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## MANUAL FOR LDEF TENSILE TESTS

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## INTRODUCTION

The NASA Long Duration Exposure Facility (LDEF) contains an experiment entitled "Space Exposure of Composite Materials for Large Space Structures", in which about twenty tensile specimens each of five candidate composite materials are mounted on one of the LDEF trays. During the flight the LDEF will be oriented so that this tray will be exposed to atomic oxygen, thermal cycling, particle impingements, UV radiation, vacuum, and possible contamination from outgassing products from other materials, or from rocket exhaust during launch and recovery. 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. The purpose of this manual is to codify details of testing, and data acquisition and handling used in obtaining the baseline data, so that the same procedures and equipment will be used on the subsequent tests. Pre-test planning, testing, and data collection, manipulation, and storage are covered. A standard ASTM test method was used for these tests. Ultimate tensile stress, strain at failure, secant modulus, stress-strain curves, and Poisson's ratio as a function of stress comprise the baseline data.

## TEST SET UP AND EQUIPMENT REQUIREMENTS

Reference 1 is the standard ASTM test method used for these tests. The tests are 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 are measured with MTS Model 632.11b-20 extensometers (numbers 292 and 330). Transverse strain is measured with an Instron strain sensor catalog number 2640-003. The leads from these sensors and from the Instron Load Cell and Bridge voltage meter are connected to a terminal board which is connected to a Hewlett Packard 3497A Data Acquisition System. A Hewlett Packard HP85 computer/HP7470A plotter system connected to the Data Acquisition System stores and plots data.

The connections to the terminal board are as follows:

	Terminal Board Channel	Console Analog Digital Voltmeter Channel
Bridge voltage	001	000
Load cell output	002	001
Longitudinal extensometer 292	003	002
" " 330	004	003
Transverse strain sensor	005	004

The bridge voltage and raw data are collected in computer memory, converted to engineering units, plotted immediately on the 7470A plotter for examination, and stored on a 3M DC 100A data cartridge in the HP85. Subsequently, using a coupled HP85/HP9845B system the data are copied onto another tape cartridge which is used in the HP9845B for manipulating the data. After manipulation the corrected data are stored on one more tape cartridge.

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The software and stored data requirements are as follows:

1. HP85 Data Tape - collects test data and has these PROGRAM FILES:
  - Autost - loads TENS1 automatically
  - TENS1 - inputs test parameters and conversion factors and starts data collection
  - TENS2 - converts, plots, and stores data
  - RS232C - used with MATH PAK to transfer data to HP9845 Data Tape
2. MATH PAK - has PROGRAM FILES which enable data to be transferred to and stored on an HP9845B data tape; at a later time the MATH PAK is used with the HP9845B data tape to manipulate the data stored in those files.

KEYS	}	used for data transfer
RS232C		
AUTOST	}	used for data manipulation
LIST		
EDIT		
SUBFIL		
TRANSF		
FCOPY		
POLY		
NSTART		
STORE		used to store corrected data

3. HP9845B Data Tape - has data files only, no program files
4. CORRECTED DATA TAPE - has corrected data files only, no program files; the manipulated and corrected HP9845B data are stored on this tape with the special function STORE key and the STORE file on the MATH PAK

The software used in item 1, above, are available from the NASA LaRC Advanced Materials Branch Software Library. Reference 2 contains the software used for item 2.

#### 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 <sup>2</sup> )	" 2 and 4	C2528	5
# 6	Epoxy/Graphite (934/T300)(95 g/m <sup>2</sup> )	" 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<sup>2</sup> and 95 g/m<sup>2</sup> are fiber aerial weights to indicate the fiber quantity per unit area.

Panels of four ply laminations with ply lay up of [ $\pm 45^\circ$ ]<sub>s</sub> were fabricated in the LaRC Materials Processing and Development Laboratory. The panels were layed up in sheets 50 in. x 26 in. in size except for the P1700/C6000 which was layed up in a sheet 37 in. x 25 in. 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 3 and 4 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 x 0.500 in. and 6.750 x 0.375 in. Figure 3 indicates nominal dimensions of the two sizes of specimens that were used. Preliminary tests did not show any significant differences in the results obtained for the two sizes of specimens. However, the extensometers that are being used have blades that are one inch wide and therefore are probably more appropriately sized for the wider (1/2-in. wide) specimens than for the narrower (3/8-in. wide) specimens.

End-tabs were machined from epoxy/glass cloth to the dimensions shown in figure 4. These fiberglass tabs were bonded to the specimens with EA934, a bonding agent containing 30 micron diameter microballoons, which enable attainment of uniformly thick bondlines. Attachment 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 0.5000-in. wide specimens, and #30 drill (0.128 in. dia) for the 0.375-in. wide specimens. In attaching the tabs excess bonding agent that oozes out on the material along the tapered ends of the tabs should be removed with a sharp razor blade when dry. Any excess adhesive on the sides of the tabs is of cosmetic interest only. Cleaning the sides in a manner that changes the width dimension should be avoided. For example, holding the specimen on edge and rubbing lengthwise on sand paper is inadvisable.

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.

#### PRE-TEST PREPARATION

Thicknesses and widths.- The first step to take in preparation for a test is to engrave specimen numbers on the fiberglass tabs of the specimens and to measure specimen thicknesses and widths. These measurements are made with a hand operated

Mitutoyo 0-1 in. 0.0001 in. micrometer supported in a vise. The thicknesses and widths should be tabulated as in table III and used as input for the TENS1 program.

The two longitudinal extensometers used in these tests have blades that are spaced one inch apart. They are attached as a pair, back-to-back, on the flat surfaces of the specimens, spanning the middle one inch of the specimen length. The specimen width should be the average of two measurements made along this middle portion of the specimen.

The thickness measurement is a more critical or sensitive measurement than the width measurement. Therefore thickness measurements are made at six points along the middle one inch portion of each specimen and the average of these six measurements is the TENS1 program specimen thickness input.

Pre-load calculations.- In a tensile test of a composite material, after the specimen is mounted in the Instron, and before attaching longitudinal extensometers to the specimen, it is desirable to apply a small preload to the specimen to straighten or flatten it. Therefore a small load was applied to stress each specimen to 350 psi. The preload settings for the load cell were obtained from

$$350 \text{ psi} = \frac{x \text{ lb. on the load cell}}{\text{specimen area, sq in.}}$$

Values for pounds on the load cell (to the nearest tenth of a pound) should be tabulated as in table III.

Instron settings.- Preparation for a test consists of determining and defining test parameters, then translating that data into switch and control settings on the equipment (see ref. 5). Estimates of specimens' ultimate stress and strain are required for optimal control settings. In preliminary tests of these materials the 5208/T300, 934/T300 (95 g/m<sup>2</sup>) and 934/T300 (145 g/m<sup>2</sup>) specimens' ultimate strain was less than 0.025 in/in; however, one specimen of 934/T300 (95 g/m<sup>2</sup>) strained to 0.035 in/in. Therefore an estimate of 0.040 in/in maximum possible strain for these materials seemed reasonable. A smaller estimate may not provide for sufficient ramp excursion. A larger estimate would ensure that the ramp would not reach the end of its excursion before fracturing a specimen, but this would be achieved at the cost of fewer data points and less detail in the earlier portion of the stress-strain curve where, as will be shown later, the data are manipulated to correct for the approximately three pound preload at the start of the test. The two polysulfone materials do not fracture cleanly as the other materials do. Specimens of both of these materials strained beyond 0.040 in/in without fracturing. Most of the polysulfone specimens tested cracked before that value, although one specimen of P1700/C6000 strained to 0.061 in/in without cracking. Cracks occurred in the outer plies and the reinforcing fibers did not break. It appeared, the fibers tend to realign themselves from 45° to 0°, and continue straining. Considerably different measurements would be obtained depending on whether or not the extensometers straddle the crack. For all of the sixteen polysulfone specimens tested in the preliminary test, the knees of the stress-strain curves occurred at less than 0.015 in/in strain. Therefore arbitrarily basing the Instron settings on an estimated value of 0.080 in/in strain for the polysulfones should ensure obtaining not only the initial, most important portion, of the curve, but also some data beyond, where most of the specimens start to crack.

All of the LDEF tests are run in the STROKE CONTROL MODE and 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. The start of the ramp is set by the MEAN LEVEL control, and the amplitude, or overall travel of the ramp, is set with the INPUT control.

Instron settings which are dependent on specimen size and material characteristics are presented in table IV. The settings in table IV were obtained by referring to the preliminary tests or estimated stress-strain curves, using specimen gage lengths of 5.2 in. for the 1/2-in. wide specimens and 3.95 in. for the 3/8-in. wide specimens, and a strain rate of 0.005 in/in per minute.

Load Factor and Ramp Excursion are set on the console by the Controller LOAD range switch and the Stroke Controller setting, respectively. The Load Factor is obtained by finding the maximum stress on the stress-strain curve and multiplying that value by the area of the specimen to obtain maximum estimated load and by then selecting a Load Factor somewhat larger than that. The Ramp Excursion is obtained by finding the maximum strain and multiplying that by the specimen gage length and by then selecting a Ramp Excursion somewhat larger than that.

The Strain Rate (actually, the elongation rate) is obtained by multiplying the strain rate of 0.005 in/in per minute by the gage length of the specimen. Time to full scale in seconds, or TFS, equals Ramp Excursion divided by the elongation rate. The Function Generation rate, or FG rate is the reciprocal of TFS. RANGE and MULT are the console potentiometer settings for the FG rate.

HP85 computer tape.- Obtained a 3M DC 100A or equivalent data cartridge to use for storing data. Initialize the tape by typing ERASE TAPE ENDLIN and CTAPE ENDLIN. Load the program files Autost, TENSL 1, TENSL2, and RS232C onto the tape from the Master Tape, as follows: Insert the Master Tape, type LOAD "program file" ENDLIN, replace the Master Tape with the initialized tape and type STORE "program file" ENDLIN. Do this consecutively for the four program files.

#### EXPERIMENTAL PROCEDURES

Assemble equipment.- After the pre-test preparations are made, assemble the equipment mentioned in TEST SET UP AND EQUIPMENT REQUIREMENTS.

Extensometer calibrations.- Before using the extensometers, they should be calibrated with Structures Research Laboratory's stage micrometer (see fig. 5). An extensometer is mounted to the heavy anvils of the micrometer, in the same orientation that it will be mounted on the specimen during testing, and its leads are attached to the terminal board leading to the console voltmeter. It should be attached to the same channel that it will be attached to while testing. The vernier is turned to several displacement settings and the resulting voltages are read on the digital voltmeter. There are  $n$  paired observations  $(x_i, y_i)$ , see table V, for which it is assumed that the regression of  $y$  on  $x$  is linear, i.e. displacement versus volts should be linear and slope equals displacement divided by volts. Using a least squares method to minimize the vertical error between data points and line, the straight line  $y = a_0 + a_1x$  is fitted to the data. The sensitivity factor for that extensometer when used in that channel is equal to  $a_1$ . Similarly, the sensitivity factors for the other extensometer and the transverse strain sensor are found. The factors for the extensometers are based on a one inch spacing between the

extensometer blades. The spacing between the arms of the transverse strain sensor should be set to the width of the specimens that it will be used on. Therefore in order to correct for its other than one inch spacing its  $a_1$  value has to be multiplied by (1/specimen width). For example, in the Update TENS1 section below, the input sensitivity factors will be:

$$\begin{aligned} S(3) &= 18.0234 \\ S(4) &= 18.7436 \\ S(5) &= 11.3117 * (1/0.5000) = 22.6235 \end{aligned}$$

for extensometer 292, extensometer 330, and the transverse strain sensor, respectively.

