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DEVELOPMENT OF ENGINEERING DATA ON ADVANCED COMPOSITE MATERIALS

UNIVERSITY OF DAYTON RESEARCH INSTITUTE
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Engineering data have been generated on four graphite reinforced advanced composite materials; SP313 (graphite/epoxy by 3M); AS/3004 (graphite/polysulfone by Hercules); AS/4397 (graphite/polyimide by Hercules) and; T300/F178 (graphite/polyimide by Hexcel). Prepreg tape was obtained from each vendor and laminates and test specimens prepared at UDRI. Five different static mechanical properties (tension, compression, flexure, inplane shear, and interlaminar

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shear) were measured on three fiber orientations (0°, 90°, and ±45°) at four different temperatures (-67°F, 72°F, and two elevated temperatures). Tensile fatigue, creep, and stress-rupture tests were also conducted and four thermophysical properties (thermal expansion, thermal conductivity, specific heat, and glass transition temperature) were determined. Environmental agings (at 160°F and 100% R.H.) were conducted on each material and the effects of this exposure on several mechanical properties were determined.

PREFACE

This summary report covers work performed during the period from 1 March 1975 to 30 June 1977 under Air Force Contract F33615-75-C-5085. The contract was initiated under Project Number 7381, "Materials Application". The work was administered under the direction of the Systems Support Division of the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. David Watson (AFML/MXA) acted as Project Engineer.

This work was conducted under the general supervision of Mr. D. Gerdeman, Project Supervisor. The Principal Investigator for this program was D. Robert Askins. Research Technicians who made major contributions to the program include: R. J. Kuhbander, F. Tittl, D. Maxwell, R. Glett, J. Graham, J. Conner, T. Green, D. Klosterman, and D. McCullum.

This report was submitted by the authors in September 1977. The contractor's report number is UDRI-TR-77-37.

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SECTION 1

INTRODUCTION

Fiber reinforced composite materials have been used in Aerospace structures for many years. The use of these materials is continually growing, and as new fiber reinforcements and matrix materials become available, the problem of selecting materials becomes an ever-growing task for aircraft builders and designers. In order to select material for a particular aircraft structure, a certain minimal amount of engineering data must be available to the aircraft designer. It was with this need in mind that a program of this nature has been undertaken. The general objective of this program is to develop engineering data on advanced composite materials. These materials are newly developed composite materials systems which are commercially available, but which at the same time are new enough that little data are available for the purpose of evaluating their potential. The purpose was to generate physical, mechanical, and thermophysical property data on a number of these advanced composite materials, which would provide an aircraft designer or builder with sufficient information to enable him to decide whether the material is a feasible candidate for his particular application. The data generated in this program are not sufficient to eliminate the need for more detailed and more comprehensive design data programs. Rather, the program provides initial data to facilitate the selection of candidate materials, and provides a basis for developing subsequent design allowable efforts on selected materials. It provides the information required to make preliminary assessments of composite materials for potential aerospace service.

SECTION 2
SELECTION OF MATERIALS

The initial portion of the program involved an identification of available candidate composite materials. This identification process consisted of several phases. One phase involved a review of the available literature on composite materials with an emphasis on the more newly developed or advanced composite materials. The second phase involved establishing both written and verbal contact with a wide cross-section of industry and government representatives who are active in the area of composite materials research, development, and application. Letter questionnaires were sent to individuals representing all the services, all the major aircraft companies, and nearly all of the major material suppliers. The questionnaire was directed towards obtaining each individual's feelings as to what materials should be considered for inclusion in this program, what their assessment of the current data availability on the various materials was, and their feelings as to potential applications for which the various advanced and newly available composite material systems might be considered. In addition, these representatives were asked what they felt the most useful and most needed type of engineering data were, as well as their feeling about the effect of manufacturing processes required for a specific composite material or its potential usage by the Aerospace community. These letter-questionnaires were sent to a total of 85 individuals. A total of 23 written responses were received, representing 31% of the total mailing. In addition to the written inputs numerous telephone contacts were made to contact individuals who did not respond in writing to our questionnaires and to obtain additional information to that requested in the letter. All the verbal as well as written inputs to this phase of the program were tabulated and discussed with AFML representatives prior to the establishment of a list of tentative candidate materials for possible inclusion in the program. The criteria employed to determine and select these candidate materials included (a) the present or imminent commercial availability of the material, (b) the degree of interest in the material expressed in the written responses and telephone contacts, (c) the material's potential to overcome specific problems of current concern to USAF, and (d) the potential value to the USAF if the material proves applicable to AF weapons systems. Table 1 lists the candidate materials which were considered during the materials selection portion of this program. The epoxy matrices are all identified with a specific reinforcement since these were the standard products of the various prepreg suppliers indicated in parenthesis. All of the other materials listed in Table 1 are matrix resins and are not associated with any specific fiber, since this could vary according to the desire of the user. The companies listed in parenthesis after these latter materials produce the matrix resin and in some cases, but not all, the prepreg. This list of candidate materials was subsequently narrowed and reduced to the final five selections; SP313 (3M), AS/HME (TRW), AS/3004 (Hercules), AS/4397 (Hercules), and T300/F178 (Hexcel).

The SP313 system (T300 fiber and PR313 resin) was selected because it represented an alternative to Narmco's 5208, a 350°F epoxy system which has found extensive application in USAF fighter aircraft structures. It was felt that two competitive systems would result in lower materials costs to aircraft builders. Other epoxy systems had been looked at previously and found wanting in one way or another, such as elevated temperature property retention after high humidity environmental aging.

The AS/HME system was developed under a previous AFML contract and was designed as a low-flow 250°F epoxy system with good resistance to property loss during high humidity environmental aging. A low-flow matrix offers considerable cost saving features from a fabrication standpoint and was of considerable interest to many aircraft builders. The enhanced moisture resistance of this matrix material also was an attractive feature of this system.

TABLE 1

PRELIMINARY CANDIDATE MATERIALS

Epoxies	Polyimides	Thermoplastics	Other
AS/HME - Low Flow (TRW)	NR-150 (DuPont)	Polysulfone (Hercules, Whittaker)	PIQ-polyimidazoquinazoline (Whittaker)*
AS/3501-6 (Hercules)	F178 (Hexcel)	Polyethersulfone (ICI)	
T300/PR13 - SP313 (3M)	HR600 (Hughes)	PPQ-polyphenylquinoxaline (Whittaker)	
T300/5209 (Narmco)	PMR-15 (TRW)	Polyarylsulfone (3M)	
T300/5213 (Narmco)	Kerimid 353 (Rhodia)	Polyphenylene sulfide	
Kevlar 49/E715 (U.S. Poly.)	2080 (Upjohn)		
Kevlar 49/E782 (U.S. Poly.)	4397 (Hercules)		
	5230 (Narmco)		

*NOTE: The Whittaker Corporation no longer exists under this name.

The AS/3004 material is a thermoplastic polysulfone matrix system which was of considerable interest to aircraft companies as a material with the potential for substantial cost savings in fabrication due to its very low flow and potential for formability into complex contours.

The AS/4397 polyimide system was selected because it was of interest as a potential alternative to the 350°F epoxy systems, offering better dry and wet properties at comparable temperatures. This system is considered a 450°F material and as such, offers, at equivalent cost, a larger margin of safety than the 350°F epoxies when used at comparable conditions.

The T300/F178 polyimide system is also a 450°F material which costs about the same as the 350°F epoxies but offers improved wet and dry performance at comparable temperatures as well as an overall higher temperature capability.

SECTION 3
TEST PROGRAM AND PROCEDURES

The laboratory efforts required during this program consisted of four generally sequential steps for each of the five materials characterized. These consisted of prepreg physical property characterization, laminate fabrication and specimen machining, laminate physical property characterization, and laminate mechanical and thermophysical property measurements. Each of the test methods and type of specimen used in the determination of these various properties, as well as the panel fabrication and specimen preparation procedures, are described in this section.

3.1 PREPREG PHYSICAL PROPERTY CHARACTERIZATION

The prepreg physical properties which were measured consisted of volatile content, resin content, and flow. The test methods used to determine these properties, for the most part, were those recommended or used by the prepreg manufacturer. Table 2 identifies the particular specification which was followed in determining these properties for each resin system. In some cases one or two of these tests were omitted for a particular prepreg. These variations are identified and explained in Table 2 and its footnotes. In the case of the AS/HME prepreg, the prepreg supplier did not recommend particular tests for resin content or flow, so the University adopted tests which it considered appropriate for this purpose. The summarized prepreg properties themselves are presented in Section 4 for each specific material. These prepreg physical property characterizations were not intended primarily as a means of accepting or rejecting a particular batch of material if it deviated slightly from prespecified tolerance limits. Rather, they were conducted to provide the reader with an estimate of the normal property levels and variability encountered in purchased prepreg and also to provide a basis for the subsequent assessment of laminate properties obtainable from such prepreg.

TABLE 2

PREPREG PHYSICAL PROPERTY TEST SPECIFICATIONS

Prepreg Material	Test Specification Identification[1]		
	Volatile Content	Resin Content	Flow
SP313 (3M)	3M method	3M method	3M method
AS/3004 (Hercules)	HD-SG-500/232	HD-SG-2-6006C (5.2.6,F)	N.A.[2]
AS/4397 (Hercules)	HD-SG-2-6006C (5.1)	HD-SG-2-6006C (5.2.6,F)	HD-SG-2-6006C (5.3.1,A)
T300/F178 (Hexcel)	N.A.[3]	Hexcel method	N.A.[4]
AS/HME (TRW)	I.1.1 (TRW method)	AFML-TR-67-243[5]	3M method[6]

[1]All of the test methods specified in this table are reproduced in their entirety in Appendix A.

[2]No flow test was run on the AS/3004 prepreg because this thermoplastic material exhibits negligible flow during laminate consolidation.

[3]The F178 prepreg contains no volatiles.

[4]It was indicated by Hexcel that they did not run a flow test on this prepreg since they had found that if used within the specified shelf life period, the prepreg produced consistently good laminates if its resin content fell in the range of 42 $\pm$ 3%. It was obvious during laminate preparation, however, that this is a relatively high flow system.

[5]It was found that neither hot acetone (recommended by TRW) or dimethylformamide (SP313, 3M procedure) extraction succeeded in complete resin removal. The method referenced here utilizes a hot nitric acid digestion of the resin.

[6]No flow test procedure was recommended since this was a low-flow system. As a consequence it was arbitraily decided to use the same test as was used for the SP313 material. The comparative results, presented in Section 4, illustrate the reduced flow characteristics of the HME resin. One must keep in mind, however, that this flow test imposed 90 psi upon the sample while the actual cure schedule for the HME system goes only to 14 psi.

Samples for the prepreg physical property tests were obtained from each roll of prepreg tape and three specimens were used for each test. The complete tabulation of these prepreg test results is presented in Appendix A. All of the prepreg used in this program except for the AS/3004 and AS/HME was stored at -30°F when not in use and all of the laminates needed for the program were prepared prior to the expiration of the manufacturer's stated storage life for each specific material. In addition, a written record was maintained for each roll of prepreg which noted the cumulative total time the material was exposed to room temperature conditions during the period in which laminates were being fabricated from the tape. The AS/3004 and AS/HME materials were stored at room temperature (≐72°F) since there were no storage life limitations with these two materials.

3.2 LAMINATE PROCESSING AND SPECIMEN FABRICATION

When laminates were to be made, the roll of prepreg was removed from the freezer and allowed to warm to room temperature without opening the sealed bag in which the prepreg was contained. This was done in order to eliminate the chance of moisture condensation directly on the prepreg material. After the prepreg had warmed thoroughly to room temperature, it was removed from its package and unrolled on a clean countertop. Pieces were cut from the tape in the required shape and size with a razor and after removing the release paper, carefully layed up in the desired stacking sequence for a particular laminate panel. This stack was then carefully rebagged and returned to the freezer for storage until lamination and curing. When a laminate was to be cured, it was removed from the freezer and warmed to ambient before reopening its storage bag. The prepreg was then removed from the storage bag and placed in an autoclave for curing. The detailed curing schedules for each specific prepreg material are presented in Section 4. After lamination and cure, machining diagrams were sketched onto the panel surfaces and individual specimens were cut out of the panels with a diamond cut-off wheel and finish machined to the required dimensions on a Tensile-Cut belt sander. Specimens from each panel were set aside for measurement of panel physical characteristics.

Some of the mechanical test specimens required doubling tabs in the grip sections. A 1/16-inch thick glass fabric reinforced phenolic laminate material was used for this purpose. Scotchply is specified in the Design Guide for tab material but it proved unsatisfactory for the elevated temperatures. Loctite 306 adhesive was used to bond the tabs to the specimen and was cured at 275°F for 15 minutes under spring clamp pressure.

3.3 LAMINATE PHYSICAL PROPERTY CHARACTERIZATION

Four different physical properties were measured on each laminate to insure acceptable laminate quality. These were specific gravity, resin content, fiber content, and void content. Each of the procedures used for these measurements is discussed in detail in the following paragraphs and is summarized in Table 3. The summarized laminate physical properties obtained for each of the materials investigated are summarized in the tables in Section 4 and are presented in their entirety in Appendix B.

3.3.1 Specific Gravity

Three specimens from widely scattered locations on each laminate were selected for specific gravity determinations. Specimen size depended upon both panel size and the number and size of mechanical test specimens required from the panel, but in general ranged from a minimum of 1/2" x 1/2" to a maximum of 1" x 3/4". The method used was ASTM D792, a weight-in-air/weight-in-water technique.

3.3.2 Resin Content

The same specimens which were used for specific gravity measurements were used for resin content determinations.

TABLE 3

LAMINATE PHYSICAL PROPERTY TEST PROCEDURES

Laminate Material	Procedure Identification		
	Specific Gravity	Resin/Fiber Content	Void Content[1]
SP313 (3M)	ASTM D792-66	AFML-TR-67-243 (Acid digestion)	Grid point count and ASTM D2734-70(B)
AS/3004 (Hercules)	ASTM D792-66	HD-SG-2-6006C (5.2.6,F)(Hercules Method)	Grid point count and ASTM D2734-70(B)
AS/4397 (Hercules)	ASTM D792-66	HD-SG-2-6006C (5.2.1,A)(Hercules Method)	Grid point count and ASTM D2734-70(B)
T300/F178 (Hexcel)	ASTM D792-66	Grid point count on photomicrographs[2]	Grid point count
AS/HME (TRW)	ASTM D792-66	---[3]	---[3]

[1]Void contents were computed as described in ASTM D2734-70(B) and also determined by a point counting technique which essentially integrates the areas on a cross sectional photomicrograph which represent resin, fiber, and voids.

[2]It was found impossible to digest the cured F178 resin away with several different acids and solvents.

[3]Since evaluation of this material was terminated prematurely, no panel resin, fiber, or void contents were determined.

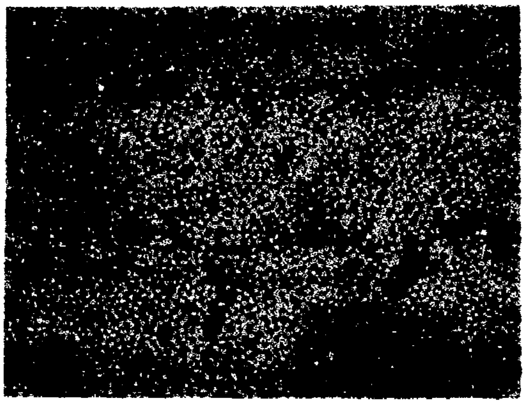
The methods listed in Table 3 were followed in these determinations. The grid point count method involves placing a transparent grid over a specimen photomicrograph and counting the number of grid intersections which fall on resin, fiber, or void areas. This method produces statistically accurate values if a sufficiently large sample is utilized. In this program, we have used a grid containing 1530 intersections and have used three photomicrographs (300X) per laminate.

3.3.3 Fiber Content

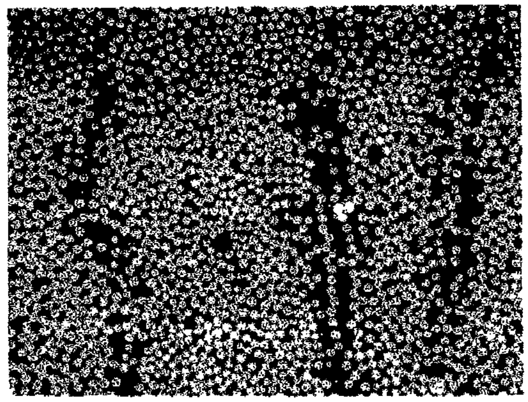
The fiber contents of the SP313 laminates were computed, as percent by volume, from the same data used for the resin content determinations. The computational procedure is illustrated in AFML-TR-67-243 and employed values for fiber and resin specific gravity reported by the respective manufacturers.

3.3.4 Void Content

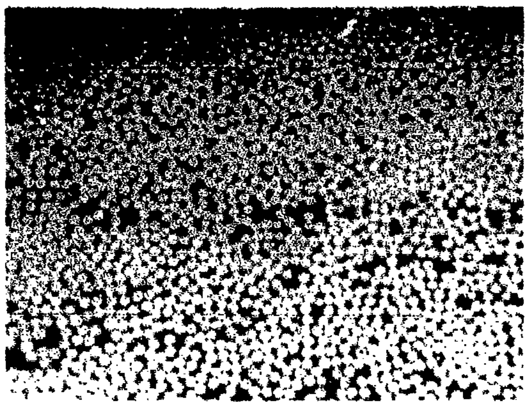
The void contents, just as the fiber contents, of the SP313 laminates were computed, as percent by volume, from the same data obtained in the resin content determinations. The computational procedure is described in ASTM D2734-70, method B. The result of this procedure frequently gives negative values for laminates having low void contents. This occurs because minor errors or variations in the values for resin, fiber, and composite specific gravities become significant at low void contents. This result was obtained for numerous laminates made in this program, even though photomicrographs did sometimes reveal the presence of porosity. A point counting technique using a grid superimposed over photomicrographs of laminate cross sections was consequently used in conjunction with the computed values. It is felt that the photographically obtained value is more realistic than the computed values for low porosity laminates and for this reason, these values are reported in place of the computed negative values. Figure 1 illustrates typical laminate cross sections for each of the composite materials characterized.



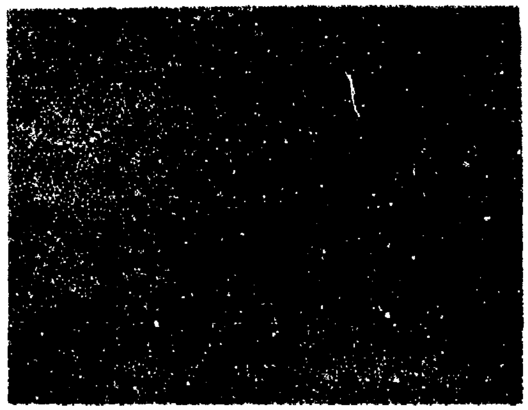
(a) SP313, 250X



(b) AS/3004, 290X



(c) AS/4397, 300X



(d) T300/F178, 150X

Figure 1. Typical Cross Sections of Fabricated Composites.

3.4 SPECIMEN CONDITIONING

Three different types of conditioning were involved in this program. The first was simply a dry dessicated storage of finished specimens at ambient temperature until they were to be tested. This provides a data base for the dry material to which both humidity aging data and data for other materials systems can be compared.

The second type of conditioning was the elevated and reduced test temperatures. In all of the mechanical testing except for specimens which were humidity aged, the specimens were soaked for one-half hour at the test temperature prior to loading. Thermal conductivity specimens were soaked at temperature for periods of up to several hours in order to provide sufficient time for the test stack to reach thermal equilibrium before readings were taken. The thermal expansion specimens were not soaked for extended periods at any one temperature. Rather, they were heated from some starting temperature to the ending temperature at a constant rate of about 2°C/min.

The third type of conditioning was an elevated temperature, high humidity exposure. The specimens involved in these tests were exposed to conditions of 160°F and 100% R.H. until they either reached saturation, as evidenced by constant weight, or about 50% of their saturated weight gain. Specimens were removed from the humidity cabinets for weighing periodically to determine weight gain. The frequency of removal varied from material to material depending upon whether the aging was being carried to saturation or half-saturation and upon the rate and extent of moisture absorption by the particular matrix system being aged. The half-saturation agings, for example, typically required less than one day, and normally two or three weighings were made during this period at intervals of from 3 to 16 hours. The fully saturated agings, on the other hand, typically required from four to eight weeks to complete, during which time the specimens were removed from the aging cabinet and weighed between four and ten times at intervals of three to seven days. After final removal from the humidity aging, the specimens were tested at both 72°F and at one of the elevated temperatures for which data on dry specimens were obtained. After removal from the humidity aging cabinet, the specimens were kept in a 72°F, 100% R.H. environment until tested (less than one-half day). During this period the specimens were exposed to ambient conditions for a maximum of about twenty minutes, during which time strain gages and gripping tabs were mounted on the specimens (interlaminar shear, short beam specimens of course, did not need this). The specimens tested at room temperature were tested as soon as they were ready. Those tested at elevated temperature were placed in a preheated test oven and tested after the same 30-minute soak used for dry specimens. The insertion of the specimens for elevated temperature testing into the grips in the test oven required less than one minute, during which time, the oven temperature fell about 50°F below its setpoint. The 30-minute soak time was counted from the reclosing of the test oven door after specimen insertion. Hence, the first several minutes of this 30-minute period was required for the oven temperature to recover to the setpoint while, simultaneously, the test specimen required ten minutes or so of this 30-minute soak to approach the test temperature. This length of soak was initially used to insure complete cure of the tab adhesive prior to loading since the tabs were applied with an elevated temperature cure adhesive to insure adequate tab performance during loadup and the specimens were placed in the test oven immediately after application of the tabs so that specimen heat-up and tab adhesive cure occurred simultaneously. It is recognized that a 30-minute soak of a "wet" composite can produce a drying effect so that the test results are not actually representative of a truly "saturated" material. A compromise must be made, however, between the length of time required for a specimen to heat up to the test temperature and the rate at which a specimen dries out. Ideally, a steam test chamber would eliminate the requirement to make such a compromise. Few organizations have such a test chamber, however. The heat-up, dry-out compromise, in this case, however, was also influenced by the requirement to cure the tab adhesive prior to load application. It was found that the use of room temperature curing tab adhesives for elevated temperature tests resulted in debonding of the tabs prior to specimen failure. Consequently, elevated temperature curing tab adhesives were used to overcome this problem and, hence, the need to simultaneously cure the tab adhesive while heating the "wet" specimens up to the test temperature during the 30-minute "soak".

One experiment was conducted to measure the magnitudes of possible error introduced by the 30-minute soak before load application by measuring both the heat-up and dry-out rate of an AS/3004 polysulfone matrix specimen. This material absorbs only about 1/4-1/3 as much moisture as the other materials characterized in this program when aged to saturation and the first 50-60% of this gain occurs very rapidly (3-9 hours). An untabbed 90° tensile specimen was used for this experiment. Figure 2 illustrates the results of this experiment. It can be seen that even after 30 minutes, the specimen temperature (as indicated by a small thermocouple embedded in the center of the specimen) is not quite up to the nominal test temperature. The moisture content, however, has fallen to less than 50% of the saturated value in this period. Some investigators recommend only a three-minute soak to minimize drying. For the AS/3004 material, it can be seen that one would be testing a material with a moisture content of about 85% of the saturated value at a temperature 40°F below the nominal test temperature for this test criteria. What it boils down to is that each investigator must decide upon his own compromise.

Another experiment which was conducted, involved testing some saturated T300/F178 short beam shear specimens after a 30-minute soak and after a five-minute soak. Table 4 presents

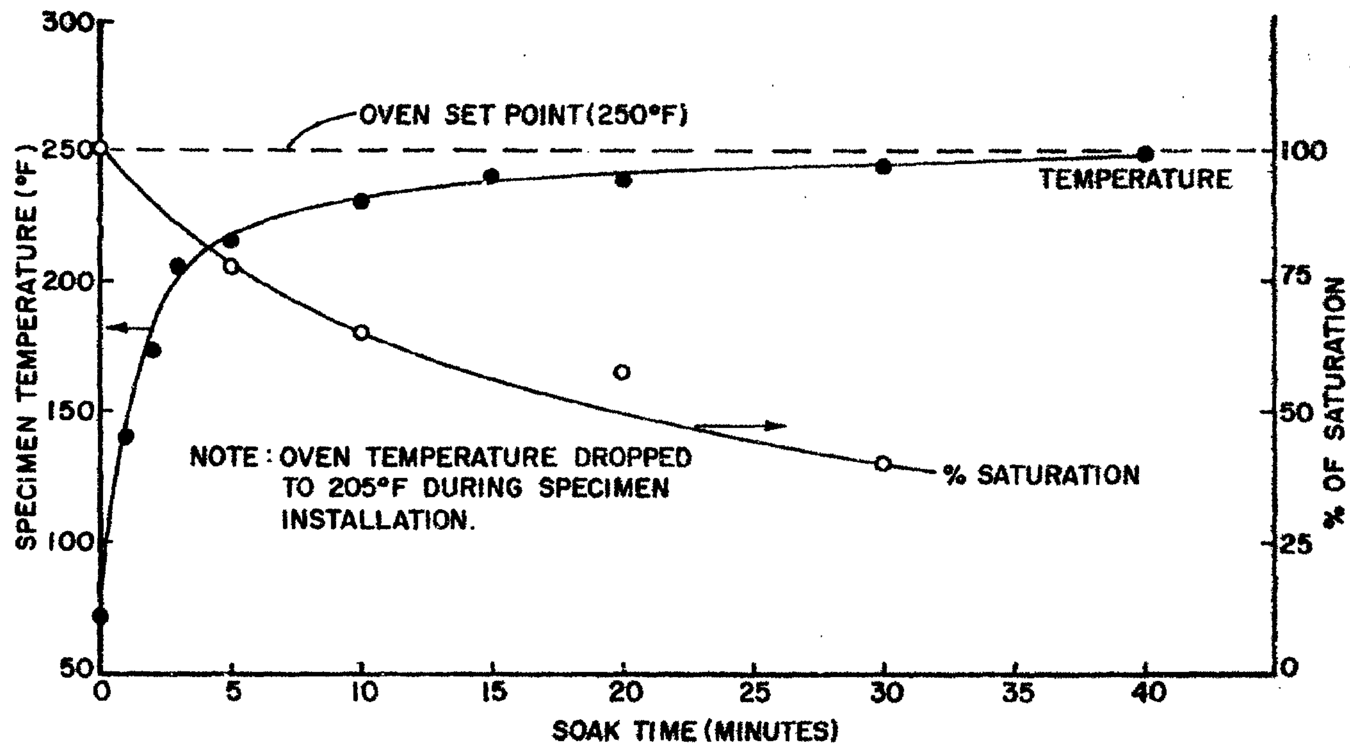


Figure 2. Heat-Up and Dry-Out Behavior of Saturated AS/3004 Composite Laminates.

TABLE 4

COMPARISON OF THE EFFECTS OF TEST OVEN SOAK TIMES UPON RETAINED INTERLAMINAR SHEAR STRENGTH OF SATURATED T300/F178 COMPOSITE LAMINATES

Test Condition	Test Temp. (°F)	Strength (ksi)	Std. Dev. (ksi)	No. Specimens
dry	72	14.82	0.89	5
dry	350	10.17	0.29	5
saturated	72	11.33	0.29	3
saturated	350, 30-min. soak	7.38	0.41	3
saturated	350, 5-min. soak	6.69	0.09	2

the results of this experiment. It can be seen that the five-minute soak produced a lower strength, indicating perhaps that the higher moisture content present after only five minutes was more detrimental to the shear strength than the lower specimen temperature. The difference, however, is only marginal so it seems that the 30-minute soak data are still quite useful. In fact, inspection of all the humidity aging data appearing in Section 4 indicates that considerable and consistent strength drop-offs occur for all of the materials evaluated in this fashion.

3.5 LAMINATE MECHANICAL AND THERMOPHYSICAL PROPERTY CHARACTERIZATION

A total of eight types of mechanical property tests were performed on the composite materials evaluated during this program; tension, compression, flexure, inplane shear, interlaminar shear, tensile creep, tensile stress-rupture, and tensile-tensile fatigue. In addition, four thermophysical properties were measured; specific heat, thermal conductivity, coefficient of thermal expansion, and glass transition temperature. Tables 5-8 summarize the test matrices for the static, dynamic/time dependent, thermophysical, and humidity aged static tests. It can be seen that the original test plan called for a total of 612 specimens to be tested for some sort of mechanical or thermophysical property for each material system. In addition to these specimens, however, numerous instances were encountered where extra or replacement specimens had to be tested. These situations included instances where failures occurred in the tabbed grip areas rather than in the gage section, where instrumentation failures prevented full data acquisition or aborted a test, or simply occasions when anomalous results were obtained which dictated rechecking. Another source of extra specimen testing involved the creep and fatigue tests. In these tests it was found on several occasions that the stress levels initially selected produced premature failures. Consequently, the stress levels at which these tests were conducted were lowered and extra

TABLE 5

STATIC MECHANICAL PROPERTY TEST MATRIX

Test Type	Test Temperature[1]			
	-67°F	72°F	T_3	T_4
0° Tension	5	5	5	5
90° Tension	5	5	5	5
±45° Tension	5	5	5	5
0° Compression	5	5	5	5
90° Compression	5	5	5	5
0° Flexure	5	5	5	5
90° Flexure	5	5	5	5
Inplane Shear[2]	5	5	5	5
Interlaminar Shear	5	5	5	5

[1]The two elevated temperatures varied, depending upon the matrix resin.

[2]Except for some rail shear tests run with the SP313 system, all of the inplane shear data were obtained from the ±45° tension data.

TABLE 6

DYNAMIC AND TIME DEPENDENT MECHANICAL PROPERTY TEST MATRIX

Test Type	Test Temperature[1]			
	-67°F	72°F	T_3	T_4
0° Tensile Creep	0	9	9	9
90° Tensile Creep	0	9	9	9
±45° Tensile Creep	0	9	9	9
0° Tensile Stress Rupture[2]	0	9	9	9
90° Tensile Stress Rupture[2]	0	9	9	9
±45° Tensile Stress Rupture[2]	0	9	9	9
0° Tensile-Tensile Fatigue	12	12	12	12
90° Tensile-Tensile Fatigue	12	12	12	12
±45° Tensile-Tensile Fatigue	12	12	12	12

[1]The two elevated temperatures varied, depending upon the matrix resin.

[2]The stress rupture lifetimes were obtained from the same specimens used for creep tests.

Extra Note: The 9 specimens tested in tensile-creep at each condition were subdivided into 3 groups of 3 specimens each and these groups of three were then loaded at different stress levels. The 12 specimens tested in fatigue at each condition were subdivided into 3 groups of 4 specimens each and these groups of four were then tested at different maximum cyclic stress levels.

TABLE 7

THERMOPHYSICAL PROPERTY TEST MATRIX

Test Type	Test Temperature[1]			
	-67°F	72°F	T_3	T_4
Specific Heat	3[2]	3	3	3
Thermal Conductivity	3	3	3	3
0° Thermal Expansion	3	3	3	3
90° Thermal Expansion	3	3	3	3
±45° Thermal Expansion	3	3	3	3
Glass Transition Temp. (dry)[3]	1[4]			
(wet)[3]	1			

[1]The two elevated temperatures varied, depending upon the matrix resin.

[2]In most cases a value at each test temperature was obtained from each specimen, so that, usually, three specimens provided all twelve data points.

[3]Dry refers to the as-fabricated composite condition, while wet refers to the condition of the specimen after it has reached an equilibrium weight gain during humidity aging at 160°F and 100% R.H.

[4]Since these tests required access to instrumentation not under UDRI's control, only one determination could be made for each material at each condition.

TABLE 8

TEST MATRIX FOR STATIC MECHANICAL PROPERTY TESTS AFTER ELEVATED TEMPERATURE, HIGH HUMIDITY AGINGS

Test Type	Saturation Level			
	50%		100%	
	Test Temp.		Test Temp.	
	72°F	T_3[1]	72°F	T_3[1]
90° Tension	5	5	5	5
±45° Tension/Inplane Shear[2]	5	5	5	5
Interlaminar Shear	5	5	5	5

[1] This temperature varied depending upon the specific material.

[2] These tests were not performed on the latter materials tested in this program (AS/4397 and T300/F178) because of the relatively small effect which humidity aging has upon these properties.

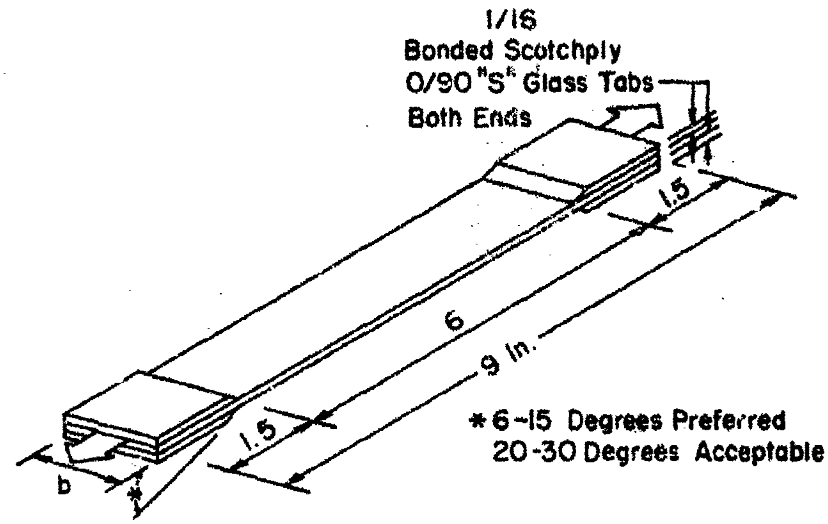
specimens tested so as to provide the full complement of results required for the test plan outlined in Tables 5-8. It will be noted in the summarized results in Section 4 that the number of specimens for which the average property values are reported varies from property to property. As discussed above, however, in some cases extra tests were conducted which raised the number of specimens above the original plan. In other cases, the behavior of the test specimen during test prevented the acquisition of one or more properties from that particular specimen. If, for example, the specimens underwent excessive elongation before failure, the strain gages were lost and ultimate elongation data were not obtained, even though strength, modulus, proportional limit, and Poisson ratio values were. In some cases, strain gage data were lost due to breaks in the lead wire-gage terminal connection.

In the succeeding sections, descriptions of the test methods used to obtain the mechanical and thermophysical properties are presented. The summarized test results for each specific material system are presented in Section 4 and a complete tabulation of all of these test results is presented in Appendices C thru M.

3.5.1 Tension

Tensile tests were conducted in accordance with the recommendations of the Advanced Composites Design Guide[2] using the straight-sided IITRI specimen illustrated in Figure 3. The doubling tabs were a glass fabric/phenolic laminate material as discussed previously (Section 3.2). The tensile tests were conducted at an extension rate of 0.05 inch/minute on an Instron Universal Testing Machine. All of the tensile strains were monitored with strain gages. This test procedure also corresponds to ASTM method D3039-74 except for the tab materials. In the ASTM specification, the tab material called for is a non-woven 0°/90° Scotchply material 1/8 inch thick, while in this program a woven glass/phenolic material 1/16 inch thick was used satisfactorily.

TENSILE TEST SPECIMEN



SPECIAL REMARKS

LAMINATE	NO. OF PLIES(n)	SPECIMEN WIDTH b
$[0]_C$	n=6	1/2
$[90]_C$	n=15	1
$[0/90]_C$	$n \geq 3$	1
$[0/+45/90]_C$	$n \geq 6$	1

(1) Specimens may be individually molded or cut (diamond tool recommended) to width required.

(2) Inner ply of tab material should have fibers in the longitudinal direction.

(3) Self-aligning grips should be used, completely enclosing the tab area.

(4) The aspect ratio of the test area must be noted when testing off-axis orientations. The aspect ratio may be varied to represent a specific application.

Figure 3. IITRI Straight-Sided Tensile Specimen.

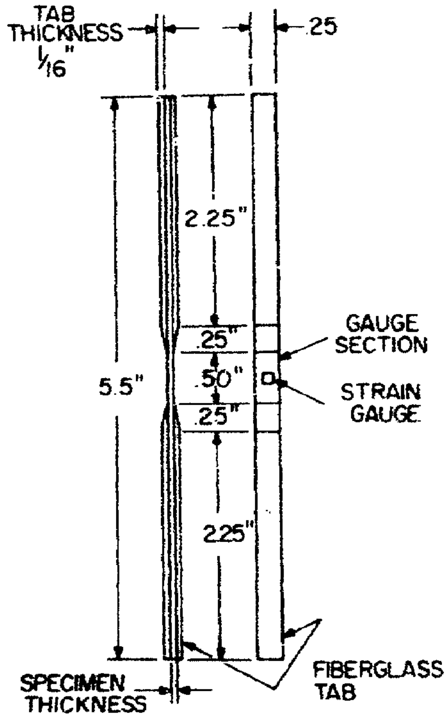
The tensile proportional limits were determined with the understanding that the proportional limit should represent the point at which a significant departure from linearity in the slope of the stress-strain curve, presumably indicative of damage to the specimen, occurs. This can produce a substantially different value than if one were to simply take the point of first deviation from linearity. The first deviation of the stress-strain curve from linearity on the 0° fiber orientations actually occurred at roughly one-third of the ultimate stress but at this point the slope of the curve increased rather than decreased. It is generally conceded that this phenomena is due to the behavior of the reinforcing graphite fiber since the same behavior is noted when testing bare graphite fibers. Consequently, this is not felt to indicate damage to the specimen. No decrease in the slope of the stress-strain curve was in fact noted for most of the 0° or 90° fiber orientations prior to failure except for the high temperature tests on the 90° fiber orientations, and for this reason the proportional limit is reported as equivalent to the ultimate strengths. On the high temperature tests with the 90° fiber orientation and on all of the ±45° fiber orientations, a significant decrease in the slope of the stress-strain curves was observed below the ultimate strength. Whether this indicates the onset of real and significant damage, at least at the point of first departure, is a moot point. Perhaps the determination of the elastic limit would be of more value than the proportional limit.

The Poisson's ratio values were experimentally measured on the 0° and ±45° fiber orientations and computed for the 90° fiber orientation from the relationship:

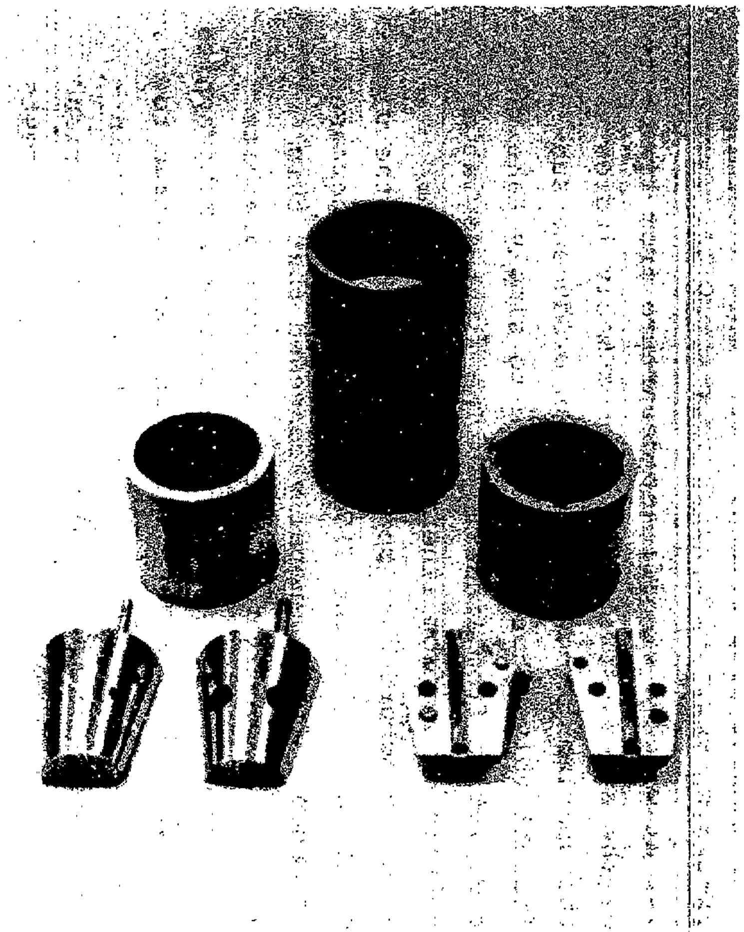
$$\nu_{21} = \nu_{12}\left(\frac{E_{22}}{E_{11}}\right)$$

3.5.2 Compression

Compression tests were conducted using ASTM method D3410-75. Figures 4 and 5 illustrate the specimen and fixture

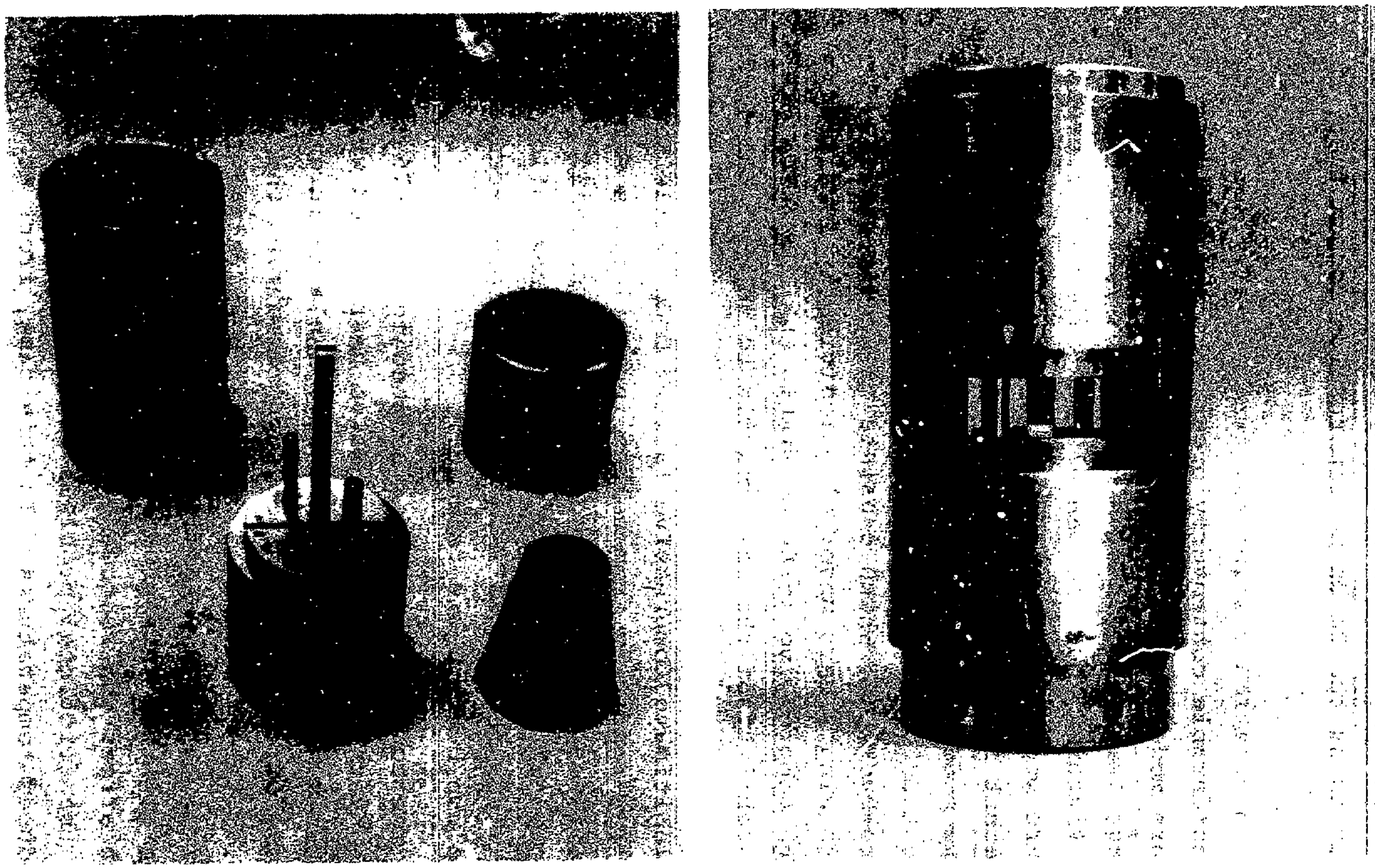


(a) CELANESE COMPRESSION
COUPON SPECIMEN



(b) DISASSEMBLED CELANESE
COMPRESSION FIXTURE

Figure 4. Celanese Compression Coupon Specimen and Disassembled Compression Fixture.



(a) PARTIALLY ASSEMBLED

(b) FULLY ASSEMBLED WITH SPECIMEN IN PLACE

Figure 5. Celanese Compression Fixture.

details. Prior to the adoption by ASTM, this test method was widely referred to as the Celanese compression coupon test method.

Compression testing has traditionally been the subject of considerable controversy because of the various types of failure modes one can encounter. Not only can one obtain different failure modes with different types of test specimens and fixtures, but one can also experience different types of failure modes from the same type of test specimen and fixture. Inherent in the question of what is or is not a desirable failure mode is the requirement to avoid a gross specimen buckling-type of failure. This is different from what is called micro-buckling, which consists of longitudinally oriented reinforcing fibers undergoing individual, localized buckling due to compressive stresses within the composite exceeding the capability of the resin matrix to support the fiber and maintain its axial alignment. Micro-buckling is generally considered a legitimate compressive failure mode, while gross specimen buckling resulting from column instability is not. In order to eliminate the occurrence of column instability failures, specimens are designed with a slenderness ratio sufficient to insure compressive failure before the load necessary to initiate column buckling is reached.

The compression test described in D3410-75 is considered to be a very promising compressive test method which, with proper specimen design, produces acceptable failure modes without the need of lateral specimen supports during the test. One objection to this test method which has been raised is that the mated conical surfaces make line rather than surface contact during testing and that this produces frictional and alignment problems which affect the recorded results.[3] Our experience has been that the frictional problems are minimal except when testing at reduced temperatures. In this case, frost accumulates on the fixture and the sliding surfaces do not slide freely, producing some spurious load recordings. Misalignment has proven to be a problem, however. Although the specimens were designed to eliminate buckling instability, it has been found that buckling frequently occurred anyway at stresses between 75% and 100% of ultimate. This behavior is evident in the load-strain curve illustrated in Figure 6 and by the failed specimen in Figure 7. The misalignment apparently is induced by the nonuniform seating of the fixture cone in the conical socket. This nonuniform seating, in turn, results from the distortion imposed upon the split cone by the thickness of the specimen.

3.5.3 Flexure

All flexural testing, with the exception of the 0° AS/4397 specimens, was conducted using the four-point loading method described in the January, 1971, issue of the Advanced Composite Design Guide.[4] In this volume a three-point technique is recommended for 0° fiber orientations and a four-point technique for 90° fiber orientations. It has been observed, however, that one not infrequently encounters undesirable failure modes under the loading nose and subsequent anomalous strength values when using three-point loading on high modulus composite materials with a 0° fiber orientation. For this reason, the four-point method was used, with the one exception, for both fiber orientations in this program. The reason for this one exception is discussed in further detail in Section 4.3. All flexure tests were conducted at a testing speed of 0.05 in/min.

3.5.4 Inplane Shear

Two types of inplane shear tests were conducted. The principle technique, used for all of the different systems, utilized data obtained from a uniaxial tensile test on a ±45° crossplied laminate. This method is quite simple and is described in two articles in the Journal of Composite Materials.[5,6] The second type of inplane shear test was a double rail shear technique described as Method B in a proposed ASTM standard titled

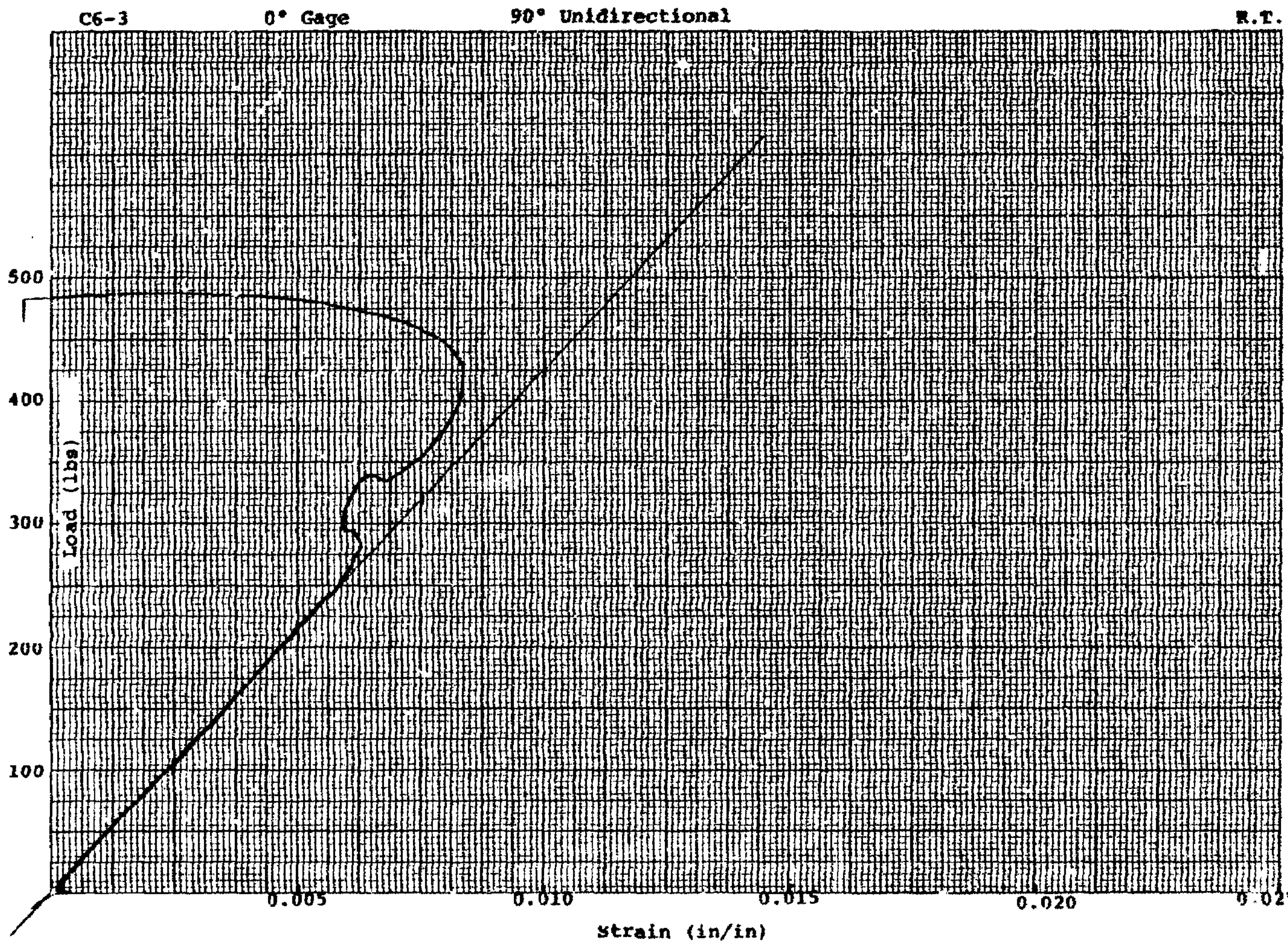


Figure 6. Compressive Load-Strain Curve for Specimen Exhibiting Buckling Prior to Failure.

Figure 7. Appearance of Failed Compressive Specimen Which Buckled.

"Proposed Method of Test for Inplane Shear Properties of Composite Laminates." Figures 8 and 9 illustrate the specimen and fixture used in this technique. This latter method was used only with the SP313 system. The testing speed in the double rail shear test was 0.05 in/min.

All of the tabular data for inplane shear in Section 4 was obtained with the ±45° tensile test specimen. For comparative purposes, however, the data obtained with the rail shear method is also presented in Section 4 for the SP313 material, along with pertinent commentary.

3.5.5 Interlaminar Shear

Interlaminar shear is another property for which no simple or problem-free test exists. The two most widely used tests are the opposed double notch specimen with side supports and the short beam. A third test utilizes torsional loading of a rod but requires special fixturing. Each of these tests is subject to certain objections. The notched specimen is known to have high stress concentrations at the notch edges, the short beam specimen produces high strength values because of its short span and the compressive stresses introduced by the loading nose and supporting points, and the torsional specimen is not felt to have a straight line stress distribution at the higher stresses even though this assumption is made in computing the failure strength.

Because of the simplicity of the specimen and the test and because of the widespread use of the specimen for quality control, the short beam specimen was selected for generation of interlaminar shear properties in this evaluation. This method is described in the January 1971 issue of the Advanced Composite Design Guide and is also described by ASTM method D2344-76. The only differences between the two is that the ASTM method calls for ten replications, while only five were conducted in this program.

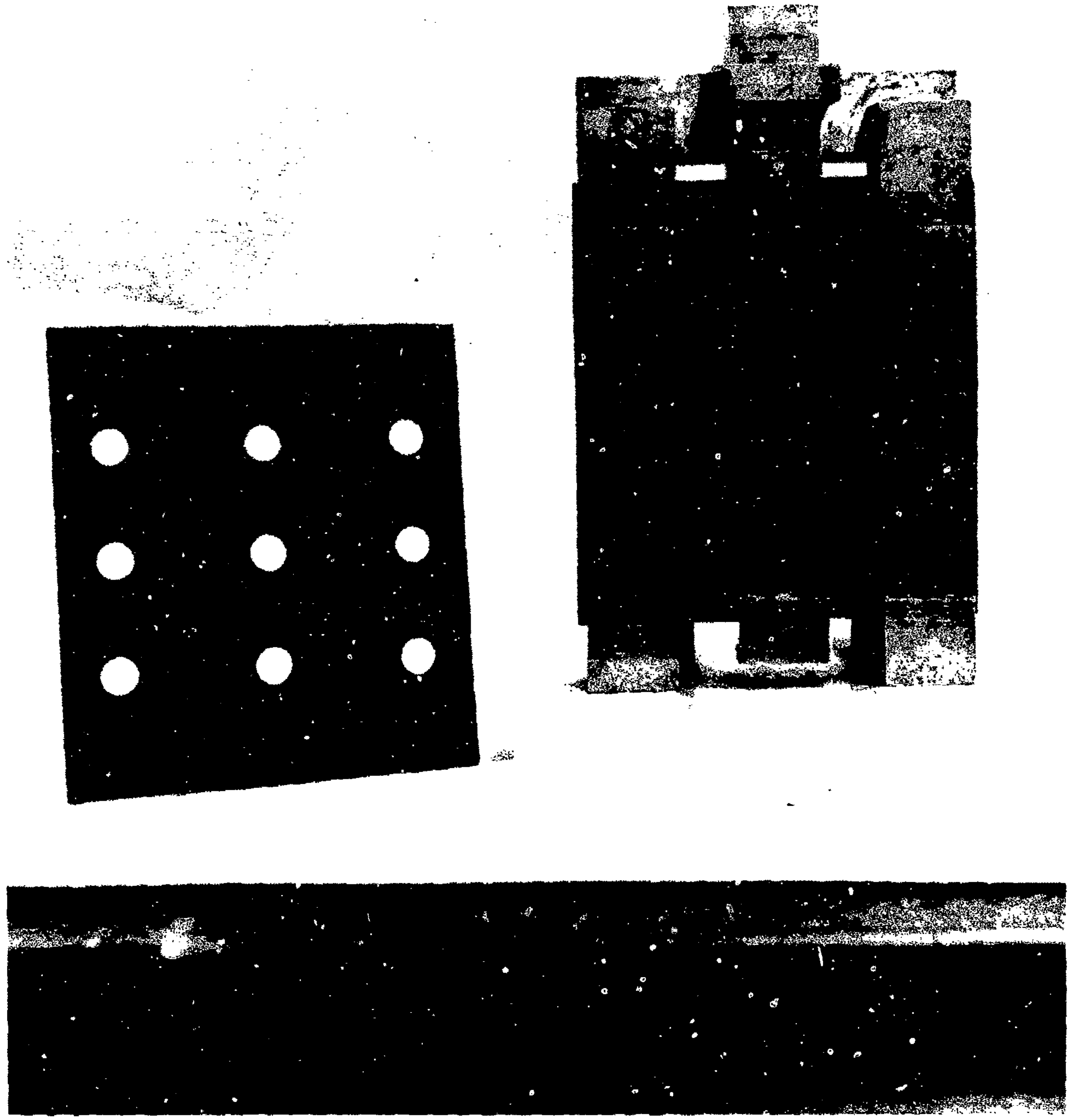


Figure 8. Double Rail Shear Specimen and Fully Assembled Test Fixture.

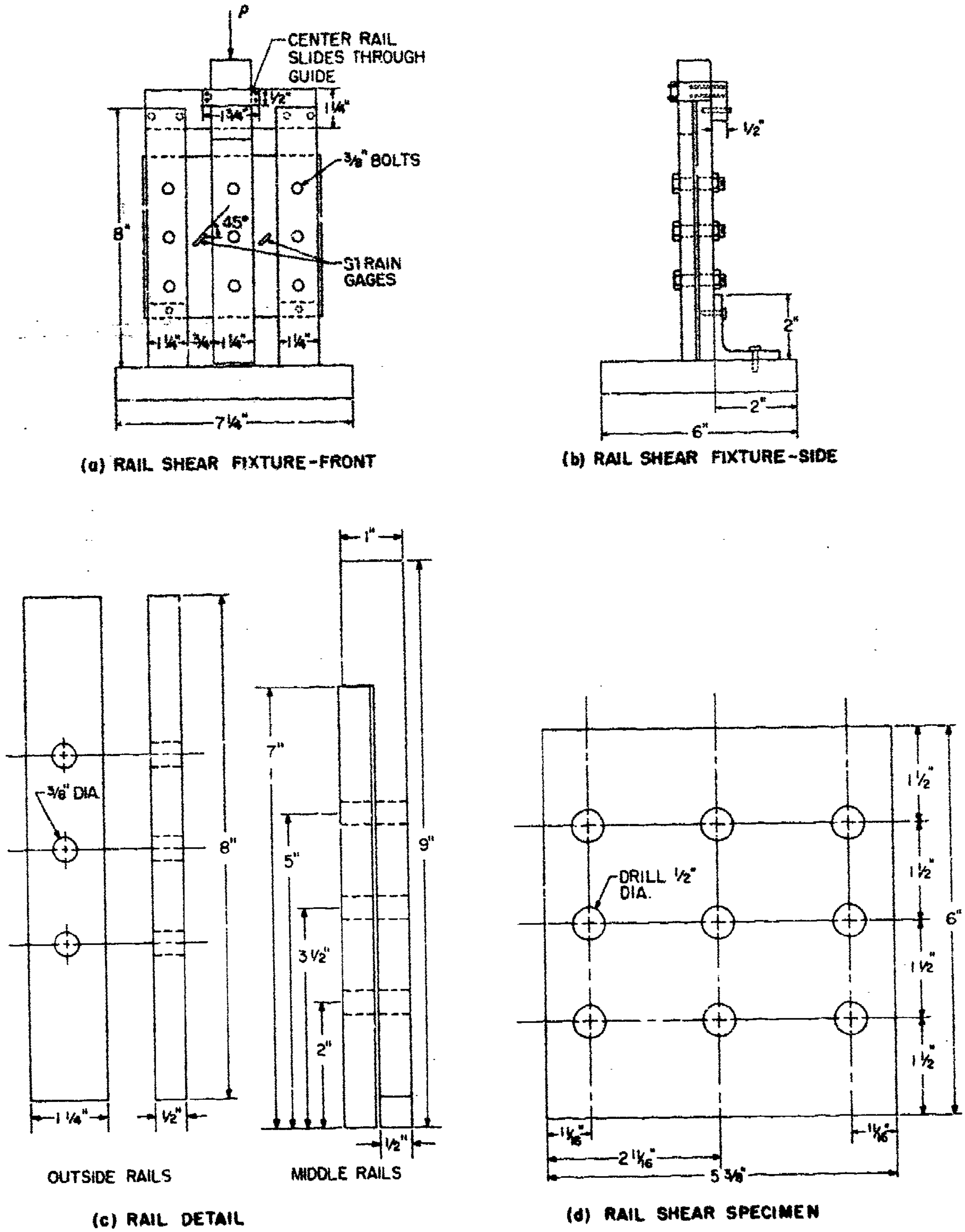


Figure 9. Schematic Illustration of Rail Shear Specimen and Fixture.

3.5.6 Tensile Fatigue

Fatigue tests were conducted on all three fiber orientations at all four test temperatures and at three different levels of maximum stress. At least four replications were run for each condition. The same type of specimen was used for fatigue as was used for tensile tests. All of the tests were constant load amplitude at a frequency of 30 Hz with the minimum stress equal to one-tenth the maximum stress. The specimens were cycled to a maximum of 10^7 cycles, at which time, if no failure had occurred, they were removed and tested for residual tensile properties. All residual property tests were conducted at 72°F, regardless of the temperature at which the specimens were fatigue loaded.

The fatigue tests were carried out on MTS, closed-loop, electrohydraulic, servo-actuated testing machines. Specimen gripping was by means of wedge-type Instron and Templin grips. The grips are locked into place on the loading ram and load cell to insure constant alignment. Axial and concentric alignment of the ram and load cell was verified with a dial gage to within 0.001 inch and grip alignment was insured by the use of a specially machined straight aluminum bar in place of a specimen. Spacers were utilized to center the one-half-inch wide specimens in the one-inch wide jaws and periodically, a specially strained gaged specimen was placed in the grips and the strains on opposite sides and edges monitored during loading to insure that eccentric loading was held below 1%.

Both reduced and elevated temperature tests (except for the 0° orientations at 450°F) were conducted in Instron circulating air environmental test cabinets (Figure 10). Extra styrofoam insulation was placed along the interior walls of the Instron chambers during reduced temperature tests (-67°F) in order to reduce coolant (liquid nitrogen) consumption. Temperature control in both elevated and reduced temperature tests was maintained with Instron oven proportional temperature controllers with the chromel/alumel control thermocouples positioned directly adjacent to the specimen gage section. Two additional thermocouples were mounted one inch above and one inch below the control thermocouple and monitored separately to verify that the temperature of the entire gage section was constant and that transient temperature fluctuations were less than ±2°F around the setpoint during elevated temperature tests and ±5°F during reduced temperature tests. Figure 11 illustrates the position of the control and two extra monitoring thermocouples along the gage section of a fatigue specimen.

The 450°F tests on the 0° specimens of the two polyimide systems utilized a short tube furnace (Figure 12) in place of the Instron environmental cabinets. This arrangement was necessitated by the inability of the tab adhesive to withstand the 450° temperature for an extended time period (up to 93 hours) at the high stress levels required for the 0° specimens. With these short furnaces (four inches long and one and one-half inches diameter tube), only the gage section of the specimen was in the heated zone. Temperature control on these tube furnaces was maintained with a thermistor actuated, time-proportioning controller employing a zero crossover switching triac and transient fluctuations were less than ±3°F around the setpoint. The temperature controlling thermistor was mounted on the side of the one-half-inch wide test specimens and the specimen centered in the uniform temperature region of the furnaces. Additionally, two thermocouples were attached to the specimen at a distance of one-half inch on either side of the thermistor to insure that the thermistor was at the optimum location. Figure 13 presents a typical temperature profile of the tube furnaces used for these 450°F tests. It can be seen that the central two-inch portion of this type tube furnace maintains a relatively "flat" temperature profile which is within ±5°F of the setpoint.

Figure 10. Fatigue Specimen Mounted in Instron Grips and Environmental Cabinet.

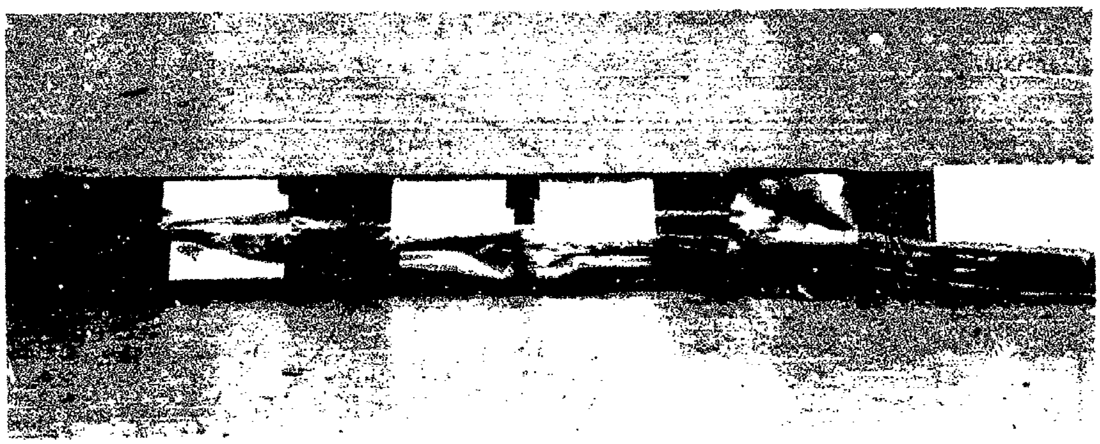


Figure 11. Location of Temperature Controlling and Monitoring Thermocouples on Fatigue Specimen.

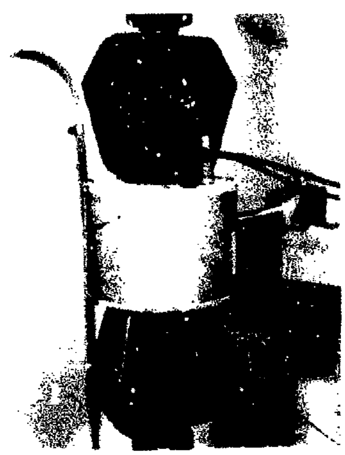


Figure 12. Short Tube-Furnace Used in 450°F Fatigue Tests on 0° Fiber Orientation and in Elevated Temperature Creep Tests.

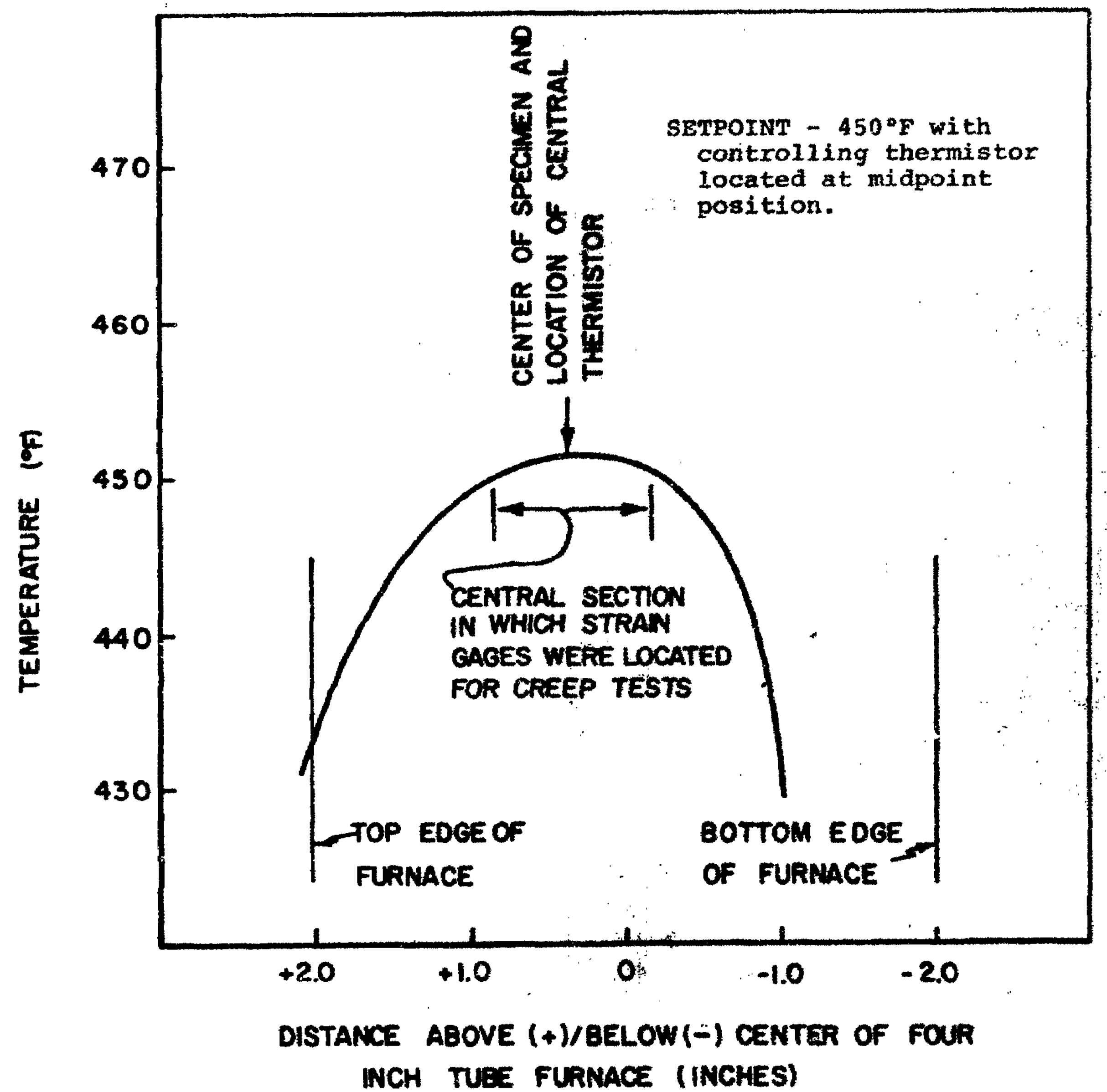


Figure 13. Typical Temperature Profile of Four-Inch Tube Furnaces.

3.5.7 Tensile Creep

Creep tests were conducted on all three fiber orientations at three temperatures and at least three stress levels. No creep tests were conducted at -67°F because of the low levels of creep exhibited at 72°F and because of the large refrigerant expense for long term tests. The same specimen design used in tensile testing was used for the creep tests. Creep strain measurements were recorded using one-inch long strain gages and were carried out to a maximum of 500 hours, at which time, if a specimen had not fractured, it was unloaded and creep recovery measurements recorded for a period of three hours. Each of these surviving specimens was then tested for residual tensile properties at 72°F. It will be noted that the creep recovery data are not included in the tabulated summaries of Section 4 . The recovery data are presented, however, in Appendix I.

The creep tests were carried out on Arcweld creep frames. Each frame has the capacity, through a 20:1 counter-balanced lever arm, of putting loads of up to 12,000 lbs. on the test specimen. Each frame is also equipped with an electric timer and automatic shutoff switch, which monitors the total creep time as well as time to failure. Each frame also has an electrically driven load weight elevator and self-aligning couplings.

Two types of specimen gripping were employed. All of the 0° fiber orientations were gripped with wedge-type jaw grips as illustrated in Figure 14. The 90° and ±45° fiber orientations were drilled in their doubling tab areas to accept three 3/16-inch loading pins, as illustrated in Figure 15. These holes were carefully aligned axially to insure that no eccentric loading was introduced.

Elevated temperature tests were conducted in the short tube-furnaces described in the preceding section. The furnaces were controlled with a thermistor, as previously

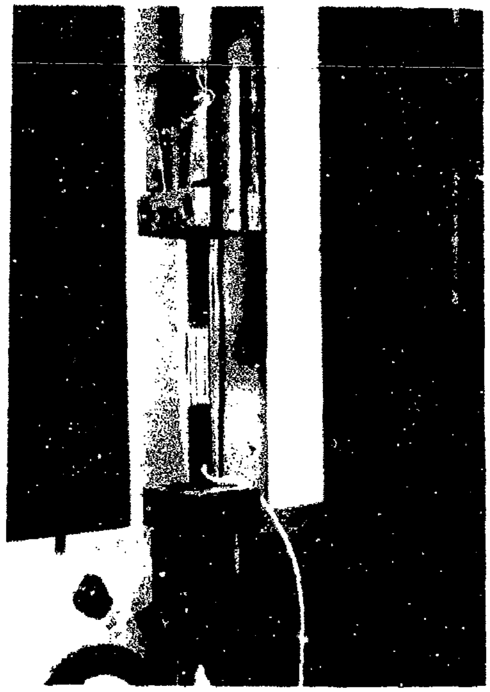


Figure 14. Wedge-Type Jaw Grips Used in Creep Tests.

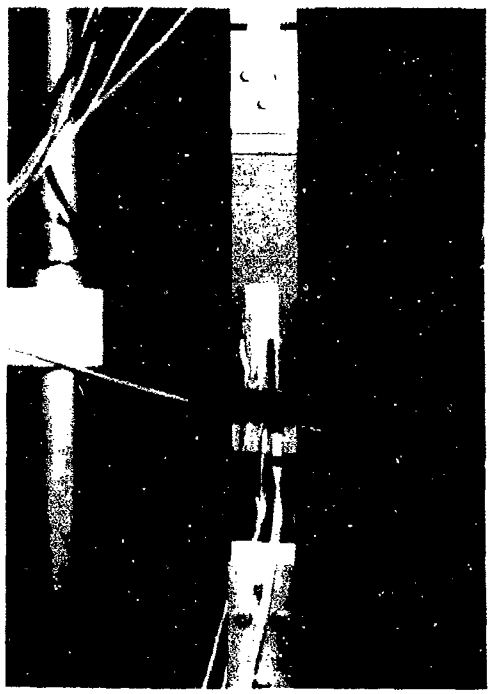


Figure 15. Pin-Type Grips Used in Creep Tests.

described, and temperature uniformity along the gage section was monitored with two thermocouples mounted one-half inch above and below the thermistor bead (Figure 15) to insure a "flat" temperature distribution across this section. As in the fatigue tests, transient fluctuations were ±3°F around the setpoint. Specimens were stabilized at the test temperature for at least two hours before the load was applied.

Strain measurements were obtained from one-inch long strain gages mounted on the specimen surfaces and feeding into a Vishay model P-350A digital strain indicator through a Vishay model SB-1 ten-channel switch and balance unit. Figure 16 illustrates the strain indicator and switch and balance located on a table in front of the creep frames. Also illustrated here is a portable temperature monitoring instrument and a 24-channel switching unit for thermocouple input. Compensation for thermal expansion during elevated temperature tests was achieved by utilizing a compensating gage on a short (about three-inch) section of unstressed specimen material taped to the gage section of the actual test specimen (Figure 17). The output from this compensating gage was fed into an adjacent leg of a half-bridge circuit.

Many of the creep specimens were stacked in a series loading arrangement of up to three specimens in order to increase the rate of data acquisition. Figure 18 illustrates such an arrangement, with one oven moved aside for greater clarity. In cases where one of the specimens in a series broke prior to the 500-hour termination point, the remaining specimens were replaced and new tests conducted.

It will be noted in the tables in the text, as well as in Appendix I, that many creep specimens failed on loading even though the applied stress was less than the strength obtained in the static test at the same temperature. The only factor to which this can be attributed is that the creep load was applied at a considerably more rapid (though not instantaneous) rate than the load applied during the static test. The

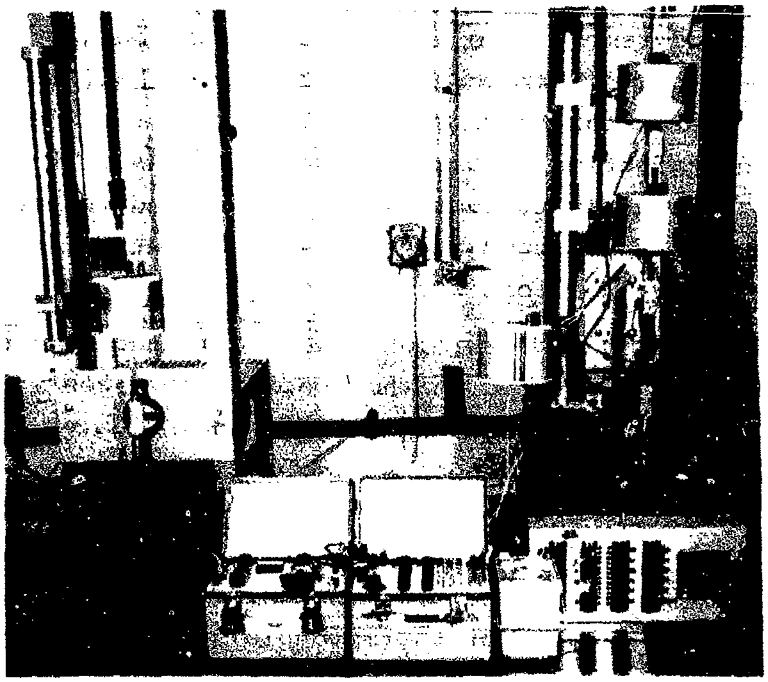


Figure 16. Strain Indicator and Switch-and-Balance Unit Used for Strain Measurements During Creep Tests.

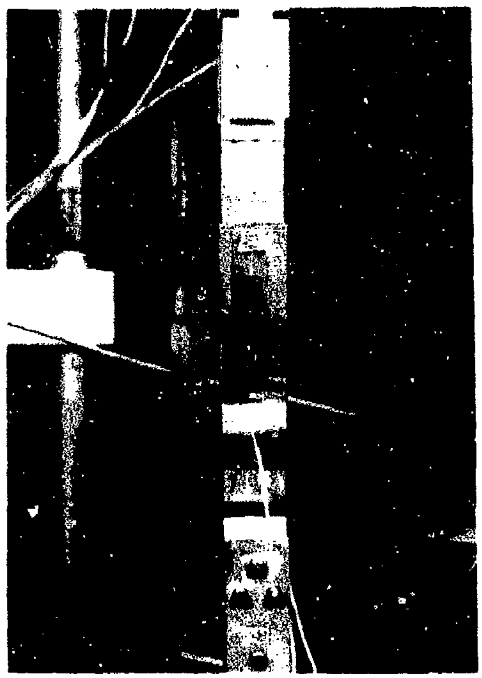


Figure 17. Compensating Gage for Thermal Expansion Compensation During Creep Tests.

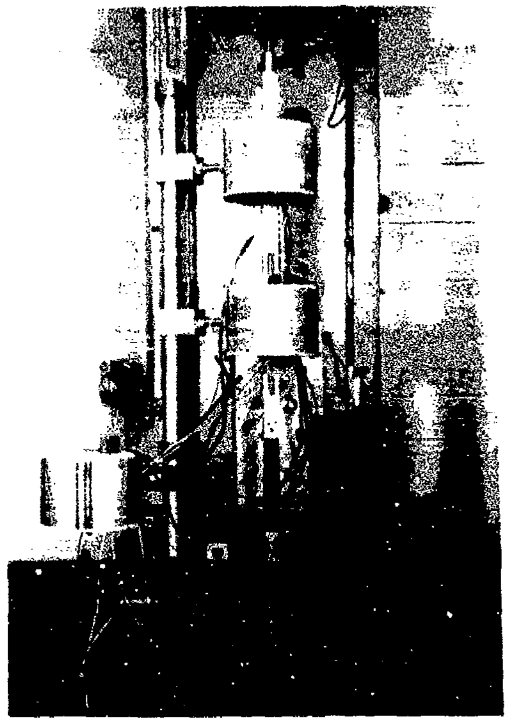


Figure 18. Stacking Arrangement for Testing Three Creep Specimens Simultaneously.

reason for this is that the load pans on the creep frames are raised and lowered by a motor driven elevator, which operates much more rapidly than the 0.05 inch/minute rate utilized during static testing.

3.5.8 Tensile Stress Rupture

Stress rupture data were obtained from the same specimens used for the creep tests, the only difference being that time-to-failure rather than strain as a function of time was the measured variable of interest.

3.5.9 Specific Heat

Two techniques were used to determine specific heat of the laminated composite materials. On the SP313 material, a drop calorimetry technique was employed. This is a relatively simple procedure in which a sample is brought to thermal equilibrium at a desired temperature and then transferred adiabatically to a receiver at room temperature. A measure of the heat content of the sample is then obtained as a function of the corresponding temperature change of the receiver as it comes to thermal equilibrium with the sample. The receiver consists of a circular copper plate housed in a quartz cylinder and has three thermocouples, connected in series, embedded in it. These thermocouples are connected in series to magnify the change in temperature of the receiver after the drop, as well as to insure a good average temperature indication over the entire area of the receiver plate. The sample is also a disc shape, only slightly smaller in diameter than the receiver plate, so that upon dropping, a large contacting surface area exists to promote rapid heat transfer and thermal equilibrium. The receiver cup has been calibrated with standards of known specific heat to obtain a relationship between the receiver cup temperature and its heat content. The tests with the SP313 consisted of heating the samples to the desired temperatures and dropping them onto the receiver plate. The values so obtained actually represent specific heat values at the average temperature between the initial and final sample temperatures. These data were all obtained from unidirectionally reinforced samples and represent averages of three tests each.

On all of the other materials, specific heat was determined with a differential scanning calorimeter (DSC) technique. This technique compares the rate of heat input required to maintain a constant rate of temperature rise in an unknown sample to that required to maintain the same rate of temperature rise in a known reference material and is considerably simpler and less time-consuming to run than the drop calorimetry tests. A Perkin-Elmer, model DSC1-B, instrument was used for these determinations.

3.5.10 Coefficient of Thermal Expansion

Thermal expansion was measured using a quartz tube dilatometer. Both the apparatus and the experimental procedure are described in ASTM D696-70. Low temperature measurements were performed by cooling the specimen to -67°F in an insulated chamber and then allowing the system to warm to room temperature at a rate controlled by an electric resistance heater. Elevated temperature measurements are achieved by slowly heating the specimen with a wire wound resistance furnace. In each case, expansion is measured continuously throughout the temperature range. Measurement of the thermal expansion of unidirectionally reinforced specimens in the direction of the fiber axis (0°) proved most tedious because the expansions were so minute. For this reason, the values obtained for this orientation are reported as approximately zero. An optical interferometric technique would probably prove more useful for measurements with this orientation.

3.5.11 Thermal Conductivity

Thermal conductivity was measured in the direction normal to the laminate surface for both unidirectional and ±45° fiber orientations. A comparative technique was employed in which the sample is sandwiched between two identical reference materials of known conductivity. These, in turn, are held firmly between a heater and a heat sink. The heat flux through this stack establishes a temperature gradient which is measured with thermocouples placed on the upper and lower surfaces of both reference plates and the specimen plate in small precisely machined grooves. Radial heat flow to and from the test stack is minimized with a cylindrical guard heater in which a linear temperature gradient, closely matching that of the test stack, is maintained. A Dynatech model TCFCM-N20 thermal conductivity instrument was used for these measurements. Data points were taken at approximately equal temperature intervals over the range of interest and a "best-fit" curve (or straight-line) plotted through these data points. The reported values in Section 4 were taken from these plotted curves at the specific temperatures. The maximum scatter of the individual data points on either side of the plotted curves was about ±15% of the reported values.

3.5.12 Glass Transition Temperature

Glass transition temperatures were determined with a Perkin-Elmer Thermomechanical Analyzer, model TMS-1. This measurement simply consists of noting the temperature at which a relatively abrupt change in the thermal expansion characteristics of the sample occurs. Specimens were run both "dry" and "wet", the "wet" condition implying that the sample was humidity aged at 160°F and 100% R.H. to an equilibrium weight gain prior to the determination. Unfortunately, there was no way to prevent the "wet" specimen from drying somewhat during the test. Hence, the specimen was no doubt at some moisture content less than saturation when the indicated Tg was observed. Nonetheless, the "wet" values were lower than the "dry" values in every case, indicating a definite softening due to whatever moisture level still remained in the samples.

SECTION 4
SUMMARIZED COMPOSITE DATA

This section presents tabulated summaries of all the data generated for each composite system evaluated during the program. Also presented are the averaged stress-strain, creep, and fatigue S-N curves for each of the systems.

In addition to the summarized data and averaged mechanical property curves, pertinent observations made during the characterization of each material are discussed.

Of the five materials systems specified in Section 2 as having been selected for characterization in this program, only four were finally characterized. Testing of the fifth, the AS/HME (low flow) graphite/epoxy, was terminated early because of difficulty in fabricating high quality laminates with the prepreg supplied. The principle problem was a large variability in resin content from point to point in the prepreg, due to nonuniform resin distribution when the prepreg was fabricated. A comprehensive study of this resin content variability showed that prepreg resin contents varied from as low as 22% in visibly resin-starved areas to as high as 46% in visibly resin-rich areas. The resin-starved areas of prepreg contributed to the development of large unbonded areas in the laminate interiors since the low flow characteristic prevented the resin from the resin-rich areas from flowing into the resin-starved areas. Four panels were prepared and it was found that one-half of the specimens were unusable because of grossly visible interior defects. Test results from the remainder of the specimens produced low strength values for properties sensitive to porosity, such as 90° tension. Since replacement of the prepreg proved impossible, and also since further development work with this resin was anticipated (which might even alter slightly the basic chemistry of the resin), it was decided to terminate work on this matrix system. No data are consequently presented in this Section for the AS/HME graphite/epoxy material.

4.1 SP313

Tables 9-22 present the data generated for this graphite/epoxy composite system. Figures 19-40 illustrate the stress-strain, fatigue, and creep behavior of this material, as well as the effects of humidity aging upon the composite material.

As indicated in Section 3.5.4, a comparison of the in-plane shear data obtained from both the ±45° tensile coupon and the double rail shear technique is presented here. Table 16 presents the double rail shear data and Figure 25 illustrates the stress-strain data obtained from the two different test procedures.

It is readily apparent that good agreement exists between the two different test methods except for the case in which a ±45° fiber orientation was used in the rail shear fixture. In this case, however, considerable tensile stresses are developed in the fibers of the rail shear specimens and the loads necessary to deform and fracture the specimen are considerably higher than in the other three orientations.

It is interesting to note that the strength obtained for the 0°/90° orientation with the rail shear test is almost exactly equal to the sum of strengths obtained with the 0° and the 90° orientations. The large differences encountered with these different fiber orientations is traceable to the different failure modes and stresses developed in the specimens. The 0° specimens, with the fibers running parallel to the load direction, experienced splitting in the fiber direction at locations very near the edge of the gripping rails. For the type of failure, only resin and/or resin-fiber interfacial bonds had to be fractured. Since the panel is clamped in a relatively rigid fixture, no lateral contraction is permitted during the test. This constraint serves to develop internal tensile stresses acting perpendicular to the load direction. In a 0° orientation this is easily the weakest direction and failure probably is caused by these internally developed tensile stresses rather than the shear stresses. The 90° specimens, with fibers running perpendicular to the load direction and across the width of the loaded section, sustained considerably higher loads. When they did fail, they experienced numerous splits again the fiber direction, but now at 90° to the direction of splitting in the 0° specimens. The tensile stresses which develop because of the rigid fixture constraints are more readily bourne by the 90° orientation because the fibers can carry the load and consequently, a substantially higher strength is obtained. The behavior of the 0°/90° specimen is essentially a composite of the separate 0° and 90° behaviors with the 0° plies splitting longitudinally to cause failure but the 90° plies carrying sufficient load to reduce the internally developed tensile strain and postpone failure to a markedly higher stress than is obtained with 0° orientations alone. No damage was visible on the ±45° rail shear specimen. The higher apparent shear modulus values obtained with the 0° or 90° orientations can probably be attributed to the mixed mode stresses induced in this specimen.

TABLE 9

PROCESSING DATA FOR SP313 SYSTEM

Composite Processing Information	
Material System - SP313 Fiber - T300 Matrix - PR313	Graphite/Epoxy SP313
Maximum Rated Temperature - 350°F	Prepreg by - 3M

Laminate Processing Schedule

Layup Procedure: Prepreg warmed to R.T. in closed wrapper. Prepreg removed from package and plies cut to desired size using razor blade. Plies stacked in desired sequence (release paper removed from each ply). Stack placed in Mini-Clave on sheet of non-porous Teflon and surrounded with cork dam to restrict fiber flow. Sheet of porous Teflon placed on top of stack and one ply of bleeder paper placed on top of this. One ply of style 112 glass fabric is layed over the bleeder paper and this is capped with another sheet of non-porous Teflon and a pressure plate. Three plies of bleeder paper large enough to extend over the cork dam are then placed over the pressure plate and a silicone rubber bladder then placed over the Mini-Clave. The Mini-Clave was placed in an unheated press and a nominal 1 psi platen pressure applied to keep the Mini-Clave closed during cure.

Cure Schedule: Temperature was increased from R.T. at a rate of 3 to 5°F per minute under 28-29 in. Hg vacuum. When the temperature reached 250°F, 80 psi air pressure was applied above the bladder. At 260°F, the vacuum under the bladder was vented to the atmosphere. At 350°F, the temperature was held for four hours. The panel was then cooled under pressure to below 150°F at a rate of 3-5°F per minute.

Postcure Schedule: None

TABLE 10

PREPREG AND COMPOSITE PHYSICAL PROPERTIES: SP313

Composite Physical Property Information				
Material System - SP313 Fiber - T300 Matrix - PR313			Graphite/Epoxy	
Maximum Rated Temperature - 350°F			Prepreg by - 3M	
Prepreg Physical Properties				
(Property)	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content - 0.23% by wt.	0.05	0.14-0.27	3M methods as described in spec. sheets provided by 3M	
Resin Content - 39.1% by wt.	0.4	38.4-39.4		
Resin Flow - 15.9% by wt.	0.5	15.1-16.3		
No. of Rolls Involved - 5				
No. of Batches Involved - 2				
Laminate Physical Properties[1]				
	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels - 62				
Fiber Content - 61.2% by vol.	3.2	57.4-65.9	Acid Digestion	AFML-TR-67-243
Resin Content - 31.4% by wt.	2.6	27.2-33.9	Acid Digestion	AFML-TR-67-243
Void Content - ≤2% by vol.			Point count	
Laminate Sp. Gr. - 1.55	0.03	1.46-1.62		
Fiber Sp. Gr. - 1.70	As reported by manufacturer.			
Matrix Sp. Gr. - 1.27	As reported by manufacturer.			
Thickness per ply - 0.0054 inch			---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

TABLE 11

TENSILE PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - SP313	Prepreg by - 3M — Graphite/Epoxy
Fiber - T300 Matrix - PR313	Laminate Sp. Gr. - 1.47
Maximum Rated Temperature - 350°F	Average Ply Thickness - 0.0052 in.
Resin Content - 29.1% by wt.	No. of panels from which specimens were tested in this table - 12
Fiber Content - 64.7% by vol.	Thickness of each type specimen 0°-6 ply, 90°-15 ply
Void Content - 2.4% by vol.	

TENSION: 0°

	-67°F	72°F	260°F	350°F
F_x^{tu} (ksi)	146.2	198.7	176.6	141.7
stnd. dev. (ksi)	7.9	14.9	8.6	15.0
Range (ksi)	133.2-153.6	182.0-218.2	162.3-184.5	117.2-156.3
No. of Specimens	5	6	5	5
F_x^{tpl} (ksi)	146.2	198.7	176.6	130.8
stnd. dev.	---	14.9	8.6	26.5
No. of Specimens	2	7	5	5
E_x^t (Msi)	20.7	20.3	19.3	19.5
stnd. dev.	1.2	1.1	0.6	0.3
No. of Specimens	6	7	5	5
ϵ_x^{tu} (μin/in)	7050	9000	8600	7400
stnd. dev.	71	449	600	316
No. of Specimens	2	5	5	4
ν_{xy}^t	0.36	0.32	0.32	0.34
stnd. dev.	0.06	0.03	0.02	0.02
No. of Specimens	4	7	5	3
Test Method Reference	Straight-sided tension Design Guide			

TENSION: 90°

	-67°F	72°F	260°F	350°F
F_y^{tu} (ksi)	5.2	4.9	4.8	3.7
stnd. dev. (ksi)	0.7	0.3	0.6	0.4
Range (ksi)	4.1-5.8	4.6-5.4	4.0-5.4	3.3-4.2
No. of Specimens	5	5	5	5
F_y^{tpl} (ksi)	5.2	4.9	4.1	1.6
stnd. dev.	0.7	0.3	0.6	0.7
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.4	1.3	1.1	1.05
stnd. dev.	0.1	0.03	0.05	0.01
No. of Specimens	5	5	5	5
ϵ_y^{tu} (μin/in)	3700	3800	4400	4100
stnd. dev.	540	250	640	410
No. of Specimens	5	5	5	5
ν_{yx}^t	0.024[1]	0.020[1]	0.015[1]	0.014[1]
Test Method Reference	Straight-sided tension Design Guide			

[1] Computed using elastic moduli and longitudinal Poisson's ratio.

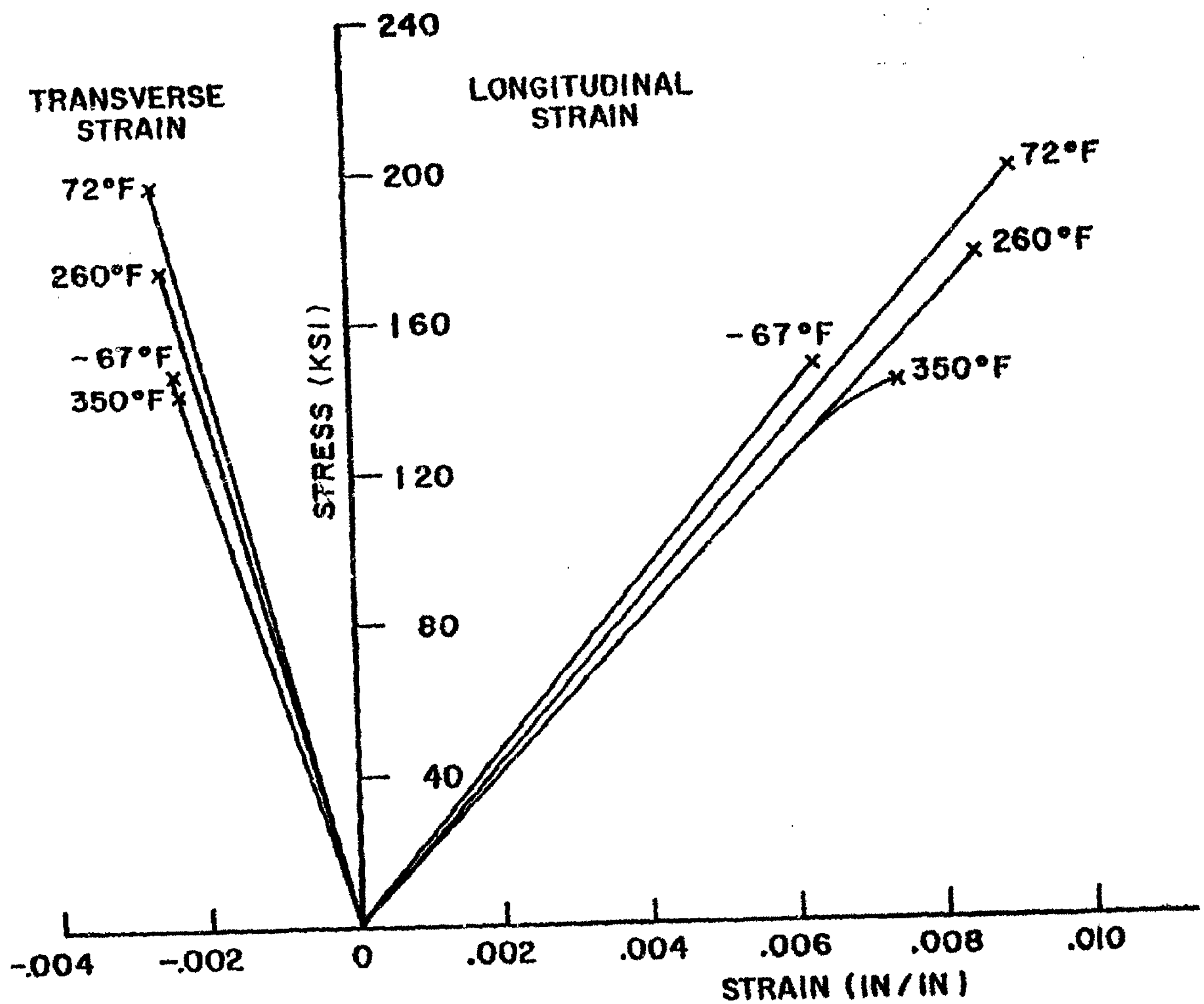


Figure 19. Tensile Stress-Strain Curves for Unidirectional SP313 Composite Laminates: 0° Fiber Orientation.

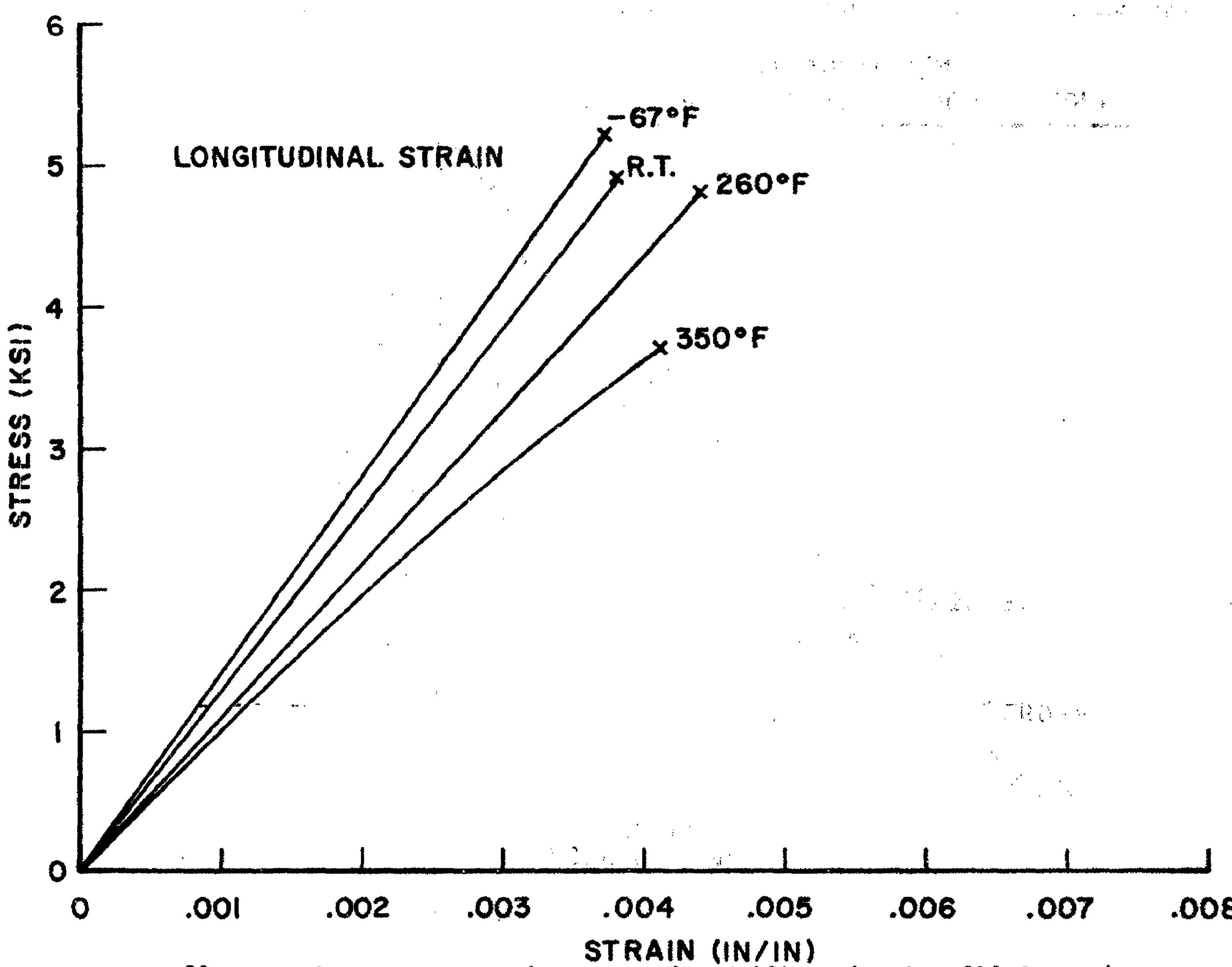


Figure 20. Tensile Stress-Strain Curves for Unidirectional SP313 Composite Laminates: 90° Fiber Orientation.

TABLE 12

TENSILE PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - SP313 Fiber - T300 Matrix - PR313 Maximum Rated Temperature - 350°F Resin Content - 32.5% by wt. Fiber Content - 59.5% by vol. Void Content - 2% by vol.		Prepreg by - 3M Laminate Sp. Gr. - 1.55 Average Ply Thickness - 0.0055 inch No. of panels from which specimens were tested in this table - 5 Thickness of specimens - 8 plies	Graphite/Epoxy	
TENSION: ± 45°				
	-67°F	72°F	260°F	350°F
F_x^{tu} (ksi)	24.50	20.99	15.02	10.94
stnd. dev. (ksi)	0.36	0.39	0.38	1.04
Range (ksi)	24.2-25.1	20.67-21.58	14.52-15.56	10.33-12.73
No. of Specimens	5	5	5	5
F_x^{tpl} (ksi)	8.28	5.86	3.86	2.63
stnd. dev. (ksi)	0.78	0.72	0.43	0.37
No. of Specimens	5	5	5	5
E_x^t (Msi)	3.01	2.70	2.12	1.92
stnd. dev.	0.16	0.17	0.10	0.10
No. of Specimens	5	5	5	5
ε_x^{tu} (μin/in)	11,200	14,200	27,000	28,000
stnd. dev.	894	2,150	5,440	4,500
No. of Specimens	5	5	5	5
ν_{xy}^t	0.66	0.73	0.74	0.83
stnd. dev.	0.04	0.05	0.04	0.02
No. of Specimens	5	5	5	5
Test Method	Straight-sided tension			
Reference	Design Guide			

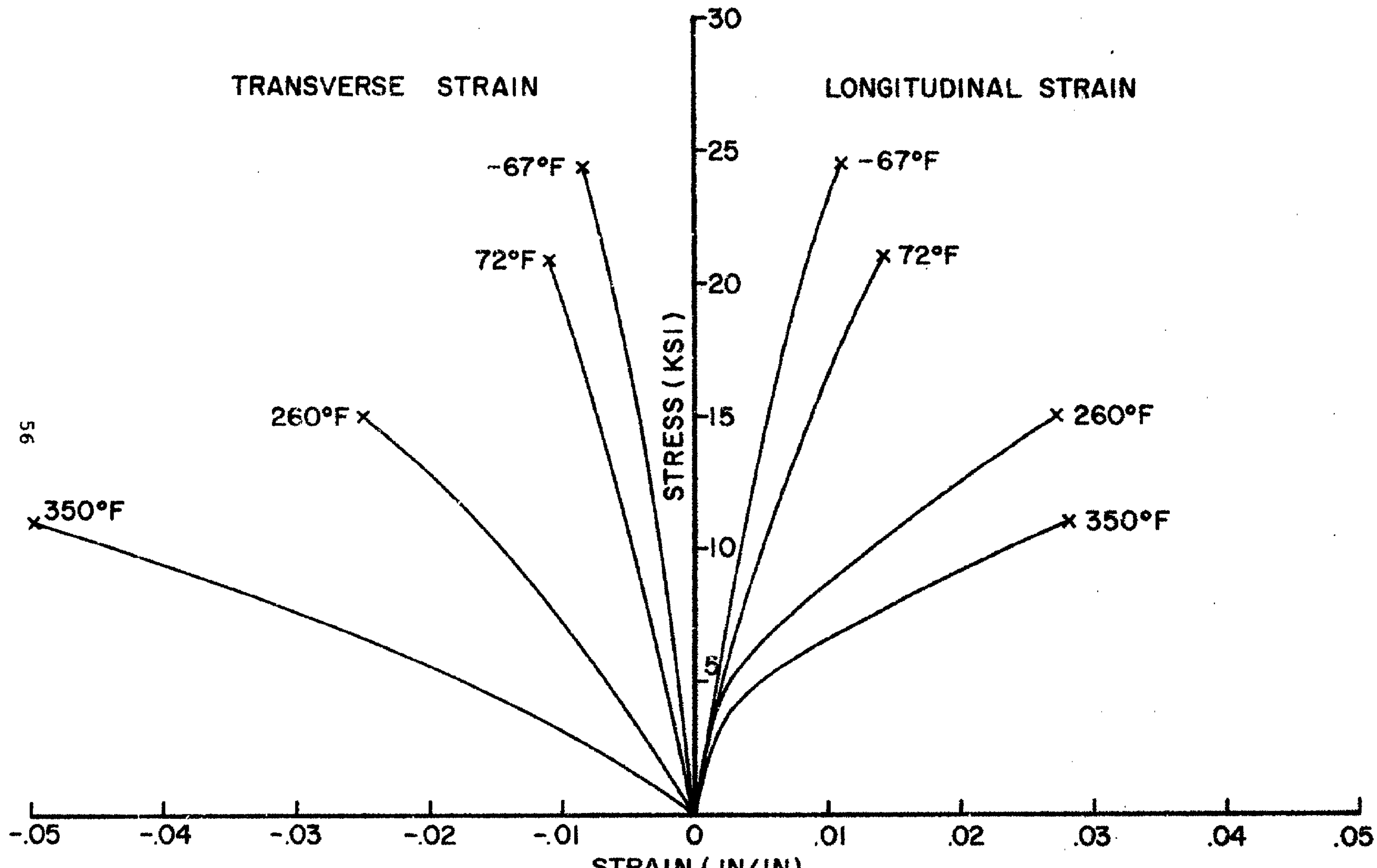


Figure 21. Tensile Stress-Strain Curves for Bidirectional SP313 Composite Laminates: ±45° Fiber Orientation.

TABLE 13

COMPRESSIVE PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - SP313 | Graphite/Epoxy

Fiber - T300 Matrix - PR313

Maximum Rated Temperature - 350°F

Resin Content - 31.3% by wt.

Fiber Content - 60.5% by vol.

Void Content - 1.7% by vol.

Prepreg by - 3M

Laminate Sp. Gr. - 1.55

Average Ply Thickness - 0.0055 in.

No. of panels from which specimens were tested in this table - 3

Thickness of each type specimen: 0°-14 plies; 90°-14 plies

COMPRESSION: 0°

	-67°F	72°F	260°F	350°F
F_x^{cu} (ksi)	166.3	157.4	147.9	148.1
stnd. dev. (ksi)	35.0	12.1	25.6	6.8
Range (ksi)	123.1-225.4	143.6-172.8	119.8-194.6	141.3-159.1
No. of Specimens	7	5	6	5
F_x^{cpl} (ksi)	53.0	35.8	63.5	53.0
stnd. dev.	23.0	7.9	19.5	23.8
No. of Specimens	5	5	6	5
E_x^c (Msi)	21.15	19.8	19.34	25.0[2]
stnd. dev.	4.36	0.9	1.91	1.9
No. of Specimens	7	5	6	5
ϵ_x^{cu} (μ in/in)	20,200[1]	12,600[1]	11,400[1]	7,300[1]
stnd. dev.	13,200	6,400	6,000	4,100
No. of Specimens	7	5	7	5
Test Method	Celanese coupon and test fixture			
Reference	AFML-TR-72-205, pt. 1			

COMPRESSION: 90°

	-67°F	72°F	260°F	350°F
F_y^{cu} (ksi)	42.4	26.4	19.9	16.6
stnd. dev. (ksi)	7.1	3.33	1.9	2.2
Range (ksi)	34.7-51.5	22.9-32.3	18.4-22.8	13.8-19.7
No. of Specimens	5	6	5	5
F_y^{cpl} (ksi)	18.0	3.93	4.5	4.3
stnd. dev.	12.8	1.7	1.9	1.1
No. of Specimens	4	4	5	5
E_y^c (Msi)	1.85	1.72	1.49	1.56
stnd. dev.	0.32	0.20	0.11	0.3
No. of Specimens	5	6	5	5
ϵ_y^{cu} (μ in/in)	33,500[1]	17,200[1]	20,500[1]	34,700[1]
stnd. dev.	12,300	10,900	12,500	18,400
No. of Specimens	5	6	5	5
Test Method	Celanese coupon and test fixture			
Reference	AFML-TR-72-205, pt. 1			

[1] Ultimate strain values represent maximum observed strain rather than ultimate values. Buckling was observed in majority of tests.

[2] It is recognized that this value appears abnormally high, but it nevertheless was obtained in the same manner as the other values and there was very little scatter in the five values.

