

3.5.2 Reduced engineering stress at failure data which were analyzed are tabulated in Table E-2 and plotted in Figures E1 and E2. Each entry in Table E-2 is the mean of three values in Table E-1.

3.5.3 The ANOVA summary for engineering stress at failure is tabulated in Table E-3.

3.5.3.1 Rubber type, temperature, and the rubber type-temperature interaction are significant effects at the 0.01 level. All other main effects and interactions are not significant at the 0.05 level.

3.5.4 Analysis indicates that rubber type, temperature, and the rubber type-temperature interaction and the rubber concentration-temperature influence engineering stress at failure results. Average results at 77F are 4.2 psi for TPO44 rubber and 3.5 psi for GT274, at 39.2F, 112.8 psi for TPO44 and 81.5 psi for GT274, and at -20F, 285.9 psi for TPO44 and 445.7 psi for GT274. The effect of temperature is that as temperature decreases, engineering stress at failure increases. Engineering stress at failure at 77 and 39.2F are approximately the same for TPO44 and GT274 rubber mixtures, however, a large difference exists between results at -20F for TPO44 and GT274 mixtures (285.9 psi for TPO44 compared to 445.7 psi for GT274). These trends can be seen in Figures E1 and E2. These results indicate that mixtures containing GT274 rubber are stronger at low temperatures than mixtures containing TPO44 rubber.

3.6 Force-Ductility Engineering Strain at Failure

3.6.1 Measured engineering strain at failure values are tabulated in Appendix F in Table F-1. Three determinations were obtained for each matrix cell replication.

3.6.2 Reduced engineering strain at failure data are tabulated in Table F-2 and are plotted in Figures F1 and F2. Each entry in Table F-2 is the mean of three values from Table F-1.

3.6.3 In order to satisfy variance homogeneity requirements, log transformations of the data were required. Analyzed data are tabulated in Table F-3.

3.6.4 The ANOVA summary for log of engineering strain at failure is tabulated in Table F-4.

3.6.4.1 Rubber type, temperature, and the rubber type-temperature interaction are significant effects at the 0.01 level. Rubber concentration, and the rubber concentration-temperature interaction are significant at the 0.05 level but not at the 0.01 level. Asphalt and other interactions are not significant at the 0.05 level.

3.6.5 Analysis indicates that rubber type, rubber concentration, temperature, and several interactions influence engineering strain at failure results. Lowest engineering strain at failure results were at -20F (overall average of 0.33 mm/mm). Lower engineering strain at failure at 77F when compared to results at 39.2F were noted for TPO44 mixtures while comparable results were noted for GT274 mixtures. The effect is similar to that with elongation at failure as discussed in Section 3.4.5 of this report.

3.7 Force-Ductility True Stress at Failure

3.7.1 Calculated force ductility true stress at failure data are tabulated in Appendix G in Table G-1. Three determinations were obtained for each matrix cell replication.

3.7.2 Reduced true stress at failure data are tabulated in Appendix G in Table G-2 and plotted in Figures G1 and G2. Each entry in Table G-2 is the mean of three values from Table G-1.

3.7.3 In order to satisfy variance homogeneity requirements, log transformations of the data were required. Analyzed data are tabulated in Table G-3.

3.7.4 The ANOVA summary for log of true stress at failure data is tabulated in Table G-4.

3.7.4.1 Rubber type, temperature, and the rubber type-temperature interaction are significant effects at the 0.01 level. Asphalt, the concentration-rubber interaction, and the asphalt-temperature interaction are significant at the 0.05 level but not at the 0.01. Rubber concentration and other interactions are not significant at the 0.05 level.

3.7.5 Analysis indicates that rubber type, asphalt, temperature and several interactions influence true stress at failure results. Lowest true stress at failure results are at 77F (overall average of 21.7 psi) and highest results are at 39.2F (697 psi overall average). Results at -20F are lower than at 39.2F which is contrary to engineering stress at failure results. These trends can be seen in Figures G1 and G2. The reason for higher results at 39.2F is due to the specimen cross sectional area used in calculations. At 39.2F, very small cross sectional areas are used (when compared to the cross section at failure at -20F) as cross sectional areas are calculated based on specimen initial gage length and elongation at failure assuming constant specimen volume between gage points as discussed in Section 6.3.3.5 of the project Summary Report (1).

3.8 Force-Ductility True Strain at Failure

3.8.1 Measured true strain at failure data are tabulated in Appendix H in Table H-1. Three determinations were obtained for each matrix cell replication.

3.8.2 Reduced true strain at failure data are tabulated in Appendix H in Table H-2 and plotted in Figures H1 and H2. Each entry in Table H-2 is the mean of three values from Table H-1.

3.8.3 In order to satisfy variance homogeneity requirements, log transformations of the data were required. Analyzed data are tabulated in Table H-3.

3.8.4 The ANOVA summary for log of true strain at failure is tabulated in Table H-4.

3.8.4.1 Rubber type, temperature, the rubber type-temperature interaction, and the concentration-rubber-temperature interaction are significant effects at the 0.01 level. Rubber concentration and asphalt are significant effects at the 0.05 level but not at the 0.01. Other interactions are not significant at the 0.05 level.

3.8.5 Analysis indicates that rubber type, asphalt, rubber concentration, temperature, and several interactions influence true strain at failure results. Lowest true strain at failure results are at -20F (0.28 mm/mm overall average). Lower true strain at failure at 77F when compared to results at 39.2F were noted for TPO44 mixtures, while comparable results were noted for GT274 mixtures. These trends are noted in Figures H1 and H2. The effect is similar to that with elongation at failure as discussed in Section 3.4.5 of this report.

3.9 Force-Ductility Engineering Creep Compliance at Failure

3.9.1 Calculated engineering creep compliance data are tabulated in Appendix I in Table I-1. Three determinations were made for each matrix cell replication.

3.9.2 Reduced engineering creep compliance at failure data which were analyzed are tabulated in Table I-2 and plotted in Figures I1 and I2. Each entry in Table I-2 is the mean of three values from Table I-1.

3.9.3 The ANOVA summary for engineering creep compliance at failure is tabulated in Table I-3.

3.9.3.1 Rubber type, asphalt, temperature, the rubber type-temperature interaction, the concentration-temperature interaction, and the asphalt-temperature interaction are significant effects at the 0.01 level. Concentration, the asphalt-rubber type interaction, and the asphalt-rubber type-temperature interaction are significant at the 0.05 level but not at the 0.01. Other interactions are not significant at the 0.05 level.

3.9.4 Analysis indicates that all main effects and several interactions influence engineering creep compliance at failure results. Average results at 77F are .57 psi^{-1} for TPO44 rubber and 2.44 psi^{-1} for GT274, at 39.2F, 0.04 psi^{-1} for TPO44 and .09 psi^{-1} for GT274, and at -20F, .0012 psi^{-1} for TPO44 and .0009 psi^{-1} for GT274. The effect of temperature is that as temperature decreases, engineering creep compliance at failure decreases. At 77 and 39.2F, mixtures containing GT274 rubber have higher average engineering creep compliance at failure results than TPO44 mixtures, while at -20F, GT274 mixtures have slightly lower average results. This indicates that asphalt rubber mixtures which contain GT274 rubber have a higher degree of temperature susceptibility than mixtures containing TPO44 rubber as indicated by engineering creep compliance at failure. These trends are noted in Figures I1 and I2.

3.10 Force-Ductility True Creep Compliance at Failure

3.10.1 Calculated true creep compliance data are tabulated in Appendix J in Table J-1. Three determinations were made for each matrix cell replication.

3.10.2 Reduced true creep compliance data are tabulated in Table J-2 and plotted in Figures J1 and J2.

3.10.3 In order to satisfy variance homogeneity requirements, log transformations of the data were required. For ease of calculation, the negative log of the data were analyzed. Analyzed data are tabulated in Table J-3.

3.10.4 The ANOVA summary for log of true creep compliance at failure is tabulated in Table J-4.

3.10.4.1 Rubber type, asphalt and temperature, are significant effects at the 0.01 level. Rubber concentration, the rubber-temperature interaction, and the asphalt-temperature interaction are significant at the 0.05 level but not at the 0.01 level. Other interactions are not significant at the 0.05 level.

3.10.5 Analysis indicates that all main effects and two interactions influence true creep compliance at failure. Average results at 77F are .0901 psi^{-1} for TPO44 rubber and .0751 psi^{-1} for GT274, at 39.2F, .0031 psi^{-1} for TPO44 and .0027 psi^{-1} for GT274, and at -20F, 0.0008 psi^{1} for TPO44 and .0004 psi^{1} for GT274. The effect of temperature is that as temperature decreases true creep compliance at failure decreases. At 77 and 39.2F, average results for TPO44 and GT274 rubbers are approximately the same, while, at -20F, TPO44 mixtures have higher average results (.0008 psi^{-1} average) than GT274 mixtures (.0004 psi^{-1} average). These results indicate differences in temperature susceptibilities of mixtures containing TPO44 and GT274 rubber as measured by true creep compliance at failure. These trends are noted in Figures J1 and J2.

3.11 Force-Ductility Maximum True Creep Compliance

3.11.1 Maximum true creep compliance data are tabulated in Appendix K in Table K-1. Three determinations were made for each matrix cell replication.

3.11.2 Reduced maximum true creep compliance data are tabulated in Appendix K in Table K-2 and plotted in Figures K1 and K2. Each entry in Table K-2 is the mean of three values in Table K-1.

3.11.3 In order to satisfy variance homogeneity requirements, log transformations of the data were required. For ease of calculation, negative logs of the data were analyzed. Analyzed data are tabulated in Table K-3.

3.11.4 The ANOVA summary for log of maximum true creep compliance data are tabulated in Table K-4.

3.11.4.1 Asphalt, temperature, the rubber-temperature interaction, the concentration-temperature interaction, and the asphalt-temperature interaction are significant at the 0.01 level. Rubber type and the concentration-rubber interaction are significant at the 0.05 level but not at the 0.01. Rubber concentration and other interactions are not significant at the 0.05 level.

3.11.5 Analysis indicates that rubber type, asphalt, temperature, and several interactions influence maximum true creep compliance. Average results at 77F are .0917 psi^{-1} for TPO44 rubber and .1120 psi^{-1} for GT274, at 39.2F, .00481 psi^{-1} for TPO44 and .00756 psi^{-1} for GT274, and at -20F, .00079 psi^{-1} for TPO44 and .00056 psi^{-1} for GT274. These results indicate that the effect of temperature is that as temperature decreases maximum true creep compliance decreases. These trends are noted in Figures J1 and J2.

3.12 Force-Ductility Time to Maximum True Creep Compliance

3.12.1 Time to maximum true creep compliance data are tabulated in Appendix L in Table L-1. Three determinations were made for each matrix cell replication.

3.12.2 Reduced time to maximum true creep compliance data are tabulated in Appendix L in Table L-2 and plotted in Figures L1 and L2. Each entry in Table L-2 is the mean of three values in Table L-1.

3.12.3 Numerous attempts were made to transform data to satisfy variance homogeneity requirements, but all were unsuccessful. Therefore, ANOVA was not performed on time to maximum true creep compliance data.

3.12.4 Average result at 77F is 12.1 minutes, at 39.2F, 10.2 minutes, and at -20F, 1 minute. Results indicate that as temperature decreases time to maximum true creep compliance decreases. This trend can be seen in Figures L1 and L2.

4.0 CONCLUSIONS

4.1 A summary of four-way ANOVA results is tabulated in Table 1. This table indicates independent variables and interactions which were found to significantly affect test parameters studied. From Table 1, it is noted that temperature influences all parameters studied and that rubber type and concentration influence nearly all parameters studied (as noted and discussed in Volume I of this investigation). Additionally, several interactions exist including a rubber type-temperature interaction and an asphalt-temperature interaction.

4.2 The effect of temperature is to stiffen and strengthen mixtures as temperature is lowered as evidenced by increased loads and stresses at failure, increased viscosity, and decreased elongation, strains, and compliances at failure.

4.3 The existance of the rubber-temperature and asphalt-temperature interactions for several parameters indicate that asphalt-rubber mixtures containing the different rubber and asphalt types studied react differently at different temperatures, or, more simply stated, have differing temperature susceptibilities.

Table 1 Summary of Four-Way ANOVA Results at the 0.05 Level of Significance

	R	Q	A	T	RQ	RA	RT	QA	QT	AT	RQA	RAT	QAT	RQT	RQAT
Schweyer Rheometer															
Constant (C), F-tube	Y	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
App.Viscosity, F-tube	-	Y	-	Y	-	-	Y	-	-	-	-	-	-	-	-
Force-Ductility															
Load at Failure	Y	-	-	Y	-	-	Y	-	-	-	-	-	-	-	-
Elongation at Failure	Y	Y	-	Y		-	Y	-	Y		-			Y	
Eng. Stress at Failure	Y	-	-	Y	-	-	Y	-	-	-	-	-	-	-	-
Eng. Strain at Failure	Y	Y	-	Y	-	-	Y	-	-	-	-	-	-	Y	-
True Stress at Failure	Y	-	Y	Y	Y	-	Y	-	-	Y	-	-	-	-	-
True Strain at Failure	Y	Y	Y	Y	-	-	Y	-	-	-	-	-	-	Y	-
Eng. Creep Compliance	Y	Y	Y	Y	-	Y	Y	-	Y	Y	-	Y	-	-	-
True Creep Compliance	Y	Y	Y	Y	-	-	Y	-	-	Y	-	-	-	-	-
Max.True Creep Compliance	Y	-	Y	Y	Y	-	Y	-	Y	Y	-	-	-	-	-

Note: Y = Significant at the 0.05 level.
- = Not significant at the 0.05 level.

References

1. Rosner, J. C. and Chehovits, J. G., "Chemical and Physical Properties of Asphalt-Rubber - Phase III - Project Summary Report, April, 1982.

2. Burr, I. W. and Foster, L. A., "A Test For Equality of Variances", Mimeograph Series No. 282, Statistics Department, Purdue University, Lafayette, Indiana, 1972.

APPENDIX A

SCHWEYER RHEOMETER CONSTANT

(C), F-TUBE

Table A-1 Schweyer Rheometer Constant (C), F-tube

a. Measured and Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.33	.71	.68	.90	.15	.31
		.42	.63	.59	1.7	.29	.23
	25%	.55	.66	1.1	1.1	.37	.22
		.17	.59	.70	1.5	.19	.25
AR1000	20%	.31	.42	.13	1.1	.32	.28
		.51	.26	.98	.92	.20	.32
	25%	.64	.44	1.1	.75	.15	.26
		.42	.37	.98	.82	.20	.33

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.38	.67	.64	1.30	.22	.27
		s	.08	.07	.08	.71	.12	.07
		cv	21.3	10.6	12.6	54.5	56.4	26.3
	25%	$\bar{x}$	.36	.63	.90	1.30	.28	.24
		s	.34	.06	.35	.35	.16	.03
		cv	93.5	9.9	39.4	27.3	57.0	11.3
AR1000	20%	$\bar{x}$	.41	.34	.56	1.01	.26	.30
		s	.18	.14	.75	.16	.11	.04
		cv	43.2	41.7	135.7	15.8	40.9	11.8
	25%	$\bar{x}$	.53	.41	1.04	.79	.18	.30
		s	.19	.06	.11	.06	.04	.06
		cv	36.8	15.3	10.2	7.9	25.3	21.0

Table A-2 ANOVA Summary, Schweyer Rheometer, Constant (C), F-tube

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	0.2685	0.2685	6.11	4.26	7.82
Q	1	0.0285	0.0285	0.65	4.26	7.82
A	1	0.0945	0.0945	2.15	4.26	7.82
T	2	3.9565	1.9782	45.05	3.40	5.61
RQ	1	0.0963	0.0963	2.19	4.26	7.82
RA	1	0.1788	0.1788	4.07	4.26	7.82
RT	2	0.1716	0.0858	1.95	3.40	5.61
QA	1	0.0013	0.0013	0.03	4.26	7.82
QT	2	0.0453	0.0226	0.52	3.40	5.61
AT	2	0.0741	0.0370	0.84	3.40	5.61
RQA	1	0.0072	0.0072	0.17	4.26	7.82
RAT	2	0.1567	0.0783	1.78	3.40	5.61
QAT	2	0.0170	0.0085	0.19	3.40	5.61
RQT	2	0.1432	0.0716	1.63	3.40	5.61
RQAT	2	0.0500	0.0250	0.57	3.40	5.61
Error	24	1.0538	0.0439			
TOTAL	47	6.3438				

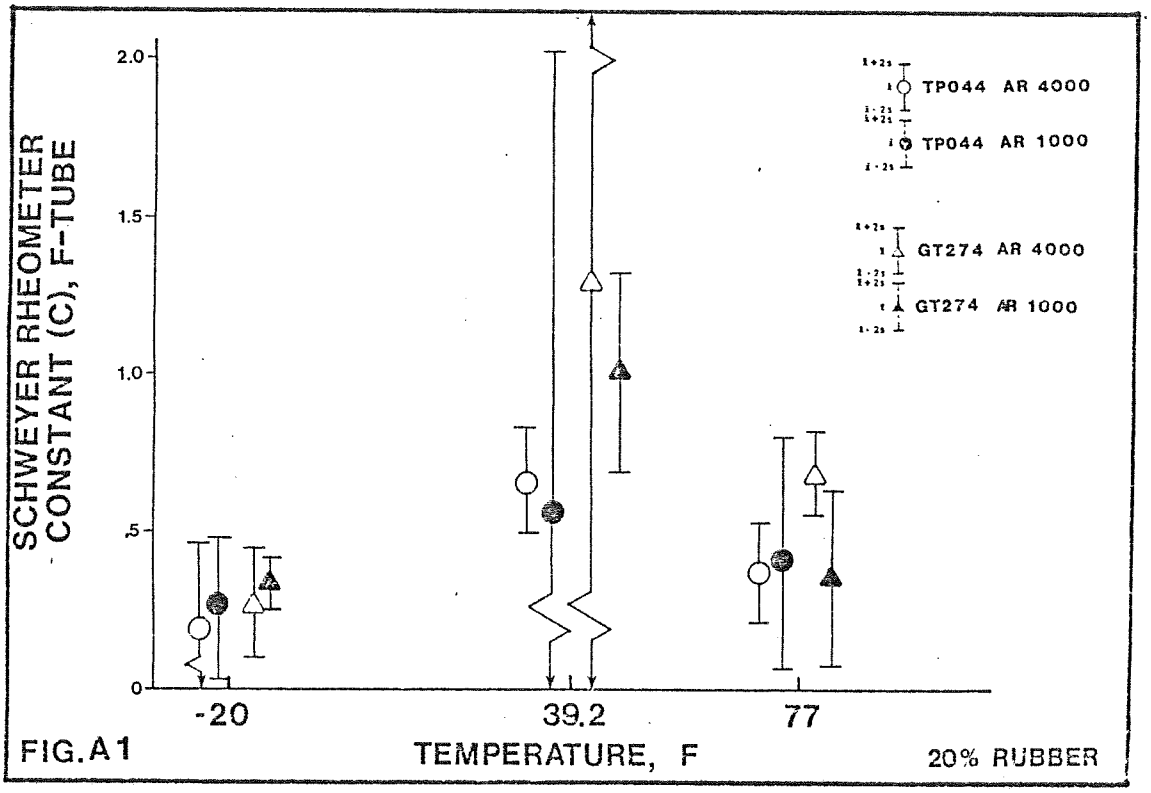
SCHWEYER RHEOMETER CONSTANT (C), F-TUBE
2.0
1.5
1.0
.5
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. A1