Load cell zero.- Prior to loading the specimen, the load cell must be zeroed. A technician attaches the upper grip with a specimen in it to the load cell; and the load cell channel in the Instron voltmeter is set to zero. This setting is made at the beginning of a test day and is checked several times during the day.

Grips and specimens.- The gripping assembly is shown in figure 6. In attaching the specimens to the grips, the backup plate is placed on a horizontal surface with the two grips in the approximate positions shown in figure 6(a). The end-tabs are inserted between the serrated faces of the wedges with the wedge face pin inserted in the holes of the tabs. The tightening devices are put in place and alternately tightened while keeping the specimen taut and straight. A 13 mm open end wrench is used to tighten the devices as snugly as possible by hand. This presses the wedges into the angled opening which forces the wedge faces together, thus "setting" the ends in the grips and minimizing the tensile load carried by the pins. Now one grip is clamped into place, and while holding the other grip so that the specimen is taut and straight, the second grip is clamped into place. The assembly is carried to the Instron and the upper grip is screwed into the load cell. Then the actuator is moved into position for pinning the lower grip to it. (The lower portion of the lower grip attachment has previously been screwed to the actuator.) With the grips attached to the load cell and actuator, the backup plate is removed.

With the grips and specimens attached to the load cell and actuator and the load cell previously set to zero, the actuator is moved down to exert the pre-load from table III on the specimen. In this position the extensometers are attached. The technician attaches the longitudinal extensometers near the midpoint of the specimen with orthodontic rubber bands. The transverse strain sensor is attached just above them. Each extensometer weighs from 0.74 oz to 0.92 oz depending on how its wires are supported. With three extensometers in place the load cell senses an additional 2.5 oz (approximately) and its output increases accordingly. The actual tensile load on the portion of the specimen below the extensometers is diminished by that amount. A weight of 2.5 oz is negligible compared with the maximum loads experienced by the specimens, (less than 0.2%). Therefore no adjustment is made for the extensometers' weight. With the load cell reading approximately 3 or 4 lbs plus approximately 2.5 oz, the extensometers and the strain sensor (channels 3, 4, and 5) are zeroed. This part of the procedure is done concurrently with Update TENS1 below.

Update TENS1.- Load TENS1 into computer memory. Input the date and the sensitivity factors for the extensometers and the transverse strain sensor, for example:



```
type EDIT 980 ENDLINE; retype 980 with the correct date, such as,  
          980 A$[37] = "85/1/15"  
and input the correct sensitivity factors,  
          1980 S(3) = 18.0234  
          1990 S(4) = 18.7436  
          2000 S(5) = 22.6235
```

After these inputs are made to the TENS1 program in the computer memory they can be stored in the program file by typing RESTORE "TENS1" ENDLINE. Now turn off the power to the computer and when the power is turned back on TENS1 will start to run automatically. Answer the questions that appear with the information that was prepared previously in tables III and IV. Take a data-0 after the extensometers and strain sensor are zeroed (see Grips and specimens above). This data-0 will become Observation #1 in the data print out. The data-0 is not subtracted from the data.

Test and plot, store, and print out data.- Immediately after the data-0's are taken the TENS1 program proceeds to the PUSH CONT command. The PUSH CONT command starts the data scanning and acquisition system. Coordinate with the technician so that when the PUSH CONT command is executed, the technician is simultaneously or thereabouts starting the load application to the specimen in the Instron. An oscilloscope on the Instron control console should be used to monitor stress and strain as the test proceeds, in order to detect the occurrence of peak stress. For the epoxy/graphite specimens this is the point of ultimate tensile failure and maximum strain. The same is true for some of the polysulfone/graphite specimens. Most of the polysulfone/graphite specimens however, did not break cleanly but only cracked and continued straining beyond maximum stress. At the moment of peak stress the technician stops the loading cycle and calls out to stop taking data. The initial scan interval for these tests is 0.5 sec. During the test, key 3 on the computer can be used to increase or decrease scan rate (see table IV). When the test stops a digital voltmeter (DVM) on the Instron control console displays the peak load that had been reached on the load cell. This value should be noted (see table III) and later compared with the maximum load obtained in the HP85 print out. If there is a large difference, it would be necessary to look for a problem. After the test TENS1 chains TENS2 and soon the computer is ready to print out data. Both raw data and data converted to engineering units can be printed out on the HP85 roll paper. For the LDEF tests both are obtained. After the data are printed out the computer starts asking questions regarding plotting data on the 7470A plotter. Figures 7(a), (b), and (c) are typical plots. Plot parameters are printed out on the HP85 data tape, also. Figures 7(a) presents complete uncorrected stress-strain curves for the three extensometers. Figures 7(b) and (c) are enlargements of the initial portions of the curves, which are used later for obtaining y-axis offset corrections (see Data Manipulation). The numbers 3.2, 4.2, and 5.2 on the plots refer to the channel numbers of the variables. Stress is on channel 2. Strain from extensometers 292 and 330 are on channels 3 and 4, respectively. Transverse strain is on channel 5. Observing figures 7(b) and (c) note that the curves do not start exactly at the origin. The distance from the x-axis is due to the pre-load on the load cell mentioned previously in the pre-load calculations section. The distances from the y-axis are due to two reasons. First, there is electronic noise in the system. Second, due to the noise, at the zero value the voltage can vary between positive and negative, and therefore the channels are zeroed purposely with a slight positive bias in order to avoid possibly obtaining a curve with an initial zig-zag shape. This can happen when the signal goes from negative to positive, since in the electronics the sign of the voltage is dropped and all signals come out positive. After plotting, the computer asks questions pertaining to storing the converted data on the DC 100A magnetic

tape. A number of questions are asked, including a request for a file name for the data to be stored. A file name is input and the data is stored.

#### DATA MANIPULATION

Y-axis offset.- Before entering the NSTART program for manipulating the data it is necessary to examine the HP85 data print out and the 7470A plots (fig. 7) in order to get inputs (see table VI) that are necessary for manipulating the data. Go to figures 7(b) and (c), draw straight line extrapolations of the curves to the x-axis. Measure the offsets of the intersections from the y-axis and list them as in table VI. Also, using the HP85 print out determine subfiles of the data from the observations where "good" data starts, subjectively evaluated, to the observation where peak stress occurs. Note the total number of observations on the HP85 print out. Also, note a small range of observations at approximately 0.004 in/in strain. After data manipulation these observations will be printed out and secant modulus can be calculated at 0.004 in/in from them.

Transfer data.- Data files are transferred from the HP85 data tapes to HP9845B data tapes using the HP85/HP9845B equipment as follows:

1. Check the connectors in the back of the HP9845B to see that they are set on 7 and 11 and turn on the power to both computers.
2. Place an HP85 data tape into the HP85; type LOAD "RS232C"; press RUN but do not enter a filename yet.
3. Depress the AUTOST key on the HP9845B; insert an initialized blank tape into the T14 tape drive and the MATH PAK into T15; and load the AUTOST program from tape drive T15 into memory.
4. "Transfer Data" appears on the HP9845B screen. Input "Y" for yes. This will load RS232C from T15.
5. The HP85 will display "Go to HP85A, Input FILENAME now."
6. Go to the HP85 and enter the FILENAME. The screen will display "PRESS CONTINUE on 9845B THEN PRESS CONT on 85".
7. Go to the HP9845B and press CONT. The 9845B screen will display "Goto HP85A, Press CONT."
8. Go back to the HP85 and press CONT.
9. The HP85 will transfer the data file to the HP9845B and after it is transferred the HP9845B will store it on the blank tape in the T14 tape drive.
10. The HP85 will display "DATA TRANSFER COMPLETE"; the HP9845B will display "DONE."
11. The HP9845 automatically loads AUTOST and "TRANSFER DATA" appears again on the screen. If "Y" is entered steps (4) through (11) are repeated. If "N" for no is entered the data manipulation program NSTART will be entered.

Manipulation.- Enter a data tape into the HP9845B T14 tape drive as in steps (1-11) under transfer data, or if the data have already been transferred to an HP9845B data tape, turn on the HP9845B, depress the AUTOST key, insert the data tape into T14 and the MATH PAK into T15, load the AUTOST program from the MATH PAK and answer "N" to "Transfer Data." This will load NSTART. In order to load a data file into computer memory several questions in NSTART must be answered as shown below. Figure 8 presents a sketch of the data manipulation overlay referred to in the first question. The inputs for specimen 4L4 are used as an example.

- Q. Is data manipulation overlay on Keys?  
A. YES CONT
- Q. Hard copy option?  
A. 2 CONT
- Q. Data Entry Mode  
A. 2 CONT
- Q. Data file name?  
A. 4L4:T14
- Q. Was data stored by this program?  
A. NO
- Q. Project title for this data set (<=80 char)=?  
A. 4L4
- Q. Input 1 if voltages are to be converted into stress and strain  
A. CONT
- Q. Number of variables  
A. 5 CONT
- Q. Number of observations/variable=?  
A. 219 CONT
- Q. Variable #1 name (<10 char)=?  
#2  
#3  
#4  
#5
- A. Volts CONT  
Stress, ksi CONT  
Ext 292 CONT  
Ext 330 CONT  
Tr Ext CONT
- Q. Is above information correct?  
A. Yes
- Q. Are missing values denoted by -99999.999  
A. CONT
- Q. Then input "Missing value=?"  
A. CONT
- Q. Is data in proper configuration, i.e. var=rows, obs=col  
A. NO
- Q. Data stored as contiguous array with obs=rows, var=col  
A. YES
- Q. Is data medium placed in device T14  
A. YES

Appendix A is a print out of a typical DATA Manipulation. The first two lists of observations contain initial values and peak values. These can be compared with the HP85 data to make certain that the data have transferred correctly.

The first two transformations added the y-axis offsets to the longitudinal extensometers' data. The third transformation averages the two extensometers' data and stores it as corrected strain in variable #8.

The fourth transformation corrects the transverse strain sensor data. In this case the y-axis offset was zero. The corrected transverse strain is stored in variable #9.

The fifth transformation obtains Poisson's ratio by dividing the corrected transverse strain by the corrected longitudinal strain. Poisson's ratio is stored in variable #10.

The next three lists of observations contain corrected initial values, values at approximately 0.004 in/in, and peak values.

Create subfiles with the SUBFIL program and the values from table VI. Then load POLY program and plot a stress-strain curve; variable #2 is the dependent variable and variable #8 is the independent variable.

Finally, reload SUBFIL and create subfiles to use in plotting Poisson's ratio as a function of stress. Reload POLY and plot Poisson's ratio, variable #10, as the dependent variable and stress, variable #2, as the independent variable.

Secant modulus at 0.004 in/in can be obtained by linear interpolation of the values for stress, variable #2, and strain, variable #8, listed in the print out of observations 79 and 80.

Report figures.- The plots obtained from the 7470A plotter and the figures obtained in the regression program on the 9845B computer are not sufficiently high in quality to be used in a report. Report quality figures can be obtained on a HP9845/HP9872C computer/plotter system.

Starting with a corrected 9845 data file, the first step is to transfer the dependent and independent variables of interest to another magnetic tape and arrange them in the form that is compatible with the 9872C.

A Report Graphics tape which is part of the software supplied with the 9872C is used for making figures. The program files of main interest are:

AUTOST  
DATSAV  
FIGURE  
VUTEXT  
MERG  
FUNCTN  
LABEL  
COPY  
VUGRAPH  
SYMBOL

DATSAV is used to add or delete data points (or observations as they are called in the regression program). In the present study some of the data points which were obtained during the moments between turning on the data acquisition system and initiating actuator movement, were deleted. Also the points obtained after maximum stress was reached, were deleted.

Up to this point in the study all of the data are in English units. Now a modification of DATSAV can be used to convert stress to SI units.

