NASA Technical Memorandum 89069

BASELINE TENSILE TESTS OF COMPOSITE MATERIALS FOR LDEF EXPOSURE

(NASA-TM-89069) BASELINE TENSILE TESTS OF COMPOSITE MATERIALS FOR LDEF (LONG DURATION EXPOSURE FACILITY) EXPOSURE (NASA) 62 p N87-20386
CSCL 11D Unclas
G3/24 45220

William G. Witte

March 1987

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

SUMMARY

Tensile specimens of five graphite fiber reinforced composite materials, were tested at room temperature to provide baseline data for similar specimens exposed to the space environment in low Earth orbit on the NASA Long Duration Exposure Facility. All specimens were 4-ply [±45°]s layups; at least five replicate specimens were tested for each parameter evaluated. Three epoxy-matrix materials and two polysulfone-matrix materials, several fiber volume fractions, and two sizes of specimen were evaluated. Stress-strain and Poisson's ratio-stress curves, ultimate stress, strain at failure, secant modulus at 0.004 mm/mm strain, inplane shear stress-strain curves, and unidirectional shear modulus at 0.004 mm/mm shear strain are presented.

Tensile data for the three epoxy/graphite materials were similar. Thus, on a specific strength and stiffness basis, the least dense (lowest fiber volume fraction material) was the most efficient for the ±45° layup evaluated. The polysulfone-matrix composites exhibited much larger variations in strain to failure for the replicate specimens than the epoxy-matrix specimens. The failure mode for the graphite/epoxy specimens was a clean separation of the outer plies from the inner plies in interlaminar shear. The failure mechanism for the polysulfone-matrix composites was quite different. The fibers in the inner plies tended to adhere to the outer plies and to realign themselves from 45° towards the axis of loading as fracture occurred. They continued to carry load to relatively high values of breaking strain. The results of the present study (baseline data) will be compared with the data obtained with the exposed specimens in order to evaluate the effects of the space environment on the mechanical properties of these materials.

INTRODUCTION

The combination of low density, low coefficient of thermal expansion, and comparatively high stiffness and strength of graphite fiber reinforced polymeric matrix composite materials make them attractive for space structural applications; they are increasingly being used for these purposes. As future spacecraft will be required to operate for many years in orbit it is necessary to determine the effects of the space environment on the key properties of composite materials. The NASA Long Duration Exposure Facility (LDEF) contains an experiment entitled "Space Exposure of Composite Materials for Large Space Structures", in which tensile specimens of five composite materials (about twenty specimens of each material) are mounted on one of the LDEF trays. The space environment has negligible effect on graphite fibers, therefore major consideration in the choice of composite materials was given to the selection of the matrix materials. Fiberite 934 epoxy, Narmco 5208 epoxy, and Union Carbide P1700 polysulfone were selected; the two epoxy resins because they are well documented, standard thermosetting resins, and the polysulfone because it is a promising thermoplastic resin. All of these materials were cured at 350°F, or above, and meet space outgassing standards. All materials were 4-ply laminations with ply layups of [±45°]s. Forty five degree layups were selected as a compromise between 0° and 90°, because 0° plies are fiber dominated and 90° plies are very brittle. Also, this layup allows shear data which emphasize matrix behavior to be obtained from uniaxially loaded tension tests. Two different composite densities (lower density = lower fiber volume percent) of the polysulfone and of the 934 epoxy materials were used in order to determine whether there are density related effects. The specimens were made in two different sizes in order to determine whether there is an effect due to specimen size. During the flight the LDEF is oriented so that the test tray is exposed to atomic oxygen, thermal cycling, micrometeoroid particle impingements, low levels of electron/proton radiation, UV radiation, vacuum, and possible contamination during launch and recovery from rocket exhaust or from outgassing products from other materials. Tensile tests of representative samples of each material will be made (1) before the LDEF flight to obtain baseline data, (2) after exposure to the LDEF environment, and (3) after storage in a controlled environment on Earth for the length of the LDEF flight. Stress-strain and Poisson's ratio-stress curves, ultimate stress, strain at failure, secant modulus at 0.004 mm/mm strain, inplane shear stress-strain curves, and unidirectional shear modulus at 0.004 mm/mm shear strain comprise the baseline data presented in this report.

EQUIPMENT AND MATERIALS

Testing and Data Acquisition Equipment

The tests were performed in a Model 1350 Instron Servohydraulic testing machine. Figure 1 is a photograph of the test set up. Figure 2 is a close-up of the test specimen, grips and sensors. Longitudinal tensile strains were measured with MTS Model 632.11b-20 extensometers. Transverse strain was measured with an Instron strain sensor Model A327-2 type G57-12. The leads from these sensors and from the Instron Load Cell and Bridge voltage were connected to a terminal board which fed the signals into a console containing a Hewlett Packard 3497A Data Acquisition System and a Hewlett Packard HP85 computer/HP7470A plotter system. Reference 1 gives a complete description of the test procedure. Reference 2 is the standard ASTM test method used for these tests.

A modified TENSL1/TENSL2 program was loaded in the HP85. This program enabled the computer to record data zero-points and to start and stop the data acquisition system. It allowed specimen characteristics and sensor sensitivity factors to be input and subsequently used for converting the raw data to engineering data such as stress and strain. This program had the additional capability for print outs, plotting and storage of the data. A coupled HP85/HP9845B system was used to copy the data to an HP9845 tape cartridge. This tape was used in the HP9845 with a regression analysis program (ref. 3) for manipulating the data. Inplane shear stress-strain response was determined by the procedure presented in reference 4.

LDEF Materials

Fabrication and characterization.- The five LDEF candidate space structure composite materials used in this experiment were:

Panel	Material		Batch/Roll
#12	Polysulfone/Graphite(P1700/C6000)	Note 1	3W2407/1
#3	Polysulfone/Graphite(P1700/C3000)	" 1	2W5272/1
#4	Epoxy/Graphite(934/T300)(145 g/m^2)	" 2 and 4	C2528/5
#6	Epoxy/Graphite(934/T300)(95 g/m^2)	" 2 and 4	C2637/2
#7	Epoxy/Graphite(5208/T300)	" 3	1483/18

Note 1.- P1700 polysulfone is produced by Union Carbide Corp.* C3000 and C6000 are graphite fibers produced by the Celanese Corp.

2.- 934 is a 350°F cured epoxy produced by the Fiberite Corp. T300 is a graphite fiber produced by Union Carbide Corp.

3.- 5208 is a 350°F cured epoxy produced by the Narmco Material Corp.

4.- 145 g/m^2 and 95 g/m^2 are fiber aerial weights to indicate the fiber quantity per unit area.

*Certain commercial materials and products are identified herein in order to specify adequately which materials and products were investigated in the research effort. In no case does such identification imply recommendation or endorsement of the product by NASA, nor does it imply that the materials and products are necessarily the only ones or the best ones available for the purposes. In many cases equivalent materials and products are available and could produce equivalent results.

Panels of 4-ply laminations with ply layups of [±45°]s were fabricated in the NASA Langley Research Center (LaRC) Materials Processing and Development Laboratory. The panels were layed up in sheets 50 inches by 26 inches in size except for the P1700/C6000 which was layed up in a sheet 37 inches by 25 inches in size due to difficulties in handling. Temperatures were recorded and monitored while the panels were being B-staged and autoclaved. As a quality assurance procedure, C-scans were made; no objectionable flaws were detected. Glass transition temperature measurements were made with a DuPont 990 Thermal analyzer/943 Composite thermomechanical analyzer. These values and weight per unit area of the panels are presented in Table I. The results of a fiber volume analysis performed by the LaRC/Bionetics Contract Analytical Chemistry Laboratory are presented in Table II. References 5 and 6 contain the applicable test methods for this analysis.

Tensile test specimens for these tests were cut from these panels with a water cooled diamond saw. Two sizes were cut, 8.000 × 0.500 inch and 6.750 × 0.375 inch. Figure 3 indicates nominal dimensions of the two sizes of specimens that were used.

End-tabs were machined from epoxy/glass cloth to the dimensions shown in figure 3. These fiberglass tabs were bonded to the specimens with EA934, a bonding agent containing 30 micron diameter microballoons, to achieve uniformly thick bondlines. Alinement holes were drilled normal to the plane of the specimen, on the specimen centerline, and 0.75 inches from the ends of the specimens; #15 drill (0.180 in. dia.) was used for the 1/2 in.-wide, and #30 drill (0.128 in. dia.) for the 3.8 in.-wide specimens.

Storage.- The tensile specimens were stored in a Boeckel dessicator of approximately one cubic foot capacity for nine days or more prior to testing. Davison Chemical PA 400 Refrigerator grade silica gel, mesh size 8-20, was used as the dessicant.

Control specimens are similarly stored in a dessicator at atmospheric pressure and room temperature. At the time of LDEF retrieval these specimens will be tensile tested. Comparisons of the control data with the baseline data will indicate whether changes in mechanical characteristics have occurred due to long term storage in a low moisture environment. Spacecraft are sometimes stored for several years prior to launch in such environments. Therefore it would be useful to know whether changes occur.

EXPERIMENTAL PROCEDURES

The gripping assembly used in the LDEF tests is shown in figure 4. Figure 4(a) shows a disassembled view of the grip mechanism. The specimen-grip assembly is shown in figure 4(b). In attaching the specimens to the grips, the backup plate was placed on a horizontal surface with the two grips in the approximate positions shown in figure 4(b). The end-tabs were inserted between the serrated faces of the wedges with the wedge face pin inserted in the holes of the tabs. The tightening devices were put in place and alternately tightened while keeping the specimen taut and straight. An open end wrench was used to tighten the devices as snugly as possible by hand. This pressed the wedges into the angled opening which forced the wedge faces together, thus "setting" the ends in the grips and minimizing the tensile load carried by the pins. Then one grip was clamped into place, and while holding the other grip so that the specimen was taut and straight, the second grip was clamped into place. The assembly was carried to the Instron and the upper grip was screwed into the load cell. Then the actuator was moved into position for pinning the lower grip to it. (The lower portion of the lower grip attachment had previously been screwed to the actuator.) With the grips attached to the load cell and actuator, the backup plate was removed.

Prior to loading the specimen the load cell was zeroed by attaching the upper grip (with a specimen in it) to the load cell and then setting the load cell channel in the Instron voltmeter to zero. With the grips and specimens attached to the load cell and actuator and the load cell previously set to zero, the actuator was moved down to exert a pre-load on the specimen. It was desirable to apply a small preload to the specimen to straighten or flatten it. A load was applied to stress each specimen to 350 psi. In this position the extensometers (ref. 1) were attached. The two extensometers had blades that were one half inch wide and spaced one inch apart. They were attached as a pair, back-to-back, with orthodontic rubber bands, on the flat surfaces of the specimens, spanning the middle one inch of the specimen length. The transverse strain sensor for Poisson's ratio determination was attached just above them. Each extensometer weighed from 0.74 oz. to 0.92 oz. depending on how its wires were supported. With three extensometers in place the load cell sensed an additional 2.5 oz. (approximately) and its output increased accordingly. The actual tensile load on the portion of the specimen below the extensometers was diminished by that amount. A weight of 2.5 oz. was negligible compared with the maximum loads experienced by the specimens (less than 0.2 percent). Therefore no adjustment was made for the extensometers' weight. With the load cell reading approximately 3 or 4 lbs., the extensometers and the strain sensor (channels 3, 4, and 5) were zeroed.

All of the tests were run in the STROKE CONTROL MODE on the Instron, at a strain rate of 0.005 in./in. per minute using the RAMP function. This is a non-cyclic test starting at zero stress and strain and building to a level high enough to fracture or, in the case of the polysulfones, to crack the specimens.

Immediately after the channels were zeroed and data zeroes were taken, the computer program proceeded to the point where it was ready to start recording data. The movement of the load actuator was independent of the computer. It was thus necessary to have the computer start recording data from the data acquisition system just before the actuator started applying load to the specimen.

An oscilloscope on the Instron console was used to monitor stress and strain as the test proceeded, in order to independently monitor ultimate stress and strain. Immediately after failure the loading cycle was stopped and the data acquisition was stopped. When the test stopped a digital volt meter (DVM) on the Instron control console displayed the peak load that had been reached on the load cell. This value was noted. Shortly after the test the computer was ready to print out data. Both raw data and data converted to engineering units were tabulated on the computer printout. Then stress-strain curves were plotted on the HP7470A plotter and the raw stress-strain data were stored on the HP85 magnetic tape.

Subsequently, the data were transferred from the HP85 tapes to HP9845 tapes. Then the data were corrected for the y-axis offset due to the preload and manipulated with the use of the programs listed in reference 3. Data from the two extensometers were averaged and Poisson's ratio was obtained by dividing the data from the transverse strain sensor by the average extensometer data. Printouts of the data manipulations and corrected data were obtained. The corrected data were stored on another HP9845 tape cartridge. Finally, secant modulus at 0.004 mm/mm strain was obtained from the corrected data printout. Secant modulus was obtained at 0.004 mm/mm because the stress-strain curves at this value were still nearly linear. Shear stress and shear strain were obtained from stress and longitudinal and transverse strain data, respectively, as shown in reference 4. Unidirectional shear moduli were obtained from the slopes of the shear stress-strain curves at shear strain of 0.004 mm/mm which is within the linear portions of the curves.

RESULTS AND DISCUSSION

Presentation of the Data

The test results are presented in figures 5-14 and 15-19 as stress-strain curves and Poisson's ratio-stress curves, respectively. The ultimate values of stress and strain and the calculated values of secant modulus at 0.004 mm/mm strain are presented in Table III; the averages of these results are presented in Table IV. Figures 20-23 present bar charts of the data. These graphically show the results presented in Table IV and in figures 5-14. Figures 24-33 present inplane shear stress-strain curves. Table V presents unidirectional shear moduli obtained from the shear stress-strain curves.

Failure Mode Explanation

The data presented in Tables III and IV and figures 5 through 23 show that there are large deviations in stress and strain for the replicate specimens of the polysulfone/graphite materials as compared with the epoxy/graphite materials. These deviations may be attributed to the manner in which fracture occurs in the specimens. Figure 34 presents photographs showing post-test physical appearances of the fracture regions of some typical specimens. The polysulfone specimens (shown in figure 34(a) and (b)) are distorted in the fracture region. The fibers are bent and the fiber ends are moved away from their original positions. In figures 34(c) and (d) such distortion is not evident in the epoxy/graphite specimens. Not only are the fibers distorted in the polysulfone/graphite specimens, but often the fiber ends are missing. This indicates that the epoxy/graphite specimens separate relatively easily along the laminae interfaces, whereas when a polysulfone/graphite specimen starts to fracture, the fiber ends of the inner plies do not separate immediately from the outer plies. Rather the fiber ends of the inner plies continue to adhere to the outer plies and the specimens continue straining with the inner plies' fibers tending to move from +45° towards 0° orientation, until at last, the fibers themselves fracture; and the fiber ends continue to adhere inside the outer plies. This happened with most of the #3 (P1700/C3000) specimens and occasionally with the #12 (P1700/C6000) specimens. This behavior is due to the thermoplastic nature of the P1700, and is indicative of a good fiber/resin interface. In figure 34(d) note that sometimes the fiber ends of the #6 [934C/T300 (95 g/m^2)] specimens are missing. This is a different phenomenon. The fibers are not distorted; and sometimes it is the fibers in the outer plies that are missing. These fibers may be missing due to the fragility of this material. Figure 35 is a display of the test results showing individual specimen results. Note that several polysulfone/graphite specimens have strained to approximately the 0.01 mm/mm level. This may be tantamount to a "basic strain level" where interlaminar shear occurs similar to that which occurs in the epoxy/graphite specimens. The rest of the polysulfone/graphite specimens strain to varying levels depending on how well and/or how many fibers are adhering to the outer plies of the specimens.

Stress-Strain Curves

Material comparison and size effects.- With the exception of the curves for the 9.525 mm-wide specimens of P1700/C6000 and P1700/C3000 (figs. 6 and 8), the curves for each of the two sizes of the five materials are clustered closely together. The curves for the three epoxy/graphite materials are very similar. The curves for the polysulfone/graphite materials have a lower slope, and almost half the ultimate tensile strength of the epoxy/graphite materials, but strain at failure reaches values much greater than those of the epoxy/graphite materials. Referring to figures 20-23 and 35, the epoxy/graphite materials have higher mean levels of stress with smaller standard deviations and ranges of data than the polysulfone/graphite materials. The polysulfone/graphite materials have much higher levels of strain at failure with much greater standard deviations and ranges of data than the epoxy/graphite materials. The large differences in ultimate strain between the two classes of material, and the large deviations in stress and strain for the replicate specimens of the polysulfone/graphite may be attributed to the manner in which fracture occurs in the specimens, as discussed previously.

Secant modulus.- Secant moduli for the epoxy/graphite materials are almost double the moduli for the polysulfone/graphite materials. The differences in secant modulus between the polysulfone and epoxy materials can be attributed to the differences in mechanical properties of these resins since the reinforcing fibers have similar properties.

Inplane Shear Stress-Strain Curves

Material comparison and size effects.- The inplane shear stress-strain curves were generated from the longitudinal and transverse stress-strain data; therefore the individual curves and groups of curves are similar in shape to the stress-strain curves from which they were generated.

Shear modulus.- Shear moduli for the epoxy/graphite materials are almost double the moduli for the polysulfone/graphite materials.

Poisson's Ratio

Material comparison.- Referring to figures 15-19 it is noticeable that the Poisson's ratio-stress curves contain a lot of dispersion, particularly for the polysulfone/graphite specimens. Also, the levels of Poisson's ratio are generally higher for the polysulfone-matrix than for the epoxy-matrix composites.

Size effects.- The curves for the narrower and the wider specimens and for all combined, for each material were averaged. These curves are presented in figure 36. The averaged curves for the two sizes of specimen are separate; and in all cases the Poisson's ratio for the narrower specimens is slightly higher than for the wider specimens. This may be caused by free edge effects having a relatively greater influence on the narrower specimens. Another observation can be made from the data. For the range of stress from 15 to 50 MPa the increase in Poisson's ratio for the polysulfone/graphite specimens is greater than for the epxoy/graphite specimens.

CONCLUDING REMARKS

Specimens of five candidate 4-ply [±45°]s composite space station materials were tensile tested in a servohydraulic Instron testing machine. Stress-strain and Poisson's ratio-stress curves, ultimate stress, strain at peak stress, and secant, modulus at 0.004 mm/mm strain, shear stress-strain curves, and shear modulus at 0.004 mm/mm strain, shear stress-strain curves, and shear modulus at 0.004 mm/mm shear strain were obtained. The following observations were made:

1. Results for the two types of material, epoxy/graphite and polysulfone/graphite, were dissimilar. Ultimate stress was higher and more consistent for the epoxy/graphite, strain at failure was lower and more consistent, secant modulus was higher, and Poisson's ratio was lower. The shear stress-strain curves were similar in shape to the tensile stress-strain curves. The shear moduli showed the same trends as the secant moduli, but at lower magnitudes.

2. The large deviations in stress and strain for the replicate polysulfone/graphite specimens were attributable to the mode of tensile failure. Instead of clean fractures as in the case of the epoxy/graphite specimens, when a polysulfone/graphite specimen started to fracture, the fiber ends of the inner plies did not separate immediately from the outer plies. Rather they continued to adhere and the specimen continued straining with the fibers tending to move from ±45° towards 0° orientation until at last the fibers themselves fractured. The effects of this mode of failure were most pronounced in the P1700/C3000 results.

3. Among the three epoxy/graphite materials the results for ultimate stress, strain at failure, secant modulus and Poisson's ratio were very similar. Therefore the material which was the lightest and least dense [934/T300(95 g/m^2)] could be considered the most efficient on a weight per area or density basis. There was some indication, however, that this material was somewhat more brittle than the other two epoxies.

4. Poisson's ratio-stress curves showed large variations, particularly for the polysulfone/graphite materials. Poisson's ratio was generally higher for the polysulfones than for the epoxies, although the data overlapped. For the range of stress from 15 to 50 MPa the increase in Poisson's ratio for the polysulfones was greater than for the epoxies. When the replicate results were averaged, the curves for the narrower specimens for all five materials were higher than for the wider specimens. This may be caused by free edge effects having a relatively greater influence on the narrower specimens.

5. With the exceptions of the higher Poisson's ratios for the narrower specimens, mentioned in 4), and the more widely dispersed stress-strain curves for the narrower polysulfone/graphite specimens, no effects attributable to specimen size were noticed.

REFERENCES

1. Witte, William G.: Manual for LDEF Tensile Tests. NASA TM 87624, October 1985.

2. "Standard Test Method for Tensile Properties of Fiber-Resin Composites" ASTM Designation D 3039-76 (Reapproved 1982), Annual Book of ASTM Standards 1983, Part 35.

3. "Regression Analysis", Software on Tape Cartridge, Part No. 09845-15011 and "Regression Analysis" Manual, Part No. 09845-15111, Hewlett Packard Co., Desktop Computer Division, 3404 East Harmony Road, Fort Collins, CO 80525.

4. "Standard Recommended Practise for Inplane Shear Stress-Strain Response of Unidirectional Reinforced Plastics" ASTM Designation D 3518-76 (1982) Annual Book of ASTM Standards 1986, Section 15, Volume 15.03.

5. "Standard Test Method for Fiber Content of Resin-Martix Composites by Matrix Digestion" ASTM Designation D 3171-76 (1982) Annual Book of ASTM Standards 1986, Section 15, Volume 15.03.

6. "Standard Test Methods for Specific Gravity and Density of Plastics by Displacement" ASTM Designation D 792-66 (1979) Annual Book of ASTM Standards 1986, Section 8, Volume 8.01.

TABLE I.- MATERIALS

Weight per unit area:

Panel number	Panel weight, gram (pound)	Panel size, cm (inch)	Laminate thickness, mm (inch)	Weight per unit area g/m^2 (psf)
#12	519 (1.144)	94 × 63.5 (37 × 25)	.660 + .025 (.026 + .001)	870 (.1782)
#3	377 (.831)	127 × 66 (50 × 26)	.381 + .025 (.015 + .001)	449 (.0921)
#4	672 (1.481)	127 × 66 (50 × 26)	.584 + .051 (.023 + .002)	801 (.1642)
#6	484 (1.069)	127 × 55 (50 × 26)	.457 + .025 (.018 + .001)	577 (.1182)
#7	715 (1.576)	127 × 66 (50 × 26)	.625 + .028 (.0246 + .0011)	853 (.1747)

Glass transition temperature:

Panel number	Material	Flat probe, 15 g.	U probe, 15 g.
#12	Polysulfone/Graphite(P1700/C6000)	162°C	165°C
#3	Polysulfone/Graphite(P1700/C3000)	174	172
#4	Epoxy/Graphite(934/T300)(145 g/m^2)	192	191
#6	Epoxy/Graphite(934/T300)(95 g/m^2)	202	200
#7	Epoxy/Graphite(5208/T300)	210	202

TABLE II.- FIBER VOLUME ANALYSIS

Panel number	Initial weight, g	Weight after heating, g	% Volatile	% Volatile (ave.)	Fiber weight, g	Fiber weight %	Fiber, weight % (ave.)	Fiber density, g/ml	Composite density, g/cc	Fiber, volume %	Fiber, volume % (average)
12	0.52801	0.52516	0.5	0.5	0.35315	67.2	67.2	1.53	1.32	58.0	57.95
	0.53547	0.53273	0.5		0.35775	67.2				57.9	
3	0.36227	0.36114	0.3	0.3	0.23422	64.8	65.7	1.51	1.18	50.7	51.4
	0.31322	0.31223	0.3		0.20805	66.6				52.1	
4	0.87724	0.85905	2.0	1.95	0.64206	74.7	74.4	1.59	1.37	64.4	64.15
	0.79463	0.77956	1.9		0.57793	74.1				63.9	
6	0.67633	0.66762	1.3	1.5	0.48117	72.1	72.05	1.57	1.26	57.8	57.8
	0.65194	0.64089	1.7		0.46152	72.0				57.8	
7	0.55930	0.55218	1.3	1.25	0.39572	71.7	73.0	1.59	1.36	61.3	62.4
	0.54387	0.53724	1.2		0.39863	74.3				63.5	

Note:

Panel number	Material
#12	Polysulfone/Graphite(P1700/C6000)
#3	Polysulfone/Graphite(P1700/C3000)
#4	Epoxy/Graphite(934/T300)(145 g/m^2)
#6	Epoxy/Graphite(934/T300)(95 g/m^2)
#7	Epoxy/Graphite(5208/T300)