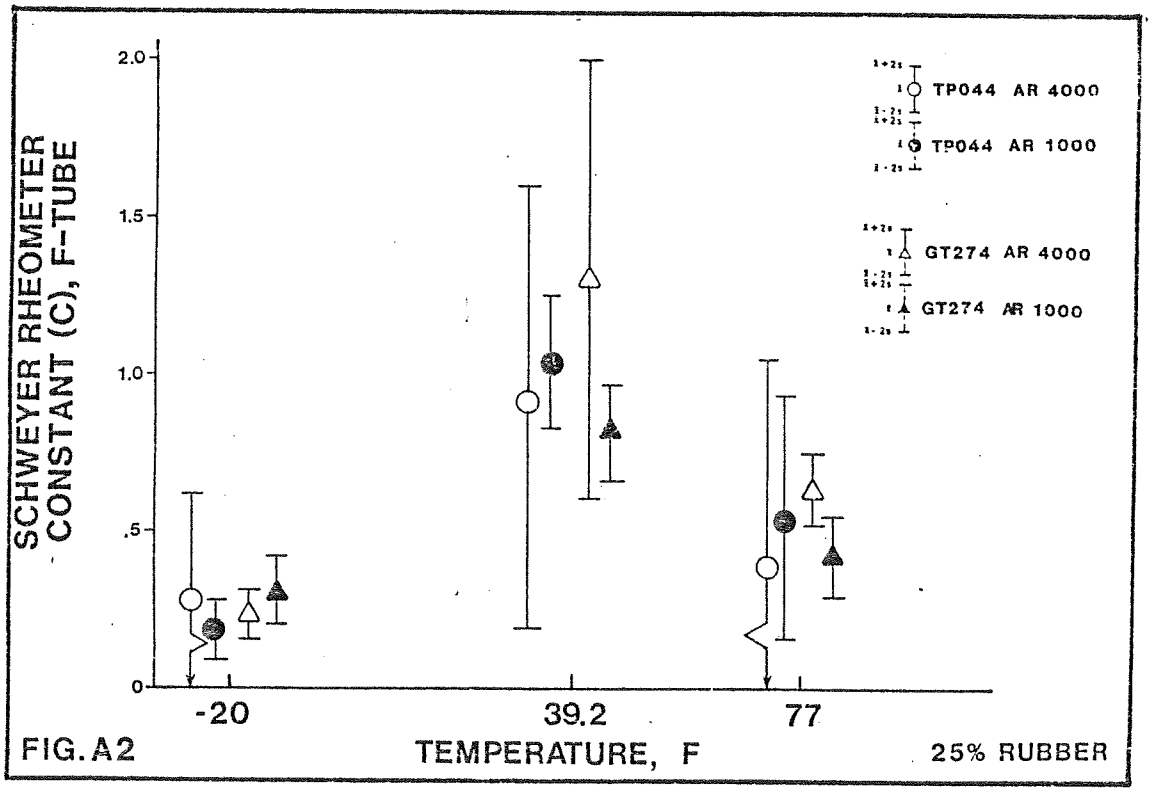
SCHWEYER RHEOMETER CONSTANT (C), F-TUBE
2.0
1.5
1.0
.5
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. A2

APPENDIX B

VISCOSITY ($\eta_{0.05}$) BY SCHWEYER RHEOMETER F-TUBE

Table B-1 Schweyer Rheometer $\eta_{0.05}$, 10^6 Pa-s, F-tube

a. Measured Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.47	1.2	24	34	64	110
		.65	1.1	410	21	110	79
	25%	.71	2.0	130	34	210	76
		.39	1.3	150	49	69	98
AR1000	20%	.43	.42	95	35	130	100
		.40	.40	8.8	42	84	120
	25%	.93	.78	2500	16	60	89
		.74	.50	230	91	75	100

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.56	1.15	217	27.5	87	94.5
		s	.1595	.0886	34.9	11.52	40.76	27.47
		cv	28.5	7.7	157.6	41.9	46.9	20.1
	25%	$\bar{x}$	.55	1.65	140	41.5	139.5	87
		s	.2835	.6202	17.72	13.29	124.93	19.49
		cv	51.6	37.6	16.7	32.0	89.6	22.4
AR1000	20%	$\bar{x}$	.42	.41	51.9	38.5	107	110
		s	.0266	.0177	76.37	6.20	40.76	17.72
		cv	6.4	4.3	147.2	16.1	38.1	16.1
	25%	$\bar{x}$	.84	.64	1365	53.5	67.5	94.5
		s	.1683	.2481	2011.22	66.45	13.29	9.75
		cv	20.2	38.8	147.3	124.2	19.7	10.3

Table B-2 Log Schweyer Rheometer $\eta_{0.05}$, 10^6 Pa-s, F-tube

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	-.3279	.0792	1.3802	1.5315	1.8062	2.0414
		-.1871	.0414	2.6128	1.3222	2.0414	1.8976
	25%	-.1487	.3010	2.1138	1.5315	2.3222	1.8808
		-.4089	.1139	2.1761	1.6902	1.8388	1.9912
AR1000	20%	-.3665	-.3768	1.9777	1.5441	2.1139	2.0000
		-.3979	-.3979	.9445	1.6232	1.9243	2.0792
	25%	-.0315	-.1079	3.3979	1.2041	1.7782	1.9494
		-.1308	-.3010	2.3617	1.9590	1.8751	2.0000

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	-.2575	.0603	1.9965	1.4269	1.9238	1.9695
		s	.1247	.0335	1.0921	.1854	.2084	.1274
		cv	48.4	55.5	54.7	13.0	10.8	6.5
	25%	$\bar{x}$	-.2788	.2075	2.1450	1.6109	2.0805	1.9360
		s	.2305	.1658	.0552	.1406	.4283	.0978
		cv	-82.7	80.0	2.6	8.7	20.6	5.1
AR1000	20%	$\bar{x}$	-.3822	-.3874	1.4611	1.5837	2.0191	2.0396
		s	.0278	.0187	.9154	.0701	.1630	.0702
		cv	7.3	4.8	62.7	4.4	8.3	3.4
	25%	$\bar{x}$	-0.0812	-.2045	2.8798	1.5816	1.8267	1.9747
		s	.0880	.1711	.9181	.6688	.0859	.0448
		cv	108.4	-83.7	31.9	42.3	4.7	2.3

Table B-3 ANOVA Summary, Schweyer Rheometer, Log Apparent Viscosity, F-tube

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	0.2281	0.2281	2.25	4.26	7.82
Q	1	0.4583	0.4583	4.53	4.26	7.82
A	1	0.0125	0.0125	0.12	4.26	7.82
T	2	46.4721	23.2360	229.58	3.40	5.61
RQ	1	0.1358	0.1358	1.34	4.26	7.82
RA	1	0.0316	0.0316	0.31	4.26	7.82
RT	2	1.1490	0.5745	5.68	3.40	5.61
QA	1	0.0738	0.0738	0.73	4.26	7.82
QT	2	0.4442	0.2220	2.19	3.40	5.61
AT	2	0.1256	0.0620	0.62	3.40	5.61
RQA	1	0.1991	0.1991	1.97	4.26	7.82
RAT	2	0.1522	0.0760	0.75	3.40	5.61
QAT	2	0.2703	0.1350	1.34	3.40	5.61
RQT	2	0.3521	0.1760	1.74	3.40	5.61
RQAT	2	0.3978	0.1990	1.97	3.40	5.61
Error	24	1.4290	0.1012			
TOTAL	47	52.9323				

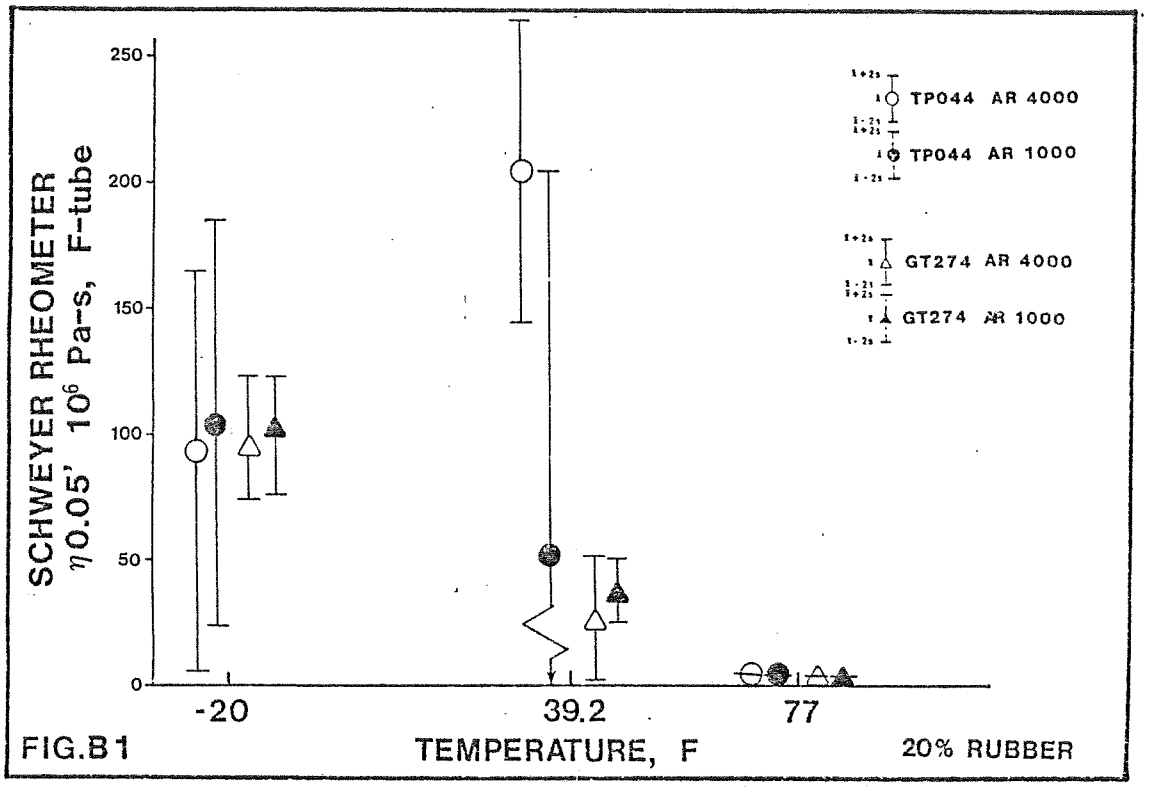
SCHWEYER RHEOMETER
η0.05' 10^6 Pa-s, F-tube
250
200
150
100
50
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG.B1

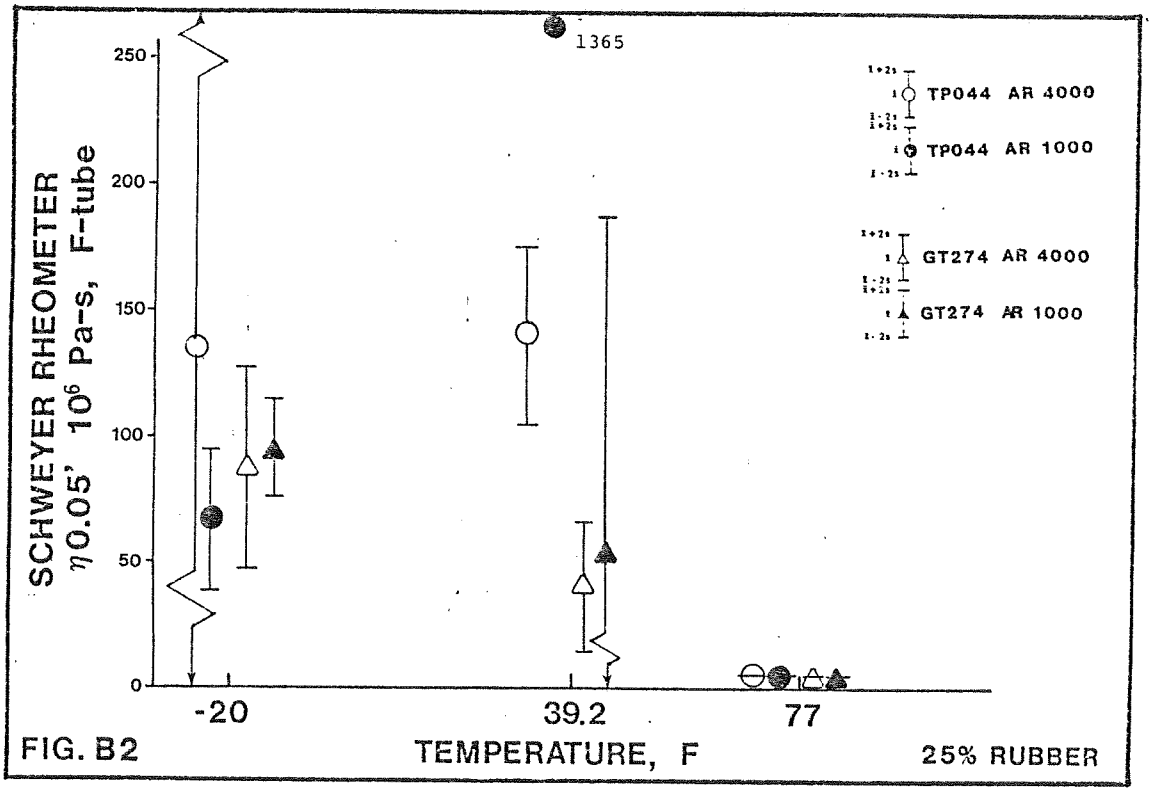
SCHWEYER RHEOMETER
η0.05' 10^6 Pa-s, F-tube
250
200
150
100
50
0
1365
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. B2

APPENDIX C

FORCE-DUCTILITY LOAD AT FAILURE

Table C-1 Load at Failure, pounds

a. Measured Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.6124	.4241	23.04	18.10	41.327	82.472
		.7199	.5048	21.62	18.98	48.319	84.623
		.6124	.4510	18.79	19.00	24.116	77.093
		.6392	.6661	21.64	19.95	49.932	58.538
		.6392	.6392	20.89	19.41	46.167	66.068
		.6661	.58546	19.89	18.25	48.857	78.824
	25%	.8813	.6661	23.71	18.17	39.176	57.731
		.7737	.4779	23.47	18.93	44.016	83.816
		.9082	.7468	21.29	19.22	41.865	
		.3006	.6661	23.20	19.30	47.781	80.051
		.7737	.6392	22.13	19.41	43.478	62.203
		.8813	.6661	18.87	18.98	55.311	75.749
AR1000	20%	.4510	.4779	9.27	11.10	46.167	86.505
		.4510	.3434	13.28	10.60	23.578	86.505
		.4510	.4510	10.12	10.80	36.486	94.573
		.4510	.7468	13.79	10.00	42.403	55.741
		.4779	.5048	12.74	10.27	44.554	77.228
		.4779	.4510	12.10	10.94	55.311	73.060
	25%	.77370	.6392	17.13	12.69	57.462	46.167
		.69303	.5048	18.68	12.58	54.235	*
		.8813	.4510	20.24	13.90	55.849	*
		.7200	.5048	16.21	13.70	61.227	75.458
		.7200	.5048	16.37	14.00	32.184	*
		.6661	.4510	14.19	12.70	58.000	*

*Note: Specimens fractured before readings could be taken.

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.6482	.5451	20.98	18.95	43.120	74.603
		s	.0405	.1002	1.489	.697	9.798	10.171
		cv	6.24	18.39	7.10	3.68	22.72	13.63
	25%	$\bar{x}$	.8365	.6437	22.11	19.00	45.271	71.910
		s	.0606	.0891	1.831	.447	5.668	11.380
		cv	7.24	13.83	8.28	2.35	12.52	15.83
AR1000	20%	$\bar{x}$	.4600	.4958	11.88	10.62	41.417	78.935
		s	.0139	.1356	1.806	.418	10.667	13.671
		cv	3.02	27.16	15.20	3.93	25.76	17.32
	25%	$\bar{x}$	.7424	.5093	17.15	13.26	53.160	60.313
		s	.0769	.0689	2.104	.676	10.539	25.07
		cv	10.35	13.53	12.27	5.10	19.83	41.57

Table C-2 Load at Failure, pounds

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.648	.460	21.1	18.7	37.9	81.4
		.648	.630	20.8	19.2	48.3	67.8
	25%	.854	.630	22.8	18.8	41.7	70.8
		.819	.657	21.4	19.2	48.9	72.7
AR1000	20%	.451	.424	10.9	10.8	35.4	89.2
		.469	.568	12.9	10.4	47.4	68.7
	25%	.783	.532	18.7	13.1	55.8	46.2
		.700	.487	14.6	13.5	50.5	75.5

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{X}$	.648	.549	21.0	19.0	43.1	74.6
		s	0	.144	.22	.44	9.2	12.1
		cv	0	26.1	1.2	2.3	21.4	16.2
	25%	$\bar{X}$	.837	.644	22.1	19.0	45.3	71.8
		s	.03	.02	1.24	.35	6.38	1.68
		cv	3.7	3.7	5.6	1.9	14.1	2.3
AR1000	20%	$\bar{X}$	.460	.496	11.9	10.6	41.4	79.0
		s	.016	.128	1.77	.35	10.6	18.2
		cv	3.5	25.7	14.9	3.3	25.7	23.0
	25%	$\bar{X}$	.742	.510	16.7	13.3	53.2	60.9
		s	.074	.040	3.6	.35	4.70	26.0
		cv	9.9	7.8	21.8	2.7	8.8	42.7

Table C-3 ANOVA Summary, Load at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	720.09	720.09	18.96	4.26	7.82
Q	1	0.41	0.41	0.01	4.26	7.82
A	1	72.10	72.10	1.90	4.26	7.82
T	2	28724.28	14362.14	378.15	3.40	5.61
RQ	1	122.93	122.93	3.24	4.26	7.82
RA	1	12.30	12.30	0.32	4.26	7.82
RT	2	1966.28	983.14	25.89	3.40	5.61
QA	1	0.02	0.02	0.00	4.26	7.82
QT	2	30.62	15.31	0.40	3.40	5.61
AT	2	131.76	65.88	1.73	3.40	5.61
RQA	1	56.02	56.02	1.48	4.26	7.82
RAT	2	28.07	14.03	0.37	3.40	5.61
QAT	2	17.86	8.93	0.24	3.40	5.61
RQT	2	184.08	92.04	2.42	3.40	5.61
RQAT	2	97.97	48.98	1.29	3.40	5.61
Error	24	911.52	37.98			
TOTAL	47	33076.37				