With the data tape with the selected, organized, and converted data in the T14 tape drive of the 9845 computer and the Report Graphics tape in the T15 drive the computer can be turned off and on (with the computer AUTOST key depressed) and the AUTOST program loads the FIGURE program. A frame with tick marks, x and y values, and labels can be plotted and stored in a file. Next, data curves can be plotted and stored separately. The LABEL program can be loaded into memory and used to add additional labels and curve identification lists to the figure. Figures 9 and 10 are typical stress-strain and Poisson's ratio-stress curves, respectively, obtained with this procedure.

Groups of data curves can be averaged, stored, and plotted as above, using the Average Curve program available from the NASA LaRC Advanced Materials Branch Software Library. Figures 11 and 12 are typical figures presenting averaged data.

#### DATA ARCHIVING

The material accumulated during this study consists of broken specimens, HP85 paper tapes, HP7470A plots, HP9845B printouts, report graphics figures, HP85 magnetic data tapes, HP9845B data tapes, corrected 9845 data tapes, duplicates of corrected 9845 data tapes, HP9872C compatible data files and report graphics data files. These materials are being stored at NASA Langley Research Center. Also a special LDEF logbook and a duplicate logbook containing specimen measurements and test data are being kept in the same location.

#### REFERENCES

1. "Standard Test Method for Tensile Properties of Fiber-Resin Composites", ASTM Designation D3039. Annual Book of ASTM Standards, Part 35.
2. "Regression Analysis", Part No. 09845-15011, Hewlett Packard Co.
3. "Standard Test Method for fiber Content of Resin-Matrix Composites by Matrix Digestion" ASTM Designation D3171-76.
4. "Standard Test Methods for Specific Gravity and Density of Plastics by Displacement", ASTM Designation D792-66.
5. "Instruction Manual for Series 2150 Servohydraulic Control System", Manual No. 11-1-10(B), Instron Corporation.

APPENDIX A  
Typical HP9845B Computer Printout

\*\*\*\*\*  
\* DATA MANIPULATION \*  
\*\*\*\*\*  
4L4

Data file name: 4L4:T14  
Number of observations: 219  
Number of variables: 5

Variables names:  
1. VOLTS  
2. STRESS KSI  
3. EXT 292  
4. EXT 330  
5. TR EXT

4L4

OBS#	Variable # 1	Variable # 2	Variable # 3	Variable # 4	Variable # 5
4	3.000200	.475654	.000126	.000094	.000136
5	3.000200	.620893	.000198	.000150	.000181
6	3.000200	.799008	.000234	.000206	.000204
7	3.000200	.908735	.000306	.000244	.000226

4L4

OBS#	Variable # 1	Variable # 2	Variable # 3	Variable # 4	Variable # 5
212	3.000200	20.856625	.014058	.013852	.011674
213	3.000200	20.930202	.014148	.013983	.011764
214	3.000200	20.855349	.014184	.014001	.011787

The following transformation was performed:  $a \cdot (X^b) + c$   
where  $a = 1$   
 $b = 1$   
 $c = .000034$   
X is Variable # 3  
Transformed data is stored in Variable # 6 (FEXT).

The following transformation was performed:  $a \cdot (X^b) + c$   
where  $a = 1$   
 $b = 1$   
 $c = .000068$   
X is Variable # 4  
Transformed data is stored in Variable # 7 (GEXT).

The following transformation was performed:  $aX+bY+c$   
 where  $a = .5$   
 $b = .5$   
 $c = 0$   
 $X$  is Variable # 6  
 $Y$  is Variable # 7  
 Transformed data is stored in Variable # 8 (AVG EXT).

The following transformation was performed:  $a(X^b)+c$   
 where  $a = 1$   
 $b = 1$   
 $c = 0$   
 $X$  is Variable # 5  
 Transformed data is stored in Variable # 9 (TRANS EXT).

The following transformation was performed:  $a(X^b)*(Y^c)$   
 where  $a = 1$   
 $b = 1$   
 $c = -1$   
 $X$  is Variable # 9  
 $Y$  is Variable # 8  
 Transformed data is stored in Variable # 10 (POIS RATIO).

4L4

OBS#	Variable # 1	Variable # 2	Variable # 3	Variable # 4	Variable # 5
	Variable # 6	Variable # 7	Variable # 8	Variable # 9	Variable # 10
4	3.000200	.475654	.000126	.000094	.000136
	.000160	.000162	.000161	.000136	.843423
5	3.000200	.620893	.000198	.000150	.000181
	.000232	.000218	.000225	.000181	.804024
6	3.000200	.799008	.000234	.000206	.000204
	.000268	.000274	.000271	.000204	.750665
7	3.000200	.908735	.000306	.000244	.000226
	.000340	.000312	.000326	.000226	.693905



4L4

OBS#	Variable # 1	Variable # 2	Variable # 3	Variable # 4	Variable # 5
	Variable # 6	Variable # 7	Variable # 8	Variable # 9	Variable # 10
77	3.000200	9.379102	.003857	.003749	.002783
	.003891	.003817	.003854	.002783	.722053
78	3.000100	9.510519	.003893	.003786	.002851
	.003927	.003854	.003891	.002851	.732674
79	3.000200	9.596854	.003947	.003842	.002873
	.003981	.003910	.003946	.002873	.728167
80	3.000200	9.698501	.004001	.003899	.002896
	.004035	.003967	.004001	.002896	.723784
81	3.000100	9.799296	.004055	.003936	.002964
	.004089	.004004	.004047	.002964	.732368
82	3.000200	9.910725	.004109	.003992	.003009
	.004143	.004060	.004102	.003009	.733552
83	3.000200	10.008118	.004163	.004030	.003054
	.004197	.004098	.004148	.003054	.736365
84	3.000200	10.098281	.004199	.004086	.003099
	.004233	.004154	.004194	.003099	.739053
85	3.000000	10.223319	.004272	.004142	.003122
	.004306	.004210	.004258	.003122	.733229
86	3.000100	10.313482	.004326	.004199	.003167
	.004360	.004267	.004313	.003167	.734344
87	3.000000	10.411301	.004362	.004255	.003190
	.004396	.004323	.004359	.003190	.731762

4L4

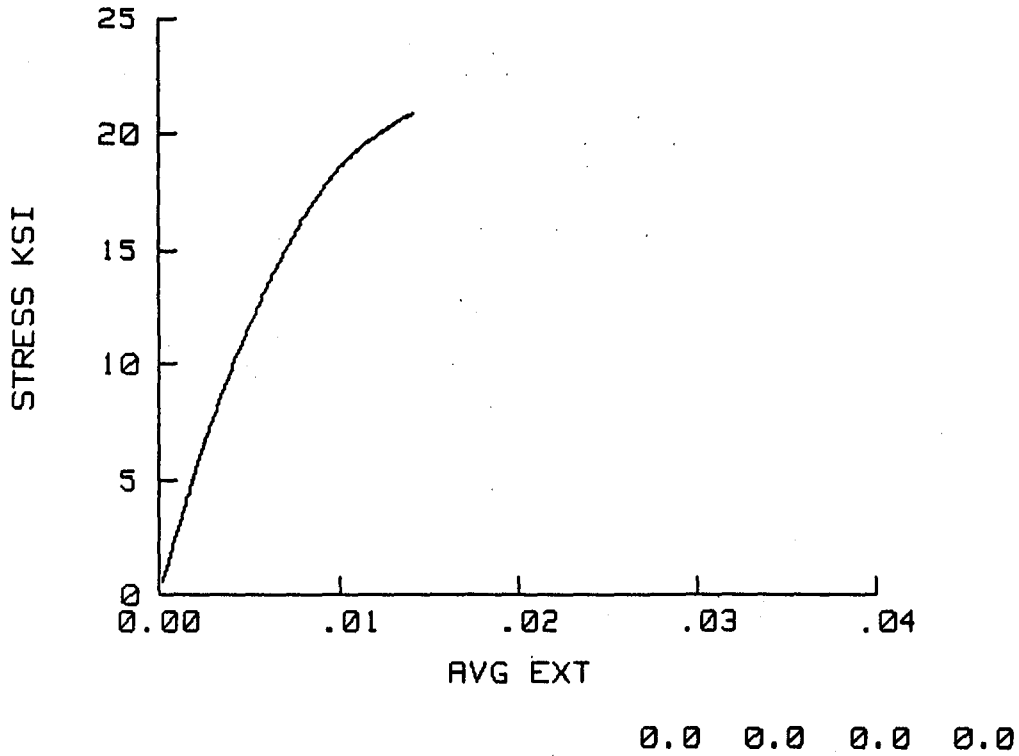
OBS#	Variable # 1	Variable # 2	Variable # 3	Variable # 4	Variable # 5
	Variable # 6	Variable # 7	Variable # 8	Variable # 9	Variable # 10
212	3.000200	20.856625	.014058	.013852	.011674
	.014092	.013920	.014006	.011674	.833488
213	3.000200	20.930202	.014148	.013983	.011764
	.014182	.014051	.014117	.011764	.833365
214	3.000200	20.855349	.014184	.014001	.011787
	.014218	.014069	.014144	.011787	.833350

Subfile name: beginning observation--number of observations  
 1. SF1 1 4  
 2. SF2 5 209  
 3. SF3 214 6

\*\*\*\*\*  
 POLYNOMIAL REGRESSION on Subfile 'SF2' OF  
 4L4  
 \*\*\*\*\*

--where: Dependent variable = STRESS KSI  
 Independent variable = AVG EXT

4L4

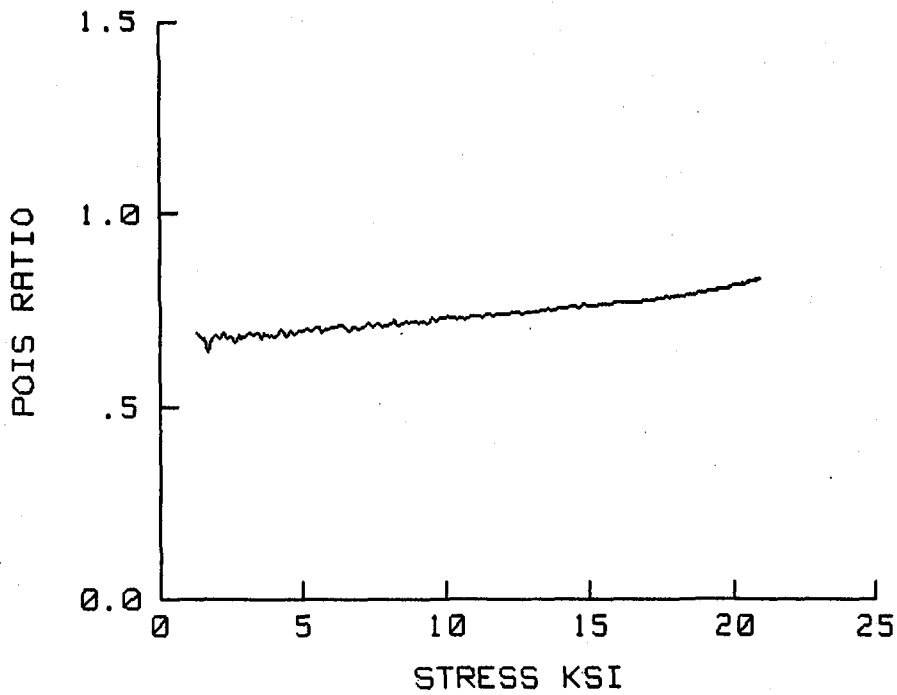


Subfile name: beginning observation--number of observations  
 1. SF1 1 9  
 2. SF2 10 204  
 3. SF3 214 6

