DEVELOPMENT
OF A
BIAXIAL TEST FIXTURE

January 1980

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AEROSPACE STRUCTURES
INFORMATION AND ANALYSIS CENTER

OPERATED FOR THE AIRFORCE FLIGHT DYNAMICS LABORATORY
BY ANAMET LABORATORIES, INC.
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OF A
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Aerospace Structures
Information and Analysis Center
This report describes the development, fabrication and testing of fixturing designed to determine the biaxial properties of materials. The fixturing was designed to be particularly compatible with composite materials, although it is not limited to use with those materials. As part of the work, a second fixture was built which applies only internal pressure to thin ring specimens.

The work was done by the Aerospace Structures Information and Analysis Center, which is operated for the Air Force Flight Dynamics Laboratory, by Anamet Laboratories, Inc., under Contract No. F33615-77-C-3046. The work was performed under ASIAC Problem No. 112.

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I. **INTRODUCTION**

The Aerospace Structures Information and Analysis Center has designed and fabricated a specimen load system for conducting biaxial material characterizations of composite materials. In particular, the system is useful for determining a major portion of the biaxial failure envelopes for composite materials. Portions of the triaxial failure surface where at least two of the principal stresses are negative may also be explored with the system. In addition, with proper control, the system may be used to evaluate the multiaxial fatigue properties of composites. Materials with high Poisson's ratios, which cannot usually be evaluated with ring burst tests, may be easily tested in the ASIAC system. Theoretical aspects of the system have been described in Anamet Laboratories, Inc. Report No. 277.502, "Technical Proposal for Test System for Conducting Biaxial Tests of Composite Laminates." Design of the test system is such that it is best used with any standard compression or universal testing machine with a minimum capacity of 100,000 lbs.

The test system, which is useful for examining quadrants II, III and IV of the biaxial stress plane, utilizes short cylindrical specimens. The specimens may be loaded with combinations of axial compression, internal pressure and external pressure. A unique feature of the test system is that end restraints are minimized by applying all loads through hydrostatic pressures. Hoop stresses are produced by applying internal or external pressures through the use of pressurized oil. Radial stresses may be produced by simultaneously applying internal and external pressures. Axial stress is induced through specimen interaction with a high pressure lubricant trapped between the specimen ends and parallel platens.

Because of the mechanism of loading, restraint to end dilation and twisting is governed by the viscous or plastic
shear strength of the lubricant. Lead foil, indium foil, polyethylene film and combination stacks of films and foils have been evaluated for use as the solid high pressure lubricant. The solid lubricant serves other functions in addition to minimizing restraint. For example, the foil compensates for slight irregularities and mismatch between platens and specimens. It also assists in the attainment of an oil-tight seal between the specimen ends and platens. Such a seal is necessary for the application of surface oil pressures.

This report describes the development of the system to date and some of the problems encountered. It also presents the results of biaxial testing of specially made and strain gaged composite specimens. The test results are quite encouraging, and they show that further refinement and use of the system is warranted.
II. DESCRIPTION OF TEST SYSTEM

Principal components of the platen and pressure system are shown in Figure 1. A dimensioned drawing of the system is given in Figure 2. The small hollow cylinder acts as the lower platen. A step in the solid cylinder serves as the upper platen bearing surface. The upper platen is stepped to reduce the area perpendicular to the specimen axis. This reduces the axial load required to overcome the axial resultant of the oil pressure and allows a smaller testing machine to be used. The platens are made from through-hardened 4340 steel to minimize specimen damage to the platen surfaces. If damage or wear should occur, the through-hardening allows the platens to be reground without the necessity for repeating case hardening or heat treating.

Specimens compatible with the biaxial fixture are approximately 4 inch in diameter and less than 3 inches in length. Typical test specimens and foil gaskets are shown in Figure 3. The specimens are sandwiched between gaskets which bear against the two platens. Gasket performance was evaluated by crushing a series of Fiberglas epoxy specimens using various gasket combinations. During those tests, specimen hourglassing, or barreling, was monitored using dial gages. It was found that a laminate gasket consisting of 0.003 inch polyethylene sandwiched between 0.002 inch soft lead foil generally produced the least amount of hourglassing or barreling.

A photograph of the fixturing installed in an MTS Model 810, 110 kip, servohydraulic testing machine is given in Figure 4. In this figure, the specimen is about to be tested under axial compression. A self-aligning platen is secured to the load cell to eliminate eccentricity of the load axis. When internal pressure is applied, a splash guard and catch pan are incorporated in the system. For the application of external oil pressures, the heavy pressure collet is placed about the specimen,
Figure 1  Principal Components of the Platen and Pressure System

A - Upper Platen
B - Lower Platen
C - External Pressure Collet
Figure 2
Dimensioned Drawing of Biaxial Test Fixture

O-RING GROOVE DETAIL
USE - NATIONAL O-RING
PART NO. 772740, E.R.A.

SCALE - FULL
MATERIAL - 304, 316 OR 310
HEAT TREAT AFTER WELDING &ION
BREAK ALL CORNERS
Figure 3  Typical Test Specimens and Foil Gaskets
Figure 4  Fixture Installed in Testing Machine Prior to Axial Compression Test
as shown in Figure 5. The collet has been designed to withstand working pressures of 10,000 psi. In a few tests, an Enerpac 10,000 psi hydraulic power supply has been used to furnish the pressurized oil; however, hydraulic pressure for most of the tests was provided by an HIP, Inc. Model 87-6-5 manual pressure generator. Internal and external oil pressures were monitored with a standard pressure gage and a Datronic Model 502-3000G pressure transducer.

Many of the composite specimens tested in the fixture have been instrumented with resistive foil strain gages. Strain gage readings, as well as readings from the pressure transducer and MTS load cell, were taken using a Sun Systems ADACUS Data Processing and Readout System. This system contains an AD-I-SCE-10/32 Data Monitor with analog to digital converter, a DCP-10/P2/ADC-1 Display/Control Printer and two IM32/16 input multiplexers. Bridge completion, balancing and calibration are all internal to the Sun System. Internal calibrations are always checked with external shunt resistors. In the print mode, the ADACUS System scans at a rate of \( \frac{1}{2} \) channels per second. As composite materials may be viscoelastic, the strain gage data should be taken as rapidly as possible. To speed up the system scan rate, the ADACUS System was modified to bypass the printer and send the data directly to the memory of an IMSAI 8080 microprocessor. This allowed the scan rate to be increased to \( 12\frac{1}{2} \) channels per second. After completion of a test, the stored data was read into an ASR33 TTY, where punch tape and hardcopy records were made. Later, the punch tapes were read through the ASR33 and a file created in a PDP11/34. Loads corresponding to strain values were found through linear interpolation with time. A specially written program in the PDP11/34 allowed plots to be made of strains vs. stresses (see Appendix A). The plots were made on a TEKTRONIX Model 4631 hardcopy unit.
Figure 5  Fixture Installed in Testing Machine Prior to External Pressure and Axial Compression Test
It was discovered early in the program that the foil gaskets by themselves could not adequately contain the pressurized oil. To overcome this problem, and to prevent the oil from contacting the specimens, rubber gaskets were designed and incorporated into the system. The gaskets were molded from butyl rubber with a Shore A hardness of 60. They were precision molded tubes with wall thicknesses of 0.125 inches and heights 0.025 inches higher than the composite specimens. The rubber gasket diameters were such that some gaskets could be slipped inside the specimens and others could be slipped outside the specimens. Small openings were cut in the rubber gaskets to allow penetration of strain gage leads. After the leads were passed through the openings, RTV rubber was applied as a sealant. Small connector plugs were epoxy potted inside the pressure collet and in a groove machined in the center plug. Strain gage leads were terminated with plugs mating with the potted plugs. With this arrangement, hydraulic oil pressures could be applied to the specimens, and at the same time, strain gage readings taken.
III. DESCRIPTION OF SPECIMENS

In the initial development of the system, numerous specimens were tested to evaluate various gasket combinations and seal systems. Those tests were largely qualitative, and data was not recorded. Due to availability and attractive cost, the preliminary test specimens were made from Bondstrand 2000 Fiberglas-reinforced epoxy resin pipe. Details of the ply layup were unknown; however, it appeared to be a wound $\pm 45^\circ$ structure. The Fiberglas epoxy specimens had an outside diameter of 4.375 in., a wall thickness of typically 0.100 in. and heights of either 1.000 in. or 2.000 in.

After seal and gasket problems were solved, a number of uninstrumented graphite-epoxy specimens were tested under internal pressure and axial load. Those specimens had outside diameters of 4.000 in., wall thicknesses of 0.043 in. and heights of either 1.000 in. or 2.000 in. Localized buckling problems with the first two of these specimens suggested the specimen ends were either not flat or not parallel. Careful measurements of the remaining specimens disclosed variations in height of as much as $\pm 0.003$ inches. The specimen ends were then ground flat and parallel to within 0.0005 in. With this change, the localized buckling problems ceased. The purpose of the preliminary graphite-epoxy tests was to use dial gages to semi-quantitatively evaluate system performance with relatively thin walled high strength materials.

As the preliminary graphite-epoxy tests yielded promising results, a series of tests were performed on carefully made strain gaged specimens. The specimens were graphite-epoxy, and measured 4.000 inches O.D., were 1.000 inches high and had a wall thickness of 0.043 inches. The ends were ground flat and parallel to within 0.0005 inches. Four specimens had a $[0^\circ/\pm 45^\circ/90^\circ]_s$ ply layup. All specimens were strain gaged, as shown in Figure 6. The instrumented specimens were provided by AFFDL.
Figure 6  Unrolled view of specimen showing relative rosette locations and identifications. Rosettes 6, 7 & 8 are stacked rosettes with 0.062" gage lengths. The remaining rosettes are standard rosettes with 0.125" gage lengths.
IV. TEST RESULTS

Tests performed on the seven strain gaged specimens are summarized in Table 1.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Specimen Type</th>
<th>Loading</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>±45°</td>
<td>Axial only</td>
<td>200 lb. axial preload</td>
</tr>
<tr>
<td>2</td>
<td>0°/±45°/90°</td>
<td>Internal pressure</td>
<td>Constant 100 lb. axial load</td>
</tr>
<tr>
<td>3</td>
<td>±45°</td>
<td>Internal pressure</td>
<td>Same specimen, partial compressions</td>
</tr>
<tr>
<td>4-A</td>
<td>±45°</td>
<td>Axial only</td>
<td>Same specimen, partial compressions</td>
</tr>
<tr>
<td>4-B</td>
<td>±45°</td>
<td>Axial only</td>
<td>Same specimen, partial compressions</td>
</tr>
<tr>
<td>4-C</td>
<td>±45°</td>
<td>Axial only</td>
<td>Same specimen, partial compressions</td>
</tr>
<tr>
<td>5</td>
<td>±45°</td>
<td>External pressure</td>
<td>Same specimen as used in 4-A,B,C</td>
</tr>
<tr>
<td>6</td>
<td>0°/±45°/90°</td>
<td>Internal pressure and axial load</td>
<td>Internal pressure equals axial load, pure shear condition</td>
</tr>
<tr>
<td>7</td>
<td>0°/±45°/90°</td>
<td>External pressure and axial load</td>
<td>Hoop stress equal to axial stress</td>
</tr>
<tr>
<td>8</td>
<td>0°/±45°/90°</td>
<td>External pressure</td>
<td>Edge damaged - not tested</td>
</tr>
</tbody>
</table>

For each of the tests performed, stress-strain plots were created from strain gage, load cell and pressure transducer outputs. The stress-strain plots for each test are summarized in Table 2.
## TABLE 2
### SUMMARY OF PLOTS