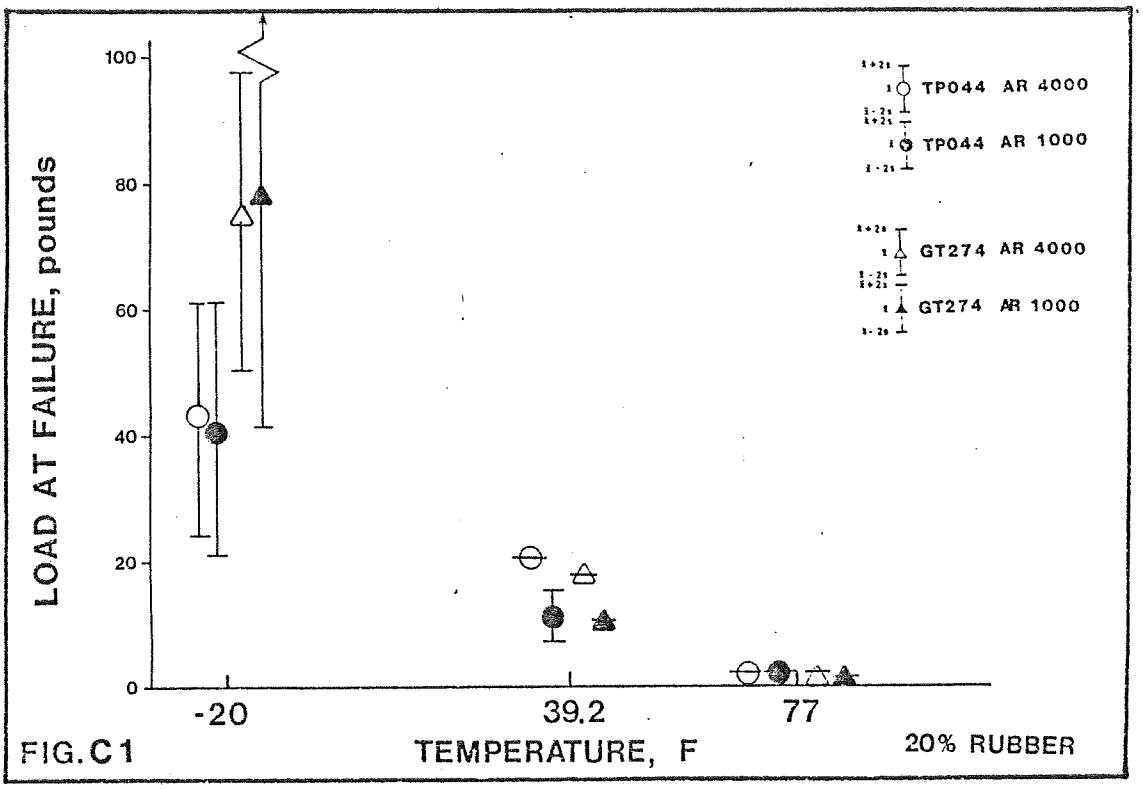
LOAD AT FAILURE, pounds
100
80
60
40
20
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. C1

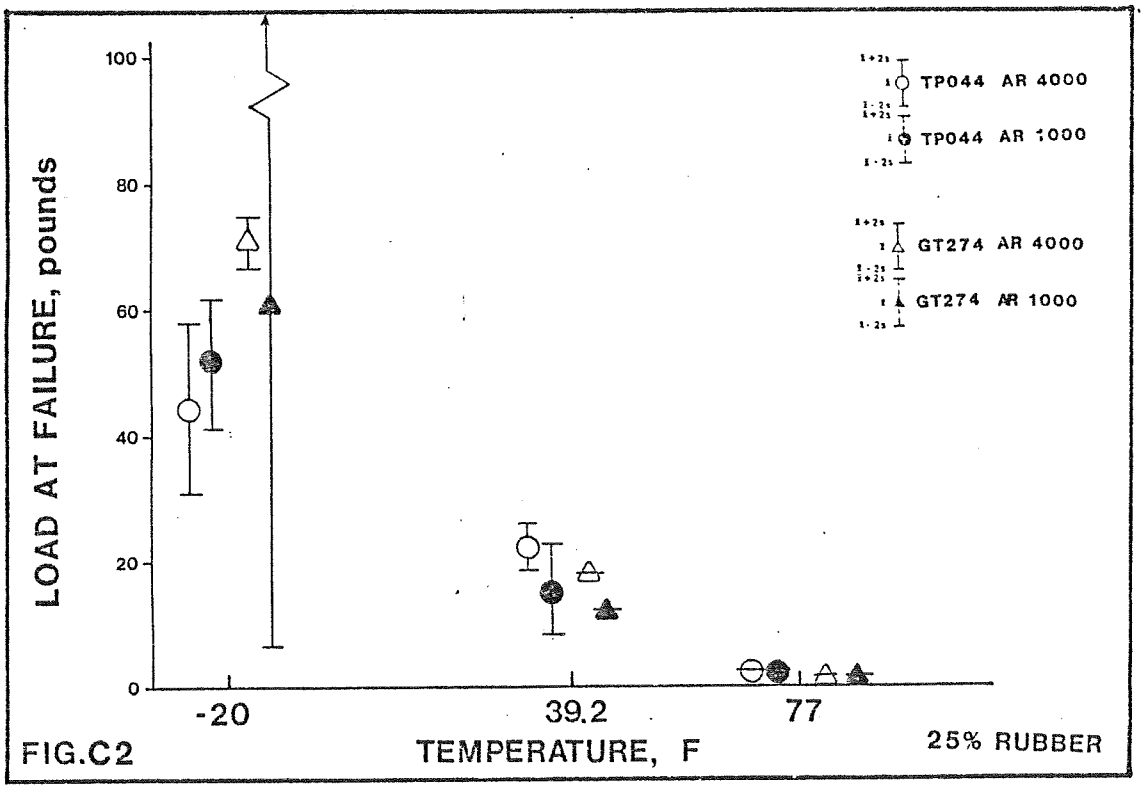
LOAD AT FAILURE, pounds
100
80
60
40
20
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. C2

APPENDIX D

FORCE-DUCTILITY ELONGATION AT FAILURE

Table D-1 Elongation at Failure, mm

a. Measured Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	111	433	201	387	11	13
		123	377	193	378	16	16
		107	499	205	388	18	27
		117	391	202	357	20	20
		203	298	189	392	17	22
		184	491	210	412	13	23
	25%	104	247	178	358	16	16
		98	72	203	351	20	20
		55	183	175	376	21	
		62	361	174	367	23	21
		96	380	192	397	18	17
		68	367	244	346	16	16
AR1000	20%	113	550	253	499	15	20
		164	460	235	452	15	20
		131	498	240	462	13	17
		100	546	280	409	13	18
		109	479	209	394	15	20
		119	412	239	463	20	20
	25%	122	574	181	451	20	17
		68	359	183	421	25	*
		108	427	184	445	17	*
		69	520	189	425	20	17
		73	467	202	406	16	*
		82	442	174	406	20	*

*Note: Specimens fractured before readings could be taken.

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	140.83	414.83	200.00	385.67	15.83	20.17
		s	41.59	75.98	7.75	18.01	3.31	5.04
		cv	29.53	18.32	3.87	4.67	20.92	24.98
	25%	$\bar{x}$	80.50	268.33	194.33	365.83	19.00	18.00
		s	21.20	124.16	26.84	18.71	2.83	2.35
		cv	26.34	46.27	13.81	5.12	14.89	13.03
AR1000	20%	$\bar{x}$	122.67	490.83	242.67	446.50	15.17	19.17
		s	22.74	52.73	23.30	38.63	2.56	1.33
		cv	18.54	10.74	9.60	8.65	16.90	6.93
	25%	$\bar{x}$	87.00	464.83	185.50	425.67	19.67	17.00
		s	22.68	74.99	9.44	19.03	3.14	0
		cv	26.07	16.13	5.09	4.47	15.97	0

Table D-2 Elongation at Failure, mm

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	114	436	200	384	15	19
		168	393	200	387	17	22
	25%	86	167	185	362	19	12
		75	369	203	370	19	18
AR1000	20%	136	503	243	471	14	19
		109	479	243	422	16	19
	25%	99	453	183	439	21	17
		75	476	188	412	19	17

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	141.0	414.5	200.0	385.5	16.0	20.5
		s	47.84	38.10	0	2.66	1.77	2.66
		cv	33.9	9.2	0	.7	11.1	13.0
	25%	$\bar{x}$	80.5	268.0	194.0	366.0	19.0	15.0
		s	9.75	178.97	15.95	7.09	0	5.32
		cv	12.1	66.8	8.2	1.9	0	35.4
AR1000	20%	$\bar{x}$	122.5	491.0	243.0	446.5	15.0	19.0
		s	23.92	21.26	0	43.41	1.77	0
		cv	19.5	4.3	0	9.7	11.8	0
	25%	$\bar{x}$	87.0	464.5	185.5	425.5	20.0	17.0
		s	21.26	20.38	4.43	23.92	1.77	0
		cv	24.4	4.4	2.4	5.6	8.9	0

Table D-3 $\sqrt{\ }$ Log Elongation at Failure

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	1.434	1.625	1.517	1.608	1.084	1.131
		1.492	1.611	1.517	1.609	1.109	1.159
	25%	1.391	1.491	1.506	1.600	1.131	1.039
		1.369	1.602	1.519	1.603	1.131	1.120
AR1000	20%	1.461	1.644	1.545	1.635	1.071	1.131
		1.427	1.637	1.545	1.620	1.097	1.131
	25%	1.413	1.630	1.504	1.620	1.150	1.109
		1.369	1.636	1.508	1.617	1.131	1.109

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	1.463	1.618	1.517	1.609	1.097	1.145
		s	.061	.012	0	.001	.022	.025
		cv	3.5	.8	0	.1	2.0	2.2
	25%	$\bar{x}$	1.380	1.547	1.513	1.602	1.131	1.080
		s	.019	.098	.012	.003	0	.072
		cv	1.4	6.4	.8	.2	0	6.6
AR1000	20%	$\bar{x}$	1.444	1.641	1.545	1.628	1.084	1.131
		s	.030	.000	0	.013	.023	0
		cv	2.1	.4	0	.8	2.1	0
	25%	$\bar{x}$	1.391	1.633	1.506	1.622	1.141	1.109
		s	.039	.005	.004	.008	.017	0
		cv	2.8	.3	.2	.5	1.5	0

Table D-4 ANOVA Summary, $\sqrt{\text{Log}}$ Elongation at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	.10983	.10983	181.92	4.26	7.82
Q	1	.00612	.00612	10.14	4.26	7.82
A	1	.00244	.00244	4.04	4.26	7.82
T	2	1.95984	.97992	1623.16	3.40	5.61
RQ	1	.00074	.00074	1.22	4.26	7.82
RA	1	.00188	.00188	3.11	4.26	7.82
RT	2	.06986	.03493	57.86	3.40	5.61
QA	1	.00126	.00126	2.09	4.26	7.82
QT	2	.00632	.00316	5.24	3.40	5.61
AT	2	.00098	.00049	0.81	3.40	5.61
RQA	1	.00065	.00065	1.07	4.26	7.82
RAT	2	.00169	.00085	1.40	3.40	5.61
QAT	2	.00235	.00118	1.95	3.40	5.61
RQT	2	.00823	.00412	6.82	3.40	5.61
RQAT	2	.00002	.00001	0.02	3.40	5.61
Error	24	.01449	.00060			
TOTAL	47	2.18668				

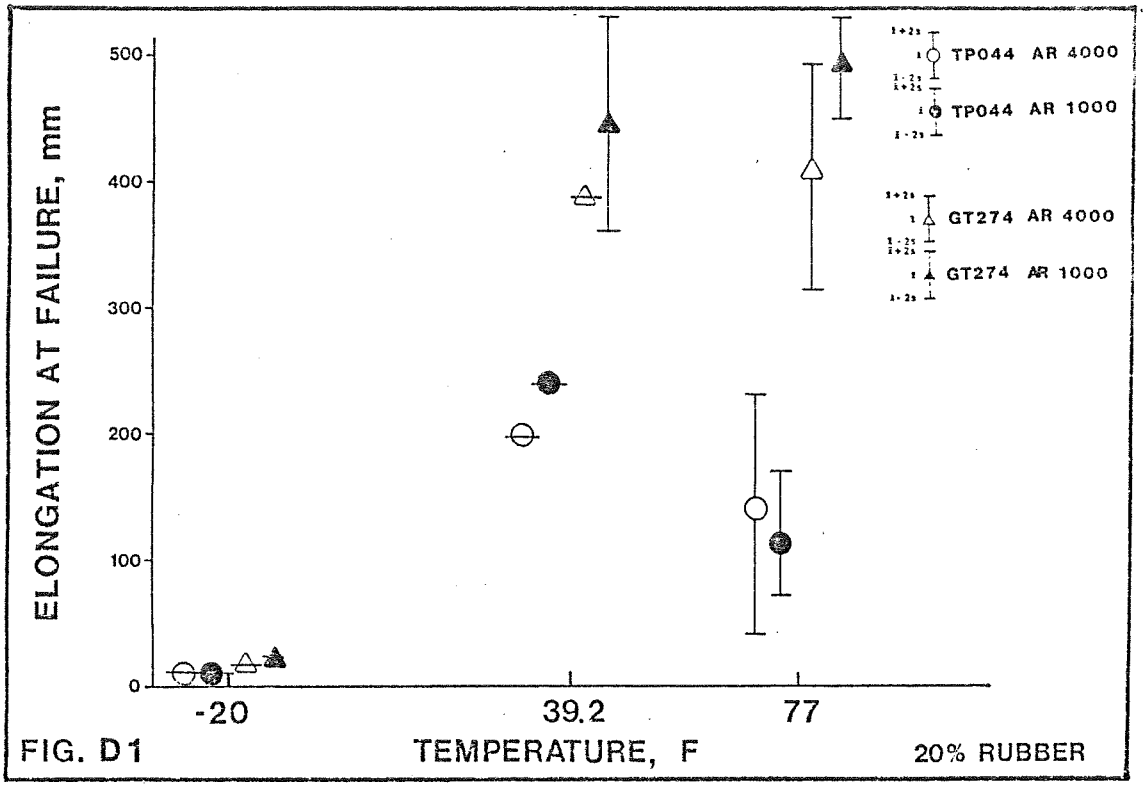
ELONGATION AT FAILURE, mm
500
400
300
200
100
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. D1

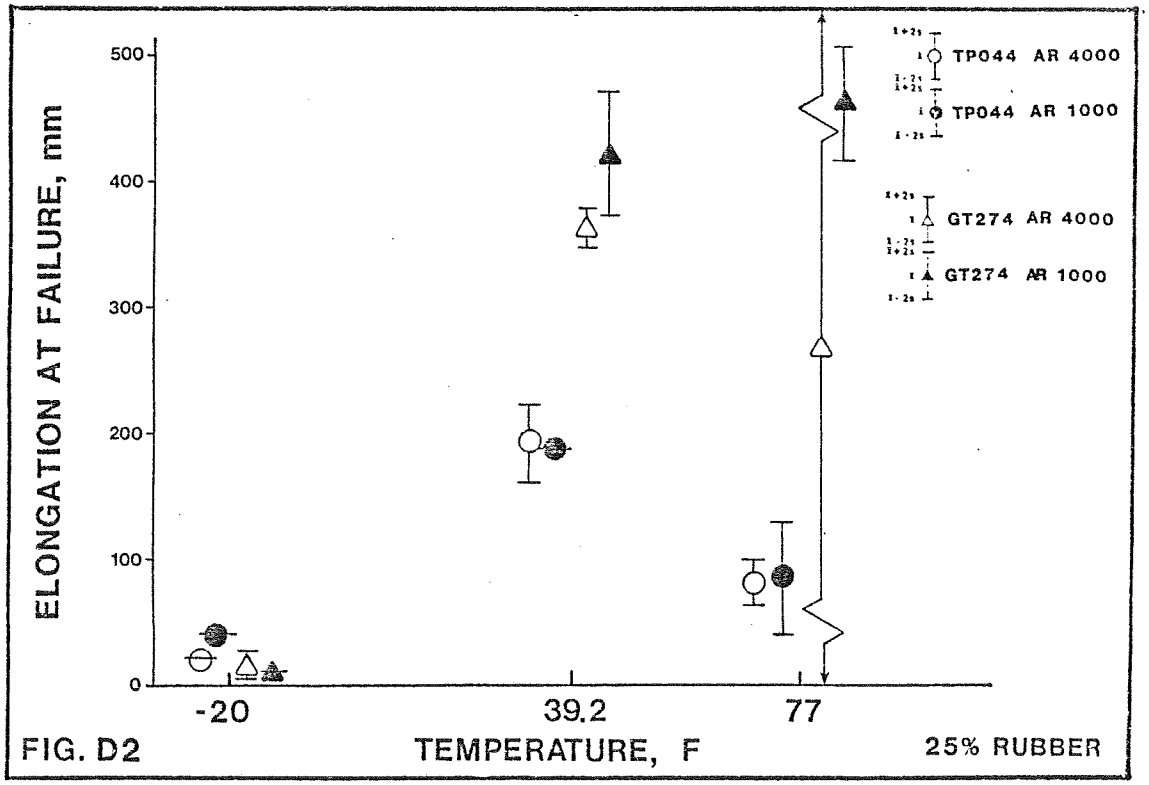
ELONGATION AT FAILURE, mm
500
400
300
200
100
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. D2

APPENDIX E

FORCE-DUCTILITY ENGINEERING

STRESS AT FAILURE

Table E-1 Engineering Stress at Failure, psi

a. Calculated Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	3.8	2.7	144.0	113.4	258.3	515.4
		4.5	3.2	135.1	118.6	302.0	528.9
		3.8	2.8	117.4	118.5	150.7	481.8
		4.0	4.2	135.3	124.7	312.1	365.9
		4.0	4.0	130.6	121.3	288.5	412.9
		4.2	3.7	124.3	114.1	305.4	480.2
	25%	5.5	4.2	148.2	113.6	244.8	360.8
		4.8	3.0	146.7	118.3	275.1	523.9
		5.7	4.7	133.1	120.1	261.7	
		5.0	4.2	145.0	120.6	298.6	500.3
		4.8	4.0	138.3	121.3	271.7	389.4
		5.5	4.2	118.0	118.6	345.7	473.4
AR1000	20%	2.8	3.0	57.9	69.2	288.5	540.7
		2.8	2.1	83.0	66.2	147.4	540.7
		2.8	2.8	63.2	67.5	228.0	591.1
		2.8	4.7	86.2	62.5	265.0	348.4
		3.0	3.2	79.6	64.2	278.5	482.7
		3.0	2.8	75.6	68.2	345.7	456.6
	25%	4.8	4.0	107.4	79.1	359.1	288.5
		4.3	3.2	116.8	78.6	339.0	*
		5.5	2.8	126.5	86.5	349.1	*
		4.5	3.2	101.3	84.8	382.7	465.4
		4.5	3.2	102.3	87.5	201.1	*
		4.2	2.8	88.7	79.1	362.5	*

*Note: Specimens fractured before readings could be taken.