\*\*\*\*\*  
 POLYNOMIAL REGRESSION on Subfile 'SF2' OF  
 4L4  
 \*\*\*\*\*

--where: Dependent variable = POIS RATIO  
 Independent variable = STRESS KSI

4L4



0.0 0.0 0.0 0.0

\*\*\*\*\* The data and related information are stored in C4L4:T14 \*\*\*\*\*

TABLE I.- MATERIALS

Weight per unit area -								
Panel number	Panel gram	Weight (pound)	Panel size		Laminate thickness		Weight per unit area	
			cm	(inch)	mm	(inch)	g/m <sup>2</sup>	(psf)
#12	519	(1.144)	94 × 63.5	(37 × 25)	0.660 ± .026	(0.026 ± 0.001)	870	(0.1782)
# 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 × 66	(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	Flat probe, 15g	U probe, 15g
#12	162°C	165°C
# 3	174	172
# 4	192	191
# 6	202	200
# 7	210	202

TABLE II.- FIBER VOLUME ANALYSIS

Material 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	0.36113	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	

TABLE III.- THICKNESS, WIDTH, AND PRELOAD VALUES

Specimen No.	Thickness		Width		Preload pounds on Load Cell	Maximum load from DVM, pounds	Ultimate Tensile Stress from DVM, ksi
	mm	(inch)	mm	(inch)			
12L1	.659	(0.02595)	12.73	(0.5012)	4.55		
2	.645	(.02538)	12.70	(.5000)	4.44		
3	.659	(.02595)	12.74	(.5016)	4.55		
4	.650	(.02561)	12.77	(.5029)	4.50		
5	.654	(.02576)	12.77	(.5029)	4.53		
6	.663	(.02612)	12.75	(.5023)	4.59		
12T1	.670	(.02636)	9.55	(.3762)	3.47		
2	.651	(.02564)	9.52	(.3749)	3.36		
3	.641	(.02524)	9.54	(.3757)	3.31		
4	.657	(.02586)	9.53	(.3753)	3.39		
5	.675	(.02659)	9.62	(.3789)	3.52		
3L1	.351	(.01380)	12.71	(.5007)	2.41		
2	.412	(.01621)	12.73	(.5014)	2.84		
3	.408	(.01605)	12.70	(.5003)	2.81		
4	.412	(.01622)	12.74	(.5019)	2.85		
5	.401	(.01579)	12.74	(.5016)	2.77		
6	.407	(.01604)	12.74	(.5019)	2.81		
7	.407	(.01601)	12.69	(.4997)	2.80		
3T1	.383	(.01509)	9.46	(.3728)	1.96		
2	.403	(.01586)	9.50	(.3743)	2.07		
3	.394	(.01551)	9.51	(.3747)	2.03		
4	.394	(.01550)	9.42	(.3712)	2.01		
5	.414	(.01631)	9.54	(.3759)	2.14		
4L1	.614	(.02418)	12.77	(.5029)	4.25		
2	.560	(.02206)	12.76	(.5026)	3.88		
3	.606	(.02384)	12.74	(.5016)	4.18		
4	.594	(.02338)	12.77	(.5030)	4.11		
5	.594	(.02339)	12.75	(.5023)	4.11		
6	.562	(.02214)	12.72	(.5010)	3.88		
7	.573	(.02256)	12.77	(.5030)	3.97		
4T1	.594	(.02340)	9.53	(.3752)	3.07		
2	.585	(.02303)	9.52	(.3751)	3.02		
3	.604	(.02377)	9.52	(.3749)	3.11		
4	.595	(.02341)	9.51	(.3747)	3.07		
5	.578	(.02274)	9.52	(.3748)	2.98		
6L1	.452	(.01778)	12.83	(.5051)	3.14		
2	.457	(.01800)	12.80	(.5042)	3.17		
3	.454	(.01789)	12.80	(.5043)	3.15		
4	.442	(.01740)	12.80	(.5041)	3.07		
5	.454	(.01788)	12.80	(.5042)	3.15		
6	.454	(.01786)	12.80	(.5040)	3.15		

TABLE III.- Concluded

Specimen No.	Thickness		Width		Preload pounds on Load Cell	Maximum load from DVM, pounds	Ultimate Tensile Stress from DVM, ksi
	mm	(inch)	mm	(inch)			
6T1	.439	(0.01729)	9.54	(0.3756)	2.27		
2	.449	(.01769)	9.60	(.3782)	2.34		
3	.461	(.01814)	9.56	(.3765)	2.39		
4	.437	(.01720)	9.57	(.3771)	2.27		
5	.438	(.01726)	9.56	(.3764)	2.27		
6	.445	(.01751)	9.53	(.3752)	2.30		
7L1	.599	(.02358)	12.79	(.5038)	4.15		
2	.607	(.02389)	12.78	(.5035)	4.20		
3	.583	(.02295)	12.76	(.5026)	4.03		
4	.609	(.02396)	12.81	(.5044)	4.23		
5	.598	(.02355)	12.79	(.5036)	4.15		
6	.627	(.02468)	12.77	(.5029)	4.34		
7	.620	(.02441)	12.76	(.5027)	4.29		
7T1	.614	(.02417)	9.57	(.3771)	3.19		
2	.611	(.02406)	9.52	(.3748)	3.15		
3	.615	(.02423)	9.52	(.3749)	3.17		
4	.623	(.02453)	9.54	(.3758)	3.22		
5	.600	(.02363)	9.52	(.3748)	3.09		

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

Specimen Size Designation:

L = 1/2-in. wide specimens

T = 3/8-in. wide specimens

TABLE IV.- INSTRON SETTINGS FOR LDEF TESTS

Spec.	Load factor	Controller load range switch	Ramp excursion	Stroke controller setting	Strain rate (.005 in/in min)	TFS of ramp Excursion	FG rate	Range	Mult	HIT key 3 to double Scan Interval at these elapsed times (using 5 channels)	
	lbs	%	inch	%	in/min	Sec				min	sec
12L	250	5	0.4	20	0.026	923	0.0010834	0.01	1.08	0 2 4	50 10 10
3L	250	5	0.4	20	.026	923	.0010834	.01	1.08	0 2 4	50 10 10
4L	500	10	0.2	10	.026	461	.0021667	.01	2.16	1 3	00 20
6L	500	10	0.2	10	.026	461	.0021667	.01	2.16	1 3	00 20
7L	500	10	0.2	10	.026	461	.0021667	.01	2.16	1 3	00 20
12T	250	5	0.4	20	.01975	1215	.0008229	.01	.822	0 2 4	50 10 10
3T	250	5	0.4	20	.01975	1215	.0008229	.01	.822	0 2 4	50 10 10
4T	500	10	0.2	10	.01975	607	.0016458	.01	1.64	1 3	00 20
6T	250	5	0.2	10	.01975	607	.0016458	.01	1.64	1 3	00 20
7T	500	10	0.2	10	.01975	607	.0016458	.01	1.64	1 3	00 20



TABLE V.- EXTENSOMETER CALIBRATIONS (TYPICAL)

Vernier' inch ( $y_i$ )	Extensometer 292, volts ( $x_i$ )	Extensometer 330, volts ( $x_i$ )	Transverse Strain Sensor, volts ( $x_i$ )
0	.000001	.000007	.000001
.005	.000278	.000261	.00044
.010	.000555	.000528	.000888
.015	.000832	.000798	.001329
.020	.001110	.001064	.001771
.025	.001386	.001331	.002212
.030	.001665	.001599	.002654
.035	.001943	.001867	.003094
.040	.002220	.002135	.003540
$a_1 =$	18.0234	18.7436	11.3117

TABLE VI.- Y-AXIS OFFSETS AND SUBFILES

Specimen number	Number of observations	Variable #3 and #4 subfile	Variable #5 subfile	Variable #3 offset, inch	Variable #4 offset, inch	Variable #5 offset, inch	Secant modulus observations
4L4	219	5-213	6-213	0.000034	0.000068	0	77-87
-	-						
-	-						

Obtain from HP85 data print out:

Number of observations

Variable #3 and #4 subfile

Variable #5 subfile

Range of observations where secant modulus at .004 in/in occurs

Obtain from 740A plots:

Offsets (see figs. 7(b) and (c))

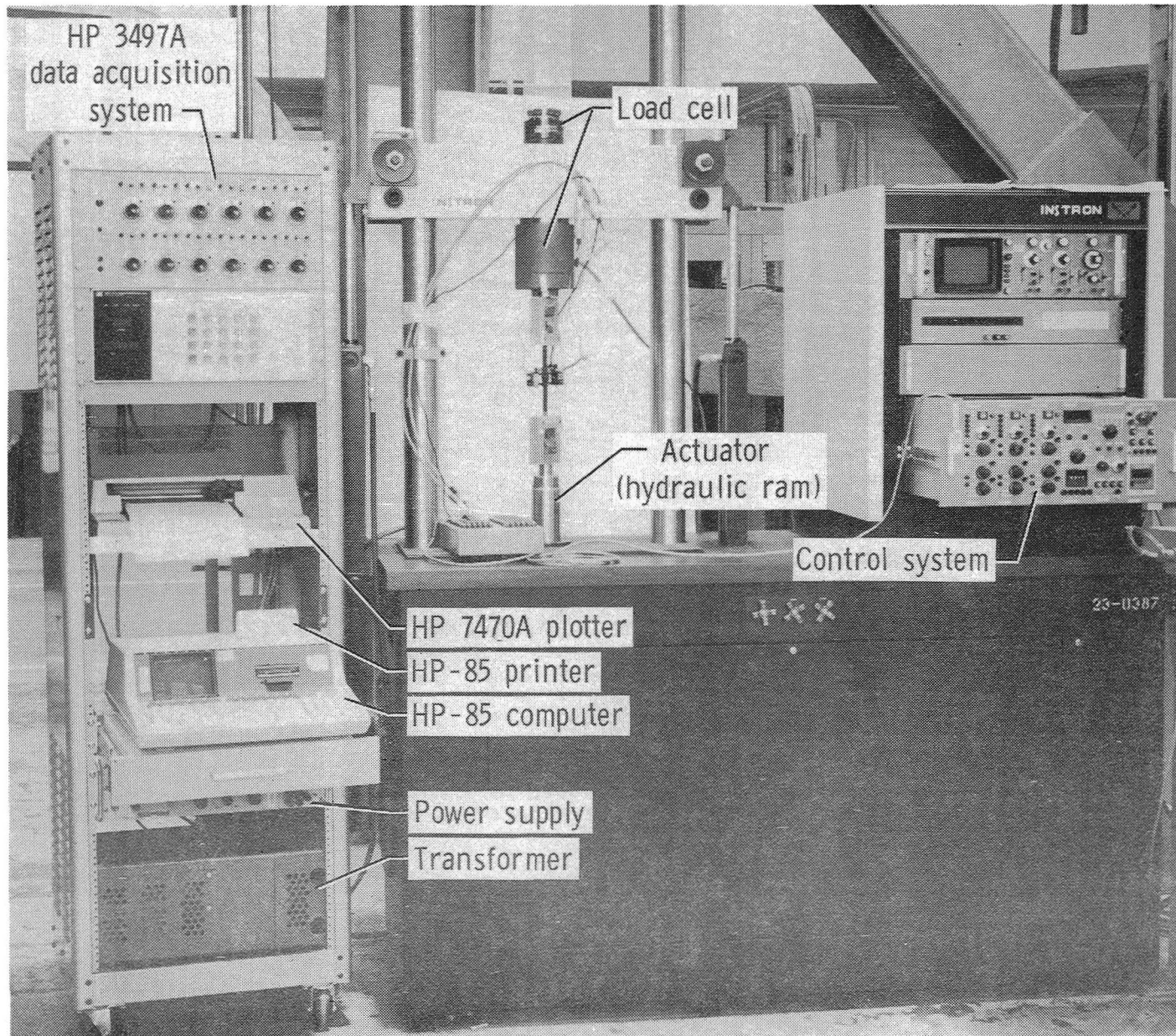


Figure 1. - Tensile testing and data acquisition equipment.