TABLE III.- LDEF BASELINE TENSILE TEST RESULTS

Specimen No.	Thickness mm	(inch)	Width mm	(inch)	Ultimate Tensile Strength MPa	(ksi)	Strain at Failure	Tensile Modulus GPa	(Msi)	DVM Maximum load Newtons	(pounds)
Polysulfone/Graphite (P1700/C6000)											
12L1	.659	(.02595)	12.73	(.5012)	64.47	(9.350)	.01184	9.40	(1.364)	540.9	(121.6)
2	.645	(.02538)	12.70	(.5000)	57.91	(8.399)	.01073	9.55	(1.385)	473.7	(106.5)
3	.659	(.02595)	12.74	(.5016)	63.84	(9.259)	.01068	9.69	(1.405)	536.5	(120.6)
4	.650	(.02561)	12.77	(.5029)	78.72	(11.418)	.02923	10.20	(1.480)	655.2	(147.3)
5	.654	(.02576)	12.77	(.5029)	64.18	(9.308)	.01014	9.93	(1.440)	536.5	(120.6)
6	.663	(.02612)	12.75	(.5023)	66.31	(9.618)	.01012	10.20	(1.480)	562.7	(126.5)
12T1	.670	(.02636)	9.55	(.3762)	83.59	(12.124)	.04566	9.89	(1.434)	534.7	(120.2)
2	.651	(.02564)	9.52	(.3749)	63.04	(9.143)	.00950	9.83	(1.425)	391.4	(88.0)
3	.641	(.02524)	9.54	(.3757)	64.67	(9.379)	.01621	9.09	(1.319)	395.9	(89.0)
4	.657	(.02586)	9.53	(.3753)	51.65	(7.491)	.00861	8.33	(1.208)	311.4	(70.0)
5	.675	(.02659)	9.62	(.3789)	96.00	(13.923)	.03588	10.76	(1.561)	624.1	(140.3)
Polysulfone/Graphite (P1700/C3000)											
3L1	.351	(.01380)	12.71	(.5007)	92.84	(13.465)	.06554	9.27	(1.345)	414.1	(93.1)
2	.412	(.01621)	12.73	(.5014)	117.20	(16.999)	.0951	8.45	(1.226)	614.7	(138.2)
3	.408	(.01605)	12.70	(.5003)	100.81	(14.621)	.06827	8.53	(1.237)	516.0	(116.0)
4	.412	(.01622)	12.74	(.5019)	75.10	(10.892)	.03502	8.38	(1.216)	394.6	(88.7)
5	.401	(.01579)	12.74	(.5016)	126.34	(18.324)	.1094	8.83	(1.280)	645.4	(145.1)
6	.407	(.01604)	12.74	(.5019)	59.18	(8.584)	.01126	8.71	(1.263)	307.4	(69.1)
7	.407	(.01601)	12.69	(.4997)	89.82	(13.028)	.06174	8.54	(1.239)	464.8	(104.5)
3T1	.383	(.01509)	9.46	(.3728)	94.52	(13.709)	.04511	9.55	(1.385)	342.5	(77.1)
2	.403	(.01586)	9.50	(.3743)	58.56	(8.493)	.01036	8.87	(1.286)	224.2	(50.4)
3	.394	(.01551)	9.51	(.3747)	89.15	(12.930)	.03110	9.84	(1.427)	334.5	(75.2)
4	.394	(.01550)	9.42	(.3712)	93.75	(13.597)	.06361	8.99	(1.304)	348.3	(78.3)
5	.414	(.01631)	9.54	(.3759)	98.79	(14.328)	.08586	8.69	(1.261)	391.0	(87.9)
Epoxy/Graphite (934/T300)(145 g/m^2)											
4L1	.614	(.02418)	12.77	(.5029)	140.55	(20.385)	.01377	17.51	(2.539)	1102.3	(247.8)
2	.560	(.02206)	12.76	(.5026)	149.58	(21.695)	.01653	17.20	(2.494)	1070.2	(240.6)
3	.606	(.02384)	12.74	(.5016)	129.58	(18.794)	.01005	17.98	(2.608)	999.5	(224.7)
4	.594	(.02338)	12.77	(.5030)	144.31	(20.930)	.01411	16.71	(2.424)	1095.6	(246.3)
5	.594	(.02339)	12.75	(.5023)	146.63	(21.267)	.01549	17.24	(2.500)	1109.8	(249.8)
6	.562	(.02214)	12.72	(.5010)	151.95	(22.039)	.01868	17.00	(2.465)	1089.9	(245.0)
7	.573	(.02256)	12.77	(.5030)	143.11	(20.757)	.01513	17.03	(2.470)	1048.4	(235.7)
4T1	.594	(.02340)	9.53	(.3752)	153.46	(22.257)	.01649	17.77	(2.578)	869.2	(195.4)
2	.585	(.02303)	9.52	(.3751)	146.84	(21.297)	.01586	16.83	(2.441)	817.6	(183.8)
3	.604	(.02377)	9.52	(.3749)	146.85	(21.299)	.01450	17.84	(2.588)	844.7	(189.9)
4	.595	(.02341)	9.51	(.3747)	148.36	(21.518)	.01401	18.17	(2.635)	839.8	(188.8)
5	.578	(.02274)	9.52	(.3748)	143.50	(20.813)	.01455	17.27	(2.505)	791.8	(178.0)

TABLE III.- Concluded

Specimen No.	Thickness mm	(inch)	Width mm	(inch)	Ultimate Tensile Strength MPa	(ksi)	Strain at Failure	Tensile Modulus GPa	(Msi)	DVM Maximum load Newtons	(pounds)
					Epoxy/Graphite(934/T300)(95 g/m^2)						
6L1	.452	(.01778)	12.83	(.5051)	150.44	(21.819)	.01949	16.05	(2.328)	871.9	(196.0)
2	.457	(.01800)	12.80	(.5042)	151.79	(22.015)	.01997	15.95	(2.313)	889.6	(200.0)
3	.454	(.01789)	12.80	(.5043)	152.02	(22.049)	.02146	15.56	(2.257)	887.4	(199.5)
4	.442	(.01740)	12.80	(.5041)	155.81	(22.598)	.01976	16.62	(2.411)	881.6	(198.2)
5	.454	(.01788)	12.80	(.5042)	148.98	(21.608)	.01996	15.53	(2.252)	866.1	(194.7)
6	.454	(.01786)	12.80	(.5040)	149.16	(21.634)	.01904	15.84	(2.298)	866.5	(194.8)
6T1	.439	(.01729)	9.54	(.3756)	158.19	(22.943)	.02199	15.80	(2.291)	662.8	(149.0)
2	.449	(.01769)	9.60	(.3782)	148.88	(21.593)	.01773	16.26	(2.359)	642.8	(144.5)
3	.461	(.01814)	9.56	(.3765)	148.15	(21.487)	.01711	16.84	(2.442)	652.6	(146.7)
4	.437	(.01720)	9.57	(.3771)	152.71	(22.149)	.01898	16.29	(2.362)	639.2	(143.7)
5	.438	(.01726)	9.56	(.3764)	158.50	(22.988)	.02241	15.84	(2.298)	663.7	(149.2)
6	.445	(.01751)	9.53	(.3752)	158.54	(22.994)	.02039	16.44	(2.385)	673.5	(151.4)
					Epoxy Graphite(5208/T300)						
7L1	.599	(0.2358)	12.79	(.5038)	136.44	(19.789)	.01294	16.16	(2.344)	1046.2	(235.2)
2	.607	(0.2389)	12.78	(.5035)	143.61	(20.829)	.01473	16.35	(2.372)	1114.7	(250.6)
3	.583	(.02295)	12.76	(.5026)	132.08	(19.156)	.01106	17.11	(2.482)	983.9	(221.2)
4	.609	(.02396)	12.81	(.5044)	149.37	(21.665)	.01578	16.27	(2.360)	1165.0	(261.9)
5	.598	(.02355)	12.79	(.5036)	146.60	(21.263)	.01376	17.15	(2.487)	1121.8	(252.2)
6	.627	(.02468)	12.77	(.5029)	134.97	(19.576)	.01269	16.08	(2.332)	1080.5	(242.9)
7	.620	(.02441)	12.76	(.5027)	139.99	(20.304)	.01362	16.38	(2.375)	1108.9	(249.3)
7T1	.614	(.02417)	9.57	(.3771)	142.98	(20.737)	.01520	15.67	(2.273)	841.6	(189.2)
2	.611	(.02406)	9.52	(.3748)	139.49	(20.232)	.01371	16.22	(2.353)	811.8	(182.5)
3	.615	(.02423)	9.52	(.3749)	142.91	(20.728)	.01285	17.22	(2.497)	837.2	(188.2)
4	.623	(.02453)	9.54	(.3758)	138.34	(20.064)	.01232	16.80	(2.437)	822.5	(184.9)
5	.600	(.02363)	9.52	(.3748)	142.51	(20.669)	.01250	17.24	(2.501)	814.0	(183.0)

Note: Specimen Number = Panel Number/Specimen Size Designation and Number

Specimen Size Designation
L = 1/2-in. wide specimens
T = 3/8-in. wide specimens

TABLE IV.- LDEF BASELINE TENSILE TEST RESULTS AVERAGED

Specimen Identification		Ultimate Tensile Strength MPa	(ksi)	Strain at Failure	Tensile Modulus GPa	(Msi)
		Polysulfone/Graphite (P1700/C6000)				
12L	$\bar{x}$	65.90	(9.558)	.01379	9.83	(1.425)
	s	6.89	(1.000)	.007589	0.34	(0.0487)
	$100(s/\bar{x})$ =	10.4628 %		55.032 %	3.420 %	
	n = 6					
12T	$\bar{x}$	71.79	(10.412)	.02317	9.58	(1.389)
	s	17.74	(2.5723)	.016693	0.92	(0.1328)
	$100(s/\bar{x})$ =	24.705 %		72.0465 %	9.5595 %	
	n = 5					
12L+T	$\bar{x}$	68.58	(9.946)	.01805	9.71	(1.409)
	s	12.61	(1.829)	.012816	0.64	(0.0927)
	$100(s/\bar{x})$ =	18.390 %		71.007 %	6.581 %	
	n = 11					
		Polysulfone/Graphite (P1700/C3000)				
3L	$\bar{x}$	94.47	(13.701)	.06375	8.67	(1.258)
	s	23.15	(3.358)	.03335	0.30	(0.04409)
	$100(s\bar{x})$ =	24.509 %		52.31 %	3.505 %	
	n = 7					
3T	$\bar{x}$	86.95	(12.611)	.04720	9.18	(1.332)
	s	16.24	(2.355)	.02908	0.48	(0.0703)
	$100(s/\bar{x})$ =	18.674 %		61.61 %	5.276 %	
	n = 5					
3L+T	$\bar{x}$	91.33	(13.247)	.05685	8.89	(1.289)
	s	20.08	(2.912)	.03141	0.45	(0.6583)
	$100(s/\bar{x})$ =	21.982 %		55.25 %	5.107 %	
	n = 12					

TABLE IV.- Continued

Specimen Identification		Ultimate Tensile Strength MPa	(ksi)	Strain at Failure	Tensile Modulus GPa	(Msi)
		Epoxy/Graphite (934/T300) (145 g/m^2)				
4L	$\bar{x}$	143.67	(20.838)	.0148	17.24	(2.500)
	s	7.32	(1.061)	.00266	0.41	(.0593)
	100(s/$\bar{x}$) =	5.092 %		18.003 %	2.372 %	
	n = 7					
4T	$\bar{x}$	147.80	(21.436)	.0150	17.57	(2.549)
	s	3.63	(0.526)	.00104	0.53	(0.0763)
	100(s/$\bar{x}$) =	2.454 %		6.920 %	2.996 %	
	n = 5					
4L+T	$\bar{x}$	145.39	(21.087)	.0149	17.37	(2.520)
	s	6.20	(0.899)	.00207	0.47	(0.0684)
	100(s/$\bar{x}$) =	4.267 %		13.885 %	2.716 %	
	n = 12					
		Epoxy/Graphite (934/T300) (95 g/m^2)				
6L	$\bar{x}$	151.36	(21.953)	.0199	15.92	(2.309)
	s	2.52	(0.365)	.000819	0.40	(0.0580)
	100(s/$\bar{x}$) =	1.662 %		4.107 %	2.514 %	
	n = 6					
6T	$\bar{x}$	154.16	(22.359)	.0197	16.24	(2.356)
	s	4.90	(0.711)	.00222	0.39	(0.0563)
	100(s/$\bar{x}$) =	3.181 %		11.279 %	2.390 %	
	n = 6					
6L+T	$\bar{x}$	152.76	(22.156)	.0198	16.09	(2.333)
	s	3.99	(0.579)	.00159	0.41	(0.0596)
	100(s/$\bar{x}$) =	2.614 %		8.047 %	2.557 %	
	n = 12					

TABLE IV.- Concluded

Specimen Identification		Ultimate Tensile Strength MPa	(ksi)	Strain at Failure	Tensile Modulus GPa	(Msi)
		Epoxy/Graphite (5208/T300)				
7L	$\bar{x}$	140.43	(20.368)	.0135	16.50	(2.393)
	s	6.37	(0.924)	.00151	0.44	(0.00642)
	$100(s/\bar{x})$ =	4.539 %		11.189 %	2.682 %	
	n = 7					
7T	$\bar{x}$	141.25	(20.486)	.0133	16.63	(2.412)
	s	2.17	(0.315)	.00118	0.68	(0.0981)
	$100(s/\bar{x})$ =	1.538 %		8.869 %	4.070 %	
	n = 5					
7L+T	$\bar{x}$	140.77	(20.417)	.0134	16.55	(2.401)
	s	4.90	(0.711)	.00132	0.53	(0.0764)
	$100(s/\bar{x})$ =	3.484 %		9.890 %	3.184 %	
	n = 12					

Note: Specimen Identification = Panel Number/Specimen Size Designation

Specimen Size Designation
L = 1/2-in. wide specimens
T = 3/8-in. wide specimens

TABLE V.- UNIDIRECTIONAL SHEAR MODULUS AT .004 mm/mm SHEAR STRAIN

Specimen Number	Shear Modulus GPa	(Msi)	Averaged	
			Polysulfone/Graphite (P1700/C6000)	
12L1	2.77	.402		
2	2.98	.432		
3	3.04	.442		
4	3.27	.474	$\bar{x}$ = 3.06 (0.444)	
5	3.15	.457	s = 0.171 (0.025)	
6	3.13	.454	100(s/$\bar{x}$) = 5.60 %	
				$\bar{x}$ = 2.98 (0.432)
12T1	3.04	.440		s = 0.250 (0.036)
2	2.93	.425		100(s/$\bar{x}$) = 8.41 %
3	2.47	.358	$\bar{x}$ = 2.88 (0.419)	n = 11
4	2.69	.390	s = 0.315 (0.046)	
5	3.29	.477	100(s/$\bar{x}$) = 10.93 %	
			Polysulfone/Graphite (P1700/C3000)	
3L1	2.80	.406		
2	2.61	.379		
3	2.56	.372		
4	2.55	.371		
5	2.74	.397	$\bar{x}$ = 2.67 (0.387)	
6	2.76	.401	s = 0.009 (0.014)	
7	2.64	.383	100(s/$\bar{x}$) = 3.73 %	
				$\bar{x}$ = 2.65 (0.386)
3T1	2.53	.368		s = 0.103 (0.015)
2	2.50	.363		100(s/$\bar{x}$) = 3.90 %
3	2.77	.401	$\bar{x}$ = 2.64 (0.383)	n = 12
4	2.74	.398	s = 0.118 (0.017)	
5	2.64	.384	100(s/$\bar{x}$) = 4.50 %	
			Epoxy/Graphite (934/T300) (145 g/m^2)	
4L1	5.36	.778		
2	5.41	.785		
3	5.44	.789		
4	5.24	.760		
5	5.31	.770	$\bar{x}$ = 5.31 (0.771)	
6	5.07	.735	s = 0.126 (0.018)	
7	5.36	.778	100(s/$\bar{x}$) = 2.37 %	
				$\bar{x}$ = 5.31 (0.772)
4T1	5.06	.734		s = 0.204 (0.030)
2	5.16	.748		100(s/$\bar{x}$) = 3.84 %
3	5.12	.742	$\bar{x}$ = 5.32 (0.772)	n = 12
4	5.76	.836	s = 0.302 (0.044)	
5	5.50	.798	100(s/$\bar{x}$) = 5.67 %	

TABLE V.- Concluded

Specimen Number	Shear Modulus GPa	(Msi)	Averaged	
			Epoxy/Graphite (934/T300) (95 g/m^2)	
6L1	4.72	.684		
2	4.87	.706		
3	4.92	.714		
4	4.95	.718	$\bar{x}$ = 4.87 (0.707)	
5	4.74	.688	s = 0.125 (0.018)	
6	5.04	.731	100(s/$\bar{x}$) = 2.56 %	
				$\bar{x}$ = 4.99 (0.725)
6T1	4.62	.670		s = 0.509 (0.074)
2	4.83	.700		100(s/$\bar{x}$) = 10.18 %
3	4.44	.644		n = 12
4	5.12	.742	$\bar{x}$ = 5.11 (0.742)	
5	6.46	.937	s = 0.722 (0.105)	
6	5.21	.755	100(s/$\bar{x}$) = 14.12 %	
			Epoxy/Graphite (5208/T300)	
7L1	4.72	.685		
2	4.90	.710		
3	5.36	.778		
4	5.07	.736		
5	5.16	.749	$\bar{x}$ = 5.03 (0.730)	
6	4.96	.720	s = 0.202 (0.029)	
7	5.01	.726	100(s/$\bar{x}$) = 4.01 %	
				$\bar{x}$ = 4.96 (0.721)
7T1	4.65	.675		s = 0.231 (0.034)
2	4.80	.697		100(s/$\bar{x}$) = = 4.65 %
3	4.62	.670	$\bar{x}$ = 4.88 (0.708)	n = 12
4	5.14	.746	s = 0.263 (0.038)	
5	5.17	.750	100(s/$\bar{x}$) = 5.39 %	

Note: Specimen Number = Panel Number/Specimen Size Designation and Number

Specimen Size Designation
L = 1/2-inch wide specimens
T = 3/8-inch wide specimens

ORIGINAL PAGE IS
OF POOR QUALITY

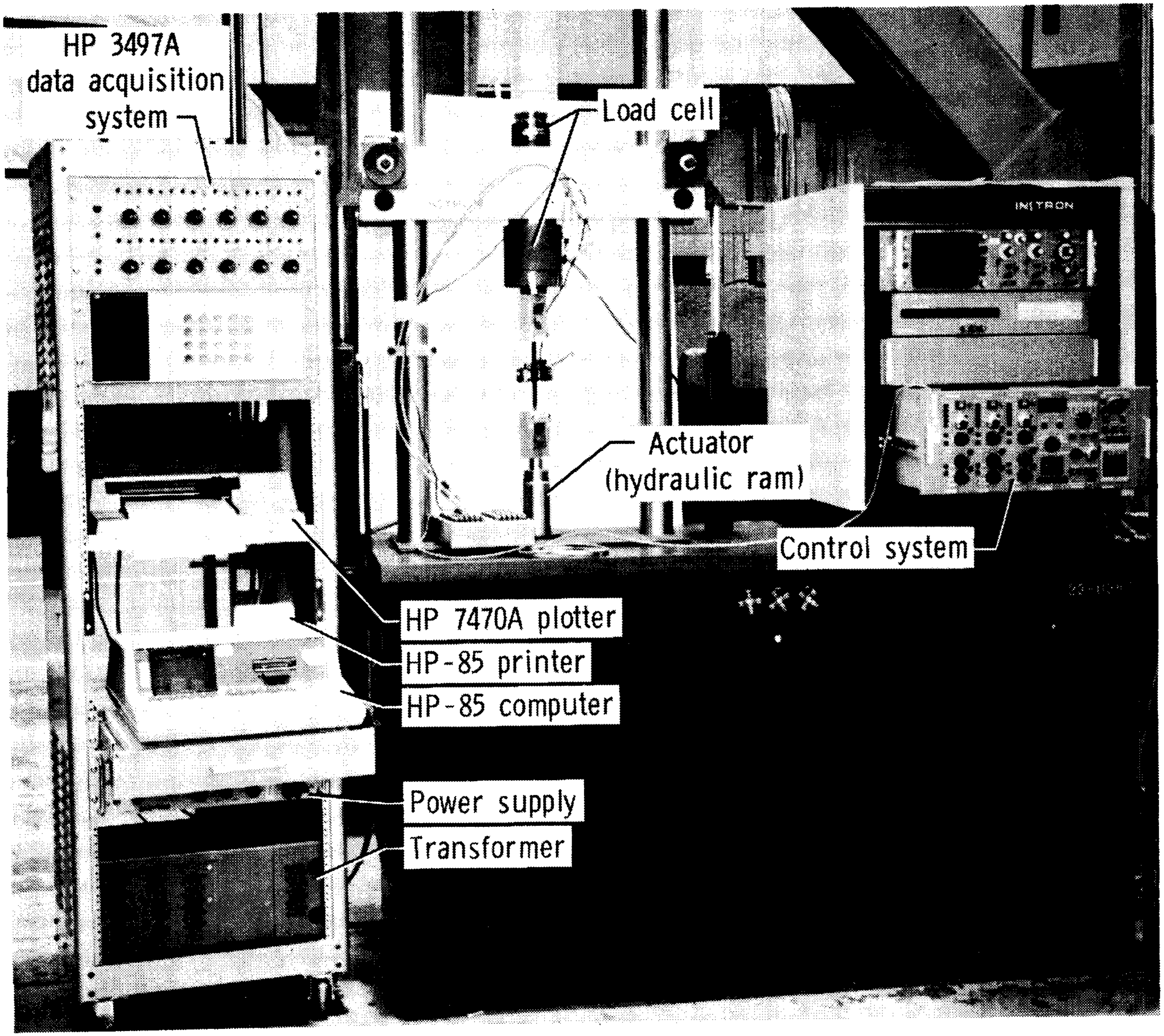


Figure 1.- Tensile testing and data acquisition equipment.

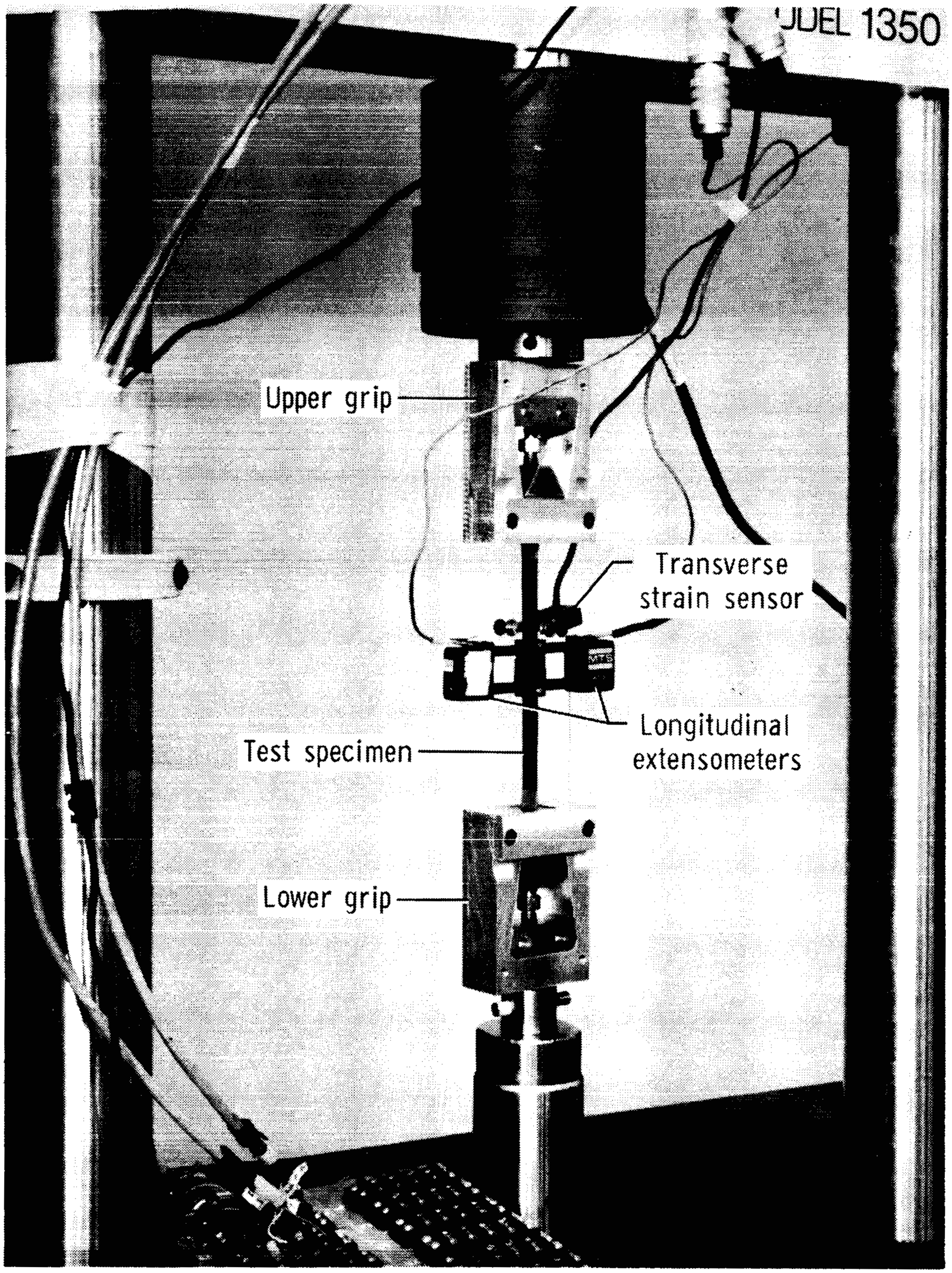
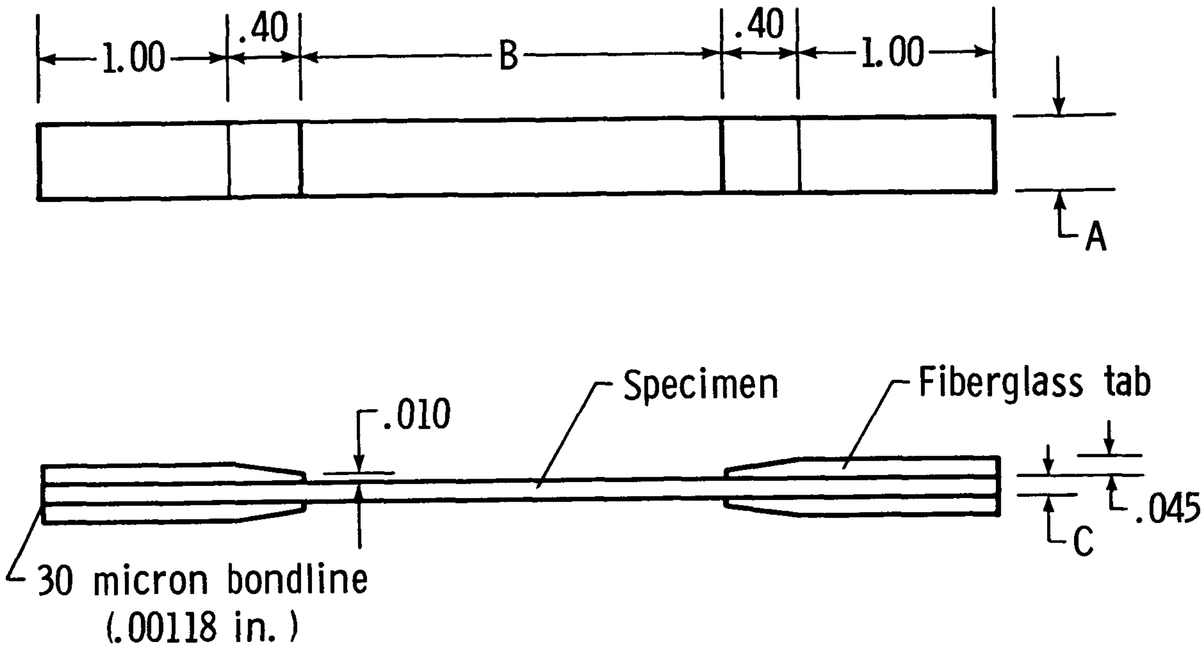


