

AD-A044 031

SOUTHERN RESEARCH INST BIRMINGHAM ALA

F/G 11/9

EVALUATION OF THE COMPRESSIVE PROPERTIES OF A SPECIAL 3DQP.(U)

SEP 76 J R KOENIG, G F FORNARO

DNA001-75-C-0037

UNCLASSIFIED

SORI-76-483-3406-9-I-F

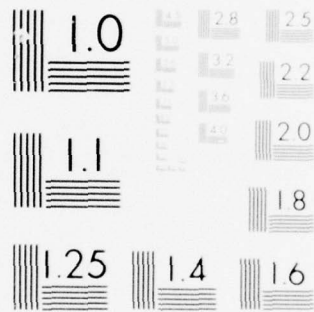
DNA-4174F

NL

1 OF 2

AD
A044031





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DNA 4174F

AD A044031

EVALUATION OF THE COMPRESSIVE PROPERTIES OF A SPECIAL 3DQP

Southern Research Institute
2000 Ninth Avenue South
Birmingham, Alabama 35205

16 September 1976

Final Report for Period October 1975—August 1976

CONTRACT No. DNA 001-75-C-0037

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

DDC
SEP 13 1977
A

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B342075464 N99QAXAC31320 H2590D.

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Prepared for

Director

DEFENSE NUCLEAR AGENCY

Washington, D. C. 20305

DDC FILE COPY

Destroy this report when it is no longer
needed. Do not return to sender.



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 4174F	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EVALUATION OF THE COMPRESSIVE PROPERTIES OF A SPECIAL 3DQP		5. TYPE OF REPORT & PERIOD COVERED Final Report for Period Oct 75—Aug 76
6. PERFORMING ORG. REPORT NUMBER 76-483-3406-9-1-F		7. CONTRACT OR GRANT NUMBER(s) DNA 001-75-C-0037
8. AUTHOR(s) J. R. Koenig G. F. Fornaro		9. PERFORMING ORGANIZATION NAME AND ADDRESS Southern Research Institute 2000 Ninth Avenue South Birmingham, Alabama 35205
10. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		11. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Subtask N99QAXAC313-20
12. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) DCASD Birmingham 908 South 20th Street Birmingham, Alabama 35205		13. REPORT DATE 16 September 1976
14. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15. NUMBER OF PAGES 188
16. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		15. SECURITY CLASS (of this report) UNCLASSIFIED
17. SUPPLEMENTARY NOTES This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B342075464 N99QAXAC31320 H2590D.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
18. KEY WORDS (Continue on reverse side if necessary and identify by block number) Compression 3DQP Test Techniques Composites		
19. ABSTRACT (Continue on reverse side if necessary and identify by block number) The compression properties of two cylinders of 3DQP composites were evaluated in the axial and hoop directions using two test techniques.		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	7
TEST MATRIX	7
CUTTING PLAN	7
NONDESTRUCTIVE TEST TECHNIQUES	9
Radiography	9
Gravimetric Bulk Density	9
Ultrasonic Velocity	10
COUPON COMPRESSION TEST TECHNIQUE	10
SoRI Axial Specimen Configuration	11
SoRI Circumferential Specimen Configuration	11
Rectangular Axial Specimen Configuration	12
Rectangular Circumferential Specimen Configuration	12
NONDESTRUCTIVE CHARACTERIZATION OF 3DQP ARCS AND SPECIMENS	13
COMPRESSIVE TEST RESULTS	14
Prior Data and Materials	17
Clip-on Gages versus Strain Gages	17
Inside versus Outside	19
Effect of Specimen Design	19
Seven Inch (6.1.4) versus Fourteen Inch (4.1.18) Cylinder Data	19
CONCLUSIONS	20
APPENDIX A	83
APPENDIX B	177

ACCESSION for	
NTIS	White Section ☒
DOC	Buff Section ☐
UNANNOUNCED	☐
JUSTIFICATION	
<i>Letter on file</i>	
<i>OK per H.</i>	
DISTRIBUTION AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
<i>A</i>	<i>23</i>
	<i>OK</i>

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Cut Up of 6.1.4	22
2	Cut Up of 4.1.18	23
3	Compressive Test Apparatus for Curved Circumferential and Axial Coupons	24
4	Details of the Curved Circumferential, Compressive Test (Additional Clip-On Gages Were Mounted on the Edges [not shown in photo])	25
5	SoRI Design Axial Specimen	26
6	SoRI Design Axial Specimen - Clip-On and Strain Gage Configuration	27
7	SoRI Design Circumferential (Hoop) Specimen	28
8	SoRI Design Circumferential Specimen - Clip-On and Strain Gage Configuration	29
9	Rectangular Design Axial Specimen 1.000 x 0.550 x 0.200	30
10	Rectangular Design Axial Specimen - Clip-On and Strain Gage Configuration (1.000 x 0.550 x 0.200)	31
11	Rectangular Design Circumferential (Hoop) Specimens (1.000 x 0.300 x 0.300)	32
12	Rectangular Design Circumferential (Hoop) Specimens - Clip-On and Strain Gage Configuration (1.000 x 0.300 x 0.300)	33
13	X-ray Print of Axial Specimens from Cylinder 6.1.4	34
14	X-ray Print of Circumferential Specimens from Cylinder 6.1.4	35
15	X-ray Print of Axial Specimens from Cylinder 4.1.18	36
16	X-ray Print of Circumferential Specimens from Cylinder 4.1.18	37

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
17	20X Photomicrograph Showing Circumferential "Waviness" in Arc 6	38
18	Composite Plot Axial Compression SoRI Specimen Configuration 3DQP - 6.1.14 (Clip-On Data) . . .	39
19	Composite Plot Axial Compression SoRI Specimen Configuration 3DQP - 6.1.14 (Strain Gage Data). .	40
20	Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-6.1.14 (Clip-On Data)	41
21	Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-6.1.4 (Strain Gage Data)	42
22	Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-4.1.18 (Clip-On Data)	43
23	Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-4.1.18 (Strain Gage Data)	44
24	Composite Plot Circumferential Compression-SoRI Specimen Configuration 3DQP-6.1.4 (Clip-On Data). .	45
25	Composite Plot Circumferential Compression-SoRI Specimen Configuration 3DQP-6.1.4 (Strain Gage Data)	46
26	Composite Plot Circumferential Compression- Rectangular Specimen Configuration 3DQP-6.1.4 (Clip-On Data)	47
27	Composite Plot Circumferential Compression- Rectangular Specimen Configuration 3DQP-6.1.4 (Strain Gage Data)	48
28	Composite Plot Circumferential Compression- Rectangular Specimen Configuration 3DQP-4.1.18 (Clip-On Data)	49
29	Composite Plot Circumferential Direction- Rectangular Specimen Configuration 3DQP-4.1.18 (Strain Gage Data)	50

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
30	Typical Axial Compression Data from CRS (with one run from 6.1.14)	51
31	Typical Circumferential Compression Data from CRS	52
32	Comparison of SoRI Axial Clip-On versus Strain Gage Data 6.1.4	53
33	Comparison of Rectangular Axial Clip-On versus Strain Gage Data 6.1.4	54
34	Comparison of Rectangular Axial Clip-On versus Strain Gage Data 4.1.18	55
35	Comparison of SoRI Circumferential Clip-On versus Strain Gage Data 6.1.4	56
36	Comparison of Rectangular Circumferential Clip-On versus Strain Gage Data 6.1.4	57
37	Comparison of Rectangular Circumferential Clip-On versus Strain Gage Data 4.1.18	58
38	Rectangular versus SoRI Design Specimens Modulus Calculated from Clip-On	59
39	Rectangular versus SoRI Design Specimens Modulus Calculated from Strain Gage	60
40	Rectangular versus SoRI Design Specimens Ultimate Stress	61
41	Comparison of Rectangular versus SoRI Design Specimens Ultimate Strain from Clip-Ons	62
42	Rectangular Axial Specimens 6.1.4 versus 4.1.18 Modulus (Clip-On)	63
43	Rectangular Axial Specimens 6.1.4 versus 4.1.18	64
44	Rectangular Circumferential Specimens 6.1.4 versus 4.1.18	65
45	Rectangular Circumferential Specimens 6.1.4 versus 4.1.18 Modulus (Clip-On)	66
46	Rectangular Circumferential Specimens 6.1.4 versus 4.1.18 Modulus (Strain Gage)	67

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Test Matrix	68
2	Nondestructive Characterization Results on Twelve Arcs from Cylinder 6.1.4	69
3	Densities of Hoop and Axial Specimens from Cylinder 4.1.18	70
4	Densities of Five Specimens Machined from the Inside Surface Adjacent to Respective Arcs in Cylinder 6.1.4	71
5	Axial Compressive Tests SoRI Specimen Configuration 3DQP 6.1.4	72
6	Axial Compressive Tests Rectangular Specimen Configuration 3DQP 6.1.4	73
7	Axial Compressive Tests Rectangular Specimen Configuration 3DQP 4.1.18	74
8	Circumferential Compressive Tests SoRI Specimen Configuration 3DQP 6.1.4	75
9	Circumferential Compressive Tests Rectangular Specimen Configuration 3DQP 6.1.4	76
10	Circumferential Compressive Tests Rectangular Specimen Configuration 3DQP 4.1.18	77
11	70°F Axial Compressive Data Comparison	78
12	70°F Hoop Compressive Data Comparison	79
13	Outside/Inside Comparison	80
14	Comparison of Rectangular and SoRI Specimen Configurations 6.1.4	81
15	Comparison of 6.1.4 versus 4.1.18 Rectangular Specimen Configuration 3DQP	82

EVALUATION OF THE COMPRESSIVE PROPERTIES OF A SPECIAL 3DQP

INTRODUCTION

The intent of this program was the evaluation of the hoop and axial compressive properties of two cylinders of three dimensional quartz phenolic. Both cylinders were manufactured by the C process/slat technique and both had an A_r/A_t of roughly 0.7. Cylinder 6.1.4 was seven inches in diameter and cylinder 4.1.18 was approximately 14 inches in diameter.

Two basic specimen configurations were utilized. One was the curved coupon as originally designed by Southern Research Institute (SoRI) in the conduction of the Composite Response Study (CRS). The other was a somewhat shorter and thinner specimen with straight edges and no reduced gage section. These will be referred to as the SoRI design, and the rectangular design, respectively, throughout this report. The resulting data enabled a direct comparison of specimen types, as well as the associated test techniques, to be made. This program was conducted under DNA Contract DNA001-75-C-0037.

TEST MATRIX

SoRI received 2 in. x 2 in. arcs from cylinder 6.1.4 from which hoop and axial specimens of the two design types were machined. In addition specimens of the rectangular design were premachined and sent to SoRI. The test matrix indicating the type and quantity of specimens is shown in Table 1.

CUTTING PLAN

The cutting plan for excising the specimen blanks from cylinder 6.1.4 is shown in Figure 1. From this cylinder SoRI received the twelve arcs labeled SoRI 1 through 12. Arcs 1, 3, 6, 7, 9, and 11 were labeled for use in making

circumferential specimens and arcs 2, 4, 5, 8, 10 and 12 were labeled for making axial specimens.

After NDC of the arcs, these were machined by SoRI into specimens per the following table.

	<u>Side One</u>	<u>Side Two</u>
C-1	1 SoRI ¹ Circ	2 Rectangular Circs ²
A-2	1 SoRI Axial	-
C-3	1 SoRI Circ	2 Rectangular Circs ²
A-4	1 SoRI Axial	-
A-5	1 SoRI Axial	1 Rectangular Axial ³
C-6	-	1 SoRI Circ
C-7	1 SoRI Circ	1 SoRI Circ
A-8	1 SoRI Axial	1 Rectangular Axial ³
C-9	-	1 SoRI Circ
A-10	1 SoRI Axial	-
C-11	1 SoRI Circ	1 SoRI Circ
A-12	1 SoRI Axial	

¹Refers to specimen design - see Test Technique section

²Consisted of four pieces - two from inside and two from outside (labeled In and Out)

³Labeled 5-AC-Rect* and 8-AC-Rect*

In addition, SoRI received six axial specimens of the rectangular design pre-machined by the sponsor from the segments directly below arcs 2, 4, 5, 8, 10 and 12, which were labeled 2-AC-Rect, 4-AC-Rect, etc. The remainder of the material was retained for further use by the sponsor.

The cutting plan used by the sponsor for cylinder 4.1.18 is shown in Figure 2. Of the specimens indicated, SoRI received axial specimens A4, A13, A19, A30, and A39,

and hoop specimens H7, H16, H24, H32, and H33. In addition, axial specimens A43, A46, A48 and A50 were machined from the portion indicated as spare and sent to SoRI.

NONDESTRUCTIVE TEST TECHNIQUES

Radiography

Radiography was performed using state-of-the-art X-ray techniques for low absorptive materials. The radiography unit is a Radiflour 360 manufactured by Torr X-Ray Corporation, rated for operation from 0 to 120KV at either 3 or 5 MA. A beryllium window and small focal spot size (0.35mm) are two characteristics which enable it to examine low absorptive materials with high resolution and sensitivity. Radiographic sensitivity using extra-fine grain film is less than two percent.

The twelve arcs from cylinder 6.1.4 were radiographed simultaneously using a turntable technique before machining into finished specimens. After machining, the SoRI design, the rectangular design, and the premachined specimens were radiographed in groups of varying size. All arcs and specimens were positioned with the axial fibers parallel to the source to enable variations in the circumferential fibers to be viewed. In addition the SoRI design axial specimens were also X-rayed in the circumferential direction.

Gravimetric Bulk Density

Bulk density was determined from direct measurements of weight and dimensions. Weight measurements were made on an analytical balance having a sensitivity of +0.0001 gram. Dimensional measurements were made to the nearest 0.0005 inch using micrometers.

The densities of the twelve arcs were determined before final machining, while those of the additional specimens received by SORI were calculated for each individual specimen.

Ultrasonic Velocity

Acoustic velocity was measured using the through-transmission, elapsed-time technique. In this method, an electrical pulse originated in a pulse generator and was applied to a ceramic piezo-electric crystal (SFZ). The pulse generated by this crystal was transmitted through a short delay line and inserted into the specimen. The time of insertion of the leading edge of this sound beam was the reference point on the time base of the oscilloscope, which was used as a high speed stop watch. When the leading edge of this pulse of energy reached the other end of the specimen, it was displayed on the oscilloscope. The difference between the entrance and exit times was used with the specimen length in calculating ultrasonic velocity. Appendix B should be consulted for a more extensive explanation of the ultrasonic velocity technique.

For Arcs 1, 3, 6, 7, 9, 11, those from which hoop specimens were to be machined, velocity was determined in both the radial and circumferential directions. The remaining arcs, designated for axial specimens, had velocity calculated in the axial direction only.

COUPON COMPRESSION TEST TECHNIQUE

The basic compressive test apparatus had three structural components: a sleeve, a lower grip, and an upper grip as shown in Figures 3 and 4. The lower grip rested on the fixed platform of a conventional loading

frame, while the upper grip was located between the specimen and the moving crosshead. A Tinius Olsen screw-driven compression machine, with a maximum capacity of 30,000 pounds was used in this program. The applied load was monitored directly from the built-in load cell in the platform of the machine. Perpendicular alignment of the load was ensured by the guiding action of the sleeve which fits (within 0.001 in.) around the upper and lower grips. The specimen was held firmly in place in precision inserts which were bolted into the grips. A separate set of inserts was designed to exactly match each of the four specimen configurations used.

SoRI Axial Specimen Configuration

The axial compressive test was used to determine the axial compressive modulus and axial ultimate compressive strength. The axial specimen designed at SoRI having an overall length of 2 in. with a 0.5 in. x 0.6 in. x 0.7 in. gage section is shown in Figure 5. The inside and outside radii of the specimen were approximately the same as the original cylinder which allowed the circumferential fibers to remain intact across the gage section of the specimen.

Axial strain was measured by two independent systems. Clip-ons and surface strain gages were mounted on both edges of the specimens (see Figure 6). Each set of gages was wired in series and the signals from each were monitored on individual x-y recorders. This provided an immediate indication of the relative accuracy of the two strain measuring techniques.

SoRI Circumferential Specimen Configuration

The SoRI circumferential specimen (Figure 7) was designed to enable the determination of circumferential

compressive modulus and ultimate strength. Ideally, inside and outside radii would have been carefully machined in order to provide a uniform distribution of circumferential fibers. However, due to time constraints, the specimens were machined to accommodate the 4.5 in. radius hardware developed for the CRS program. This change from the optimal design allowed approximately one-half ply to "run out" over the length of the gage.

The loading apparatus was the same as used in the axial compressive test with the addition of a lateral support arm. As compressive loads were applied to the grips, the gage section of the specimen experienced both bending and axial compressive loads. However, the support arm, which was inserted through a cutout in the sleeve, was applied in a manner which negated the bending effect. Clip-on gages on the inner and outer faces continuously monitored the displacements there. By adjusting the support arm both displacements were maintained equal and the stress in the gage section was considered nominally uniform. The modulus and ultimate strength were determined as though the loading were simple uniaxial.

Again, both clip-ons and strain gages were mounted on the edges of the specimen. Figure 8 shows a schematic view of the overall instrumentation including a total of four clip-ons and two surface strain gages per specimen.

Rectangular Axial Specimen Configuration

The rectangular axial compressive specimen is shown in Figure 9. It was tested in the same apparatus as described above with a similar arrangement of clip-ons and strain gages as described previously. Except for a miniaturized set of clip-on arms designed to fit the smaller specimen size, the instrumentation (Figure 10) and recording procedures were identical to those used for the SoRI designed axial specimen.

Rectangular Circumferential Specimen Configuration

The rectangular designed circumferential specimen consisted of two separate 1.00 in. x 0.300 in. x 0.150 in.

pieces cut from a circumferential chord of a cylinder. They were mounted face to face in the inserts, with the circumferential fibers from each "half-specimen" bowing towards the center (see Figure 11). This eliminated most bending moment as the two halves tended to apply lateral support to one another during compression. This specimen is often referred to as the "belly to belly" configuration.

The instrumentation was again similar to that described before with a few minor changes. The clip-ons were mounted on opposing sides of the specimen rather than on the edges. Furthermore, a surface strain gage was located on each edge of each "half-specimen" resulting in a total of four gages per specimen (Figure 12). The four gages were monitored two at a time until it was determined that negligible discrepancies occurred between the signals. In subsequent testing all four gages were wired together in series, producing one recorded signal.

NONDESTRUCTIVE CHARACTERIZATION OF 3DQP ARCS AND SPECIMENS

The twelve arcs received were examined using ultrasonic velocity, visuals and X-rays. The gravimetric density of each arc was also determined. For the ultrasonic data three points were measured in both the axial and circumferential directions at $0.25L$, $0.5L$ and $0.75L$ along the surface. In the radial direction five points were measured, one at the center and one each at the center of four quadrants. These data are shown in Table 2 which reports only the average of the velocity data for each arc. Table 3 shows the density values for each of the specimens from 4.1.18 and Table 4 shows the densities of the six pre-machined specimens from 6.1.4. The average

data for the density of the arcs from 6.1.4 was 1.685 gm/cm^3 and for the specimens from 4.1.18, 1.625 gm/cm^3 . The difference in the densities between the cylinders probably was not as great as this would indicate since the specimens from 4.1.18 came from near the inside of the arc. Similar specimens taken adjacent to the arcs in 6.1.4 had an average density of 1.662 gm/cm^3 . The average velocities of the 6.1.4 arcs were 0.1798, 0.1809, and 0.1937 in./ μsec in the axial, circumferential and radial directions, respectively.

Prints of the X-rays of both the specimens and the arcs are included as Figures 13 through 16. Notice the nature of the circumferential yarns, especially towards the center on the arcs from 6.1.4. This bending and waving of the circumferential yarns was evident in the visual examinations and is documented in a 20X photomicrograph in Figure 17. The montage was taken through the center of the arc viewing in the axial direction.

COMPRESSIVE TEST RESULTS

The results of the compressive tests are reported in tabular form in terms of three parameters - tangent modulus, ultimate stress, and ultimate strain. The modulus for each specimen was determined by calculating the slope of a tangent to the linear portion of the stress-strain curve. In many cases a slight nonlinear portion of the curve at low stress levels was ignored in the calculations. Since two independent strain measuring systems were utilized, moduli values as determined from both clip-ons and surface strain gages are reported. The strain-to-failure data are reported from clip-ons only, since strain gages typically give ambiguous results near the end of the run. The ultimate strain reported is the strain value corresponding to the ultimate stress.

The results of the six axial compressive tests using the SoRI design are summarized in Table 5. The average modulus was 2.06×10^6 psi (clip-ons) and 2.15×10^6 psi (strain gages), the average strength 55,733 psi and the average strain-to-failure 35 mils/in. The composite stress-strain curves from these six runs are shown in Figures 18 and 19 (clip-on and strain gage data, respectively). Repeatability is demonstrated by the narrow range within which all curves lie. Individual raw data curves are provided in Appendix A.

The results from the rectangular design axial compressive tests from cylinder 6.1.4 are shown in Table 6. The average modulus for these eight runs was 2.17×10^6 psi (both methods). The average strength was 52,338 psi and the average ultimate strain 28 mils/in. These data include results from two specimens which were machined at SoRI from arcs 5 and 8. Only limited significance may be attributed to the slightly higher values from these runs due to the small sample size. The composite stress-strain curves from these eight runs are shown in Figures 20 and 21.

The results from the rectangular design axial compressive tests on material from cylinder 4.1.18 are shown in Table 7. The average moduli from these nine tests was softer than that for the 6.1.4 material, 1.93×10^6 psi (clip-ons) and 1.86×10^6 psi (strain gages). The average strength was less than that from 6.1.4, 43,656 psi and the ultimate strain was lower, 24.3 mils/in. The composite plots for these runs are shown in Figures 22 and 23. Again, a very tight envelope may be constructed around the stress-strain curves.

The circumferential compressive test data using the

SoRI design specimen for material from cylinder 6.1.4 is given in Table 8. The average modulus, as calculated from the clip-on data was 3.54×10^6 psi and 3.78×10^6 psi per strain gages. The ultimate strength was 75,050 psi and ultimate strain 23.7 mils/in. The composite plot of the stress-strain curves is shown in Figures 24 and 25.

The rectangular design circumferential data on material from cylinder 6.1.4 is given in Table 9. These were machined by SoRI from Arcs 1 and 3. One inner and one outer specimen was obtained from each arc. The average modulus using both inners and outers was 3.77×10^6 psi (clip-ons), average strength, 59,050 and average ultimate strain 17.3 mils/in. In this case the clip-ons were attached to the faces rather than the edges of the specimens. The average strain gage modulus measured was 3.61×10^6 psi. The distinction between the inner and outer specimens is evident, the inners being stronger (average strength, 61,600 psi) than the outers (56,500 psi) and, perhaps, stiffer (per clip-ons). Notice that the same trend exists for these data points as for the SoRI design specimens, arc 1 was stronger but less stiff than arc 3 (arc 3 was denser). These comparisons will be discussed further later. The composite plot of the stress-strain curves are shown in Figures 26 and 27.

The circumferential compressive data (rectangular design specimen) from cylinder 4.1.18 are given in Table 10. The moduli data from the clip-on gages vary widely due, apparently, to bending in some of the specimens. Again, the clip-ons were mounted on the faces while the strain gages were on the edges. The average modulus per the clip-ons was 4.00×10^6 psi and per the strain gages was 3.53×10^6 psi. The average strength was 63,420 psi

and ultimate strain, 17.3 mils/in. The composite stress-strain curves are shown in Figures 28 and 29. Evidence of relatively severe bending is obvious at low stress levels for specimen H32-CC-Rect. The apparent negative strain was verified by visual observation of the specimen during the test. As the load was initially applied, slight gaps, which were observed visually, opened between the two "half-specimens". This indicated that they were actually bending away from each other instead of applying mutual lateral support, as intended. The modulus as calculated from the subsequent linear portion of the curve (4.25×10^6 psi), still falls within the range of values from the other specimens in this group.

Prior Data and Materials

A summary of some prior experience with this class of materials is provided in Tables 11 (Axial) and 12(Hoop). As is evident, material differences make the comparison difficult. A large segment of the prior data was conducted on Process A materials. The best comparisons came from the CRS program. This program was conducted on Process C material (pineapple) on which optimal test techniques were developed. Examples of the data generated are given in Figures 30 (Axial) and 31 (Hoop). The 6.1.4 material is less stiff but stronger than the CRS material.

Clip-on Gages versus Strain Gages

As was mentioned earlier, both clip-on gages and surface mounted strain gages were used to monitor strain for each run. In general, good agreement has been achieved between the two techniques. This is shown graphically in Figures 32 through 37 in which the moduli calculated from both techniques are displayed for the various specimen types. Excellent agreement can be seen for specimens from the

axial direction (both designs) where, in many cases, data points from the two methods fall directly on top of one another (Figures 32 through 34). Slightly more variation is evident in the data from the circumferential direction specimens (Figures 35 through 37) with differences typically ranging up to approximately 10 percent. The fact that specimens H32 and H33 (Figure 37) vary by more than this amount can be attributed to bending in the specimens. Since the specimen halves tended to bow toward the clip-ons, the apparent strain for a given stress level was less than that recorded by surface strain gages mounted on perpendicular sides. This produced an uncharacteristically high modulus in these cases.

For composite materials of this type, clip-on data is considered to be more representative of the true material response than surface strain gages. This data does have the question of effective gage length since the clip-on flags span 0.1 inch of the gage section. However, from previous experience with composite materials, this difference has been found to be negligible. Clip-ons enable local effects, if any, to be avoided by measuring strain over a longer gage length than surface strain gages. Nevertheless, strain gages do provide valid data for comparison purposes if the cell size is sufficiently small in relation to the gage length. Proper application and alignment promotes repeatability and a degree of confidence in the data.

For specimens of both designs from the axial direction either method is suitable as was demonstrated previously, while the clip-on method is desired for the SoRI design circumferential specimen. For the case of the rectangular design circumferential specimen, the strain gage data are

preferable since the clip-on data were more adversely affected by bending in the specimen.

Inside versus Outside

The CRS program showed the distinction to be very small between the material near the ID and material near the OD. It appears to be somewhat stronger in the case of cylinder 6.1.4 but the data gathered are insufficient for a strong conclusion. A summary of pertinent data are shown in Table 13. Further study would be required to develop a correlation.

Effect of Specimen Design

The moduli of specimens from cylinder 6.1.4, as calculated from both the clip-on gages and the strain gages agree very well between the SoRI specimen design and test technique and the rectangular specimen design and test technique. A comparison is shown in Figures 38 (clip-on) and 39 (strain gage) and in Table 14. The ultimate stresses and strains do not correlate well, the SoRI technique showing the material to be stronger with a higher strain ultimate. A comparison of this data is shown in Figures 40 and 41.

Seven Inch (6.1.4) versus Fourteen Inch (4.1.18) Cylinder Data

The comparison between cylinders 6.1.4 and 4.1.18 can be made using data generated on the rectangular design specimens. These data are summarized in Table 15. The larger cylinder appears to be slightly softer and weaker than the 7 inch cylinder. However, the circumferential strength of the 4.1.18 cylinder is actually higher. This may not actually be true based on the comparison of rectangular and SoRI test techniques. The difference in the ultimate

strengths measured between the two techniques is less for the axial specimens than for the circumferential specimens. Taking this a step further, the fourteen inch cylinder with less curvature may be showing less degradation of its true strength vis a vis the 6.1.4 specimens. These data are plotted by specimens in Figures 42 through 46.

CONCLUSIONS

Several general conclusions may be drawn from the test data which has been reported and analyzed in this report. Material from cylinder 6.1.4 can be compared to that from cylinder 4.1.18 by considering results from the rectangular design specimens. Cylinder 6.1.4 is definitely stiffer and stronger in the axial direction. In the circumferential direction the moduli values are more nearly equivalent while the ultimate strength of cylinder 4.1.18 is slightly higher. Further testing of material from cylinder 4.1.18 using the SoRI design specimen would be necessary to validate the legitimacy of the circumferential strength.

The results from cylinder 6.1.4 may be compared with previous SoRI data from the CRS program since identical specimen configurations were used. The 6.1.4 material is less stiff but stronger in both directions than the CRS materials. Also the 6.1.4 material showed extreme "waviness" of the circumferential yarns, especially near the center of the original arcs. This is considered atypical when compared to the CRS material. The processing differences between the materials obviously contributed to the data variability.

Clip-on extensometers and surface mounted strain gages are both viable methods of measuring deformation in the

type of materials considered here. Results from the two techniques vary minimally except in the case of circumferential specimens. These discrepancies were able to be traced directly to specimen design. Except where other factors are involved, the clip-on data are considered to give slightly more representative results.

The SoRI and rectangular design specimens showed similar moduli values in both directions, when measured by either strain device. However, the ultimate strength values from the SoRI specimen are much higher especially in the circumferential direction, where the SoRI type produced a maximum stress approximately 27 percent higher than the rectangular specimen. Apparently, the utilization of lateral support during the test enabled an accurate assessment of the material's resistance to uniaxial compressive loads without the introduction of unknown bending stresses. The curved coupon and its associated test technique must be considered more valid than the smaller rectangular specimen test technique.