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Description</th>
<th>Rosette Nos.</th>
<th>Figure No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Axial strain vs. axial stress</td>
<td>1,2,3,4</td>
<td>7</td>
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<tr>
<td></td>
<td>Axial strain vs. axial stress</td>
<td>4,5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Axial strain vs. axial stress</td>
<td>7,8</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Hoop strain vs. axial stress</td>
<td>2,3,4</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Hoop strain vs. axial stress</td>
<td>4,5</td>
<td>12</td>
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<tr>
<td></td>
<td>Hoop strain vs. axial stress</td>
<td>6,7,8</td>
<td>13</td>
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<td></td>
<td>Max. shear strain vs. axial stress</td>
<td>2,3,4</td>
<td>14</td>
</tr>
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<td>Max. shear strain vs. axial stress</td>
<td>4,5</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Max. shear strain vs. axial stress</td>
<td>6,7,8</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Axial strain vs. hoop stress</td>
<td>1,2,3,4</td>
<td>17</td>
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<td>Axial strain vs. hoop stress</td>
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<td>Hoop strain vs. hoop stress</td>
<td>6,7,8</td>
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<td>Max. shear strain vs. hoop stress</td>
<td>4,5</td>
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<td>Max. shear strain vs. hoop stress</td>
<td>7,8</td>
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<td>Hoop strain vs. axial stress</td>
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<td>6,7,8</td>
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<td>Max. shear strain vs. hoop stress</td>
<td>1,2,3,4</td>
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<td>Hoop strain vs. axial stress</td>
<td>1,2,3,4</td>
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<td>Hoop strain vs. axial stress</td>
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<td>Max. shear strain vs. axial stress</td>
<td>1,2,3,4</td>
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<td>Max. shear strain vs. axial stress</td>
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### TABLE 2
(Continued)

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<td>Hoop strain vs. axial stress</td>
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<td>Hoop strain vs. axial stress</td>
<td>6,7,8</td>
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<td>Max. shear strain vs. axial stress</td>
<td>1,4</td>
<td>48</td>
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<td>Max. shear strain vs. axial stress</td>
<td>4,5</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Max. shear strain vs. axial stress</td>
<td>6,7,8</td>
<td>54</td>
</tr>
<tr>
<td>4-C</td>
<td>Axial strain vs. axial stress</td>
<td>1,2,3,4</td>
<td>55</td>
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<td>Axial strain vs. axial stress</td>
<td>4,5</td>
<td>58</td>
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<tr>
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<td>Axial strain vs. axial stress</td>
<td>6,7,8</td>
<td>61</td>
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<td>Max. shear strain vs. axial stress</td>
<td>6,7,8</td>
<td>63</td>
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<td>Axial strain vs. hoop stress</td>
<td>5,6</td>
<td>68</td>
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<tr>
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<td>Hoop strain vs. hoop stress</td>
<td>5,6</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Max. shear strain vs. hoop stress</td>
<td>5,6</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>Axial strain vs. axial stress</td>
<td>1,2,3</td>
<td>73</td>
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<tr>
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<td>Axial strain vs. axial stress</td>
<td>6,7,8</td>
<td>74</td>
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<td>Hoop strain vs. hoop stress</td>
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<td>76</td>
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<td>Hoop strain vs. hoop stress</td>
<td>7,8</td>
<td>77</td>
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<td>7</td>
<td>Axial strain vs. axial stress</td>
<td>1,2,4</td>
<td>80</td>
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<tr>
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<td>Axial strain vs. axial stress</td>
<td>4,5</td>
<td>82</td>
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<td>Axial strain vs. axial stress</td>
<td>7,8</td>
<td>83</td>
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<tr>
<td></td>
<td>Hoop strain vs. hoop stress</td>
<td>1,2,3,4</td>
<td>85</td>
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<td>Hoop strain vs. hoop stress</td>
<td>7,8</td>
<td>86</td>
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<tr>
<td></td>
<td>Max. shear strain vs. axial stress</td>
<td>1,2</td>
<td>81</td>
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<tr>
<td></td>
<td>Max. shear strain vs. axial stress</td>
<td>7,8</td>
<td>84</td>
</tr>
</tbody>
</table>

15
Only axial load was applied to the specimen in Test 1. The specimen layup was ±45°. Figure 7 is a comparison of the axial strains vs. axial stress for the four gages located at the center of the specimen on the outside surface. The axial strain gage elements were not in close agreement, indicating either non-uniformity of load or local variations in specimen compliance. The specimen began to buckle when a compressive axial stress of approximately 19,000 psi was reached. This is shown by the curving back of the axial stress in this plot. Figure 8 is a comparison of the axial strains vs. axial stress for the two gages located at the center of the specimen but on opposite surfaces. The output from these gages show that no bending, and thus no buckling, was occurring at this position. Figure 9 is a comparison plot of axial strains vs. axial stress for the two gages located at the top of the specimen but on opposite surfaces. These figures show that the output from the gages at Points 1, 4, 5, 6, 7 and 8 compare fairly well, but do not compare with the output from gages at Points 2 and 3. Figure 10 is a photograph of this specimen after testing. This figure shows that the buckles occurred on the end opposite from gages at Points 6, 7 and 8. Figure 11 is a comparison plot of hoop strains vs. axial stress for three gages located at the center of the specimen on the outside surface. The hoop strain component for the strain rosette at Point 1 did not produce a signal. The shape of these curves matched the corresponding curves shown in Figure 7. Figures 12 and 13 are the comparison plots of hoop strains vs. axial stress for the gage locations corresponding to those of Figures 8 and 9, respectively. Again, the shapes of the curves are in agreement with the corresponding axial strain curves. Figures 14, 15 and 16 are comparison plots of the maximum shear strain vs. axial load for the gage locations presented in Figures 7, 8 and 9, respectively.
Figure 7  Test 1. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 8
Test 1. Layup \( \pm 45^\circ \) Axial Load Only
Axial Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 9  Test 1. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Figure 10  Test Specimen No. 1 After Crushing by Axial Load. Ply Layup is ±45°.
Figure 11

Test 1. Layup ±45°, Axial Load Only
Hoop Response, Outside Rosettes

A - Rosette No. 2
B - Rosette No. 3
C - Rosette No. 4
Figure 12  Test 1. Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 13  Test 1. Layup ±45° Axial Load Only
Hoop Response, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 14  Test 1. Layup ±45° Axial Load Only
Max. Shear, Outside Rosettes
A - Rosette No. 2
B - Rosette No. 3
C - Rosette No. 4
Figure 15  Test 1. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5
Figure 16  Test 1. Layup ±45° Axial Load Only
Max. Shear Response, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Test 2 was performed on a specimen with a ply layup of $0^\circ/\pm45^\circ/90^\circ$ under internal pressure. Figures 17, 18 and 19 are comparison plots of axial strain, hoop strain and maximum shear strain, respectively, versus hoop stress for the four gages located at the center of the specimen on the outside surface. These strains show good agreement. Strains were not recorded for this specimen until the hoop stress level reached approximately 16,000 psi. This was presumably due to the data acquisition system operating in the automatic balance mode during the first few data scans. Figures 20, 21 and 22 are comparison plots of axial, hoop and maximum shear strains, respectively, versus hoop stress for the two gages located at the center of the specimen but on opposite surfaces. Figures 23, 24 and 25 present comparison plots of axial, hoop and maximum shear strains, respectively, versus hoop stress for the three gages along the top of the specimen. Two of these gages are at the same location, but on opposite surfaces. Very good agreement was found between the inside and outside gages and the maximum shear strains at all rosette locations were almost identical. Hoop stresses greater than 120,000 psi were produced by the internal pressure and final fracture was catastrophic. The specimen after failure is shown in Figure 26.

Test 3 was using a $\pm45^\circ$ ply layup specimen under internal pressure. A 100 pound axial load was applied to the specimen prior to the internal pressure. This axial load was kept constant throughout the testing. Data was recorded at only one scan during this test. Figures 27, 28 and 29 present comparisons for axial, hoop and maximum shear strains, respectively, versus hoop stress for the outside center gages. Figures 30, 31 and 32 are comparison plots for axial, hoop and maximum shear strains, respectively, versus hoop stress for the gage locations at the center of the specimen, but on opposite surfaces. Figures 33, 34 and 35 present the comparison plots for
Figure 17  Test 2.  Layup $0^\circ/\pm 45^\circ/90^\circ$ Int.
Pressure Axial Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 18  Test 2. Layup 0°/±45°/90° Int.
Pressure Hoop Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 19  Test 2.  Layup $0^\circ/\pm 45^\circ/90^\circ$ Int. Pressure Max. Shear, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 20  Test 2. Layup $0^\circ/\pm 45^\circ/90^\circ$ Int. Pressure
Axial Response, Inside/Outside Rosettes
Least Squares Fit
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 21  Test 2. Layup 0°/±45°/90° Int. Pressure
Hoop Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 22
Test 2: Layup 0°/±45°/90° Int. Pressure
Max. Shear, Inside/Outside Rosettes
A = Rosette No. 4 (outside)
B = Rosette No. 5 (inside)
Figure 23  Test 2. Layup $0^\circ/\pm 45^\circ/90^\circ$ Int. Pressure
Axial Response, Edge Rosettes
Least Squares Fit
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 24  Test 2. Layup 0°/±45°/90° Int. Pressure
Hoop Response, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 25  Test 2. Layup $0^\circ/\pm45^\circ/90^\circ$ Int. Pressure
Max. Shear, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Figure 26 Test Specimen No. 2 After Rupture by Internal Pressure. Ply layup is $0^\circ/\pm 45^\circ/90^\circ$. 
Figure 27  Test 3. ±45° Int. Pressure  
Axial Response, Outside Rosettes

A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4
Figure 28  Test 3.  $\pm 45^\circ$ Int. Pressure
Hoop Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 29 Test 3. ±45° Int. Pressure
Max. Shear, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 30  Test 3, $\pm 45^\circ$ Int. Pressure Axial Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 31  Test 3. ±45° Int. Pressure Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 32  Test 3.  ±45° Int. Pressure Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 33  Test 3.  \( \pm 45^\circ \) Int. Pressure
Axial Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 34  Test 3.  ±45° Int. Pressure  
Hoop Response, Edge Rosettes  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8
Figure 35  Test 3.  ±45° Int. Pressure
Max. Shear, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
axial, hoop and maximum shear strains, respectively, versus 
hoop stress for the gage locations along the edge of the speci-
men. These plots show excellent agreement for axial and hoop 
strains for all gages located on the outside surface. Figures 
30, 31 and 32 show that some bending was occurring. Maximum 
shear strains at all rosette locations were in very good agree-
ment. Figure 36 shows the specimen after rupture by the internal 
pressure.