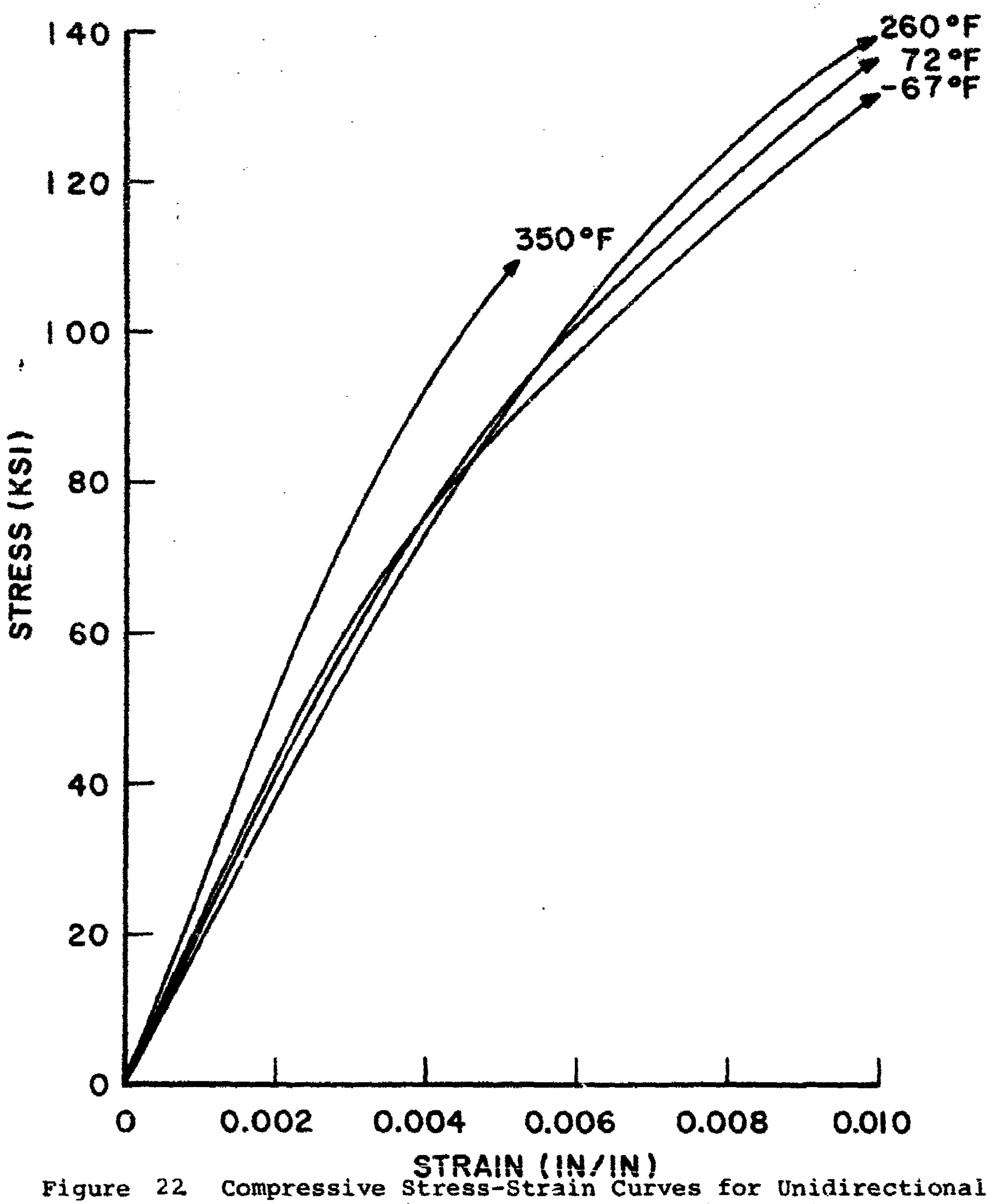


Figure 22 Compressive Stress-Strain Curves for Unidirectional SP313 Composite Laminates: 0° Fiber Orientation.

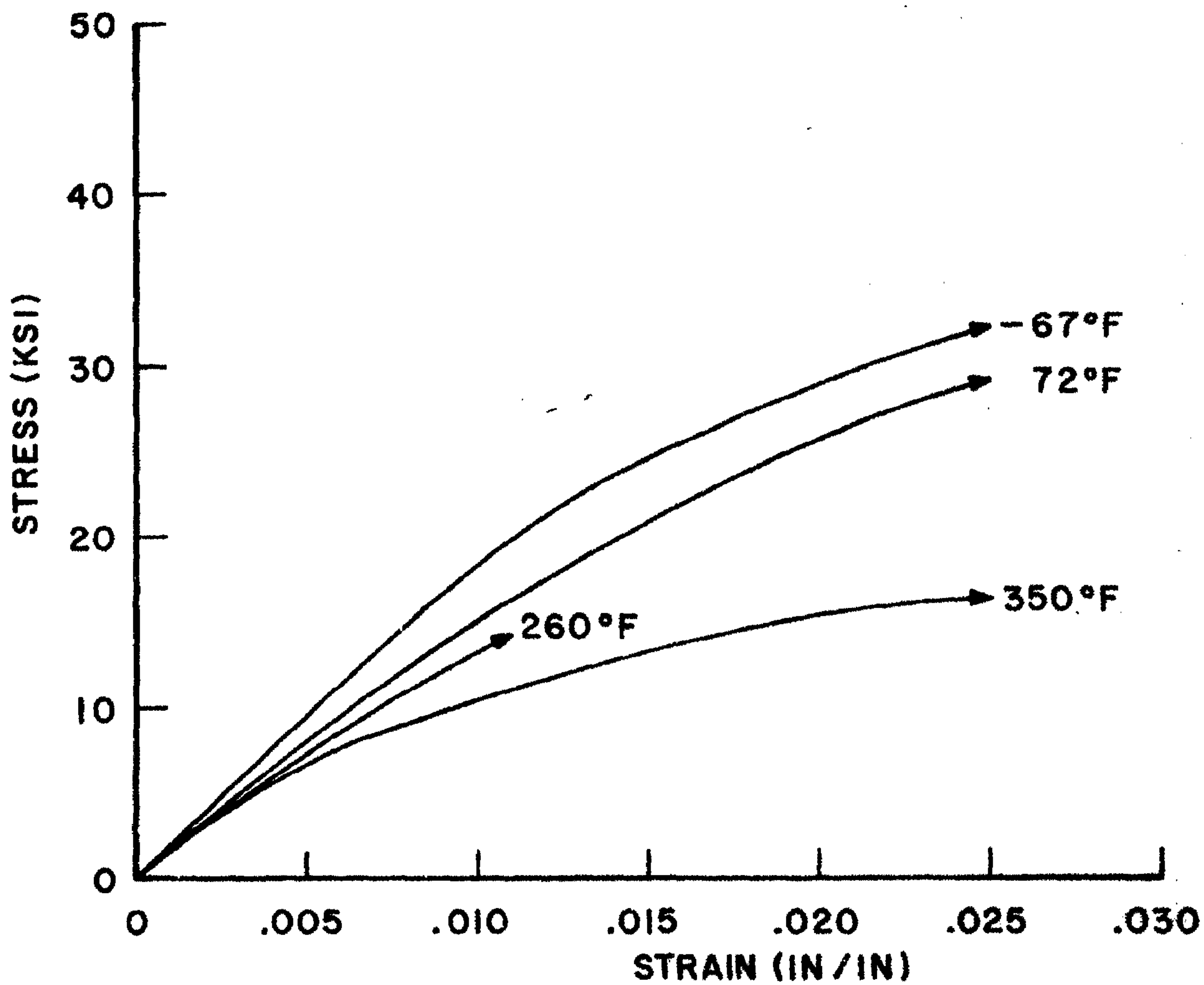


Figure 23. Compressive Stress-Strain Curves for Undirectional SP313 Composite Laminates: 90° Fiber Orientation.

TABLE 14

FLEXURE PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - SP313 | Prepreg by - 3M | Graphite/Epoxy

Fiber - T300   Matrix - PR313

Maximum Rated Temperature - 350°F

Resin Content - 32.6% by wt.

Fiber Content - 59.3% by vol

Void Content - 2% by vol.

Laminate Sp. Gr. - 1.58

Average Ply Thickness - 0.0053 inch

No. of panels from which specimens were tested in this table - 2

Thickness of each type specimen: 0°-14 plies; 90°-14 plies

FLEXURE : 0°	-67°F	72°F	260°F	350°F
F_x^{fu} (ksi)	190.0	200.7	135.7	96.4
stnd. dev. (ksi)	23.0	26.6	19.0	12.5
Range (ksi)	156.4-209.8	176.7-233.3	113.8-159.6	87.0-117.9
No. of Specimens	5	5	5	5
E_x^f (Msi)	17.63	17.77	17.33	16.29
stnd. dev.	0.52	0.76	0.65	0.63
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide Jan., 1971			

FLEXURE: 90°	-67°F	72°F	260°F	350°F
F_y^{fu} (ksi)	11.24	10.66	6.50	4.82
stnd. dev. (ksi)	0.60	0.77	0.75	0.23
Range (ksi)	10.46-11.89	9.47-11.34	5.37-7.47	4.46-5.06
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.46	1.36	1.12	0.95
stnd. dev.	0.05	0.06	0.07	0.05
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide Jan., 1971			

TABLE 15

SHEAR PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - SP313			Graphite/Epoxy	
Fiber - T300 Matrix - PR313			Prepreg by - 3M	
Maximum Rated Temperature - 350°F			Laminate Sp. Gr. - 1.55	
Resin Content - 32.8% by wt.			Nominal Ply Thickness - 0.0054 in.	
Fiber Content - 59.2% by vol.			No. of panels from which specimens were tested in this table - 6	
Void Content - 2% by vol.			Thickness of specimens - 8 ply	
INPLANE SHEAR: 0°				
	-67°F	72°F	260°F	350°F
F_{xy}^{su} (ksi)	12.27	10.50	7.56	5.47
Stnd. Dev. (ksi)	0.19	0.19	0.13	0.52
Range (ksi)	12.10-12.55	10.35-10.79	7.26-7.78	5.17-6.36
No. of Specimens	5	5	5	5
G_{xy}^{s} (Msi)	0.92	0.78	0.61	0.53
Stnd. Dev. (Msi)	0.06	0.05	0.02	0.01
No. of Specimens	5	5	5	5
Test Method	±45° straight-sided tension			
Reference	J. Comp. Mtls. [Vol. 6, p. 252 & Vol. 7, p. 124]			
INTERLAMINAR SHEAR: 0°				
F^{isu} (ksi)	14.49	12.69	8.76	7.18
Stnd. Dev. (ksi)	0.51	0.48	0.30	0.19
Range (ksi)	13.76-15.00	11.88-13.04	8.39-9.11	6.98-7.44
No. of Specimens	5	5	5	5
Test Method	Short Beam Shear			
Reference	Design Guide Jan., 1971			

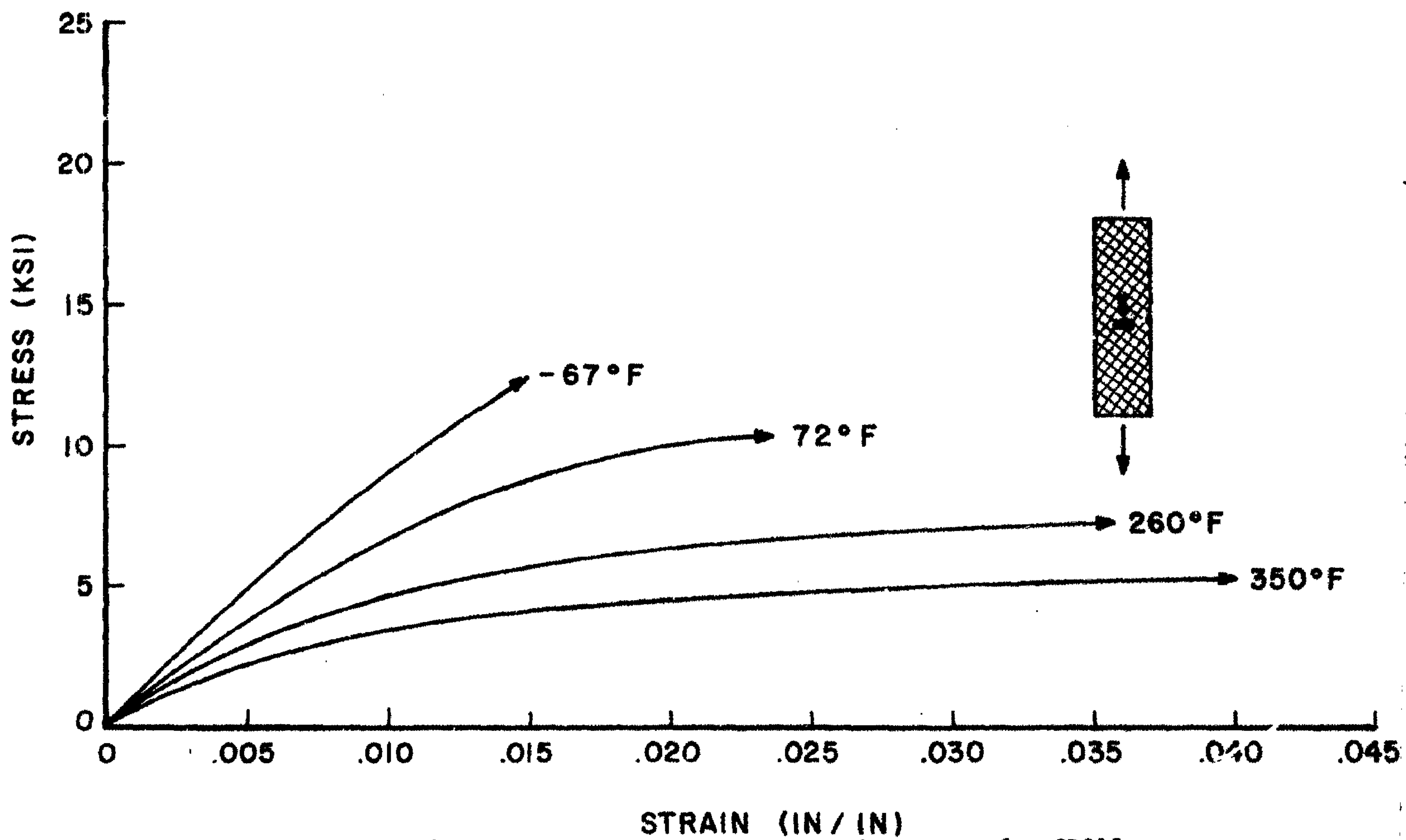


Figure 24 . Inplane Shear Stress-Strain Curves for SP313 Composite Laminates.

TABLE 16

INPLANE SHEAR PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - SP313 | Prepreg by - 3M | Graphite/Epoxy

Fiber - T300 Matrix - PR313

Laminate Sp. Gr. - 1.56

Maximum Rated Temperature - 350°F

Nominal Ply Thickness - 0.0054 inch

Resin Content - 27.86% by wt.

Fiber Content - 65.45% by vol.

Void Content - ±2% by vol.

No. of panels from which specimens were tested in this table - 9

	-67°F	72°F	260°F	350°F
Inplane Shear: 0° (fiber parallel to load direction)				
T^u_{xy} (ksi)	---	2.85	---	---
stnd. dev. (ksi)	---	0.34	---	---
No. of Specimens	---	6	---	---
G_{xy} (Msi)	---	0.97	---	---
stnd. dev. (Msi)	---	0.24	---	---
No. of Specimens	---	6	---	---
90° (fiber perpendicular to load direction)				
T^u_{xy} (ksi)	---	8.73	6.65	5.24
stnd. dev. (ksi)	---	0.37	0.17	0.25
No. of Specimens	---	6	6	6
G_{xy} (Msi)	---	0.87	0.72	0.58
stnd. dev. (Msi)	---	0.11	0.08	0.04
No. of Specimens	---	6	6	3
±45°				
T^u_{xy} (ksi)	---	15.26	---	---
stnd. dev. (ksi)	---	---	---	---
No. of Specimens	---	2	---	---
G_{xy} (Msi)	---	5.41	---	---
stnd. dev. (Msi)	---	---	---	---
No. of Specimens	---	2	---	---
0°/90°				
T^u_{xy} (ksi)	---	11.80	---	---
stnd. dev. (ksi)	---	0.32	---	---
No. of Specimens	---	8	---	---
G_{xy} (Msi)	---	0.78	---	---
stnd. dev. (Msi)	---	0.09	---	---
No. of Specimens	---	8	---	---
Test Method	Rail Shear (3 rail)			
Reference	Proposed ASTM test, Method B			

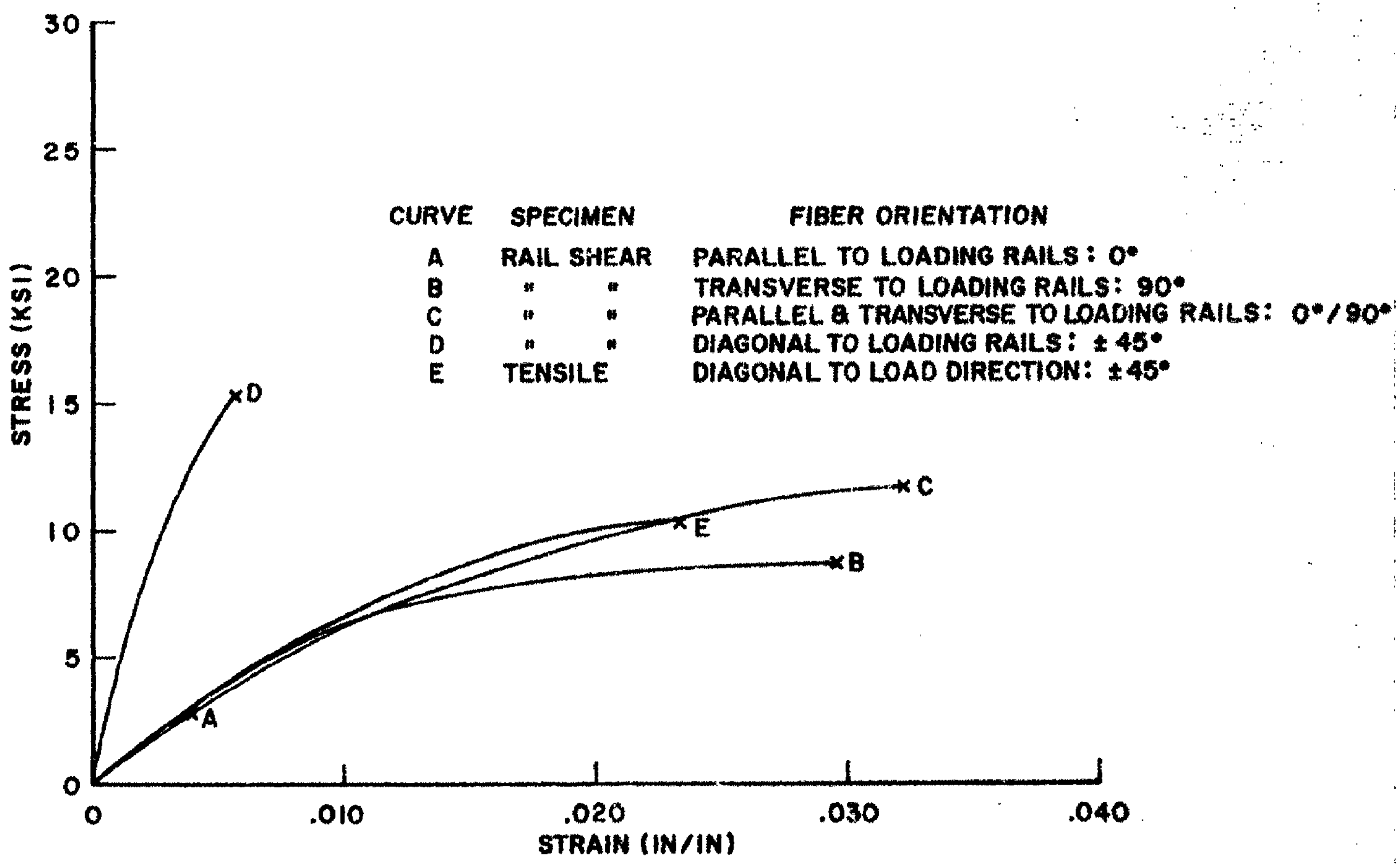


Figure 25. Inplane Shear Stress-Strain Curves for SP313 Composite Laminates from ±45° Tensile Coupon and Double Rail Shear Panels of 0°, 90°, 0°/90°, and ±45° Fiber Orientations at 72°F.

TABLE 17

FATIGUE PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES — Graphite/Epoxy

Material System - SP313 Prepreg by - 3M
Fiber - T300 Matrix - PR313
Maximum Temperature Rating - 350°F
Resin Content - 31.17% by wt.
Fiber Content - 61.40% by vol.
Void Content - ±2% by vol.
Test Method - Tension Reference - Design Guide

Laminate Sp. Gr. - 1.54
Average Ply Thickness - 0.0053 inch
No. of panels from which specimens were tested in this table - 30
Thickness of each type specimen - 0°--- 6 plies; 90°---15 plies; ±45°--- 8 plies

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Max. Stress (ksi)	138.9	4.68	18.38	260°F	Max. Stress (ksi)	157.2	4.29	12.01
	Lifetime (cycles)	216,660	790	8,610		Lifetime (cycles)	870	560	5,670
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	131.6	4.16	17.15		Max. Stress (ksi)	139.8	3.81	10.51
	Lifetime (cycles)	309,350	5,530	48,088		Lifetime (cycles)	6,915	860	197,540
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	190.2	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	1	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	117.0	3.640	14.70		Max. Stress (ksi)	122.3	3.33	9.01
	Lifetime (cycles)	$>10^7$	42,070	902,634		Lifetime (cycles)	588,330	19,090	$>10^7$
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	171.6	---	---		Residual Strength (ksi)	---	---	20.39
	No. of Specimens	4	0	0		No. of Specimens	0	0	4
72°F	Max. Stress (ksi)	173.1	4.42	16.79	350°F	Max. Stress (ksi)	127.5	3.32	8.75
	Lifetime (cycles)	2,110	2,200	9,770		Lifetime (cycles)	10,860	1,450	14,640
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	153.8	3.93	14.69		Max. Stress (ksi)	113.4	2.95	8.20
	Lifetime (cycles)	7,375	3,390	162,030		Lifetime (cycles)	122,870	2,790	3.18×10^6
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	18.32
	No. of Specimens	0	0	0		No. of Specimens	0	0	1
	Max. Stress (ksi)	134.6	3.44	12.59		Max. Stress (ksi)	99.2	2.59	7.66
	Lifetime (cycles)	307,140	156,770	2.87×10^6		Lifetime (cycles)	660,440	32,290	7.73×10^6
	No. of Specimens	4	5	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	190.6	5,010	---		Residual Strength (ksi)	176.7	---	16.46
	No. of Specimens	1	2	0		No. of Specimens	1	0	2

Note: Fatigue lifetimes are log mean values. All residual strengths determined by tensile test at 72°F.

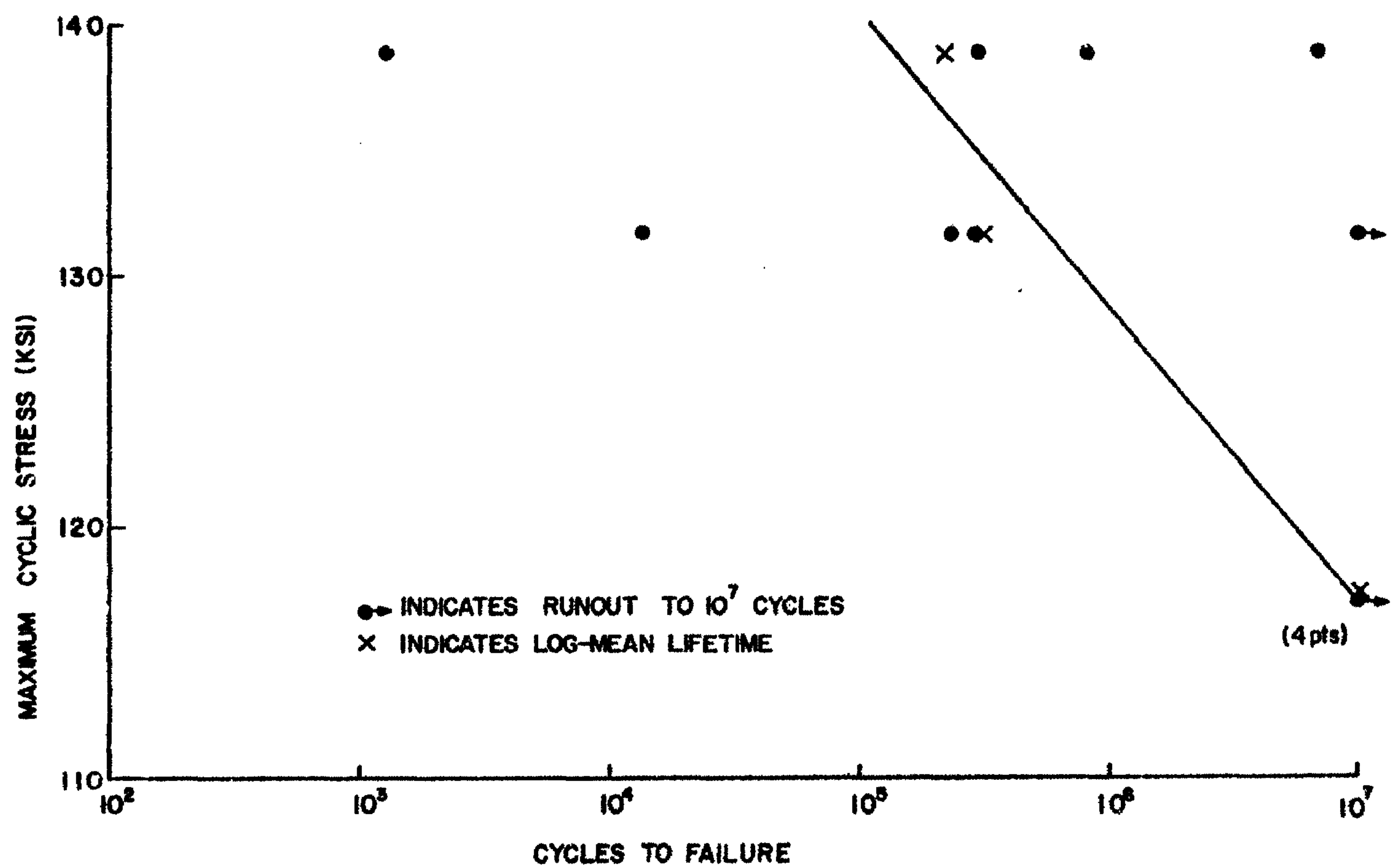


Figure 26. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at -67°F: 0° Fiber Orientation, R=0.10, 30 Hz.

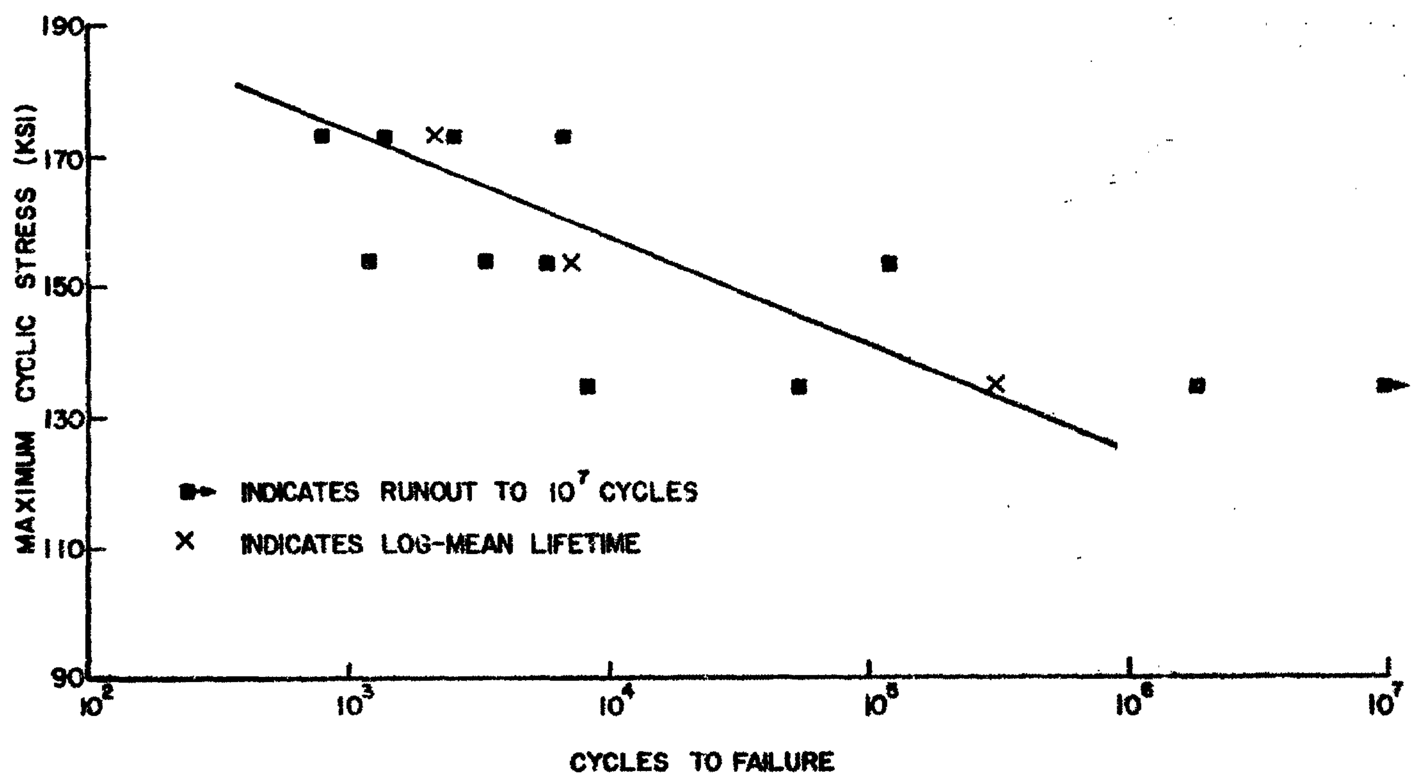


Figure 27. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at 72°F: 0° Fiber Orientation, R=0.10, 30 Hz.

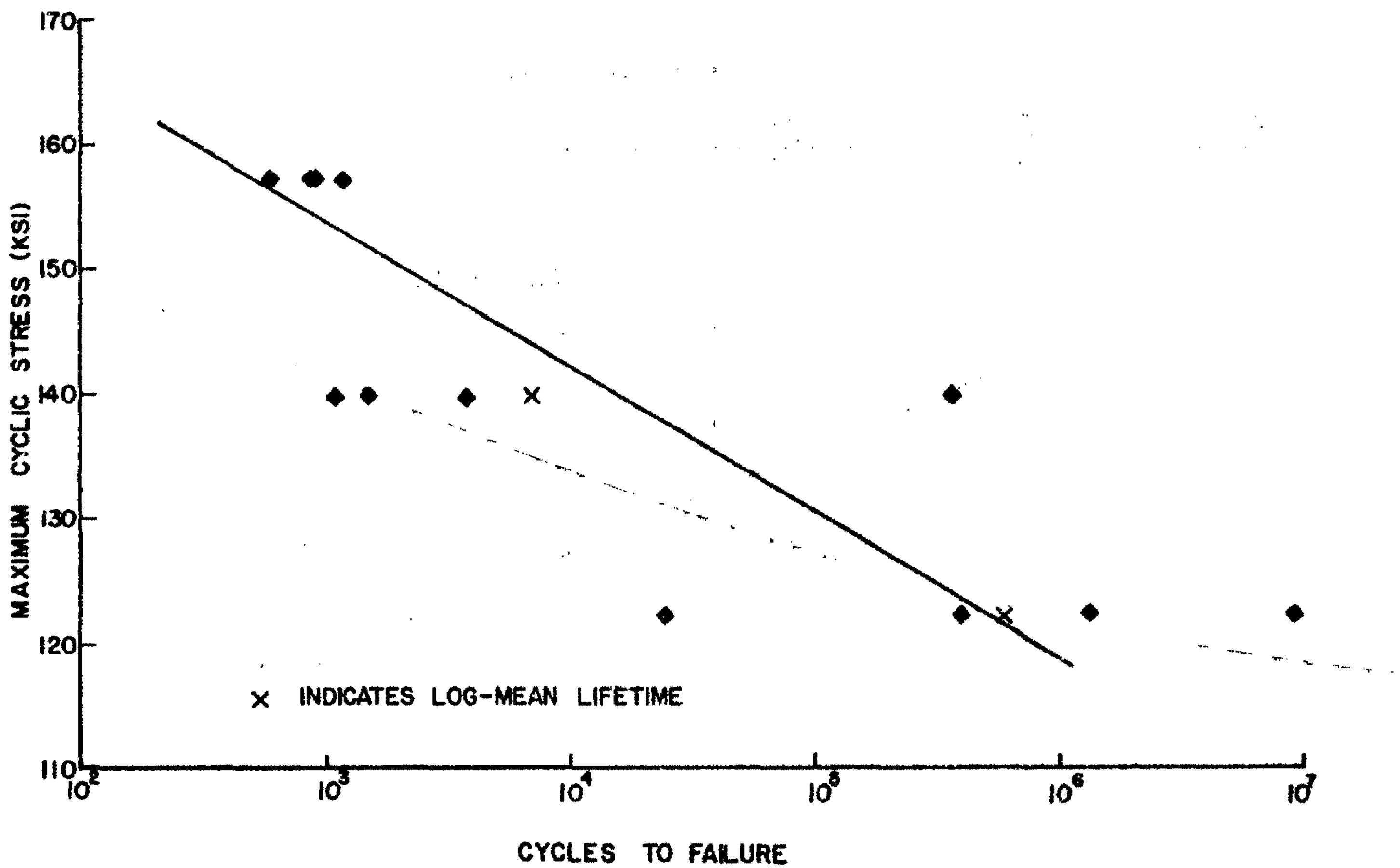


Figure 28. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at 260°F: 0° Fiber Orientation, R=0.10, 30 Hz.

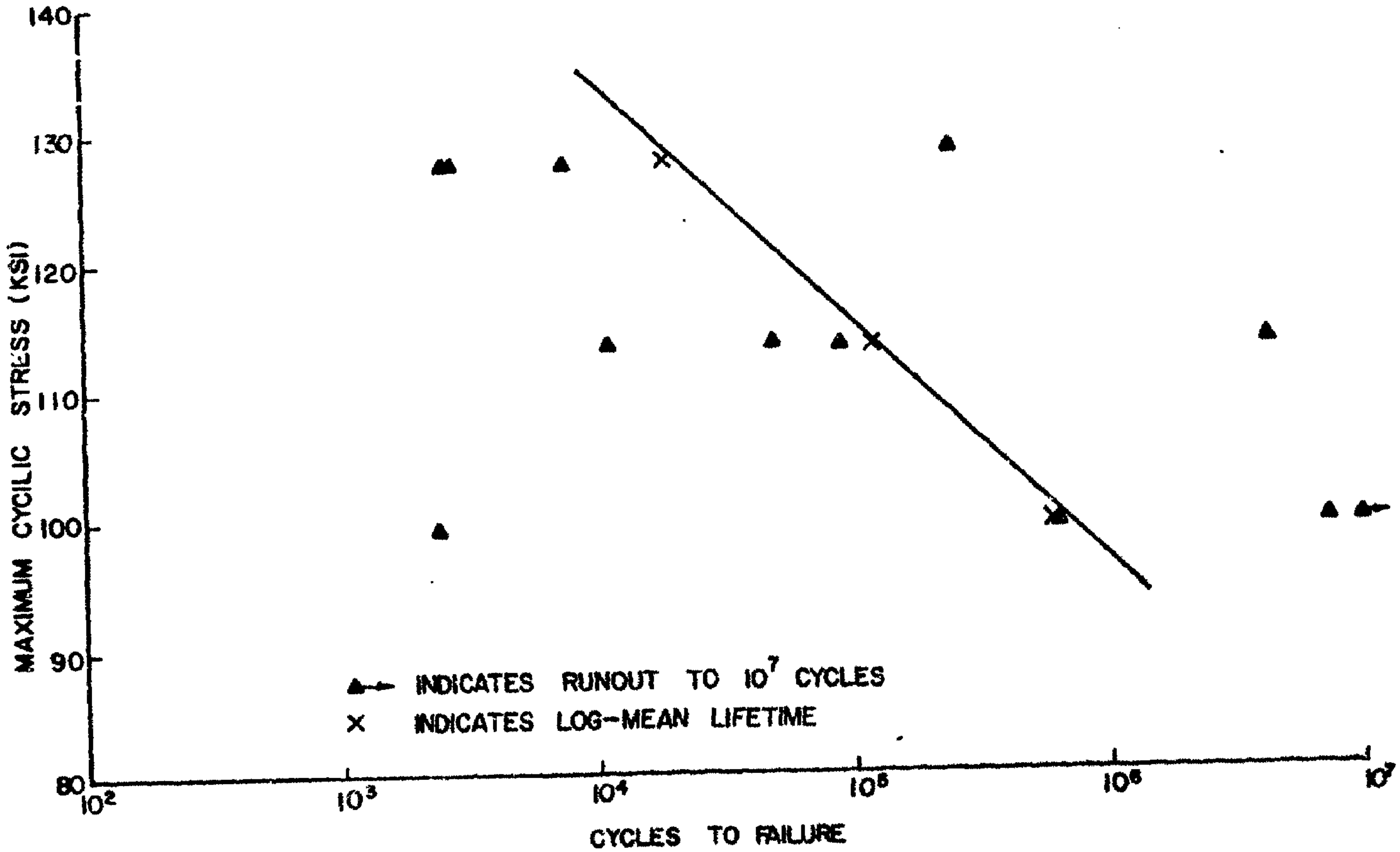


Figure 29. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at 350°F: 0° Fiber Orientation, R=0.10, 30 Hz.

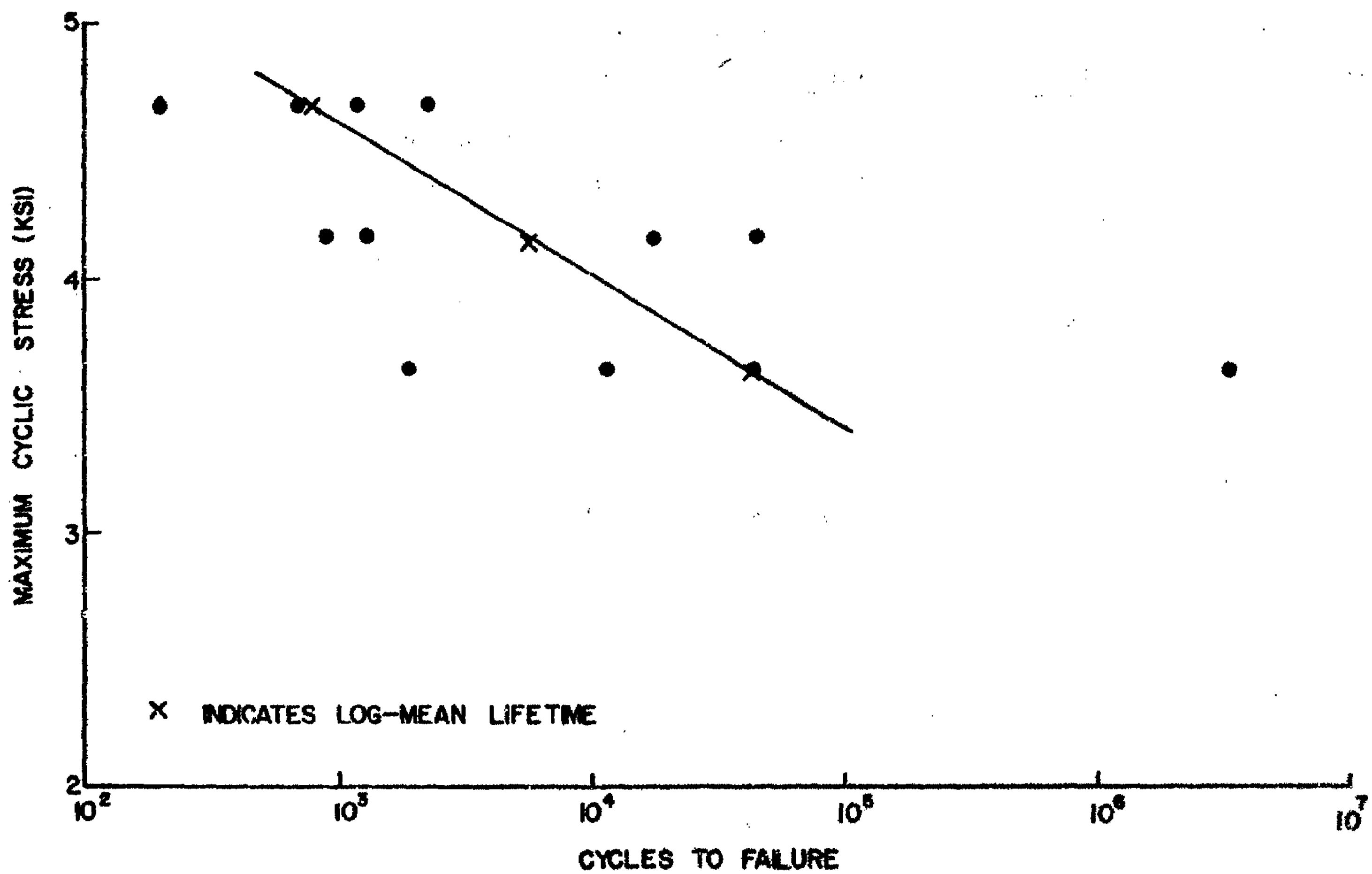


Figure 30. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at -67°F: 90° Fiber Orientation, R=0.10, 30 Hz.

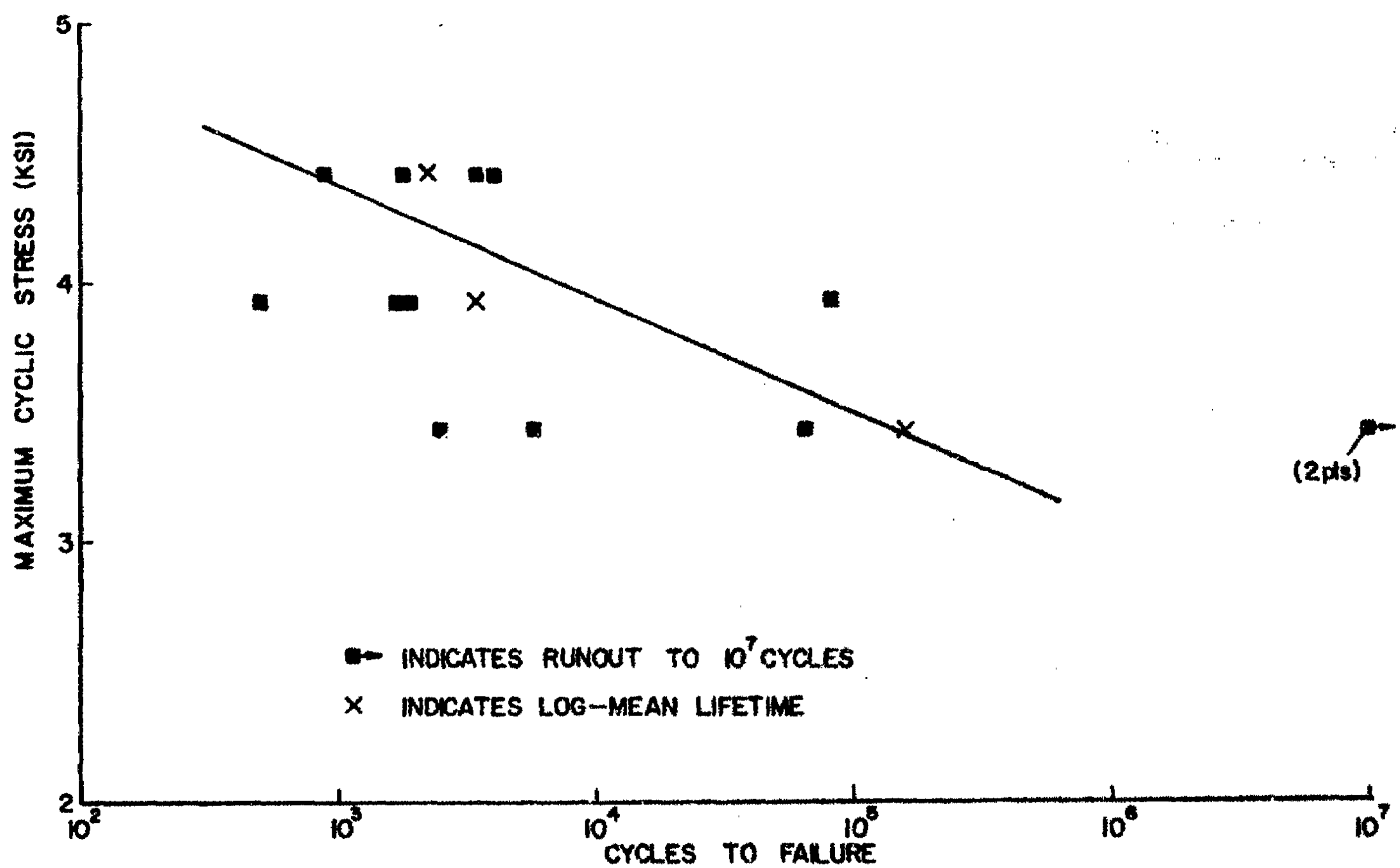


Figure 31. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at 72°F: 90° Fiber Orientation, R=0.10, 30 Hz.

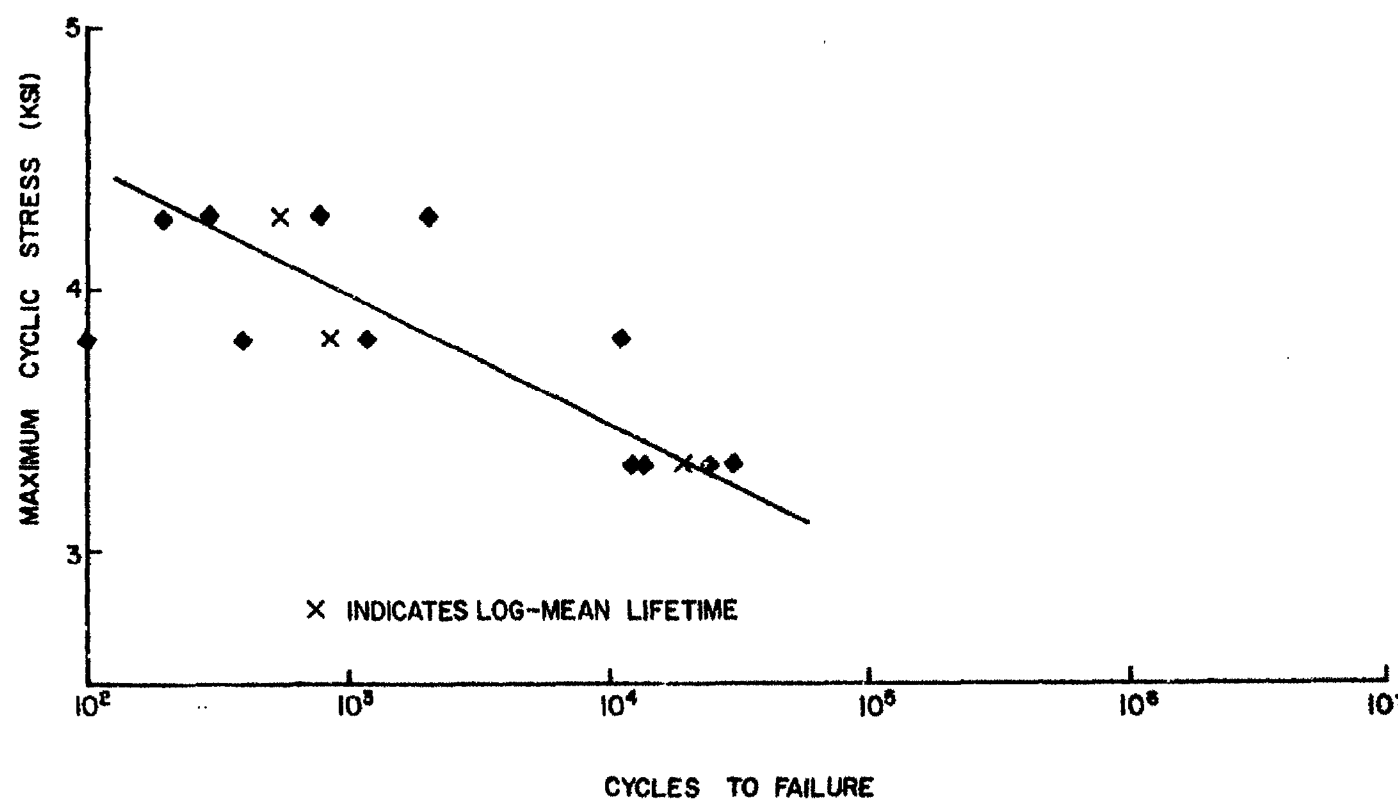


Figure 32. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at 260°F: 90° Fiber Orientation, R=0.10, 30 Hz.

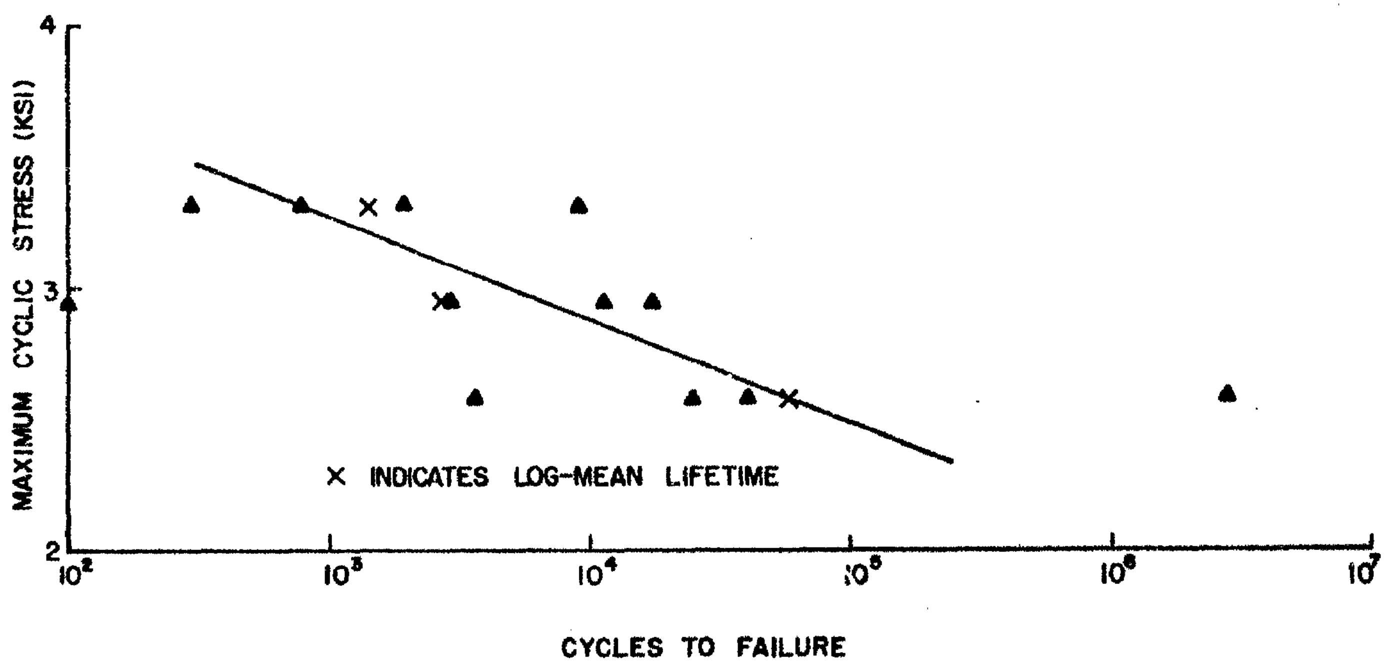


Figure 33. Tensile-Tensile Fatigue Behavior of Unidirectional SP313 Composite Laminates at 350°F: 90° Fiber Orientation, R=0.10, 30 Hz.

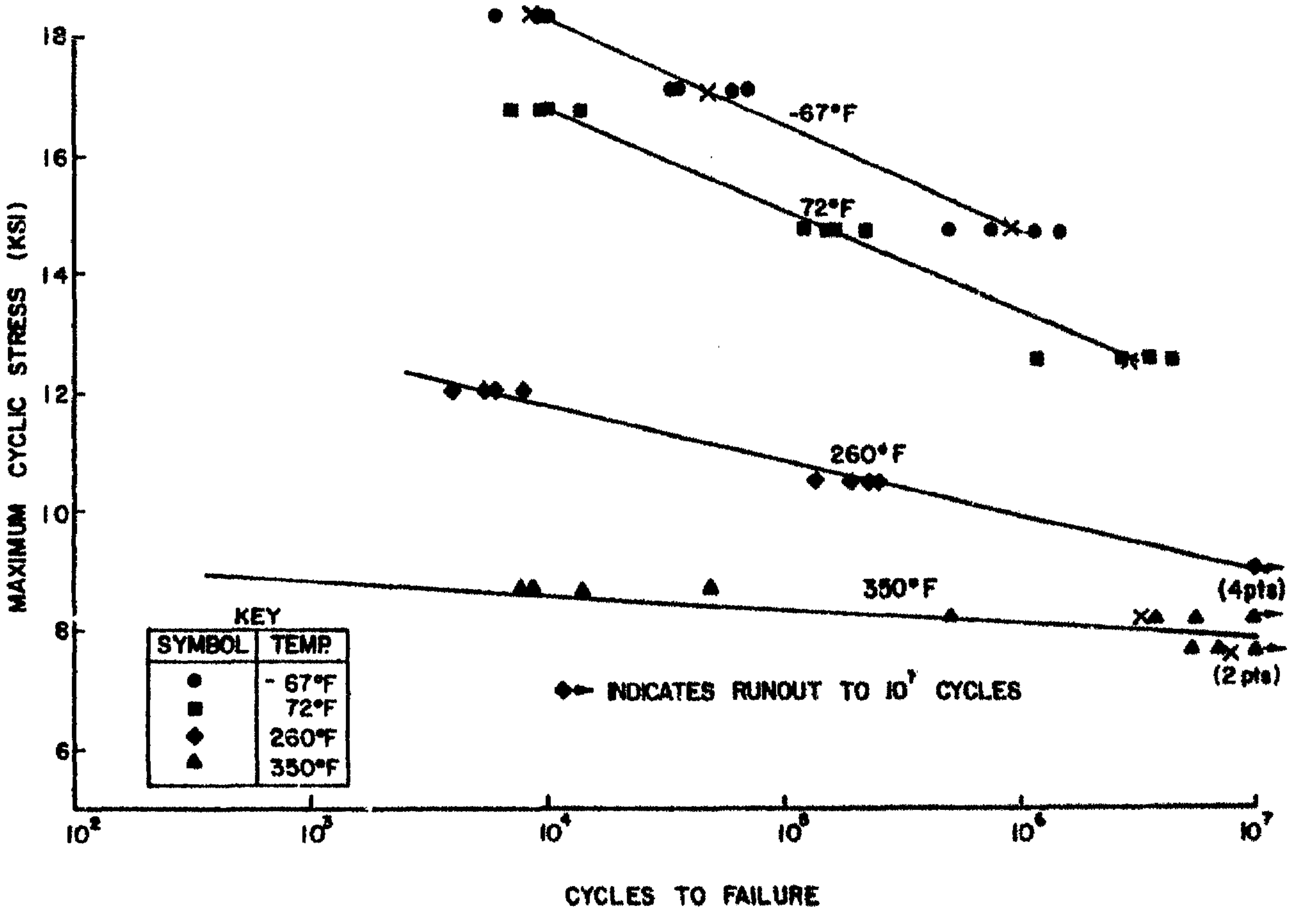


Figure 34. Tensile-Tensile Fatigue Behavior of Bidirectional SP313 Composite Laminates: ±45° Fiber Orientation, R=0.10, 30 Hz.

TABLE 18

CREEP PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES — Graphite/Epoxy

Material System - SP313 Prepreg by - 3M
Fiber - T300 Matrix - PR313
Maximum Temperature Rating - 350°F
Resin Content - 31.65% by wt.
Fiber Content - 61.08% by vol.
Void Content - ≤2% by vol.
Test Method - Tension Reference - Design Guide

Laminate Sp. Gr. - 1.55
Average Ply Thickness - 0.0054 inch
No. of panels from which specimens were tested in this table - 23
Thickness of each type specimen - 0° --- 6 plies; 90° --- 15 plies; ±45° --- 8 plies

CREEP

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				260°F	Stress Level (ksi)	157.1	3.33	13.5
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	225	1927	>20,300[5]
	No. of Specimens					No. of Specimens	1[2]	1[2]	3
	Residual Strength (ksi)					Residual Strength (ksi)	208.4	4.12	21.1
	No. of Specimens					No. of Specimens	1	1	3
	Stress Level (ksi)					Stress Level (ksi)	139.7	3.10	12.0
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	100	---[3]	9092
	No. of Specimens					No. of Specimens	1[2]	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	195.7	---	21.2
	No. of Specimens					No. of Specimens	1	0	3
	Stress Level (ksi)					Stress Level (ksi)	122.1	2.86	10.5
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	204	653	7377
	No. of Specimens					No. of Specimens	3	2[4]	3
	Residual Strength (ksi)					Residual Strength (ksi)	168.1	5.16	20.9
	No. of Specimens					No. of Specimens	3	2	3
72°F	Stress Level (ksi)	173.1	3.93	18.9	350°F	Stress Level (ksi)	127.5	2.59	7.66
	Creep Strain, 500 hr(μ in/in)	---[1]	366	---[3]		Creep Strain, 500 hr(μ in/in)	1331	---[3]	>16,700[5]
	No. of Specimens	4	1[2]	3		No. of Specimens	1[3]	3	3
	Residual Strength (ksi)	---	5.41	---		Residual Strength (ksi)	159.0	---	20.0
	No. of Specimens	0	1	0		No. of Specimens	1	0	3
	Stress Level (ksi)	153.8	3.44	16.8		Stress Level (ksi)	113.4	2.22	4.37
	Creep Strain, 500 hr(μ in/in)	66	389	5796		Creep Strain, 500 hr(μ in/in)	1253	---[3]	>21,380[4,5]
	No. of Specimens	3	3	2[4]		No. of Specimens	3	3	3
	Residual Strength (ksi)	194.6	4.76	20.6		Residual Strength (ksi)	184.6	---	15.5
	No. of Specimens	3	3	2		No. of Specimens	3	0	2
	Stress Level (ksi)	134.6	2.94	14.7		Stress Level (ksi)	99.2	1.85	2.19
	Creep Strain, 500 hr(μ in/in)	25	442	3175		Creep Strain, 500 hr(μ in/in)	611	3647	>7183
	No. of Specimens	3	3	2[4]		No. of Specimens	3	1[2]	3
	Residual Strength (ksi)	190.1	4.47	21.5		Residual Strength (ksi)	162.3	5.51	18.2
	No. of Specimens	3	3	2		No. of Specimens	3	1	3

Notes: All values represent arithmetic average. All residual strengths determined by tensile test at 72°F.
1. Four specimens failed on loading or during test.
2. Two specimens failed on loading or during test.
3. Three specimens failed on loading or during test.
4. One specimen failed on loading or during test.
5. Excessive elongation of specimens caused cracking of surface plies, which in turn, induced breaks in strain gage at strains of about 20,000μ in/in.

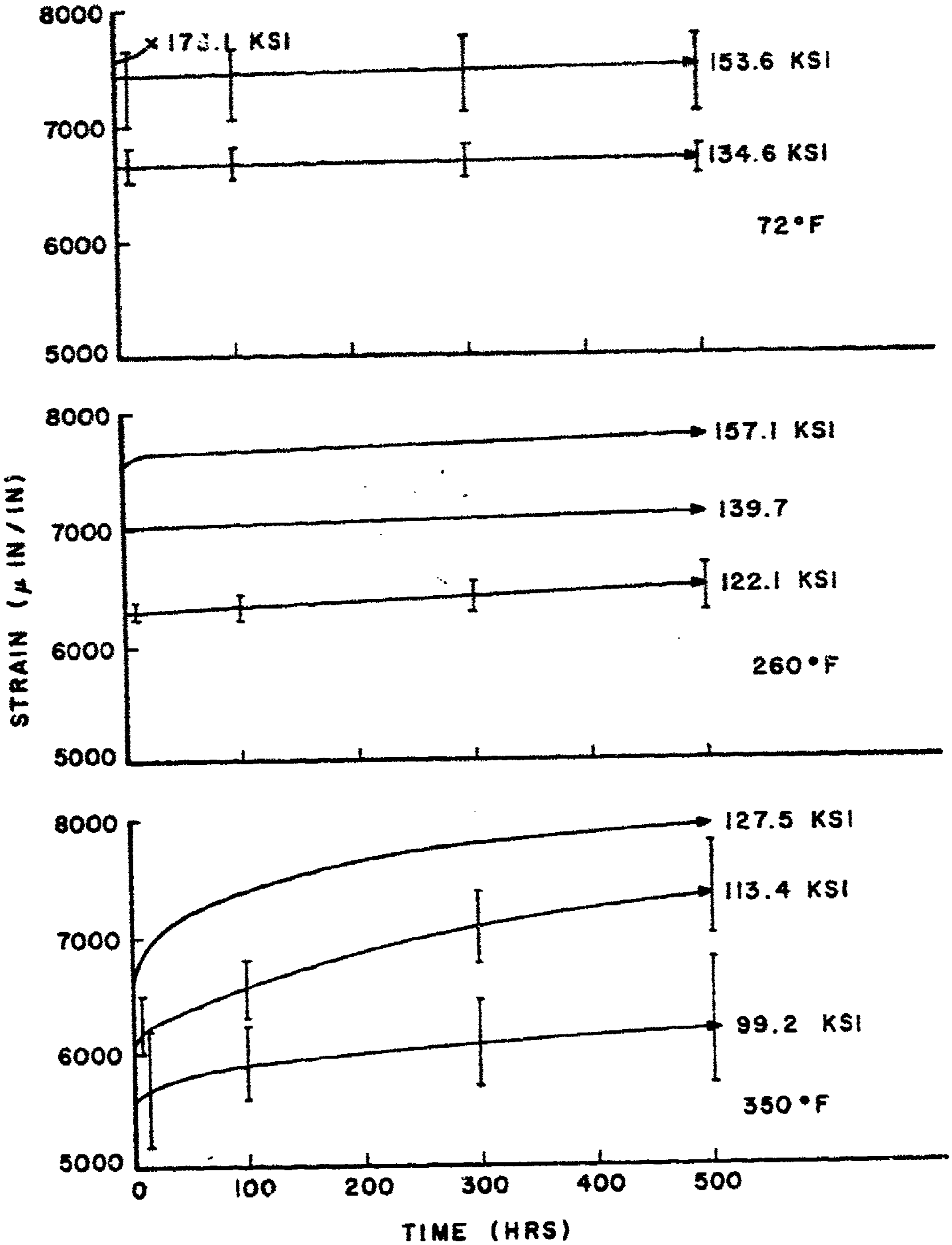


Figure 35. Tensile Creep Behavior of Unidirectional SP313 Composite Laminates: 0° Fiber Orientation.

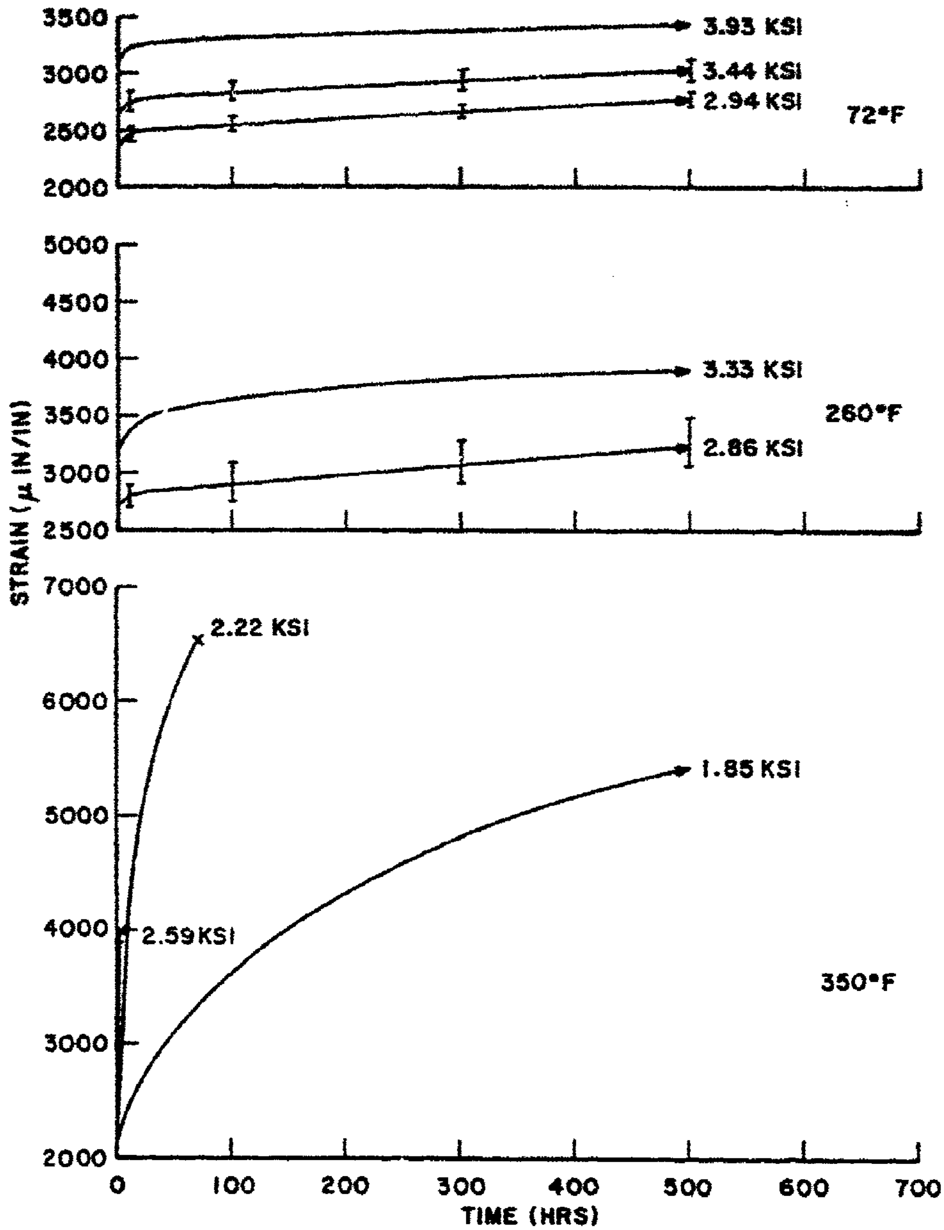


Figure 36. Tensile Creep Behavior of Unidirectional SP313 Composite Laminates: 90° Fiber Orientation.

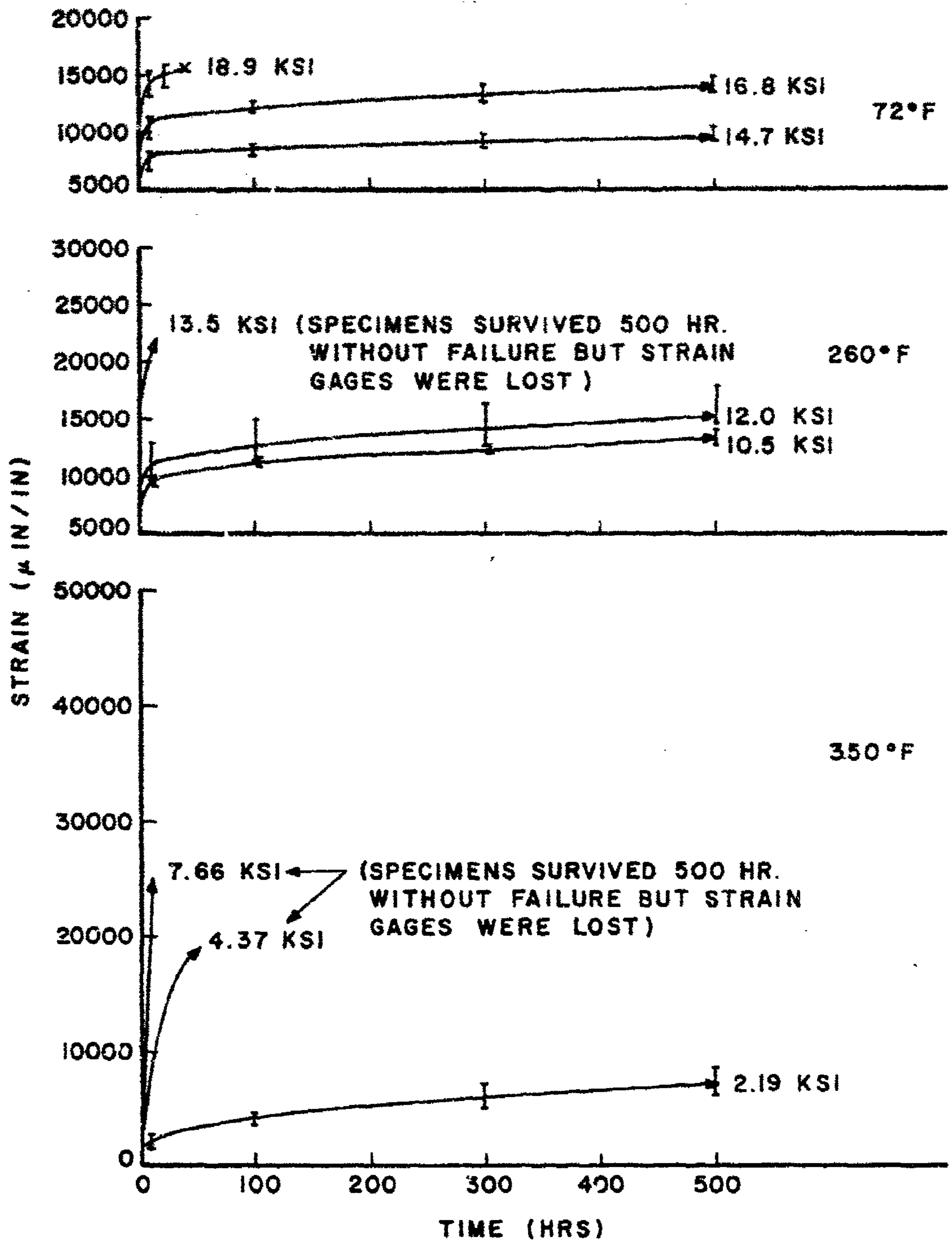


Figure 37. Tensile Creep Behavior of Bidirectional SP313 Composite Laminates: ±45° Fiber Orientation.

TABLE 19

STRESS RUPTURE PROPERTIES OF SP313 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Graphite/Epoxy

Material System - SP313 Prepreg by - 3M
Fiber - T300 Matrix - PR313
Maximum Temperature Rating - 350°F
Resin Content - 31.76% by wt.
Fiber Content - 60.93% by vol.
Void Content - ±2% by vol.
Test Method - Tension Reference - Design Guide

Laminate Sp. Gr. - 1.55
Average Ply Thickness - 0.0054 inch
No. of panels from which specimens were tested in this table - 20
Thickness of each type specimen - 0° --- 6 plies
90° --- 15 plies
±45° --- 8 plies

STRESS RUPTURE

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				260°F	Stress Level (ksi)	157.1	3.33	13.51
	Time to Failure (hrs)					Time to Failure (hrs)	168[3]	169[3]	500[1]
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	208.4	4.12	21.1
	No. of Specimens					No. of Specimens	1	1	3
	Stress Level (ksi)					Stress Level (ksi)	139.7	2.86	12.01
	Time to Failure (hrs)					Time to Failure (hrs)	169[3]	336[2]	500[1]
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	195.7	5.16	28.2
	No. of Specimens					No. of Specimens	1	2	3
72°F	Stress Level (ksi)	173.1	3.93	18.89	350°F	Stress Level (ksi)	127.5	2.59	7.66
	Time to Failure (hrs)	10.1[4]	168[3]	67.4[4]		Time to Failure (hrs)	168[3]	0.27[4]	500[1]
	No. of Specimens	3	3	3		No. of Specimens	3	3	3
	Residual Strength (ksi)	---	5.41	---		Residual Strength (ksi)	159.0	---	20.0
	No. of Specimens	0	1	0		No. of Specimens	1	0	3
	Stress Level (ksi)	153.8	3.44	16.79		Stress Level (ksi)	113.4	2.22	4.37
	Time to Failure (hrs)	504[1]	500[1]	336[2]		Time to Failure (hrs)	500[1]	70.1[4]	330[2]
	No. of Specimens	3	3	3		No. of Specimens	3	3	3
	Residual Strength (ksi)	194.6	4.76	20.6		Residual Strength (ksi)	184.6	---	15.5
	No. of Specimens	3	3	3		No. of Specimens	3	0	2

Notes: All values represent arithmetic averages. All residual strengths determined by tensile test at 72°F. The times to failure represent an average of some specimens which actually failed and some which did not fail within the 500-hour test period, as indicated below.

1. No failures within 500 hours.
2. Average of one failure and two 500-hour survivals.
3. Average of two failures and one 500-hour survival.
4. Three failures.

TABLE 20

THERMOPHYSICAL PROPERTIES OF SP313
COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - SP313 Prepreg by - 3M | Graphite/ Epoxy

Fiber - T300 Matrix - PR313

Maximum Temperature Rating - 350°F

Resin Content - 35.34% by wt.

Fiber Content - 57.00% by vol.

Void Content - *2% by vol.

Thickness of each type specimen:

Laminate Sp. Gr. - 1.53

Average Ply Thickness - 0.0052 inch

No. of panels from which specimens were tested in this table - 5

Therm. Exp.-40 ply Spec.Ht.-20 ply

Therm. Cond.-16 ply Glass Trans.-14 ply

THERMOPHYSICAL PROPERTIES: 0°

	-67°F	72°F	260°F	350°F
Thermal Expansion				
α_x (μin/in-°F)	0.16	~0	0.13	0.13
α_y (μin/in-°F)	15.4	18.5	18.5	18.5
No. of Specimens per direction	4	4	4	4
Specific Heat				
C_p (btu/lb.-°F)	0.17[1]	0.24[1]	0.24[1]	0.26[1]
No. of Specimens	3	3	3	3
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	0.23	0.29	0.37	0.41
No. of Specimens	3	3	3	3
Glass Transition Temp.				
Dry (°F)	None observed from -67°F to 450°F			
Wet (°F)	250°F			

THERMOPHYSICAL PROPERTIES: ±45°

	-67°F	72°F	260°F	350°F
Thermal Expansion				
α_x (μin/in-°F)	1.81	1.94	1.94	1.94
No. of Specimens per direction	3	3	3	3
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	0.23	0.27	0.33	0.37
No. of Specimens	3	3	3	3

Note: On unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

[1]Values obtained by dropping sample from noted temperature to 72°F receiver.

TABLE 21

TENSILE PROPERTIES OF SP313 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES — Graphite/Epoxy

Material System - SP313	Prepreg by - 3M
Fiber - T300 Matrix - PR313	Laminate Sp. Gr. - 1.55
Maximum Rated Temperature - 350°F	Average Ply Thickness - 0.0055 inch
Resin Content - 32.3% by wt.	No. of panels from which specimens were tested in this table - 15
Fiber Content - 60.3% by vol.	Aging Conditions - 160°F, 100% R.H.
Void Content - ≤2% by vol.	Thickness of each type specimen: 90°-15 plies; ±45°-8 plies

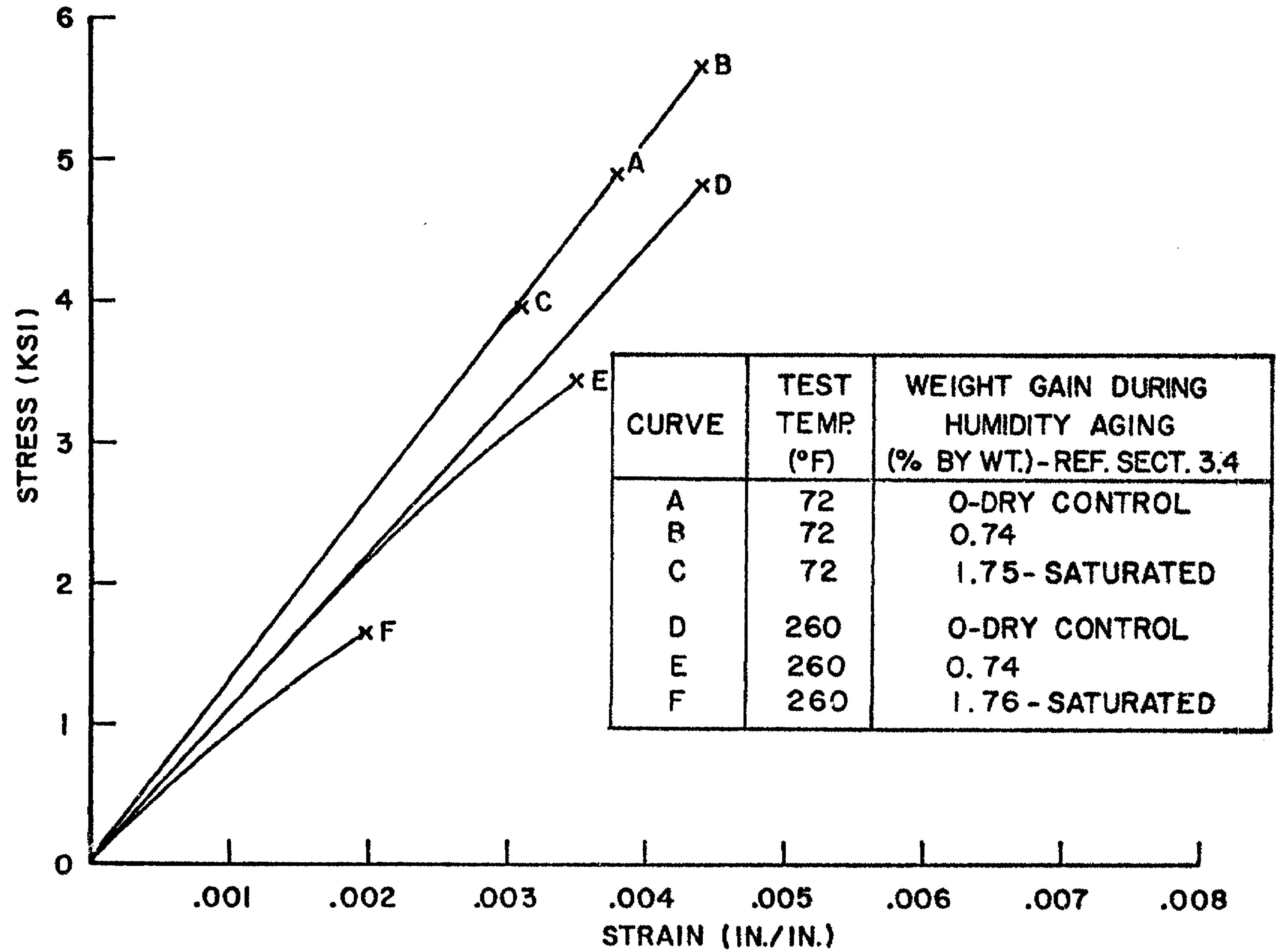
TENSION: 90°

	72°F	260°F	72°F	260°F
Exposure Time (hrs)	168	168	1990	1990
Weight Gain (% of orig. dry wt.)	0.74	0.74	1.75[1]	1.76[1]
Stnd. Dev. (%)	0.02	0.01	0.04	0.07
No. of Specimens	5	5	5	5
F_y^{tu} (ksi)	5.65	3.44	3.94	1.63
Stnd. Dev. (ksi)	0.45	0.41	0.21	0.11
Range (ksi)	5.10-6.34	2.86-3.87	3.75-4.29	1.56-1.79
No. of Specimens	5	5	5	4
F_y^{tpl} (ksi)	5.65	3.44	3.57	0.70
Stnd. Dev.	0.45	0.41	0.23	0.13
No. of Specimens	5	5	5	4
E_y^t (Msi)	1.32	1.10	1.28	0.93
Stnd. Dev.	0.02	0.07	0.03	0.05
No. of Specimens	5	5	5	4
ϵ_y^{tu} (μ in/in)	4,400	3,500	3,110	2,000
Stnd. Dev.	400	400	138	189
No. of Specimens	5	5	5	4
Test Method	Straight-sided tension			
Reference	Design Guide			

TENSION: ±45°

Exposure Time (hrs)	48	48	1512	1536
Weight Gain (% of orig. dry wt.)	0.81	0.81	1.55[1]	1.59[1]
Stnd. Dev. (%)	0.02	0.05	0.04	0.04
No. of Specimens	5	5	5	5
F_x^{tu} (ksi)	21.6	14.7	21.1	13.3
Stnd. Dev. (ksi)	0.4	1.0	0.3	0.5
Range (ksi)	21.3-22.1	13.3-15.9	20.9-21.8	12.7-14.1
No. of Specimens	5	5	5	5
F_x^{tpl} (ksi)	5.3	3.9	5.4	2.53
Stnd. Dev.	0.7	0.2	1.2	0.32
No. of Specimens	5	4	5	5
E_x^t (Msi)	2.53	1.91	2.61	1.69
Stnd. Dev.	0.28	0.13	0.15	0.29
No. of Specimens	5	4	5	5
ϵ_x^{tu} (μ in/in)	15,500	>20,000[2]	27,000	>25,000[2]
Stnd. Dev.	---	---	---	---[2]
No. of Specimens	2	5[2]	1[2]	5[2]
Test Method	Straight-sided tension			
Reference	Design Guide			

Notes: 1. 100% saturation level at aging conditions.
2. Surface plies cracked at about 80% of ultimate load, breaking gages.



CURVE	TEST TEMP. (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)-REF. SECT. 3.4
A	72	0-DRY CONTROL
B	72	0.74
C	72	1.75-SATURATED
D	260	0-DRY CONTROL
E	260	0.74
F	260	1.76-SATURATED

Figure 38. Tensile Stress-Strain Curves for Unidirectional SP313 Composite Laminates After Humidity Aging at 160°F and 100% R.H.: 90° Fiber Orientation.

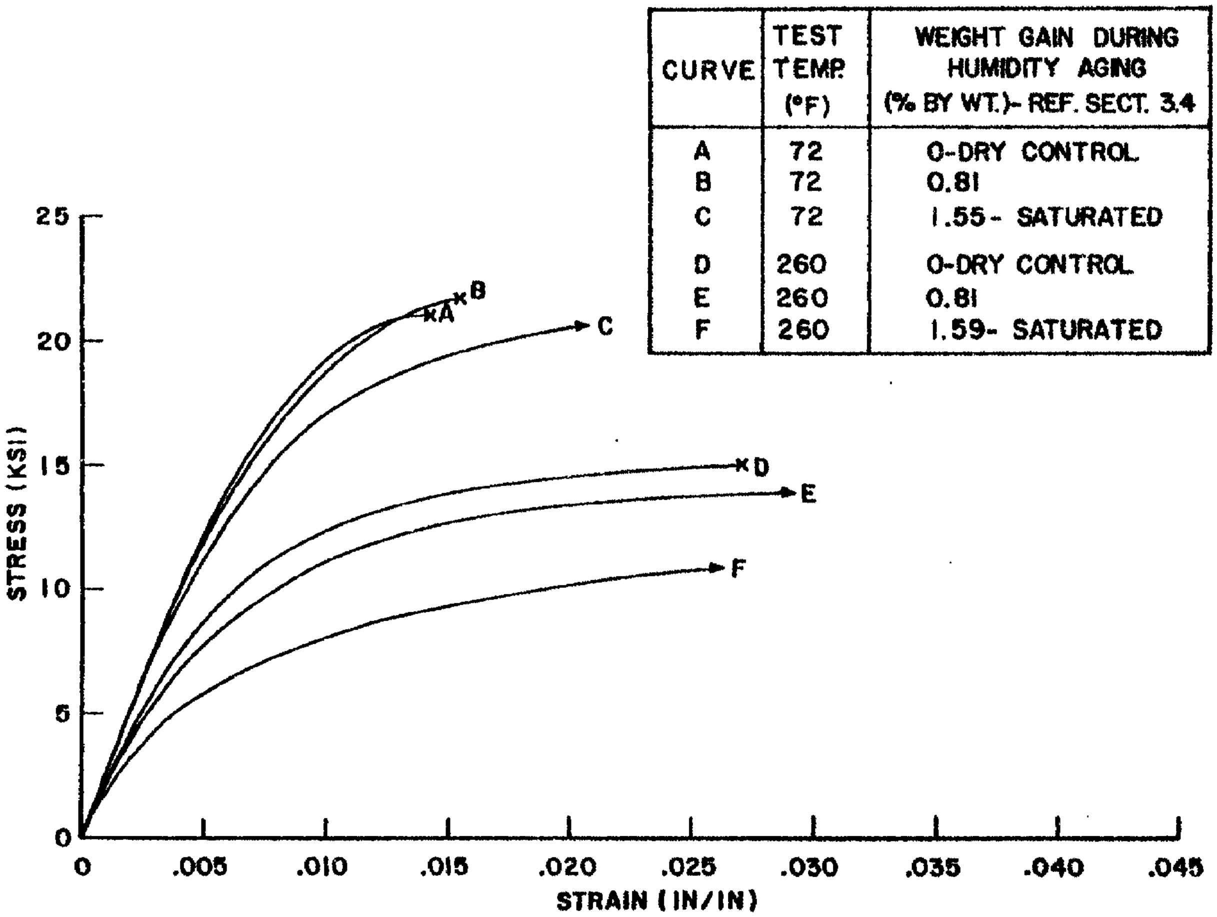


Figure 39. Tensile Stress-Strain Curves for Bidirectional SP313 Composite Laminates After Humidity Aging at 160°F and 100% R.H.: ±45° Fiber Orientation.

TABLE 22

SHEAR PROPERTIES OF SP313 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES — Graphite/Epoxy

Material System - SP313
Fiber - T300 Matrix - PR313
Maximum Rated Temperature - 350°F
Resin Content - 32.1% by wt.
Fiber Content - 59.9% by vol.
Void Content - ≤2% by vol.

Prepreg by - 3M

Laminate Sp. Gr. - 1.55
Average Ply Thickness - 0.0052 inch
No. of panels from which specimens were tested in this table - 6
Aging Conditions - 160°F, 100% R.H.
Thickness of each type specimen:
Inplane shear-8 plies; Interlaminar shear-16 plies

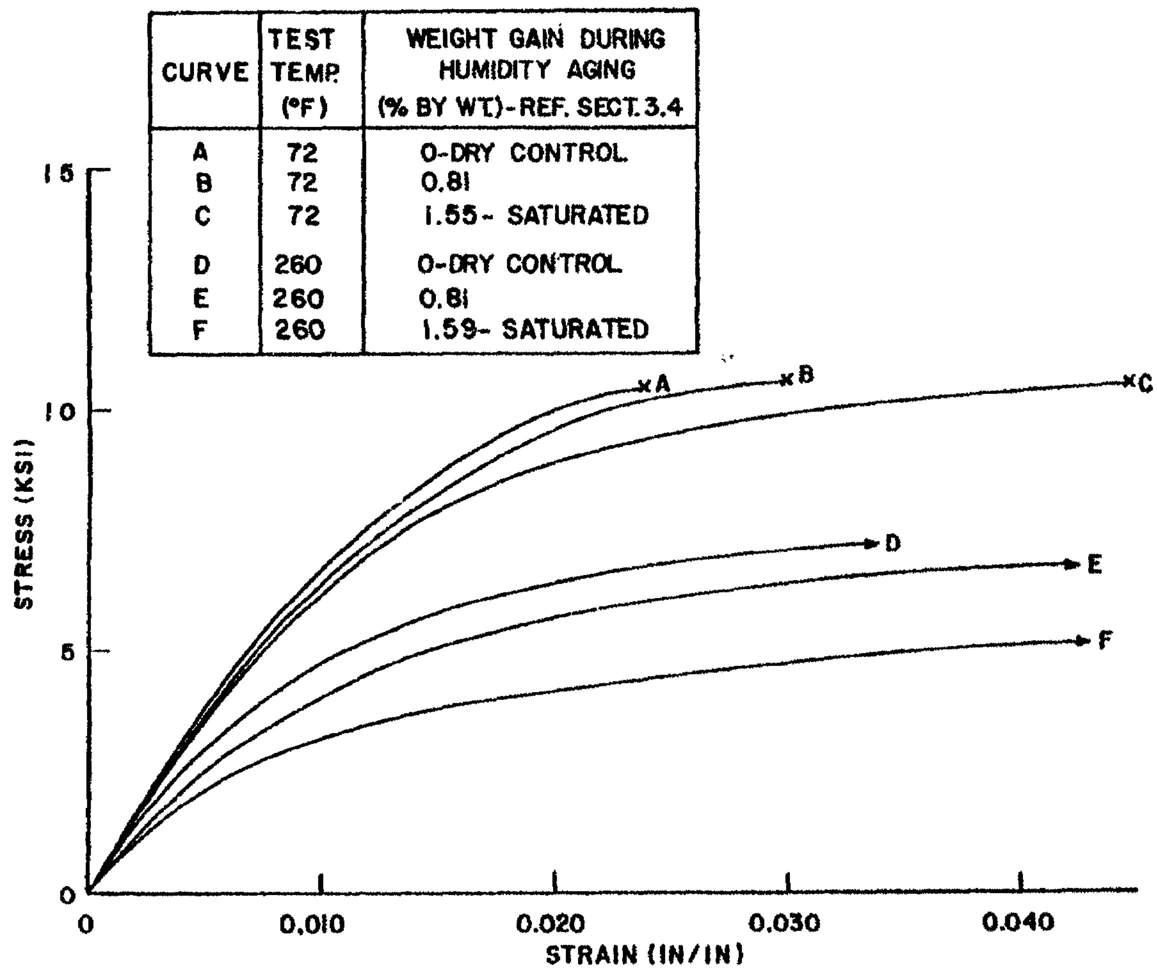
INPLANE SHEAR

Test Temperature	72°F	260°F	72°F	260°F
Exposure Time (hrs)	48	48	1512	1536
Weight Gain (% of orig. dry wt.)	0.81	0.81	1.55[1]	1.59[1]
Stnd. Dev. (%)	0.02	0.05	0.04	0.04
No. of Specimens	5	5	5	5
F_{xy}^{su} (ksi)	10.82	7.35	10.6	6.7
Stnd. Dev. (ksi)	0.2	0.48	0.1	0.3
Range (ksi)	10.65-11.05	6.65-7.95	10.5-10.9	6.4-7.1
No. of Specimens	5	5	5	5
G_{xy}^{s} (Msi)	0.74	0.55	0.75	0.46
Stnd. Dev.	0.05	0.05	0.05	0.05
No. of Specimens	5	4	5	4
Test Method	±45° straight-sided tension			
Reference	J. Comp. Mtls. [V6, p252 & V7, p124]			

INTERLAMINAR SHEAR

Test Temperature	72°F	260°F	72°F	260°F
Exposure Time (hrs)	504	504	1870	1870
Weight Gain (% of orig. dry wt.)	0.74	0.77	1.67[1]	1.78[1]
Stnd. Dev. (%)	0.08	0.05	0.12	0.14
No. of Specimens	5	5	5	5
F^{isu} (ksi)	12.19	6.64	9.95	6.02
Stnd. Dev. (ksi)	0.41	0.12	0.34	0.11
Range (ksi)	11.71-12.66	6.45-6.78	9.44-10.25	5.83-6.11
No. of Specimens	5	5	5	5
Test Method	Short Beam Shear			
Reference	Design Guide - Jan., 1971			

Note: 1. 100% saturation level at aging conditions.



CURVE	TEST TEMP. (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)-REF. SECT. 3.4
A	72	0-DRY CONTROL
B	72	0.81
C	72	1.55- SATURATED
D	260	0-DRY CONTROL
E	260	0.81
F	260	1.59- SATURATED

Figure 40. Inplane Shear Stress-Strain Curves for SP313 Composite Laminates After Humidity Aging at 160°F and 100% R.H.

4.2 AS/3004

Tables 23-35 present the data generated for this graphite/polysulfone composite system. Figures 41-64 illustrate the stress-strain, fatigue, and creep behavior of the material, as well as the effect of humidity aging upon the composite material. There are two points of particular interest worthy of special mention in the discussion of this matrix system.

Firstly, the large deformations undergone by the ±45° specimens resulted in so much energy dissipation through internal friction that the stress levels at which the cyclic fatigue loadings were conducted had to be significantly reduced. It was found that the maximum cyclic stress had to be kept at or below about 20% of the static ultimate in order to prevent the specimen from self-heating to a higher temperature than the test temperature. Specimen temperature was measured with a thermocouple taped to the side of the specimen and excursions of over 300°F above the test temperature were observed on a few specimens loaded to only 30% of static ultimate. It was found that a relatively narrow region of between 20% and 25% of static ultimate comprises the initial transition region, below which no self-heating occurs and fatigue life generally exceeds 10^7 cycles and above which, considerable self-heating occurs and fatigue life drops markedly. One specimen was tested at only 10 Hz rather than 30 Hz frequency to see if this had any effect upon the self-heating behavior of the material. This 10 Hz test was conducted with a maximum cyclic stress level of 30% of the static ultimate strength. In comparison with a 30 Hz test, also at 30% static ultimate, the 10 Hz test produced less self-heating and a longer fatigue life. The reduction in self-heating was quite marked, with the temperature rise of the 10 Hz specimen being only one-third as great as that of the 30 Hz specimen (see data in Figure 56). In spite of this, the specimen temperature still rose 95°F above the test temperature and it seems that a considerably lower cyclic frequency than 10 Hz must be used in order to avert this phenomena at cyclic stresses above 20% of static ultimate on ±45° polysulfone matrix composites. All of the temperature measurements made during the fatigue tests on this material are summarized in Figure 56 and presented in detail in Appendix H.

Self-heating has been observed in fatigue tests on the ±45° orientations with the other composite materials characterized during this program but to a much lesser extent and only at considerably higher cyclic stress levels. This difference is no doubt due to the significantly smaller plastic deformations exhibited by the thermosetting matrices since the cyclic strain levels at which self-heating commences are comparable to the AS/3004 system.

The second point to be mentioned with regard to the AS/3004 composite system is the very low flow which occurs during the laminate consolidation or "cure" schedule. Since the matrix resin is an already fully polymerized thermoplastic material, the consolidation process merely serves to resoften the resin so the plies will become integrally bonded to each other. The resin does not liquify during this process and practically no flow occurs. This represents a distinct processing advantage.

TABLE 23

PROCESSING DATA FOR AS/3004 SYSTEM

Composite Processing Information	
Material System - AS/3004 Fiber - AS Matrix - P1700	Graphite/ Polysulfone
Maximum Rated Temperature - 250°F	Prepreg by - Hercules

Laminate Processing Schedule

Prepreg Drying Procedure: Cut prepreg to desired size and quantity. Remove release paper and place prepreg pieces in a 250-275°F circulating air oven and dry for a minimum of four hours. Extra drying time is not detrimental to the prepreg.

Layup Procedure: Use a three-sided steel mold of appropriate size. Clean mold and coat with release agent such as Frekote 33. Release agent must be capable of withstanding 675°F mold temperature. Bake release treated mold per manufacturer's instructions. Place dried prepreg in mold with a release ply on either side of the stack between the mold and the prepreg. Use either Teflon film or Teflon coated glass fabric, depending on whether a smooth-glossy or matte surface is desired.

Consolidation Procedure: Preheat the press to 675°F (a higher temperature may be necessary depending on mold size and mass). Place mold in the preheated press and apply contact pressure (about 15 psi). When the laminate reaches 650°F (as indicated by a thermocouple touching the edge of the prepreg stack), apply 250 psi and hold for 15 minutes. Cool the laminate slowly (about 5°F/minute) to below 150°F before releasing pressure and removing from press.

Postcure Schedule: None.

TABLE 24

PREPREG AND COMPOSITE PHYSICAL PROPERTIES :AS/3004

Composite Physical Property Information				
Material System - AS/3004 Fiber - AS Matrix - P1700 Maximum Rated Temperature - 250°F			Graphite/Polysulfone Prepreg by - Hercules	
Prepreg Physical Properties				
(Property)	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content - 4.79% by wt.	0.42	4.31-5.34	HS-SG-500/232	Hercules
Resin Content - 37.63% by wt.	2.34	35.48-40.75	HD-SG-2-6006C	Hercules
Resin Flow - Not Applicable	---	---	(5.2.6,F)	---
No. of Rolls Involved - 4				
No. of Batches Involved - 1				
Laminate Physical Properties[1]				
	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels - 56				
Fiber Content - 57.17% by vol.	1.72	52.67-60.35	HD-SG-2-6006C	Hercules
Resin Content - 33.64% by wt.	1.55	30.80-38.13	" (5.2.6,F)	
Void Content - 1.12% by vol.	0.91	0-3.51	Grid pt. count	
Laminate Sp. Gr. - 1.53	0.02	1.50-1.56		
Fiber Sp. Gr. - 1.78	As reported by manufacturer.			
Matrix Sp. Gr. - 1.24	As reported by manufacturer.			
Thickness per ply - 0.0055 in.	0.0002 in.	0.0051-0.0058	---	

[1]The properties reported here represent averages for all panels of this material used throughout the program.

TABLE 25

TENSILE PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/3004 Fiber - AS Matrix - P1700 Maximum Rated Temperature - 250°F Resin Content - 34.0% by wt. Fiber Content - 57.2% by vol. Void Content - 0.5% by vol.		Prepreg by - Hercules	Graphite/Polysulfone Laminate Sp. Gr. - 1.54 Average Ply Thickness - 0.0053 inch No. of panels from which specimens were tested in this table - 11 Thickness of each type specimen - 0°-6 ply; 90°-15 ply	
TENSION: 0°				
	-67°F	72°F	180°F	250°F
F_x^{tu} (ksi)	200.5	187.9	191.5	179.1
stnd. dev. (ksi)	21.6	22.4	47.9	18.7
Range (ksi)	162.4-214.9	160.0-222.6	124.6-258.3	149.7-197.7
No. of Specimens	5	5	5	5
F_x^{tpl} (ksi)	200.5	187.9	191.5	179.1
stnd. dev.	21.6	22.4	47.9	18.7
No. of Specimens	5	5	5	5
E_x^t (Msi)	18.1	16.3	16.2	17.5
stnd. dev.	0.4	0.8	0.4	1.0
No. of Specimens	5	5	5	5
ϵ_x^{tu} (μin/in)	10,400	10,100	10,600	9,400
stnd. dev.	1,100	700	3,100	430
No. of Specimens	4	4	4	5
ν_{xy}^t	0.31	0.34	0.32	0.34
stnd. dev.	0.02	0.05	0.06	0.06
No. of Specimens	5	5	5	4
Test Method	Straight-sided Tension			
Reference	Design Guide			
TENSION: 90°				
F_y^{tu} (ksi)	6.82	5.02	4.93	5.39
stnd. dev. (ksi)	1.45	0.98	1.31	0.94
Range (ksi)	4.58-8.26	3.41-6.02	3.17-6.76	4.19-6.56
No. of Specimens	5	5	5	5
F_y^{tpl} (ksi)	6.82	4.31	4.55	4.03
stnd. dev.	1.45	1.32	1.41	0.59
No. of Specimens	5	5	5	4
E_y^t (Msi)	1.06	1.15	1.07	1.07
stnd. dev.	0.10	0.14	0.04	0.03
No. of Specimens	5	5	5	5
ϵ_y^{tu} (μin/in)	6,200	4,600	4,600	4,900
stnd. dev.	1,100	900	1,100	500
No. of Specimens	5	5	5	4
ν_{yx}^t	0.020[1]	0.024[1]	0.021[1]	0.020[1]
Test Method	Straight-sided Tension			
Reference	Design Guide			

[1] Computed using elastic moduli and longitudinal Poisson's ratio.

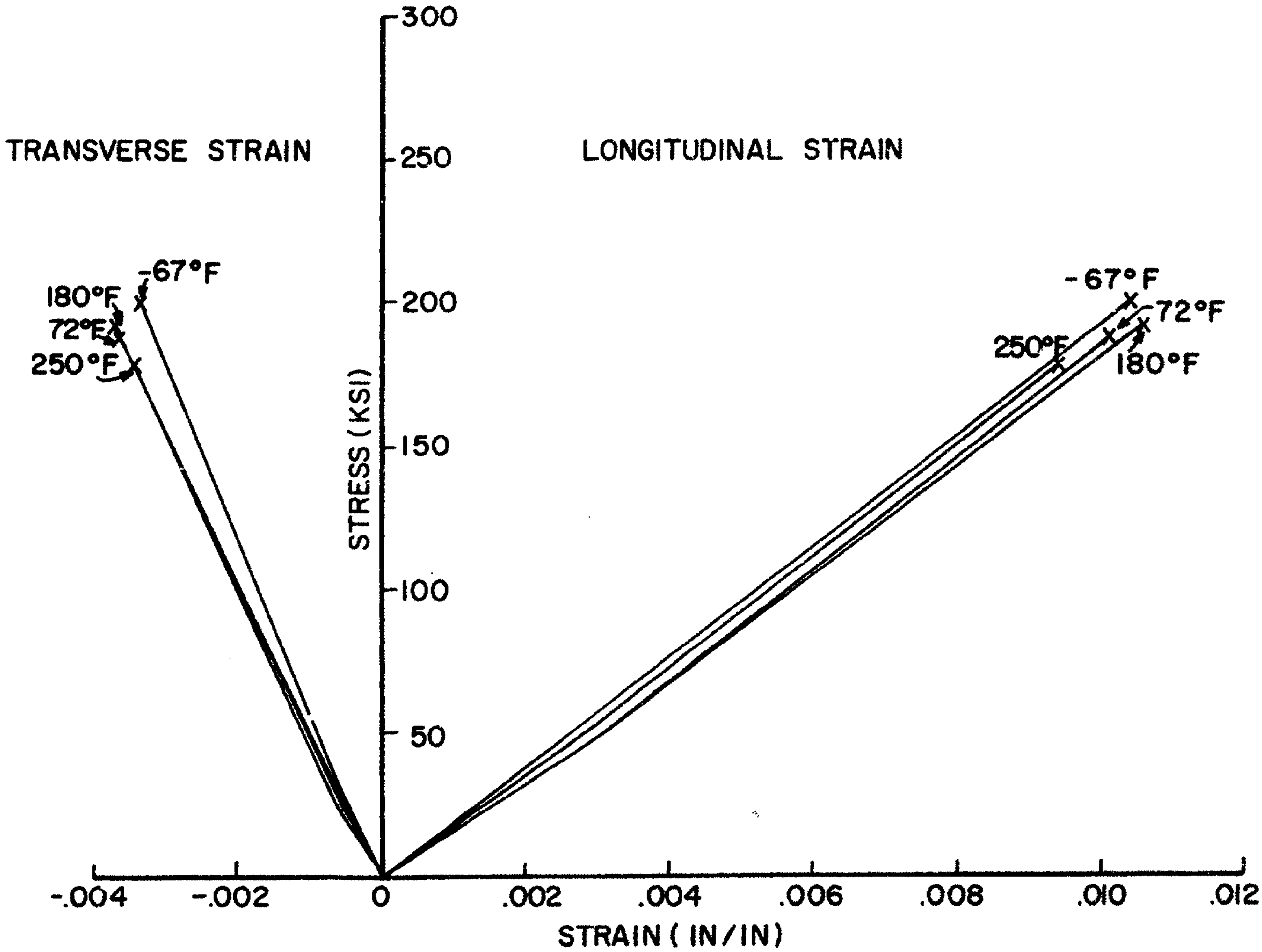


Figure 41. Tensile Stress-Strain Curves for Unidirectional AS/3004 Composite Laminates: 0° Fiber Orientation.

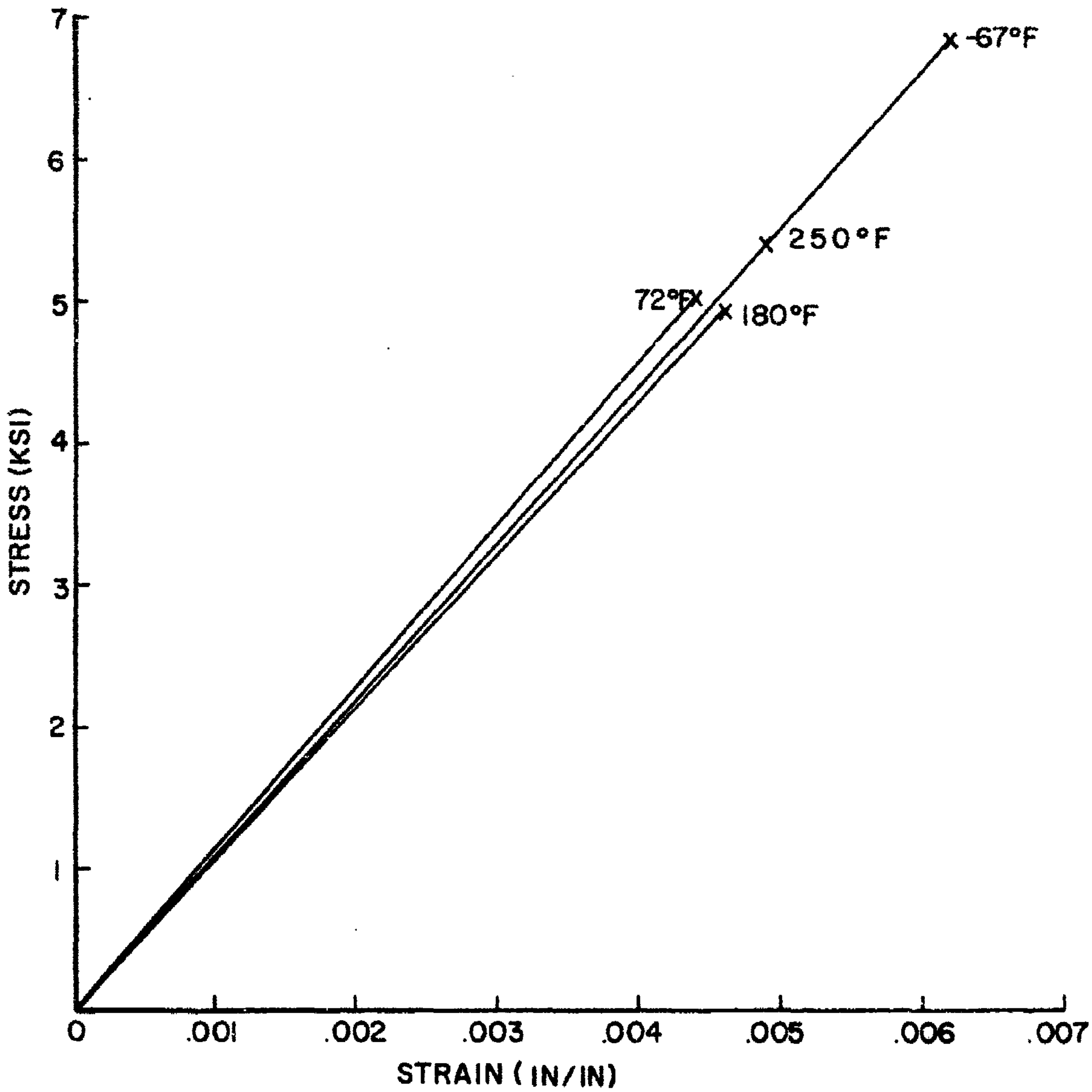


Figure 42. Tensile Stress-Strain Curves for Unidirectional AS/3004 Composite Laminates: 90° Fiber Orientation.

TABLE 26

TENSILE PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/3004 Prepreg by - Hercules; Fiber - AS Matrix - P1700; Maximum Rated Temperature - 250°F; Resin Content - 33.9% by wt.; Fiber Content - 57.2% by vol.; Void Content - 0.4% by vol.	Graphite/Polysulfone; Laminate Sp. Gr. - 1.54; Average Ply Thickness - 0.0054 inch; No. of panels from which specimens were tested in this table - 6; Thickness of specimen - 3 ply			
TENSION: ± 45°				
	67°F	72°F	180°F	250°F
F_x^{tu} (ksi)	41.62	31.93	27.76	24.30
stnd. dev. (ksi)	2.05	1.79	2.09	0.70
Range (ksi)	38.05-43.12	29.96-34.87	25.09-30.04	23.53-25.14
No. of Specimens	5	5	5	5
F_x^{tpl} (ksi)	4.97	3.94	3.97	3.13
stnd. dev. (ksi)	0.75	0.38	0.23	0.46
No. of Specimens	5	5	5	5
E_x^t (Msi)	2.00	1.98	1.93	1.84
stnd. dev.	0.07	0.11	0.05	0.09
No. of Specimens	5	5	5	5
ϵ_x^{tu} (μin/in)	>19,500[1]	>40,000[1]	>40,600[1]	>41,600[1]
stnd. dev.	---	---	---	---
No. of Specimens	5	5	5	5
ν_{xy}^t	0.81	0.75	0.86	0.81
stnd. dev.	0.06	0.13	0.05	0.07
No. of Specimens	4	5	5	5
Test Method	Straight-Sided Tension			
Reference	Design Guide			

[1]Visible neckdown occurred and surface plies cracked, creating electrical discontinuities in strain gages.