Dimensions of Specimens

Axial Compression: 1 inch long x 2 cells wide x 0.2 inch thick
 Hoop Compression: 1 inch long x 0.3 inch wide x 0.15 inch thick
 SORI Blanks: 2 inches long x 2 inches long x full wall thickness

Figure 1. Cut Up of 6.1.4

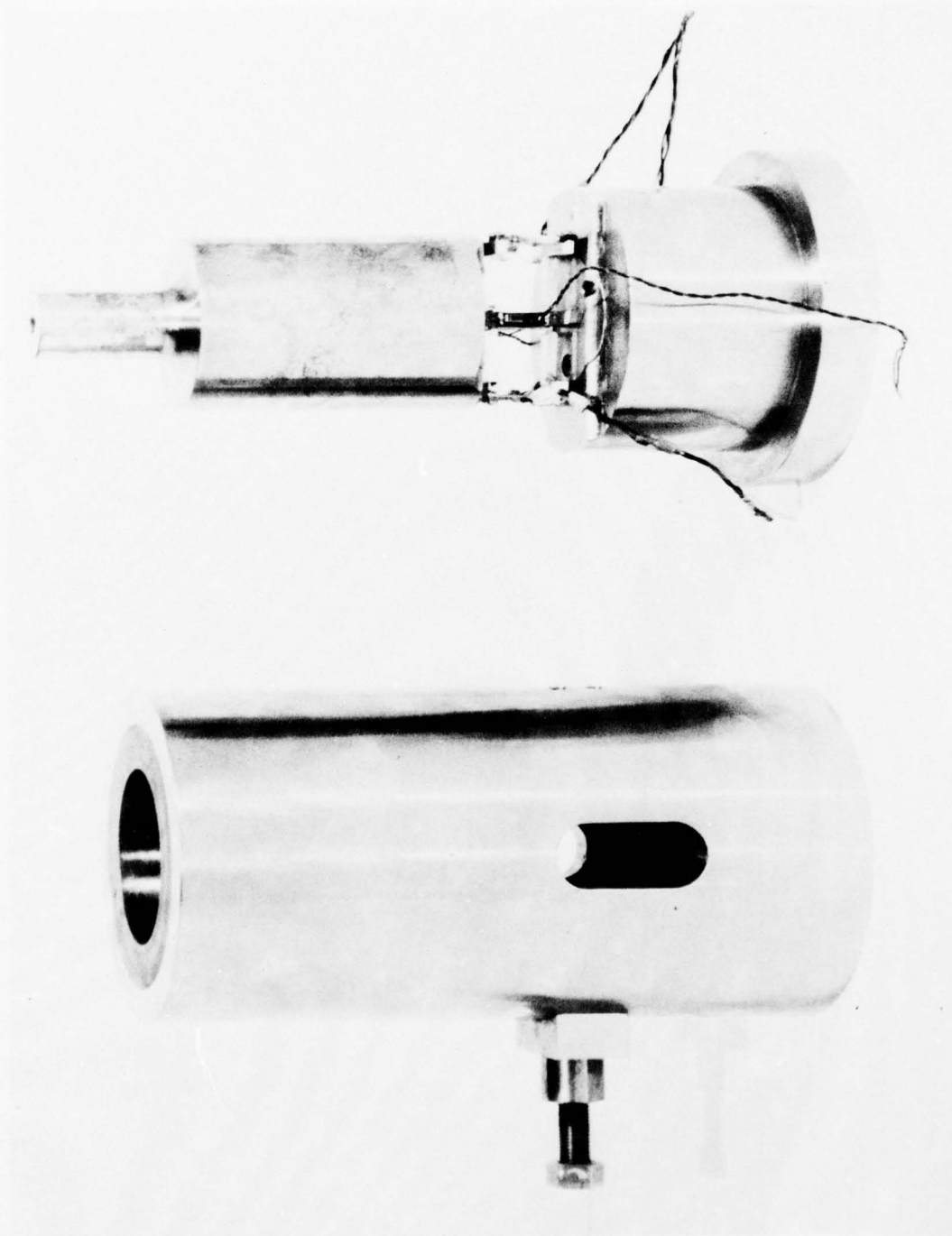


Figure 3. Compressive Test Apparatus for Curved, Circumferential and Axial Coupons

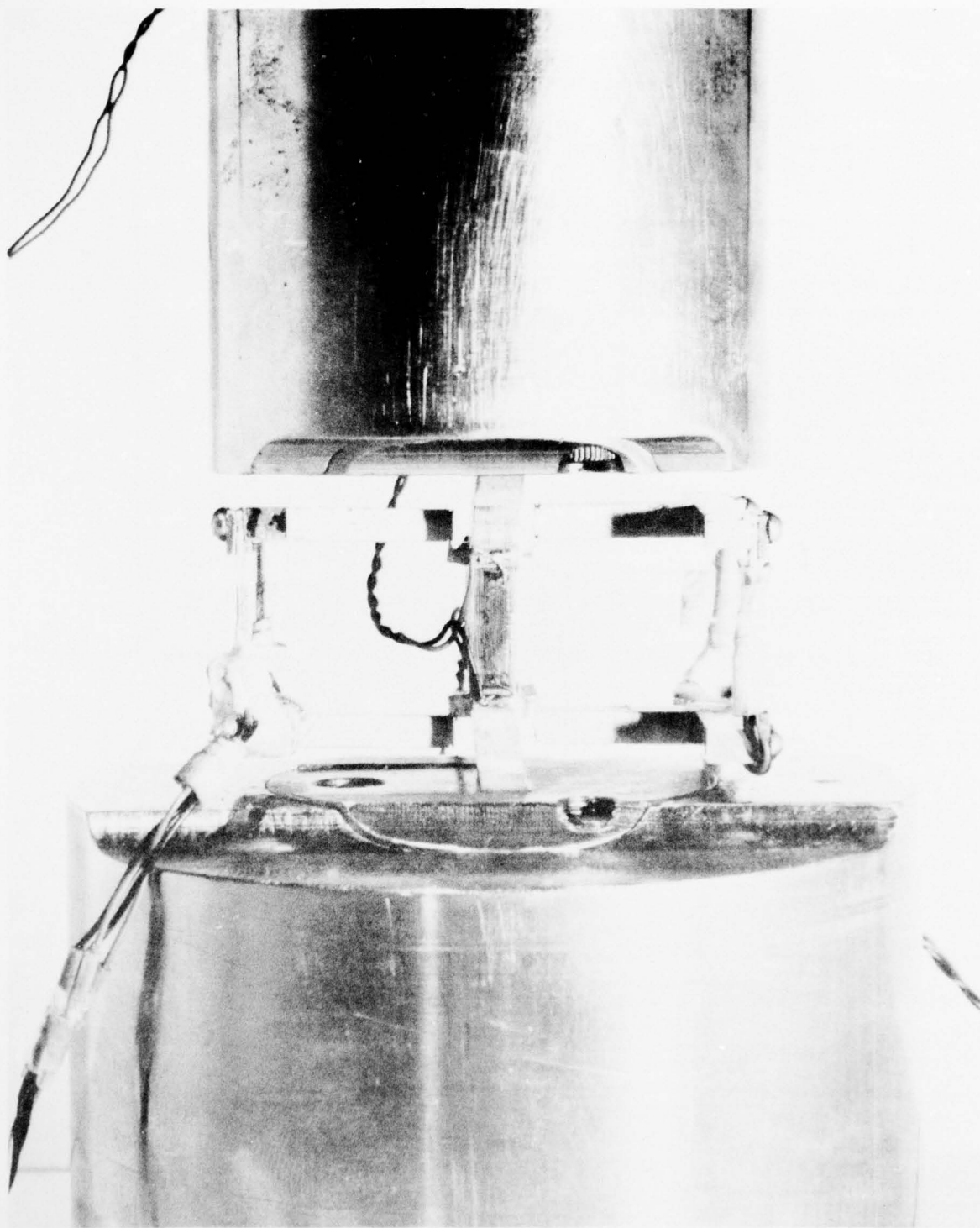


Figure 4. Details of the Curved Circumferential, Compressive Test (Additional Clip-On Gages Were Mounted on the Edges [not shown in photo])

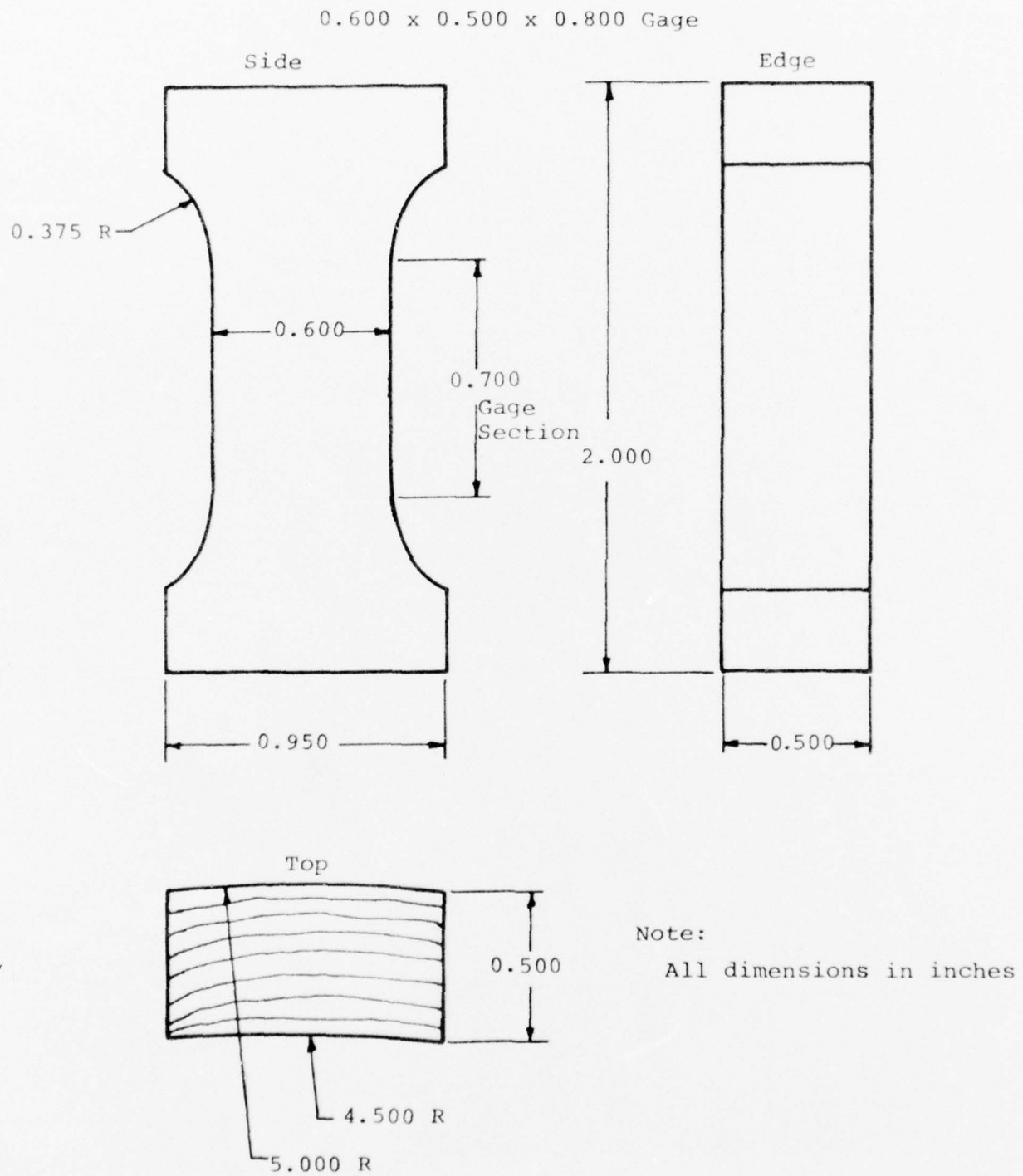


Figure 5. SORI Design Axial Specimen

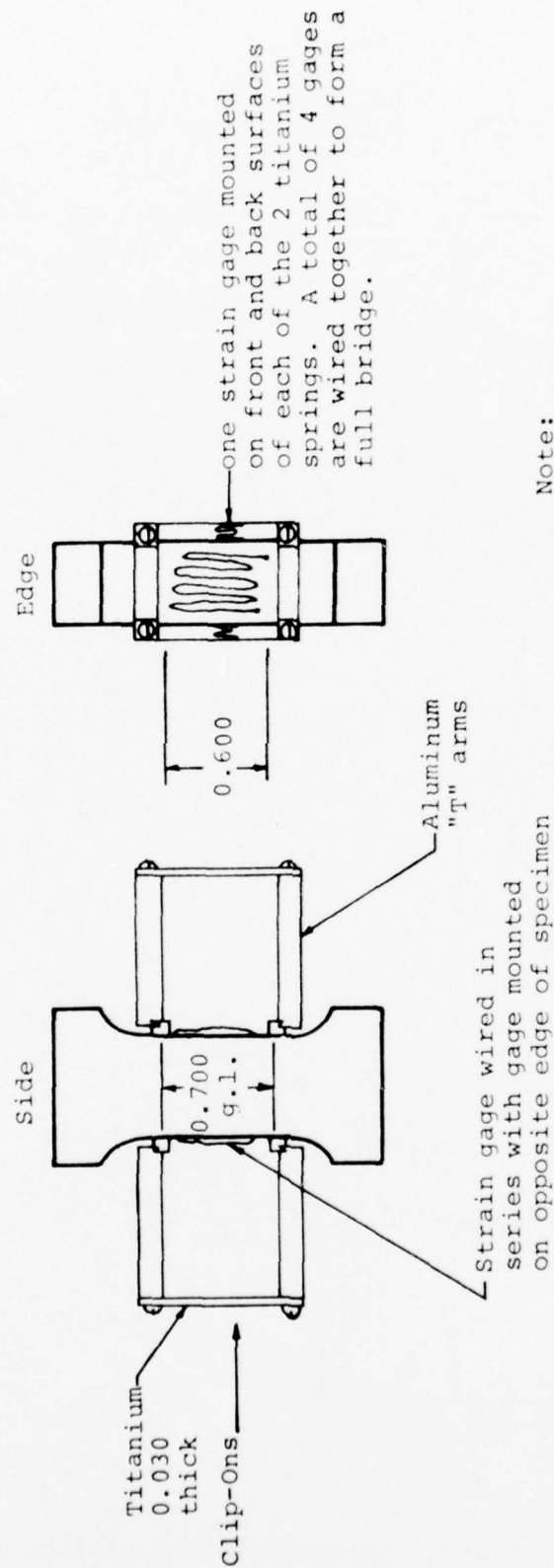


Figure 6. SoRI Design Axial Specimen - Clip-On and Strain Gage Configuration

0.600 x 0.500 x 0.800 Gage

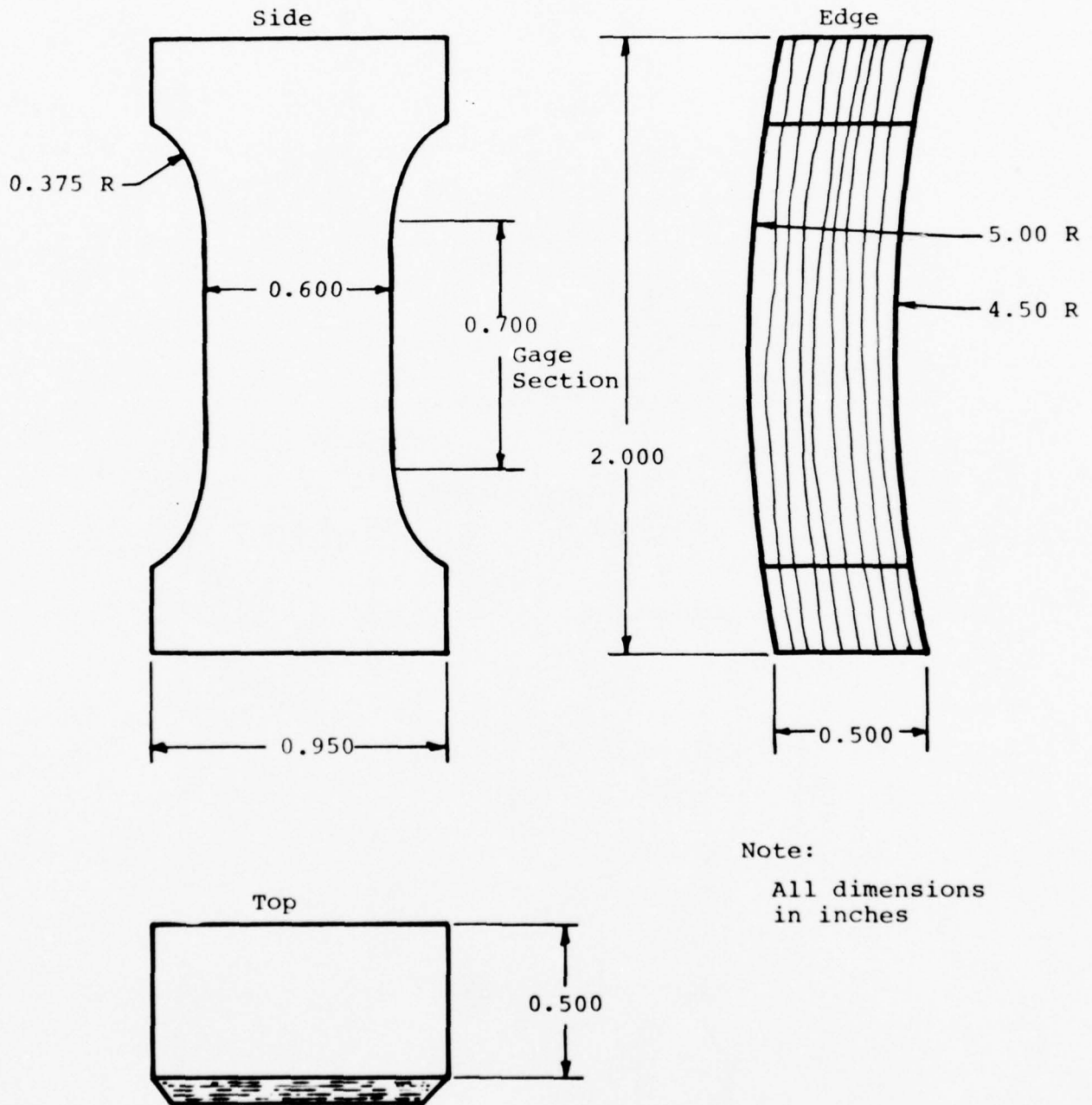


Figure 7. SoRI Design Circumferential (Hoop) Specimen

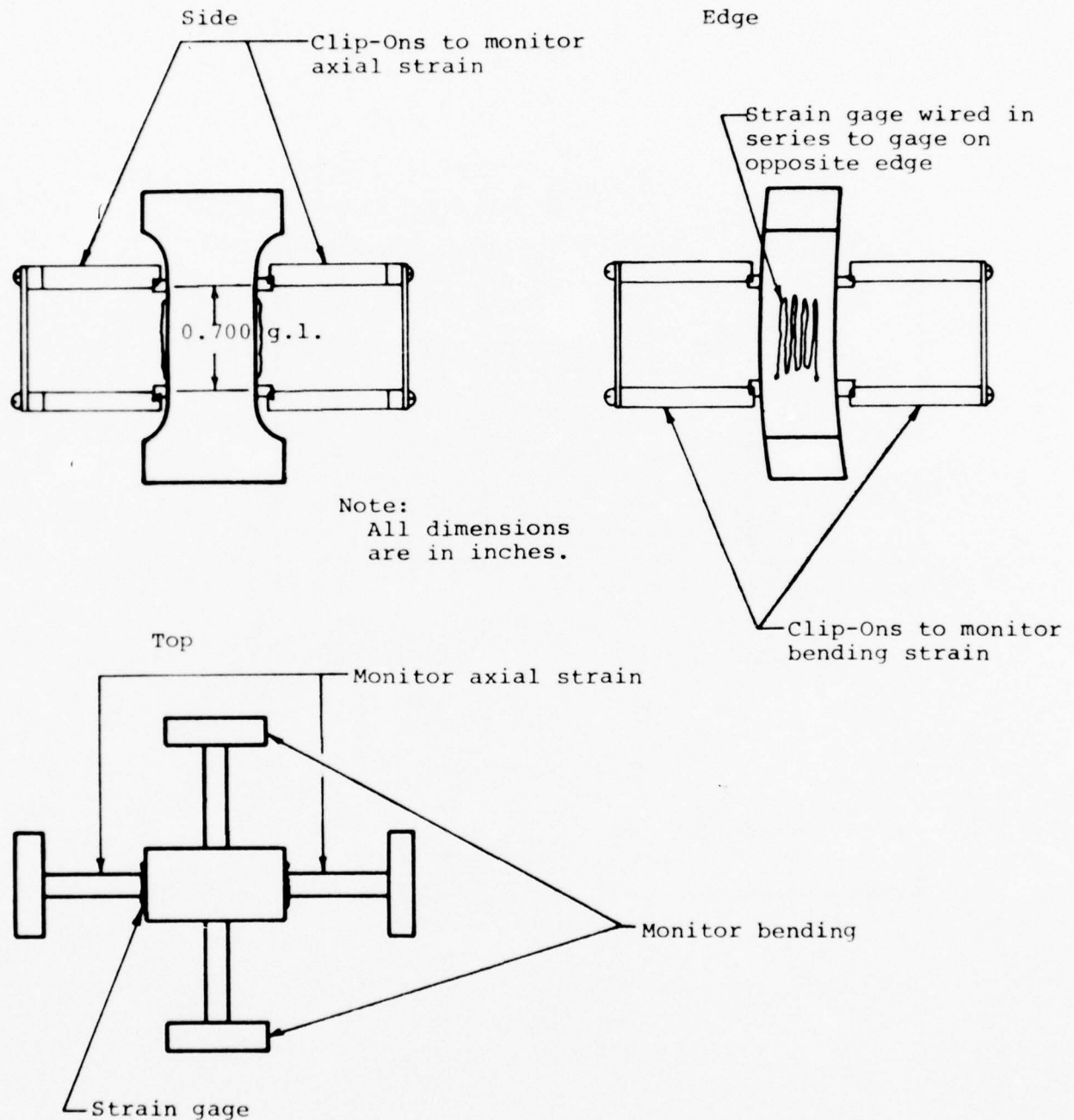
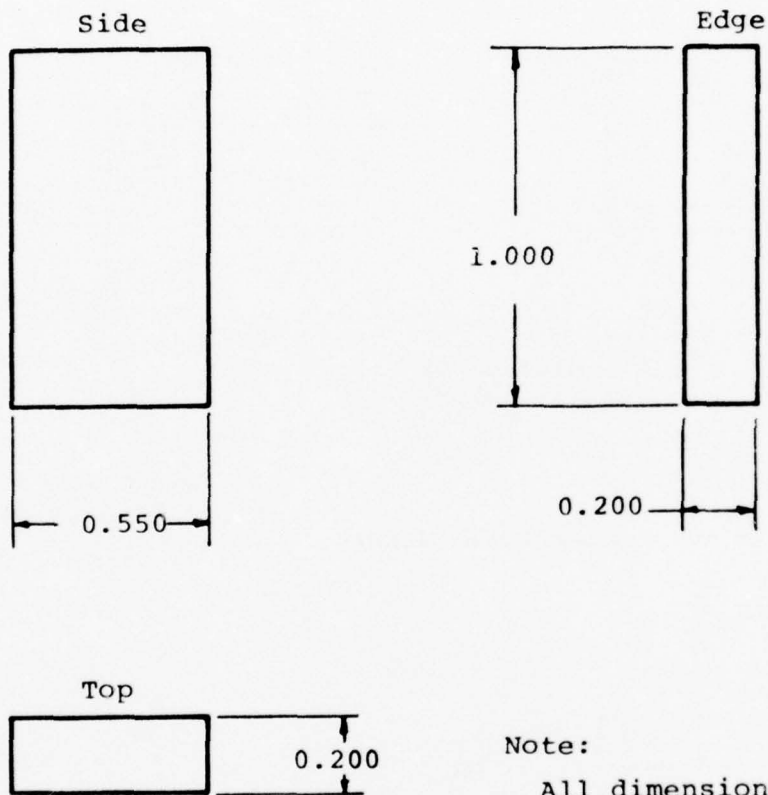


Figure 8. SoRI Design Circumferential Specimen - Clip-On and Strain Gage Configuration



Note:

All dimensions in inches

Figure 9. Rectangular Design Axial Specimen 1.000 x 0.550 x 0.200

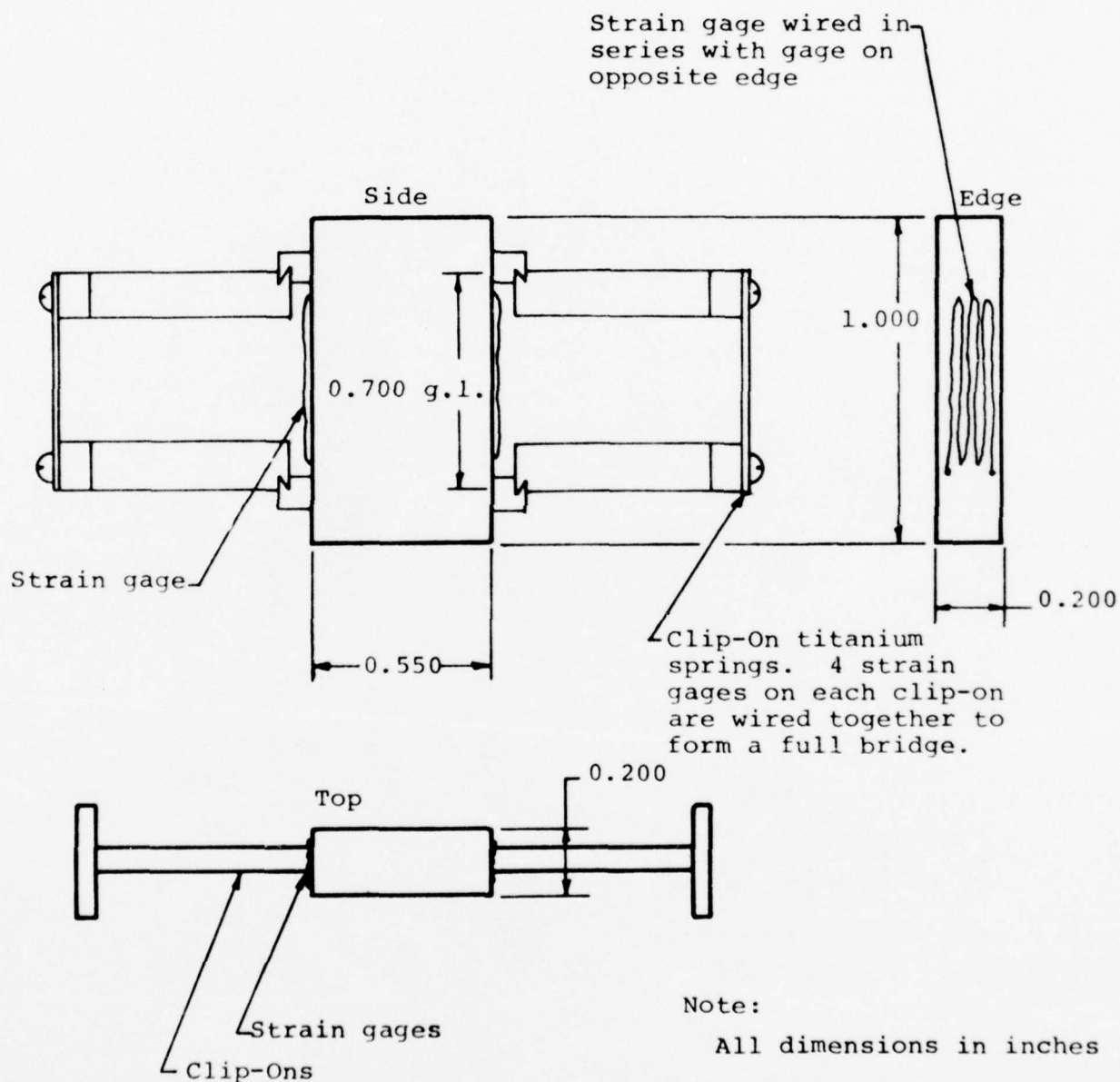


Figure 10. Rectangular Design Axial Specimen - Clip-On and Strain Gage Configuration (1.000 x 0.550 x 0.200)

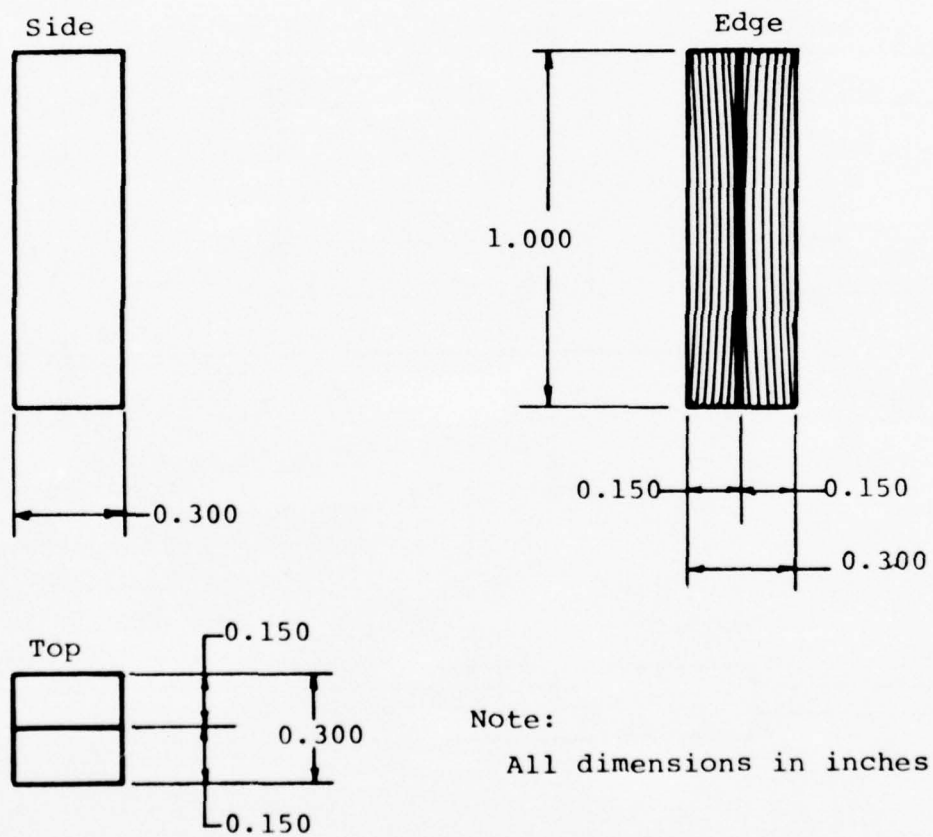


Figure 11. Rectangular Design Circumferential (Hoop) Specimens (1.000 x 0.300 x 0.300)

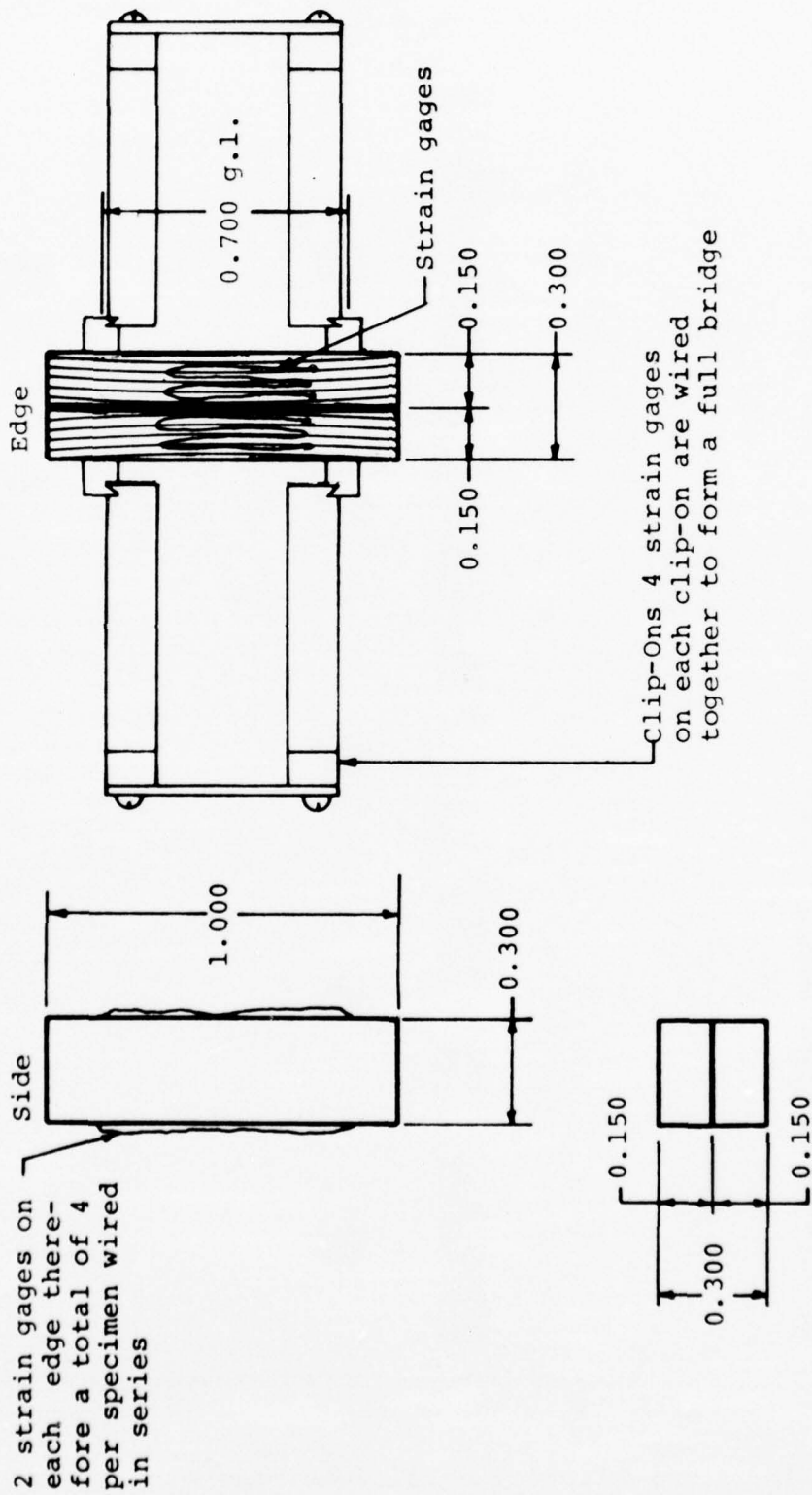
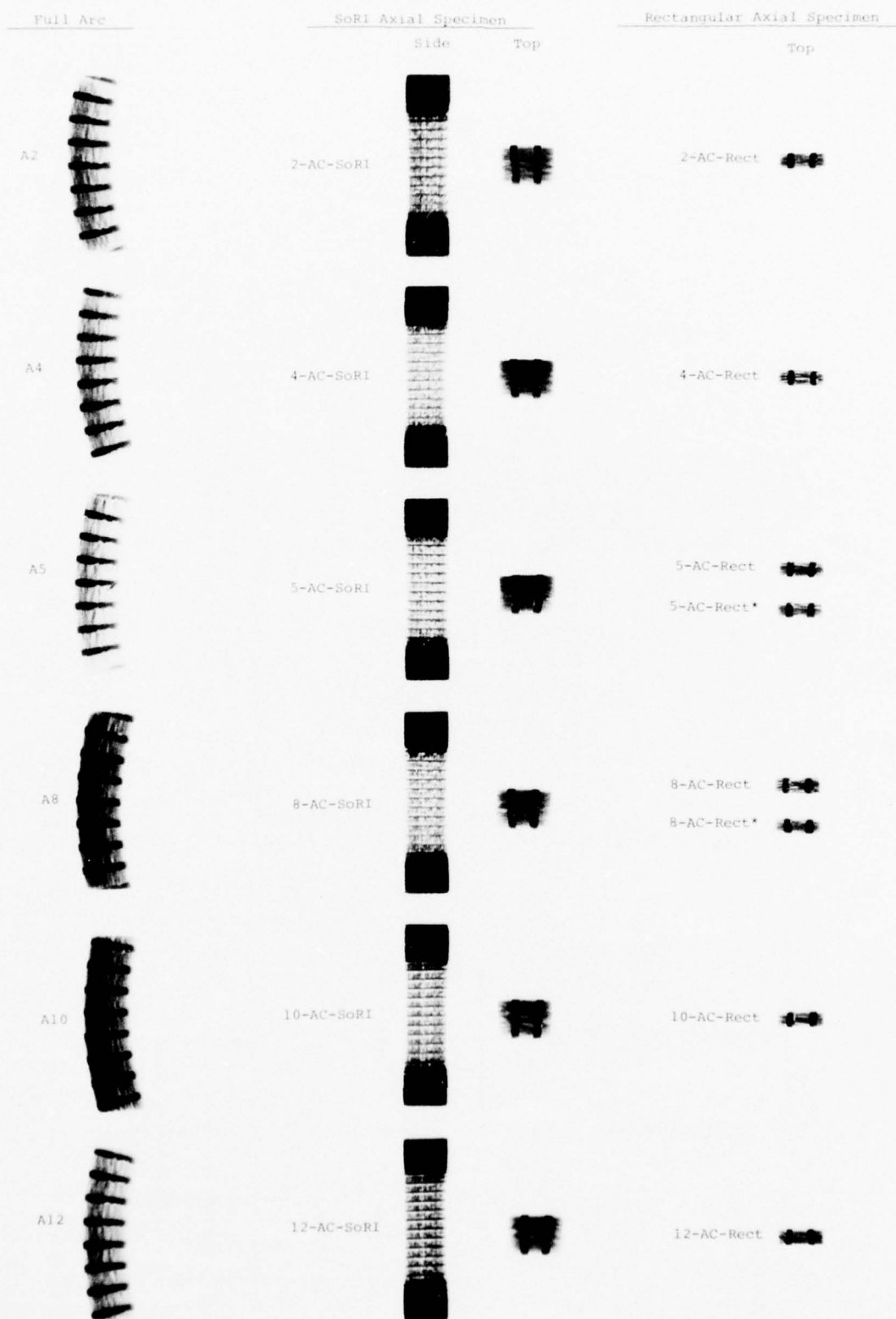


Figure 12. Rectangular Design Circumferential (Hoop) Specimens - Clip-On and Strain Gage Configuration (1.000 x 0.300 x 0.300)



*Machined at SoRI from arc. All other rectangular specimens pre-machined from material adjacent to the respective arc.