Test 4 consisted of applying three different partial 
compressions to the same specimen. The specimen layup was ±45°. 
For the first partial compression, which was designated as Test 
4-A, the axial stress was taken to approximately 5,300 psi. 
The resulting strain versus axial stress curves are given in 
Figures 37 through 45. During Test 4-B, the axial stress 
reached 10,800 psi, twice the value of Test 4-A. Figures 46, 
47 and 48 present the comparison plots for axial, hoop and maxi-
mum shear strains, respectively, for the locations along the 
outside center of the specimen. Figures 49, 50 and 51 present 
the corresponding information for the two gages located at the 
same location but on the inside and outside surfaces. Figures 
52, 53 and 54 are comparison plots for the edge locations. 
Comparing the figures for Test 4-B (Figures 46 through 54) with 
those of Test 4-A (Figures 37 through 45) shows excellent 
agreement between the two tests. This indicates the tests 
were repeatable for this specimen up to at least 5,300 psi 
axial stress. These two tests show considerable scatter between 
the four gages located on the outside surface along the center 
of the specimen. Scatter of data is also seen between the edge 
gage locations. The comparison between inside and outside 
gage results (see Figures 49, 50 and 51) shows little bending 
is occurring at this location. Figures 55, 56 and 57 are com-
parison plots of axial, hoop and maximum shear strains, respec-
tively, versus axial stress for the locations along the outside
Figure 36  Test Specimen No. 3 After Rupture by Internal Pressure. Ply Layup is ±45°.
Figure 37  Test 4-A.  Layup \( \pm 45^\circ \) Axial Load Only
Axial Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 38  Test 4-A. Layup ±45° Axial Load Only
Hoop Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 39  Test 4-A. Layup ±45° Axial Load Only
Max. Shear, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 40
Test 4-A, Layup +45° Axial Load Only
Axial Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 41
Test 4-A. LayUp \( 45^\circ \) Axial Load Only
Hoop Response, Inside/Outside Rosettes

A = Rosette No. 4 (outside)
B = Rosette No. 5 (inside)
Figure 42  Test 4-A. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 43  Test 4-A. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 44

Test h-A, Layup +45° Axial Load Only
Hoop Response, Edge Rosettes
A = Rosette No. 5
B = Rosette No. 7
C = Rosette No. 8
Figure 45  Test 4-A. Layup ±45° Axial Load Only
Max. Shear, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 46  Test 4-B. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 47
Test 4-B: Layup 45° Axial Load Only
Hoop Response, Outside Rosettes
A = Rosette No. 1
B = Rosette No. 4
Figure 49  Test 4-B. Layup ±45° Axial Load Only
Axial Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 50  Test 4-B. Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 51  Test 4-B. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes
A - Rosette No. 4
B - Rosette No. 5 (inside)
Figure 52  Test 4-B. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 53  Test 4-B.  Layup ±45° Axial Load Only  
Hoop Response, Edge Rosettes  
A - Rosette No. 6  
B - Rosette No. 7  
C - Rosette No. 8
Figure 54  Test 4-B. Layup ±45° Axial Load Only
Max. Shear, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 55  Test 4-C. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 56  Test 4-C. Layup ±45° Axial Load Only
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
Figure 57  Test 4-C. Layup ±45 Axial Load Only
Max. Shear Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4
surface of the specimen for Test 4-C. Strains at Locations 1 and 4 are in good agreement. Figures 58, 59 and 60 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the inside/outside comparison gages. Here good agreement is shown, indicating very little bending is occurring. Figures 61, 62 and 63 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the edge rosettes. Fairly good agreement is shown, much better than the gages located at the center of the specimen showed.

If the results of Tests 4-A, 4-B and 4-C are plotted together, such as in Figures 64 through 67, an interesting point comes to light. From these figures, one sees that Test 4-A and Test 4-B give almost identical results, while Test 4-C produced much higher strains. Also, note that the axial stress of Test 4-B is higher than that of Test 4-C. It is thought that Test 4-B damaged the specimen (internal breakage of fibers), and this could account for the behavior of Test 4-C.

For Test 5, external pressure was applied to the same specimen as used in Tests 4-A, 4-B and 4-C. Figures 68, 69 and 70 present the axial, hoop and maximum shear strains, respectively, for two rosettes located on the inside surface, one at the center and one at the edge. Both rosettes are located at the same angular location. The results are in very poor agreement. This could be because the specimen was damaged in Test 4, as discussed above, or because buckling was taking place. Fracture of the specimen, shown in Figure 71, was from ply delamination and hoop direction blooming.
Figure 58  Test 4-C  Layup ±45° Axial Load Only  
Axial Response, Inside/Outside Rosettes  
A - Rosette No. 4 (outside)  
B - Rosette No. 5 (inside)
Figure 59  Test 4-C.  Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 60  Test 4-C. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 61  Test 4-C. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 63  Test 4-C. Layup ±45° Axial Load Only
Max. Shear, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 64  Tests 4-A, B, C. Layup ±45° Axial Only
Axial Response, Rosette No. 2
A - Test 4-A
B - Test 4-B
C - Test 4-C
Figure 65
Aerospace Structures
Information and Analysis Center

Tests 4-A, B, C. Layup ±45°, Axial Only
A = Test 4-A
B = Test 4-B
C = Test 4-C
Figure 66. Tests 4-A, B, C. Layup ±45° Axial Only
Hoop Response, Rosette No. 3
A - Test 4-A
B - Test 4-B
C - Test 4-C
Figure 67  Tests 4-A, B, C.  Layup ±45° Axial Only
Hoop Response, Rosette No. 4

A - Test 4-A
B - Test 4-B
C - Test 4-C
Figure 69  Test 5.  Layup +45° Ext. Pressure

Hoop Response
A - Rosette No. 5
B - Rosette No. 6
Figure 70  Test 5. Layup \( \pm 45^\circ \) Ext. Pressure
Max. Shear
A - Rosette No. 5
B - Rosette No. 6
Figure 71. Test Specimen Used in Tests 4-A, 4-B, 4-C and 5 After Fracture from External Pressure. Ply Layup is ±45°.
Both internal pressure and axial load were applied to the specimen for Test 6. The internal pressure was manually served to the axial load such that a pure shear condition existed in the specimen. Figure 72 is a plot of the hoop stress versus axial stress. The layup for this specimen was 0°/±45°/90°. Figure 73 is a comparison plot of the axial strain versus axial stress for the rosettes located at the center of the specimen on the outside surface. Strains from Rosette Nos. 1 and 3 are in excellent agreement, and the strain in Rosette No. 2 is very close to these strains. Figure 74 is the axial response of the rosettes located at the edge of the specimen. The strains for these rosettes do not agree with each other. Also, these strains are two to four times higher than the strains recorded at the center of the specimen (see Figure 73). Figures 75, 76 and 77 are comparison plots of hoop strain versus hoop stress with the rosettes located at the center of the specimen on the outside surface, the inside and outside comparison rosettes and the edge rosettes, respectively. The gages at the center on the outside surface are in good agreement, as were the gages at the edge of the specimen. However, the gages recorded strains approximately twice as large as the center gages. The inside-outside comparison gages were in very poor agreement. The maximum shear strain plots for this test were uninterpretable and are not reproduced here. The final failure in Test 6, shown in Figure 78, was from a fracture running approximately half-way across the specimen at a 45° angle. The fracture then changed directions and propagated the remainder of the way across the specimen in an axial direction. The final fracture was accompanied by eight 45° partial fractures distributed around the specimen.

Test 7 was to be conducted such that hoop stress equaled axial stress. The loads were applied using external pressure and axial load. The specimen layup was 0°/±45°/90°. Figure 79
Figure 72: Hoop Stress Versus Axial Stress for Test 6
Figure 73  Test 6. Layup 0°/±45°/90° Pure Shear Load
Axial Response, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
Figure 74: Test 6. Layup $0^\circ/\pm 45^\circ/90^\circ$ Pure Shear Load Axial Response, Edge Rosettes
A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8
Figure 75: Test 6. Layup $0^\circ/\pm 45^\circ/90^\circ$ Pure Shear Load
Hoop Response, Inside/Outside Rosettes
Least Squares Fit
A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)
Figure 77  Test 6. Layup $0^\circ/\pm 45^\circ/90^\circ$ Shear Load
Hoop Response, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Figure 78  Test Specimen No. 6 After Failure from Internal Pressure and Axial Load. Stress Conditions were Equivalent to Pure Shear. Ply Layup is $0^\circ/\pm 45^\circ/90^\circ$. 
Figure 79  Hoop Stress Versus Axial Stress for Test 7
is a plot of the hoop stress versus axial stress. An axial stress of 7000 psi compression was applied to the specimen before any external pressure was applied. The external pressure was manually servoed to the axial load. In the future, this type of test (test with a loading manually servoed) should be conducted much slower to allow adequate reaction time. Strain gage output during Test 7 was erratic. As the specimen could not be observed through the external pressure collet, it is not known with certainty why the erratic strains arose. Figures 80 through 86 are the comparison strain plots for this test. Very poor agreement was obtained between the gages located along the outside center of the specimen; however, the gages between the inside and outside surfaces produced axial results in agreement. The remaining results from this test indicate that hourglassing or buckling could have been taking place. Figure 87 is a photograph of the specimen used in Test 7 after failure occurred.
Figure 81  Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Max. Shear, Outside Rosettes
A - Rosette No. 1
B - Rosette No. 2
Figure 82
Test 7, Layup 0°/±45°/90° Axial & Ext. Pr.
Axial Response, Inside/Outside Rosettes
A = Rosette No. 4 (outside)
B = Rosette No. 5 (inside)
Figure 83  Test 7.  Layup $0^\circ/\pm 45^\circ/90^\circ$ Axial & Ext. Pr.
Axial Response, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Figure 84  Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Max. Shear, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Figure 85  Test 7.  Layup 0°/±45°/90° Axial & Ext. Pr.  
Hoop Response, Outside Rosettes  
A - Rosette No. 1  
B - Rosette No. 2  
C - Rosette No. 3  
D - Rosette No. 4
Figure 86  Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Hoop Response, Edge Rosettes
A - Rosette No. 7
B - Rosette No. 8
Figure 87  Test Specimen No. 7 After Failure from Axial Load and External Pressure. Stress Conditions Were Such That Axial Stress Equaled Hoop Stress. Ply Layup is $0^\circ/\pm 45^\circ/90^\circ$. 
V. CONCLUSIONS

Based on the testing, the test technique has been shown to be promising as a simple test system for determining the biaxial properties of materials. In the early elastic regime, elastic properties may be determined for compression-compression, as well as for tension-compression. The fixture has demonstrated its ability to apply axial compression, internal or external pressure, or a combination of loadings. It appears that the solid lubricant system works well in retaining the pressure while allowing the ends to be relatively free of constraint.

Although the fixture was originally designed for biaxial tests, it has been shown to be capable of rupturing high Poisson's ratio tubes under internal pressure. This is possible as the platens may be advanced as the specimen length decreases so that no gap appears and oil pressure is maintained. Prior to the development of this fixture, free end constraint internal pressure tests on high Poisson's ratio tubes could not be performed.

The tests to date have only demonstrated that the testing technique is very promising. Additional tests need to be performed to improve the fixture and demonstrate repeatability of the results on identical specimens. Different length specimens, such as .5 inches and 2.0 inches, should be tested.
APPENDIX A

LISTING OF
COMPUTER PROGRAM
"STRAINS"
COMPUTER PROGRAM "STRAIN"

As part of the effort reported here, a computer program was developed for processing strain gage data. The program is specifically tailored to the Sun System used by Anamet for monitoring and digitizing strain gage data readings. It is presently running on Anamet's PDP 11/34 under RSX-11M, in an interactive mode. All the plots reproduced in this report were generated by the computer on a Tektronix 4014 display screen.

STRAIN operates in two phases. First, a raw data file, which has been transferred directly from the Sun System to disk, is read and checked for format errors and for overload or open circuit conditions. The information is sorted by channels and stored in a binary disk file. The user is asked to identify each channel as either a load channel or a strain channel. For strain channels, the rosette number and the leg of the rosette are requested. Raw data files may consist of one or more test runs, each with different assignments of data channels. Once the binary file has been established, the second phase may be executed repeatedly to obtain plots and/or printouts of reduced data.