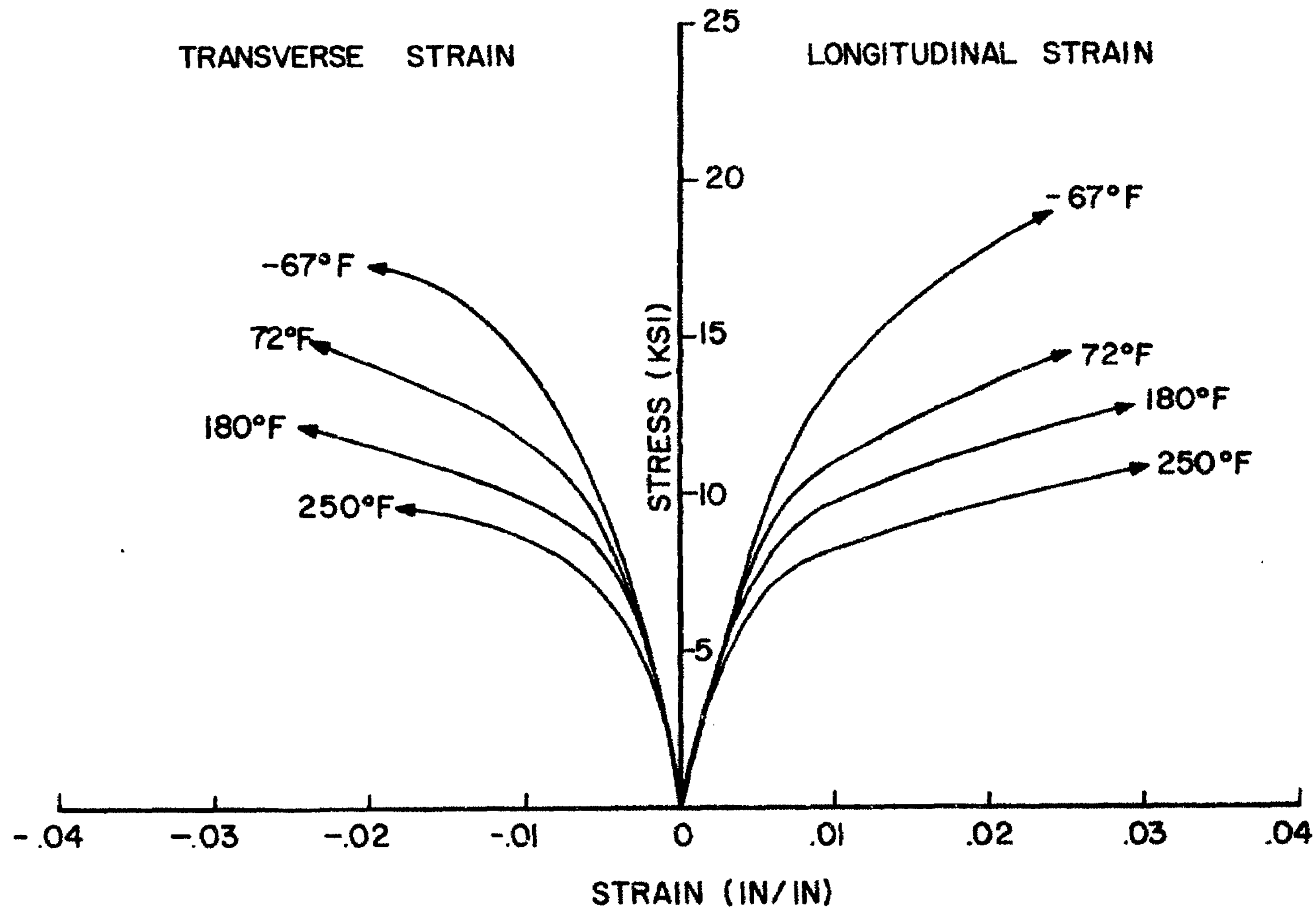


Figure 43. Tensile Stress-Strain Curves for Bidirectional AS/3004 Composite Laminates: ±45° Fiber Orientation.

TABLE 27

COMPRESSIVE PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES	
Material System - AS/3004	Graphite/Polysulfone
Fiber - AS Matrix - P1700	Prepreg by - Hercules
Maximum Rated Temperature - 250°F	Laminate Sp. Gr. - 1.54
Resin Content - 33.1% by wt.	Average Ply Thickness ~0.0052 in.
Fiber Content - 57.9% by vol.	No. of panels from which specimens were tested in this table - 2
Void Content - ≈ 0	Thickness of specimens - 20 ply

COMPRESSION : 0°		-67°F	72°F	180°F	250°F
F_x^{cu}	(ksi)	147.9	102.1	102.6	90.2
stnd. dev.	(ksi)	2.6	10.8	13.4	11.2
Range	(ksi)	143.2-149.8	83.8 - 110.3	91.9-125.8	73.8-105.0
No. of Specimens		5	5	5	5
F_x^{cpl}	(ksi)	76.0	83.4	69.9	76.4
stnd. dev.		16.8	24.7	28.3	28.8
No. of Specimens		5	5	5	5
E_x^c	(Msi)	18.7	17.3	18.1	18.5
stnd. dev.		3.0	0.5	0.9	1.4
No. of Specimens		5	5	5	5
ϵ_x^{cu}	(μ in/in)	8,500	6,300	6,000	5,000
stnd. dev.		1,600	1,200	1,400	1,000
No. of Specimens		5	5	5	5
Test Method		Celanese coupon and test fixture			
Reference		AFML-TR-72-205, Pt. 1			

COMPRESSION: 90°		-67°F	72°F	180°F	250°F
F_y^{cu}	(ksi)	31.8	18.9	15.3	13.4
stnd. dev.	(ksi)	2.0	1.5	0.7	1.3
Range	(ksi)	29.9-34.0	16.8-20.7	14.8-16.5	11.3-14.8
No. of Specimens		5	5	5	5
F_y^{cpl}	(ksi)	16.5	7.9	8.7	4.9
stnd. dev.		7.8	2.8	2.8	0.9
No. of Specimens		5	4	5	5
E_y^c	(Msi)	1.22	1.60	1.21	1.33
stnd. dev.		0.07	0.32	0.25	0.34
No. of Specimens		5	5	5	5
ϵ_y^{cu}	(μ in/in)	47,000	11,900[1]	38,400	37,000
stnd. dev.		18,000	5,000	32,900	18,000
No. of Specimens		5	4	5	5
Test Method		Celanese coupon and test fixture			
Reference		AFML-TR-72-205, Pt. 1			

[1] Ultimate strain values represent maximum observed strain rather than ultimate values. Buckling was observed in majority of tests.

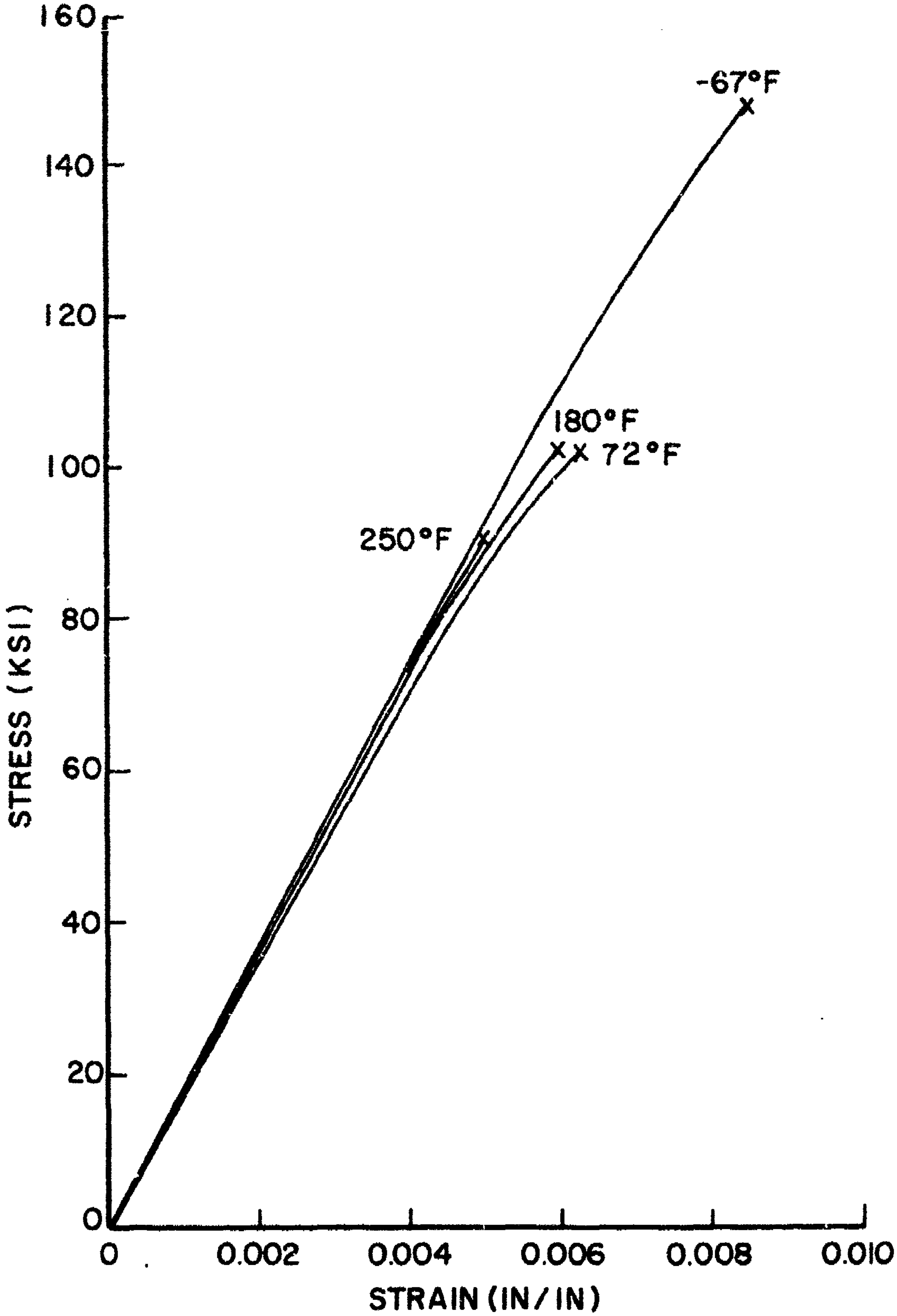


Figure 44. Compressive Stress-Strain Curves for Unidirectional AS/3004 Composite Laminates: 0° Fiber Orientation.

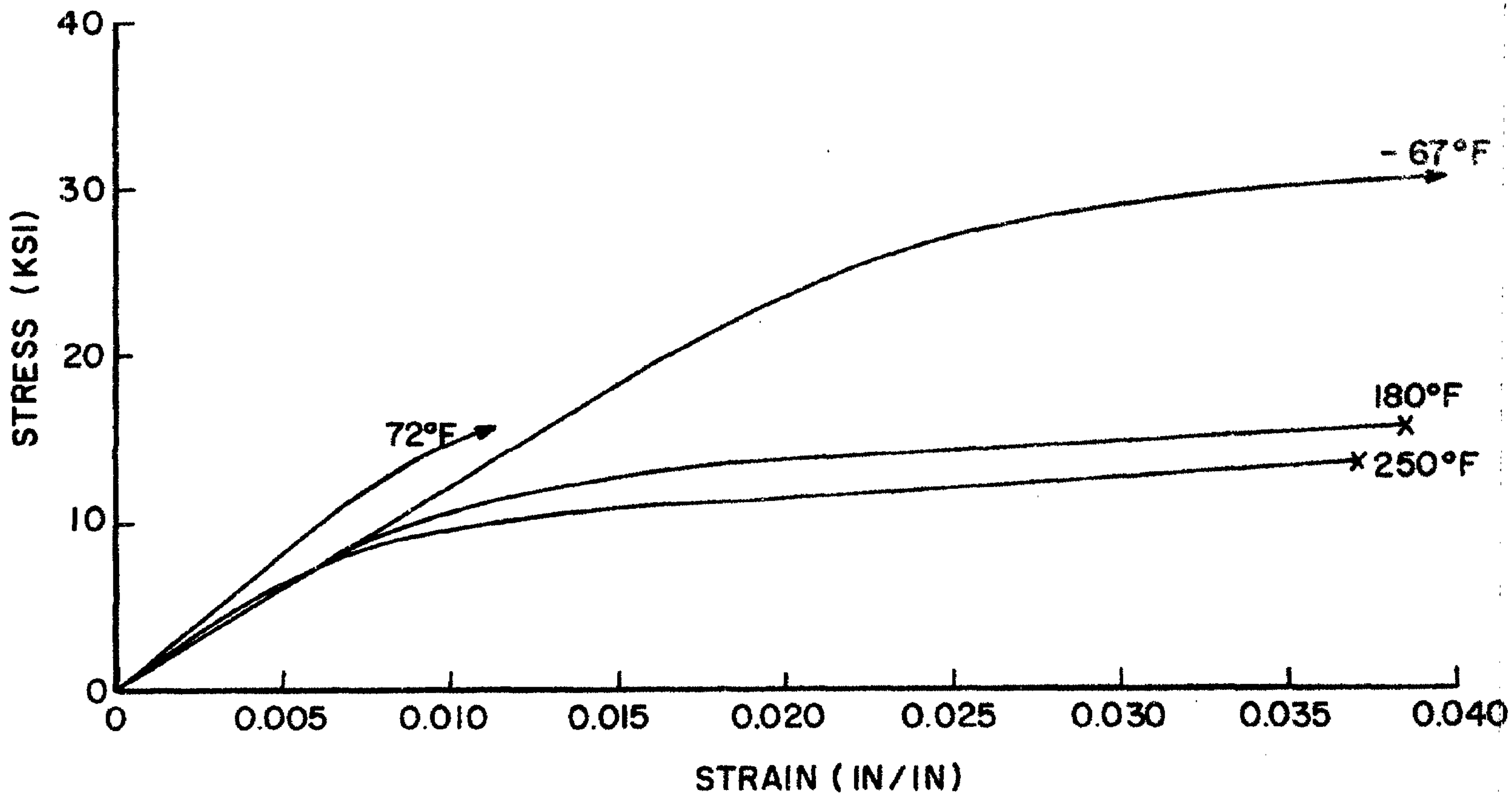


Figure 45. Compressive Stress-Strain Curves for Unidirectional AS/3004 Composite Laminates: 90° Fiber Orientation.

TABLE 28

FLEXURAL PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/3004; Fiber - AS; Matrix - P1700; Maximum Rated Temperature - 250°F; Resin Content - 32.9% by wt.; Fiber Content - 57.7% by vol.; Void Content - 1.9% by vol.		Prepreg by - Hercules; Graphite/Polysulfone; Laminate Sp. Gr. - 1.52; Average Ply Thickness - 0.0056 inch; No. of panels from which specimens were tested in this table - 4; Thickness of specimens - 14 ply		
FLEXURE : 0°				
	-67°F	72°F	180°F	250°F
F_x^{fu} (ksi)	227.9	191.5	156.3	135.2
stnd. dev. (ksi)	4.3	10.1	2.3	3.2
Range (ksi)	222.9-232.0	176.2-201.5	153.6-159.0	129.9-138.2
No. of Specimens	5	5	5	5
E_x^f (Msi)	20.0	17.8	19.1	20.0
stnd. dev.	0.7	1.4	1.7	0.5
No. of Specimens	5	5	5	5
Test Method	4 pt. flexure			
Reference	Design Guide; Jan., 1971			
FLEXURE: 90°				
F_y^{fu} (ksi)	13.40	13.00	11.33	10.11
stnd. dev. (ksi)	0.99	1.15	1.53	0.72
Range (ksi)	11.81-14.12	11.59-14.62	9.38-12.96	8.88-10.69
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.31	1.28	1.17	1.08
stnd. dev.	0.03	0.04	0.09	0.01
No. of Specimens	5	5	5	5
Test Method	4 pt. flexure			
Reference	Design Guide; Jan., 1971			

TABLE 29

SHEAR PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/3004				Graphite/Polysulfone
Fiber - AS	Matrix - P1700		Prepreg by - Hercules	
Maximum Rated Temperature - 250°F			Laminate Sp. Gr. - 1.53	
Resin Content - 33.6% by wt.			Average Ply Thickness - 0.0054 in.	
Fiber Content - 57.4% by vol.			No. of panels from which specimens were tested in this table - 9	
Void Content - 1.0% by vol.			Thickness of each type specimen- Inplane-3 ply; Interlaminar-14 ply	
INPLANE SHEAR				
	-67°F	72°F	180°F	250°F
F^{su}_{xy} (ksi)	20.81	15.97	13.88	12.15
stnd. dev. (ksi)	0.99	1.00	1.04	0.35
Range	19.03-21.56	14.98-17.44	12.55-15.02	11.77-12.57
No. of Specimens	5	5	5	5
G^{s}_{xy} (Msi)	0.55	0.56	0.52	0.56
stnd. dev. (Msi)	0.03	0.04	0.02	0.08
No. of Specimens	5	5	5	5
Test Method	±45° Straight-sided Tension			
Reference	J. Comp. Mtls [Vol. 6, p. 252 & Vol. 7, p. 124]			
INTERLAMINAR SHEAR				
F^{isu} (ksi)	14.0	11.6	9.6	8.4
Stnd. Dev. (ksi)	1.0	1.0	0.5	0.5
Range (ksi)	11.9-15.3	10.2-13.3	8.4-10.0	7.9-9.6
No. of Specimens	9	9	10	7
Test Method	Short Beam Shear, S/D=4			
Reference	Design Guide, Jan., 1971			

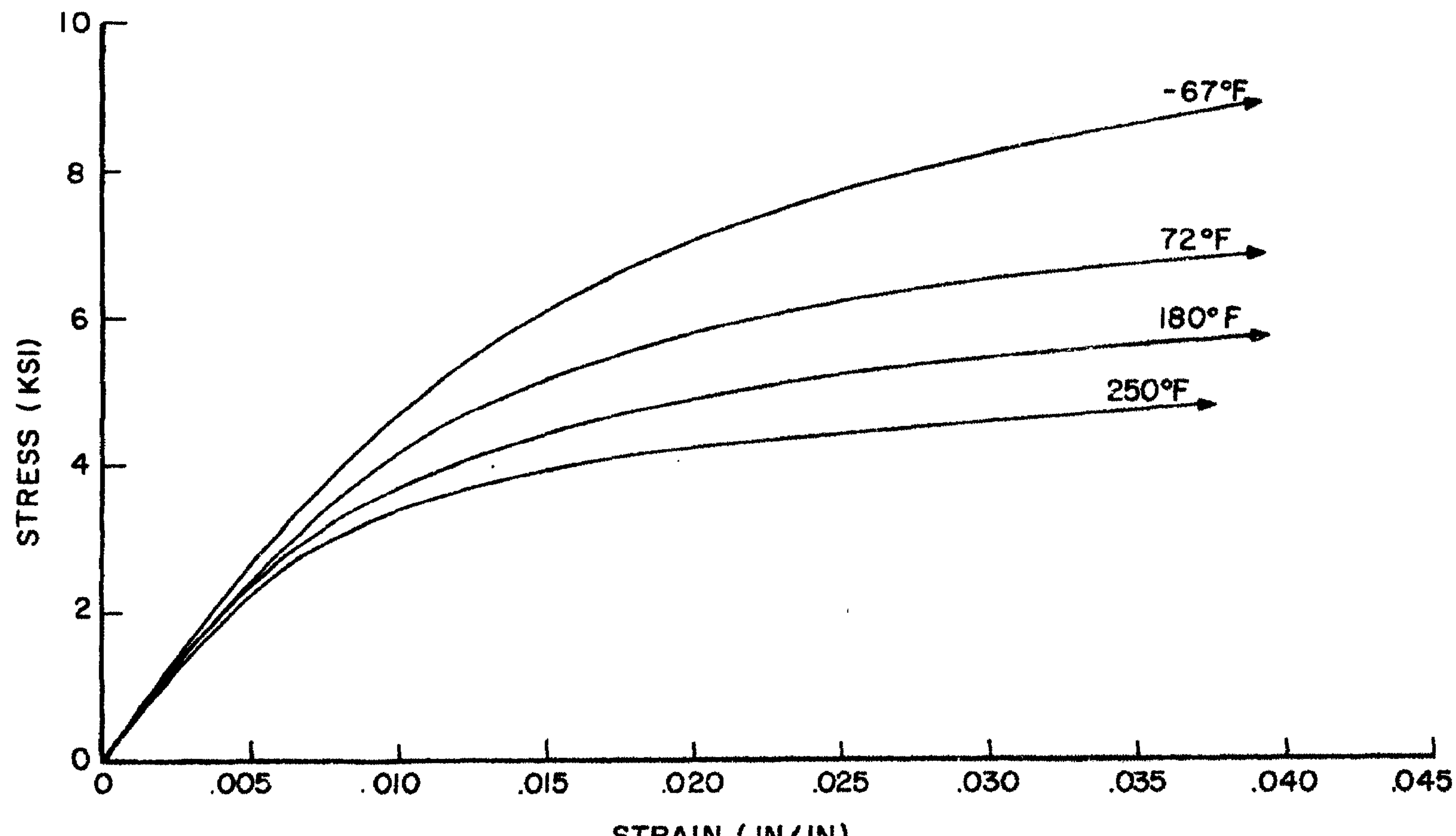


Figure 46. Inplane Shear Stress-Strain Curves for AS/3004 Composite Laminates.

TABLE 30

FATIGUE PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

* Graphite/Polysulfone

Material System - AS/3004 Prepreg by - Hercules
Fiber - AS Matrix - P1700
Maximum Temperature Rating - 250°F
Resin Content - 33.6% by wt.
Fiber Content - 57.2% by vol.
Void Content - 1.2% by vol.

Laminate Sp. Gr. - 1.53
Average Ply Thickness - 0.0055 inch
No. of panels from which specimens were tested in this table - 38
Thickness of each type specimen - 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply

Test Method - Straight-sided Tension Reference - Design Guide

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Max. Stress (ksi)	180.4	4.09	10.40	180°F	Max. Stress (ksi)	153.2	3.94	6.94
	Lifetime (cycles)	2820	14,410	622,790 [4]		Lifetime (cycles)	1840	2080	1.17×10^6 [2]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	160.4	2.73	8.32		Max. Stress (ksi)	134.1	2.96	5.55
	Lifetime (cycles)	257,400	163,640	5.77×10^6		Lifetime (cycles)	61,710	10,760	10^7+
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	22.48		Residual Strength (ksi)	---	---	18.85
	No. of Specimens	0	0	1		No. of Specimens	0	0	4
	Max. Stress (ksi)	140.3	1.36	6.24		Max. Stress (ksi)	114.9	1.97	2.78
	Lifetime (cycles)	708,830	8.60×10^6	10^7+		Lifetime (cycles)	1.55×10^6	73,314	10^7+
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	182.2	5.73	26.3		Residual Strength (ksi)	---	---	31.71
	No. of Specimens	2	3	4		No. of Specimens	0	0	4
72°F	Max. Stress (ksi)	150.3	4.02	8.01	250°F	Max. Stress (ksi)	143.3	3.24	6.08
	Lifetime (cycles)	5819	5010	600,860 [1]		Lifetime (cycles)	2600	2740	1.21×10^6 [3]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	131.5	3.52	6.40		Max. Stress (ksi)	125.3	2.16	4.86
	Lifetime (cycles)	63,610	23,180	8.91×10^6		Lifetime (cycles)	92,430	8990	6.78×10^6
	No. of Specimens	4	4	4		No. of Specimens	5	4	5
	Residual Strength (ksi)	---	---	27.93		Residual Strength (ksi)	---	---	29.71
	No. of Specimens	0	0	3		No. of Specimens	0	0	2
	Max. Stress (ksi)	112.7	3.01	3.20		Max. Stress (ksi)	107.5	1.88	3.64
	Lifetime (cycles)	3.86×10^6	58,860	10^7+		Lifetime (cycles)	206,430	79,250	10^7+
	No. of Specimens	4	4	4		No. of Specimens	5	4	4
	Residual Strength (ksi)	---	---	30.01		Residual Strength (ksi)	---	---	30.0
	No. of Specimens	0	0	4		No. of Specimens	0	0	4

Notes: Fatigue lifetimes are log-mean values. All residual strengths determined by tensile test at 72°F.

1. Internal energy dissipation caused specimens to self-heat to between 160°F and 240°F at time of failures.
2. Internal energy dissipation caused specimens to self-heat to between 210°F and 240°F at time of failures.
3. Internal energy dissipation caused specimens to self-heat to between 270°F and 310°F at time of failures.
4. Internal energy dissipation caused specimens to self-heat to between -57°F and 150°F at time of failures.

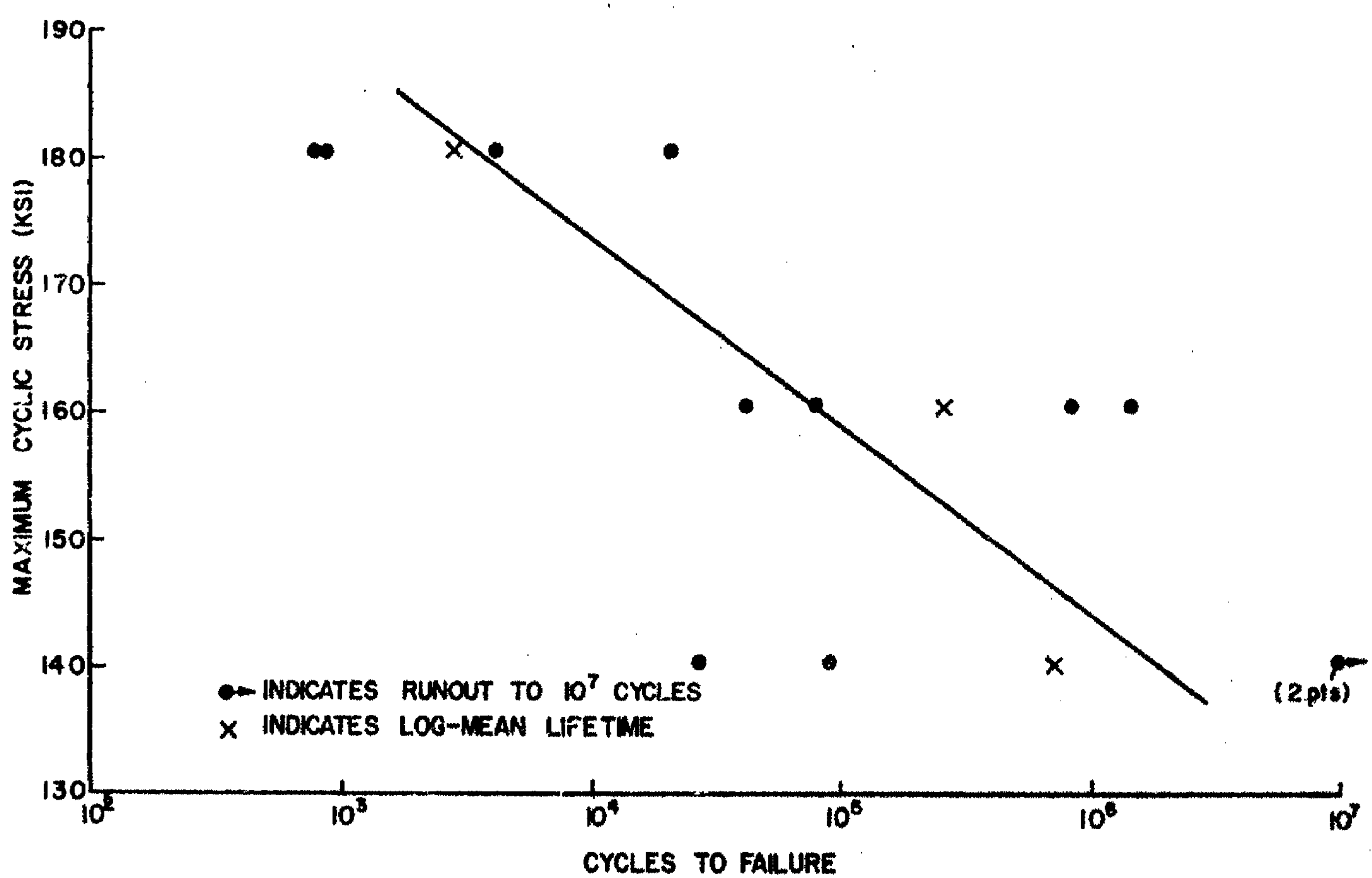


Figure 47. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at -67°F: 0° Fiber Orientation, R=0.10, 30 Hz.

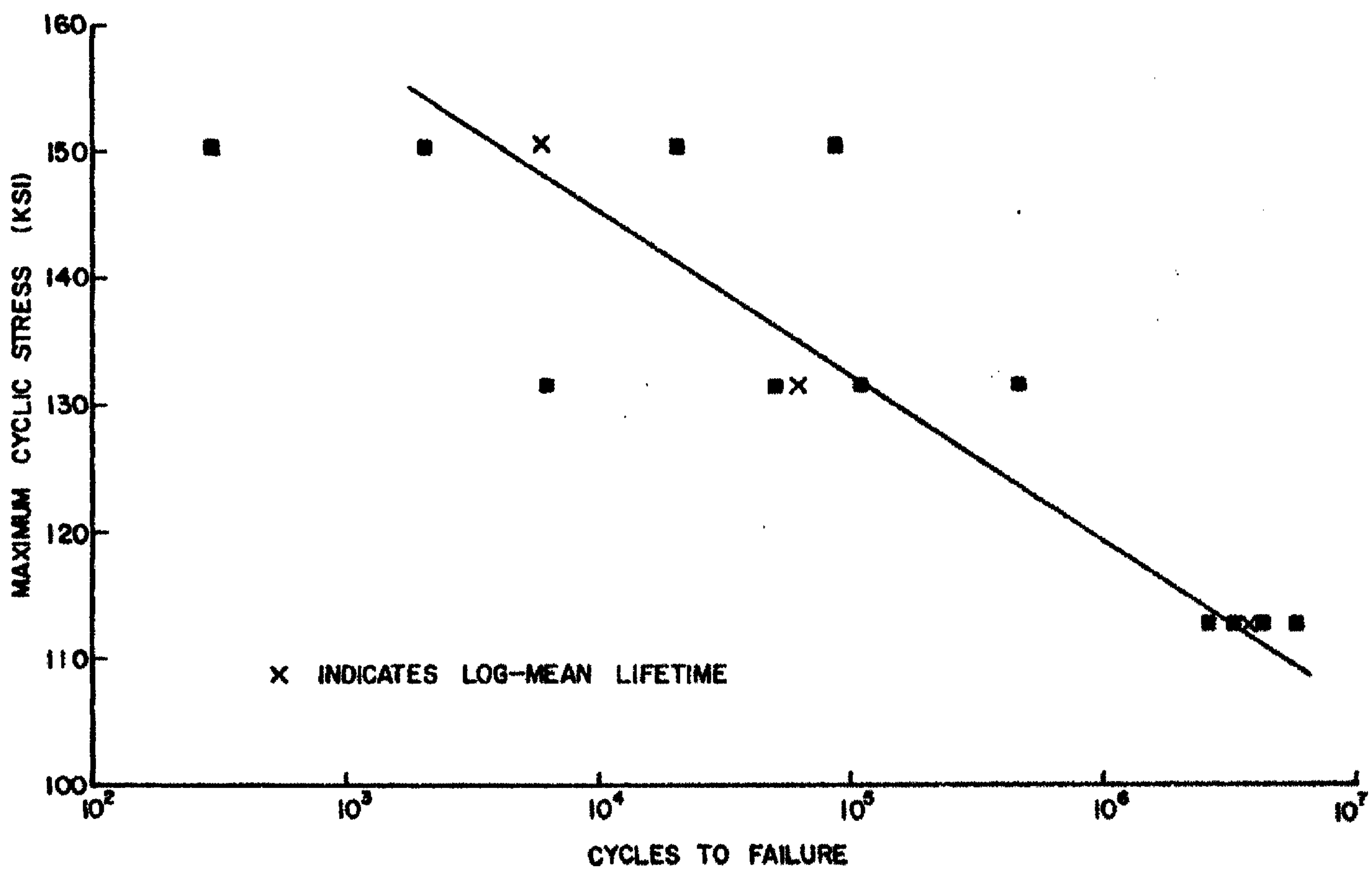


Figure 48. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at 72°F: 0° Fiber Orientation, R=0.10, 30 Hz.

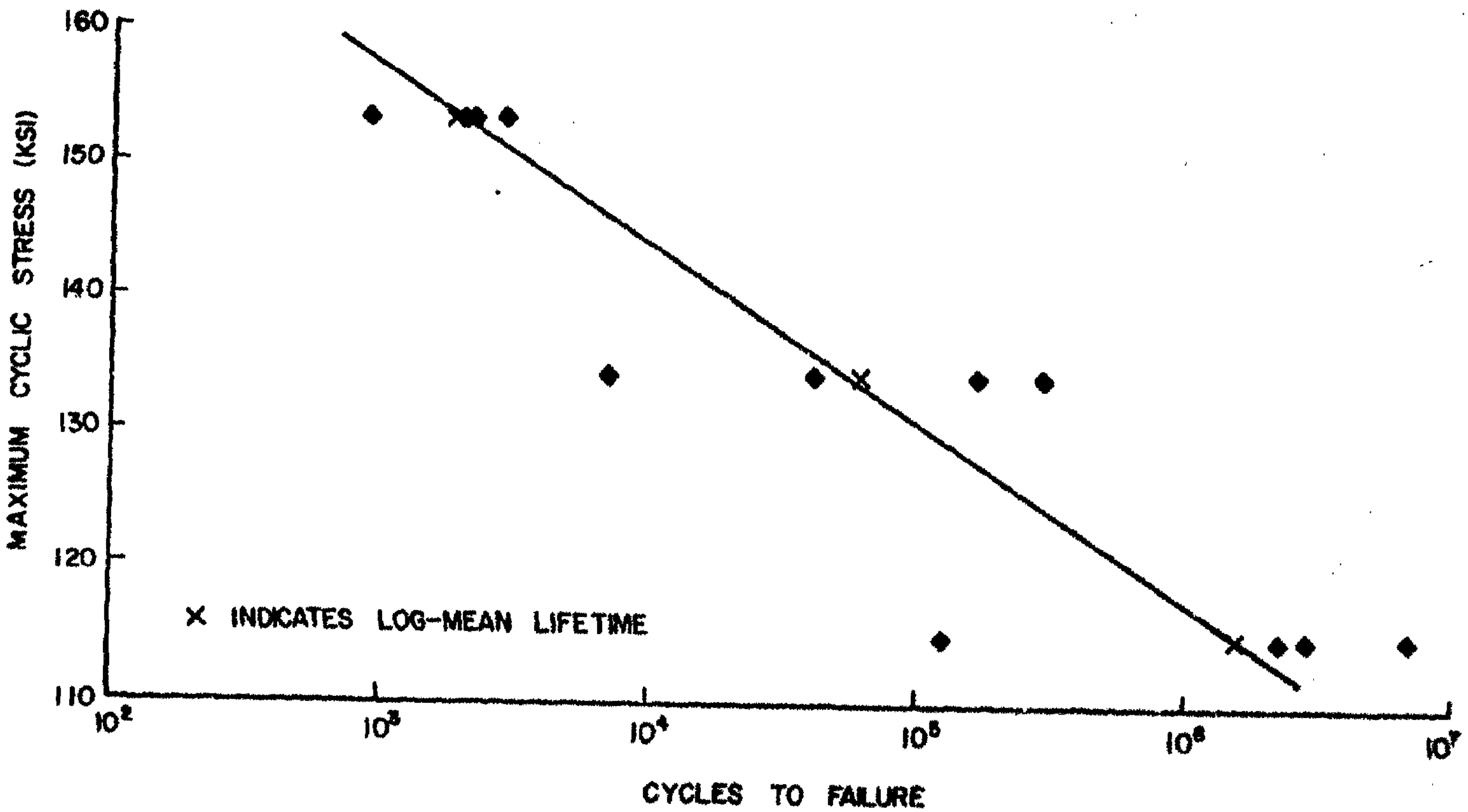


Figure 49. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at 180°F: 0° Fiber Orientation, R=0.10, 30 Hz.

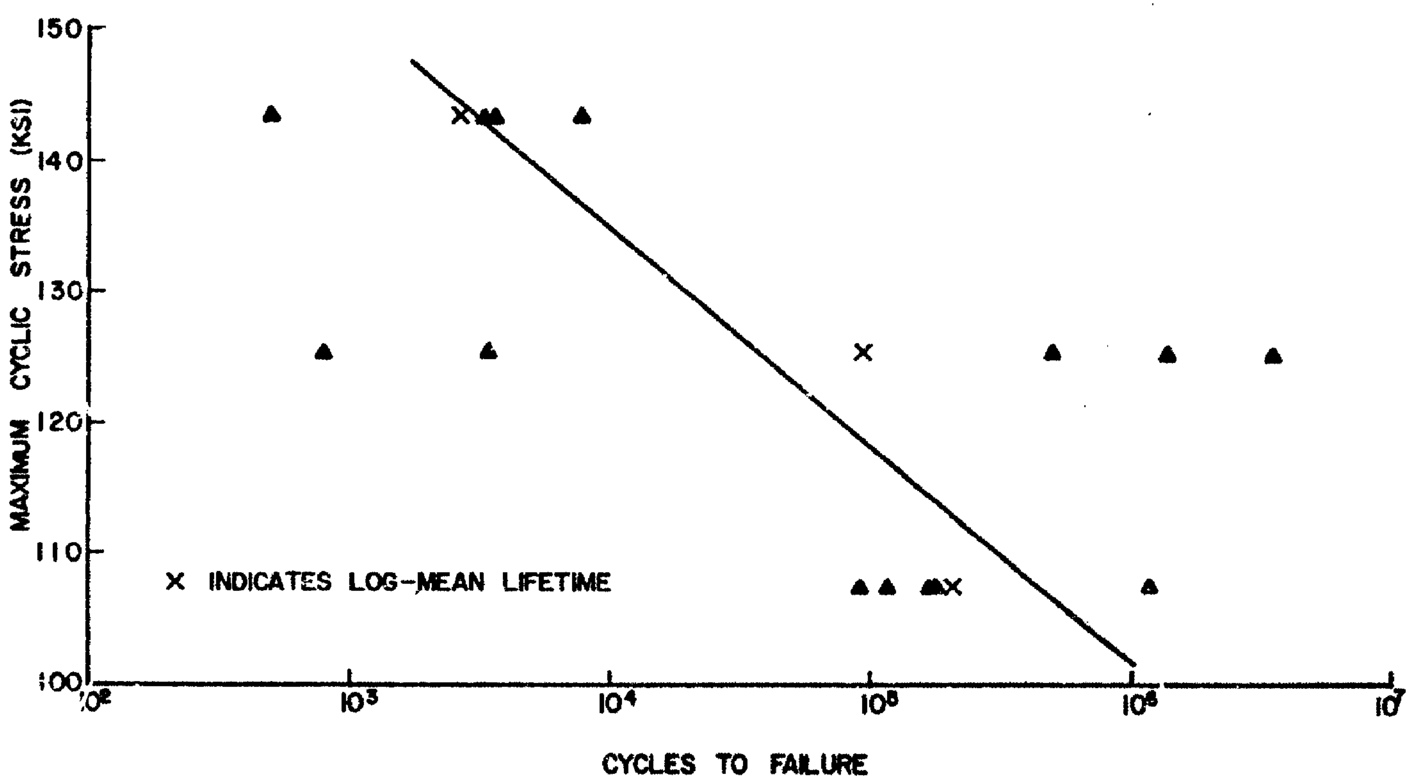


Figure 50. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at 250°F: 0° Fiber Orientation, R=0.10, 30 Hz.

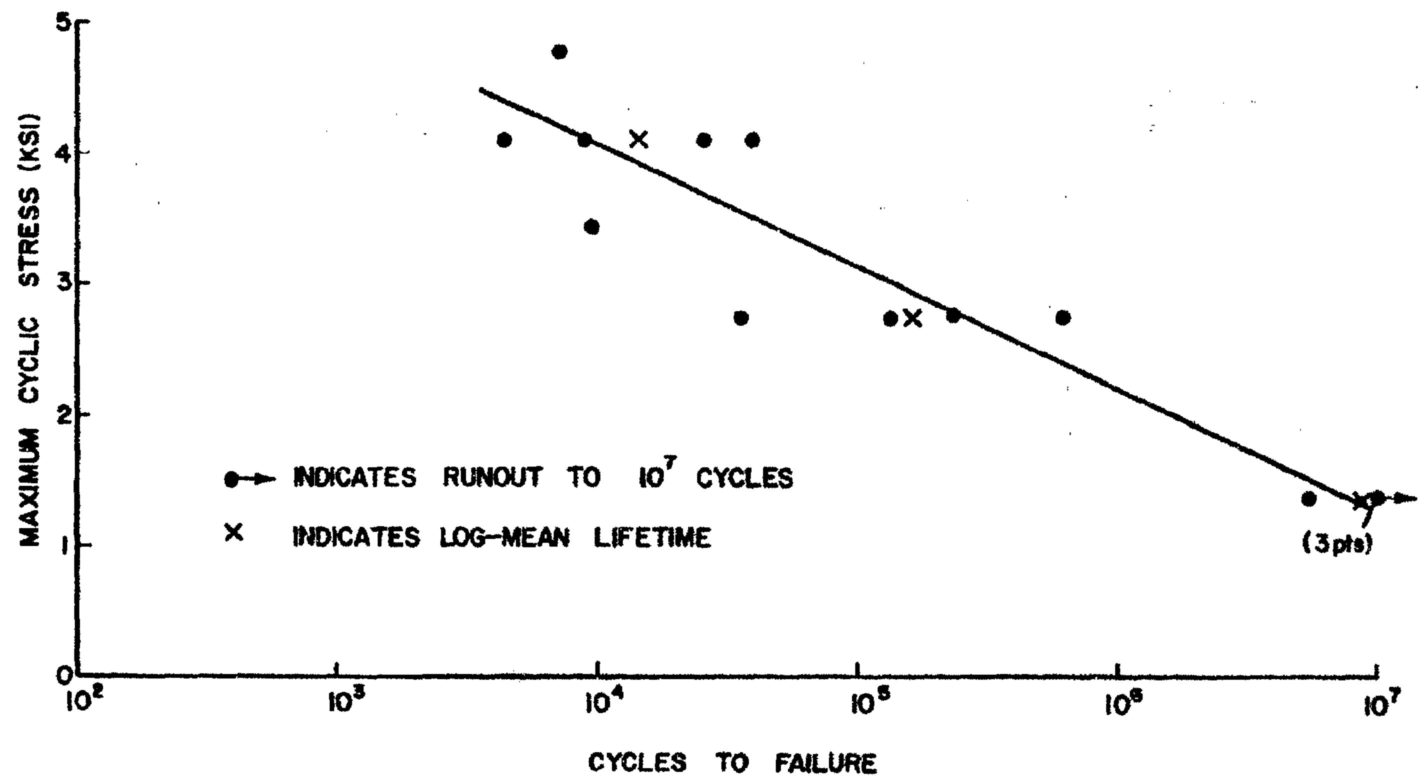


Figure 51. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at -67°F: 90° Fiber Orientation, R=0.10, 30 Hz.

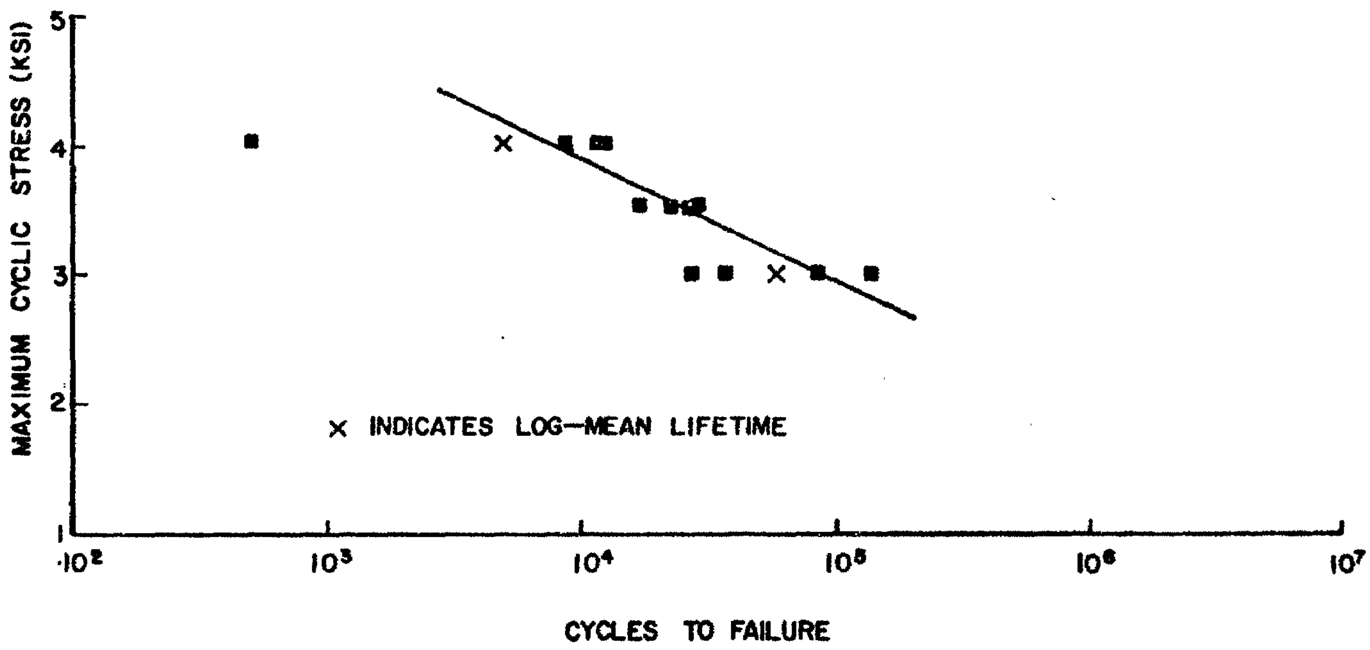


Figure 52. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at 72°F: 90° Fiber Orientation, R=0.10, 30 Hz.

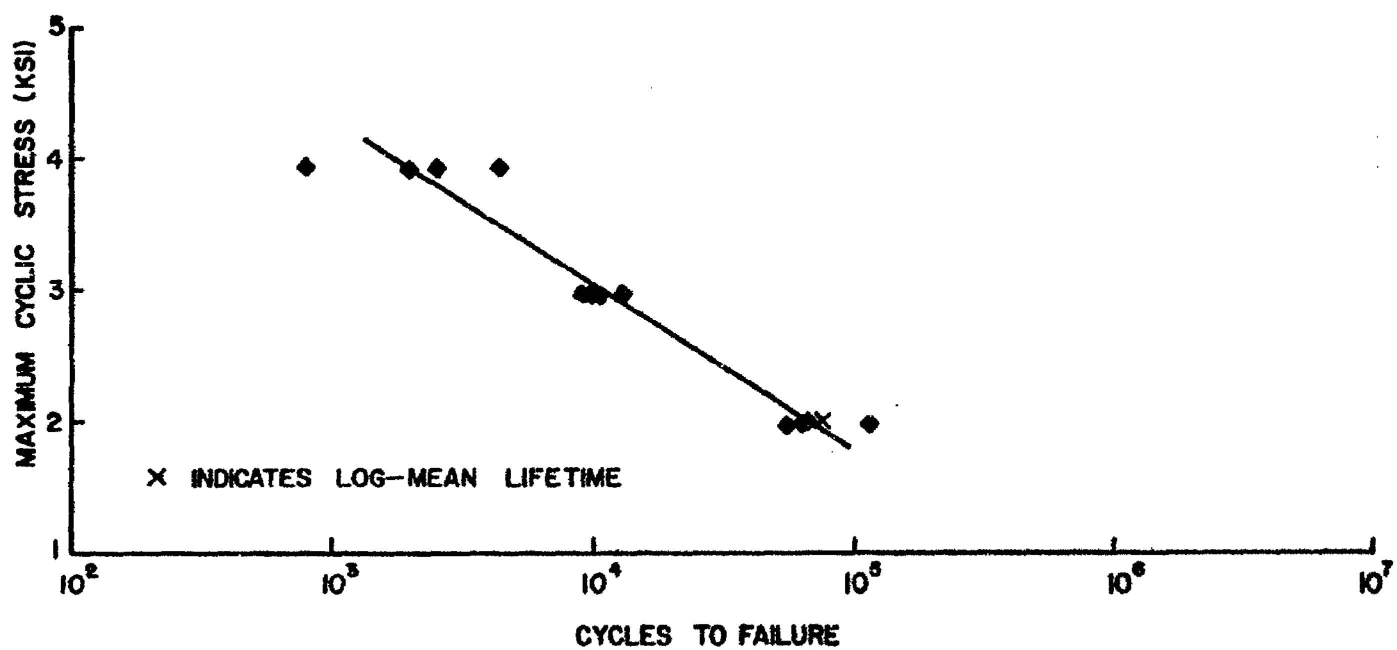


Figure 53. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at 180°F: 90° Fiber Orientation, R=0.10, 30 Hz.

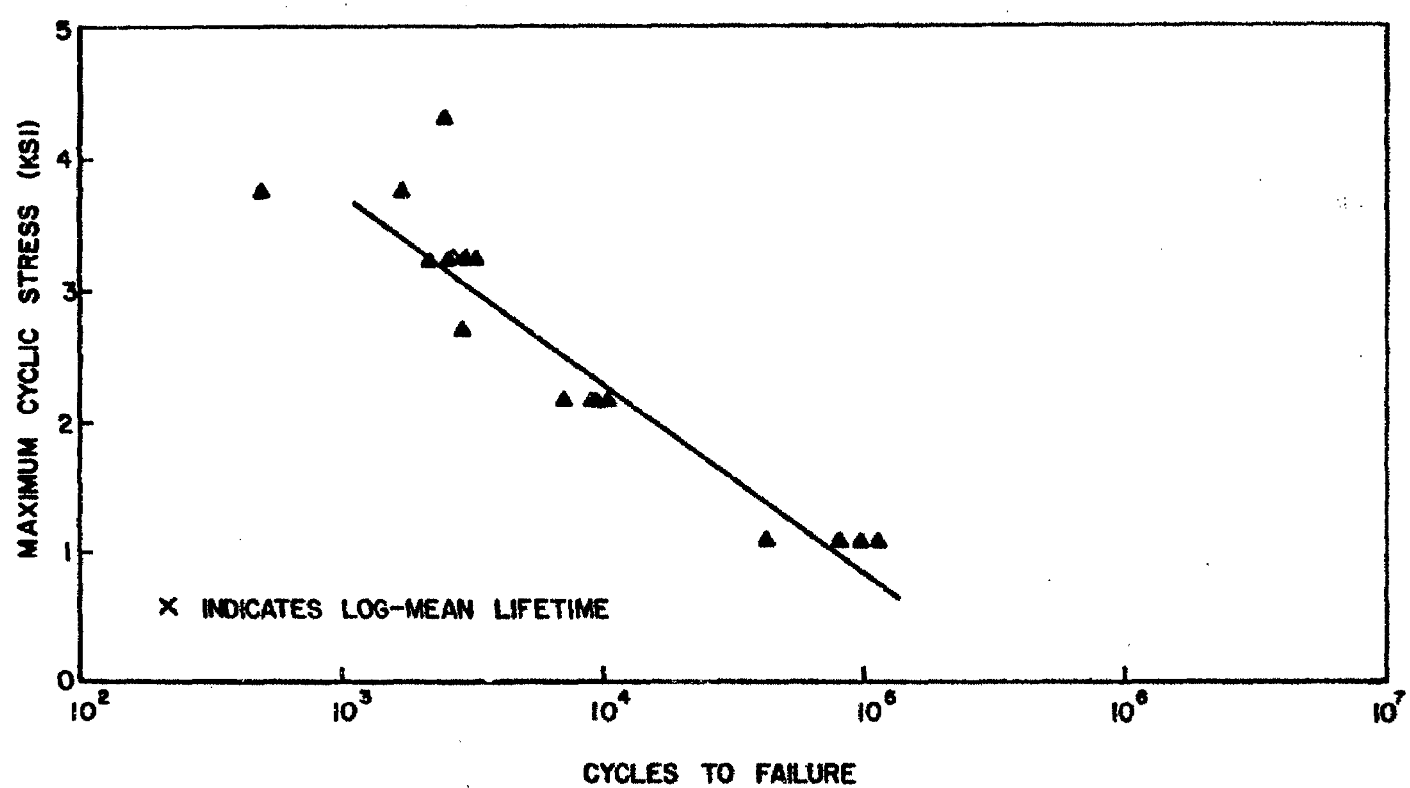


Figure 54. Tensile-Tensile Fatigue Behavior of Unidirectional AS/3004 Composite Laminates at 250°F: 90° Fiber Orientation, R=0.10, 30 Hz.

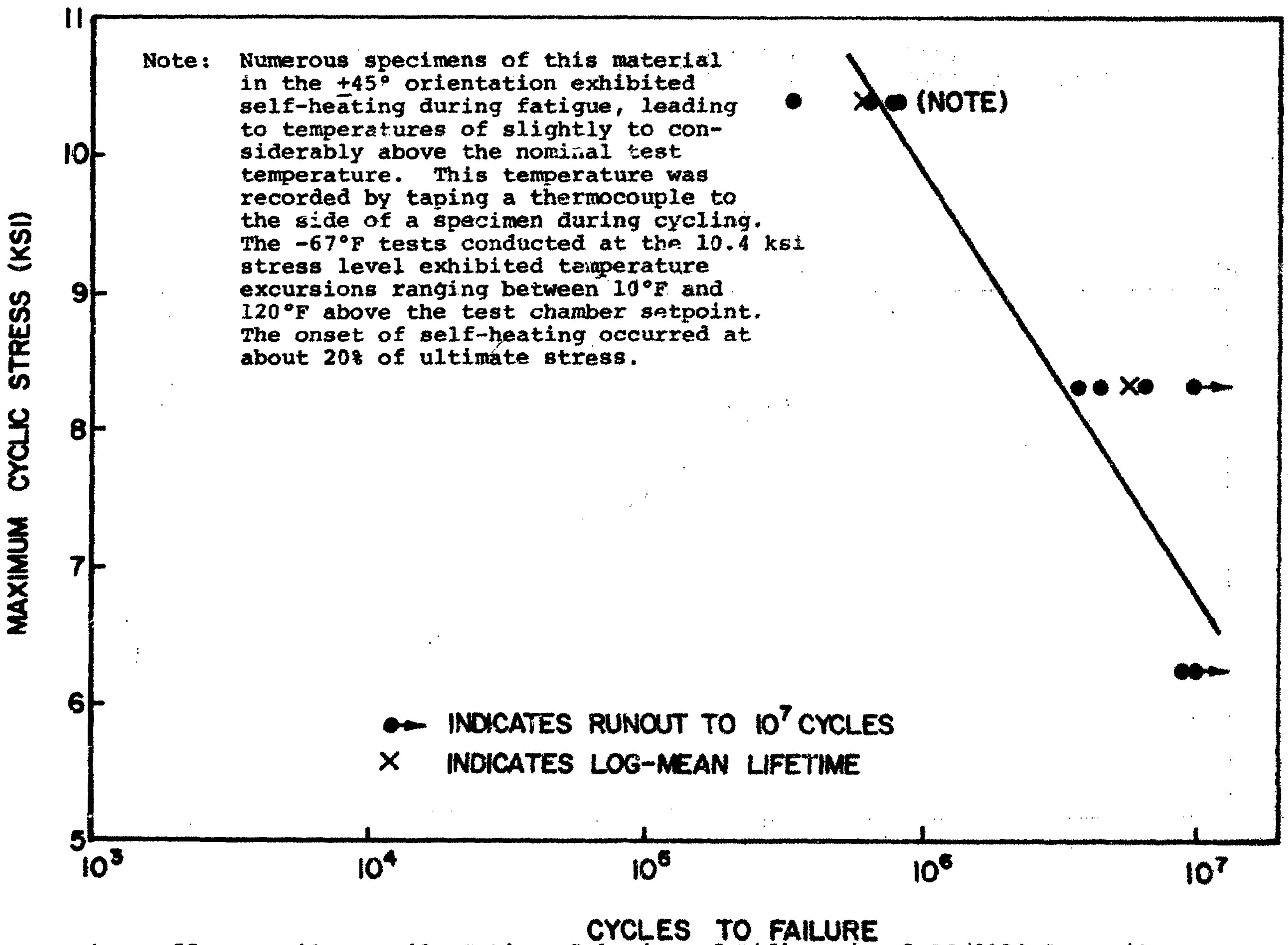


Figure 55. Tensile-Tensile Fatigue Behavior of Bidirectional AS/3004 Composite Laminates at -67°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

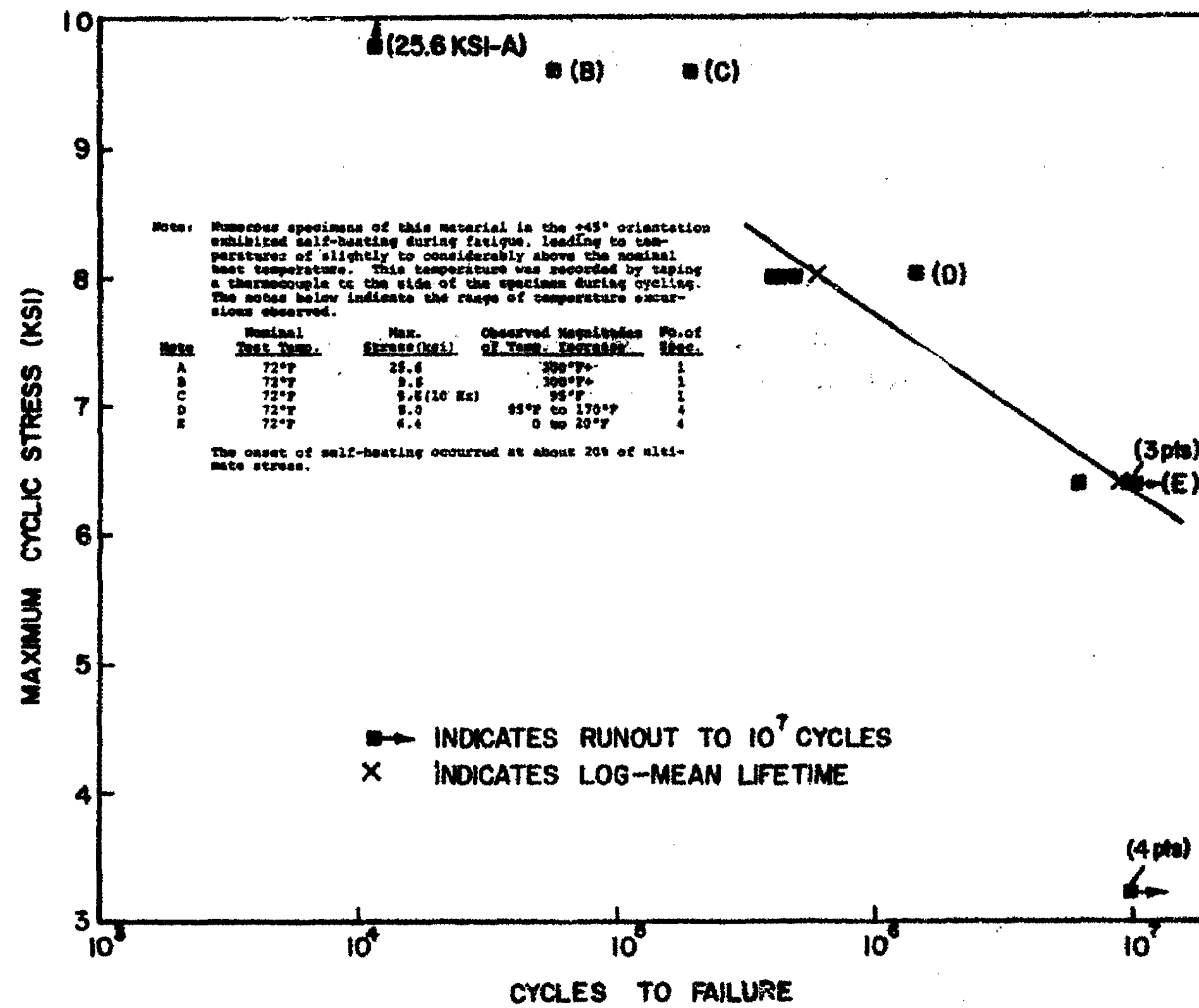


Figure 56. Tensile-Tensile Fatigue Behavior of Bidirectional AS/3004 Composite Laminates at 72°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

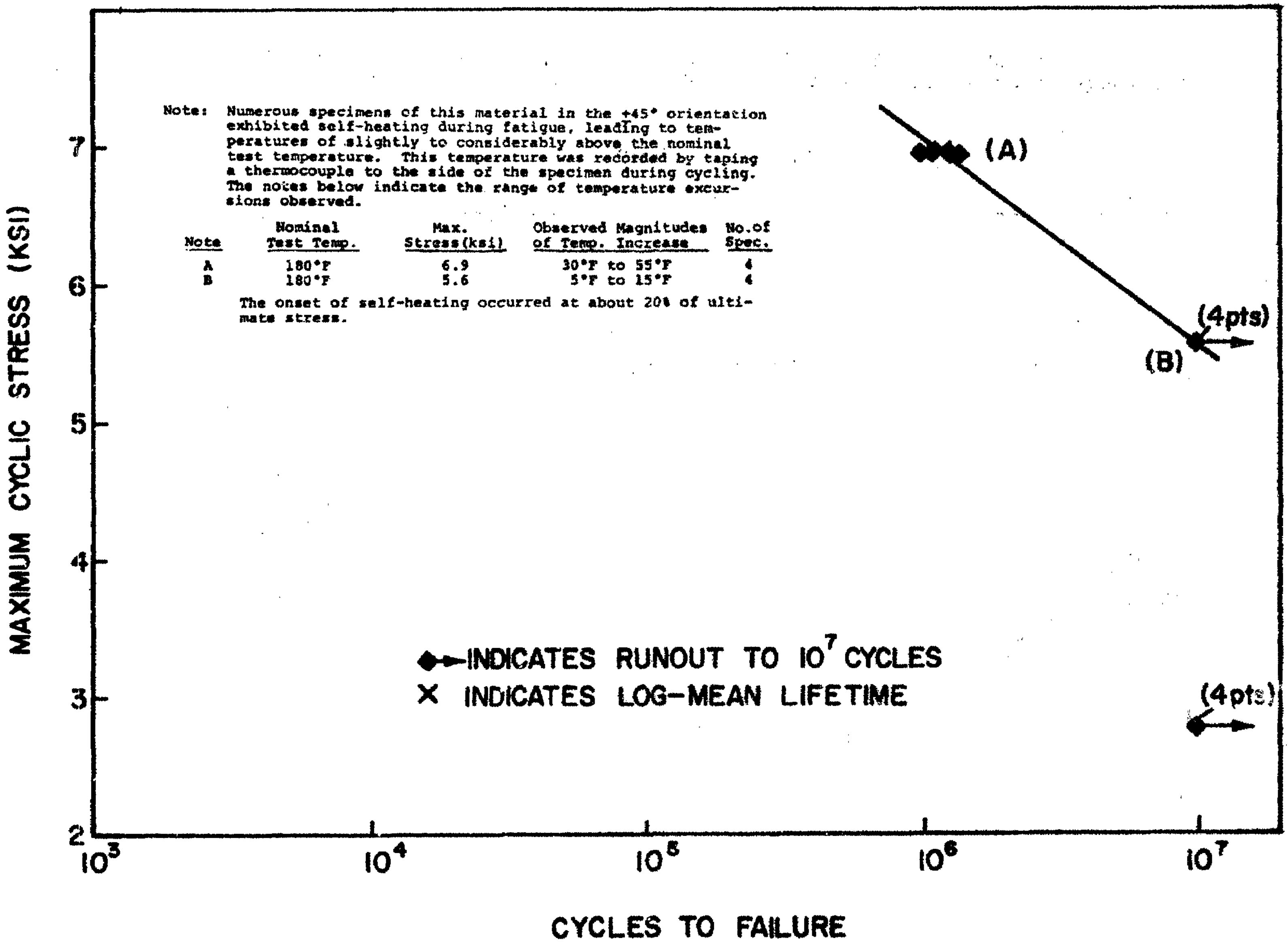


Figure 57. Tensile-Tensile Fatigue Behavior of Bidirectional AS/3004 Composite Laminates at 180°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

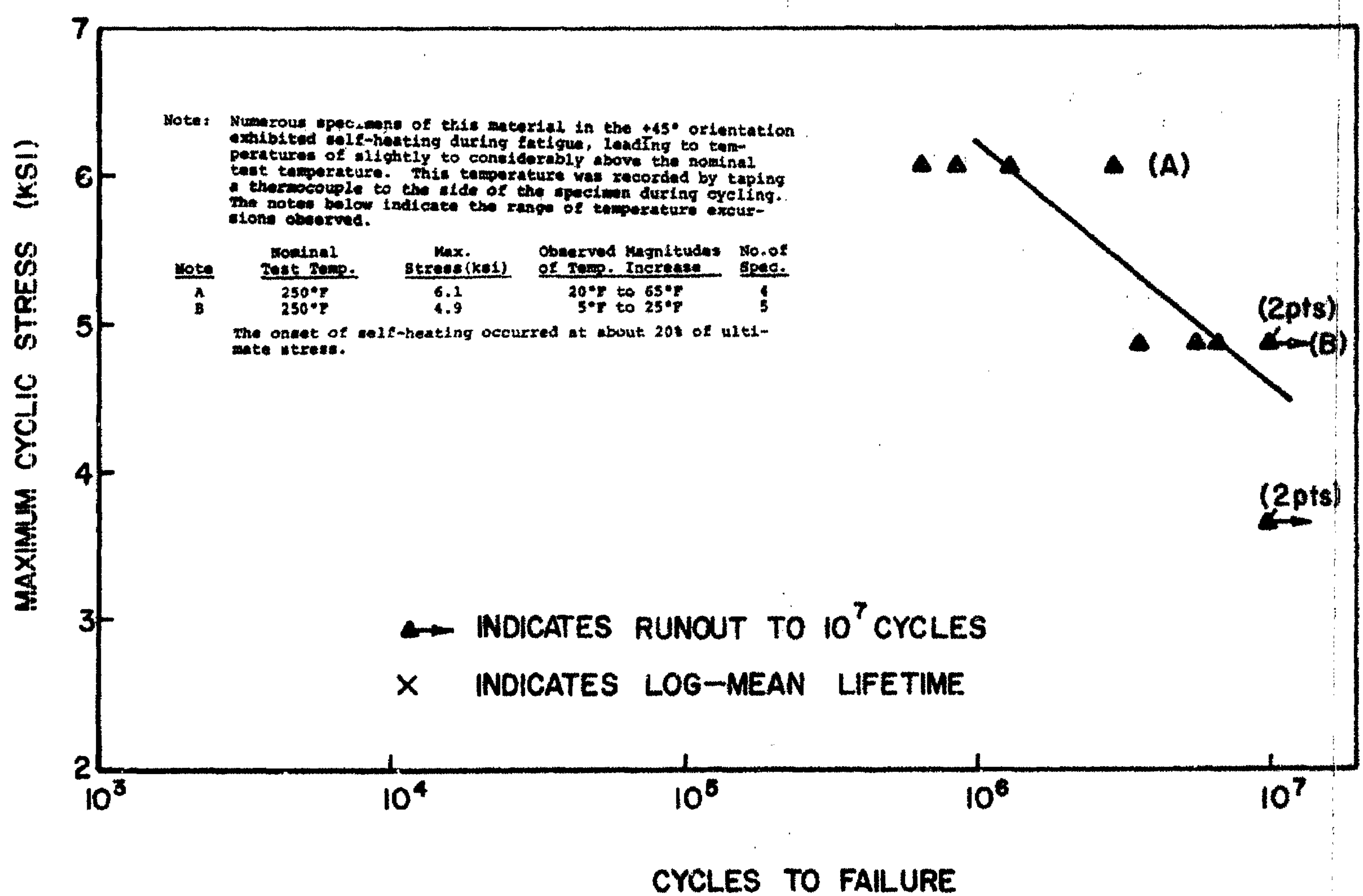


Figure 58. Tensile-Tensile Fatigue Behavior of Bidirectional AS/3004 Composite Laminates at 250°F: $\pm 45°$ Fiber Orientation, R=0.10, 30 Hz.

TABLE 31

CREEP PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Graphite/Polysulfone

Material System - AS/3004 Prepreg by - Hercules
Fiber - AS Matrix - P1700
Maximum Temperature Rating - 250°F
Resin Content - 34.2% by wt.
Fiber Content - 56.9% by vol.
Void Content - 1.0% by vol.

Laminate Sp. Gr. - 1.53
Average Ply Thickness - 0.0055 inch
No. of panels from which specimens were tested in this table - 32
Thickness of each type specimen - 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply

Test Method - Straight-sided Tension Reference - Design Guide

CREEP

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				180°F	Stress Level (ksi)	153.2	2.96	8.33
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	939	149	4003
	No. of Specimens					No. of Specimens	2[6]	1[3]	3
	Residual Strength (ksi)					Residual Strength (ksi)	202.3	5.65	32.92
	No. of Specimens					No. of Specimens	2	1	3
	Stress Level (ksi)					Stress Level (ksi)	134.1	2.47	5.56
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	100	116	1103
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	209.7	4.55	30.83
	No. of Specimens					No. of Specimens	3	3	3
	Stress Level (ksi)					Stress Level (ksi)	107.5	1.97	2.78
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	30	76	349
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	182.1	5.34	31.94
	No. of Specimens					No. of Specimens	3	3	3
72°F	Stress Level (ksi)	150.3	4.02	9.61	250°F	Stress Level (ksi)	143.3	2.70	7.29
	Creep Strain, 500 hr(μ in/in)	118	---[1]	5285		Creep Strain, 500 hr(μ in/in)	554	---[1]	11,570
	No. of Specimens	3	4	3		No. of Specimens	1[4]	3	3
	Residual Strength (ksi)	172.0	---	26.95		Residual Strength (ksi)	181.2	---	29.95
	No. of Specimens	3	0	3		No. of Specimens	1	0	3
	Stress Level (ksi)	131.5	3.52	6.40		Stress Level (ksi)	125.4	2.16	4.86
	Creep Strain, 500 hr(μ in/in)	136	284	827		Creep Strain, 500 hr(μ in/in)	736[2]	400	3836[5]
	No. of Specimens	3	3	3		No. of Specimens	3	1[3]	2
	Residual Strength (ksi)	185.9	5.26	28.63		Residual Strength (ksi)	181.5	2.86	29.85
	No. of Specimens	3	3	3		No. of Specimens	3[2]	1	2
	Stress Level (ksi)	112.7	3.01	3.20		Stress Level (ksi)	107.5	1.62	2.43
	Creep Strain, 500 hr(μ in/in)	105	245	367		Creep Strain, 500 hr(μ in/in)	135	---[1]	895[5]
	No. of Specimens	3	3	3		No. of Specimens	2[5]	3	2
	Residual Strength (ksi)	197.4	5.67	29.36		Residual Strength (ksi)	151.7	---	33.69
	No. of Specimens	3	3	3		No. of Specimens	3	0	3

Notes: All values represent arithmetic averages. All residual strength determined by tensile test at 72°F.

1. All specimens failed during test.
2. One specimen split along edge and exhibited considerably more strain than other two, but it still held load.
3. Two specimens failed during test.
4. Three specimens failed on loading.
5. Lost strain gage on one specimen early in test.
6. One specimen failed on loading.

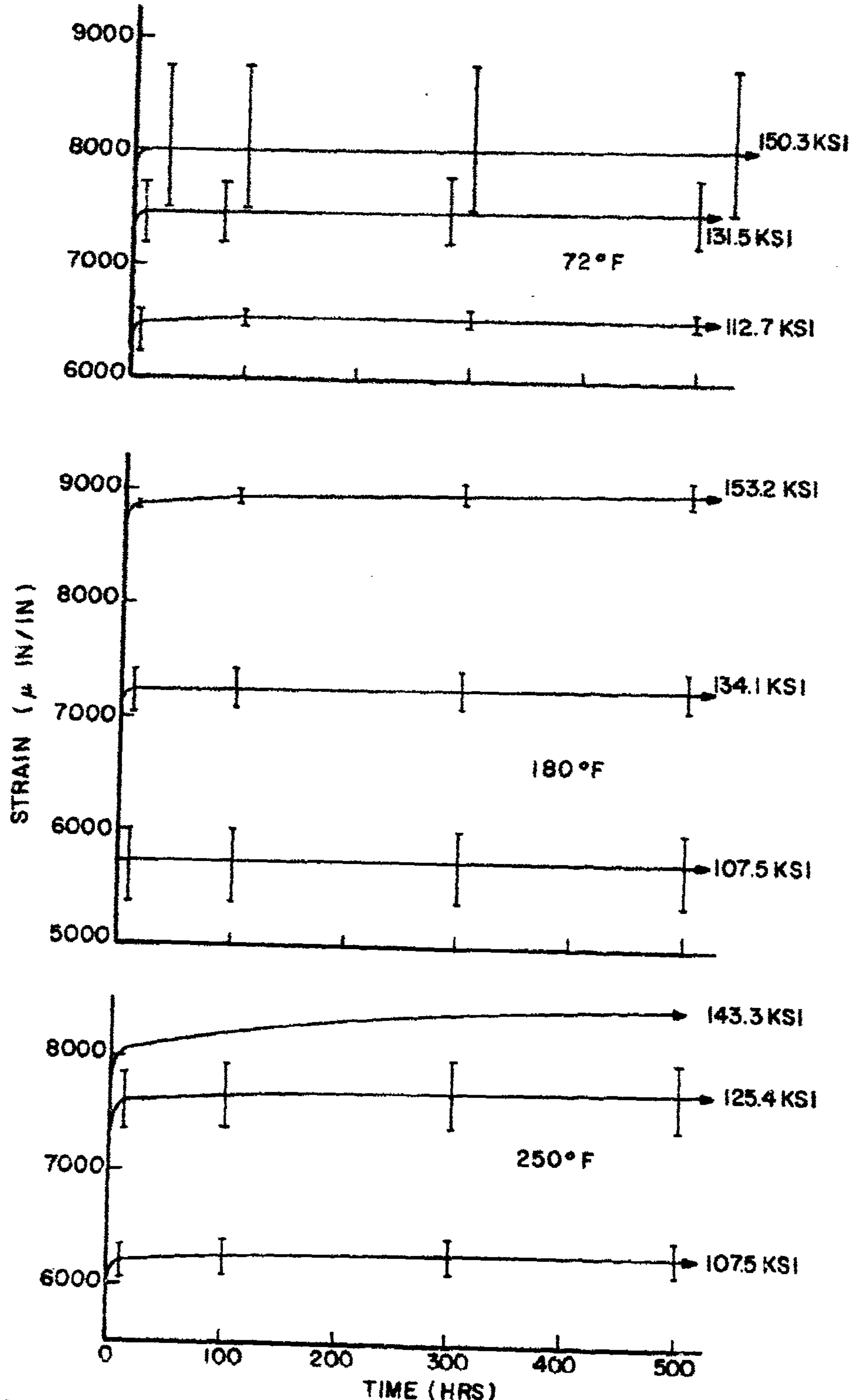


Figure 59. Tensile Creep Behavior of Unidirectional AS/3004 Composite Laminates: 0° Fiber Orientation.

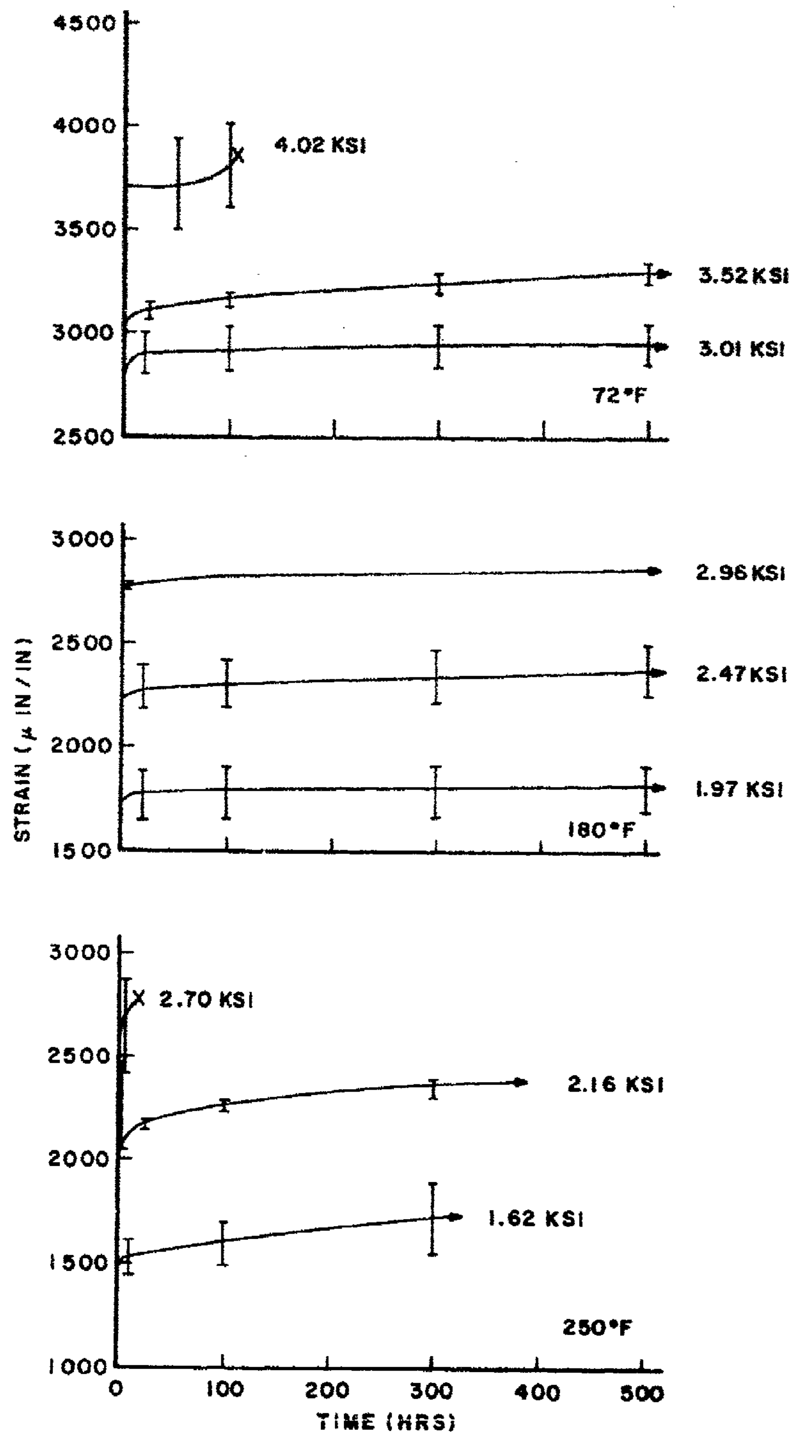


Figure 60. Tensile Creep Behavior of Unidirectional AS/3004 Composite Laminates: 90° Fiber Orientation.

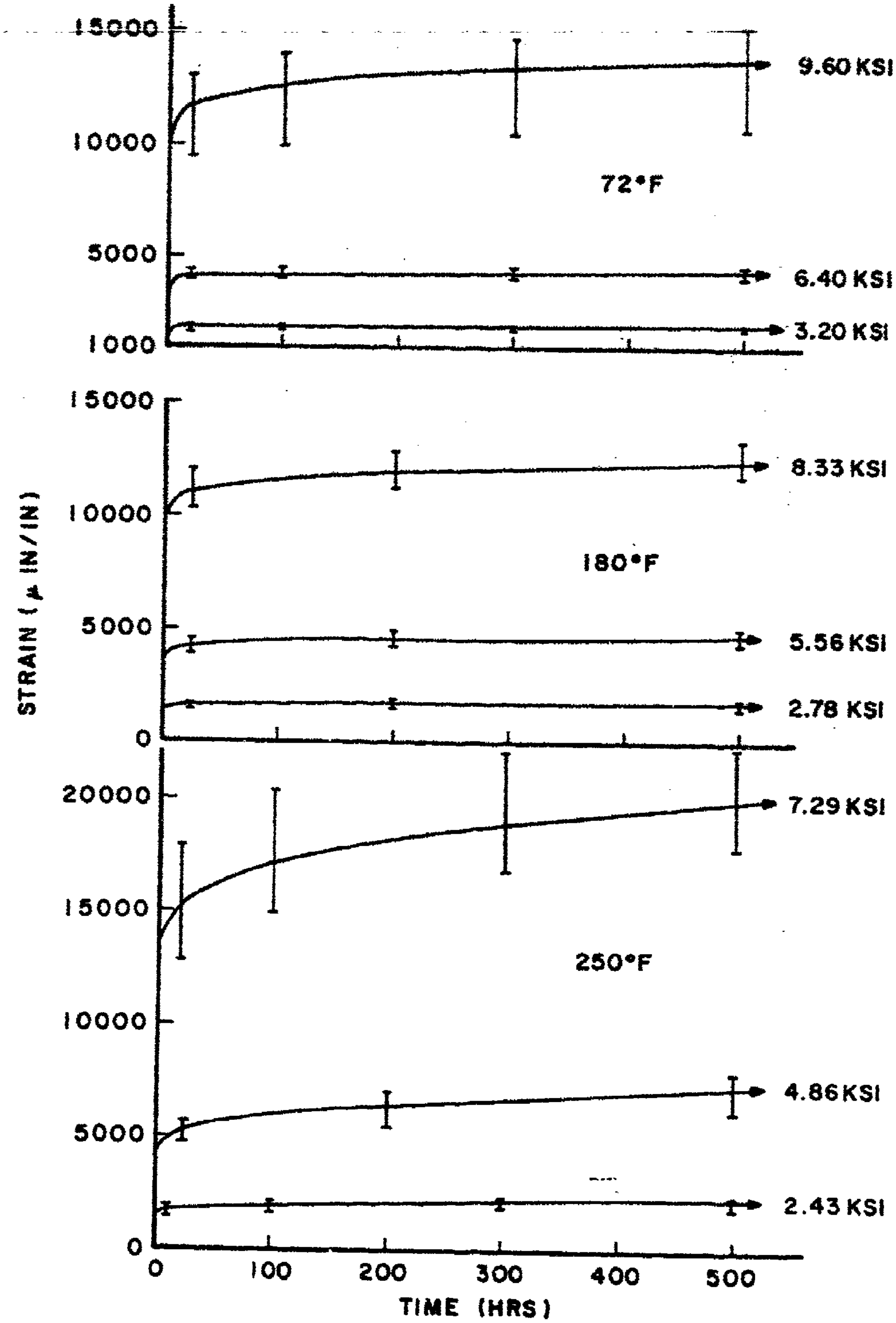


Figure 61. Tensile Creep Behavior of Bidirectional AS/3004 Composite Laminates: ±45° Fiber Orientation.

TABLE 32

STRESS RUPTURE PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Graphite/Polysulfone

Material System - AS/3004 Prepreg by - Hercules
Fiber - AS Matrix - P1700
Maximum Temperature Rating - 250°F
Resin Content - 34.0% by wt.
Fiber Content - 57.0% by vol.
Void Content - 1.0% by vol.

Laminate Sp. Gr. - 1.53
Average Ply Thickness - 0.0056 inch
No. of panels from which specimens were tested in this table - 20
Thickness of each type specimen - 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply

Test Method - Straight-sided Tension Reference - Design Guide

STRESS RUPTURE

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				180°F	Stress Level (ksi)	153.2	2.96	8.33
	Time to Failure (hrs)					Time to Failure (hrs)	500+	500+	500+
	No. of Specimens					No. of Specimens	2[2]	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	202.3	5.65	32.92
	No. of Specimens					No. of Specimens	2	1	3
	Stress Level (ksi)					Stress Level (ksi)	134.1	2.47	5.56
	Time to Failure (hrs)					Time to Failure (hrs)	500+	500+	500+
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	209.7	4.55	30.83
	No. of Specimens					No. of Specimens	3	3	3
72°F	Stress Level (ksi)	150.3	4.02	9.61	250°F	Stress Level (ksi)	143.3	2.70	7.29
	Time to Failure (hrs)	500+	70.3	500+		Time to Failure (hrs)	78[1]	17.4	500+
	No. of Specimens	3	3	3		No. of Specimens	4	3	3
	Residual Strength (ksi)	172.0	---	26.95		Residual Strength (ksi)	181.2	---	29.95
	No. of Specimens	3	0	3		No. of Specimens	1	0	3
	Stress Level (ksi)	131.5	3.52	6.40		Stress Level (ksi)	125.4	2.16	4.86
	Time to Failure (hrs)	500+	500+	500+		Time to Failure (hrs)	500+	500+	500+
	No. of Specimens	3	3	3		No. of Specimens	3	3	3
	Residual Strength (ksi)	185.9	5.26	28.63		Residual Strength (ksi)	181.5	2.84	29.85
	No. of Specimens	3	3	3		No. of Specimens	3	1	3

Notes: All values represent arithmetic averages. All residual strengths determined by tensile test at 72°F.
1. Three specimens failed on loading.
2. One specimen failed on loading.

TABLE 33

THERMOPHYSICAL PROPERTIES OF AS/3004 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/3004 Prepreg by - Hercules (Graphite/Polysulfone) Fiber - AS Matrix - P1700 Maximum Temperature Rating - 250°F Resin Content - 33.7% by wt. Fiber Content - 57.4% by vol. Void Content - ±0 Thickness of each type specimen:	Laminate Sp. Gr. - 1.55 Average Ply Thickness -0.0052 inch No. of panels from which specimens were tested in this table -5 Therm. Exp.- 40 ply Spec.Ht.-20 ply Therm. Cond.- 30 ply Glass Trans.-14 ply			
THERMOPHYSICAL PROPERTIES: 0°				
	-67°F	72°F	180°F	250°F
Thermal Expansion				
α_x (μin/in-°F)	-0.007	-0.006	-0.006	-0.006
α_y (μin/in-°F)	17.00	17.00	17.00	17.00
No. of Specimens per direction	3	3	3	3
Specific Heat				
C_p (btu/lb.-°F)	0.142	0.183	0.215	0.235
No. of Specimens	4	4	4	4
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	0.26	0.30	0.34	0.36
No. of Specimens	6	6	6	5
Glass Transition Temp.				
Dry (°F)	417°F			
Wet (°F)	379°F			
THERMOPHYSICAL PROPERTIES: ±45°				
Thermal Expansion				
α_x (μin/in-°F)	±0	1.6	1.8	1.8
No. of Specimens per direction	3	3	3	3
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	0.23	0.27	0.30	0.32
No. of Specimens	3	3	4	4

Note: On unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

TABLE 34

TENSILE PROPERTIES OF AS/3004 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES

Graphite/Polysulfone

Material System - AS/3004	Prepreg by - Hercules
Fiber - AS / Matrix - P1700	Laminate Sp. Gr. - 1.51
Maximum Rated Temperature - 250°F	Average Ply Thickness - 0.0054 inch
Resin Content - 35.9% by wt.	No. of panels from which specimens were tested in this table - 6
Fiber Content - 56.1% by vol.	
Void Content - 12% by vol.	Aging Conditions - 160°F & 100% R.H.

Thickness of each type specimen: 90°-15 plies; ±45°-8 plies

TENSION: 90°

	72°F	250°F	72°F	250°F
Exposure Time (hrs)	9	9	744	744
Weight Gain (% of orig. dry wt.)	0.19	0.20	0.32[3]	0.31[3]
Stnd. Dev. (%)	0.01	0.03	0.02	0.02
No. of Specimens	5	5	5	5
F_y^{tu} (ksi)	5.72	4.13	3.96	3.03
Stnd. Dev. (ksi)	0.77	0.73	0.45	0.38
Range (ksi)	5.00-6.95	2.90-4.81	3.45-4.48	2.79-3.62
No. of Specimens	5	5	5	5
F_y^{tpl} (ksi)	3.00	2.99	2.76	2.04
Stnd. Dev.	0.52	0.57	0.42	0.52
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.20	1.09	1.11	1.08
Stnd. Dev.	0.02	0.08	0.03	0.02
No. of Specimens	5	5	5	5
ϵ_y^{tu} (μ in/in)	4960	4000	3640	2960
Stnd. Dev.	710	840	450	420
No. of Specimens	5	5	5	5
Test Method	Straight-sided tension			
Reference	Design Guide			

TENSION: ±45°

	72°F	250°F	72°F	250°F
Exposure Time (hrs)	3	3	576	576
Weight Gain (% of orig. dry wt.)	0.25	0.21	0.43[3]	0.43[3]
Stnd. Dev. (%)	0.2	0.03	0.02	0.02
No. of Specimens	5	5	5	5
F_x^{tu} (ksi)	37.48	20.46	32.52	23.97
Stnd. Dev. (ksi)	8.13	1.82	1.44	2.47
Range (ksi)	27.08-45.23	17.99-22.02	31.22-34.45	20.75-26.56
No. of Specimens	5	4	5	4
F_x^{tpl} (ksi)	3.46	2.36	4.40	2.47
Stnd. Dev.	0.10	0.29	0.30	0.31
No. of Specimens	5	4	5	4
E_x^t (Msi)	1.94	1.84	2.20	2.07
Stnd. Dev.	0.15	0.29	0.08	0.10
No. of Specimens	5	4	5	4
ϵ_x^{tu} (μ in/in)	58,200[1]	38,900[1]	50,500[1]	167,000[2]
Stnd. Dev.	7,600[1]	11,000[1]	8100[1]	---
No. of Specimens	5	4	5[1]	1[2]
Test Method	Straight-sided tension			
Reference	Design Guide			

Notes:

1. Surface plies cracked at about 60% of ultimate stress, breaking gages.
2. Surface plies on three specimens cracked at 60% of ultimate stress, breaking gages.
3. 100% saturation level at aging conditions.

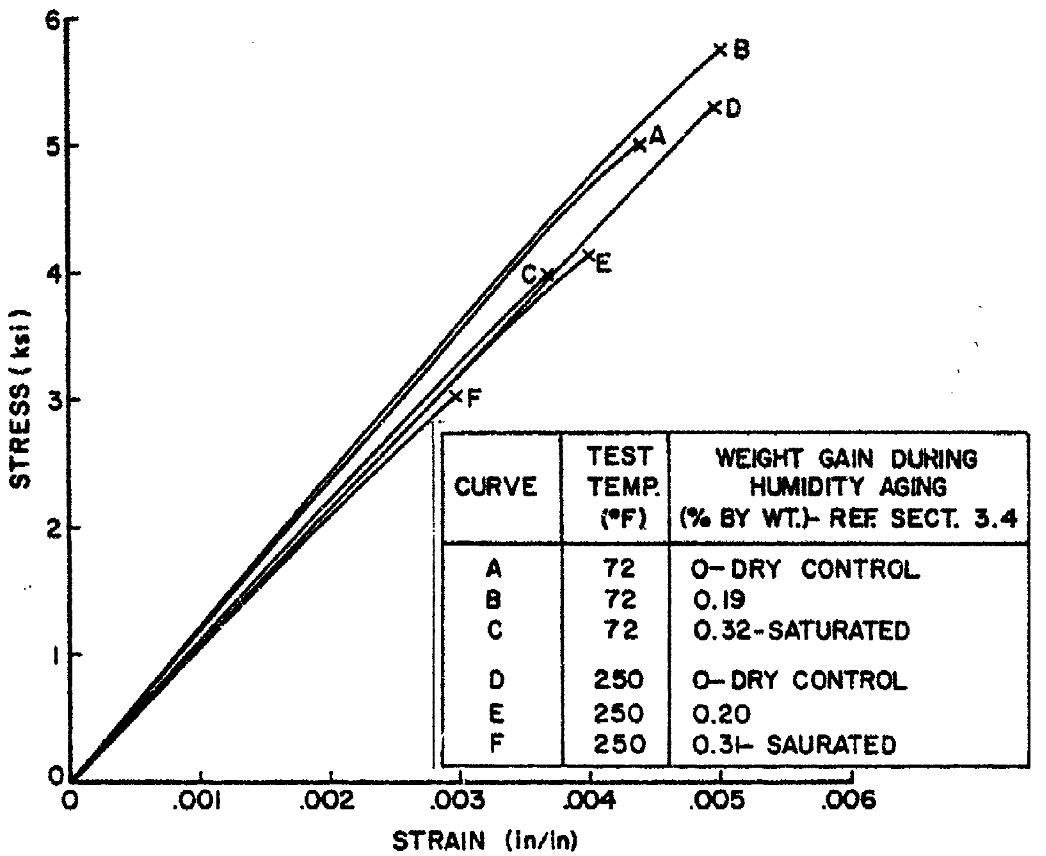
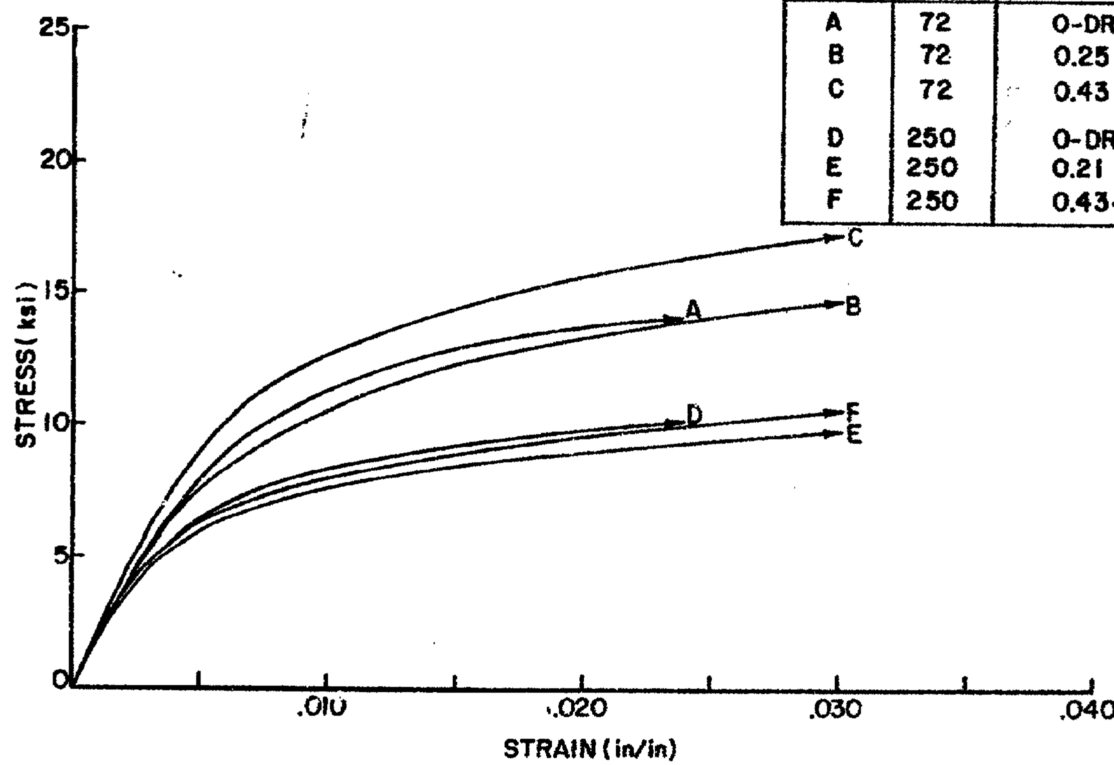


Figure 62. Tensile Stress-Strain Curves for Unidirectional AS/3004 Composite Laminates After Humidity Aging: 90° Fiber Orientation.



CURVE	TEST TEMP. (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)-REF. SECT. 3.4
A	72	0-DRY CONTROL
B	72	0.25
C	72	0.43 - SATURATED
D	250	0-DRY CONTROL
E	250	0.21
F	250	0.43- SATURATED

Figure 63. Tensile Stress-Strain Curves for Bidirectional AS/3004 Composite Laminates After Humidity Aging: ±45° Fiber Orientation.

TABLE 35

SHEAR PROPERTIES OF AS/3004 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES

Graphite/Polysulfone

Material System - AS/3004
Fiber - AS   Matrix - P1700
Maximum Rated Temperature - 250°F
Resin Content - 33.2% by wt.
Fiber Content - 57.1% by vol.
Void Content - 12% by vol.

Prepreg by - Hercules
Laminate Sp. Gr. - 1.52
Average Ply Thickness - 0.0053 inch
No. of panels from which specimens were tested in this table -
Aging Conditions - 160°F & 100% R.H.

Thickness of each type specimen: Inplane shear-8 plies; Interlaminar shear-14 plies

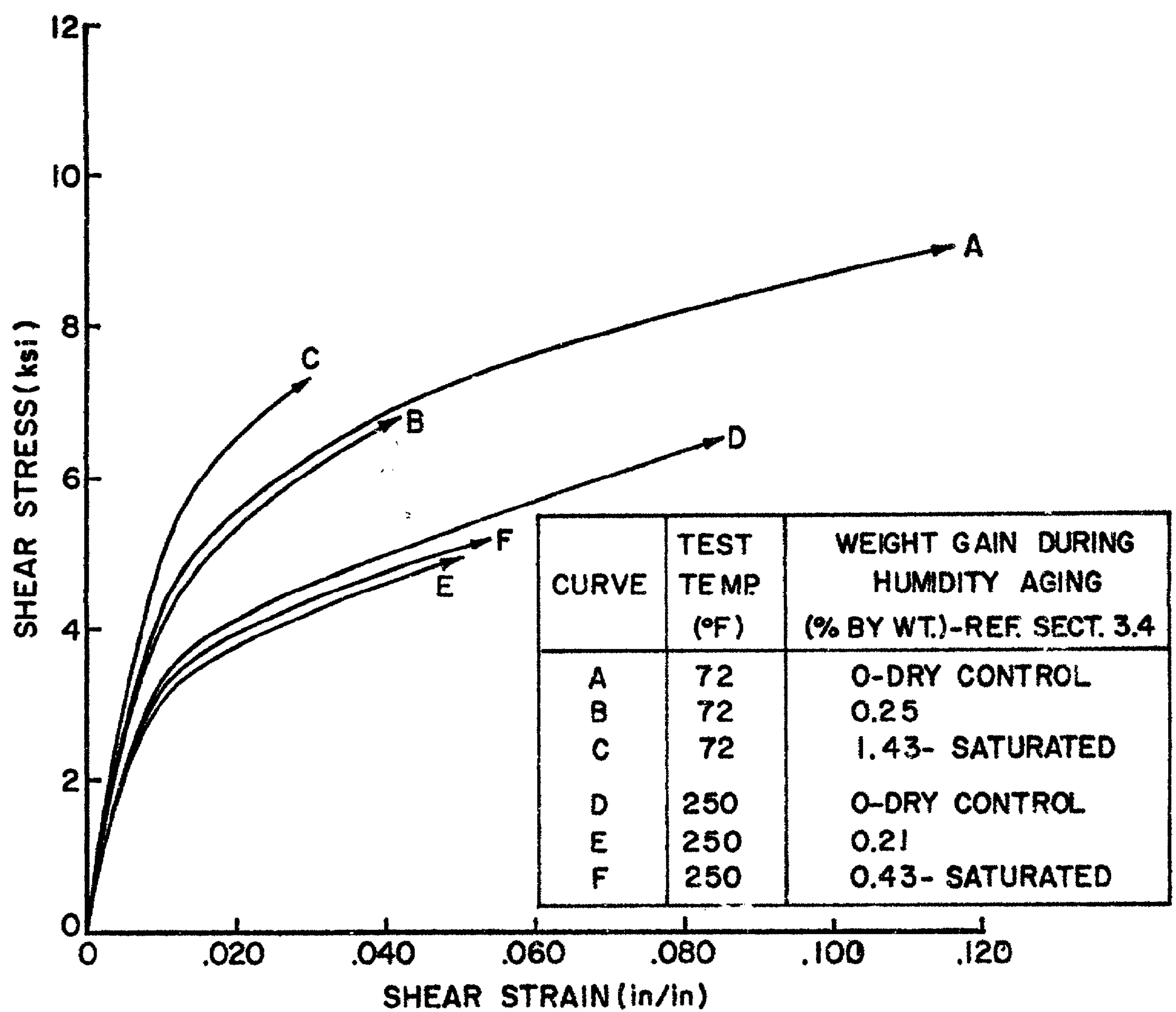
INPLANE SHEAR

Test Temperature	72°F	250°F	72°F	250°F
Exposure Time (hrs)	3	3	576	576
Weight Gain (% of orig. dry wt.)	0.25	0.21	0.43[1]	0.43[1]
Stnd. Dev. (%)	0.02	0.03	0.02	0.02
No. of Specimens	5	5	5	5
F_{xy}^{su} (ksi)	18.74	10.23	16.26	11.98
Stnd. Dev. (ksi)	4.07	0.91	0.72	1.23
Range (ksi)	13.54-22.33	8.99-11.01	15.61-17.23	10.38-13.28
No. of Specimens	5	4	5	4
G_{xy}^{s} (Msi)	0.54	0.48	0.60	0.48
Stnd. Dev.	0.04	0.07	0.03	0.02
No. of Specimens	5	4	5	4
Test Method	±45° straight-sided tension			
Reference	J. Comp. Mtls. [V6, p252 & V7, p124]			

INTERLAMINAR SHEAR

Exposure Time (hrs)	552	552	625	625
Weight Gain (% of orig. dry wt.)	0.69	0.69	0.87[1]	0.87[1]
Stnd. Dev. (%)	0.46	0.47	0.19	0.15
No. of Specimens	5	5	5	5
F^{isu} (ksi)	8.80	7.06	8.49	6.53
Stnd. Dev. (ksi)	0.87	0.59	0.44	0.52
Range (ksi)	7.35-9.33	6.30-7.61	8.08-9.09	6.07-7.42
No. of Specimens	5	5	4	5
Test Method	Short Beam Shear, S/D=4			
Reference	Design Guide - Jan., 1971			

[1] 100% saturation level at aging conditions.



CURVE	TEST TEMP (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)-REF. SECT. 3.4
A	72	0-DRY CONTROL
B	72	0.25
C	72	1.43- SATURATED
D	250	0-DRY CONTROL
E	250	0.21
F	250	0.43- SATURATED

Figure 64. Inplane Shear Stress-Strain Curves for AS/3004 Composite Laminates After Humidity Aging.

4.3 AS/4397

Tables 36-48 present the data generated for this graphite/polyimide composite system. Figures 65-87 illustrate the stress-strain, fatigue, and creep behavior of the material, as well as the effect of humidity aging upon the composite material. Two points of particular interest must be pointed out relative to this material system.

The first item concerns the fabrication of thick (15-20 plies and above) laminates with AS/4397. It has been found impossible to prevent delamination of panels over 20 plies thick from occurring during the postcure cycle. No delaminations are present at the conclusion of the cure schedule, prior to post-curing, but gross delaminations occur during the postcuring cycle. Since the cure schedule takes the panel to 400°F while the postcuring schedule takes it to 450°F, the damage evidently occurs somewhere in this temperature range. A TGA was conducted on a sample of the cured but not postcured AS/4397 material which indicated that no volatiles were being released in the 400-450°F temperature region so this apparently does not account for the problem. A number of variations in the postcuring schedule were tried including very slow heat up rates, greatly extended hold times at intermediate temperatures, and the maintenance of pressure throughout the postcure, all without success. Perhaps the thermal stresses induced by raising a panel thicker than 20 plies to a temperature of 450°F are sufficient to cause the delamination.

The second point pertains to flexure testing for the AS/4397. As mentioned in Section 3.5.3, all flexure testing with the exception of the 0°, AS/4397 specimens was performed with a four-point loading technique. It was found necessary on the 0°/AS/4397 flexure specimens to use a three-point loading technique in order to insure consistent flexural failure modes rather than delamination failure modes. Fourteen room temperature four-point flexural tests were conducted on 0°, AS/4397 specimens with four good flexural failures, five mixed-mode failures, and five outright shear failures resulting. The average flexural stress of each of these type failures was 224.4 ksi, 211.4 ksi, and 160.8 ksi, respectively. It is apparent that the flexural strength obtained from good failure modes in four-point loading is identical to the value reported in Table 41 for three-point loading. The flexural stress at failure understandably falls off as the failure mode changes to a combination of flexure and shear and ultimately, to pure shear. The shear stresses present in these fourteen specimens at failure ranged from 6700 to 7060 psi on the good flexural failures, between 6450 and 7430 psi on the mixed-mode failures, and between 4490 and 6111 psi on the shear failures.

TABLE 36

PROCESSING CONDITIONS FOR AS/4397 COMPOSITE LAMINATES

Composite Processing Information	
Material System - AS/4397 Fiber - AS Matrix - 4397	Graphite/Polyimide
Maximum Rated Temperature - 450°F Prepreg by - Hercules	
Laminate Processing Schedule	
Layup Procedure: Prepreg warmed to R. T. in closed wrapper. Prepreg removed from package and plies cut to desired size using razor blade. Plies stacked in desired sequence (release paper removed from each ply). Stack placed in autoclave on sheet of nonporous Teflon and surrounded with cork dam to restrict fiber flow. Sheet of porous Teflon placed on top of stack and one ply of bleeder paper per four plies of prepreg placed on top of this. A sheet of nonporous Teflon is placed over the bleeder paper and covered by the silicone rubber bladder.	
Cure Schedule: Under full vacuum, the temperature was increased to 275°F at a rate of 4 to 5°F per minute. When 275°F is reached, a pressure of 85 psi was applied above the bladder. At this pressure and still under full vacuum, the part is held at 275°F for 30 minutes. The temperature was then raised to 400°F at 5°F per minute and held at 400°F for 2 hours. The panel was cooled under pressure to below 150°F before removal.	
Postcure Schedule: After trimming of flash, the panels were placed, unrestrained, in an oven and heated to 400°F at 5°F per minute. After 1 hour at this temperature, the temperature was raised to 450°F at 5°F per minute and then held for 48 hours before cooling to room temperature.	

Note: It was found that when laminates thicker than about twenty plies were made, gross interply delamination occurred during postcure. Several modifications of the postcure schedule outlined in the table above were tried, including much slower heat-up rates, extended hold times at intermediate temperatures, and application of pressure, all without success.

TABLE 37

PREPREG AND COMPOSITE PHYSICAL PROPERTIES: AS/4397

Composite Physical Property Information				
Material System - AS/4397 Fiber - AS Matrix - 4397 Maximum Rated Temperature - 450°F			Graphite/Polyimide Prepreg by -Hercules	
Prepreg Physical Properties				
(Property)	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content- 0.21% by wt.	0.04	0.18-0.27	HD-SG-2-6006C(5.1)	Hercules
Resin Content-42.6% by wt.	1.3	40.4-43.8	HD-SG-2-6006C(5.2.6,F)	Hercules
Resin Flow- 25.9% by wt.	2.2	23.2-29.6	HD-SG-2-6006C(5.3.1,A)	Hercules
No. of Rolls Involved- 2				
No. of Batches Involved - 1				
Laminate Physical Properties[1]				
	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 46				
Fiber Content-63.6% by vol.	2.1	52.5-66.4	HD-SG-2-6006C(5.2.1)	Hercules
Resin Content-28.5% by wt.	1.8	25.8-34.4	HD-SG-2-6006C(5.2.1)	Hercules
Void Content- ≐0% by vol.	---	---	Grid pt. count	
Laminate Sp. Gr. - 1.57	0.02	1.53-1.60		
Fiber Sp. Gr. - 1.78	As reported by manufacturer.			
Matrix Sp. Gr. - 1.26	As reported by manufacturer.			
Thickness per ply- 0.0056 inch			---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

TABLE 38

TENSILE PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - AS/4397 Prepreg by - Hercules | Graphite/Polyimide

Fiber - AS Matrix - 4397

Maximum Rated Temperature - 450°F

Resin Content - 28.2% by wt.

Fiber Content - 63.6% by vol.

Void Content - ≈ 0 % by vol.

Laminate Sp. Gr. - 1.57

Average Ply Thickness - 0.0057 inch

No. of panels from which specimens were tested in this table - 10

Thickness of each type specimen 0°-6 plies, 90°-15 plies

TENSION: 0°

	-67°F	72°F	350°F	450°F
F_x^{tu} (ksi)	195.4	203.3	187.4	206.5
stnd. dev. (ksi)	3.9	6.6	27.9	13.0
Range (ksi)	189.5-200.0	194.4-209.4	149.7-222.7	185.4-217.6
No. of Specimens	5	6	6	5
F_x^{tpl} (ksi)	195.4	203.3	179.1	206.5
stnd. dev.	3.9	6.6	30.8	13.0
No. of Specimens	5	6	6	5
E_x^t (Msi)	19.4	18.3	18.9	18.1
stnd. dev.	0.5	0.6	1.2	0.6
No. of Specimens	5	6	6	5
ϵ_x^{tu} (μin/in)	9300	10,300	9850	10,900
stnd. dev.	100	475	1240	200
No. of Specimens	4	6	4	4
ν_{xy}^t	0.31	0.30	0.31	0.33
stnd. dev.	0.02	0.02	0.03	0.03
No. of Specimens	5	5	5	5
Test Method	Straight-sided tension			
Reference	Design Guide			

TENSION: 90°

	-67°F	72°F	350°F	450°F
F_y^{tu} (ksi)	5.29	5.37	3.81	2.96
stnd. dev. (ksi)	0.51	0.33	0.38	0.21
Range (ksi)	4.56-5.78	4.94-5.85	3.22-4.40	2.75-3.28
No. of Specimens	5	5	5	5
F_y^{tpl} (ksi)	5.29	5.37	2.76	2.14
stnd. dev.	0.51	0.33	0.73	0.30
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.47	1.39	1.09	0.76
stnd. dev.	0.02	0.01	0.13	0.05
No. of Specimens	5	5	5	5
ϵ_y^{tu} (μin/in)	3600	3900	3400	4200
stnd. dev.	300	260	300	300
No. of Specimens	5	5	5	5
ν_{yx}^t	0.023[1]	0.023[1]	0.018[1]	0.014[1]
Test Method	Straight-sided tension			
Reference	Design Guide			

[1] Computed using elastic moduli and longitudinal Poisson's ratio.