Figure 13. X-ray Print of Axial Specimens from Cylinder 6.1.4

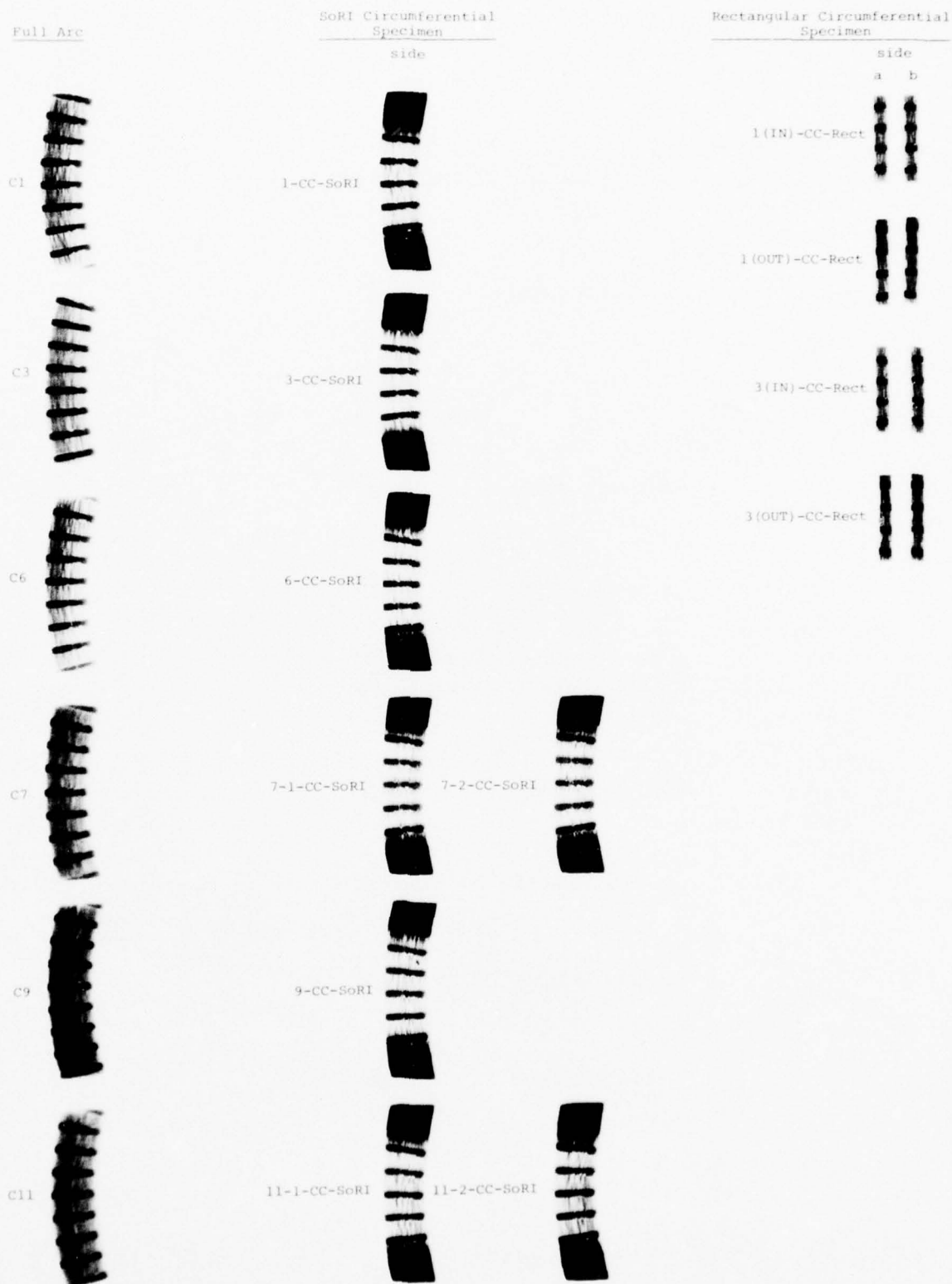


Figure 14. X-ray Print of Circumferential Specimens from Cylinder 6.1.4

Rectangular Axial Specimens

Top View

A4-AC-Rect	
A13-AC-Rect	
A19-AC-Rect	
A30-AC-Rect	
A39-AC-Rect	
A43-AC-Rect	
A46-AC-Rect	
A48-AC-Rect	
A50-AC-Rect	

Figure 15. X-ray Print of Axial Specimens from Cylinder 4.1.18

Rectangular Circumferential Specimens

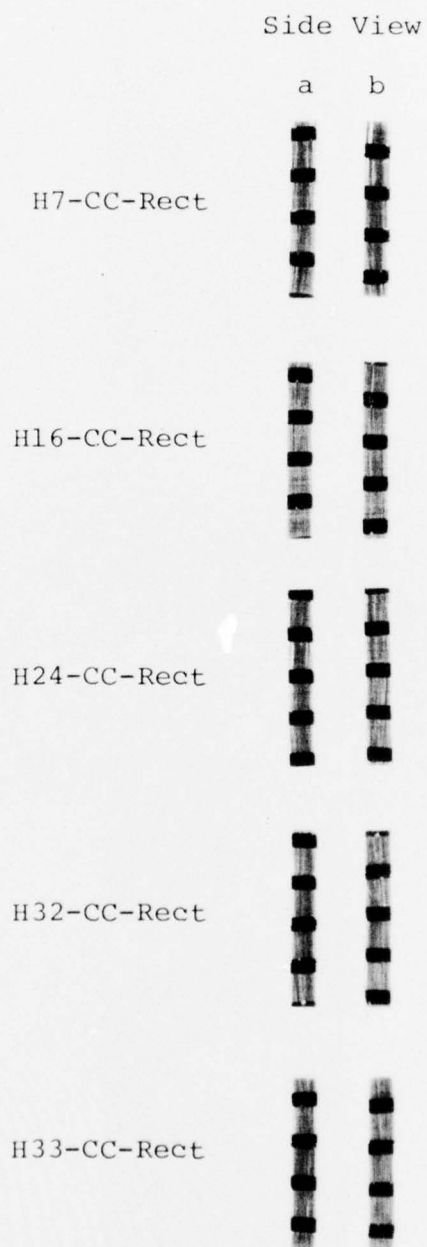


Figure 16. X-ray Print of Circumferential Specimens
from Cylinder 4.1.18



Figure 17. 20X Photomicrograph Showing Circumferential "Waviness" in Arc 6

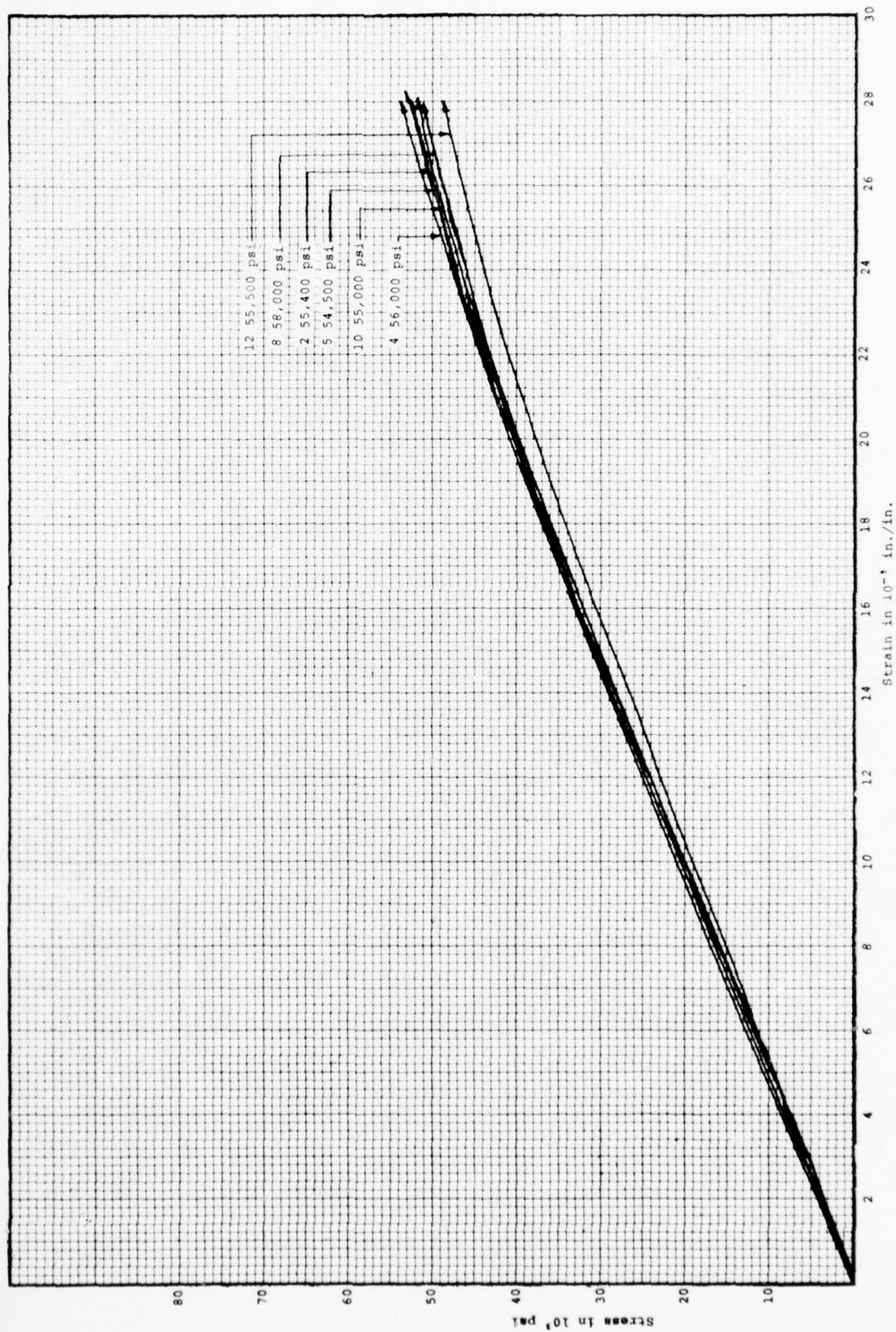


Figure 18. Composite Plot Axial Compression SORI Specimen Configuration 3DQP - 6.1.14 (Clip-On Data)

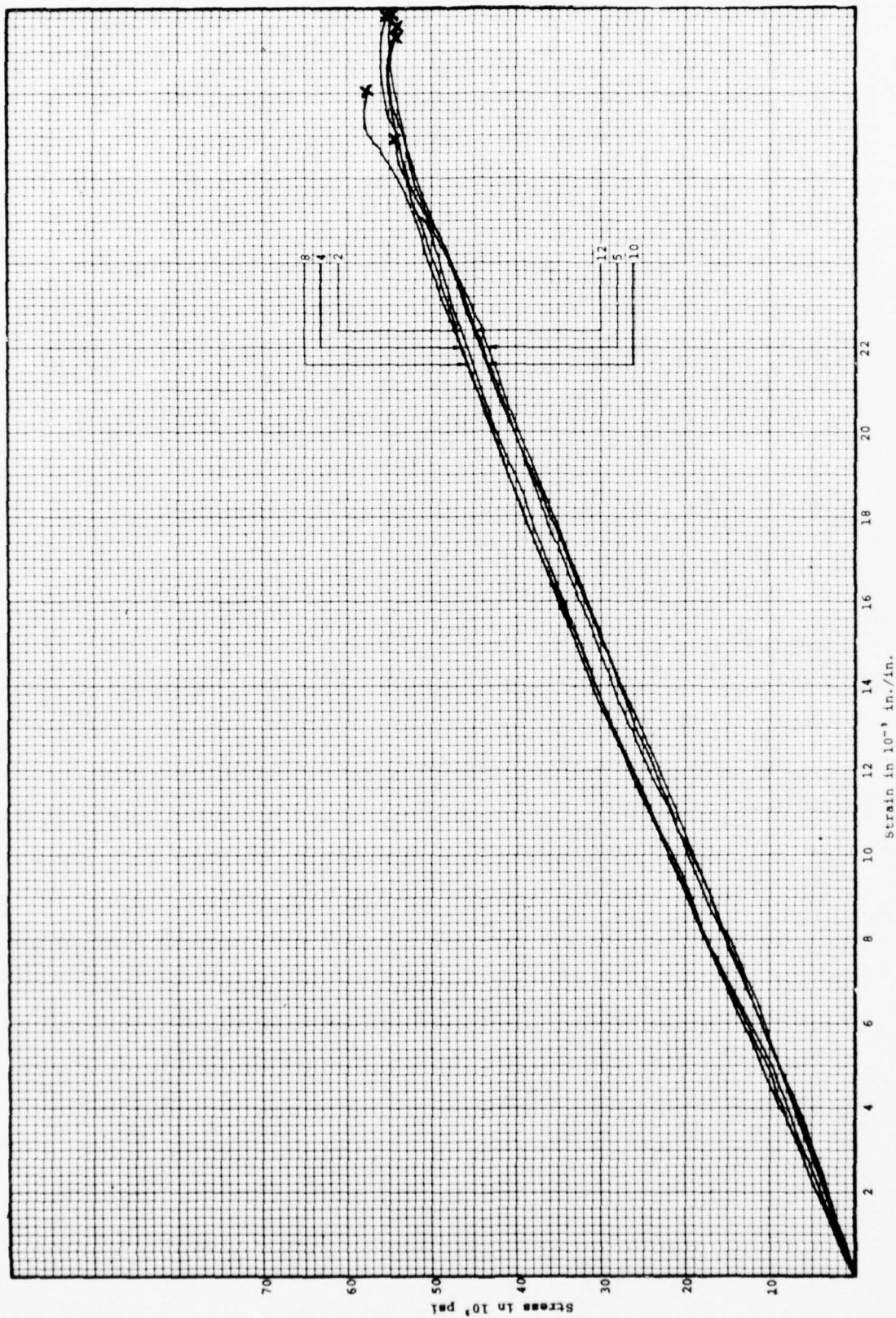


Figure 19. Composite Plot Axial Compression SOR Specimen Configuration 3DOP - 6.1.4 (Strain Gage Data)



Figure 20. Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-6.1.4 (Clip-on Data)

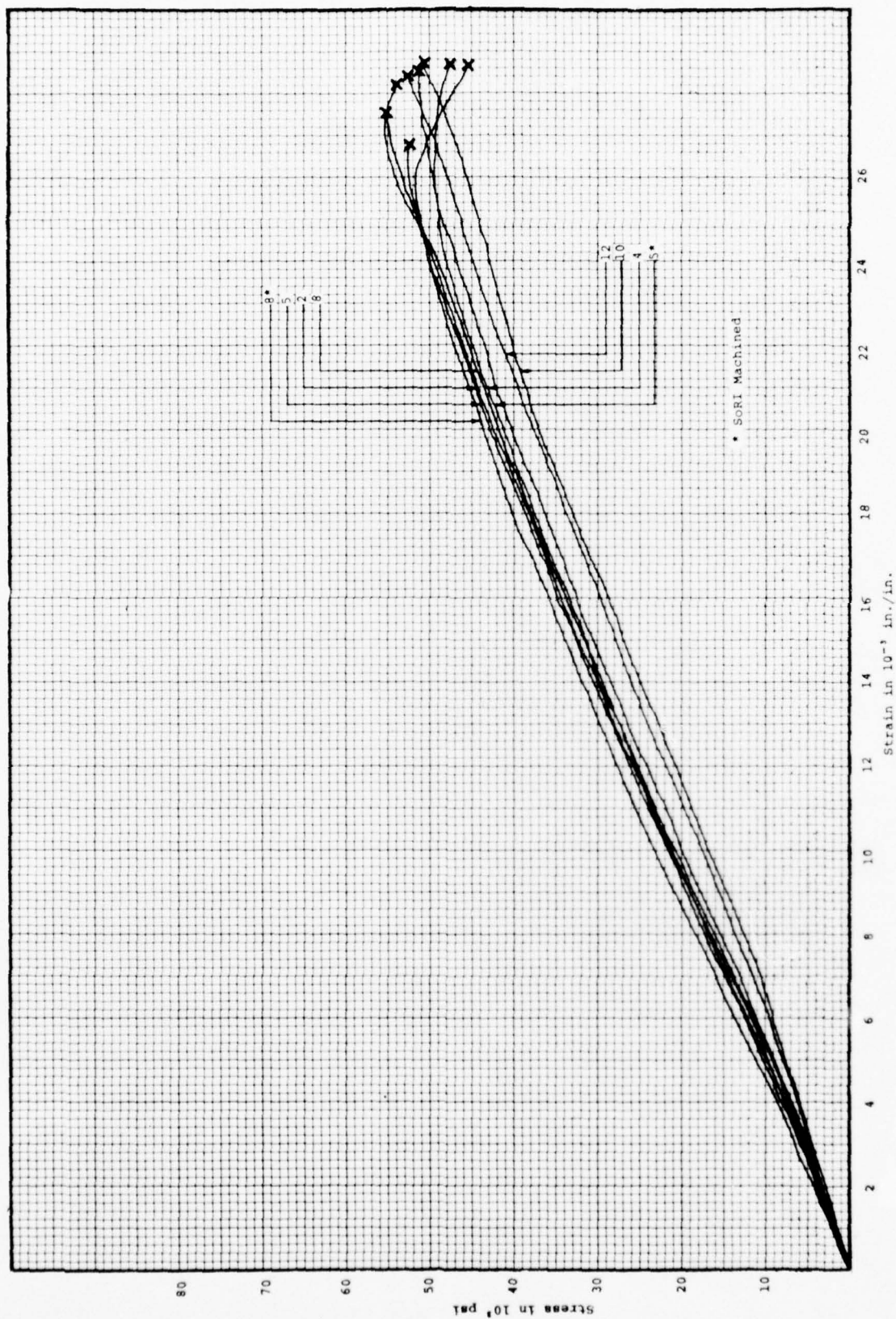


Figure 21. Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-6.1.4 (Strain Gage Data)

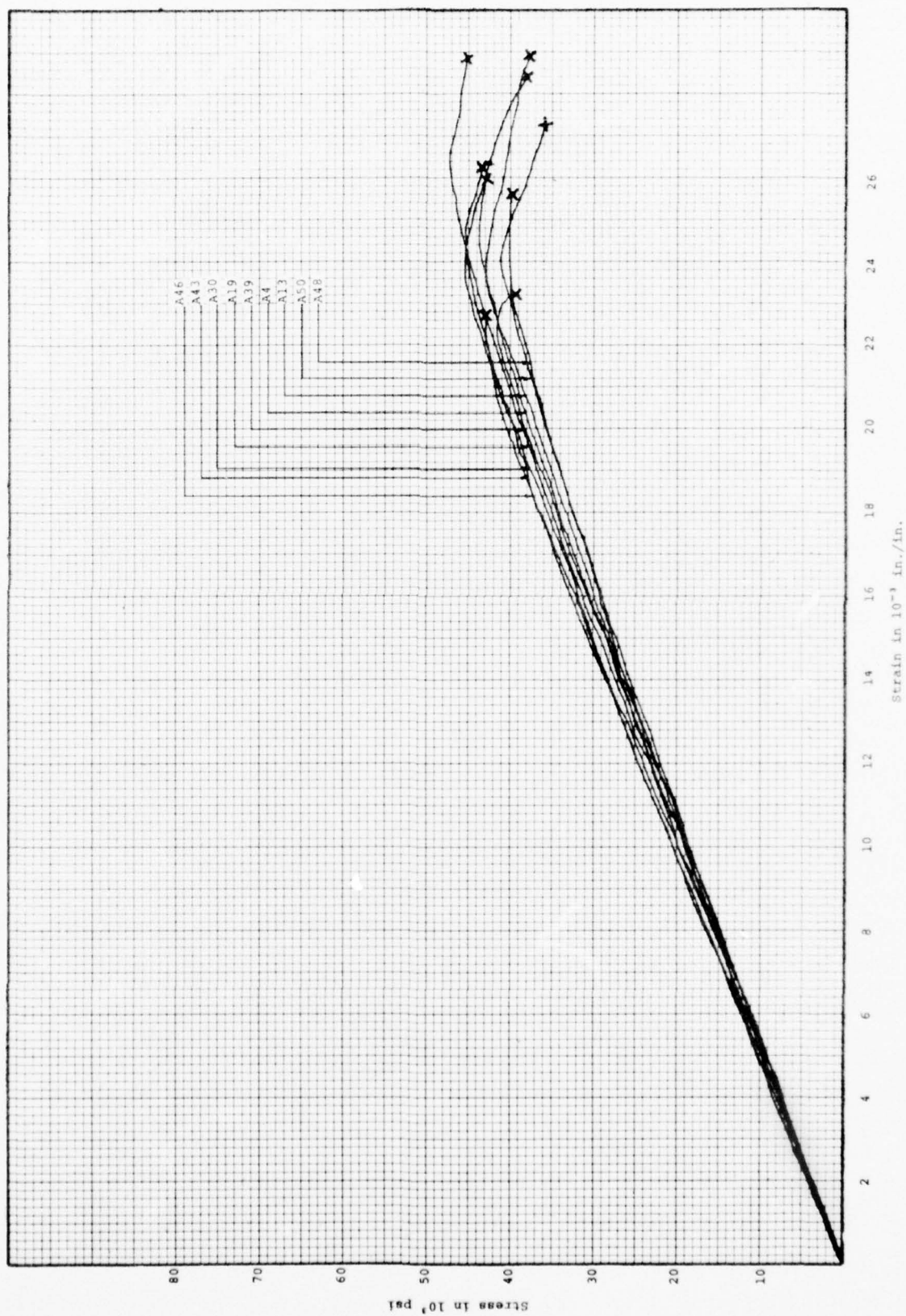


Figure 22. Composite Plot Axial Compression-Rectangular Specimen Configuration IQP-4.1.18 (Clip-on Data)

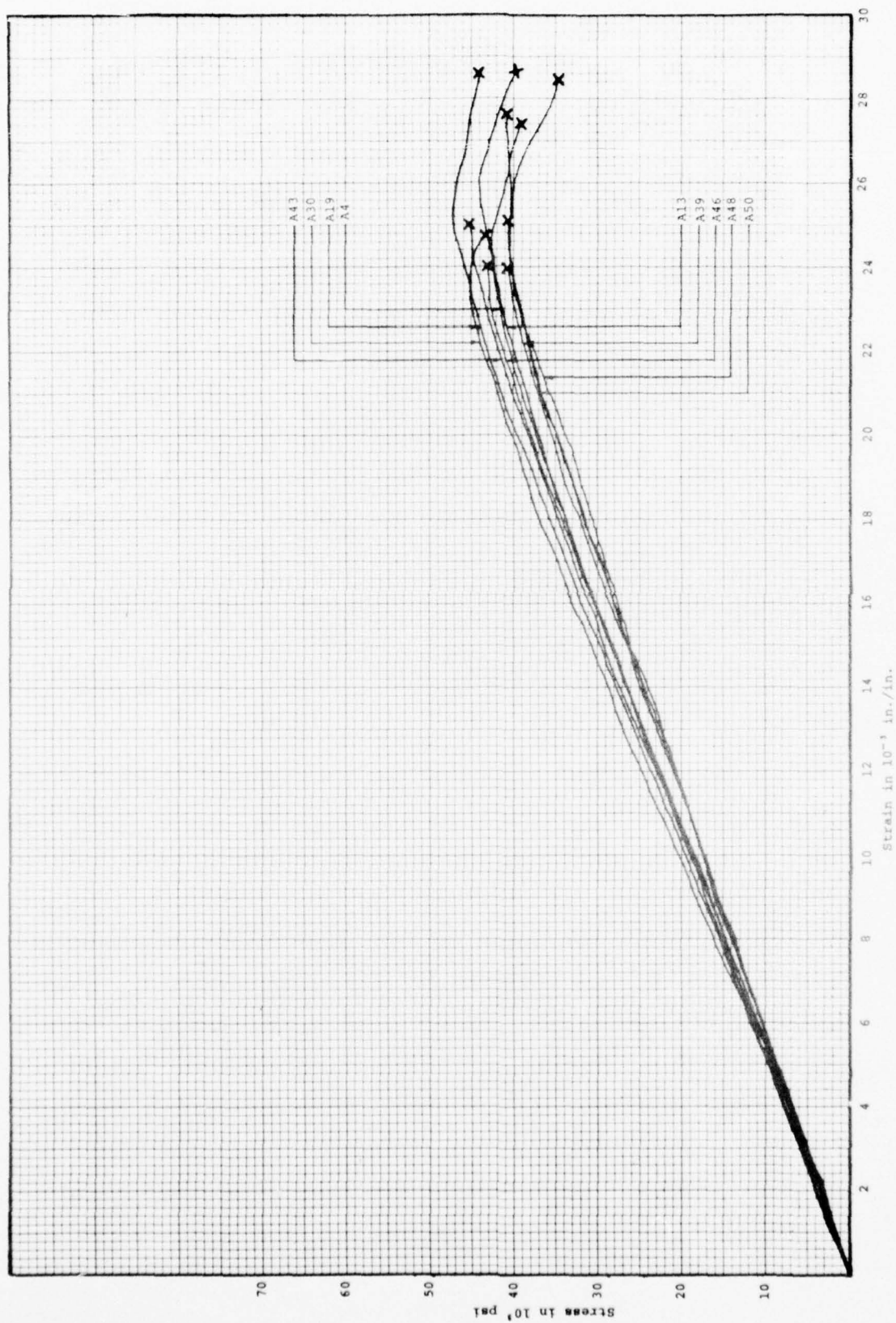


Figure 23. Composite Plot Axial Compression-Rectangular Specimen Configuration 3DQP-4.1.18 (Strain Gage Data)