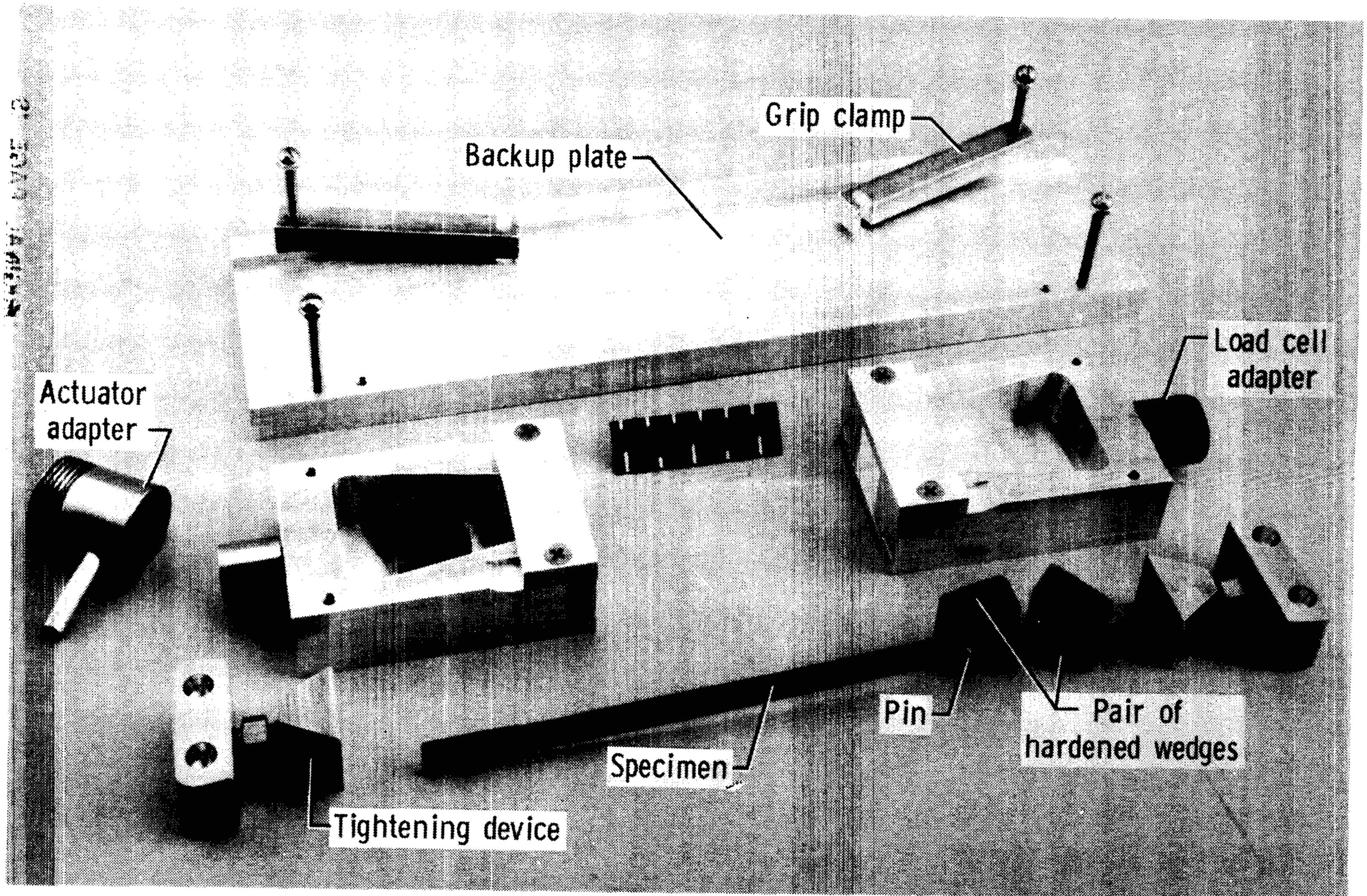
Figure 2.- Close-up view of test specimen, grips and sensors.



A	B	C
.500	5.20	Laminate thickness varies with material, see Table 1
.375	3.95	

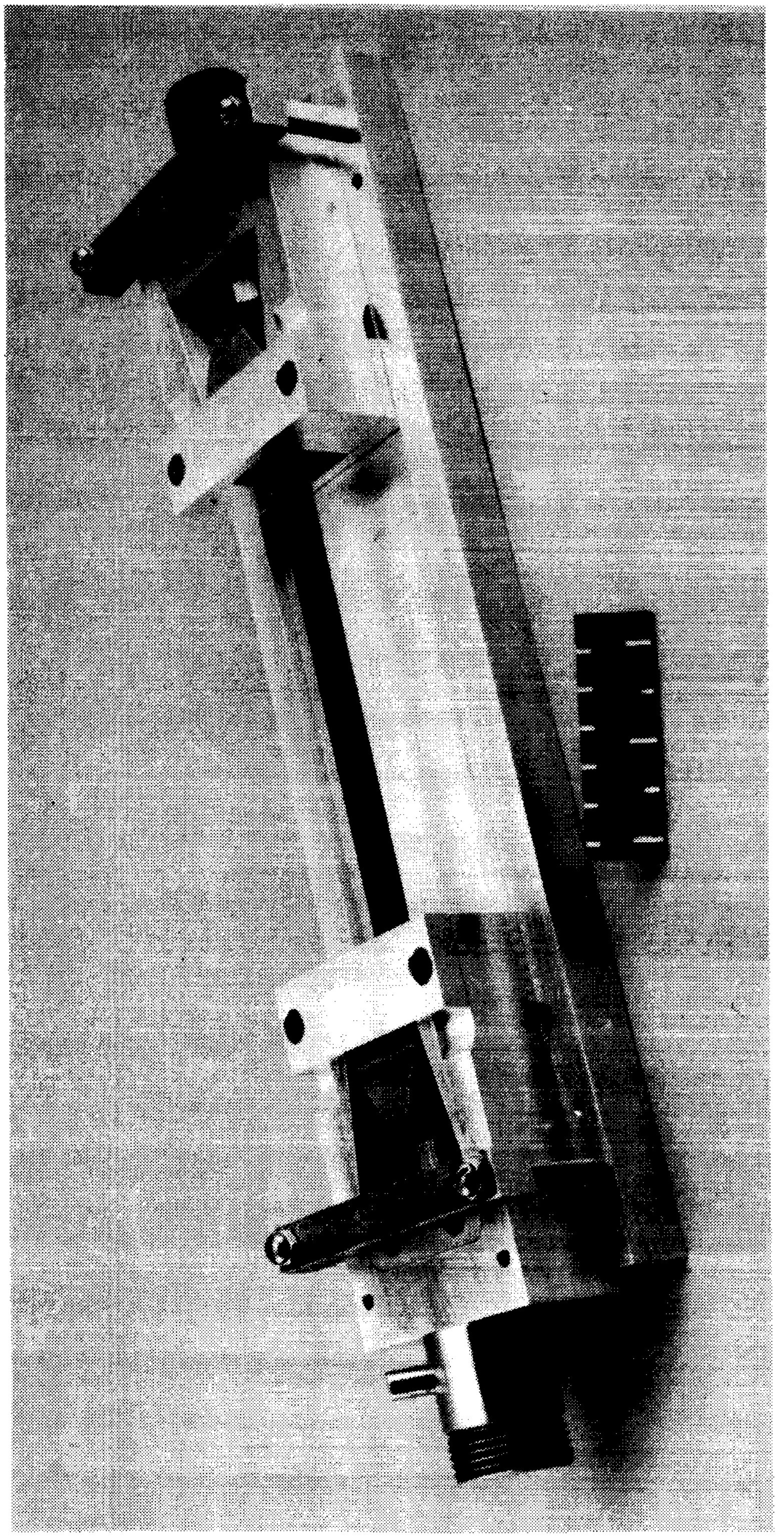
Note: dimensions shown are in inches.

Figure 3.- Tensile test specimens.



(a) Dissassembled.

Figure 4.- Lightweight tensile specimen grips.



(b) Assembled.

Figure 4.- Concluded.

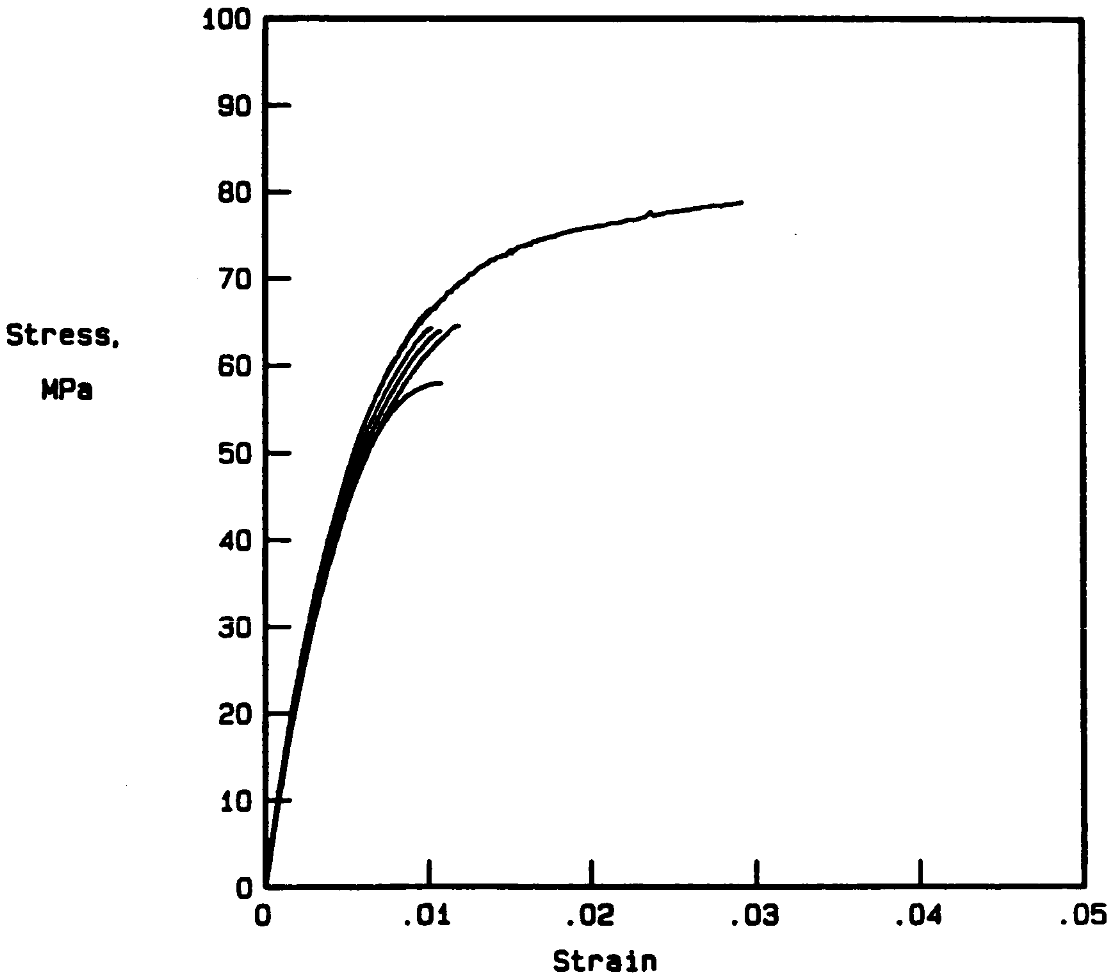


Figure 5.- Stress-strain curves for material #12 (P1700/C6000) (12.7 mm-wide specimens).

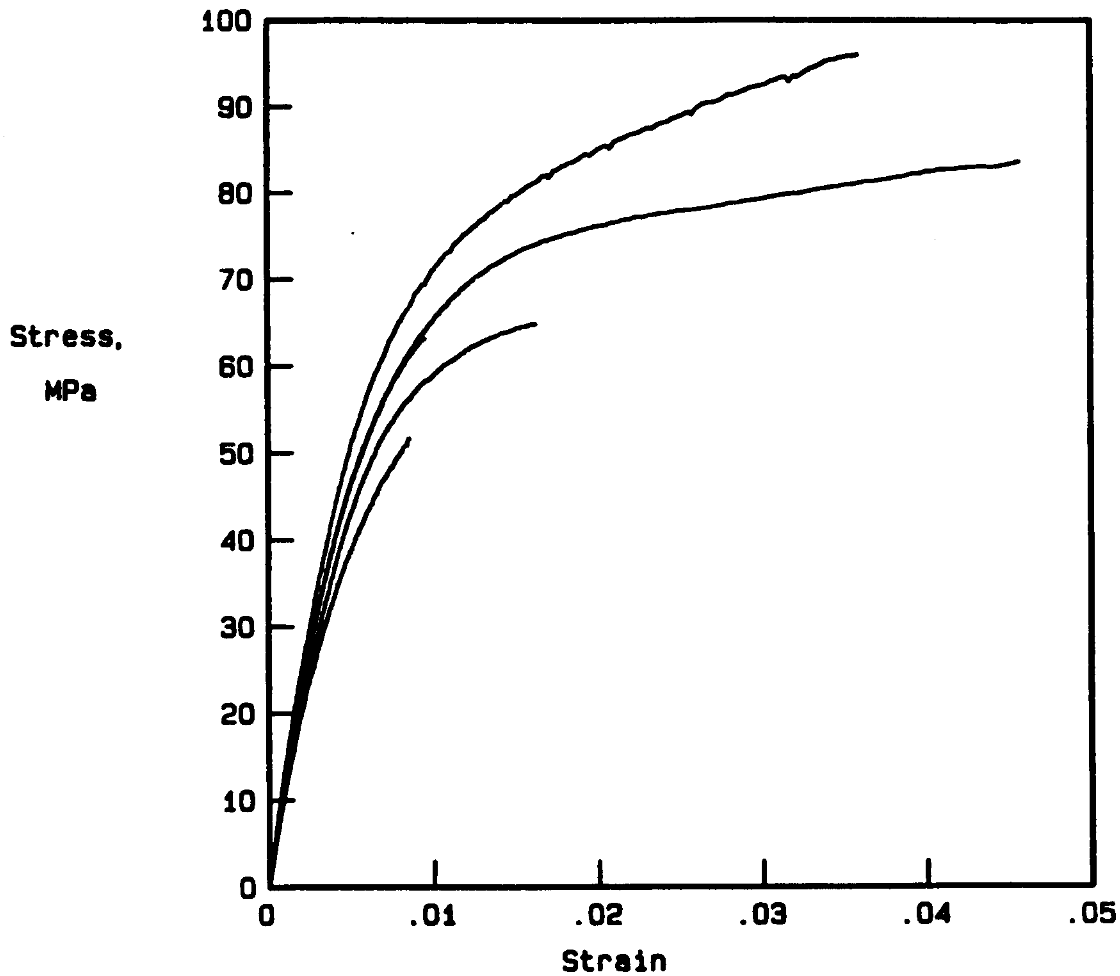


Figure 6.- Stress-strain curves for material #12 (P1700/C6000) (9.525 mm-wide specimens).

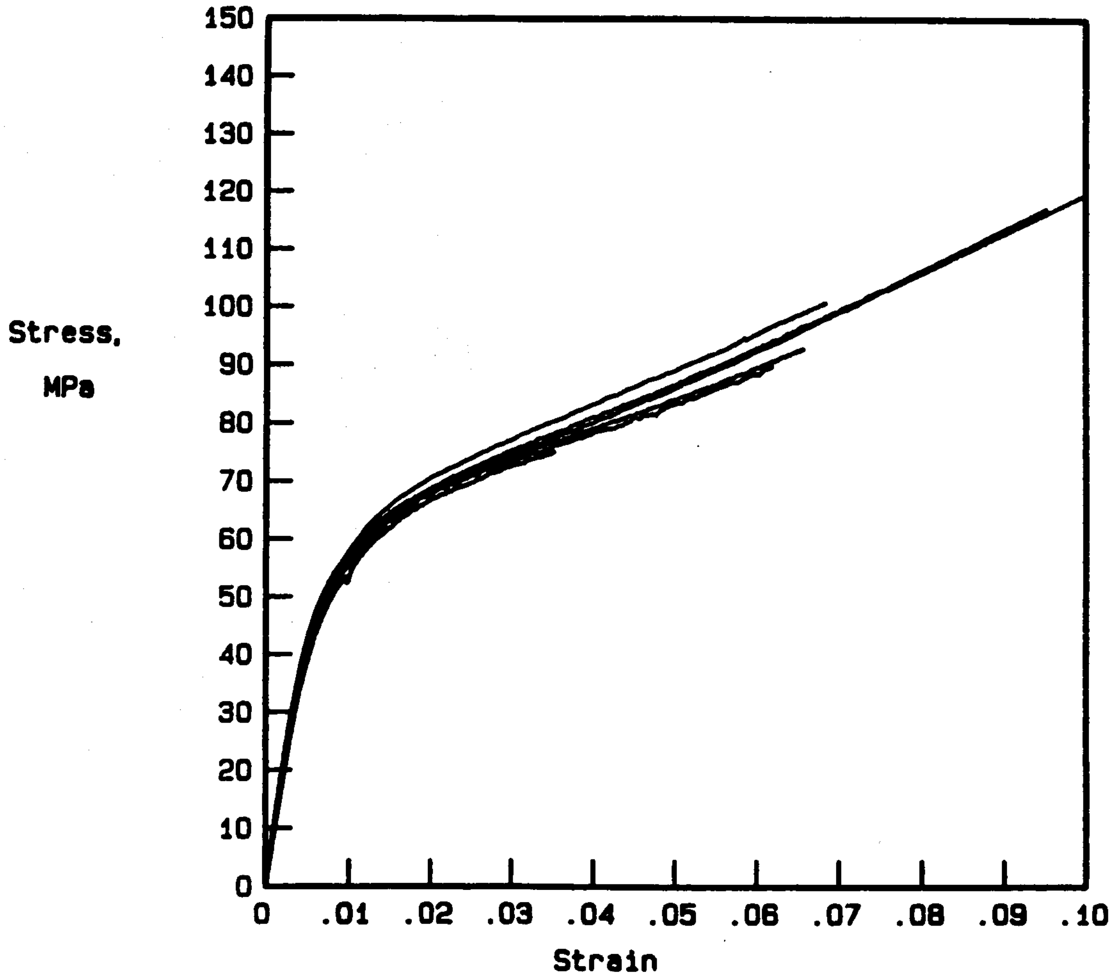


Figure 7.- Stress-strain curves for material #3 (P1700/C3000) (12.7 mm-wide specimens).

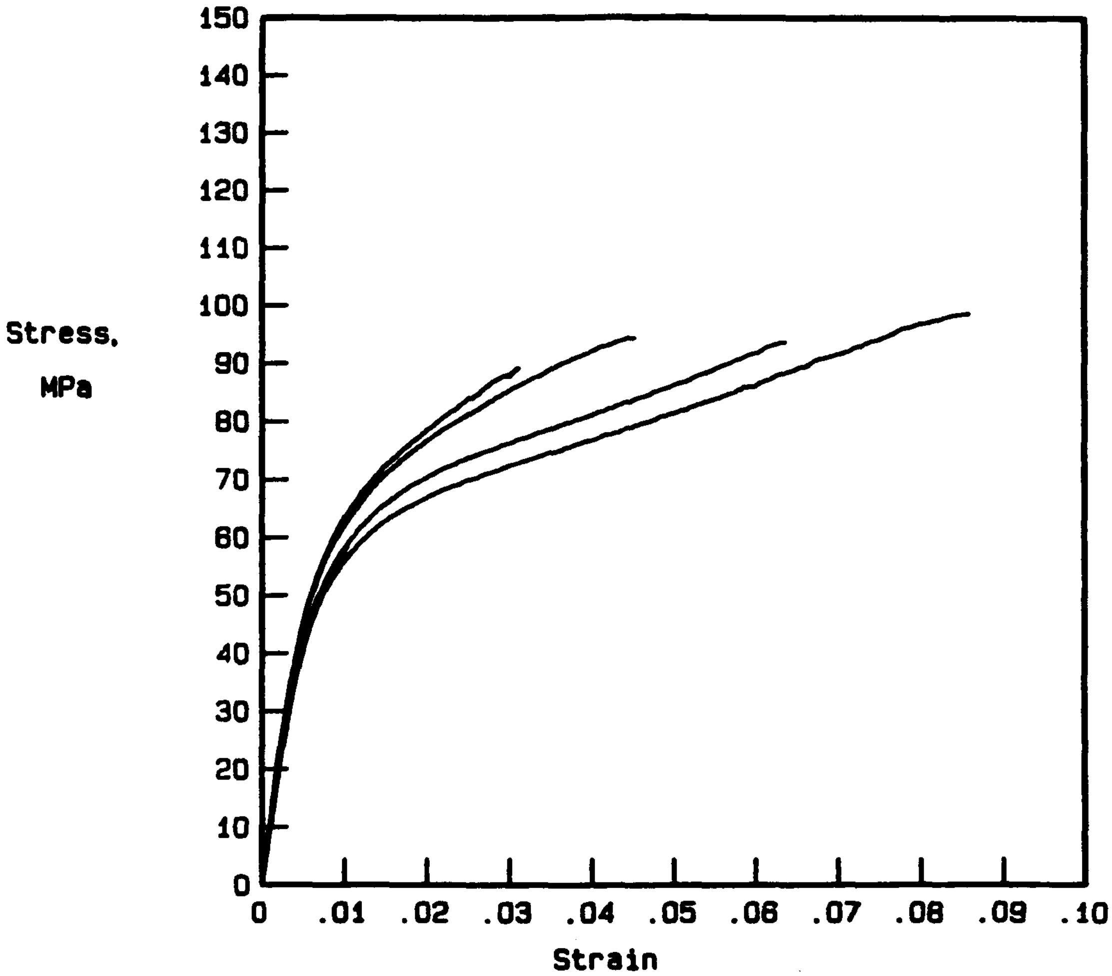


Figure 8.- Stress-strain curves for material #3 (P1700/C3000) (9.525 mm-wide specimens).

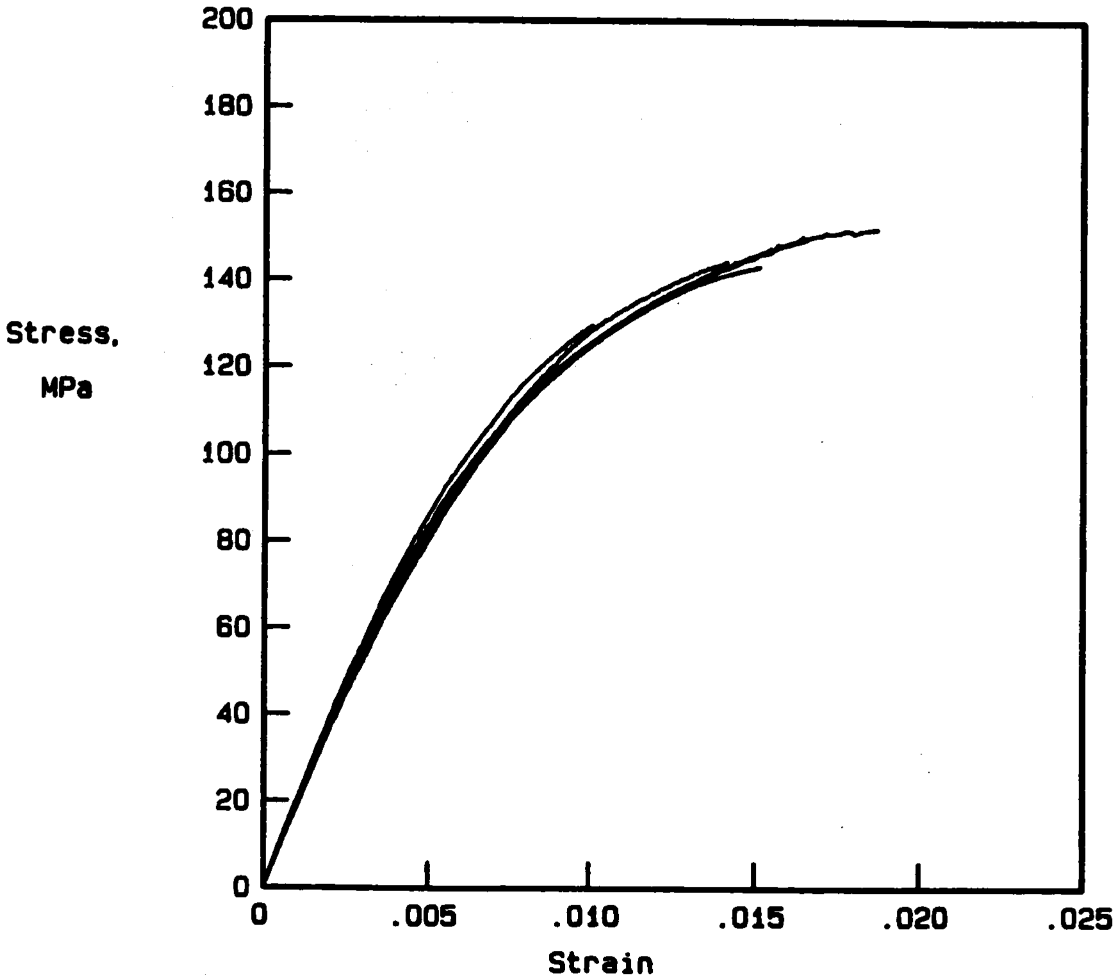


Figure 9.- Stress-strain curves for material #4 (934/T300)(145 g/m^2) (12.7 mm-wide specimens).