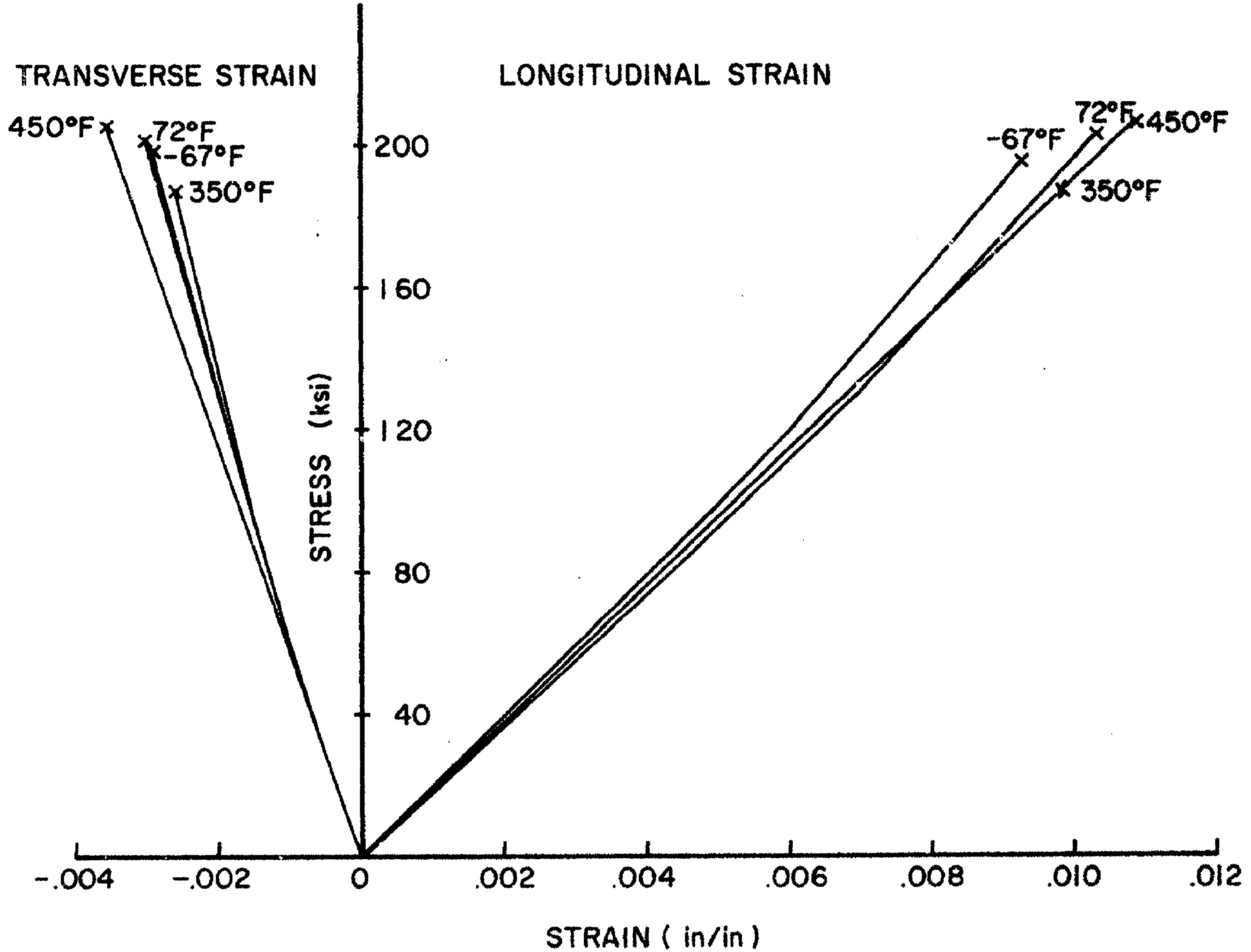


Figure 65. Tensile Stress-Strain Curves for Unidirectional AS/4397 Composite Laminates: 0° Fiber Orientation.

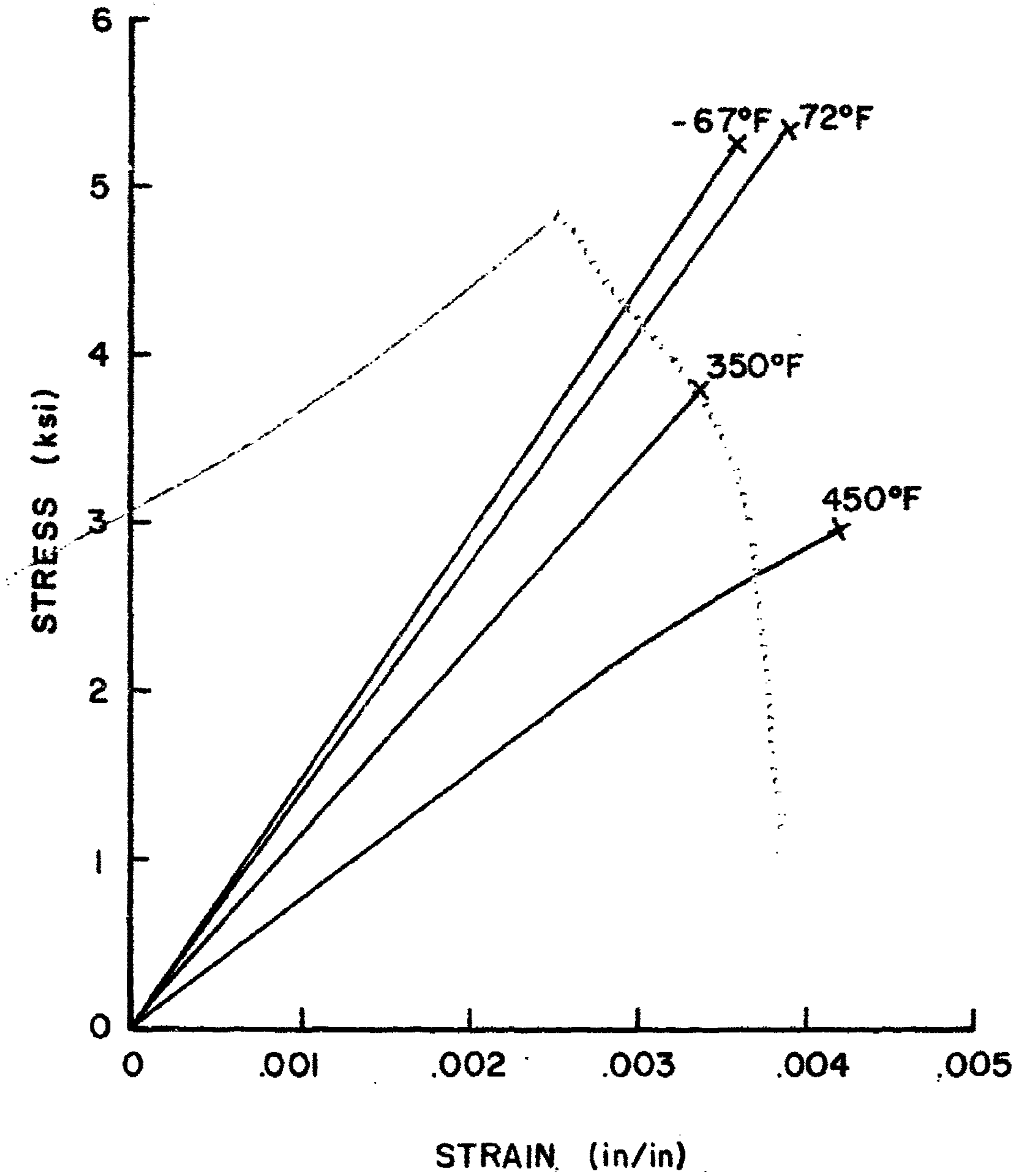


Figure 66. Tensile Stress-Strain Curves for Unidirectional AS/4397 Composite Laminates: 90° Fiber Orientation.

TABLE 39

TENSILE PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - AS/4397	Prepreg by - Hercules	Graphite/Polyimide
Fiber - AS	Matrix - 4397	Laminate Sp. Gr. - 1.58
Maximum Rated Temperature - 450°F		Average Ply Thickness - 0.0057 inch
Resin Content - 27.5% by wt.		
Fiber Content - 65.1% by vol.		No. of panels from which specimens were tested in this table - 4
Void Content - ±0		Thickness of specimens: 8 ply

TENSION: ± 45°

	-67°F	72°F	350°F	450°F
F_x^{tu} (ksi)	19.26	18.72	16.61	16.70
stnd. dev. (ksi)	0.37	0.37	0.76	0.41
Range (ksi)	18.78-19.81	18.20-19.20	15.26-16.93	16.34-17.40
No. of Specimens	5	5	5	5
F_x^{tpl} (ksi)	8.69	7.46	3.68	2.78
stnd. dev. (ksi)	1.45	0.73	0.96	0.67
No. of Specimens	5	5	5	5
E_x^t (Msi)	2.81	2.66	2.05	1.79
stnd. dev.	0.14	0.09	0.17	0.19
No. of Specimens	5	5	5	5
ϵ_x^{tu} (μin/in)	10,700	11,800	>25,000[1]	>17,000[1]
stnd. dev.	800	1,700	---	---
No. of Specimens	5	5	5	4
ν_{xy}^t	0.71	0.72	0.71	0.65
stnd. dev.	0.06	0.07	0.06	0.05
No. of Specimens	4	5	5	3
Test Method	Straight-sided tension			
Reference	Design Guide			

Notes: 1. Surface plies cracked, creating electrical discontinuities in strain gages.

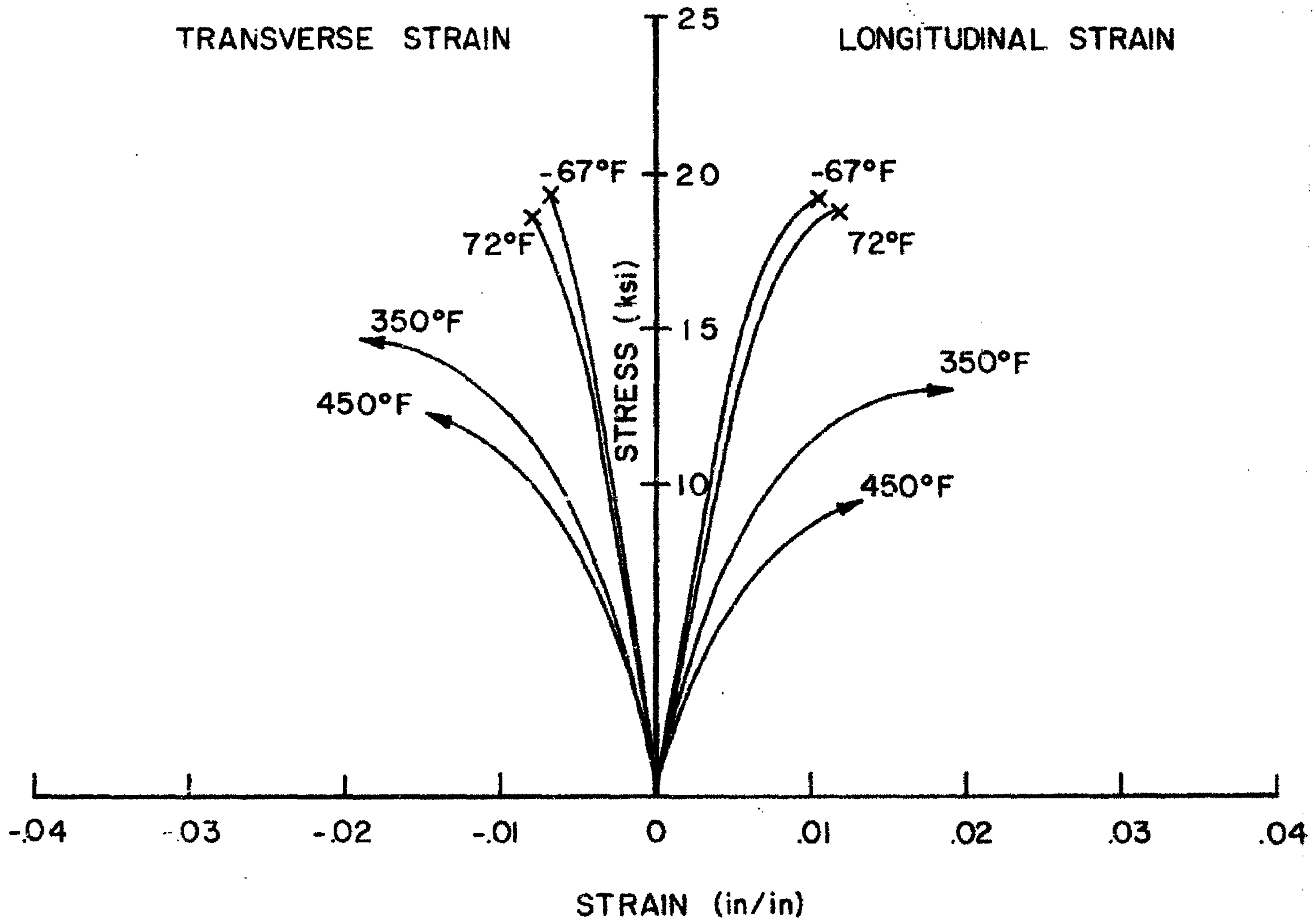


Figure 67. Tensile Stress-Strain Curves for Bidirectional AS/4397 Composite Laminates: ±45° Fiber Orientation.

TABLE 40

COMPRESSIVE PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - AS/4397 | Graphite/Polyimide

Fiber - AS Matrix - 4397	Prepreg by - Hercules
Maximum Rated Temperature -	Laminate Sp. Gr. - 1.50
Resin Content - 28.2% by wt.	Average Ply Thickness - 0.0054 in.
Fiber Content - 62.9% by vol.	No. of panels from which specimens were tested in this table - 1
Void Content - ±0% by vol.	
Thickness of specimens -- 20 ply	

COMPRESSION : 0°

		-67°F	72°F	350°F	450°F
F_x^{cu}	(ksi)	235.8	206.1	164.6	152.8
stnd. dev.	(ksi)	7.2	14.1	15.2	36.9
Range	(ksi)	232.1-243.7	189.7-221.9	151.8-182.9	110.7-179.8
No. of Specimens		5	5	5	3
F_x^{cpl}	(ksi)	105.9	172.2	121.7	70.5
stnd. dev.		15.8	47.4	28.3	27.1
No. of Specimens		5	3	5	3
E_x^{c}	(Msi)	21.3	18.7	19.1	18.2
stnd. dev.		1.0	0.81	2.2	3.1
No. of Specimens		5	5	5	4
ϵ_x^{cu}	(μ in/in)	13,200[1]	11,800[2]	8800	9900[3]
stnd. dev.		5900	3800	1700	5600
No. of Specimens		5	5	5	3
Test Method		Celanese coupon and test fixture			
Reference		AFML-TR-72-205, Pt. 1			

COMPRESSION: 90°

		-67°F	72°F	350°F	450°F
F_y^{cu}	(ksi)	36.1	30.0	21.1	21.5
stnd. dev.	(ksi)	2.8	2.9	2.0	3.0
Range	(ksi)	35.0-39.5	26.0-34.0	18.5-22.8	18.0-25.4
No. of Specimens		5	5	5	5
F_y^{cpl}	(ksi)	10.7	14.5	7.6	7.91
stnd. dev.		---	7.8	1.4	2.78
No. of Specimens		2	5	3	3
E_y^{c}	(Msi)	1.97	1.45	1.16	1.69[4]
stnd. dev.		0.25	0.31	0.07	0.62
No. of Specimens		5	5	5	5
ϵ_y^{cu}	(μ in/in)	21,900	19,000	24,200	>9,400[5]
stnd. dev.		4,700	7000	8400	---
No. of Specimens		5	4	5	5
Test Method		Celanese coupon and test fixture			
Reference		AFML-TR-72-205, Pt. 1			

Notes:
1. Three of five specimens exhibited evidence of buckling.
2. One of five specimens exhibited evidence of buckling.
3. One of three specimens exhibited evidence of buckling. The tabs debonded on a fourth specimen prior to failure.
4. This value appears high in comparison with the 72°F and 350°F values but nonetheless, is the measured average.
5. Lost strain gage signal prior to failure on four of the five specimens.

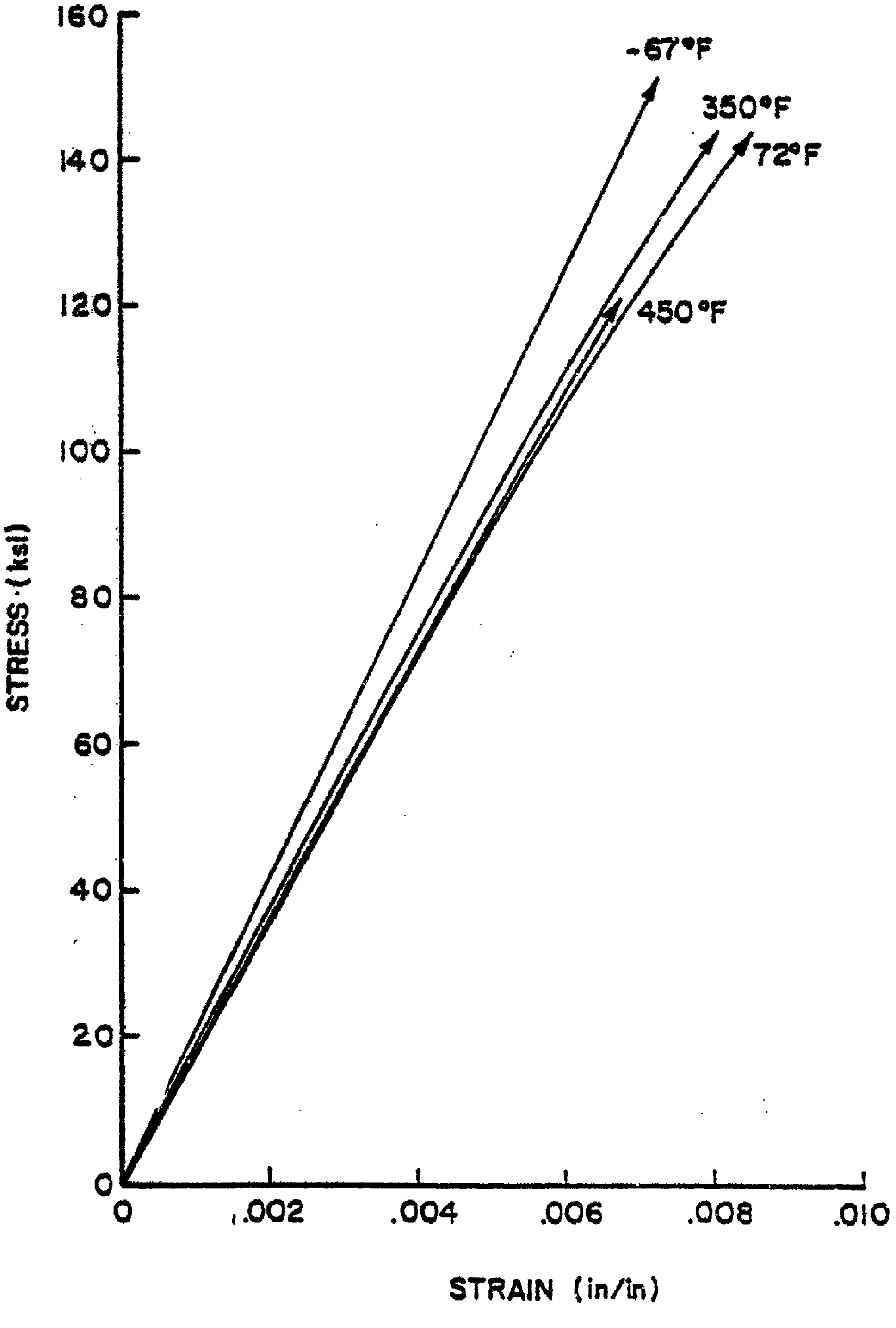


Figure 68. Compressive Stress-Strain Curves for Unidirectional AS/4397 Composite Laminates: 0° Fiber Orientation.

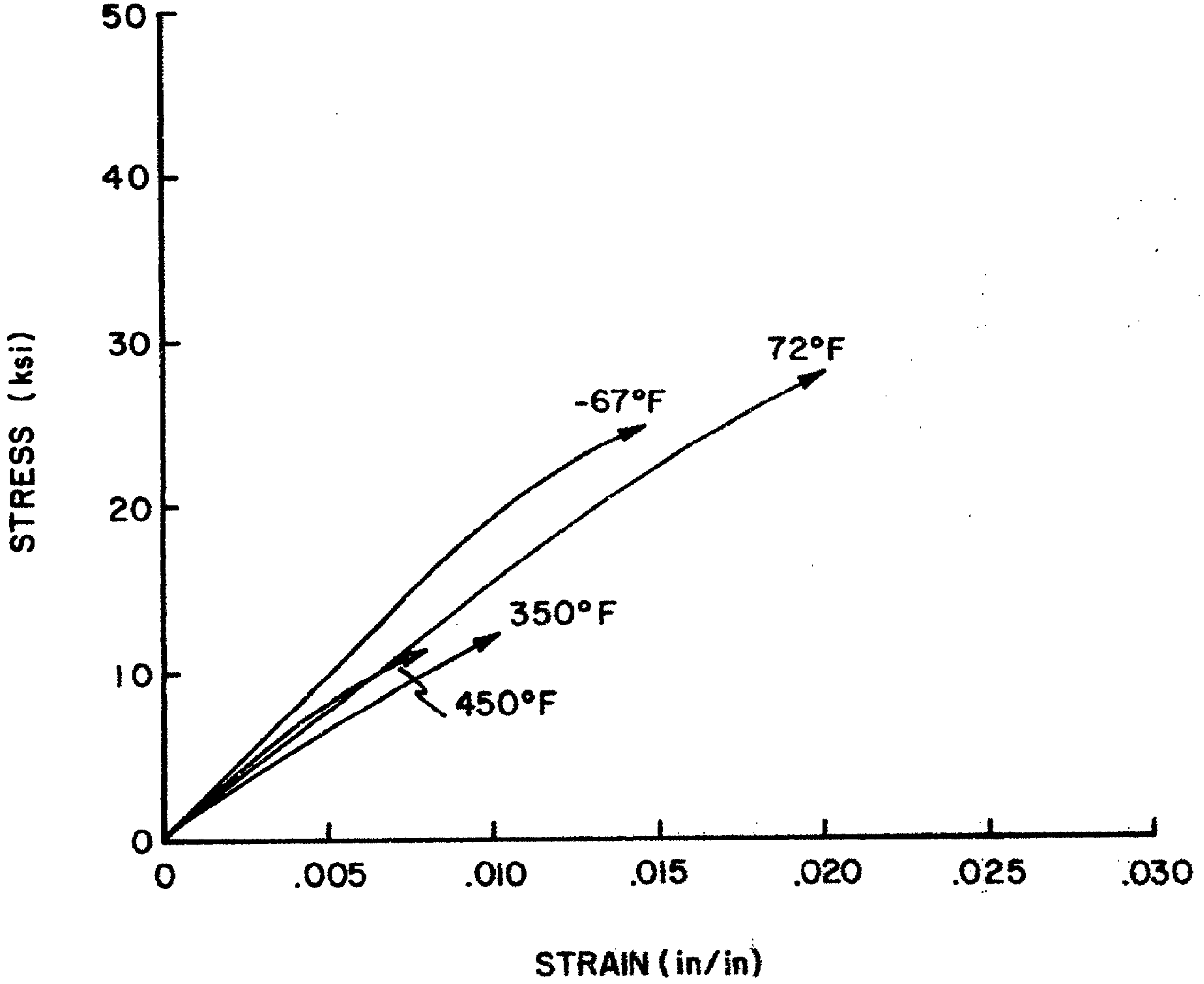


Figure 69. Compressive Stress-Strain Curves for Unidirectional AS/4397 Composite Laminates: 90° Fiber Orientation.

TABLE 41

FLEXURAL PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/4397 Prepreg by - Hercules; Graphite/Polyimide; Fiber - AS Matrix - 4397; Maximum Rated Temperature - 450°F; Resin Content - 31.2% by wt.; Fiber Content - 61.4% by vol.; Void Content - ≤0 % by vol.	Laminate Sp. Gr. - 1.57; Average Ply Thickness - 0.0058 inch; No. of panels from which specimens were tested in this table - 2; Thickness of each type specimen: 0°-14 plies; 90°-14 plies			
FLEXURE : 0°				
	-67°F	72°F	350°F	450°F
F_x^{fu} (ksi)	239.9	224.4	178.8	128.6
stnd. dev. (ksi)	11.8	10.5	15.9	4.5
Range (ksi)	228.5-257.5	212.3-239.5	165.8-204.6	123.9-133.7
No. of Specimens	5	5	5	5
E_x^f (Msi)	17.3	18.4	17.3	16.7
stnd. dev.	1.1	0.6	1.6	0.6
No. of Specimens	5	5	5	5
Test Method	3 pt. flexure			
Reference	Design Guide Jan., 1971			
FLEXURE: 90°				
F_y^{fu} (ksi)	9.28	8.88	5.34	4.32
stnd. dev. (ksi)	1.03	0.51	0.77	0.80
Range (ksi)	7.74-10.31	8.31-9.65	4.44-6.20	3.28-5.34
No. of Specimens	5	5	5	6
E_y^t (Msi)	1.55	1.50	1.19	0.66
stnd. dev.	0.12	0.21	0.04	0.09
No. of Specimens	5	5	5	6
Test Method	4 pt. flexure			
Reference	Design Guide Jan., 1971			

TABLE 42

SHEAR PROPERTIES OF AS/4397
COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Material System - AS/4397	Graphite/Polyimide
Fiber - AS Matrix - 4397	Prepreg by - Hercules
Maximum Rated Temperature - 450°F	Laminate Sp. Gr. - 1.59
Resin Content - 27.8% by wt.	Average Ply Thickness - 0.0057 in.
Fiber Content - 65.6% by vol.	No. of panels from which specimens
Void Content - ≈0	were tested in this table - 5
Thickness of specimens: inplane-8 ply; interlaminar-14 ply	

INPLANE SHEAR

	-67°F	72°F	350°F	450°F
F_{xy}^{su} (ksi)	9.63	9.36	8.31	8.35
stnd.dev. (ksi)	0.19	0.19	0.38	0.21
Range	9.39-9.90	9.10-9.60	7.63-8.49	8.17-8.70
No. of Specimens	5	5	5	5
G_{xy}^{s} (Msi)	0.83	0.77	0.56	0.54
stnd. dev. (Msi)	0.04	0.02	0.05	0.07
No. of Specimens	4	5	5	3
Test Method	±45° Straight-sided tension			
Reference	J.Comp.Mtls. [Vol.6, p. 252 & Vol.7, p. 124]			

INTERLAMINAR SHEAR

	-67°F	72°F	350°F	450°F
F^{isu} (ksi)	14.73	13.62	9.79	6.21
Stnd. Dev. (ksi)	3.41	1.73	1.18	0.89
Range (ksi)	10.77-18.96	10.96-15.14	8.71-11.47	5.13-7.24
No. of Specimens	5	5	5	5
Test Method	Short Beam Shear			
Reference	Design Guide - Jan., 1971			

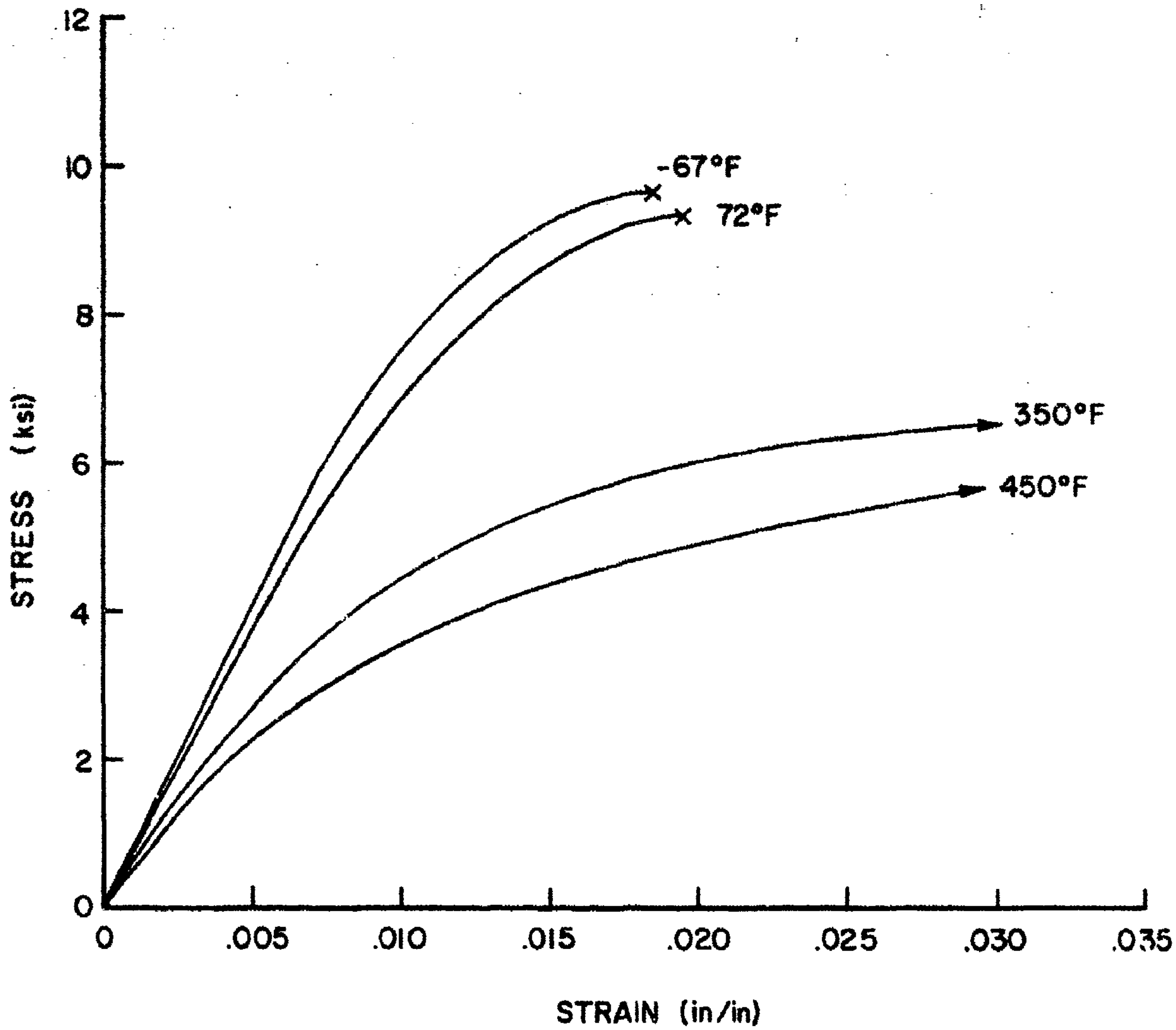


Figure 70. Inplane Shear Stress-Strain Curves for AS/4397 Composite Laminates.

TABLE 43

FATIGUE PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Graphite/Polyimide

Material System - AS/4397 Prepreg by - Hercules
Fiber - AS Matrix - 4397
Maximum Temperature Rating - 450°F
Resin Content - 28.1% by wt.
Fiber Content - 64.0% by vol.
Void Content - 40

Laminate Sp. Gr. - 1.57
Average Ply Thickness - 0.0057 inch
No. of panels from which specimens were tested in this table - 36
Thickness of each type specimen: 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply

Test Method - Straight-sided tension Reference - Design Guide

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Max. Stress (ksi)	175.8	3.70	13.48	350°F	Max. Stress (ksi)	168.7	3.05	11.63
	Lifetime (cycles)	1,580	10,130	4,540[1]		Lifetime (cycles)	5,370	9,610	21,550[3]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	156.3	3.44	11.56		Max. Stress (ksi)	149.9	2.86	10.80
	Lifetime (cycles)	59,150	35,020	95,860		Lifetime (cycles)	11,990	10,740	122,200[1]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	5.09	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	1	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	136.8	3.18	10.59		Max. Stress (ksi)	131.2	2.67	9.97
	Lifetime (cycles)	931,930	472,030	5.6×10^6[2]		Lifetime (cycles)	527,480	294,956	841,000[1]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	200.7	---	14.90		Residual Strength (ksi)	---	---	---
	No. of Specimens		0	2		No. of Specimens	0	0	0
72°F	Max. Stress (ksi)	182.1	3.76	14.98	450°F	Max. Stress (ksi)	165.2	2.07	11.69
	Lifetime (cycles)	43,050	9,670	3,990[3]		Lifetime (cycles)	2,410	11,260	1,700[3]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	161.9	3.22	13.10		Max. Stress (ksi)	154.9	1.77	8.35
	Lifetime (cycles)	28,975	12,560	15,820[3]		Lifetime (cycles)	612,460	73,866	18,280[4]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---		Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0		No. of Specimens	0	0	0
	Max. Stress (ksi)	141.6	2.68	11.23		Max. Stress (ksi)	144.6	1.48	6.68
	Lifetime (cycles)	5.2×10^6	61,109	819,750[3]		Lifetime (cycles)	2.1×10^6	1.4×10^6	6.5×10^6[2]
	No. of Specimens	4	4	4		No. of Specimens	4	4	4
	Residual Strength (ksi)	194.6	---	---		Residual Strength (ksi)	---	3.74	13.54
	No. of Specimens	2	0	0		No. of Specimens	0	1	1

Note: Fatigue lifetimes are log-mean values. All residual strengths determined by tensile test at 72°F.

1. Internal energy dissipation caused specimens to self heat between 9°F and 15°F above nominal test temperature at time of failure.
2. Internal energy dissipation caused specimens to self heat between 4°F and 6°F above nominal test temperature at time of failure.
3. Internal energy dissipation caused specimens to self heat between 29°F and 37°F above normal test temperature at time of failure.
4. Internal energy dissipation caused specimens to self heat between 48°F and 52°F above normal test temperature at time of failure.

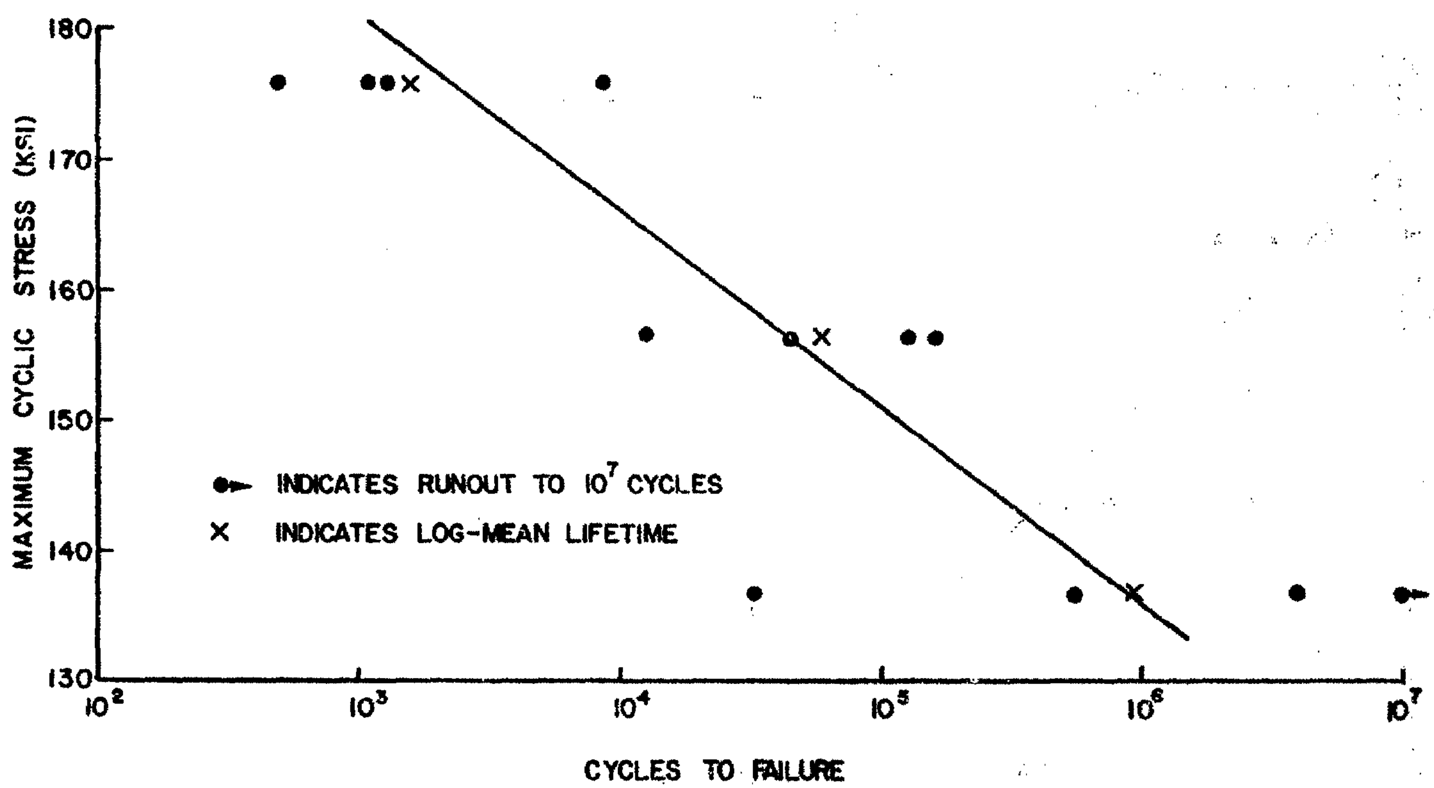


Figure 71. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at -67°F: 0° Fiber Orientation, R=0.10, 30 Hz.

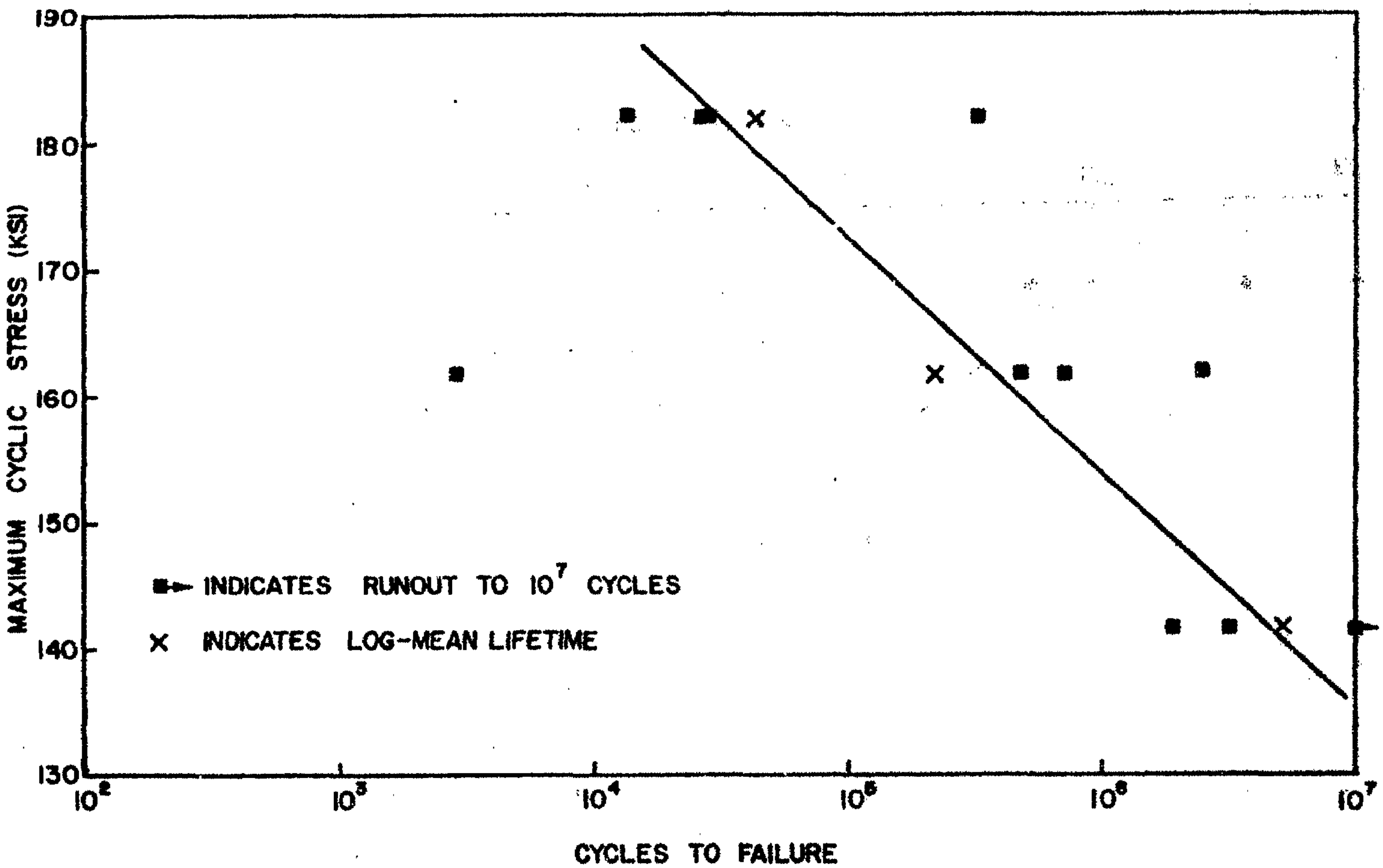


Figure 72. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at 72°F: 0° Fiber Orientation, R=0.10, 30 Hz.

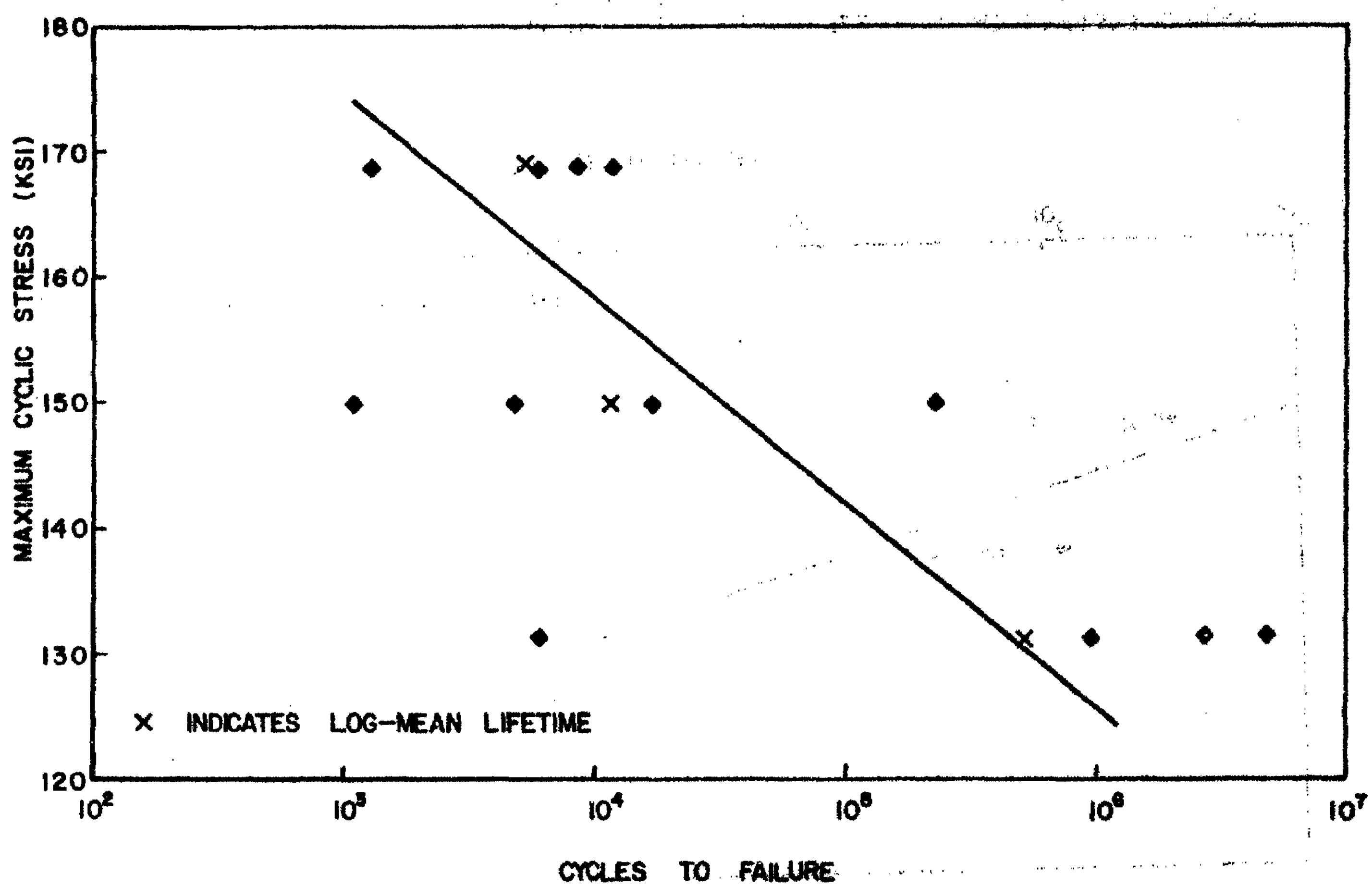


Figure 73. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at 350°F: 0° Fiber Orientation, R=0.10, 30 Hz.

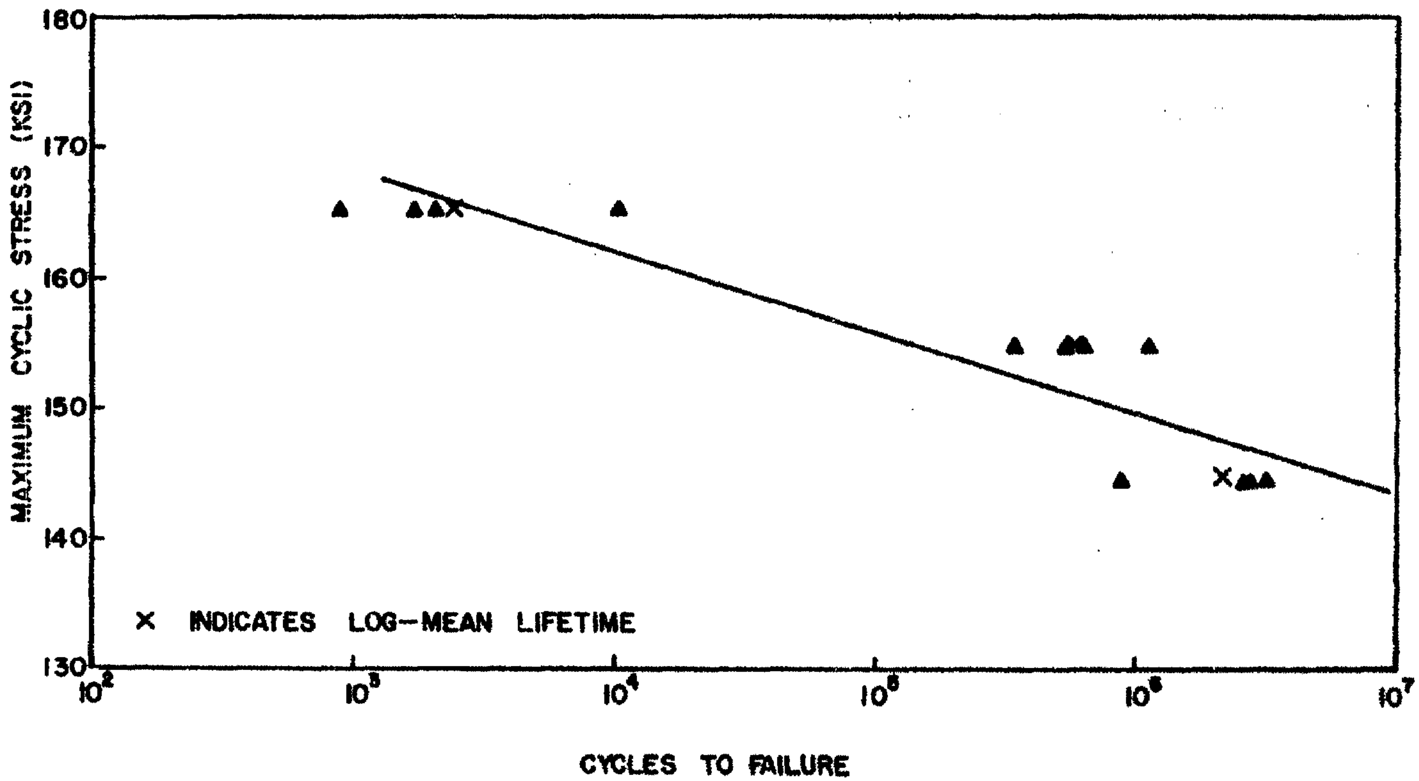


Figure 74. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at 450°F: 0° Fiber Orientation, R=0.10, 30 Hz.

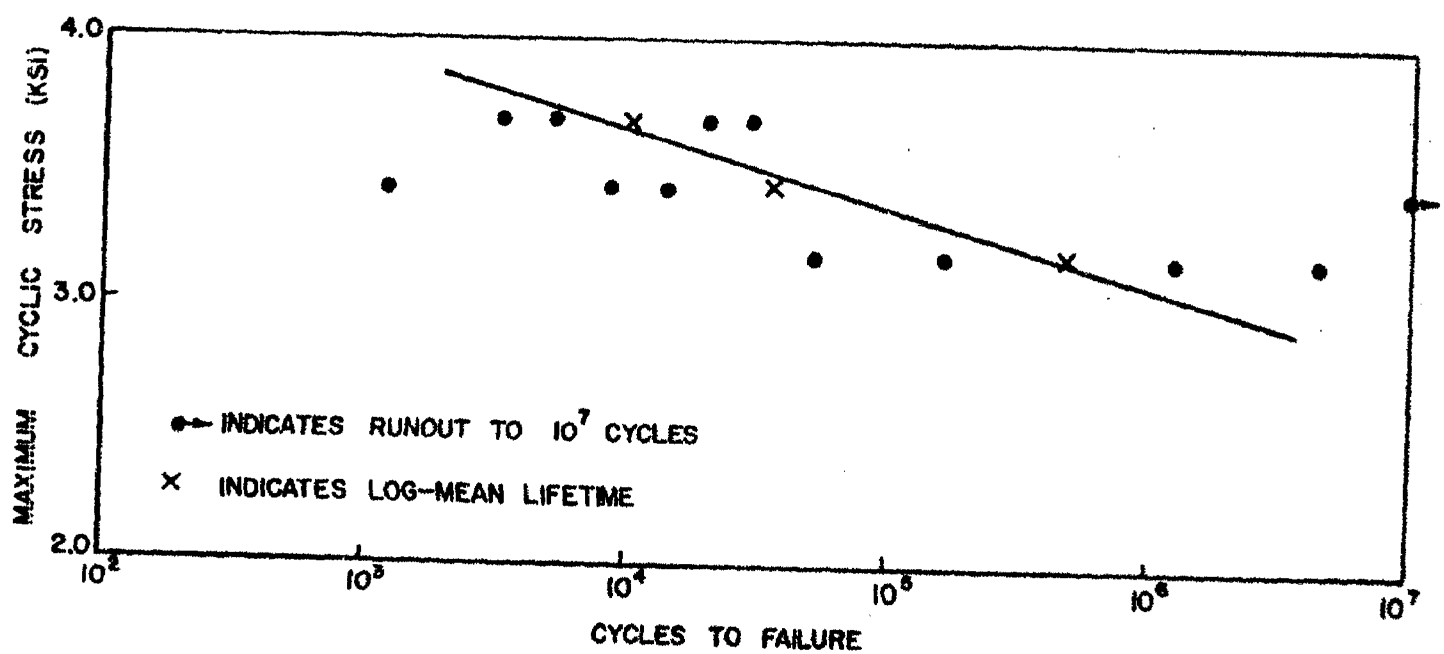


Figure 75. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at -67°F: 90° Fiber Orientation, R=0.10, 30 Hz.

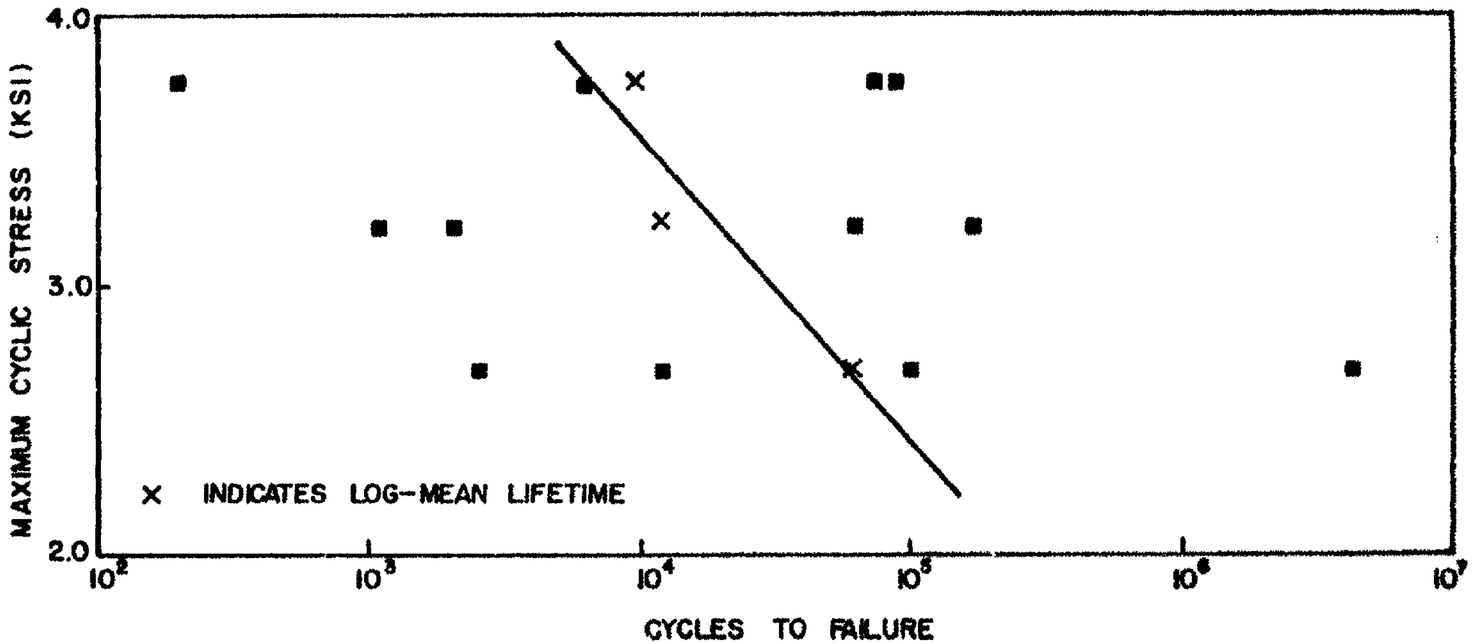


Figure 76. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at 72°F: 90° Fiber Orientation, R=0.10, 30 Hz.

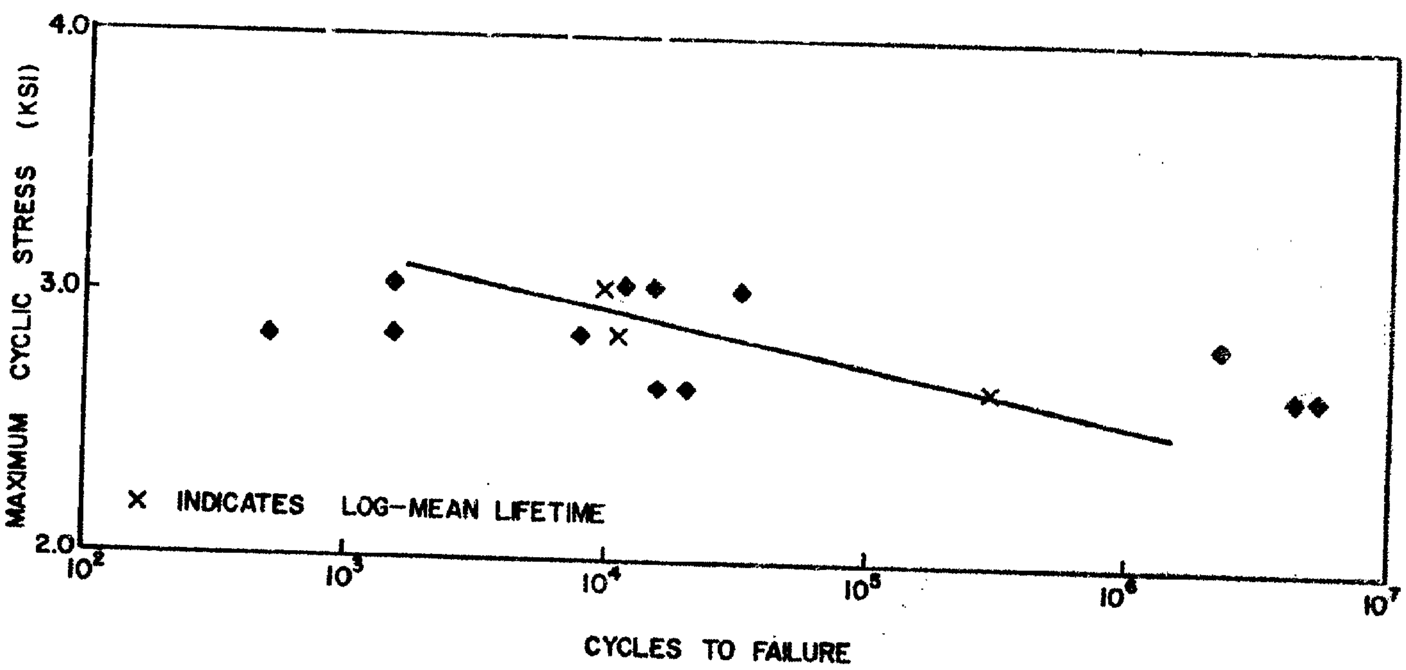


Figure 77. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at 350°F: 90° Fiber Orientation, R=0.10, 30 Hz.

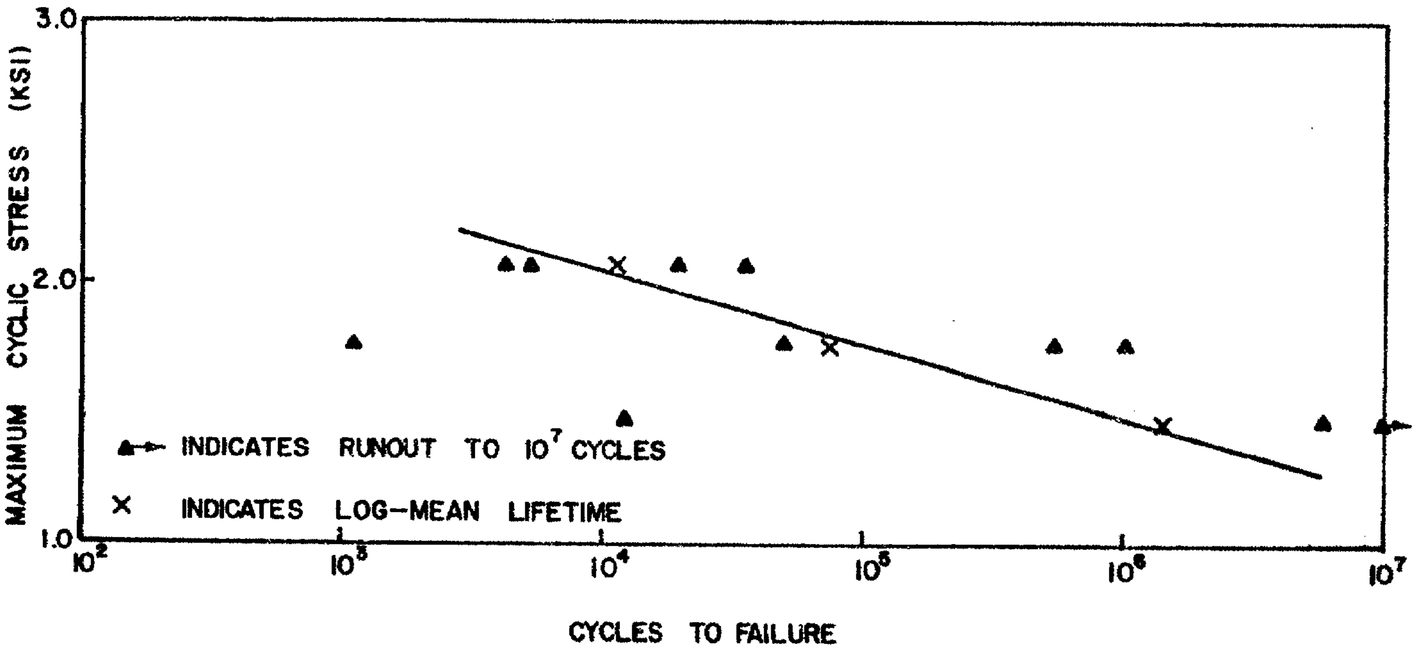


Figure 78. Tensile-Tensile Fatigue Behavior of Unidirectional AS/4397 Composite Laminates at 450°F: 90° Fiber Orientation, R=0.10, 30 Hz.

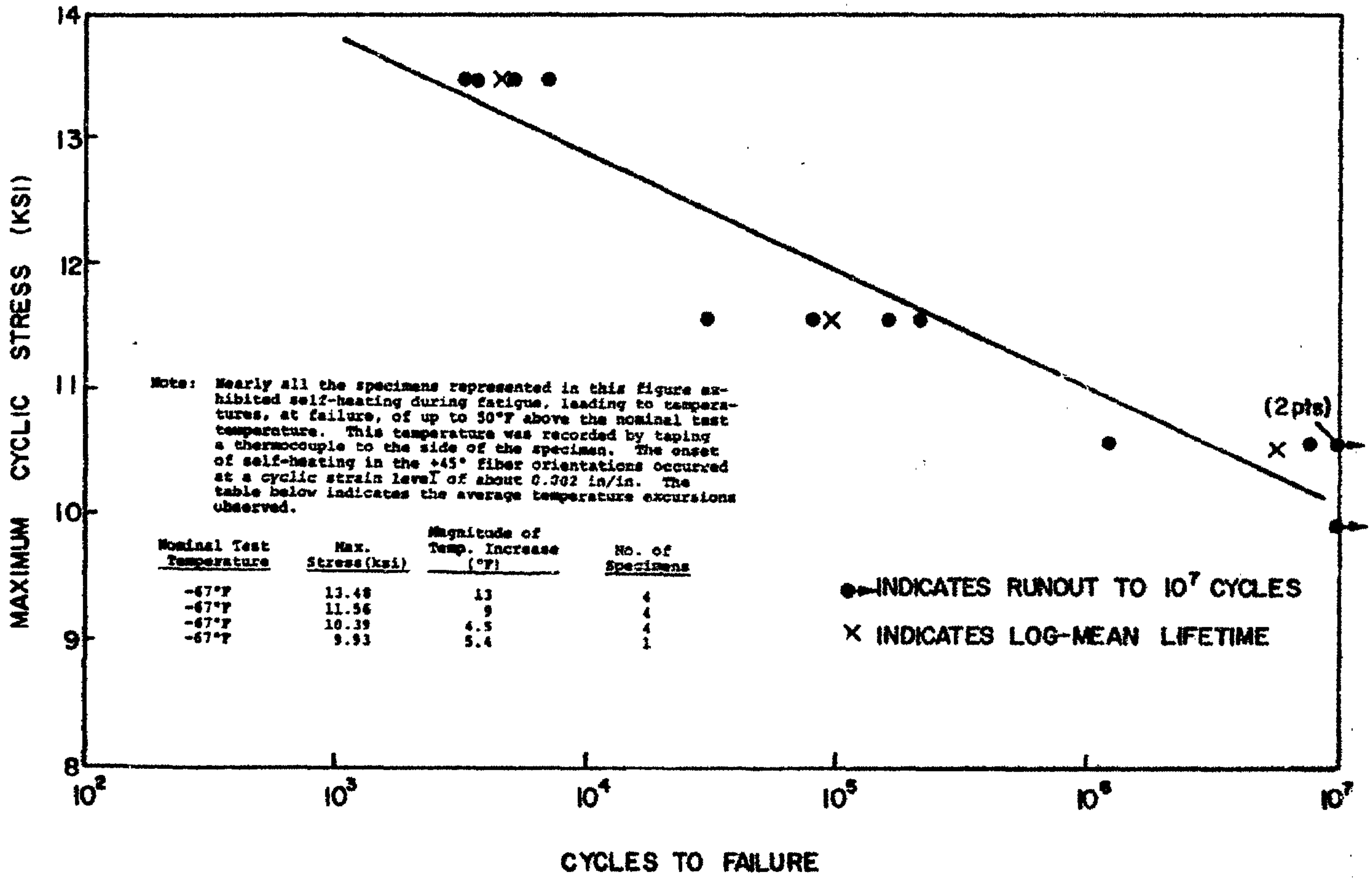


Figure 79. Tensile-Tensile Fatigue Behavior of Bidirectional AS/4397 Composite Laminates at -67°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

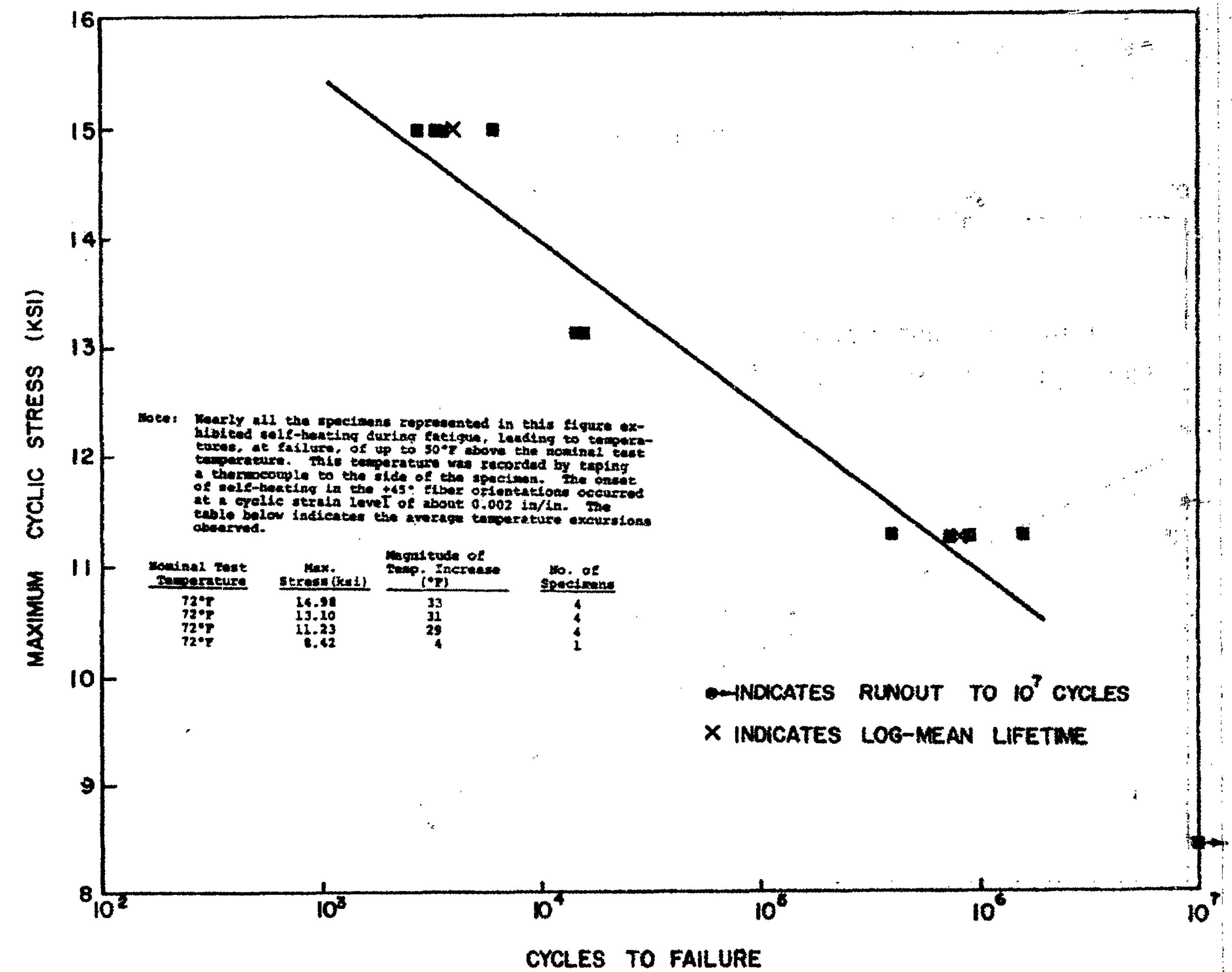


Figure 80. Tensile-Tensile Fatigue Behavior of Bidirectional AS/4397 Composite Laminates at 72°F: $\pm 45°$ Fiber Orientation, R=0.10, 30 Hz.

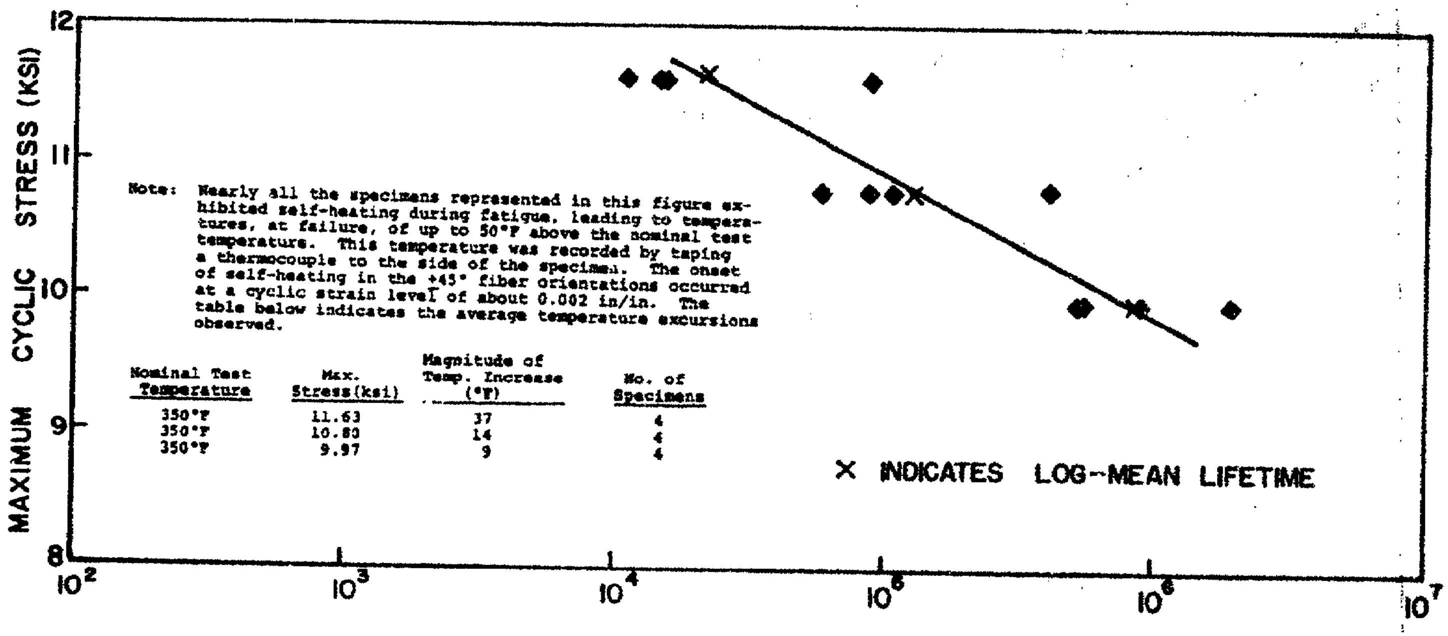


Figure 81. Tensile-Tensile Fatigue Behavior of Bidirectional AS/4397 Composite Laminates at 350°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

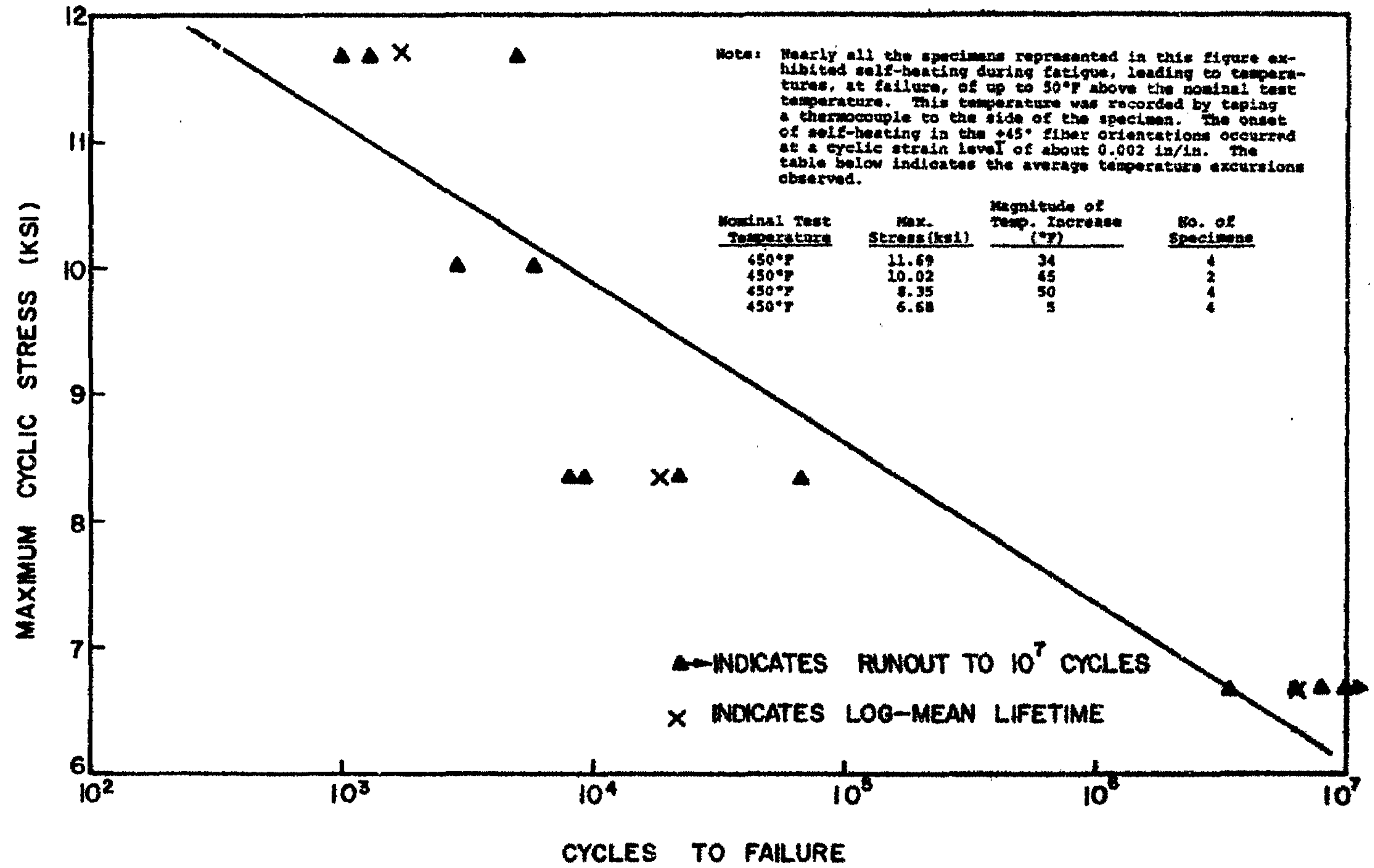


Figure 82. Tensile-Tensile Fatigue Behavior of Bidirectional AS/4397 Composite Laminates at 450°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

TABLE 44

CREEP PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Graphite/Polyimide

Material System - AS/4397 Prepreg by - Hercules
Fiber - AS Matrix - 4397
Maximum Temperature Rating - 450°F Laminate Sp. Gr. - 1.57
Resin Content - 28.1% by wt. Average Ply Thickness - 0.0057 inch
Fiber Content - 64.0% by vol. No. of panels from which specimens were tested in this table - 29
Void Content - ±0% Thickness of each type specimen: 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply
Test Method - Straight-sided tension Reference - Design Guide

CREEP

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				350°F	Stress Level (ksi)	131.2	2.67	8.31
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	240	1319	---[5]
	No. of Specimens					No. of Specimens	2[1]	1[2]	3
	Residual Strength (ksi)					Residual Strength (ksi)	189.9	4.13	18.04
	No. of Specimens					No. of Specimens	2	1	3
	Stress Level (ksi)					Stress Level (ksi)	112.5	2.29	4.98
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	362	1235	6076
	No. of Specimens					No. of Specimens	3	2[3]	3
	Residual Strength (ksi)					Residual Strength (ksi)	208.3	3.54	18.12
	No. of Specimens					No. of Specimens	3	2	3
	Stress Level (ksi)					Stress Level (ksi)	93.7	1.90	3.32
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	80	662	2081
	No. of Specimens					No. of Specimens	3	2[3]	3
	Residual Strength (ksi)					Residual Strength (ksi)	209.7	3.85	18.06
	No. of Specimens					No. of Specimens	3	2	3
72°F	Stress Level (ksi)	182.1	4.83	13.10	450°F	Stress Level (ksi)	144.5	1.48	8.35
	Creep Strain, 500 hr(μ in/in)	57	610	2020		Creep Strain, 500 hr(μ in/in)	---[2]	---[1]	---[5]
	No. of Specimens	3	1[6]	3		No. of Specimens	1	2	3
	Residual Strength (ksi)	213.7	5.06	18.58		Residual Strength (ksi)	---	---	17.97
	No. of Specimens	3	1	3		No. of Specimens	0	0	1
	Stress Level (ksi)	161.9	4.29	11.23		Stress Level (ksi)	123.9	1.18	5.01
	Creep Strain, 500 hr(μ in/in)	12	633	1380		Creep Strain, 500 hr(μ in/in)	5371	---[4]	---[5]
	No. of Specimens	3	3	3		No. of Specimens	2[3]	4	3
	Residual Strength (ksi)	203.0	5.14	18.74		Residual Strength (ksi)	193.1	---	17.73
	No. of Specimens	3	3	3		No. of Specimens	2	0	3
	Stress Level (ksi)	141.6	3.76	9.36		Stress Level (ksi)	103.2	0.99	1.67
	Creep Strain, 500 hr(μ in/in)	9	469	765		Creep Strain, 500 hr(μ in/in)	4299	---[2]	---[5]
	No. of Specimens	3	3	3		No. of Specimens	2	3	2
	Residual Strength (ksi)	218.4	4.85	18.10		Residual Strength (ksi)	218.0	---	16.87
	No. of Specimens	3	3	3		No. of Specimens	2	0	1

Notes: All values represent arithmetic averages. All residual strengths determined by tensile test at 72°F.

1. Two specimens failed on loading or during test.
2. Three specimens failed on loading or during test.
3. One specimen failed on loading or during test.
4. Four specimens failed on loading or during test.
5. Specimens underwent so much strain that surface plies cracked, creating electrical discontinuities in strain gages early in test.
6. Five specimens failed on loading.

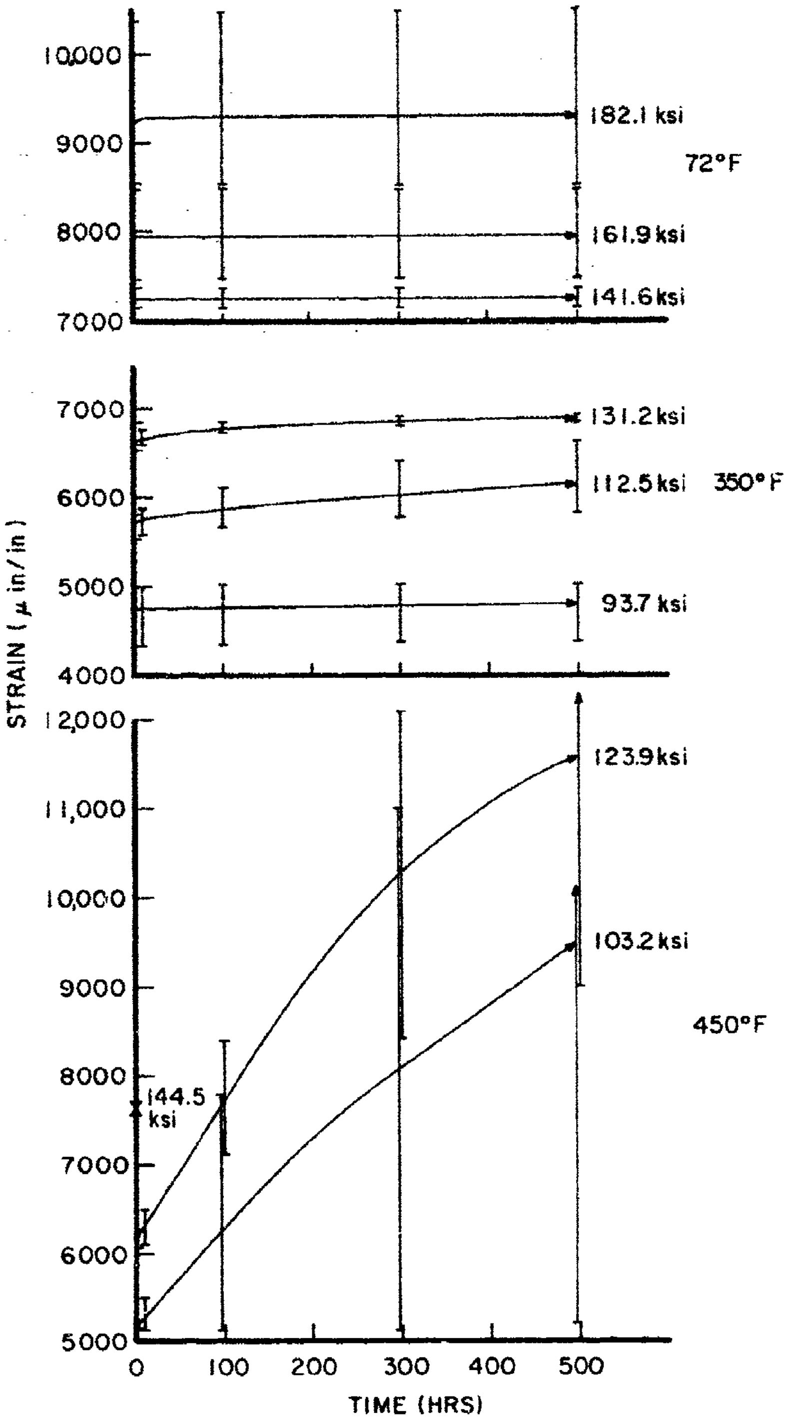


Figure 83. Tensile Creep Behavior of Unidirectional AS/4397 Composite Laminates: 0° Fiber Orientation.

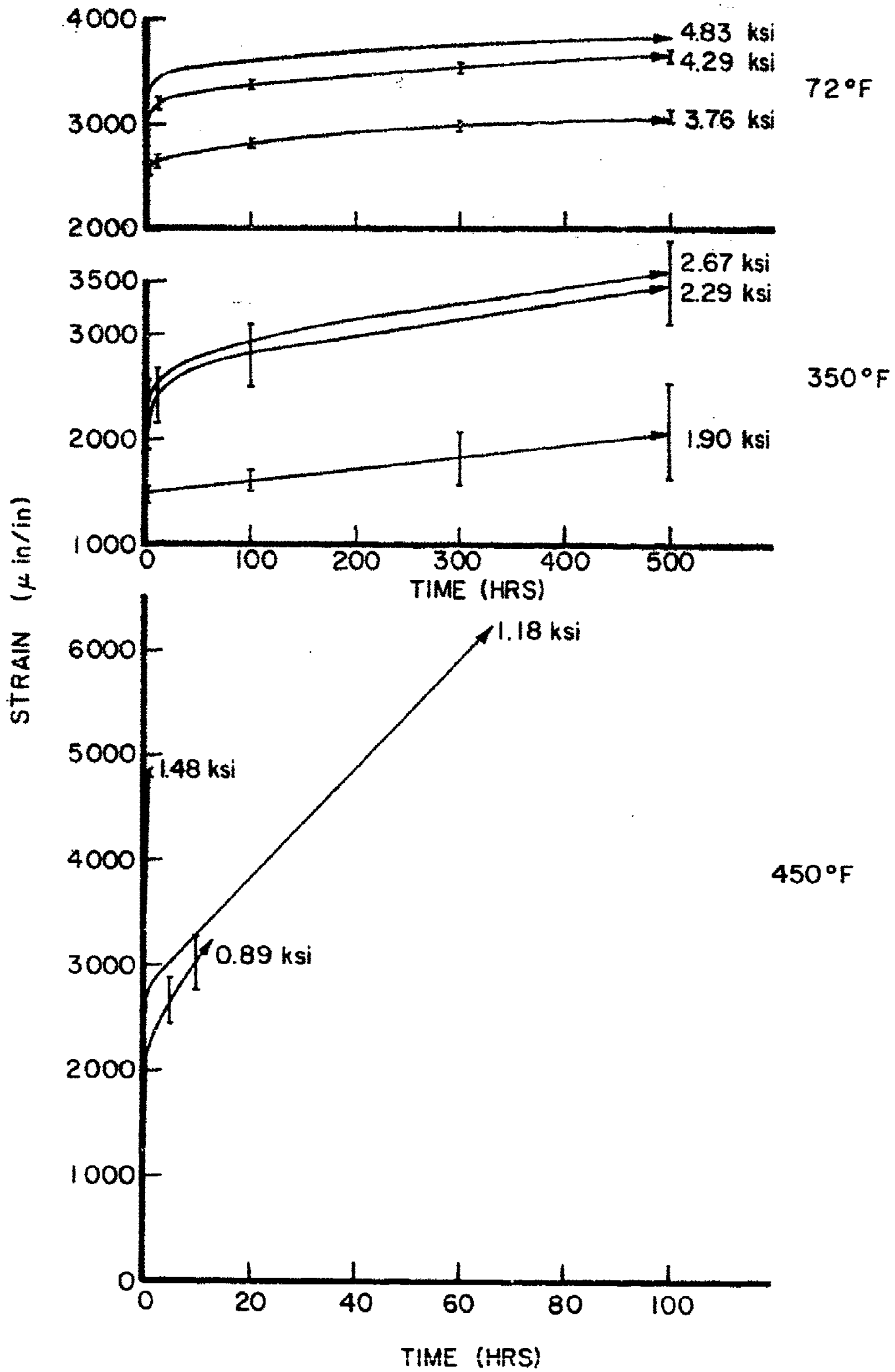


Figure 84. Tensile Creep Behavior of Unidirectional AS/4397 Composite Laminates: 90° Fiber Orientation.

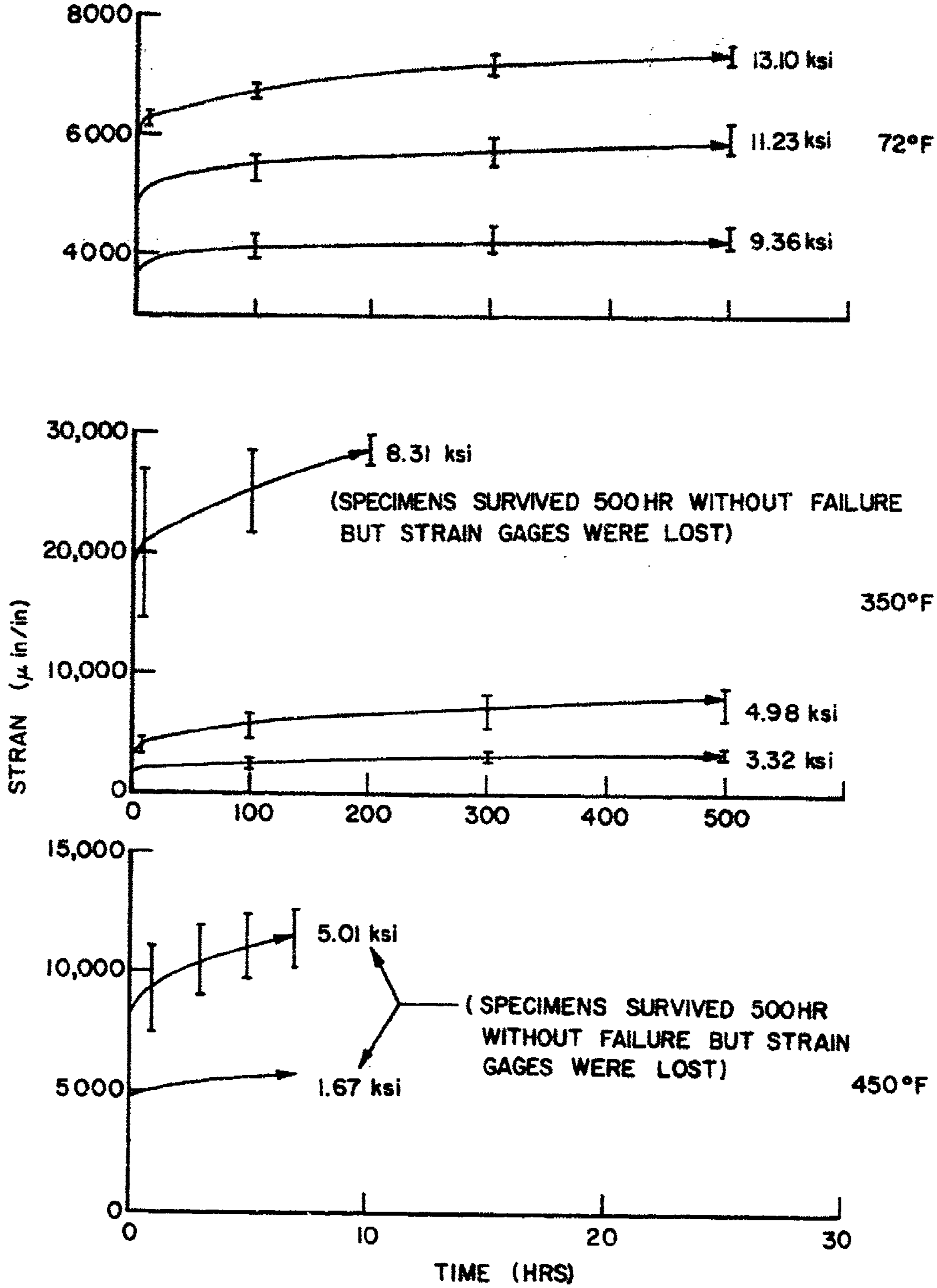


Figure 85. Tensile Creep Behavior of Bidirectional AS/4397 Composite Laminates: $\pm 45°$ Fiber Orientation.

TABLE 45

STRESS RUPTURE PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES

Graphite/Polyimide

Material System - AS/4397 Prepreg by - Hercules
Fiber - AS Matrix - 4397
Maximum Temperature Rating - 450°F
Resin Content - 28.0% by wt.
Fiber Content - 64.0% by vol.
Void Content - <0%
Test Method - Straight-sided tension

Laminate Sp. Gr. - 1.57
Average Ply Thickness - 0.0057 inch
No. of panels from which specimens were tested in this table - 26
Thickness of each type specimen: 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply
Reference - Design Guide

STRESS RUPTURE

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				350°F	Stress Level (ksi)	131.2	2.67	11.63
	Time to Failure (hrs)					Time to Failure (hrs)	270+[1]	127[2]	500+
	No. of Specimens					No. of Specimens	4	4	2
	Residual Strength (ksi)					Residual Strength (ksi)	169.9	4.13	18.58
	No. of Specimens					No. of Specimens	2	1	2
	Stress Level (ksi)					Stress Level (ksi)	112.5	2.29	8.31
	Time to Failure (hrs)					Time to Failure (hrs)	530+	339[3]	500+
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	208.3	3.54	18.04
	No. of Specimens					No. of Specimens	3	2	3
72°F	Stress Level (ksi)	182.1	4.83	13.10	450°F	Stress Level (ksi)	144.5	1.48	8.35
	Time to Failure (hrs)	531+	85[4]	500+		Time to Failure (hrs)	0.6[2]	1.6[1]	258[1]
	No. of Specimens	3	6	3		No. of Specimens	3	2	3
	Residual Strength (ksi)	213.7	5.06	18.58		Residual Strength (ksi)	----	----	17.97
	No. of Specimens	3	1	3		No. of Specimens	0	0	1
	Stress Level (ksi)	161.9	4.29	11.23		Stress Level (ksi)	123.9	1.18	5.01
	Time to Failure (hrs)	522+	504+	500+		Time to Failure (hrs)	370+	119[1]	529+
	No. of Specimens	3	3	3		No. of Specimens	3	4	3
	Residual Strength (ksi)	203.0	5.14	13.74		Residual Strength (ksi)	193.1	----	17.73
	No. of Specimens	3	3	3		No. of Specimens	2	0	3

Notes: All values represent arithmetic averages. Residual strengths determined by tensile test at 72°F.
1. Two specimens failed on loading or during test.
2. Three specimens failed on loading or during test.
3. One specimen failed on loading or during test.
4. Five specimens failed on loading.

TABLE 46

THERMOPHYSICAL PROPERTIES OF AS/4397 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - AS/4397	Prepreg by - Hercules	Graphite/Polyimide		
Fiber - AS	Matrix - 4397			
Maximum Temperature Rating - 450°F	Laminate Sp. Gr. - 1.55			
Resin Content - 30.3% by wt.	Average Ply Thickness - 0.0053 inch			
Fiber Content - 61.9% by vol.	No. of panels from which specimens were tested in this table - 4			
Void Content - ≈0%				
Thickness of each type specimen:	Therm. Exp. - 20 ply	Spec.Ht. - 20 ply		
	Therm. Cond. - 20 ply	Glass Trans. - 14 ply		
THERMOPHYSICAL PROPERTIES: 0°				
	-67°F	72°F	350°F	450°F
Thermal Expansion				
α_x (μin/in-°F)	≈0	≈0	≈0	≈0
α_y (μin/in-°F)	14.1	15.7	19.3	26.2
No. of Specimens per direction	3	9	5	3
Specific Heat				
C_p (btu/lb.-°F)	0.14	0.19	0.31	0.33
No. of Specimens	1	1	1	1
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	0.33	0.38	0.47	0.51
No. of Specimens	4	4	6	3
Glass Transition Temp.				
Dry (°F)	472°F			
Wet (°F)	264°F			
THERMOPHYSICAL PROPERTIES: ±45°				
Thermal Expansion				
α_x (μin/in-°F)	0.35	0.53	3.70	4.51
No. of Specimens per direction	4	5	2	2
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	--	0.33	0.39	--[1]
No. of Specimens	--	5	5	--

NOTE: On unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness. On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

1. The 20-ply specimen being used for conductivity measurements delaminated when heated above 350°F so no accurate data were obtained at 450°F.

TABLE 47

TENSILE PROPERTIES OF AS/4397 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES

Material System - AS/4397	Prepreg by - Hercules — Graphite/Polyimide
Fiber - AS Matrix - 4397	Laminate Sp. Gr. - 1.58
Maximum Rated Temperature - 450°F	Average Ply Thickness - 0.0055 inch
Resin Content - 27.5% by wt.	No. of panels from which specimens were tested in this table - 11
Fiber Content - 64.7% by vol.	Aging Conditions - 160°F, 100% R.H.
Void Content - 0%	Thickness of each type specimen: 90°-15 plies; ±45°-8 plies

TENSION: 90°

	72°F	350 °F	72°F	350°F
Exposure Time (hrs)	21.5	21.5	1320	1320
Weight Gain (% of orig. dry wt.)	0.51	0.49	1.01	1.01
Stnd. Dev. (%)	0.03	0.03	.04	.03
No. of Specimens	5	5	5	5
F_y^{tu} (ksi)	5.13	2.92	3.91	1.55
Stnd. Dev. (ksi)	0.41	0.27	0.40	0.27
Range (ksi)	4.57-5.61	2.70-3.38	3.47-4.45	1.19-1.91
No. of Specimens	5	5	5	5
F_y^{tpl} (ksi)	3.20	1.52	1.99	0.84
Stnd. Dev.	0.75	0.36	0.32	0.30
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.40	1.11	1.54	0.82
Stnd. Dev.	0.04	0.06	0.09	0.06
No. of Specimens	5	5	5	5
ϵ_y^{tu} (μ in/in)	3700	2700	2700	2200
Stnd. Dev.	300	300	300	200
No. of Specimens	5	5	5	5
Test Method	Straight-sided tension			
Reference	Design Guide			

TENSION: ±45°

Exposure Time (hrs)			984	
Weight Gain (% of orig. dry wt.)			1.31	
Stnd. Dev. (%)			0.13	
No. of Specimens			5	
F_x^{tu} (ksi)			18.66	
Stnd. Dev. (ksi)			0.51	
Range (ksi)			18.05-19.29	
No. of Specimens			5	
F_x^{tpl} (ksi)			6.83	
Stnd. Dev.			1.48	
No. of Specimens			5	
E_x^t (Msi)			2.61	
Stnd. Dev.			0.08	
No. of Specimens			5	
ϵ_x^{tu} (μ in/in)			16,600	
Stnd. Dev.			2540	
No. of Specimens			5	
Test Method	Straight-sided tension			
Reference	Design Guide			

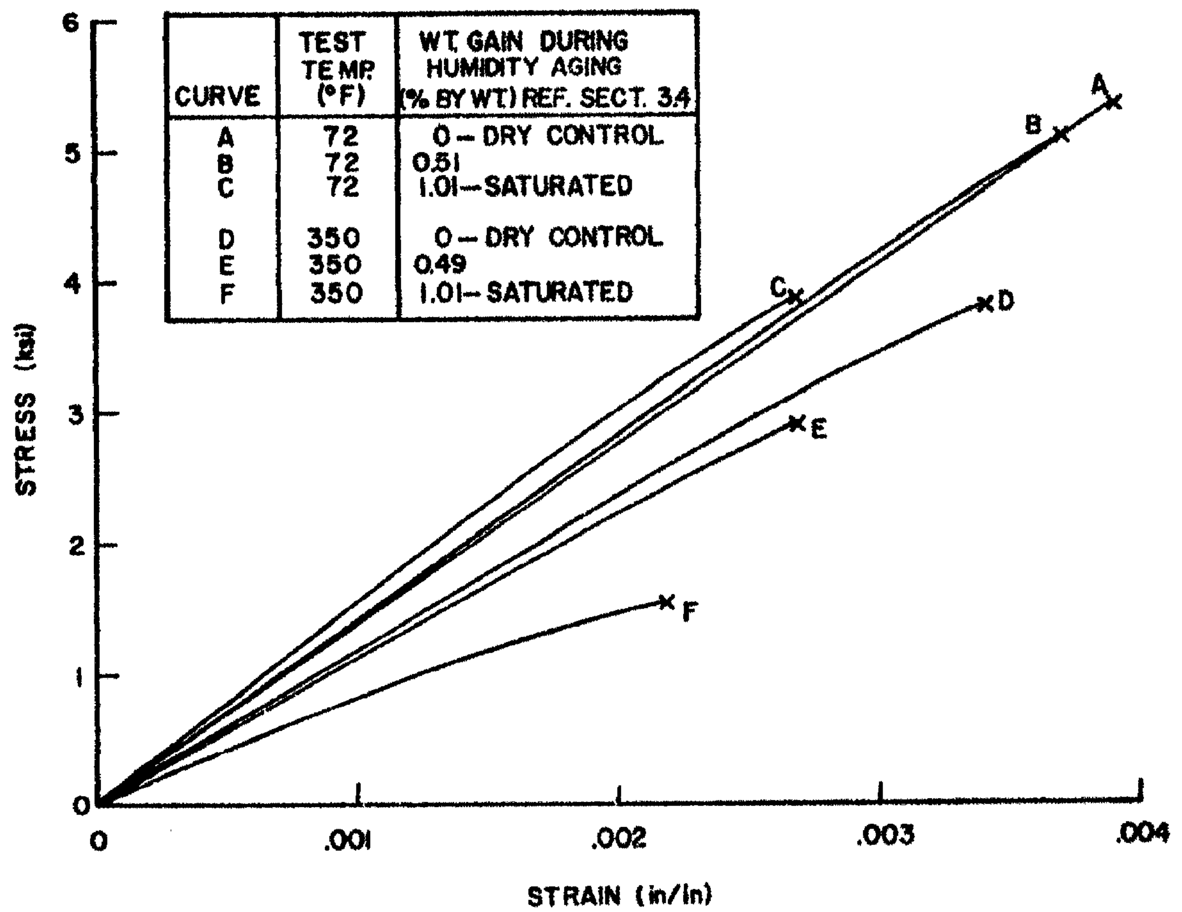


Figure 86. Tensile Stress-Strain for AS/4397 Composite Laminates After Humidity Aging at 160°F and 100% R.H.: 90° Fiber Orientation.

TABLE 48

SHEAR PROPERTIES OF AS/4397 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES — Graphite/Polyimide

Material System - AS/4397
Fiber - AS   Matrix - 4397
Maximum Rated Temperature - 450°F
Resin Content - 28.1% by wt.
Fiber Content - 64.5% by vol.
Void Content - ≈0%

Prepreg by - Hercules
Laminate Sp. Gr. - 1.58
Average Ply Thickness - 0.0058 inch
No. of panels from which specimens were tested in this table - 5
Aging Conditions - 160°F, 100% R.H.
Thickness of each type specimen:
Inplane shear-8 plies; Interlaminar shear-14 plies

INPLANE SHEAR

Test Temperature	72°F	350°F	72°F	350°F
Exposure Time (hrs)			984	
Weight Gain (% of orig. dry wt.)			1.31	
Stnd. Dev. (%)			0.13	
No. of Specimens			5	
F_{xy}^{su} (ksi)			9.33	
Stnd. Dev. (ksi)			0.26	
Range (ksi)			9.03-9.64	
No. of Specimens			5	
G_{xy}^{s} (Msi)			0.75	
Stnd. Dev.			0.01	
No. of Specimens			5	
Test Method	±45° straight-sided tension			
Reference	J. Comp. Mtls. [V6, p252 & V7, p124]			

INTERLAMINAR SHEAR

Exposure Time (hrs)	44	44	840	840
Weight Gain (% of orig. dry wt.)	0.63	0.59	1.45	1.28
Stnd. Dev. (%)	0.04	0.10	0.81	0.37
No. of Specimens	5	5	5	5
F^{isu} (ksi)	16.37	11.62	12.13	6.49
Stnd. Dev. (ksi)	1.94	0.70	1.62	0.61
Range (ksi)	13.45-18.35	11.12-12.82	9.35-13.45	5.75-7.29
No. of Specimens	5	5	5	5
Test Method	Short Beam Shear			
Reference	Design Guide - Jan., 1971			

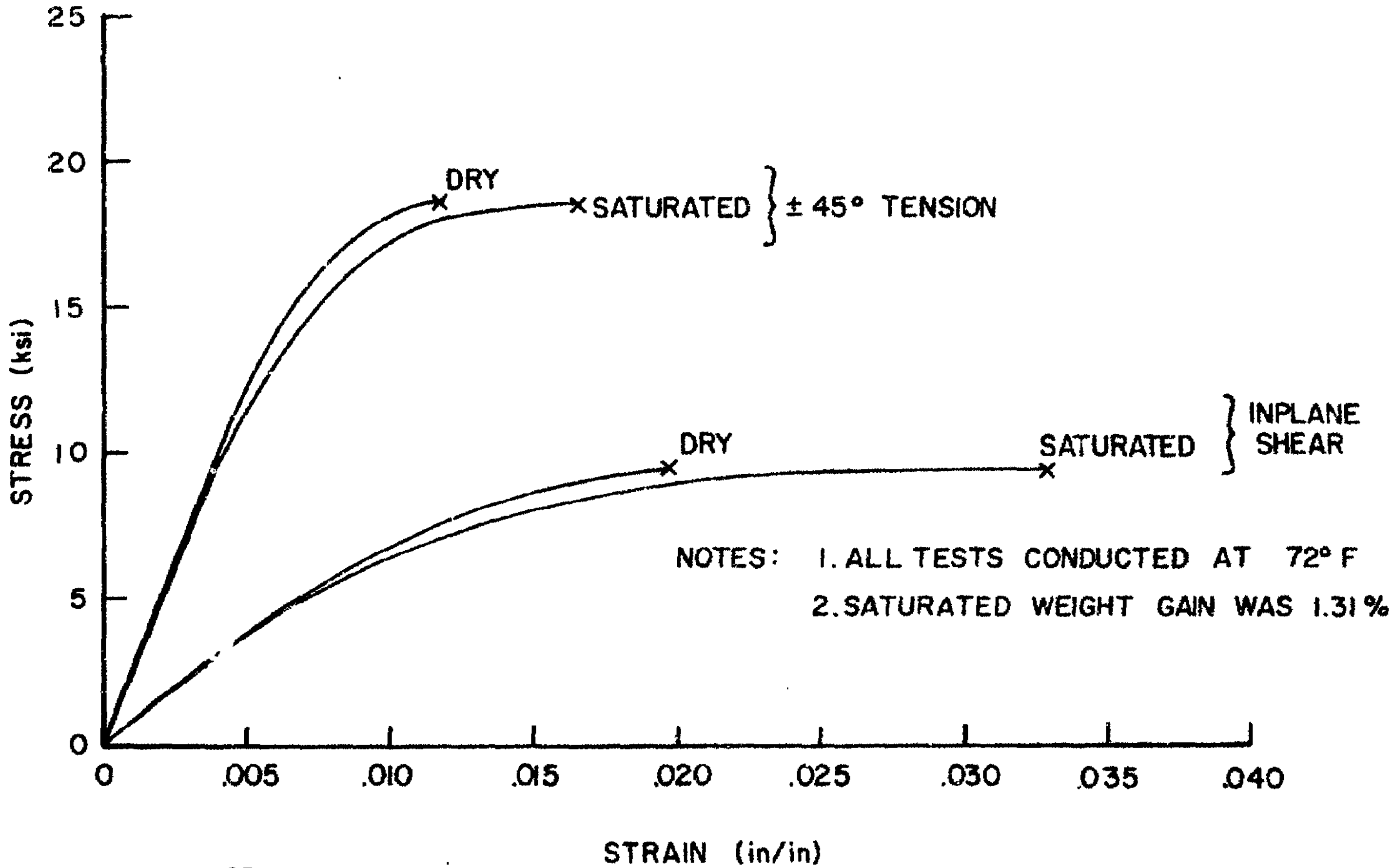


Figure 87. Tensile and Inplane Shear Stress-Strain Curves for AS/4397 Composite Laminates After Humidity Aging at 160°F and 100% R.H.

4.4 T300/F178

Tables 49-60 present the data generated for this graphite/polyimide composite system. Figures 88-105 illustrate the stress-strain, fatigue, and creep behavior of the material, as well as the effect of humidity aging upon the composite material. One item which caused some concern during the characterization of this material relates to the tensile strengths.

The values reported in Table 51 appear low in comparison with those appearing in the Hexcel literature. After considerable review and rechecking of our results, however, including the specimen tabbing procedures (which are of increased importance with brittle materials), it has been concluded that the values in Table 51 for 0° tension are in fact realistic. Data corroborating this is reported by Jones[7] in a SAMPE paper (where the F178 was still designated HX580) and also by a private communication with Hexcel in which it was mentioned that the higher values, reported in their literature, may well have been obtained with lower temperature postcures (the use of higher temperature postcures to increase the high temperature capabilities of the resin result in a sacrifice of room temperature properties. The F178 resin seems to be a rather brittle matrix system, as attested to both by Jones[7] and by the observation during this program that audible cracking occurs much much earlier in a 0° tension test than for any of the other materials evaluated in this program. Because of this brittle nature, some investigators utilize a sandwich beam specimen rather than a coupon to generate tensile properties. The values so generated are generally higher than those obtained with coupons.

The strength and ultimate strain values for the 90° tension at 72°F also seem low in comparison with similar data from other sources[7,8]. No explanation of this discrepancy can be made. The elevated temperature results reported in Table 51 do not disagree with similar data from these same sources.

TABLE 49

PROCESSING CONDITIONS FOR T300/F178 COMPOSITE LAMINATES

Composite Processing Information

Material System - T300/F178

Fiber - T300 Matrix - F178

Maximum Rated Temperature - 450°F   Prepreg by - Hexcel

Graphite/Polyimide T300/F178

Laminate Processing Schedule

Layup Procedure: Prepreg warmed to R.T. in closed wrapper. Prepreg removed from package and plies cut to desired size using razor blade. Plies stacked in desired sequence (release paper removed from each ply). Stack placed in autoclave on sheet of nonporous teflon and surrounded by cork dam to restrict fiber flow. Sheet of porous teflon placed on top of stack and one ply of bleeder cloth (style 181 glass) per four plies of prepreg placed on top of this. A layer of porous teflon is placed atop the bleeder cloth and another layer of 181 glass over this to act as a vent. This entire stack is then covered by the silicone rubber bladder.

Cure Schedule: A low vacuum (2-3 psi) is applied and the temperature is then raised to 270°F at 3-4°F/min., where it is held for 30 minutes. At this time, a full vacuum is drawn and a pressure of 85 psi applied above the bladder. The temperature is then raised at 3-4°F/min. to 350°F, where it is held for 2 hours. The panel is cooled under pressure to below 200°F before removal.

Postcure Schedule: After trimming of flash, the panels were placed, unrestrained, in an oven and heated to 400°F at a rate of 3-4°F/min. After a 4-hour hold at 400°F, the temperature is again raised at 3-4°F/min. to 475°F, where it is held for 10 hours. The panel is cooled to R.T. at 3-4°F/min.

TABLE 50

PREPREG AND COMPOSITE PHYSICAL PROPERTIES:T300/F178

Composite Physical Property Information

Material System - T300/F178 Fiber - T300 Matrix - F178 Maximum Rated Temperature - 450°F	Graphite/Polyimide Prepreg by - Hexcel

Prepreg Physical Properties

(Property)	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content-N.A.[1]	---	---	---	---
Resin Content- 41.7%	0.60%	41.1-42.2%	Hexcel, undesignated	---
Resin Flow- (Note 2 below)				
No. of Rolls Involved- 3				
No. of Batches Involved - 1				

Laminate Physical Properties[3]

	(Stnd. Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 47				
Fiber Content-59.5% by vol.	3.7%	52-67	Grid	
Resin Content-31.6% by wt.	2.7%	25.4-37.4	Point	
Void Content- 0.2%	0.03	0-1.0	Count	
Laminate Sp. Gr.-1.58			D792	ASTM
Fiber Sp. Gr.- 1.70	As reported by manufacturer.			
Matrix Sp. Gr.- 1.24	As reported by manufacturer.			
Thickness per ply-0.0053 inch			---	---

Notes:
1. This prepreg contains no volatiles.
2. Flow was not measured.
3. The properties reported here represent averages for all panels of this material used throughout the program.