In the second phase, the user is asked to supply the constants required to convert load data to stresses, thus making the program independent of the geometry of the specimen. Two load channels are provided for: an axial force channel and a pressure channel. Eight rosettes are allowed. For each plot to be generated, the user may choose to plot either stresses or strains on either axis. These may be direct stresses and strains, or principal stresses and strains, calculated by the program. As many as eight curves may be drawn on a single plot, with the user choosing a different rosette for each curve, and if the data file contains multiple runs, the curves may be selected from different runs. The user is also given the option to print the data that is plotted. The values plotted on the vertical axis are interpolated to agree with the times corresponding to the values on the horizontal axis.
PROGRAM STRAIN

PROGRAM TO DIGEST AND PRINT DATA FROM SUN SYSTEM

COMMUN/MISC/MOVED,TLD(T,2),TOH(T,2),JUMP(T,60)
BYTL TL1,TL1,JUMP1
COMMUN/CONSULT/RESET,PLOT(T)
LOGICAL REPEAT
COMMUN/STUFF/STUFF(19932)
BYTL STUFF,FNAME(30)
ENDVALLANG(STUFF,FNAME)
COMMUN/SLDL/SLD,S,2
LOGICAL MAN1,NEW
DATA,STUFF/19932/
CALL ERASE
CALL CLEAR(SLD,2)
CALL DISPLAY
('ANAGE SUN SYSTEM STRAIN GAGE DATA REDUCTION & PLOTTING PROGRAM')
REPEAT=.FALSE.,
CALL DISPLAY('NOTE: TO SELECT DEFAULT INPUT VALUES, STRIKE RETURN')
CALL DISPLAY('NEW NOT WANT')
IF (.NOT.,NEW)
CALL ASSIGN(1,FNAME,1,SHREAD('NAME DATA FILE NAME',FNAME,3,30))
CALL ASSIGN(2,FNAME,1,SHREAD('BINARY DATA FILE NAME',FNAME,3,30))
CALL DISPLAY('IF NO PRINT FILE IS WANTED, TYPE "NL" IN RESPONSE TO THE FOLLOWING')
CALL ASSIGN(3,FNAME,1,SHREAD('PRINT FILE NAME',FNAME,3,30))
IF (.NOT.,NEW) GO TO 30
SHREAD('JOB TITLE',JUMP1,1,60)
GET INFO FROM USER ON NEW FILE
CALL DISPLAY('THIS PROGRAM ALLOWS TWO LOAD CHANNELS')
CALL DISPLAY('PLEASE CHARACTERIZE EACH LOAD CHANNEL')
CALL DISPLAY('E.G., AXIAL OR PRESSURE OR UNUSED')
SHREAD('NAME OF LOAD TYPE 1',TLD(T,2),10)
SHREAD('NAME OF LOAD TYPE 2',TLD(T,2),10)
CALL DISPLAY('THE PHограм ALSO EXPECTS THREE STRAIN CHANNELS PER ROSETTE')
CALL DISPLAY('PLEASE CHARACTERIZE THE TWO NORMAL STRAIN DIRECTIONS')
CALL DISPLAY('E.G., AXIAL OR MOOD OR TRANSVERSE')
SHREAD('NAME OF STRAIN DIRECTION 1',TOH(T),10)
SHREAD('NAME OF STRAIN DIRECTION 2',TOH(T),10)
ENCOD(10,5,TOH(T),133)
S FORMAT (10.4S DEGREE)
CALL PAUSE
READ IN RAM DATA

C
C
0040 DU 10 NRUN=1000
0041 IF (RANDAT(NRUN),LT,0.0) GO TO 20
C
0043 10 CONTINUE
C
0044 20 NRUN=NRUN-1
C
0045 WRITE(2) NRUN,TLD,TDI,JOBTII
C
0046 CALL CLOSE(I)
C
0047 GU TO 40
C
0048 30 CALL GETDAT(1)
C
0049 CALL GETDAT(-1)
C
0050 CALL REVIEW
C
C
KEEP PLOTTING TILL USER MEEKS OUT
C
0051 40 CALL PLOTGEN
C
0052 REP=1,TRUE
C
0053 50 CALL PLOTIT
C
0054 IF (WANT('WANT TO FIT A CURVE')) CALL LINFIT
C
0056 IF (.NOT,WANT('WANT TO THMUT \NIVU POINTS')) GO TO 60
C
0058 CALL WILD
C
0059 GU TO 50
C
0060 60 IF (WANT('WANT ANY MORE PLOT?')) GU TO 40
C
0062 CALL DISPLAY('REMINDER: IF YOU GENERATED A PRTN FILE,')
C
0063 CALL DISPLAY('PLEASE EITHER DELETE IT!')
C
0064 CALL DISPLAY('PIP FILENAME')
C
0065 CALL DISPLAY('PIE FILENAME')
C
0066 CALL DISPLAY('PIE FILENAME')
C
0067 CALL CLOSE(2)
C
0068 STOP
C
0069 END
FUNCTION RANDAT(NRUN)

C Routines reads raw data file as output by Run System
INTERNAL AND STORES DATA FOR SUBSEQUENT PLOTTING

COMMON/BINARY/
1 NACT, 1 NO. OF ACTIVE CHANNELS
2 NROBS, 1 NO. OF ACTIVE ROBETS
3 MSHTMT, 1 LENGTH OF THE SHIEST RECORD
4 MLNG, 1 LENGTH OF THE LONTEST RECORD
5 LCM(20), 1 CHANNEL NO. FOR UDAP TYPE 1 & 2
6 ICHM(3,10), 1 CHANNEL NO. FOR SIAIN TYPE 1. ROBETE J
7 TITLE(40,4), 1 TITLE INFO FROM RAW DATA FILE
8 NRD(30), 1 NO. OF READINGS ON CHANNEL I
9 R083(30), 1 ROBETE NO. FOR CHANNEI 1 (OK UDAP IF < 0)

COMMON/BINARY/
1 TYPE(30), 1 SIAIN TYPE FOR CHANNEL I
2 A(30), U(30), 1 CONVERSION FACTORS FOR SIAIN CHANNELS
3 TIME(80,30), 1 TIMES FOR READING NO. 1 ON CHANNEI J
4 VALUE(80,30), 1 SIAIN READNG NU. 1 ON CHANNEI J

BYTE TITLE
BYTE STUFF(1932)
BYTE EQUIVALENCE (STUFF,NAC1)
COMMON/MISC/NRUN,N,AISTD(10,2), TiKIR(10,3), JOUTIT(80)
BYTE TI0, TID, JOUTIT
LOGICAL NAME, CHECK
COMMON/PLT/NP(30),YNTE(126), LYNE2(126), LYN3(126)
BYTE LYN, LYN2, LYN3
BYTE BLANK, DOLLAR, E,W,H/'I,',S,'T', 'O', 'R', 'L'
DATA BLANK, DOLLAR, E, W, H/ 'I', 'S', 'T', 'O', 'R', 'L'
DATA LTUFF/1932/
DATA IWPAY/2049/
CALL ERASE
CALL BLANKIT(TITLE, 4, 60)
NTIT2
READ1, 22, END=30 (TITLE(J,1), J=1, 60)
TYPE I, NRUN
FORMAT (' READING RAW DATA FOR RUN NUMBER', 13/
' TITLE LINES READ FROM FILE')
AD00
B000
CALL CLEAR(NROBS, 30)
CALL CLEAR(LNAME, 30)
CALL CLEAR(TYPE, 30)
CALL CLEAR(ICHM, 30)
CALL CLEAR(LCM, 2)
WRITE(*, 41) (TITLE(J, 1), J=1, 60)
GET TITLE LINES
READ1, 22, END=31 (TITLE(J, NTIT), J=1, 60)
FORMAT (60A1)
FOUND $, END OF TITLE INFO
C
0032 IF (TITLE(1,NTIT)*',',DULLAR) GO TO 40
0034 TITLE(1,NTIT)*BLANK
0035 NTIT=NTIT+1
0036 GO TO 50

C
0037 30 RAWDAT=1
0038 RETURN
0039 31 CALL DISPLAY('EUR MISSING UN LAST RUN')
0040 RAWDAT=1
0041 RETURN
0042 32 CALL DISPLAY('YUU ANL FORGIVEN')
0043 GO TO 200

C
0045 40 WRITE(5,41) TITLE(J,NTIT),J=1,60
0046 NTIT=NTIT+1
0047 WRITE(5,41) TITLE(J,NTIT),J=1,60
0048 41 FORMAT ('X','B01')
0049 IF (NTIT.LE.4) GO TO 20
0051 45 READ(1,22) X
0052 NTIT=NTIT+1
0053 IF (X,'E0',DULLAR) GO TO 50
0055 IF (NTIT.GT.10) STOP 'S MISSING AFTER TITLE LINES'
0057 GO TO 45

C
0058 50 READ(1,51) END=32 NL,LINE
0059 51 FORMAT (1X,20A1)
0060 IF (LINE(1),NL,E) GO TO 100
0062 IF (LINE(2),NL,D) GO TO 100
0064 IF (LINE(3),NL,R) GO TO 100

C
0065 END OF RECORD, GO PROCESS II

C
0066 GO TO 200

C
0067 IF (CHECK(LINE,NL)) GO TO 100
0069 55 WRITE(5,60) (LINE(J),J=1,NL)
0070 60 FORMAT ('(THE FOLLOWING LINE HAS A FORMAT ERROR:1X,20A1')
0071 IF (.NOT.,WANT('WANT TO DISCARD THIS LINE AND CONTINUE'))
0073 STOP

C
0074 END DECODE CHANNEL NO., TIME, VALUE

C
0075 DECODE(20,110,LINE) JCHN,MIN,SEC,IFRAC,IVALLE
0075  110  FORMAT (I1, I1, I1, I1, I1, I1)
0076      IF (JCHN(LE, DOH, JCHN, G1, 90)) GO TO 55
C
C      CHECK FOR OVERLOAD
C
0078      IF (IABS(1.setValue), LE, IVMAX) GO TO 130
0080  120  FORMAT (' OVERLOAD ON CHANNEL', I13)
0082      GO TO 50
0083  130  NKU(JCHN) = NKD(JCHN) + 1
0084      NKH(JCHN) = NKU(JCHN)
0086      IF (I15, G1, 59) GO TO 55
0087      TIME(NR, JCHN) = 0 & 0 & 1 & 0 * IFKAC
0089      VALUE(NK, JCHN) = 1 * VALUE
C
C      GO GET ANOTHER LINE
C
0089      GU TO 50
C
C      DONE READING, NOW HAVE TO HUNT THRU EACH CHANNEL
C      AND GET MUNE INFO FROM USER
C
0099  200  MSNUKH = JU0000
0099      MLONG = 0
0092      DU 400 JCHN = 1, 10
0093      NKW(JCHN) = NKH(JCHN)
0094      IF (NK, EQ, 0) GO TO 400
0096      MSHORT = INF(NSHRT, NR)
0097      MLONGMAX = MLONG, NR
C
0099      205  WRITE(5, 210) JCHN
C
0099  210  FORMAT (' PLEASE IDENTIFY CHANNEL', I13)
C
0100      N = ISREADE('S FOR STRAIN, 'L' FOR LOAD, 'X' IF UNUSBD', X, 1, 1)
C
C      STRAIN CHANNEL
C
0101      IF (X, NE, ',9') GO TO 250
0103      JFREE = ISREAD('ROSETTE NO.', I, 12, 'NONE')
0104      NR1E = 5, 2200, IDIR
C
0105  220  FORMAT (' STRAIN TYPE IS', 1, I5, 1, '
C
0106      JTYPE = ISREAD('STRAIN TYPE FOR THIS CHANNEL', I, 1, 'NONE')
C
0107      IF (1, JCHN, JTYPE, JNO) EQ, 0) GO TO 240
C
0109      WRITE(5, 230) ICHN(JTYPE, JNO), (DIR(J, JTYPE), J, 1, 10)
C
0110  230  FORMAT (' CHANNEL', I13, 'HAS BEEN IDENTIFIED WITH ROSETTE', I13,
C
0111      250  GO TO 255
C
0112  240  ITYPE = JCHN(JTYPE)
C
0113      JNO(JCHN) = JNO(JCHN)
C
0114  240  CALL DISPLAY( ENTER FACTORS A AND B TO CONVERT TO STRAIN UNITS)
C
0115  240  CALL DISPLAY( "AARVY")
C
0117  240  CALL DISPLAY( "HARRAM DATA, X*STRAIN UNITS")
A(JCNM) = #READ('A', 'NONE', 'NONE', 'AD')
A(JCNM) = #READ('B', 'NONE', 'NONE', 'BD')
B(JCNM) = #LOAD('B', 'NONE', 'NONE', 'BD')
GO TO 400