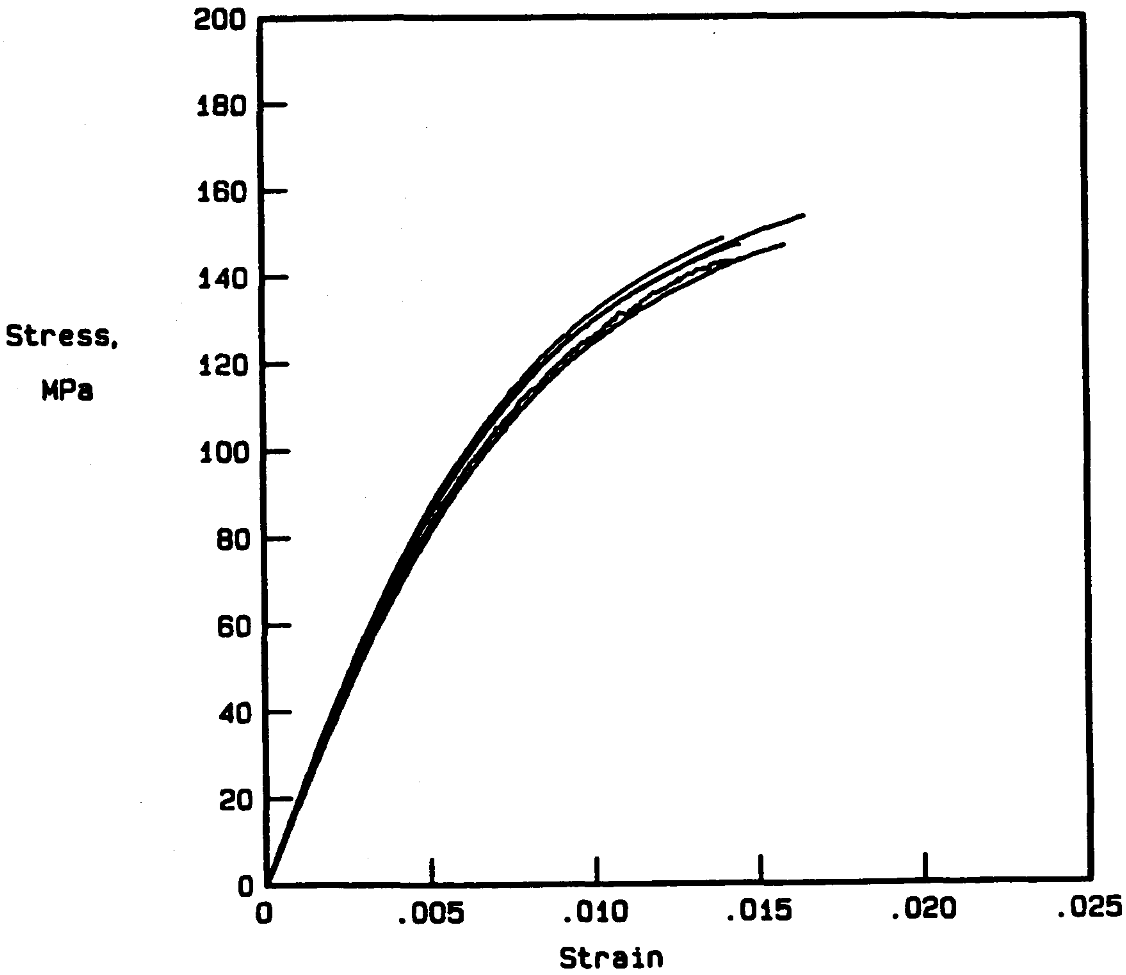


Figure 10.- Stress-strain curves for material #4 (934/T300)(145 g/m^2) (9.525 mm-wide specimens).

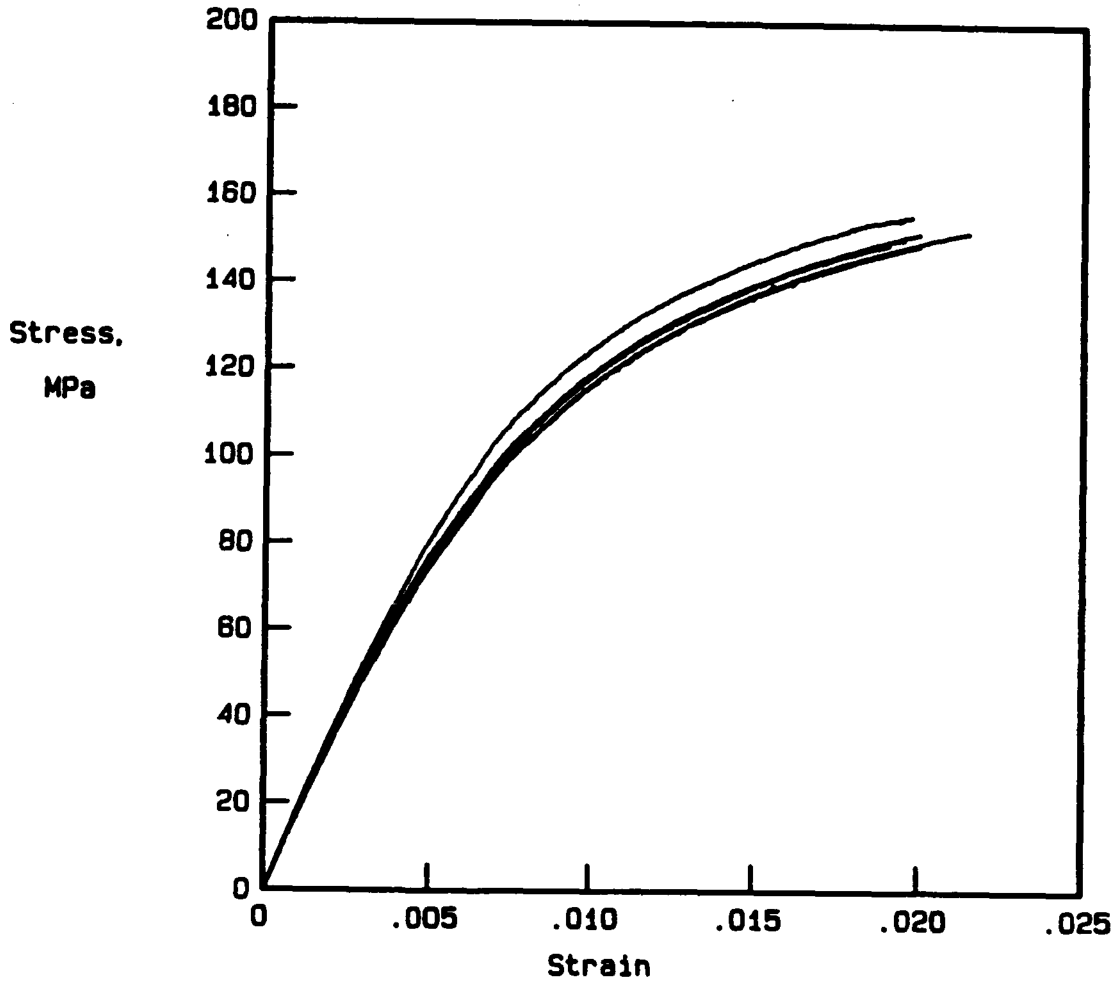


Figure 11.- Stress-strain curves for material #6 (934/T300)(95 g/m^2) (12.7 mm-wide specimens).

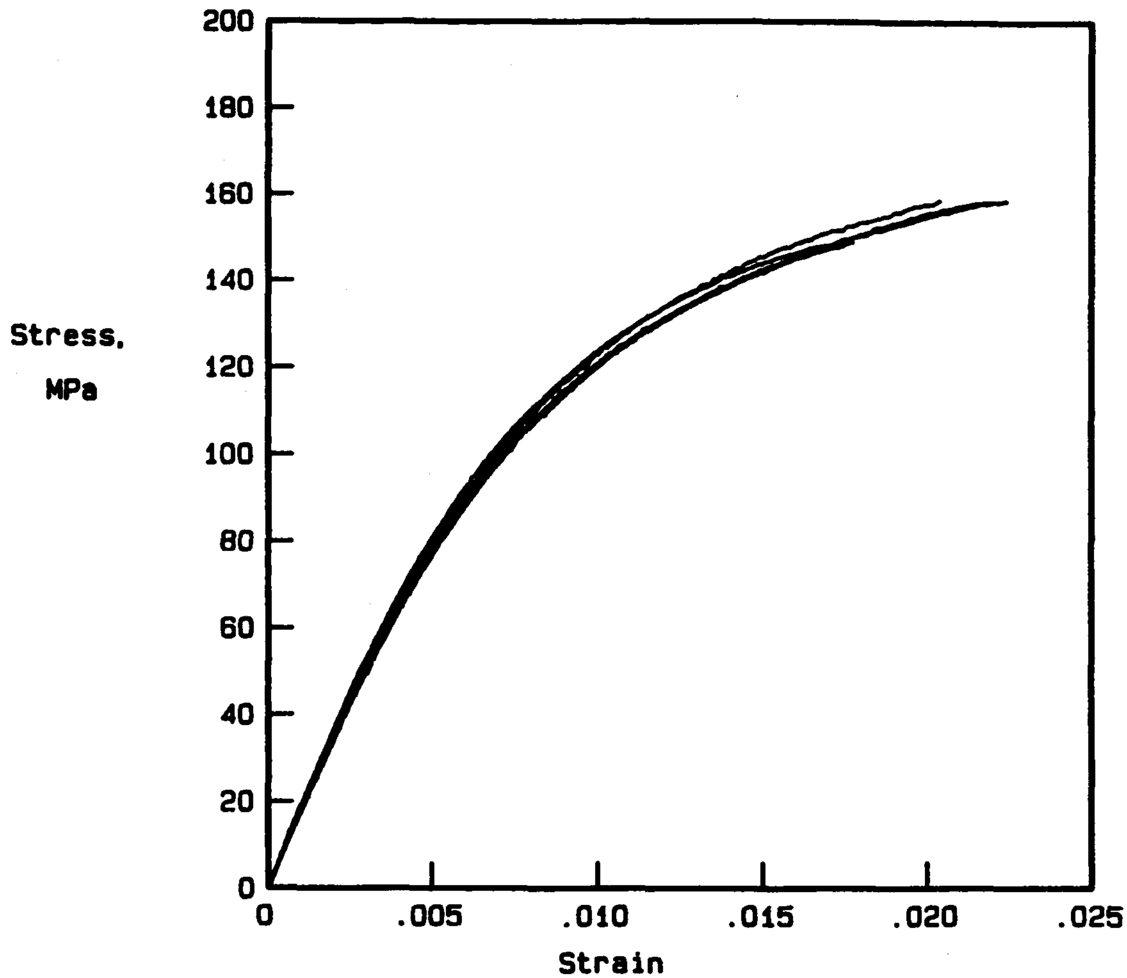


Figure 12.- Stress-strain curves for material #6 (934/T300)(95 g/m^2) (9.525 mm-wide specimens).

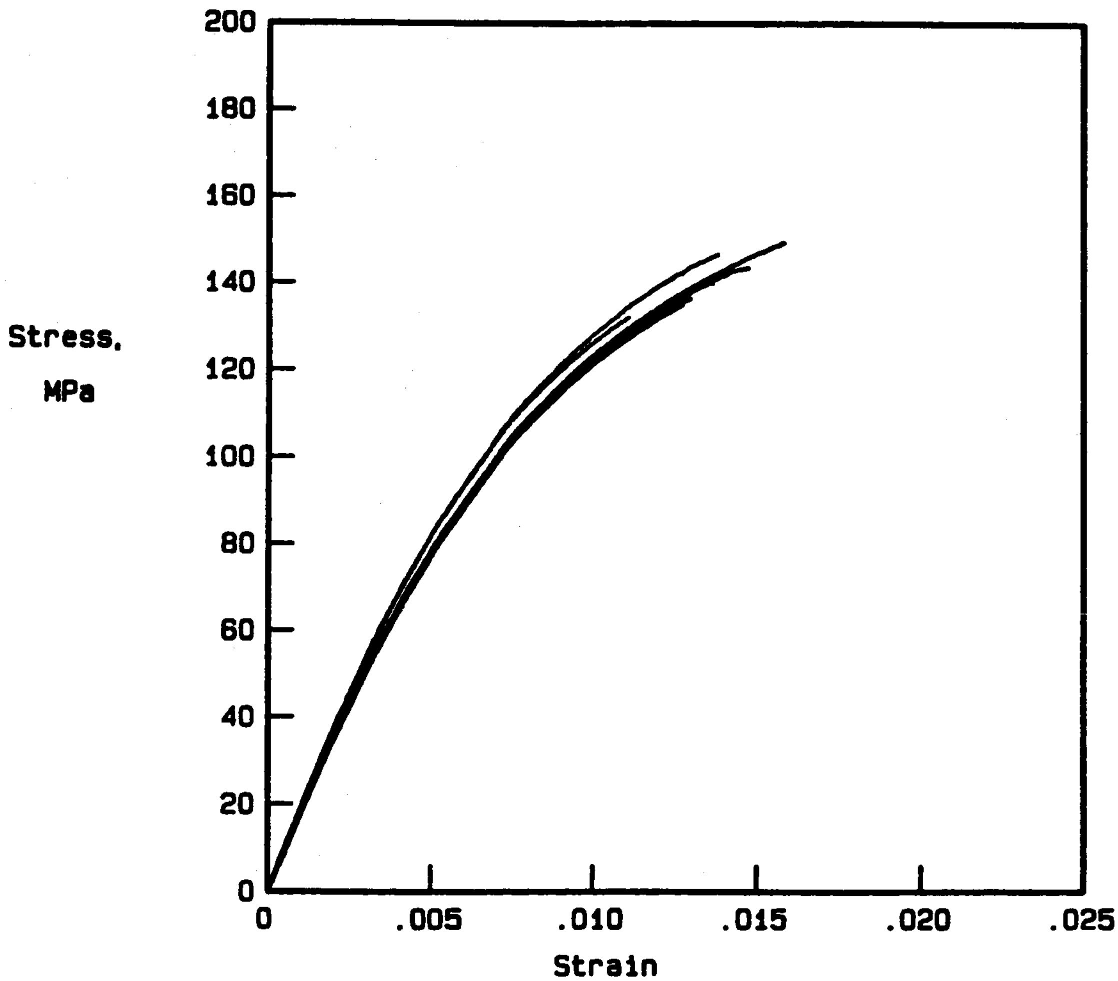


Figure 13.- Stress-strain curves for material #7 (5208/T300) (12.7 mm-wide specimens).

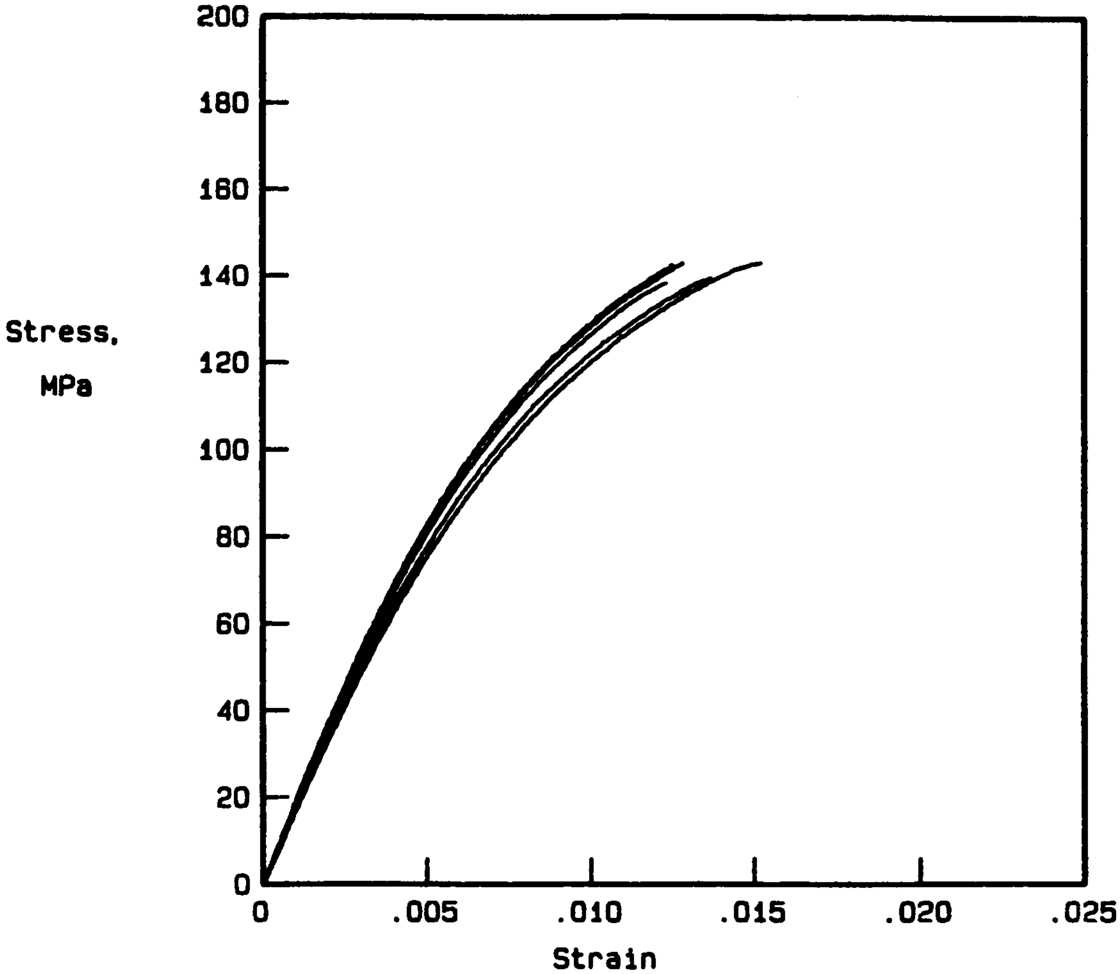
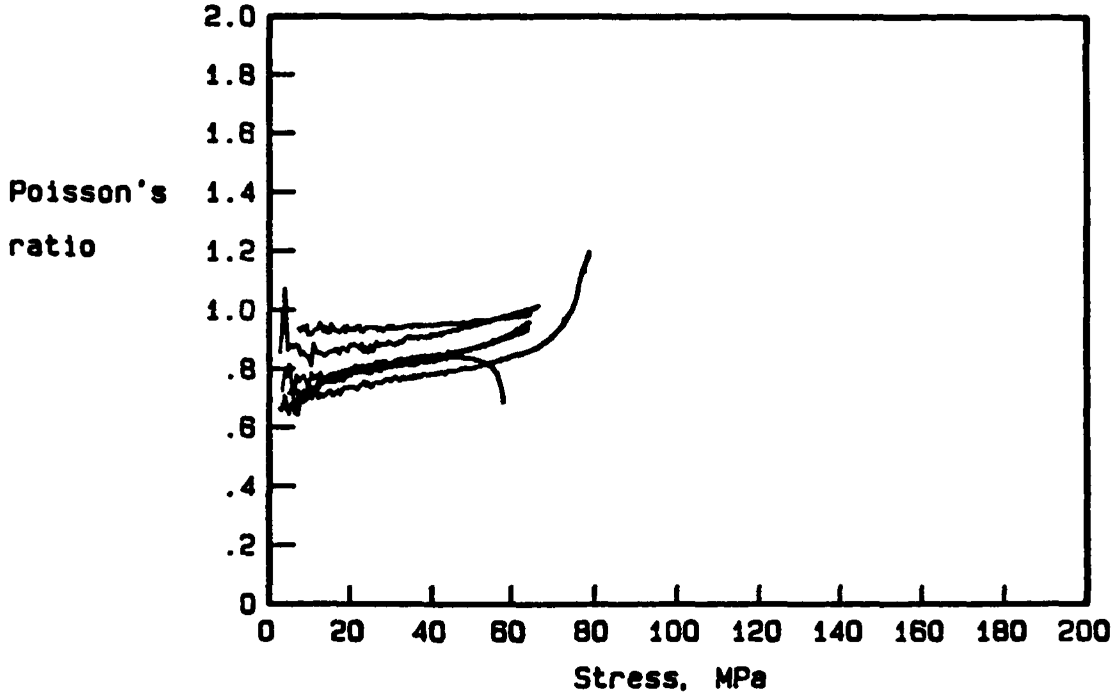
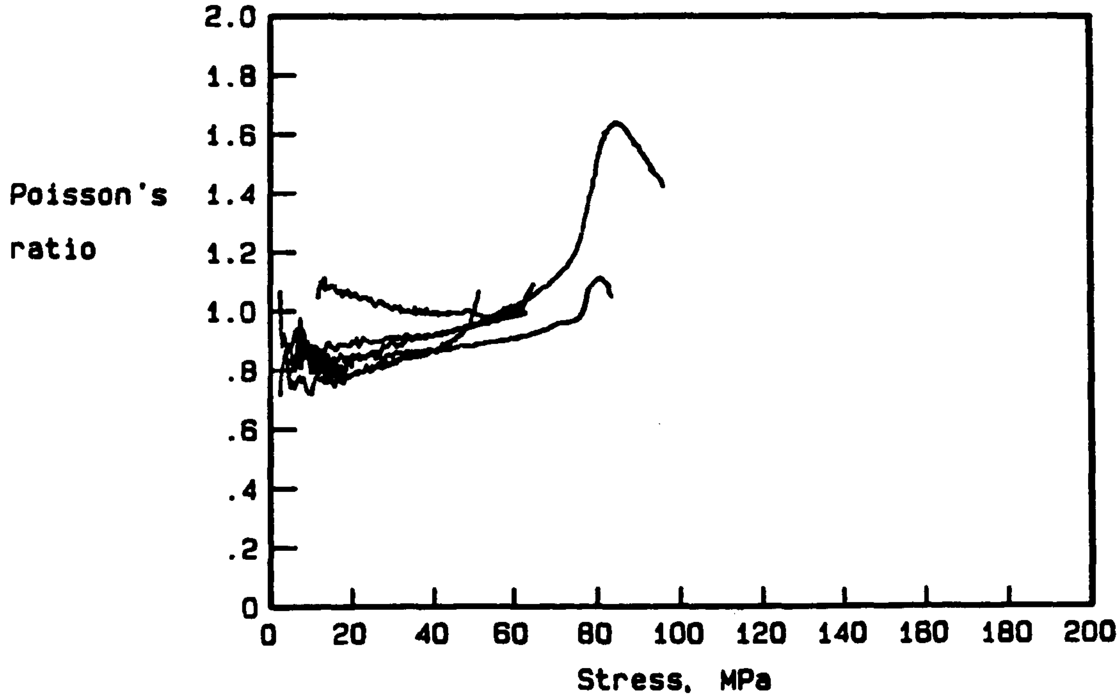


Figure 14.- Stress-strain curves for material #7 (5208/T300) (9.525 mm-wide specimens).