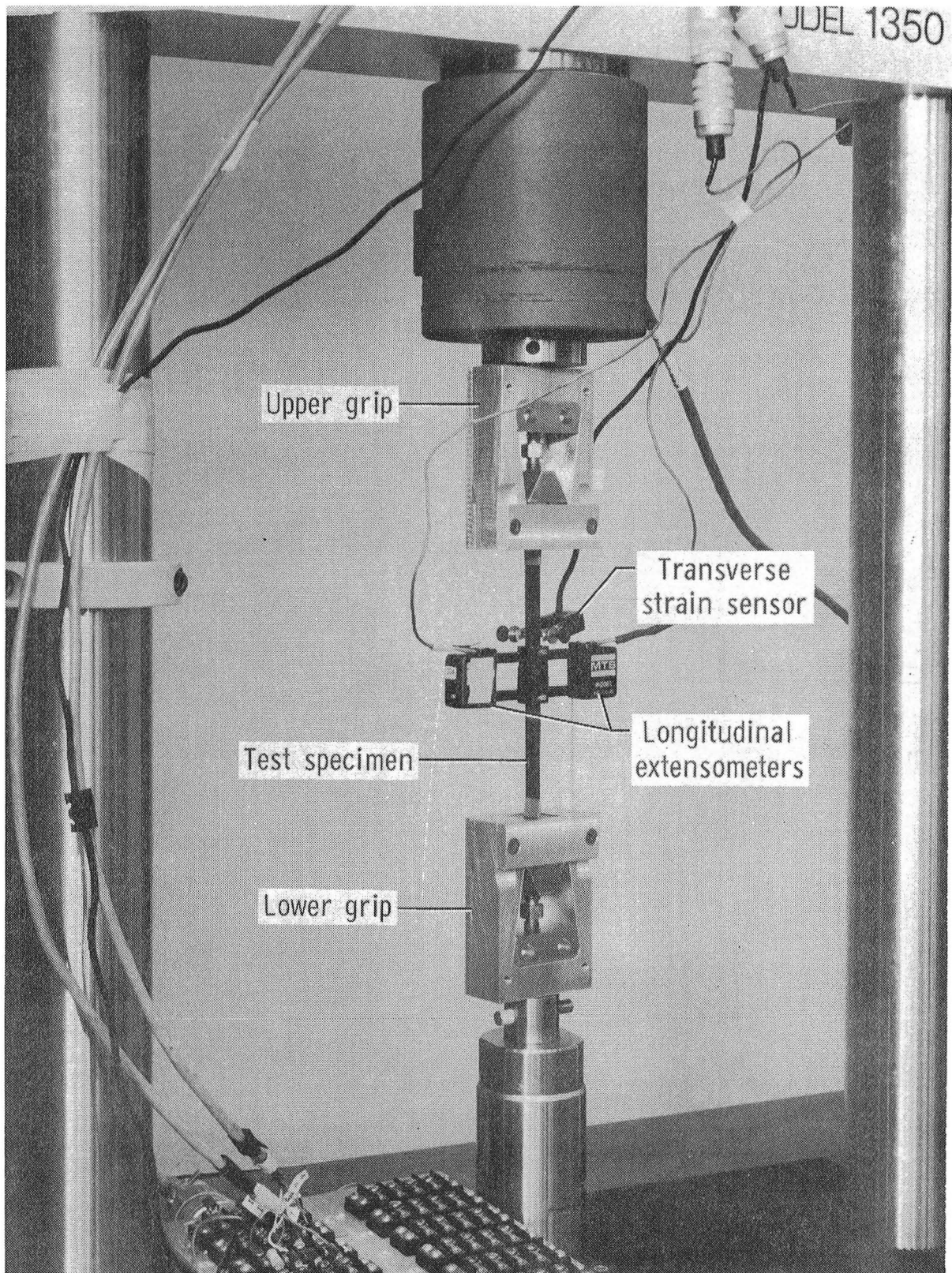
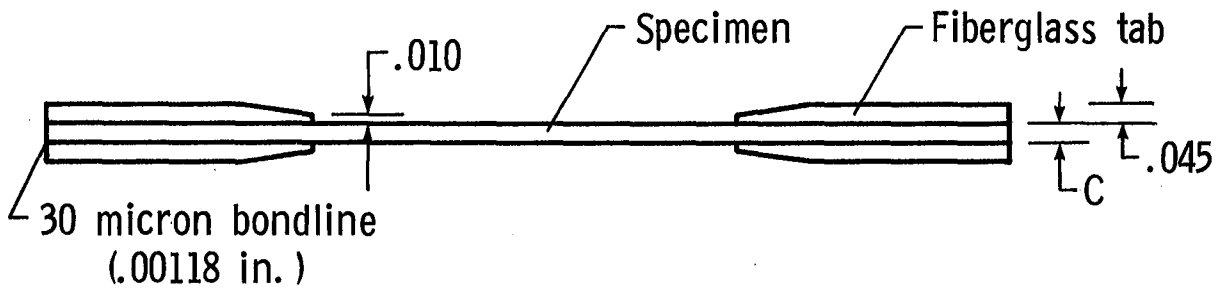
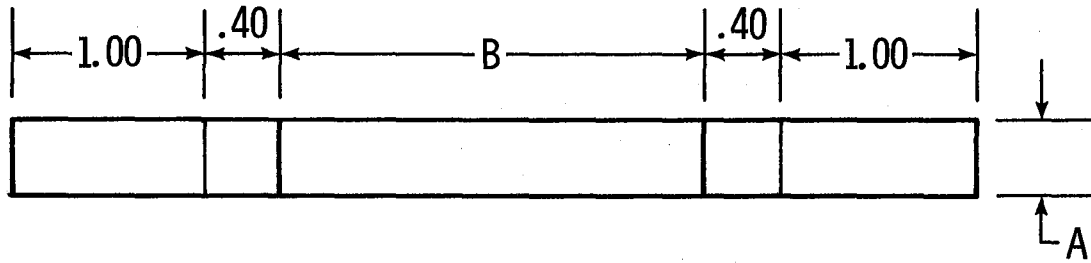


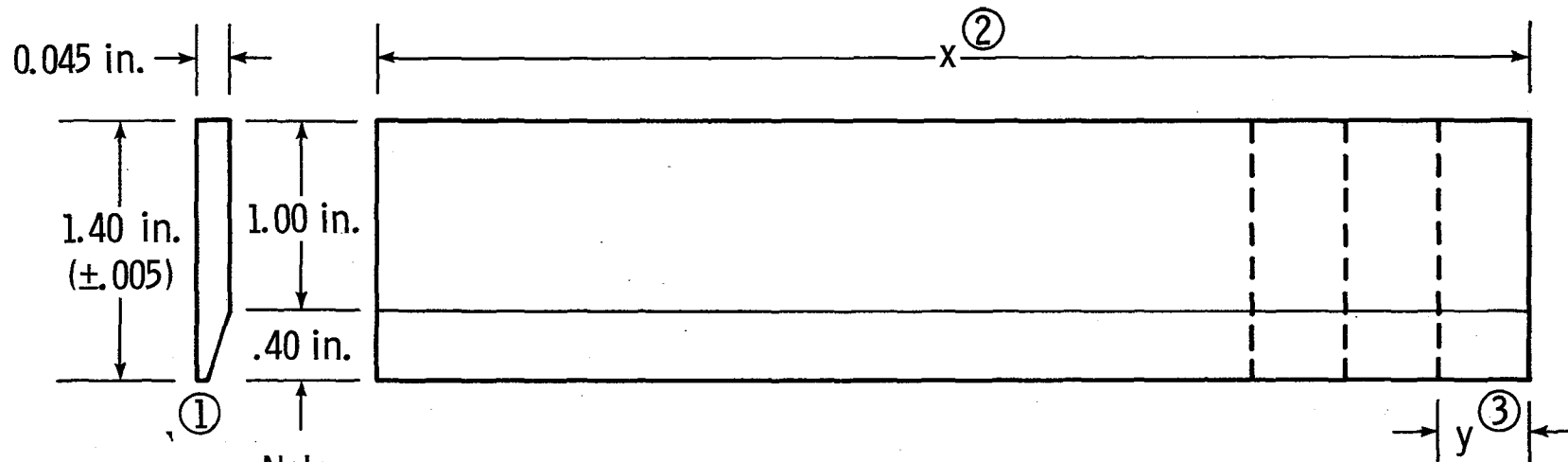
Figure 2. - Close-up view of test specimen, grips and sensors.



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.



Note

- ① End to be 0.010 in. thick
- ② Dimension "x" to be as long as can be handled comfortably
- ③ Strip x is to be cut into tabs; dimension "y" is as follows:  
 $y = 0.500 \text{ in.}$   
 $y = 0.375 \text{ in.}$

Strips to be cut from 36 in. x 48 in. panel of nominal 0.045 in. thick fiberglass/epoxy

Figure 4. - Fiberglass end-tabs.