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	4.05	3.43	131.12	118.43	269.5	464.18
		s	.267	.628	9.319	4.281	61.253	62.718
		cv	6.58	18.30	7.11	3.62	22.73	13.51
	25%	$\bar{x}$	5.22	4.05	138.22	118.75	282.93	449.6
		s	.397	.565	11.424	2.775	35.434	71.005
		cv	7.61	13.95	8.27	2.34	12.52	15.79
AR1000	20%	$\bar{x}$	2.87	3.10	74.25	66.30	258.85	499.37
		s	.103	.867	11.307	2.542	66.662	73.697
		cv	3.60	27.97	15.23	3.84	25.75	14.78
	25%	$\bar{x}$	4.63	3.20	107.17	82.83	332.25	376.95
		s	.472	.438	13.159	4.311	65.895	156.733
		cv	10.18	13.69	12.28	5.20	19.83	41.58

Table E-2 Engineering Stress at Failure, psi

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	4.0	2.9	132.2	116.8	237.0	508.7
		4.1	4.0	130.1	120.0	302.0	419.7
	25%	5.3	4.0	142.7	117.3	260.5	442.4
		5.1	4.1	133.8	120.2	305.3	454.4
AR1000	20%	2.8	2.6	68.0	67.6	221.3	557.5
		3.0	3.6	80.5	65.0	296.4	429.2
	25%	4.9	3.3	116.9	81.4	349.1	288.5
		4.4	3.1	97.4	83.8	315.4	465.4

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	4.1	3.5	131.2	118.4	269.5	464.2
		s	.1	1.0	1.9	2.8	57.6	78.9
		cv	2.2	28.2	1.4	2.4	21.4	17.0
	25%	$\bar{x}$	5.2	4.1	138.3	118.8	282.9	448.4
		s	.2	.1	7.9	2.6	39.7	10.6
		cv	3.4	2.2	5.7	2.2	14.0	2.4
AR1000	20%	$\bar{x}$	2.9	3.1	74.3	66.3	258.9	493.4
		s	.2	.9	11.1	2.3	66.5	113.7
		cv	6.1	28.6	14.9	3.5	25.7	23.0
	25%	$\bar{x}$	4.7	3.2	107.2	82.6	332.3	376.9
		s	.4	.2	17.3	2.1	29.9	156.8
		cv	9.5	5.5	16.1	2.6	9.0	41.6

Table E-3 ANOVA Summary, Engineering Stress at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	27231.97	27231.97	18.81	4.26	7.82
Q	1	18.37	18.37	0.01	4.26	7.82
A	1	2783.13	2783.13	1.92	4.26	7.82
T	2	1116826.32	558413.16	385.77	3.40	5.61
RQ	1	4983.72	4983.72	3.44	4.26	7.82
RA	1	543.38	543.38	0.38	4.26	7.82
RT	2	76026.50	38013.25	26.26	3.40	5.61
QA	1	0.13	0.13	0.00	4.26	7.82
QT	2	1302.45	651.23	0.45	3.40	5.61
AT	2	4988.22	2494.11	1.72	3.40	5.61
RQA	1	2452.45	2452.45	1.69	4.26	7.82
RAT	2	1096.94	548.47	0.38	3.40	5.61
QAT	2	847.72	423.86	0.29	3.40	5.61
RQT	2	7144.04	3572.02	2.47	3.40	5.61
RQAT	2	4020.19	2010.10	1.39	3.40	5.61
Error	24	34740.56	1447.52			
TOTAL	47	1285006.16				

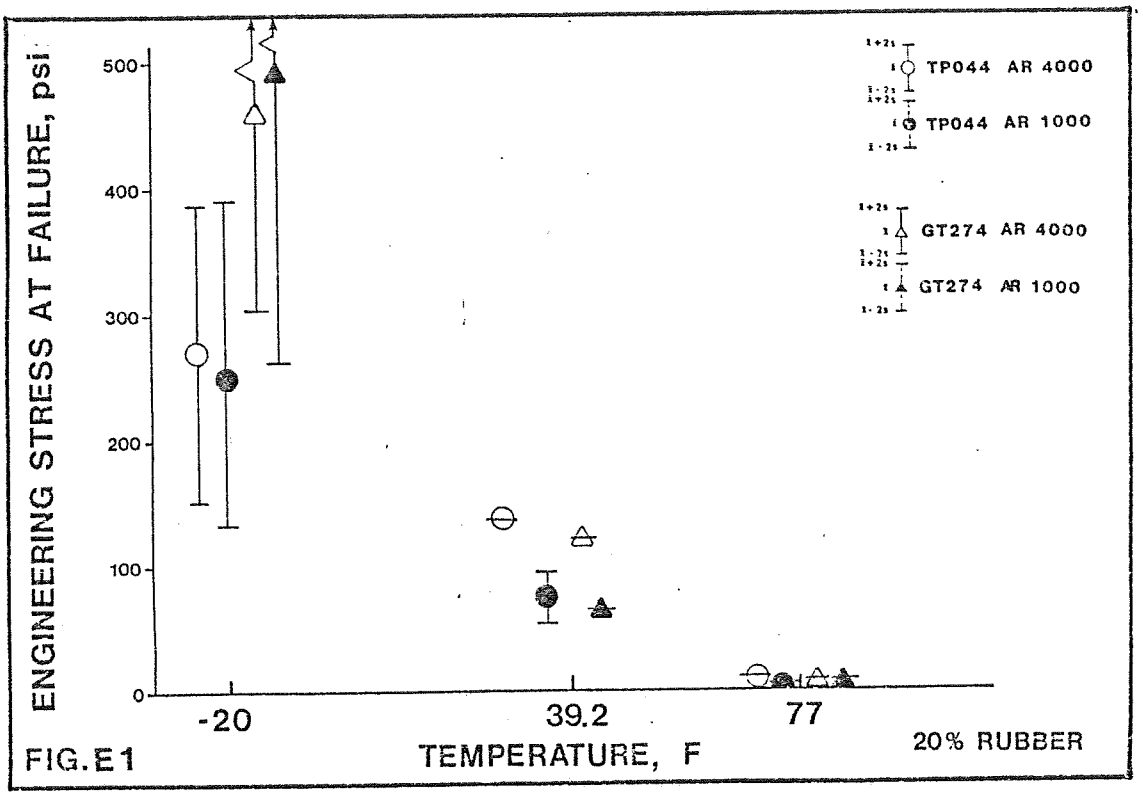
ENGINEERING STRESS AT FAILURE, psi
500
400
300
200
100
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. E1

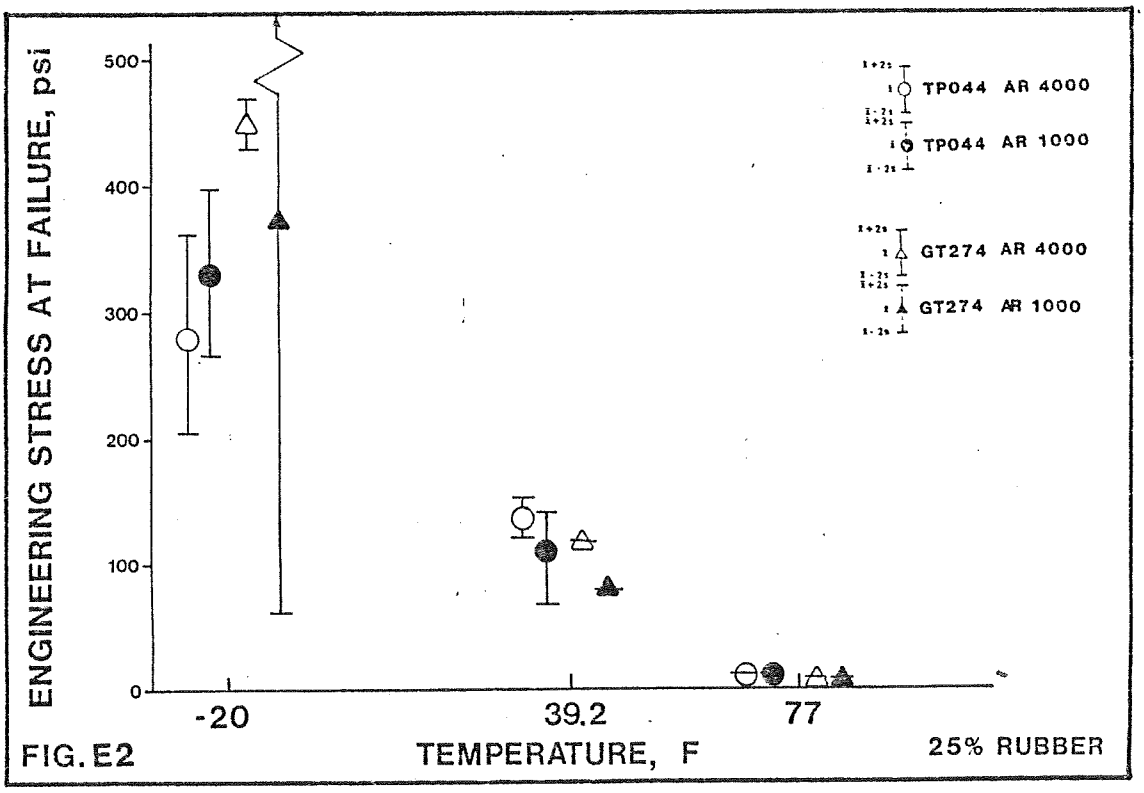
ENGINEERING STRESS AT FAILURE, psi
500
400
300
200
100
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. E2

APPENDIX F

FORCE-DUCTILITY ENGINEERING STRAIN AT FAILURE

Table F-1 Engineering Strain at Failure, mm/mm

a. Measured Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	2.22	8.17	3.94	7.76	.22	.27
		2.51	7.25	3.86	7.41	.31	.33
		2.10	9.78	3.94	7.30	.37	.54
		2.29	7.98	3.81	7.29	.42	.42
		4.06	5.96	3.57	7.54	.34	.43
		3.76	9.44	3.89	8.24	.25	.46
	25%	2.08	4.84	3.42	7.16	.33	.33
		1.92	1.41	3.90	6.75	.39	.41
		1.10	3.66	3.24	7.09	.42	
		1.24	9.75	3.55	7.06	.46	.45
		1.92	9.39	3.52	7.49	.37	.35
		1.36	8.08	3.54	6.78	.31	.33
AR1000	20%	2.26	10.58	4.87	9.45	.31	.40
		3.22	8.36	4.43	8.86	.29	.40
		2.57	10.16	4.53	9.24	.25	.34
		1.89	7.22	4.96	8.18	.25	.37
		2.18	7.60	4.75	8.38	.30	.41
		2.38	7.34	4.38	9.08	.39	.42
	25%	2.49	10.83	3.35	8.67	.41	.35
		1.36	6.77	3.62	8.25	.48	*
		2.16	8.54	4.69	8.24	.33	*
		1.38	10.40	3.50	8.02	.41	.34
		1.46	8.65	3.81	7.81	.31	*
		1.67	8.67	3.35	7.96	.39	*

*Note: Specimens fractured before readings could be taken.

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	2.82	8.10	3.84	7.59	.32	.41
		s	.858	1.410	.139	.363	.075	.096
		cv	30.37	17.41	3.62	4.79	25.46	23.46
	25%	$\bar{x}$	1.60	6.19	3.53	7.06	.38	.37
		s	.418	3.393	.216	.272	.056	.0537
		cv	26.05	54.83	6.13	3.86	14.70	14.35
AR1000	20%	$\bar{x}$	2.42	8.54	4.65	8.86	.30	.39
		s	.454	1.475	.241	.490	.052	.030
		cv	18.76	17.27	5.18	5.53	17.28	7.61
	25%	$\bar{x}$	1.75	8.98	3.72	8.16	.39	.345
		s	.468	1.464	.506	.302	.062	.009
		cv	26.69	16.31	13.61	3.70	15.83	2.57

Table F-2 Engineering Strain at Failure, mm/mm

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	2.28	8.40	3.91	7.49	.30	.38
		3.37	7.79	3.76	7.69	.34	.44
	25%	1.70	3.30	3.52	7.00	.38	.25
		1.51	9.07	3.54	7.11	.38	.38
AR1000	20%	2.68	9.70	4.61	9.17	.28	.38
		2.15	7.39	4.70	8.55	.31	.40
	25%	2.00	8.71	3.89	8.39	.41	.35
		1.50	9.24	3.55	7.93	.37	.34

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	2.83	8.10	3.84	7.59	.32	.41
		s	.9657	.5405	.1329	.1772	.0354	.0532
		CV	34.2	6.7	3.5	2.3	11.1	13.0
	25%	$\bar{x}$	1.61	6.19	3.53	7.06	.38	.32
		s	.1683	5.1122	.0177	.0975	0	.1152
		CV	10.49	82.66	.50	1.38	0	36.57
AR1000	20%	$\bar{x}$	2.42	8.55	4.66	8.86	.30	.39
		s	.4696	2.0467	.0797	.5493	.0266	.0177
		CV	19.4	24.0	1.7	6.2	9.0	4.5
	25%	$\bar{x}$	1.75	8.98	3.72	8.16	.39	.345
		s	.4430	.4696	.3012	.4076	.0354	.009
		CV	23.4	5.2	8.1	5.0	9.1	2.6

Table F-3 Log Engineering Strain at Failure, mm/mm

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.3579	.9243	.5922	.8745	-.5229	-.4202
		.5276	.8915	.5752	.8859	-.4685	-.3565
	25%	.2304	.5185	.5465	.8451	-.4202	-.6021
		.1790	.9576	.5490	.8519	-.4202	-.4202
AR1000	20%	.4281	.9868	.6637	.9624	-.5528	-.4202
		.3324	.8686	.6721	.9320	-.5086	-.3979
	25%	.3010	.9400	.5899	.9238	-.3872	-.4559
		.1761	.9657	.5502	.8993	-.4318	-.4685

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.4428	.9079	.5837	.8802	-.4957	-.3884
		s	.1504	.0291	.0151	.0101	.0482	.0564
		cv	34.0	3.2	2.6	1.1	9.7	14.5
	25%	$\bar{x}$	.2047	.7381	.5478	.8485	-.4202	-.5112
		s	.0455	.3890	.0022	.0060	.0000	.1612
		cv	22.3	52.7	.4	.7	.0	31.5
AR1000	20%	$\bar{x}$	.3803	.9277	.6679	.9116	-.5307	-.4091
		s	.0848	.1047	.0074	.0217	.0392	.0198
		cv	22.3	11.3	1.1	2.4	7.4	4.8
	25%	$\bar{x}$	.2386	.9529	.5701	.9472	.4095	.4622
		s	.1107	.0228	.0352	.0269	.0395	.0112
		cv	46.4	2.4	6.2	2.8	9.6	2.4

Table F-4 ANOVA Summary, Log Engineering Strain at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	1.05812	1.05812	162.16	4.26	7.82
Q	1	.04137	.04137	6.34	4.26	7.82
A	1	.01659	.01659	2.54	4.26	7.82
T	2	13.67398	6.83699	1047.80	3.40	5.61
RQ	1	.00042	.00042	0.06	4.26	7.82
RA	1	.00958	.00958	1.47	4.26	7.82
RT	2	.59145	.29573	45.32	3.40	5.61
QA	1	.00970	.00970	1.49	4.26	7.82
QT	2	.03754	.01877	2.88	3.40	5.61
AT	2	.00798	.00399	0.61	3.40	5.61
RQA	1	.00273	.00273	0.42	4.26	7.82
RAT	2	.00854	.00427	0.65	3.40	5.61
QAT	2	.01598	.00799	1.22	3.40	5.61
RQT	2	.04925	.02463	3.77	3.40	5.61
RQAT	2	.00071	.00036	0.05	3.40	5.61
Error	24	.15660	.00653			
TOTAL	47	15.68054				

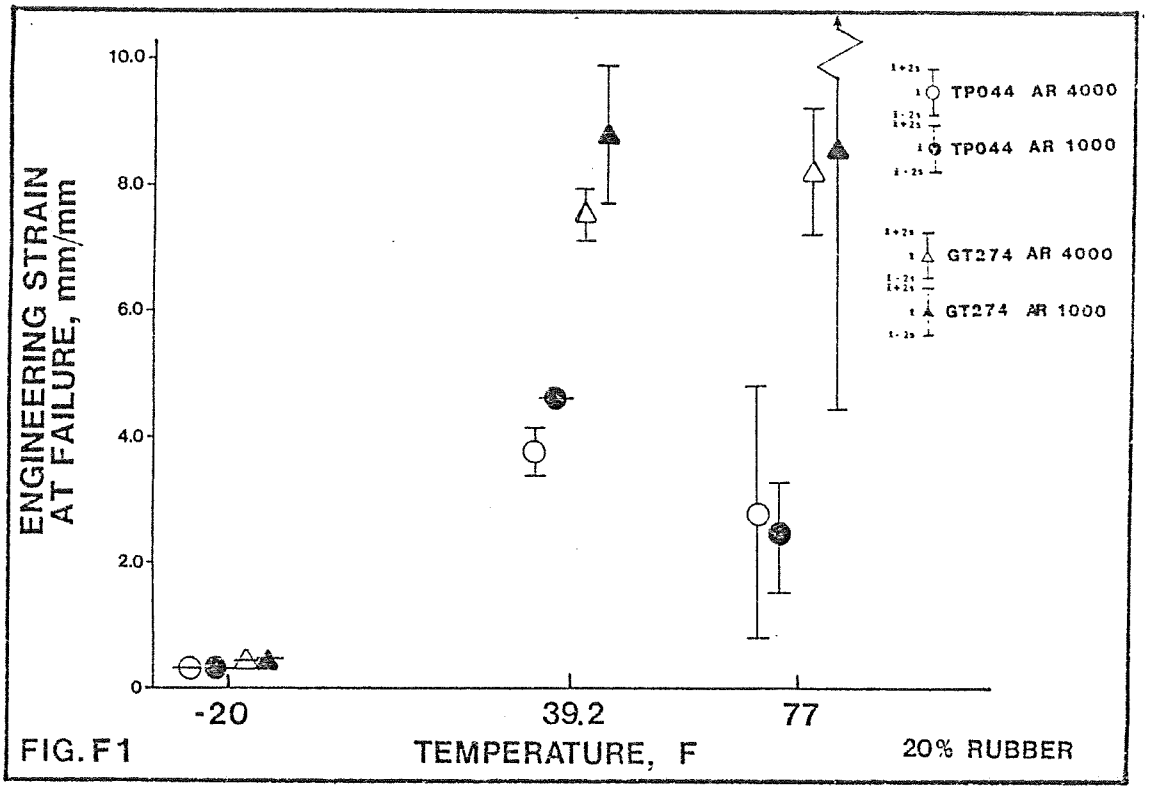
ENGINEERING STRAIN
AT FAILURE, mm/mm
10.0
8.0
6.0
4.0
2.0
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. F1