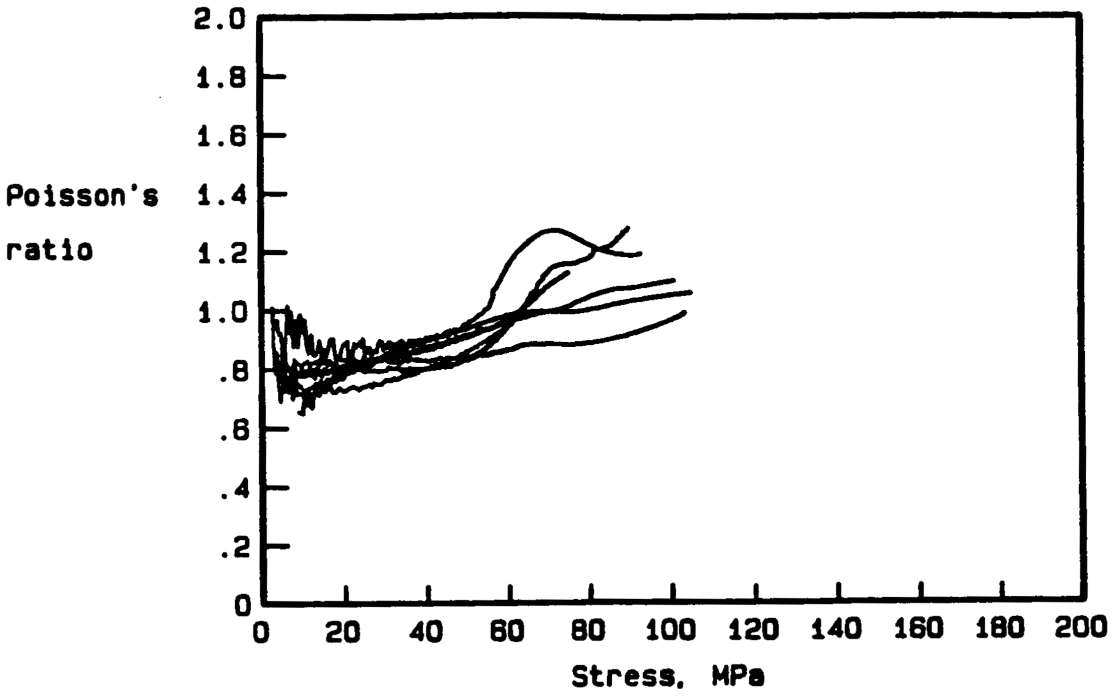


(a) 12.7 mm-wide specimens.

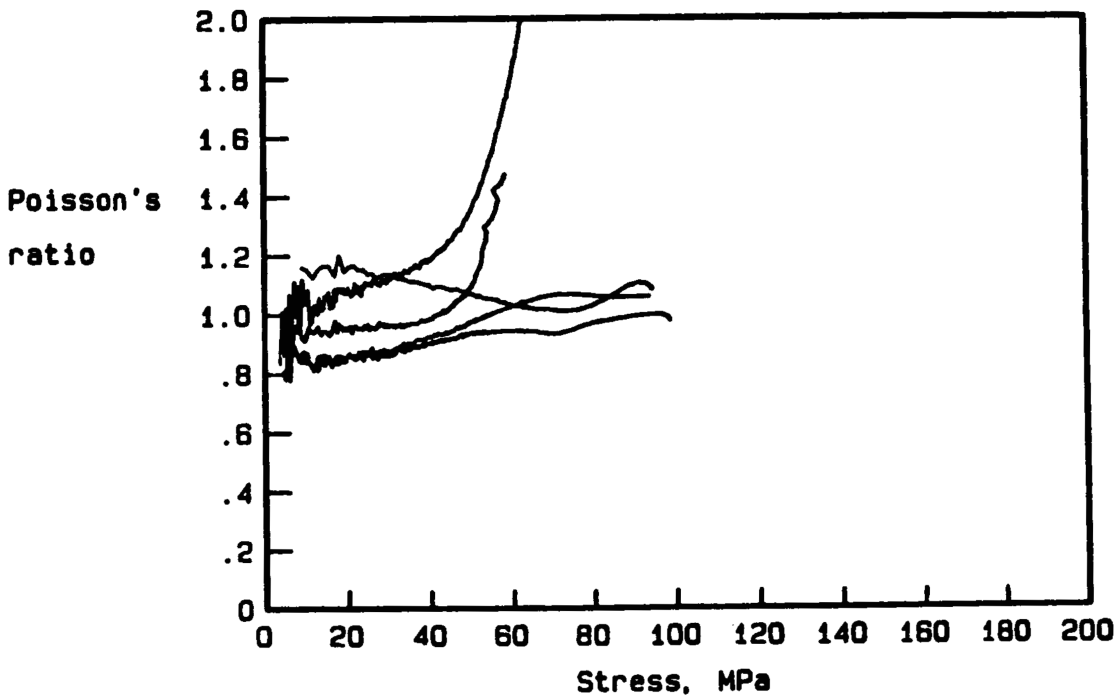


(b) 9.525 mm-wide specimens.

Figure 15.- Poisson's ratio vs. stress for material #12 (P1700/C6000).

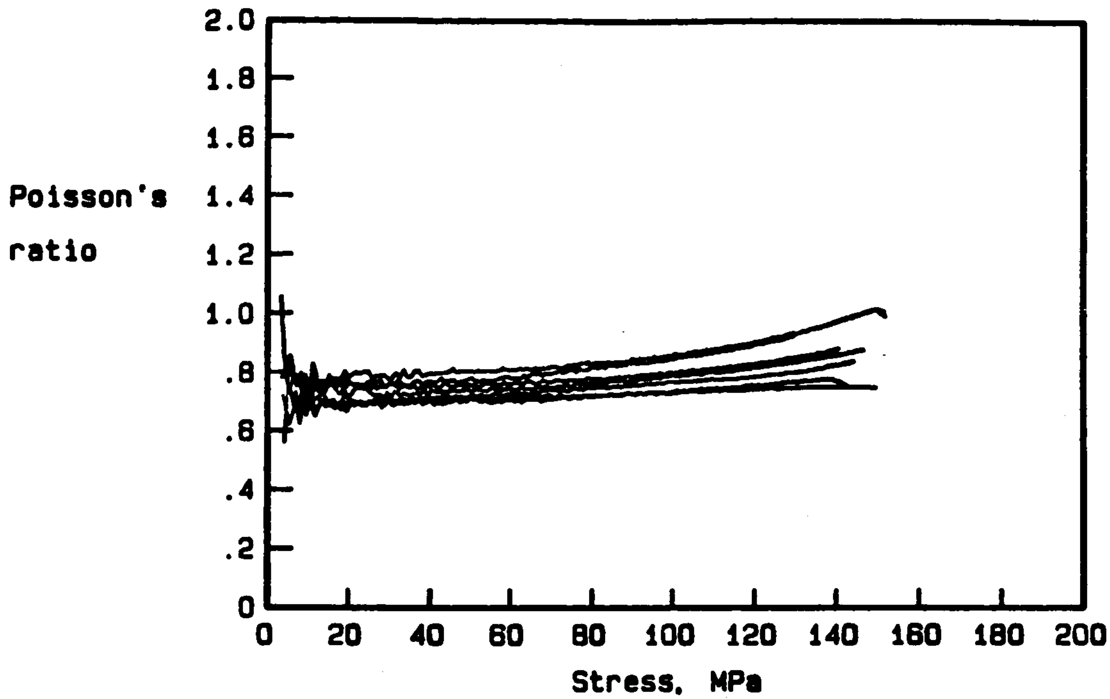


(a) 12.7 mm-wide specimens.

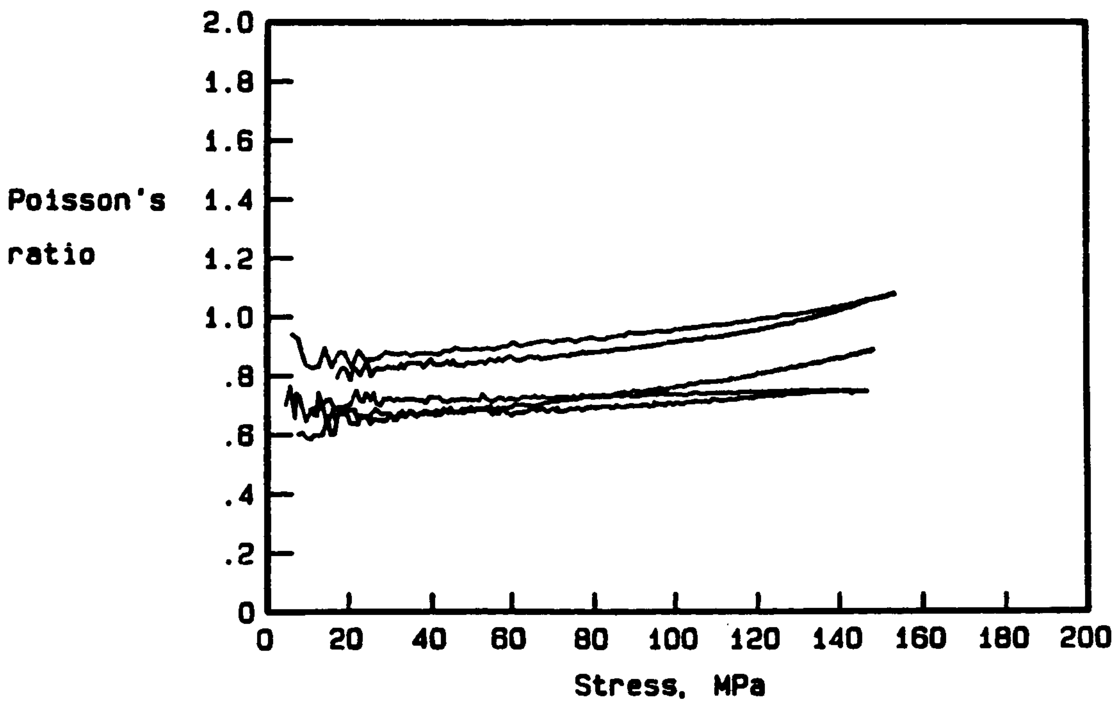


(b) 9.525 mm-wide specimens.

Figure 16.- Poisson's ratio vs. stress for material #3 (P1700/C3000).

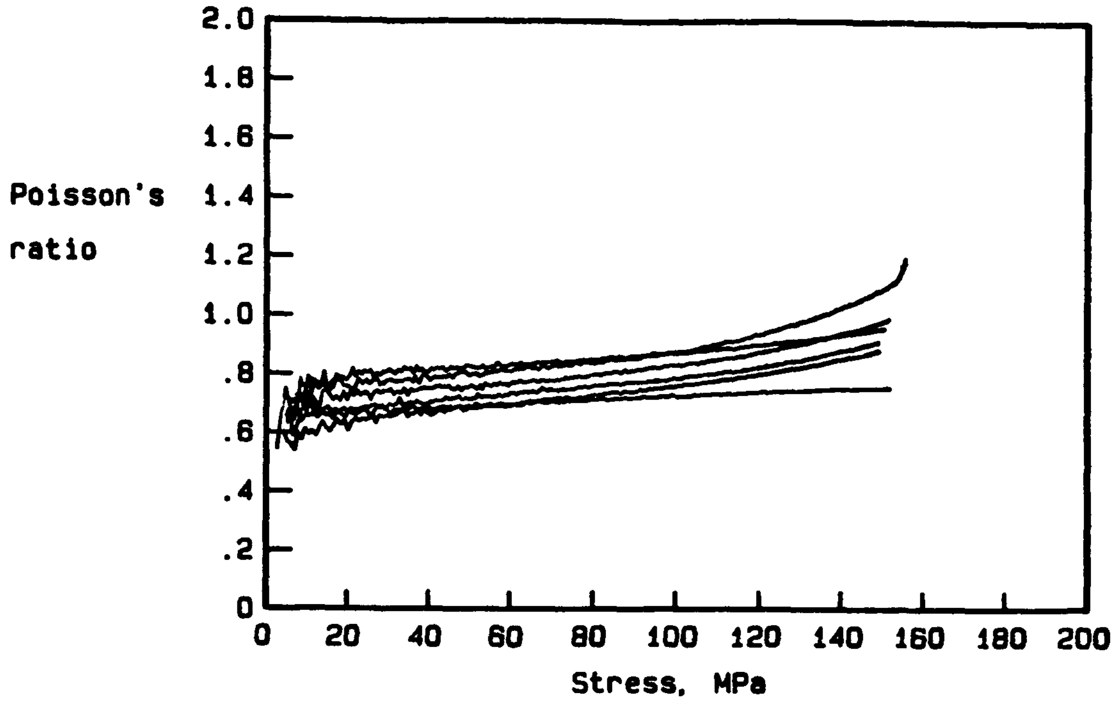


(a) 12.7 mm-wide specimens.

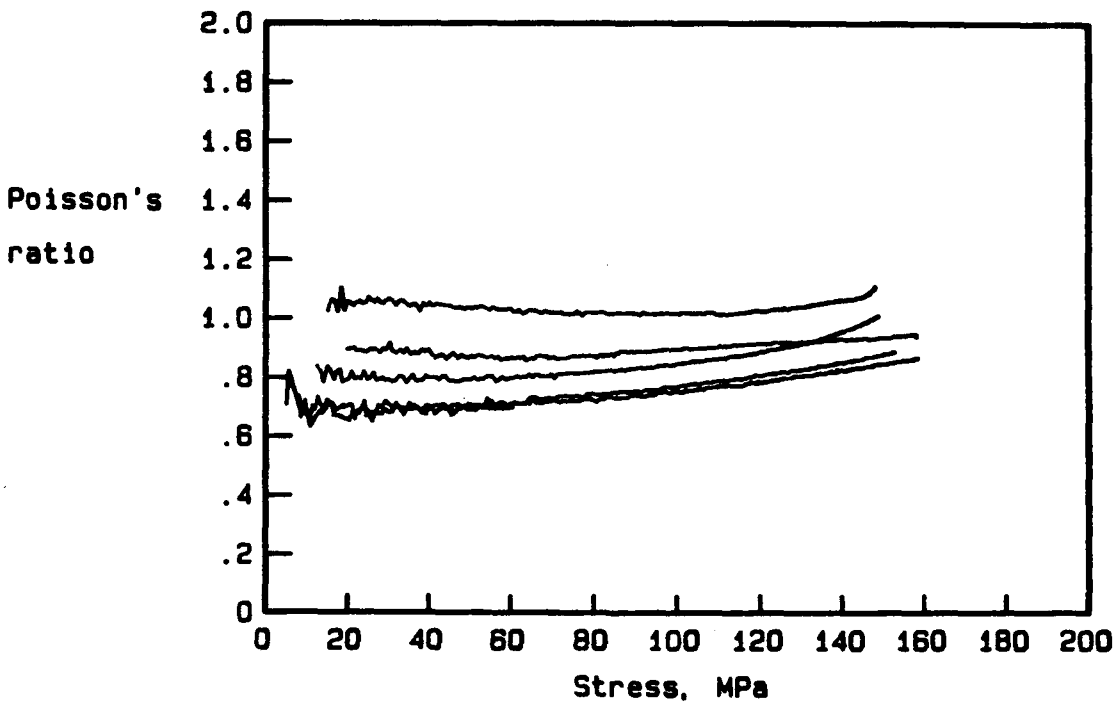


(b) 9.525 mm-wide specimens.

Figure 17.- Poisson's ratio vs. stress for material #4 (934/T300)(145 g/m^2).

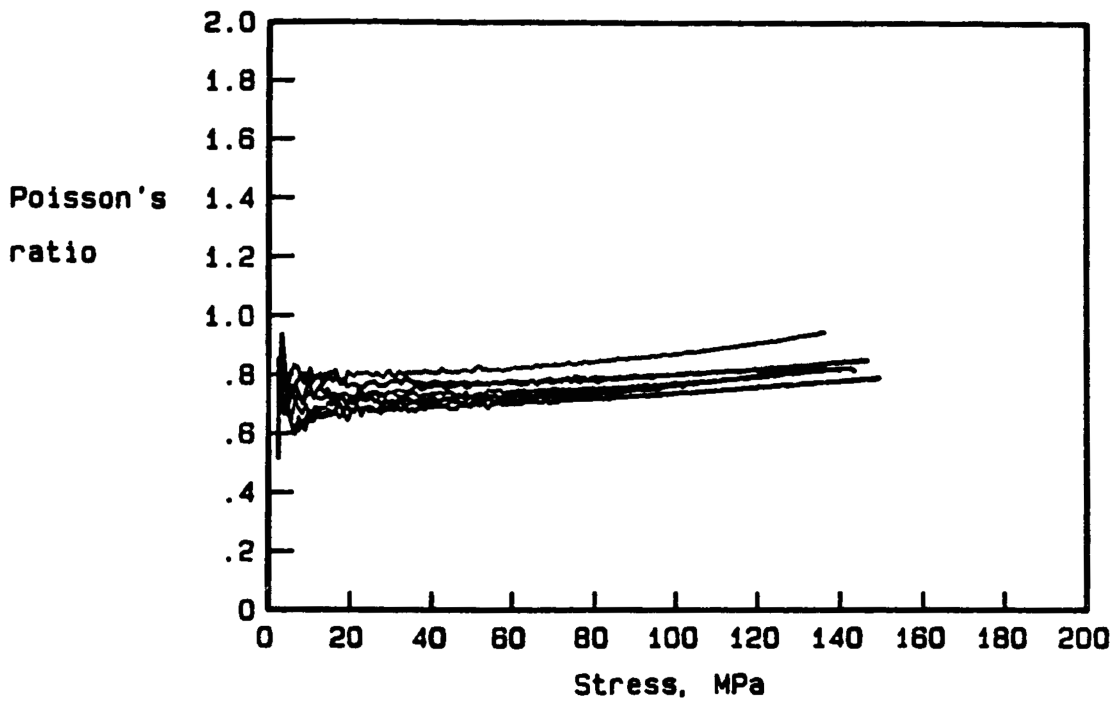


(a) 12.7 mm-wide specimens.

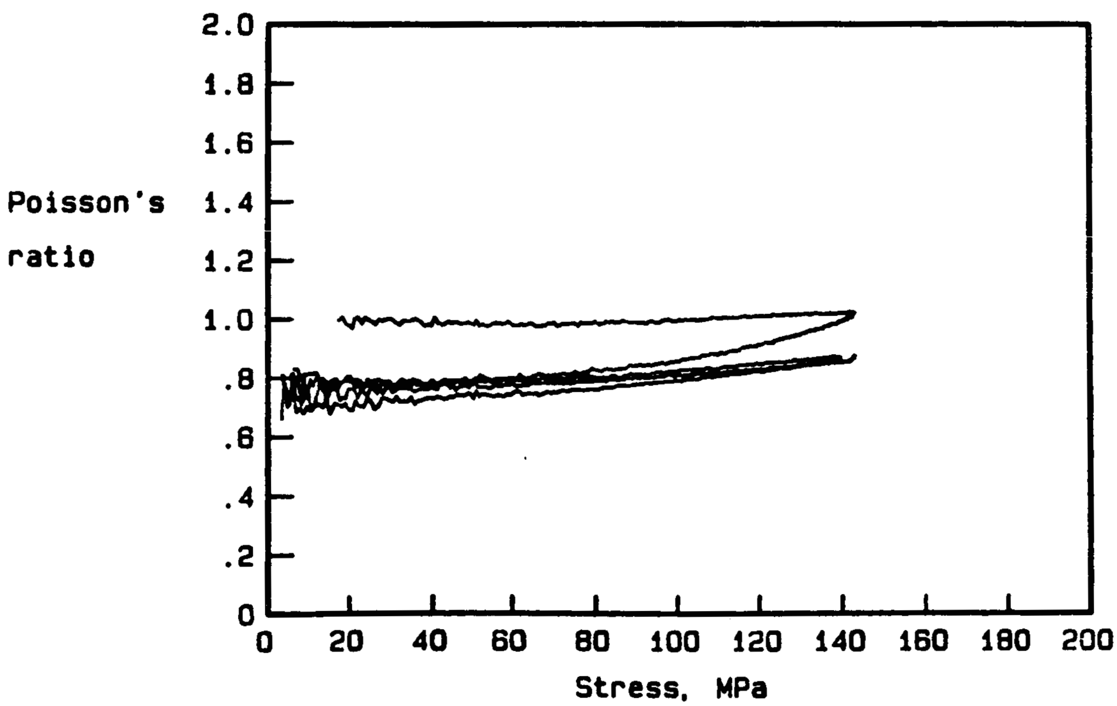


(b) 9.525 mm-wide specimens.

Figure 18.- Poisson's ratio vs. stress for material #6 (934/T300)(95 g/m^2).

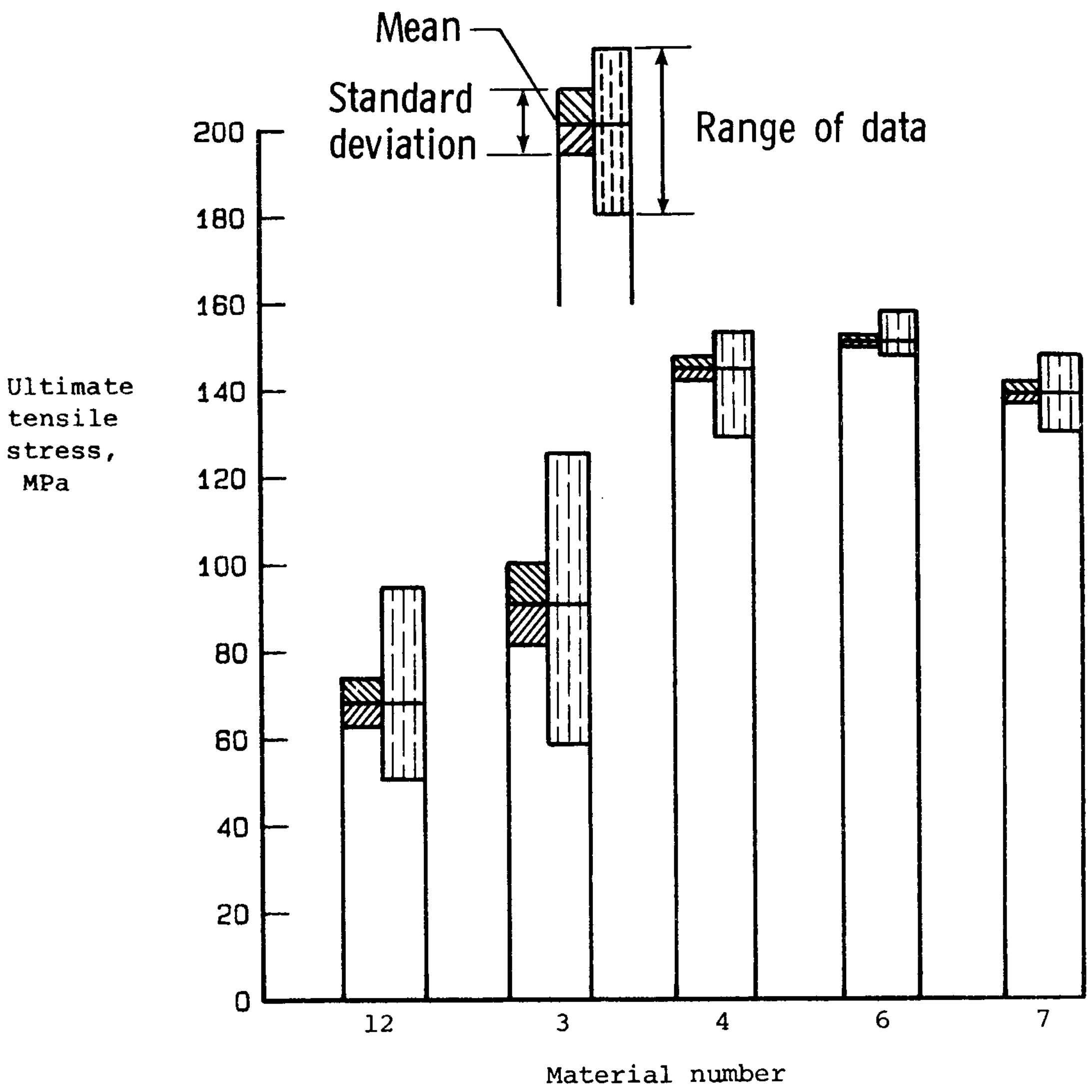


(a) 12.7 mm-wide specimens.



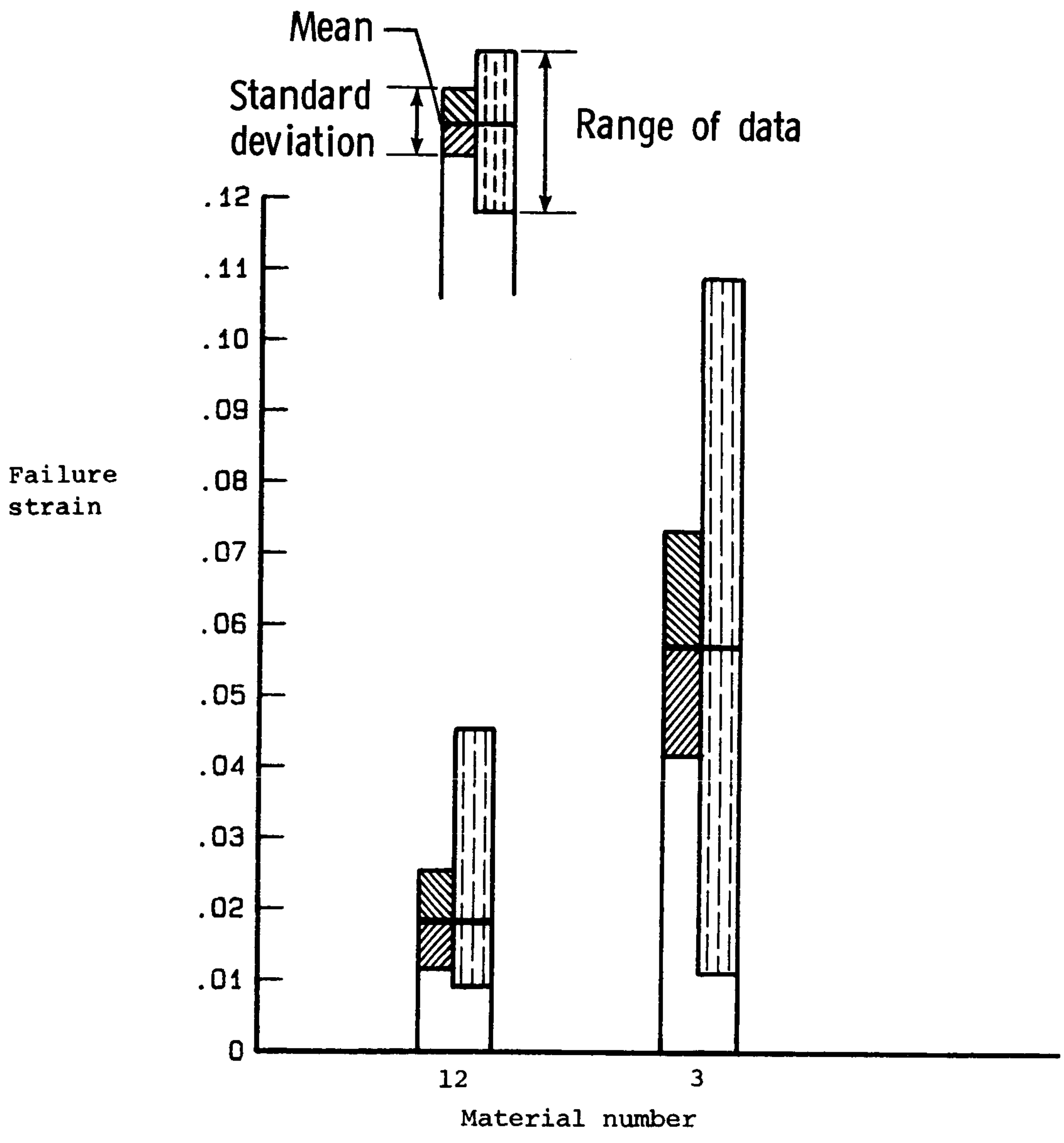
(b) 9.525 mm-wide specimens.