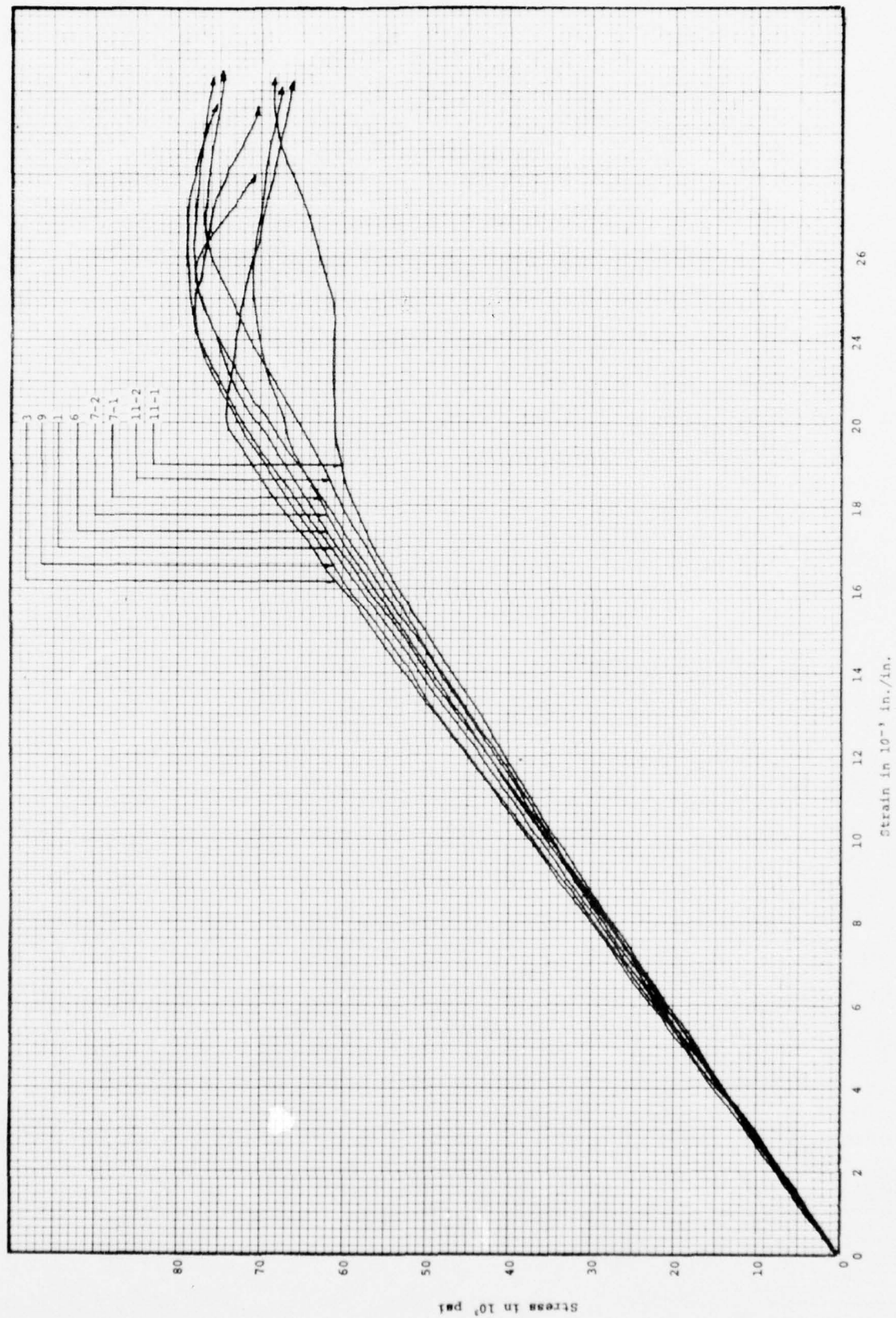


Figure 24. Composite Plot Circumferential Compression-SORI Specimen Configuration 3DCP-6.1.4 (Clip-on Data)

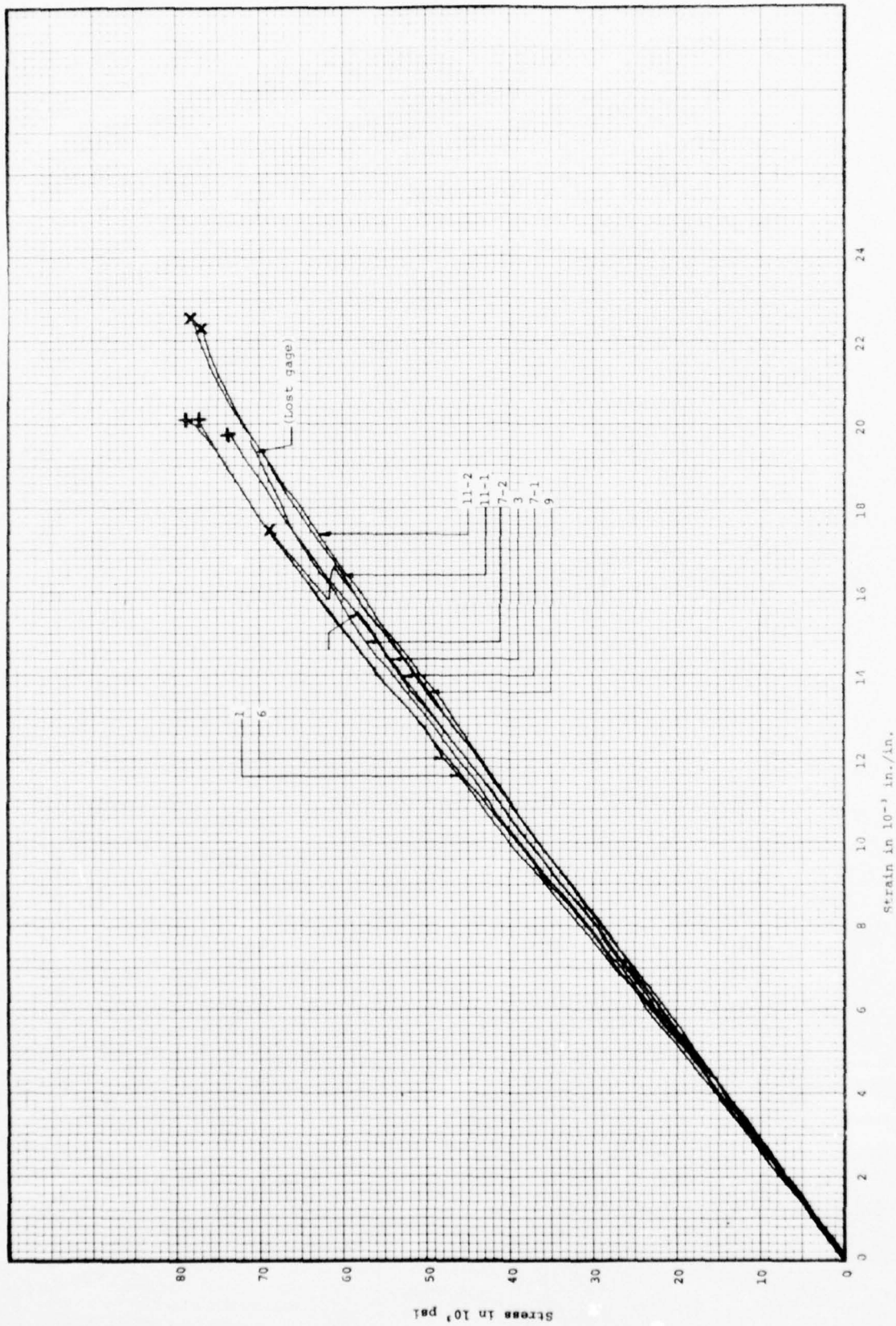


Figure 25. Composite Plot Circumferential Compression-SoRI Specimen Configuration 3DQP-6.1.4 (Strain Gage Data)

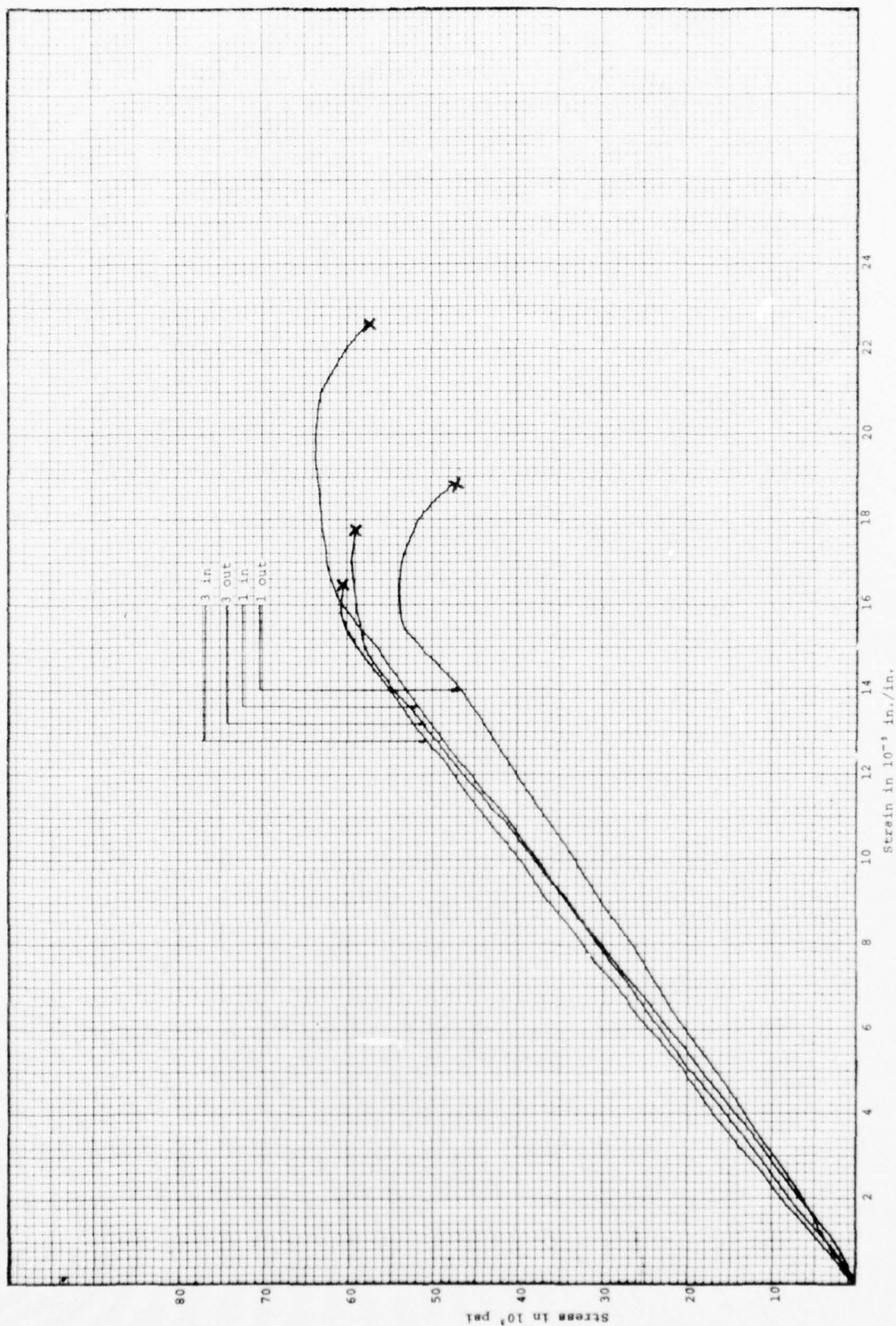


Figure 26. Composite Plot Circumferential Compression-Rectangular Specimen Configuration 3QPF-6.1.4 (Clip-on Data)

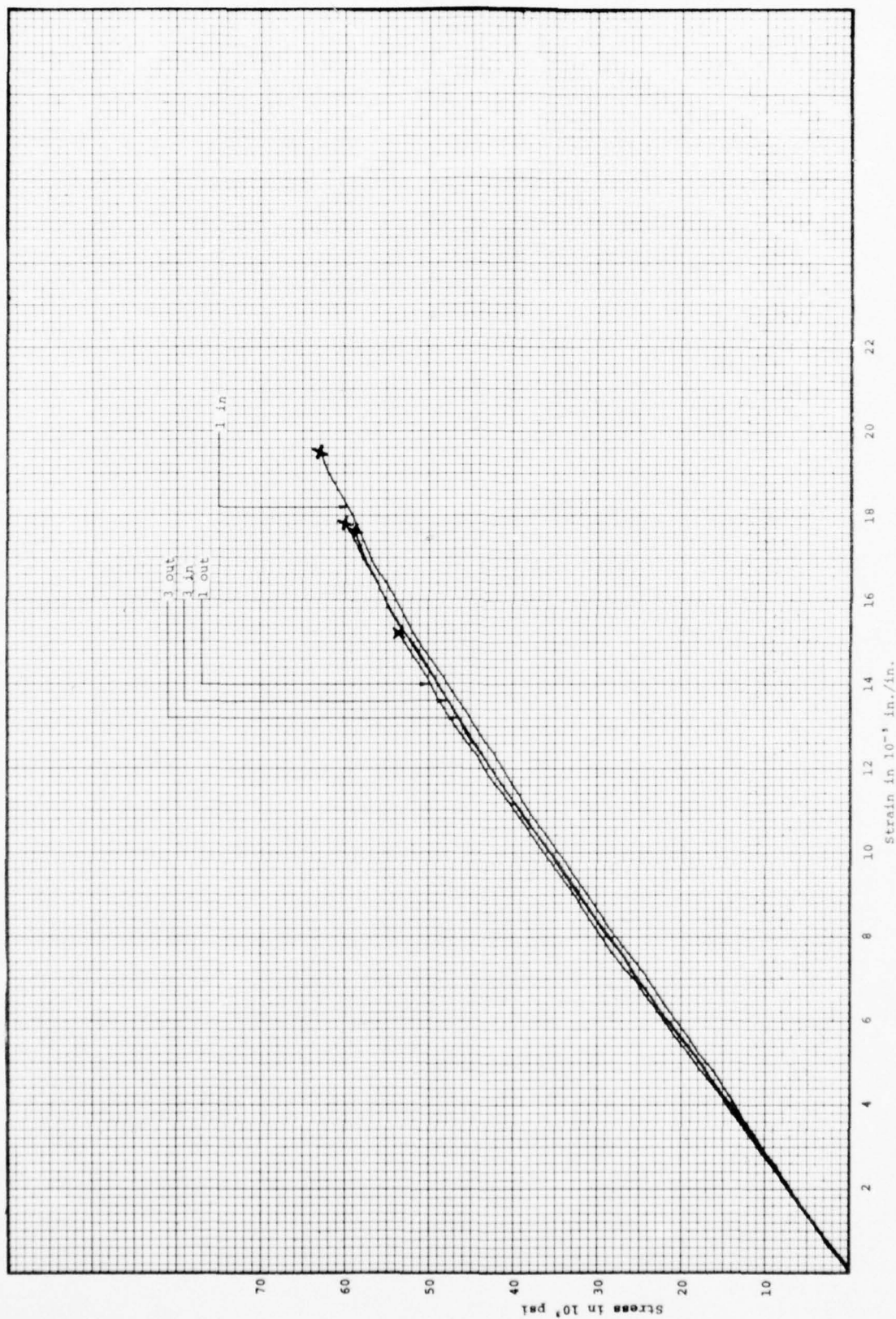


Figure 27. Composite Plot Circumferential Compression-Rectangular Specimen Configuration 35QP-6.1.4 Strain Gage Data

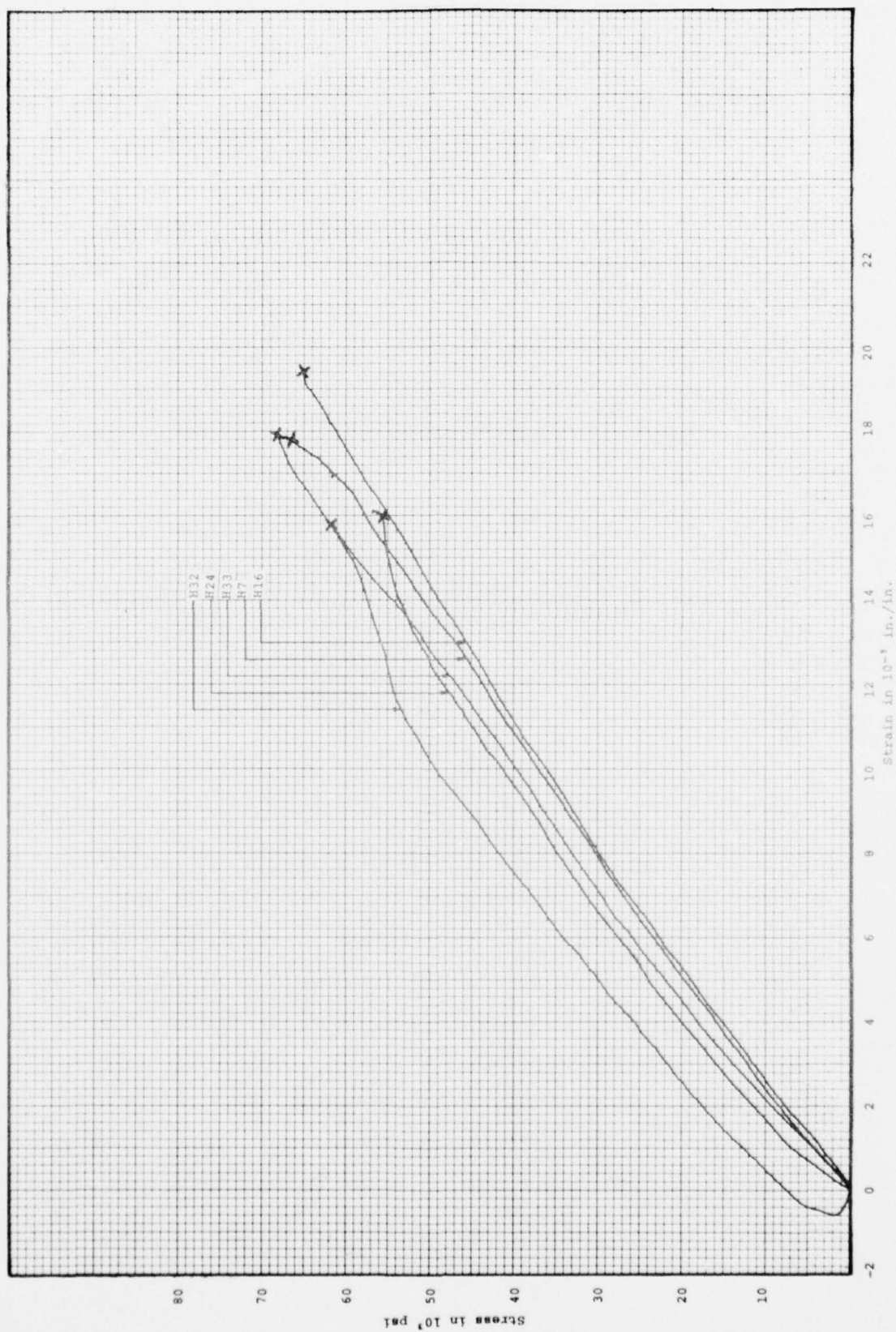


Figure 28. Composite Plot Circumferential Compression-Rectangular Specimen Configuration 3DQP-4.1.18 (Clip-on Data)

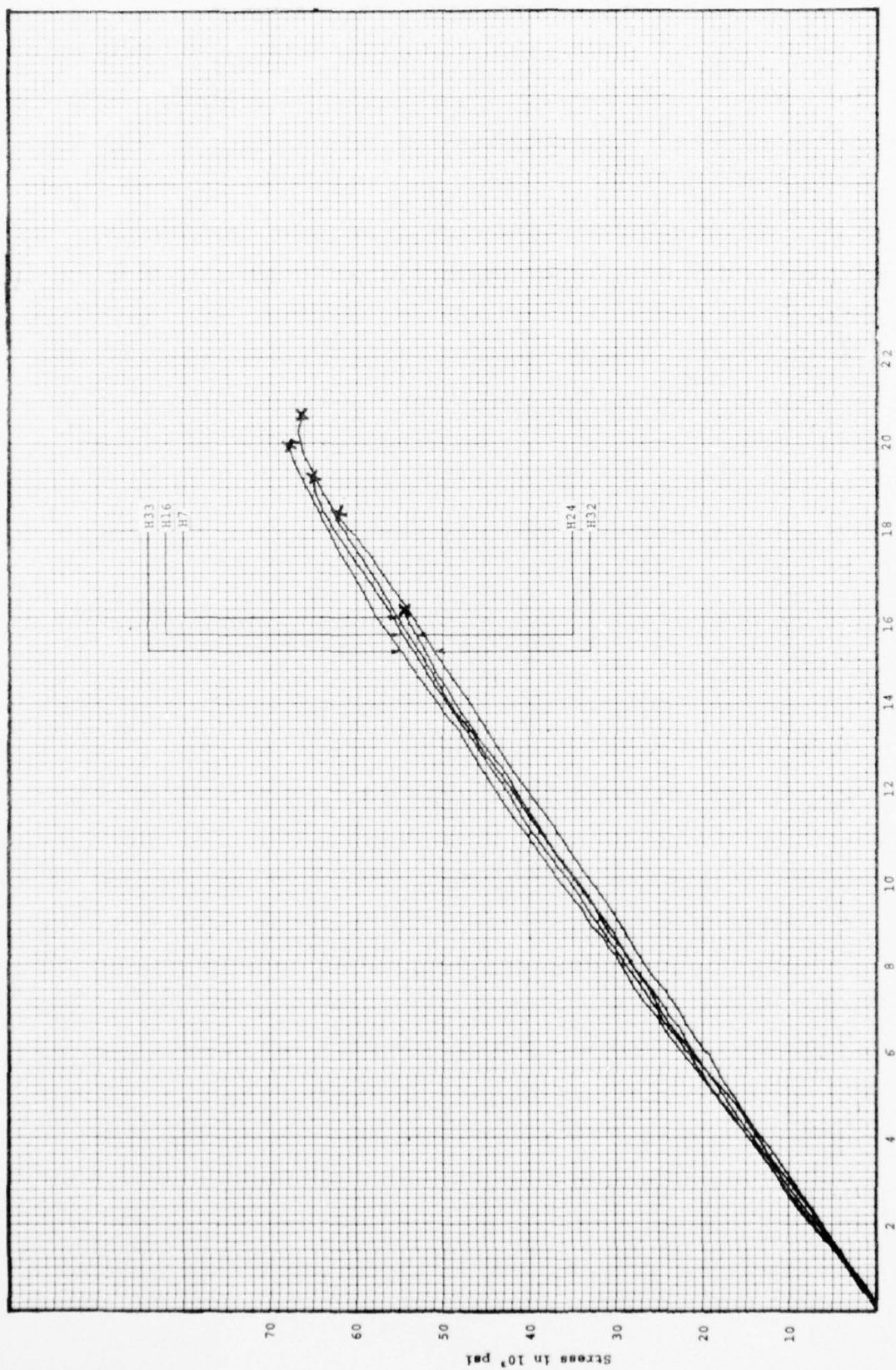


Figure 29. Composite Plot Circumferential Direction-Rectangular Specimen Configuration 3DQP-4.1.18 (Strain Gage Data)

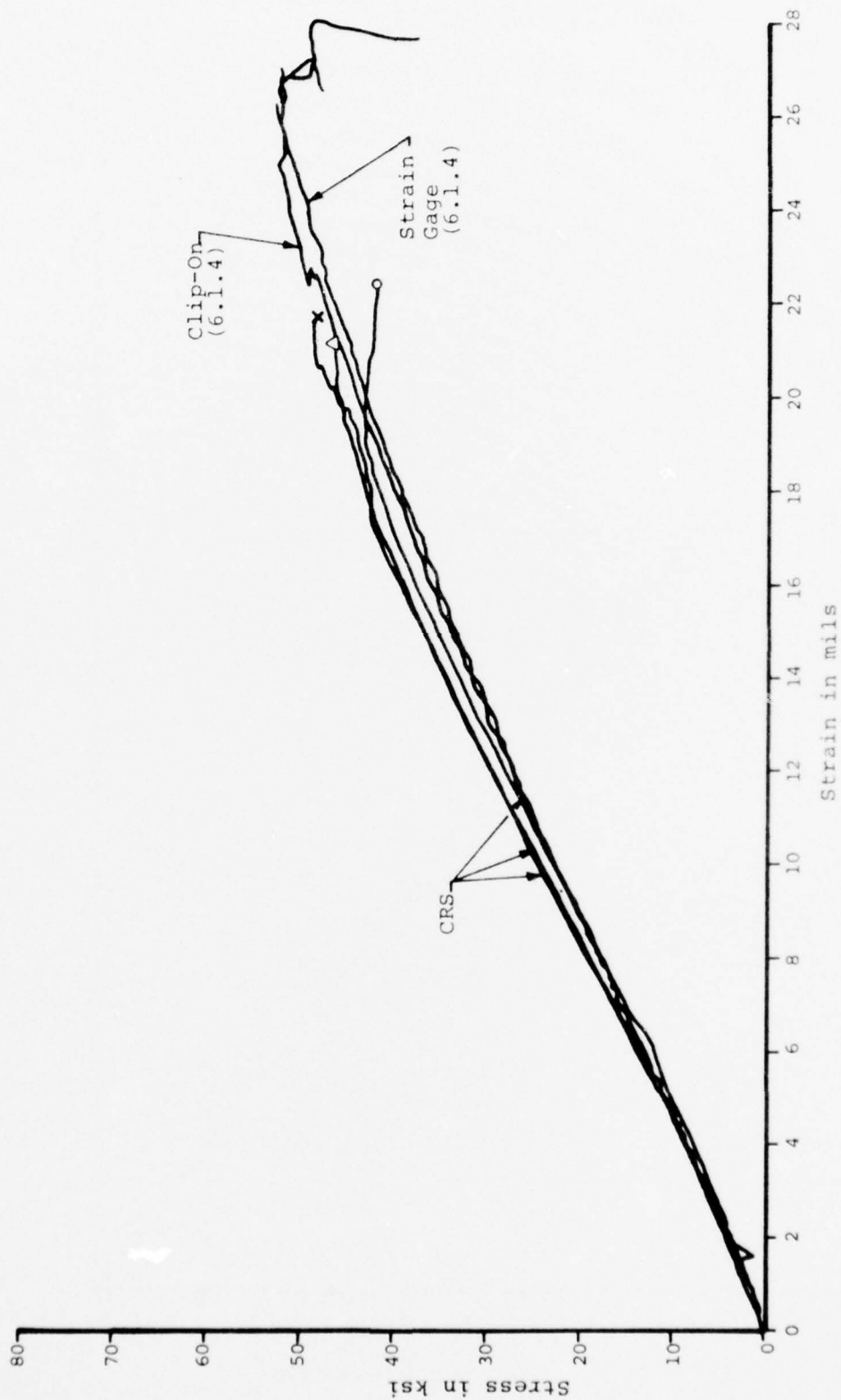


Figure 30. Typical Axial Compression Data from CRS (with one run from 6.1.4)