TABLE 51

TENSILE PROPERTIES OF T300/F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES	
Material System - T300/F178 Prepreg by - Hexcel	Graphite/Polyimide
Fiber - T300 Matrix - F178	Laminate Sp. Gr. - 1.57
Maximum Rated Temperature - 450°F	Average Ply Thickness - 0.0052 inch
Resin Content -	No. of panels from which specimens were tested in this table - 12
Fiber Content -	
Void Content -	Thickness of each type specimen: 0°-6 ply; 90°-15 ply

TENSION: 0°

	67°F	72°F	350°F	450°F
F_x^{tu} (ksi)	129.9	156.7	152.2	152.9
stnd. dev. (ksi)	31.4	21.0	19.9	20.4
Range (ksi)	93.6-162.1	134.2-194.3	134.9-177.1	132.4-177.8
No. of Specimens	5	9	5	5
F_x^{tpl} (ksi)	129.9	156.7	152.2	152.9
stnd. dev.	31.4	21.0	19.9	20.4
No. of Specimens	5	9	5	5
E_x^t (Msi)	20.22	20.25	19.56	19.32
stnd. dev.	0.97	0.82	0.61	1.16
No. of Specimens	5	9	5	5
ϵ_x^{tu} (μin/in)	6400	7500	7500	7800
stnd. dev.	1500	1200	800	1000
No. of Specimens	5	9	5	4
ν_{xy}^t	0.31	0.33	0.28	0.35
stnd. dev.	0.03	0.03	0.02	0.01
No. of Specimens	5	9	4	3
Test Method	Straight-sided tension			
Reference	Design Guide			

TENSION: 90°

	67°F	72°F	350°F	450°F
F_y^{tu} (ksi)	3.28	3.82	2.97	2.14
stnd. dev. (ksi)	0.83	0.40	0.83	0.64
Range (ksi)	2.03-4.13	3.22-4.35	2.03-4.16	1.10-2.70
No. of Specimens	5	7	5	5
F_y^{tpl} (ksi)	2.85	3.33	2.95	1.35
stnd. dev.	0.47	0.71	0.53	0.50
No. of Specimens	5	7	3	5
E_y^t (Msi)	1.61	1.50	1.15	0.97
stnd. dev.	0.10	0.08	0.10	0.15
No. of Specimens	5	7	5	5
ϵ_y^{tu} (μin/in)	2100	2600	3000	2600
stnd. dev.	500	300	900	1000
No. of Specimens	5	7	4	5
ν_{yx}^t	0.025[1]	0.024[1]	0.016[1]	0.018[1]
Test Method	Straight-sided tension			
Reference	Design Guide			

1. Computed using elastic moduli and longitudinal Poisson's ratio.

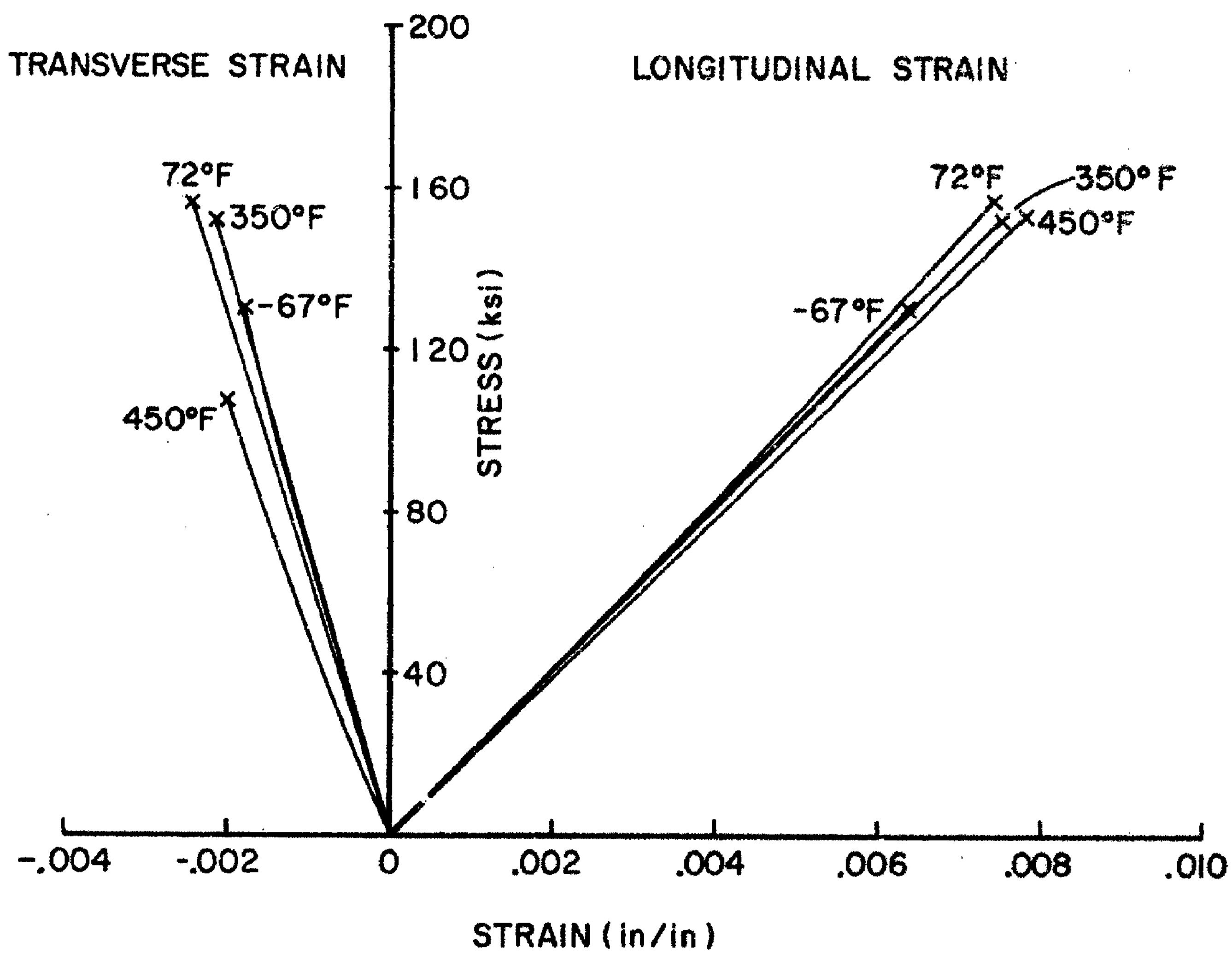


Figure 88. Tensile Stress-Strain Curves for Unidirectional T300/F178 Composite Laminates: 0° Fiber Orientation.

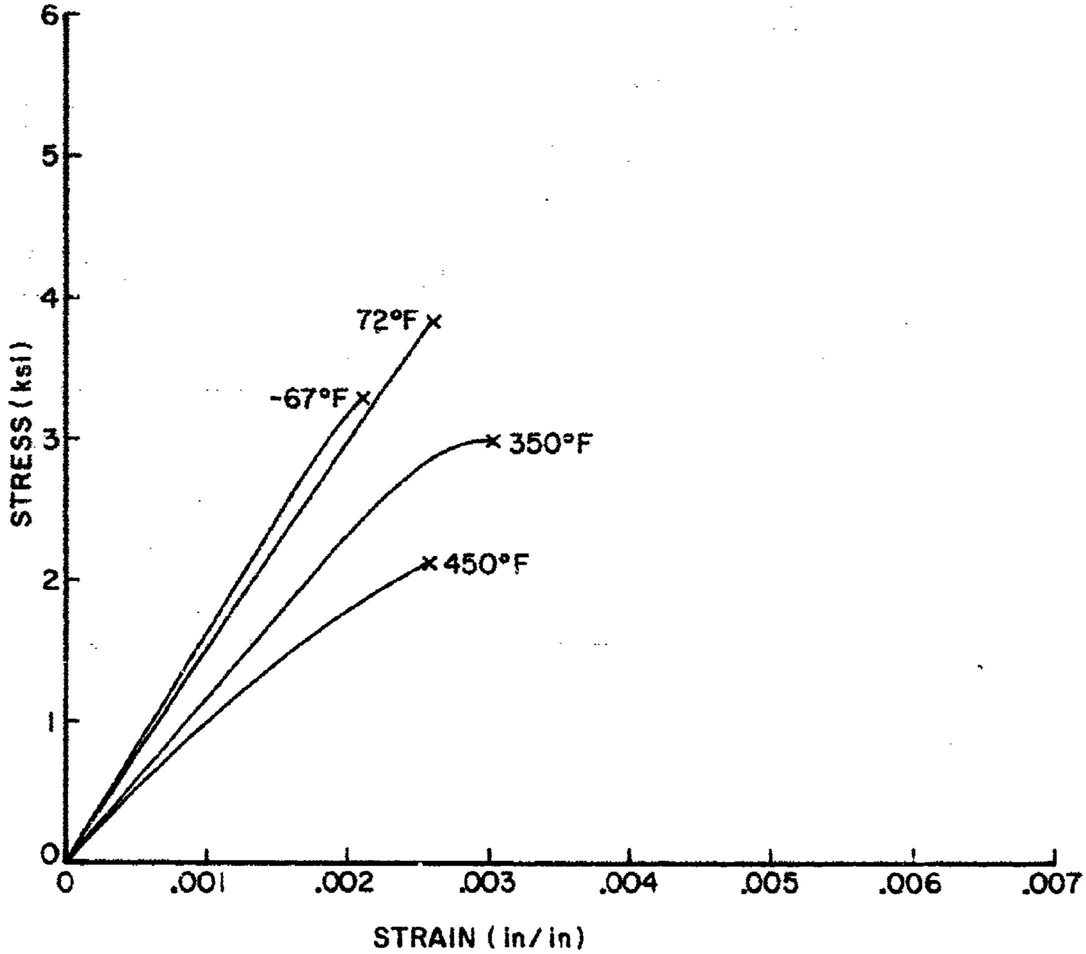


Figure 89. Tensile Stress-Strain Curves for Unidirectional T300/F178 Composite Laminates: 90° Fiber Orientation.

TABLE 52

TENSILE PROPERTIES OF T300/F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - T300/F178 Prepreg by - Hexcel Graphite/Polyimide Fiber - T300 Matrix - F178 Laminate Sp. Gr. - N.A. Maximum Rated Temperature - 450°F Average Ply Thickness - 0.0058 inch Resin Content - No. of panels from which specimens were tested in this table-5 Fiber Content - Void Content - Thickness of specimens - 15 ply				
TENSION: ± 45°				
	-67°F	72°F	350°F	450°F
F_x^{tu} (ksi)	15.82	17.17	14.61	12.18
stnd. dev. (ksi)	1.02	1.19	0.55	0.36
Range (ksi)	14.30-17.14	15.44-18.24	14.21-15.52	11.81-12.73
No. of Specimens	5	5	5	5
F_x^{tpl} (ksi)	9.02	7.28	4.71	3.03
stnd. dev. (ksi)	2.31	0.76	0.23	0.36
No. of Specimens	5	5	5	5
E_x^t (Msi)	2.59	2.66	1.94	1.49
stnd. dev.	0.20	0.13	0.06	0.07
No. of Specimens	5	5	5	5
ε_x^{tu} (μin/in)	9,000	9,400	15,700+[1]	18,000+[1]
stnd. dev.	1,100	1,500	---	---
No. of Specimens	5	5	5	5
ν_{xy}^t	0.66	0.76	0.87	0.79
stnd. dev.	0.07	0.03	0.04	0.08
No. of Specimens	5	5	5	5
Test Method	Straight-sided tension			
Reference	Design Guide			

1. Specimens elongated so much that surface plies cracked, creating electrical discontinuities in strain gages.

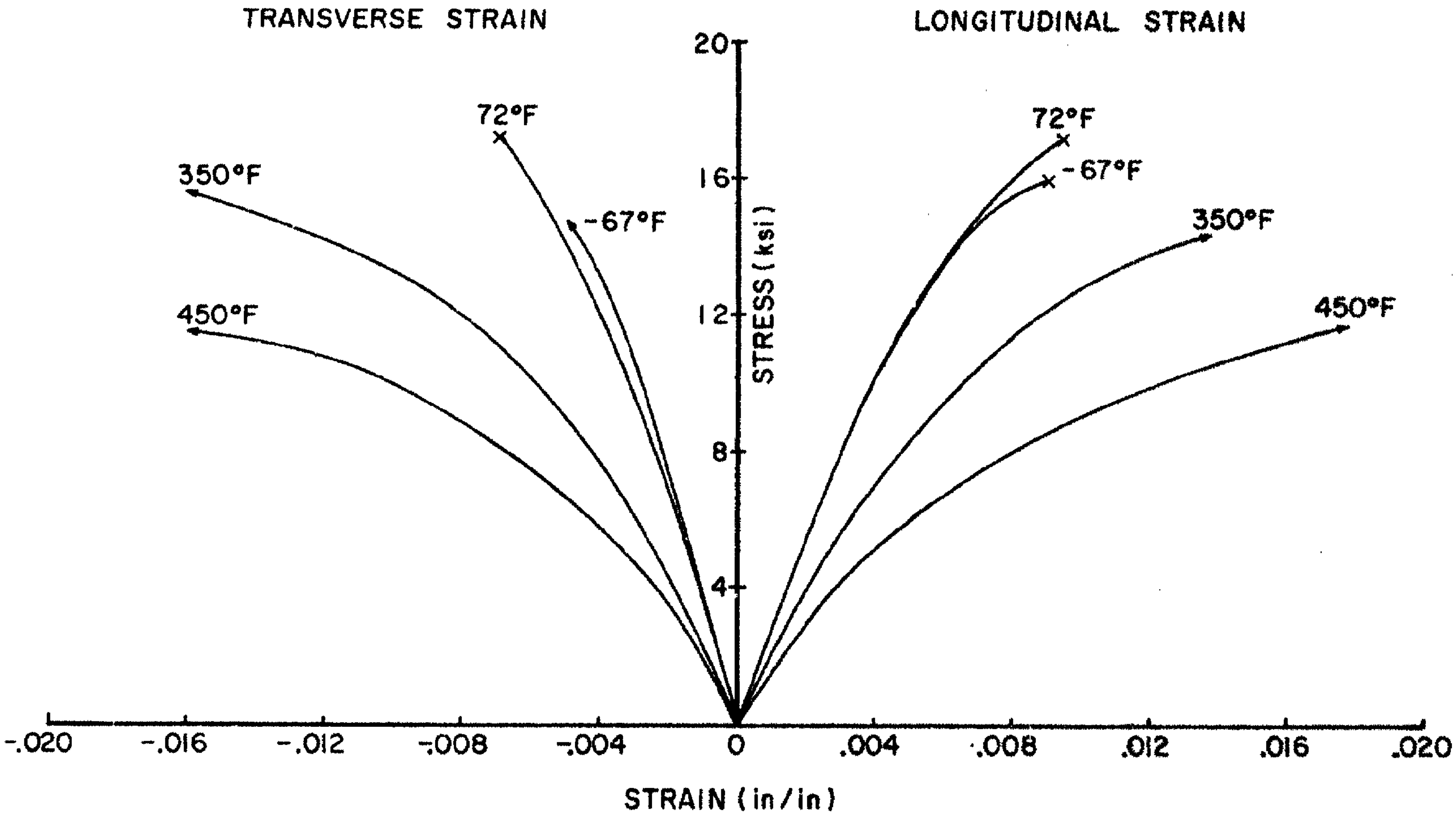


Figure 90. Tensile Stress-Strain Curves for Bidirectional T300/F178 Composite Laminates: ±45° Fiber Orientation.

TABLE 53

COMPRESSIVE PROPERTIES OF F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - F178; Fiber - T300; Matrix - F178; Maximum Rated Temperature - 450°F; Resin Content -; Fiber Content -; Void Content -		Graphite/Polyimide; Prepreg by - Hexcel; Laminate Sp. Gr. - N.A.; Average Ply Thickness -0.0054 in.; No. of panels from which specimens were tested in this table - 1; Thickness of specimens: 20 ply		
COMPRESSION : 0°				
	-67°F	72°F	350°F	450°F
F_x^{cu} (ksi)	200.0	180.0	120.0	137.4
stnd. dev. (ksi)	9.6	12.0	15.3	27.9
Range (ksi)	192.4-215.2	167.1-195.6	106.1-137.7	112.7-180.5
No. of Specimens	5	5	5	5
F_x^{cpl} (ksi)	94.9[1]	69.5[1]	54.7	105.1
stnd. dev.	21.3	21.2	13.6	33.3
No. of Specimens	5	5	5	5
E_x^c (Msi)	18.1	18.2	20.5	17.9
stnd. dev.	1.3	0.7	1.1	0.8
No. of Specimens	5	5	5	5
ϵ_x^{cu} (μ in/in)	10,500[2]	10,400[2]	6,900	8,100
stnd. dev.	3,200	4,200	1,200	2,000
No. of Specimens	5	5	5	5
Test Method	Celanese Compression Coupon & Test Fixture			
Reference	AFML-TR-72-205, Pt. 1			
COMPRESSION: 90°				
F_y^{cu} (ksi)	No compression tests were conducted on T300/F178 composite laminates with the 90° fiber orientation.			
stnd. dev. (ksi)				
Range (ksi)				
No. of Specimens				
F_y^{cpl} (ksi)				
stnd. dev.				
No. of Specimens				
E_y^c (Msi)				
stnd. dev.				
No. of Specimens				
ϵ_y^{cu} (μ in/in)				
stnd. dev.				
No. of Specimens				
Test Method				
Reference				

Notes: 1. Proportional limits reported here represent first deviation from linearity. In majority of cases, this deviation was due, apparently, to buckling.

2. Ultimate strain values represent maximum observed strain rather than ultimate values. Buckling was observed in majority of tests.

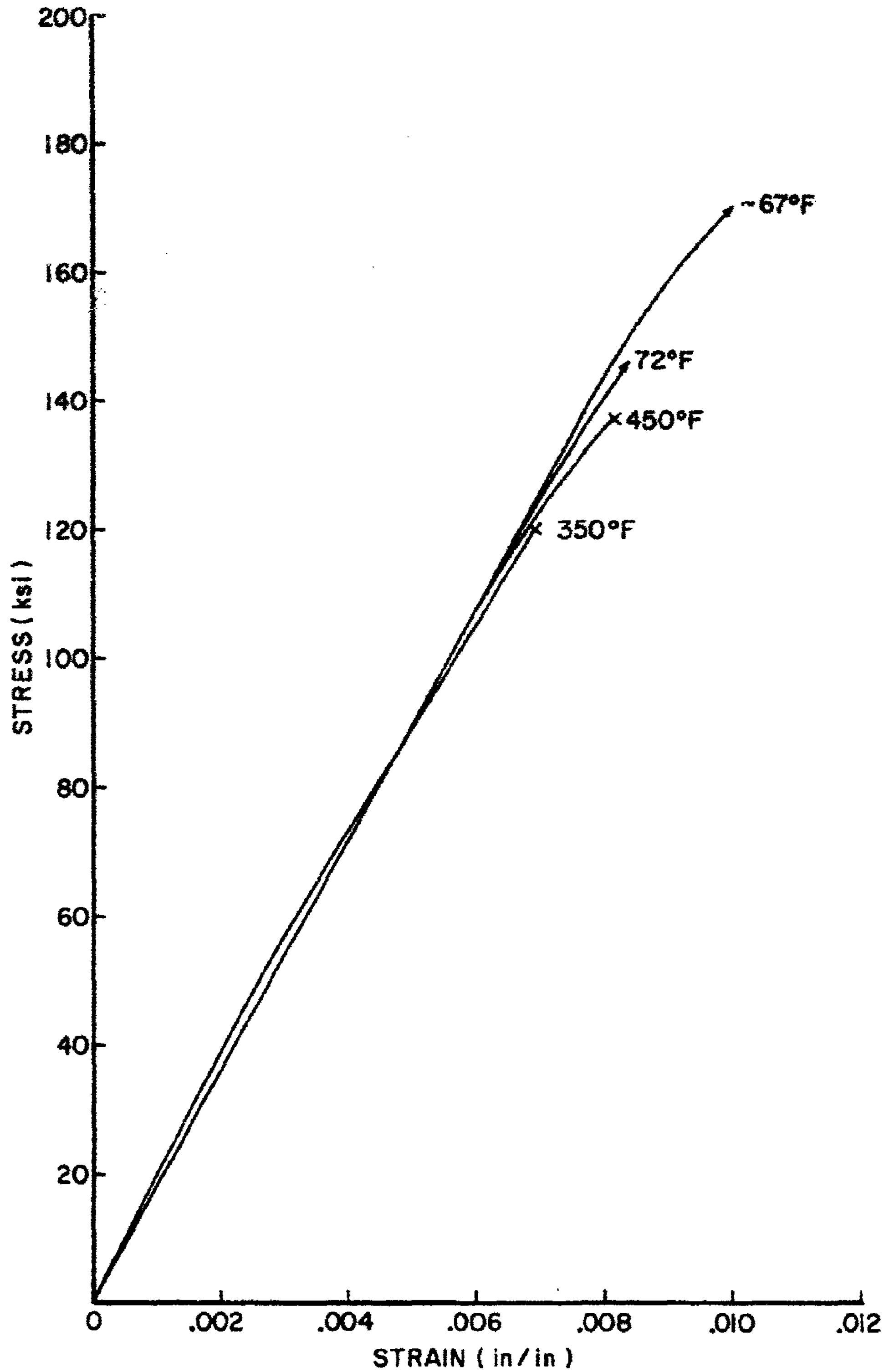


Figure 91. Compressive Stress-Strain Curves for Unidirectional T300/F178 Composite Laminates: 0° Fiber Orientation.

TABLE 54

FLEXURAL PROPERTIES OF F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - F178 Prepreg by - Hexcel Graphite/Polyimide Fiber - T300 Matrix - F178 Maximum Rated Temperature - Resin Content - Fiber Content - Void Content -	Laminate Sp. Gr. - 1.56 Average Ply Thickness - 0.0052 in. No. of panels from which specimens were tested in this table - 2 Thickness of each type specimen: 0°-14 plies; 90°-14 plies			
FLEXURE : 0°				
	-67°F	72°F	350°F	450°F
F_x^{fu} (ksi)	200.9	204.0	179.1	147.4
stnd. dev. (ksi)	9.9	9.5	11.8	7.9
Range (ksi)	188.0-214.7	189.3-215.1	163.3-195.8	137.4-159.4
No. of Specimens	5	5	5	5
E_x^f (Msi)	17.06	16.89	18.43	18.26
stnd. dev.	0.87	1.21	0.92	1.04
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide Jan., 1971			
FLEXURE: 90°				
F_y^{fu} (ksi)	9.36	8.12	4.91	4.14
stnd. dev. (ksi)	1.40	1.55	0.87	0.33
Range (ksi)	7.91-11.42	6.55-10.25	3.77-5.87	3.86-4.70
No. of Specimens	5	5	5	5
E_y^t (Msi)	1.50	1.26	1.05	0.93
stnd. dev.	0.08	0.10	0.09	0.15
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide Jan., 1971			

TABLE 55

SHEAR PROPERTIES OF T300/F178
COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - T300/F178			Graphite/Polyimide	
Fiber - T300	Matrix - F178		Prepreg by - Hexcel	
Maximum Rated Temperature -450°F			Laminate Sp. Gr. -N.A.	
Resin Content -			Nominal Ply Thickness - 0.0057 in.	
Fiber Content -			No. of panels from which specimens were tested in this table - 6	
Void Content -				
Thickness of each type specimen:			Inplane shear - 15 ply Interlaminar shear - 14 ply	
INPLANE SHEAR				
	-67°F	72°F	350°F	450°F
T_{xy}^u (ksi)	7.91	7.59	7.30	6.09
stnd. dev. (ksi)	0.51	0.60	0.27	0.18
No. of Specimens	5	5	5	5
G_{xy} (Msi)	0.76	0.72	0.52	0.41
stnd. dev. (Msi)	0.08	0.05	0.02	0.03
No. of Specimens	5	5	5	5
Test Method	±45° straight-sided tension			
Reference	J. Comp. Mtls. [V.6, p.252, and V.7, p.124]			
INTERLAMINAR SHEAR				
F^{isu} (ksi)	15.9	14.8	10.2	8.0
Stnd. Dev. (ksi)	1.3	0.9	0.3	0.4
Range (ksi)	14.8-17.7	14.1-16.1	9.9-10.6	7.4-8.3
No. of Specimens	5	5	5	5
Test Method	Short Beam Shear, S/D=4			
Reference	Design Guide - Jan., 1971			

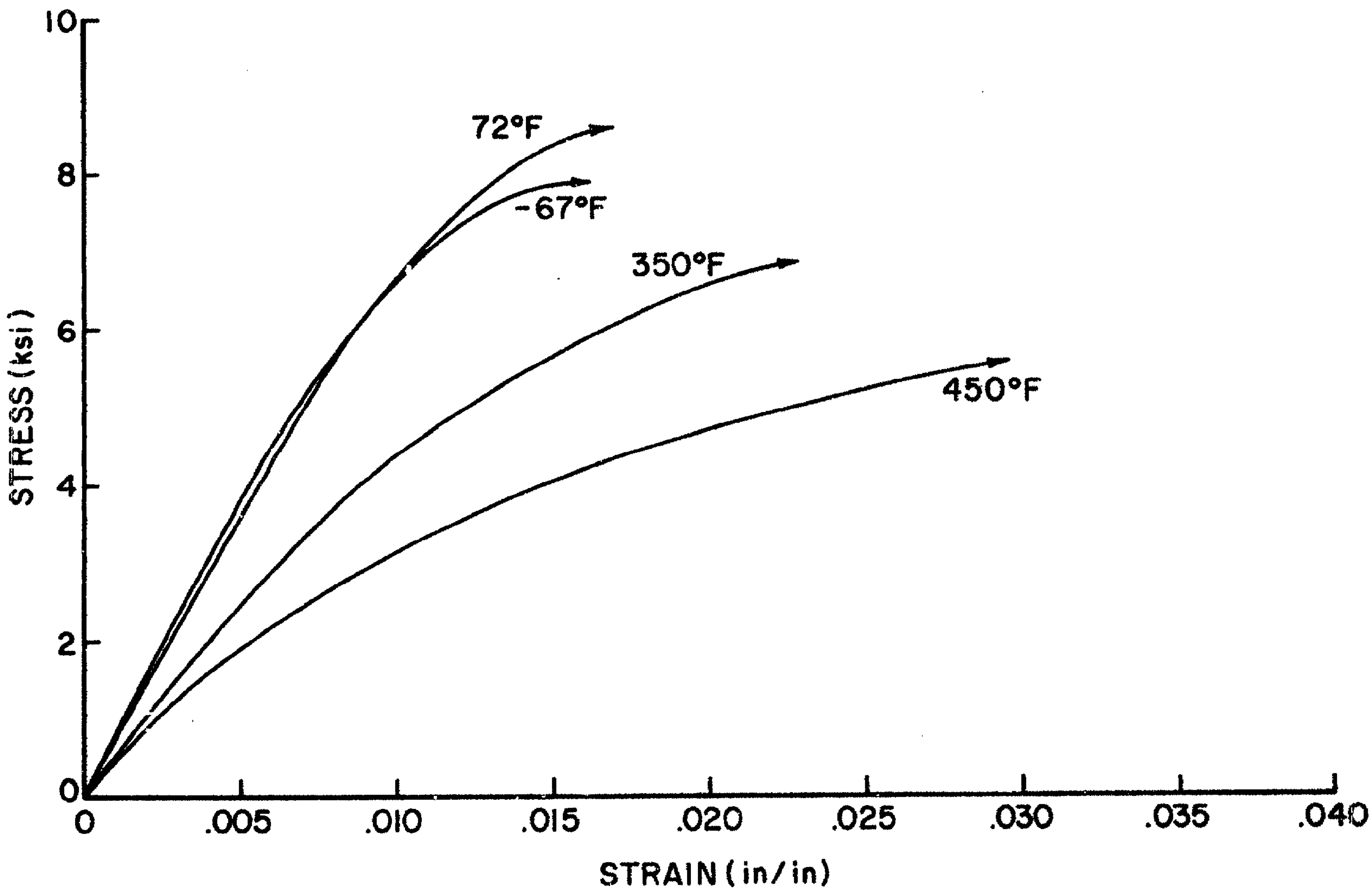


Figure 92. Inplane Shear Stress-Strain Curves for T300/F178 Composite Laminates.

TABLE 56

FATIGUE PROPERTIES OF T300/F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES — Graphite/Polyimide

Material System - T300/F178 Prepreg by - Hexcel
Fiber - T300 Matrix - F178
Maximum Temperature Rating - 450°F
Resin Content - 34.9% by wt.
Fiber Content - 55.5% by vol.
Void Content - ~0%

Laminate Sp. Gr. - 1.58
Average Ply Thickness - 0.0055 inch
No. of panels from which specimens were tested in this table - 27
Thickness of each type of specimen: 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply

Test Method - Straight-sided tension
Reference - Design Guide

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Max. Stress (ksi)			
	Lifetime (cycles)			
	No. of Specimens			
	Residual Strength (ksi)			
	No. of Specimens			
	Max. Stress (ksi)			
	Lifetime (cycles)			
	No. of Specimens			
	Residual Strength (ksi)			
	No. of Specimens			
	Max. Stress (ksi)			
	Lifetime (cycles)			
	No. of Specimens			
	Residual Strength (ksi)			
	No. of Specimens			
72°F	Max. Stress (ksi)	133.2	3.06	12.02
	Lifetime (cycles)	34,325	2910	36,170
	No. of Specimens	4	4	4
	Residual Strength (ksi)	189.9	---	---
	No. of Specimens	1	0	0
	Max. Stress (ksi)	125.4	2.67	11.16
	Lifetime (cycles)	$1.9x10^6$	13,730	463,660
	No. of Specimens	4	4	4
	Residual Strength (ksi)	175.1	N.A.[5]	---
	No. of Specimens	1	1	0
	Max. Stress (ksi)	109.7	1.31	10.30
	Lifetime (cycles)	$9.9x10^6$	740,12	$2.58x10^6$
	No. of Specimens	4	4	4
	Residual Strength (ksi)	169.8	4.64	16.53
	No. of Specimens	3	3	1
350°F	Max. Stress (ksi)	121.8	1.78	10.95
	Lifetime (cycles)	35,940	940[1]	7490
	No. of Specimens	4	4	4
	Residual Strength (ksi)	---	5.96	---
	No. of Specimens	0	1	0
	Max. Stress (ksi)	114.2	1.63	10.22
	Lifetime (cycles)	$1.6x10^6$	1040+[2]	67,520
	No. of Specimens	4	5	4
	Residual Strength (ksi)	---	5.46	---
	No. of Specimens	0	1	0
	Max. Stress (ksi)	106.6	1.49	9.49
	Lifetime (cycles)	$3.0x10^6$	177,840	736,970
	No. of Specimens	4	4	4
	Residual Strength (ksi)	150.6	6.23	---
	No. of Specimens	1	3	0
450°F	Max. Stress (ksi)	114.7	1.50	9.75
	Lifetime (cycles)	134,500	75,482[4]	4550
	No. of Specimens	4	4	4
	Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress (ksi)	107.0	1.29	9.14
	Lifetime (cycles)	944,470	436[3]	56,210
	No. of Specimens	4	5	4
	Residual Strength (ksi)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress (ksi)	99.4	1.07	8.53
	Lifetime (cycles)	$5.4x10^6$	88,500+[4]	$1.4x10^6$
	No. of Specimens	4	4	4
	Residual Strength (ksi)	---	5.28	---
	No. of Specimens	0	1	0

Notes: Fatigue lifetimes are log-mean values. All residual strengths determined by tensile test at 72°F.
1. Two specimens failed during first cycle.
2. Two specimens failed during first cycle and one slipped in grips after 602,000 cycles and was inadvertantly broken before cycling could resume.
3. Three specimens failed during first cycle.
4. One specimen failed during first cycle.
5. Specimen loaded too fast, no value obtained.

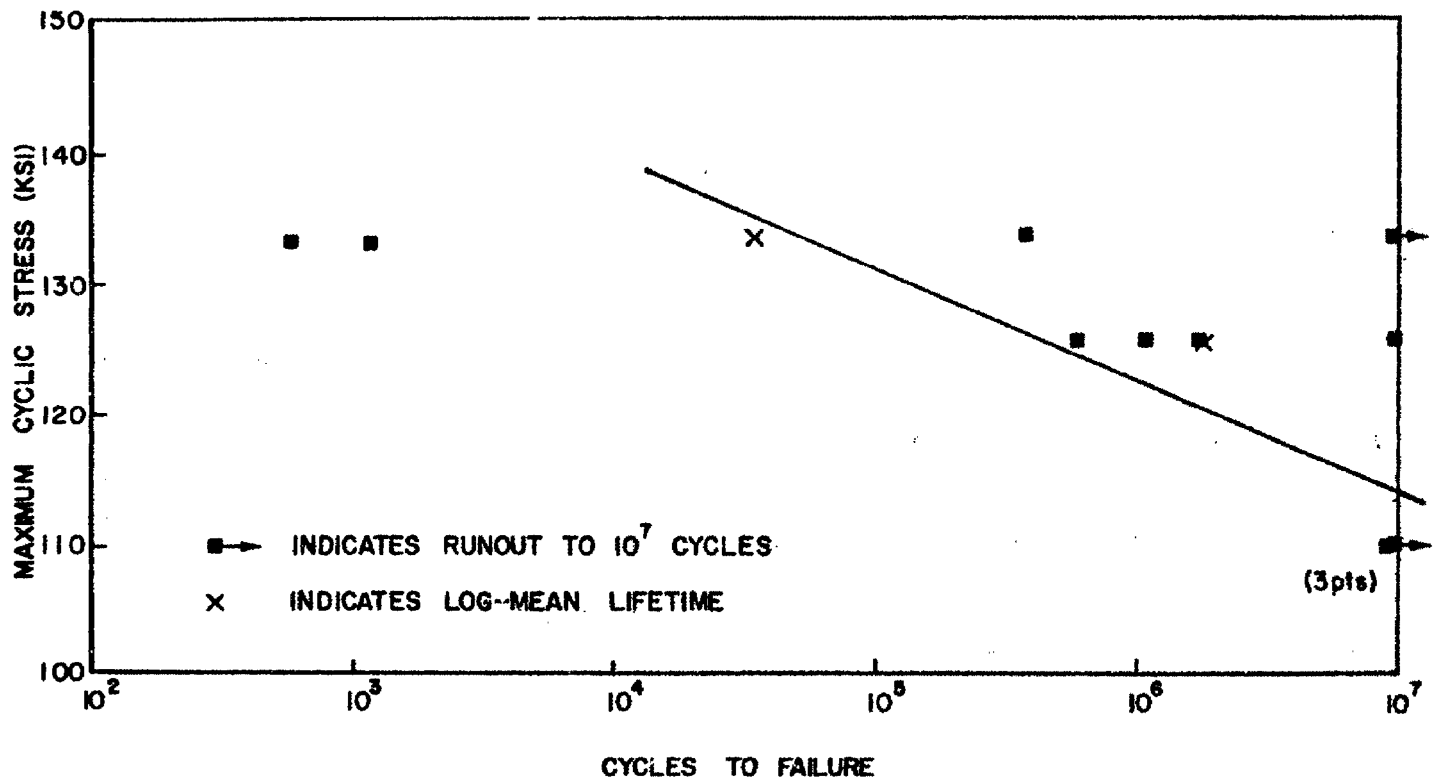


Figure 93. Tensile-Tensile Fatigue Behavior of Unidirectional T300/F178 Composite Laminates at 72°F: 0° Fiber Orientation, R=0.10, 30 Hz.

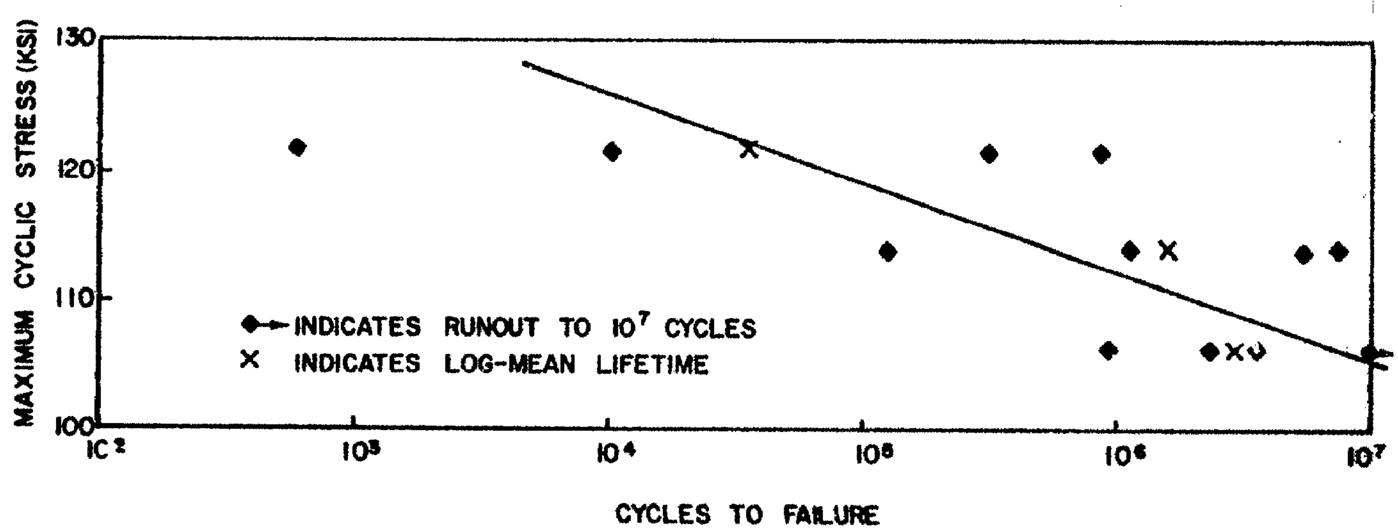


Figure 94. Tensile-Tensile Fatigue Behavior of Unidirectional T300/F178 Composite Laminates at 350°F: 0° Fiber Orientation, R=0.10, 30 Hz.

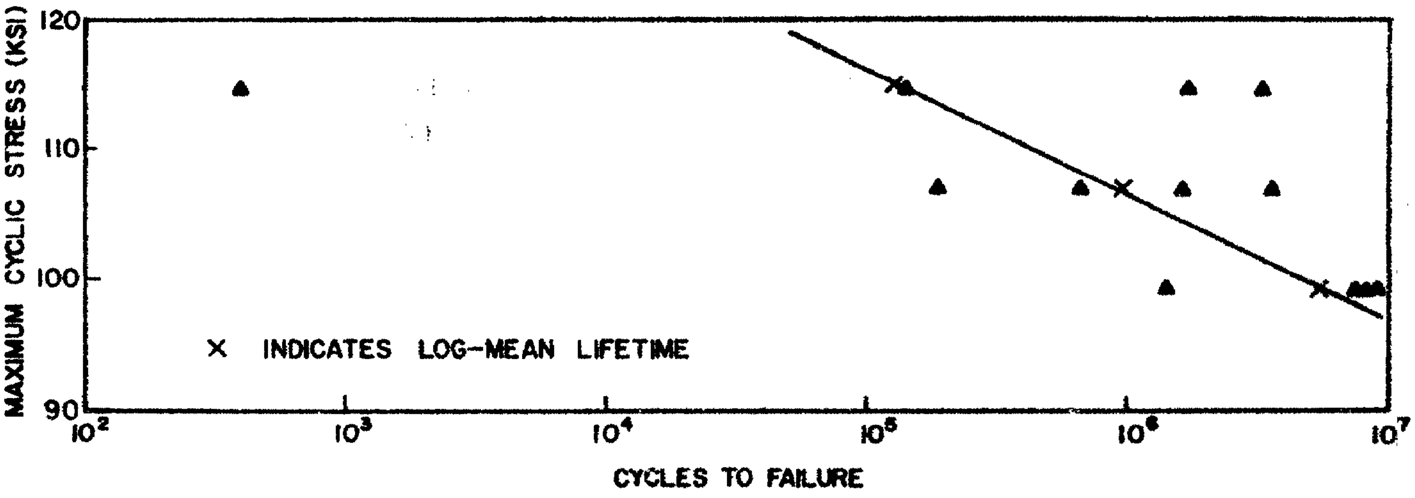


Figure 95. Tensile-Tensile Fatigue Behavior of Unidirectional T300/F178 Composite Laminates at 450°F: 0° Fiber Orientation, R=0.10, 30 Hz.

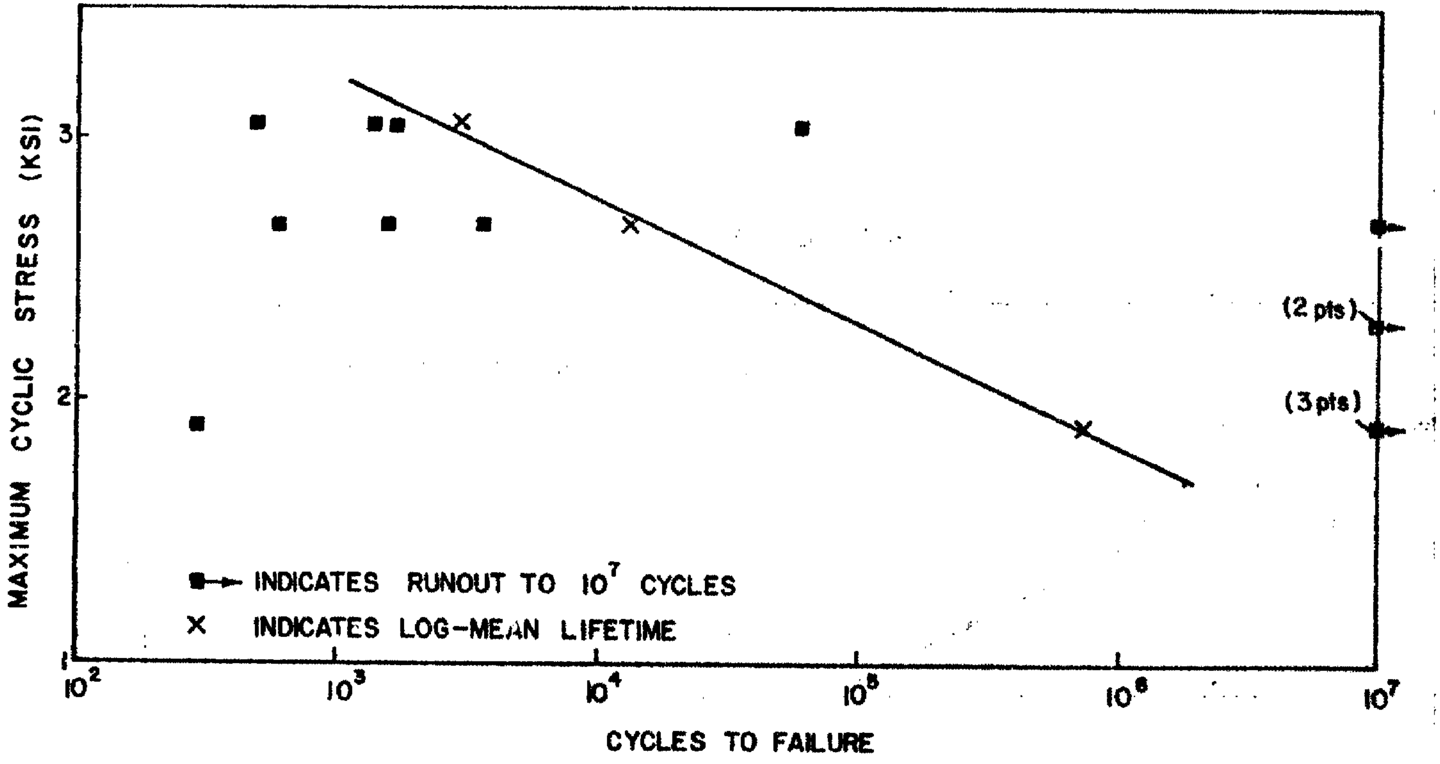


Figure 96. Tensile-Tensile Fatigue Behavior of Unidirectional T300/F178 Composite Laminates at 72°F: 90° Fiber Orientation, R=0.10, 30 Hz.

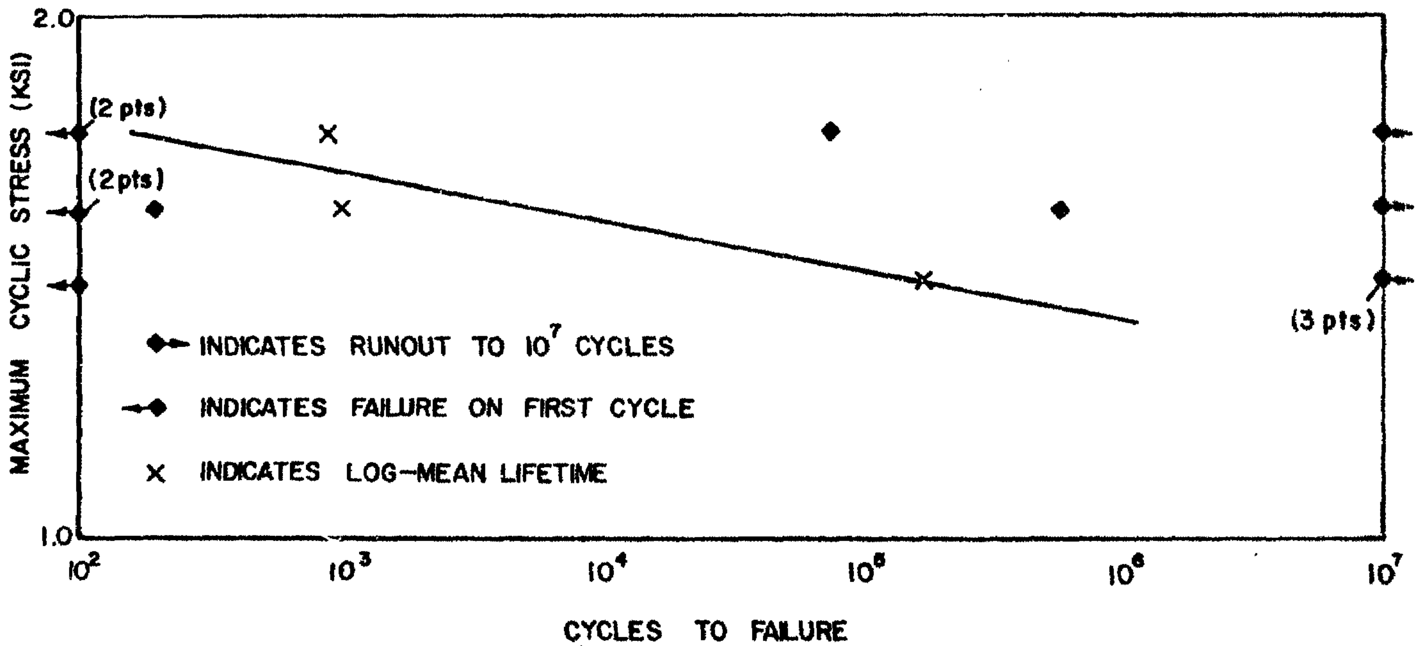


Figure 97. Tensile-Tensile Fatigue Behavior of Unidirectional T300/F178 Composite Laminates at 350°F: 90° Fiber Orientation, R=0.10, 30 Hz.

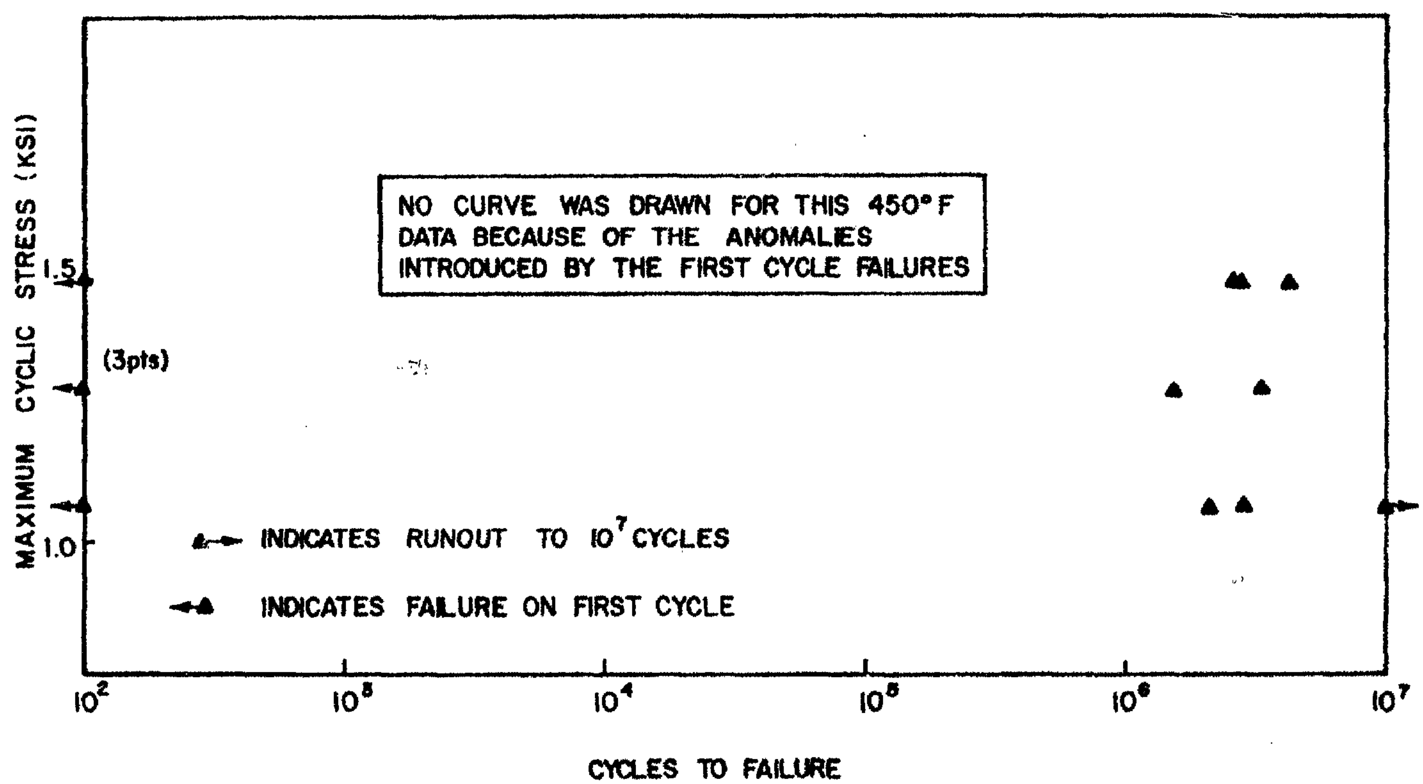


Figure 98. Tensile-Tensile Fatigue Behavior of Unidirectional T300/F178 Composite Laminates at 450°F: 90° Fiber Orientation, R=0.10, 30 Hz.

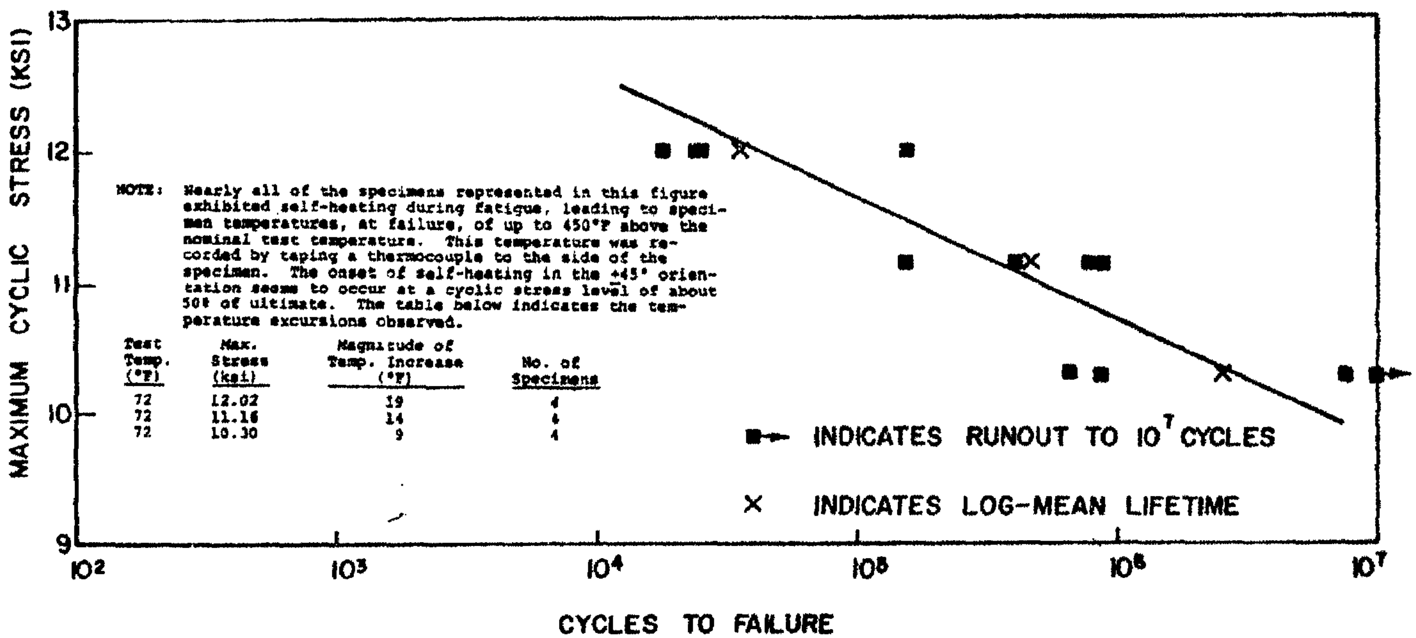


Figure 99. Tensile-Tensile Fatigue Behavior of Bidirectional T300/F178 Composite Laminates at 72°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

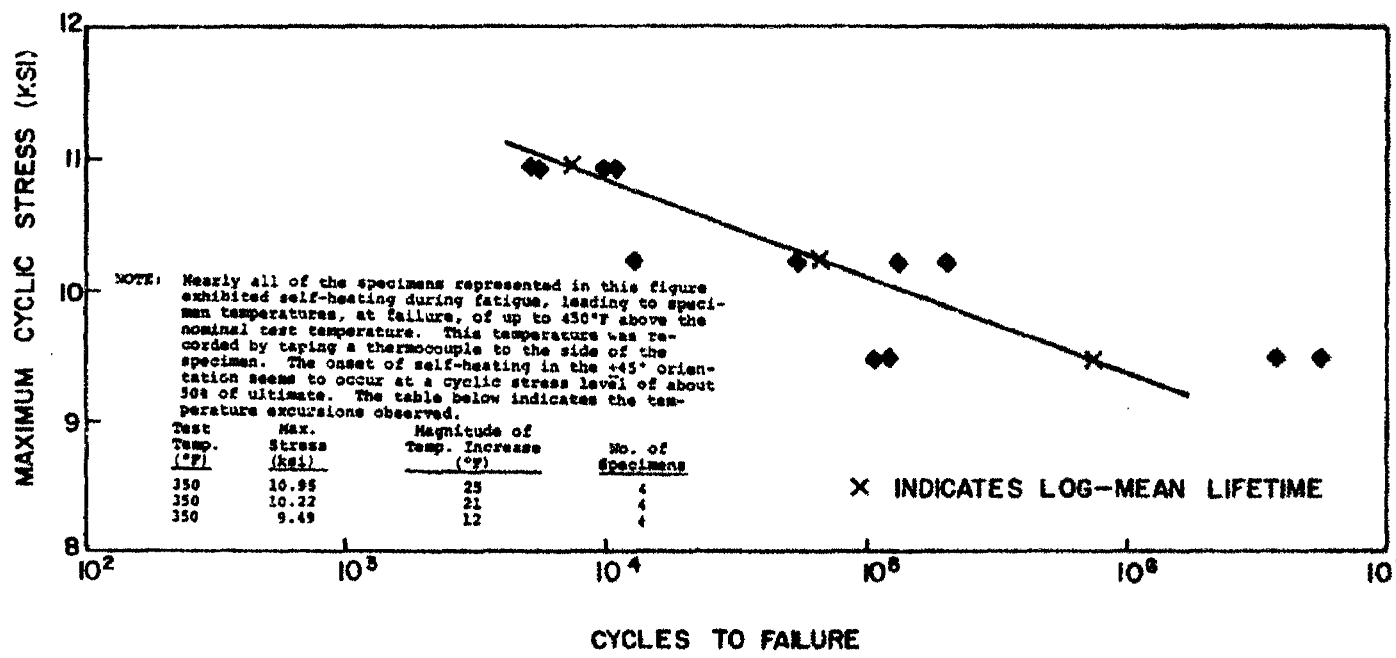


Figure 100. Tensile-Tensile Fatigue Behavior of Bidirectional T300/F178 Composite Laminates at 350°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

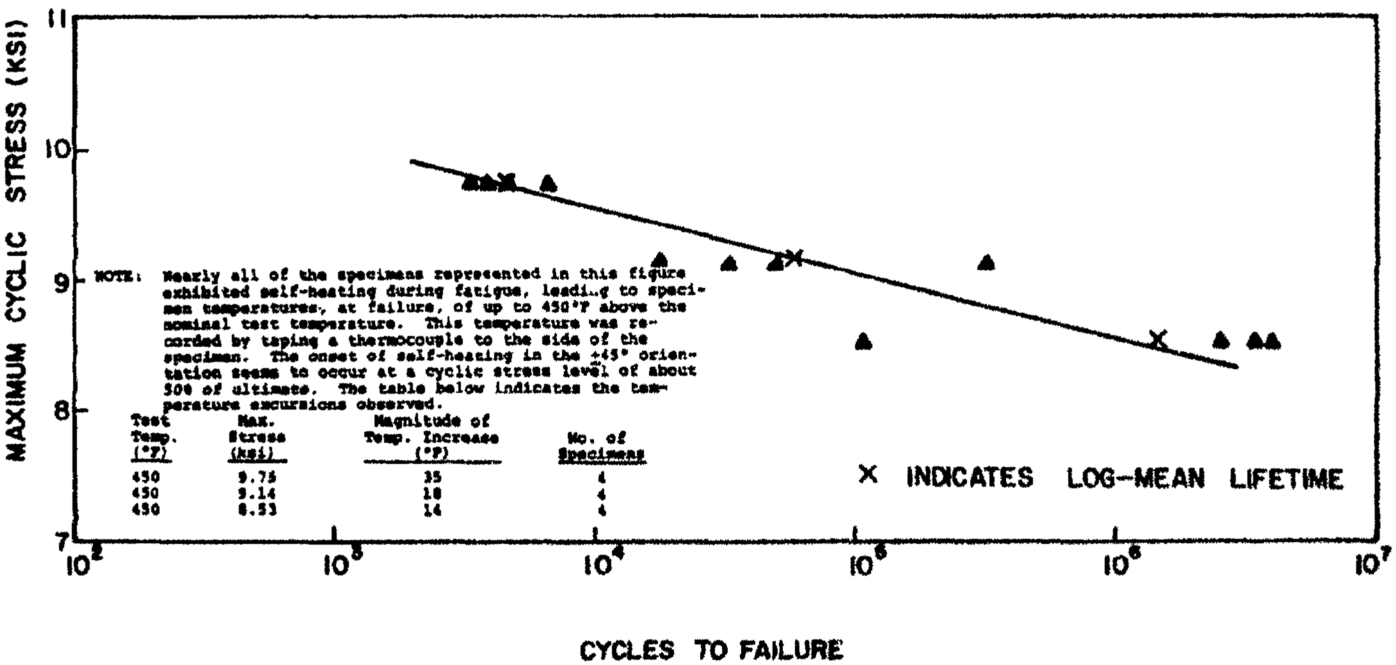


Figure 101. Tensile-Tensile Fatigue Behavior of Bidirectional T300/F178 Composite Laminates at 450°F: ±45° Fiber Orientation, R=0.10, 30 Hz.

TABLE 57

CREEP PROPERTIES OF T300/F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES — Graphite/Polyimide

Material System - T300/F178 Prepreg by - Hexcel
Fiber - T300 Matrix - F178
Maximum Temperature Rating - 450°F
Resin Content - 34.8% by wt.
Fiber Content - 55.6% by vol.
Void Content - +0%

Laminate Sp. Gr. - 1.59
Average Ply Thickness - 0.0055 inch
No. of panels from which specimens were tested in this table - 27
Thickness of each type specimen: 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply

Test Method - Straight-sided tension Reference - Design Guide

CREEP

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				350°F	Stress Level (ksi)	121.8	1.78	7.30
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	101	---[1]	4185
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	174.7	---	20.27
	No. of Specimens					No. of Specimens	3	0	3
	Stress Level (ksi)					Stress Level (ksi)	106.6	1.07	5.84
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	40[2]	1660	2401
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	141.1	5.40	18.06
	No. of Specimens					No. of Specimens	2	3	3
	Stress Level (ksi)					Stress Level (ksi)	---	---	4.38
	Creep Strain, 500 hr(μ in/in)					Creep Strain, 500 hr(μ in/in)	---	---	1945
	No. of Specimens					No. of Specimens	---	---	3
	Residual Strength (ksi)					Residual Strength (ksi)	---	---	20.54
	No. of Specimens					No. of Specimens	---	---	3
72°F	Stress Level (ksi)	141.1	3.06	12.02	450°F	Stress Level (ksi)	107.0	1.07	4.87
	Creep Strain, 500 hr(μ in/in)	---[1]	447	2607		Creep Strain, 500 hr(μ in/in)	192	2102[3]	5972
	No. of Specimens	3	3	2		No. of Specimens	3	3	3
	Residual Strength (ksi)	---	3.40	19.33		Residual Strength (ksi)	138.7	3.02	15.55
	No. of Specimens	0	3	2		No. of Specimens	2	1	3
	Stress Level (ksi)	125.4	2.67	10.30		Stress Level (ksi)	91.8	0.86	3.65
	Creep Strain, 500 hr(μ in/in)	43	535	2057		Creep Strain, 500 hr(μ in/in)	99	---[4]	3562
	No. of Specimens	3	3	3		No. of Specimens	3	3	3
	Residual Strength (ksi)	166.6	3.80	19.38		Residual Strength (ksi)	164.0	3.74	15.26
	No. of Specimens	3	3	3		No. of Specimens	3	1	3
	Stress Level (ksi)	---	---	8.59		Stress Level (ksi)	---	---	---
	Creep Strain, 500 hr(μ in/in)	---	---	1740		Creep Strain, 500 hr(μ in/in)	---	---	---
	No. of Specimens	---	---	3		No. of Specimens	---	---	---
	Residual Strength (ksi)	---	---	19.85		Residual Strength (ksi)	---	---	---
	No. of Specimens	---	---	3		No. of Specimens	---	---	---

Notes: All values represent arithmetic averages. Residual strengths determined by tensile test at 72°F.
1. Three specimens failed on loading or during test.
2. One specimen failed on loading or during test.
3. Two specimens failed on loading or during test.
4. Two specimens failed on loading or during test and strain gage failed on third specimen.

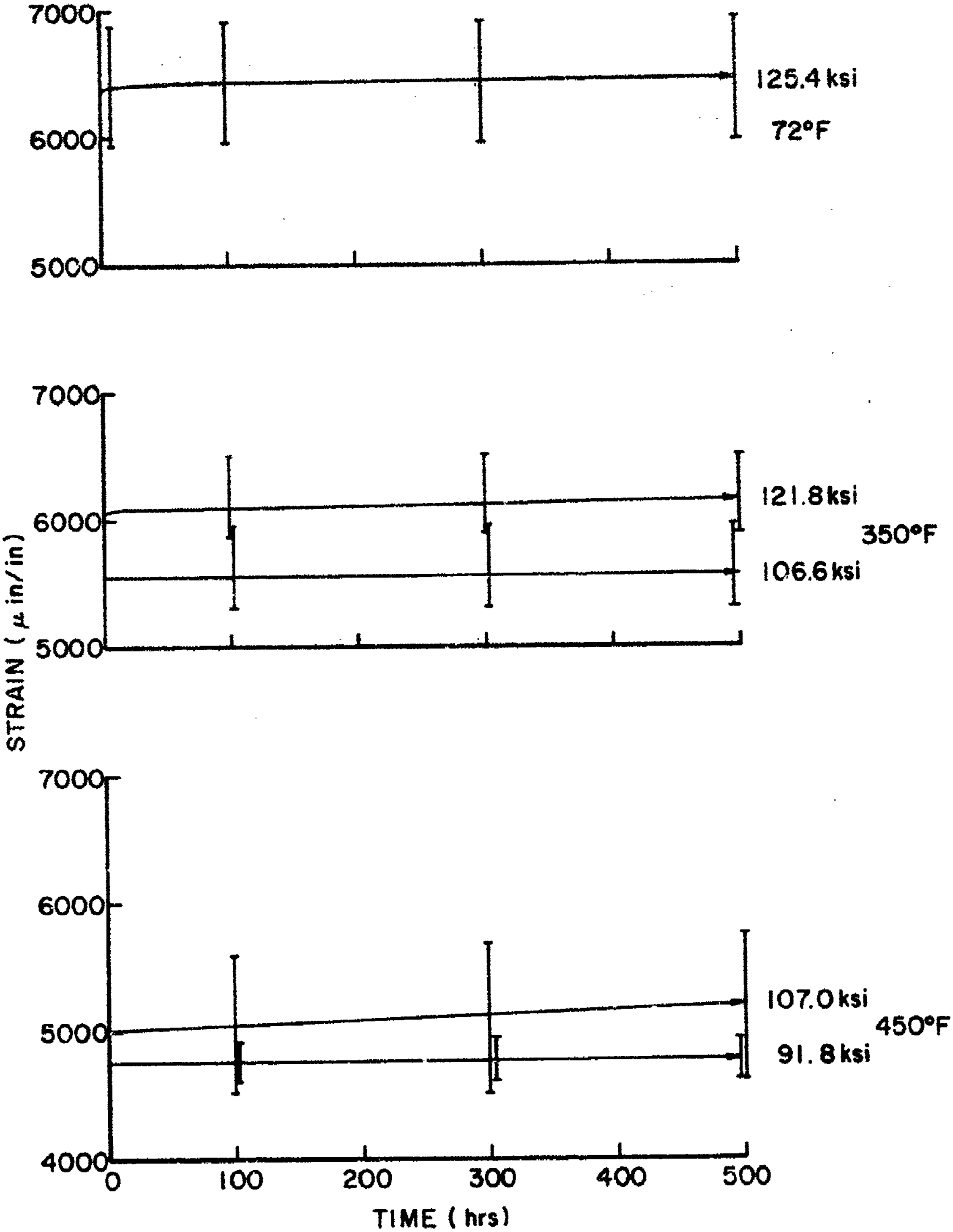


Figure 102. Tensile Creep Behavior of Unidirectional T300/F178 Composite Laminates: 0° Fiber Orientation.

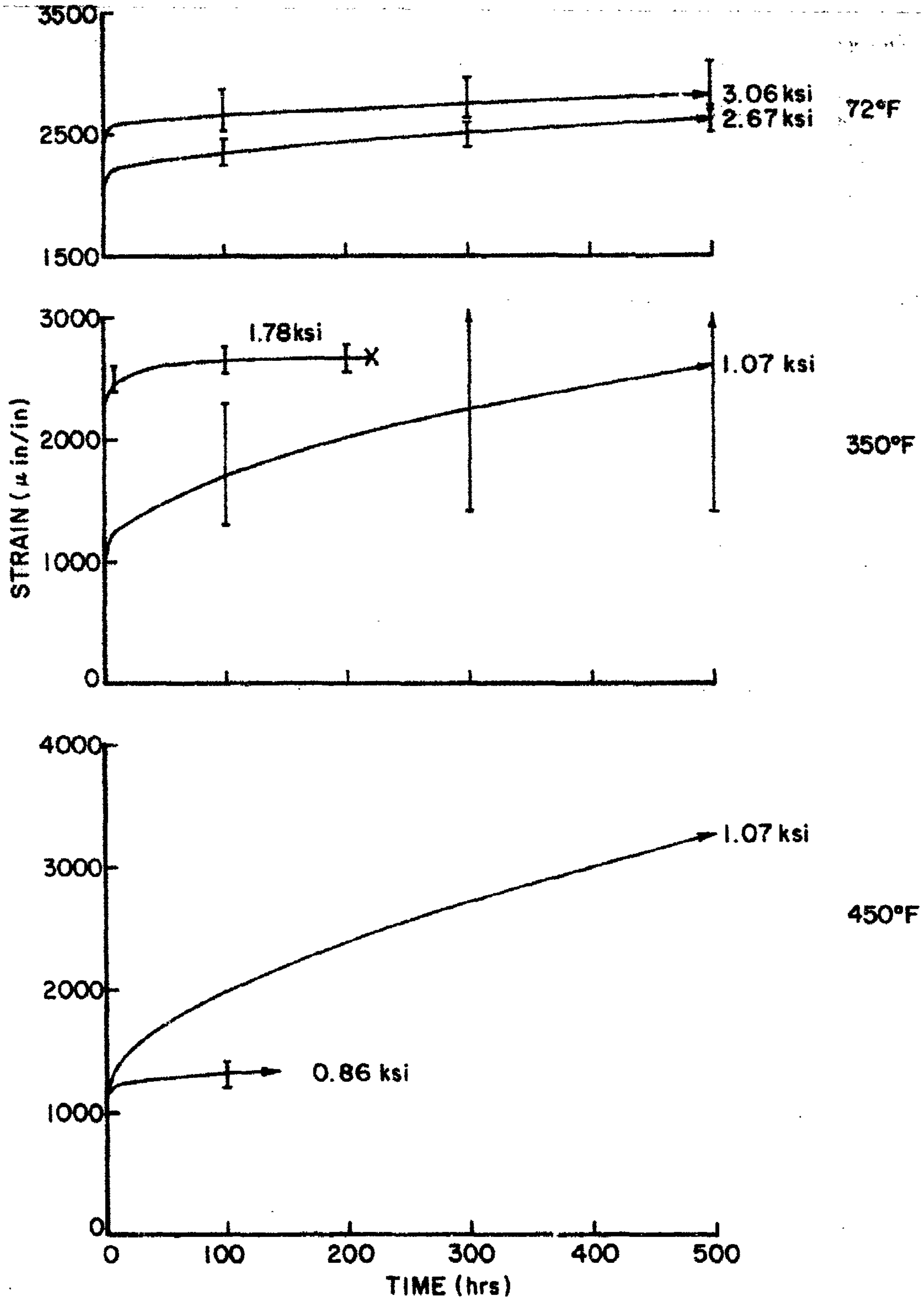


Figure 103. Tensile Creep Behavior of Unidirectional T300/F178 Composite Laminates: 90° Fiber Orientation.

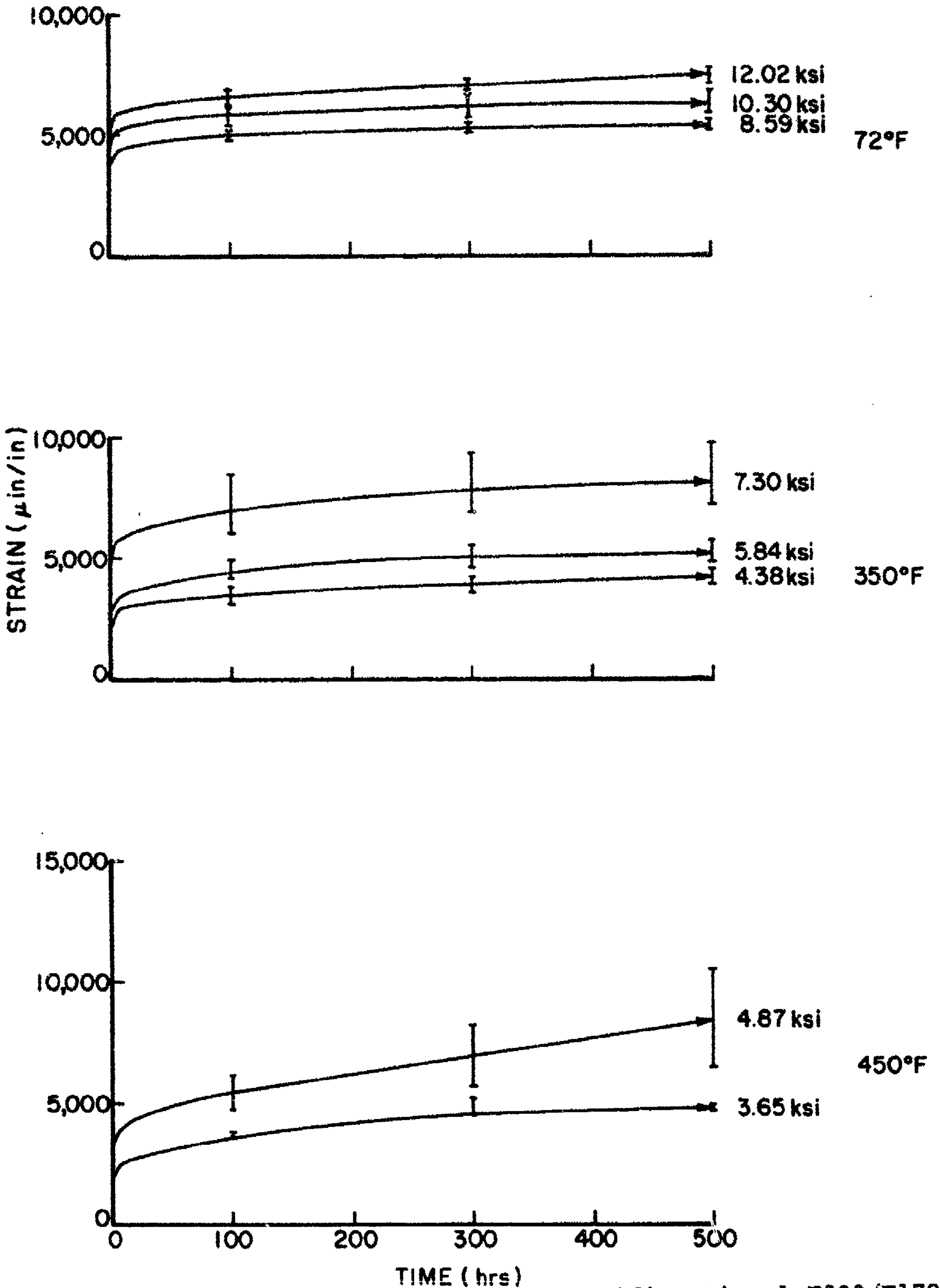


Figure 104. Tensile Creep Behavior of Bidirectional T300/F178 Composite Laminates: ±45° Fiber Orientation.

TABLE 58

STRESS RUPTURE PROPERTIES OF T300/F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES — Graphite/Polyimide

Material System - T300/F178 Prepreg by - Hexcel
Fiber - T300 Matrix - F178
Maximum Temperature Rating - 450°F
Resin Content - 34.8% by wt.
Fiber Content - 55.6% by vol.
Void Content - ≈0%
Test Method - Straight-sided tension

Laminate Sp. Gr. - 1.58
Average Ply Thickness - 0.0055 inch
No. of panels from which specimens were tested in this table - 27
Thickness of each type specimen: 0° -- 6 ply; 90° -- 15 ply; ±45° -- 8 ply
Reference - Design Guide

STRESS RUPTURE

Temperature	Fiber Orientation:	0°	90°	±45°	Temperature	Fiber Orientation:	0°	90°	±45°
-67°F	Stress Level (ksi)				350°F	Stress Level (ksi)	121.8	1.78	7.30
	Time to Failure (hrs)					Time to Failure (hrs)	500+	147[4]	500+
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	174.7	---	20.27
	No. of Specimens					No. of Specimens	3	0	3
	Stress Level (ksi)					Stress Level (ksi)	106.6	1.07	5.84
	Time to Failure (hrs)					Time to Failure (hrs)	349[2]	505+	500+
	No. of Specimens					No. of Specimens	3	3	3
	Residual Strength (ksi)					Residual Strength (ksi)	141.1	5.40	18.06
	No. of Specimens					No. of Specimens	2	3	3
72°F	Stress Level (ksi)	1.41	3.06	12.02	350°F	Stress Level (ksi)	107.7	1.07	4.87
	Time to Failure (hrs)	≈0[1]	505+	597+		Time to Failure (hrs)	355+	144[3]	500+
	No. of Specimens	3	3	2		No. of Specimens	3	3	3
	Residual Strength (ksi)	---	3.40	19.33		Residual Strength (ksi)	138.7	3.02	15.55
	No. of Specimens	0	3	2		No. of Specimens	2	1	3
	Stress Level (ksi)	125.4	2.67	10.30		Stress Level (ksi)	91.8	0.86	3.65
	Time to Failure (hrs)	509+	520+	504+		Time to Failure (hrs)	533+	248[5]	500+
	No. of Specimens	3	3	3		No. of Specimens	3	3	3
	Residual Strength (ksi)	166.6	3.80	19.38		Residual Strength (ksi)	164.0	3.74	15.26
	No. of Specimens	3	3	3		No. of Specimens	3	1	3

Notes: All values represent arithmetic averages. Residual strengths determined by tensile test at 72°F.
1. Three specimens failed on loading.
2. One specimen failed during test.
3. Two specimens failed on loading.
4. Three specimens failed on loading or during test.
5. Two specimens failed on loading or during test.

TABLE 59

THERMOPHYSICAL PROPERTIES OF F178 COMPOSITE LAMINATES

COMPOSITE MATERIAL PROPERTIES				
Material System - F178 Prepreg by - Hexcel; Graphite/Polyimide Fiber - T300 Matrix - F178 Maximum Temperature Rating - 450°F Resin Content - Fiber Content - Void Content - Thickness of each type specimen:	Laminate Sp. Gr. - 1.57 Average Ply Thickness - 0.0052 inch No. of panels from which specimens were tested in this table - 4 Therm. Exp.- 20 ply Spec.Ht.- 14 ply Therm. Cond.- 20 ply Glass Trans.- 14 ply			
THERMOPHYSICAL PROPERTIES: 0°				
	-67°F	72°F	350°F	450°F
Thermal Expansion				
α_x(µin/in-°F)	≈0	≈0	≈0	≈0
α_y(µin/in-°F)	17.2	17.3	23.9	23.9
No. of Specimens per direction	3	4	7	3
Specific Heat				
C_p (btu/lb.-°F)	0.14	0.19	0.30	0.31
No. of Specimens	1	1	1	1
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	---	0.21	0.36	0.43
No. of Specimens	---	3	8	7
Glass Transition Temp.				
Dry (°F)	None observed up to 450°F			
Wet (°F)	246°F			
THERMOPHYSICAL PROPERTIES: ±45°				
Thermal Expansion				
α_x(µin/in-°F)	2.1	1.8	1.8	1.6
No. of Specimens per direction	4	5	6	3
Thermal Conductivity				
k_z (btu-ft/ft^2-hr-°F)	---	---	---	---
No. of Specimens	---	---	---	---

Note: On unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

TABLE 60

TENSILE AND SHEAR PROPERTIES OF T300/F178 COMPOSITE LAMINATES AFTER HUMIDITY AGING

COMPOSITE MATERIAL PROPERTIES — Graphite/Polyimide

Material System - T300/F178	Prepreg by - Hexcel
Fiber - T300 Matrix - F178	Laminate Sp. Gr. - 1.57
Maximum Rated Temperature - 450°F	Average Ply Thickness - 0.0054 inch
Resin Content - 34.5% by wt.	No. of panels from which specimens were tested in this table - 3
Fiber Content - 56.3% by vol.	Aging Conditions - 160°F and 100% R.H.
Void Content - ≈0%	Thickness of each type specimen: 90°-15 ply; Inter. Shear - 14 ply

TENSION: 90°

	72°F	350°F	72°F	350°F
Exposure Time (hrs)	24.5	24.5	642	642
Weight Gain (% of orig. dry wt.)	0.85	0.80	1.63	1.63
Stnd. Dev. (%)	0.03	0.02	0.07	0.02
No. of Specimens	4	4	5	4
F_y^{tu} (ksi)	2.42	2.51	2.16	0.50
Stnd. Dev. (ksi)	2.40	0.81	1.55	0.20
Range (ksi)	0.99-6.00	1.57-3.73	0.4-3.8	0.33-0.71
No. of Specimens	4	4	5	3
F_y^{tpl} (ksi)	1.85	1.90	2.16	0.50
Stnd. Dev.	1.28	0.63	1.55	0.20
No. of Specimens	4	4	5	3
E_y^t (Msi)	1.33	0.85	1.33	0.71
Stnd. Dev.	0.07	0.08	0.09	0.16
No. of Specimens	4	4	5	3
ϵ_y^{tu} (μ in/in)	1900	2900	1700	770
Stnd. Dev.	1800	1000	1200	300
No. of Specimens	4	4	5	3
Test Method	Straight-sided tension			
Reference	Design Guide			

INTERLAMINAR SHEAR

Exposure Time (hrs)	21.5	21.5	408	408
Weight Gain (% of orig. dry wt.)	0.77	0.77	1.39	1.41
Stnd. Dev. (%)	0.09	0.13	0.10	0.06
No. of Specimens	5	5	3	3
F^{isu} (ksi)	13.05	8.00	11.33	7.38
Stnd. Dev. (ksi)	0.61	0.44	0.29	0.41
Range (ksi)	12.24-13.95	7.43-8.40	11.10-11.66	6.94-7.76
No. of Specimens	5	5	3	3
Test Method	Short Beam Shear			
Reference	Design Guide - Jan., 1971			

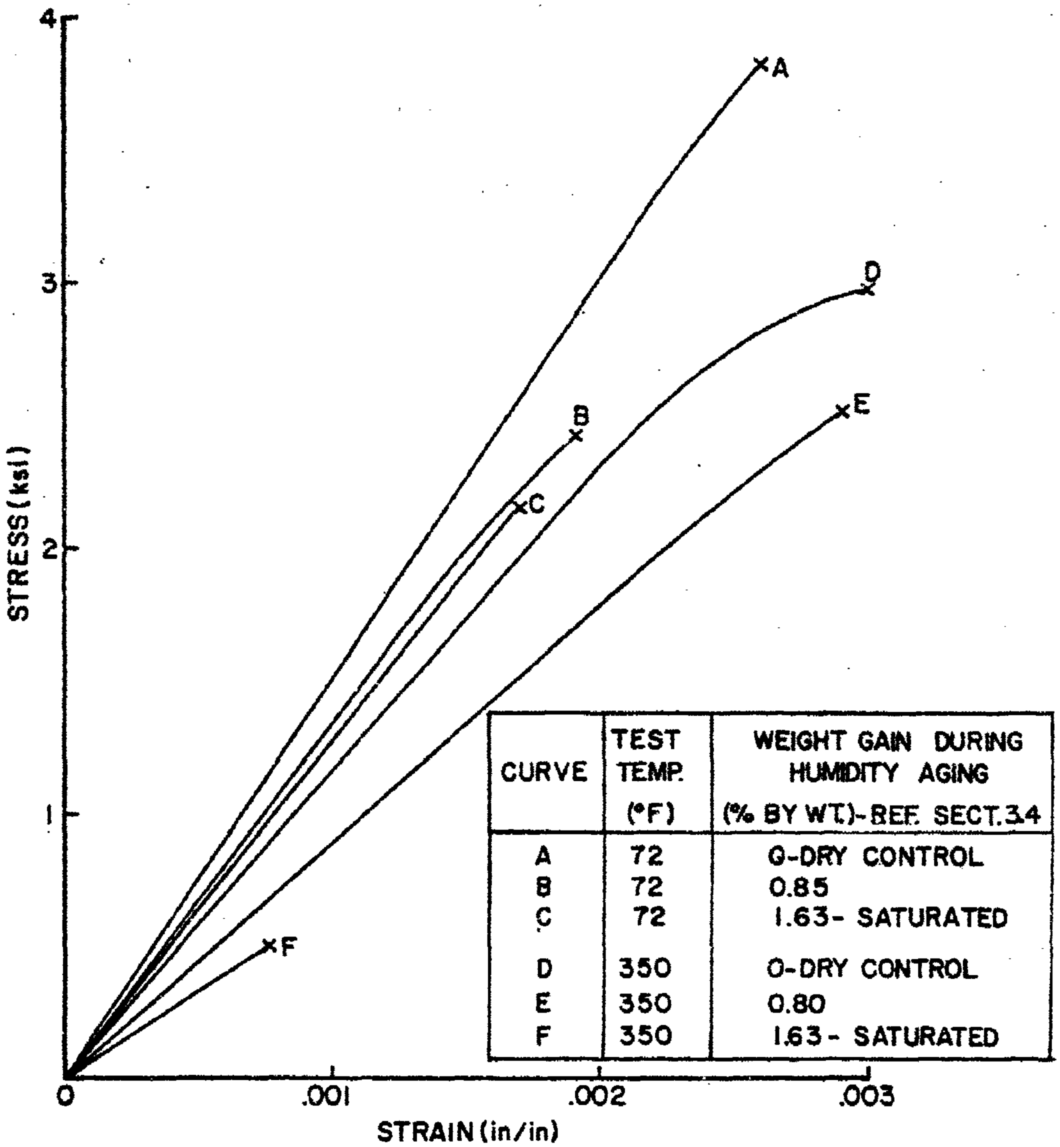


Figure 105. Tensile Stress-Strain Curves for Unidirectional T300/F178 Composite Laminates After Humidity Aging at 160°F and 100% R.H.: 90° Fiber Orientation.

4.5 COMPARATIVE ENVIRONMENTAL BEHAVIOR

One of the points of particular interest relative to the data generated in this program is the comparative susceptibility of the different composite materials to degradation during, or as the result of, elevated temperature, high humidity aging. Figures 106 and 107 illustrate the effect of both test temperature and moisture absorption upon the strength retention of these composite materials. The notations "saturated" and "50% saturated", recall, refer to the specimen condition just prior to testing. As discussed in Section 3.4, the specimens tested at elevated temperature undoubtedly dry out to some extent during the testing process. A few seeming anomalies are apparent in these figures: (1) the 72°F values for partially saturated SP313 and AS/3004 90° tension specimens are higher than the values for dry specimens; (2) the 90° tension strengths of the partially saturated T300/F178 specimens seems uninfluenced by test temperature; and (3) the partially saturated interlaminar shear specimens of AS/4397 were stronger than the dry specimens. No definitive reason for these apparent anomalies can be stated.

Comparisons of the general trends indicated by the data indicate that (1) the polysulfone matrix is slightly less degraded than the epoxy matrix during humidity aging; (2) the two polyimide matrices resist degradation better than either the epoxy or polysulfone matrices do insofar as interlaminar shear strength retention is concerned; (3) up to 250°F, the polysulfone matrix seems to retain more 90° tensile strength than either of the two polyimide matrices although 250°F data for the two polyimides were not obtained.

Other investigators have obtained humidity aged data for the T300/F178 system which shows little, if any, strength loss in 90° tensile coupons as the result of humidity aging[8]. Since the data here indicate a marked (although not unusual) loss of strength with moisture absorption, this area no doubt deserves more thorough evaluation.

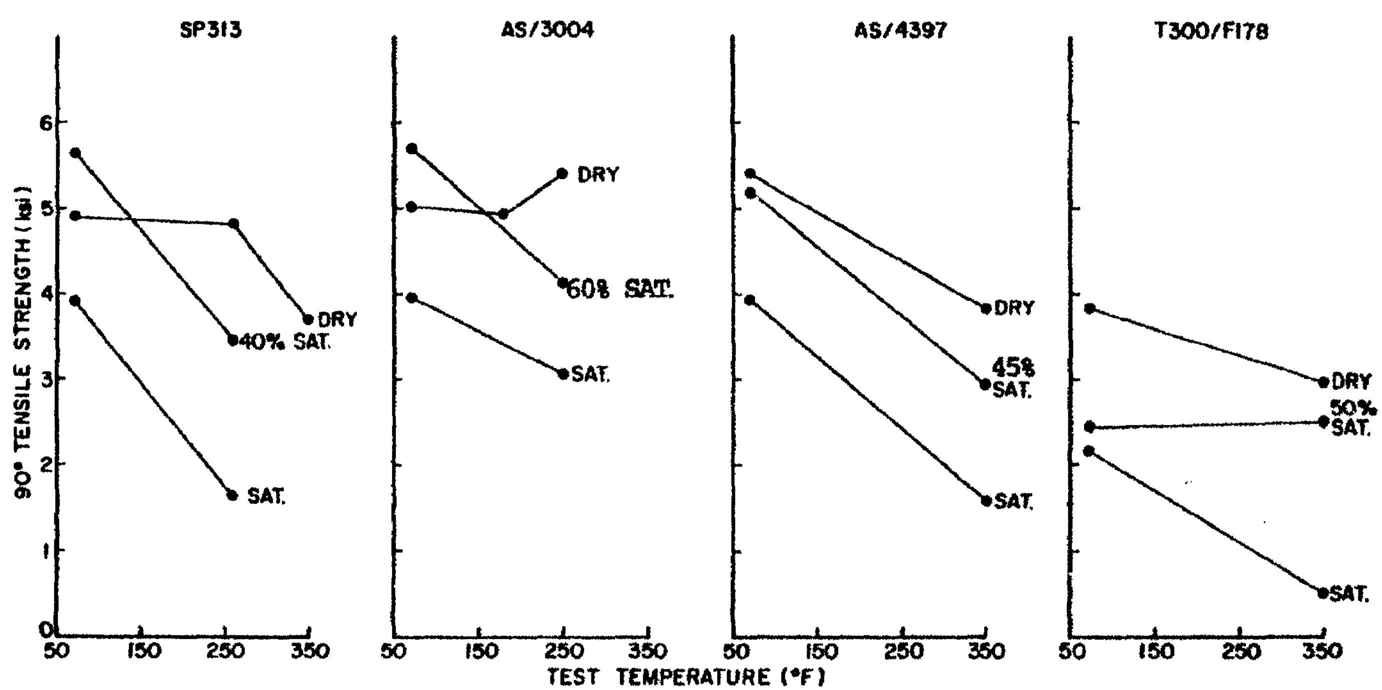


Figure 106. Comparative 90° Tensile Strength Retention of Composite Laminates After Aging at 160°F and 100% R.H.

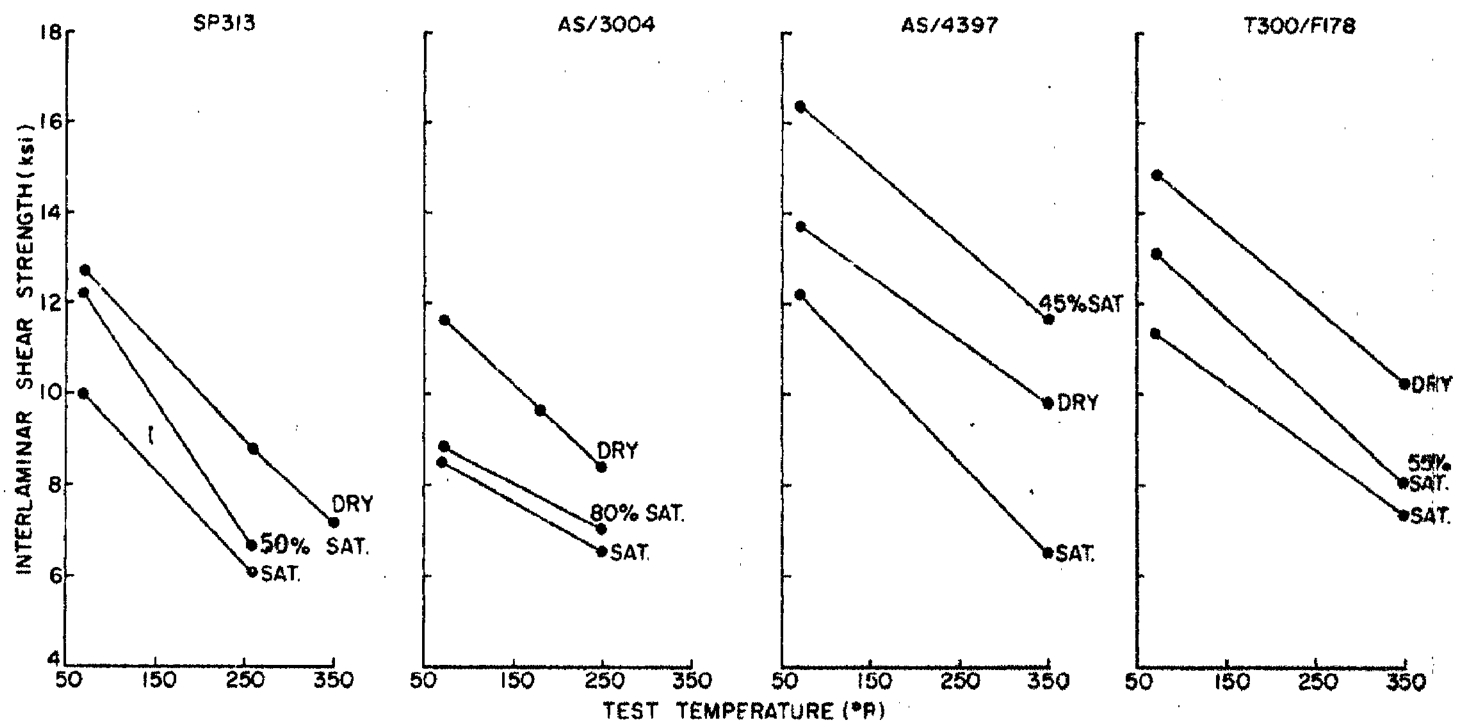


Figure 107. Comparative Interlaminar Shear Strength Retention After Humidity Aging.

SECTION 5

CONCLUSIONS

Each of the conclusions listed in this section was arrived at through inspection of the data in Section 4 and represent generalizations of overall composite behavior. Exceptions to each of these generalized conclusions can be found if the data are scrutinized in sufficient detail. In most cases, these exceptions are at least mentioned and discussed.

1. The static strengths (tensile, compressive, flexural, inplane, and interlaminar shear) of each material evaluated in this program decreased with increasing test temperature. In those cases where this was not true, the exception usually proved to be a lower strength at -67°F than at 72°F. This most probably is due to increased sensitivity to brittle failure at the lower temperature.

2. In those cases where the elastic modulus is primarily fiber dependent, the test temperature had relatively little effect on the modulus (0° tension, 0° compression, 0° flexure). In those cases where the composite modulus is primarily matrix dependent, however, the modulus for each material decreased with increasing temperature just as the strengths did.

3. The ultimate elongations of the fiber dependent specimens behaved in roughly the same fashion as the strength, decreasing with increasing temperature. The ultimate elongations of the matrix dependent specimens (90° and ±45° tension and 90° compression) increased with increasing temperature for any specific stress. Since the ultimate stress for these specimens, however, was simultaneously decreasing, the actual ultimate elongations for these type specimens exhibited some increases and some decreases with increasing test temperature.

4. The thermal conductivity and specific heat increased with increasing temperature for all four systems.

5. The coefficient of thermal expansion seemed relatively independent of temperature for the SP313 and AS/3004 material. With the AS/4397 and 90° orientation with T300/F178, the coefficient increased with increasing temperature while that for the ±45° orientation with T300/F178 decreased.

6. Fatigue life for each material decreased with increasing temperature at equivalent stress levels.

7. The relatively large plastic strains undergone by the AS/3004 ±45° orientation leads to substantial internal energy dissipation and self-heating in fatigue tests at 30 Hz. This phenomena also occurred for the other three materials but only at significantly higher stresses. The onset of this phenomena seems to occur at cyclic strain levels of above about 20% of the static ultimate strain.

8. Creep increased with increasing temperature for each material while the stress rupture lifetime decreased.

9. Humidity aging decreases the strength of each material evaluated. The polysulfone system seems less affected than the epoxy system by moisture absorbtion but the interlaminar shear data indicate that, on an absolute basis, the two polyimide systems withstand moisture degradation better than either the epoxy or polysulfone system. The 90° tensile data, however, are not as clear-cut; with the polysulfone system looking best up to 250°F but unusable at the 350°F temperature at which the two polyimides were tested.

REFERENCES

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3. Hofer, K.E., et. al., "Development of Engineering Data on the Mechanical and Physical Properties of Advanced Composite Materials," AFML-TR-72-205, Pt. I, September 1972.

4. Advanced Composites Design Guide, Section 7.3-Composite Laminate Property Tests, January 1971.

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7. Jones, J.S., "Graphite/Polyimide Composite Material Systems for Potential Space Shuttle Use," 21st SAMPE Proceedings, p.438, 1976.

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APPENDIX A

PREPREG QUALITY CONTROL TEST SPECIFICATIONS AND TEST RESULTS

This appendix contains copies of the test specifications adhered to in determining prepreg properties. It also contains the test results obtained from running these various tests upon the prepreg materials. Summaries of these data are presented in Section 4.

PREPREG TEST METHOD

VOLATILE CONTENT

1. Cut 3 specimens of 3" X 3" in size.
2. Weigh to the nearest 0.001 gram. Record the weight as W_1.
3. Preheat an air circulation oven to 250°F. and immediately after weighing suspend the specimens in the oven on a removable rack.
4. Expose the specimens to 250°F. for 15 minutes. Remove the rack.
5. Place the specimens in a desiccator.
6. When the specimens have cooled to room temperature, remove them from the desiccator and weigh to the nearest 0.001 gram. Record this weight as W_2.
7. Calculation.

$$\% \text{ Volatile Content} = \frac{W_1 - W_2}{W_1} \times 100$$

8. Report % volatile content by weight as the average of three specimens.

PREPREG TEST METHOD

UNCURED RESIN CONTENT

1. Cut 3 specimens 3" X 3".

2. Weigh the samples to the nearest .001 gram. Record this weight as W_1.

3. Wash each sample in a separate beaker of Dimethyl Formamide (DMF) at 180°F. under a hood for 5 minutes. Repeat for three complete washings. Rinse in MEK at 75°F. for one minute. Repeat for a total of 2 rinses. Separate fibers in solvent.

4. Fold and place washed fibers in preweighed aluminum dish and dry in circulating oven for 15 minutes at 300°F.

5. Cool in a desiccator at 75°F. for 15 minutes.

6. Reweigh the sample to the nearest .001 gram. Record as W_2.

7. Calculate.

$$\text{Resin Content - \% Weight} = \frac{W_1 - W_2}{W_1} \times 100$$

8. Report % resin content by weight as the average of 3 specimens.

PREPREG TEST

FLOW

The following flow test is designed to correlate with current autoclave and blanket press molding techniques for flowing resin over the surface area of a composite layup.

1. Prepare 3 flow specimens from the prepreg sample. Each specimen shall consist of 2 ply of prepreg oriented at $0^{\circ} - 90^{\circ}$. Specimen size is 3" X 3".

2. Weigh prepreg specimen and record as W_1.

3. For each specimen cut (2) two 4" X 4" squares of TX-1040 porous bleeder release fabric. Also for each specimen cut four (4) 4" X 4" squares of style 181 bleeder fabric and two (2) 8" X 8" squares of 1 - 2 mil mylar.

4. Center the prepreg sample between the squares of TX-1040 fabric. Place 2 ply of Style 180 bleeder fabric on each side of the TX-1040 followed with the mylar film.

5. Place the layup sandwich between two (2) caul plates.

6. Insert the total layup into a platen press preheated to 350°F. and apply 90 psi immediately. Cure for 15 minutes.

7. Remove the layup from the press. Remove any resin flash from the composite specimen and weigh. Record as W_2.

8. Calculate.

$$\% \text{ Flow} = \frac{W_1 - W_2}{W_1} \times 100$$

9. Report average of 3 specimens.

NOTE:

- Three or more specimens can be cured in one cycle.
- Temperature and cure cycle can be varied to correlate with specific cure conditions.

APPENDIX I

TEST PROCEDURES FOR CHARACTERIZATION OF GRAPHITE TAPE AND COMPOSITES

I.1 GRAPHITE TAPE CHARACTERIZATION

I.1.1 Volatile Matter

Volatile content of graphite prepreg was determined by thermally treating a tarred sample for 30 minutes at 350°F. After cooling to R.T., the specimen was reweighed and the volatile content was calculated by the following formula:

$$\text{Volatile Content} = \frac{W_1 - W_2}{W_1} \times 100$$

Where:

W_1 = Weight Sample
W_2 = Weight Sample After Heat Aging

HS-SG-500/232
2-7-73

Table II. Mechanical Properties (at $77^{o} \pm 5^{o}$ F)

Property	Unit	Minimum average Value
Longitudinal, flexural strength	Psi	200,000
Longitudinal flexural modulus	Psi	15,000,000
Short beam shear	Psi	10,500

TEST METHODS:

Test specimens. Test specimens for mechanical and thickness tests shall be prepared in accordance with HD-SG-2-6007.

Volatiles content test. The volatiles content of the tape shall be determined as follows:

a. Weigh a nominal 10 gram specimen of prepreg to the nearest milligram. No vessel required.

b. Place weighed specimen on aluminum foil or other suitable base and bake 2 hours in a 300-320°F circulating air oven.

c. Reweigh baked specimen after cooling to ambient temperature.

d. Calculate volatiles content as follows:

Volatiles Content, weight percent =

$$100 - 100 \left(\frac{\text{Wt of Baked Prepreg}}{\text{Init Wt of Prepreg}}\right)$$

Resin content test. Resin content shall be determined in accordance with procedure ~~E~~ F of HD-SG-2-6006.

5.2.6 Procedure F (methylene chloride extraction method). Determine resin content of prepreg tape by methylene chloride extraction as follows:

a. Prepreg samples shall be as specified in table I. Take duplicate test specimens, one from each end of the sample.

b. Weigh the first specimen to the nearest 0.001 g.

c. Place specimen in a 250 ml Erlenmeyer flask and add 100 to 125 ml methylene chloride.

d. Place rubber stopper on flask and shake gently for about 1 minute.

e. Decant off methylene chloride, being careful not to lose any fiber.

f. Repeat steps c, d, and e two more times.

g. Remove specimen from flask and remove excess methylene chloride by patting with a clean towel.

h. Place specimen in an oven for a minimum of 5 minutes at $177 \pm 5^{\circ}$ C.

i. Remove specimen from oven, cool to room temperature, and weigh to the nearest 0.001 g.

j. Calculate resin content as follows:

$$\text{Resin content, weight percent} = \frac{W_1 - W_2}{W_1} \times 100$$

where: W_1 = original weight of sample, g

W_2 = final weight of sample, g

k. Repeat steps b through j for the second specimen.

l. Report the resin content as the average of the two determinations to the nearest whole percent.

5.3 Resin flow. The resin flow properties of the prepreg shall be determined in accordance with procedure A or procedure B as specified in the applicable prepreg specification sheet.

5. **TEST PROCEDURES**

5.1 Volatiles content. The volatiles content of the prepreg shall be determined in accordance with the following:

5.1.1 Test specimens. Test specimens shall be as follows:

a. Two 2-inch square specimens (1.0 ± 0.2 grams) of prepreg are to be analyzed.

b. Release paper must be removed prior to analyzing. Any resin adhering to the release paper will be lost to the test.

5.1.2 Test procedure. The test procedure shall be as follows:

a. Condition new Gooch filtering crucibles in beaker containing concentrated HNO_3 for a minimum of 1 hour at 100 ± 5° C. Wash with water, dry in oven at 93 ± 3° C and desiccate.

b. Weigh conditioned filtering crucible to the nearest 0.1 milligram (mg).

c. Carefully remove release paper from prepreg specimen and place specimen in tared crucible.

d. Weigh crucible containing specimen to the nearest 0.1 mg.

e. ~~Condition crucible and specimen in an oven maintained at 93.5° ± 3° C for a minimum of 90 minutes and a maximum of 120 minutes, unless otherwise specified in the applicable prepreg specification.~~

NOTE

Prepregs with polyimide resin systems should be conditioned at 288 ± 3° C for 60 ± 1 minutes.

f. Remove crucible from oven, cool to room temperature in a desiccator, and reweigh.

g. Calculate volatiles content of prepreg as follows:

$$\text{Weight \% Volatiles} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where: W_1 = weight of empty conditioned filtering crucible, grams (g)

W_2 = original weight of crucible and specimen before heating, g

W_3 = final weight of crucible and specimen after heating, g

5.3 Resin flow. The resin flow properties of the prepreg shall be determined in accordance with procedure A or procedure B as specified in the applicable prepreg specification sheet.

5.3.1 Procedure A. Determine resin flow as follows:

a. The test specimen shall consist of two uniformly cut pieces of preg. Each piece shall be 2 inch by 2 inch.

b. Cut four approximately 3-inch squares of glass bleeder cloth for each test.

c. Cut two approximately 3-inch squares of porous tetrafluoroethylene (TFE) release cloth.

d. Cut one approximately 6-inch by 12-inch piece of aluminum foil.

e. If the prepreg has release paper on both sides, remove the release paper from one side of each of two 2 x 2 inch specimens.

f. Sandwich the exposed sides of the graphite together so that the fibers are oriented 90 degrees to each other. Then remove the release paper from one side of the specimen sandwich.

g. Weigh the sandwiched specimen to the nearest milligram on a precision balance. The side of the sandwiched specimen with the release paper attached is to be placed on the balance pan. Record the weight as W_1.

h. Fold the 6 x 12 inch sheet of aluminum in half to form a 6 x 6 inch square. Then unfold and lay on a flat surface.

i. Stack two pieces of the fiberglass bleeder cloth on one another and lay them on top of the aluminum foil aligning one edge with the center crease of the foil.

j. Center one piece of release cloth on top of the bleeder cloths.

k. Center the exposed side of the prepreg specimen on top of the release cloth.

l. Remove the final piece of release paper from the specimen and weigh the release paper to the nearest milligram. Record the weight as W_2.

m. Center one piece of TFE release cloth on top of the freshly exposed graphite surface of the specimen; then place two pieces of bleeder cloth on top of the release cloth.

n. Fold the aluminum foil over to form a 6 x 6 inch square completing the sandwich lay-up.

o. Pre-set the temperature of the platen press to the temperature specified in the applicable prepreg specification sheet and check.

p. Place the sandwiched specimen on the top platen of the press and immediately (within 15 seconds) apply the pressure specified in the applicable prepreg specification sheet to the specimen. Start a timer when the required pressure is obtained.

q. Remove the specimen from the press after the time specified in the applicable prepreg specification sheet has elapsed. Allow specimen to cool to room temperature.

r. Remove the graphite specimen from the lay-up. Insure that no fibers are removed with the release cloth.

s. Remove any resin which has extruded from the body of the graphite specimen and is clinging to the edges.

t. Re-weigh the graphite specimen to the nearest milligram. Record weight as W_3.

u. Calculate the percent resin flow as follows:

$$\text{Resin flow, percent} = \frac{(W_1 - W_2) - W_3}{W_1 - W_2} \times 100$$

where: W_1 = initial weight of specimen plus one piece of release paper, g.

W_2 = weight of release paper from W_1, g.

W_3 = final weight of specimen, g.

v. Report individual results of two determinations and also mean value.

Note: In step o, the temperature used for AS/4397 prepreg was 400°F.

HEXCEL TEST METHOD
T300/F178
PREPREG RESIN CONTENT

Dissolve two specimens 4" x 4" in NMP (n-methyl pyrrolidone). Heat up to 125°F for approximately 15 minutes. Filter off resin. Wash off with acetone.

PREPREG PHYSICAL PROPERTIES				
Material: SP313			Vendor: 3M	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
661	SLPS07606J#1&2	0.25	39.0	15.9
662	SLPS07606J-1-1	0.25	39.2	16.1
662	SLPS07606JBG-1-2	0.27	39.4	16.2
662	SLPS07606J-1-3	0.26	39.4	16.3
662	SLPS07606J-1-4	0.14	38.4	15.1

Graphite/epoxy prepreg

T300 fiber
PR313 epoxy resin
0.005 inch nominal thickness
3-inch wide tape

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	No Numerical Designation	3M
Resin Content	No Numerical Designation	3M
Resin Flow	No Numerical Designation	3M

Prepreg test procedures supplied by 3M.

RP-1051

3 cc: with shipment
1 cc: G.A. Toren-230-1
1 cc: J.W. Davis-230-1
cc:

AFFIDAVIT

STATE OF MINNESOTA

ss.

COUNTY OF RAMSEY

The authorized representative of the Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, whose signature is given below, being first duly sworn, does depose and say that the "SCOTCHPLY" Brand Reinforced Plastics Material described below, complies with mutually agreed Specifications and Purchase Order Requirements. The Quality Control System complies with all essential principles of Specifications MIL-I-45208A and MIL-Q-9858. Test reports and traceability records will be kept on file, available for review by the buyer. Copies of 3M Lot Acceptance Data Reports and the Shipment Check List, as may be required, are attached to this Affidavit.

Customer Name and Plant Location: UNIVERSITY OF DAYTON DAYTON, OHIO

Customer Purchase Order Number: RI-72095

3M Company Shipment Invoice Number: RP-31112

Applicable Customer Specification: 3M TEST METHODS

3M Company Product Identification: SP-313 (5.0) T300, GRAPHITE-EPOXY PREPREG

3M Company Product Mfg. Code: SLP S07606, LOT 661 J. # 1 -2 (119 net ft.)

Shipment Summary:

5.8 POUNDS OF 12" WIDTH

PHYSICAL PROPERTIES: Volatile = 0.1 %
Resin Content = 39.5 %
Fiber Content = 60.4 %
Flow = 19.8 %

Further this Affiant sayeth not.

Title: Inspector, Quality Control

Subscribed and sworn to before me this 23 day of JUNE 1975 A.D.