Figure 19.- Poisson's ratio vs. stress for material #7 (5208/T300).



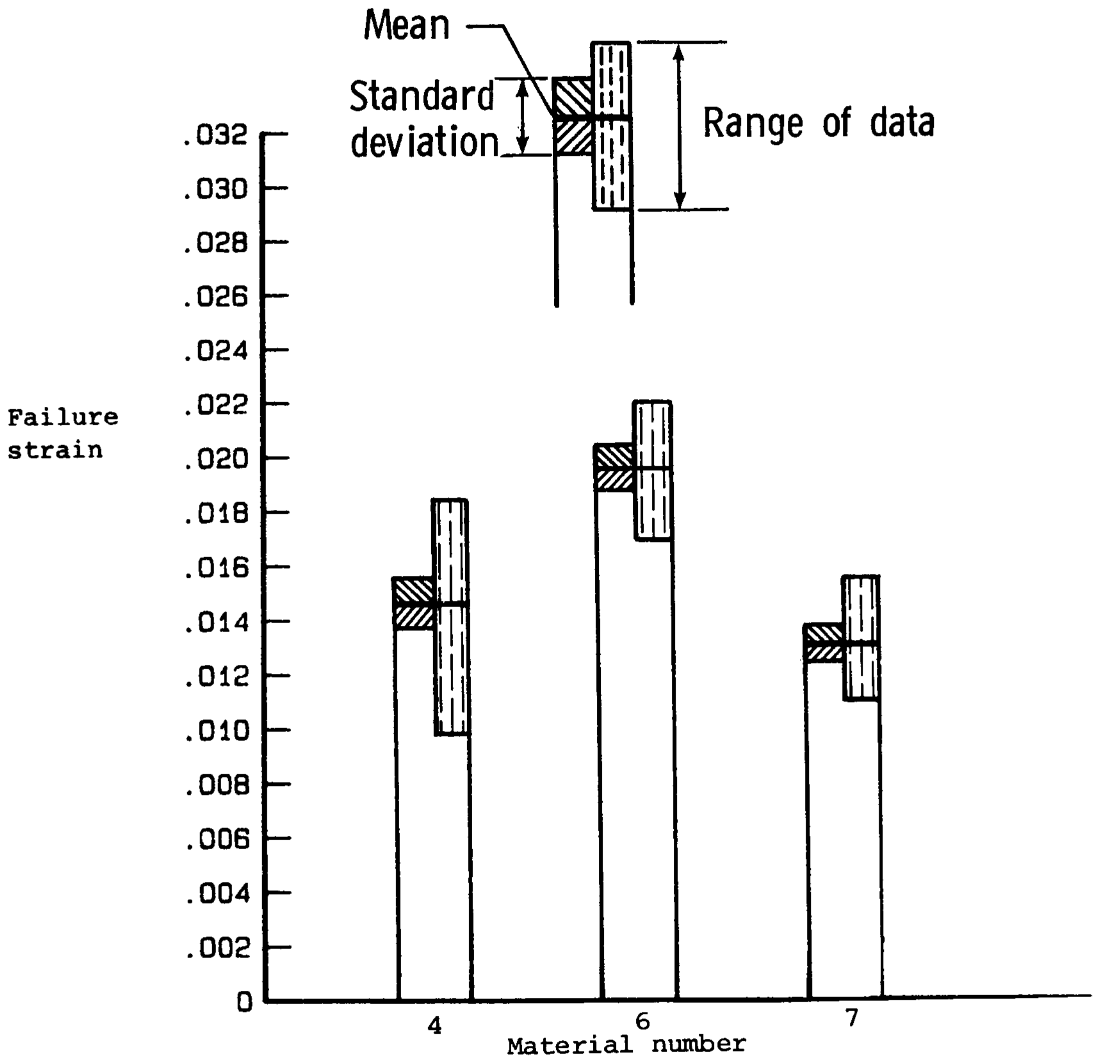
Number	Material
12	Polysulfone/graphite (P1700/C6000)
3	" " (P1700/C3000)
4	Epoxy/graphite (934/T300) (145 g/m^2)
6	" " (934/T300) (95 g/m^2)
7	" " (5208/T300)

Figure 20.- Bar chart of ultimate tensile stress



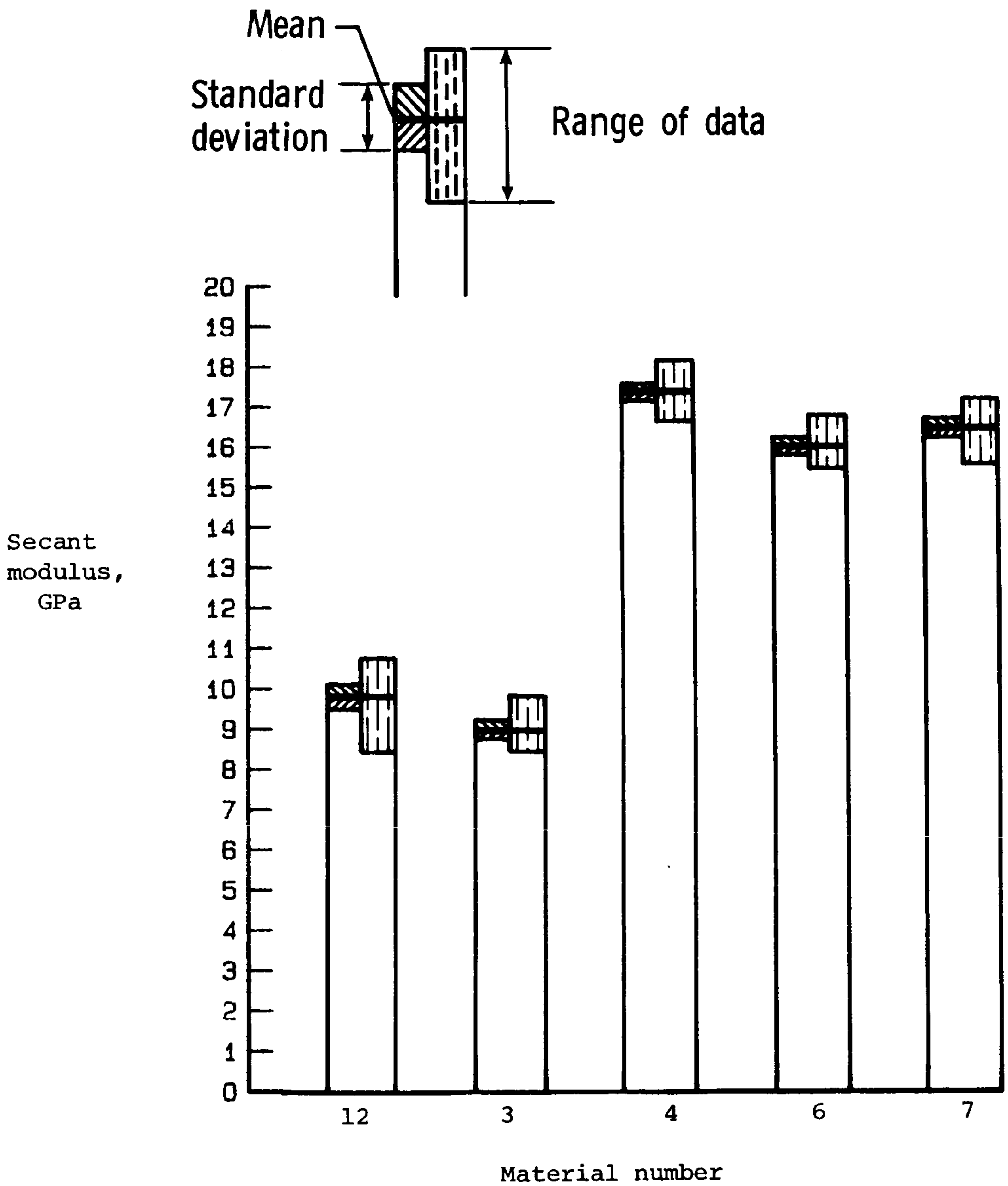
Number	Material	
12	Polysulfone/graphite	(P1700/C6000)
3	" "	(P1700/C3000)

Figure 21.- Bar chart of strain at failure for materials #3 and #12.



Number	Material		
4	Epoxy/graphite	(934/T300)	(145 g/m^2)
6	" "	(934/T300)	(95 g/m^2)
7	" "	(5208/T300)	

Figure 22.- Bar chart of strain at failure for materials #4, #6, and #7.



Number	Material
12	Polysulfone/graphite (P1700/C6000)
3	" " (P1700/C3000)
4	Epoxy/graphite (934/T300) (145 g/m^2)
6	" " (934/T300) (95 g/m^2)
7	" " (5208/T300)

Figure 23.- Bar chart of secant modulus at 0.004 strain.

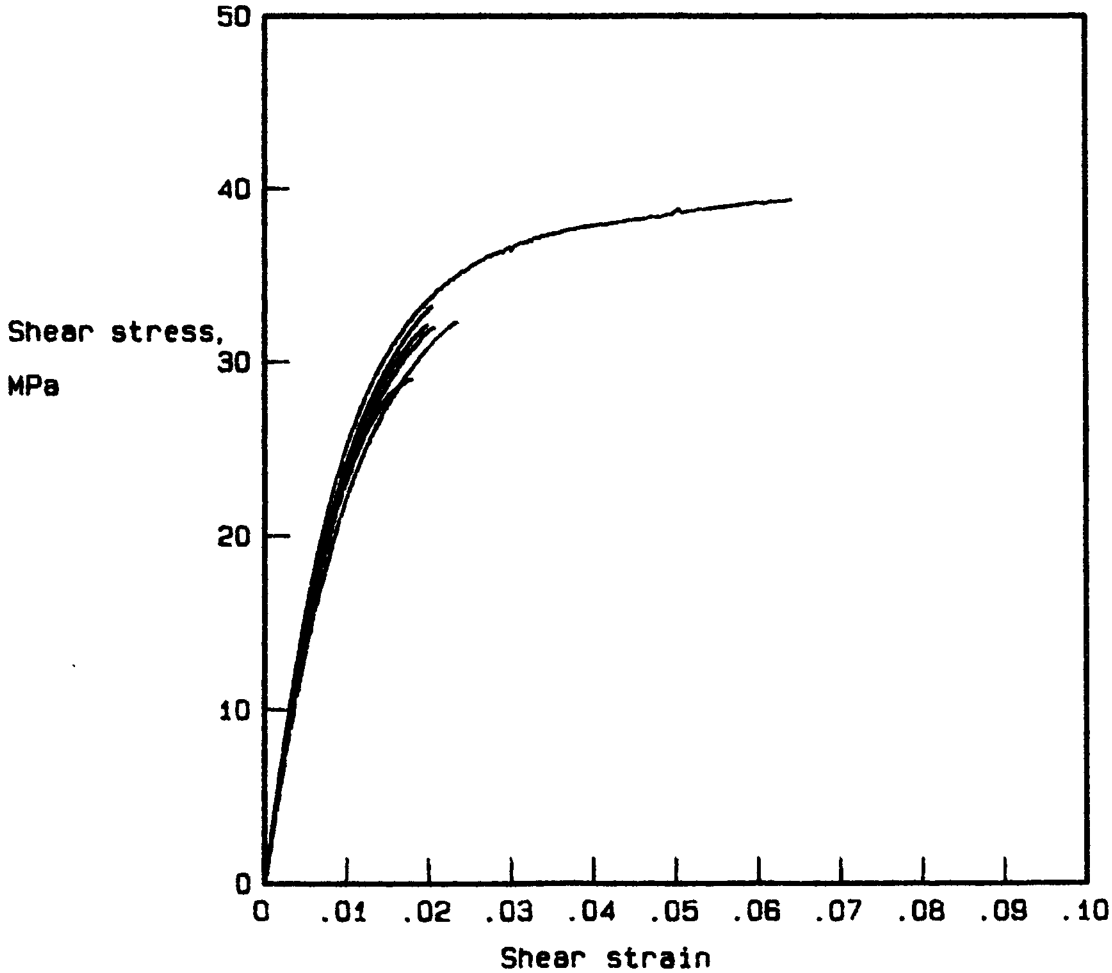


Figure 24.- Shear stress-strain curves for 12.7 mm-wide specimens of material #12 (P1700/C6000).

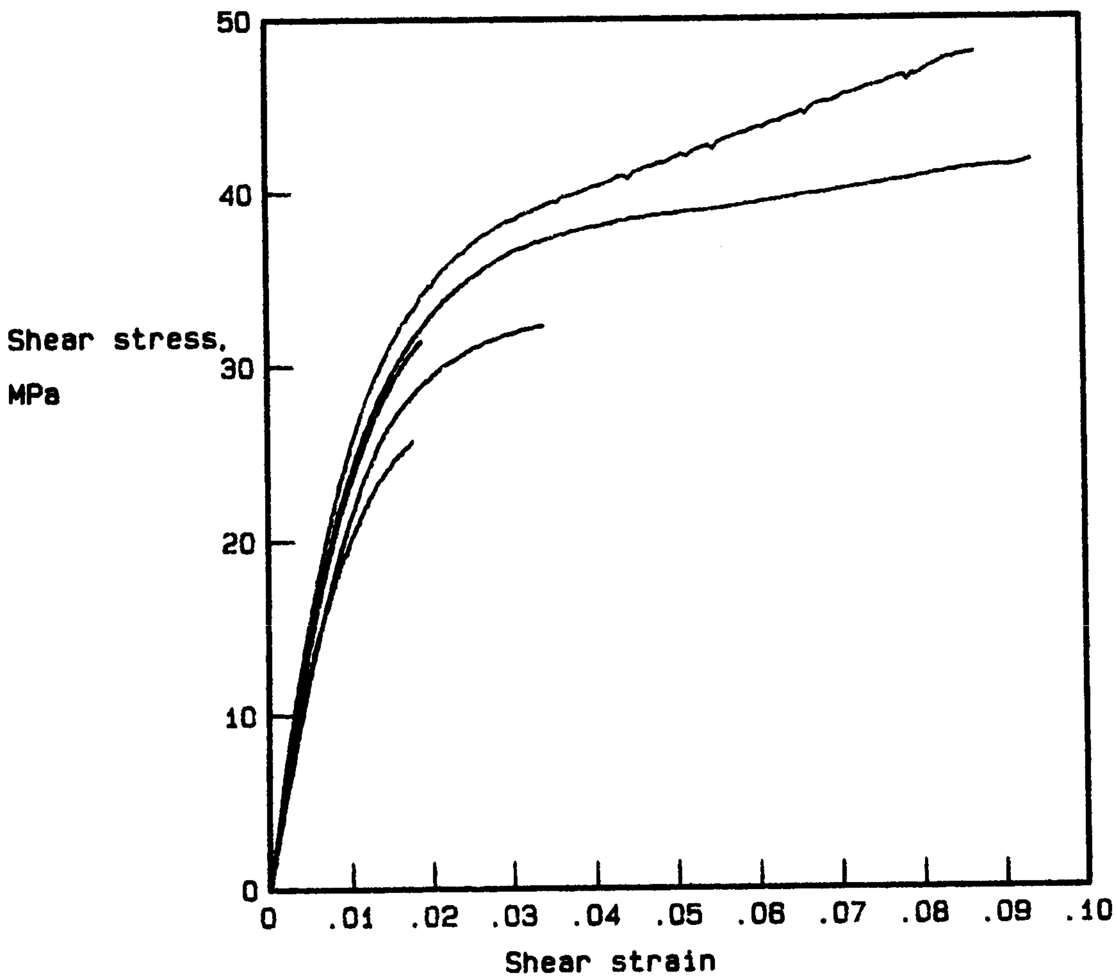


Figure 25.- Shear stress-strain curves for 9.525 mm-wide specimens of material #12 (P1700/C6000).

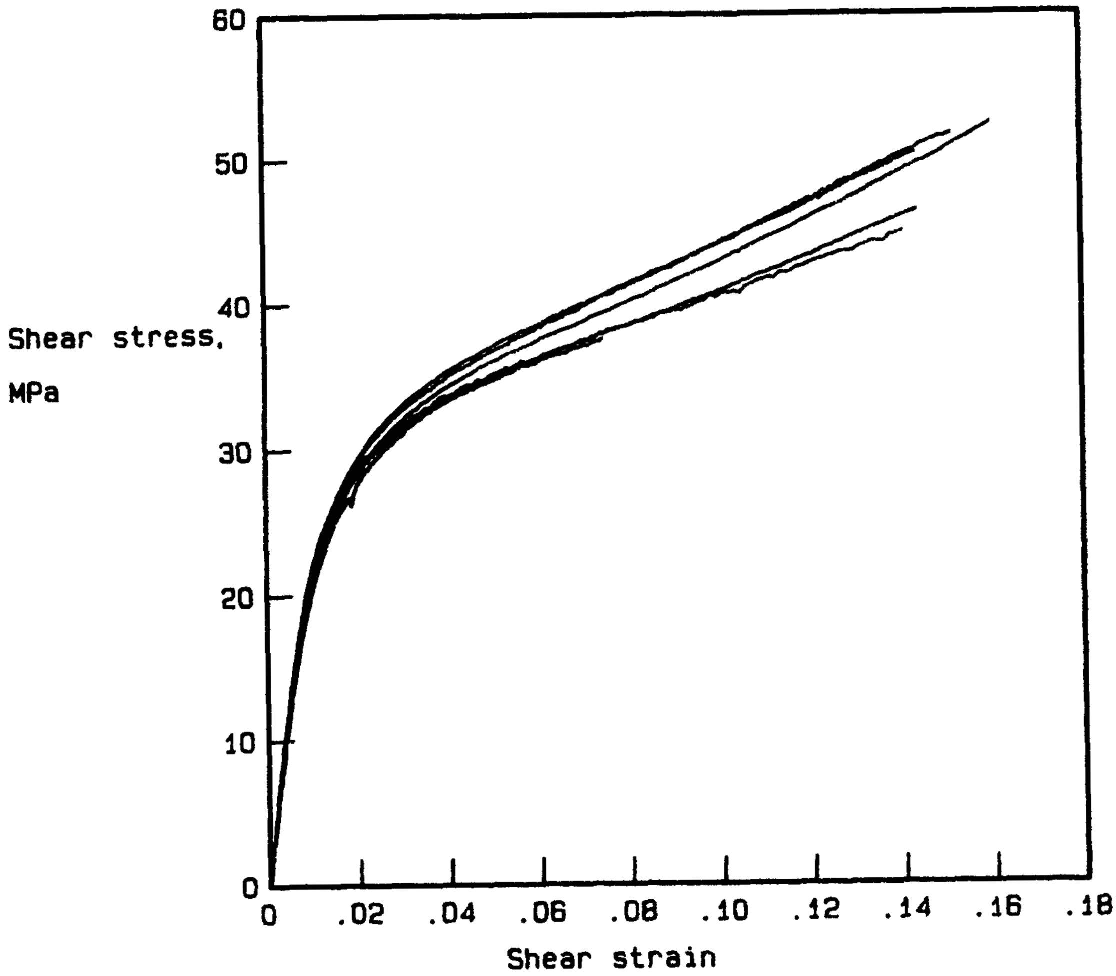


Figure 26.- Shear stress-strain curves for 12.7 mm-wide specimens of material #3 (P1700/C3000).

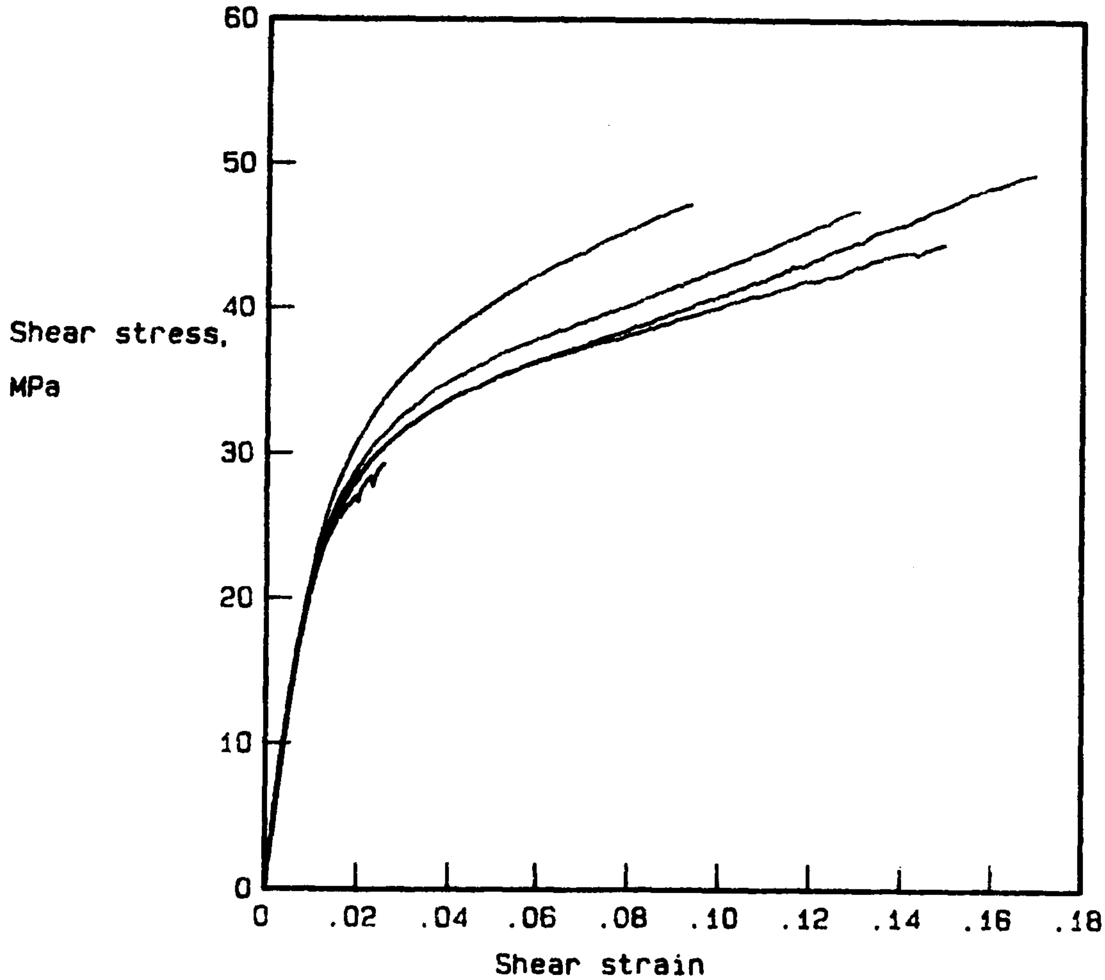


Figure 27.- Shear stress-strain curves for 9.525 mm-wide specimens of material #3 (P1700/C3000).