C LOAD CHANNEL

IF (X, NL, 'L') GO TO 300
WRITE(3, 200) LD
FORMAT (' LOAD TYPES'/'
 1  , 'A', 10AI/
 2  , 'B', 10AI/

ILD=#READ('LOAD TYPE FOR THIS CHANNEL', '1, 2', 'NONE')
IF (ILD(ILD)) EQ 01 GO TO 270
WRITE(15, 205) LCH(1LD), (1LD(J, ILD), J=1, 10)
FORMAT (' CHANNEL', '13', ' HAS BEEN IDENTIFIED WITH ', '10AI', ' LOAD')
GO TO 205

LCH(ILD) = JCNM
CALL DISPLAY('ENTER FACTORS A & B TO CONVERT TO LOAD UNITS')
CALL DISPLAY(' WHERE RAM DATA, X=LOAD UNITS')
A(JCNM) = #READ('A', 'NONE', 'NONE', 'AD')
B(JCNM) = #READ('B', 'NONE', 'NONE', 'BD')
B(JCNM) = #LOAD('B', 'NONE', 'NONE', 'BD')
GO TO 400

C NEXT CHANNEL

IF (X, NL, 'X') GO TO 205
FORMAT(' THIS ALL; DUMP IT OUT')
WRITE(2) STUFF
NANDAT=1
PRINT STUFF OUT
IF (NOT (M(H) (= WANT TO PRINT OUT RAM DATA')) GO TO 800
WRITE(3, 505) TITLE
FORMAT (1HM/(1HM, 60AI))
DU 508 1H, 30
WRITE (3, 511) LYNE(120*3)
WRITE(3, 511) LYNE
FORMAT (1X, 120AI)
WRITE(0) LTH@0
DO 610 IM=1, 30

C
0159  IF (NP(1),EQ,0) GO TO 610
0161  ENCUD(21,550,LYNE(2+1,LTAB+1))
0162  FUNKMA(6,3,7MCHAN(2),13,5A)
0163  IF (IKOSU(1)) 500,500,535
0164  ENCUD(21,540,LYNE(2+1,LTAB+1)) IMOS(1)
0165  FUNKMA(6,3,7MCHAN(2),13,5X)
0166  ENCUD(21,550,LYNE(2+1,LTAB+1)) (TDIN(J,JTYPE(1)),J=1,10)
0167  550  FUNKMA (2X,10A,1,7M STRAIN,2X)
0168  GO TO 600
0169  560  ENCUD(21,570,LYNE(2+1,LTAB+1))
0170  570  FUNKMA (0X,0,UNUSED,7A)
0171  575  CALL BLANKIT(LYNE(2+1,LTAB+1),21)
0172  GO TO 600
0173  580  ENCUD(21,590,LYNE(2+1,LTAB+1)) (TLD(J,=IMOS(1)),J=1,10)
0174  590  FUNKMA (3X,10A,1,5H LMAX,5X)
0175  CALL BLANKIT(LYNE(2+1,LTAB+1),21)
0176  GO TO 575
0177  600  LTAG=LTAB+1
0178  IF (LTAB,Equ,6) GO TO 620
0179  610  CONTINUE
0180  IF (LTAG,Equ,0) GO TO 600
0181  620  WRITE(3,511) LYTEN,LYNE(2),LYNE(3)
0182  DU 625 ITAB=1,LTAB
0183  625  ENCUD(21,620,LYNE(2+1,LTAB+1))
0184  WRITE(3,511) LYTE
0185  FUNKMA (4X,45TIME,1X,7MREADING,5X)
0186  630  LTAB=0
0187  DU 630 YES,1,30
0188  640  IF (NP(1)) 670,680,640
0189  640  NNP(1)=NP(1)+1
0190  IF (NP(1),EQ,0) GO TO 670
0191  650  ENCUD(21,660,LYNE(2+1,LTAB+1)) TIME(N1),VALUE(N,1)
0192  660  FUNKMA (F8.2,F8.2,F8.2,5X)
0193  NP(1)=NP(1)-1
0194  670  IF (NP(1),EQ,0) NP(1)=1
0195  GO TO 675
0200  670  CALL BLANKIT(LYNE(2+1,LTAB+1),21)
0201  675  LTAG=LTAB+1
0202  IF (LTAB,Equ,6) GO TO 685
0203  CONTINUE
0204  685  WRITE(3,511) LYTEN
0205  DU 680 YES,1,26
0206  IF (LYNE(1),NE,1) GO TO 630
0207  IF (LYNE(1),NE,1) GO TO 630
0208  CONTINUE
0209  L=0
0210  GO 700 J=1,30
0211  700  IF (NP(1),EQ,-1) NP(1)=0
0212  L=1+NP(1)
0213  700 CONTINUE
0214  IF (L,NE,0) GO TO 510
0215  800  CALL PAUSE
0216  800  RETURN
0217  END
0001  LOGICAL FUNCTION CHECK (LINE, N)
0002  BYTE LINE (20)
0003  LOGICAL NUM
0004  BYTE SHOULD (13), CHAR, ZERU, NINL
0005  DATA SHOULD /2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 16, 17, 18, 19/ 
0006  DATA ZERU, NINE /0, 10, 11, 12, 13, 16, 17, 18, 19/ 
0007  NUM (CHAR) = CHAN, GE, ZERU, AND, CHAR, LE, NINE
0008  CHECK = n, GE, 19
0009  DU 10 = F, 13
0010  10 CHECK = CHECK, AND, NUM (LINE (SHOULD (1)))
0011  KILUNK
0012  END
SUBROUTINE REVIEW

CUMMUL/MISC/MHUN, LLD(10,2), TDIR(10,3), JUNTL(60)
BYTE TLD, TDIR, JUNTL
COMM/BNARY/MAC, MDS, MSINT, MNUM
1 LCM(2), IC(13,10), TILL(60,4), MND(30), MINC(30),
2 IYPE(30), A(30), M(30),
3 TLM(90,30), VALUE(80,30)

BYTE TITLE
LOGICAL WANT
DATA VMAX/2040,
IF (AU.S WANT('WANT TO REVIEW MUNS ON FILE')) RETURN
CALL BMAX
DU 100 IUNNE, NHUN
CALL GETUP(IUN)
WRITE(5,10) IHM, TITLE
10 FORMAT('KUN', 'I3/(4X,64A1)')
DU BY ICMX, 30
NH=MND(ICH)
IF (NA.LU, 0) GO TO 50
UU 12 JH, NR
IF (ABS(VALUE(J, ICM)), GT, VMAX) GO TO 15
CONTINUE
JH
NH=MND(ICH)
IF (IORDS(ICH) .EQ. 40, 50, 20)
WRITE(5, 30) A(ICH), B(ICH), C(ICH), D(ICH), (TDIR(J, IYPE(ICH)), J=1,10)
30 FORMAT ('TSO', 'A5', 'E10.4', 'S', 'E10.4', 'T1', 'T1', 'T1', T1',
1 ' NBOSET NO.', 'I3', 'S', 'I3', 'D', 'D')
GO TO 50
WRITE(5, 45) A(ICH), B(ICH), C(ICH), TDIR(J, IORDS(ICH)), J=1,10)
45 FORMAT ('TSO', 'A5', 'E10.4', 'S', 'E10.4', 'T1', 'T1', 'T1', T1',
1 ' T0', 'COL', 'T0', 'LOAD')
CONTINUE
CALL PAUSE
RETURN
END
SUBROUTINE GETDAT(IR)

HEADS IA DATA FOR ONE RUN INTO COMMON BLOCK "BINARY"
EXCEPT IF IHRUN=0, READS INTO BLOCK "MISC" FROM LAST REC

COMMON/ISG,NHRUN,TLD(10,2),TDIR(19,3),JUBIT(60)
BYTE TLD,TDIR,JUBIT
COMMON/BINARY/STUFF(19932)
BYTE STUFF
DATA IPUS=10/
IHRUN=IAMS(IR)
IF (IHRUN.NE.0) GO TO 50
HEAD(2,END=20)
GO TO 10
BACKSPACE 2
HEAD(2) NHRUN,TLD,TDIR,JUBIT
.REWIND 2
IPUS=1
RETURN
IF (IHRUN.LT.0 OR IHRUN.GT.NHUN)
1 STOP 'BAD CALL TO GETDAT'
IF (IPUS,EW.-10) GO TO 60
IF (IPUS,EW.EQ.1 AND IHRUN.GT.0) RETURN
IF (IPUS.EQ.IHRUN) GO TO 70,60
NSKIP=IHRUN-IPUS
DO 50 IU=1,NSKIP
READ(2)
50 READ(2) STUFF
IPUS=IHRUN+1
IF (IHRUN.LT.NHUN) RETURN
.REWIND 2
IPUS=1
RETURN
.REWIND 2
IPUS=1
NSKIP=IHRUN-1
IF (NSKIP.GT.0) GO TO 50
GO TO 70
END
SUBROUTINE PLTGEN
C
GENERICATES DATA FOR ONE GRAPH CONSISTING OF SEVERAL CURVES
PER USER SPECIFICATION
CALL TO GETDAT FILLS COMMON BLOCK "BINARY"
WITH RAW DATA FOR SPECIFIED RUN
COMMON/Y3C, NRMN, TL0(10,2), TD1(10,3), JUSB(10,0)
BYTE TL0(10,3), JUSB
COMMON/CONTUL/REPEAT,JPLT(2)
LOGICAL REPEAT
COMMON/BINARY/FACTA, NROS, MSHMT, MLUNG,
1 LCM(2), ICHN(3,10), TITILE(6,9), NND(30), IINS(30),
2 TYPF(30), A(30), B(30),
3 TIME(00,30), VALUE(00,30)
BYTE TITLE
COMMON/J, TMTY, YMIN, XMIN, XMAX, YSC, XSC, XL, YL,
1 XPAK, XMIN, MAX, YMIN, XSC, YSC, XL, YL,
2 XY(70,2,2),
3 XYT(70,2),
4 NY(60),
5 NLAB(2,2, LABEL(20,2),
6 NPI(20,2),
7 LEGEND(20),
8 LABEL(20), PLT11, LEGEND
BYTE AX, TYPE, SHEAR(10)
COMMON/SLD/SL/(3,2,2)
1 FACTORS TO CALCULATE STRESS FROM LOAD
I=1,2,3 STRESS TYPE
J=AXIS
K=LOAD1, LOAD2
C
DIMENSION JCM(3), S(3), T(3)
LOGICAL WANT
BYTE ABC
ABC(1)*100*
DATA OVER/OVER/
C
GET USER SPECS FOR X & Y AXES
C
ENGIN(10,5), SHEAR
FORMAT(10,MAX, SHEAR )
CALL ERASE
CALL DISPLAY(' PREPARING TO PLOT')
CALL GETDAT(*)
AX=X
DO 100 JAK=X,2
WRITE(5,10) AX
10 FORMAT (' THE FOLLOWING INFORMATION IS REQUESTED FOR THE ',
', 1, 'AXIS !')
IF (NOT.REPEAT) GO TO 12
IF (WANT(' NEED THE SAME INFO FOR THIS AXIS AS FOR PREVIOUS PLOT'))
1 GO TO 100
WRITE(6,9) TO PLOT A STRAIN ON THIS AXIS; "T" TO PLOT A STRESS ,
1 TYPE, 1,1)
0031 IF (TYPE,NE,'S') GO TO 35