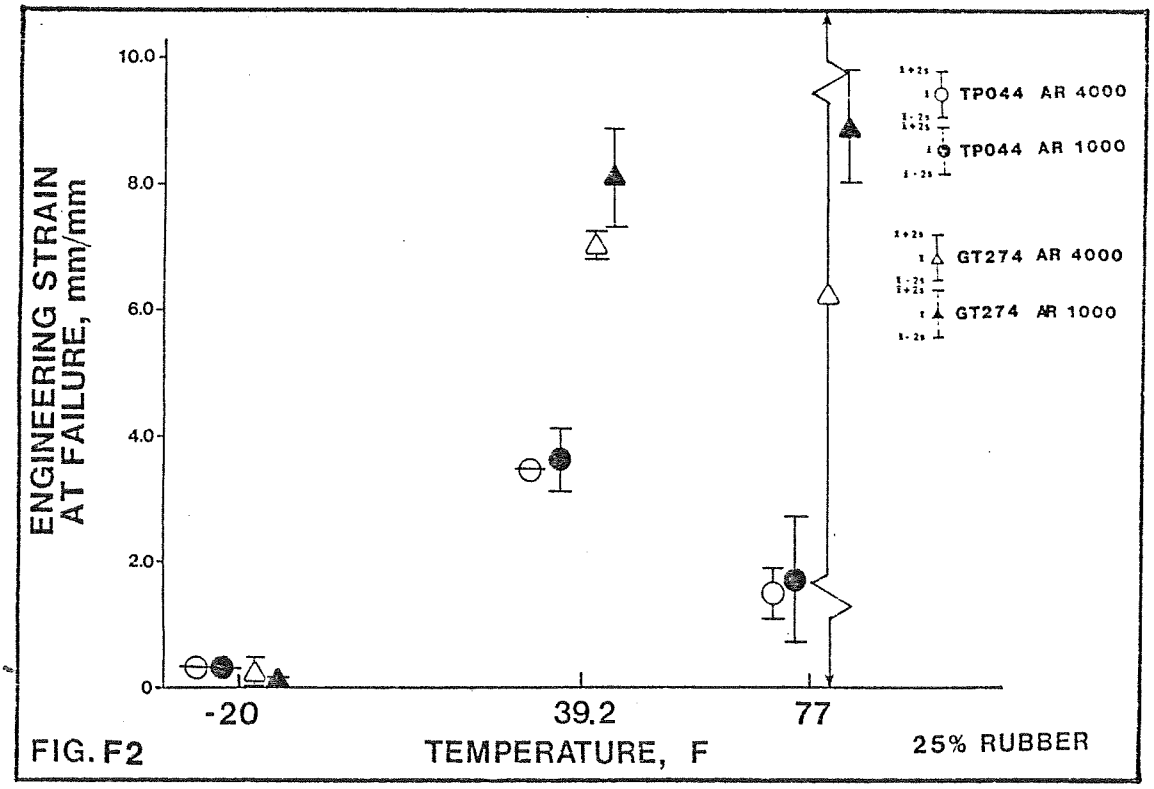
ENGINEERING STRAIN
AT FAILURE, mm/mm
10.0
8.0
6.0
4.0
2.0
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. F2

APPENDIX G

FORCE-DUCTILITY TRUE STRESS AT FAILURE

Table G-1 True Stress at Failure, psi

a. Calculated Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	12.3	24.3	711.5	993.5	315.1	655.0
		15.8	26.0	656.6	997.8	396.7	701.6
		11.9	30.4	580.5	983.4	206.1	742.0
		13.2	37.4	650.8	1033.0	442.1	518.3
		20.2	27.8	596.1	1035.8	386.7	591.0
		19.8	38.2	607.9	1054.1	381.7	701.0
	25%	17.0	24.3	655.5	926.8	324.8	478.6
		14.1	7.2	719.3	916.7	383.0	737.1
		11.9	21.8	564.3	972.4	371.5	
		11.2	34.2	659.7	972.1	436.0	723.9
		14.1	34.4	625.0	1030.6	371.6	524.5
		13.0	34.7	535.3	923.4	454.1	628.0
AR1000	20%	9.2	34.6	339.9	720.8	376.9	756.9
		11.9	20.1	451.0	652.7	190.7	756.9
		10.1	31.5	349.2	691.7	285.0	792.0
		8.1	50.2	513.7	573.6	331.3	476.4
		9.5	32.8	457.5	602.1	362.0	679.1
		10.1	25.6	406.5	689.0	481.3	646.9
	25%	16.9	47.3	466.6	765.4	505.7	388.7
		10.2	24.5	539.8	727.6	501.9	*
		17.4	26.9	720.2	802.6	465.4	*
		10.7	36.0	455.9	774.2	538.9	623.6
		11.1	30.4	492.3	770.9	263.0	*
		11.1	27.2	385.5	709.0	504.7	*

*Note: Specimens fractured before readings could be taken.

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	15.5	30.7	633.9	1016.3	354.7	651.5
		s	3.72	5.88	48.54	28.40	83.43	83.15
		cv	23.94	19.15	7.66	2.79	23.52	12.76
	25%	$\bar{x}$	13.6	26.1	626.5	957.0	390.2	618.4
		s	2.05	10.84	67.44	43.70	47.34	115.84
		cv	15.14	41.53	10.77	4.57	12.13	18.72
AR1000	20%	$\bar{x}$	9.8	32.5	419.6	655.0	337.9	684.7
		s	1.26	10.20	67.46	57.03	97.13	115.58
		cv	12.83	31.42	16.08	8.71	28.75	16.88
	25%	$\bar{x}$	12.9	32.1	510.1	758.3	463.3	506.2
		s	3.31	8.46	114.63	34.05	100.84	208.12
		cv	25.68	26.40	22.47	4.49	21.77	41.12

Table G-2 True Stress at Failure, psi

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	13.3	26.9	649.53	991.57	306.0	699.5
		17.7	34.5	618.27	1040.97	403.5	603.4
	25%	14.3	17.8	646.37	938.63	359.8	607.9
		12.8	34.4	606.67	975.37	420.6	625.5
AR1000	20%	10.4	28.7	380.03	688.40	284.2	768.6
		9.2	36.2	459.23	621.57	391.5	600.8
	25%	14.8	32.9	575.53	765.20	491.0	388.7
		11.0	31.2	444.57	751.37	435.5	623.6

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{X}$	15.5	30.7	633.9	1016.3	354.8	651.5
		S	3.90	6.73	27.70	43.77	86.39	85.15
		CV	25.2	21.9	4.4	4.3	24.4	13.1
	25%	$\bar{X}$	13.6	26.1	626.5	957.0	390.2	616.7
		S	1.33	14.71	35.17	32.6	53.9	15.6
		CV	9.8	56.4	5.6	3.4	13.8	2.5
AR1000	20%	$\bar{X}$	9.8	32.5	419.63	655.0	337.9	684.7
		S	1.06	6.65	70.17	59.21	95.07	148.67
		CV	10.8	20.5	16.7	9.0	28.1	21.7
	25%	$\bar{X}$	12.9	32.1	510.1	758.3	463.4	506.2
		S	3.37	1.51	116.03	12.25	49.17	208.12
		CV	26.1	4.7	22.8	1.6	10.6	41.1

Table G-3 Log True Stress at Failure, psi

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	1.1239	1.4298	2.8126	2.9963	2.4857	2.8448
		1.2480	1.5378	2.7912	3.0174	2.6058	2.7806
	25%	1.1553	1.2504	2.8105	2.9725	2.5561	2.7838
		1.1072	1.5366	2.7830	2.9892	2.6239	2.7962
AR1000	20%	1.0170	1.4579	2.5798	2.8378	2.4536	2.8857
		.9638	1.5587	2.6620	2.7935	2.5927	2.7787
	25%	1.1703	1.5172	2.7601	2.8838	2.6911	2.5896
		1.0414	1.4942	2.6479	2.8759	2.6390	2.7949

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{X}$	1.1860	1.4838	2.8019	3.0069	2.5458	2.8127
		S	.1100	.0957	.0190	.0187	.1064	.0569
		CV	9.3	6.4	.7	.6	4.2	2.0
	25%	$\bar{X}$	1.1313	1.3935	2.7968	2.9809	2.5900	2.7900
		S	.0426	.2536	.0244	.0148	.0601	.0110
		CV	3.8	18.2	.9	.5	2.3	.4
AR1000	20%	$\bar{X}$	.9904	1.5083	2.6209	2.8157	2.5232	2.8322
		S	.0471	.0893	.0728	.0392	.1232	.0948
		CV	4.8	5.9	2.8	1.4	4.9	3.4
	25%	$\bar{X}$	1.1059	1.5057	2.7040	2.8799	2.6651	2.6923
		S	.1142	.0204	.0994	.0070	.0462	.1819
		CV	10.3	1.4	3.7	.2	1.7	6.8

Table G-4 ANOVA Summary, Log True Stress at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	0.7700	0.7700	140.38	4.26	7.82
Q	1	0.0009	0.0009	0.18	4.26	7.82
A	1	0.0379	0.0379	6.92	4.26	7.82
T	2	23.0783	11.5300	2103.70	3.40	5.61
RQ	1	0.0245	0.0245	4.48	4.26	7.82
RA	1	0.0035	0.0035	0.65	4.26	7.82
RT	2	0.0081	0.0400	7.40	3.40	5.61
QA	1	0.0145	0.0145	2.65	4.26	7.82
QT	2	0.0028	0.0010	0.26	3.40	5.61
AT	2	0.0437	0.0220	3.99	3.40	5.61
RQA	1	0.0073	0.0073	1.33	4.26	7.82
RAT	2	0.0327	0.0160	2.99	3.40	5.61
QAT	2	0.0102	0.0050	0.93	3.40	5.61
RQT	2	0.0121	0.0060	1.11	3.40	5.61
RQAT	2	0.0059	0.0020	0.54	3.40	5.61
Error	24	0.1316	0.0054			
TOTAL	47	24.2578				

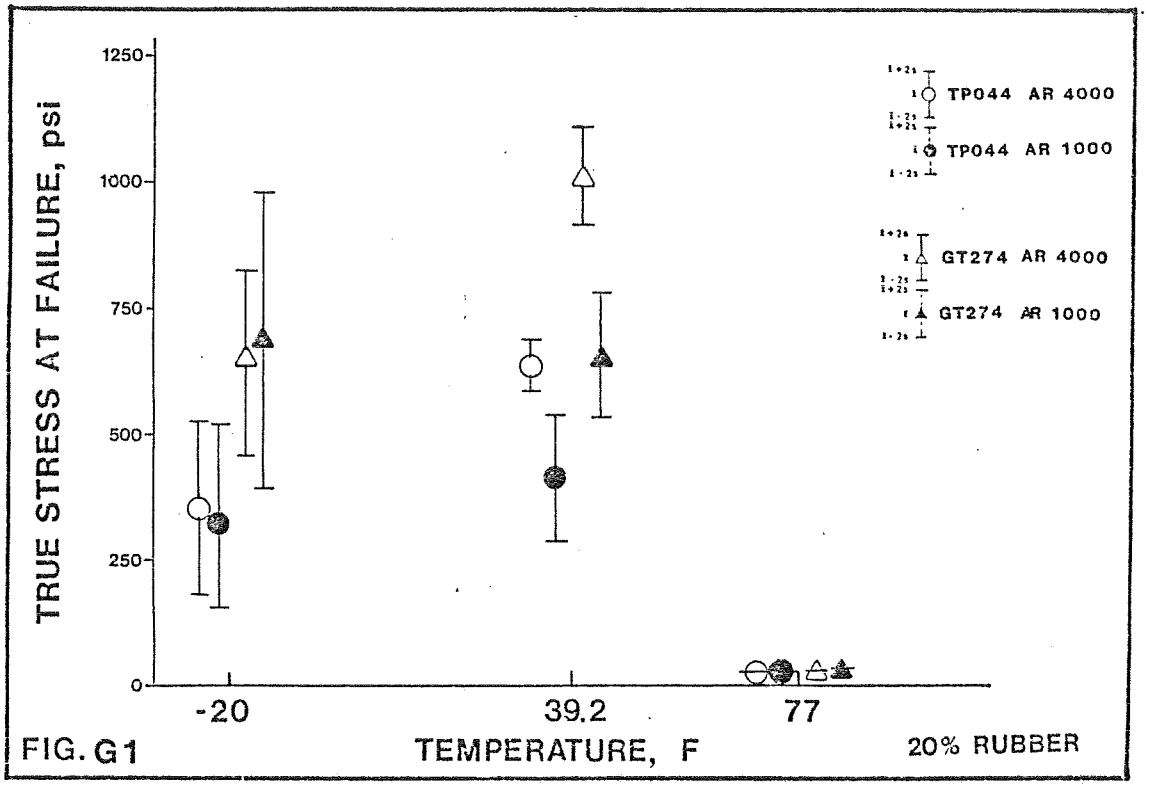
TRUE STRESS AT FAILURE, psi
1250
1000
750
500
250
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. G1

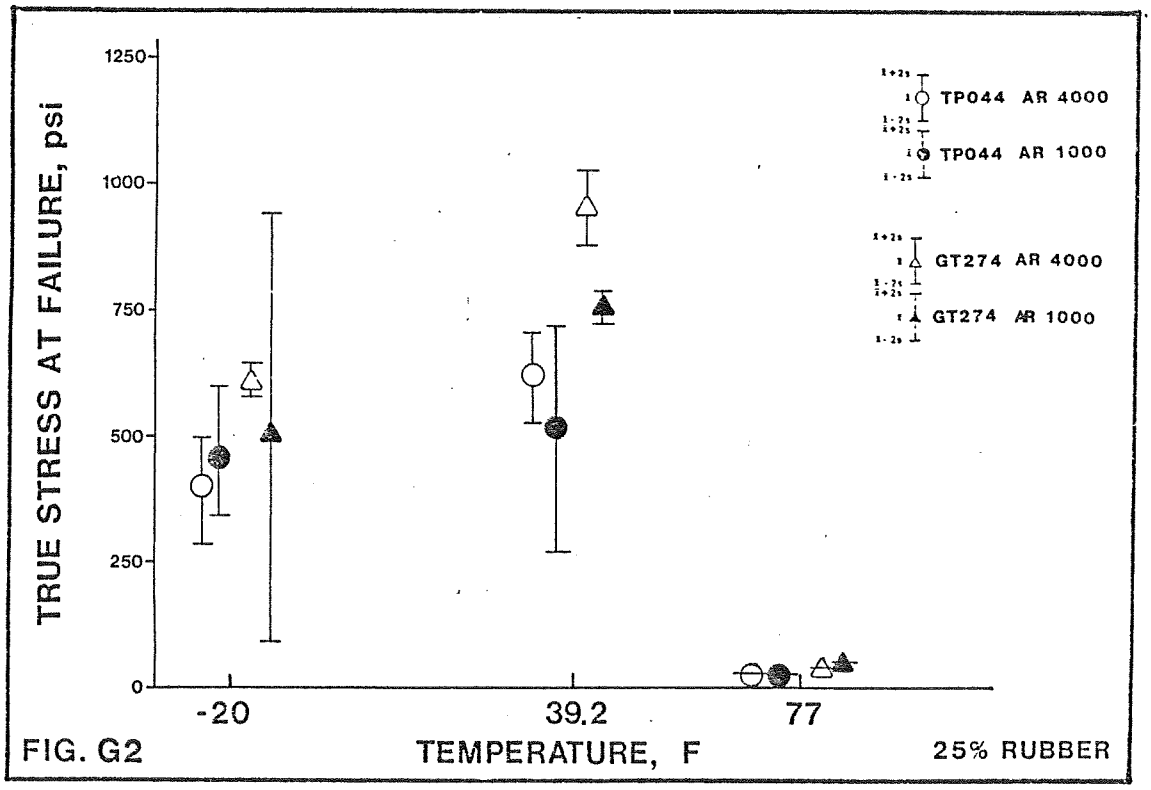
TRUE STRESS AT FAILURE, psi
1250
1000
750
500
250
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. G2

APPENDIX H

FORCE-DUCTILITY TRUE STRAIN AT FAILURE

Table H-1 True Strain at Failure, mm/mm

a. Measured Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	1.17	2.22	1.60	2.17	.20	.24
		1.26	2.11	1.58	2.13	.27	.28
		1.13	2.38	1.60	2.12	.31	.43
		1.19	2.19	1.57	2.11	.35	.35
		1.62	1.94	1.52	2.14	.29	.36
		1.56	2.35	1.59	2.22	.22	.38
	25%	1.12	1.77	1.49	2.10	.28	.28
		1.07	.88	1.59	2.05	.33	.34
		.74	1.54	1.44	2.09	.35	
		.81	2.11	1.51	2.09	.38	.37
		1.07	2.15	1.51	2.14	.31	.30
		.86	2.12	1.51	2.05	.27	.28
AR1000	20%	1.18	2.45	1.77	2.34	.27	.34
		1.44	2.24	1.69	2.39	.26	.34
		1.27	2.41	1.71	2.33	.22	.29
		1.06	2.37	1.79	2.22	.22	.31
		1.16	2.34	1.75	2.24	.26	.34
		1.22	2.21	1.68	2.31	.33	.35
	25%	1.25	2.47	1.47	2.27	.34	.30
		.86	2.05	1.53	2.23	.39	
		1.15	2.26	1.74	2.22	.29	
		.87	2.43	1.50	2.20	.34	.29
		.90	2.27	1.57	2.18	.27	
		.98	2.27	1.47	2.19	.33	

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	1.32	2.20	1.58	2.15	.27	.34
		s	.213	.162	.030	.041	.056	.069
		cv	16.11	7.37	1.91	1.90	20.52	20.29
	25%	$\bar{x}$	.95	1.76	1.51	2.09	.32	.31
		s	.161	.495	.048	.034	.042	.040
		cv	17.02	28.12	3.21	1.62	13.11	12.66
AR1000	20%	$\bar{x}$	1.22	2.34	1.73	2.31	.26	.33
		s	.128	.095	.045	.064	.041	.023
		cv	10.46	4.05	2.59	2.78	15.58	7.06
	25%	$\bar{x}$	1.00	2.29	1.55	2.22	.33	.295
		s	.162	.149	.102	.033	.042	.009
		cv	16.21	6.51	6.60	1.48	12.94	3.05