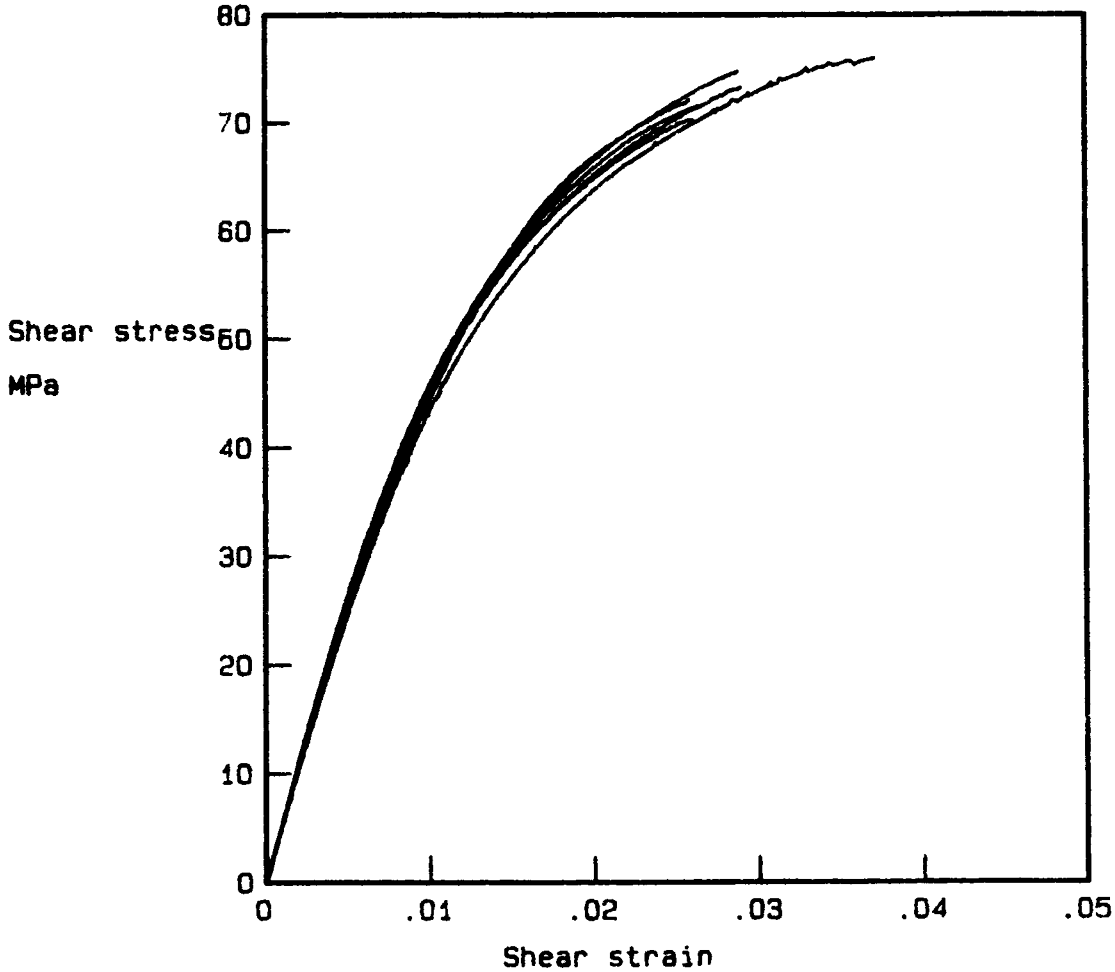


Figure 28.- Shear stress-strain curves for 12.7 mm-wide specimens of material #4 (934/T300) (145 g/m^2).

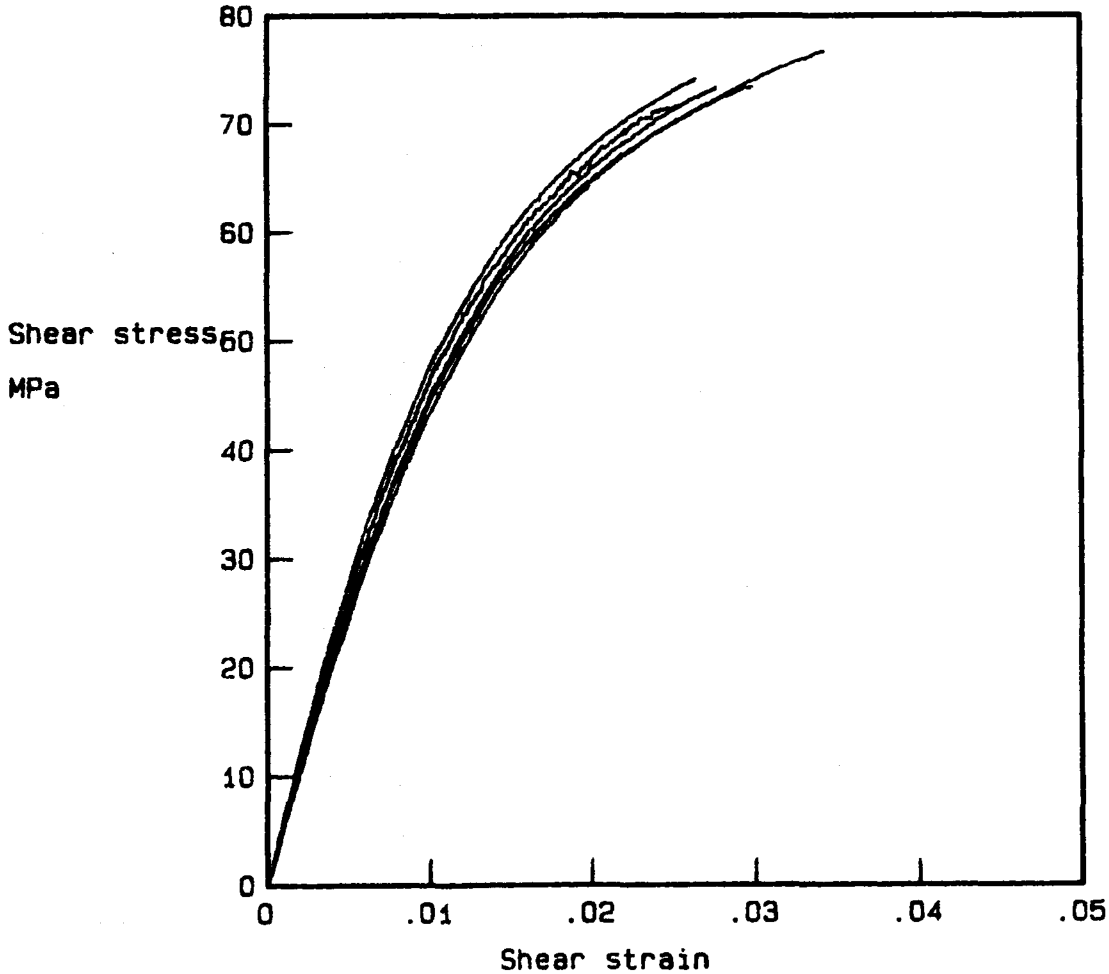


Figure 29.- Shear stress-strain curves for 9.525 mm-wide specimens of material #4 (934/T300) (145 g/m^2).

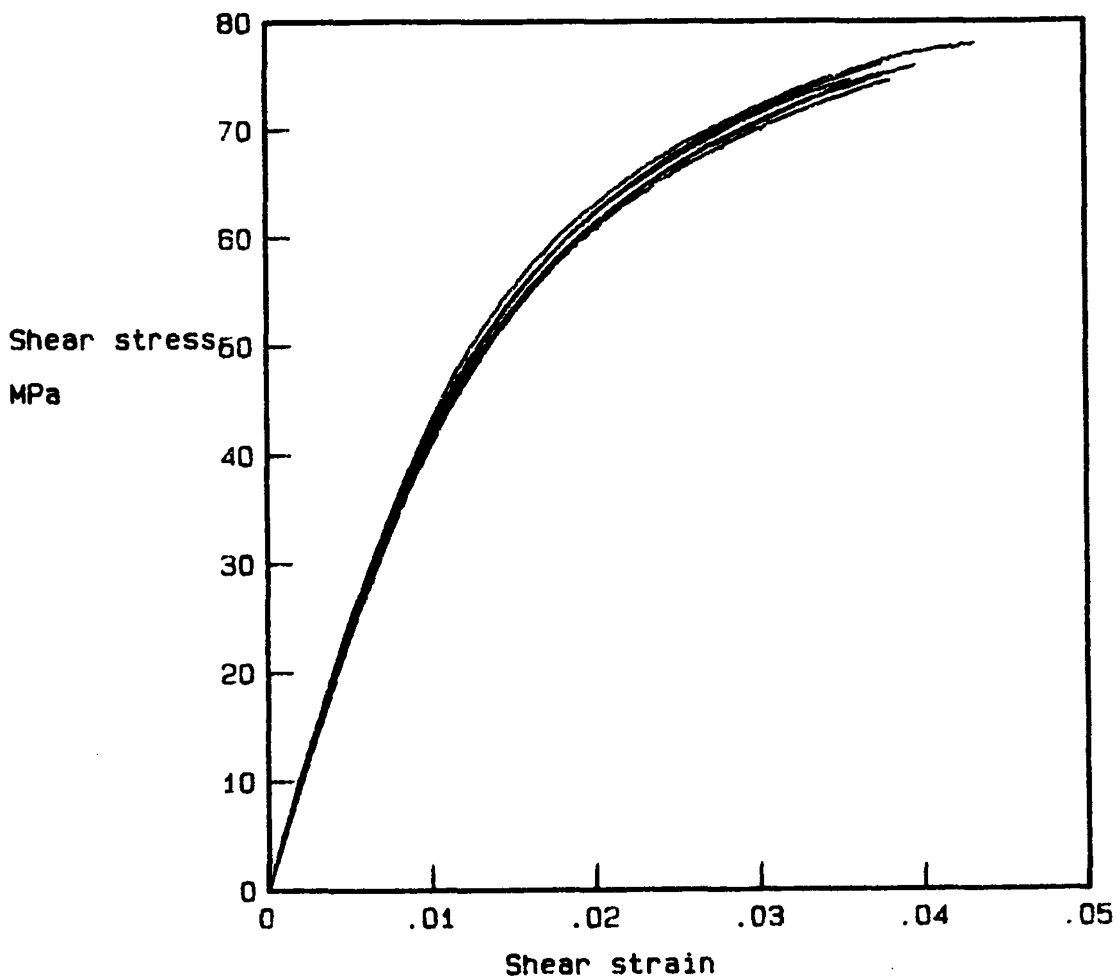


Figure 30.- Shear stress-strain curves for 12.7 mm-wide specimens of material #6 (934/T300) (95 g/m^2).

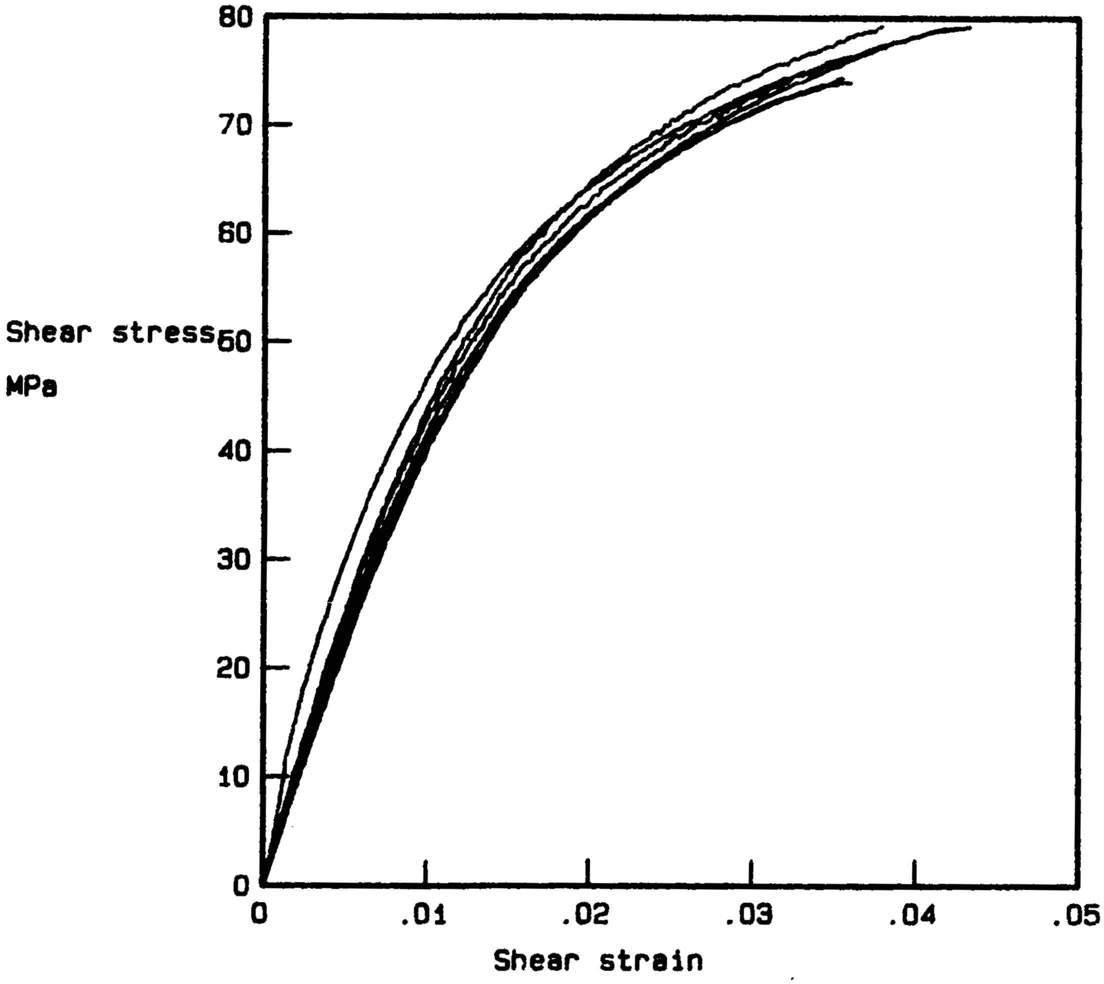


Figure 31.- Shear stress-strain curves for 9.525 mm-wide specimens of material #6 (934/T300) (95 g/m^2).

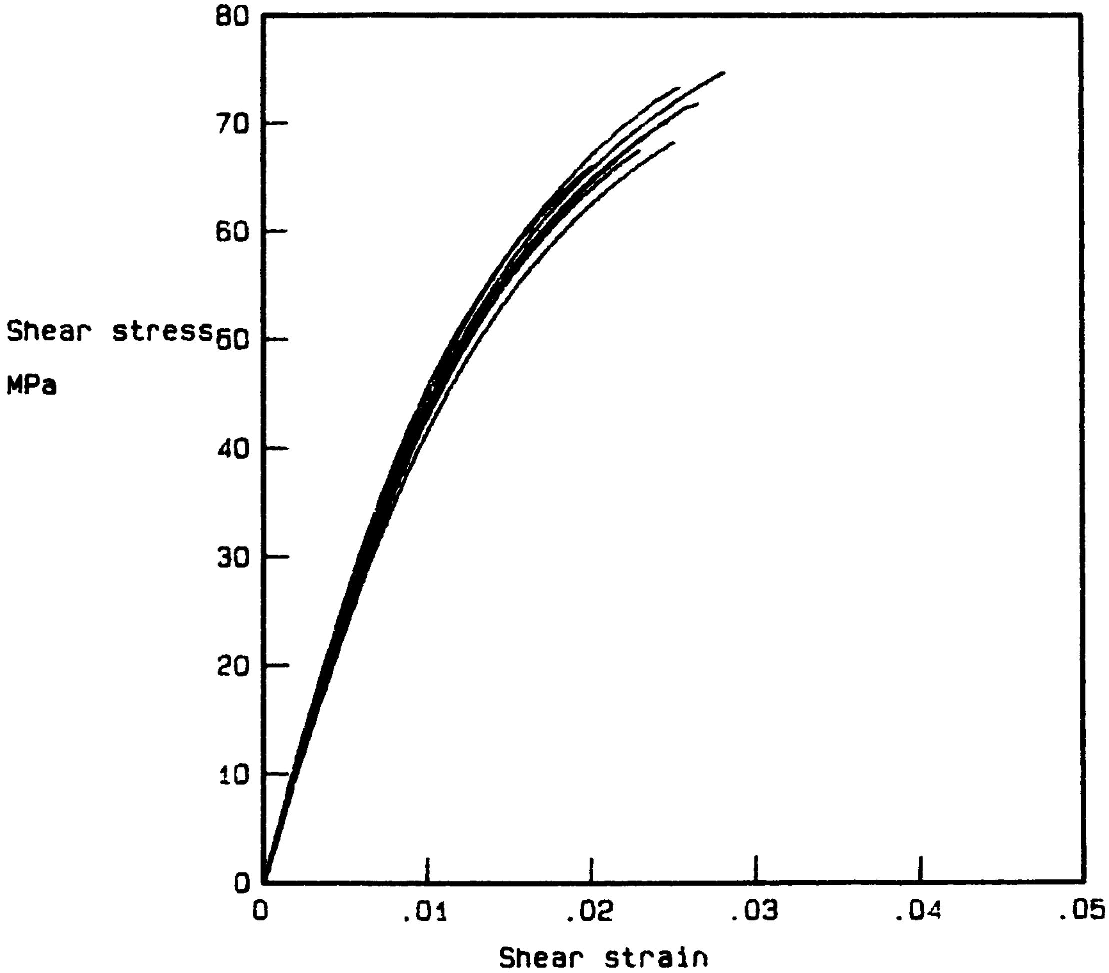


Figure 32.- Shear stress-strain curves for 12.7 mm-wide specimens of material #7 (5208/T300).

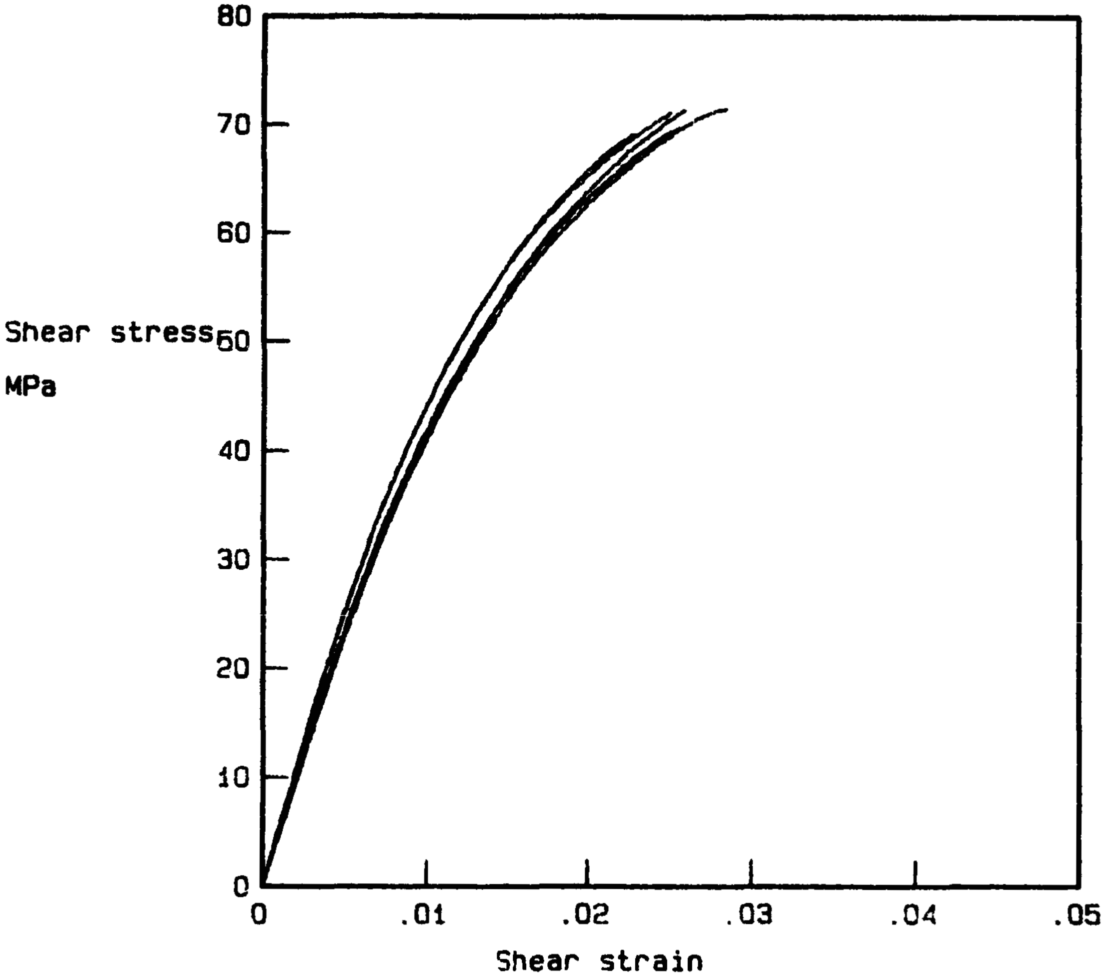
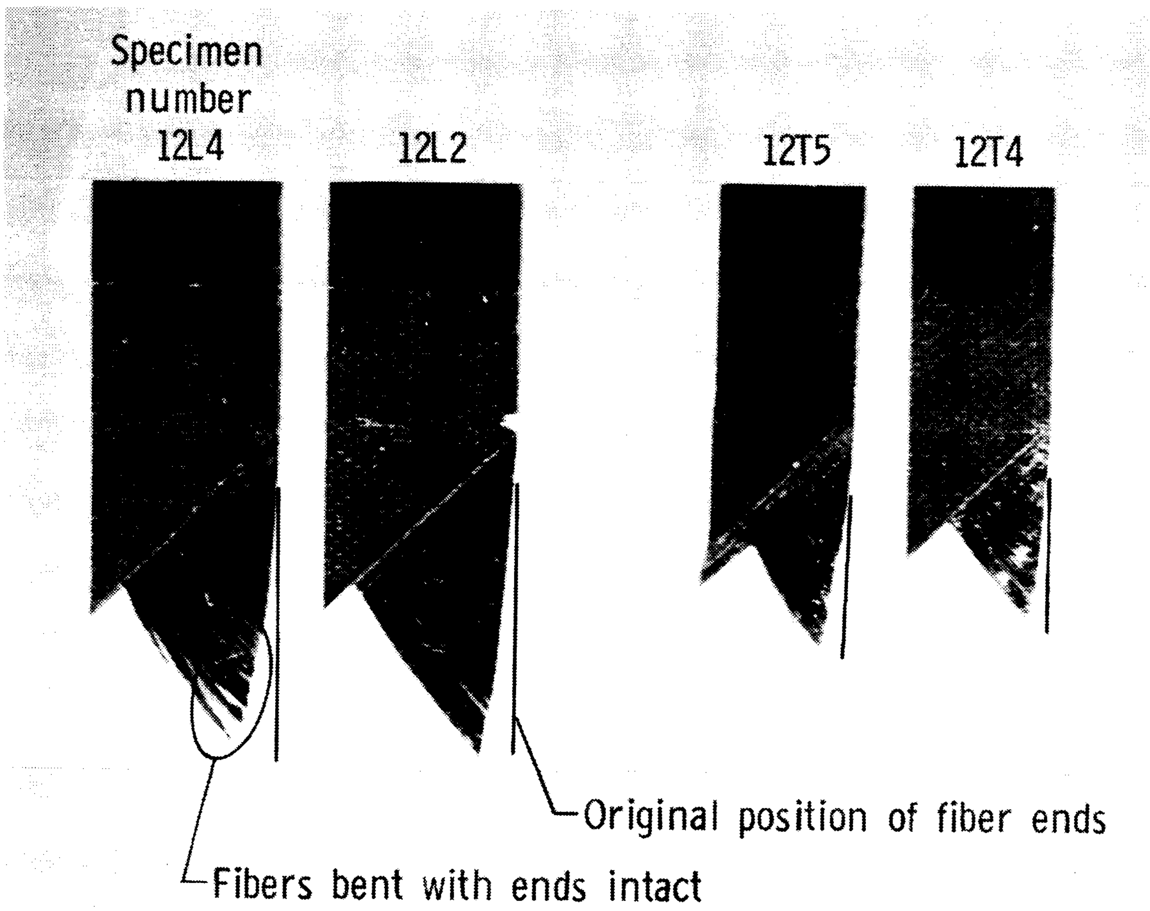


Figure 33.- Shear stress-strain curves for 9.525 mm-wide specimens of material #7 (5208/T300).

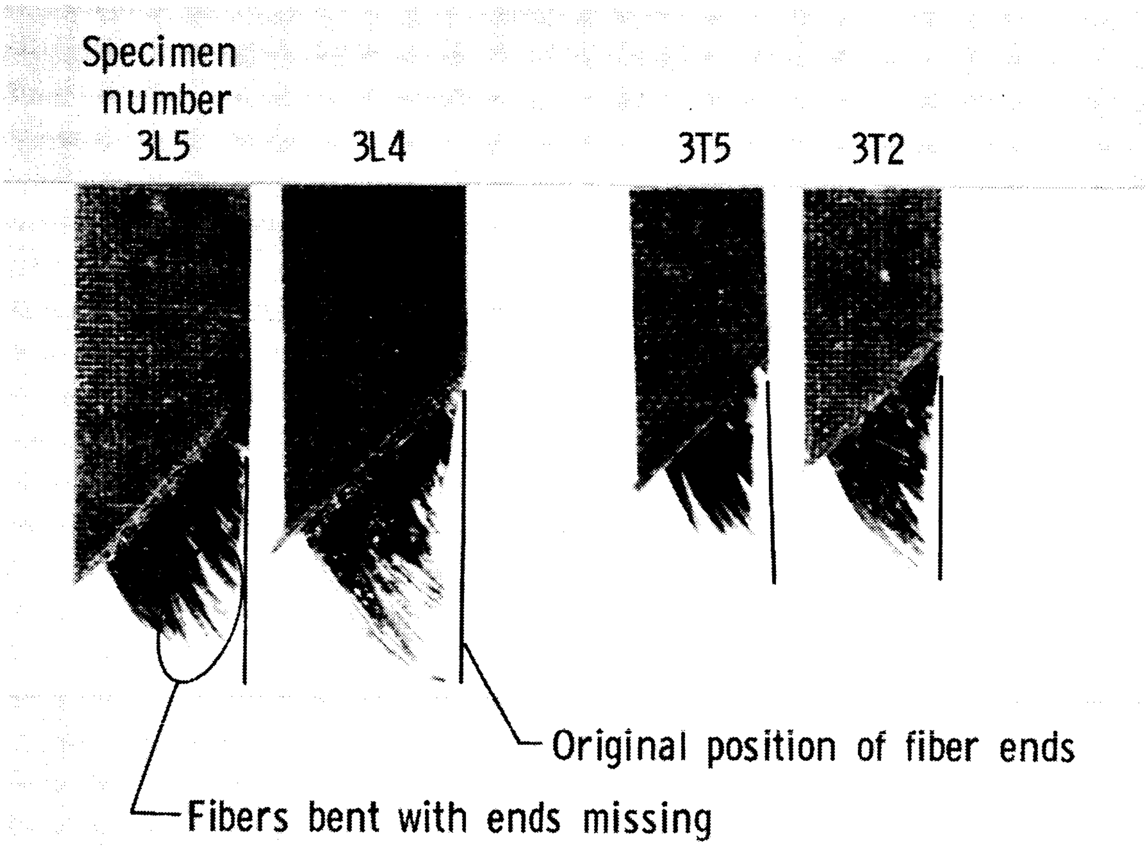
ORIGINAL PAGE IS
OF POOR QUALITY



(a) Material #12 (P1700/C6000).