PREPREG PHYSICAL PROPERTIES				
Material: AS/3004			Vendor: Hercules	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
376	10A	5.34	40.75	---
376	9	4.75	38.01	---
376	6	4.75	36.26	---
376	3	4.31	35.48	---

Graphite/polysulfone

AS graphite fiber
P1700 polysulfone thermoplastic
0.005 inch nominal tape thickness
12-inch wide tape

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	HD-SG-500/232	Hercules
Resin Content	HD-SG-2-6006C(5.2.6F)	Hercules
Resin Flow	Not Applicable	

PREPREG PHYSICAL PROPERTIES

Material: AS/4397 **Vendor:** Hercules

Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
382	2	0.23	42.5	25.2
382	3	0.19	42.6	26.5

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	HD-SG-2-600C(5.1)	Hercules
Resin Content	HD-SG-2-6006C(5.2.6F)	Hercules
Resin Flow	HD-SG-2-6006C(5.3.1A)	Hercules

May 4, 1976

HERCULES INCORPORATED
QUALITY ASSURANCE LOT DATA REPORT

Customer: Universtiy of Dayton

Purchase Order No: R1-76095

Material: Graphite Fiber/Epoxy Material Type AS/4397

Quantity: 39# x 12" nominal

Lot No: 382

Spool No: 2,3

I. Fiber Properties 53-5

Tensile Strength	463 psi x 10^3
Tensile Modulus	35.5 psi x 10^6
Wt./Unit Length	44.57 lb/in x 10^{-6}
Density	0.0646 lb/in^3

II. Laminate Mechanical Properties	Panel No.	Test Value Average/Minimum
0^o Tensile Strength, RT, ksi	3176	255/252
0^o Tensile Modulus, RT, msi	3176	22.1/21.9
0^o Flex Strength, RT, ksi	3175	252/246
0^o Flex Strength 400^{o}F., ksi	3175	198/168
0^o Flex Strength, 450^{o}F, ksi	3175	174/162
0^o Flex Modulus, RT, msi	3175	18.6/18.1
0^o Flex Modulus, 400^{o}F, msi	3175	17.8/16.5
0^o Flex Modulus, 450^{o}F, msi	3175	17.0/15.8
Short Beam Shear, RT, ksi	3175	14.7/14.6
Short Beam Shear, 400^{o}F, ksi	3175	10.5/10.0
Short Beam Shear, 450^{o}F., ksi	3175	8.4/8.1
90^o Tensile Strength, RT, psi	3175	7,240/7,100
90^o Tensile Modulus, RT, msi	3175	1.36/1.31
90^o Tensile Elongation, %	3175	0.56/0.54

III. Panel Physical Properties

Panel No.	3175	3176
Fiber Volume, %	63.1	65.0
Resin Content, %	28.75	27.29
Density (lb/in^3)	0.0572	0.0578
Void Content, %	0.99	0.56
Ply Thickness, Inches	0.0058	0.0057

IV. Individual Spool Physical Properties

Spool No.	2	3
Resin Content, %	44	41

R. L. Frankenfield, Representative
QUALITY ASSURANCE DEPARTMENT

RLF:ldo

PREPREG PHYSICAL PROPERTIES				
Material: T300/F178			Vendor: Hexcel	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
DP021	4	---	41.1	---
DP021	5	---	42.2	---

Graphite/polyimide

T300 graphite fiber (3000 tow, 309 finish)
F178 polyimide resin
0.005 inch nominal tape thickness
12-inch wide tape

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	Not Applicable	---
Resin Content	No Numerical Designation	Hexcel
Resin Flow	Not Applicable	---

Flow test not performed. It is a high flow system, however; 22 ± 5% according to Hexcel literature.

9/7/76

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Research Institute
300 College Park Ave.
Dayton, Ohio

P.O. # RI 77135

S.O. # B499243-1

B.O. # DP021

<u>Flexural Strength</u>

DRT (psi x 10^3)	248
Mod (psi x 10^6)	17.9
500°F	145
Mod	18.0

<u>Short Beam Shear</u>

DRT - psi	14,800
500°F - psi	7,500

PREPREG PHYSICAL PROPERTIES

Material: AS/HME | Vendor: TRW

Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
10904	73-1	0.72	See special sheet	2.9
10904	73-2	1.20	See special sheet	2.8
10904	73-3	1.50	See special sheet	6.1
10904	73-4	1.40	See special sheet	8.0
10904	73-5	0.75	See special sheet	4.0
10904	73-6	0.62	See special sheet	3.2
10904	73-7	1.10	See special sheet	3.7
10904	73-8	0.67	See special sheet	3.4
10904	73-10	1.33	See special sheet	6.3

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	I.1.1	TRW
Resin Content	AFML-TR-67-243	AFML-TR-67-243
Resin Flow	No Numerical Designation*	3M

*Same test as used for SP313. This method employs a 90 psi pressure while the actual cure schedule for the HME resin called for only 14 psi (vacuum bag). Hence, the actual flow during cure would be less than that measured here.

PREPREG PHYSICAL PROPERTIES				
Material: AS/HME			Vendor: TRW	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
10904	73-11	1.43	See special sheet	6.2
10904	73-12	1.88	See special sheet	12.2
10904	73-13	0.83	See special sheet	9.7
10904	73-14	0.94	See special sheet	6.5
10904	73-15	1.16	See special sheet	10.9
10904	73-16	0.59	See special sheet	7.9
10904	73-17	1.28	See special sheet	8.8

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	I.1.1	TRW
Resin Content	AFML-TR-67-243	AFML-TR-67-243
Resin Flow	No Numerical Designation*	3M

*Same test as used for SP313. This method employs a 90 psi pressure while the actual cure schedule for the HME resin called for only 14 psi (vacuum bag). Hence, the actual flow during cure would be less than that measured here.

PREPREG PHYSICAL PROPERTIES				
Material: AS/HME			Vendor: TRW	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
10904	75-1	1.88	See special sheet	7.0
10904	75-2	1.36	See special sheet	5.8
10904	75-3	1.54	See special sheet	6.4
10904	75-4	1.64	See special sheet	8.6
10904	75-5	1.43	See special sheet	7.5
10904	75-6	1.58	See special sheet	12.9
10904	75-7	2.08	See special sheet	9.5

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	I.1.1	TRW
Resin Content	AFML-TR-67-243	AFML-TR-67-243
Resin Flow	No Numerical Designation*	3M

*Same test as used for SP313. This method employs a 90 psi pressure while the actual cure schedule for the HME resin called for only 14 psi (vacuum bag). Hence, the actual flow during cure would be less than that measured here.

PREPREG PHYSICAL PROPERTIES				
Material: AS/HME			Vendor: TRW	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
11939	27-1	0.80	See special sheet	5.2
11939	27-2	1.46	See special sheet	7.9
11939	27-3	1.14	See special sheet	5.2
11939	27-4	1.94	See special sheet	11.2
11939	27-5	1.01	See special sheet	4.4
11939	27-6	1.52	See special sheet	10.5
11939	27-7	3.45	See special sheet	12.8
11939	27-8	1.55	See special sheet	14.5

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	I.1.1	TRW
Resin Content	AFML-TR-67-243	AFML-TR-67-243
Resin Flow	No Numerical Designation*	3M

*Same test as used for SP313. This method employs a 90 psi pressure while the actual cure schedule for the HME resin called for only 14 psi (vacuum bag). Hence, the actual flow during cure would be less than that measured here.

As discussed in the introduction to Section 4, the high degree of scatter in the resin content of the HME low-flow system resulted in a comprehensive study of the resin content variability of this prepreg. The special supplementary table at the end of Appendix A presents the results of this study and vividly illustrates the magnitude of the problem. In short, although each batch of prepreg did indeed fall within the 35% ± 5% limit quoted by TRW, in-batch resin content variations were quite substantial, ranging from a low value of about 22% to a high value of over 46%. The problem was one of non-uniform resin distribution across the width of the prepreg tape.

AS/HME PREPREG RESIN CONTENT

Roll No.	Resin Content (% by wt.)[1]						Max.
	Pos. 1	Pos. 2	Pos. 3	Pos. 4	Pos. 5	Avg.	Spread
10904-73-1	45.88	44.74	35.74	34.31	29.39	38.01	16.49
10904-73-2	37.77	34.99	35.24	33.05	38.18	35.85	5.13
10904-73-3	41.09	34.89	38.61	33.90	32.84	36.27	8.25
10904-73-4	30.03	36.92	36.04	42.01	41.46	37.29	11.98
10904-73-5	33.18	39.60	35.71	29.97	36.05	34.90	9.63
10904-73-6	30.09	33.66	42.39	28.30	31.70	33.23	14.09
10904-73-7	34.40	33.26	38.89	37.45	34.84	35.77	5.63
10904-73-8	29.57	33.83	36.69	30.92	35.46	33.29	7.12
10904-73-10	41.91	33.33	30.80	34.81	36.60	35.49	11.11
10904-73-11	46.14	36.21	39.00	40.14	28.97	38.09	17.17
10904-73-12	35.79	42.80	31.90	30.32	31.95	34.55	12.48
10904-73-13	40.69	39.13	34.61	34.68	29.94	35.81	10.75
10904-73-14	38.36	32.73	37.45	41.13	32.62	36.46	8.51
10904-73-15	36.77	35.65	34.35	40.34	32.79	35.98	7.55
10904-73-16	35.04	37.48	36.26	36.82	32.69	35.59	4.79
10904-73-17	37.14	32.02	31.20	34.18	21.76	31.26	15.38
10904-75-1	35.01	32.33	38.41	37.19	42.73	37.13	10.40
10904-75-2	30.54	37.80	39.44	37.10	40.74	37.12	10.20
10904-75-3	41.28	34.27	33.27	36.04	27.38	34.45	13.90
10904-75-4	29.76	34.41	37.71	36.48	39.32	35.57	9.56
10904-75-5	35.93	36.93	35.14	31.35	33.07	34.48	5.58
10904-75-6	40.24	30.43	34.18	37.53	35.17	35.51	9.81
10904-75-7	38.22	43.05	33.37	36.61	27.79	35.81	15.26
11939-27-1	27.99	38.39	33.47	34.79	32.89	33.51	10.40
11939-27-2	23.93	39.50	32.89	35.03	30.63	32.40	15.57
11939-27-3	30.52	25.95	30.89	34.48	42.43	32.85	16.48
11939-27-4	38.83	34.52	35.73	32.77	28.09	33.99	10.72
11939-27-5	42.67	41.53	44.87	31.99	28.81	37.98	16.06
11939-27-6	32.25	41.27	36.46	37.66	43.59	38.25	11.34
11939-27-7	32.72	36.39	38.40	42.68	39.19	37.88	9.96
11939-27-8	39.29	43.10	40.10	38.17	34.34	39.00	8.76

[1]Positions 1 through 5 represent locations distributed uniformly across the width of the prepreg tape from which samples were taken.

Intra-Roll Spread (%)	4-6	6-8	8-10	10-12	12+
Population	4	2	7	8	10

APPENDIX B

LAMINATE PHYSICAL PROPERTY DATA

All of the physical property measurements conducted upon the panels fabricated and used in this program are presented here. Summaries of these data appear in Section 4.

LAMINATE PHYSICAL PROPERTIES

Material: SP313

Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
A1	0°	6	1.48	30.3	57.9	5.7	5.2	661	J-1-2
A2	0°	6	1.47	29.9	61.2	3.9	5.2	661	J-1-2
A3	0°	6	1.47	27.2	65.9	5.6	5.3	661	J-1-2
A4	0°	6	1.46	28.4	61.7	5.7	5.1	661	J-1-2
A5	0°	6	1.57	29.0	64.6	≐0	5.1	661	J-1-2
A6	0°	6	1.56	29.8	63.9	≐0	5.2	661	J-1-2
A7	0°	6	1.56	29.3	64.3	≐0	5.2	661	J-1-2
A8	0°	6	1.56	29.1	64.5	≐0	5.2	661	J-1-2
A9	0°	6	1.55	28.0	63.7	3.2	5.2	661	J-1-2
A10	0°	10	1.58	26.0	68.0	≐0	5.2	661	J-1-2
A11	0°	10	1.57	26.8	67.1	≐0	5.4	661	J-1-2
A12	0°	10	1.57	27.1	66.8	≐0	5.9	661	J-1-2
A13	0°	10	1.57	26.2	66.2	≐0	5.3	661	J-1-2
A14	0°	10	1.59	24.9	69.3	≐0	5.4	661	J-1-2
A15	0°	10	1.58	27.1	66.7	≐0	5.3	661	J-1-2
A16	90°	15	1.56	29.9	63.7	≐0	5.3	662	J-1-3
A17	90°	15	1.56	31.4	62.0	≐0	5.4	662	J-1-3
A18	90°	15	1.55	32.9	60.4	≐0	5.3	662	J-1-3
A19	90°	15	1.57	30.3	63.2	≐0	5.3	662	J-1-3
A20	90°	15	1.56	30.2	63.4	≐0	5.3	662	J-1-3
A21	90°	15	1.57	30.0	63.5	≐0	5.4	662	J-1-3
A22	90°	15	1.56	33.0	60.3	≐0	5.3	662	J-1-3
A23	90°	15	1.56	32.3	61.0	≐0	5.5	662	J-1-3
A24	90°	15	1.55	33.9	59.2	≐0	5.3	662	J-1-3
A25	90°	15	1.55	32.7	60.6	≐0	5.4	662	J-1-3

*Computed according to ASTM D2734-70(B). Values indicated as ≐0 actually computed as negative values, but since negative void content is meaningless, they are reported as ≐0 (approximately zero). Inspection of photomicrographs revealed an average void content of about 2% by volume and this is the value reported in Section 4.

LAMINATE PHYSICAL PROPERTIES									
Material: SP313									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
A26	90°	15	1.56	31.6	61.8	≐0	5.3	662	J-1-3
A27	90°	15	1.55	33.8	59.4	≐0	5.3	662	J-1-3
A28	90°	15	1.53	33.0	60.2	0.2	5.7	662	J-1-3
A30	90°	15	1.56	33.9	57.4	≐0	5.8	662	JBO-1-2
A31	90°	15	1.56	32.5	59.5	≐0	5.3	662	JBO-1-2
A32	90°	15	1.53	32.5	59.5	≐0	5.3	662	JBO-1-2
A33	0°	14	1.62	31.7	60.3	≐0	5.4	662	JBO-1-2
A34	0°	14	1.61	32.0	60.0	≐0	5.4	662	JBO-1-2
A35	0°	16	1.56	34.3	57.6	≐0	5.3	662	JBO-1-2
A36	0°	20	1.56	35.5	56.2	≐0	5.3	662	JBO-1-2
A37	0°	40	1.56	35.4	66.3	≐0	5.1	662	JBO-1-2
A38	±45°	8	1.54	33.7	58.1	≐0	5.6	662	JBO-1-2
A39	±45°	8	1.57	31.0	61.2	≐0	5.6	662	JBO-1-2
A40	±45°	12	1.52	32.3	60.7	0.6	5.5	662	JBO-1-2
A43	±45°	12	1.52	32.4	58.8	0.9	5.5	662	JBO-1-2
A44	±45°	8	1.54	32.2	59.8	≐0	5.4	662	JBO-1-2
A46	0°	14	1.56	33.2	58.7	≐0	5.6	662	JBO-1-2
A47	±45°	8	1.55	31.9	60.1	≐0	5.5	662	J-1-1
A48	±45°	8	1.55	32.7	59.2	≐0	5.6	662	J-1-1
A50	±45°	8	1.56	31.9	60.1	≐0	5.5	662	J-1-1
A51	±45°	8	1.55	32.0	60.0	≐0	5.5	662	J-1-1
A52	±45°	8	1.55	31.7	60.3	≐0	5.5	662	J-1-1
A53	±45°	8	1.54	30.7	60.5	≐0	5.5	662	J-1-1
A54	±45°	8	1.54	31.8	60.2	≐0	5.6	662	J-1-1
A55	±45°	8	1.55	31.3	60.7	≐0	5.5	662	J-1-1

*Computed according to ASTM D2734-70(B). Values indicated as ≐0 actually computed as negative values, but since negative void content is meaningless, they are reported as ≐0 (approximately zero). Inspection of photomicrographs revealed an average void content of about 2% by volume and this is the value reported in Section 4.

LAMINATE PHYSICAL PROPERTIES									
Material: SP313									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
A56	±45°	8	1.54	32.5	59.5	≐0	5.6	662	J-1-1
A57	±45°	8	1.55	31.4	62.0	≐0	5.5	662	J-1-1
A58	±45°	8	1.55	32.5	60.8	≐0	5.7	662	J-1-1
A59	0°	10	1.47	34.5	55.3	4.7	5.6	662	J-1-1
A60	0°	20	1.47	41.1	50.9	1.6	5.9	662	J-1-1
A61	±45°	40	1.52	32.6	60.4	0.4	5.5	662	J-1-1
A62	±45°	8	1.54	30.7	62.7	0.2	5.5	662	J-1-4
A63	±45°	8	1.54	30.9	62.5	0.1	5.6	662	J-1-4
A64	0°	14	1.56	32.1	59.3	0.3	5.6	662	J-1-4
A65	±45°	20	1.54	33.4	59.6	≐0	5.5	662	J-1-4
A66	90°	14	1.54	31.3	62.1	≐0	5.4	662	J-1-4
A67	0°	14	1.54	30.5	60.1	2.00	5.7	662	J-1-4
Avg.			1.55	31.4	61.2	≐0*	5.4		
St. Dv.			0.03	2.6	3.2	---	0.1		

*Computed according to ASTM D2734-70(B). Values indicated as ≐0 actually computed as negative values, but since negative void content is meaningless, they are reported as ≐0 (approximately zero). Inspection of photomicrographs revealed an average void content of about 2% by volume and this is the value reported in Section 4.

LAMINATE PHYSICAL PROPERTIES									
Material: AS/3004									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
C1	0°	14	1.52	34.5	56.3	1.1	5.1	376	6
C2	0°	14	1.53	32.6	58.1	1.5	5.8	376	3
C3	0°	20	1.55	33.3	57.0	1.6	5.3	376	3
C4	0°	14	1.52	32.6	57.6	2.3	5.4	376	3
C5	0°	14	1.52	31.9	58.7	2.6	5.2	376	3
C6	0°	20	1.52	33.0	57.7	1.8	5.3	376	3
C7	0°	6	1.55	32.8	58.6	0.3	5.7	376	6
C8	0°	6	1.54	31.8	59.1	1.3	5.7	376	3
C9	0°	6	1.56	31.4	60.1	0.4	5.7	376	3
C10	0°	6	1.53	35.9	55.1	0.6	5.7	376	3
C11	0°	6	1.51	37.8	52.7	1.2	5.7	376	3
C12	0°	6	1.54	31.4	59.4	1.4	5.7	376	3
C13	0°	6	1.55	33.2	57.6	≐0	5.7	376	3
C14	0°	6	1.51	38.1	52.7	0.6	5.7	376	3
C15	90°	15	1.54	36.0	55.3	≐0	5.5	376	3
C16	90°	15	1.55	32.9	58.5	0.2	5.7	376	3
C17	90°	15	1.56	32.4	59.2	≐0	5.8	376	3
C18	90°	15	1.55	33.5	57.4	0.2	5.8	376	3
C19	±45°	8	1.54	34.8	55.7	≐0	5.5	376	6
C20	±45°	8	1.54	34.0	57.3	0.2	5.3	376	6
C21	±45°	8	1.54	33.8	57.4	0.5	5.5	376	6
C22	±45°	8	1.55	33.5	57.8	0.2	5.4	376	6
C23	±45°	8	1.54	33.4	57.9	0.5	5.4	376	6
C24	±45°	8	1.53	33.6	57.2	1.3	5.4	376	6
C25	0°	6	1.51	38.0	52.7	0.9	5.7	376	3

*ASTM D2734-70(B)

LAMINATE PHYSICAL PROPERTIES									
Material: AS/3004									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
C26	90°	15	1.54	30.8	59.9	1.7	5.5	376	3
C27	90°	15	1.56	31.2	60.4	0.2	5.4	376	3
C28	90°	15	1.54	33.4	57.7	0.7	5.5	376	3
C29	90°	15	1.54	34.8	56.4	0.2	5.4	376	3
C30	0°	40	1.56	31.6	60.1	0.1	5.4	376	3&9
C31	90°	15	1.53	33.5	57.2	1.3	5.5	376	3
C32	90°	15	1.52	34.5	56.1	1.3	5.4	376	3
C33	90°	30	1.54	34.4	57.0	0.1	5.1	376	3&9
C34	90°	15	1.53	34.4	56.6	0.7	5.3	376	3
C35	90°	15	1.54	32.0	59.0	1.2	5.5	376	9
C36	±45°	30	1.53	35.1	55.7	0.9	5.2	376	9
C37	90°	15	1.54	33.1	58.0	0.8	5.4	376	9
C38	90°	15	1.53	35.1	55.7	0.9	5.3	376	6
C39	90°	15	1.54	33.6	57.6	0.6	5.7	376	6
C40	±45°	30	1.54	34.1	57.2	0.2	5.3	376	6
C41	±45°	8	1.51	32.8	57.3	2.6	5.4	376	6
C42	±45°	8	1.52	32.9	57.1	2.6	5.5	376	6
C43	±45°	8	1.50	33.9	55.9	2.9	5.5	376	6
C44	±45°	8	1.50	32.7	56.8	3.5	5.6	376	6
C45	±45°	8	1.52	32.7	57.4	2.4	5.4	376	6
C46	±45°	8	1.51	33.6	56.3	2.[illegible]	5.4	376	6
C47	±45°	8	1.51	33.7	56.3	[illegible]	5.4	376	6
C48	±45°	8	1.53	33.6	57.3	1.[illegible]	5.4	376	6
C49	±45°	8	1.54	33.7	57.3	0.8	5.4	376	6
C50	±45°	8	1.53	34.2	56.7	1.0	5.4	376	6

*ASTM D2734-70(B)

LAMINATE PHYSICAL PROPERTIES

Material: AS/3004

Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
C51	90°	15	1.51	35.3	53.7	1.7	5.4	376	10A
C52	90°	15	1.51	33.8	56.4	2.2	5.4	376	10A
C53	90°	15	1.53	33.6	57.3	1.1	5.3	376	10A
C54	±45°	8	1.53	33.0	57.6	1.7	5.3	376	10A
C55	±45°	8	1.52	32.1	58.2	2.2	5.3	376	10A
C56	±45°	8	1.52	34.0	56.6	1.5	5.4	376	10A
Avg.			1.53	33.6	57.2	1.1	5.5		
St.Dv.			0.02	1.6	1.7	0.9	0.2		

*ASTM D2734-70(B)

LAMINATE PHYSICAL PROPERTIES									
Material: AS/4397									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thickness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
D1	0°	6	1.59	25.8	66.4	0.9	5.9	382	2
D3	0°	6	1.56	29.6	62.4	1.2	5.9	382	2
D4	0°	6	1.58	29.2	63.0	0.3	5.8	382	2
D5	0°	6	1.53	34.1	56.5	2.2	5.8	382	2
D6	0°	6	1.57	29.4	62.7	0.3	5.7	382	2
D7	0°	6	1.56	28.5	62.7	2.0	5.7	382	2
D9	0°	14	1.60	28.0	66.0	≐0	5.5	382	2
D10	0°	20	1.56	28.2	62.9	2.2	5.3	382	2
D12	90°	15	1.58	26.7	65.3	1.0	5.5	382	2
D13	90°	15	1.59	26.3	65.8	1.0	5.5	382	2
D14	90°	15	1.58	28.0	63.9	1.0	5.5	382	2
D15	90°	15	1.57	27.3	64.4	1.5	5.5	382	2
D16	90°	15	1.59	26.7	65.6	0.6	5.7	382	2
D17	90°	15	1.57	26.7	64.8	1.8	5.7	382	2
D18	90°	15	1.56	28.1	63.1	2.0	5.5	382	2
D19	90°	15	1.59	27.6	64.6	0.3	5.3	382	2
D20	90°	15	1.58	26.7	65.2	1.3	5.5	382	2
D21	90°	15	1.58	26.8	65.0	1.4	5.5	382	2
D22	90°	15	1.57	26.3	65.3	1.8	5.8	382	2
D23	90°	15	1.56	28.3	63.9	1.7	5.5	382	2
D24	90°	15	1.54	34.4	56.7	1.2	5.6	382	2
D25	90°	15	1.60	26.5	66.3	≐0	5.6	382	2
D26	90°	15	1.59	27.8	64.6	≐0	5.7	382	2
D27	±45°	8	1.57	27.8	64.7	≐0	5.6	382	2
D28	±45°	8	1.58	27.2	65.5	≐0	5.6	382	2

*ASTM D2734-70(B). Photomicrographs showed all laminates to be practically void free.

LAMINATE PHYSICAL PROPERTIES									
Material: AS/4397									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content* (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
D29	±45°	8	1.58	28.0	64.6	≐0	5.6	382	2
D30	±45°	8	1.59	27.1	65.5	≐0	5.6	382	2
D31	±45°	8	1.58	28.5	63.9	≐0	5.6	382	2
D32	±45°	8	1.57	29.7	62.6	≐0	5.7	382	2
D33	±45°	8	1.56	28.1	64.1	≐0	5.8	382	2
D34	±45°	8	1.58	27.4	65.2	≐0	5.8	382	2
D35	±45°	8	1.59	28.6	63.7	0.3	5.7	382	2
D36	±45°	8	1.56	30.0	62.3	≐0	5.9	382	2
D37	±45°	8	1.56	29.1	63.2	≐0	5.7	382	2
D38	±45°	8	1.55	29.6	62.7	≐0	5.8	382	2
D39	±45°	8	1.59	28.3	64.1	≐0	5.9	382	2
D40	±45°	8	1.58	28.5	63.4	≐0	5.9	382	2
D41	±45°	8	1.56	28.6	63.9	≐0	5.8	382	2
D44	0°	20	1.54	31.0	61.2	≐0	5.5	382	2
D46	0°	6	1.58	28.0	64.0	≐0	5.8	382	3
D48	0°	14	1.55	30.9	61.3	≐0	5.7	382	3
D49	0°	20	1.55	30.1	62.1	≐0	5.5	382	3
D57	0°	6	1.54	30.5	61.8	≐0	5.4	382	3
D58	90°	15	1.55	29.2	63.2	≐0	5.7	382	3
D59	±45°	20	1.55	30.2	62.0	≐0	5.5	382	3
D60	±45°	20	1.55	29.9	62.4	≐0	5.5	382	3
Avg.			1.57	28.5	63.6	≐0	5.6		
St.Dv.			0.02	1.8	2.1	---	0.2		

*ASTM D2734-70(B). Photomicrographs showed all laminates to be practically void free.

LAMINATE PHYSICAL PROPERTIES									
Material: T300/F178									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
E4	0°	6	1.57	33.3	56.6	0.2	6.0	DPO21	5
E5	0°	6	1.57	27.1	65.3	≐0	5.2	DPO21	5
E6	0°	6	1.55	30.6	60.3	0.3	5.2	DPO21	5
E7	0°	6	1.54	30.1	60.7	0.3	5.0	DPO21	5
E8	0°	6	1.55	29.7	60.4	1.0	5.0	DPO21	5
E9	0°	14	1.55	28.9	61.4	1.0	5.4	DPO21	5
E10	90°	15	1.58	32.1	57.3	0.7	5.0	DPO21	4
E11	90°	15	1.58	30.3	60.5	0.2	5.1	DPO21	4
E12	90°	14	1.57	35.5	53.5	≐0	5.1	DPO21	4
E13	90°	15	1.58	29.6	61.6	0.3	5.1	DPO21	4
E14	90°	15	1.58	29.1	62.1	0.1	5.2	DPO21	4
E15	90°	15	1.60	31.7	58.5	0.3	5.1	DPO21	4
E17	90°	15	1.59	32.5	57.5	0.2	5.2	DPO21	4
E18	90°	15	1.58	31.6	59.2	0.1	5.1	DPO21	4
E19	90°	15	1.59	28.8	62.3	0.3	5.1	DPO21	4
E20	90°	15	1.58	31.8	58.6	0.1	5.1	DPO21	4
E21	0°	6	1.57	33.4	56.4	0.2	5.3	DPO21	4
E22	0°	6	1.57	29.5	61.8	0.2	5.2	DPO21	4
E23	90°	15	1.59	32.2	55.6	≐0	5.3	DPO21	4
E24	0°	6	1.59	26.7	65.9	≐0	5.0	DPO21	4
E25	0°	6	1.56	30.3	59.2	0.2	5.5	DPO21	4
E26	90°	15	1.53	33.8	55.8	1.0	5.8	DPO21	4
E27	90°	15	1.57	37.4	53.2	≐0	5.4	DPO21	4
E28	90°	15	1.56	36.2	52.1	0.8	5.6	DPO21	4
E29	90°	15	1.53	33.6	55.3	1.0	5.7	DPO21	4

LAMINATE PHYSICAL PROPERTIES									
Material: T300/F178									
Lam. No.	Fiber Orien.	No. Plies	Spec. Grav.	Resin Content (%by wt)	Fiber Content (%by vol)	Void Content (%by vol)	Thick-ness per ply (mils)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
E30	90°	15	1.58	33.3	56.4	0.3	5.4	DPO21	4
E31	0°	20	1.57	35.5	53.8	0.1	5.4	DPO21	4
E32	0°	40	1.59	32.2	58.0	0.2	5.0	DPO21	4
E33	0°	40	1.60	32.8	56.8	0.6	5.2	DPO21	5
E34	±45°	8	1.62	30.9	59.7	0.1	5.5	DPO21	5
E35	±45°	8	1.62	27.4	66.4	≐0	6.0	DPO21	5
E36	±45°	8	1.64	30.4	60.5	≐0	5.4	DPO21	5
E37	±45°	8	1.57	31.4	59.0	0.2	5.5	DPO21	5
E39	±45°	8	1.59	27.7	64.0	≐0	6.1	DPO21	5
E40	±45°	8	1.57	28.4	63.1	≐0	6.0	DPO21	5
E41	±45°	8	1.58	28.3	63.2	≐0	5.1	DPO21	5
E42	±45°	8	1.61	25.4	67.0	≐0	5.5	DPO21	5
E43	±45°	8	1.59	27.7	64.0	0.2	5.3	DPO21	5
E44	±45°	8	1.59	26.7	65.1	0.1	5.2	DPO21	5
E46	±45°	40	1.58	32.6	57.5	0.2	5.1	DPO21	5
E47	±45°	40	1.59	30.7	60.2	0.1	5.3	DPO21	5
E48	±45°	8	1.58	28.3	63.4	0.1	5.4	DPO21	5
E49	90°	15	1.58	32.9	56.1	≐0	5.7	DPO21	5
E50	90°	15	1.57	34.1	55.6	0.1	5.7	DPO21	5
E51	90°	15	1.58	33.4	56.3	0.3	5.7	DPO21	5
E52	90°	15	1.59	28.4	63.2	0.2	5.6	DPO21	5
E53	90°	15	1.56	31.9	58.9	≐0	5.6	DPO21	5
Avg.			1.58	31.6	59.5	0.2	5.4		
St.Dv.			0.01	2.7	3.7	0.3	0.3		

APPENDIX C
TENSION DATA

All of the tension data generated during this program are listed in this section. These data are summarized and presented in both tabular and graphical form in Section 4.

Test: Tension				Material: SP313				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
A1-6	0°	-67	147.7	21.5	147.7	0.40	0.0070	
A2-6	0°	-67	145.5	20.0	---	0.29	---	
A4-14	0°	-67	153.6	19.9	---	---	---	
A1-12	0°	-67	133.2	19.4	---	---	---	
A6-15	0°	-67	151.0	20.6	151.0	0.36	0.0071	
Avg.			146.2	20.7	---	0.36	0.00705	
Std.Dev			7.9	1.2	---	0.06	0.00007	
A1-10	0°	72	183.9	19.3	183.9	0.31	0.0092	
A2-11	0°	72	182.0	20.5	182.0	0.32	0.0084	
A4-5	0°	72	218.2	19.5	218.2	0.27	---	
A5-16	0°	72	200.8	20.1	200.8	0.33	0.0093	
A6-2	0°	72	213.1	21.1	213.1	0.34	0.0094	
A3-17	0°	72	194.3	21.1	194.3	0.36	0.0086	
A3-2	0°	72	---	19.9	---	0.32	---	
Avg.			198.7	20.3	198.7	0.32	0.0090	
Std.Dev			14.9	1.1	14.9	0.03	0.000449	
A4-15	0°	260	162.3	19.4	162.3	0.33	0.0079	
A5-11	0°	260	177.8	20.2	177.8	0.29	0.0080	
A6-6	0°	260	182.0	19.0	182.0	0.34	0.0091	
A7-2	0°	260	176.5	18.5	176.5	0.32	0.0091	
A3-7	0°	260	184.5	19.6	184.5	0.30	0.0089	
Avg.			176.6	19.3	176.6	0.32	0.0086	
Std.Dev			8.6	0.6	8.6	0.02	0.0006	

Test: Tension Material: SP313

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
A1-5	0°	350	139.4	19.6	139.4	0.35	0.0069	
A4-6	0°	350	117.2	19.6	85.8	0.31	---	
A6-11	0°	350	149.3	20.0	134.7	0.35	0.0076	
A3-13	0°	350	146.2	19.3	137.8	---	0.0073	
A7-17	0°	350	156.3	19.2	156.3	---	0.0077	
Avg.			141.7	19.5	130.8	0.34	0.0074	
Std.Dev.			15.0	0.3	26.5	0.02	0.000316	
A16-8	90°	-67	5.24	1.47	5.24	---	0.0037	
A17-3	90°	-67	5.83	1.19	5.83	---	0.0043	
A18-10	90°	-67	5.60	1.44	5.60	---	0.0038	
A19-11	90°	-67	5.26	1.40	5.26	---	0.0037	
A20-1	90°	-67	4.08	1.46	4.08	---	0.0028	
Avg.			5.20	1.39	5.20	---	0.0037	
Std.Dev.			0.67	0.12	0.67	---	0.000540	
A16-3	90°	72	4.60	1.28	4.60	---	0.0035	
A17-9	90°	72	4.82	1.30	4.82	---	0.0037	
A18-4	90°	72	4.88	1.28	4.88	---	0.0038	
A19-1	90°	72	4.87	1.34	4.87	---	0.0037	
A20-10	90°	72	5.36	1.28	5.36	---	0.0042	
A22-1	90°	72	5.15	1.31	5.15	---	0.0040	
Avg.			4.94	1.30	4.94	---	0.0038	
Std.Dev.			0.27	0.03	0.27	---	0.0003	

Test: Tension				Material: SP313				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
A16-9	90°	260	4.22	1.05	3.55	---	0.0040	
A17-7	90°	260	5.05	1.02	5.05	---	0.0049	
A18-7	90°	260	4.01	1.00	3.37	---	0.0040	
A19-5	90°	260	5.41	1.12	5.17	---	0.0049	
A20-7	90°	260	5.11	1.09	3.45	---	0.0048	
Avg.			4.76	1.06	4.[illegible]2	---	0.0045	
Std.Dev.			0.61	0.05	0.61	---	0.0005	
A16-4	90°	350	3.86	1.17	0.60	---	0.0041	
A17-1	90°	350	4.21	1.03	1.95	---	0.0046	
A18-2	90°	350	3.31	0.99	1.93	---	0.0036	
A19-3	90°	350	3.84	1.16	1.16	---	0.0044	
A20-11	90°	350	3.25	0.90	2.29	---	0.0038	
Avg.			3.69	1.05	1.59	---	0.0041	
Std.Dev.			0.41	0.12	0.69	---	0.00041	
A38-8	±45°	-67	24.20	2.87	8.44	0.68	0.0126	
A39-3	±45°	-67	24.30	3.03	9.56	0.63	0.0104	
A44-10	±45°	-67	24.50	3.03	7.66	0.72	0.0115	
A47-1	±45°	-67	25.10	3.25	7.23	0.68	0.0103	
A50-11	±45°	-67	24.40	2.87	8.00	0.61	0.0111	
Avg.			24.50	3.01	8.28	0.66	0.0112	
Std.Dev.			0.36	0.16	0.78	0.04	0.000894	
A38-7	±45°	72	20.67	2.61	6.00	0.74	0.0174	
A39-9	±45°	72	21.18	2.80	5.01	0.70	0.0150	
A44-4	±45°	72	20.85	2.76	6.33	0.80	0.0124	
A47-10	±45°	72	20.68	2.46	6.71	0.68	0.0143	
A50-1	±45°	72	21.58	2.87	5.23	0.74	0.0121	
Avg.			20.99	2.70	5.86	0.73	0.0142	
Std.Dev.			0.39	0.17	0.72	0.05	0.0022	

Test: Tension   Material: SP313

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
A38-9	±45°	260	14.89	2.19	4.33	0.75	0.0285	
A39-7	±45°	260	15.56	2.04	3.89	0.72	---	
A44-7	±45°	260	15.00	2.24	4.09	0.80	0.0275	
A47-7	±45°	260	15.11	2.00	3.18	0.71	0.0330	
A50-5	±45°	260	14.52	2.13	3.78	0.72	0.0199	
Avg.			15.02	2.12	3.86	0.74	0.0270	
Std.Dev.			0.38	0.10	0.43	0.04	0.0054	
A38-4	±45°	350	10.33	1.93	2.22	0.82	0.025	
A39-1	±45°	350	10.33	1.78	2.67	0.80	0.031	
A44-2	±45°	350	10.95	2.03	2.68	0.85	0.029	
A47-11	±45°	350	12.73	1.99	3.18	0.83	0.033	
A50-3	±45°	350	10.34	1.89	2.39	0.85	0.022	
Avg.			10.94	1.92	2.63	0.83	0.028	
Std.Dev.			1.04	0.10	0.37	0.02	0.005	

Test: Tension — Material: AS/3004

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
C9-8	0°	-67	206.3	17.84	206.3	0.33	---	
C11-8	0°	-67	206.1	18.42	206.1	0.31	0.0107	
C8-11	0°	-67	162.4	17.66	162.4	0.32	0.0088	
C7-8	0°	-67	212.8	17.81	212.8	0.27	0.0110	
C11-9	0°	-67	214.9	18.53	214.9	0.32	0.0110	
Avg.			200.5	18.05	200.5	0.31	0.0104	
Std.Dev.			21.6	0.39	21.6	0.02	0.0011	
C7-7	0°	72	184.9	16.36	184.9	0.38	0.0100	
C9-1	0°	72	160.0	16.32	160.0	0.34	0.0091	
C11-1	0°	72	184.9	15.33	---	0.27	---	
C10-5	0°	72	187.1	16.24	187.1	0.32	0.0105	
C7-14	0°	72	222.6	17.46	222.6	0.40	0.0107	
Avg.			187.9	16.34	187.9	0.34	0.0101	
Std.Dev.			22.4	0.76	22.4	0.05	0.0007	
C10-15	0°	180	124.6	16.21	124.6	0.34	0.0070	
C8-14	0°	180	191.4	16.30	191.4	0.24	0.0105	
C7-13	0°	180	180.6	15.88	180.6	0.31	0.0105	
C7-9	0°	180	202.6	15.79	202.6	0.40	---	
C10-1	0°	180	258.3	16.73	258.3	0.33	0.0145	
Avg.			191.5	16.18	191.5	0.32	0.0106	
Std.Dev.			47.9	0.37	47.9	0.06	0.0031	
C9-9	0°	250	149.7	15.73	149.7	0.41	0.0090	
C11-14	0°	250	197.7	18.00	197.7	0.34	0.0097	
C7-6	0°	250	192.8	18.04	192.8	0.28	0.0100	
C9-15	0°	250	176.1	17.66	176.1	---	0.0091	
C10-7	0°	250	179.4	18.06	179.4	0.34	0.0092	
Avg.			179.1	17.50	179.1	0.34	0.0094	
Std.Dev.			18.7	1.00	18.7	---	0.0004	

Test: Tension — Material: AS/3004

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
C26-8	90°	-67	6.27	1.14	6.27	---	0.0055	
C26-3	90°	-67	7.67	1.13	7.67	---	0.0067	
C27-1	90°	-67	4.58	0.91	4.58	---	0.0049	
C26-6	90°	-67	7.32	1.11	7.32	---	0.0063	
C27-2	90°	-67	8.26	1.02	8.26	---	0.0078	
Avg.			6.82	1.06	6.82	---	0.0062	
Std.Dev.			1.45	0.10	1.45	---	0.0011	
C17-7	90°	72	5.01	1.40	5.01	---	0.0035	
C16-3	90°	72	5.54	1.07	5.54	---	0.0051	
C15-4	90°	72	3.41	1.08	3.41	---	0.0032	
C16-6	90°	72	5.14	1.05	5.14	---	0.0048	
C17-5	90°	72	6.02	1.14	2.46	---	0.0054	
Avg.			5.02	1.15	4.31	---	0.0044	
Std.Dev.			0.98	0.14	1.32	---	0.0010	
C15-5	90°	180	3.17	1.06	3.17	---	0.0030	
C17-3	90°	180	6.76	1.11	6.76	---	0.0063	
C16-1	90°	180	4.57	1.02	4.57	---	0.0045	
C15-7	90°	180	5.40	1.08	3.49	---	0.0051	
C18-8	90°	180	4.75	1.10	4.75	---	0.0044	
Avg.			4.93	1.07	4.55	---	0.0046	
Std.Dev.			1.31	0.04	1.41	---	0.0011	
C27-8	90°	250	4.80	1.09	4.80	---	0.0044	
C27-7	90°	250	6.56	1.08	---	---	---	
C27-6	90°	250	5.98	1.09	3.81	---	0.0057	
C26-1	90°	250	4.19	1.01	3.39	---	0.0043	
C26-4	90°	250	5.45	1.10	4.12	---	0.0051	
Avg.			5.39	1.07	4.03	---	0.0049	
Std.Dev.			0.94	0.03	0.59	---	0.0005	

Test: Tension				Material: AS/3004				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
C23-1	±45°	-67	41.96	2.00	4.37	0.83	0.0200+	Surface plies
C22-7	±45°	-67	43.12	2.09	6.26	0.75	0.0200+	cracked creating
C21-6	±45°	-67	42.12	2.04	4.93	0.89	0.0200+	discontinuities
C23-6	±45°	-67	42.84	1.99	4.65	---	0.0340+	in gages
C24-4	±45°	-67	38.05	1.88	4.65	0.77	0.0035+	↓
Avg.			41.62	2.00	4.97	0.81	0.0195+	
Std.Dev.			2.05	0.07	0.75	0.06	---	
C21-1	±45°	72	33.06	1.91	3.63	0.53	0.0280+	↓
C20-3	±45°	72	29.96	1.99	3.82	0.78	0.0790+	
C20-5	±45°	72	31.09	2.14	4.09	0.77	0.0230+	
C19-4	±45°	72	30.67	1.98	4.54	0.87	0.0160+	
C21-3	±45°	72	34.87	1.86	3.63	0.78	0.0520+	
Avg.			31.93	1.98	3.94	0.75	0.0400+	
Std.Dev.			1.79	0.11	0.38	0.13	---	
C20-8	±45°	180	25.09	1.88	3.80	0.89	0.0390+	↓
C19-6	±45°	180	29.30	2.00	4.28	0.84	0.0530+	
C19-8	±45°	180	28.23	1.90	3.80	0.89	0.0540+	
C21-7	±45°	180	30.04	1.92	3.80	0.83	0.0290+	
C20-4	±45°	180	26.16	1.95	4.28	0.83	0.0270+	
Avg.			27.76	1.93	3.97	0.86	0.0406+	
Std.Dev.			2.09	0.05	0.23	0.05	---	
C24-6	±45°	250	23.53	1.72	3.26	0.77	0.0315+	↓
C19-1	±45°	250	24.14	1.77	3.78	0.76	0.0375+	
C19-7	±45°	250	23.77	1.89	2.56	0.89	0.0330+	
C23-3	±45°	250	25.14	1.84	3.20	0.75	0.0580+	
C21-2	±45°	250	24.90	1.96	2.84	0.89	0.0580+	
Avg.			24.30	1.84	3.13	0.81	0.0416+	
Std.Dev.			0.70	0.09	0.46	0.07	---	

Test: Tension Material: AS/4397

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
D1-13	0°	-67	194.1	18.85	---	0.31	---	
D1-5	0°	-67	197.7	19.88	197.7	0.32	0.0093	
D4-8	0°	-67	200.0	19.78	200.0	0.33	0.0093	
D3-3	0°	-67	189.6	19.41	189.6	0.31	0.0093	
D5-9	0°	-67	195.6	19.00	195.6	0.29	0.0094	
Avg.			195.4	19.38	195.7	0.31	0.0093	
Std.Dev.			3.9	0.46	4.5	0.02	0.0001	
D4-19	0°	72	209.4	18.47	209.4	0.27	0.0107	
D1-19	0°	72	208.0	17.64	208.0	0.28	0.0108	
D4-1	0°	72	204.0	17.49	204.0	0.31	0.0107	
D5-3	0°	72	194.4	18.11	194.4	0.31	0.0099	
D5-10	0°	72	195.8	18.74	195.8	0.31	0.0097	
D3-5	0°	72	208.4	19.06	208.4	---	0.0101	
Avg.			203.3	18.25	203.3	0.30	0.0103	
Std.Dev.			6.6	0.62	6.6	0.02	0.0005	
D4-12	0°	350	222.7	19.59	222.7	0.29	0.0115	
D3-1	0°	350	149.7	16.52	149.7	0.28	0.0086	
D1-3	0°	350	190.7	19.24	178.1	0.32	---	
D1-8	0°	350	193.7	19.37	193.7	0.37	0.0093	
D3-4	0°	350	159.9	18.78	138.9	0.31	---	
D3-8	0°	350	207.9	19.80	191.6	---	0.0100	
Avg.			187.4	18.88	179.1	0.31	0.0099	
Std.Dev.			27.9	1.21	30.8	0.03	0.0012	

Test: Tension Material: AS/4397

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
D4-7	0°	450	217.1	17.81	217.1	0.29	0.0111	
D5-18	0°	450	217.6	18.55	217.6	0.36	0.0110	
D3-10	0°	450	206.3	18.97	206.3	---	0.0106	
D3-19	0°	450	206.1	17.80	206.1	0.32	---	
D5-13	0°	450	185.4	17.57	185.4	0.33	0.0109	
Avg.			206.5	18.14	206.5	0.33	0.0109	
Std.Dev.			13.0	0.59	13.0	0.03	0.0002	
D15-6	90°	-67	5.00	1.46	5.00	---	0.0034	
D19-2	90°	-67	4.56	1.49	4.56	---	0.0031	
D17-8	90°	-67	5.45	1.47	5.45	---	0.0037	
D20-5	90°	-67	5.78	1.49	5.78	---	0.0039	
D20-2	90°	-67	5.66	1.45	5.66	---	0.0039	
Avg.			5.29	1.47	5.29	---	0.0036	
Std.Dev.			0.51	0.02	0.51	---	0.0003	
D15-1	90°	72	5.25	1.39	5.25	---	0.0038	
D16-8	90°	72	4.94	1.39	4.94	---	0.0036	
D18-6	90°	72	5.46	1.40	5.46	---	0.0039	
D17-6	90°	72	5.34	1.38	5.34	---	0.0039	
D19-1	90°	72	5.85	1.39	5.85	---	0.0043	
Avg.			5.37	1.39	5.37	---	0.0039	
Std.Dev.			0.33	0.01	0.33	---	0.0003	

Test: Tension				Material: AS/4397				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop. Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
D19-3	90°	350	4.40	1.21	2.41	---	0.0039	
D18-7	90°	350	3.88	1.09	3.88	---	0.0036	
D18-7	90°	350	3.91	1.27	1.75	---	0.0033	
D16-4	90°	350	3.64	1.17	2.56	---	0.0032	
D15-4	90°	350	3.22	1.13	3.22	---	0.0029	
Avg.			3.81	1.17	2.76	---	0.0034	
Std.Dev.			0.38	0.07	0.73	---	0.0003	
D19-10	90°	450	3.04	0.79	2.56	---	0.0043	
D16-10	90°	450	2.93	0.81	1.83	---	0.0040	
D17-9	90°	450	2.75	0.69	1.89	---	0.0042	
D18-10	90°	450	3.28	0.76	2.11	---	0.0048	
D15-2	90°	450	2.79	0.76	2.32	---	0.0038	
Avg.			2.96	0.76	2.14	---	0.0042	
Std.Dev.			0.21	0.05	0.30	---	0.0003	
D27-10	±45°	-67	19.13	2.86	10.68	0.67	0.0105	
D29-1	±45°	-67	19.29	2.83	8.00	---	0.0099	
D28-7	±45°	-67	18.78	2.95	9.57	0.80	0.0106	
D29-9	±45°	-67	19.81	2.84	8.25	0.66	0.0102	
D30-3	±45°	-67	19.29	2.58	6.95	0.69	0.0121	
Avg.			19.26	2.81	8.69	0.71	0.0107	
Std.Dev.			0.37	0.14	1.45	0.06	0.0008	
D27-9	±45°	72	18.91	2.72	8.44	0.75	0.0112	
D27-1	±45°	72	18.63	2.75	7.98	0.82	0.0110	
D30-5	±45°	72	18.20	2.49	7.10	0.63	0.0142	
D29-4	±45°	72	18.65	2.70	7.10	0.68	0.0098	
D28-3	±45°	72	19.20	2.61	6.67	0.70	0.0130	
Avg.			18.72	2.66	7.46	0.72	0.0118	
Std.Dev.			0.37	0.09	0.73	0.07	0.0017	

Test: Tension Material: AS/4397

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
D29-3	±45°	350	16.98	1.81	4.44	0.62	0.0200+	Surface plies
D28-10	±45°	350	16.94	2.10	2.02	0.72	0.0200+	cracked, creating
D28-5	±45°	350	16.94	1.99	3.89	0.71	0.0200+	electrical breaks
D27-5	±45°	350	16.93	2.07	4.18	0.75	0.0373+	in strain gages
D30-1	±45°	350	15.26	2.28	3.88	0.76	0.0274+	↓
Avg.			16.61	2.05	3.68	0.71	0.0250+	
Std.Dev.			0.76	0.17	0.96	0.06	---	
D30-4	±45°	450	17.40	1.97	3.62	0.70	0.0180+	↓
D29-8	±45°	450	16.67	1.84	3.04	---	---	
D29-2	±45°	450	16.50	1.87	2.77	0.64	0.0112+	
D27-3	±45°	450	16.34	1.79	1.78	---	0.0114+	
D28-8	±45°	450	16.57	1.47	2.73	0.62	0.0262+	
Avg.			16.70	1.79	2.78	0.65	0.0167+	
Std.Dev.			0.41	0.19	0.67	---	---	

Test: Tension				Material: T300/F178				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
E22-4	0°	-67	100.7	18.97	100.6	0.33	0.0051	
E6-8	0°	-67	162.1	21.49	162.1	0.33	0.0072	
E7-5	0°	-67	137.0	20.65	137.0	0.32	0.0064	
E8-4	0°	-67	93.6	20.36	93.6	0.31	0.0048	
E5-11	0°	-67	156.3	19.63	156.3	0.26	0.0085	
Avg.			129.9	20.22	129.9	0.31	0.0064	
Std.Dev.			31.4	0.97	31.4	0.03	0.0015	
E6-16	0°	72	146.4	19.56	146.4	0.34	0.0072	
E5-10	0°	72	176.6	20.31	176.6	0.34	0.0083	
E8-1	0°	72	194.3	19.83	194.3	0.32	0.0092	
E22-11	0°	72	134.2	20.41	134.2	0.30	0.0070	
E7-19	0°	72	152.7	19.35	152.7	0.38	0.0075	
E24-1	0°	72	137.8	19.89	137.8	0.34	0.0067	
E24-4	0°	72	135.9	19.92	135.9	0.29	0.0067	
E8-19	0°	72	174.3	22.05	174.3	0.32	0.0077	
E5-8	0°	72	158.4	20.96	158.4	0.33	0.0074	
Avg.			156.7	20.25	156.7	0.33	0.0075	
Std.Dev.			21.0	0.82	21.0	0.03	0.0012	
E22-12	0°	350	177.1	20.41	177.1	---	0.0080	
E8-17	0°	350	134.9	19.68	134.9	0.30	0.0067	
E5-5	0°	350	170.4	19.29	170.4	0.28	0.0085	
E7-4	0°	350	140.7	18.74	140.7	0.28	0.0075	
E6-3	0°	350	138.1	19.68	138.1	0.25	0.0068	
Avg.			152.2	19.56	152.2	0.28	0.0075	
Std.Dev.			19.9	0.61	19.9	0.02	0.0008	

Test: Tension Material: T300/F178

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
E22-6	0°	450	141.8	20.58	141.8	0.33	0.0067	
E6-14	0°	450	140.8	18.31	140.8	0.35	---	
E8-12	0°	450	177.8	20.33	177.8	---	0.0085	
E5-18	0°	450	171.9	19.38	171.9	---	0.0088	
E7-6	0°	450	132.4	17.99	132.4	0.35	0.0073	
Avg.			152.9	19.32	152.9	0.35	0.0078	
Std.Dev.			20.4	1.16	20.4	0.01	0.0010	
E14-4	90°	-67	2.03	1.70	2.03	---	0.0012	
E10-6	90°	-67	3.17	1.47	3.17	---	0.0021	
E23-5	90°	-67	4.13	1.59	2.94	---	0.0026	
E13-10	90°	-67	3.95	1.70	2.98	---	0.0024	
E11-5	90°	-67	3.13	1.58	3.13	---	0.0020	
Avg.			3.28	1.61	2.85	---	0.0021	
Std.Dev.			0.83	0.10	0.47	---	0.0005	
E10-3	90°	72	3.94	1.55	3.68	---	0.0026	
E10-5	90°	72	4.35	1.52	3.49	---	0.0030	
E10-4	90°	72	3.22	1.62	2.17	---	0.0021	
E13-6	90°	72	3.37	1.49	3.37	---	0.0023	
E11-7	90°	72	4.07	1.40	4.07	---	0.0029	
E14-2	90°	72	3.82	1.54	2.56	---	0.0026	
E23-3	90°	72	3.97	1.39	3.97	---	0.0028	
Avg.			3.82	1.50	3.33	---	0.0026	
Std.Dev.			0.40	0.08	0.71	---	0.0003	

Test: Tension Material: T300/F178

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
E10-2	90°	350	2.03	1.31	---	---	---	
E23-6	90°	350	4.16	1.02	3.45	---	0.0042	
E14-7	90°	350	2.38	1.12	---	---	0.0020	
E11-2	90°	350	3.28	1.17	2.40	---	0.0029	
E13-2	90°	350	2.99	1.14	2.99	---	0.0027	
Avg.			2.97	1.15	2.95	---	0.0030	
Std.Dev.			0.83	0.10	0.53	---	0.0009	
E14-8	90°	450	2.01	1.05	1.10	---	0.0024	
E11-3	90°	450	2.37	0.93	0.92	---	0.0030	
E13-7	90°	450	2.70	1.01	1.91	---	0.0030	
E23-7	90°	450	2.54	0.74	1.88	---	0.0036	
Avg.			2.40	0.93	1.45	---	0.0030	
Std. Dev.			0.30	0.14	0.51	---	0.0005	
E42-5	±45°	-67	14.30	2.37	5.11	0.55	0.0097	
E39-1	±45°	-67	15.88	2.74	10.66	0.69	0.0074	
E40-3	±45°	-67	17.14	2.77	10.71	0.72	0.0086	
E36-2	±45°	-67	15.71	2.38	8.92	0.69	0.0104	
E35-4	±45°	-67	16.06	2.67	9.69	0.67	0.0090	
Avg.			15.82	2.59	9.02	0.66	0.0090	
Std.Dev.			1.02	0.20	2.31	0.07	0.0011	
E35-3	±45°	72	17.61	2.70	7.65	0.76	0.0090	
E39-7	±45°	72	18.24	2.69	7.76	0.73	0.0114	
E40-2	±45°	72	18.10	2.73	7.65	0.79	0.0086	
E36-1	±45°	72	16.48	2.75	5.95	0.77	0.0077	
E42-6	±45°	72	15.44	2.44	7.38	0.73	0.0104	
Avg.			17.17	2.66	7.28	0.76	0.0094	
Std.Dev.			1.19	0.13	0.76	0.03	0.0015	

Test: Tension				Material: T300/F178				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Pois. Ratio	Ultimate Strain (in/in)	Remarks
E39-8	±45°	350	14.71	1.88	4.60	0.88	0.0174+	Surface plies
E35-2	±45°	350	14.27	1.89	4.59	0.91	0.0171+	cracked, destroying
E42-7	±45°	350	14.21	2.01	4.55	0.89	0.0139	gages
E36-9	±45°	350	14.32	1.95	5.11	0.86	0.0132	↓
E40-1	±45°	350	15.52	1.98	4.69	0.80	0.0167+	
Avg.			14.61	1.94	4.71	0.87	0.0157+	
Std.Dev.			0.55	0.06	0.23	0.04	---	
E39-9	±45°	450	12.05	1.48	2.76	0.75	0.0189+	↓
E35-1	±45°	450	12.35	1.54	3.04	0.88	0.0188+	
E42-2	±45°	450	11.81	1.49	2.95	0.72	0.0164+	
E36-6	±45°	450	12.73	1.56	3.64	0.74	0.0180+	
E40-10	±45°	450	11.98	1.37	2.77	0.86	0.0178+	
Avg.			12.18	1.49	3.03	0.79	0.0180+	
Std.Dev.			0.36	0.07	0.36	0.08	---	

APPENDIX D
COMPRESSION DATA

All of the compression data generated during this program are presented in this section. They are summarized in tabular and graphical form in Section 4.

Test: Compression   Material: SP313

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
A64-3	0°	-67	124.1	18.36	---	0.0246	
A64-18	0°	-67	225.4	21.46	59.3	0.0320	
A64-15	0°	-67	178.8	27.76	43.9	0.0048	Buckling
A64-12	0°	-67	173.2	25.10	35.6	0.0240	
A64-51	0°	-67	123.1	14.41	---	0.0112	Buckling
A67-20	0°	-67	170.2	20.07	35.6	0.0058	Buckling
A67-22	0°	-67	169.4	20.92	90.4	0.0390	Buckling
Avg.			166.3	21.15	53.0	0.0202	
Std.Dev			35.0	4.36	23.0	0.0132	
A64-1	0°	72	143.6	20.9	31.3	0.0056	Buckling
A64-2	0°	72	150.7	19.4	47.1	0.0099	Buckling
A64-6	0°	72	152.6	18.4	40.6	0.0190	
A64-10	0°	72	172.8	20.0	27.5	0.0089	Buckling
A64-19	0°	72	167.1	20.1	32.6	0.0197	
Avg.			157.4	19.8	35.8	0.0126	
Std.Dev.			12.1	0.9	7.9	0.0058	
A64-8	0°	260	139.5	19.74	42.5	0.0177	
A64-11	0°	260	136.6	18.46	42.4	0.0073	Buckling
A64-16	0°	260	155.5	21.59	78.4	0.0077	Buckling
A64-17	0°	260	194.6	21.44	59.9	0.0220	
A67-17	0°	260	119.8	17.01	91.1	0.0067	Buckling
A67-18	0°	260	141.5	17.79	67.0	0.0082	Buckling
A67-16	0°	260	---	---	---	0.0104	
Avg.			147.9	19.34	63.5	0.0114	
Std.Dev.			25.6	1.91	19.5	0.0060	

Test: Compression					Material: SP313		
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
A64-7	0°	350	145.7	22.62	28.8	0.0146	
A64-20	0°	350	149.2	25.44	73.7	0.0055	Buckling
A64-13	0°	350	141.3	23.55	42.2	0.0057	Buckling
A64-4	0°	350	159.1	27.49	83.0	0.0048	Buckling
A64-14	0°	350	145.2	25.70	37.5	0.0057	Buckling
Avg.			148.1	24.96	53.0	0.0073	
Std.Dev.			6.8	1.91	23.8	0.0041	
A66-9	90°	-67	41.01	2.12	6.11	0.0297	Buckling
A67-2	90°	-67	51.52	1.80	26.42	0.0498	
A67-13	90°	-67	37.15	1.55	8.10	0.0268	Buckling
A67-3	90°	-67	34.67	1.55	---	0.0419	Buckling
A66-6	90°	-67	47.51	2.23	31.33	0.0191	Buckling
Avg.			42.38	1.85	17.99	0.0335	
Std.Dev.			7.05	0.32	12.75	0.0123	
A67-9	90°	72	24.05	1.77	2.74	0.0130	Buckling
A67-3	90°	72	32.29	1.53	6.46	0.0377	
A67-5	90°	72	25.22	1.80	---	0.0120	Buckling
A67-8	90°	72	26.28	1.99	---	0.0060	Buckling
A67-11	90°	72	27.55	1.78	3.00	0.0154	Buckling
A67-21	90°	72	22.86	1.43	3.52	0.0193	
Avg.			26.38	1.72	3.93	0.0172	
Std.Dev.			3.33	0.20	1.72	0.0109	

Test: Compression   Material: SP313

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
A66-4	90°	260	18.37	1.61	4.02	0.0117	Buckling
A66-13	90°	260	19.09	1.51	5.65	0.0106	Buckling
A66-3	90°	260	22.75	1.54	7.19	0.0269	Buckling
A66-11	90°	260	18.42	1.32	3.04	0.0395	
A66-7	90°	260	20.78	1.46	2.55	0.0137	Buckling
Avg.			19.88	1.49	4.49	0.0205	
Std Dev.			1.88	0.11	1.92	0.0125	
A66-17	90°	350	15.32	1.37	2.83	0.0500	
A66-15	90°	350	19.71	1.91	4.39	0.0388	
A66-8	90°	350	17.32	1.18	5.21	0.0508	
A66-12	90°	350	17.04	1.57	4.98	0.0275	
A66-10	90°	350	13.78	1.78	---	0.0065	Buckling
Avg.			16.63	1.56	4.35	0.0347	
Std Dev.			2.23	0.30	1.07	0.0184	

Test: Compression Material: AS/3004

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
C3-7	0°	-67	149.0	18.5	65.1	0.0104	
C3-3	0°	-67	149.8	16.2	72.8	0.0082	
C3-9	0°	-67	149.4	17.1	105.4	0.0093	
C3-16	0°	-67	143.2	23.8	64.7	0.0061	
C6-21	0°	-67	147.6	17.8	72.1	0.0084	
Avg.			147.9	18.7	76.0	0.0085	
Std Dev.			2.6	3.0	16.8	0.0016	
C3-1	0°	72	101.4	18.2	52.9	0.0061	
C3-15	0°	72	105.9	16.9	105.9	0.0064	
C3-16	0°	72	110.3	17.1	65.3	0.0068	
C3-8	0°	72	83.8	17.6	83.8	0.0045	
C3-2	0°	72	109.3	16.7	109.3	0.0078	
Avg.			102.1	17.3	83.4	0.0063	
Std Dev.			10.8	0.5	24.7	0.0012	
C3-5	0°	180	100.9	17.7	100.9	0.0053	
C3-10	0°	180	97.1	17.8	39.8	0.0063	
C3-19	0°	180	97.3	19.7	97.3	0.0048	
C6-22	0°	180	125.8	17.7	65.1	0.0083	
C3-18	0°	180	91.9	17.9	46.2	0.0057	
Avg.			102.6	18.1	69.9	0.0060	
Std.Dev.			13.4	0.9	28.3	0.0014	
C3-22	0°	250	87.6	20.9	87.6	0.0040	
C3-4	0°	250	91.9	17.2	28.7	0.0060	
C3-21	0°	250	73.8	18.5	73.8	0.0037	
C3-11	0°	250	105.0	18.2	105.0	0.0058	
C3-23	0°	250	92.4	17.6	86.7	0.0054	
Avg.			90.2	18.5	76.4	0.0050	
Std.Dev.			11.2	1.4	28.8	0.0010	

Test: Compression Material: AS/3004

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
C6-7	90°	-67	33.9	1.12	23.5	0.040	
C3-24	90°	-67	29.9	1.23	10.7	0.020	
C6-11	90°	-67	34.0	1.29	24.2	0.056	
C6-15	90°	-67	31.1	1.19	17.4	0.050	
C6-16	90°	-67	30.0	1.29	6.5	0.067	
Avg.			31.8	1.22	16.5	0.047	
Std.Dev.			2.0	0.07	7.8	0.018	
C6-1	90°	72	16.8	1.47	9.6	0.0076	Buckling
C6-2	90°	72	19.7	2.12	8.1	0.0130	Buckling
C6-6	90°	72	18.3	1.29	---	---	
C6-5	90°	72	20.7	1.43	3.9	0.0185	Buckling
C6-3	90°	72	19.1	1.67	10.0	0.0084	Buckling
Avg.			18.9	1.60	7.9	0.0119	
Std.Dev.			1.5	0.32	2.8	0.0050	
C6-4	90°	180	15.1	1.64	6.9	0.0064	
C3-28	90°	180	16.5	1.16	11.6	0.0136	
C6-9	90°	180	15.1	1.13	7.9	0.0280	
C6-17	90°	180	15.2	1.09	11.6	0.0850	
C6-14	90°	180	14.8	1.03	5.6	0.0590	
Avg.			15.3	1.21	8.7	0.0384	
Std.Dev.			0.7	0.25	2.8	0.0329	
C3-25	90°	250	14.1	1.89	4.1	0.042	
C6-20	90°	250	13.4	1.24	6.1	0.025	
C3-26	90°	250	14.8	1.06	5.2	0.065	
C6-18	90°	250	13.5	1.40	5.0	0.018	
C3-27	90°	250	11.3	1.06	3.8	0.033	
Avg.			13.4	1.33	4.9	0.037	
Std.Dev.			1.3	0.34	0.9	0.018	

Test: Compression Material: AS/4397

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
D10-37	0°	-67	237.3	21.17	104.9	0.0095	Buckling
D10-41	0°	-67	243.7	21.37	129.6	0.0198	
D10-26	0°	-67	240.4	22.78	86.5	0.0084	Buckling
D10-47	0°	-67	225.5	20.19	99.1	0.0195	
D10-27	0°	-67	232.1	20.83	109.7	0.0086	Buckling
Avg.			235.8	21.27	105.9	0.0132	
Std.Dev.			7.2	0.95	15.8	0.0059	
D10-28	0°	72	220.0	19.22	---	0.0185	
D10-29	0°	72	200.6	18.06	200.6	0.0110	
D10-34	0°	72	221.9	19.75	---	0.0103	
D10-33	0°	72	189.7	17.82	117.4	0.0105	
D10-40	0°	72	198.4	18.42	198.4	0.0089	Buckling
Avg.			206.1	18.65	172.2	0.0118	
Std.Dev.			14.1	0.81	47.4	0.0038	
D10-30	0°	350	151.8	20.72	151.8	0.0073	
D10-35	0°	350	153.6	18.08	153.6	0.0083	
D10-39	0°	350	179.3	21.84	100.3	0.0085	
D10-38	0°	350	182.9	16.44	101.4	0.0117	
D10-36	0°	350	155.5	18.41	101.3	0.0083	
Avg.			164.6	19. 0	121.7	0.0088	
Std.Dev.			15.2	2.16	28.3	0.0017	
D10-46	0°	450	179.8	16.89	54.0	0.0163	
D10-32	0°	450	---	17.19	55.6	---	
D10-44	0°	450	110.7	15.93	101.8	0.0071	
D10-45	0°	450	168.0	22.69	---	0.0062	Buckling
Avg.			152.8	18.18	---	0.0099	
Std.Dev.			36.9	3.06	70.5	0.0056	
					27.1	---	

Test: Compression					Material: AS/4397		
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
D10-3	90°	-67	32.17	1.64	---	0.0227	
D10-9	90°	-67	35.00	1.96	15.36	0.0262	
D10-8	90°	-67	37.83	1.83	6.10	0.0209	
D10-13	90°	-67	36.22	2.25	---	0.0143	
D10-19	90°	-67	39.47	2.18	---	0.0252	
Avg.			36.14	1.97	10.73	0.0219	
Std.Dev.			2.79	0.25	---	0.0047	
D10-1	90°	72	30.78	1.14	8.76	---	
D10-7	90°	72	29.36	2.02	8.44	0.0106	
D10-10	90°	72	33.95	1.30	27.39	0.0277	
D10-14	90°	72	29.65	1.54	12.48	0.0180	
D10-21	90°	72	26.00	1.25	15.21	0.0195	
Avg.			29.95	1.45	14.46	0.0190	
Std.Dev.			2.86	0.31	7.75	0.007	
D10-2	90°	350	18.52	1.07	---	0.012	
D10-12	90°	350	22.77	1.15	---	0.028	
D10-20	90°	350	22.68	1.19	7.34	0.034	
D10-25	90°	350	22.15	1.25	9.09	0.020	
D10-24	90°	350	19.34	1.13	6.31	0.027	
Avg.			21.09	1.16	7.58	0.024	
Std.Dev.			2.01	0.07	1.41	0.008	
D10-11	90°	450	25.41	2.00	11.11	0.0098+	lost strain gage before failure
D10-23	90°	450	22.32	1.73	6.27	0.0045+	lost strain gage before failure
D10-15	90°	450	19.02	1.36	---	0.0155	
D10-18	90°	450	18.00	0.87	---	0.0128+	lost strain gage before failure
D10-5	90°	450	22.49	2.49	6.34	0.0045+	lost strain gage before failure
Avg.			21.45	1.69	7.91	0.0094	
Std.Dev.			2.97	0.62	2.78	---	

Test: Compression					Material: T300/F178		
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (in/in)	Remarks
E31-39	0°	-67	203.5	18.50	127.4	0.0154	
E31-45	0°	-67	192.6	19.77	78.0	0.0088+	Both Prop.Limit & Ult. Strain
E31-33	0°	-67	196.2	16.54	76.9	0.0102+	Represent onset of buckling
E31-36	0°	-67	215.2	18.55	87.6	0.0111+	
E31-43	0°	-67	192.4	17.14	104.8	0.068+	
Avg.			200.0	18.10	94.9	0.0105	
Std.Dev.			9.6	1.28	21.3	0.0032	
E31-41	0°	72	167.1	18.21	69.6	0.0086+	Buckling
E31-35	0°	72	186.7	17.60	36.2	0.0175	
E31-48	0°	72	181.5	17.47	86.8	0.0078+	Buckling
E31-37	0°	72	195.7	18.53	88.9	0.0109	
E31-44	0°	72	169.0	19.07	65.8	0.0073+	Buckling
Avg.			180.0	18.18	69.5	0.0104	
Std.Dev.			12.0	0.66	21.2	0.0042	
E31-38	0°	350	110.3	19.49	49.8	0.0063	
E31-34	0°	350	110.3	21.11	73.9	0.0059	
E31-42	0°	350	135.4	19.15	62.7	0.0082	
E31-47	0°	350	137.7	20.79	47.2	0.0081	
E31-46	0°	350	106.1	21.79	39.8	0.0060	
Avg.			120.0	20.42	54.7	0.0069	
Std.Dev.			15.3	1.11	13.6	0.0012	
E31-40	0°	450	119.5	17.88	119.5	0.0067	
E31-30	0°	450	124.0	19.32	124.0	0.0064	
E31-31	0°	450	150.0	17.46	68.8	0.0097	
E31-28	0°	450	180.5	17.68	142.4	0.0107	
E31-29	0°	450	112.7	17.27	70.9	0.0068	
Avg.			137.4	17.92	105.2	0.0081	
Std.Dev.			28.0	0.81	33.3	0.0020	

APPENDIX E

FLEXURE DATA

All of the flexure data generated during this program are listed in this appendix. Summaries of these data are tabulated in Section 4.

Test: Flexure				L/D Ratio: 32:1	
Materials: SP313					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
A46-1	0°	-67	197.0	17.34	
A46-5	0°	-67	177.1	17.10	
A46-12	0°	-67	156.4	17.56	
A46-14	0°	-67	209.8	18.45	
A46-21	0°	-67	209.5	17.69	
Avg.			190.0	17.63	
Std.Dev.			23.0	0.52	
A46-4	0°	72	176.8	17.47	
A46-7	0°	72	176.7	16.88	
A46-17	0°	72	192.4	17.60	
A46-18	0°	72	233.3	18.94	
A46-30	0°	72	224.3	17.95	
Avg.			200.7	17.77	
Std.Dev.			26.6	0.76	
A46-6	0°	260	136.9	17.85	
A46-13	0°	260	113.8	17.51	
A46-15	0°	260	147.9	17.40	
A46-19	0°	260	159.6	17.70	
A46-26	0°	260	120.1	16.18	
Avg.			135.7	17.33	
Std.Dev.			19.0	0.65	
A46-10	0°	350	96.2	15.78	
A46-16	0°	350	117.9	17.24	
A46-20	0°	350	87.0	15.64	
A46-24	0°	350	89.7	16.33	
A46-25	0°	350	91.3	16.44	
Avg.			96.4	16.29	
Std.Dev.			12.5	0.63	

Test: Flexure			L/D Ratio: 32:1		
Materials: SP313					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
A34-1	90°	-67	11.71	1.54	
A34-5	90°	-67	10.46	1.47	
A34-12	90°	-67	11.89	1.43	
A34-14	90°	-67	11.31	1.41	
A34-21	90°	-67	10.84	1.43	
Avg.			11.24	1.46	
Std.Dev.			0 60	0.05	
A34-4	90°	72	11.34	1.30	
A34-7	90°	72	11.34	1.39	
A34-17	90°	72	9.47	1.37	
A34-18	90°	72	10.65	1.32	
A34-30	90°	72	10.51	1.44	
Avg.			10.66	1.36	
Std.Dev.			0.77	0.06	
A34-6	90°	260	6.55	1.13	
A34-13	90°	260	6.40	1.13	
A34-15	90°	260	6.69	1.06	
A34-19	90°	260	7.47	1.24	
A34-26	90°	260	5.37	1.06	
Avg.			6.50	1.12	
Std.Dev.			0.75	0.07	
A34-10	90°	350	5.06	1.01	
A34-16	90°	350	4.46	0.97	
A34-20	90°	350	4.67	0.89	
A34-24	90°	350	5.02	0.93	
A34-25	90°	350	4.92	0.97	
Avg.			4.82	0.95	
Std.Dev.			0.26	0.05	

Test: Flexure				L/D Ratio: 32:1	
Materials: AS/3004					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
C2-9	0°	-67	231.4	20.3	
C2-11	0°	-67	232.0	19.2	
C2-18	0°	-67	229.6	20.7	
C2-15	0°	-67	223.6	20.3	
C2-6	0°	-67	222.9	19.3	
Avg.			227.9	20.0	
Std.Dev.			4.3	0.7	
C1-3	0°	72	189.3	18.3	
C1-4	0°	72	201.5	19.0	
C1-1	0°	72	190.5	15.5	
C1-2	0°	72	199.9	17.9	
C1-5	0°	72	176.2	18.5	
Avg.			191.5	17.8	
Std.Dev.			10.1	1.4	
C2-8	0°	180	157.5	19.6	
C2-16	0°	180	157.2	19.4	
C2-12	0°	180	154.2	19.0	
C2-13	0°	180	153.6	19.8	
C2-7	0°	130	159.0	20.8	
Avg.			156.3	19.7	
Std.Dev.			2.3	0.7	
C2-20	0°	250	138.2	20.8	
C2-17	0°	250	136.1	19.6	
C2-10	0°	250	129.9	19.9	
C2-19	0°	250	136.7	19.7	
C2-14	0°	250	135.3	19.9	
Avg.			135.2	20.0	
Std.Dev.			3.2	0.5	

Test: Flexure				L/D Ratio: 32:1	
Materials: AS/3004					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
C2-31	90°	-67	11.81	1.30	
C2-30	90°	-67	13.05	1.28	
C2-26	90°	-67	14.06	1.29	
C2-27	90°	-67	13.94	1.34	
C2-28	90°	-67	14.12	1.36	
Avg.			13.40	1.31	
Std.Dev.			0.99	0.03	
C2-23	90°	72	13.49	1.22	
C2-22	90°	72	12.96	1.26	
C2-21	90°	72	12.36	1.31	
C2-29	90°	72	11.59	1.32	
C2-24	90°	72	14.62	1.30	
Avg.			13.00	1.28	
Std.Dev.			1.15	0.04	
C2-32	90°	180	11.86	1.26	
C2-25	90°	180	12.96	1.28	
C5-1	90°	180	9.38	1.06	
C5-2	90°	180	10.07	1.13	
C4-6	90°	180	12.36	1.13	
Avg.			11.33	1.17	
Std.Dev.			1.53	0.09	
C4-4	90°	250	10.51	1.08	
C4-2	90°	250	10.34	1.09	
C4-1	90°	250	8.88	1.07	
C4-3	90°	250	10.13	1.07	
C4-5	90°	250	10.69	1.08	
Avg.			10.11	1.08	
Std.Dev.			0.72	0.01	

Test: Flexure				L/D Ratio: 32:1	
Materials: AS/4397					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
D9-20	0°	-67	228.5	17.05	
D9-12	0°	-67	257.5	19.06	
D48-11	0°	-67	244.0	17.25	
D48-5	0°	-67	238.8	16.80	
D48-20	0°	-67	230.8	16.17	
Avg.			239.9	17.27	
Std.Dev.			11.8	1.08	
D48-12	0°	72	229.1	17.59	
D48-22	0°	72	222.9	18.76	
D48-6	0°	72	212.3	18.20	
D9-3	0°	72	239.5	18.96	
D9-21	0°	72	218.1	18.71	
Avg.			224.4	18.44	
Std.Dev.			10.5	0.55	
D48-15	0°	350	182.9	18.13	
D48-19	0°	350	172.3	14.62	
D9-15	0°	350	204.6	17.46	
D9-14	0°	350	168.2	18.84	
D9-13	0°	350	165.8	17.25	
Avg.			178.8	17.26	
Std.Dev.			15.9	1.60	
D9-4	0°	450	133.7	17.25	
D48-14	0°	450	129.3	16.13	
D48-7	0°	450	123.9	16.17	
D48-17	0°	450	124.0	16.56	
D48-10	0°	450	132.0	17.51	
Avg.			128.6	16.72	
Std.Dev.			4.5	0.63	

Test: Flexure			L/D Ratio: 32:1		
Materials: AS/4397					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
D9-44	90°	-67	10.31	1.54	
D9-36	90°	-67	9.51	1.60	
D48-25	90°	-67	10.02	1.55	
D48-35	90°	-67	8.83	1.37	
D9-25	90°	-67	7.74	1.70	
Avg.			9.28	1.55	
Std.Dev.			1.03	0.12	
D9-41	90°	72	8.31	1.44	
D48-30	90°	72	9.65	1.45	
D9-40	90°	72	8.97	1.43	
D9-45	90°	72	8.92	1.87	
D48-36	90°	72	8.56	1.33	
Avg.			8.88	1.50	
Std.Dev.			0.51	0.21	
D9-35	90°	350	4.87	1.24	
D48-31	90°	350	6.08	1.18	
D9-28	90°	350	4.44	1.15	
D48-23	90°	350	6.20	1.16	
D48-42	90°	350	5.15	1.20	
Avg.			5.34	1.19	
Std.Dev.			0.77	0.04	

Test: Flexure				L/D Ratio: 32:1	
Materials: AS/4397					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
D9-46	90°	450	3.80	0.59	
D48-27	90°	450	5.34	0.72	
D9-42	90°	450	3.28	0.53	
D48-39	90°	450	4.84	0.75	
D48-45	90°	450	4.87	0.72	
D9-30	90°	450	3.80	0.68	
Avg.			4.32	0.66	
Std.Dev.			0.80	0.09	

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/F178					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
E9-10	0°	-67	188.0	15.85	
E9-12	0°	-67	205.3	17.28	
E9-7	0°	-67	196.7	16.60	
E12-8	0°	-67	199.6	18.13	
E12-10	0°	-67	214.7	17.43	
Avg.			200.9	17.06	
Std.Dev.			9.9	0.87	
E9-1	0°	72	189.3	14.97	
E9-17	0°	72	204.6	16.89	
E9-20	0°	72	202.7	16.79	
E12-12	0°	72	215.1	17.76	
E12-5	0°	72	208.1	18.06	
Avg.			204.0	16.89	
Std.Dev.			9.5	1.21	
E9-13	0°	350	163.3	17.29	
E12-11	0°	350	178.7	18.65	
E12-6	0°	350	195.8	19.13	
E12-13	0°	350	182.3	17.66	
E9-11	0°	350	175.2	19.41	
Avg.			179.1	18.43	
Std.Dev.			11.8	0.92	
E9-4	0°	450	145.2	16.96	
E9-14	0°	450	137.4	17.31	
E9-5	0°	450	146.6	18.76	
E12-4	0°	450	148.4	19.16	
E12-7	0°	450	159.4	19.10	
Avg.			147.4	18.26	
Std.Dev.			7.9	1.04	

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/F178					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
E9-24	90°	-67	7.91	1.37	
E9-34	90°	-67	8.49	1.51	
E9-33	90°	-67	8.87	1.58	
E9-26	90°	-67	10.08	1.51	
E12-1	90°	-67	11.42	1.55	
Avg.			9.36	1.50	
Std.Dev.			1.40	0.08	
E9-39	90°	72	9.04	1.34	
E9-36	90°	72	7.98	1.23	
E9-41	90°	72	6.78	1.31	
E9-32	90°	72	6.55	1.10	
E12-4	90°	72	10.25	1.34	
Avg.			8.12	1.26	
Std.Dev.			1.55	0.10	
E9-35	90°	350	4.65	1.03	
E9-25	90°	350	3.77	1.13	
E9-43	90°	350	4.57	0.96	
E12-3	90°	350	5.87	0.98	
E9-30	90°	350	5.68	1.15	
Avg.			4.91	1.05	
Std.Dev.			0.87	0.09	
E9-44	90°	450	4.02	0.85	
E9-37	90°	450	4.18	0.82	
E12-2	90°	450	3.95	0.86	
E9-28	90°	450	3.86	1.18	
E9-27	90°	450	4.70	0.93	
Avg.			4.14	0.93	
Std.Dev.			0.33	0.15	

APPENDIX F
INPLANE SHEAR DATA

All of the inplane shear data generated during this program are presented in this section. These data are both tabularly and graphically summarized in Section 4.

Test: Inplane Shear						
Materials: SP313						
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
A38-8	±45°	-67	12,110	0.82		Tensile Coupon
A39-3	±45°	-67	12,170	0.91		Tensile Coupon
A44-10	±45°	-67	12,290	0.88		Tensile Coupon
A47-1	±45°	-67	12,560	0.98		Tensile Coupon
A50-11	±45°	-67	12,220	0.90		Tensile Coupon
Avg.			12,270	0.92		
Std. Dev.			190	0.06		
A38-7	±45°	72	10,330	0.75		Tensile Coupon
A39-9	±45°	72	10,590	0.81		Tensile Coupon
A44-4	±45°	72	10,430	0.76		Tensile Coupon
A47-10	±45°	72	10,340	0.74		Tensile Coupon
A50-1	±45°	72	10,790	0.86		Tensile Coupon
Avg.			10,500	0.78		
Std. Dev.			190	0.05		
A38-9	±45°	260	7440	0.63		Tensile Coupon
A39-7	±45°	260	7780	0.59		Tensile Coupon
A44-7	±45°	260	7500	0.62		Tensile Coupon
A47-7	±45°	260	7560	0.58		Tensile Coupon
A50-5	±45°	260	7510	0.62		Tensile Coupon
Avg.			7560	0.61		
Std. Dev.			130	0.02		
A38-4	±45°	350	5170	0.53		Tensile Coupon
A39-1	±45°	350	5170	0.53		Tensile Coupon
A44-2	±45°	350	5480	0.55		Tensile Coupon
A47-11	±45°	350	6360	0.54		Tensile Coupon
A50-3	±45°	350	5170	0.51		Tensile Coupon
Avg.			5470	0.53		
Std. Dev.			520	0.01		

Test: Inplane Shear						
Materials: SP313						
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
A40-1A	±45°	72	15,110	4.76		Dbl. Rail Shear
A40-1B	±45°	72	15,400	6.06		Dbl. Rail Shear
Avg.			15,260	5.41		
A10-1A	0°	72	3220	0.75		Dbl. Rail Shear
A10-1B	0°	72	3130	1.33		Dbl. Rail Shear
A11-1A	0°	72	2910	0.98		Dbl. Rail Shear
A11-1B	0°	72	2980	0.85		Dbl. Rail Shear
A14-1A	0°	72	2490	1.18		Dbl. Rail Shear
A14-1B	0°	72	2390	0.74		Dbl. Rail Shear
Avg.			2850	0.97		
Std. Dev.			340	0.24		
A10-3A	90°	72	8360	0.82		Dbl. Rail Shear
A10-3B	90°	72	8410	1.04		Dbl. Rail Shear
A14-3B	90°	72	8580	0.78		Dbl. Rail Shear
A14-3A	90°	72	8670	0.89		Dbl. Rail Shear
A13-2A	90°	72	9230	0.94		Dbl. Rail Shear
A13-2B	90°	72	9140	0.76		Dbl. Rail Shear
Avg.			8730	0.87		
Std. Dev.			370	0.11		
A11-2A	90°	260	6700	0.85		Dbl. Rail Shear
A11-2B	90°	260	6800	0.65		Dbl. Rail Shear
A11-3A	90°	260	6850	0.78		Dbl. Rail Shear
A11-3B	90°	260	6610	0.70		Dbl. Rail Shear
A15-2A	90°	260	6480	0.63		Dbl. Rail Shear
A15-2B	90°	260	6440	0.73		Dbl. Rail Shear
Avg.			6650	0.72		
Std. Dev.			170	0.08		

Test: Inplane Shear						
Materials: SP313						
Specimen Number	Fiber Orien- tation	Test Temp. (°F)	Ultimate Strength (psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
A12-2A	90°	350	---	---		Dbl. Rail Shear
A12-2B	90°	350	5160	0.56		Dbl. Rail Shear
A13-3A	90°	350	5040	0.61		Dbl. Rail Shear
A13-3B	90°	350	5150	0.54		Dbl. Rail Shear
A14-2A	90°	350	---	---		Dbl. Rail Shear
A14-2B	90°	350	5610	0.62		Dbl. Rail Shear
Avg.			5240	0.58		
Std. Dev.			250	0.04		
A43-1A	0°/90°	72	11,860	0.75		Dbl. Rail Shear
A43-1B	0°/90°	72	11,640	0.89		Dbl. Rail Shear
A43-2A	0°/90°	72	11,750	0.74		Dbl. Rail Shear
A43-2B	0°/90°	72	12,090	0.83		Dbl. Rail Shear
A43-3A	0°/90°	72	11,520	0.77		Dbl. Rail Shear
A43-3B	0°/90°	72	11,950	0.68		Dbl. Rail Shear
A43-4A	0°/90°	72	11,570	0.65		Dbl. Rail Shear
A43-4B	0°/90°	72	12,030	0.89		Dbl. Rail Shear
Avg.			11,800	0.78		
Std. Dev.			330	0.09		

Test: Inplane Shear

Materials: AS/3004

Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
C23-1	±45°	-67	20,980	0.55		Tensile Coupon
C22-7	±45°	-67	21,560	0.59		Tensile Coupon
C21-6	±45°	-67	21,060	0.54		Tensile Coupon
C23-6	±45°	-67	21,420	---		Tensile Coupon
C24-4	±45°	-67	19,030	0.53		Tensile Coupon
Avg.			20,810	0.55		
Std. Dev.			990	0.03		
C21-1	±45°	72	16,530	0.63		Tensile Coupon
C20-3	±45°	72	14,980	0.54		Tensile Coupon
C20-5	±45°	72	15,550	0.56		Tensile Coupon
C19-4	±45°	72	15,330	0.53		Tensile Coupon
C21-3	±45°	72	17,440	0.52		Tensile Coupon
Avg.			15,970	0.56		
Std. Dev.			1,000	0.04		
C20-8	±45°	180	12,550	0.50		Tensile Coupon
C19-6	±45°	180	14,650	0.55		Tensile Coupon
C19-8	±45°	180	14,110	0.50		Tensile Coupon
C21-7	±45°	180	15,020	0.53		Tensile Coupon
C20-4	±45°	180	13,080	0.54		Tensile Coupon
Avg.			13,880	0.52		
Std. Dev.			1,040	0.02		
C24-6	±45°	250	11,770	0.49		Tensile Coupon
C19-1	±45°	250	12,070	0.50		Tensile Coupon
C19-7	±45°	250	11,890	0.53		Tensile Coupon
C23-3	±45°	250	12,570	0.57		Tensile Coupon
C21-2	±45°	250	12,450	0.69		Tensile Coupon
Avg.			12,150	0.56		
Std. Dev.			350	0.08		

Test: Inplane Shear						
Materials: AS/4397						
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
D27-10	±45°	-67	9570	0.85		
D29-1	±45°	-67	9640	---		
D28-7	±45°	-67	9390	0.82		
D29-9	±45°	-67	9900	0.86		
D30-3	±45°	-67	9642	0.77		
Avg.			9630	0.83		
Std. Dev.			190	0.04		
D27-9	±45°	72	9460	0.77		
D27-1	±45°	72	9320	0.76		
D30-5	±45°	72	9100	0.77		
D29-4	±45°	72	9320	0.81		
D28-3	±45°	72	9600	0.77		
Avg.			9360	0.77		
Std. Dev.			190	0.02		
D29-3	±45°	350	8490	0.56		
D28-10	±45°	350	8470	0.61		
D28-5	±45°	350	8480	0.51		
D27-5	±45°	350	8470	0.51		
D30-1	±45°	350	7630	0.61		
Avg.			8310	0.56		
Std. Dev.			380	0.05		
D30-4	±45°	450	8700	0.58		
D29-8	±45°	450	8330	---		
D29-2	±45°	450	8250	0.57		
D27-3	±45°	450	8170	---		
D28-8	±45°	450	8290	0.45		
Avg.			8350	0.54		
Std. Dev.			210	0.07		

Test: Inplane Shear						
Materials: T300/F178						
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
E42-5	±45°	-67	7150	0.65		
A39-1	±45°	-67	7940	0.80		
E40-3	±45°	-67	8570	0.80		
E36-2	±45°	-67	7860	0.70		
E35-4	±45°	-67	8030	0.83		
Avg.			7910	0.76		
Std. Dev.			510	0.08		
E35-3	±45°	72	8810	0.67		
E29-7	±45°	72	9120	0.69		
E40-2	±45°	72	9050	0.77		
E36-1	±45°	72	8240	0.77		
E42-6	±45°	72	7720	0.71		
Avg.			8590	0.72		
Std. Dev.			600	0.05		
E39-8	±45°	350	7350	0.50		
E35-2	±45°	350	7140	0.49		
E42-7	±45°	350	7100	0.53		
E36-9	±45°	350	7160	0.53		
E40-1	±45°	350	7760	0.55		
Avg.			7300	0.52		
Std. Dev.			270	0.02		
E39-9	±45°	450	6030	0.42		
E35-1	±45°	450	6170	0.41		
E42-2	±45°	450	5900	0.44		
E36-6	±45°	450	6360	0.44		
E40-10	±45°	450	5990	0.37		
Avg.			6090	0.41		
Std. Dev.			180	0.03		

APPENDIX G

INTERLAMINAR SHEAR DATA

All of the interlaminar shear data generated during this program are tabulated in this appendix. Tabular summaries of these data appear in Section 4.

Test: Interlaminar (Short-Beam) Shear			
Materials: SP313			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
A35-5	-67	15.00	
A35-9	-67	14.89	
A35-12	-67	14.57	
A35-37	-67	14.21	
A35-47	-67	13.76	
Avg.		14.49	
Std.Dev.		0.51	
A35-3	72	12.65	
A35-4	72	12.88	
A35-22	72	13.02	
A35-31	72	11.88	
A35-40	72	13.04	
Avg.		12.69	
Std.Dev.		0.48	
A35-15	260	8.39	
A35-18	260	8.86	
A35-20	260	8.53	
A35-28	260	8.93	
A35-41	260	9.11	
Avg.		8.76	
Std.Dev.		0.30	
A35-1	350	7.29	
A35-6	350	6.98	
A35-35	350	7.44	
A35-39	350	7.21	
A35-46	350	6.99	
Avg.		7.18	
Std.Dev.		0.19	

Test: Interlaminar (Short-Beam) Shear			
Materials: AS/3004			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
C5-29	-67	13.93	
C5-8	-67	11.91	
C5-9	-67	13.36	
C5-11	-67	14.54	
C5-35	-67	14.09	
C38-5	-67	15.23	
C38-14	-67	15.30	
C38-15	-67	13.94	
C38-16	-67	14.13	
Avg.		14.05	
Std.Dev.		1.02	
C1-6	72	10.97	
C1-11	72	12.47	
C1-8	72	12.74	
C1-10	72	11.31	
C1-12	72	13.26	
C5-4	72	10.15	
C5-14	72	10.69	
C38-5-3	72	11.08	
C38-5-12	72	11.54	
Avg.		11.58	
Std.Dev.		1.03	

Test: Interlaminar (Short-Beam) Shear			
Materials: AS/3004			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
C5-26	180	9.41	
C5-12	180	9.62	
C5-24	180	9.05	
C5-19	180	9.12	
C5-17	180	8.41	
C38-5-9	180	9.92	
C38-5-4	180	10.02	
C38-5-6	180	9.19	
C38-5-8	180	9.35	
C38-5-13	180	9.69	
Avg.		9.38	
Std.Dev.		0.47	
C1-7	250	8.72	
C1-9	250	9.55	
C5-5	250	8.15	
C5-27	250	7.92	
C5-7	250	8.35	
C38-5-7	250	8.35	
C38-5-10	250	8.09	
Avg.		8.45	
Std.Dev.		0.55	

Test: Interlaminar (Short-Beam) Shear			
Materials: AS/4397			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
D9-20	-67	10.77	
D9-35	-67	15.91	
D9-39	-67	18.96	
D9-1	-67	16.32	
D9-12	-67	11.71	
Avg.		14.73	
Std.Dev.		3.41	
D9-38	72	14.87	
D9-30	72	12.86	
D9-41	72	15.14	
D9-13	72	10.96	
D9-2	72	14.27	
Avg.		13.62	
Std.Dev.		1.73	
D9-40	350	11.47	
D9-21	350	8.71	
D9-27	350	9.48	
D9-7	350	10.59	
D9-11	350	8.71	
Avg.		9.79	
Std.Dev.		1.18	
D9-6	450	7.24	
D9-45	450	6.56	
D9-23	450	5.44	
D9-17	450	5.13	
D9-26	450	6.67	
Avg.		6.21	
Std.Dev.		0.89	

Test: Interlaminar (Short-Beam) Shear			
Materials: T300/F178			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
E9-5	-67	15.12	
E9-12	-67	15.12	
E9-17	-67	17.69	
E9-14	-67	16.86	
E9-21	-67	14.82	
Avg.		15.92	
Std.Dev.		1.28	
E9-3	72	14.10	
E9-13	72	14.06	
E9-16	72	15.42	
E9-4	72	16.08	
E9-15	72	14.44	
Avg.		14.82	
Std.Dev.		0.89	
E9-19	350	10.58	
E9-6	350	10.35	
E9-7	350	10.13	
E9-18	350	9.96	
E9-9	350	9.86	
Avg.		10.17	
Std.Dev.		0.29	
E9-1	450	8.10	
E9-10	450	7.38	
E9-11	450	8.19	
E9-2	450	8.07	
E9-20	450	8.26	
Avg.		8.00	
Std.Dev.		0.36	

FATIGUE DATA

All of the tensile fatigue data generated during the program, along with residual strengths of specimens which "ran out" to 10^7 cycles are presented here. The residual strengths were all determined with a tensile test at 72°F, regardless of what temperature the specimen saw during the fatigue test. Summaries of these data are presented in Section 4 where the fatigue lifetimes are reported as log-mean values.