Table H-2 True Strain at Failure, mm/mm

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	1.19	2.24	1.59	2.14	.26	.32
		1.46	2.16	1.56	2.16	.29	.36
	25%	.98	1.40	1.51	2.08	.32	.21
		.91	2.13	1.51	2.09	.32	.32
AR1000	20%	1.30	2.37	1.72	2.35	.25	.32
		1.15	2.31	1.74	2.26	.27	.33
	25%	1.09	2.26	1.58	2.24	.34	.30
		.92	2.32	1.51	2.19	.31	.29

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	1.33	2.20	1.58	2.15	.28	.34
		s	.239	.071	.027	.018	.027	.035
		cv	18.1	3.2	1.7	.8	9.7	10.4
	25%	$\bar{x}$	.95	1.77	1.51	2.085	.32	.27
		s	.062	.647	0	.009	0	.097
		cv	6.6	36.7	0	.4	0	36.8
AR1000	20%	$\bar{x}$	1.23	2.34	1.73	2.31	.26	.325
		s	.133	.053	.018	.080	.018	.009
		cv	10.9	2.3	1.0	3.5	6.8	2.7
	25%	$\bar{x}$	1.01	2.29	1.55	2.22	.33	.295
		s	.151	.053	.062	.044	.027	.009
		cv	15.0	2.3	4.0	2.0	8.2	3.1

Table H-3 Log True Strain at Failure, mm/mm

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.0755	.3502	.2014	.3304	-.5850	-.4949
		.1644	.3345	.1931	.3345	-.5376	-.4437
	25%	-.0088	.1461	.1790	.3181	-.4949	-.6778
		-.0410	.3284	.1790	.3201	-.4949	-.4949
AR1000	20%	.1139	.3747	.2355	.3711	-.6021	-.4949
		.0607	.3636	.2405	.3541	-.5686	-.4815
	25%	.0374	.3541	.1987	.3502	-.4685	-.5229
		-.0362	.3655	.1790	.3404	-.5086	-.5376

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.1200	.3424	.1973	.3325	-.5613	-.4693
		s	.0788	.0139	.0074	.0036	.0420	.0454
		cv	65.7	4.1	3.7	1.1	7.5	9.7
	25%	$\bar{x}$	-.0249	.2373	.1790	.3191	-.4949	-.5864
		s	.0285	.1615	0	.0018	0	.1620
		cv	144.6	68.1	0	.6	0	27.6
AR1000	20%	$\bar{x}$	.0873	.3692	.2380	.3626	-.5854	-.4882
		s	.0471	.0098	.0044	.0151	.0297	.0119
		cv	54.0	2.7	1.9	4.2	5.1	2.4
	25%	$\bar{x}$	.0006	.3598	.1889	.3453	-.4886	-.5303
		s	.0652	.0101	.0175	.0087	.0355	.0130
		cv	10868.3	2.8	9.2	2.5	7.3	2.5

Table H-4 ANOVA Summary, Log True Strain at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	.23248	.23248	125.70	4.26	7.82
Q	1	.01155	.01155	6.24	4.26	7.82
A	1	.00845	.00845	4.57	4.26	7.82
T	2	6.14100	3.07050	1660.18	3.40	5.61
RQ	1	.00305	.00305	1.65	4.26	7.82
RA	1	.00376	.00376	2.03	4.26	7.82
RT	2	.12777	.06389	34.54	3.40	5.61
QA	1	.00438	.00438	2.37	4.26	7.82
QT	2	.01107	.00554	2.99	3.40	5.61
AT	2	.00414	.00207	1.12	3.40	5.61
RQA	1	.00029	.00029	0.16	4.26	7.82
RAT	2	.00214	.00107	0.58	3.40	5.61
QAT	2	.00590	.00295	1.60	3.40	5.61
RQT	2	.02579	.01290	6.97	3.40	5.61
RQAT	2	.00064	.00032	0.17	3.40	5.61
Error	24	.04439	.00185			
TOTAL	47	6.62675				

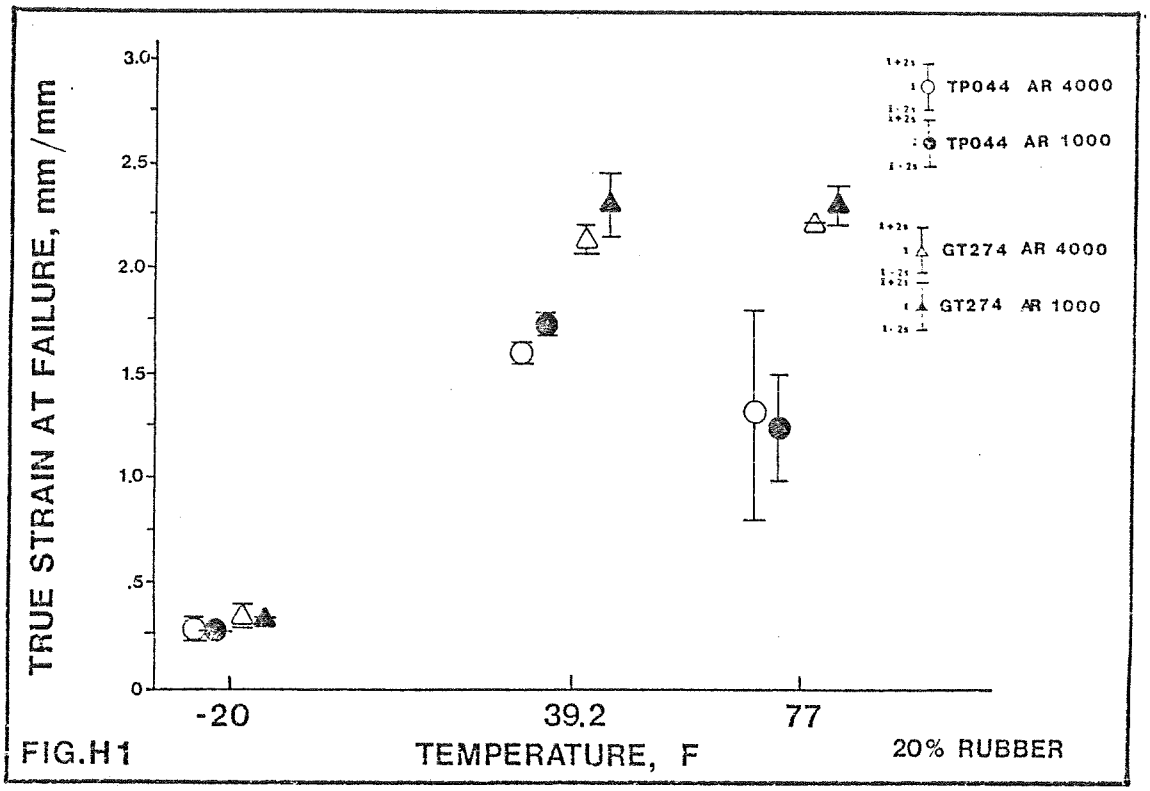
TRUE STRAIN AT FAILURE, mm/mm
3.0
2.5
2.0
1.5
1.0
.5
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG.H1

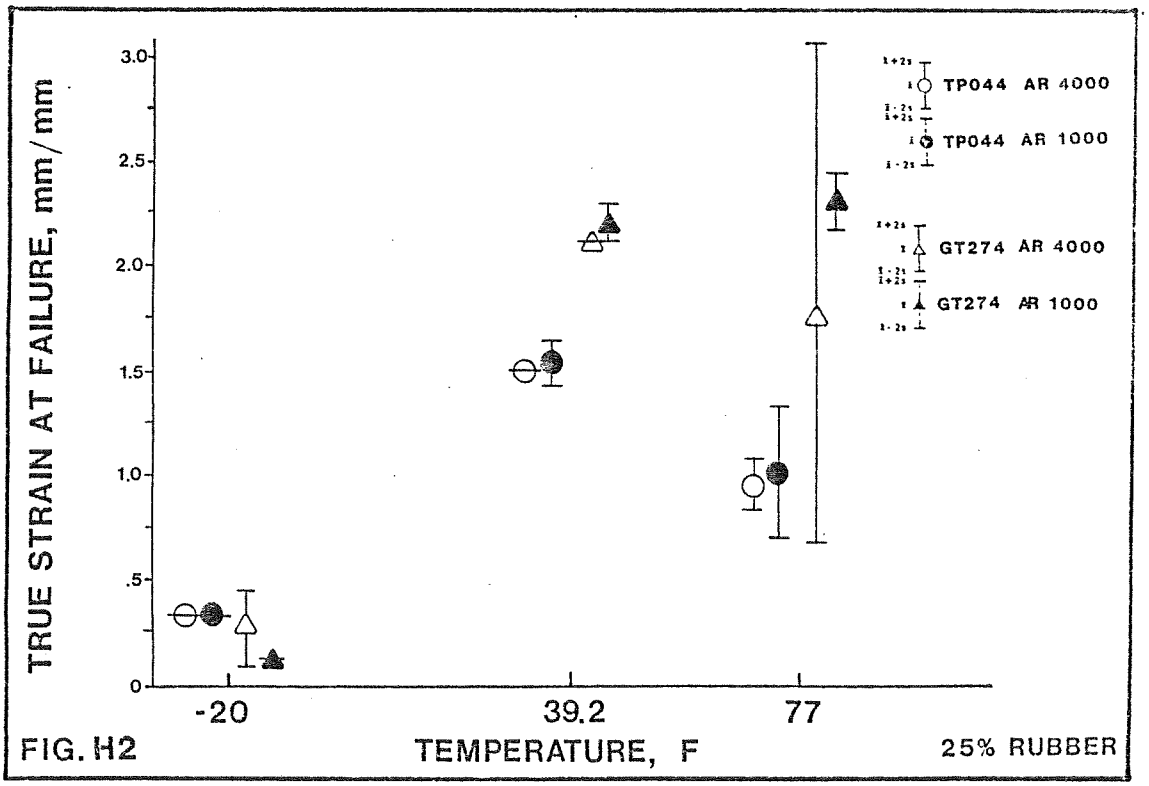
TRUE STRAIN AT FAILURE, mm/mm
3.0
2.5
2.0
1.5
1.0
.5
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. H2

APPENDIX I

FORCE-DUCTILITY ENGINEERING

CREEP COMPLIANCE

Table I-1 Engineering Creep Compliance at Failure, psi^{-1}

a. Calculated Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.5801	3.0822	.0274	.068	.0009	.0005
		.558	2.2980	.0286	.063	.0010	.0006
		.548	3.4712	.0336	.062	.0024	.0011
		.574	1.9166	.0282	.0584	.0013	.0011
		1.016	1.4918	.0273	.0621	.0012	.0010
		.902	2.5805	.0313	.0722	.0008	.0010
	25%	.378	1.1633	.0231	.0630	.0013	.0009
		.397	.4727	.0266	.0571	.0014	.0008
		.194	.7841	.0244	.0591	.0016	
		.248	1.7342	.0245	.0584	.0015	.0009
		.397	1.9022	.0254	.0618	.0014	.0009
		.247	1.7630	.0300	.0572	.0009	.0007
AR1000	20%	.8018	3.5412	.0840	.136	.0011	.0007
		1.1408	3.8965	.0534	.134	.0020	.0007
		.9113	3.6056	.0717	.137	.0011	.0006
		.6694	2.0889	.0576	.131	.0009	.0011
		.730	2.9770	.0596	.131	.0011	.0008
		.797	2.8660	.0579	.133	.0011	.0009
	25%	.515	2.7107	.0312	.110	.0011	.0012
		.314	2.1470	.0310	.105	.0014	
		.392	3.0297	.0371	.0949	.0010	
		.307	3.2965	.0346	.093	.0011	.0007
		.325	2.7412	.0373	.089	.0015	
		.402	3.0746	.0377	.101	.0011	

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.6964	2.4734	.0294	.0643	.0127	.0009
		s	.2069	.7324	.0025	.0050	.0006	.0003
		cv	29.72	29.61	8.57	7.71	46.21	29.88
	25%	$\bar{x}$	.3102	1.3033	.0257	.0595	.0014	.0008
		s	.0906	.5890	.0024	.0024	.0024	.0009
		cv	29.21	45.20	9.43	4.10	17.99	10.65
AR1000	20%	$\bar{x}$	.8417	3.1625	.0640	.1337	.0012	.0008
		s	.1674	.6563	.0116	.0025	.0004	.0002
		cv	19.88	20.75	18.07	1.87	32.22	22.36
	25%	$\bar{x}$	.3758	2.8333	.0341	.0988	.0012	.0010
		s	.0793	.4015	.0031	.0079	.0002	.0004
		cv	21.11	14.17	8.84	8.02	16.67	46.63

Table I-2 Engineering Creep Compliance at Failure, psi^{-1}

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.562	2.950	.0299	.064	.0014	.0008
		.831	1.996	.0289	.064	.0011	.0010
	25%	.323	.807	.0247	.0597	.0013	.0008
		.297	1.800	.0266	.0591	.0011	.0007
AR1000	20%	.951	3.681	.0697	.1360	.0013	.0007
		.732	2.644	.0584	.1320	.0010	.0009
	25%	.407	2.629	.0331	.103	.0012	.0012
		.345	3.037	.0365	.097	.0012	.0007

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{X}$	.697	2.473	.0294	.064	.0013	.0009
		S	.238	.845	.0009	0	.0003	.0002
		CV	34.2	34.2	3.0	0	21.3	19.7
	25%	$\bar{X}$	.310	1.304	.0257	.0594	.0012	.0008
		S	.023	.880	.0016	.0005	.0002	.0001
		CV	7.4	67.5	6.6	.9	14.8	11.8
AR1000	20%	$\bar{X}$	.8415	3.163	.0641	.1340	.0012	.0008
		S	.1940	.919	.0100	.0035	.0003	.0002
		CV	23.1	29.1	15.6	2.6	23.1	22.2
	25%	$\bar{X}$	.376	2.833	.0348	.0985	.0012	.0010
		S	.055	.362	.0030	.0080	0	.0004
		CV	14.6	12.8	8.7	8.1	0	46.6

Table I-3 ANOVA Summary, Engineering Creep Compliance at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	5.0053	5.0053	73.63	4.26	7.82
Q	1	0.4890	0.4890	7.19	4.26	7.82
A	1	0.5565	0.5565	8.19	4.26	7.82
T	2	22.9882	11.4940	169.08	3.40	5.61
RQ	1	0.0354	0.0354	0.52	4.26	7.82
RA	1	0.3588	0.3588	5.28	4.26	7.82
RT	2	9.2480	4.6200	68.02	3.40	5.61
QA	1	0.0415	0.0415	0.61	4.26	7.82
QT	2	0.8939	0.4460	6.58	3.40	5.61
AT	2	0.9255	0.4630	6.81	3.40	5.61
RQA	1	0.0698	0.0698	1.03	4.26	7.82
RAT	2	0.6503	0.3250	4.78	3.40	5.61
QAT	2	0.1039	0.0520	0.76	3.40	5.61
RQT	2	0.0691	0.0350	0.51	3.40	5.61
RQAT	2	0.1413	0.0700	1.04	3.40	5.61
Error	24	1.6315	0.0679			
TOTAL	47	43.2089				

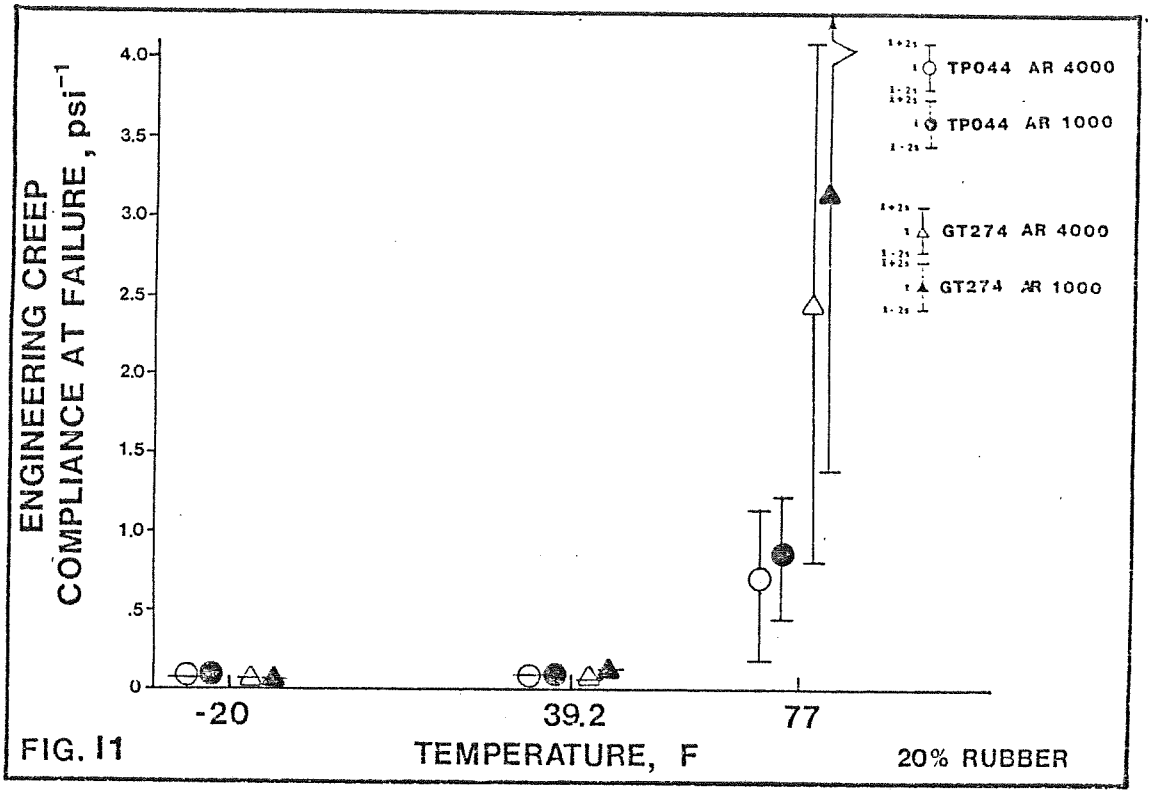
ENGINEERING CREEP
COMPLIANCE AT FAILURE, psi^{-1}
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. I1