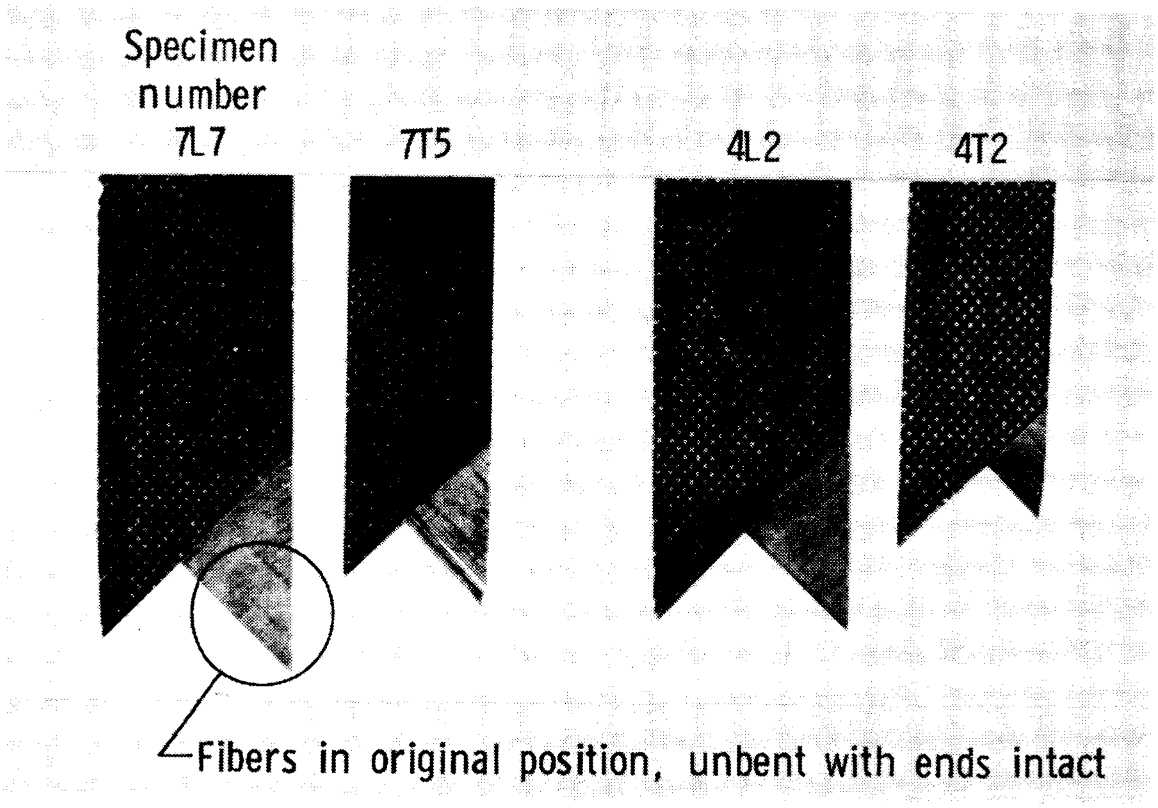
Figure 34.- Photographs of typical test specimens.

ORIGINAL PAGE IS
OF POOR QUALITY



(b) Material #3 (P1700/C3000).

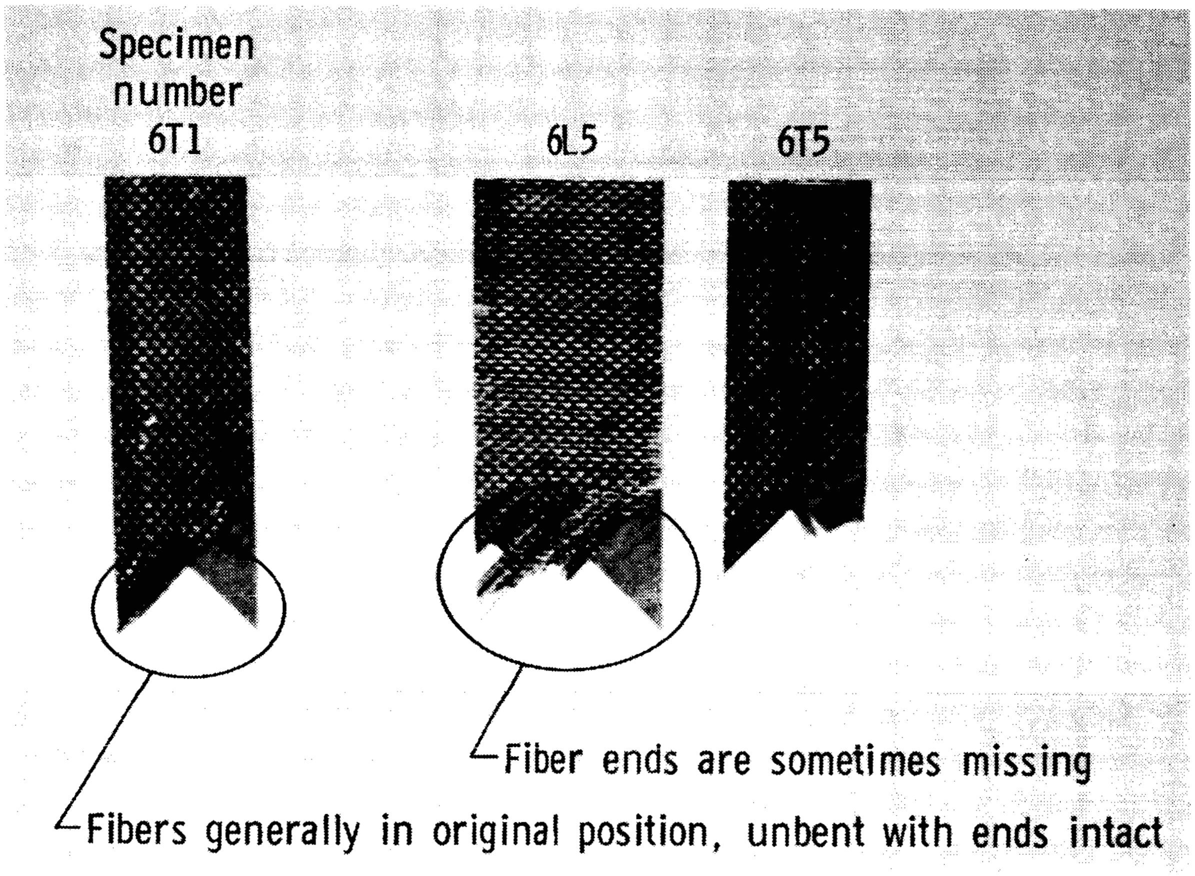
Figure 34.- Continued.



(c) Materials #4 (934/T300)(145 g/m^2) and #7 (5208/T300).

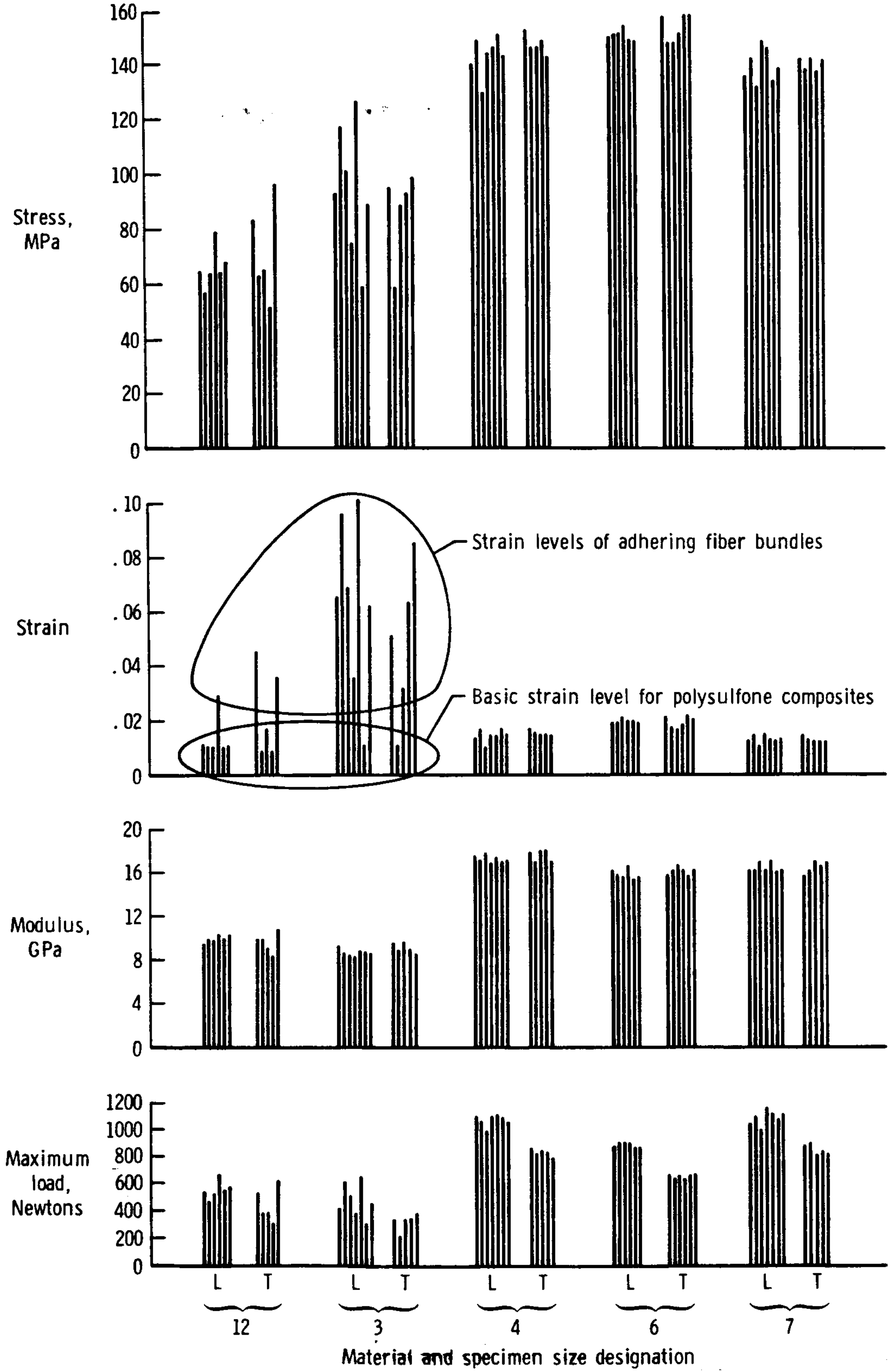
Figure 34.- Continued.

ORIGINAL PAGE IS
OF POOR QUALITY



(d) Material #6 (934/T300)(95 g/m^2).

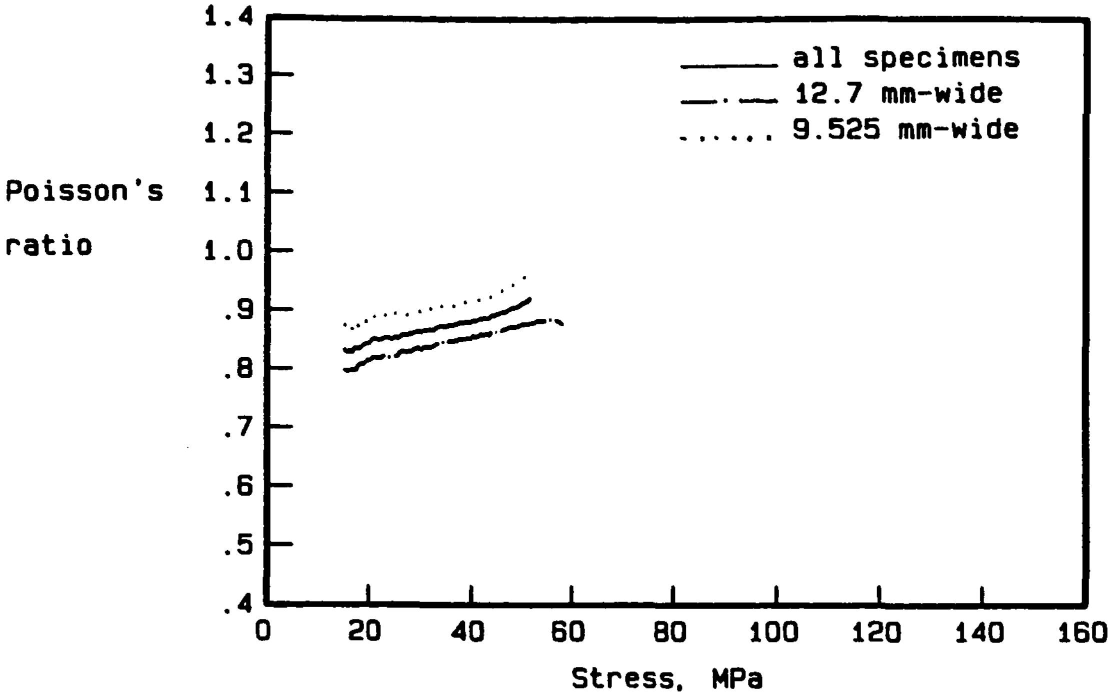
Figure 34.- Concluded.



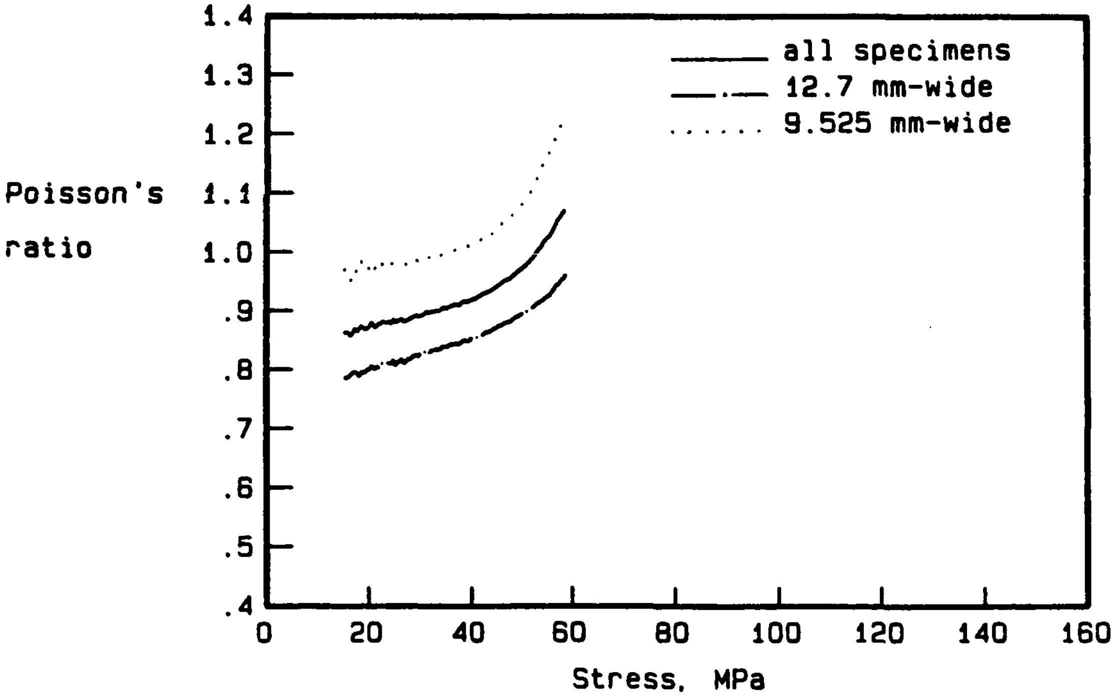
Note: Material and specimen size designation

Number	Material
12	Polysulfone/graphite (P1700/C6000)
3	" " (P1700/C3000)
4	Epoxy/graphite (934/T300)(145 g/m^2)
6	" " (934/T300)(95 g/m^2)
7	" " (5208/T300)

Figure 35. - Display of test results

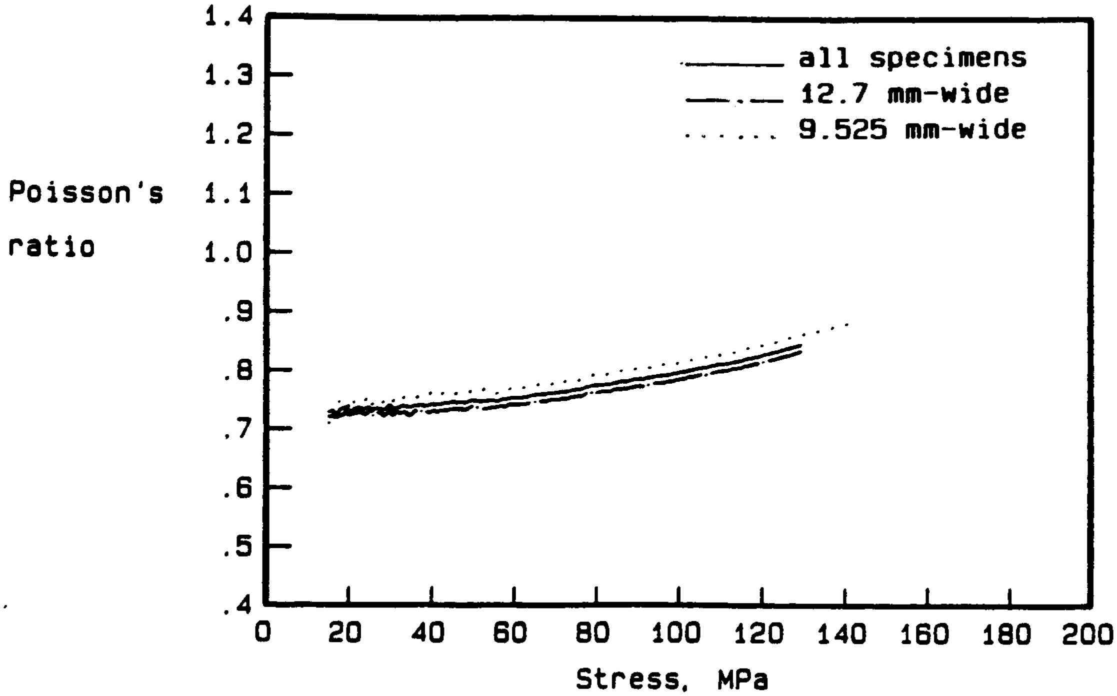


(a) Material #12 (P1700/C6000).

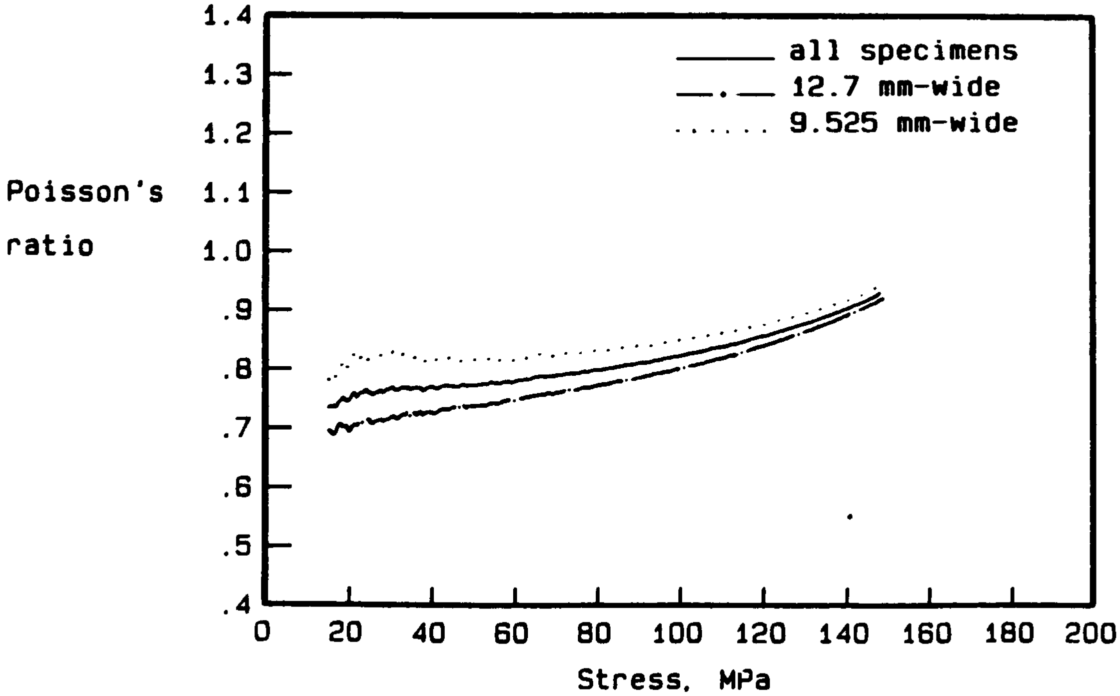


(b) Material #3 (P1700/C3000).

Figure 36.- Averaged Poisson's ratio-stress curves.

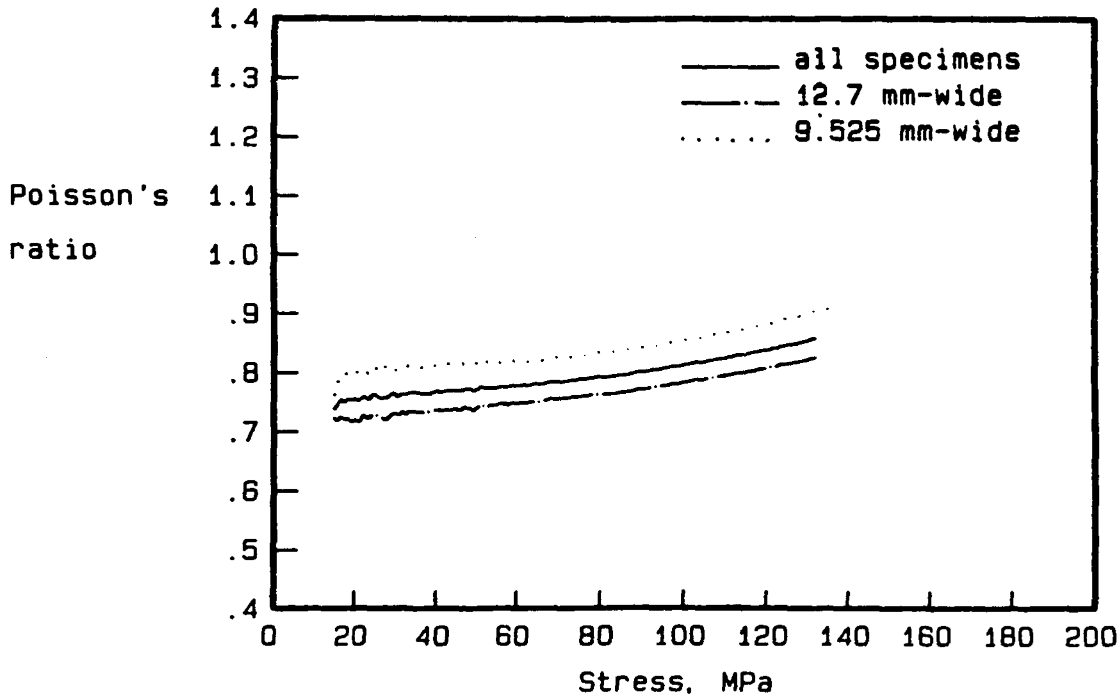


(c) Material #4 (934/T300)(145 g/m^2).



(d) Material #6 (934/T300)(95 g/m^2).

Figure 36.- Continued.



(e) Material #7 (5208/T300).

Figure 36.- Concluded.

Standard Bibliographic Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-89069		
4. Title and Subtitle BASELINE TENSILE TESTS OF COMPOSITE MATERIALS FOR LDEF EXPOSURE		5. Report Date March 1987
		6. Performing Organization Code 506-43-21-04
7. Author(s) William G. Witte		8. Performing Organization Report No.
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665-5225		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Tensile specimens of five graphite fiber reinforced composite materials, were tested at room temperature to provide baseline data for similar specimens exposed to the space environment in low-Earth orbit on the NASA Long Duration Exposure Facility. All specimens were 4-ply [±45°]s layups; at least five replicate specimens were tested for each parameter evaluated. Three epoxy-matrix materials and two polysulfone-matrix materials, several fiber volume fractions, and two sizes of specimen were evaluated. Stress-strain and Poisson's ratio-stress curves, ultimate stress, strain at failure, secant modulus at 0.004 strain, inplane shear stress-strain curves, and unidirectional shear modulus at .004 shear strain are presented.

17. Key Words (Suggested by Authors(s))	18. Distribution Statement
Tensile specimens epoxy-matrix materials polysulfone-matrix materials	Unclassified - Unlimited Subject Category 24

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	60	A04

For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA Langley Form 63 (June 1985)