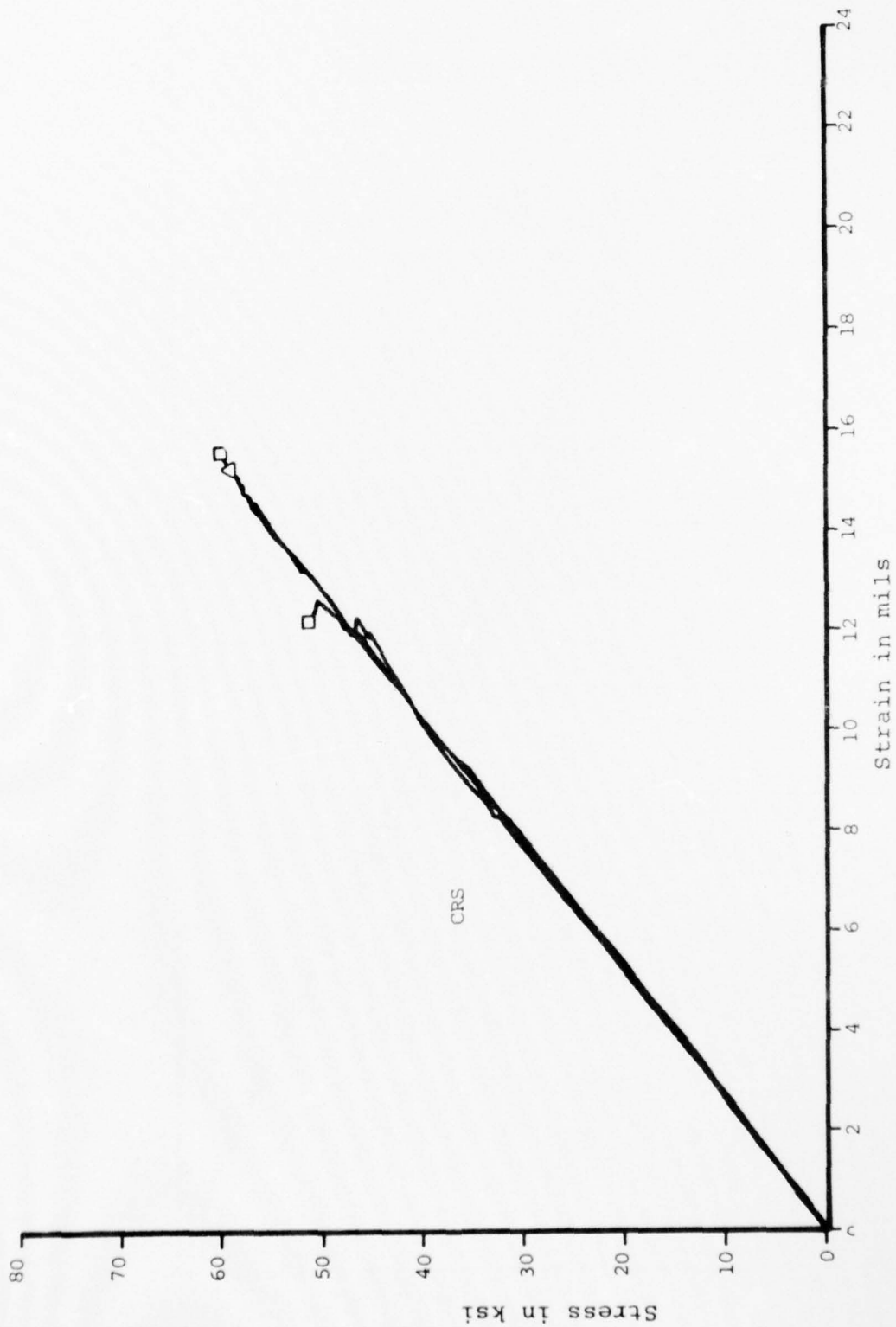


Figure 31. Typical Circumferential Compression Data from CRS

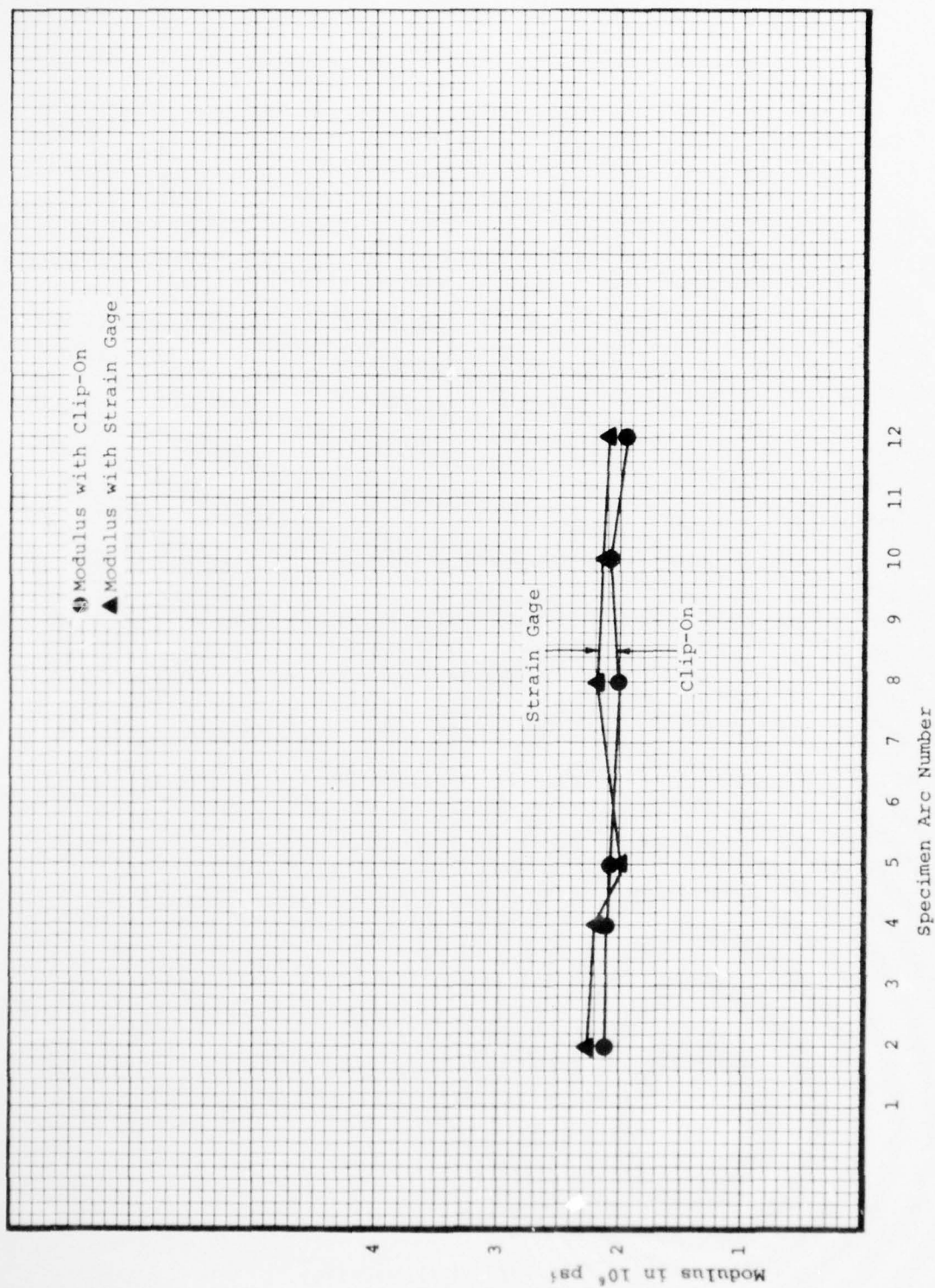


Figure 32. Comparison of SoRI Axial Clip-On versus Strain Gage Data 6-1-4

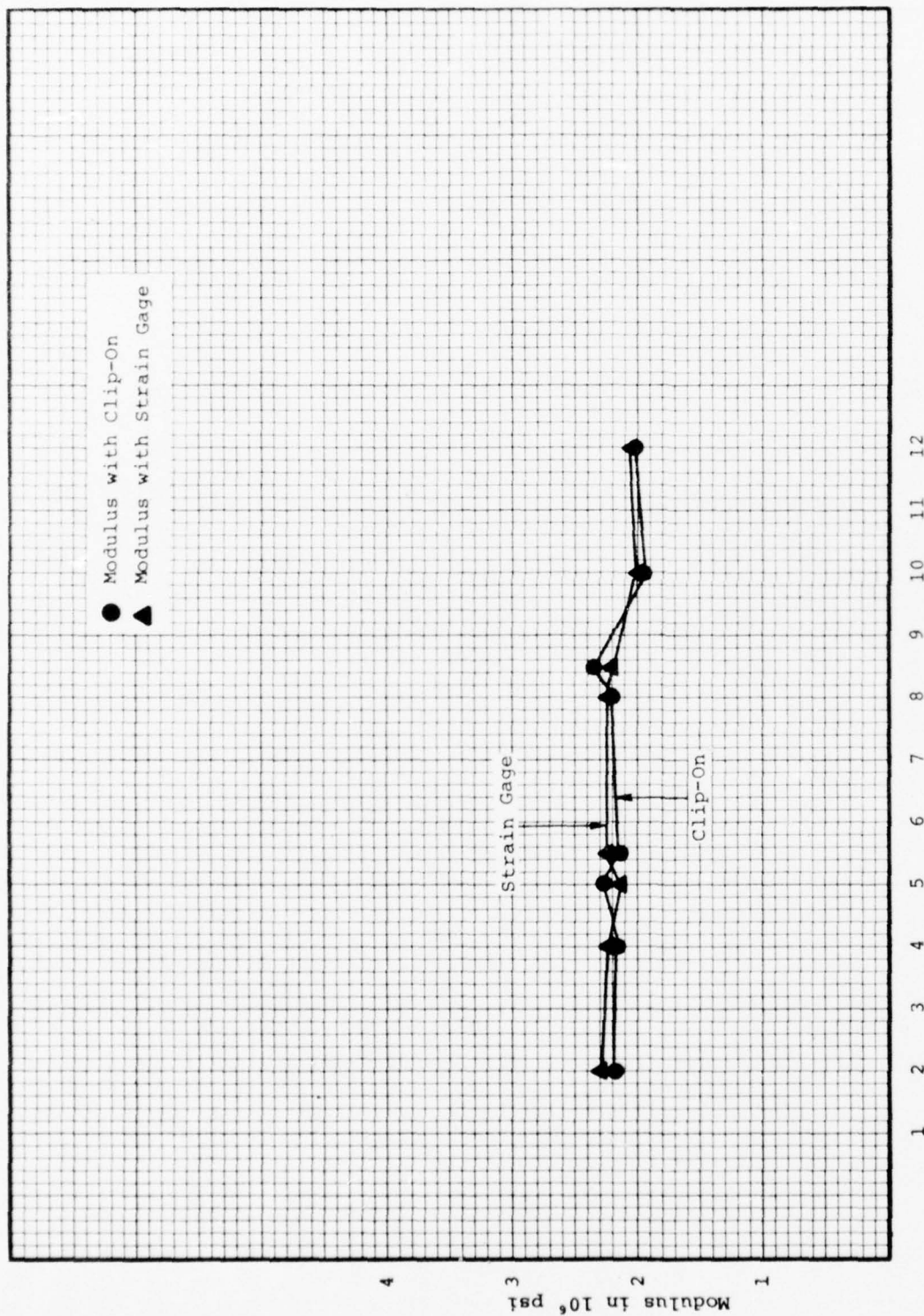


Figure 33. Comparison of Rectangular Axial Clip-on versus Strain Gage Data 6.1.4

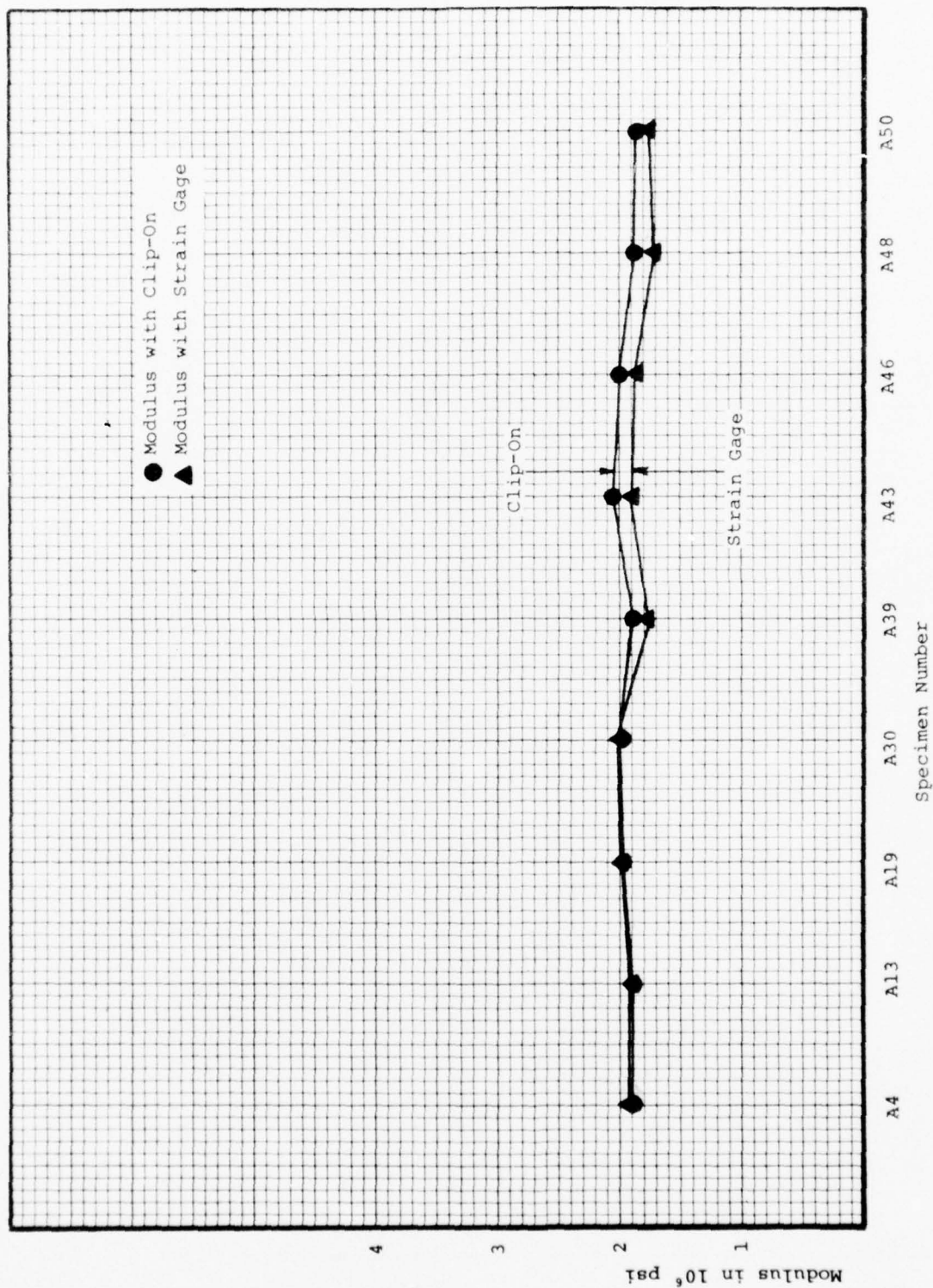


Figure 34. Comparison of Rectangular Axial Clip-On versus Strain Gage Data 4.1.18

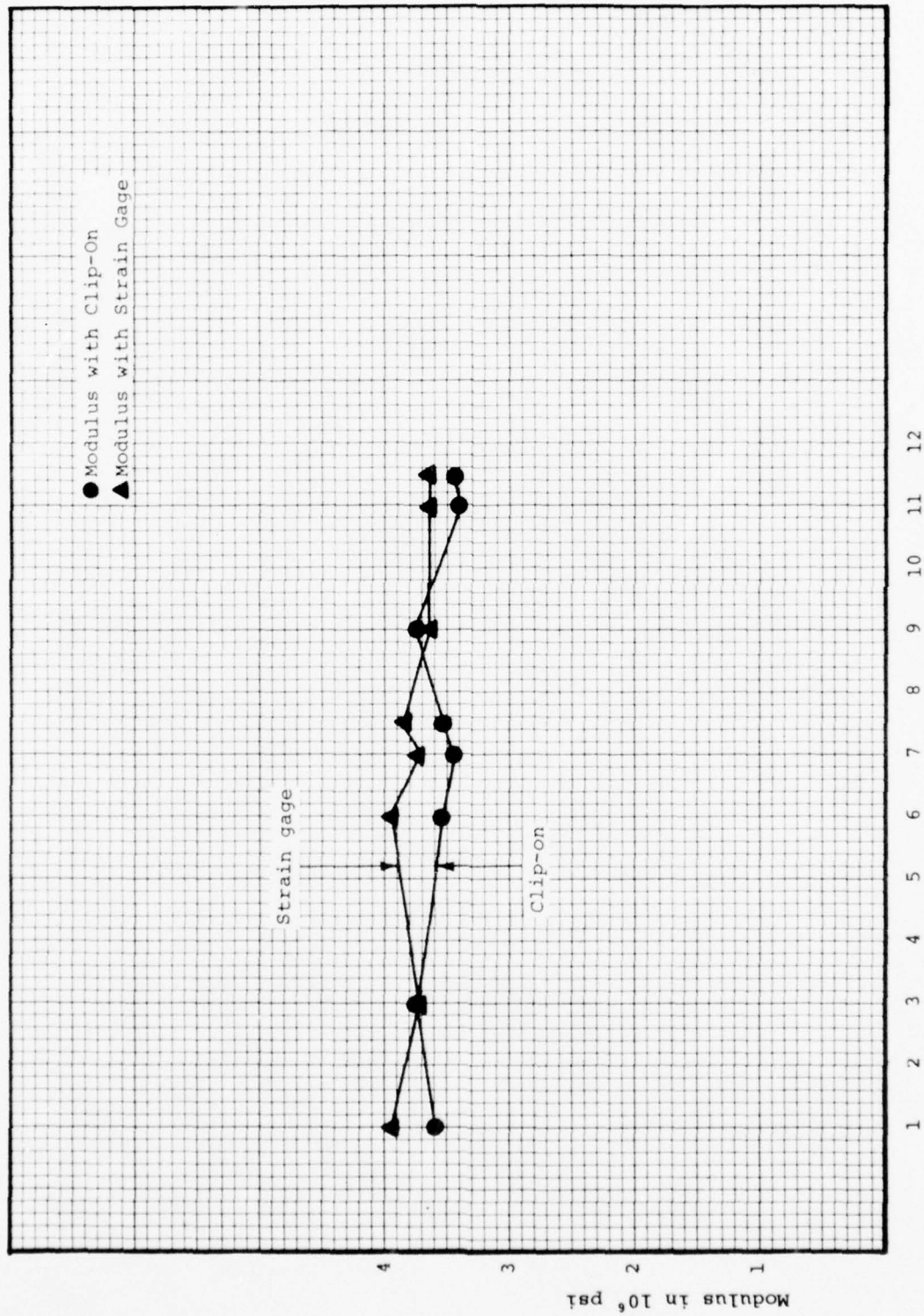


Figure 35. Comparison of SoRI Circumferential Clip-On versus Strain Gage Data 6.1.4

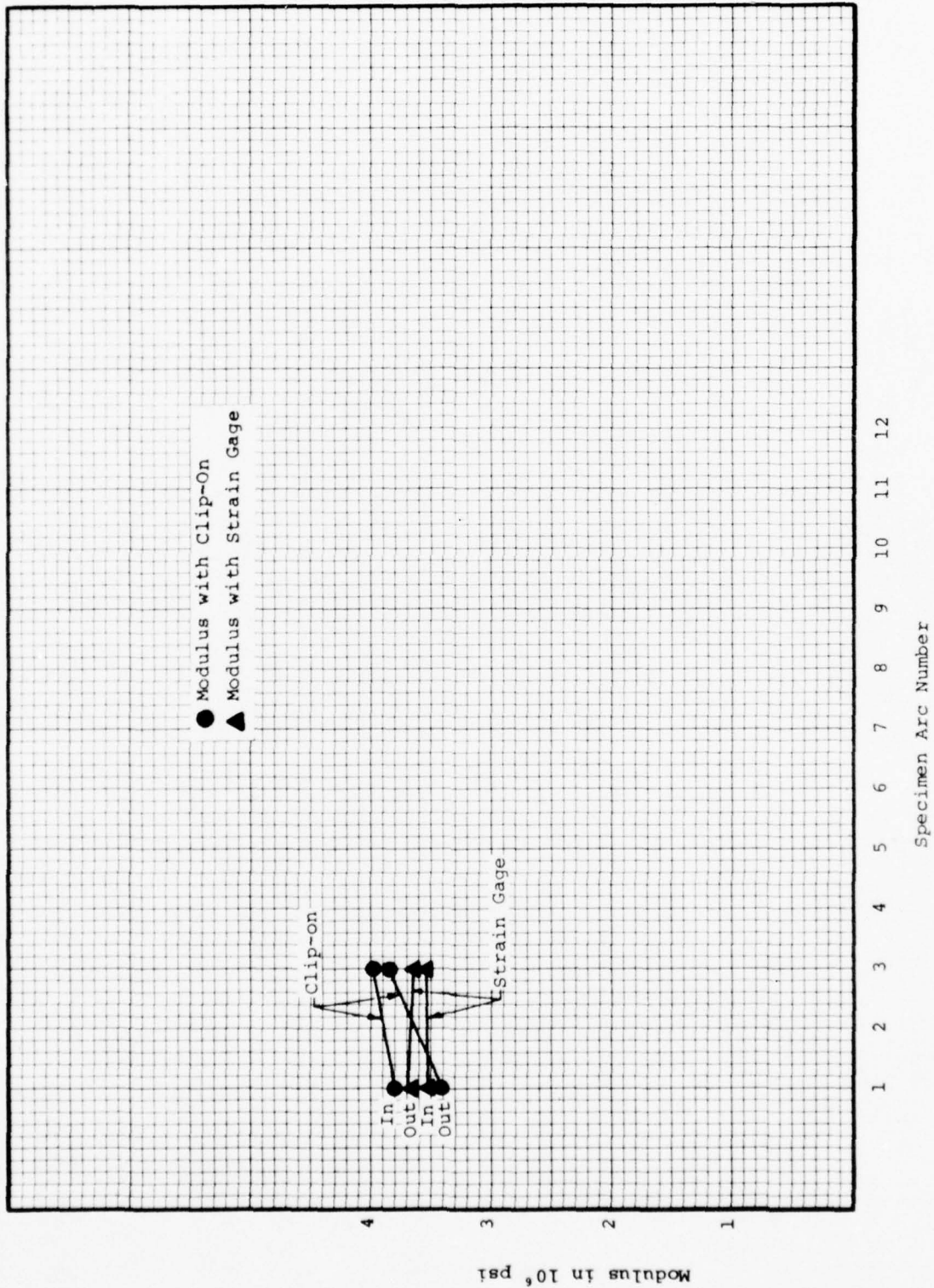


Figure 36. Comparison of Rectangular Circumferential Clip-on versus Strain Gage Data 6.1.4

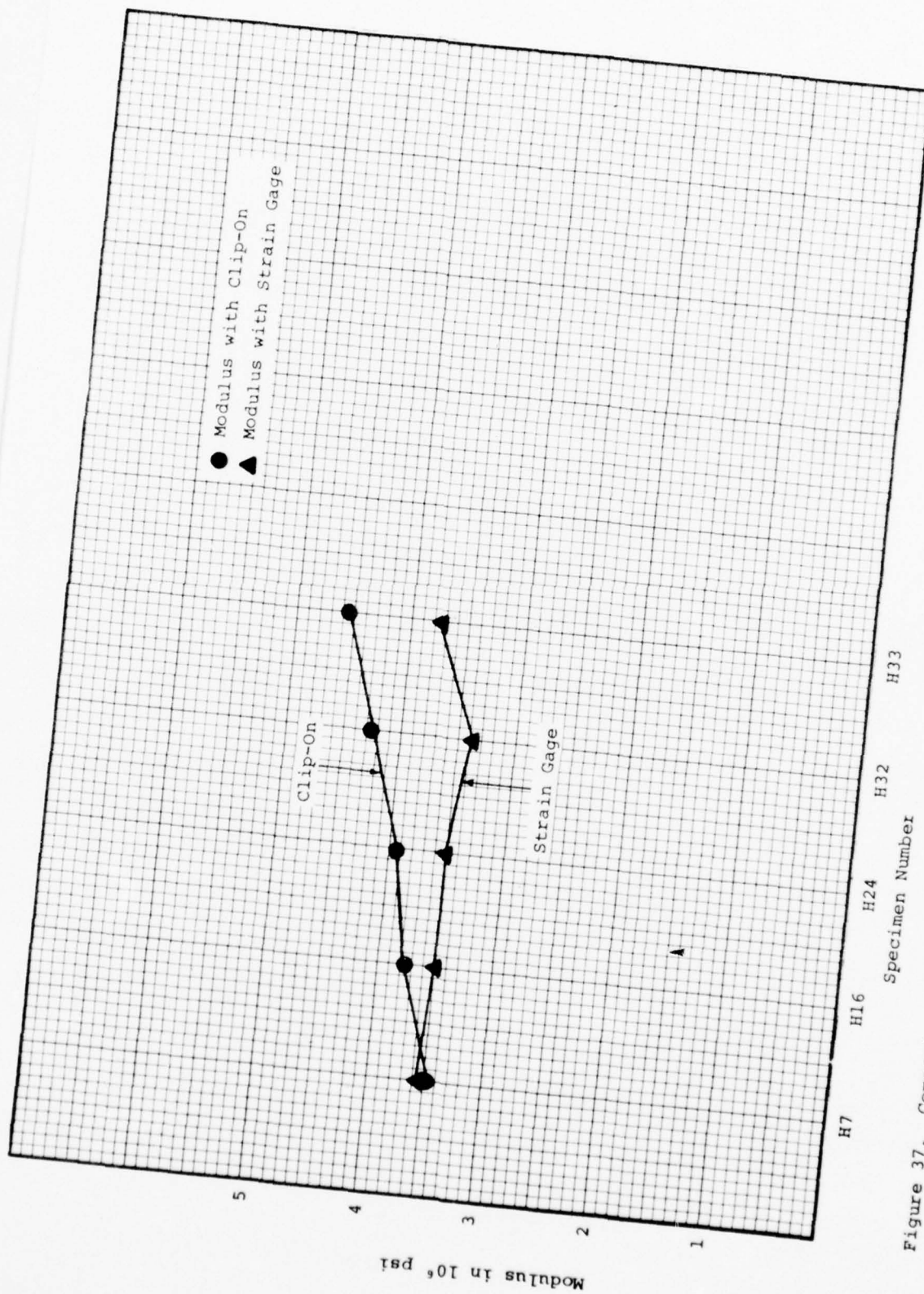


Figure 37. Comparison of Rectangular Circumferential Clip-On versus Strain Gage Data 4.1.18

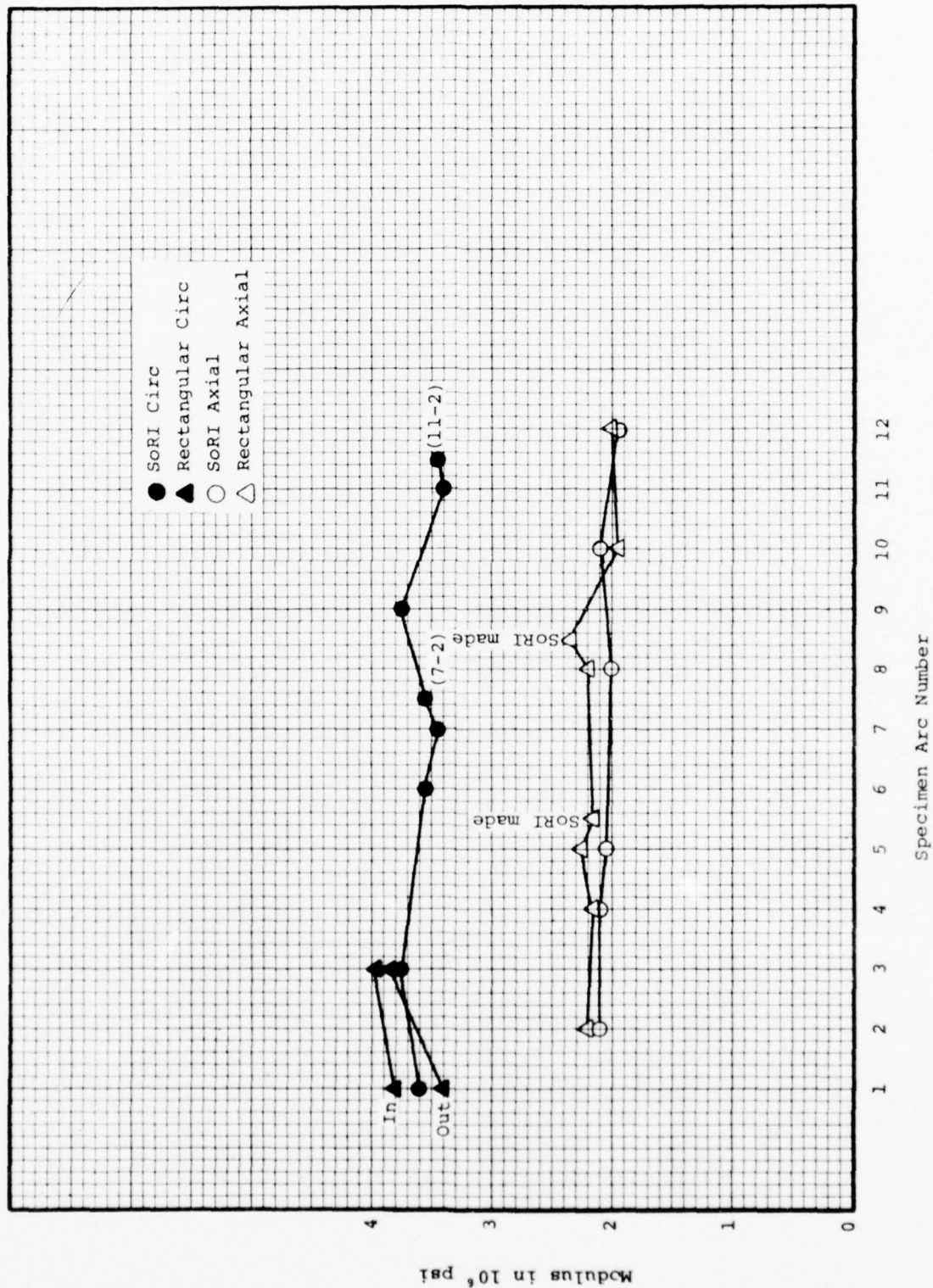


Figure 38. Rectangular versus SoRI Design Specimens Modulus Calculated From Clip-on

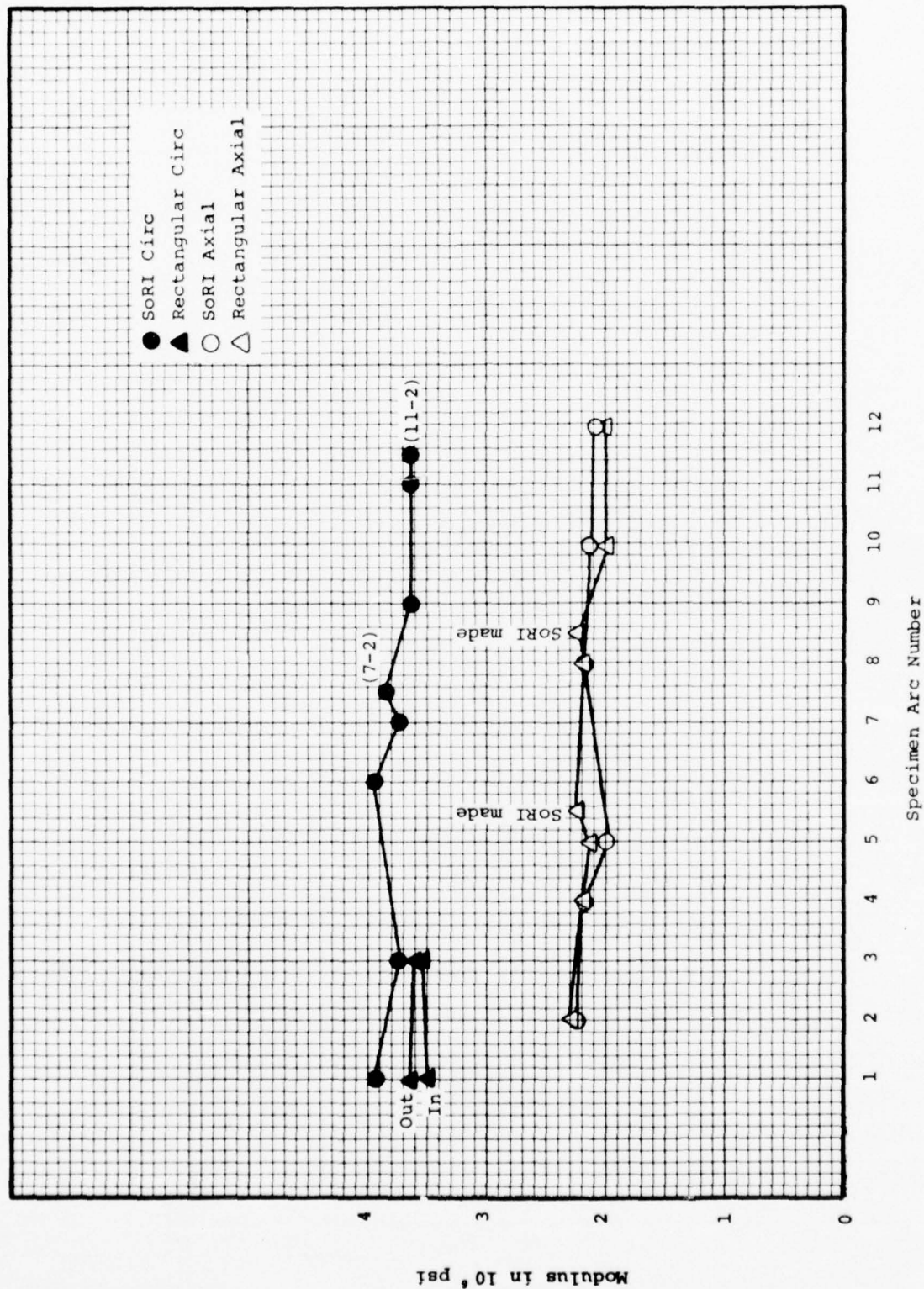


Figure 39. Rectangular versus SoRI Design Specimens Modulus Calculated From Strain Gage