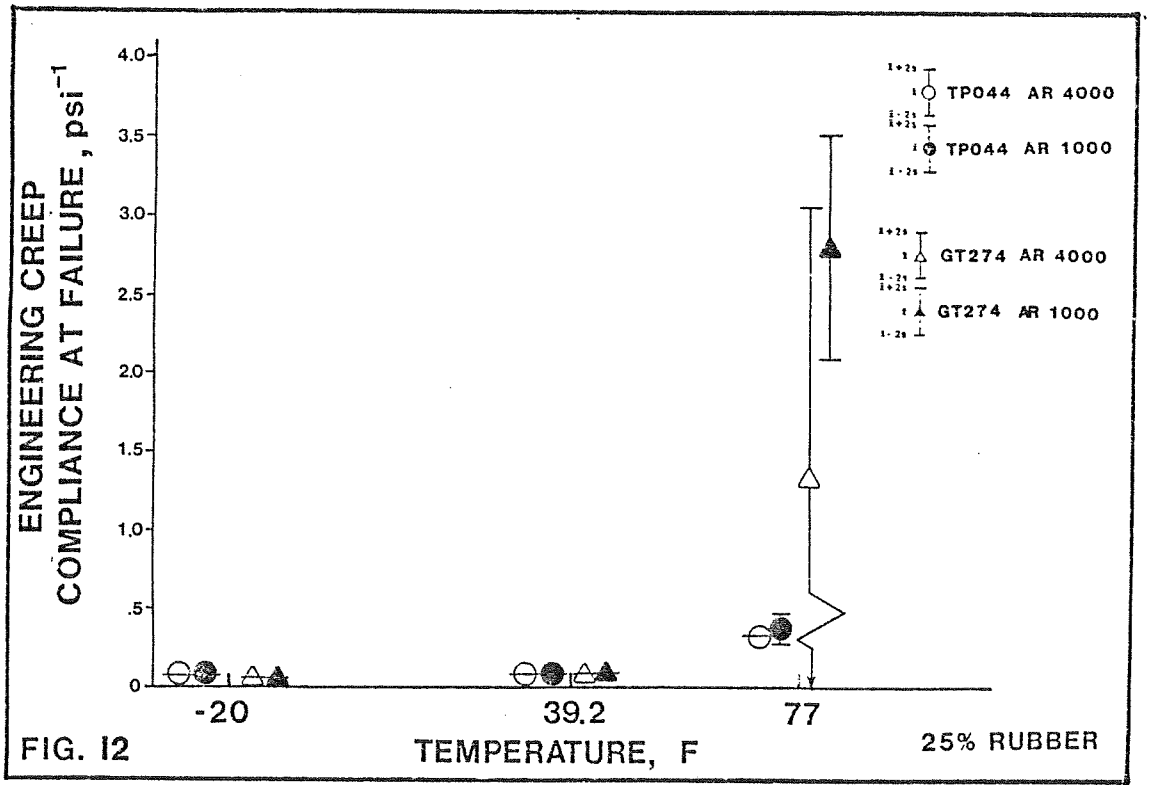
ENGINEERING CREEP
COMPLIANCE AT FAILURE, psi^{-1}
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. I2

APPENDIX J

FORCE-DUCTILITY TRUE CREEP COMPLIANCE AT FAILURE

Table J-1 True Creep Compliance at Failure, psi^{-1}

a. Calculated Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.0949	.0912	.0022	.00218	.0006	.0004
		.0795	.0811	.0024	.00213	.0007	.0004
		.0954	.0782	.0028	.00215	.0015	.0006
		.0906	.0587	.00241	.00205	.0008	.0007
		.0802	.0698	.00255	.00207	.0008	.0006
		.0788	.0614	.00261	.00311	.0006	.0005
	25%	.0663	.0726	.00227	.00227	.0009	.0006
		.0759	.1222	.00221	.00223	.0009	.0005
		.0622	.0708	.00256	.00215	.0009	
		.0720	.0616	.0023	.00215	.0009	.0005
		.0759	.0626	.0024	.00208	.0008	.0006
		.0661	.0611	.0028	.00222	.0006	.0004
AR1000	20%	.1286	.0708	.00521	.00325	.0007	.0004
		.1211	.1113	.00375	.00351	.0014	.0004
		.1265	.0767	.00490	.00336	.0008	.0004
		.1303	.0473	.00348	.00387	.0007	.0007
		.122	.0714	.00382	.00372	.0007	.0005
		.121	.0862	.00414	.00325	.0007	.0005
	25%	.0741	.0523	.00315	.00296	.0007	.0008
		.0840	.0836	.00284	.00306	.0008	
		.0661	.0839	.00241	.00277	.0006	
		.0810	.0677	.00330	.00284	.0006	.0005
		.0810	.0745	.00330	.00284	.0006	
		.0884	.0833	.00381	.00309	.0007	

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.0866	.0734	.0025	.0023	.0008	.0005
		s	.0079	.0124	.0002	.0004	.0003	.0001
		cv	9.16	16.93	8.26	17.91	40.64	22.71
	25%	$\bar{x}$	.0698	.0752	.0024	.0022	.0008	.0005
		s	.0057	.0236	.0002	.00007	.0001	.0008
		cv	8.19	31.36	9.14	3.17	14.53	16.09
AR1000	20%	$\bar{x}$	.1249	.0773	.0042	.0035	.0008	.0005
		s	.0041	.0210	.0007	.0003	.0003	.0001
		cv	3.27	27.22	16.35	7.35	33.66	24.19
	25%	$\bar{x}$	.0792	.0742	.0031	.0029	.0007	.0007
		s	.0079	.0126	.0005	.0001	.0002	.0003
		cv	10.00	16.91	15.03	4.56	20.53	40.89

Table J-2 True Creep Compliance at Failure, psi^{-1}

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.0899	.0835	.0025	.0022	.0009	.0005
		.0832	.0633	.0025	.0024	.0007	.0006
	25%	.0681	.0885	.0024	.0022	.0009	.0004
		.0713	.0618	.0025	.0022	.0008	.0005
AR1000	20%	.1254	.0863	.0046	.0034	.0010	.0004
		.1244	.0683	.0038	.0036	.0007	.0006
	25%	.0747	.0733	.0028	.0029	.0007	.0008
		.0836	.0752	.0034	.0029	.0008	.0005

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.0866	.0734	.0025	.0023	.0008	.00055
		s	.0059	.0179	0	.0002	.0002	.00009
		cv	6.9	24.4	0	7.7	22.2	16.1
	25%	$\bar{x}$	.0697	.0752	.00245	.0022	.00085	.00045
		s	.0028	.0237	.00009	0	.00009	.00009
		cv	4.1	31.5	3.6	0	10.4	19.7
AR1000	20%	$\bar{x}$	.1249	.0773	.0042	.0035	.0009	.0005
		s	.00089	.0160	.0007	.0002	.0003	.0002
		cv	.7	20.6	16.9	5.1	31.3	35.4
	25%	$\bar{x}$	.0792	.0743	.0031	.0029	.00075	.0007
		s	.0079	.0017	.0005	0	.00009	.0003
		cv	10.0	2.3	17.2	0	11.8	40.9

Table J-3 -Log True Creep Compliance at Failure, psi^{-1}

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	1.0462	1.0783	2.6021	2.6576	3.0458	3.3010
		1.0799	1.1986	2.6021	2.6198	3.1549	3.2218
	25%	1.1669	1.0531	2.6198	2.6576	3.0458	3.3979
		1.1469	1.2090	2.6021	2.6576	3.0969	3.3010
AR1000	20%	.9017	1.0640	2.3372	2.4685	3.0000	3.3979
		.9052	1.1656	2.4202	2.4437	3.1549	3.2218
	25%	1.1267	1.1349	2.5528	2.5376	3.1549	3.0969
		1.0778	1.1238	2.4685	2.5376	3.0969	3.3010

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	1.0631	1.1385	2.6021	2.5863	3.1004	3.2614
		s	.0299	.1066	0	.0594	.0967	.0702
		cv	2.8	9.4	0	2.3	3.1	2.2
	25%	$\bar{x}$	1.1569	1.1311	2.6110	2.6576	3.0714	3.3495
		s	.0177	.1381	.0157	0	.0453	.0859
		cv	1.5	12.2	16.0	0	1.5	2.6
AR1000	20%	$\bar{x}$	.9035	1.1148	2.3787	2.4561	3.0775	3.3099
		s	.0031	.0900	.0735	.0220	.1372	.1560
		cv	.3	8.1	3.1	.9	4.5	4.7
	25%	$\bar{x}$	1.1023	1.1294	2.5107	2.5376	3.1259	3.1990
		s	.0433	.0098	.0747	0	.0514	.1808
		cv	3.9	.9	3.0	0	1.6	5.7

Table J-4 ANOVA Summary, -Log True Creep Compliance at Failure

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	.12535	.12535	29.93	4.26	7.82
Q	1	.02371	.02371	5.66	4.26	7.82
A	1	.07216	.07216	17.23	4.26	7.82
T	2	36.86416	18.43208	4400.84	3.40	5.61
RQ	1	.01107	.01107	2.64	4.26	7.82
RA	1	.00043	.00043	0.10	4.26	7.82
RT	2	.04475	.02238	5.34	3.40	5.61
QA	1	.00322	.00322	0.77	4.26	7.82
QT	2	.01344	.00672	1.60	3.40	5.61
AT	2	.04118	.02059	4.92	3.40	5.61
RQA	1	.01509	.01509	3.60	4.26	7.82
RAT	2	.01341	.00671	1.60	3.40	5.61
QAT	2	.01286	.00643	1.54	3.40	5.61
RQT	2	.01015	.00508	0.21	3.40	5.61
RQAT	2	.00737	.00369	0.88	3.40	5.61
Error	24	.10052	.00419			
TOTAL	47	37.35887				

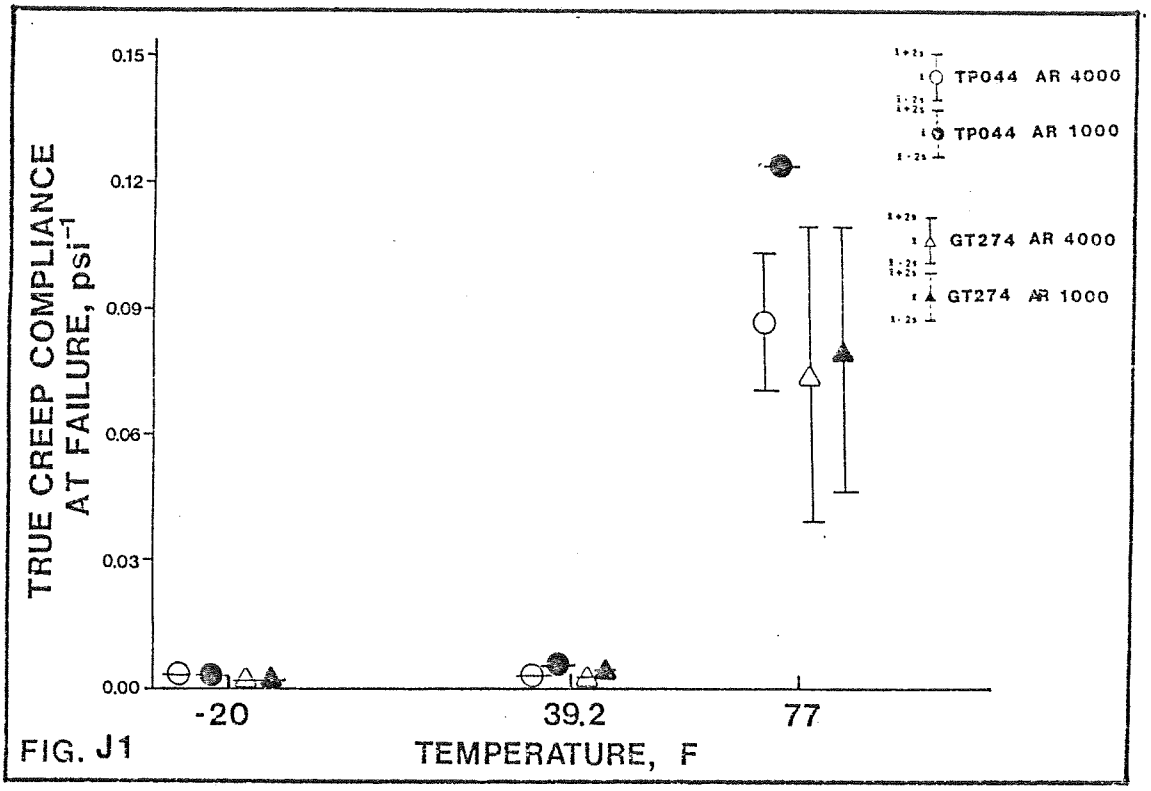

FIG. J1

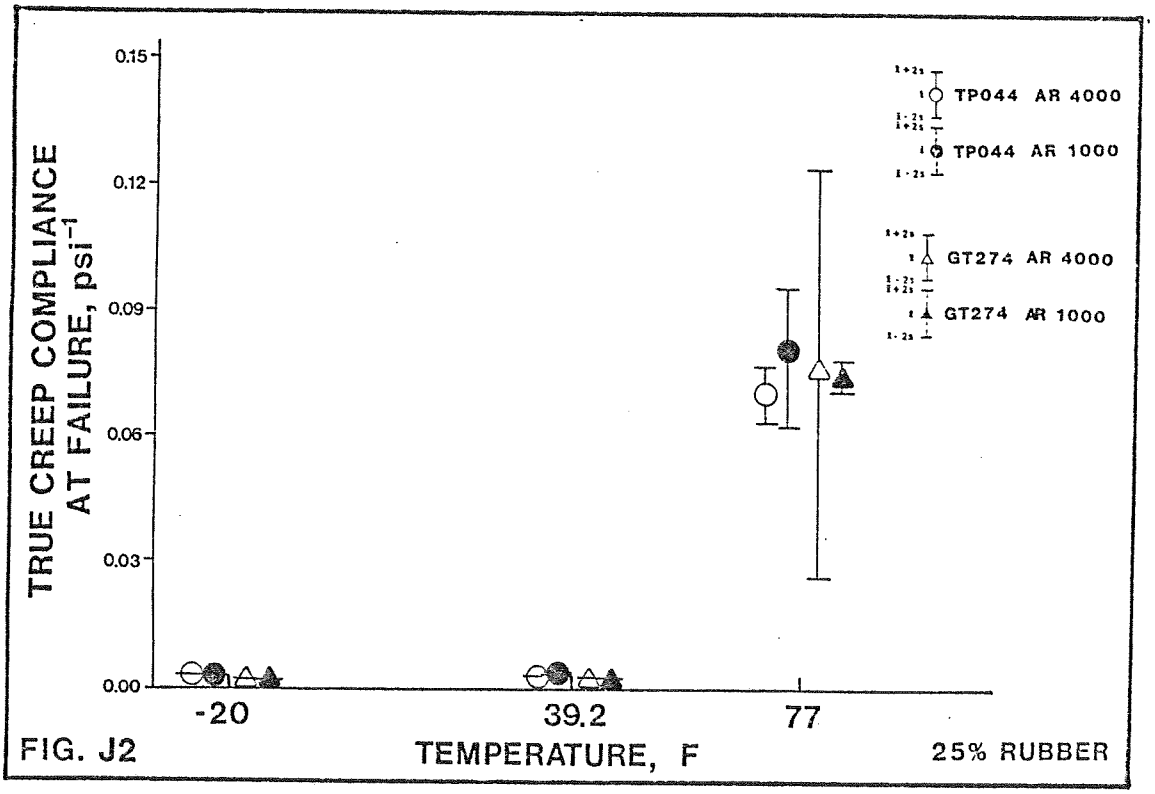

FIG. J2

25% RUBBER

APPENDIX K

FORCE-DUCTILITY MAXIMUM TRUE CREEP COMPLIANCE

Table K-1 Maximum True Creep Compliance, psi^{-1}

a. Calculated Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.0949	.1388	.0033	.0512	.0006	.0004
		.0818	.1164	.0034	.00509	.0007	.0004
		.0954	.1305	.0037	.0493	.0015	.0006
		.0921	.0884	.00343	.00435	.0008	.0007
		.0882	.0920	.00338	.00452	.0008	.0006
		.0883	.1005	.00346	.00501	.0006	.0005
	25%	.0663	.0883	.00336	.00694	.0009	.0006
		.0759	.1274	.00348	.00659	.0009	.0005
		.0622	.0761	.00376	.00649	.0009	
		.0720	.0849	.0037	.00688	.0009	.0005
		.0759	.0883	.0035	.00657	.0008	.0006
		.0661	.0883	.0043	.00680	.0006	.0004
AR1000	20%	.1305	.1294	.00744	.00931	.0007	.0004
		.1303	.1656	.00562	.00981	.0014	.0004
		.1304	.1304	.00678	.00939	.0008	.0004
		.1305	.0768	.00565	.00990	.0007	.0007
		.123	.1299	.00583	.00993	.0007	.0005
		.123	.1305	.00615	.00924	.0007	.0005
	25%	.0741	.1005	.00621	.00938	.0007	.0008
		.0840	.1165	.00538	.00977	.0008	
		.0661	.1305	.00496	.00838	.0006	
		.0810	.1106	.00604	.00948	.0006	.0005
		.0813	.1165	.00598	.00875	.0006	
		.0884	.1304	.00642	.00968	.0007	

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	.09012	.11110	.0034	.0048	.00083	.00053
		s	.00512	.02080	.00014	.00033	.00034	.00012
		CV	5.68	18.73	3.95	6.83	40.64	22.71
	25%	$\bar{x}$	.06973	.09222	.0037	.0067	.00083	.00052
		s	.00571	.01787	.00034	.00019	.00012	.00008
		CV	8.19	19.38	9.13	2.77	14.53	16.09
AR1000	20%	$\bar{x}$	.12795	.12710	.0062	.0096	.00083	.00048
		s	.00383	.02845	.00073	.00032	.00028	.00012
		CV	3.00	22.39	11.64	3.30	33.66	24.19
	25%	$\bar{x}$	.07915	.11750	.0058	.0092	.00067	.00665
		s	.00791	.01161	.00055	.00055	.00008	.00027
		CV	10.00	9.88	9.45	5.99	12.25	40.89

Table K-2 Maximum True Creep Compliance, psi^{-1}

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	.0907	.1286	.00347	.00505	.0009	.0005
		.0895	.0936	.00342	.00465	.0007	.0006
	25%	.0681	.0973	.00353	.00667	.0009	.0006
		.0713	.0872	.00383	.00675	.0008	.0005
AR1000	20%	.1304	.1418	.00661	.00950	.0010	.0004
		.1256	.1124	.00588	.00969	.0007	.0006
	25%	.0747	.1158	.00552	.00918	.0007	.0008
		.0836	.1192	.00615	.00930	.0006	.0005

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{X}$	.09010	.11110	.00345	.00485	.00080	.00055
		S	.00106	.03101	.00004	.00035	.00018	.00009
		CV	1.2	27.9	1.2	7.2	22.2	16.1
	25%	$\bar{X}$	.06970	.09225	.00368	.00671	.00085	.00055
		S	.00284	.00895	.00027	.00007	.00009	.00009
		CV	4.1	9.7	7.3	1.0	10.4	16.1
AR1000	20%	$\bar{X}$	.12800	.12710	.00625	.00945	.00085	.00050
		S	.00425	.02605	.00065	.00010	.00027	.00018
		CV	3.3	20.5	10.4	1.1	31.3	35.4
	25%	$\bar{X}$	.07915	.11750	.00584	.00924	.00065	.00065
		S	.00789	.00301	.00056	.00011	.00009	.00027
		CV	10.0	2.6	9.6	1.2	13.6	40.9