Test: Tensile-Tensile Fatigue

Material: SP313

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A3-18	0°	-67	138.9	13.9	95	6,920,500	—	—	
A2-15	0°	-67	138.9	13.9	95	301,400	—	—	
A4-13	0°	-67	138.9	13.9	95	1,300	—	—	
A6-17	0°	-67	138.9	13.9	95	811,500	—	—	
A1-7	0°	-67	131.6	13.2	90	294,100	—	—	
A2-4	0°	-67	131.6	13.2	90	235,900	—	—	
A4-4	0°	-67	131.6	13.2	90	10,000,100+	—	—	
A6-14	0°	-67	131.6	13.2	90	13,200	—	—	
A1-1	0°	-67	117.0	11.7	80	10,000,100+	—	186.7	
A2-3	0°	-67	117.0	11.7	80	10,000,100+	—	167.9	
A4-11	0°	-67	117.0	11.7	80	10,000,000+	—	177.1	
A6-5	0°	-67	117.0	11.7	80	10,265,400+	—	154.5	
A6-3	0°	72	173.1	19.3	90	6,800	—	—	
A4-17	0°	72	173.1	19.3	90	2,600	—	—	
A2-14	0°	72	173.1	19.3	90	1,400	—	—	
A1-15	0°	72	173.1	19.3	90	800	—	—	
A6-16	0°	72	153.8	15.4	80	122,900	—	—	
A4-10	0°	72	153.8	15.4	80	5,900	—	—	
A2-5	0°	72	153.8	15.4	80	3,400	—	—	
A1-18	0°	72	153.8	15.4	80	1,200	—	—	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: SP313 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A6-4	0°	72	134.6	13.5	70	10,280,300+	—	190.6	
A4-16	0°	72	134.6	13.5	70	8,400	—	—	
A2-13	0°	72	134.6	13.5	70	1,872,200	—	—	
A1-8	0°	72	134.6	13.5	70	54,900	—	—	
A1-3	0°	260	157.2	15.7	90	1,200	—	—	
A2-8	0°	260	157.2	15.7	90	600	—	—	
A4-12	0°	260	157.2	15.7	90	900	—	—	
A6-12	0°	260	157.2	15.2	90	900	—	—	
A1-17	0°	260	139.8	14.0	80	1,100	—	—	
A2-1	0°	260	139.8	14.0	80	1,500	—	—	
A4-2	0°	260	139.8	14.0	80	3,800	—	—	
A6-1	0°	260	139.8	14.0	80	364,600	—	—	
A2-16	0°	260	122.3	12.2	70	24,400	—	—	
A4-18	0°	260	122.3	12.2	70	1,324,200	—	—	
A6-8	0°	260	122.3	12.2	70	9,270,700	—	—	
A7-18	0°	260	122.3	12.2	70	399,700	—	—	
A1-13	0°	350	127.5	12.8	90	2,600	—	—	
A2-10	0°	350	127.5	12.8	90	245,300	—	—	
A4-1	0°	350	127.5	12.8	90	7,800	—	—	
A6-18	0°	350	127.5	12.8	90	2,800	—	—	

Test: Tensile-Tensile Fatigue

Material: SP313

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A1-16	0°	350	113.4	11.3	80	11,100	—	—	
A2-18	0°	350	113.4	11.3	80	91,400	—	—	
A4-3	0°	350	113.4	11.3	80	4,520,600	—	—	
A6-7	0°	350	113.4	11.3	80	49,700	—	—	
A1-2	0°	350	99.2	0.99	70	2,400	—	—	
A2-7	0°	350	99.2	0.99	70	640,800	—	—	
A4-7	0°	350	99.2	0.99	70	11,406,700+	—	176.7	
A6-13	0°	350	99.2	0.99	70	7,409,400	—	—	
A16-5	90°	-67	4.68	0.47	90	700	—	—	
A17-10	90°	-67	4.68	0.47	90	200	—	—	
A19-8	90°	-67	4.68	0.47	90	2,300	—	—	
A22-10	90°	-67	4.68	0.47	90	1,200	—	—	
A16-11	90°	-67	4.16	0.42	80	45,000	—	—	
A17-11	90°	-67	4.16	0.42	80	1,300	—	—	
A21-5	90°	-67	4.16	0.42	80	17,800	—	—	
A23-10	90°	-67	4.16	0.42	80	900	—	—	
A18-1	90°	-67	3.64	0.36	70	11,400	—	—	
A18-3	90°	-67	3.64	0.36	70	3,295,300	—	—	
A22-9	90°	-67	3.64	0.36	70	1,900	—	—	
A22-11	90°	-67	3.64	0.36	70	43,900	—	—	

Test: Tensile-Tensile Fatigue

R = +0.1

Material: SP313

Frequency = .30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A23-3	90°	72	4.42	0.44	90	3,500	——	——	
A23-7	90°	72	4.42	0.44	90	4,100	——	——	
A26-7	90°	72	4.42	0.44	90	1,800	——	——	
A32-4	90°	72	4.42	0.44	90	900	——	——	
A30-4	90°	72	3.93	0.39	80	1,900	——	——	
A20-3	90°	72	3.93	0.39	80	500	——	——	
A20-5	90°	72	3.93	0.39	80	1,700	——	——	
A22-7	90°	72	3.93	0.39	80	82,200	——	——	
A18-11	90°	72	3.44	0.34	70	65,300	——	——	
A21-9	90°	72	3.44	0.34	70	5,800	——	——	
A23-4	90°	72	3.44	0.34	70	2,500	——	——	
A26-1	90°	72	3.44	0.34	70	10,000,100+	——	6.32	
A19-4	90°	72	3.44	0.34	70	10,000,100+	——	3.70	
A19-9	90°	260	4.29	0.43	90	2,100	——	——	
A21-11	90°	260	4.29	0.43	90	300	——	——	
A23-8	90°	260	4.29	0.43	90	800	——	——	
A23-9	90°	260	4.29	0.43	90	200	——	——	
A16-1	90°	260	3.81	0.38	80	1,200	——	——	
A16-2	90°	260	3.81	0.38	80	11,200	——	——	
A18-5	90°	260	3.81	0.38	80	400	——	——	
A18-8	90°	260	3.81	0.38	80	100	——	——	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: SP313 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A17-2	90°	260	3.33	0.33	70	14,000	—	—	
A18-4	90°	260	3.33	0.33	70	25,000	—	—	
A20-9	90°	260	3.33	0.33	70	30,600	—	—	
A22-4	90°	260	3.33	0.33	70	12,400	—	—	
A19-10	90°	350	3.32	0.33	90	2,000	—	—	
A20-2	90°	350	3.32	0.33	90	9,200	—	—	
A21-7	90°	350	3.32	0.33	90	300	—	—	
A22-7	90°	350	3.32	0.33	90	800	—	—	
A16-10	90°	350	2.95	0.30	80	100	—	—	
A17-5	90°	350	2.95	0.30	80	3,000	—	—	
A19-2	90°	350	2.95	0.30	80	11,300	—	—	
A19-7	90°	350	2.95	0.30	80	17,800	—	—	
A17-8	90°	350	2.59	0.26	70	40,900	—	—	
A20-4	90°	350	2.59	0.26	70	2,851,600	—	—	
A21-3	90°	350	2.59	0.26	70	3,700	—	—	
A23-2	90°	350	2.59	0.26	70	25,200	—	—	
A38-3	±45°	-67	18.38	1.84	75	10,100	—	—	
A39-11	±45°	-67	18.38	1.84	75	6,100	—	—	
A47-8	±45°	-67	18.38	1.84	75	9,500	—	—	
A50-8	±45°	-67	18.38	1.84	75	9,400	—	—	

Test: Tensile-Tensile Fatigue

Material: SP313

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A38-11	±45°	-67	17.15	1.72	70	61,200	----	----	
A44-1	±45°	-67	17.15	1.72	70	71,400	----	----	
A48-7	±45°	-67	17.15	1.72	70	33,900	----	----	
A51-2	±45°	-67	17.15	1.72	70	36,100	----	----	
A44-9	±45°	-67	14.70	1.47	60	1,487,300	----	----	
A48-3	±45°	-67	14.70	1.47	60	753,200	----	----	
A48-10	±45°	-67	14.70	1.47	60	505,000	----	----	
A51-10	±45°	-67	14.70	1.47	60	1,173,400	----	----	
A39-8	±45°	72	16.79	1.68	80	9,300	----	----	
A47-4	±45°	72	16.79	1.68	80	14,000	----	----	
A48-5	±45°	72	16.79	1.68	80	7,200	----	----	
A50-4	±45°	72	16.79	1.68	80	9,700	----	----	
A38-10	±45°	72	14.69	1.47	70	166,200	----	----	
A39-5	±45°	72	14.69	1.47	70	153,500	----	----	
A50-9	±45°	72	14.69	1.47	70	224,200	----	----	
A51-4	±45°	72	14.69	1.47	70	120,500	----	----	
A39-10	+45°	72	12.59	1.26	60	1,641,700	----	----	
A44-5	±45°	72	12.59	1.26	60	3,533,400	----	----	
A47-5	±45°	72	12.59	1.26	60	4,359,500	----	----	
A58-10	±45°	72	12.59	1.26	60	2,670,100	----	----	

Test: Tensile-Tensile Fatigue R = +0.1

Material: SP313 Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A39-2	±45°	260	12.01	1.20	80	5,400	—	—	
A47-2	±45°	260	12.01	1.20	80	6,000	—	—	
A50-10	±45°	260	12.01	1.20	80	8,000	—	—	
A53-8	±45°	260	12.01	1.20	80	4,000	—	—	
A38-5	±45°	260	10.51	1.05	70	193,400	—	—	
A44-2	±45°	260	10.51	1.05	70	227,300	—	—	
A48-4	±45°	260	10.51	1.05	70	137,900	—	—	
A51-5	±45°	260	10.51	1.05	70	251,200	—	—	
A44-8	±45°	260	9.01	0.90	60	10,000,000+	—	20.84	
A48-11	±45°	260	9.01	0.90	60	10,000,100+	—	19.80	
A50-2	±45°	260	9.01	0.90	60	10,000,100+	—	20.87	
A51-3	±45°	260	9.01	0.90	60	10,000,100+	—	20.03	
A38-1	±45°	350	8.75	0.88	80	49,500	—	—	
A39-4	±45°	350	8.75	0.88	80	7,500	—	—	
A44-1	±45°	350	8.75	0.88	80	14,400	—	—	
A47-3	±45°	350	8.75	0.88	80	8,600	—	—	
A53-9	±45°	350	8.20	0.82	75	492,500	—	—	
A55-1	±45°	350	8.20	0.82	75	3,750,600	—	—	
A57-2	±45°	350	8.20	0.82	75	10,000,100+	—	18.32	
A62-2	±45°	350	8.20	0.82	75	5,555,200	—	—	

Test: Tensile-Tensile Fatigue

Material: SP313

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
A50-7	±45°	350	7.66	0.77	70	5,119,900	----	----	
A51-8	±45°	350	7.66	0.77	70	10,000,100	----	16.43	
A53-11	±45°	350	7.66	0.77	70	6,974,800	----	----	
A63-7	±45°	350	7.66	0.77	70	10,000,100	----	16.50	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/3004 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C13-3	0°	-67	180.4	18.0	90	21,000	——	——	
C13-10	0°	-67	180.4	18.0	90	900	——	——	
C12-2	0°	-67	180.4	18.0	90	4,200	——	——	
C12-4	0°	-67	180.4	18.0	90	800	——	——	
C12-10	0°	-67	160.4	16.0	80	1,463,600	——	——	
C12-11	0°	-67	160.4	16.0	80	857,800	——	——	
C12-12	0°	-67	160.4	16.0	80	42,900	——	——	
C25-4	0°	-67	160.4	16.0	80	81,500	——	——	
C9-5	0°	-67	140.3	14.0	70	91,800	——	——	
C11-12	0°	-67	140.3	14.0	70	10,000,100+	——	158.6	
C12-3	0°	-67	140.3	14.0	70	27,500	——	——	
C10-14	0°	-67	140.3	14.0	70	15,500	——	——	
C12-13	0°	-67	140.3	14.0	70	10,000,000+	——	205.71	
C13-6	0°	72	169.1	16.9	90	1,700	——	——	
C8-15	0°	72	169.1	16.9	90	1,000	——	——	
C13-9	0°	72	150.3	15.0	80	300	——	——	
C13-11	0°	72	150.3	15.0	80	2,100	——	——	
C7-4	0°	72	150.3	15.0	80	20,700	——	——	
C9-3	0°	72	150.3	15.0	80	87,900	——	——	

Test: Tensile-Tensile Fatigue | R = +0.1

Material: AS/3004 | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C13-14	0°	72	131.5	13.2	70	6,200	——	——	
C14-4	0°	72	131.5	13.2	70	462,300	——	——	
C14-10	0°	72	131.5	13.2	70	51,500	——	——	
C10-2	0°	72	131.5	13.2	70	110,900	——	——	
C11-5	0°	72	112.7	11.3	60	2,632,500	——	——	
C8-1	0°	72	112.7	11.3	60	5,868,700	——	——	
C9-14	0°	72	112.7	11.3	60	3,315,300	——	——	
C10-11	0°	72	112.7	11.3	60	4,335,000	——	——	
C11-2	0°	180	172.4	17.2	90	3,500	——	——	
C9-13	0°	180	172.4	17.2	90	1,800	——	——	
C8-9	0°	180	153.2	15.3	80	900	——	——	
C14-14	0°	180	153.2	15.3	80	2,900	——	——	
C11-10	0°	180	153.2	15.3	80	2,000	——	——	
C8-8	0°	180	153.2	15.3	80	2,200	——	——	
C12-15	0°	180	134.1	13.4	70	290,800	——	——	
C14-11	0°	180	134.1	13.4	70	7,100	——	——	
C14-1	0°	180	134.1	13.4	70	169,200	——	——	
C11-11	0°	180	134.1	13.4	70	41,500	——	——	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/3004 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orienta-tion	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C8-14	0°	180	114.9	11.5	60	2,269,500	----	----	
C25-14	0°	180	114.9	11.5	60	6,849,600	----	----	
C9-10	0°	180	114.9	11.5	60	127,500	----	----	
C9-11	0°	180	114.9	11.5	60	2,892,200	----	----	
C25-1	0°	250	161.2	16.1	90	600	----	----	
C25-3	0°	250	143.3	14.3	80	3,300	----	----	
C25-6	0°	250	143.3	14.3	80	500	----	----	
C25-7	0°	250	143.3	14.3	80	7,700	----	----	
C25-8	0°	250	143.3	14.3	80	3,600	----	----	
C25-11	0°	250	125.3	12.5	70	3,400	----	----	
C25-15	0°	250	125.3	12.5	70	3,552,500	----	----	
C14-3	0°	250	125.3	12.5	70	501,400	----	----	
C14-5	0°	250	125.3	12.5	70	1,392,500	----	----	
C13-5	0°	250	125.3	12.5	70	800	----	----	
C14-7	0°	250	107.5	10.8	60	116,100	----	----	
C14-8	0°	250	107.5	10.8	60	92,200	----	----	
C14-12	0°	250	107.5	10.8	60	171,700	----	----	
C13-2	0°	250	107.5	10.8	60	171,800	----	----	
C25-10	0°	250	107.5	10.8	60	1,187,200	----	----	
C39-8	90°	-67	4.77	0.48	70	7,400	----	----	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/3004 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C38-8	90°	-67	4.09	0.41	60	4,500	——	——	
C26-7	90°	-67	4.09	0.41	60	40,300	——	——	
C37-7	90°	-67	4.09	0.41	60	9,100	——	——	
C35-2	90°	-67	4.09	0.41	60	26,100	——	——	
C35-8	90°	-67	3.41	0.34	50	9,700	——	——	
C39-2	90°	-67	2.73	0.27	40	134,200	——	——	
C37-7	90°	-67	2.73	0.27	40	620,000	——	——	
C32-5	90°	-67	2.73	0.27	40	239,400	——	——	
C37-8	90°	-67	2.73	0.27	40	36,000	——	——	
C32-6	90°	-67	1.36	0.14	20	10,000,000+	——	4.93	
C35-3	90°	-67	1.36	0.14	20	10,000,000+	——	6.24	
C37-5	90°	-67	1.36	0.14	20	10,000,000+	——	6.02	
C38-3	90°	-67	1.36	0.14	20	5,461,300	——	——	
C29-8	90°	72	4.02	0.40	80	8,700	——	——	
C29-6	90°	72	4.02	0.40	80	12,400	——	——	
C29-5	90°	72	4.02	0.40	80	11,700	——	——	
C29-1	90°	72	4.02	0.40	80	500	——	——	
C28-8	90°	72	3.52	0.35	70	22,600	——	——	
C28-7	90°	72	3.52	0.35	70	28,200	——	——	
C28-4	90°	72	3.52	0.35	70	17,100	——	——	
C27-5	90°	72	3.52	0.35	70	26,500	——	——	

Test: Tensile-Tensile Fatigue | R = +0.1

Material: AS/3004 | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C27-4	90°	72	3.01	0.30	60	140,000	——	——	
C27-3	90°	72	3.01	0.30	60	84,800	——	——	
C34-8	90°	72	3.01	0.30	60	36,900	——	——	
C34-6	90°	72	3.01	0.30	60	27,400	——	——	
C34-3	90°	180	3.94	0.39	80	4,500	——	——	
C34-1	90°	180	3.94	0.39	80	800	——	——	
C32-8	90°	180	3.94	0.39	80	2,000	——	——	
C32-7	90°	180	3.94	0.39	80	2,600	——	——	
C32-2	90°	180	2.96	0.30	60	13,200	——	——	
C32-1	90°	180	2.96	0.30	60	10,800	——	——	
C31-8	90°	180	2.96	0.30	60	10,000	——	——	
C31-4	90°	180	2.96	0.30	60	9,400	——	——	
C31-2	90°	180	1.97	0.20	40	66,000	——	——	
C39-6	90°	180	1.97	0.20	40	118,900	——	——	
C16-5	90°	180	1.97	0.20	40	56,900	——	——	
C18-4	90°	180	1.97	0.20	40	64,700	——	——	
C28-2	90°	250	4.31	0.43	80	2,500	——	——	
C26-2	90°	250	4.31	0.43	80	——	——	——	Failed on installation
C29-2	90°	250	3.76	0.38	70	500	——	——	
C35-4	90°	250	3.76	0.38	70	1,700	——	——	

Test: Tensile-Tensile Fatigue

Material: AS/3004

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C37-1	90°	250	3.24	0.32	60	2,200	—	—	
C38-2	90°	250	3.24	0.32	60	3,300	—	—	
C39-1	90°	250	3.24	0.32	60	3,000	—	—	
C35-5	90°	250	3.24	0.32	60	2,600	—	—	
C37-3	90°	250	2.70	0.27	50	2,900	—	—	
C33-3	90°	250	2.16	0.22	40	9,400	—	—	
C26-5	90°	250	2.16	0.22	40	10,500	—	—	
C35-6	90°	250	2.16	0.22	40	7,100	—	—	
C37-4	90°	250	2.16	0.22	40	9,300	—	—	
C28-3	90°	250	1.08	0.11	20	42,600	—	—	
C35-7	90°	250	1.08	0.11	20	114,900	—	—	
C37-6	90°	250	1.08	0.11	20	99,000	—	—	
C38-4	90°	250	1.08	0.11	20	81,400	—	—	
C43-8	±45°	-67	10.4	1.04	25	645,700	9	—	no temp. rise data above 300,000 cycles
C43-6	±45°	-67	10.4	1.04	25	830,900	117	—	
C43-1	±45°	-67	10.4	1.04	25	804,400	18	—	
C42-4	±45°	-67	10.4	1.04	25	348,600	110	—	
C42-3	±45°	-67	8.32	0.83	20	4,519,300	9	—	
C42-2	±45°	-67	8.32	0.83	20	3,769,600	—	—	
C42-1	±45°	-67	8.32	0.83	20	6,490,600	—	—	
C41-8	±45°	-67	8.32	0.83	20	10,000,000+	—	22.43	

Test: Tensile-Tensile Fatigue

Material: AS/3004

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C44-6	±45°	-67	6.24	0.62	15	9,085,500	—	—	
C44-2	±45°	-67	6.24	0.62	15	10,000,000+	—	26.28	
C22-3	±45°	72	25.6	2.56	80	11,500	—	—	specimen heated up and couldn't ever reach load
C22-8	±45°	72	9.61	0.96	30	57,600	275+	—	
C24-2	±45°	72	9.61	0.96	30	196,200	90+	—	10 Hz. frequency
C24-3	±45°	72	8.01	0.80	25	1,448,800	?	—	Temp. not measured
C24-8	±45°	72	8.01	0.80	25	434,600	158	—	
C46-1	±45°	72	8.01	0.80	25	409,100	228	—	
C50-1	±45°	72	8.01	0.80	25	506,000	240	—	
C23-5	±45°	72	6.40	0.64	20	10,000,000+	—	29.36	
C23-7	±45°	72	6.40	0.64	20	10,000,000+	—	28.87	
C49-8	±45°	72	6.40	0.64	20	10,004,400+	15	25.55	
C47-8	±45°	72	6.40	0.64	20	6,301,200	20	—	
C22-5	±45°	72	3.20	0.32	10	10,000,000+	—	32.10	
C23-2	±45°	72	3.20	0.32	10	10,000,000+	—	34.23	
C46-4	±45°	72	3.20	0.32	10	10,259,508+	—	27.09	
C46-3	±45°	72	3.20	0.32	10	10,033,700+	—	26.60	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/3004 — Frequency = .30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C46-8	±45°	180	6.94	0.69	25	1,021,600	41	——	
C49-5	±45°	180	6.94	0.69	25	1,055,400	28	——	
C49-1	±45°	180	6.94	0.69	25	1,289,800	32	——	
C49-6	±45°	180	6.94	0.69	25	1,363,700	56	——	
C49-7	±45°	180	5.55	0.56	20	10,000,000+	10	20.87	
C48-8	±45°	180	5.55	0.56	20	10,009,500+	4	27.79	
C46-7	±45°	180	5.55	0.56	20	10,006,800+	5	17.20	
C49-4	±45°	180	5.55	0.56	20	10,009,700+	12	9.53	
C46-5	±45°	180	2.78	0.28	10	10,000,000+	——	28.78	
C48-1	±45°	180	2.78	0.28	10	10,000,100+	——	31.29	
C56-7	±45°	180	2.78	0.28	10	10,000,000+	——	33.25	
C54-7	±45°	180	2.78	0.28	10	10,013,800+	——	33.53	
C56-5	±45°	250	6.08	0.61	25	1,300,000	63	——	
C49-3	±45°	250	6.08	0.61	25	646,000	59	——	
C56-2	±45°	250	6.08	0.61	25	859,900	60	——	
C55-6	±45°	250	6.08	0.61	25	2,982,900	20	——	
C55-4	±45°	250	4.86	0.49	20	5,666,200	25	——	
C54-5	±45°	250	4.86	0.49	20	3,654,400	8	——	
C54-3	±45°	250	4.86	0.49	20	10,454,500+	6	29.70	
C45-6	±45°	250	4.86	0.49	20	10,054,600+	7	29.73	
C45-5	±45°	250	4.86	0.49	20	6,596,200	4	——	

Test: Tensile-Tensile Fatigue

Material: AS/3004

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
C44-8	±45°	250	3.65	0.37	15	10,000,000+	----	26.89	
C48-6	±45°	250	3.65	0.37	15	10,000,000+	----	33.17	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/4397 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D7-9	0°	-67	175.8	17.6	90	8,700	---	---	
D3-9	0°	-67	175.8	17.6	90	500	---	---	
D1-7	0°	-67	175.8	17.6	90	1,100	---	---	
D6-12	0°	-67	175.8	17.6	90	1,300	---	---	
D5-2	0°	-67	156.3	15.6	80	129,600	---	---	
D7-17	0°	-67	156.3	15.6	80	45,900	---	---	
D6-5	0°	-67	156.3	15.6	80	162,000	---	---	
D1-18	0°	-67	156.3	15.6	80	12,700	---	---	
D6-9	0°	-67	136.8	13.7	70	10,000,100+	---	200.7	
D3-2	0°	-67	136.8	13.7	70	562,800	---	---	
D5-8	0°	-67	136.8	13.7	70	4,024,700	---	---	
D46-17	0°	-67	136.8	13.7	70	33,300	---	---	
D4-5	0°	72	182.1	18.2	90	324,700	---	---	
D4-6	0°	72	182.1	18.2	90	13,600	---	---	
D3-11	0°	72	182.1	18.2	90	27,100	---	---	
D3-18	0°	72	182.1	18.2	90	28,100	---	---	
D5-1	0°	72	161.9	16.2	80	2,900	---	---	
D3-15	0°	72	161.9	16.2	80	721,300	---	---	
D5-6	0°	72	161.9	16.2	80	481,400	---	---	
D4-16	0°	72	161.9	16.2	80	2,527,206	---	---	

Test: Tensile-Tensile Fatigue | R = +0.1

Material: AS/4397 | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D7-14	0°	72	141.6	14.2	70	1,919,000	—	—	
D5-12	0°	72	141.6	14.2	70	10,000,000+	—	208.1	
D7-2	0°	72	141.6	14.2	70	3,160,500	—	—	
D4-10	0°	72	141.6	14.2	70	11,681,400+	—	181.1	
D6-15	0°	350	168.7	16.9	90	12,000	—	—	
D1-9	0°	350	168.7	16.9	90	6,200	—	—	
D46-4	0°	350	168.7	16.9	90	8,600	—	—	
D46-14	0°	350	168.7	16.9	90	1,300	—	—	
D3-7	0°	350	149.9	15.0	80	1,100	—	—	
D4-11	0°	350	149.9	15.0	80	17,100	—	—	
D5-14	0°	350	149.9	15.0	80	228,900	—	—	
D46-15	0°	350	149.9	15.0	80	4,800	—	—	
D6-19	0°	350	131.2	13.1	70	2,739,300	—	—	
D4-3	0°	350	131.2	13.1	70	968,000	—	—	
D7-6	0°	350	131.2	13.1	70	4,865,800	—	—	
D46-16	0°	350	131.2	13.1	70	6,000	—	—	
D6-3	0°	450	165.2	16.5	80	2,100	—	—	
D7-12	0°	450	165.2	16.5	80	900	—	—	
D1-15	0°	450	165.2	16.5	80	1,700	—	—	
D7-13	0°	450	165.2	16.5	80	10,500	—	—	

Test: Tensile-Tensile Fatigue

Material: AS/4397

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D6-16	0°	450	154.9	15.5	75	649,000	——	——	
D7-3	0°	450	154.9	15.5	75	549,300	——	——	
D7-10	0°	450	154.9	15.5	75	1,132,200	——	——	
D6-13	0°	450	154.9	15.5	75	348,600	——	——	
D6-11	0°	450	144.6	14.5	70	2,740,600	——	——	
D6-18	0°	450	144.6	14.5	70	887,500	——	——	
D7-15	0°	450	144.6	14.5	70	3,207,200	——	——	
D6-7	0°	450	144.6	14.5	70	2,694,600	——	——	
D19-9	90°	-67	3.70	0.37	70	20,200	——	——	
D23-3	90°	-67	3.70	0.37	70	5,300	——	——	
D14-10	90°	-67	3.70	0.37	70	3,300	——	——	
D21-5	90°	-67	3.70	0.37	70	29,800	——	——	
D21-1	90°	-67	3.44	0.34	65	10,000,100+	——	4.37	
D14-6	90°	-67	3.44	0.34	65	8,700	——	——	
D21-3	90°	-67	3.44	0.34	65	14,400	——	——	
D26-5	90°	-67	3.44	0.34	65	1,200	——	——	
D16-5	90°	-67	3.18	0.32	60	53,200	——	——	
D23-7	90°	-67	3.18	0.32	60	165,400	——	——	
D22-3	90°	-67	3.18	0.32	60	4,476,300	——	——	
D12-9	90°	-67	3.18	0.32	60	1,260,400	——	——	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/4397 — Frequency = .30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D22-1	90°	-67	2.65	0.27	50	10,000,100+	---	4.09	
D12-8	90°	72	3.76	0.38	70	90,000	---	---	
D13-4	90°	72	3.76	0.38	70	75,800	---	---	
D20-7	90°	72	3.76	0.38	70	6,400	---	---	
D15-9	90°	72	3.76	0.38	70	200	---	---	
D12-5	90°	72	3.22	0.32	60	171,000	---	---	
D23-1	90°	72	3.22	0.32	60	2,100	---	---	
D23-5	90°	72	3.22	0.32	60	1,100	---	---	
D17-5	90°	72	3.22	0.32	60	63,000	---	---	
D18-3	90°	72	2.68	0.27	50	12,200	---	---	
D23-9	90°	72	2.68	0.27	50	4,357,100	---	---	
D26-8	90°	72	2.68	0.27	50	2,600	---	---	
D22-7	90°	72	2.68	0.27	50	100,900	---	---	
D14-2	90°	350	3.05	0.31	80	11,700	---	---	
D25-2	90°	350	3.05	0.31	80	1,500	---	---	
D13-10	90°	350	3.05	0.31	80	32,600	---	---	
D12-2	90°	350	3.05	0.31	80	14,900	---	---	
D58-6	90°	350	2.86	0.29	75	7,800	---	---	
D22-5	90°	350	2.86	0.29	75	500	---	---	
D13-8	90°	350	2.86	0.29	75	2,276,000	---	---	
D22-9	90°	350	2.86	0.29	75	1,500	---	---	

Test: Tensile-Tensile Fatigue

Material: AS/4397

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D19-8	90°	350	2.67	0.27	70	20,300	—	—	
D20-1	90°	350	2.67	0.27	70	15,900	—	—	
D13-1	90°	350	2.67	0.27	70	4,348,600	—	—	
D21-9	90°	350	2.67	0.27	70	5,392,000	—	—	
D12-6	90°	450	2.07	0.21	70	4,300	—	—	
D20-8	90°	450	2.07	0.21	70	19,900	—	—	
D14-5	90°	450	2.07	0.21	70	5,300	—	—	
D15-5	90°	450	2.07	0.21	70	—	—	—	Grips slipped
D58-10	90°	450	2.07	0.21	70	35,400	—	—	
D13-7	90°	450	1.77	0.18	60	543,700	—	—	
D17-10	90°	450	1.77	0.18	60	1,100	—	—	
D16-3	90°	450	1.77	0.18	60	49,500	—	—	
D20-3	90°	450	1.77	0.18	60	—	—	—	Grips slipped
D19-7	90°	450	1.77	0.18	60	—	—	—	Grips slipped
D58-9	90°	450	1.77	0.18	60	1,005,600	—	—	
D20-9	90°	450	1.48	0.15	50	5,788,000	—	—	
D18-4	90°	450	1.48	0.15	50	12,300	—	—	
D20-10	90°	450	1.48	0.15	50	5,933,400	—	—	
D58-8	90°	450	1.48	0.15	50	10,001,000+	—	3.74	
D37-9	±45°	-67	13.48	1.35	70	3,600	16	—	
D33-3	±45°	-67	13.48	1.35	70	7,000	8	—	
D41-6	±45°	-67	13.48	1.35	70	5,100	18	—	
D40-4	+45°	-67	13.48	1.35	70	3,300	11	—	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: AS/4397 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D39-9	±45°	-67	11.56	1.16	60	160,300	11	—	
D37-10	±45°	-67	11.56	1.16	60	30,400	9	—	
D35-1	±45°	-67	11.56	1.16	60	215,000	5	—	
D41-7	±45°	-67	11.56	1.16	60	80,300	11	—	
D41-5	+45°	-67	10.59	1.06	55	1,241,500	3	—	
D34-4	±45°	-67	10.59	1.06	55	7,781,800	5	—	
D41-8	±45°	-67	10.59	1.06	55	10,001,500	2	14.23	
D33-1	±45°	-67	10.59	1.06	55	10,011,500	9	15.57	
D38-3	±45°	-67	9.93	0.99	50	10,010,900+	5	16.21	
D31-3	±45°	72	14.98	1.50	80	6,400	36	—	
D29-6	±45°	72	14.98	1.50	80	3,600	41	—	
D28-4	±45°	72	14.98	1.50	80	3,800	29	—	
D27-4	±45°	72	14.98	1.50	80	2,900	25	—	
D31-9	±45°	72	13.10	1.31	70	15,900	36	—	
D28-1	±45°	72	13.10	1.31	70	15,900	23	—	
D32-9	±45°	72	13.10	1.31	70	16,400	32	—	
D31-6	±45°	72	13.10	1.31	70	15,100	32	—	
D32-3	±45°	72	11.23	1.12	60	913,900	23	—	
D29-10	±45°	72	11.23	1.12	60	1,628,100	25	—	
D27-7	±45°	72	11.23	1.12	60	408,300	37	—	
D28-9	±45°	72	11.23	1.12	60	743,300	31	—	

Test: Tensile-Tensile Fatigue

Material: AS/4397

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D32-6	±45°	72	8.42	0.84	45	10,000,000+	4	18.72	
D40-9	±45°	350	11.63	1.16	70	15,000	40	----	
D38-4	±45°	350	11.63	1.16	70	14,900	59	----	
D35-4	±45°	350	11.63	1.16	70	87,700	14	----	
D40-2	±45°	350	11.63	1.16	70	11,000	35	----	
D40-1	±45°	350	10.80	1.08	65	107,900	14	----	
D35-5	±45°	350	10.80	1.08	65	405,600	13	----	
D36-9	±45°	350	10.80	1.08	65	87,700	15	----	
D38-7	±45°	350	10.80	1.08	65	58,100	15	----	
D41-3	±45°	350	9.97	1.00	60	542,800	11	----	
D38-2	±45°	350	9.97	1.00	60	1,945,100	9	----	
D33-7	±45°	350	9.97	1.00	60	896,000	8	----	
D37-5	±45°	350	9.97	1.00	60	528,800	7	----	
D39-6	±45°	450	11.69	1.17	70	4,900	47	----	
D37-6	±45°	450	11.69	1.17	70	1,300	32	----	
D36-8	±45°	450	11.69	1.17	70	1,000	22	----	
D38-5	±45°	450	11.69	1.17	70	1,300	34	----	
D37-4	±45°	450	10.02	1.00	60	5,800	42	----	
D41-4	±45°	450	10.02	1.00	60	2,900	48	----	

Test: Tensile-Tensile Fatigue

Material: AS/4397

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
D34-2	±45°	450	8.35	0.84	50	9,200	53	----	
D37-8	±45°	450	8.35	0.84	50	67,600	36	----	
D41-10	±45°	450	8.35	0.84	50	21,900	49	----	
D36-4	±45°	450	8.35	0.84	50	8,200	63	----	
D36-7	±45°	450	6.68	0.67	40	6,227,000	7	----	
D41-1	±45°	450	6.68	0.67	40	3,449,800	7	----	
D33-10	±45°	450	6.68	0.67	40	10,001,000+	2	13.54	
D34-7	±45°	450	6.68	0.67	40	8,124,700	4	----	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: T300/F178 Graphite/Polyimide — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
E5-1	0°	72	141.1	14.1	90	2,400	—	—	
E7-12	0°	72	141.1	14.1	90	300	—	—	
E4-5	0°	72	133.2	13.3	85	10,000,100	—	189.9	
E8-16	0°	72	133.2	13.3	85	385,600	—	—	
E7-11	0°	72	133.2	13.3	85	1,200	—	—	
E22-2	0°	72	133.2	13.3	85	300	—	—	
E4-13	0°	72	125.4	12.5	80	608,000	—	—	
E21-5	0°	72	125.4	12.5	80	10,000,100+	—	175.1	
E8-6	0°	72	125.4	12.5	80	1,775,300	—	—	
E6-9	0°	72	125.4	12.5	80	1,106,700	—	—	
E4-17	0°	72	109.5	11.0	70	10,000,100+	—	181.7	
E6-11	0°	72	109.5	11.0	70	9,519,600	—	—	
E8-13	0°	72	109.5	11.0	70	10,000,100+	—	140.6	
E21-4	0°	72	109.5	11.0	70	10,000,100+	—	187.0	
E4-2	0°	350	121.8	12.2	80	312,300	—	—	
E21-3	0°	350	121.8	12.2	80	873,000	—	—	
E6-5	0°	350	121.8	12.2	80	600	—	—	
E8-5	0°	350	121.8	12.2	80	10,200	—	—	

Test: Tensile-Tensile Fatigue | R = +0.1

Material: T300/F178 Graphite/Polyimide | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
E4-11	0°	350	114.2	11.4	75	5,584,300	—	—	
E5-4	0°	350	114.2	11.4	75	1,146,300	—	—	
E6-13	0°	350	114.2	11.4	75	127,100	—	—	
E21-9	0°	350	114.2	11.4	75	7,426,900	—	—	
E5-6	0°	350	106.6	11.0	70	2,346,900	—	—	
E6-17	0°	350	106.6	11.0	70	3,592,300	—	—	
E7-9	0°	350	106.6	11.0	70	10,002,000+	—	150.6	
E21-16	0°	350	106.6	11.0	70	934,000	—	—	
E21-7	0°	450	114.7	11.5	75	1,730,500	—	—	
E22-7	0°	450	114.7	11.5	75	400	—	—	
E5-2	0°	450	114.7	11.5	75	3,338,500	—	—	
E7-17	0°	450	114.7	11.5	75	141,600	—	—	
E21-14	0°	450	107.0	10.7	70	1,679,500	—	—	
E22-8	0°	450	107.0	10.7	70	3,671,200	—	—	
E8-18	0°	450	107.0	10.7	70	190,400	—	—	
E6-7	0°	450	107.0	10.7	70	677,800	—	—	
E4-16	0°	450	99.4	9.9	65	7,670,900	—	—	
E21-1	0°	450	99.4	9.9	65	8,238,800	—	—	
E5-16	0°	450	99.4	9.9	65	9,416,700	—	—	
E7-14	0°	450	99.4	9.9	65	1,434,200	—	—	

Test: Tensile-Tensile Fatigue | R = +0.1

Material: T300/F178 Graphite/Polyimide | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
E13-5	90°	72	3.06	0.31	80	1,400	—	—	
E18-7	90°	72	3.06	0.31	80	1,700	—	—	
E27-10	90°	72	3.06	0.31	80	60,200	—	—	
E29-6	90°	72	3.06	0.31	80	500	—	—	
E18-2	90°	72	2.67	0.27	70	10,001,000+	—	—	No residual-loaded too fast
E27-4	90°	72	2.67	0.27	70	3,700	—	—	
E29-1	90°	72	2.67	0.27	70	1,600	—	—	
E30-4	90°	72	2.67	0.27	70	600	—	—	
E17-3	90°	72	2.29	0.23	60	10,001,000	—	—	Broke after 10^7 cycles
E18-3	90°	72	2.29	0.23	60	10,009,600+	—	3.95	
E28-3	90°	72	1.91	0.19	50	300	—	—	
E30-5	90°	72	1.91	0.19	50	10,000,100+	—	4.70	
E28-4	90°	72	1.91	0.19	50	10,001,000+	—	4.55	
E11-9	90°	72	1.91	0.19	50	10,001,000+	—	4.65	
E28-6	90°	350	2.08	0.21	70	—	—	—	Failed on loading
E28-7	90°	350	1.78	0.18	60	—	—	—	Failed on loading
E50-6	90°	350	1.78	0.18	60	—	—	—	Failed on loading
E30-9	90°	350	1.78	0.18	60	78,300	—	—	Failed inside tabs
E53-8	90°	350	1.78	0.18	60	10,000,600+	—	5.96	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: T300/F178 Graphite/Polyimide — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
E50-5	90°	350	1.63	0.16	55	—	—	—	Failed on loading
E53-9	90°	350	1.63	0.16	55	601,900	—	—	Grips slipped. Broken while outside machine.
E52-8	90°	350	1.63	0.16	55	10,001,100+	—	5.46	
E52-1	90°	350	1.63	0.16	55	—	—	—	Failed on loading
E53-2	90°	350	1.63	0.16	55	200	—	—	
E30-6	90°	350	1.49	0.15	50	10,000,400	—	6.37	
E28-5	90°	350	1.49	0.15	50	10,001,300	—	6.13	
E53-10	90°	350	1.49	0.15	50	—	—	—	Failed on loading
E52-9	90°	350	1.49	0.15	50	10,000,800	—	6.20	
E28-8	90°	450	1.50	0.15	70	—	—	—	Failed on loading
E53-5	90°	450	1.50	0.15	70	2,838,700	—	—	
E30-8	90°	450	1.50	0.15	70	4,234,200	—	—	
E52-3	90°	450	1.50	0.15	70	2,700,800	—	—	
E50-4	90°	450	1.29	0.13	60	—	—	—	Failed on loading
E30-7	90°	450	1.29	0.13	60	—	—	—	Failed on installation
E53-6	90°	450	1.29	0.13	60	1,580,900	—	—	
E52-5	90°	450	1.29	0.13	60	3,358,400	—	—	
E53-1	90°	450	1.29	0.13	60	—	—	—	Failed on loading
E50-8	90°	450	1.07	0.11	50	—	—	—	Failed on loading
E30-10	90°	450	1.07	0.11	50	2,121,800	—	—	
E53-7	90°	450	1.07	0.11	50	10,000,100+	—	5.28	
E52-6	90°	450	1.07	0.11	50	2,891,200	—	—	

Test: Tensile-Tensile Fatigue

R = +0.1

Material: T300/F178 Graphite/Polyimide

Frequency = .30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
E35-5	±45°	72	12.02	1.20	70	24,400	29	—	
E36-10	±45°	72	12.02	1.20	70	18,200	16	—	
E37-8	±45°	72	12.02	1.20	70	24,700	13	—	
E39-5	±45°	72	12.02	1.20	70	156,100	18	—	
E37-5	±45°	72	11.16	1.12	65	411,400	22	—	
E39-2	±45°	72	11.16	1.12	65	903,800	18	—	
E40-8	±45°	72	11.16	1.12	65	798,800	7	—	
E42-3	±45°	72	11.16	1.12	65	155,600	11	—	
E40-6	±45°	72	10.3	1.03	60	7,614,500	5	—	
E42-9	±45°	72	10.3	1.03	60	660,300	13	—	
E35-7	±45°	72	10.3	1.03	60	10,014,400+	2	16.53	
E36-7	±45°	72	10.3	1.03	60	878,200	14	—	
E48-9	±45°	350	10.95	1.10	75	10,900	23	—	
E39-3	±45°	350	10.95	1.10	75	5,200	29	—	
E40-5	±45°	350	10.95	1.10	75	9,900	36	—	
E42-8	±45°	350	10.95	1.10	75	5,600	11	—	
E48-5	±45°	350	10.22	1.02	70	55,700	14	—	
E36-4	±45°	350	10.22	1.02	70	13,200	18	—	
E37-7	±45°	350	10.22	1.02	70	136,200	25	—	
E39-6	±45°	350	10.22	1.02	70	207,500	29	—	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: T300/F178 Graphite/Polyimide — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
E40-4	±45°	350	9.49	0.95	65	5,660,100	11	—	
E42-1	+45°	350	9.49	0.95	65	3,810,400	11	—	
E34-3	±45°	350	9.49	0.95	65	110,300	9	—	
E36-8	±45°	350	9.49	0.95	65	124,000	18	—	
E48-1	±45°	450	9.75	0.98	80	4,000	43	—	
E34-1	±45°	450	9.75	0.98	80	6,700	27	—	
E43-6	±45°	450	9.75	0.98	80	3,400	38	—	
E37-3	±45°	450	9.75	0.98	80	4,700	31	—	
E48-3	±45°	450	9.14	0.91	75	322,000	11	—	
E43-2	+45°	450	9.14	0.91	75	33,500	27	—	
E44-4	+45°	450	9.14	0.91	75	51,400	14	—	
E35-6	±45°	450	9.14	0.91	75	18,000	23	—	
E43-1	±45°	450	8.53	0.85	70	111,000	23	—	
E48-7	±45°	450	8.53	0.85	70	3,573,900	13	—	
E44-9	±45°	450	8.53	0.85	70	2,599,300	9	—	
E35-8	±45°	450	8.53	0.85	70	4,108,400	11	—	

APPENDIX I

CREEP AND STRESS RUPTURE DATA

All of the tensile creep data generated during this program, along with residual strengths of specimens which "ran out" to 500 hours are presented in this section. The residual strengths were all determined with a 72°F tensile test regardless of what temperature the specimen saw during the creep test.

The stress rupture data were also obtained from these same specimens with the characteristic of interest being time to fracture rather than elongation.

Summaries of these data are presented in Section 4 in both tabular and graphical form.

In the succeeding tables the specimen numbering system can be used to identify the material being tested. The letter, appearing first, in the specimen numbering code indicates the material, as follows:

A - SP313
C - AS/3004
D - AS/4397
E - T300/F178.

Test: Creep
Orient: 0°
Spec. No: A3-14
Temp: R.T.
Stress: 173.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	failed on	loading

Recovery

Test: Creep
Orient: 0°
Spec. No: A7-4
Temp: R.T.
Stress: 173.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7560	8/6/75
1	7560	
2	7580	
3	7570	
4	7570	
8	7590	
12	7510	
18.8	7720	
24	7730	
31.3	7670	slipped
33.8		failure

Recovery

Test: Creep
Orient: 0°
Spec. No: A5-5
Temp: R.T.
Stress 173.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	failed on	loading

Recovery

Test: Creep
Orient: 0°
Spec. No: A3-5
Temp: R.T.
Stress: 153.8 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6990	
1/2	7000	
1	7000	
2	7000	
3	7000	
4	7000	
8	6990	
12	6990	
24	6990	
36	6990	
48	6990	
72	6990	
168	7140	
216	7140	
240	7130	
248	7120	
336	7120	
384	7100	
432	7100	
504	7090	
694.5	7100	
Resid.	Str.	207.7 ksi
Recovery		
0	300	
3	290	

Test: Creep
Orient: 0°
Spec. No: A5-4
Temp: R.T.
Stress: 153.8 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7574	
0.1	7582	
0.5	7594	
1	7587	
2	7595	
3	7604	
72	7595	
120	7604	
168	7610	
264	7618	
288	7620	
337	7616	
408	7612	
456	7609	
504	7610	
Resid.	Str.	187.7 ksi
Recovery		
0	16	
1	0	
2	-7	
3	-8	

Test: Creep
Orient: 0°
Spec. No: A7-14
Temp: R.T.
Stress 153.8 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7721	
0.016	7723	
0.1	7727	
0.5	7730	
1	7730	
2	7737	
3	7738	
4	7736	
5	7741	
6	7746	
7	7750	
8	7752	
24	7750	
48	7767	
120	7760	
168	7770	
216	7779	
288	7778	
336	7772	
384	7782	
456	7772	
500	7782	
Resid.	Str.	188.4 ksi
Recovery		
0	50	
1	34	
2	26	
3	22	

SP313

Test: Creep
Orient: 0°
Spec. No: A5-17
Temp: R.T.
Stress: 134.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6515	
0.016	6534	
0.1	6537	
0.5	6537	
1	6540	
2	6540	
3	6540	
4	6540	
5	6542	
6	6542	
7	6543	
8	6543	
24	6550	
48	6556	
120	6556	
168	6556	
216	6557	
288	6574	
336	6578	
384	6573	
456	6577	
502	6576	
Resid.	Str.	210.9 ksi
Recovery		
0	110	
1	102	
2	94	
3	91	

Test: Creep
Orient: 0°
Spec. No: A7-7
Temp: R.T.
Stress: 134.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5860	
0.5	5860	
1	5860	
2	5870	
3	5870	
4	5840	
8	5840	
12	5820	
24	5790	
36	5780	
48	5790	
72	5750	
168	5790	
216	5790	
264	5780	
336	5770	
384	5780	
432	5800	
527	5820	
530	5840	
Resid.	Str.	201.0 ksi
Recovery		
0	71	
3	72	

Test: Creep
Orient: 0°
Spec. No: A8-6
Temp: R.T.
Stress: 134.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6804	
0.016	6807	
0.5	6813	
1	6816	
2	6813	
3	6813	
4	6814	
5	6822	
6	6824	
7	6826	
8	6827	
72	6834	
120	6842	
168	6834	
240	6836	
288	6830	
336	6828	
408	6831	
456	6829	
500	6819	
Resid.	Str.	158.4 ksi
Recovery		
0	26	
1	6	
2	8	
3	3	

Test: Creep

Orient: 0°

Spec. No: A3-4

Temp: 260°F

Stress: 157.2 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7605	
1	7634	
2	763[illegible]	
3	7634	
4	7634	
5	7643	
6	7652	
7	7660	
8	7658	
24	7668	
48	7689	
72	7694	
144	7750	
192	7759	
240	7741	
312	7750	
360	7770	
408	7779	
480	7803	
504	7800	
Resid.	Str.	208.9 ksi
Recovery		
0	151	
1	133	
2	128	
3	125	

Test: Creep

Orient: 0°

Spec. No: A5-18

Temp: 260°F

Stress: 157.2 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8360	
0.016	8720	
0.1	Failure	
Recovery		

Test: Creep

Orient: 0°

Spec. No: A7-3

Temp: 260°F

Stress 157.2 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7948	
0.016	8418	
0.06	8443	
0.1	Failure	
Recovery		

SP313

Test: Creep
Orient: 0°
Spec. No: A3-1
Temp: 260°F
Stress: 139.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7948	
0.016	8418	
0.06	8443	
0.1	Failure	

Recovery

Test: Creep
Orient: 0°
Spec. No: A5-8
Temp: 260°F
Stress: 139.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7621	
0.1	7060	
0.33	Failure	

Recovery

Test: Creep
Orient: 0°
Spec. No: A7-5
Temp: 260°F
Stress 139.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7032	
0.5	7044	
1.5	7049	
2	7049	
3	7050	
4	7056	
5	7015	
7	7010	
24	7028	
96	7054	
120	7060	
267	7085	
315	7098	
435	7120	
483	7134	
507	7132	
Resid. Str.		195.7 ksi

Recovery

0	134	
1	134	
2	134	
3	130	

Test: Creep
Orient: 0°
Spec. No: A3-3
Temp: 260°F
Stress: 122.3 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6236	
0.5	6232	
1	6233	
2	6236	
3	6240	
4	6240	
5	6240	
6	6240	
7	6240	
8	6236	
120	6256	
168	6274	
216	6276	
288	6293	
336	6300	
384	6302	
456	6316	
504	6298	
Resid.	Str.	150.1 ksi
Recovery		
0	92	
1	66	
2	63	
3	62	

Test: Creep
Orient: 0°
Spec. No: A5-15
Temp: 260°F
Stress: 122.3 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6240	
0.5	6252	
1	6254	
2.5	6257	
3	6260	
4	6262	
5	6264	
6	6267	
7	6267	
8	6267	
72	6322	
120	6348	
240	6403	
288	6418	
336	6437	
408	6470	
456	6485	
504	6504	
Resid.	Str.	161.5 ksi
Recovery		
0	275	
1	263	
2	263	
3	263	

Test: Creep
Orient: 0°
Spec. No: A7-8
Temp: 260°F
Stress 122.3 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6392	
0.5	6400	
1	6400	
2	6404	
3	6404	
4	6404	
5	6404	
6	6404	
7	6404	
24	6418	
48	6428	
96	6442	
168	6500	
336	6586	
384	6600	
504	6678	
Resid.	Str.	192.6 ksi
Recovery		
0	346	
1	341	
2	330	
3	326	

SP313

Test: Creep		
Orient: 0°		
Spec. No: A7-10		
Temp: 350°F		
Stress: 127.5 ksi 90% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6783	
0.1	Failure	
Recovery		

Test: Creep		
Orient: 0°		
Spec. No: A5-13		
Temp: 350°F		
Stress: 127.5 ksi 90% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6604	
1	6728	
2	6738	
3	6740	
4	6747	
5	6752	
6		
7	6775	
8	6779	
75.3	7288	
120	7528	
168	7537	
240	7718	
288	7791	
336	7908	
411	7900	
457	7921	
480	7928	
504	7935	
Resid.	Str.	159.0 ksi
Recovery		
0	970	
1	1000	
2	1020	
3	1020	

Test: Creep		
Orient: 0°		
Spec. No: A7-12		
Temp: 350°F		
Stress 127.5 ksi 90% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6695	
0.1	6880	
0.5	7000	
0.6	7019	
0.6	Failure	
Recovery		

SP313

Test: Creep
Orient: 0°
Spec. No: A3-6
Temp: 350°F
Stress: 113.4 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (µ in/in)	Remarks
0	5900	
0.1	5923	
0.5	5937	
1	5949	
2	5952	
3	5954	
5	5963	
6	5967	
7	5976	
8	5978	
24	6018	
48	6094	
72	6176	
144	6479	
192	6567	
240	6667	
312	6758	
360	6837	
408	6885	
480	6894	
504	6911	
Resid.	Str.	219.0 ksi
Recovery		
0	1130	
1	1042	
2	1036	
3	1020	

Test: Creep
Orient: 0°
Spec. No: A5-1
Temp: 350°F
Stress: 113.4 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (µin/in)	Remarks
0	6463	
0.2	6470	
0.7	6486	
1.2	6492	
2.2	6496	
4.2	6501	
8.2	6496	
23.2	6491	
48.2	6524	
120.2	6710	
168.2	6829	
220.2	6940	
291.2	7057	
336.2	7113	
384.2	7164	
456.2	7238	
505.2	7284	
Resid.	Str.	156.4 ksi
Recovery		
0	866	
1	794	
2	781	
3	776	

Test: Creep
Orient: 0°
Spec. No: A3-11
Temp: 350°F
Stress 113.4 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (µin/in)	Remarks
0	5875	
0.5	5935	
1	5958	
2	5979	
3	5993	
4	6014	
5	6022	
6	6041	
7	6051	
8	6065	
24	6266	
48	6486	
96	6773	
168	7025	
216	7159	
264	7284	
336	7473	
384	7588	
432	7685	
504	7802	
Resid.	Str.	178.3 ksi
Recovery		
0	2038	
1	1933	
2	1912	
3	1903	

Test: Creep
Orient: 0°
Spec. No: A7-13
Temp: 350°F
Stress: 99.2 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6170	
0.5	6169	
1	6172	
2	6172	
3	6172	
4	6172	
5	6170	
6	6170	
7	6168	
24	6170	
48	6200	
72	6240	
96	6264	
144	6287	
192	6295	
240	6270	
312	6272	
360	6268	
408	6278	
504	6304	
528	6312	
Resid	Str.	123.0 ksi
Recovery		
0	1144	
1	1100	
2	1090	
3	1090	

Test: Creep
Orient: 0°
Spec. No: A5-6
Temp: 350°F
Stress: 99.2 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5196	
0.5	5250	
1	5260	
2	5284	
3	5300	
4	5307	
5	5321	
6	5328	
7	5331	
24	5450	
48	5546	
96	5641	
168	5687	
216	5688	
264	5696	
336	5673	
384	5672	
432	5638	
504	5600	
Resid	Str.	164.6 ksi
Recovery		
0	373	
1	277	
2	265	
3	263	

Test: Creep
Orient: 0°
Spec. No: A3-16
Temp: 350°F
Stress 99.2 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5084	
24	5200	
72	5545	
146	5962	
194	6135	
266	6366	
314	6473	
Resid.	Str.	199.4 ksi
Recovery		
0	1372	
1	1318	
2	1318	
3	1319	

SP313

Test: Creep
Orient: 90°
Spec. No: A27-3
Temp: R.T.
Stress: 3.93 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3068	
0.1	3114	
0.2	3130	
0.5	3158	
1	3172	
2	3182	
4	3197	
5	3201	
72	3250	
168	3309	
240	3403	
288	3375	
336	3403	
408	3406	
456	3417	
504	3434	
Resid.	Str.	5.41 ksi
Recovery		
0	433	
1	311	
2	302	
3	295	

Test: Creep
Orient: 90°
Spec. No: A30-7
Temp: R.T.
Stress: 3.93 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

Test: Creep
Orient: 90°
Spec. No: A25-2
Temp: R.T.
Stress 3.93 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

SP313

Test: Creep
Orient: 90°
Spec. No: A25-9
Temp: R.T.
Stress: 3.44 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2506	
1	2610	
2	2624	
3	2635	
20	2674	
24	2692	
72	2701	
144	2758	
192	2794	
236	2818	
308	2795	
356	2826	
404.	2841	
476	2898	
501	2890	
Resid.	Str.	5.41 ksi
Recovery		
0	267	
1	198	
2	186	
15.5	121	

Test: Creep
Orient: 90°
Spec. No: A30-11
Temp: R.T.
Stress: 3.44 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2636	
1	2719	
2	2735	
3	2748	
20	2793	
24	2812	
72	2820	
144	2880	
192	2920	
236	2945	
308	2920	
356	2956	
404	2975	
476	3042	
501	3029	
Resid.	Str.	3.97 ksi
Recovery		
0	347	
1	262	
2	247	
15.5	174	

Test: Creep
Orient: 90°
Spec. No: A32-7
Temp: R.T.
Stress 3.44 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2683	
1	2767	
2	2783	
3	2795	
20	2837	
24	2859	
72	2865	
144	2926	
192	2964	
236	2988	
308	2968	
356	3000	
404	3018	
476	3079	
501	3074	
Resid.	Str.	4.91 ksi
Recovery		
0	370	
1	275	
2	263	
15.5	191	

SP313

Test: Creep
Orient: 90°
Spec. No: A31-4
Temp: R.T.
Stress: 2.94 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2275	
0.2	2322	
0.5	2348	
1	2360	
2	2378	
4	2394	
5	2404	
6	2410	
7	2415	
8	2416	
24	2444	
96	2461	
144	2493	
192	2505	
264	2515	
312	2564	
360	2600	
456	2668	
480	2706	
504	2679	
Resid.	Str.	4.52 ksi
Recovery		
0	460	
1	389	
2	379	
3	369	

Test: Creep
Orient: 90°
Spec. No: A23-11
Temp: R.T.
Stress: 2.94 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2300	
0.2	2366	
0.5	2387	
1	2407	
2	2419	
4	2440	
5	2448	
6	2454	
7	2457	
8	2467	
24	2489	
96	2514	
144	2548	
192	2562	
264	2573	
312	2629	
360	2664	
456	2739	
480	2782	
504	2752	
Resid	Str.	5.04 ksi
Recovery		
0	522	
1	425	
2	407	
3	397	

Test: Creep
Orient: 90°
Spec. No: A27-9
Temp: R.T.
Stress 2.94 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2355	
0.2	2405	
0.5	2430	
1	2456	
2	2461	
4	2485	
5	2488	
6	2493	
7	2496	
8	2501	
24	2527	
96	2555	
144	2591	
192	2610	
264	2622	
312	2683	
360	2721	
456	2810	
480	2864	
504	2826	
Resid.	Str.	3.84 ksi
Recovery		
0	573	
1	485	
2	471	
3	462	

Test: Creep
Orient: 90°
Spec. No: A24-11
Temp: 260°F
Stress: 3.33 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3211	
0.016	3447	
0.1	3639	
0.2	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: A28-10
Temp: 260°F
Stress: 3.33 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3015	
0.016	3118	
0.1	3209	
0.33	3270	
0.5	3285	
1	3311	
1.33	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: A30-9
Temp: 260°F
Stress 3.33 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2995	
0.016	3102	
0.1	3181	
0.2	3286	
0.5	3278	
1	3317	
2	3352	
3	3400	
4	3420	
5	3430	
6	3436	
7	3438	
8	3442	
2[illegible]	3446	
49	3503	
73	3570	
144	3698	
193	4820	
240	4834	
312	4870	
360	4890	
408	4895	
480	4921	
504	4922	
Resid.	Str.	4.12 ksi
Recovery		
0	2121	
1	1875	
2	1865	
3	1839	

SP313

Test: Creep
Orient: 90°
Spec. No: A26-2
Temp: 260°F
Stress: 3.10 ksi 65% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on loading	

Recovery

Test: Creep
Orient: 90°
Spec. No: A26-11
Temp: 260°F
Stress: 3.10 ksi 65% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	

Recovery

Test: Creep
Orient: 90°
Spec. No: A28-1
Temp: 260°F
Stress 3.10 ksi 65% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2550	
0.016	2603	
0.1	2654	
0.5	2720	
1	2740	
2	2772	
3	2790	
4	2815	
5	2828	
6	2839	
7	2852	
8	2860	
24	2971	
108.8	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: A26-4
Temp: 260°F
Stress: 2.86 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on loading	

Recovery

Test: Creep
Orient: 90°
Spec. No: A27-5
Temp: 260°F
Stress: 2.86 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2535	
0.016	2605	
0.1	2644	
0.4	2645	
0.5	2646	
1	2662	
2	2673	
3	2676	
4	2677	
5	2681	
6	2680	
7	2679	
8	2679	
24	2664	
48	2673	
120	2742	
169	2782	
217	2821	
288	2875	
336	2907	
384	2936	
456	2977	
504	3000	
Resid.	Str.	4.96 ksi

Recovery

0	570	
1	510	
2	492	
3	477	

Test: Creep
Orient: 90°
Spec. No: A31-2
Temp: 260°F
Stress 2.86 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2566	
0.016	2707	
0.1	2767	
0.4	2790	
0.5	2796	
1	2810	
2	2823	
3	2836	
4	2848	
5	2856	
6	2860	
7	2864	
8	2871	
24	2941	
48	3000	
120	3107	
169	3145	
217	3181	
288	3248	
336	3290	
384	3332	
456	3380	
504	3406	
Resid.	Str.	5.37 ksi

Recovery

0	928	
1	828	
2	805	
3	792	

SP313

Test: Creep
Orient: 90°
Spec. No: A32-5
Temp: 350°F
Stress: 2.59 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on loading	

Recovery

Test: Creep
Orient: 90°
Spec. No: A30-10
Temp: 350°F
Stress: 2.59 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2928	
0.016	3230	
0.03	3311	
0.1	3765	
0.13	3834	
	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: A28-3
Temp: 350°F
Stress 2.59 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2620	
0.016	2742	
0.1	2916	
0.2	3034	
0.5	3360	
	Failure	

Recovery

SP313

Test: Creep
Orient: 90°
Spec. No: A31-8
Temp: 350°F
Stress: 2.22 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2182	
0.016	2305	
0.1	2517	
0.2	2667	
0.5	2837	
1	2990	
2	3233	
3	3384	
4	3497	
5	3616	
6	3767	
12.4	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: A24-9
Temp: 350°F
Stress: 2.22 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2166	
0.3	2691	
0.5	2815	
1.2	3070	
2	3291	
3	3438	
4	3557	
5	3639	
6	3712	
7	3788	
8	3843	
24	5006	
48	6006	
72	6597	
127	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: A28-11
Temp: 350°F
Stress 2.22 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2245	
0.25	2654	
0.5	2802	
1	2946	
2	3151	
3	3343	
71	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: A28-4
Temp: 350°F
Stress: 1.65 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on loading	
Recovery		

Test: Creep
Orient: 90°
Spec. No: A32-2
Temp: 350°F
Stress: 1.85 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2213	
0.016	2655	
0.033	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: A32-10
Temp: 350°F
Stress: 1.85 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1786	
0.016	1316	
0.1	1991	
0.25	2025	
0.75	2085	
1	2101	
2	2150	
3	2195	
4	2236	
5	2280	
6	2303	
7	2338	
8	2378	
9	2398	
24	2792	
48	3204	
96	3719	
168	4210	
216	4465	
264	4685	
336	4966	
384	5101	
432	5241	
500	5433	
Resid. Str.		
Recovery		
0	3762	
1	3346	
2	3182	
3	2995	

SP313

Test: Creep
Orient: ±45°
Spec. No: A51-7
Temp: R.T.
Stress: 18.89 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8720	
	Failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: A56-5
Temp: R.T.
Stress: 18.89 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	10,000	
0.016	11,213	
0.033	11,583	
0.1	12,145	
0.25	12,694	
0.5	13,064	
1	13,474	
2	13,920	
3	14,181	
4	14,405	
5	14,600	
6	14,785	
7	149,325	
8	15,045	
24	15,997	
48	16,888	
53.9	Failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: A62-10
Temp: R.T.
Stress 18.89 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9030	
0.016	9910	
0.1	10,570	
0.5	11,361	
1	11,643	
3	12,308	
5	12,638	
6	12,774	
7	12,880	
8	12,986	
24	14,113	
80.8	Failure	

Recovery

SP313

Test: Creep
Orient: ±45°
Spec. No: A48-1
Temp: R.T.
Stress: 16.79 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7904	
0.016	8565	
0.1	9034	
0.2	9242	
0.57	9560	
0.97	9717	
2	9964	
3	10,116	
4	10,230	
5	10,308	
6	10,383	
7	10,450	
8	10,514	
24	11,002	
48	11,390	
72	11,657	
144	12,143	
192	12,598	
240	13,156	
312	13,437	
360	13,584	
408	13,330	
480	13,491	
504	13,542	
Resid. Str.		20.66 ksi
Recovery		
0	5725	
1	3658	
2	3583	
3	3549	

Test: Creep
Orient: ±45°
Spec. No: A54-11
Temp: R.T.
Stress: 16.79 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: A58-3
Temp: R.T.
Stress 16.79 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8525	
0.016	9200	
0.1	9685	
0.2	9898	
0.5	10,173	
1.2	10,482	
2	10,671	
3	10,826	
4	10,940	
5	11,050	
6	11,111	
7	11,185	
8	11,255	
24	11,736	
48	12,101	
72	12,369	
144	12,848	
192	13,283	
240	13,790	
312	14,033	
360	14,165	
408	14,303	
480	14,436	
504	14,478	
Resid. Str.		20.55 ksi
Recovery		
0	6152	
1	3750	
2	3486	
3	3358	

Test: Creep
Orient: ±45°
Spec. No: A62-4
Temp: R.T.
Stress: 14.69 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6396	
0.016	6779	
0.1	6997	
0.5	7245	
1	7340	
2	7413	
3	7536	
4	7573	
5	7617	
21	7892	
48	8078	
72	8179	
144	8330	
192	8503	
240	8620	
336	8899	
360	8985	
408	9070	
480	9175	
504	9210	
Resid.	Str.	22.2 ksi
	Recovery	
0	2760	
1	1606	
2	1508	
3	1439	

Test: Creep
Orient: ±45°
Spec. No: A54-2
Temp: R.T.
Stress: 14.69 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6506	
0.016	6820	
0.1	7254	
0.25	7442	
0.5	7590	
1	7741	
2	7893	
3	8000	
4	8062	
5	8115	
6	8162	
7	8203	
8	8242	
24	8505	
96	8888	
144	9018	
168	9129	
288	9624	
312	9702	
360	9862	
432	10,021	
480	10,034	
504	10,042	
Resid.	Str.	20.79 ksi
	Recovery	
0	2868	
1	2610	
2	2443	
3	2320	

Test: Creep
Orient: ±45°
Spec. No: A55-9*
Temp: R.T.
Stress: 14.69 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6470	
0.016	6939	
0.1	7184	
0.3	7442	
0.5	7558	
1	7670	
2	7828	
3	7913	
4	7955	
5	8025	
6	8060	
7	8090	
8	8114	
24	8350	
48	8506	
84.25	Failure	
	Recovery	

*Specimen had 0.020" notch in side near edge of tab before testing

Test: Creep
Orient: ±45°
Spec. No: A57-8
Temp: 260°F
Stress: 13.51 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8500	
0.016	1000	
0.1	12,260	
0.25	13,465	
0.5	14,518	
1	15,806	
2	17,065	
3	17,735	
4	18,394	
5	19,650	
No data, gage failed		
360	Load taken off	
Resid.	Str.	20.61 ksi
Recovery		

Test: Creep
Orient: ±45°
Spec. No: A62-11
Temp: 260°F
Stress: 13.51 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9830	
0.016	11,615	
0.1	13,465	
0.25	14,827	
0.5	16,034	
1	17,667	
1.25	23,200	
1.33	50,000	
	No data	
Strain greater than limits of indicator		
360	Load taken off	
Resid.	Str.	21.07 ksi
Recovery		

Test: Creep
Orient: ±45°
Spec. No: A52-3
Temp: 260°F
Stress 13.51 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8940	
0.016	10,627	
0.1	14,083	
0.25	14,919	
0.5	15,784	
1	16,620	
2.5	18,065	
3	18,437	
No Data - Gage Failed		
500	Run-Out	
Resid.	Str.	21.52 ksi
Recovery		

SP313

Test: Creep
Orient: +45°
Spec. No: A53-2
Temp: 260°F
Stress: 12.01 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6484	
0.016	7259	
0.1	7952	
0.25	8422	
0.5	8786	
1	9218	
2	9639	
3	9850	
4	10,040	
5	10,206	
6	10,334	
7	10,444	
8	10,543	
24	11,206	
48	11,735	
120	12,781	
168	13,129	
240	13,457	
312	13,947	
360	14,221	
408	14,430	
480	14,715	
500	14,786	
Resid	Str.	19.65 ksi
Recovery		
0	9167	
1	8166	
2	7918	
3	7791	

Test: Creep
Orient: +45°
Spec. No: A57-9
Temp: 260°F
Stress: 12.01 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7496	
0.016	7996	
0.1	9136	
0.25	9850	
0.5	10,340	
1	10,830	
2	11,400	
3	11,809	
4	12,070	
5	12,338	
6	12,507	
7	12,652	
8	12,777	
24	13,648	
48	14,297	
120	15,054	
168	15,202	
240	15,360	
312	16,010	
360	16,670	
408	17,065	
480	17,649	
500	17,794	
Resid.	Str.	21.79 ksi
Recovery		
0	11,521	
1	10,063	
2	9800	
3	9570	

Test: Creep
Orient: +45°
Spec. No: A62-5
Temp: 260°F
Stress 12.01 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5785	
0.016	6564	
0.1	7488	
0.25	8000	
0.5	8393	
1	8595	
2	8894	
3	9054	
4	9180	
5	9287	
6	9378	
7	9455	
8	9533	
24	10,100	
48	10,532	
120	11,267	
168	11,608	
216	11,877	
288	12,236	
336	12,496	
384	12,964	
456	14,000	
501	14,460	
Resid	Str.	22.02 ksi
Recovery		
0	9318	
1	7474	
2	7176	
3	6963	

Test: Creep
Orient: +45°
Spec. No: A53-6
Temp: 260°F
Stress: 10.51 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6185	
0.1	8770	
	No data gage failed	
500	load taken off	
	Run-out	
Resid. Str.		21.43 ksi
Recovery		

Test: Creep
Orient: +45°
Spec. No: A56-10
Temp: 250°F
Stress: 10.51 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5854	
0.016	6724	
0.1	7402	
0.25	7806	
0.5	8074	
1	8391	
2	8690	
3	8870	
4	9048	
5	9138	
6	9308	
7	9500	
8	10,108	
48	10,585	
120	11,295	
168	11,656	
216	11,991	
288	12,444	
336	12,691	
384	12,943	
456	13,490	
500	13,779	
Resid. Str.		21.04 ksi
Recovery		
0	8696	
1	7523	
2	7330	
3	7225	

Test: Creep
Orient: +45°
Spec. No: A57-11
Temp: 260°F
Stress 10.51 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5855	
0.016	6479	
0.1	7200	
0.25	7666	
0.5	7954	
1	8297	
2	8647	
3	8864	
4	9003	
5	9089	
6	9204	
7	9268	
8	9340	
24	9955	
48	10,400	
120	11,094	
168	11,422	
216	11,687	
288	12,041	
336	12,251	
384	12,453	
456	12,598	
500	12,683	
Resid. Str.		20.23 ksi
Recovery		
0	7676	
1	6640	
2	6445	
3	6341	

SP313

Test: Creep
Orient: ±45°
Spec. No: A56-2
Temp: 350°F
Stress: 7.66 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6190	
0.016	8268	
0.033	9467	
0.066	13,640	
0.1	14,917	
0.166	15,890	
0.25	18,227	
0.5	27,350	
	No data	
	gage failed	
500	Load taken off	
	No failure	
Resid.	Str.	19.68 ksi
	Recovery	

Test: Creep
Orient: ±45°
Spec. No: A51-1
Temp: 350°F
Stress: 7.66 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0		
0.016		
0.033		
0.05		
0.066		
0.1		
0.166		
0.5		
1		
2		
3		
4		
5		
6		
	No data	
	Gage failed	
504	Load taken off	
	No failure	
Dramatic	neckdown	
width	reduced	8%
thickness	unchanged	
Resid.	Str.	19.6 ksi
	Recovery	

Test: Creep
Orient: ±45°
Spec. No: A57-5
Temp: 350°F
Stress 7.66 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5422	
0.016	6453	
0.1	8066	
0.25	9283	
0.5	10,344	
1	11,724	
2	13,276	
3	14,424	
4	15,450	
5	16,283	
6	17,120	
7	17,684	
7.5	18,020	
	No data	
	Gage failed	
500	Load taken off	
	No failure	
Resid.	Str.	20.7 ksi
	Recovery	

Test: Creep
Orient: +45°
Spec. No: A54-3
Temp: 350°F
Stress: 4.37 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2382	
0.016	2660	
0.05	2954	
0.21	3882	
0.3	4062	
0.4	4492	
0.5	4681	
1	5486	
2	6444	
3	7121	
4	7750	
5	8541	
6		
7	9000	
8	9267	
15	11,152	
24	13,650	
48	17,141	
57	22,105	
58	31,982	
No	data	
Gage	failed	
330	test terminated	
	No failure	
Recovery		

Test: Creep
Orient: +45°
Spec. No: A56-7
Temp: 350°F
Stress: 4.37 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2532	
0.016	2674	
0.05	2875	
0.16	3175	
0.21	3976	
0.3	4181	
0.4	4445	
0.5	4700	
1	4916	
2	5961	
3	7226	
4	8121	
5	8930	
6	9947	
7	10,540	
8	10,880	
15	13,222	
24	15,835	
No	data	
Gage	failed	
330	test terminated	
	No failure	
Recovery		

Test: Creep
Orient: +45°
Spec. No: A58-7
Temp: 350°F
Stress: 4.37 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: A51-11
Temp: 350°F
Stress: 2.19 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1210	
0.016	1483	
0.1	1524	
0.25	1559	
0.5	1595	
1	1652	
2	1747	
3	1816	
4	1886	
5	1941	
6	1998	
7	2047	
8	2090	
72.5	3842	
120.5	4598	
168	5088	
240	5674	
288	6045	
333.5	6352	
432	6853	
456	6971	
500	7212	
Resid.	Str.	20.48 ksi
Recovery		
0	6247	
1	6045	
2	5989	
3	5939	

Test: Creep
Orient: ±45°
Spec. No: A57-7
Temp: 350°F
Stress: 2.19 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5715	
0.016	7207	
0.1	8400	
0.25	9715	
0.5	No data	
	Gage failed	
500	test terminated	
Resid	Str.	15.24 ksi
Recovery		

Test: Creep
Orient: ±45°
Spec. No: A62-7
Temp: 350°F
Stress 2.19 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1270	
0.016	1294	
0.1	1384	
0.25	1476	
0.5	1542	
1	1627	
2	1749	
3	1827	
4	1896	
5	1949	
6	1999	
7	2042	
8	2088	
72.5	3400	
120.5	3990	
168	4528	
240	8827	
288	9203	
333.5	9409	
432	9531	
456	9577	
500	9625	
Resid.	Str.	18.94 ksi
Recovery		
0	8662	
1	8429	
2	8368	
3	8309	

Test: Creep		
Orient: 0°		
Spec. No: C9-2		
Temp: R.T.		
Stress: 150.3 ksi 80% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7465	
0.016	7471	
0.1	7476	
0.25	7482	
0.5	7482	
1.3	7488	
2	7484	
3	7484	
25	7486	
48	7491	
120	7468	
168	7501	
216	7505	
288	7496	
336	7505	
384	7495	
456	7540	
504	7468	
Resid.	Str.	186.4 ksi
Recovery		
0	38	
1	38	
2	39	
3	20	

Test: Creep		
Orient: 0°		
Spec. No: C11-3		
Temp: R.T.		
Stress: 150.3 ksi 80 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7622	
0.016	7633	
0.1	7636	
0.25	7636	
0.5	7636	
1	7640	
2	7640	
3	7654	
4	7657	
5	7660	
6	7667	
7	7668	
8	7672	
24	7672	
48	7653	
72	7657	
144	7758	
192	7737	
240	7756	
312	7768	
360	7750	
406.3	7743	
500	7803	
Resid.	Str.	140.6 ksi
Recovery		
0	218	
1	210	
2	203	
3	210	

Test: Creep		
Orient: 0°		
Spec. No: C12-7		
Temp: R.T.		
Stress 150.3 ksi 80 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8684	
0.016	8692	
0.1	8719	
0.5	8729	
1	8733	
2	8734	
72	8745	
96	8741	
120	8742	
168	8732	
240	8803	
288	8787	
336	8799	
408	8810	
456	8793	
594	8782	
Resid.	Str.	189.0 ksi
Recovery		
0	370	
1	361	
2	359	
3	360	

Test: Creep
Orient: 0°
Spec. No: C12-5
Temp: R.T.
Stress: 131.5 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7130	
0.016	7140	
0.1	7140	
0.25	7147	
0.5	7149	
1.25	7158	
2	7159	
18	7196	
24	7183	
96	7170	
144	7199	
192	7204	
264	7203	
312	7216	
360	7215	
432	7258	
480	7210	82°F
500	7208	82°F
Resid.	Str.	202.4 ksi
Recovery		
0	124	
1	116	
2	127	
3	132	

Test: Creep
Orient: 0°
Spec. No: C9-13
Temp: R.T.
Stress: 131.5 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7365	
0.016	7366	
0.1	7367	
0.25	7371	
0.5	7377	
1.25	7381	
2	7388	
18	7416	
24	7404	
96	7388	
144	7417	
192	7423	
264	7414	
312	7419	
360	7416	
432	7454	
480	7404	82°F
500	7401	82°F
Resid.	Str.	179.4 ksi
Recovery		
0	91	
1	89	
2	97	
3	102	

Test: Creep
Orient: 0°
Spec. No: C11-6
Temp: R.T.
Stress: 131.5 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7665	
0.016	7670	
0.1	7676	
0.25	7678	
0.5	7692	
1.25	7698	
2	7709	
18	7757	
24	7752	
96	7739	
144	7772	
192	7777	
264	7778	
312	7801	
360	7802	
432	7852	
480	7804	82°F
500	7801	82°F
Resid.	Str.	175.8 ksi
Recovery		
0	167	
1	166	
2	166	
3	178	

Note: Lab temperature rose 10°F above normal during last 40 hours.

Test: Creep
Orient: 0°
Spec. No: C8-5
Temp: R.T.
Stress: 112.7 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6508	
0.016	6510	
0.1	6509	
0.25	6508	
0.5	6511	
1.16	6511	
2	6512	
4	6513	
5	6513	
6	6509	
96	6514	
120	6511	
168	6512	
240	6514	
288	6512	
336	6512	
408	6512	
431	6511	
Resid.	Str.	198.5 ksi
Recovery		
0	0	
1	-10	
2	-10	
3	-14	

Test: Creep
Orient: 0°
Spec. No: C7-11
Temp: R.T.
Stress: 112.7 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6174	
0.016	6175	
0.1	6184	
0.25	6188	
0.5	6189	
1.16	6194	
2	6198	
4	6200	
5	6202	
6	6204	
96	6452	
120	6452	
168	6458	
240	6460	
288	6461	
336	6468	
408	6465	
431	6466	
Resid.	Str.	206.5 ksi
Recovery		
0	289	
1	274	
2	273	
3	269	

Test: Creep
Orient: 0°
Spec. No: C7-2
Temp: R.T.
Stress 112.7 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6596	
0.016	6596	
0.1	6596	
0.25	6598	
0.5	6594	
1.16	6596	
2	6598	
4	6598	
5	6599	
6	6600	
96	6605	
120	6604	
168	6605	
240	6606	
288	6607	
336	6610	
408	6607	
431	6601	
Resid.	Str.	187.1 ksi
Recovery		
0	0	
1	-5	
2	-5	
3	-8	

Test: Creep
Orient: 0°
Spec. No: C9-12
Temp: 180°F
Stress: 153.2 ksi 80$ ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8291	
0.016	8424	
0.1	8544	
0.25	8605	
0.5	8652	
1	8695	
2	8732	
3	8755	
5	8785	
6.5	8800	
7	8808	
8	8819	
13	8845	
15	8865	
24	8904	
96	9018	
144	9050	
192	9064	
264	9077	
293	9080	
Resid.	Str.	218.6 ksi
Recovery		
0	692	
1	536	
2	532	
3	528	

Test: Creep
Orient: 0°
Spec. No: C18-8
Temp: 180°F
Stress: 153.2 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8851	
0.016	8860	
0.1	8866	
0.25	8869	
0.5	8871	
1	8874	
2	8866	
3	8864	
4	8856	
5	8866	
6	8868	
7	8868	
8	8862	
24	8870	
48	8875	
120	8895	
168	8898	
214.75	8900	
Resid.	Str.	191.9 ksi
Recovery		
0	168	
1	144	
2	148	
3	142	

Test: Creep
Orient: 0°
Spec. No: C8-13
Temp: 180°F
Stress 153.2 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

Test: Creep		
Orient: 0°		
Spec. No: C7-1		
Temp: 180°F		
Stress: 134.1 ksi 70% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7158	
0.016	7172	
0.1	7182	
0.25	7183	
0.5	7186	
1	7188	
2	7193	
3	7194	
4	7195	
5	7196	
6	7196	
7	7198	
8	7198	
24	7206	
48	7219	
120	7231	
168.6	7246	
216	7261	
Resid.	Str.	189.0 ksi
Recovery		
0	90	
1	76	
2	74	
3	73	

Test: Creep		
Orient: 0°		
Spec. No: C8-4		
Temp: 180°F		
Stress: 134.1 ksi 70% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7408	
0.016	7408	
0.1	7414	
0.25	7414	
0.5	7414	
1	7415	
2	7415	
3	7419	
4	7418	
5	7420	
6	7419	
7	7419	
8	7420	
72	7435	
121	7439	
168	7436	
216	7440	
Resid.	Str.	210.9 ksi
Recovery		
0	28	
1	15	
2	15	
3	14	

Test: Creep		
Orient: 0°		
Spec. No: C11-13		
Temp: 180°F		
Stress 134.1 ksi 70% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7005	
0.016	7003	
0.1	7005	
0.25	7015	
0.5	7016	
1	7016	
2	7017	
3	7027	
4	7028	
5	7028	
6	7029	
7	7035	
8	7040	
10	7058	
24	7060	
49	7063	
96	7060	
192	7089	
216.2	7079	
Resid.	Str.	229.1 ksi
Recovery		
0	92	
1	79	
2	80	
3	130	

AS/3004

Test: Creep
Orient: 0°
Spec. No: C8-2
Temp: 180°F
Stress: 107.5 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5346	
0.1	5360	
0.25	5361	
0.5	5361	
1	5363	
2	5367	
3	5366	
4	5365	
5	5364	
6	5365	
7	5367	
8	5369	
48	5368	
144	5380	
168.5	5377	
216	5379	
288	5378	
336	5377	
384	5382	
432	5376	
476	5379	
Resid.	Str.	192.7 ksi
	Recovery	
0	49	
1.25	33	
2	32	
3	32	

Test: Creep
Orient: 0°
Spec. No: C25-13
Temp: 180°F
Stress: 107.5 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5991	
0.1	5998	
0.25	5995	
0.5	6001	
1	6001	
2	6003	
3	6005	
4	6006	
5	6006	
6	6008	
7	6008	
8	6008	
48	6008	
144	6009	
168.5	6012	
216	6006	
288	6008	
336	6005	
384	6007	
432	6013	
476	6016	
Resid	Str.	150.0 ksi
	Recovery	
0	20	
1.25	6	
2	4	
3	4	

Test: Creep
Orient: 0°
Spec. No: C10-12
Temp: 180°F
Stress 107.5 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5803	
0.1	5805	
0.25	5804	
0.5	5811	
1	5812	
2	5811	
3	5815	
4	5813	
5	5814	
6	5814	
7	5815	
8	5815	
48	5827	
144	5838	
168.5	5836	
216	5837	
288	5834	
336	5843	
384	5843	
432	5835	
476	5832	
Resid.	Str.	203.8 ksi
	Recovery	
0	75	
1.25	57	
2	57	
3	53	

AS/3004

Test: Creep
Orient: 0°
Spec. No: C9-4
Temp: 250°F
Stress: 143.3 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on loading	

Recovery

Test: Creep
Orient: 0°
Spec. No: C13-4
Temp: 250°F
Stress: 143.3 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7850	
0.016	7897	
0.1	7849	
0.25	7852	
0.65	7862	
1.6	7973	
2	7980	
3	7983	
4	8000	
5	8005	
6	8029	
7	8035	
8	8042	
10	8049	
12	8056	
16	8066	
24	8123	
48.4	8155	
168	8263	
216		
288	8390	
312	8404	
Resid	Str.	181.2 ksi

Recovery

0	512	
1	386	
2	372	
3	368	

Test: Creep
Orient: 0°
Spec. No: C14-6
Temp: 250°F
Stress 143.3 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	

Recovery

AS/3004

Test: Creep
Orient: 0°
Spec. No: C14-9
Temp: 250°F
Stress: 125.4 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	9448	
0.016	9540	
0.1	9668	
0.25	9822	
0.5	9870	
1	9906	
2	9968	
3	9975	
4	9990	
5	10,018	
6	10,020	
7	10,040	
8	10,065	
24	10,392	
72	10,611	
120	10,675	
168	10,688	
240	11,037	
Resid	Str.	169.4 ksi
Recovery		
0	2368	
1	1949	
2	1912	
3.25	1885	

Test: Creep
Orient: 0°
Spec. No: C7-10
Temp: 250°F
Stress: 125.4 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7699	
0.016	7758	
0.1	7787	
0.25	7799	
0.5	7806	
1	7820	
2	7825	
3	7834	
4	7838	
5	7848	
6	7848	
7	7853	
8	7853	
24	7884	
72	7920	
120	7937	
168	7952	
240	7970	
Resid	Str.	201.9 ksi
Recovery		
0	1135	
1	1103	
2	1098	
3.25	1086	

Test: Creep
Orient: 0°
Spec. No: C12-6
Temp: 250°F
Stress 125.4 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7240	
0.016	7258	
0.1	7294	
0.25	7301	
0.5	7309	
1	7316	
2	7326	
3	7333	
4	7338	
5	7327	
6	7332	
7	7332	
8	7333	
24	7351	
72	7374	
120	7379	
168	7388	
240	7387	
Resid.	Str.	173.3 ksi
Recovery		
0	416	
1	410	
2	410	
3.25	410	

Test: Creep
Orient: 0°
Spec. No: C13-1
Temp: 250°F
Stress: 107.5 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6319	
0.016	6313	
0.1	6319	
0.25	6324	
0.5	6326	
1	6326	
2	6327	
3	6336	
4	6338	
5	6342	
6	6338	
7	6337	
8	6342	
24	6354	
96	6379	
144	6405	
192	6419	
264	6404	
308	6430	
Resid	Str.	135.5 ksi
Recovery		
0	223	
1	199	
2	194	
3.5	188	

Test: Creep
Orient: 0°
Spec. No: C25-9
Temp: 250°F
Stress: 107.5 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5940	
0.016	5970	
0.1	6003	
0.25	6006	
0.5	6010	
1	6012	
2	6026	
3	6029	
4	6032	
5	6034	
6	6038	
7	6041	
8	6042	
24	6059	
96	6087	
144	6094	
192	6102	
264	6058	
308	6050	
Resid	Str.	185.3 ksi
Recovery		
0	337	
1	307	
2	306	
3.5	298	

Test: Creep
Orient: 0°
Spec. No: C13-8
Temp: 250°F
Stress: 107.5 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	No data	
	gage failed	
308	test terminated	
Resid.	Str.	134.3 ksi
Recovery		

AS/3004

Test: Creep
Orient: 90°
Spec. No: C16-8
Temp: R.T.
Stress: 4.02 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4020	
0.016	4044	
0.05	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: C15-8
Temp: R.T.
Stress: 4.02 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3865	
0.016	3874	
0.1	3884	
0.25	3992	
0.55	3907	
1	3911	
2	3920	
4	3926	
5	3923	
6	3924	
7	3930	
8	3929	
24	3959	
72	4001	
105.4	4100	
	Failed After Restart	

Recovery

Test: Creep
Orient: 90°
Spec. No: C17-6
Temp: R.T.
Stress 4.02 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3428	
0.016	3438	
0.1	3440	
0.25	3455	
0.55	3460	
1	3470	
2	3481	
4	3484	
5	3480	
6	3486	
7	3487	
8	3494	
24	3528	
72	3591	
105.3	Failure	

Recovery

AS/3004

Test: Creep
Orient: 90°
Spec. No: C18-5
Temp: R.T.
Stress: 3.52 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3032	
0.016	3049	
0.1	3062	
0.3	3064	
0.5	3071	
1	3080	
2	3086	
3.3	3090	
4.16	3089	
5.25	3090	
6	3089	
7	3102	
8	3109	
24	3122	
48	3162	
120	3178	
168	3148	
216	3152	
288	3270	
336	3183	
384	3306	
457	3227	
504	3312	
Resid.	Str.	3.71 ksi
	Recovery	
0	288	
1	248	
2	245	
3	240	

Test: Creep
Orient: 90°
Spec. No: C18-7
Temp: R.T.
Stress: 3.52 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3065	
0.016	3077	
0.1	3085	
0.3	3092	
0.5	3095	
1	3105	
2	3115	
3.3	3120	
4.16	3117	
5.25	3117	
6	3117	
7	3131	
8	3137	
24	3149	
48	3189	
120	3202	
168	3175	
216	3178	
288	3293	
336	3200	
384	3326	
457	3244	
504	3329	
Resid.	Str.	6.56 ksi
	Recovery	
0	286	
1	251	
2	245	
3	244	

Test: Creep
Orient: 90°
Spec. No: C18-3
Temp: R.T.
Stress 3.52 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2986	
0.016	2996	
0.1	3005	
0.3	3015	
0.5	3015	
1	3025	
2	3038	
3.3	3040	
4.16	3040	
5.25	3040	
6	3040	
7	3054	
8	3064	
24	3072	
48	3116	
120	3130	
168	3107	
216	3111	
288	3239	
336	3155	
384	3280	
457	3208	
504	3294	
Resid.	Str.	5.49 ksi
	Recovery	
0	321	
1	291	
2	283	
3	284	

Test: Creep
Orient: 90°
Spec. No: C18-1
Temp: R.T.
Stress: 3.01 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2565	
0.016	2711	
0.1	2723	
0.25	2732	
0.5	2744	
1	2765	
2	2765	
18	2724	
24	2777	
48	2836	
96	2838	
168	2789	
216	2842	
264	2861	
336	2886	
384	2896	
432	2838	
522.1	2811	
Resid.	Str.	5.22 ksi
Recovery		
0	171	
1	134	
2	102	
3	100	

Test: Creep
Orient: 90°
Spec. No: C15-2
Temp: R.T.
Stress: 3.01 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2671	
0.016	2820	
0.1	2830	
0.25	2835	
0.5	2843	
1	2869	
2	2864	
18	2831	
24	2873	
48	2920	
96	2943	
168	2888	
216	2954	
264	2942	
336	2961	
384	2974	
432	2920	
522.1	2901	
Resid.	Str.	6.20 ksi
Recovery		
0	114	
1	75	
2	71	
3	70	

Test: Creep
Orient: 90°
Spec. No: C16-2
Temp: R.T.
Stress 3.01 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2774	
0.016	2932	
0.1	2944	
0.25	2952	
0.5	2961	
1	2976	
2	2979	
18	2966	
24	2990	
48	3038	
96	3061	
168	3009	
216	3073	
264	3062	
336	3082	
384	3095	
432	3052	
522.1	3033	
Resid.	Str.	5.60 ksi
Recovery		
0	132	
1	101	
2	94	
3	97	

Test: Creep
Orient: 90°
Spec. No: C17-8
Temp: 180°F
Stress: 2.96 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2666	
0.016	2696	
0.1	2691	
0.25	2699	
0.5	2696	
1.1	2715	
2	2727	
3	2733	
4	2737	
5	2746	
6	2754	
7	2761	
7.75	2765	
53.1	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: C16-7
Temp: 180°F
Stress: 2.96 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2710	
0.016	2727	
6	2734	
1	2745	
3	2756	
4	2764	
5	2766	
47	2808	
77	2823	
168	2833	
216	2841	
264	2840	
360	2852	
385	2851	
433	2860	
505	2859	
Resid.	Str.	5.65 ksi
Recovery		
0	-27	
1	-47	
2	-55	
3	-60	

Test: Creep
Orient: 90°
Spec. No: C15-1
Temp: 180°F
Stress 2.96 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2926	
0.016	2937	
0.1	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: C18-2
Temp: 180°F
Stress: 2.47 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2196	
0.016	2222	
0.1	2234	
0.4	2242	
0.5	2245	
1.16	2246	
2	2246	
3	2242	
19	2237	
24	2237	
48	2246	
96	2270	
168	2291	
216	2295	
264	2307	
336	2311	
384	2321	
432	2330	
504	2332	
Resid.	Str.	4.55 ksi
Recovery		
0	98	
1	87	
2	83	
3	81	

Test: Creep
Orient: 90°
Spec. No: C17-1
Temp: 180°F
Stress: 2.47 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2356	
0.016	2368	
0.1	2375	
0.4	2382	
0.5	2381	
1.16	2387	
2	2387	
3	2387	
19	2390	
24	2389	
48	2406	
96	2423	
168	2442	
216	2453	
264	2459	
336	2473	
384	2491	
432	2486	
504	2498	
Resid.	Str.	3.53 ksi
Recovery		
0	186	
1	160	
2	151	
3	145	

Test: Creep
Orient: 90°
Spec. No: C18-6
Temp: 180°F
Stress 2.47 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2172	
0.016	2176	
0.1	2188	
0.4	2187	
0.5	2188	
1.16	2188	
2	2188	
3	2186	
19	2170	
24	2167	
48	2176	
96	2189	
168	2203	
216	2207	
264	2212	
336	2220	
384	2230	
432	2238	
504	2241	
Resid.	Str.	5.58 ksi
Recovery		
0	49	
1	48	
2	45	
3	42	

Test: Creep
Orient: 90°
Spec. No: C38-1
Temp: 180°F
Stress: 1.97 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1827	
0.016	1836	
0.25	1846	
0.6	1850	
1.16	1854	
2.25	1857	
3	1860	
5	1865	
6	1867	
8	1873	
72	1894	
120	1905	
170	1901	
266	1905	
288	1904	
336	1908	
408	1910	
456	1908	
504	1906	
Resid.	Str.	3.79 ksi
Recovery		
0	58	
1	45	
2	44	
3	44	

Test: Creep
Orient: 90°
Spec. No: C29-7
Temp: 180°F
Stress: 1.97 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1612	
0.016	1614	
0.1	1608	
0.25	1608	
0.6	1610	
1.16	1613	
2.25	1616	
3	1615	
5	1618	
6	1623	
8	1624	
72	1644	
120	1653	
170	1650	
266	1668	
288	1664	
336	1670	
408	1670	
456	1680	
504	1668	
Resid.	Str.	5.51 ksi
Recovery		
0	84	
1	76	
2	74	
3	72	

Test: Creep
Orient: 90°
Spec. No: C31-3
Temp: 180°F
Stress 1.97 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1763	
0.016	1764	
0.1	1770	
0.25	1774	
0.6	1775	
1.16	1783	
2.25	1784	
3	1784	
5	1793	
6	1793	
8	1798	
72	1822	
120	1834	
170	1834	
266	1845	
288	1843	
336	1854	
408	1859	
456	1859	
504	1856	
Resid.	Str.	6.74 ksi
Recovery		
0	116	
1	101	
2	100	
3	97	

AS/3004

Test: Creep
Orient: 90°
Spec. No: C29-3
Temp: 250°F
Stress: 2.70 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2383	
0.016	2428	
0.1	2478	
0.25	2568	
0.5	2658	
1	2762	
1.6	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: C15-3
Temp: 250°F
Stress: 2.70 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2775	restart
0.016	2778	
0.1	2781	
0.25	2793	
0.5	2807	
7	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: C29-4
Temp: 250°F
Stress 2.70 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2324	
0.016	2320	
0.1	2335	
0.25	2363	
0.6	2375	
1	2387	
2	2401	
3	2415	
4	2420	
5	2427	
6	2438	
7	2441	
24	2511	
43.3	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: C34-7
Temp: 250°F
Stress: 2.12 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2006	
0.016	2023	
0.1	2036	
0.25	2042	
0.5	2058	
1	2066	
2.25	2080	
3	2085	
4	2093	
5	2099	
6	2103	
7	2106	
8	2110	
24	2155	
48	2200	
120	2262	
168	2282	
216	2298	
288	2326	
336	2343	
357.8	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: C31-6
Temp: 250°F
Stress: 2.12 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2028	
0.016	2070	
0.1	2180	
0.25	2224	
0.5	2316	
1	2476	
2	2742	
2.8	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: C34-2
Temp: 250°F
Stress 2.12 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2031	
0.016	2049	
0.1	2068	
0.25	2075	
0.5	2090	
1	2100	
2.25	2110	
3	2117	
4	2125	
5	2129	
6	2135	
7	2137	
8	2142	
24	2192	
48	2243	
120	2316	
168	2342	
216	2360	
288	2392	
336	2408	
338	Test terminated	
Resid.	Str.	2.86 ksi

Recovery

Test: Creep
Orient: 90°
Spec. No: C31-5
Temp: 250°F
Stress: 1.62 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1397	
0.016	1425	
0.1	1433	
0.25	1437	
0.5	1438	
1	1438	
2	1441	
3	1443	
4	1444	
5	1444	
6	1447	
7	1449	
8	1449	
24	1460	
48	1470	
96	1490	
168	1508	
216.5	1525	
264	1535	
346	1587	
349.3	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: C34-5
Temp: 250°F
Stress: 1.62 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1460	
0.016	1465	
0.1	1469	
0.25	1476	
0.5	1484	
1	1488	
2	1500	
3	1517	
4	1514	
5	1518	
6	1520	
7	1526	
8	1528	
24	1570	
96	1670	
144	1723	
192	1778	
245.8	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: C34-4
Temp: 250°F
Stress 1.62 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1570	
0.016	1583	
0.1	1588	
0.25	1589	
0.5	1592	
1	1595	
2	1598	
3	1596	
20.3	Failure	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: C41-1
Temp: R.T.
Stress: 9.61 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8920	
0.016	9363	
0.1	10,107	
0.25	10,483	
0.5	10,808	
1	11,183	
1.5	11,413	
2	11,584	
3	11,853	
4	12,034	
5	12,157	
6	12,274	
7	12,363	
24	13,085	
48	13,493	
72	13,756	
96	13,984	
168	14,344	
216	14,500	
264	14,641	
336	14,784	
384	14,972	
432	15,109	
504	15,222	
Resid.	Str.	29.24 ksi
	Recovery	
0	8764	
1	8090	
2	7997	
3.25	7936	

Test: Creep
Orient: ±45°
Spec. No: C41-5
Temp: R.T.
Stress: 9.61 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6950	
0.016	7381	
0.1	7746	
0.25	7992	
0.5	8175	
1	8397	
1.5	8534	
2	8633	
3	8793	
4	8894	
5	8964	
6	9030	
7	9082	
24	9499	
48	9730	
72	9884	
96	10,015	
168	1228	
216	10,288	
264	10,376	
336	10,429	
384	10,575	
432	10,662	
504	10,724	
Resid.	Str.	23.35 ksi
	Recovery	
0	5118	
1	4692	
2	4619	
3.25	4574	

Test: Creep
Orient: ±45°
Spec. No: C24-1
Temp: R.T.
Stress 9.61 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9248	
0.016	9806	
0.1	10,310	
0.25	10,739	
0.5	11,016	
1	11,372	
1.5	11,578	
2	11,743	
3	11,988	
4	12,153	
5	12,263	
6	12,369	
7	12,451	
24	13,107	
48	13,476	
72	13,717	
96	13,923	
168	14,236	
216	14,374	
264	14,508	
336	14,618	
384	14,799	
432	14,930	
504	15,028	
Resid.	Str.	28.25 ksi
	Recovery	
0	7923	
1	7369	
2	7275	
3.25	7215	

AS/3004

Test: Creep
Orient: ±45°
Spec. No: C41-2
Temp: R.T.
Stress: 6.41 ksi 20 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3638	
0.016	3804	
0.1	3897	
0.25	3938	
0.75	4005	
1	4027	
2	4082	
3	4114	
4	4138	
5	4159	
6	4178	
7	4193	
8	4211	
24	4308	
96	4429	
144	4482	
192	4517	
264	4521	
312	4532	
360	4548	
432	4540	
480	4591	
502	4594	
Resid.	Str.	31.00 ksi
	Recovery	
0	1257	
1	1063	
2	1040	
3	1022	

Test: Creep
Orient: ±45°
Spec. No: C41-4
Temp: R.T.
Stress: 6.41 ksi 20 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3400	
0.016	3504	
0.1	3579	
0.25	3613	
0.75	3664	
1	3681	
2	3724	
3	3748	
4	3766	
5	3783	
6	3798	
7	3812	
8	3824	
24	3900	
96	4005	
144	4054	
192	4076	
264	4089	
312	4097	
360	4109	
432	4101	
480	4144	
502	4146	
Resid.	Str.	25.42 ksi
	Recovery	
0	1015	
1	877	
2	853	
3	841	

Test: Creep
Orient: ±45°
Spec. No: C41-7
Temp: R.T.
Stress 6.41 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3468	
0.016	3543	
0.1	3609	
0.25	3643	
0.75	3691	
1	3707	
2	3752	
3	3774	
4	3792	
5	3819	
6	3824	
7	3838	
8	3850	
24	3929	
96	4050	
144	4101	
192	4132	
264	4148	
312	4157	
360	4171	
432	4167	
480	4237	
502	4248	
Resid.	Str.	29.46 ksi
	Recovery	
0	988	
1	865	
2	838	
3	831	

Test: Creep		
Orient: +45°		
Spec. No: C21-8		
Temp: R.T.		
Stress: 3.20 ksi 10 % ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1595	
0.016	1648	
0.1	1660	
0.25	1670	
0.5	1674	
1	1682	
2	1691	
3	1696	
4	1702	
5	1700	
6	1711	
7	1718	
8	1722	
25.5	1745	
48.5	1752	
72	1800	
144	1885	
192	1857	
240	1878	
312	1893	
361	1891	
409	1893	
504	1926	
Resid.	Str.	30.36 ksi
Recovery		
0	342	
1	305	
2	297	
3	293	

Test: Creep		
Orient: +45°		
Spec. No: C22-2		
Temp: R.T.		
Stress: 3.20 ksi 10% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1616	
0.016	1645	
0.1	1669	
0.25	1679	
0.5	1687	
1	1701	
2	1712	
3	1720	
4	1729	
5	1737	
6	1744	
7	1752	
8	1755	
25.5	1785	
48.5	1793	
72	1844	
144	1951	
192	1922	
240	1944	
312	1962	
361	1958	
409	1960	
504	2005	
Resid.	Str.	32.15 ksi
Recovery		
0	451	
1	407	
2	401	
3	396	

Test: Creep		
Orient: +45°		
Spec. No: C21-4		
Temp: R.T.		
Stress 3.20 ksi 10% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1490	
0.016	1510	
0.1	15[illegible]7	
0.25	1570	
0.5	1580	
1	1588	
2	1597	
3	1602	
4	1610	
5	1616	
6	1621	
7	1628	
8	1631	
25.5	1655	
48.5	1659	
72	1707	
144	1819	
192	1792	
240	1812	
312	1828	
361	1823	
409	1824	
504	1872	
Resid.	Str.	25.58 ksi
Recovery		
0	422	
1	380	
2	371	
3	369	

Test: Creep
Orient: ±45°
Spec. No: C48-5
Temp: 180°F
Stress: 8.33 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7038	
0.016	8177	
0.1	8745	
0.25	8947	
0.5	9120	
1	9366	
2	9587	
3	9718	
4	9810	
8	10,038	
9	10,080	
10	10,119	
24	10,416	
96	10,982	
144	11,160	
192	11,299	
266	11,465	
312	11,532	
360	11,603	
442	11,681	
480	11,758	
500.1	11,780	
Resid.	Str.	31.40 ksi
	Recovery	
0	7132	
1	6763	
2	6675	
3	6647	

Test: Creep
Orient: ±45°
Spec. No: C42-7
Temp: 180°F
Stress: 8.33 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8090	
0.016	9068	
0.1	9286	
0.25	9413	
0.5	9498	
1	9612	
2	9740	
3	9832	
4	9900	
8	10,092	
9	10,128	
10	10,163	
24	10,447	
96	11,018	
144	11,229	
192	11,371	
266	11,557	
312	11,631	
360	11,723	
442	11,800	
480	11,870	
500.1	11,903	
Resid.	Str.	32.97 ksi
	Recovery	
0	7090	
1	6657	
2	6561	
3	6534	

Test: Creep
Orient: ±45°
Spec. No: C48-3
Temp: 180°F
Stress 8.33 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9999	
0.016	11,039	
0.1	11,361	
0.25	11,410	
0.5	11,452	
1	11,519	
2	11,598	
3	11,660	
4	11,713	
8	11,862	
9	11,890	
10	11,922	
24	12,158	
96	12,651	
144	12,822	
192	12,957	
266	13,123	
312	13,203	
360	13,294	
442	13,361	
480	13,427	
500.1	13,454	
Resid.	Str.	34.38 ksi
	Recovery	
0	8520	
1	7832	
2	7728	
3	7694	

Test: Creep
Orient: ±45°
Spec. No: C47-5
Temp: 180°F
Stress: 5.55 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3400	
0.016	3517	
0.1	3594	
0.25	3626	
0.5	3654	
1	3699	
2	3731	
3	3757	
4	3787	
5	3804	
6	3813	
7	3821	
24	3953	
48	4050	
96	4202	
168	4283	
216	4312	
264	4349	
336	4377	
384	4406	
432	4426	
504	4459	
Resid.	Str.	31.47 ksi
Recovery		
0	1408	
1	1240	
2	1220	
3	1197	

Test: Creep
Orient: ±45°
Spec. No: C47-1
Temp: 180°F
Stress: 5.55 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3862	
0.016	3973	
0.1	4082	
0.25	4163	
0.5	4222	
1	4281	
2	4348	
3	4388	
4	4418	
5	4440	
6	4456	
7	4474	
24	4626	
48	4720	
96	4837	
168	4936	
216	4972	
264	5018	
336	5061	
384	5086	
432	5110	
504	5132	
Resid.	Str.	28.33 ksi
Recovery		
0	1742	
1	1550	
2	1516	
3	1493	

Test: Creep
Orient: ±45°
Spec. No: C47-6
Temp: 180°F
Stress 5.55 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3477	
0.016	3656	
0.1	3724	
0.25	3752	
0.5	3778	
1	3812	
2	3852	
3	3878	
4	3894	
5	3910	
6	3921	
7	3936	
24	4049	
48	4130	
96	4224	
168	4302	
216	4330	
264	4361	
336	4394	
384	4418	
432	4440	
504	4458	
Resid.	Str.	32.68 ksi
Recovery		
0	1322	
1	1184	
2	1159	
3	1137	

Test: Creep
Orient: ±45°
Spec. No: C22-1
Temp: 180°F
Stress: 2.78 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1522	
0.016	1553	
0.1	1590	
0.25	1607	
0.5	1618	
1	1630	
3	1664	
4	1680	
24	1757	
48	1791	
144	1856	
168	1869	
216	1891	
288	1910	
336	1910	
384	1922	
456	1930	
504	1967	
Resid.	Str.	30.99 ksi
Recovery		
0	525	
1	490	
2	485	
3	481	

Test: Creep
Orient: ±45°
Spec. No: C23-8
Temp: 180°F
Stress: 2.78 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1419	
0.016	1436	
0.1	1462	
0.25	1473	
0.5	1482	
1	1493	
3	1521	
4	1534	
24	1588	
48	1621	
144	1673	
168	1680	
216	1696	
288	1713	
336	1710	
384	1717	
456	1723	
504	1741	
Resid.	Str.	33.79 ksi
Recovery		
0	397	
1	354	
2	349	
3	345	

Test: Creep
Orient: ±45°
Spec. No: C24-7
Temp: 180°F
Stress 2.78 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1367	
0.016	1375	
0.1	1397	
0.25	1406	
0.5	1413	
1	1420	
2		
3	1445	
4	1456	
24	1508	
48	1534	
144	1585	
168	1599	
216	1611	
288	1623	
336	1620	
384	1629	
456	1631	
504	1648	
Resid.	Str.	31.04 ksi
Recovery		
0	360	
1	331	
2	322	
3	316	

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Test: Creep
Orient: +45°
Spec. No: C45-2
Temp: 250°F
Stress: 7.29 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	9280	
0.008	10,770	
0.025	12,090	
0.05	12,856	
0.1	14,942	
0.15	15,268	
0.2	15,330	
0.25	15,381	
0.5	15,558	
1	15,774	
2	16,111	
3	16,321	
4	16,506	
5	16,677	
6	16,802	
7	16,928	
8	17,020	
10	17,280	
12	17,442	
14	17,610	
16	17,762	
18	17,905	
20	18,019	
23	18,708	
72	19,863	
120	20,737	
168	21,359	
216	22,009	
Recovery		

Continued on next page

Test: Creep
Orient: +45°
Spec. No: C43-3
Temp: 250°F
Stress: 7.29 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7716	
0.008	8042	
0.025	8160	
0.05	8332	
0.1	9330	
0.15	9524	
0.2	9633	
0.25	9692	
0.5	10,043	
1	10,377	
2	10,830	
3	11,076	
4	11,281	
5	11,475	
6	11,614	
7	11,749	
8	11,902	
10	12,103	
12	12,251	
14	12,422	
16	12,558	
18	12,695	
20	12,807	
23	12,970	
72	14,444	
120	15,244	
168	15,794	
216	16,378	
Recovery		

Continued on next page

Test: Creep
Orient: +45°
Spec. No: C42-6
Temp: 250°F
Stress 7.29 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7902	
0.008	12,022	
0.025	12,661	
0.05	13,180	
0.1	13,239	
0.15	13,258	
0.2	13,260	
0.25	13,273	
0.5	13,346	
1	13,441	
2	13,578	
3	13,674	
4	13,762	
5	13,848	
6	13,907	
7	13,967	
8	14,031	
10	14,123	
12	14,209	
14	14,315	
16	14,393	
18	14,471	
20	14,535	
23	14,636	
72	15,557	
120	16,124	
168	16,598	
216	17,124	
Recovery		

Continued on next page

C45-2 continued

Test: Creep
Orient: ±45°
Spec. No: C45-2
Temp: 250°F
Stress: 7.29 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
288.8	22,378	
336	22,668	
408	23,054	
456	23,286	
506.5	23,487	
Resid.	Str.	31.21 ksi
Recovery		
0	19,264	
1	18,629	
2	18,521	
3	18,493	

C43-3 continued

Test: Creep
Orient: ±45°
Spec. No: C43-3
Temp: 250°F
Stress: 7.29 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
288.8	16,695	
336	16,970	
408	17,305	
456	17,522	
506.5	17,704	
Resid.	Str.	33.36 ksi
Recovery		
0	13,162	
1	11,939	
2	11,798	
3	11,780	

C42-6 continued

Test: Creep
Orient: ±45°
Spec. No: C42-6
Temp: 250°F
Stress 7.29 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
288.8	17,432	
336	17,677	
408	18,022	
456	18,219	
506.5	18,406	
Resid.	Str.	25.29 ksi
Recovery		
0	14,520	
1	14,292	
2	14,259	
3	14,247	

Test: Creep
Orient: ±45°
Spec. No: C48-4
Temp: 250°F
Stress: 4.86 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3093	
0.016	3357	
0.1	4162	
0.3	4346	
0.5	4422	
1	4608	
2.2	4882	
3	4937	
4	4998	
5	5049	
6	5098	
7	5153	
8	5252	
24	5712	
48	6127	
120	6722	
168	6993	
216	7212	
288	7452	
336	7589	
384	7708	
Test terminated		
Resid.	Str.	27.41 ksi
Recovery		

Test: Creep
Orient: ±45°
Spec. No: C48-7
Temp: 250°F
Stress: 4.86 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3814	
0.016	4344	
0.1	4908	
0.3	5144	
0.5	5254	
1	5608	
2.2	Gage failed	
391.8	Failure	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: C47-7
Temp: 250°F
Stress 4.86 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3185	
0.016	3253	
0.1	3428	
0.3	4063	
0.5	4100	
1	4180	
2.2	4288	
3	4339	
4	4386	
5	4427	
6	4459	
7	4482	
8	4540	
24	4782	
48	4992	
120	5336	
168	5467	
216	5566	
288	5681	
336	5757	
384	5821	
Test terminated		
Resid.	Str.	32.28 ksi
Recovery		

Test: Creep
Orient: ±45°
Spec. No: C50-3
Temp: 250°F
Stress: 2.43 ksi 10 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1220	
0.016	1388	
0.1	1444	
0.25	1415	
0.5	1423	
1	1432	
2	1437	
3.5	1449	
5	1457	
6	1464	
7	1471	
8	1475	
24	1538	
72	1632	
144	1710	
192	1750	
240.4	1786	
312	1819	
360.2	1838	
408	1865	
480	1922	
528	1960	
Resid	Str.	34.85 ksi
Recovery		
0	785	
1	740	
2	725	
3	721	

Test: Creep
Orient: ±45°
Spec. No: C50-8
Temp: 250°F
Stress: 2.43 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1442	
0.016	1642	
0.1	1638	
0.25	1684	
0.5	1705	
1	1742	
2	1769	
3.5	1800	
5	1824	
6	1837	
7	1847	
8	1858	
24	1950	
72	2109	
144	2218	
192	2270	
240.4	2315	
312	2352	
360.2	2387	
408	2420	
480	2462	
528	2492	
Resid.	Str.	33.27 ksi
Recovery		
0	1340	
1	1310	
2	1237	
3	1223	

Test: Creep
Orient: ±45°
Spec. No: C48-2
Temp: 250°F
Stress 2.43 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1631	
	No data	
	gage failed	
528	no failure	
Resid	Str.	32.94 ksi
Recovery		

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Test: Creep
Orient: 0°
Spec. No: D46-1
Temp: R.T.
Stress: 182.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8912	
0.016	8911	
0.1	8913	
0.25	8914	
0.5	8914	
1	8922	
2.25	8924	
4	8922	
5.15	8924	
6	8925	
7	8926	
24	8926	
120	8931	
218	8933	
290	8937	
336.5	8935	
385	8933	
505.7	8935	
Resid.	Str.	201.0 ksi
Recovery		
0	46	
1	35	
2	22	
3	23	

Test: Creep
Orient: 0°
Spec. No: D46-13
Temp: R.T.
Stress: 182.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8455	
0.016	8459	
0.1	8460	
0.25	8461	
0.5	8462	
1	8466	
2	8463	
3	8462	
4	8463	
5	8464	
6	8465	
7	8465	
8	8463	
96	8462	
120	8465	
144	8464	
168	8466	
264	8459	
313.5	8459	
362	8458	
434	8459	
482.5	8465	
531	8461	
Resid.	Str.	206.5 ksi
Recovery		
0	38	
1	22	
2	22	
3	22	

Test: Creep
Orient: 0°
Spec. No: D46-7
Temp: R.T.
Stress 182.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	10,382	
0.016	10,395	
0.1	10,403	
0.25	10,401	
0.5	10,403	
1	10,406	
2	10,407	
3	10,408	
4	10,408	
5	10,408	
6	10,412	
7	10,408	
8	10,408	
96	10,441	
120	10,447	
144	10,439	
168	10,445	
264.2	10,444	
312	10,448	
362	10,444	
434	10,445	
482	10,450	
531	10,525	
Resid.	Str.	233.4 ksi
Recovery		
	no data	

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Test: Creep
Orient: 0°
Spec. No: D5-7
Temp: R.T.
Stress: 161.9 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7463	
1	7464	
2	7464	
3	7467	
4	7467	
5	7471	
6	7471	
7	7472	
19	7479	
24	7465	
48	7465	
72	7467	
96	7470	
168	7471	
336	7473	
384	7466	
433	7473	
504	7472	
522	7477	
Resid.	Str.	234.4 ksi
Recovery		
0	42	
3	25	

Test: Creep
Orient: 0°
Spec. No: D6-17
Temp: R.T.
Stress: 161.9 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7867	
1	7867	
2	7869	
3	7873	
4	7875	
5	7875	
6	7877	
7	7877	
19	7885	
24	7870	
48	7870	
72	7868	
96	7868	
168	7869	
336	7869	
384	7864	
433	7869	
504	7871	
522	7876	
Resid.	Str.	188.7 ksi
Recovery		
0	30	
3	10	

Test: Creep
Orient: 0°
Spec. No: D7-19
Temp: R.T.
Stress 161.9 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8519	
1	8519	
2	8520	
3	8522	
4	8525	
5	8522	
6	8526	
7	8525	
19	8535	
24	8521	
48	8525	
72	8525	
96	8528	
168	8530	
336	8533	
384	8528	
433	8533	
504	8537	
522	8534	
Resid.	Str.	185.8 ksi
Recovery		
0	56	
3	35	

Test: Creep
Orient: 0°
Spec. No: D1-14
Temp: R. T.
Stress: 141.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7360	
0.016	7369	
0.1	7375	
0.25	7375	
0.5	7371	
3	7381	
26	7382	
120	7388	
168	7408	
216	7415	
264	7398	
336	7388	
360	7383	
384	7404	
408	7375	
432	7384	
504	7379	
Resid.	Str.	204.0 ksi
Recovery		
0	19	
1.25	2	
2	-4	
3	-4	

Test: Creep
Orient: 0°
Spec. No: D3-13
Temp: R, T.
Stress: 141.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7138	
0.016	7140	
0.1	7144	
0.25	7145	
0.5	7146	
3	7152	
26	7153	
120	7162	
168	7179	
216	7186	
264	7170	
336	7179	
360	7153	
384	7175	
408	7145	
432	7150	
504	7146	
Resid.	Str.	218.6 ksi
Recovery		
0	-6	
1.25	-22	
2	-23	
3	-24	

Test: Creep
Orient: 0°
Spec. No: D4-13
Temp: R. T.
Stress 141.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7253	
0.016	7255	
0.1	7260	
0.25	7257	
0.5	7259	
3	7261	
26	7256	
120	7273	
168	7290	
216	7297	
264	7284	
336	7274	
360	7270	
384	7290	
408	7260	
432	7269	
504	7267	
Resid.	Str.	232.4 ksi
Recovery		
0	38	
1.25	11	
2	4	
3	1	

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Test: Creep

Orient: 0°

Spec. No: D5-4

Temp: 350°

Stress: 131.2 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6746	
0.016	6746	
0.1	6753	
0.25	6753	
0.5	6755	
1	6760	
2	6766	
3	6769	
4	6774	
5	6773	
6	6775	
72	6837	
120	6854	
168	6870	
240	6884	
264	6894	
288	6901	
312	6909	
336	6923	
408	6953	
456	6965	
504	6946	
576	6961	
Resid.	Str.	217.1 ksi
Recovery		
0	284	
4	187	

Test: Creep

Orient: 0°

Spec. No: D46-6

Temp: 350°

Stress: 131.2 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6539	
0.016	6542	
0.1	6538	
0.25	6545	
0.5	6546	
1.1	6552	
3.5	6564	
4	6569	
5	6571	
6	6575	
7	6579	
24	6646	
49	6695	
72	6717	
96	6743	
168	6770	
192	6786	
240	6806	
264	6821	
385	6833	
432.5	6823	
504.5	6828	
Resid.	Str.	162.7 ksi
Recovery		
0	344	
1	332	
2	328	
3	324	

Test: Creep

Orient: 0°

Spec. No: D1-1

Temp: 350°

Stress 131.2 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on	Loading
Recovery		

Test: Creep		
Orient: 0°		
Spec. No: D46-11		
Temp: 350°F		
Stress: 112.5 ksi 60% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5548	
0.016	5558	
0.134	5562	
0.25	5564	
0.5	5577	
1.5	5578	
2	5576	
3	5585	
5	5589	
6	5592	
7	5593	
8	5593	
24.5	5632	
48	5657	
72	5707	
96	5668	
170.2	5720	
216	5796	
240	5835	
268	5840	
341	5850	
365	5868	
384	5882	
409	5904	
432	5921	
504	5947	
Resid.	Str.	229.7 ksi
Recovery		
0	358	
1	352	
2	340	
3	311	

Test: Creep		
Orient: 0°		
Spec. No: D4-2		
Temp: 350°F		
Stress: 112.5 ksi 60% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5757	
0.016	5744	
0.1	5768	
0.3	5772	
0.5	5772	
1	5776	
2.16	5776	
3.25	5776	
4.5	5780	
6	5787	
24	5776	
49	5785	
63	5800	
87	5814	
159	5809	
184	5802	
208.1	5800	
256	5802	
328	5793	
376	5803	
424.1	5822	
496	5831	
544	5840	
Resid.	Str.	211.1 ksi
Recovery		
0	112	
1	96	
2	105	
3	98	

Test: Creep		
Orient: 0°		
Spec. No: D3-6		
Temp: 350°F		
Stress 112.5 ksi 60% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5816	
0.016	5826	
0.1	5850	
0.3	5853	
0.5	5853	
1	5854	
2.16	7873	
3.25	5873	
4.5	5881	
6	5893	
24	5928	
49	5996	
63	6052	
87	6106	
159	6224	
184	6268	
208.1	6298	
256	6374	
328	6451	
376	6497	
424.1	6573	
496	6646	
544	6686	
Resid.	Str.	184.2 ksi
Recovery		
0	868	
1	862	
2	852	
3	836	

Test: Creep
Orient: 0°
Spec. No: D7-5
Temp: 350°F
Stress: 93.7 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4948	
0.066	5023	
0.1	4946	
0.25	4945	
0.5	4953	
1	4953	
2	4958	
3	4965	
4.6	4969	
5	4971	
6.5	4978	
7	4978	
8	4981	
24.25	4983	
72	4927	
144	4867	
192	4828	
240	4756	
312.8	4754	
336	4742	
360	4728	
480	4721	
552	4699	
576	4690	
Resid	Str.	203.0 ksi
Recovery		
0	-193	
1	-187	
2	-213	
3	-217	

Test: Creep
Orient: 0°
Spec. No: D6-4
Temp: 350°F
Stress: 93.7 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5005	
0.066	5008	
0.1	5010	
0.25	5007	
0.5	5010	
1	5011	
2	5013	
3	5015	
4.6	5020	
5	5023	
6.5	5024	
7	5022	
8	5024	
24.25	5021	
72	5024	
144	5054	
192	5061	
240	5107	
312.8	5086	
336	5086	
360	5090	
480	5115	
552	5104	
576	5106	
Resid.	Str.	212.6 ksi
Recovery		
0	89	
1	108	
[illegible]	89	
[illegible]	79	

Test: Creep
Orient: 0°
Spec. No: D5-15
Temp: 350°F
Stress 93.7 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4326	
0.066	4328	
0.1	4327	
0.25	4331	
0.5	4331	
1	4332	
2	4333	
3	4333	
4.6	4334	
5	5335	
6.5	4333	
7	4335	
8	4337	
24.25	4386	
72	4375	
144	4358	
192	4329	
240	4299	
312.8	4253	
336	4242	
360	4234	
480	4210	
552	4184	
576	4189	
Resid	Str.	213.5
Recovery		
0	170	
1	184	
2	173	
3	177	

Test: Creep
Orient: 0°
Spec. No: D5-11
Temp: 450°F
Stress: 144.5 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Gage failed on loading	

Recovery

Test: Creep
Orient: 0°
Spec. No: D6-1
Temp: 450°F
Stress: 144.5 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7859	
0.016	7864	
0.1	7877	
0.25	7886	
0.5	7896	
1	Failure	

Recovery

Test: Creep
Orient: 0°
Spec. No: D7-11
Temp: 450°F
Stress: 144.5 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7419	
0.016	7425	
0.1	7425	
0.25	7448	
0.5	7453	
1	Failure	

Recovery

Test: Creep
Orient: 0°
Spec. No: D4-18
Temp: 450°F
Stress: 123.9 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6341	
0.016	6365	
0.1	6438	
0.25	6463	
0.5	6360	
1	6345	
2	6371	
4	6407	
5	6454	
72	7872	
144	9487	
168	9731	
240	11,290	
288	11,817	
312	12,627	
337	12,898	
409	13,652	
457	14,070	
481	14,222	
577	14,650	
Resid.	Str.	208.3 ksi
Recovery		
0	8592	
1	8574	
2	8565	
3	8563	

Test: Creep
Orient: 0°
Spec. No: D7-8
Temp: 450°F
Stress: 123.9 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6066	
0.016	6076	
0.1	6076	
0.25	6076	
0.5	6071	
1	6064	
2	6055	
3	6049	
4	6044	
8	6029	
24	6055	
96	7048	
120	7255	
264	8278	
312	8467	
362	8650	
432	8839	
479	8951	
522	9004	
Resid.	Str.	177.9 ksi
Recovery		
0	3540	
1.3	3665	
2.3	3695	
3	3686	

Test: Creep
Orient: 0°
Spec. No: D5-19
Temp: 450°F
Stress 123.9 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6965	
0.016	6998	
0.1	7067	
0.25	7165	
0.5	7307	
1	7428	
2	7468	
3	7496	
4	7502	
6	7557	
6.8	7573	
12.6	Failure	
Recovery		

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Test: Creep
Orient: 0°
Spec. No: D6-8
Temp: 450°F
Stress: 103.2 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on	Loading

Recovery

Test: Creep
Orient: 0°
Spec. No: D46-8
Temp: 450°F
Stress: 103.2 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5293	
0.016	5306	
0.1	5312	
0.25	5321	
0.5	5329	
1	5352	
2	5378	
3	5415	
4	5432	
5	5458	
6	5485	
7	5513	
8	5583	
24	5944	
50	6617	
120	8292	
168.5	9249	
216	10,192	
289	11,484	
385	12,612	
481	13,423	
505	13,594	
Resid.	Str.	212.0 ksi
Recovery		
0	8515	
1	8564	
2	8570	
3	8570	

Test: Creep
Orient: 0°
Spec. No: D46-10
Temp: 450°F
Stress 103.2 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5157	
0.016	5165	
0.1	5180	
0.25	5198	
0.5	5203	
1	5174	
2	5180	
3	5212	
4	5182	
5	5182	
6	5180	
7	5205	
8	5190	
24	5192	
50	5183	
120	5183	
168.5	5192	
216	5190	
289	5143	
385	5133	
481	5164	
505	5174	
Resid.	Str.	224.0 ksi
Recovery		
0	96	
1	68	
2	56	
3	9	

AS/4397

Test: Creep
Orient: 90°
Spec. No: D20-4
Temp: R.T.
Stress: 4.83 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3237	
0.016	3257	
0.15	3370	
0.25	3382	
0.5	3399	
1.3	3420	
2.3	3418	
3.3	3427	
4	3432	
5	3442	
6	3444	
24	3498	
48	3548	
120.1	3651	
168	3655	
216.2	3646	
288	3808	
336	3758	
388	3810	
456	3822	
508	3842	
Resid.	Str.	5.06 ksi
Recovery		
0	530	
1	432	
2	422	
3	412	

Test: Creep
Orient: 90°
Spec. No: D23-4
Temp: R.T.
Stress: 4.83 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on	Loading
Recovery		

Test: Creep
Orient: 90°
Spec. No: D23-10
Temp: R.T.
Stress 4.83 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on	Loading
Recovery		

Test: Creep

Orient: 90°

Spec. No: D14-4

Temp: R.T.