0033 IF (MANT(MANT TU PLOT A PRINCIPAL STRAIN)) GO TO 30

0035 WRITE(5,20) TUIK

0036 20 FORMAT(' STRAIN TYPES/'

1 = '1',10A1/
2 = '2',1,10A1/
3 = '3',10A1)

0037 JPLT(JAX)=IREAD('STRAIN KEY',1,3,'NONE')

0038 GO TO 90

0039 PRINCIPAL STRAIN

0040 CALL DISPLAY('PRINCIPAL STRAIN KEY?'

0041 CALL DISPLAY(' 1=MAJOR PRINCIPAL')

0042 CALL DISPLAY(' 2=MINOR PRINCIPAL')

0043 JPLT(JAX)=IREAD('PRINCIPAL STRAIN KEY',1,3,'NONE')

0044 GO TO 46

0045 PLOT A STRESS

0046 35 IF (TYPE,NE,'F') GO TO 12

0047 WRITE(5,40) ((DIM(J,J),J=1,10),JLD,J=1,2)

0048 40 FORMAT (25X,'FIND FACTORS A & B REQUIRED TO CALCULATE ',10A1,

1 = 'BMLS5'/ FROM ',10A1, ' AND ',10A1, ' LOADS'/

2 = 'WHERE?/

3 = 'SWML1 + B*ML2'/

4 = 'S=',10A1, ' STRESS?/

5 = 'L(',10A1,' LOAD?/

6 = 'L2=',10A1, ' LOAD?/

0049 SL(1,JAX)=IREAD('A','NONE','NONE',SL(1,JAX,1))

0050 SL(1,JAX,2)=IREAD('B','NONE','NONE',SL(1,JAX,2))

0051 WRITE(5,50) ((DIMR(J,J),J=1,10),J=1,2)

0052 SL(2,JAX)=IREAD('A','NONE','NONE',SL(2,JAX,1))

0053 SL(2,JAX,2)=IREAD('B','NONE','NONE',SL(2,JAX,2))

0054 WRITE(5,50) (SMLR,J=1,2)

0055 SL(3,JAX)=IREAD('A','NONE','NONE',SL(3,JAX,1))

0056 SL(3,JAX,2)=IREAD('F','NONE','NONE',SL(3,JAX,2))

0057 IF (MANT(MANT NOT A PRINCIPAL STRESS)) GO TO 46

0058 NOT PRINCIPAL STRESS

0059 WRITE(5,50) ((DIMR(J,J),J=1,10),J=1,2),SHEAR

0060 50 FORMAT (25X,'STRESS KEY?'

1 = '1',10A1/

2 = '2',1,10A1/

3 = '3',10A1)

0061 JPLT(JAX)=IREAD('STRESS KEY',1,3,'NONE')

0062
C FORTRAN IV V02.04 FRID 04-JAN-80 09:48:16 PAGE 003
C CURSE#1A, VICE(22,1)
C .PLTGEN/PLTGEN
C
C 0062   C  C  C  C  C  C  C  C  C  C  C  C  C
C GU TO 90
C
C 0063   C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL DISPLAY(('PRINCIPAL SINGE KEY'))
C 0064  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL DISPLAY(('1 MAJOR PRINCIPAL'))
C 0065  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL DISPLAY(('2 MINOR PRINCIPAL'))
C 0066  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL DISPLAY(('3 MAXIMUM SHAKE'))
C 0067  C  C  C  C  C  C  C  C  C  C  C  C  C
C JPLT(JAK)=J=JREAD('PRINCIPAL SINGE KBT',1,3,'NONE')
C
C 0069   C  C  C  C  C  C  C  C  C  C  C  C  C
C GET LABEL FOR THIS AXIS
C
C 0069  90  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL BLANK11(LABEL(1,JAX),40)
C
C 0069   C  C  C  C  C  C  C  C  C  C  C  C  C
C NLAB(JAX)1JREAD('LABEL FOR THIS AXIS',LABEL(1,JAX),1,40)
C
C 0070   C  C  C  C  C  C  C  C  C  C  C  C  C
C REPLAT FUN Y AXIS
C
C 0070  100  C  C  C  C  C  C  C  C  C  C  C  C  C
C AX='Y'
C
C 0071   C  C  C  C  C  C  C  C  C  C  C  C  C
C GET TITLE FOR THE whole PLOT
C
C 0071  00  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL BLANK11(PLT11,60)
C
C 0072   C  C  C  C  C  C  C  C  C  C  C  C  C
C NPTIT1JREAD('TITLE FOR THE whole PLOT',PLT11,1,60)
C
C 0073   C  C  C  C  C  C  C  C  C  C  C  C  C
C ASK WHAT DATA TO PLOT
C
C 0073  110  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL DISPLAY('YOU MAY NOW SPECIFY UP TO 8 CURVES')
C
C 0074   C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL DISPLAY('YOU MUST SPECIFY ONE PLOT')
C
C 0075  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL READ
C
C 0076   C  C  C  C  C  C  C  C  C  C  C  C  C
C IMUN=1
C 0077   C  C  C  C  C  C  C  C  C  C  C  C  C
C XMIN=X
C 0078   C  C  C  C  C  C  C  C  C  C  C  C  C
C XMAX=X
C 0079   C  C  C  C  C  C  C  C  C  C  C  C  C
C YMIN=Y
C 0080   C  C  C  C  C  C  C  C  C  C  C  C  C
C YMAX=Y
C
C 0081  005  C  C  C  C  C  C  C  C  C  C  C  C  C
C DU 000 ICURVE=1,6
C
C 0082  105  C  C  C  C  C  C  C  C  C  C  C  C  C
C WRITE(5,110) ABC,ICURVE,PLT11
C 0083  110  C  C  C  C  C  C  C  C  C  C  C  C  C
C FORMAT ('FUNK CURVE ',Ai,11')
C
C 0084   C  C  C  C  C  C  C  C  C  C  C  C  C
C I=1
C 0085  C  C  C  C  C  C  C  C  C  C  C  C  C
C IF (NUN,0,1) I=IREAD('RUN NO.',1,NUN,1NUN)
C 0086  C  C  C  C  C  C  C  C  C  C  C  C  C
C CALL SETDAT(IK)
C
C 0087   C  C  C  C  C  C  C  C  C  C  C  C  C
C DU X-AXIS
C
C 0088   C  C  C  C  C  C  C  C  C  C  C  C  C
C JPL=JPLT(J)
C 0089   C  C  C  C  C  C  C  C  C  C  C  C  C
C IF (JPL.LE,0) GO TO 180
C
C 0089   C  C  C  C  C  C  C  C  C  C  C  C  C
C STRAIN PLOTTED: GET DATA
C
C 0091  120  C  C  C  C  C  C  C  C  C  C  C  C  C
C JROS1JREAD('ROSETTE NO. FOR X AXIS',1,8,'NONE')
C 0092  C  C  C  C  C  C  C  C  C  C  C  C  C
C IF (JPL.GT,3) GO TO 180
C
C 0092   C  C  C  C  C  C  C  C  C  C  C  C  C
C NOT PRINCIPAL STRAIN
C
C 0094   C  C  C  C  C  C  C  C  C  C  C  C  C
C ICH=ICH(N,JPL,JROS)
F0UNDAH IV  V04.04   FRI  04-JAN-87  19:11:18   PAGE 004
CUM#51A, U1C#(212:1) ,PLTGEN/LX=PLTGEN
C
0095  NNN#ND(ICH)
0096  IF (NR,GT,0) GO TO 160
0097  MM#TE(S,1.3) (ID#M(J,JPL),J#R,10),J#US,J#N)
0099  150.  F0UNDAH (1:X,10A1,1) SIM#AIN NOT RE#LEASED FOR HUBB#L NO.1,13,1, HUN NO.1,13)
0100  GO TO 160
0101  140  D1 150 #1#1,NN
0102  X#Y(J,1,I,CURV#E)+#VALUE(1,ICH)+A(ICH)+#B(ICH)
0103  150  X#Y(J,1,I,CURV#E)+#TIME(1,ICH)
0104  GO TO 150
C
C
PRINCIPAL SIM#AIN
C
0105  160  DU 170 J#R,3
0106  J#M(J)=#L#N(J,J#US)
0107  IF (J#M(J),GT,0) GO TO 170
0109  MM#TE(S,1,3) (ID#R(#K),K=1,10),J#US,J#N)
0110  GO TO 160
0111  170  CONTINUE
0112  N#R=#M(J#M(1))
0113  N#X#Y(I,CURV#E)=#M#R
0114  DU 175 1#R,1#N
0115  S(1)=#VALUE(J,1),J#M(1))+#A(J#M(1))+#B(J#M(1))
0116  S(2)=#TIME(1,1),J#M(2))+#T#E(1,1),J#M(1))+#T#E(1,1),J#M(1))+#M#D(J#M(2))
0117  IF (S(2),GT,0) GO TO 170
0118  S(3)=#TIME(1,1),J#M(3))+#T#E(1,1),J#M(3))+#T#E(1,1),J#M(1))+#M#D(J#M(3))
0120  IF (S(3),GT,0) GO TO 170
0127  CALL PRINC(S#T,ANG)
0123  X#Y(J,1,I,CURV#E)=X(J#P#L=3)
0124  X#Y(J,1,I,CURV#E)=#TIME(1,1,J#M(1))
0125  GO TO 150
0126  176  N#X#Y(I,CURV#E)=#M#R
0127  GO TO 150
C
C
STRESS ON X AXIS
C
0128  180  J#P#L=J#P#L
0129  IF (J#P#L,GT,3) GO TO 220
C
C
NOT A PRINCIPAL STRESS
C
0131  LD#1
0132  IF (N#D(L#M(2)),GT,1) LD#2
0134  DO 200 LD#1=2
0135  IF (S#L(J#P#L),LT,0),J#R=1,10),J#M(L#D(L#L)),N#E,0) GO TO 200
0137  MM#TE(S,1,10) (L#D(L#L)),J#R=1,10),J#M(L#L)
0138  190  F0UNDAH (* NO DATA FOR 1,10A1,1 LOAD FOR HUN 1,12)
0139  GO TO 150
C
C
CONTINUE
C
0140  200  CONTINUE
C
C
NN#R=#M(L#M(L#D(L#L))
C
C
N#X#Y(I,CURV#E)=#M#R
C
C
L#M#A(L#M(3)=L#D
C
C
L#M#A=L#M(L#L)
C
C
DO 210 #I,1#N
C
C
XLD#1=#A(L#M(1))+#VALUE(1,1),L#M(1)+#B(L#M(1))
C FUNKTRAN IV V02,04 FKI 04-JAN-80 09140110 PAGE 005
C COogle, UCLA (2121), ,PLTGEN/PLTGEN
C
C 0147 XLID2=XTMP(VAVUE((1,LCH2),TIME(1,LCH2),TIME(1,LCH1),NNU(LCH2))
C 0148 IF (XLID2,0,OVER) GO TO 211
C 0150 XLID2=XLYM(XLID2)
C 0151 XTY(J,J,ICURVE)=XLYM(JPL,J,LIDO)*XLID2
C 0152 210 XTY(J,J,ICURVE)=TIME(1,LCH2)
C 0153 GO TO 300
C 0154 211 XTY(J,J,ICURVE)=J-1
C 0155 GO TO 300
C C
C C PRINCIPAL STK38
C 0156 220 DD 240 LLDO=1,2
C 0157 IF (NAD(LCH(LLDL))+,NAD,LLO,0) GU IO 240
C 0159 WRITE(5,140) (ILDO(J,100),J=1,10),IKUN
C 0160 GO TO 105
C 0161 240 CUMJUNE
C 0162 LD=1
C 0163 IF (NAD(LCH(2)),NAD,LCH(LCH1)) LD=2
C 0165 NXX(1,J)=NXX(J)
C 0166 LCH1=LCH(LCH1)
C 0167 LCH2=LCH(LCH2)
C 0169 DU 250 10,1,DU
C 0170 XLID2=(XLYM(J,J,ICURVE))
C 0171 XLID2=XLYM(VAVUE((1,LCH1)+H(LCH1),TIME(1,LCH2),TIME(1,LCH1),NNU(LCH2))
C 0172 IF (XLID2,0,OVER) GO TO 261
C 0174 XLDO2=XLDO2*XLDO2
C 0175 DU 250 J,J=J
C 0176 250 S(J,J)=S(LDL,J,LIDO)*XLDO2
C 0177 CALL PRIML(S,J,1,ANG)
C 0178 260 XTY(J,J,ICURVE)=XLYM(JPL,J)
C 0179 GO TO 300
C 0180 261 XTY(J,J,ICURVE)=J-1
C 0181 GO TO 300
C C Y AXIS
C 0182 300 JPL=JPL(J)
C 0183 GO TO 300
C C STAIN PLOTTED GET DATA
C 0185 320 JH=INHALD('ROBSTE NO, FOR Y AXIS',1,0,'NONE')
C 0186 IF (JPL(1,JPL)) GO TO 300
C C NOT PRINCIPAL STAIN
C 0188 1CH=ICHM(JPL,JROS)
C 0189 NXX(1,J)=NXX(J)
C 0190 IF (NAD(ICH),LIDO,1) GU TO 340
C 0192 WRITE(5,130) (TDIR(J,JPL,J=1,10),JROS,IKUN
C 0193 GO TO 320
C 0194 340 DU 350 10,1,DU
C 0195 XTY(1,J,ICURVE)=XLYM(1,1,ICURVE),NAD(ICH)
0196 IF (X1,E0,OVER) GO TO 351
0198 350 X1(I,2,ICURVE) = A(I,CH)X1 + B(I,CH)
0199 GO TO 300
0200 351 NNX1(ICURVE) = 1 - 1
0201 GO TO 500
0202 C
0203 PRINCIPAL STRAIN
0204 C
0205 360 DO 370 J = 1, 3
0206 361 JCH(J) = LCHN(J, J, K, 0)
0207 GO TO 370
0208 CONTINUE
0209 C
0210 IF (JCH(J), G0, 0) GO TO 370
0211 XN(J,1, ICURVE) = X1(J,1, ICURVE) + XJ(J,1, ICURVE) - XJ(J,2, ICURVE)
0212 XN(J,2, ICURVE) = X1(J,2, ICURVE) + XJ(J,1, ICURVE) - XJ(J,2, ICURVE)
0213 XN(J,3, ICURVE) = X1(J,3, ICURVE) + XJ(J,1, ICURVE) - XJ(J,2, ICURVE)
0214 GO TO 500
0215 370 CONTINUE
0216 C
0217 CALL HNIN(J, T, ANG)
0218 XN(J,1, ICURVE) = X1(J,1, ICURVE) + XJ(J,1, ICURVE) - XJ(J,2, ICURVE)
0219 XN(J,2, ICURVE) = X1(J,2, ICURVE) + XJ(J,1, ICURVE) - XJ(J,2, ICURVE)
0220 XN(J,3, ICURVE) = X1(J,3, ICURVE) + XJ(J,1, ICURVE) - XJ(J,2, ICURVE)
0221 GO TO 500
0222 C
0223 STRESS ON Y AXIS
0224 C
0225 380 JPL = JPL
0226 IF (JPL L= T, 5) GO TO 430
0227 C
0228 NOT A PRINCIPAL STRESS
0229 C
0230 400 DO 410 I = 1, 2
0231 XLOD(I) = XLOD(I) + XLOD(I)
0232 CONTINUE
0233 XLOD(I) = XLOD(I) + XLOD(I)
0234 C
0235 XL = XLOD(I) + XLOD(I)
0236 IF (XL, E0, OVER) GO TO 411
0237 XL = XLOD(I) + XLOD(I)
0238 IF (XL, E0, OVER) GO TO 411
0239 XL = XLOD(I) + XLOD(I)
0240 IF (XL, E0, OVER) GO TO 411
0241 410 XN(I, 1, ICURVE) = SL(JPL, 2, I) + SL(JPL, 2, I) * XL
0242 GO TO 500
0243 GO TO 500
0244 C
0245 PRINCIPAL STRESS
0246 C
DO 440 LL=1,2
   IF (ND(LEC(LLD)),NL,0) GO TO 430
   WRITE(*,190) (LTD(J,LLD),J=1,10),NL
   GO TO 105
   CONTINUE
   XCURVE=LCH I
   LCH=2*LCH I
   DLI=I,(1,LCH I),1,ME(I,LCH I),XT(I,ICURVE),XND(LCH I)
   IF (LD(LD,LLD),NL,0) GO TO 461
   XLD I=(LCH I)*XLD I+(LCH I)
   IF (LD(LD,LLD),NL,0) GO TO 461
   XLD I=(LCH I)*XLD I+(LCH I)
   IF (LD(LD,LLD),NL,0) GO TO 461
   XLD I=(LCH I)*XLD I+(LCH I)
   CALL PKINC(SY,ANG)
   WRITE(*,190) (LTD(J,LLD),J=1,10),NL
   GO TO 500
   XCURVE=0
   XCURVE=ICURVE*XPL=3
   GO TO 500
   XCURVE=NX+(ICURVE-1)*NX
   CALL BLANKS(LEGEND(I,ICURVE),40)
   WRITE(*,190) (LTD(J,LLD),J=1,10),NL
   IF (.NOT.WANT("WANT ANY MORE CURVES ON THIS PLOT")) GO TO 700
   CONTINUE
   ICURVE=ICURVE+1
   WRITE(*,190) (LTD(J,LLD),J=1,10),NL
   RETURN
   END
FUNCTION XTEHP(VALUE, TIME(1,N))
DIMENSION VALUE(1), TIME(1)
DATA GIVEN/GIVEN/