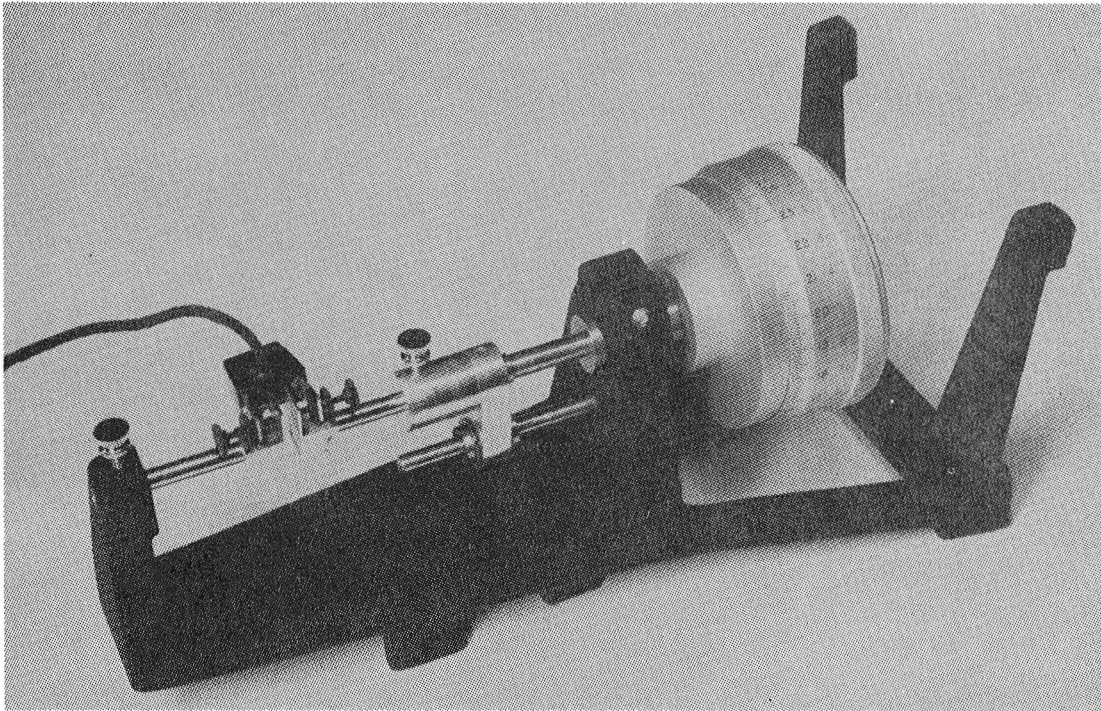
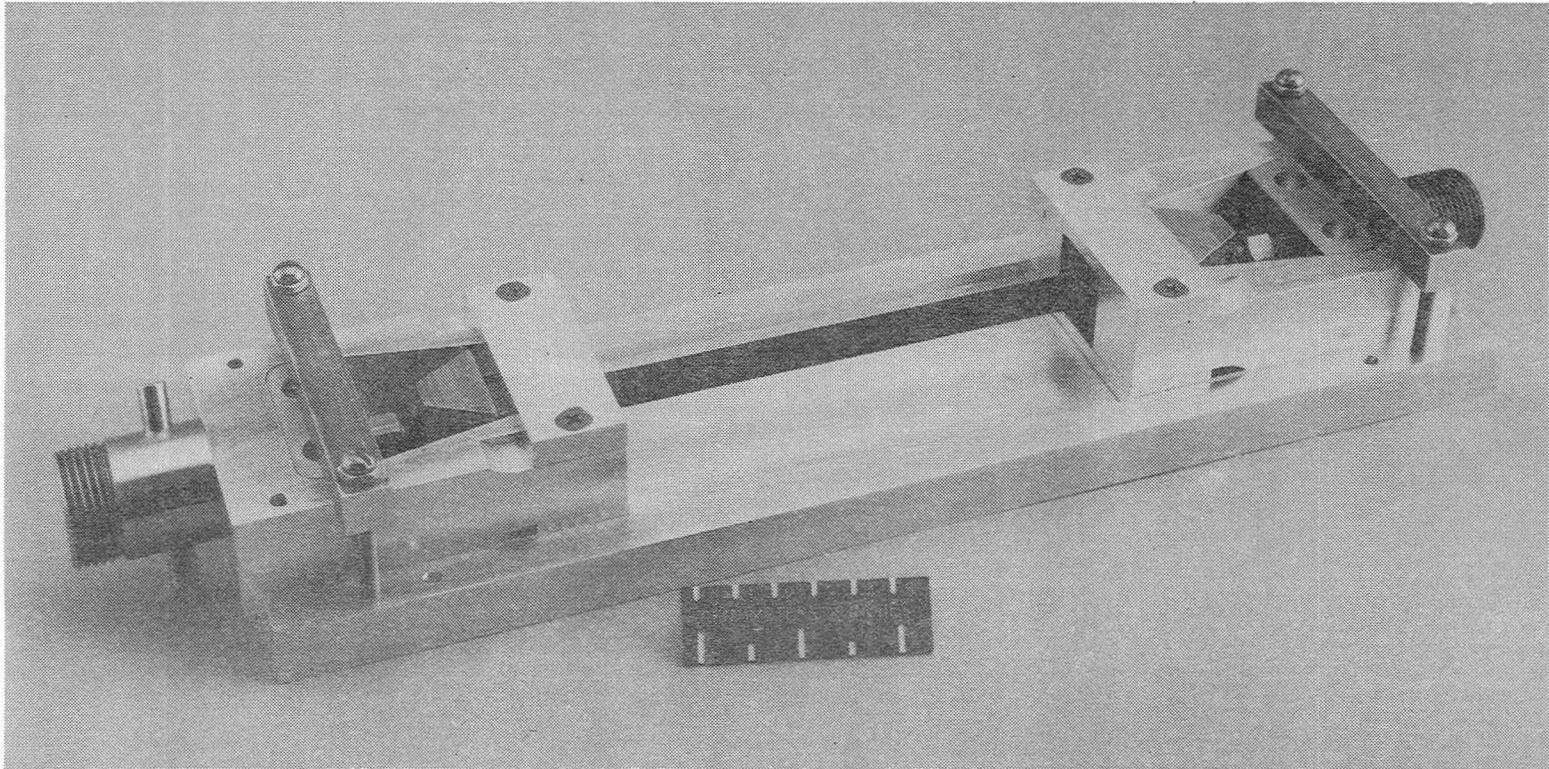
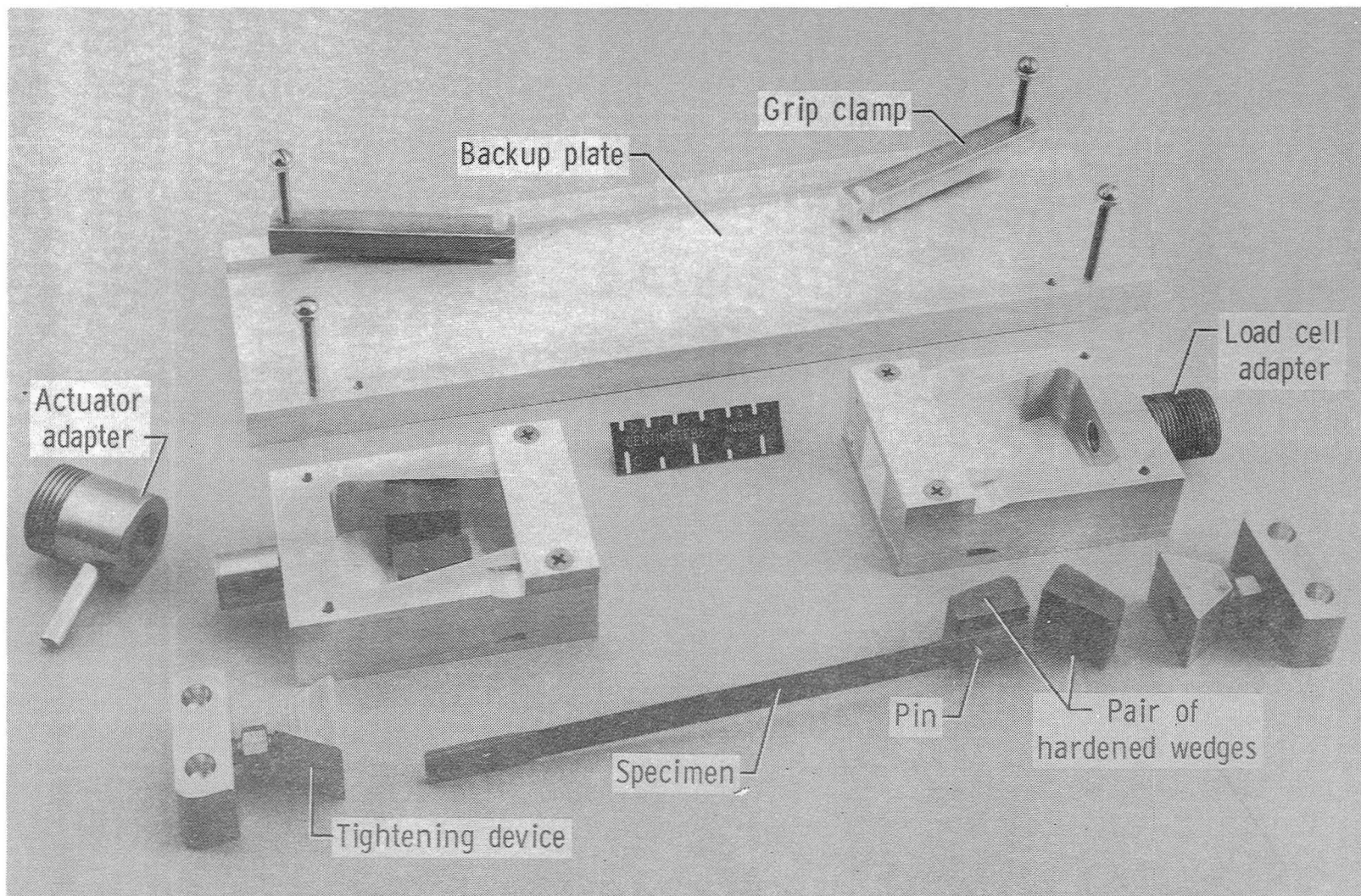


Figure 5. - Transverse strain sensor mounted on calibrator.



(a) Assembled.

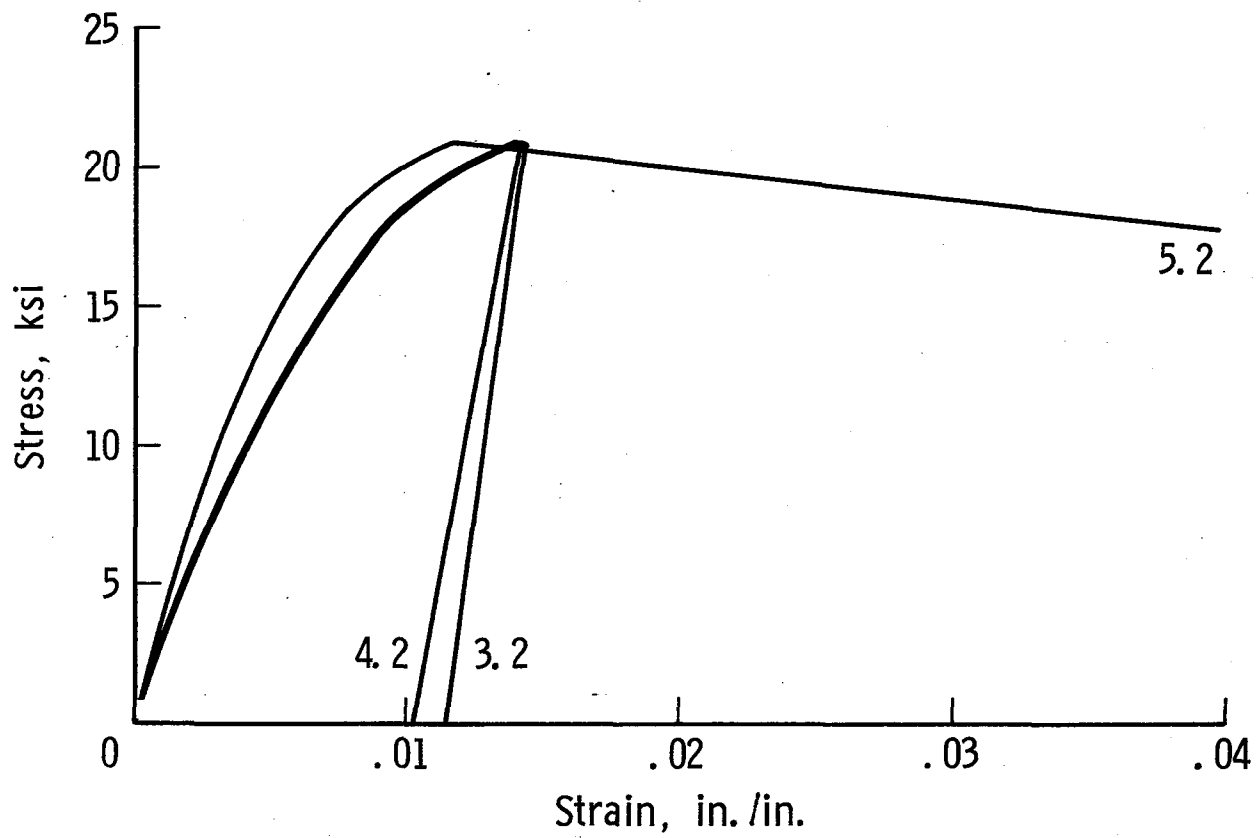
Figure 6. - Lightweight tensile specimen grips.



(b) Disassembled.