Stress: 4.29 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3028	
0.016	3050	
0.05	3062	
0.1	3092	
0.25	3087	
0.5	3099	
1	3115	
2	3122	
3	3146	
4	3153	
5	3162	
6	3169	
7	3178	
8	3182	
25	3241	
48	3298	
121	3350	
168	3417	
216	3464	
312	3511	
384	3601	
456	3605	
504	3636	
Resid.	Str.	4.82 ksi
	Recovery	
0	620	
1	562	
2	539	

Test: Creep

Orient: 90°

Spec. No: D21-4

Temp: R.T.

Stress: 4.29 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3007	
0.016	3036	
0.05	3050	
0.1	3063	
0.25	3078	
0.5	3094	
1	3112	
2	3130	
3	3146	
4	3165	
5	3173	
6	3180	
7	3187	
8	3193	
25	3261	
48	3323	
121	3380	
168	3448	
216	3495	
312	3541	
384	3576	
456	3636	
504	3668	
Resid.	Str.	6.23 ksi
	Recovery	
0	635	
1	653	
2	629	

Test: Creep

Orient: 90°

Spec. No: D12-1

Temp: R.T.

Stress 4.29 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3030	
0.016	3068	
0.05	3080	
0.1	3090	
0.25	3105	
0.5	3115	
1	3131	
2	3146	
3	3162	
4	3178	
5	3185	
6	3191	
7	3196	
8	3203	
25	3263	
48	3321	
121	3376	
168	3440	
216	3487	
312	3535	
384	3597	
456	3627	
504	3660	
Resid.	Str.	4.37 ksi
	Recovery	
0	615	
1	564	
2	539	

AS/4397

Test: Creep
Orient: 90°
Spec. No: D21-10
Temp: R.T.
Stress: 3.76 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2608	
0.05	2628	
0.1	2631	
0.25	2632	
0.5	2634	
1	2635	
2	2637	
3	2640	
4	2641	
5	2649	
6	2662	
7	2665	
8	2669	
24	2720	
72	2802	
144.5	2833	
192	2888	
240	2921	
336	2952	
408	3002	
480	3024	
502	3052	
Resid.	Str.	4.99 ksi
	Recovery	
0	426	
1	379	
2	359	
3	353	

Test: Creep
Orient: 90°
Spec. No: D25-1
Temp: R.T.
Stress: 3.76 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2628	
0.05	2644	
0.1	2646	
0.25	2646	
0.5	2648	
1	2650	
2	2654	
3	2655	
4	2659	
5	2664	
6	2680	
7	2682	
8	2688	
24	2746	
72	2839	
144.5	2882	
192	2938	
240	2976	
336	3021	
408	3087	
480	3109	
502	3138	
Resid.	Str.	4.23 ksi
	Recovery	
0	490	
1	433	
2	422	
3	413	

Test: Creep
Orient: 90°
Spec. No: D18-5
Temp: R.T.
Stress 3.76 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2569	
0.05	2584	
0.1	2584	
0.25	2585	
0.5	2586	
1	2589	
2	2592	
3	2592	
4	2597	
5	2602	
6	2622	
7	2623	
8	2629	
24	2684	
72	2777	
144.5	2810	
192	2872	
240	2908	
336	2943	
408	3000	
580	3022	
502	3050	
Resid.	Str.	5.32 ksi
	Recovery	
0	510	
1	444	
2	434	
3	424	

AS/4397

Test: Creep
Orient: 90°
Spec. No: D15-10
Temp: 350°F
Stress: 2.67 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2058	
0.016	2119	
0.05	2161	
0.1	2206	
0.25	2258	
0.5	2308	
1.25	2396	
2	2438	
3.5	2472	
4	2488	
5	2513	
6	2527	
7	2541	
24	2688	
48	2776	
120	2932	
144	2980	
168	3019	
172	3060	
196	3085	
268	3165	
316.7	3168	
364	3192	
436	3282	
460	3310	
484	3323	
509	3358	
Resid.	Str.	4.13 ksi
Recovery		
0	1601	
3	1400	
4	1411	

Test: Creep
Orient: 90°
Spec. No: D22-10
Temp: 350°F
Stress: 2.67 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2046	
0.016	2109	
0.1	2209	
0.2	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: D23-8
Temp: 350°F
Stress 2.67 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2476	
0.016	2616	
0.05	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: D15-7
Temp: 350°F
Stress: 2.29 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1817	
0.016	1841	
0.1	1879	
0.25	1912	
0.5	1934	
1	1968	
2	2010	
3	2046	
4	2073	
5	2093	
6	2095	
7	2107	
8	2121	
31	2277	
96	2502	
112.4	2555	
168	2622	
240	2737	
288	2789	
336	2858	
408	2937	
460.5	2987	
508	3066	
Resid	Str.	3.22 ksi
Recovery		
0	1154	
1	1043	
2	1016	
3	984	

Test: Creep
Orient: 90°
Spec. No: D13-2
Temp: 350°F
Stress: 2.29 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1952	
0.016	2050	
0.1	2174	
0.25	2241	
0.5	2264	
1	2364	
2	2417	
3	2459	
4	2530	
5	2554	
6	2579	
7	2607	
8	2632	
31	2814	
96	3079	
112.4	3175	
168	3269	
240	3413	
288	3480	
336	3582	
408	3146	
460.5	3169	
508	3148	
Resid.	Str.	3.87 ksi
Recovery		
0	1496	
1	1454	
2	1448	
3	1441	

Test: Creep
Orient: 90°
Spec. No: D21-6
Temp: 350°F
Stress 2.29 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on	Loading
Recovery		

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Test: Creep
Orient: 90°
Spec. No: D25-5
Temp: 350°F
Stress: 1.90 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1372	
0.016	1397	
0.1	1404	
0.25	1406	
0.5	1409	
1	1413	
3	1419	
4	1423	
5	1425	
24	1447	
48	1453	
72	1458	
145.4	1498	
169	1517	
194	1555	
218	1562	
245	1585	
316	1602	
341	1552	
367	1555	
486	1638	
501	No Failure	
Resid	Str.	3.85 ksi
Recovery		

Test: Creep
Orient: 90°
Spec. No: D25-10
Temp: 350°F
Stress: 1.90 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1513	
0.016	1513	
0.1	1506	
0.25	1513	
0.5	1513	
1	1518	
3	1532	
4	1538	
5	1537	
24	1578	
48	1639	
72	1666	
145.4	1781	
169	1813	
194	1876	
218	1951	
245	2004	
316	2094	
341	2130	
367	2172	
486	2553	
501	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: D21-2
Temp: 350°F
Stress 1.90 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Failed on	Loading
Recovery		

AS/4397

Test: Creep
Orient: 90°
Spec. No: D25-9
Temp: 450°F
Stress: 1.48 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2931	
0.016	2970	
0.15	4665	
0.28	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: D58-1
Temp: 450°F
Stress: 1.48 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2147	
0.016	2559	
0.25	4027	
0.5	4569	
1	5116	
2	5813	
3	Failure	

Recovery

Test:
Orient:
Spec. No:
Temp:
Stress ksi % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks

Recovery

AS/4397

Test: Creep
Orient: 90°
Spec. No: D25-7
Temp: 450°F
Stress: 1.18 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1480	
0.016	1591	
0.1	2863	
0.25	2849	
0.5	2949	
1	5023	
2	3031	
3	3059	
9	3026	
24	3027	
96	3338	
264	5772	
312	6649	
361	7521	
402.3	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: D26-4
Temp: 450°F
Stress: 1.18 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2055	
0.016	2140	
0.13	2255	
0.25	2302	
0.5	2383	
1	2462	
2	2578	
3	2675	
4	2723	
5	2770	
6	2820	
7	2847	
24	3341	
72		
144	21,392	
216	13,604	
228	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: D25-3
Temp: 450°F
Stress 1.18 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on	Loading

Recovery

Test: Creep
Orient: 90°
Spec. No: D58-2
Temp: 450°F
Stress: 0.89 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1654	
0.016	2018	
0.1	2321	
0.25	2533	
0.5	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: D58-5
Temp: 450°F
Stress: 0.39 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1336	
0.016	1505	
0.1	1634	
0.25	1702	
0.5	1793	
1	1882	
2	2074	
3	2188	
4	2364	
5	2494	
6	2582	
7	2641	
8	2735	
15	Failure	
Recovery		

Test: Creep
Orient: 90°
Spec. No: D58-3
Temp: 450°F
Stress 0.39 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	963	
0.016	1378	
0.1	2246	
0.25	2262	
0.5	2348	
1	2420	
2	2563	
3	2677	
4		
4	2823	
6	2927	
7	3061	
32.2	Failure	
Recovery		

AS/4397

Test: Creep
Orient: + 45°
Spec. No: D32-2
Temp: R.T.
Stress: 13.10 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5422	
0.016	5518	
0.13	5711	
0.25	5780	
0.5	5834	
1	5912	
2.3	6019	
4	6094	
5	6115	
6	6145	
7	6168	
24.4	6417	
96	6611	
144	6621	
192	6928	
264.25	7203	
288	7200	
312	7277	
360	7272	
432	7277	
504	7315	
528	7439	
600	7537	
Resid.	Str.	18.98 ksi
	Recovery	
0	1820	
1	1503	
2	1385	
3	1254	

Test: Creep
Orient: + 45°
Spec. No: D28-6
Temp: R.T.
Stress: 13.10 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5333	
0.016	5475	
0.13	5648	
0.25	5716	
0.5	5796	
1	5871	
2.3	5969	
4	6047	
5	6068	
6	6094	
7	6118	
24.4	6330	
96	6576	
144	6677	
192	6873	
264.25	7014	
288	7050	
312	7077	
360	7118	
432	7197	
504	7233	
528	7248	
600	7339	
Resid.	Str.	18.30 ksi
	Recovery	
0	1733	
1	1448	
2	1274	
3	1190	

Test: Creep
Orient: ± 45°
Spec. No: D27-2
Temp: R.T.
Stress 13.10 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5306	
0.016	5549	
0.13	5755	
0.25	5824	
1	5981	
2.3	6104	
4	6197	
5	6219	
6	6248	
7	6273	
24.4	6521	
96	6836	
144	6944	
192	7113	
264.25	7346	
288	7382	
312	7409	
360	7448	
432	7533	
504	7567	
528	7582	
600	7670	
Resid.	Str.	18.48 ksi
	Recovery	
0	1834	
1	1520	
2	1336	
3	1250	

AS/4397

Test: Creep
Orient: ± 45°
Spec. No: D28-2
Temp: R.T.
Stress: 11.23 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4363	
0.016	4528	
0.1	4611	
0.25	4672	
0.5	4702	
1	4748	
2	4806	
4	4866	
5	4878	
6	4896	
7	4909	
24.1	5034	
72	5178	
144	5325	
216	5418	
240	5422	
312	5551	
360	5593	
384	5616	
409	5622	
480	5706	
528	5722	
Resid.	Str.	18.96 ksi
	Recovery	
0	1187	
1	836	
2	788	
3	752	

Test: Creep
Orient: ± 45°
Spec. No: D32-4
Temp: R.T.
Stress: 11.23 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4811	
0.016	4934	
0.1	5021	
0.25	5093	
0.5	5121	
1	5174	
2	5238	
4	5298	
5	5310	
6	5316	
7	5326	
24.1	5464	
72	5622	
144	5780	
216	5884	
240	5895	
312	6035	
360	6082	
384	6105	
409	6117	
480	6209	
528	6225	
Resid.	Str.	18.70 ksi
	Recovery	
0	1247	
1	887	
2	830	
3	795	

Test: Creep
Orient: ±45°
Spec. No: D27-8
Temp: R.T.
Stress 11.23 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4486	
0.016	4599	
0.1	4688	
0.25	4750	
0.5	4780	
1	4835	
2	4900	
4	4960	
5	4976	
6	4992	
7	5004	
24.1	5131	
72	5282	
144	5433	
216	5526	
240	5538	
312	5664	
360	5712	
384	5731	
409	5742	
480	5824	
528	5845	
Resid.	Str.	18.55 ksi
	Recovery	
0	1176	
1	859	
2	808	
3	776	

Test: Creep
Orient: ± 45°
Spec. No: D38-8
Temp: R.T.
Stress: 9.36 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3406	
0.016	3447	
0.1	3494	
0.25	3502	
0.5	3518	
1	3570	
2	3630	
4	3676	
5	3681	
6	3707	
7	3719	
72	3949	
125	3994	
168	4016	
240	4085	
288.2	4086	
312	4108	
408	4122	
432	4143	
456	4144	
480	4145	
484	4145	
Resid.	Str.	18.05 ksi
Recovery		
0	692	
1	502	
2	464	
2.6	456	

Test: Creep
Orient: ± 45°
Spec. No: D31-4
Temp: R.T.
Stress: 9.36 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3725	
0.016	3785	
0.1	3816	
0.25	3861	
0.5	3880	
1	3935	
2	3990	
4	4034	
5	4044	
6	4072	
7	4085	
72	4310	
125	4359	
168	4383	
240	4454	
288.2	4473	
312	4497	
408	4512	
432	4527	
456	4532	
480	4530	
484	4526	
Resid.	Str.	18.57 ksi
Recovery		
0	919	
1	703	
2	663	
2.6	650	

Test: Creep
Orient: ± 45°
Spec. No: D39-10
Temp: R.T.
Stress 9.36 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3418	
0.016	3478	
0.1	3522	
0.25	3532	
0.5	3554	
1	3588	
2	3647	
4	3678	
5	3684	
6	3708	
7	3716	
72	3923	
125	3971	
168	3994	
240	4074	
288.2	4122	
312	4124	
408	4150	
432	4167	
456	4169	
480	4169	
484	4167	
Resid.	Str.	17.67 ksi
Recovery		
0	786	
1	594	
2	556	
2.6	549	

AS/4397

Test: Creep
Orient: ± 45°
Spec. No: D38-10
Temp: 350°F
Stress: 8.31 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0.1	5248	
0.016	6085	
0.1	7240	
0.28	8888	
0.5	9589	
1	10,770	
2	11,902	
3	12,730	
4.5	13,359	
5	13,571	
6	13,897	
7	14,180	
24	16,546	
48	19,157	
72	20,766	
168	24,982	
192	26,463	
216	32,160	
	Gage Failed	
505	No Failure	
Resid.	Str.	18.07 ksi
	Recovery	

Test: Creep
Orient: ± 45°
Spec. No: D40-10
Temp: 350°F
Stress: 8.31 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	15,624	
0.016	22,417	
0.1	23,672	
0.28	25,268	
0.5	25,824	
1	26,029	
2	26,213	
3	26,313	
4.5	26,389	
5	26,397	
6	26,462	
7	2[illegible],533	
24	2[illegible],137	
48	27,616	
72	28,008	
168	29,177	
192	29,414	
216	29,636	
240	29,926	
336	30,867	
384	31,499	
433	33,324	
	Gage Failed	
505	No Failure	
Resid.	Str.	18.07 ksi
	Recovery	

Test: Creep
Orient: ± 45°
Spec. No: D36-10
Temp: 350°F
Stress 8.31 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	14,399	
0.016	14,675	
0.1	20,093	
0.25	Gage Failed	
500	No Failure	
Resid.	Str.	17.98 ksi
	Recovery	

AS/4397

Test: Creep
Orient: ± 45°
Spec. No: D35-10
Temp: 350°F
Stress: 4.98 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2055	
0.016	2115	
0.1	2253	
0.25	2380	
0.5	2506	
1	2647	
2	2811	
4	3049	
5	3143	
6	3168	
7	3234	
24	3813	
48	4228	
72	4498	
96	4706	
169.5	5169	
217.5	5397	
241.5	5491	
265.5	5588	
337.5	5833	
384	5986	
408	6057	
432	6133	
504	6330	
Resid.	Str.	18.36 ksi
	Recovery	
0	4315	
1	4040	
2	3985	
3.5	3926	

Test: Creep
Orient: + 45°
Spec. No: D37-7
Temp: 350°F
Stress: 4.98 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2451	
0.016	2634	
0.1	2758	
0.25	2946	
0.5	3129	
1	3337	
2	3575	
4	3931	
5	4076	
6	4139	
7	4231	
24	5031	
48	5713	
72	6137	
96	6437	
169.5	7135	
217.5	7487	
241.5	7633	
265.5	7799	
337.5	8219	
384	8488	
408	8625	
432	8760	
504	9158	
Resid.	Str.	19.00 ksi
	Recovery	
0	6812	
1	6305	
2	6279	
2.5	6059	

Test: Creep
Orient: + 45°
Spec. No: D39-4
Temp: 350°F
Stress 4.98 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2130	
0.016	2319	
0.1	2579	
0.25	2795	
0.5	2987	
1	3226	
2	3421	
4	3817	
5	4023	
6	4045	
7	4153	
24	4971	
48	5650	
72	6097	
96	6439	
169.5	7432	
217.5	7778	
241.5	7830	
265.5	7953	
337.5	8330	
384	8524	
408	8643	
432	8785	
504	9118	
Resid.	Str.	17.00 ksi
	Recovery	
0	6898	
1	6568	
2	6530	
3.5	6452	

AS/4397

Test: Creep
Orient: ± 45°
Spec. No: D36-2
Temp: 350°F
Stress: 3.32 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1423	
0.016	1487	
0.1	1548	
0.25	1577	
0.5	1628	
1	1688	
2	1775	
3.25	1813	
4	1863	
5	1889	
6	1910	
7	1942	
24	2229	
144	2816	
192	2962	
264	3135	
312	3212	
360	3334	
432.5	3464	
528	3619	
Resid.	Str.	18.07 ksi
Recovery		
0	4114	
2	3135	
3	3519	

Test: Creep
Orient: ± 45°
Spec. No: D39-2
Temp: 350°F
Stress: 3.32 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1646	
0.016	1688	
0.1	1810	
0.25	1898	
0.5	1948	
1	2025	
2	2074	
3.25	2130	
4	2147	
5	2164	
6	2200	
7	2223	
24	2411	
144	2833	
192	2943	
264	3060	
312	3161	
360	3259	
432.5	3418	
528	3638	
Resid.	Str.	18.13 ksi
Recovery		
0	4567	
2	3100	
3	3137	

Test: Creep
Orient: ± 45°
Spec. No: D38-6
Temp: 350°F
Stress 3.32 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1498	
0.016	1565	
0.1	1635	
0.25	1652	
0.5	1682	
1	1714	
2	1748	
3.25	1784	
4	1813	
5	1828	
6	1855	
7	1870	
24	2111	
144	2670	
192	2807	
264	2915	
312	3023	
360	3140	
432.5	3265	
528	3554	
Resid.	Str.	18.00 ksi
Recovery		
0	4133	
2	3598	
3	3206	

AS/4397

Test: Creep
Orient: ± 45°
Spec. No: D38-9
Temp: 450°F
Stress: 5.01 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	Gage Failed	
529	No Failure	
Resid.	Str.	17.75 ksi

Recovery

Test: Creep
Orient: ± 45°
Spec. No: D40-7
Temp: 450°F
Stress: 5.01 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4630	
0.016	5196	
0.1	5465	
0.25	6197	
0.5	6839	
1	7546	
2	8435	
3.25	8992	
4	9395	
5	9720	
6	9996	
7	10,255	
24	Gage Failed	
529	No Failure	
Resid.	Str.	17.54 ksi

Recovery

Test: Creep
Orient: ± 45°
Spec. No: D39-1
Temp: 450°F
Stress: 5.01 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7435	
0.016	8077	
0.1	10,234	
0.25	10,550	
0.5	10,761	
1	11,056	
2	11,548	
3.25	11,908	
4	12,150	
5	12,344	
6	12,584	
7	12,783	
24	Gage Failed	
529	No Failure	
Resid.	Str.	17.91 ksi

Recovery

Test: Creep
Orient: ± 45°
Spec. No: D40-8
Temp: 450°F
Stress: 1.67 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3310	
0.016	4115	
0.1	Gage Failed	
5	Failure	

Recovery

Test: Creep
Orient: ± 45°
Spec. No: D38-1
Temp: 450°F
Stress: 1.67 ksi 10% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1667	
0.016	2013	
0.1	3979	
0.25	4431	
0.5	4837	
1	5044	
2	5086	
3	5292	
4	5413	
5	5547	
6	5650	
7.2	5741	
71	9312	
	Gage Failed	
683	No Failure	
Resid.	Str.	16.89 ksi

Recovery

Test:
Orient:
Spec. No:
Temp:
Stress ksi % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks

Recovery

AS/4397

Test: Creep Rupture
Orient: + 45°
Spec. No: D41-2
Temp: 450°F
Stress: 8.35 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	No Gages	
0	Failed on	Loading

Recovery		

Test: Creep Rupture
Orient: + 45°
Spec. No: D37-1
Temp: 450°F
Stress: 8.35 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	No Gages	
482	No Failure	

Recovery		

Test: Creep Rupture
Orient: + 45°
Spec. No: D40-3
Temp: 450°F
Stress 8.35 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	No Gages	
326	Failure	

Recovery		

T300/F178

Test: Creep
Orient: 0°
Spec. No: E4-9
Temp: R.T.
Stress: 141.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6882	
0.016	6891	
0.1	6893	
0.25	6892	
0.5	6893	
1	6893	
2	6895	
	Tabs failed	
	repeatedly	

Recovery

Test: Creep
Orient: 0°
Spec. No: E6-4
Temp: R.T.
Stress: 141.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	Failed on	Loading

Recovery

Test: Creep
Orient: 0°
Spec. No: E8-8
Temp: R.T.
Stress 141.1 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
	Failed on	Loading

Recovery

T300/F178

Test: Creep
Orient: 0°
Spec. No: E21-12
Temp: R.T.
Stress: 125.4 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6366	
0.016	6374	
0.1	6372	
0.25	6375	
0.5	6381	
1	6380	
2	6376	
3	6373	
4	6380	
6	6373	
7.5	6384	
8	6382	
24	6383	
48	6385	
72	6393	
144	6401	
168	6409	
192	6398	
240	6392	
312	6402	
337	6396	
363	6406	
389	6401	
413	6402	
509	6412	
Resid.	Str.	171.5 ksi
	Recovery	
0	85	
1	75	
2	73	

Test: Creep
Orient: 0°
Spec. No: E5-15
Temp: R.T.
Stress: 125.4 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6869	
0.016	6874	
0.1	6872	
0.25	6869	
0.5	6875	
1	6876	
2	6872	
3	6871	
4	6877	
6	6868	
7.5	6881	
8	6880	
24	6884	
48	6885	
72	6896	
144	6911	
168	6916	
192	6907	
240	6901	
312	6911	
337	6905	
363	6915	
389	6912	
413	6912	
509	6920	
Resid.	Str.	170.0 ksi
	Recovery	
0	87	
1	72	
2	70	

Test: Creep
Orient: 0°
Spec. No: E4-15
Temp: R.T.
Stress 125.4 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5924	
0.016	5925	
0.1	5916	
0.25	5919	
0.5	5922	
1	5920	
2	5915	
3	5918	
4	5922	
6	5918	
7.5	5927	
8	5926	
24	5929	
48	5927	
72	5939	
144	5946	
168	5953	
192	5945	
240	5939	
312	5948	
337	5942	
363	5948	
389	5943	
413	5944	
509	5956	
Resid.	Str.	158.2 ksi
	Recovery	
0	61	
1	52	
2	45	

T300/F178

Test: Creep
Orient: 0^{o}
Spec. No: E6-18
Temp: $350^{o}F$
Stress: 121.8 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6445	
0.016	6417	
0.1	6455	
0.25	6457	
0.5	6472	
1	6492	
2	6487	
3	6464	
4	6468	
5	6479	
6.2	6476	
7	6478	
8	6466	
24	6468	
48	6485	
96	6487	
216	6553	
263	6547	
336	6540	
432	6505	
500	No Failure	
Resid.	Str.	176.5 ksi
	Recovery	
0	126	
1	107	
3	97	

Test: Creep
Orient: 0^{o}
Spec. No: E22-10
Temp: $350^{o}F$
Stress: 121.8 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5843	
0.016	5849	
0.1	5857	
0.25	5875	
0.5	5887	
1	5928	
2	5941	
3	5936	
4	5865	
5	5888	
6.2	5879	
7	5942	
8	5942	
24	5946	
48	5959	
96	5937	
216	5988	
263	6025	
336	5992	
432	6082	
500	No Failure	
Resid.	Str.	155.1 ksi
	Recovery	
0	182	
1	136	
3	200	

Test: Creep
Orient: 0^{o}
Spec. No: E8-11
Temp: $350^{o}F$
Stress: 121.8 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5845	
0.016	5863	
0.1	5873	
0.25	5900	
0.5	5897	
1	5922	
2	5915	
3	5915	
4	5859	
5	5882	
6.2	5878	
7	5928	
8	5932	
24	5900	
48	5907	
96	5865	
216	5772	
263	5771	
336	5655	
432	5601	
500	No Failure	
Resid.	Str.	192.4 ksi
	Recovery	
0	-316	
1	-370	
3	-332	

T300/F178

Test: Creep
Orient: 0°
Spec. No: E22-9
Temp: 350°F
Stress: 106.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5380	
0.016	5393	
0.15	5402	
0.25	5400	
0.5	5402	
1	5400	
2	5405	
3	5407	
4.2	5403	
5	5407	
6	5404	
7	5405	
24	5402	
96	5386	
120	5378	
145	5359	
169.5	5351	
184	5361	
280	5335	
304	5340	
352	5327	
434	5300	
456	5306	
504	5303	
Resid	Str.	136.2 ksi
	Recovery	
0	- 1	
1	-17	
2	-20	
3	-26	

Test: Creep
Orient: 0°
Spec. No: E6-1
Temp: 350°F
Stress: 106.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5339	
0.016	5357	
0.15	5357	
0.25	5357	
0.5	5354	
1	5364	
2	5361	
3	5362	
4.2	5364	
5	5349	
6	5369	
7	5374	
24	5377	
96	5385	
120	5377	
145	5358	
169.5	5369	
184	5355	
280	5359	
304	5352	
352	5337	
434	5337	
456	5340	
504	5346	
Resid.	Str.	146.0 ksi
	Recovery	
0	22	
1	9	
2	3	
3	0	

Test: Creep
Orient: 0°
Spec. No: E7-16
Temp: 350°F
Stress 106.6 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5959	
0.016	5968	
0.1	5966	
0.25	5975	
0.5	5965	
1	5962	
2	6620	
3	6609	
4	6613	
5	6611	
6	6605	
7	6589	
8	6573	
24	6521	
	Failure	
	Recovery	

T300/F178

Test: Creep
Orient: 0°
Spec. No: E21-17
Temp: 450°F
Stress: 107.0 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5518	
0.016	5539	
0.1	5540	
0.25	5543	
0.6	5550	
1	5559	
2	5559	
3	5565	
4	5568	
5	5563	
6	5572	
7	5572	
8	5577	
26	5584	
126	5608	
164	5627	
179	5622	
251.4	5645	
314	5661	
362	5686	
432	5712	
480	5747	
528	5768	
Resid.	Str.	140.6 ksi
Recovery		
0	234	
1	181	
2	168	
3	160	

Test: Creep
Orient: 0°
Spec. No: E4-10
Temp: 450°F
Stress: 107.0 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4476	
0.016	4495	
0.1	4507	
0.25	4508	
0.6	4508	
1	4515	
2	4516	
3	4519	
4	4510	
5	4514	
6	4508	
7	4508	
8	4513	
26	4505	
179	4506	
251.4	4494	
314	4519	
362	4520	
432	4525	
480	4562	
528	4609	
Resid.	Str.	136.8 ksi
Recovery		
0	71	
1	12	
2	1	
3	-10	

Test: Creep
Orient: 0°
Spec. No: E7-15
Temp: 450°F
Stress 107.0 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on Loading	
Recovery		

T300/F178

Test: Creep		
Orient: 0°		
Spec. No: E8-15		
Temp: 450°F		
Stress: 91.8 ksi 60% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4793	
0.016	4822	
0.1	4855	
0.25	4835	
0.5	4852	
1	4843	
2	4848	
3	4860	
4	4863	
5.6	4860	
7	4875	
8	4874	
24	4888	
48	4903	
120	4913	
168	4921	
216.2	4926	
288	4923	
313	4923	
336	4931	
384	4933	
458	4941	
501	4933	
Resid	Str.	166.8 ksi
	Recovery	
0	118	
1	115	
2	115	
3	111	

Test: Creep		
Orient: 0°		
Spec. No: E5-19		
Temp: 450°F		
Stress: 91.8 ksi 60% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4691	
0.1	4710	
0.25	4711	
0.5	4716	
1	4721	
2	4721	
3	4731	
4	4730	
5	4735	
6	4732	
72	4792	
120	4816	
168	4825	
240	4833	
291	4334	
336	4830	
408	4820	
480	4809	
593	4794	
Resid.	Str.	172.9 ksi
	Recovery	
0	66	
1	53	
2	45	
3	34	

Test: Creep		
Orient: 0°		
Spec. No: E22-15		
Temp: 450°F		
Stress 91.8 ksi 60% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4560	
0.016	4559	
0.1	4562	
0.25	4565	
0.5	4567	
1	4571	
2	4574	
3	4579	
4	4579	
5	4576	
7	4580	
8	4567	
24	4591	
48	4602	
120	4601	
216	4628	
288	4619	
384	4618	
456	5066	
504	4578	
Resid.	Str.	152.3 ksi
	Recovery	
0	68	
1	70	
2	57	
3	56	

T300/F178

Test: Creep		
Orient: 90°		
Spec. No: E14-1		
Temp: R.T.		
Stress: 3.06 ksi 80% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2269	
0.016	2296	
0.1	2318	
0.25	2336	
0.5	2346	
1	2365	
2	2381	
3	2397	
4	2406	
5	2410	
6	2414	
7	2417	
8	2424	
24	2487	
48	2488	
72	2500	
144	2515	
168	2528	
192	2550	
240	2637	
314	2705	
408	2655	
505	2716	
Resid.	Str.	3.35 ksi
Recovery		
0	566	
1	501	
2	490	

Test: Creep		
Orient: 90°		
Spec. No: E18-5		
Temp: R.T.		
Stress: 3.06 ksi 80% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2597	
0.016	2620	
0.1	2649	
0.25	2661	
0.5	2678	
1	2696	
2	2718	
3	2733	
4	2745	
5	2751	
6	2751	
7	2756	
8	2762	
24	2832	
48	2832	
72	2845	
144	2860	
168	2875	
192	2900	
240	2995	
314	3064	
408	3011	
505	3069	
Resid.	Str.	3.61 ksi
Recovery		
0	615	
1	542	
2	530	

Test: Creep		
Orient: 90°		
Spec. No: E11-8		
Temp: R.T.		
Stress 3.06 ksi 80% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2288	
0.016	2307	
0.1	2335	
0.25	2353	
0.5	2367	
1	2382	
2	2405	
3	2417	
4	2429	
5	2435	
6	2437	
7	2440	
8	2449	
24	2523	
48	2524	
72	2538	
144	2553	
168	2567	
192	2591	
240	2683	
314	2751	
408	2657	
505	2709	
Resid.	Str.	3.24 ksi
Recovery		
0	508	
1	447	
2	438	

T300/F178

Test: Creep
Orient: 90°
Spec. No: E11-6
Temp: R.T.
Stress: 2.65 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1952	
0.016	1980	
0.1	2003	
0.3	2010	
0.5	2019	
1	2030	
2	2051	
4	2068	
5	2076	
6	2080	
7	2086	
24	2122	
48	2193	
72	2250	
144	2328	
168	2346	
194	2317	
218	2320	
232	[illegible]320	
328	[illegible]	
352	2439	
400	2500	
472	2515	
496	2517	
520	2500	
Resid.	Str.	3.69 ksi
Recovery		
0	531	
1	480	
2	468	
3	451	

Test: Creep
Orient: 90°
Spec. No: E14-6
Temp: R.T.
Stress: 2.65 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2110	
0.016	2124	
0.1	2147	
0.3	2157	
0.5	2160	
1	2175	
2	2192	
4	2212	
5	2214	
6	2220	
7	2221	
24	2264	
48	2332	
72	2387	
144	2468	
168	2483	
194	2450	
218	2455	
232	2452	
328	2491	
352	2579	
400	2660	
472	2670	
96	2675	
520	2665	
Resid.	Str.	3.51 ksi
Recovery		
0	627	
1	566	
2	556	
3	548	

Test: Creep
Orient: 90°
Spec. No: E13-8
Temp: R.T.
Stress 2.65 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2181	
0.016	2194	
0.1	2220	
0.3	2229	
0.5	2234	
1	2246	
2	2266	
4	2281	
5	2287	
6	2290	
7	2293	
24	2236	
48	2401	
72	2453	
144	2534	
168	2551	
194	2498	
218	2497	
232	2493	
328	2529	
352	2598	
400	2679	
472	2692	
496	2693	
520	2684	
Resid.	Str.	4.19 ksi
Recovery		
0	554	
1	492	
2	479	
3	476	

T300/F178

Test: Creep
Orient: 90°
Spec. No: E26-4
Temp: 350°F
Stress: 1.78 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1788	
0.016	1811	
0.1	1827	
0.25	1854	
0.5	1898	
1	1990	
2	2095	
3	2163	
4.5	2243	
5	2269	
6	2300	
7	2334	
8	2376	
24	2497	
96.5	2527	
144	2524	
192.1	2534	
219.9	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: E27-8
Temp: 350°F
Stress: 1.78 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1826	
0.016	1971	
0.1	2005	
0.25	2036	
0.5	2076	
1	2153	
2	2248	
3	2301	
4.5	2377	
5	2387	
6	2411	
7	2450	
8	2450	
24	2603	
96.5	2699	
144	2740	
192.1	2769	
219.9	Test interrupted	
0	Failed on	Restart

Recovery

Test: Creep
Orient: 90°
Spec. No: E50-7
Temp: 350°F
Stress: 1.78 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on	Loading

Recovery

T300/F178

Test: Creep
Orient: 90°
Spec. No: E52-7
Temp: 350°F
Stress: 1.07 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1025	
0.016	1013	
0.1	997	
0.25	1020	
0.6	1041	
1	1081	
2	1168	
3	1173	
4.1	1216	
5	1215	
6	1253	
7.1	1264	
8	1293	
24	1496	
48	1774	
144	2606	
288.5	3618	
336.75	3906	
384	4171	
456.5	4565	
504.5	4829	
Resid.	Str.	5.32 ksi
Recovery		
0	3813	
1	3806	
2	3806	
3	3796	

Test: Creep
Orient: 90°
Spec. No: E52-2
Temp: 350°F
Stress: 1.07 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	903	
0.016	950	
0.1	1096	
0.25	1105	
0.6	1112	
1	1140	
2	1164	
3	1125	
4.1	1170	
5	1176	
6	1200	
7.1	1193	
8	1235	
24	1297	
48	1325	
144	1351	
288.5	1407	
336.75	1419	
384	1408	
456.5	1429	
504.5	1405	
Resid.	Str.	5.54 ksi
Recovery		
0	493	
1	414	
2	414	
3	426	

Test: Creep
Orient: 90°
Spec. No: E52-10
Temp: 350°F
Stress 1.07 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1021	
0.016	1044	
0.1	1098	
0.25	1120	
0.6	1130	
1	1141	
2	1174	
3	1192	
4.1	1210	
5	1216	
6	1229	
7.1	1240	
8	1252	
24	1337	
48	1415	
144	1556	
288.5	1632	
336.75	1645	
384	1661	
456.5	1672	
504.5	1696	
Resid	Str.	5.34 ksi
Recovery		
0	710	
1	672	
2	666	
3	661	

T300/F178

Test: Creep
Orient: 90°
Spec. No: E14-5
Temp: 450°F
Stress: 1.07 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1159	
0.016	1195	Loose wire caused
0.1	1099	change in zero
0.25	1115	
0.5	1117	
1	1140	
3	1220	
4	1243	
5	1266	
6	1287	
7	1315	
8	1328	
24	1552	
168.5	2254	
217	2412	
264	2556	
336	2749	
384	2907	
432	3053	
504.5	3261	
Resid. Str.		3.02 ksi
Recovery		
0	2220	
1	2118	
2	2082	
3	2061	

Test: Creep
Orient: 90°
Spec. No: E27-1
Temp: 450°F
Stress: 1.07 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

Test: Creep
Orient: 90°
Spec. No: E26-9
Temp: 450°F
Stress 1.07 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	
Recovery		

T300/F178

Test: Creep
Orient: 90°
Spec. No: E27-6
Temp: 450°F
Stress: 0.86 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	949	
0.016	1021	
0.25	1056	
0.5	1067	
1	1073	
2	1079	
3	1093	
4	1126	
5.1	1121	
6	1115	
7	1147	
24	1166	
48	1171	
96	1171	
	Gage failed - data inaccurate	

Recovery

Test: Creep
Orient: 90°
Spec. No: E26-8
Temp: 450°F
Stress: 0.86 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1059	
0.016	1053	
0.1	1252	temp over 450°F
0.25	1188	
0.5	1192	
1	1193	
2	1220	
3	1241	
4	1249	
5	1263	
6	1269	
9	1274	
24	1297	
48	1275	
169	1435	
193.3	1476	
240.3	1581	
242.1	Failure	

Recovery

Test: Creep
Orient: 90°
Spec. No: E29-8
Temp: 450°F
Stress 0.86 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on loading	

Recovery

T300/F178

Test: Creep
Orient: ±45°
Spec. No: E39-4
Temp: RT
Stress: 12.02ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4833	
0.016	5017	
0.1	5269	
0.25	5381	
0.5	5491	
1	5626	
2	5771	
3.3	5882	
4	5932	
5	5982	
6	6023	
7.5	6071	
24	6327	
96.7	7010	
120	7093	
169.3	7147	
293	7254	
312	7289	
360	7350	
432	7435	
457.5	7474	
480	7515	
530	7647	
597	7775	
Resid.	Str.	18.94 ksi
Recovery		
0	3140	
1.7	2412	
2.7	2371	
3	2359	

Test: Creep
Orient: ±45°
Spec. No: E36-10
Temp: RT
Stress: 12.02ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4513	
0.016	4759	
0.1	4987	
0.25	5085	
0.5	5175	
1	5282	
2	5400	
3.3	5480	
4	5521	
5	5560	
6	5589	
7.5	5629	
24	5840	
96.7	6433	
120	6508	
169.3	6558	
293	6659	
312	6696	
360	6755	
432	6841	
457.5	6877	
480	6913	
530	7044	
597	7170	
Resid.	Str.	19.71 ksi
Recovery		
0	2790	
1.7	2035	
2.7	1984	
3	1982	

Test: Creep
Orient: ±45°
Spec. No: E37-4
Temp: RT
Stress 12.02ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4627	
0.016	5896	
0.1	6108	
0.25	6336	
0.5	6485	
1	6707	
2.5	6903	
3	6912	
4	6993	
5	7068	
6.1	7126	
8	7211	
23.3	Failure	
Recovery		

T300/F178

Test: Creep
Orient: ±45°
Spec. No: E40-9
Temp: RT
Stress: 10.30ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3870	
0.016	4081	
0.1	4265	
0.25	4348	
0.5	4454	
1	4577	
2.5	4693	
3	4700	
4	4743	
5.1	4795	
6.1	4827	
8	4877	
24	5085	
50	5283	
96	5408	
168	5646	
216	5684	
241.5	5681	
357	5737	
384	5744	
432	5776	
504	5821	
Resid.	Str.	19.60 ksi
Recovery		
0	1854	
1	1320	
2	1291	
3.5	1200	

Test: Creep
Orient: ±45°
Spec. No: E37-1
Temp: RT
Stress: 10.30ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4464	
0.016	4642	
0.1	4860	
0.25	4960	
0.5	5090	
1	5246	
2.5	5384	
3	5389	
4	5440	
5.1	5499	
6.1	5539	
8	5598	
24	5844	
50	6090	
96	6246	
168	6524	
216	6574	
241.5	6574	
357	6640	
384	6652	
432	6693	
504	6750	
Resid.	Str.	19.63 ksi
Recovery		
0	2300	
1	1601	
2	1560	
3.5	1451	

Test: Creep
Orient: ±45°
Spec. No: E35-9
Temp: RT
Stress 10.30 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4126	
0.016	4247	
0.1	4407	
0.25	4488	
0.5	4593	
1	4720	
2.5	4836	
3	4841	
4	4888	
5.1	4937	
6.1	4972	
8	5019	
24	5233	
50	5439	
96	5566	
168	5820	
216	5867	
241.5	5868	
357	5926	
384	5936	
432	5969	
504	6019	
Resid.	Str.	18.92 ksi
Recovery		
0	2033	
1	1425	
2	1390	
3.5	1294	

T300/F178

Test: Creep
Orient: ±45°
Spec. No: E37-9
Temp: RT
Stress: 8.59 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3778	
0.016	3901	
0.1	4014	
0.25	4097	
0.5	4178	
1	4267	
2	4352	
3	4417	
4	4463	
5	4501	
6	4534	
7	4563	
24	4829	
48	5007	
96	5207	
168	5372	
216	5373	
264	5392	
336	5408	
384	5503	
432.5	5563	
503	5622	
Resid. Str.		19.54 ksi
Recovery		
0	2167	
1	1706	
2	1595	

Test: Creep
Orient: ±45°
Spec. No: E36-3
Temp: RT
Stress: 8.59 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3446	
0.016	3525	
0.1	3616	
0.25	3696	
0.5	3768	
1	3850	
2	3949	
3	4035	
4	4082	
5	4121	
6	4155	
7	4178	
24	4425	
48	4598	
96	4786	
168	4928	
216	4917	
264	4935	
336	4947	
384	5044	
432.5	5110	
503	5165	
Resid.	Str.	19.98 ksi
Recovery		
0	1720	
1	1366	
2	1290	

Test: Creep
Orient: ±45°
Spec. No: E37-2
Temp: RT
Stress 8.59 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3620	
0.016	3697	
0.1	3777	
0.25	3855	
0.5	3921	
1	4005	
2	4082	
3	4137	
4	4180	
5	4218	
6	4245	
7	4267	
24	4508	
48	4677	
96	4872	
168	5035	
216	5030	
264	5048	
336	5062	
384	5154	
432.5	5219	
503	5276	
Resid. Str.		20.05 ksi
Recovery		
0	1858	
1	1474	
2	1390	

T300/F178

Test: Creep
Orient: ±45°
Spec. No: E44-2
Temp: 350°F
Stress: 7.30 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3903	
0.016	4195	
0.1	4404	
0.25	4543	
0.5	4712	
1	4819	
2	5016	
3.6	5177	
4	5224	
5	5274	
6	5342	
7	5408	
8	5455	
72	6404	
120	6725	
168	6978	
240	7195	
289	7358	
336	7459	
432.6	7672	
503.2	7810	
Resid.	Str.	20.78 ksi
Recovery		
0	4480	
1.5	3997	
2.5	3921	

Test: Creep
Orient: ±45°
Spec. No: E34-7
Temp: 350°F
Stress: 7.30 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3759	
0.016	4102	
0.1	4271	
0.25	4339	
0.5	4408	
1	4498	
2	4630	
3.6	4756	
4	4778	
5	4831	
6	4885	
7	4929	
8	4965	
72	5810	
120	6088	
168	6298	
240	6543	
289	6688	
336	6799	
432.6	7022	
503.2	7179	
Resid.	Str.	19.22 ksi
Recovery		
0	3896	
1.5	3478	
2.5	3418	

Test: Creep
Orient: ±45°
Spec. No: E48-8
Temp: 350°F
Stress 7.30 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4490	
0.016	4902	
0.1	5829	
0.25	5904	
0.5	6003	
1	6141	
2	6330	
3	6507	
4	6583	
5	6663	
6	6738	
7	6807	
8	6873	
24	7454	
96	8443	
144	8737	
192	8961	
264	9212	
312	9346	
360	9457	
432	9593	
481	9679	
506.6	9718	
Resid.	Str.	20.81 ksi
Recovery		
0	6170	
1	5626	
2	5513	
3	5445	

T300/F178

Test: Creep
Orient: ±45°
Spec. No: E37-6
Temp: 350°F
Stress: 5.84 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2997	
0.016	3182	
0.1	3278	
0.25	3377	
0.7	3479	
1.3	3581	
2	3665	
3	3740	
4	3791	
5	3830	
6.5	3881	
7	3902	
8	3923	
24	4199	
72	4687	
144.5	5045	
192	5235	
240.1	5322	
312	5395	
336	5431	
360	5469	
408	5541	
480	5645	
500	5669	
Resid	Str.	17.84 ksi
	Recovery	
0	2888	
1.5	2619	
2	2582	
3	2537	

Test: Creep
Orient: ±45°
Spec. No: E39-10
Temp: 350°F
Stress: 5.84 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2546	
0.016	2654	
0.1	2782	
0.25	2849	
0.7	2921	
1.3	2994	
2	3052	
3	3106	
4	3146	
5	3180	
6.5	3223	
7	3239	
8	3259	
24	3527	
72	4008	
144.5	4308	
192	4419	
240.1	4521	
312	4623	
336	4644	
360	4669	
408	4728	
480	4776	
500	4795	
Resid.	Str.	15.72 ksi
	Recovery	
0	2433	
1.5	2172	
2	2147	
3	2118	

Test: Creep
Orient: ±45°
Spec. No: E36-5
Temp: 350°F
Stress 5.84 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2938	
0.016	2982	
0.1	3071	
0.25	3140	
0.7	3231	
1.3	3292	
2	3348	
3	3404	
4	3447	
5	3489	
6.5	3528	
7	3545	
8	3568	
24	3830	
72	4187	
144.5	4484	
192	4624	
240.1	4742	
312	4886	
336	4943	
360	4988	
408	5067	
480	5182	
500	5217	
Resid	Str.	20.62 ksi
	Recovery	
0	2450	
1.5	2193	
2	2170	
3	2139	

T300/F178

Test: Creep		
Orient: ±45°		
Spec. No: E43-5		
Temp: 350°F		
Stress: 4.38 ksi 30 % ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2226	
0.03	2337	
0.13	2413	
0.25	2472	
0.5	2541	
1	2618	
2	2719	
3	2772	
4	2827	
5	2873	
6	2910	
7	2340	
24	3217	
48	3406	
120	4629	
168.4	3850	
216	3979	
288.5	4162	
336	4274	
384	4381	
456	4517	
504	4601	
Resid.	Str.	20.49 ksi
Recovery		
0	2704	
1	2555	
2	2536	
3	2518	

Test: Creep		
Orient: ±45°		
Spec. No: E48-2		
Temp: 350°F		
Stress: 4.38 ksi 30 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2087	
0.03	2160	
0.13	2242	
0.25	2291	
0.5	2341	
1	2397	
2	2467	
3	2510	
4	2548	
5	2583	
6	2603	
7	2627	
24	2839	
48	2981	
120	3722	
163.4	3290	
216	3371	
288.5	3517	
336	3594	
384	3685	
456	3802	
504	3866	
Resid.	Str.	20.53 ksi
Recovery		
0	2003	
1	1857	
2	1837	
3	1817	

Test: Creep		
Orient: ±45°		
Spec. No: E44-3		
Temp: 350°F		
Stress 4.38 ksi 30 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2288	
0.03	2321	
0.13	2354	
0.25	2385	
0.5	2420	
1	2470	
2	2529	
3	2571	
4	2602	
5	2631	
6	2652	
7	2671	
24	2893	
48	3054	
120	4282	
168.4	3458	
216	3561	
288.5	3696	
336	3770	
384	3842	
456	3920	
504	3969	
Resid.	Str.	20.61 ksi
Recovery		
0	2050	
1	1879	
2	1867	
3	1851	

T300/F178

Test: Creep		
Orient: ±45°		
Spec. No: E48-6		
Temp: 450°F		
Stress: 4.87 ksi 40 % ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2513	
0.016	2642	
0.1	2841	
0.25	2973	
0.5	3054	
1.1	3211	
2	3354	
3	3461	
4	3560	
5	3636	
6	3692	
7	3757	
8	3856	
24	4826	
48	5440	
120	6421	
168	6902	
216	7347	
288	8041	
337	8523	
384	9060	
480	10278	
503	10640	
Resid	Str.	13.72 ksi
	Recovery	
0	8077	
1	7464	
2	7280	
3	7197	

Test: Creep		
Orient: ±45°		
Spec. No: E43-10		
Temp: 450°F		
Stress: 4.87 ksi 40 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2490	
0.016	2538	
0.1	2958	
0.25	3129	
0.5	3268	
1.1	3469	
2	3682	
3	3838	
4	4004	
5	4135	
6	4241	
7	4399	
9	4434	
24	4693	
48	4966	
120	5556	
168	5834	
216	6118	
288	6490	
337	6750	
384	7405	
480	8125	
503	8290	
Resid	. Str.	16.37 ksi
	Recovery	
0	5978	
1	5753	
2	5666	
3	5599	

Test: Creep		
Orient: ±45°		
Spec. No: E34-6		
Temp: 450°F		
Stress 4.87 ksi 40 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2427	
0.016	2495	
0.1	2778	
0.25	2873	
0.5	2965	
1.1	3124	
2	3292	
3	3411	
4	3524	
5	3615	
6	3687	
7	3772	
8	3798	
24	4093	
48	4382	
120	4898	
168	5124	
216	5342	
288	5600	
337	5783	
384	5945	
480	6314	
503	6417	
Resid	Str.	16.56 ksi
	Recovery	
0	4079	
1	3932	
2	3888	
3	3853	

T300/F178

Test: Creep		
Orient: ±45°		
Spec. No: E44-6		
Temp: 450°F		
Stress: 3.65 ksi 30% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1677	
0.016	1733	
0.1	1831	
0.25	1912	
0.5	1977	
1.1	2067	
2	2175	
3	2279	
4	2359	
5.1	2434	
6	2475	
7	2525	
8	2576	
24	3028	
72	3390	
144	3935	
192	4146	
240	4319	
312	4596	
360	4758	
408	4931	
480	5208	
504	5283	
Resid.	Str.	15.35 ksi
Recovery		
0	3753	
1	3574	
2	3538	
3	3519	

Test: Creep		
Orient: ±45°		
Spec. No: E34-8		
Temp: 450°F		
Stress: 3.65 ksi 30% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1593	
0.016	1665	
0.1	1828	
0.25	1888	
0.5	1934	
1.1	2034	
2	2131	
3	2223	
4	2292	
5.1	2360	
6	2411	
7	2461	
8	2501	
24	2939	
72	3264	
144	3788	
192	4021	
240	4222	
312	4437	
360	4705	
408	4929	
480	5301	
504	5464	
Resid.	Str.	10.39 ksi
Recovery		
0	3826	
1	3741	
2	3715	
3	3690	

Test: Creep		
Orient: ±45°		
Spec. No: E43-3		
Temp: 450°F		
Stress 3.65 ksi 30% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1918	
0.016	2011	
0.1	2139	
0.25	2200	
0.5	2264	
1.1	2381	
2	2491	
3	2587	
4	2667	
5.1	2742	
6	2793	
7	2847	
8	2900	
24	3310	
72	3825	
144	4365	
192	4523	
240	4657	
312	4800	
360	4875	
408	4967	
460	5089	
504	5126	
Resid.	Str.	20.05 ksi
Recovery		
0	3607	
1	3424	
2	3397	
3	3353	

APPENDIX J
THERMAL EXPANSION DATA

All of the thermal expansion data generated during this program are presented in this appendix. In addition, a typical thermal expansion curve is included at the end of the section. These data are summarized in Section 4.

Test: Coefficient of Thermal Expansion				
Materials: SP313				Graphite/Epoxy
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
A37-4	0°	-67→72	0.14	Difficult to measure
A37-4	0°	72→170	0.01	these very low values
A37-4	0°	175→350	0.47	with a dilatometer
A37-5	0°	72 →200	-0.04	
A37-5	0°	200→380	0	
A37-6	0°	-70→72	-.17	
A37-6	0°	72→260	-0.02	
A37-6	0°	260→375	0.06	
A37-7	0°	72→165	±0	Double the normal length
A37-7	0°	72→175	±0	
A37-7	0°	72→165	±0	
A37-7	0°	72→165	±0	
A37-7	0°	72→215	±0	
A37-7	0°	165→350	0.16	
A37-7	0°	175→350	0.11	
A37-7	0°	165→350	0.12	
A37-7	0°	165→350	0.08	
A37-7	0°	215→350	0.19	
A37-1	90°	-71 →75	15.3	
A37-1	90°	77→350	17.1	
A37-2	90°	-69 →70	15.3	
A37-2	90°	73→350	19.1	
A37-3	90°	-69 →73	15.7	
A37-3	90°	98→350	19.7	

Test: Coefficient of Thermal Expansion

Materials: SP313 Graphite/Epoxy

Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6} in/in-°F)	Remarks
A61-1	±45°	-67→72	1.60	
A61-1	±45°	77→385	1.93	
A61-2	±45°	-67→72	1.92	
A61-2	±45°	77→354	1.97	
A61-3	±45°	-67→72	1.93	
A61-3	±45°	98→360	1.92	

Test: Coefficient of Thermal Expansion				
Materials: AS/3004				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
C30-4	0°	-70→50	-0.003	Very difficult to
C30-4	0°	80→275	-0.01	obtain accurate values
C30-5	0°	-70→65	-0.007	when the expansions are
C30-5	0°	75→275	-0.008	this low
C30-6	0°	-70→65	-0.007	
C30-6	0°	90→275	-0.004	
C30-1	90°	-70→60	16.4	
C30-1	90°	-65→70	15.9	
C30-1	90°	80→275	16.2	
C30-2	90°	-70→50	17.7	
C30-2	90°	75→275	16.7	
C30-3	90°	-70→70	18.1	
C30-3	90°	75→275	18.0	
C36-1	±45°	-75→10	≐0	
C36-1	±45°	10→53	1.26	
C36-1	±45°	119→300	1.89	
C36-1	±45°	145→300	1.78	
C36-2	±45°	-75→57	≐0	
C36-2	±45°	57→95	2.15	
C36-2	±45°	130→300	2.07	
C36-3	±45°	-70→-15	≐0	
C36-3	±45°	-15→71	1.36	
C36-3	±45°	165→305	1.44	

Test: Coefficient of Thermal Expansion				
Materials: AS/4397			Graphite/Polyimide	
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
D44-1	90°	-86→81	14.2	
D44-1	90°	72→360	17.5	
D44-1	90°	81→150	16.7	
D44-1	90°	300→400	22.8	
D44-1	90°	400→500	26.4	
D44-2	90°	69→ 60	14.1	
D44-2	90°	85→321	17.2	
D44-2	90°	72→145	15.5	
D44-2	90°	310→400	19.5	
D44-2	90°	400→460	26.9	
D44-3	90°	-78→64	13.9	
D44-3	90°	80→285	16.5	
D44-3	90°	71→170	15.3	
D44-3	90°	290→375	19.5	
D44-3	90°	375→470	25.3	
D60-1	±45°	-90→-8	≐0	
D60-1	±45°	-8 →74	1.26	
D60-2	±45°	-40→70	≐ 0	
D60-2	±45°	71→150	≐ 0	
D60-2	±45°	300→390	3.35	
D60-2	±45°	395→475	3.85	
D60-3	±45°	-100→-30	≐ 0	
D60-3	±45°	-30→43	1.40	
D60-3	±45°	72→120	≐ 0	
D60-3	±45°	285→400	4.04	
D60-3	±45°	400→485	5.16	
D44-4	0°	74→270	≐ 0	

Test: Coefficient of Thermal Expansion				
Materials: T300/F178			Graphite/Polyimide	
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
E33-1	90°	-54→72	17.7	
E33-1	90°	79→143	16.8	
E33-1	90°	252→345	24.0	
E33-1	90°	318→475	22.2	
E33-2	90°	-44→77	16.9	
E33-2	90°	77→143	16.9	
E33-2	90°	296→345	24.4	
E33-2	90°	318→475	24.1	
E33-3	90°	-63→81	16.9	
E33-3	90°	78→143	17.5	
E33-3	90°	85→147	17.9	
E33-3	90°	296→350	24.5	
E33-3	90°	301→363	22.7	
E33-3	90°	341→475	25.5	
E47-1	±45°	-100→81	2.25	
E47-1	±45°	81→475	1.47	
E47-1	±45°	77→298	1.80	
E47-1	±45°	210→387	2.10	
E47-2	±45°	-64→81	2.09	
E47-2	±45°	-69→108	2.18	
E47-2	±45°	81→475	1.90	
E47-2	±45°	86→209	1.70	
E47-2	±45°	209→386	1.93	
E47-3	±45°	-95→68	2.02	
E47-3	±45°	77→372	1.86	
E47-3	±45°	296→475	1.55	

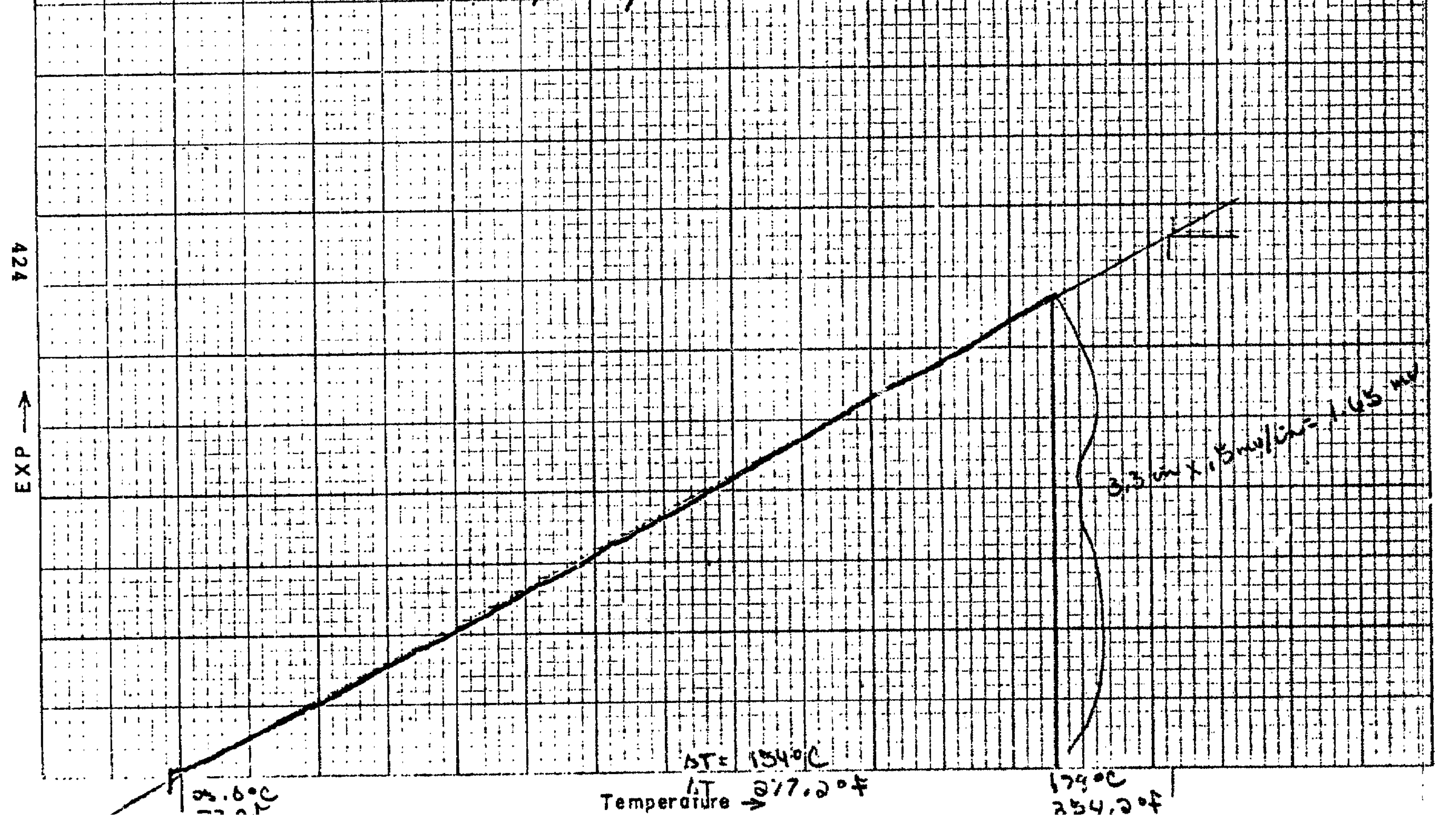
THERMAL EXPANSION

Date 12/12/75 , Sample: A61 #2 45° , Run: 1 , X 1 MV/IN Y .5 MV/IN

Y axis 0.01" = 30MV ∴ 1.65 MV/30MV = 5.5x10⁻⁴ INexp/0.01 IN, Length Sample = 1.0068

CTE = INexp/Length/Δ°C = 5.5x10⁻⁴/1.0068/154 = 3.55 x 10⁻⁶ IN/IN/°C

5.5x10⁻⁴/1.0068/277 = 1.97 x 10⁻⁶ in/in/°F



APPENDIX K
SPECIFIC HEAT DATA

All of the specific heat data generated during this program are presented in this section. A typical set of differential scanning calorimeter (DSC) traces, from which specific heat is determined, is included at the end of this section.

Test: Specific Heat			
Materials: SP313		Graphite/Epoxy	
Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks
A35-1	215	0.25	all tests on SP313 used a
A35-1	142	0.24	drop calorimeter
A35-1	110	0.24	
A35-1	83	0.23	
A35-1	-66	0.17	
A35-1	-66	0.16	
A35-2	214	0.28	
A35-2	142	0.26	
A35-2	109	0.22	
A35-2	83	0.26	
A35-2	-33	0.21	
A35-2	-66	0.17	
A35-3	213	0.24	
A35-3	142	0.23	
A35-3	109	0.26	
A35-3	83	0.27	
A35-3	-66	0.13	

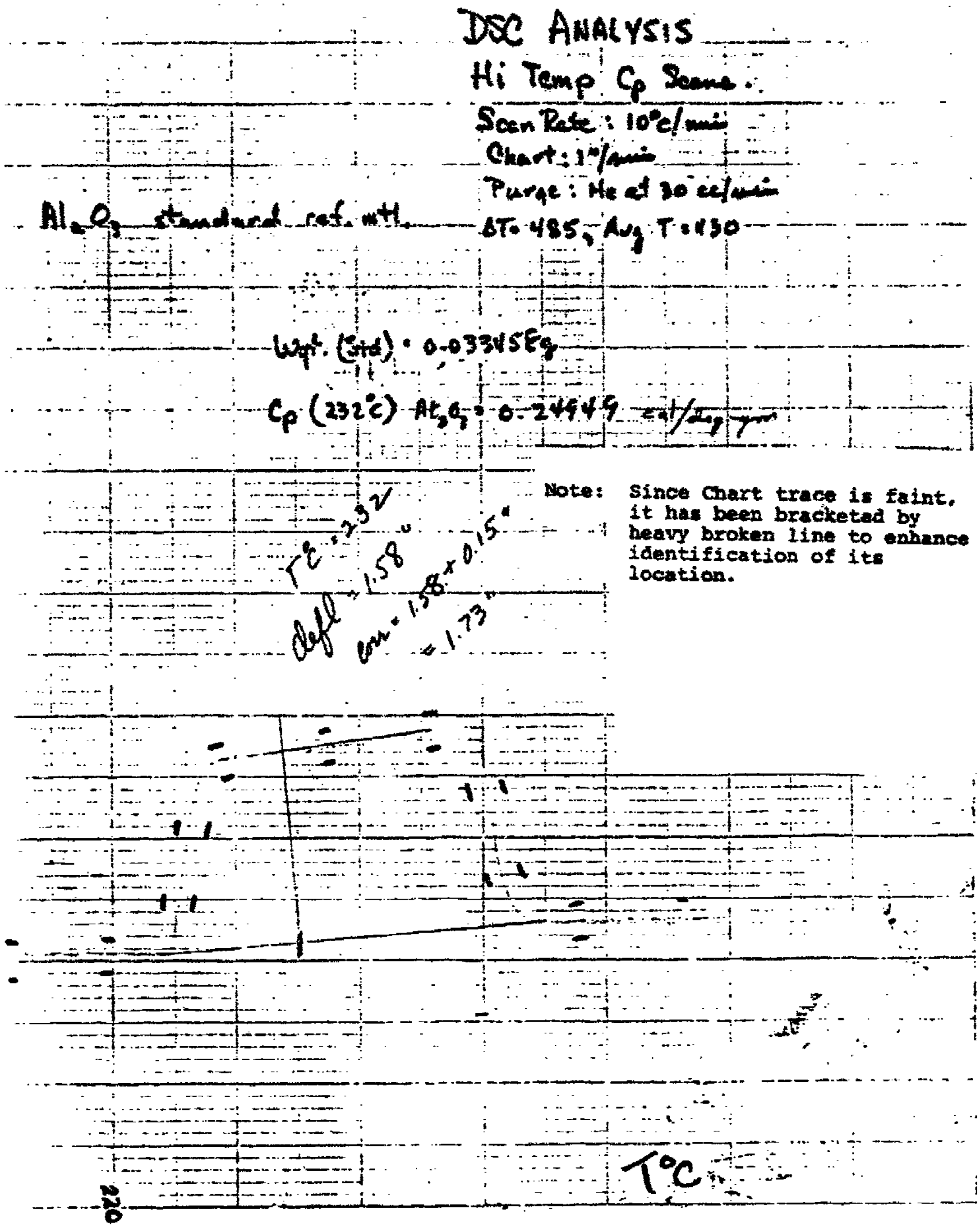
Test: Specific Heat			
Materials: AS/3004			
Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks
C3A	50	0.18	All values on this page
C3A	68	0.18	determined using a Differential
C3A	86	0.19	Scanning Calorimeter technique
C3A	104	0.19	with sapphire (Al_2O_3) as a
C3A	122	0.20	reference.
C3A	140	0.21	
C3A	158	0.21	
C3A	176	0.22	
C3A	194	0.22	
C3A	212	0.23	
C3A	230	0.23	
C3A	248	0.24	
C3A	50	0.17	
C3A	68	0.18	
C3A	86	0.18	
C3A	104	0.19	
C3A	122	0.19	
C3A	140	0.20	
C3A	158	0.20	
C3A	176	0.20	
C3A	194	0.21	
C3A	212	0.21	
C3A	230	0.21	
C3A	248	0.22	

Test: Specific Heat

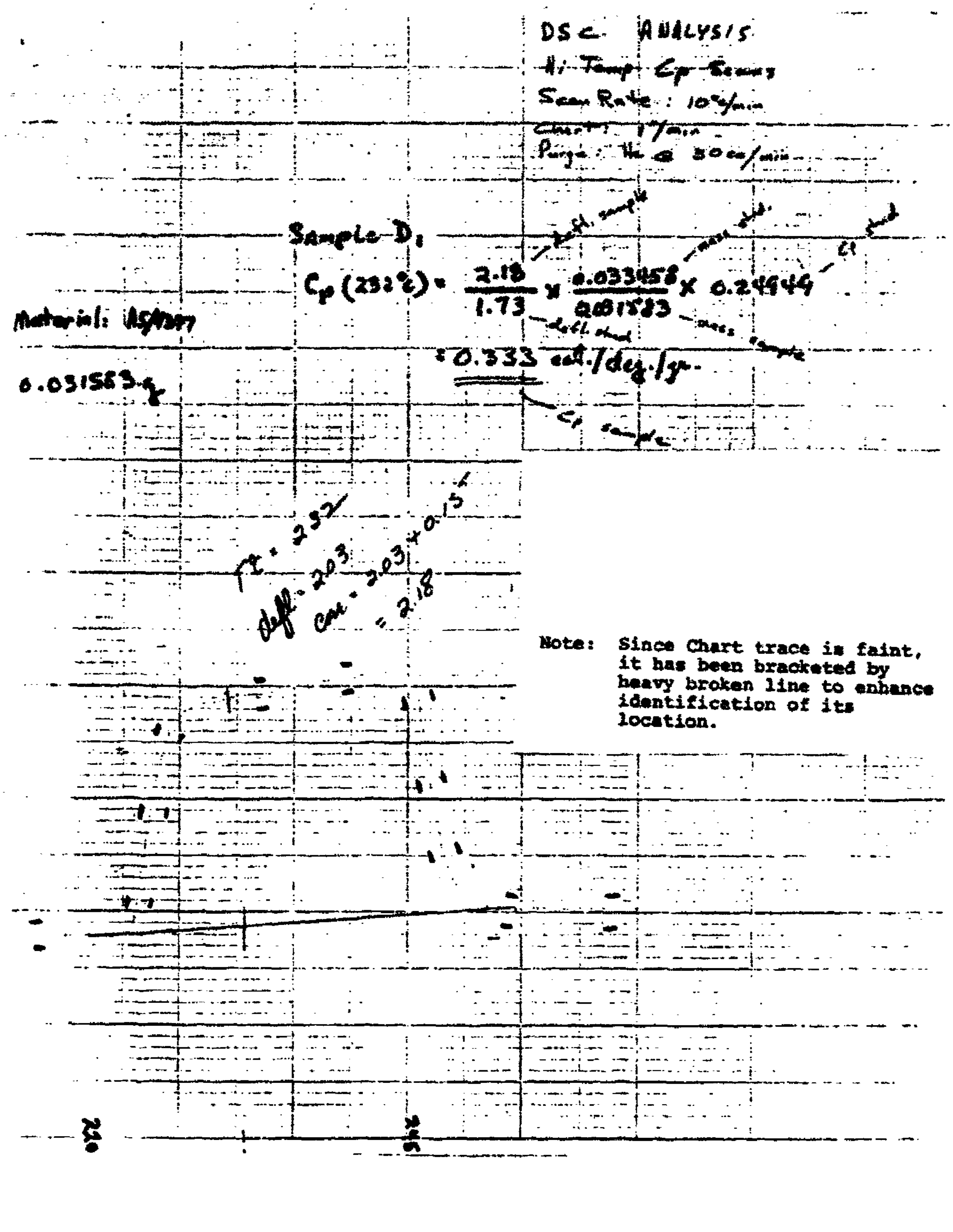
Materials: AS/3004

Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks
C3B	50	0.18	All values on this page
C3B	68	0.18	determined using a Differential
C3B	86	0.19	Scanning Calorimeter technique
C3B	104	0.19	with sapphire (Al_2O_3) as a
C3B	122	0.20	reference.
C3B	140	0.21	
C3B	158	0.21	
C3B	176	0.22	
C3B	194	0.22	
C3B	212	0.22	
C3B	230	0.23	
C3B	248	0.23	
C3B	50	0.18	
C3B	68	0.19	
C3B	86	0.19	
C3B	104	0.20	
C3B	122	0.20	
C3B	140	0.21	
C3B	158	0.22	
C3B	176	0.22	
C3B	194	0.22	
C3B	212	0.23	
C3B	230	0.23	
C3B	248	0.24	

Test: Specific Heat			
Materials: AS/4397 & T300/F178			
Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks
AS/4397	Graphite/Polyimide		All values on this page
			determined using a
D1	-67	0.142	Differential Scanning
D1	72	0.192	Calorimeter technique with
D1	350	0.309	sapphire (Al_2O_3) as a refer-
D1	450	0.333	ence.
T300/F178	Graphite/Polyimide		
E1	-67	0.136	
E1	72	0.190	
E1	350	0.298	
E1	450	0.313	



Note: Since Chart trace is faint, it has been bracketed by heavy broken line to enhance identification of its location.



Note: Since Chart trace is faint, it has been bracketed by heavy broken line to enhance identification of its location.

APPENDIX L
THERMAL CONDUCTIVITY DATA

All of the thermal conductivity measurements made during this program are tabulated in this section. Summaries of these data are presented in Section 4.

Test: Thermal Conductivity				
Materials: SP313				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
A60-1	0°	-132	0.195	
A60-1	0°	-132	0.199	
A60-1	0°	-119	0.214	
A60-1	0°	-102	0.196	
A60-1	0°	-1	0.241	
A60-1	0°	36	0.321	
A60-1	0°	68	0.272	
A60-1	0°	89	0.281	
A60-1	0°	115	0.316	
A60-1	0°	186	0.288	
A60-1	0°	210	0.360	
A60-1	0°	224	0.308	
A60-1	0°	235	0.309	
A60-1	0°	269	0.323	
A60-1	0°	302	0.323	
A60-1	0°	362	0.369	
A60-2	0°	-97	0.184	
A60-2	0°	-94	0.264	
A60-2	0°	131	0.375	
A60-2	0°	205	0.354	
A60-2	0°	217	0.377	
A60-2	0°	230	0.354	
A60-2	0°	243	0.365	
A60-2	0°	295	0.363	
A60-2	0°	351	0.425	
A60-2	0°	381	0.426	

Test: Thermal Conductivity				
Materials: SP313				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
A65-1	±45°	-48	0.235	
A65-1	±45°	59	0.275	
A65-1	±45°	227	0.317	
A65-1	±45°	358	0.349	

Test: Thermal Conductivity				
Materials: AS/3004			Graphite/Polysulfone	
Specimen Number	Fiber Orientation	Temp (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
C33-1	0°	-162	0.186	
C33-1	0°	56	0.277	
C33-1	0°	80	0.259	
C33-1	0°	91	0.330	
C33-1	0°	177	0.123	
C33-1	0°	228	0.344	
C33-1	0°	237	0.349	
C33-1	0°	289	0.336	
C33-1	0°	311	0.225	
C33-1	0°	364	0.343	
C33-1	0°	378	0.331	
C33-2	0°	-111	0.298	
C33-2	0°	-36	0.301	
C33-2	0°	-36	0.291	
C33-2	0°	12	0.313	
C33-2	0°	68	0.336	
C33-2	0°	113	0.363	
C33-2	0°	257	0.412	
C33-2	0°	324	0.339	
C40-1	±45°	-40	0.231	
C40-1	±45°	111	0.255	
C40-1	±45°	189	0.305	
C40-1	±45°	255	0.280	
C40-1	±45°	325	0.286	
C40-2	±45°	151	0.328	
C40-2	±45°	177	0.338	
C40-2	±45°	257	0.342	

Test: Thermal Conductivity				
Materials: AS/4397			Graphite/Polyimide	
Specimen Number	Fiber Orientation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
D49-1	0°	-69	0.281	
D49-1	0°	-29	0.367	
D49-1	0°	32	0.328	
D49-1	0°	61	0.404	
D49-1	0°	90	0.347	
D49-1	0°	109	0.424	
D49-1	0°	137	0.418	
D49-1	0°	161	0.441	
D49-1	0°	174	0.418	
D49-1	0°	189	0.418	
D49-1	0°	205	0.421	
D49-1	0°	225	0.406	
D49-1	0°	246	0.429	
D49-1	0°	271	0.394	
D49-1	0°	318	0.475	
D49-1	0°	322	0.449	
D49-1	0°	342	0.491	
D49-1	0°	342	0.532	
D49-1	0°	367	0.460	
D49-1	0°	388	0.469	
D49-1	0°	408	0.471	
D49-1	0°	433	0.490	
D59-1	±45°	158	0.357	
D59-1	±45°	160	0.357	
D59-1	±45°	180	0.324	
D59-1	±45°	203	0.383	
D59-1	±45°	234	0.361	
D59-1	±45°	255	0.342	
D59-1	±45°	279	0.387	

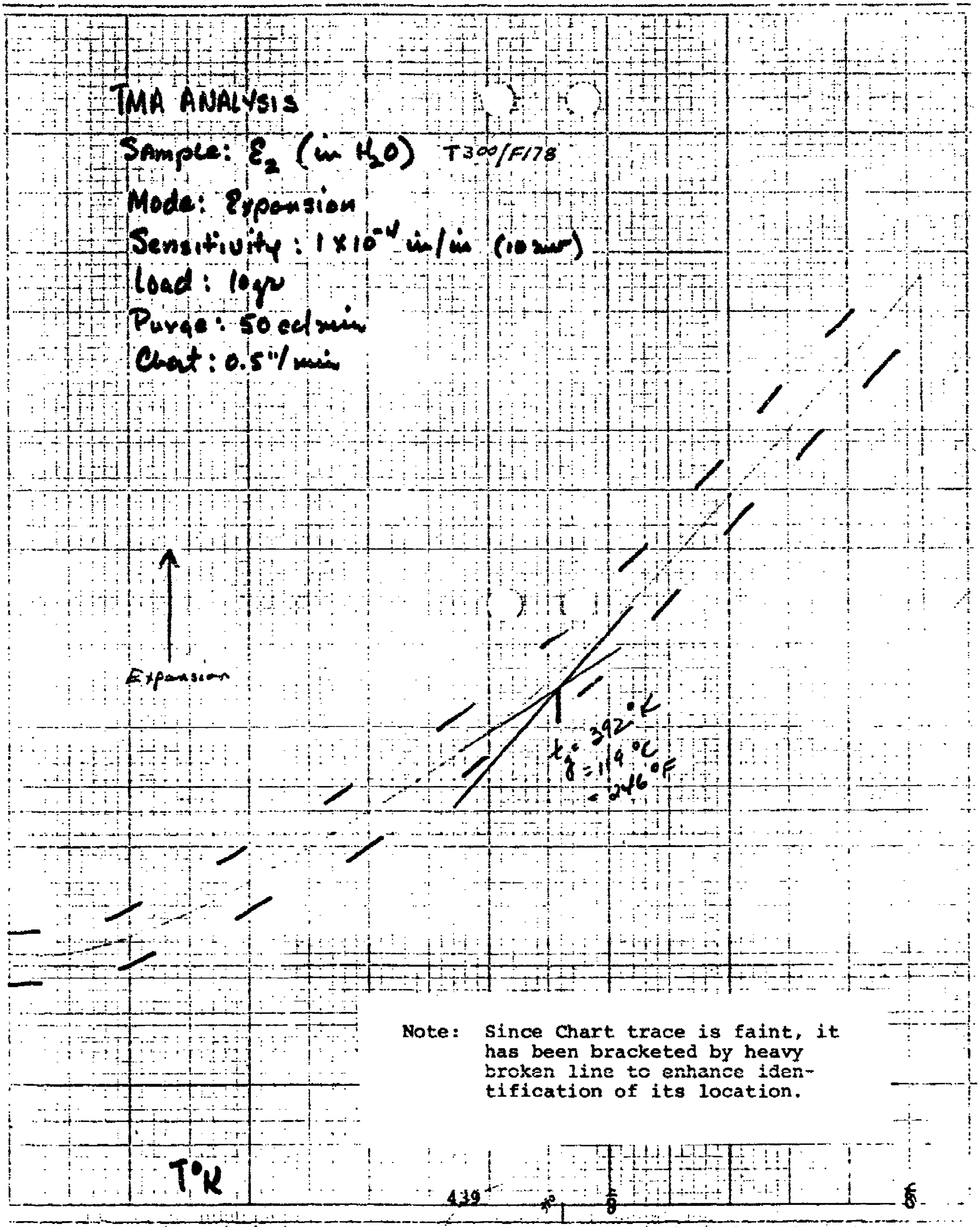
Test: Thermal Conductivity				
Materials: T300/F178			Graphite/Polyimide	
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
E32-1	0°	151	0.263	
E32-1	0°	174	0.255	
E32-1	0°	243	0.332	
E32-1	0°	266	0.327	
E32-1	0°	288	0.286	
E32-1	0°	338	0.398	
E32-1	0°	358	0.370	
E32-1	0°	367	0.369	
E32-1	0°	379	0.396	
E32-1	0°	399	0.391	
E32-1	0°	424	0.375	
E32-1	0°	446	0.360	
E32-1	0°	468	0.440	

APPENDIX M

GLASS-TRANSITION TEMPERATURE DATA

The glass-transition temperatures determined for the materials characterized during this program are presented here along with a typical thermo-mechanical analyzer (TMA) trace, from which Tg's are determined.

Composite Material	T_g (°F)	
	Dry	Wet
SP313	None observed from -67°F to 450°F	250
AS/3004	417	379
AS/4397	472	264
T300/F178	None observed up to 450°F	246



Note: Since Chart trace is faint, it has been bracketed by heavy broken line to enhance identification of its location.

APPENDIX N

HUMIDITY AGED TENSION DATA

All of the tensile data generated during this program on specimens which had been humidity aged at 160°F and 100% R.H. are presented in this section. Summaries of these data are tabulated and plotted in the form of stress-strain curves in Section 4. No ±45° tensile tests after humidity aging were conducted on the T300/F178 material. Only room temperature tests were run on saturated AS/4397 material in the ±45° configuration.

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: SP313

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
A32-8	90°	72	5.10	1.32	5.10	-	0.00390	168	0.75	50% Saturated
A22-3	90°	72	5.64	1.34	5.64	-	0.00430	168	0.76	50% Saturated
A30-1	90°	72	5.54	1.29	5.54	-	0.00440	168	0.70	50% Saturated
A28-8	90°	72	5.64	1.32	5.64	-	0.00450	168	0.74	50% Saturated
A27-4	90°	72	6.34	1.31	6.34	-	0.00500	168	0.76	50% Saturated
Avg			5.65	1.32	5.65	-	0.00440		0.74	
Std Dev			0.45	0.02	0.45	-	0.000400		0.02	
A24-4	90°	260	3.87	1.09	3.87	-	0.00390	168	0.75	50% Saturated
A22-8	90°	260	3.71	1.21	3.71	-	0.00340	168	0.74	50% Saturated
A22-2	90°	260	3.20	1.03	3.20	-	0.00380	168	0.74	50% Saturated
A27-2	90°	260	3.55	1.07	3.55	-	0.00350	168	0.72	50% Saturated
A24-2	90°	260	2.86	1.08	2.86	-	0.00290	168	0.73	50% Saturated
Avg			3.44	1.10	3.44	-	0.00350		0.74	
Std Dev			0.41	0.07	0.41	-	0.00039		0.01	
A26-9	90°	72	3.96	1.27	3.33	-	0.00315	1990	1.52	Saturated
A25-3	90°	72	3.75	1.29	3.61	-	0.00295	1990	1.55	Saturated
A31-3	90°	72	3.83	1.29	3.35	-	0.00300	1990	1.58	Saturated
A21-8	90°	72	4.29	1.32	3.71	-	0.00330	1990	1.46	Saturated
A28-5	90°	72	3.86	1.25	3.86	-	0.00313	1990	1.55	Saturated
Avg			3.94	1.28	3.57	-	0.00311		1.53	
Std Dev			0.21	0.03	0.23	-	0.00014		0.05	
A21-1	90°	260	Broken during installation					1990	1.42	Saturated
A21-2	90°	260	1.79	1.00	0.67	-	0.00223	1990	1.45	Saturated
A24-7	90°	260	1.59	0.91	0.89	-	0.00188	1990	1.50	Saturated
A25-4	90°	260	1.56	0.87	0.61	-	0.00181	1990	1.55	Saturated
A25-7	90°	260	1.57	0.93	0.64	-	0.00206	1990	1.56	Saturated
Avg			1.63	0.93	0.70	-	0.00200		1.49	
Std Dev			0.11	0.05	0.13	-	0.00019		0.06	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: SP313

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
A48-2	±45°	72	21.4	2.61	5.15	-	- *	48	0.78	50% Saturated
A48-9	±45°	72	21.4	2.30	4.13	0.71	- *	48	0.81	50% Saturated
A55-11	±45°	72	21.3	2.19	5.24	0.78	0.0152	48	0.84	50% Saturated
A52-10	±45°	72	22.1	2.76	6.12	0.80	- *	48	0.80	50% Saturated
A52-4	±45°	72	22.0	2.81	5.67	0.84	0.0158	48	0.82	50% Saturated
Avg			21.6	2.53	5.26	0.78	0.0155		0.81	
Std Dev			0.4	0.28	0.74	0.05	-		0.02	
A55-4	±45°	260	14.7	1.95	3.87	0.76	- *	48	0.84	50% Saturated
A54-1	±45°	260	13.3	1.89	3.92	0.75	- *	48	0.84	50% Saturated
A53-3	±45°	260	15.1	1.75	3.64	0.85	- *	48	0.73	50% Saturated
A52-8	±45°	260	15.9	2.05	4.09	0.78	- *	48	0.82	50% Saturated
A53-7	±45°	260	14.5	-	-	-	- *	48	0.84	50% Saturated
Avg			14.7	1.91	3.88	0.79	-		0.81	
Std Dev			1.0	0.13	0.19	0.05	-		0.05	
A48-8	±45°	72	20.9	2.78	4.45	0.75	- *	1512	1.61	Saturated
A52-9	±45°	72	21.8	2.65	4.09	0.80	0.0270	1512	1.56	Saturated
A54-9	±45°	72	21.3	2.37	6.45	0.76	- *	1512	1.54	Saturated
A55-2	±45°	72	21.4	2.59	5.42	0.75	- *	1512	1.52	Saturated
A53-4	±45°	72	21.1	2.64	6.67	0.71	- *	1512	1.51	Saturated
Avg			21.1	2.61	5.42	0.75	0.0270		1.55	
Std Dev			0.3	0.15	1.15	0.03	-		0.04	
A52-2	±45°	260	12.7	1.43	2.62	0.75	- *	1536	1.56	Saturated
A52-11	±45°	260	13.4	2.12	2.44	0.79	- *	1536	1.64	Saturated
A55-7	±45°	260	12.9	1.48	2.21	0.79	- *	1536	1.62	Saturated
A52-7	±45°	260	13.5	1.59	2.34	-	- *	1536	1.59	Saturated
A54-7	±45°	260	14.1	1.84	3.04	0.77	- *	1536	1.55	Saturated
Avg			13.3	1.69	2.53	0.78	-		1.59	
Std Dev			0.5	0.29	0.32	0.02	-		0.04	

* Surface plies cracked prior to failure, breaking strain gages.

Test: Tension After Environmental Aging @ 160°F & 100% R.H.   Material: AS/3004

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
C53-6	90°	72	6.93	1.20	3.09	-	0.0061	9	0.18	60% Saturated
C52-6	90°	72	5.00	1.19	2.84	-	0.0044	9	0.20	60% Saturated
C53-3	90°	72	6.01	1.21	3.84	-	0.0052	9	0.18	60% Saturated
C53-8	90°	72	5.37	1.20	2.78	-	0.0046	9	0.19	60% Saturated
C53-2	90°	72	5.32	1.22	2.44	-	0.0045	9	0.18	60% Saturated
Avg			5.72	1.20	3.00	-	0.0050		0.19	
Std Dev			0.77	0.02	0.52	-	0.0007		0.01	
C52-5	90°	250	4.80	1.13	3.82	-	0.0047	9	0.19	60% Saturated
C53-1	90°	250	2.90	1.14	2.84	-	0.0026	9	0.19	60% Saturated
C52-8	90°	250	4.22	0.96	2.99	-	0.0046	9	0.25	60% Saturated
C52-4	90°	250	4.27	1.11	2.22	-	0.0042	9	0.18	60% Saturated
C53-5	90°	250	4.48	1.13	3.06	-	0.0041	9	0.17	60% Saturated
Avg			4.13	1.09	2.99	-	0.0040		0.20	
Std Dev			0.73	0.08	0.57	-	0.0008		0.03	
C51-4	90°	72	3.96	1.15	2.31	-	0.0035	744	0.29	Saturated
C52-1	90°	72	3.58	1.07	2.35	-	0.0034	744	0.35	Saturated
C51-8	90°	72	4.31	1.10	3.30	-	0.0040	744	0.31	Saturated
C52-2	90°	72	3.45	1.13	2.84	-	0.0031	744	0.35	Saturated
C51-6	90°	72	4.48	1.09	2.99	-	0.0042	744	0.30	Saturated
Avg			3.96	1.11	2.76	-	0.0036		0.32	
Std Dev			0.45	0.03	0.42	-	0.0004		0.02	
C51-7	90°	250	2.74	1.10	2.65	-	0.0025	744	0.30	Saturated
C51-5	90°	250	3.21	1.07	1.91	-	0.0031	744	0.29	Saturated
C51-1	90°	250	2.80	1.05	2.16	-	0.0027	744	0.31	Saturated
C51-3	90°	250	3.62	1.08	2.22	-	0.0036	744	0.29	Saturated
C52-3	90°	250	2.79	1.11	1.24	-	0.0029	744	0.37	Saturated
Avg			3.03	1.08	2.04	-	0.0030		0.31	
Std Dev			0.38	0.02	0.52	-	0.0004		0.02	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: AS/3004

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
C42-8	±45°	72	45.23	1.95	3.41	0.81	0.0462+	3	0.23	55% Saturated
C55-1	±45°	72	31.07	1.95	3.56	0.85	0.0553+	3	0.28	55% Saturated
C56-6	±45°	72	44.66	1.91	3.47	0.78	0.0640+	3	0.26	55% Saturated
C54-8	±45°	72	39.37	1.73	3.56	0.70	0.0610+	3	0.24	55% Saturated
C55-7	±45°	72	27.08	2.16	3.31	0.81	0.0643+	3	0.26	55% Saturated
Avg			37.48	1.94	3.46	0.79	0.0582+		0.25	
Std Dev			8.13	0.15	0.10	0.06	0.0076		0.02	
C41-6	±45°	250	22.02	2.09	2.32	0.92	0.0381+	3	0.20	55% Saturated
C43-2	±45°	250	21.61	1.59	2.60	0.81	0.0508+	3	0.20	55% Saturated
C42-5	±45°	250	20.21	2.09	2.56	0.92	0.0424+	3	0.18	55% Saturated
C44-5	±45°	250	17.99	1.60	1.96	0.96	0.0244+	3	0.22	55% Saturated
Avg			20.46	1.84	2.36	0.90	0.0389+		0.20	
Std Dev			1.82	0.29	0.29	0.06	0.0110		0.02	
C47-4	±45°	72	31.22	2.13	4.27	0.76	0.0500+	576	0.44	Saturated
C46-2	±45°	72	33.64	2.33	4.27	0.80	0.0565+	576	0.39	Saturated
C45-4	±45°	72	31.82	2.21	4.26	0.89	0.0410+	576	0.45	Saturated
C45-3	±45°	72	31.48	2.14	4.26	0.81	0.0445+	576	0.42	Saturated
C50-6	±45°	72	34.45	2.18	4.95	0.75	0.0605+	576	0.43	Saturated
Avg			32.52	2.20	4.40	0.80	0.0505+		0.43	
Std Dev			1.44	0.08	0.30	0.06	0.0081		0.02	
C50-7	±45°	250	26.56	2.17	2.63	0.84	0.0570+	576	0.41	Saturated
C50-2	±45°	250	23.56	1.93	2.63	-	0.1670+	576	0.45	Saturated
C45-1	±45°	250	20.75	2.08	2.00	0.81	0.0155+	576	0.46	Saturated
C50-5	±45°	250	25.00	2.11	2.63	0.84	0.0960+	576	0.42	Saturated
Avg			23.97	2.07	2.47	0.83	0.0562+		0.43	
Std Dev			2.47	0.10	0.31	0.02	0.0403		0.02	

Note: Surface plies cracked prior to failure, breaking the strain gages.

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: AS/4397

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
D19-5	90°	72	5.19	1.37	3.78	–	0.0039	21.5	0.55	45% Saturated
D18-1	90°	72	5.61	1.40	3.66	–	0.0040	21.5	0.49	45% Saturated
D17-4	90°	72	4.88	1.44	2.35	–	0.0035	21.5	0.53	45% Saturated
D17-2	90°	72	5.40	1.44	2.41	–	0.0039	21.5	0.49	45% Saturated
D13-5	90°	72	4.57	1.36	3.79	–	0.0034	21.5	0.49	45% Saturated
Avg			5.13	1.40	3.20	–	0.0037		0.51	
Std Dev			0.41	0.04	0.75	–	0.0003		0.03	
D12-10	90°	350	3.33	1.12	1.17	–	0.0032	21.5	0.45	45% Saturated
D12-4	90°	350	2.87	1.06	1.10	–	0.0027	21.5	0.50	45% Saturated
D14-3	90°	350	2.75	1.21	1.62	–	0.0024	21.5	0.50	45% Saturated
D16-1	90°	350	2.90	1.11	1.77	–	0.0028	21.5	0.47	45% Saturated
D18-8	90°	350	2.70	1.05	1.92	–	0.0026	21.5	0.53	45% Saturated
Avg			2.92	1.11	1.52	–	0.0027		0.49	
Std Dev			0.27	0.06	0.36	–	0.0003		0.03	
D17-3	90°	72	3.79	1.52	1.69	–	0.0026	1320	1.09	Saturated
D17-1	90°	72	3.68	1.58	2.50	–	0.0025	1320	1.02	Saturated
D14-1	90°	72	4.15	1.66	1.84	–	0.0027	1320	1.09	Saturated
D19-4	90°	72	4.47	1.43	2.09	–	0.0032	1320	1.11	Saturated
D19-6	90°	72	3.47	1.51	1.83	–	0.0025	1320	1.11	Saturated
Avg			3.91	1.54	1.99	–	0.0027		1.10	
Std Dev			0.40	0.09	0.32	–	0.0003		0.04	
D18-9	90°	350	1.66	0.84	1.05	–	0.0022	1320	1.09	Saturated
D12-3	90°	350	1.57	0.75	0.62	–	0.0022	1320	1.13	Saturated
D13-3	90°	350	1.19	0.78	0.74	–	0.0018	1320	1.13	Saturated
D18-2	90°	350	1.41	0.90	0.56	–	0.0021	1320	1.11	Saturated
D16-2	90°	350	1.91	0.82	1.25	–	0.0025	1320	1.04	Saturated
Avg			1.55	0.82	0.84	–	0.0022		1.10	
Std Dev			0.27	0.06	0.30	–	0.0002		0.03	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: AS/4397

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
D31-5	± 45°	72	18.24	2.55	8.69	0.77	0.0131	984	1.52	Saturated
D33-4	± 45°	72	18.98	2.66	6.26	0.71	0.0151	984	1.31	Saturated
D34-10	± 45°	72	18.05	2.51	8.03	0.72	0.0190	984	1.18	Saturated
D35-7	± 45°	72	18.72	2.70	5.11	0.78	0.0189	984	1.26	Saturated
D35-3	± 45°	72	19.29	2.62	6.08	0.71	0.0171	984	1.29	Saturated
Avg			18.66	2.61	6.83	0.74	0.0166		1.31	
Std Dev			0.51	0.08	1.48	0.03	0.0025		0.13	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: T300/F178

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
E49-9	90°	72	0.99	1.26	0.99	–	0.0008	24.5	0.82	50% Saturated
E51-6	90°	72	6.00	1.32	3.74	–	0.0046	24.5	0.88	50% Saturated
E51-2	90°	72	1.12	1.42	1.12	–	0.0008	24.5	0.83	50% Saturated
E51-8	90°	72	1.56	1.30	1.56	–	0.0012	24.5	0.88	50% Saturated
Avg			2.42	1.33	1.85	–	0.0019		0.85	
Std Dev			2.40	0.07	1.28	–	0.0018		0.03	
E51-4	90°	350	3.73	0.95	1.26	–	0.0008	24.5	0.78	50% Saturated
E49-5	90°	350	2.04	0.84	2.04	–	0.0024	24.5	0.82	50% Saturated
E49-7	90°	350	2.72	0.85	2.72	–	0.0032	24.5	0.80	50% Saturated
E51-10	90°	350	1.57	0.76	1.57	–	0.0018	24.5	0.79	50% Saturated
Avg			2.51	0.85	1.90	–	0.0020		0.80	
Std Dev			0.81	0.08	0.63	–	0.0010		0.02	
E49-4	90°	72	2.44	1.22	2.44	–	0.0019	642	1.63	Saturated
E51-7	90°	72	3.77	1.32	3.77	–	0.0029	642	1.73	Saturated
E49-2	90°	72	0.75	1.30	0.75	–	0.0006	642	1.59	Saturated
E51-1	90°	72	0.37	1.47	0.37	–	0.0002	642	1.55	Saturated
E49-8	90°	72	3.48	1.32	3.48	–	0.0027	642	1.64	Saturated
Avg			2.16	1.33	2.16	–	0.0017		1.63	
Std Dev			1.55	0.09	1.55	–	0.0012		0.07	
E51-3	90°	350	0.46	0.89	0.46	–	0.0006	642	1.61	Saturated
E51-5	90°	350	0.71	0.64	0.71	–	0.0011	642	1.63	Saturated
E49-6	90°	350	Broken on initial loading			–	–	642	1.65	Saturated
E51-9	90°	350	0.33	0.60	0.33	-	0.0006	642	1.63	Saturated
Avg			0.50	0.71	0.50	–	0.0008		1.53	
Std Dev			0.20	0.16	0.20	–	0.0003		0.02	

APPENDIX O

HUMIDITY AGED INPLANE SHEAR DATA

All of the inplane shear data generated during this program on specimens which had been humidity aged at 160°F and 100% R.H. are presented in this section. All of the data were obtained using the $\pm45°$ tensile coupon (Sec. 3.5.4). Summary tables and stress-strain curves of these data are presented in Section 4. No inplane shear tests after humidity aging were run on the T300/F178 material and only room temperature tests on saturated AS/4397 material were run.

Test: Inplane Shear After Environmental Aging at 160°F and 100% R.H.							
Materials: SP313							
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Stregth. (ksi)	Inplane Shear Modulus (10^6 psi)	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)
A48-2	±45°	72	10.70	0.72	-	48	0.78
A48-9	±45°	72	10.68	0.81	-	48	0.81
A55-11	±45°	72	10.65	0.76	-	48	0.84
A52-10	±45°	72	11.04	0.68	-	48	0.80
A52-4	±45°	72	11.00	-	-	48	0.82
Avg			10.81	0.74	-		0.81
Std Dev			0.19	0.05	-		0.02
A55-4	±45°	260	7.33	0.55	-	48	0.84
A54-1	±45°	260	6.64	0.55	-	48	0.84
A53-3	±45°	260	7.55	0.48	-	48	0.73
A52-8	±45°	260	7.95	0.59	-	48	0.82
A53-7	±45°	260	7.27	-	-	48	0.84
Avg			7.35	0.55	-		0.81
Std Dev			0.48	0.05	-		0.05
A48-8	±45°	72	10.45	0.79	-	1512	1.61
A52-9	±45°	72	10.90	0.74	-	1512	1.56
A54-9	±45°	72	10.65	0.69	-	1512	1.54
A55-2	±45°	72	10.70	0.74	-	1512	1.52
A53-4	±45°	72	10.55	0.77	-	1512	1.51
Avg			10.55	0.75	-		1.55
Std Dev			0.13	0.05	-		0.04
A52-2	±45°	260	6.35	0.42	-	1536	1.56
A52-11	±45°	260	6.70	0.51	-	1536	1.64
A55-7	±45°	260	6.45	0.42	-	1536	1.62
A52-7	±45°	260	6.75	-	-	1536	1.59
A54-7	±45°	260	7.05	0.49	-	1536	1.55
Avg			6.65	0.46	-		1.59
Std Dev			0.25	0.05	-		0.04

Test: Inplane Shear After Environmental Aging at 160°F and 100% R.H.							
Materials: AS/3004							
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Stregth. (ksi)	Inplane Shear Modulus (10^6 psi)	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)
C42-8	±45°	72	22.61	0.54	-	3	0.23
C55-1	±45°	72	15.53	0.53	-	3	0.28
C56-6	±45°	72	22.33	0.54	-	3	0.26
C54-8	±45°	72	19.68	0.51	-	3	0.24
C55-7	±45°	72	13.54	0.60	-	3	0.26
Avg			18.74	0.54	-		0.25
Std Dev			4.07	0.04	-		0.02
C41-6	±45°	250	11.01	0.55	-	3	0.20
C43-2	±45°	250	10.80	0.44	-	3	0.20
C42-5	±45°	250	10.11	0.52	-	3	0.18
C44-5	±45°	250	8.99	0.41	-	3	0.22
Avg			10.23	0.48	-		0.22
Std Dev			0.91	0.07	-		0.02
C47-4	±45°	72	15.61	0.61	-	576	0.44
C46-2	±45°	72	16.82	0.64	-	576	0.39
C45-4	±45°	72	15.91	0.59	-	576	0.45
C45-3	±45°	72	15.74	0.55	-	576	0.42
C50-6	±45°	72	17.23	0.62	-	576	0.43
Avg			16.26	0.60	-		0.43
Std Dev			0.72	0.03	-		0.02
C50-7	±45°	250	13.28	0.50	-	576	0.41
C50-2	±45°	250	11.78	-	-	576	0.45
C45-1	±45°	250	10.38	0.47	-	576	0.46
C50-5	±45°	250	12.50	0.48	-	576	0.42
Avg			11.98	0.48	-		0.43
Std Dev			1.23	0.02	-		0.02

Test: Inplane Shear After Environmental Aging at 160°F and 100% R.H.							
Materials: AS/4397							
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Stregth. (ksi)	Inplane Shear Modulus (10^6 psi)	Ult. Strain (in/in)	Exposure Time (hrs)	Weight Gain (%)
D31-5	±45°	72	9.12	0.73	-	984	1.52
D33-4	±45°	72	9.49	0.77	-	984	1.31
D34-10	±45°	72	9.03	0.75	-	984	1.18
D35-7	±45°	72	9.36	0.75	-	984	1.26
D35-3	±45°	72	9.64	0.74	-	984	1.29
Avg			9.33	0.75	-		1.31
Std Dev			0.26	0.01	-		0.13

APPENDIX P

HUMIDITY AGED INTERLAMINAR SHEAR DATA

All of the interlaminar shear data generated during this program on specimens which had been humidity aged at 160°F and 100% R.H. are presented in this section. These data are summarized in Section 4.

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: SP313			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
A35-11	72	11,710	504	0.78	50% Saturated
A35-2	72	11,880	504	0.85	50% Saturated
A35-10	72	12,160	504	0.68	50% Saturated
A35-43	72	12,660	504	0.72	50% Saturated
A35-21	72	12,550	504	0.64	50% Saturated
Avg		12,190		0.74	
Std Dev		410		0.08	
A35-27	260	6,780	504	0.81	50% Saturated
A35-34	260	6,660	504	0.73	50% Saturated
A35-26	260	6,450	504	0.73	50% Saturated
A35-38	260	6,650	504	0.83	50% Saturated
A35-42	260	6,660	504	0.74	50% Saturated
Avg		6,640		0.77	
Std Dev		120		0.05	
A35-36	72	10,090	1870	1.41	Saturated
A35-24	72	10,250	1870	1.23	Saturated
A35-14	72	9,440	1870	1.54	Saturated
A35-30	72	9,780	1870	1.45	Saturated
A35-19	72	10,180	1870	1.48	Saturated
Avg		9,950		1.42	
Std Dev		340		0.12	
A35-8	260	6,110	1870	1.30	Saturated
A35-23	260	6,080	1870	1.53	Saturated
A35-25	260	6,030	1870	1.53	Saturated
A35-38	260	5,830	1870	1.59	Saturated
A35-44	260	6,050	1870	1.68	Saturated
Avg		6,020		1.53	
Std Dev		110		0.14	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: AS/3004			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
C5-13	72	7,350	552	1.51	75% Saturated
C5-30	72	8,640	552	0.48	75% Saturated
C5-23	72	9,370	552	0.50	75% Saturated
C5-15	72	9,330	552	0.44	75% Saturated
C5-10	72	9,320	552	0.51	75% Saturated
Avg		8,800			
Std Dev		870			
C5-25	250	6,300	552	0.46	75% Saturated
C5-22	250	7,400	552	0.47	75% Saturated
C5-31	250	6,550	552	0.92	75% Saturated
C5-38	250	7,610	552	1.39	75% Saturated
C5-28	250	7,430	552	0.20	75% Saturated
Avg		7,060		0.69	
Std Dev		590		0.47	
C5-33	72	8,520	625	0.60	Saturated
C5-37	72	8,080	625	0.82	Saturated
C5-36	72	9,090	625	0.83	Saturated
C5-34	72	8,280	625	1.09	Saturated
C5-16	72	loaded too fast	625	1.00	Saturated
Avg		8,490		0.87	
Std Dev		440		0.19	
C5-3	250	6,250	625	1.04	Saturated
C5-40	250	6,450	625	0.87	Saturated
C5-21	250	6,070	625	1.00	Saturated
C5-39	250	6,470	625	0.75	Saturated
C5-6	250	7,420	625	0.70	Saturated
Avg		6,530		0.87	
Std Dev		520		0.15	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: AS/4397			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
D9-18	72	13,450	44	0.66	45% Saturated
D9-24	72	16,000	44	0.58	45% Saturated
D9-29	72	17,930	44	0.67	45% Saturated
D9-32	72	16,130	44	0.58	45% Saturated
D9-43	72	18,350	44	0.64	45% Saturated
Avg		16,370		0.63	
Std Dev		1,940		0.04	
D9-25	350	11,620	44	0.60	45% Saturated
D9-33	350	11,120	44	0.68	45% Saturated
D9-36	350	12,590	44	0.46	45% Saturated
D9-42	350	12,150	44	0.53	45% Saturated
D9-44	350	12,820	44	0.70	45% Saturated
Avg		12,060		0.59	
Std Dev		700		0.10	
D9-28	72	12,140	840	0.80	Saturated
D9-8	72	12,990	840	1.26	Saturated
D9-3	72	12,710	840	2.85	Saturated
D9-9	72	13,450	840	1.22	Saturated
D9-19	72	9,350	840	1.10	Saturated
Avg		12,130		1.45	
Std Dev		1,620		0.81	
D9-37	350	7,290	840	0.99	Saturated
D9-10	350	6,830	840	1.25	Saturated
D9-31	350	6,680	840	1.26	Saturated
D9-15	350	5,750	840	1.91	Saturated
D9-14	350	5,880	840	1.00	Saturated
Avg		6,490		1.28	
Std Dev		810		0.37	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: T300/F178			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
E9-34	72	13,060	21.5	0.84	50% Saturated
E9-41	72	12,240	21.5	0.76	50% Saturated
E9-32	72	13,130	21.5	0.83	50% Saturated
E9-35	72	12,880	21.5	0.62	50% Saturated
E9-42	72	13,950	21.5	0.80	50% Saturated
Avg		13,050		0.77	
Std Dev		610		0.09	
E9-43	350	7,650	21.5	0.75	50% Saturated
E9-24	350	7,430	21.5	0.72	50% Saturated
E9-37	350	8,330	21.5	1.00	50% Saturated
E9-31	350	8,210	21.5	0.65	50% Saturated
E9-39	350	8,400	21.5	0.72	50% Saturated
Avg		8,000		0.77	
Std Dev		440		0.13	
E9-40	72	11,230	408	1.50	Saturated
E9-8	72	11,660	408	1.33	Saturated
E9-47	72	11,100	408	1.33	Saturated
Avg		11,330		1.39	
Std Dev		290		0.10	
E9-38	350	7,440	408	1.46	Saturated
E9-22	350	6,940	408	1.35	Saturated
E9-30	350	7,760	408	1.42	Saturated
Avg		7,380		1.41	
Std Dev		410		0.06	

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