076 FORMAT (F7.2,F6.2,Z2)
0004 IF (1.GT.TIME(1)) GO TO 10
0006 XTEHP=VALUE(1)
0007 GO TO 30
0008 10 DU IS =1,N
0009 IF (1.GE.TIME(1),AND,1.LT.TIME(1+1)) GO TO 20
0011 15 CONTINUE
0012 XTEHP=VALUE
0013 GO TO 30
0014 20 S=(VALUE(1+1)-VALUE(1))/(TIME(1+1)-TIME(1))
0015 XTEHP=VALUE(1)+S*(1-TIME(1))
0016 30 CONTINUE
0017 GO TO 77, XTEHP
0017 RETURN
0018 END
FUNCTION SCALE(X)
DATA X/LIM/1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0/
SCALE=0.0
IF(X,LT,X/LIM(1)) RETURN
SCALE=1.0
DO 10 J=1,10
        IF(X,LT,X/LIM(J)) GO TO 20
10    CONTINUE
STOP 'SCALE ERROR'
20    SCALE=SIGN(ALIM(J)-10.0, X)
RETURN
END
0001  SUMRULES PRINC(S,T,ANG)
0002  DIMENSION S(3),T(3)
C
C   S(1) S(2)=NOMINAL STRENGTHS
C   S(3)=05 ULTIMATE STRENGTH
C   T(1),T(2)=PRINCIPAL STRESSES
C   T(3)=MAX STRESS
C
0003  A=(S(1)+S(3))/2.
0004  M=(S(1)-S(3))**2+(S(3)-S(2))**2)/2.
0005  SUM=SUM+M
0006  SUM=SUM+M
0007  DIFF=A-B
0008  IF (ABS(DIFF),GT,ABS(SUM)) GO TO 10
0010  T(1)=SUM
0011  T(2)=DIFF
0012  GO TO 20
0013  10  T(1)=DIFF
0014  T(2)=SUM
0015  20  T(3)=ABS(T(1)+T(2))
0016  RETURN
0017  END
SUBROUTINE CURFIT

C

DO A LEAST SQUARES CURVE FIT THRU DATA
C

C Generated by PITGEN and PLITED
C

C Individually by PLITED

C

COMMON/MISC/NRUN,TLDIR(10,2),TLDIR(10,3),JUBITI(60)

C

BYTE TLDIR(10,2),JUBITI

C

COMMON/PLT/CURVE(NX,MIN,NX,FMAX,TMIN,XS,YS,YL)

C

1 X(0),Y(0),X(0),Y(0)

C

2 NLAB(2),LABELL(N0,2),APTIT,PLITI(60)

C

3 LEGEND(60,0)

C

BYTE LABEL,PLITI,LEGEND

C

COMMON/DINKY/X(1000),Y(1000),Z(1000)

C

BYTE SYMP

C

CALL PLT(0,0,-3)

C

CALL PLT(2,2,-3)

C

CALL AXIS(0,0,LABELL(1,1),NLAB(1),XL,0,0,ABS(XS/XL))

C

CALL AXIS(0,0,LABELL(2),NLAB(2),YL,0,0,ABS(YS/YS))

C

CALL SYMBO(10,12,5,'LEGEND',0)

C

SYMBA'1'

C

DU 20 ICUVE=1,NCUVE

C

CALL SG1(SY(1,1),ICURVE),XY(1,1),ICURVE),Z(NXY(1CUVE),14)

C

Z(NXY(1CUVE)+1)=0

C

Z(NXY(1CUVE)+2)=ABS(XS/XL)

C

CALL LINE(1,2,ICURVE),ICURVE),XY(1,1),ICURVE)

C

CALL SYMBO(10,12,5,'ICURVE',SYMP,1)

C

CALL SYMBO(10,12,5,'ICURVE',LEGEND,1,ICURVE),40)

C

SYMBSYMPH1

C

SYMBSYMPH1

C

CALL SYMBO(0,12,5,JOBITI(1,60)

C

CALL SYMBO(12,0,PLITI,APTi)

C

CALL SYMBO(0,12,5,'LEAST SQUARES FIT',17)

C

CALL PLOT(1,999)

C

RETURN

C

END
SUBROUTINE PLUTIT

PLUTIT DATA GENERATED BY PLGEN

COMMON/MUSIC/CHNUM,TL,LD(10,2),TDIN(10,5),JUBTII(60)

COMMON/PLUTIT/NCURVE,XMAX,XMIN,YMAX,YMIN,XSC,YSC,XL,YL,
1 XL(6,18),YL(7,8),X(18),
2 MLARGE(2),LABEL(40,2),NPLTII,NPLT(60),3
3 LEGEND(40,2)

COMMON/EXRNV/LOGN(128),LINE2(128),DA1(9),IIK(8)

BYTE NNT,LOGN,PLTII, Goddess

BYTE LABEL,PLTII, Legend

LOGICAL WANT

ASC(11)=100+1

GET SCALE

IF (XPIN,L1.-XMAX) GO TO 20

XSCALE=XMAX

X=10.

WRITE(5,10) 'X'

FORMAT ('X PLOITIVE VALUES ON ','AXIS')

GO TO 40

XSCALE=XMIN

X=18.