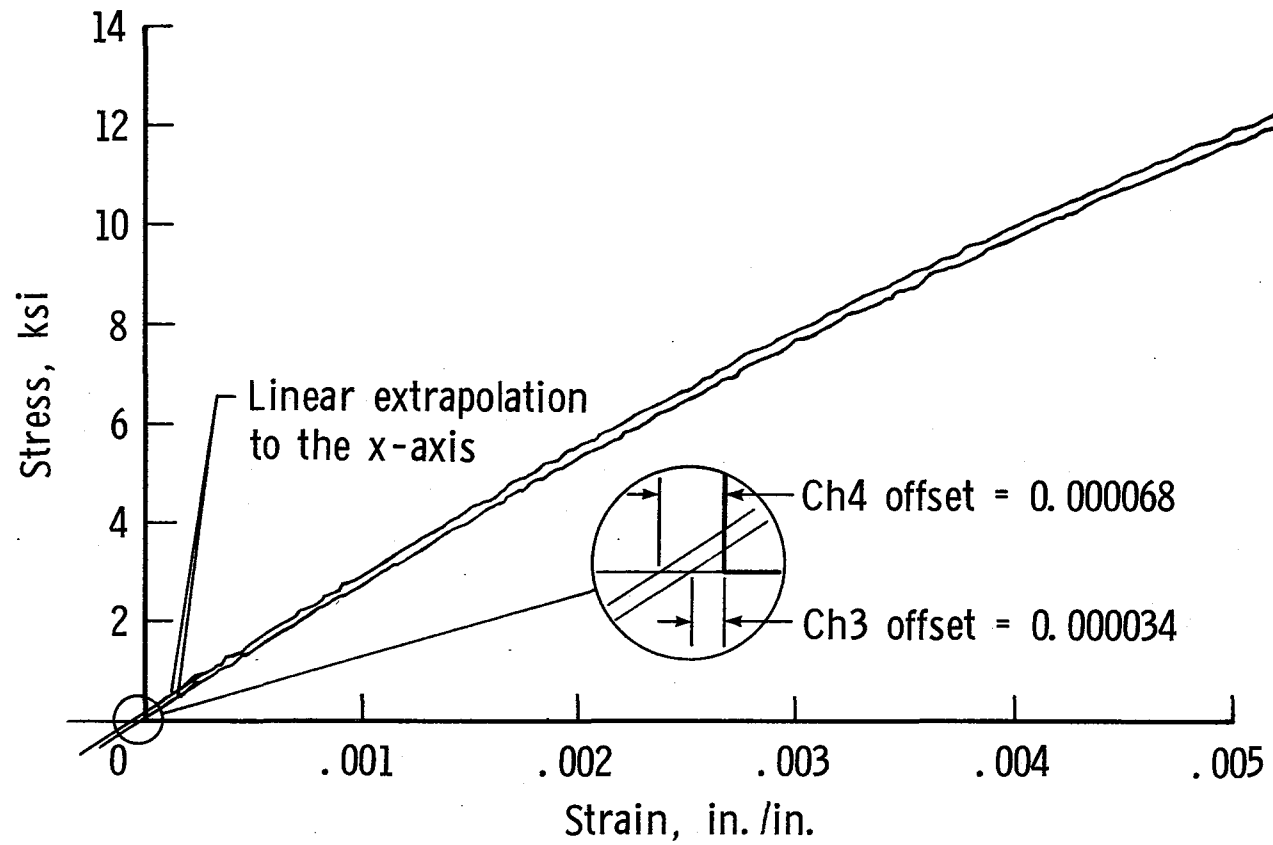
Figure 6. - Concluded.





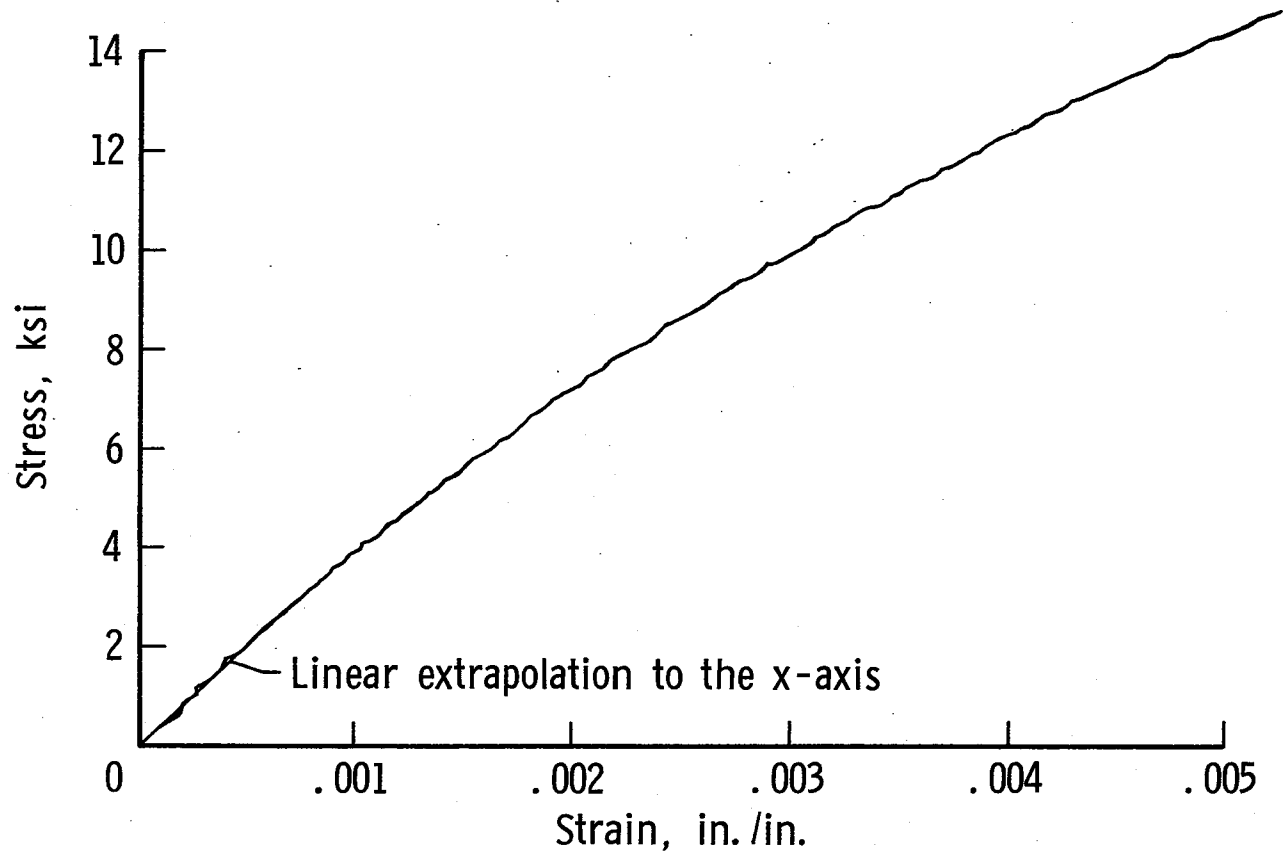
(a) Channels 3, 4 and 5.

Figure 7. - Typical stress-strain curves obtained on the 7470A plotter.



(b) Channels 3 and 4, extensometers 292 and 330, respectively.

Figure 7. - Continued.



(c) Channel 5, the transverse strain sensor.

Figure 7. - Concluded.

SPECIAL FUNCTIONS: REGRESSION ANALYSIS, 9845B							
MLR	STEP	POLY					
START	EDIT	TRANSF	RECODE	SORT	SUBFIL	NAME	STORE
LIST	JOIN	HCOPY	BASIC	MISSING VALUE	EDITLINE	YES	NO

Figure 8. - HP9845B special functions key overlay.