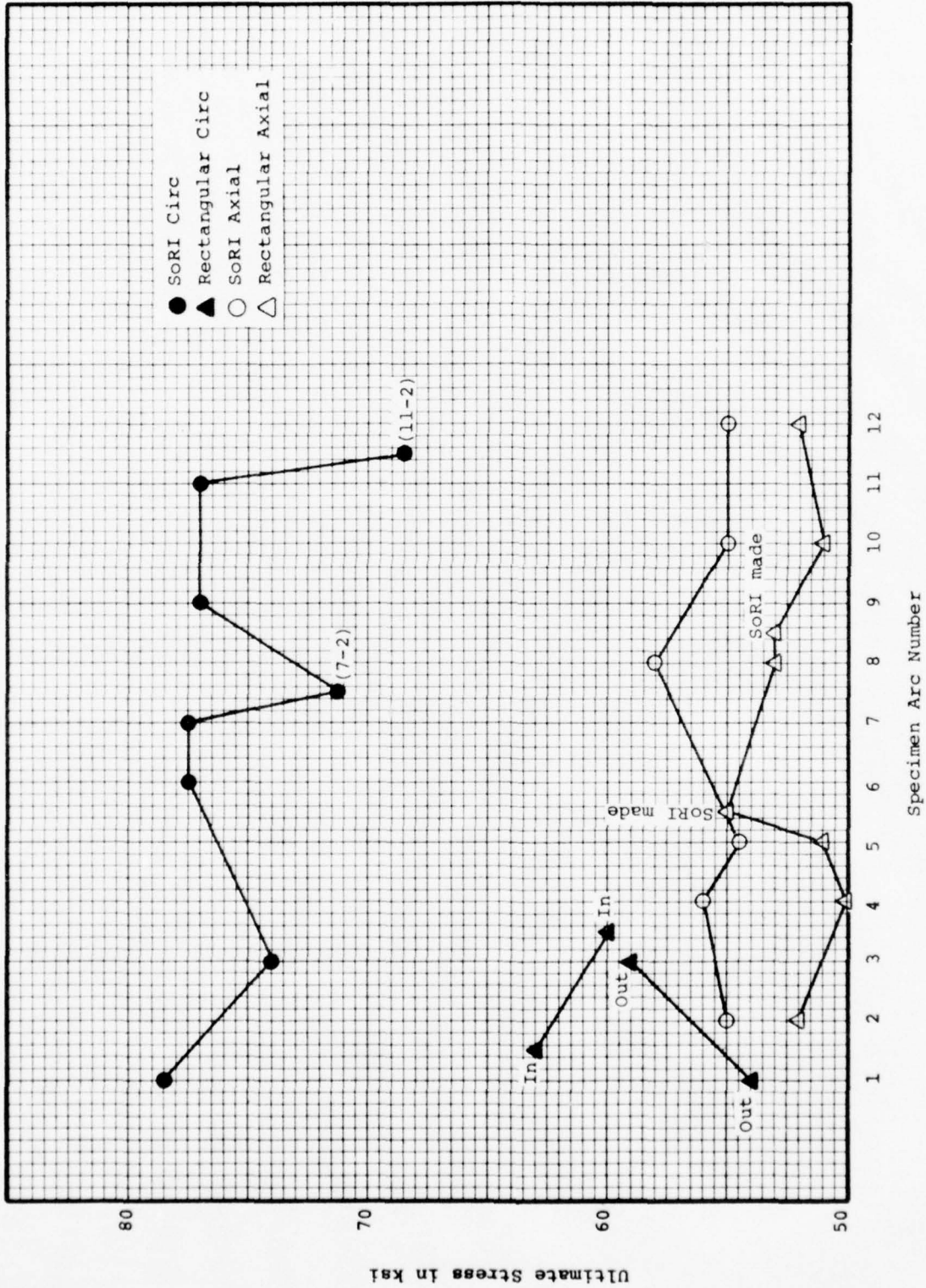


Figure 40. Rectangular versus SoRI Design Specimens Ultimate Stress

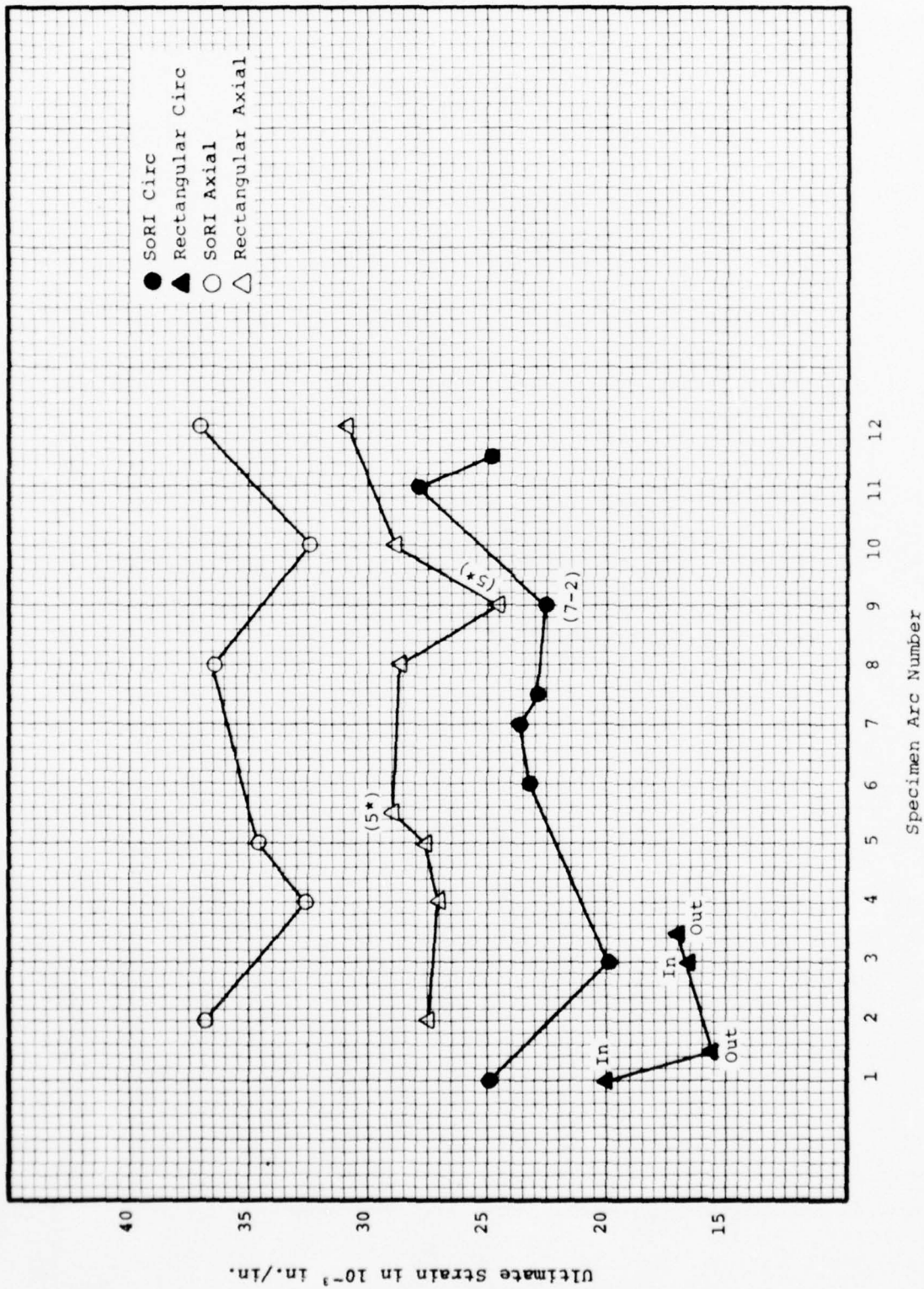


Figure 41. Comparison of Rectangular versus SoRI Design Specimens Ultimate Strain from Clip-ons

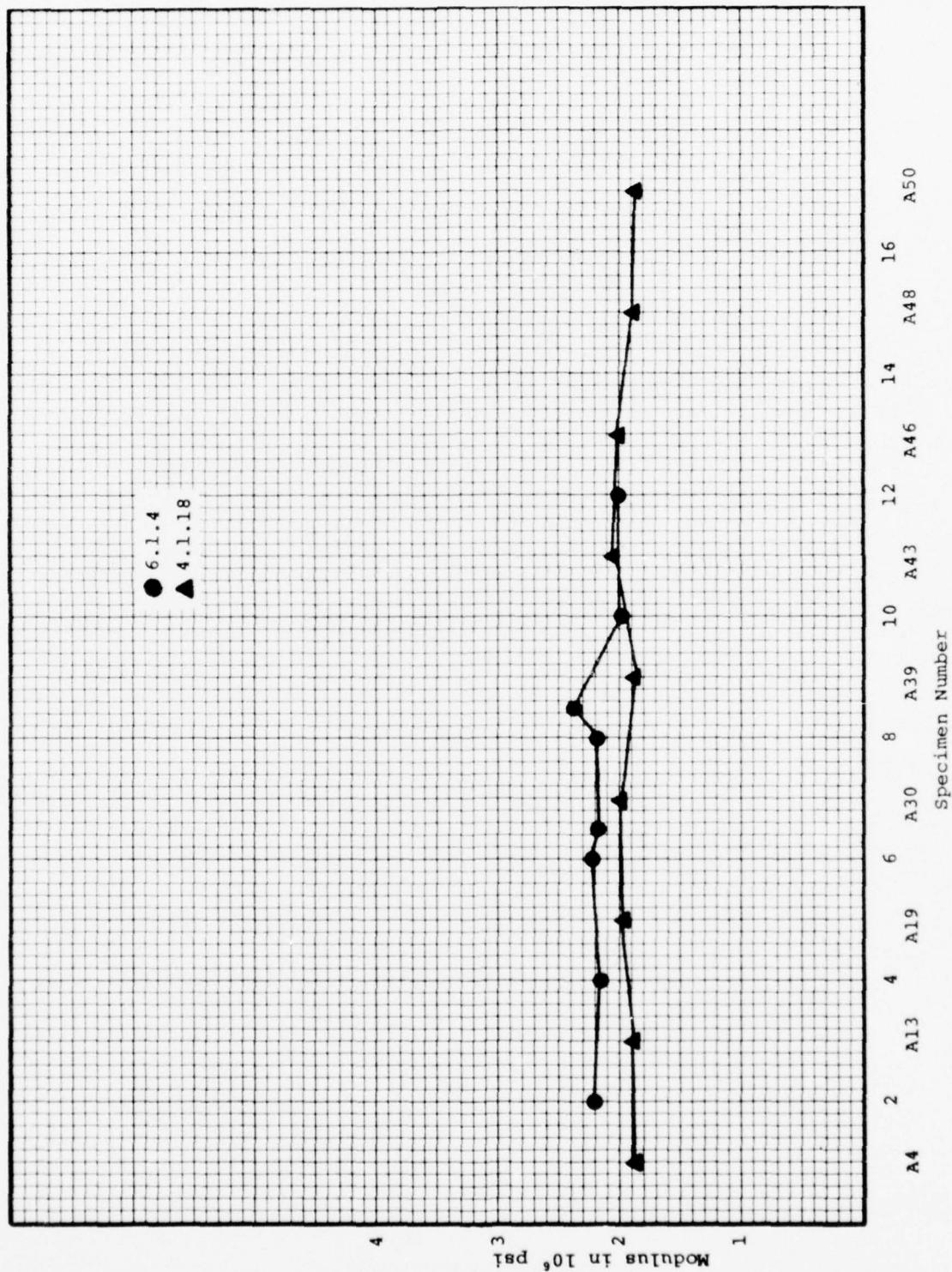


Figure 42. Rectangular Axial Specimens 6.1.4 versus 4.1.18 Modulus (Clip-on)

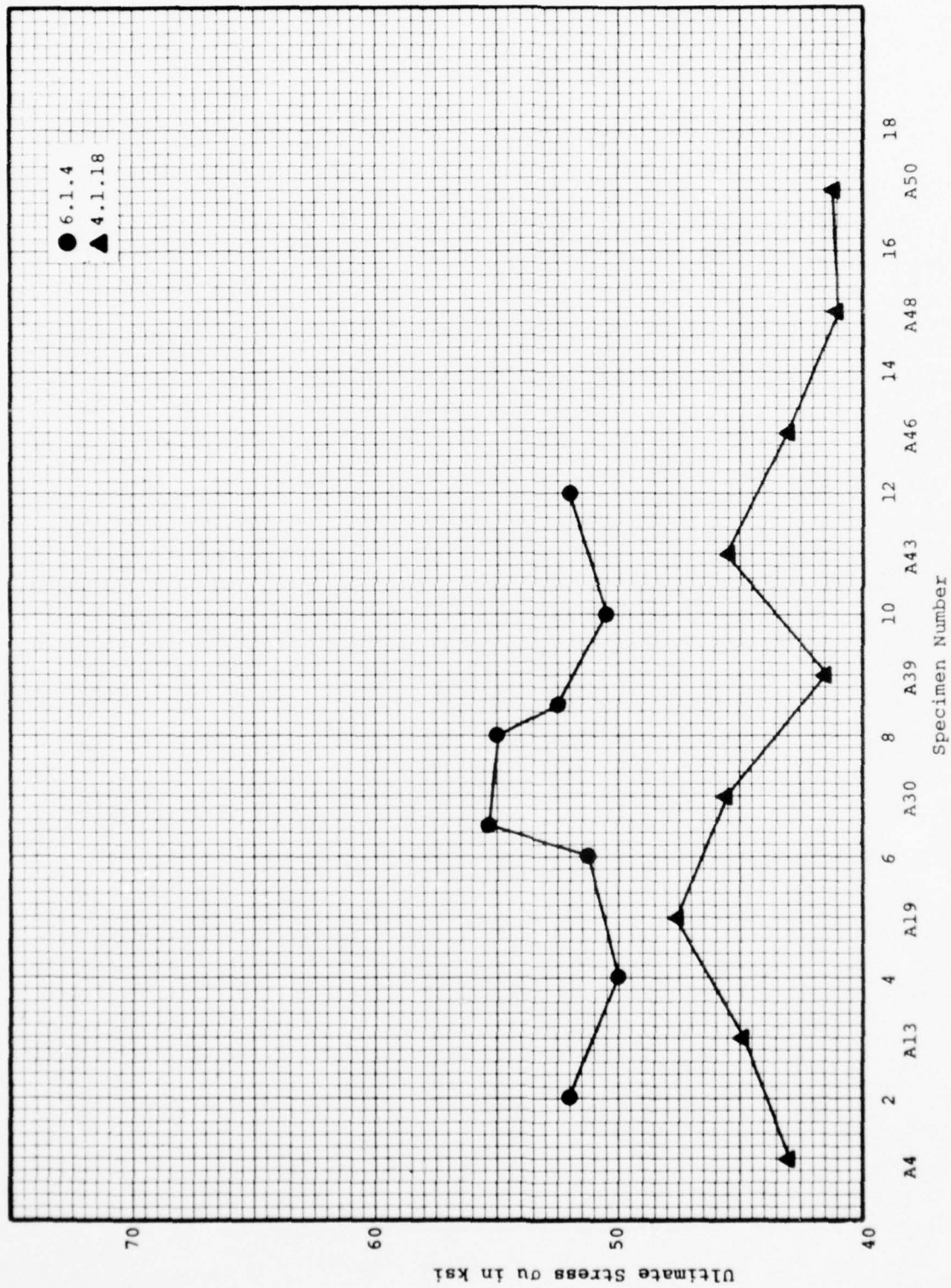


Figure 43. Rectangular Axial Specimens 6.1.4 versus 4.1.18

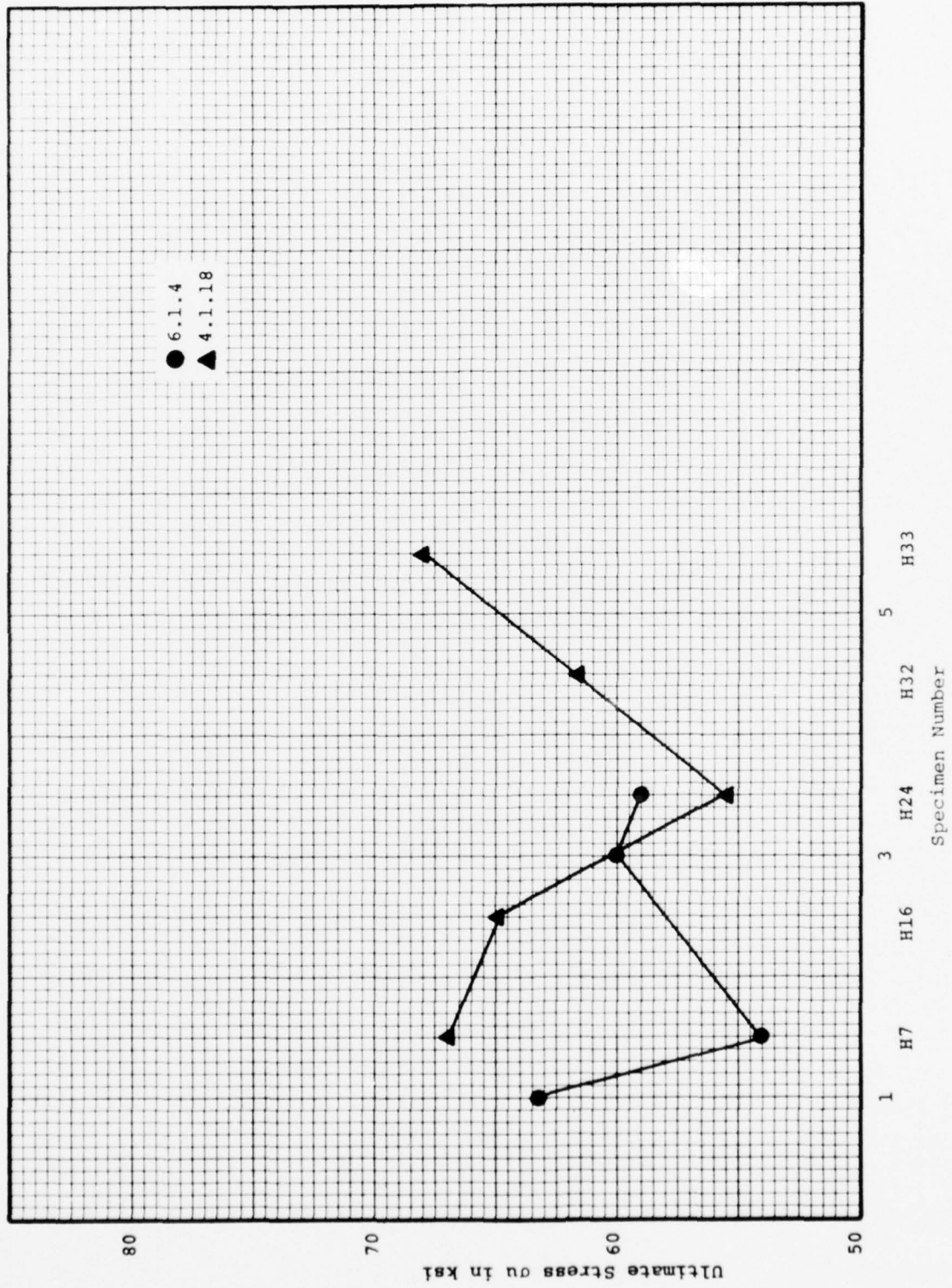


Figure 44. Rectangular Circumferential Specimens 6.1.1.4 versus 4.1.1.18

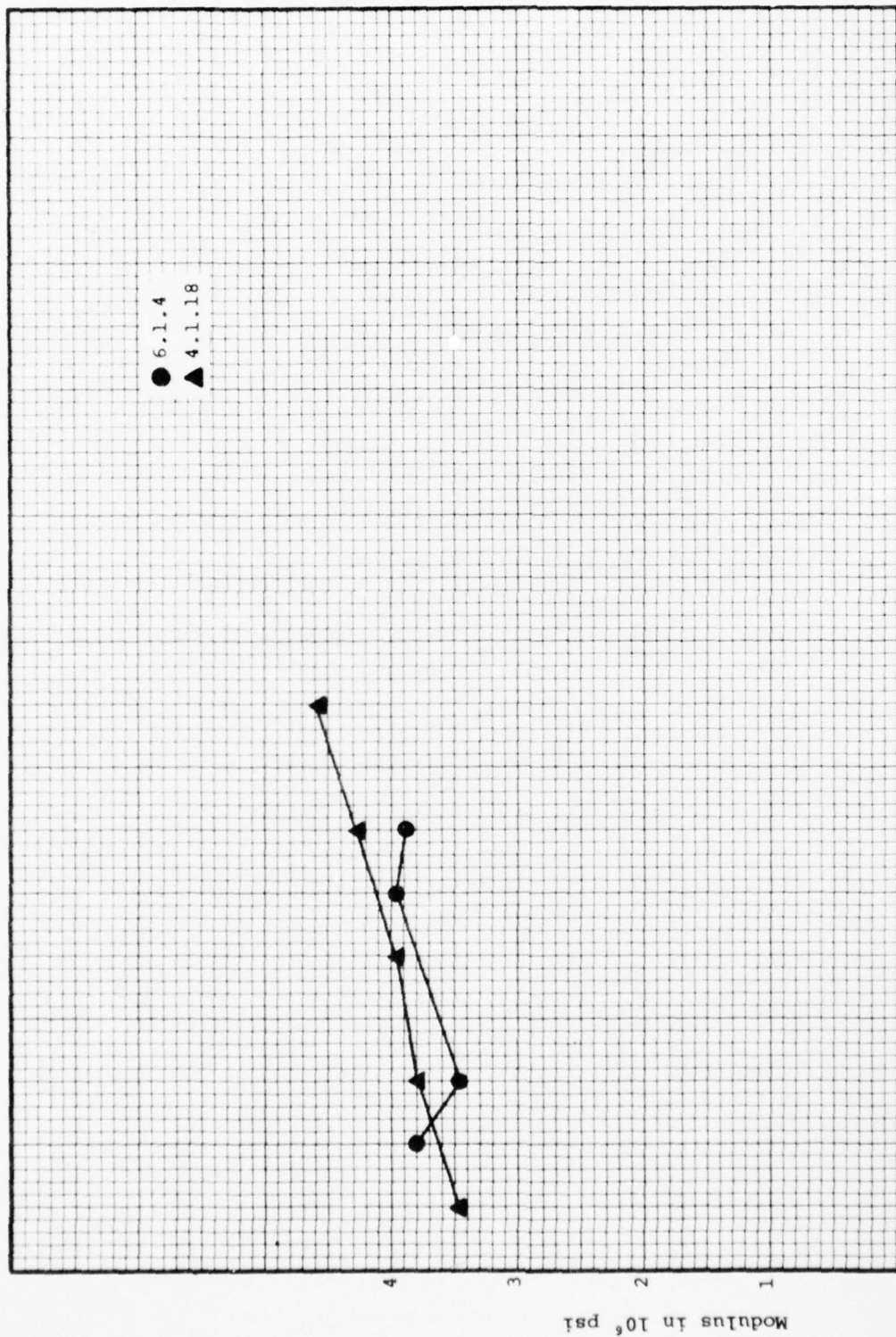


Figure 45. Rectangular Circumferential Specimens 6.1.4 versus 4.1.18 Modulus (Clip-on)

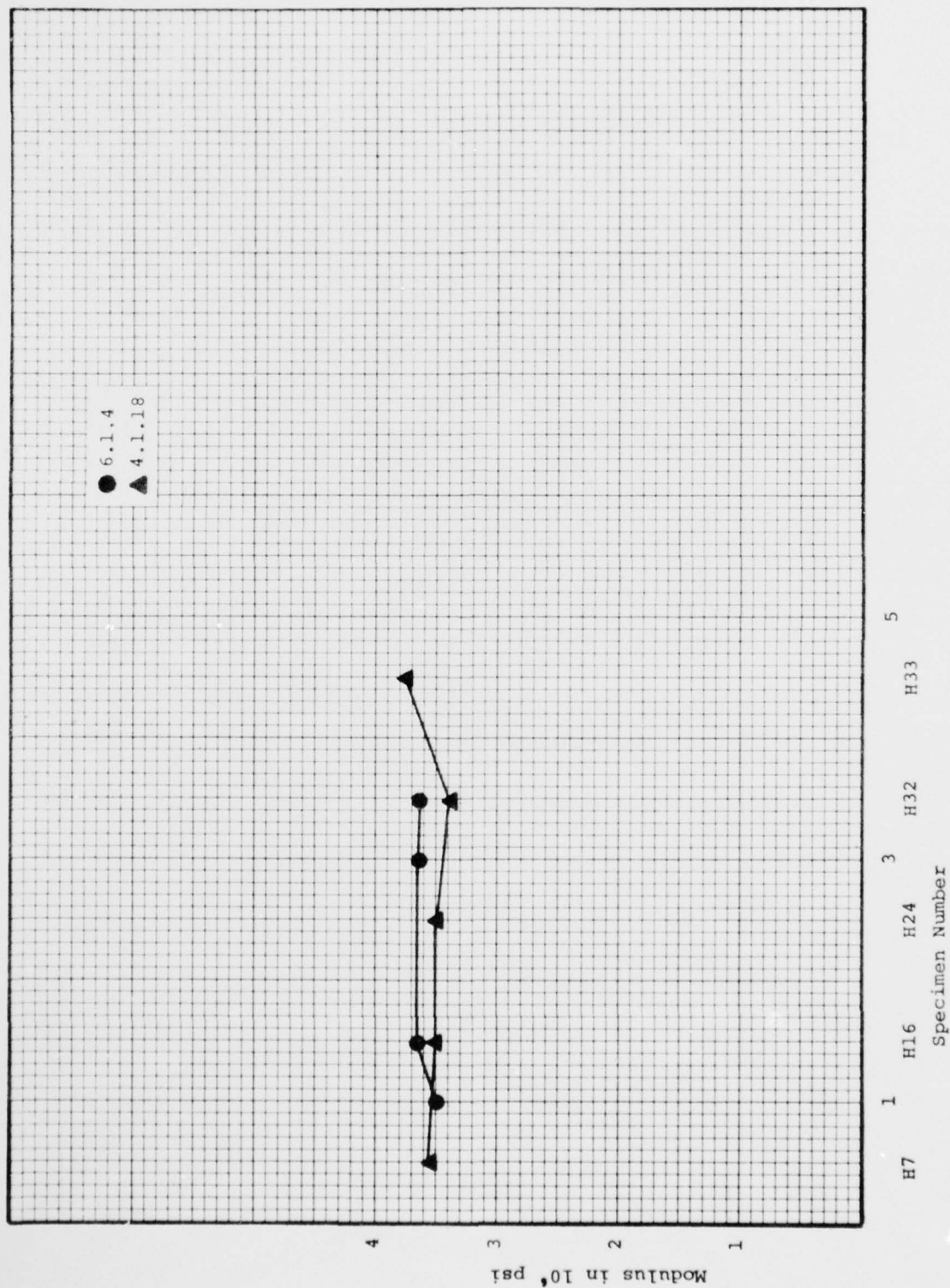


Figure 46. Rectangular Circumferential Specimens 6.1.1.4 versus 4.1.1.18 Modulus (Strain Gage)

Table 1
TEST MATRIX

	SoRI Design SoRI Machined	Rectangular Design Pre-Machined	Rectangular Design SoRI Machined
6.1.4	Hoop	--	4
	Axial	6	2
4.1.18	Hoop	5	--
	Axial	9*	--

*only 0.5 inch wide

Table 2
NONDESTRUCTIVE CHARACTERIZATION RESULTS ON TWELVE ARCS
FROM CYLINDER 6.1.4

Arc	Circs/in.	Density gm/cm ³	Axial Velocity in./μsec	Circ Velocity in./μsec	Radial Velocity in./μsec
C1	96	1.680		0.1807	0.1913
A2	96	1.688	0.1790		
C3	96	1.687		0.1804	0.1917
A4	96	1.679	0.1797		
A5	92	1.685	0.1803		
C6	96	1.685		0.1821	0.1990
C7	92	1.676		0.1798	0.1932
A8	100	1.695	0.1802		
C9	96	1.683		0.1812	0.1918
A10	96	1.685	0.1792		
C11	96	1.689		0.1801	0.1951
A12	92	1.688	0.1801		
	Average	1.685	0.1798	0.1809	0.1937
	SD	0.005	0.0008	0.0012	0.0036

Table 3

DENSITIES OF HOOP AND AXIAL SPECIMENS
FROM CYLINDER 4.1.18

Specimen		Density gm/cm ³
H7-CC-Rect	a	1.614
	b	1.611
H16-CC-Rect	a	1.621
	b	1.634
H24-CC-Rect	a	1.633
	b	1.634
H32-CC-Rect	a	1.631
	b	1.638
H33-CC-Rect	a	1.623
	b	1.623
Average		<u>1.626</u>
A4-AC-Rect		1.628
A13-AC-Rect		1.620
A19-AC-Rect		1.623
A30-AC-Rect		1.624
A39-AC-Rect		1.626
A43-AC-Rect		1.625
A46-AC-Rect		1.625
A48-AC-Rect		1.623
A50-AC-Rect		<u>1.621</u>
Average		1.624

Table 4

DENSITIES OF FIVE SPECIMENS MACHINED
FROM THE INSIDE SURFACE ADJACENT TO
RESPECTIVE ARCS IN CYLINDER 6.1.4

Specimen	Density gm/cm ³
2-AC-Rect	1.660
4-AC-Rect	1.660
5-AC-Rect	1.665
8-AC-Rect	1.663
10-AC-Rect	1.661
12-AC-Rect	1.660
Average	<u>1.662</u>

Table 5

AXIAL COMPRESSIVE TESTS
SoRI SPECIMEN CONFIGURATION 3DQP 6.1.4

Specimen Number	Tangent Modulus E ($\times 10^6$ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u ($\times 10^{-3}$ in./in.)
	Clip-on	S.G.		
2-AC-SoRI	2.10	2.24	55,400	36.8
4-AC-SoRI	2.10	2.20	56,000	32.6
5-AC-SoRI	2.07	2.00	54,500	34.6
8-AC-SoRI	2.05	2.20	58,000	36.4
10-AC-SoRI	2.09	2.15	55,000	32.4
12-AC-SoRI	1.92	2.10	55,500	37.0
$\bar{X}$	2.06	2.15	55,733	35.0
S	0.07	0.09	1,219	2.1

Table 6
AXIAL COMPRESSIVE TESTS
RECTANGULAR SPECIMEN CONFIGURATION 3DQP 6.1.4

Specimen Number	Tangent Modulus E (x 10 ⁶ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u (x 10 ⁻³ in./in.)
	Clip-on	S.G.		
2-AC-Rect	2.20	2.26	52,000	27.4
4-AC-Rect	2.16	2.20	50,000	27.0
5-AC-Rect*	2.18	2.25	55,400	28.9
5-AC-Rect	2.23	2.13	51,200	27.6
8-AC-Rect*	2.38	2.28	52,500	24.5
8-AC-Rect	2.19	2.20	55,000	28.7
10-AC-Rect	1.98	2.00	50,600	28.8
12-AC-Rect	2.00	2.02	52,000	30.8
$\bar{X}$	2.17	2.17	52,338	28.0
S	0.13	0.11	1,946	1.8

*Specimen from same arc number machined at SoRI

Table 7

AXIAL COMPRESSIVE TESTS
RECTANGULAR SPECIMEN CONFIGURATION 3DQP 4.1.18

Specimen Number	Tangent Modulus E ($\times 10^6$ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u ($\times 10^{-3}$ in./in.)
	Clip-on	S.G.		
A4-AC-Rect	1.88	1.89	43,000	23.6
A13-AC-Rect	1.88	1.91	44,800	25.0
A19-AC-Rect	1.96	1.98	47,600	26.4
A30-AC-Rect	1.99	2.00	45,500	24.1
A39-AC-Rect	1.88	1.77	41,400	22.8
A43-AC-Rect	2.05	1.90	45,500	24.4
A46-AC-Rect	2.00	1.86	43,000	22.9
A48-AC-Rect	1.88	1.71	41,000	25.6
A50-AC-Rect	1.86	1.76	41,100	24.3
$\bar{X}$	1.93	1.86	43,656	24.3
S	0.07	0.10	2,324	1.2

Table 8

CIRCUMFERENTIAL COMPRESSIVE TESTS
SoRI SPECIMEN CONFIGURATION 3DQP 6.1.4

Specimen Number	Tangent Modulus E ($\times 10^6$ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u ($\times 10^{-3}$ in./in.)	
	Clip-on	S.G.		Clip-on	
1-CC-SoRI	3.60	3.91	78,500	24.9	
3-CC-SoRI	3.73	3.78	73,800	19.9	
6-CC-SoRI	3.55	3.96	77,400	23.2	
7-1-CC-SoRI	3.45	3.76	77,600	23.7	
7-2-CC-SoRI	3.54	3.85	70,800	22.9	
9-CC-SoRI	3.70	3.65	77,000	22.6	
11-1-CC-SoRI	3.40	3.66	68,500	27.8	
11-2-CC-SoRI	3.35	3.63	76,800	24.8	
$\bar{X}$	3.54	3.78	75,050	23.7	
S	0.14	0.12	3,651	2.3	

Table 9
CIRCUMFERENTIAL COMPRESSIVE TESTS
RECTANGULAR SPECIMEN CONFIGURATION 3DQP 6.1.4

Specimen Number	Tangent Modulus E ($\times 10^6$ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u ($\times 10^{-3}$ in./in.)
	Clip-on	S.G.		
1 (In)-CC-Rect	3.80	3.50	63,200	19.9
1 (Out)-CC-Rect	3.45	3.65	54,000	15.6
3 (In)-CC-Rect	3.95	3.63	60,000	16.6
3 (Out)-CC-Rect	3.88	3.64	59,000	17.0
$\bar{X}$	3.77	3.61	59,050	17.3
S	0.22	0.07	3,814	1.9

Table 10
CIRCUMFERENTIAL COMPRESSIVE TESTS
RECTANGULAR SPECIMEN CONFIGURATION 3DQP 4.1.18

Specimen Number	Tangent Modulus E (x 10 ⁶ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u (x 10 ⁻³ in./in.)
	Clip-on	S.G.		
H7-CC-Rect	3.47	3.53	67,000	17.7
H16-CC-Rect	3.78	3.50	65,000	19.3
H24-CC-Rect	3.94	3.50	55,400	16.0
H32-CC-Rect*	4.25	3.37	61,700	15.8
H33-CC-Rect	4.55	3.75	68,000	17.8
$\bar{X}$	4.00	3.53	63,420	17.3
S	0.42	0.14	5,088	1.4