Table K-3 -Log Maximum True Creep Compliance, psi^{-1}

a. Analyzed Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	1.0424	0.8908	2.4597	2.2967	3.0458	3.3010
		1.0482	1.0284	2.4660	2.3325	3.1549	3.2218
	25%	1.1669	1.0119	2.4522	2.1759	3.0458	3.2218
		1.1469	1.0595	2.4168	2.1707	3.0969	3.3010
AR1000	20%	.8847	.8483	2.1798	2.0223	3.0000	3.3979
		.9010	.9492	2.2306	2.0137	3.1549	3.2218
	25%	1.1267	.9363	2.2581	2.0372	3.1549	3.0969
		1.0778	.9237	2.2111	2.0315	3.2218	3.3010

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{X}$	1.0453	.9596	2.4629	2.3146	3.1004	3.2614
		s	.0051	.1219	.0056	.0317	.0967	.0702
		cv	.5	12.7	.2	1.4	3.1	2.2
	25%	$\bar{X}$	1.1569	1.0357	2.4345	2.1733	3.0714	3.2614
		s	.0177	.0422	.0314	.0046	.0453	.0702
		cv	1.5	4.1	1.3	.2	1.5	2.2
AR1000	20%	$\bar{X}$	.8929	.8988	2.2052	2.0180	3.0775	3.3099
		s	.0144	.0894	.0450	.0076	.1372	.1560
		cv	1.6	10.0	2.0	.4	4.5	4.7
	25%	$\bar{X}$	1.1023	.9300	2.2346	2.0344	3.1884	3.1990
		s	.0433	.0112	.0416	.0051	.0593	.1808
		cv	3.9	1.2	1.9	.3	1.9	5.7

Table K-4 ANOVA Summary, -Log Maximum True Creep Compliance

ANOVA

SOURCE	df	SS	MS	F	F.05	F.01
R	1	0.0276	0.0276	7.80	4.26	7.82
Q	1	0.0063	0.0063	1.78	4.26	7.82
A	1	0.1173	0.1173	33.08	4.26	7.82
T	2	38.2695	19.1350	5394.19	3.40	5.61
RQ	1	0.0236	0.0236	6.66	4.26	7.82
RA	1	0.0001	0.0001	0.05	4.26	7.92
RT	2	0.2540	0.1270	35.81	3.40	5.61
QA	1	0.0073	0.0073	2.08	4.26	7.82
QT	2	0.0436	0.0220	6.15	3.40	5.61
AT	2	0.1186	0.0590	16.72	3.40	5.61
RQA	1	0.0071	0.0071	2.03	4.26	7.82
RAT	2	0.0032	0.0010	0.46	3.40	5.61
QAT	2	0.0051	0.0020	0.72	3.40	5.61
RQT	2	0.0010	0.0005	0.15	3.40	5.61
RQAT	2	0.0161	0.0080	2.28	3.40	5.61
Error	24	0.0851	0.0035			
TOTAL	47	38.9862				

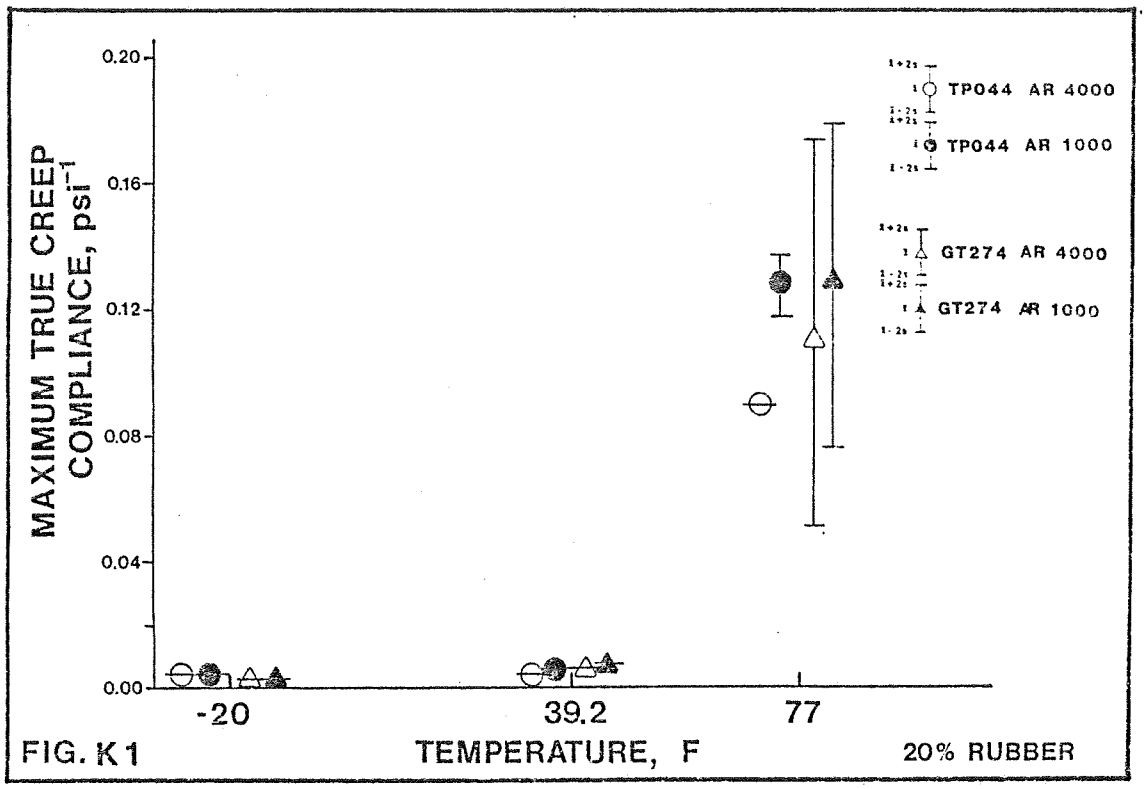
MAXIMUM TRUE CREEP COMPLIANCE, psi^{-1}
0.20
0.16
0.12
0.08
0.04
0.00
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
20% RUBBER

FIG. K1

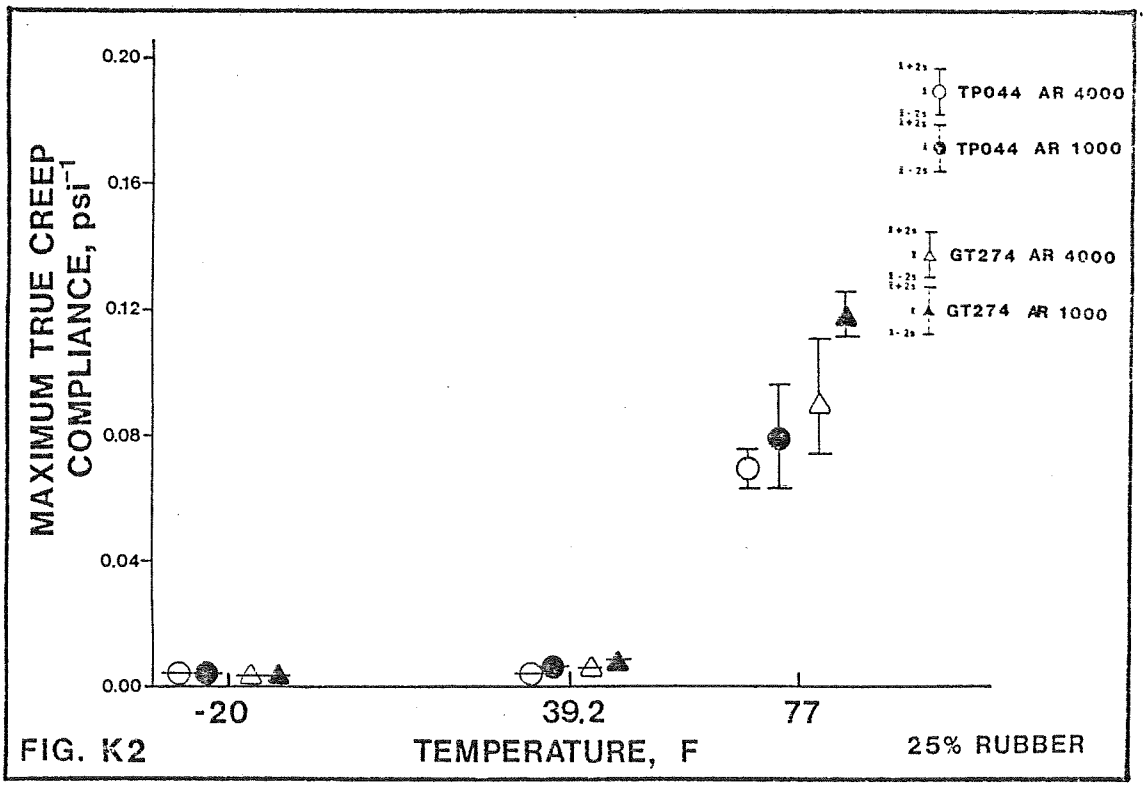
MAXIMUM TRUE CREEP COMPLIANCE, psi^{-1}
0.20
0.16
0.12
0.08
0.04
0.00
-20
39.2
77
TEMPERATURE, F
TP044 AR 4000
TP044 AR 1000
GT274 AR 4000
GT274 AR 1000
25% RUBBER

FIG. K2

APPENDIX L

FORCE DUCTILITY TIME TO MAXIMUM TRUE CREEP COMPLIANCE

Table L-1 Time to Maximum True Creep Compliance, minutes

a. Measured Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR40000	20%	14	12	10	12	1	1
		14	13	10	13	1	1
		14	12	11	13	1	1
		14	14	11	13	1	1
		12	12	11	13	1	1
		13	12	11	13	1	1
	25%	14	13	9	11	1	1
		13	12	9	11	1	1
		8	14	9	11	1	
		10	12	9	11	1	1
		13	11	9	11	1	1
		10	14	10	11	1	1
AR10000	20%	12	10	9	12	1	1
		10	16	9	12	1	1
		10	11	9	12	1	1
		12	4	9	11	1	1
		11	8	10	12	1	1
		13	12	9	11	1	1
	25%	16	14	7	10	1	1
		10	13	8	9	1	
		14	13	7	9	1	
		10	13	7	10	1	1
		10	13	7	11	1	
		12	13	7	10	1	

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR40000	20%	$\bar{X}$	13.5	12.5	10.67	12.83	1	1
		S	.84	.84	.52	.41	0	0
		CV	6.20	6.69	4.81	3.20	0	0
	25%	$\bar{X}$	11.3	12.7	9.17	11.00	1	1
		S	2.34	1.21	.41	0	0	0
		CV	20.63	9.56	4.47	0	0	0
AR10000	20%	$\bar{X}$	11.3	10.2	9.17	11.67	1	1
		S	1.21	4.02	.41	.52	0	0
		CV	10.69	39.55	4.47	4.46	0	0
	25%	$\bar{X}$	12.0	13.2	7.17	9.83	1	1
		S	2.53	.41	.41	.75	0	0
		CV	21.08	3.10	5.72	7.63	0	0

Table L-2 Time to Maximum True Creep Compliance, minutes

a. Reduced Data

		77 F		39.2 F		-20 F	
		TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	14.0	12.3	10.3	12.7	1	1
		13.0	12.7	11.0	13.0	1	1
	25%	11.7	13.0	9.0	11	1	1
		11.0	12.3	9.3	11.0	1	1
AR1000	20%	10.7	12.3	9.0	12.0	1	1
		12.0	8.0	9.3	11.3	1	1
	25%	13.3	13.3	7.3	9.3	1	1
		10.7	13.0	7.0	10.3	1	1

b. Summary

			77 F		39.2 F		-20 F	
			TP044	GT274	TP044	GT274	TP044	GT274
AR4000	20%	$\bar{x}$	13.5	12.5	10.7	12.9	1	1
		s	.89	.35	.62	.27	0	0
		cv	6.6	2.8	5.8	2.1	0	0
	25%	$\bar{x}$	11.4	12.7	9.2	11.0	1	1
		s	.62	.62	.27	0	0	0
		cv	5.5	4.9	2.9	0	0	0
AR1000	20%	$\bar{x}$	11.4	10.2	9.2	11.7	1	1
		s	1.15	3.81	.27	.62	0	0
		cv	10.2	37.5	2.9	5.3	0	0
	25%	$\bar{x}$	12.0	13.2	7.2	9.8	1	1
		s	2.30	.27	.27	.89	0	0
		cv	19.2	2.0	3.7	9.0	0	0

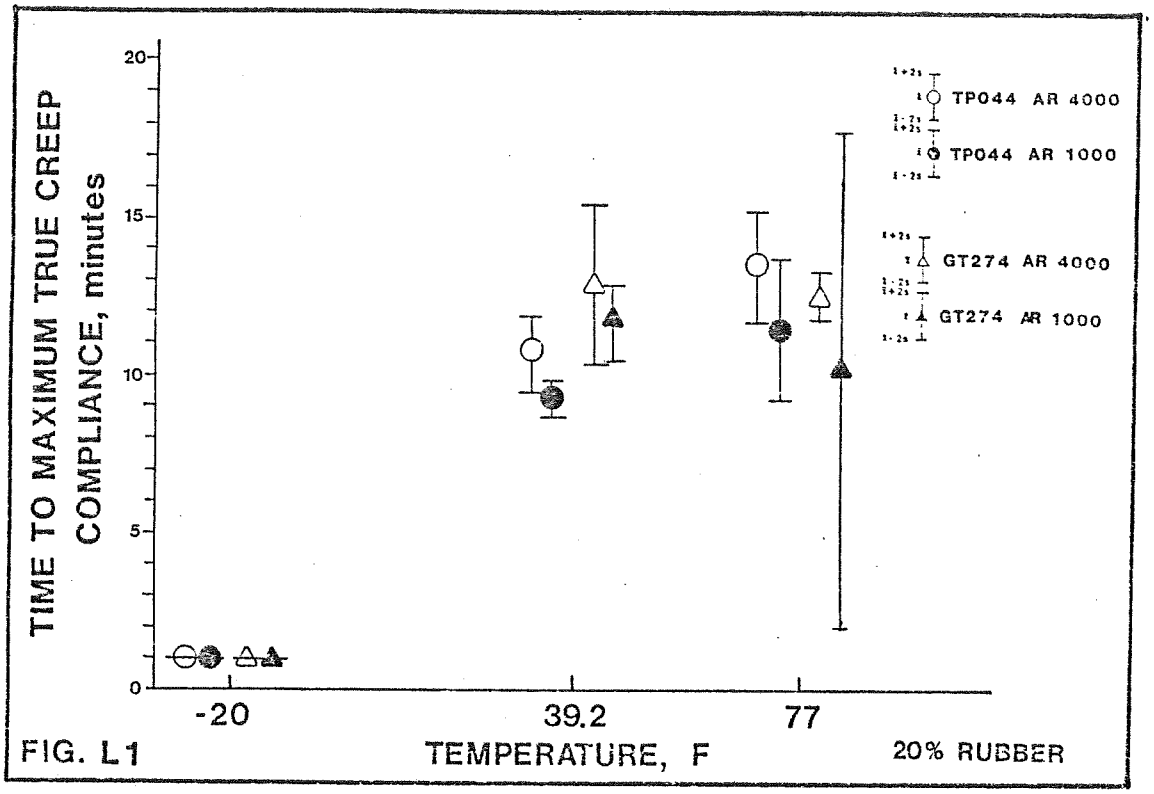

FIG. L1 20% RUBBER

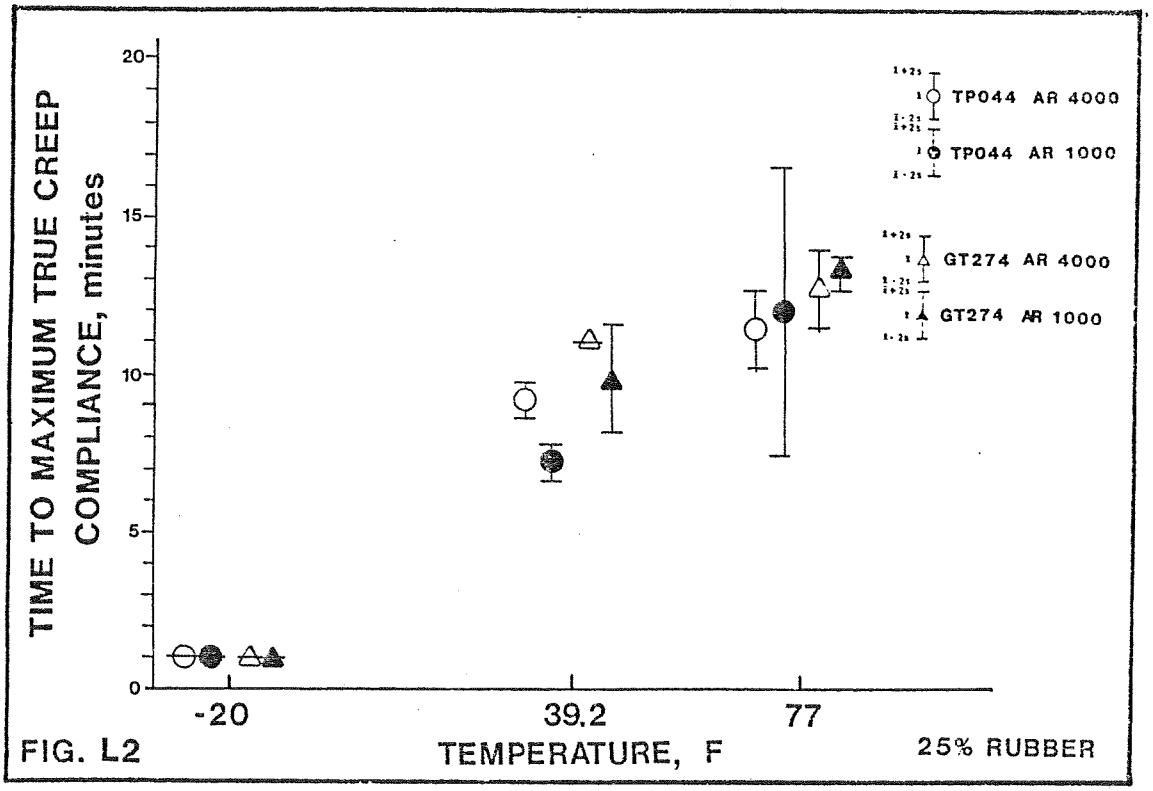

FIG. L2 25% RUBBER