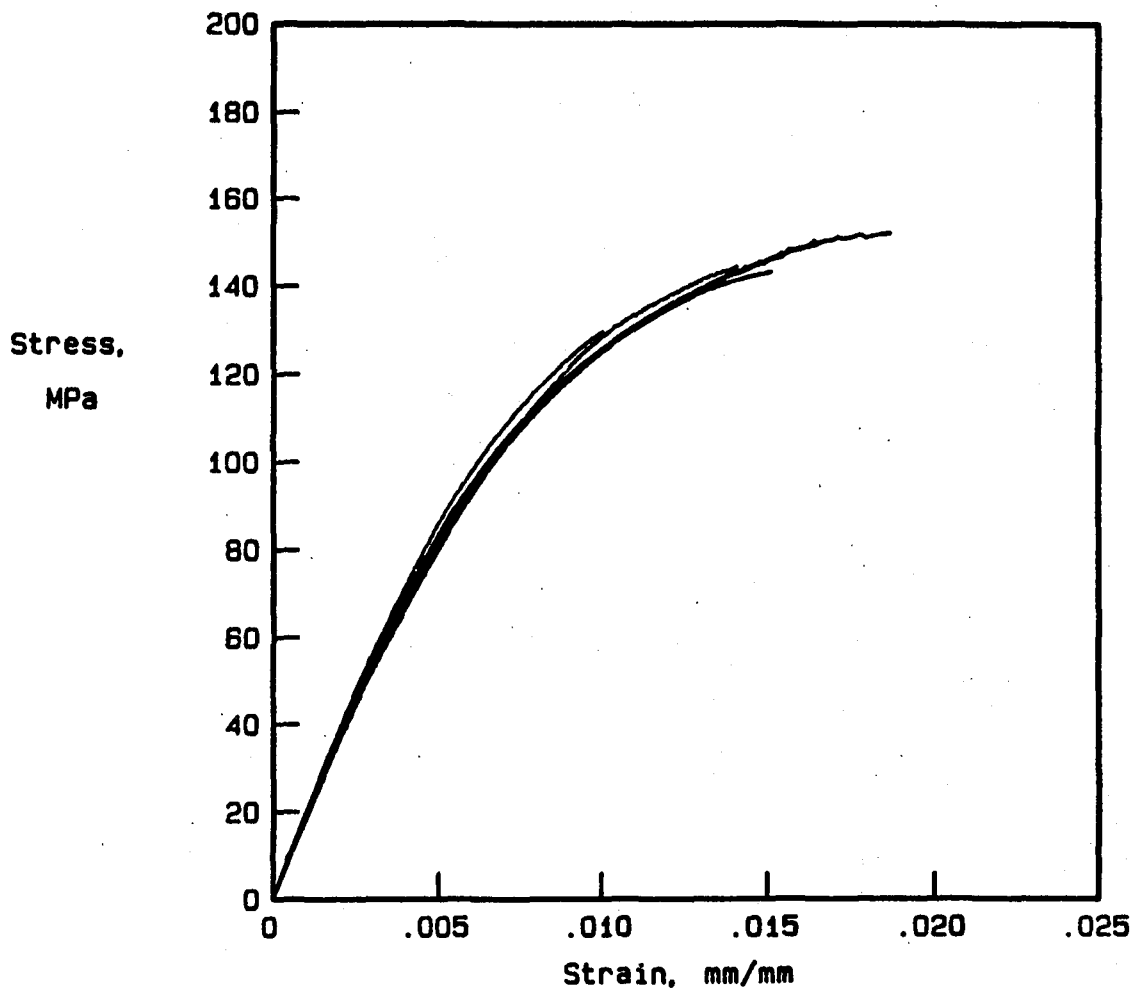
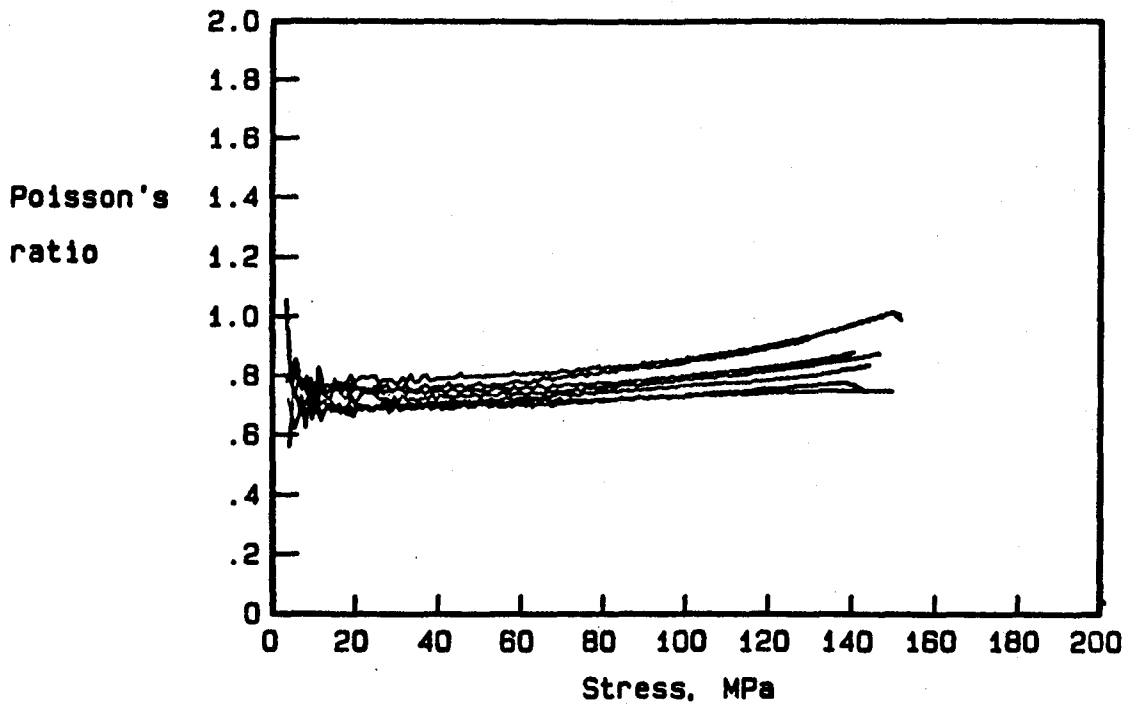
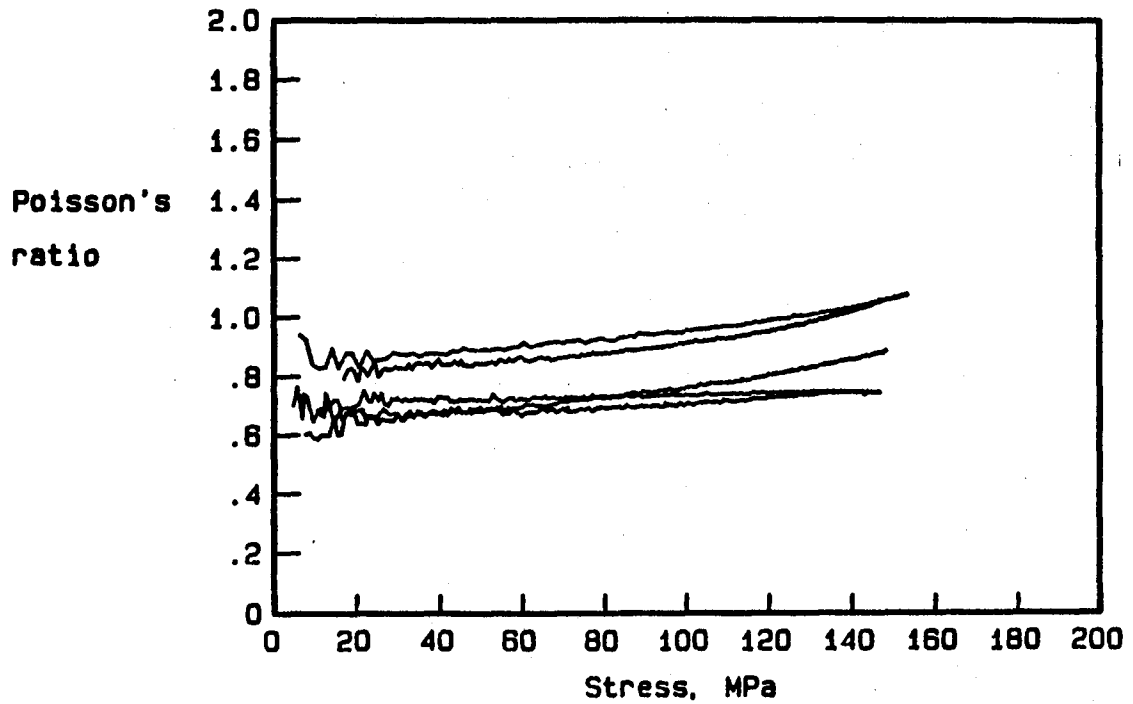


Figure 9. - Stress-strain curves for material #4 (12.7 mm-wide specimens).



(a) 12.7 mm-wide specimens.



(b) 9.525 mm-wide specimens.

Figure 10. - Poisson's ratio versus stress for material #4.

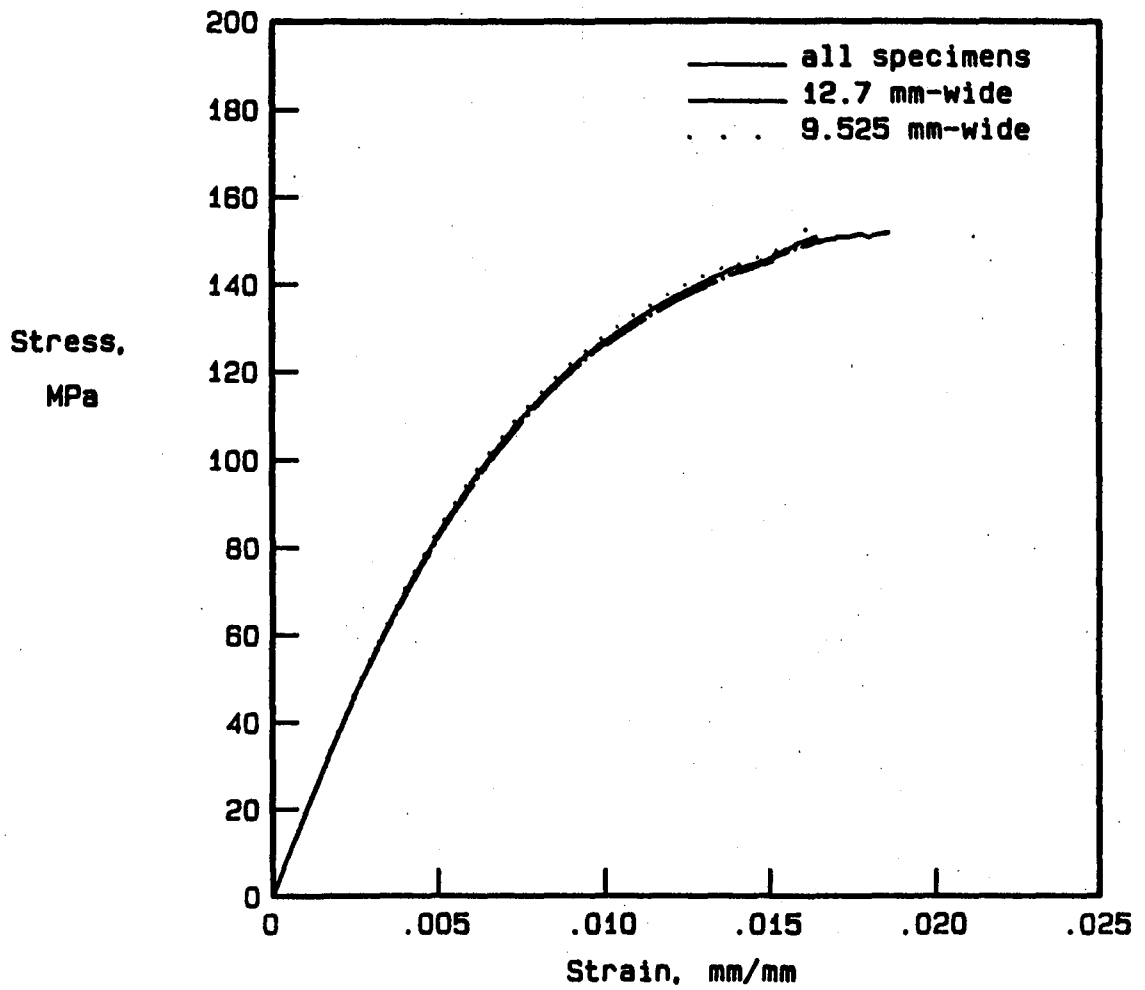


Figure 11. - Averaged stress-strain curves for material #4.

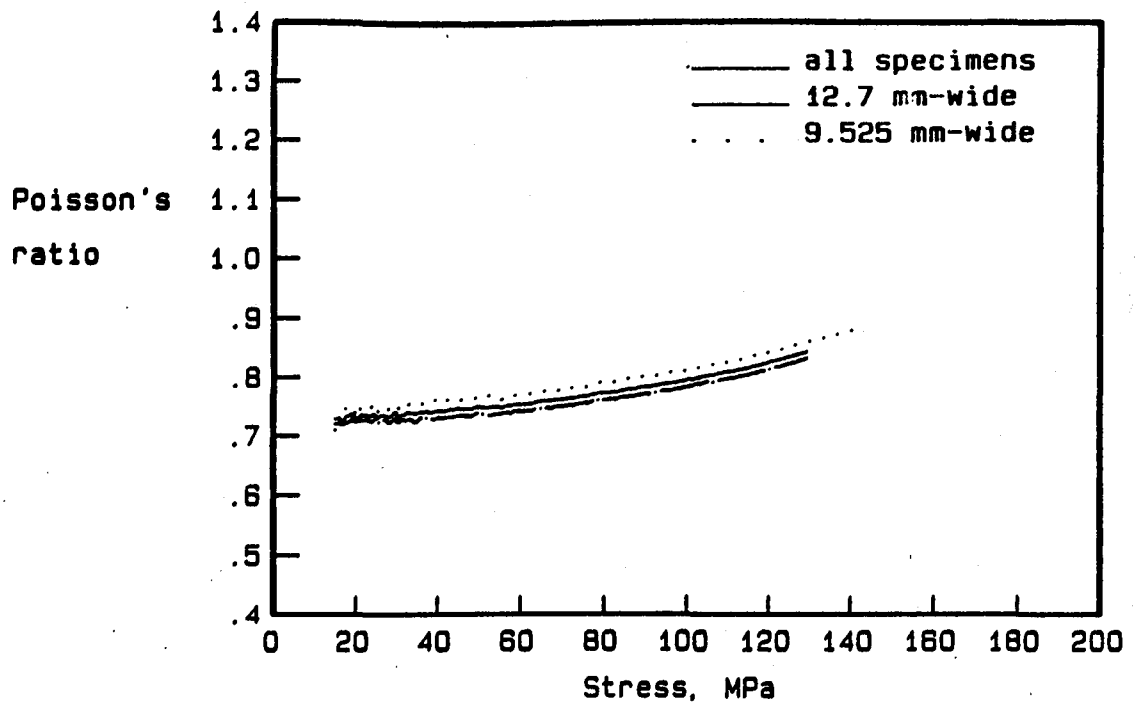


Figure 12. - Averaged Poisson's ratio-stress curves for material #4.





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15. Supplementary Notes					
16. Abstract  One of the experiments aboard the NASA Long Duration Exposure Facility (LDEF) consists of a tray of approximately one hundred tensile specimens of several candidate space structure composite materials. During the LDEF flight the materials will be subjected to the space environment and to possible contamination during launch and recovery. Tensile tests of representative samples were made before the LDEF flight to obtain baseline data. Similar tests will be made on control specimens stored on earth for the length of the LDEF flight and on recovered flight specimens. This manual codifies the details of testing, and data acquisition and handling used in obtaining the baseline data so that the same procedures and equipment will be used on the subsequent tests.					
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