*Apparent bending in specimen

Table 11
70°F AXIAL COMPRESSIVE DATA COMPARISON

Program	AHP	CRS	6.1.4	6.1.4
Material				
Process	A	C	C	C
A_r/A_t	0.48	0.607	0.700	0.700
S/P	P	P	S	S
Density	1.67	(1.64)*	1.685	1.685
Velocity				
Radial	(0.197)	(0.173)	(0.194)	(0.194)
Axial	0.1732 (0.1840)	(0.171)	0.180	0.180
Circ	0.1894	-	(0.179)	(0.179)
Type Test	Coupon	Coupon (Inners & Full)	SoRI Design	Rectangular Design
Specimen Gage (in.)	4 cells/0.5/ 1.2	(0.6 x 0.5 x 0.8) (0.6 x 0.2 x 0.8)	(0.6 x 0.5 x 0.8)	3 cells x 0.2 x 1.0
No. of Tests	3	9	6	8
$\bar{E}$ in 10^6 psi	2.23	2.60	2.06	2.17
$\bar{\sigma}_u$ in 10^6 psi	32.2	45.0	55.7	52.3
$\bar{\epsilon}_u$ in $10^{-3} \frac{\text{in.}}{\text{in.}}$	28.0	21.0	35.0	28.0

*Data not from these particular specimens in parenthesis

Table 12
70°F HOOP COMPRESSIVE DATA COMPARISON

Program	Coated Disc	Coated Disc	AHP	CRS	CRS	CRS/Spades	6.1.4	6.1.4
Material Process A _r /A _t S/P	A 0.40 P	A 0.40 P	A 0.48 P	C 0.607 P	C 0.607 P	C 0.45 S	C S	C S
Density	1.61	1.61	1.66 (1.67)	(1.64)	(1.64)	-	1.685	1.685
Velocity Radial Axial Circ	0.1988 - -	0.1988 - -	(0.1971)* (0.1840) 0.1780 (0.1894)	(0.173) (0.171) -	(0.173) (0.171) -	0.166 0.166 -	0.194 (0.180) 0.179	0.194 (0.180) 0.179
Type Test	Inner/100% CCC	Outer/100% CCC	Full/0% CCC	I, O, & Full/ 100% CCC	Hydrostatic	Hydrostatic	SoRI Design	Rectangular Design
Specimen Gage (in.)	0.2 x 0.4 x 0.6	0.2 x 0.4 x 0.6	0.4 x 0.4 x 0.625 and 0.4 x 0.2 x 0.625	0.6 x 0.5 x 0.8 0.6 x 0.2 x 0.8	2.0 x 0.5 x 1.0	2.0 x 0.5 x 1.0	0.6 x 0.5 x 0.8	2 (0.3 x 0.15 x 1.0)
No. of Tests	4	3	3	9	12	2	8	4
E in 10 ⁶ psi	3.07	3.02	2.42	3.81	3.53	3.66	3.54	3.61
σ _u in 10 ³	39.3	37.6	31.2	58.6	-	-	75.1	59.1
ε _u in 10 ⁻³ in. in.	16.5	16.1	20.0	14.3	-	-	23.7	17.3

*Data not from these particular specimens in parenthesis

Table 13

OUTSIDE/INSIDE COMPARISON

Property	ID	OD	Full
Density on full Arcs compared to ID Specimen (Axials) (Adjacent)	1.662	-	1.685
Clip-on Modulus on Circ Specimens (2)	3.87	3.66	(3.54)
S.G. Modulus on Circ Specimens (2)	3.57	3.65	(3.78)
Ultimate Stress on Circ Specimens (2)	61,600	57,000	(75,050)
Ultimate Strain on Circ Specimens (2)	18.2	16.3	(23.7)

Note: Data in parenthesis not truly comparable due to specimen design

Table 14
COMPARISON OF RECTANGULAR AND SORI SPECIMEN CONFIGURATIONS 6.1.4

	Configuration	Tangent Modulus E (x 10 ⁶ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u (x 10 ⁻³ in./in.)
		Clip-on	S.G.		
Axial	SORI	2.06	2.15	55,733	35.0
	Rectangular	2.17	2.17	52,338	28.0
Circ	SORI	3.54	3.78	75,050	23.7
	Rectangular*	3.77	3.61	59,050	17.3

*Inside and outside specimens

Table 15

COMPARISON OF 6.1.4 VERSUS 4.1.18 RECTANGULAR SPECIMEN CONFIGURATION 3DQP

	Cylinder Number	Tangent Modulus E (x 10 ⁶ psi)		Ultimate Stress σ_u (psi)	Ultimate Strain ϵ_u (x 10 ⁻³ in./in.)	
		Clip-on	S.G.		Clip-on	
Axial	6.1.4	2.17	2.17	52,338	28.0	
	4.1.18	1.93	1.86	43,656	24.3	
Circ	6.1.4*	3.88	3.57	61,600	18.3	
	4.1.18	4.00	3.53	63,420	17.3	

*Specimens from inside surface of cylinder only

APPENDIX A

Raw Data

A1

Axial Compressive Tests
SoRI Specimen Configuration

6.1.4

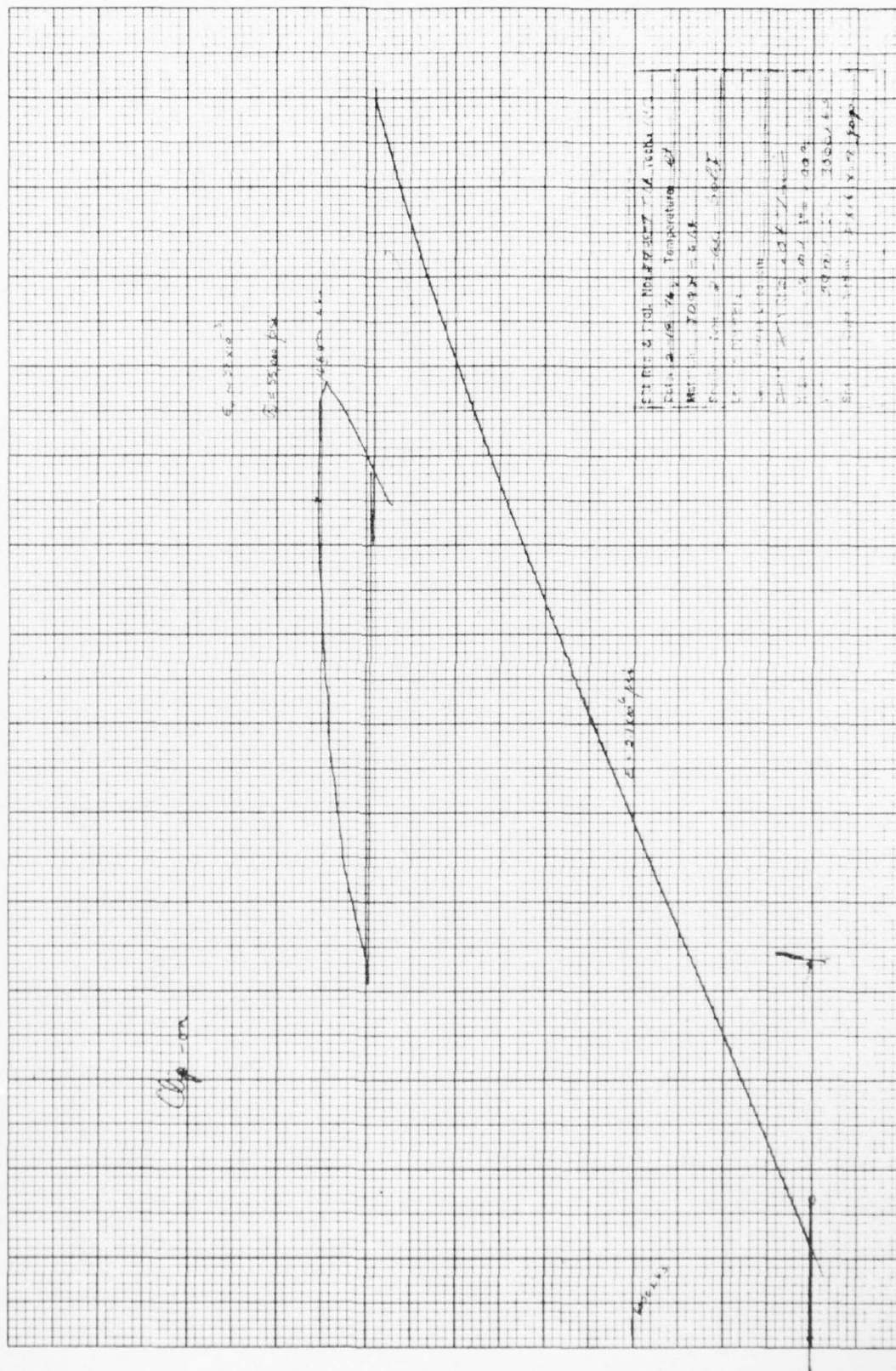


Figure A1 - Test results for Specimen 3 AC Sub 1

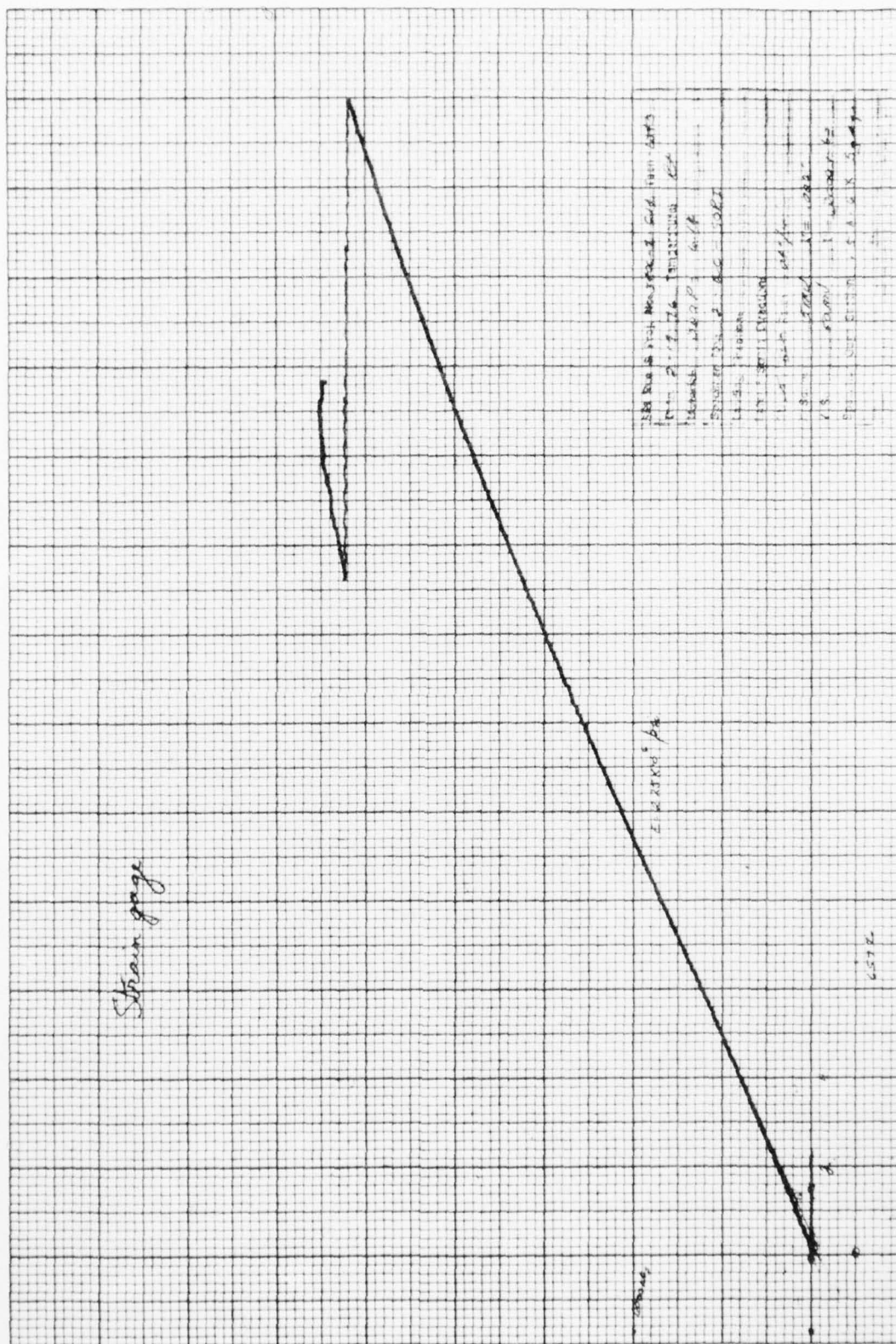
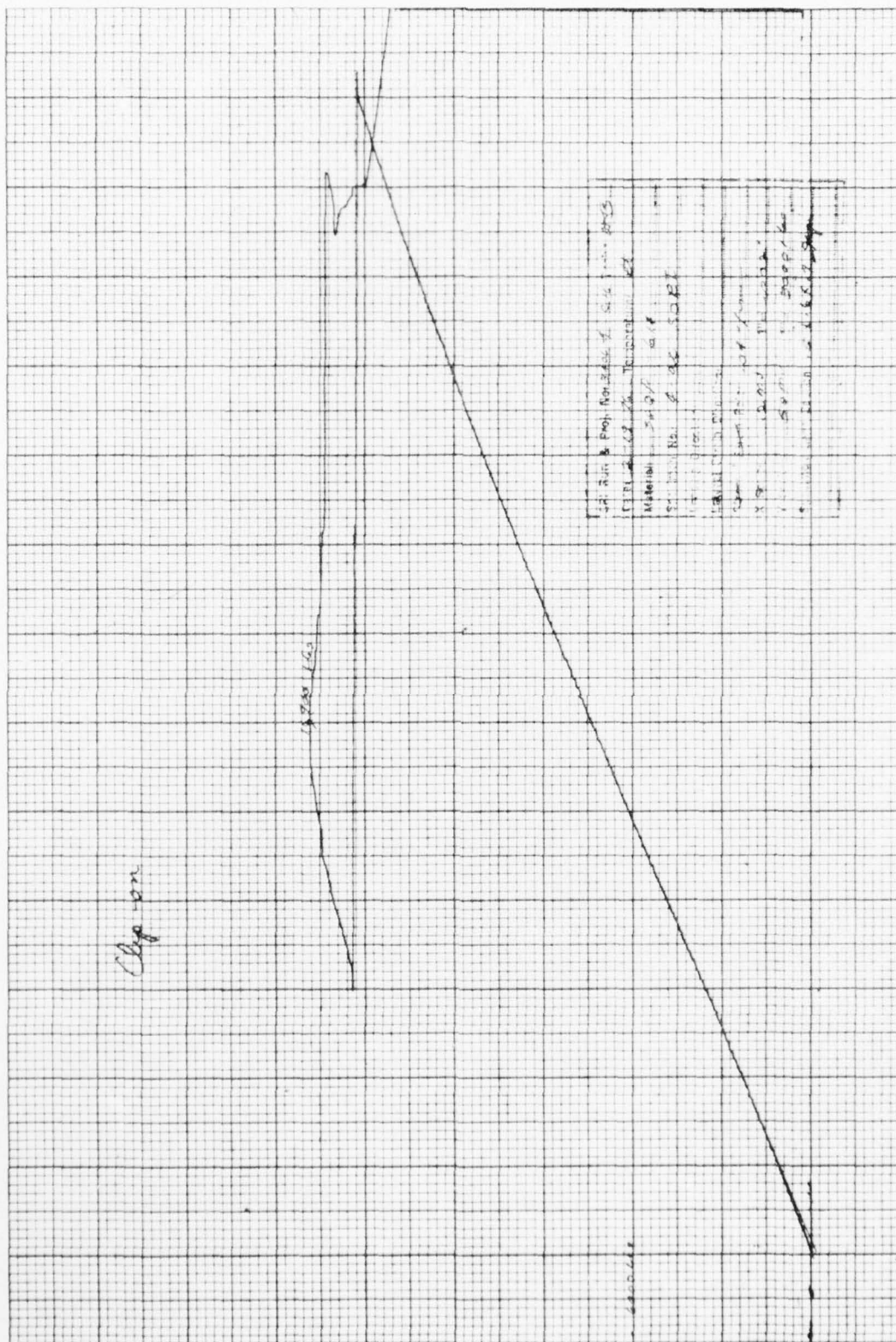


Figure 12 - True Stress vs. True Strain for Specimen 2-ABC-Sub-B

Clap on



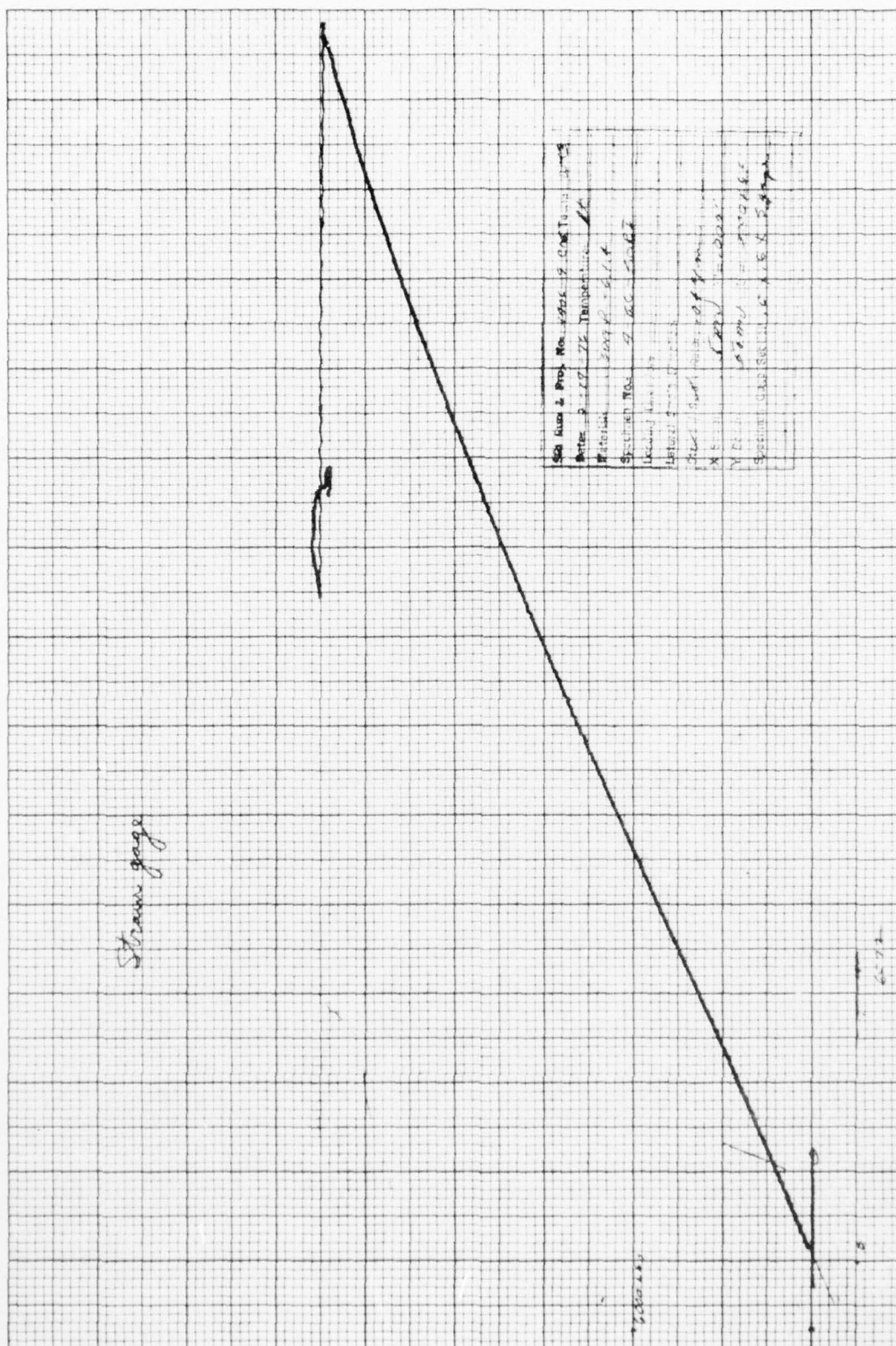
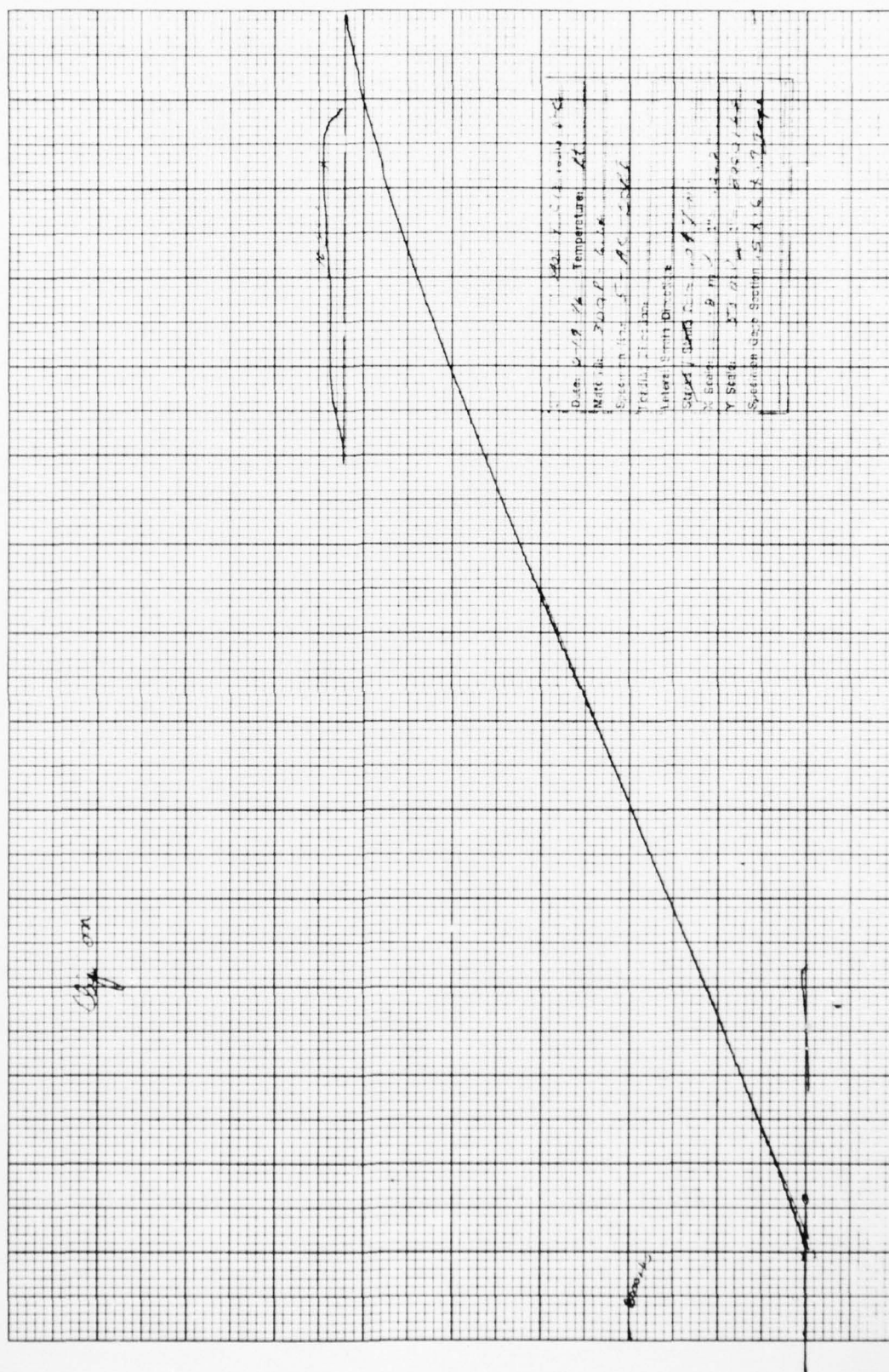


Figure 14. Test Results for Specimen 4-HC-SaB1



[illegible]

Figure A-6. Test Results for Specimen 5-AC-50A1

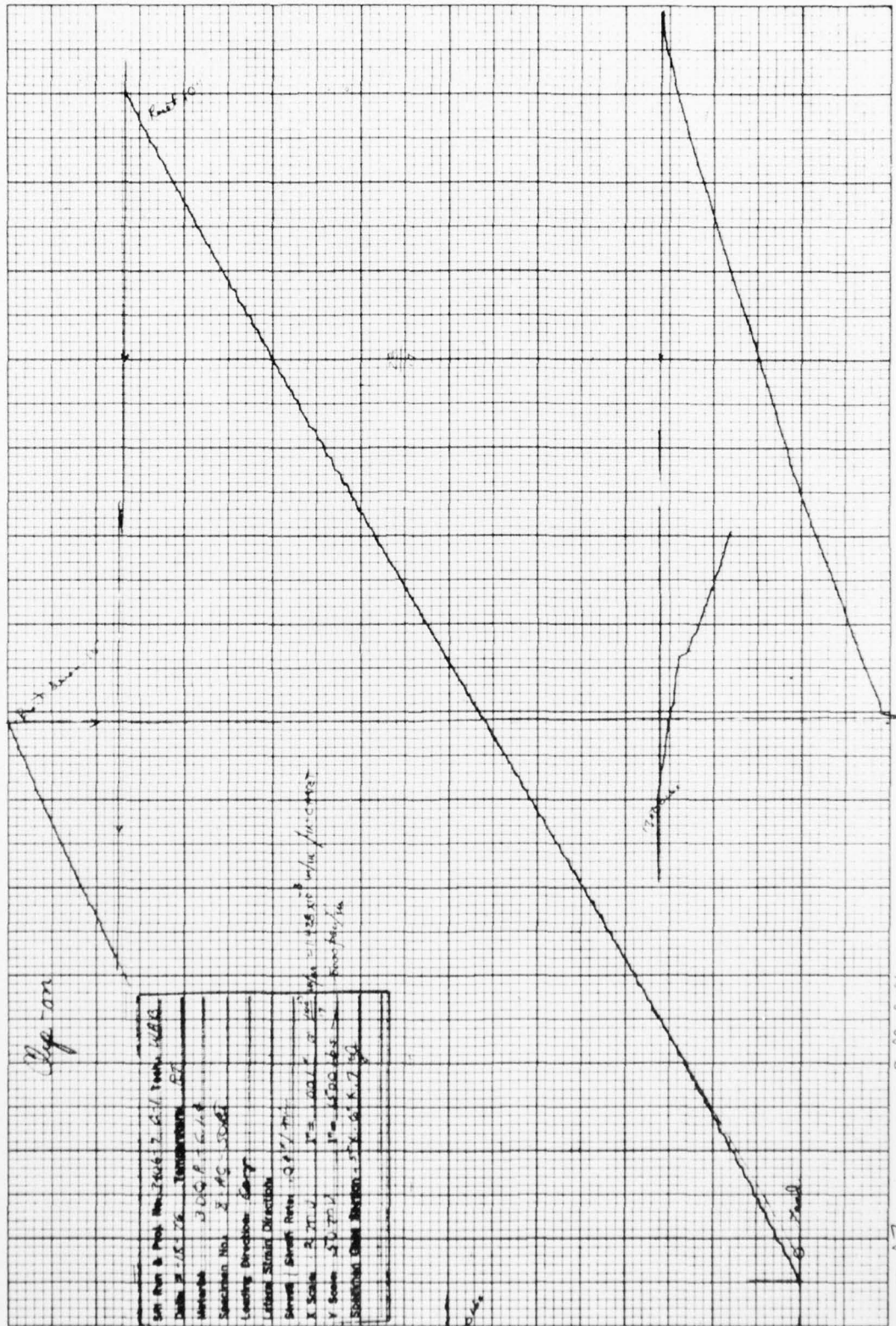
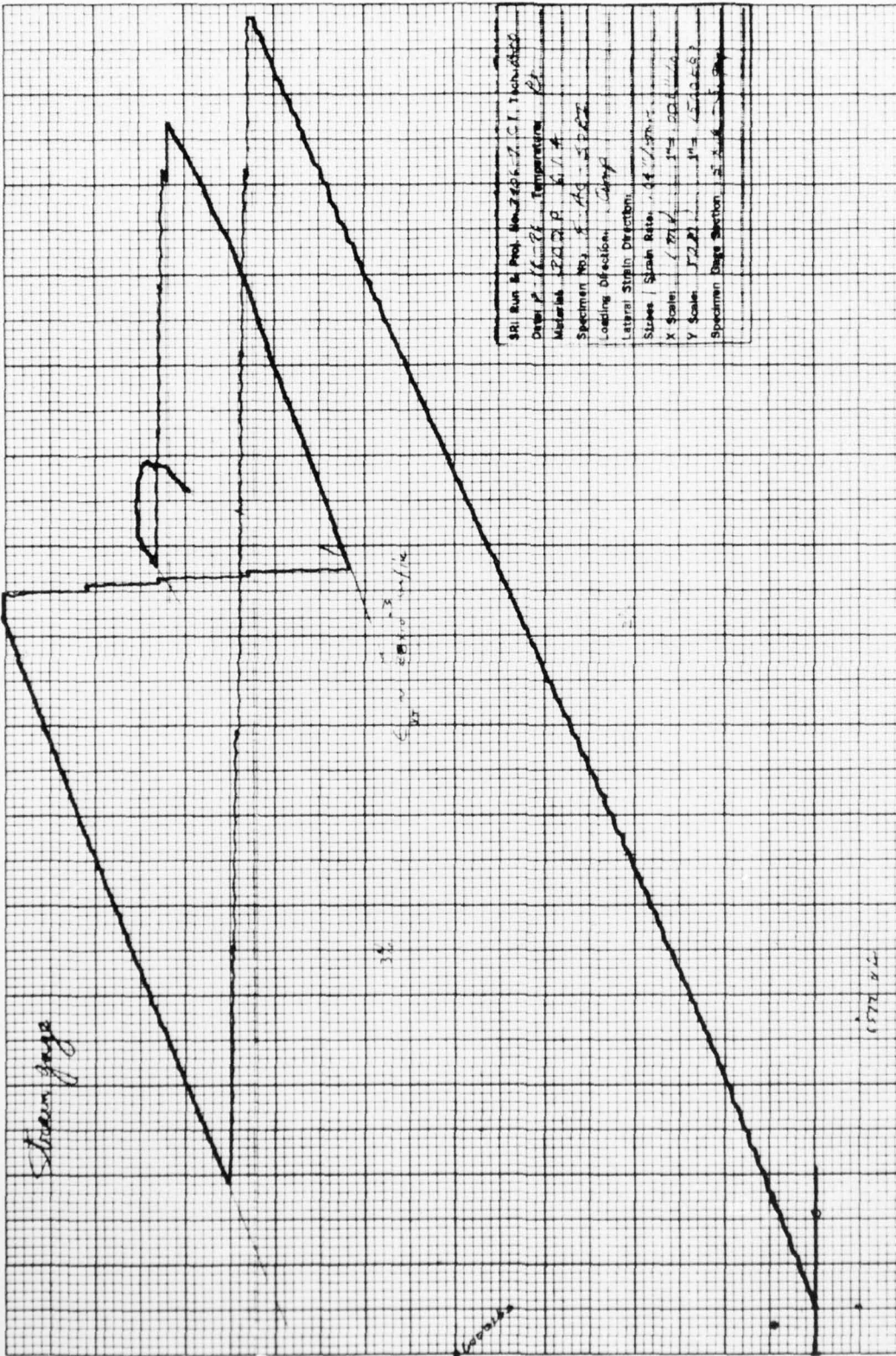