WRITE(5,30) 'X'

FORMAT ('X NEGATIVE VALUES ON ','AXIS')

WRITE(5,40) 'X',XSC

FORMAT (1X,'X AXIS RANGE FROM 0.0 TO ','E10.3/
1 WHICH YOU MAY NOT OVERRIDE IF YOU WISH')

IF (YPIN,L1.-YMAX) GO TO 50

YSCALE=YMAX

Y=10.

WRITE(5,10) 'Y'

GO TO 60

YSCALE=YMIN

Y=10.

WRITE(5,30) 'Y'

WRITE(5,40) 'Y',YSC

YSCALE=IY AXIS RANGE',0.0,'NONE',YSC

PRINT STUFF

IF (.NOI. WANT('WANT TO PRINT PLOITED DATA')) GO TO 200

CALL DATE(UAT)

CALL TIME(II)

WRITE(3,100) JUBTII,DA1,IIK,PLTII

FORMAT (1H1,60A1,60A1,2A,6A1,IX,60A1)

WRITE(3,103) LABEL

FORMAT (1H1,60A1,60A1,6A,IX,60A1)

ICURVE=0
IC2#1NDCURVE,4)
0049  102  CALL BLANK1(LYNE,2*128)
0046  101  FORMAT (1A,128A1)
0044  100  JCURVE=ICURVE+1
0051  99    ICURVE=ICURVE+1
0052  98    mLIKE(3,110) ABC(IURVE),LLEGEND(J,IURVE), J=1,40)
0051  97    mLIKE(3,110) ABC(IURVE),LLEGEND(J,IURVE), J=1,40)
0054  96    FUNCUT (1, CURVE=1,6,1,1,0,0)
0055  95    ENGUE (30,120,LYNE(30*1-29)) ABC(IURVE)
0056  94    FURMA (11x,5MCURVE,11x,11x)
0057  93    ENGUE (30,140,LYNE(30*1-29))
0058  92    FURMA (11x,5MCURVE,11x,11x)
0059  91    WRITE(3,101)
0060  90    IF (L=L,LYNE,J=13,1,0,0)
0063  89    DO 100 L=1,10000
0062  88    ICURVE=ICURVE+1
0061  87    U1 U1=1,1C2
0063  86    CALL BLANK1(LYNE(30*1+1)+1,30)
0064  85    IF (L,L,L,L,L,IDC1)
0065    110  ENCODE (30,150,LYNE(30*1-29)) XY(L,1,ICURVE),XY(L,2,ICURVE)
0067  109  FURMA (15,5,122,5,5)
0068  108  CONTINUE
0069  107  mLIKE(3,110) LYNE
0070  106  DU 170 11=1,128
0071  105  IF (LYNE(L=1,LYNE,J=13,1,0,0)) GO TO 180
0073  104  CONTINUE
0074  103  GO TO 190
0075  102  CONTINUE
0076  101  IC2#1NDCURVE=ICURVE+4)
0077  100  IF (ICURVE=LT,NDCURVE) GO TO 102

C
C
HERE GOES
C
C
0079  200  CALL dispL('READY TO PLOT.')
0080  199  CALL PAUSE
0082  198  CALL PLOT
0086  197  CALL PLOT(2,2,0.7,3)
0083  196  CALL AX1(0.0,0.0,LABEL(1,1),NLABEL(1,1),XL,0.0,0.0,ABS(XC/XL))
0087  195  CALL AX1(0.0,0.0,LABEL(1,2),NLABEL(2,1),YL,0.0,0.0,ABS(YC/YL))
0091  194  CALL CNVX(0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0)
0095  193  DO 710 ICURVE=1,NDCURVE
0090  192  IF (XL,1,1,LYNE(I,J)) XY(I,J,1,ICURVE)=XY(I,J,1,ICURVE)
0096  191  IF (YL,1,1,LYNE(I,J)) XY(I,J,2,ICURVE)=XY(I,J,2,ICURVE)
0097  190  DO 710 ICURVE=1,NDCURVE
0098  189  XY(I,J,1,ICURVE)=AMAX0(0.0,XY(I,J,1,ICURVE))
0099  188  XY(I,J,2,ICURVE)=AMAX0(0.0,XY(I,J,2,ICURVE))
0100  187  CONTINUE
0101  186  DO 710 ICURVE=1,1,ICURVE=0,0
0102  185  XY(I,J,1,ICURVE)=XY(I,J,1,ICURVE)*ABS(XC/XL)
0103  184  XY(I,J,2,ICURVE)=XY(I,J,2,ICURVE)*ABS(YC/YL)
0104  183  CALL LINEXY(I,J,ICURVE),XY(J,2,ICURVE),NYT(ICYURVE),1,1,ICURVE)
0105  182  CALL SYMDL(0,0,12.5,JUM11,1,60)
CALL SYMBOL(10,12,0,PLT1,P111)
CALL SYMBOL(10,12,5,LEGEN1,0)
SYMD='A'
DO 910 ICUNVE=1,NCUNVE
CALL SYMBOL(10,12,5,4*ICUNVE,SYMD,1)
SYMD=SYMD+1
910 CALL SYMBOL(10,5,12,5-4*ICUNVE,LEGEN(1,ICUNVE),40)
CALL PLT(1,900)
RETURN
END
SUBROUTINE SG13(X,Y,Z,NDIM,IEH)
C
C LEAST SQUARES ROUTINE
C
DIMENSION X(NDIM),Y(NDIM),Z(NDIM)

IF(NDIM=3)1,1

1 U=6

2 XM=333313333*(X(I)=2)*X(I)=1)*X(I)

3 YM=333313333*(Y(I)=2)*Y(I)=1)*Y(I)

4 T=1 X(I)=2 X=AM

5 T2=1 X(I)=1 X=AM

6 XM=1 T1=1 T2=1 T3=13

7 IF(XM)3,5,6

8 XM=11 T1=1 Y+Y+Y+12 Y(1)=1+13 Y(I)=1+Y(I)

9 IF(3)4,5,6

10 Z(I)=2 Z=AM

11 Z(I)=1.5 Z=AM

12 Z(NDIM)=AM

13 IEH=0

14 RETURN

15 IEH=1

16 RETURN

17 END
SUBROUTINE MILD

C THKUNS GUT MILD POINTS

C CUMMUN/KM/L/NKUN, TLD(10,2), TUN(10,3), JUN(11,60)
0003 BYTE TLD, TUN
0004 CUMMUN/KM/IN/K/NCI, NHYS, MSHUKI, KLUUKI
    1 LCH(2), ICHN(3,10), TILLE(60,4), NHY(30), IN(30),
    2 IHTH(30), A(30), B(30),
    3 TIME(60,30), VALUE(60,30)
0005 BYTE TILLE
0006 CALL DISPLAY('SURKHI, HAVEN''T GOT AROUND TO WRITING THIS YET!!!')
0007 C RETURN
0008 END
APPENDIX B

RING TESTER
INTERNAL PRESSURE-ONLY COMPOSITE RING TEST FIXTURE

As part of Problem No. 112, an internal pressure-only tube test fixture was designed and built. The design of the fixture is essentially the same as that of a fixture successfully used by the IIT Research Institute under contract to AFFDL. Technical Report AFFDL-TR-75-11, titled "Analytical-Experimental Correlation of the Biaxial State of Stress in Composite Laminates (T-300/5208)," may be used as a reference.

Several uninstrumented $0^\circ/\pm 45^\circ/90^\circ$ graphite epoxy rings have been successfully ruptured in the fixture. The results are disappointing, however, when specimens having high Poisson ratios, such as $\pm 45^\circ$ layups, are pressurized. In those tests, the large Poisson contraction in the axial direction allows extrusion of the internal rubber gasket between the specimen end and pressure collet. This destroys the pressure seal and prevents further application of fluid pressure.

A drawing of the fixture showing an assembly view of the main body, lock rings and pressure collets, is given in Figure B.1. A photograph showing the entire assembled fixture is given in Figure B.2. A schematic of the fixture is given in Figure B.3. The maximum pressure of this system is 5,000 psi. The gage accuracy is $\pm 2\%$ at full scale.

A pressure transducer must be installed in the pipe tee adjacent to the pressure gage. A Daytronic strain gage transducer, Model 502-3000G, has been used successfully with this fixture. If the data from the transducer is not required, a high pressure pipe plug (> 5,000 psi.) may be installed in its place.

To begin operation, fill the reservoir with hydraulic fluid. Open valves designated as Nos. 1, 2, 3 and 4 in Figure B.3. Fill the open reservoir at the end of the priming pump 3/4 full with hydraulic fluid. Close the relief valve at the other end of the priming pump. Pump the lever on the
Figure B.1 Dimensioned Drawing of Internal Pressure Only Fixture

Materials: Body - Steel
Locknuts - Steel
Collets - 4340, R=45

Scale - Full
Tol. ±0.005, except as noted
Break all corners

NLH
9-8-78

B-3
Figure B.2  Internal Pressure Only Test Fixture
Figure B.3 Schematic of the Internal Pressure-only Composite Ring Test Fixture
priming pump until a steady flow of fluid leaks out of the main body, making sure that the open reservoir is never less than 1/4 full. Crank the handwheel on the high pressure pump clockwise until it stops. Close Valve No. 3. Slowly crank the handwheel counter-clockwise while pumping the lever on the priming pump. Keep a gage pressure of about 300 psi. Continue cranking until the shaft is fully extended. Open the relief valve on the priming pump to release the pressure.

To mount the test specimen, unscrew and remove the upper lock ring and upper pressure collet from the main body. Loosen the lower lock ring and screw the lower pressure collet down about 1.5 inches from its full up position. Cut a piece of the red rubber gasket tube about an inch longer than the specimen. This gasket tube is about 3 5/8" diameter and 0.10 inches thick, and was supplied by the Air Force. Slide the tube around the outside diameter of the main body, down far enough that it is centered around the fluid/air holes. Screw the lower pressure collet up the main body so that it slides over the gasket tube as far as it will go. Lock the lower lock ring. Slide the instrumented specimen over the outside of the gasket tube so that it rests on the lower pressure collet. Screw the upper pressure collet down so that the bottom edge rests on the specimen. The upper pressure collet should slide over the gasket tube just as the lower collet did. The length of the gasket tube may have to be trimmed so that the upper collet will rest on the specimen. Screw down the upper lock ring to lock the pressure collet. A photograph of the specimen in place is shown in Figure B.4.

Now that the specimen has been mounted, set up all of the signal conditioning for the pressure transducer and the specimen strain gages. Open Valves No. 1, No. 2, No. 3 and No. 4. Close the relief valve on the priming pump. As much air as
Figure B.4  Test Specimen Mounted in Fixture
possible must be gotten out of the system. This is done by pumping the priming pump until a steady flow of fluid comes out of Valve No. 4. The air that is trapped around the specimen will leave through the fluid/air holes in the main body.

After all the air is out, the pressure transducer can be calibrated against the pressure gage. Close Valves No. 2 and No. 3. By cranking the handwheel clockwise, a pressure will be produced at the pressure gage and transducer without applying pressure to the specimen. To release the pressure, crank the handwheel counter-clockwise until the shaft is fully extended, and open Valve No. 2 and the relief valve on the priming pump.

To test the specimen, close Valves No. 2 and No. 4. Open Valve No. 3. Place the plexiglass tube over the specimen so that it rests on the lower lock ring. Apply pressure to the specimen by cranking the handwheel clockwise. To release the pressure, open Valve No. 2 and the relief valve on the priming pump. After the specimen has ruptured, drain the fluid out of the drain pan by removing the pipe plug in the bottom of the pan.