Figure A7 - Test Results for Specimen 8-AQ-500



SAI Run #	Prod. No.	3486-2	C.I. No.	1000000
Date	P.	10-21-71	Temperature	72
Material	P222	P.	61	4
Specimen No.	5	149	5	722
Loading Direction	Along			
Letter	Strain Direction			
Stress / Strain Ratio	1.5 x 10^4			
X Scale	1.5 x 10^4			
Y Scale	1.5 x 10^4			
Specimen Edge Section	2.5 x 10^4			

Figure A8 Test Results for Specimen 8-A-C-SaR1

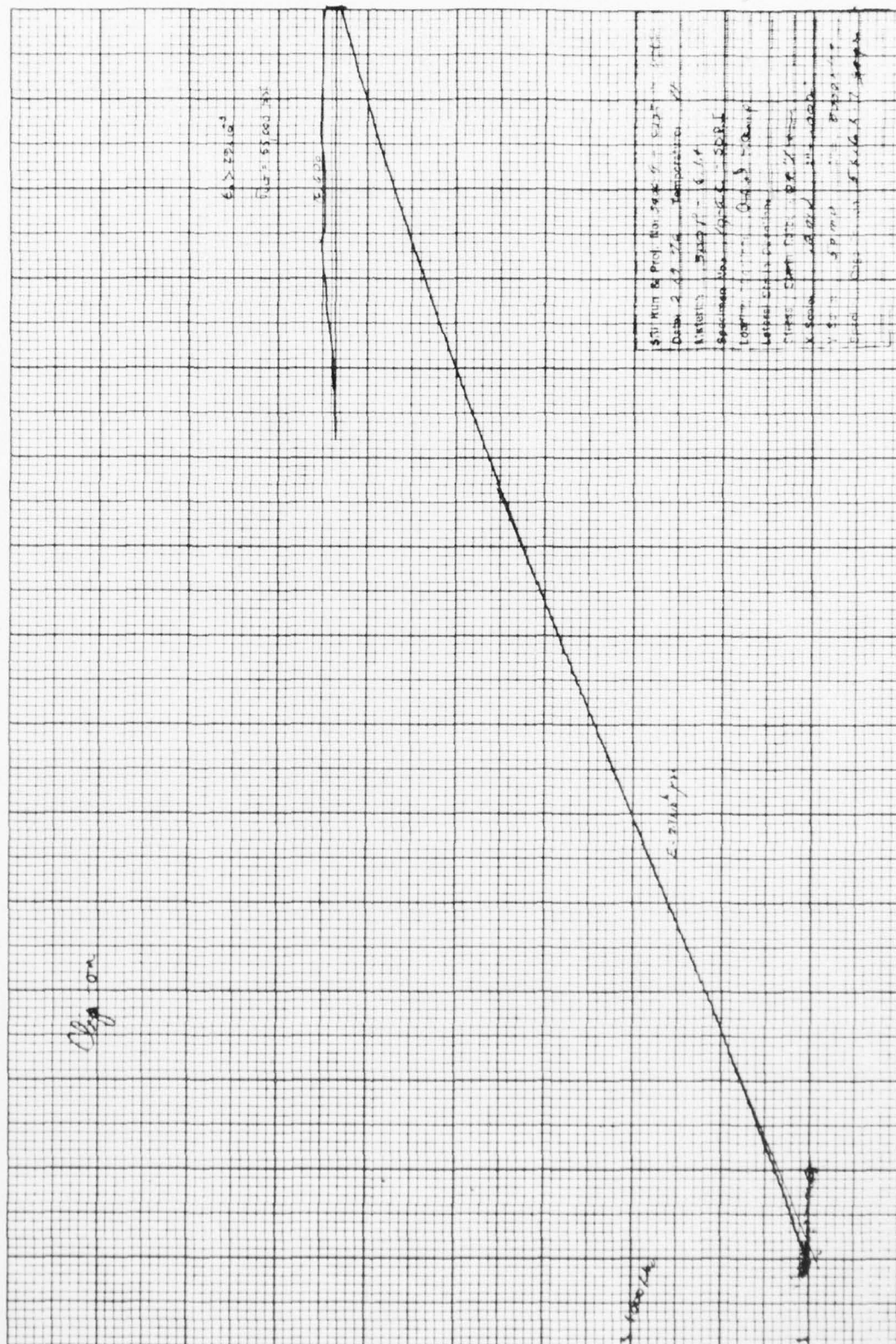


Figure 19. Test Results for Specimen 1A-HC-SAR1

[illegible][illegible]

AD-A044 031

SOUTHERN RESEARCH INST BIRMINGHAM ALA

F/G 11/9

EVALUATION OF THE COMPRESSIVE PROPERTIES OF A SPECIAL 3DQP.(U)

SEP 76 J R KOENIG, G F FORNARO

DNA001-75-C-0037

UNCLASSIFIED

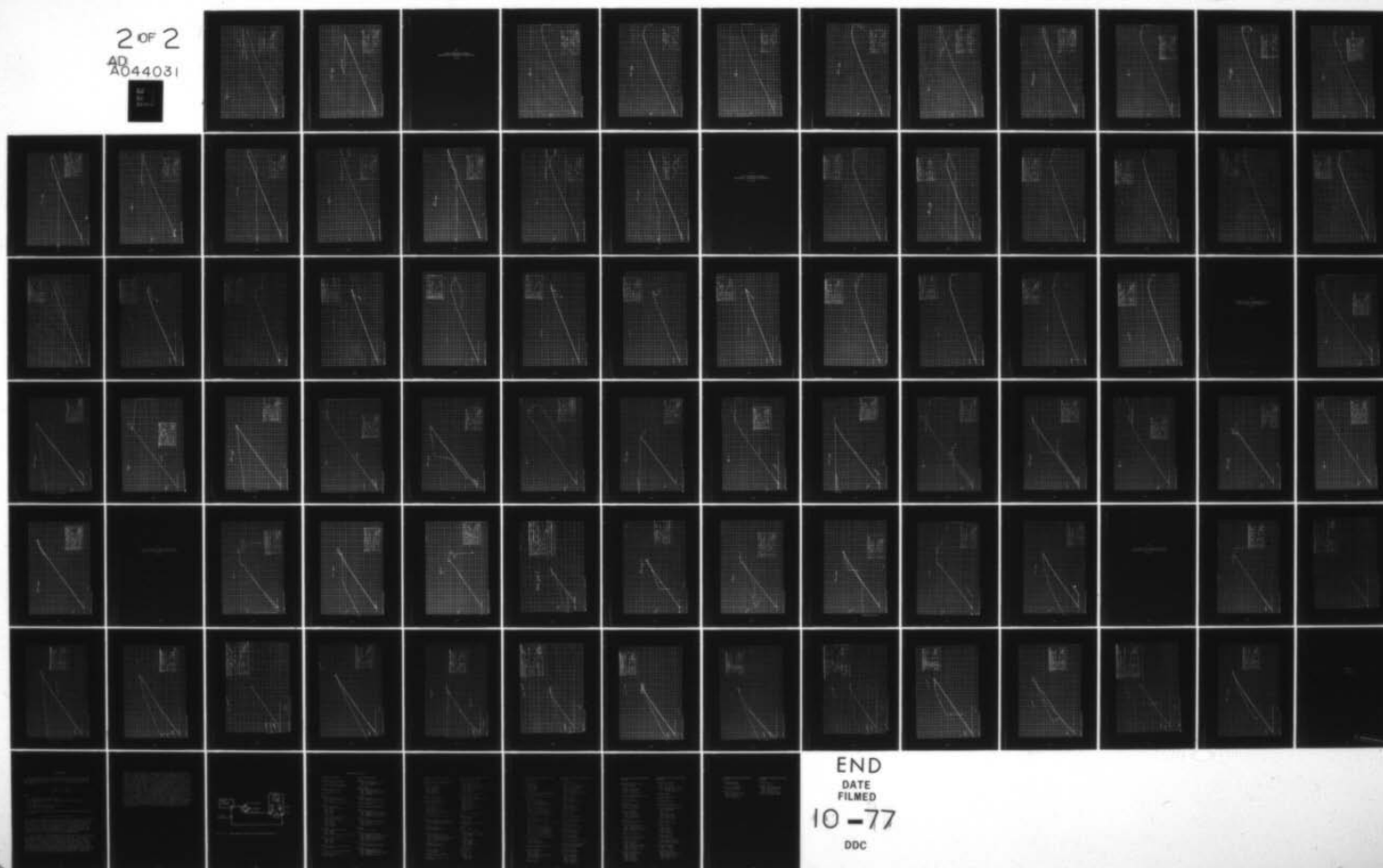
SORI-76-483-3406-9-I-F

DNA-4174F

NL

2 OF 2

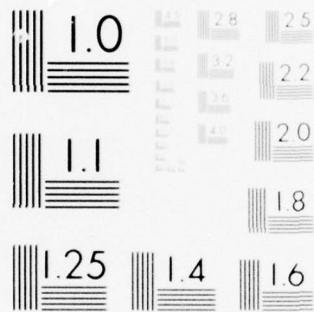
AD
A044031



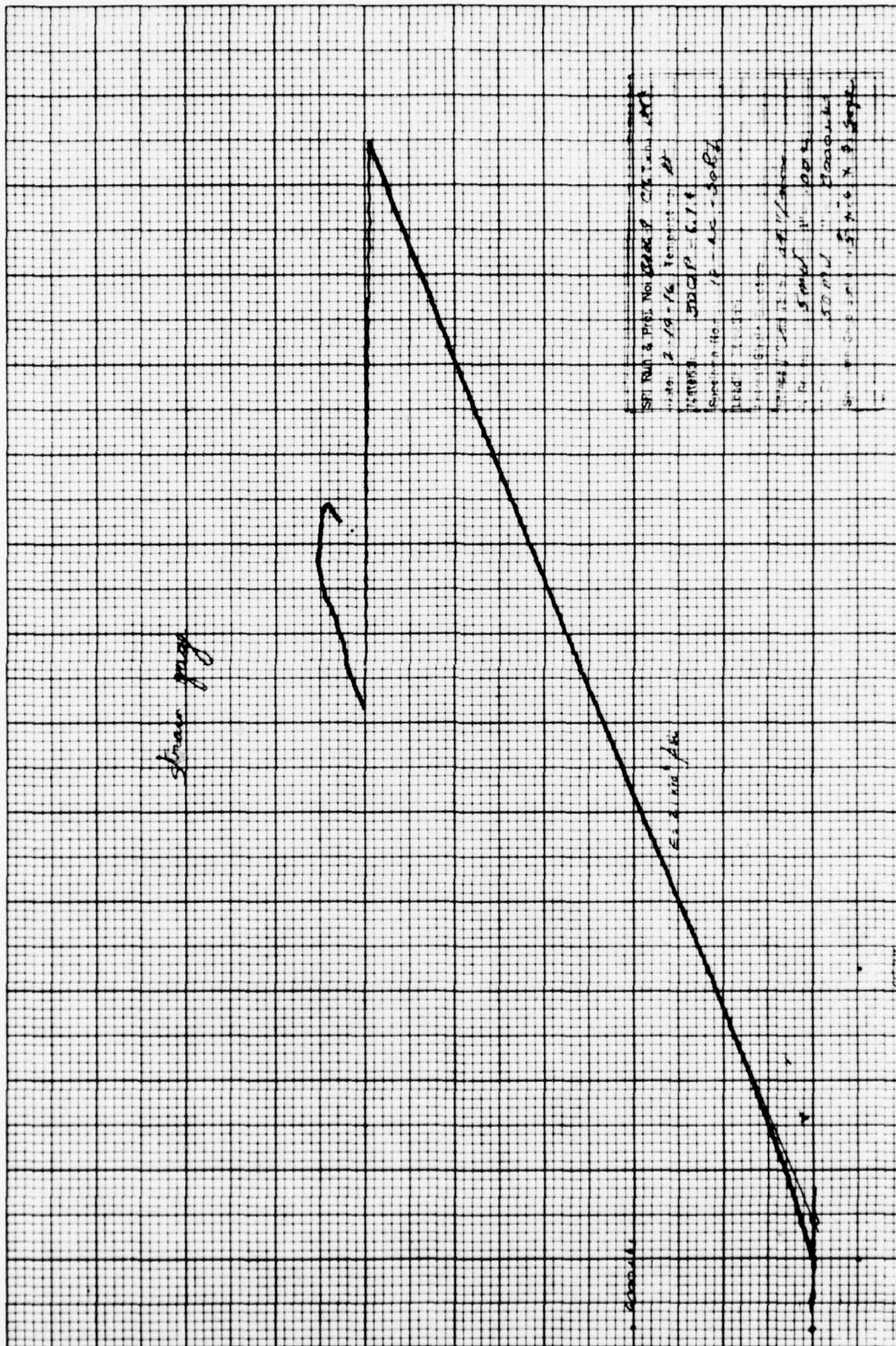
END
DATE
FILMED

10-77

DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



Normal A12, Test Results for Specimens 12-AC-S0 R1

A2

Axial Compressive Tests
Rectangular Specimen Configuration

6.1.4

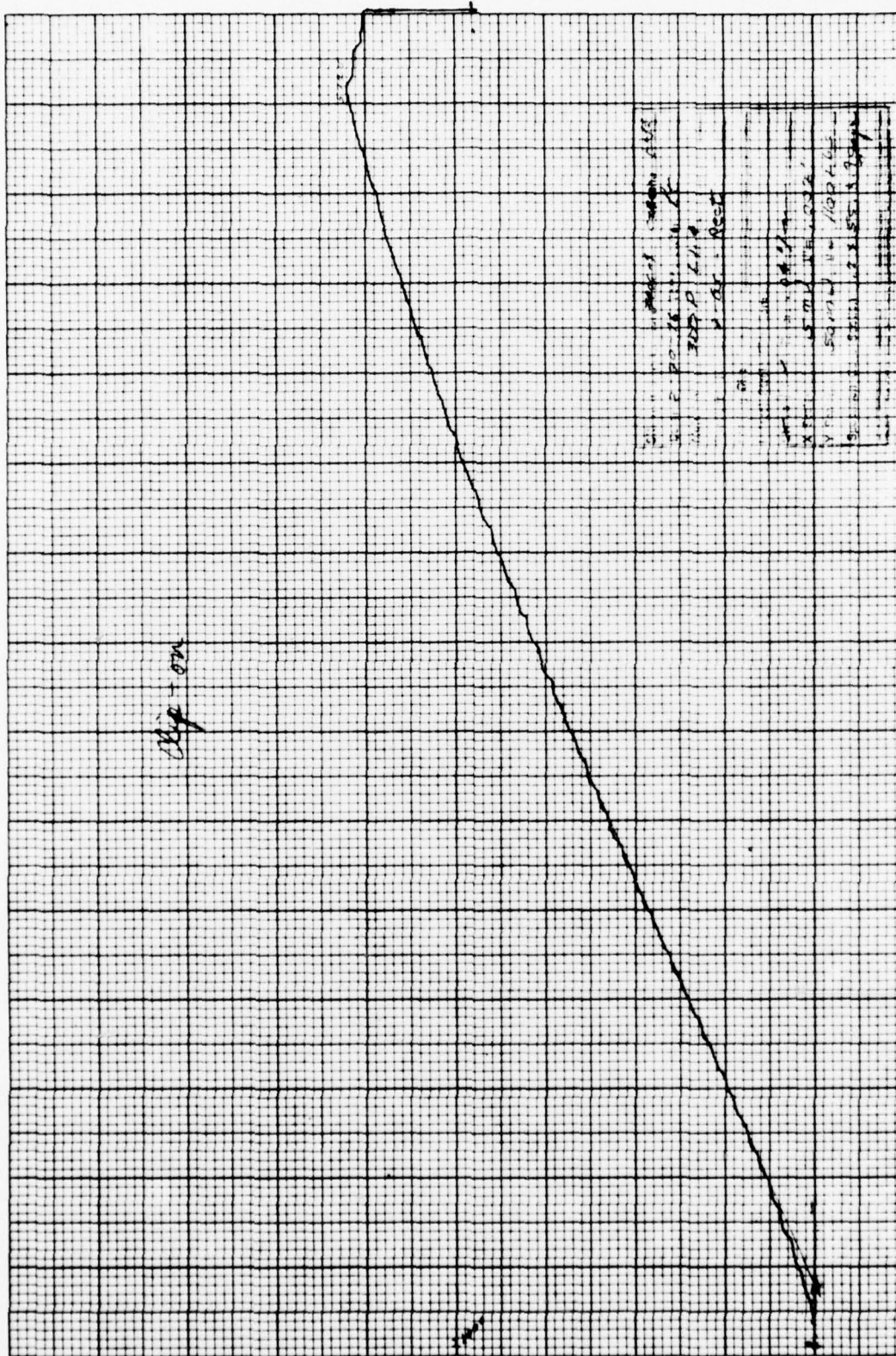
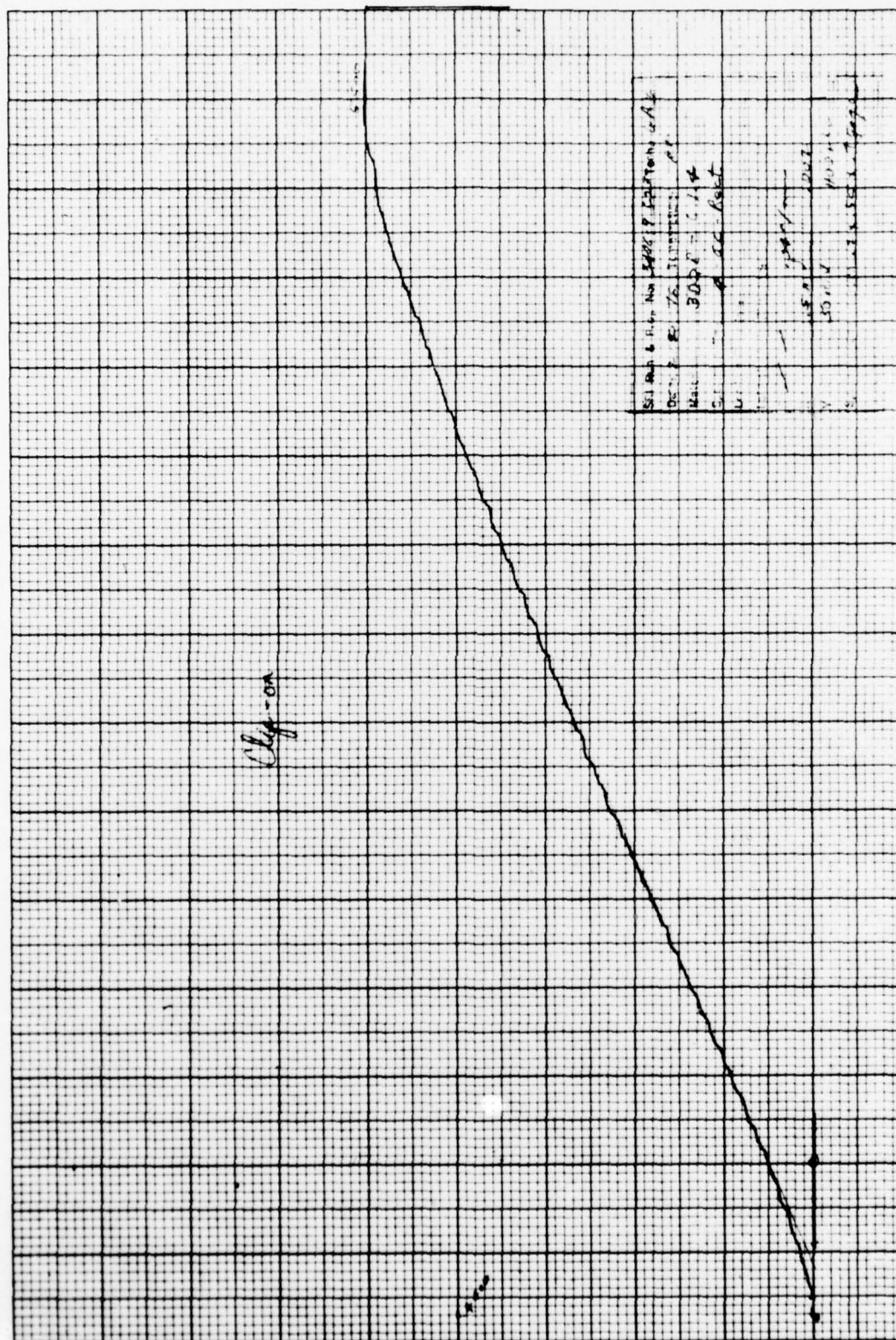
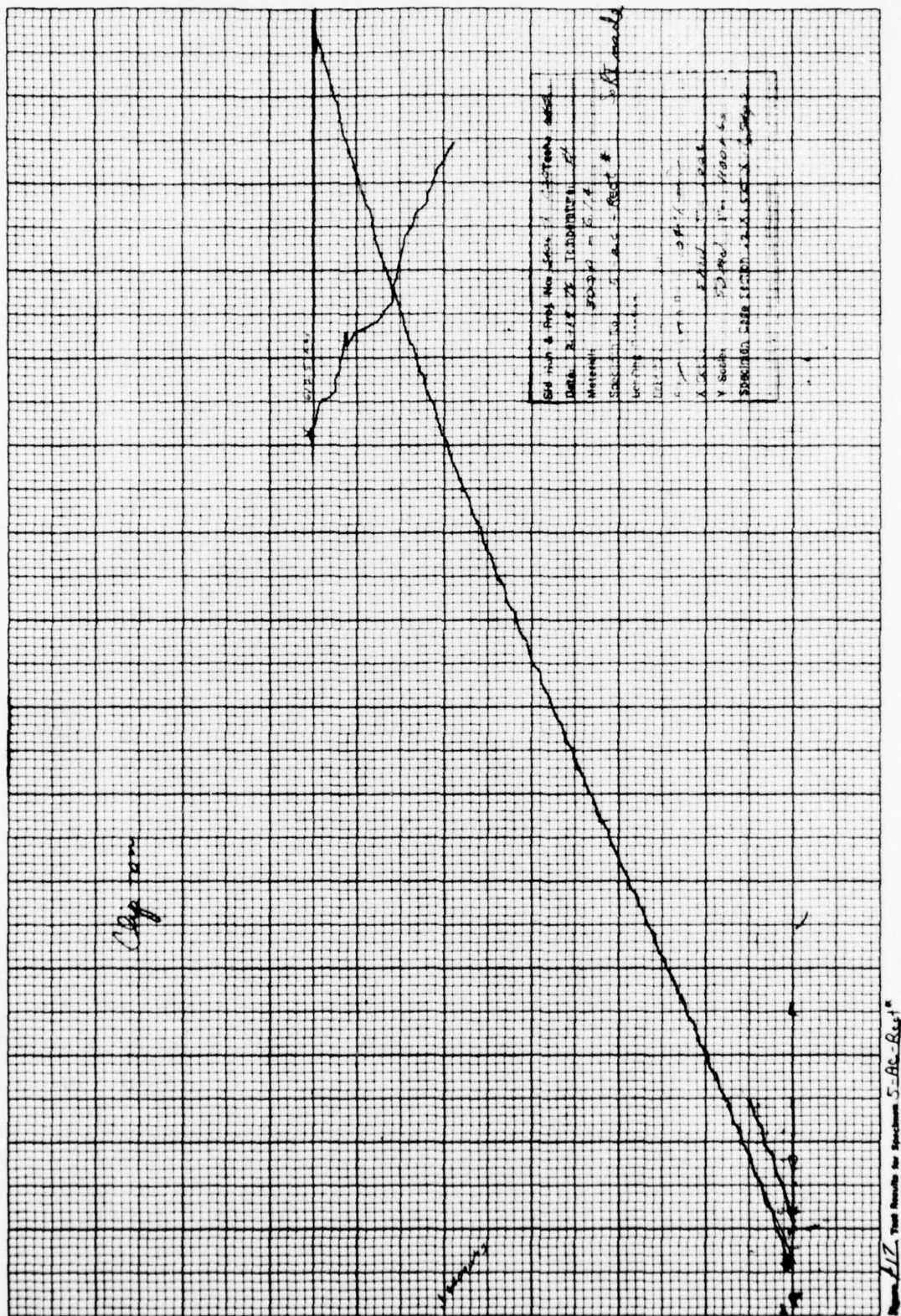
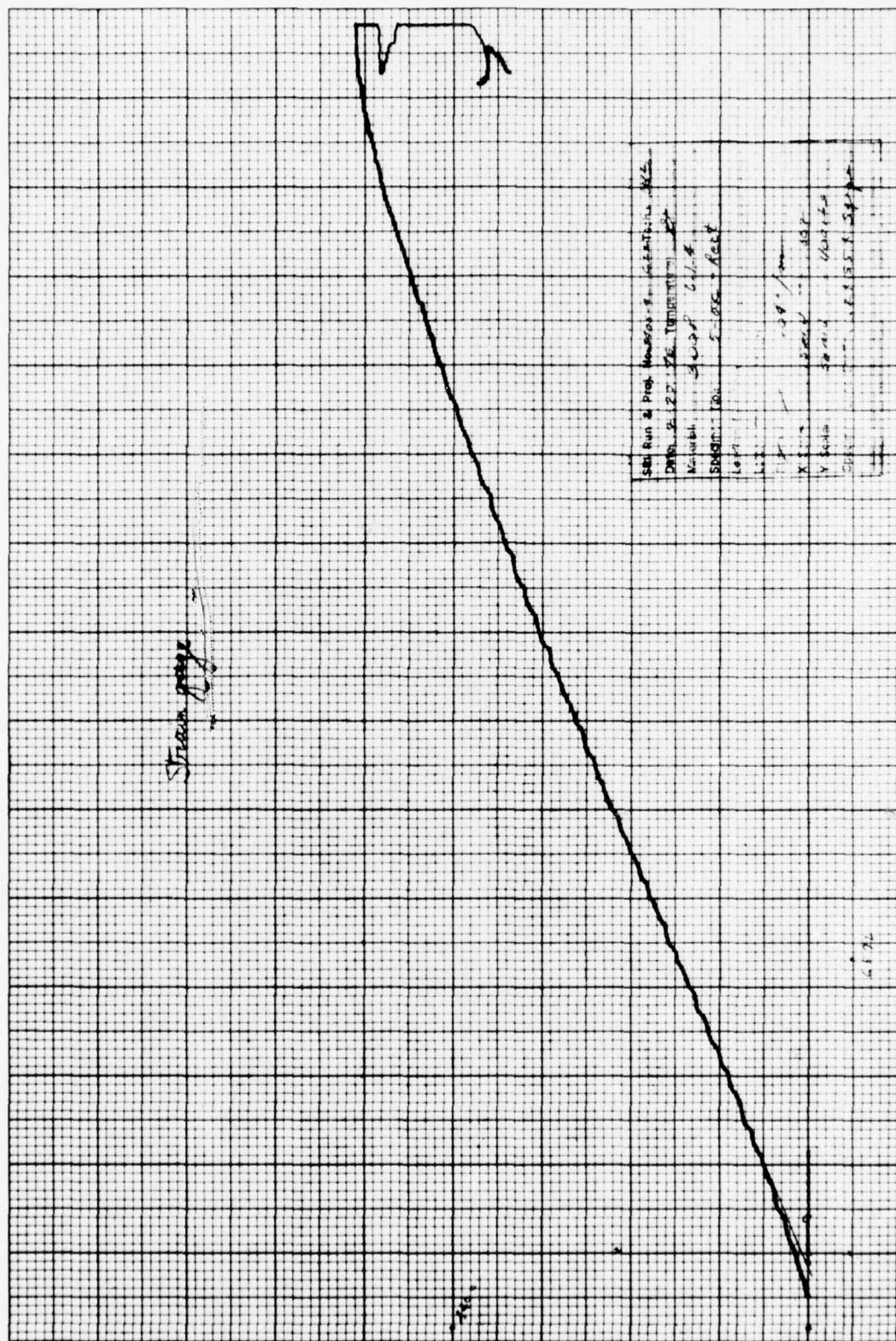
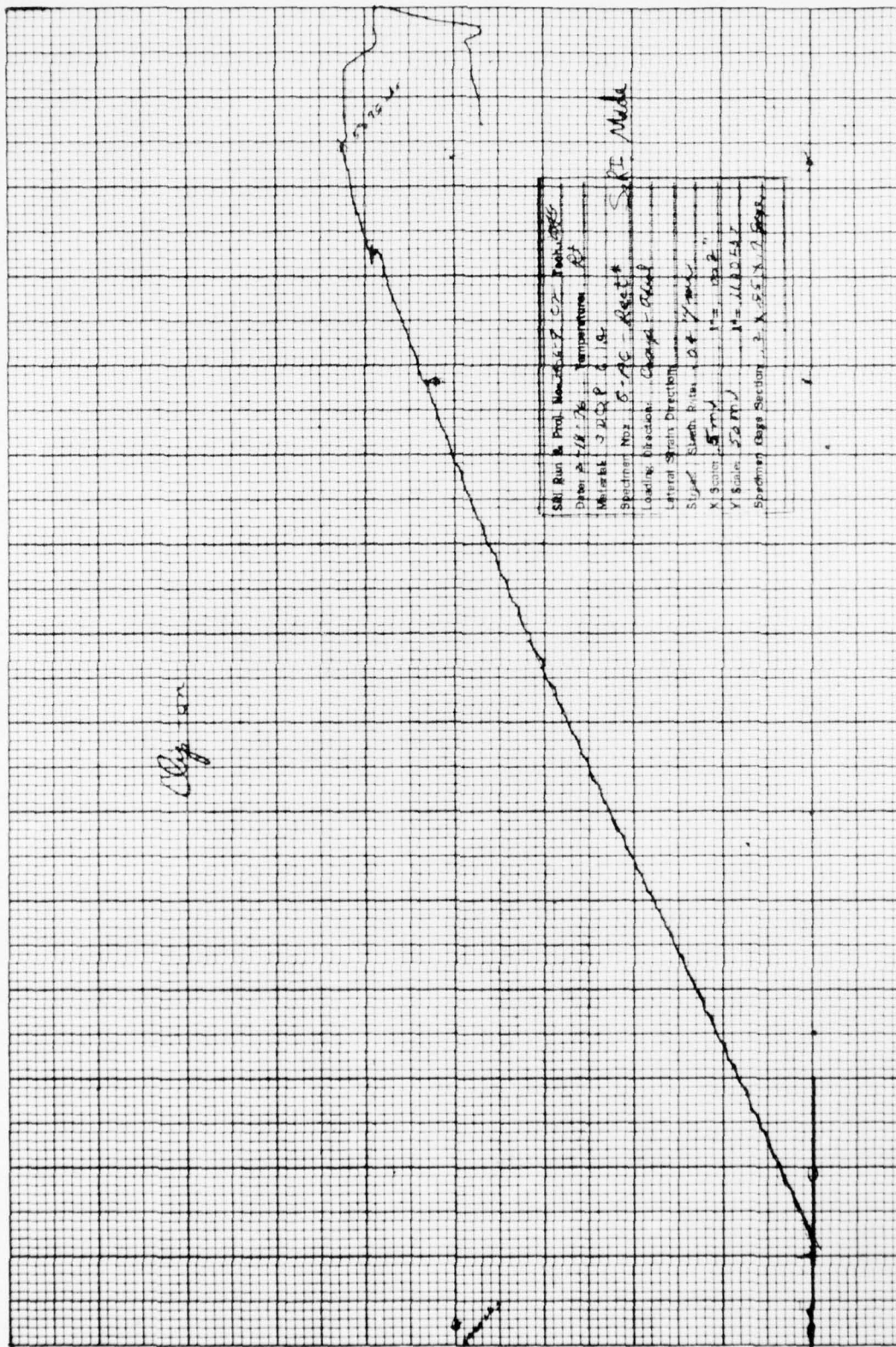


Figure 1-3 Test Results for Specimen P-AC-REST

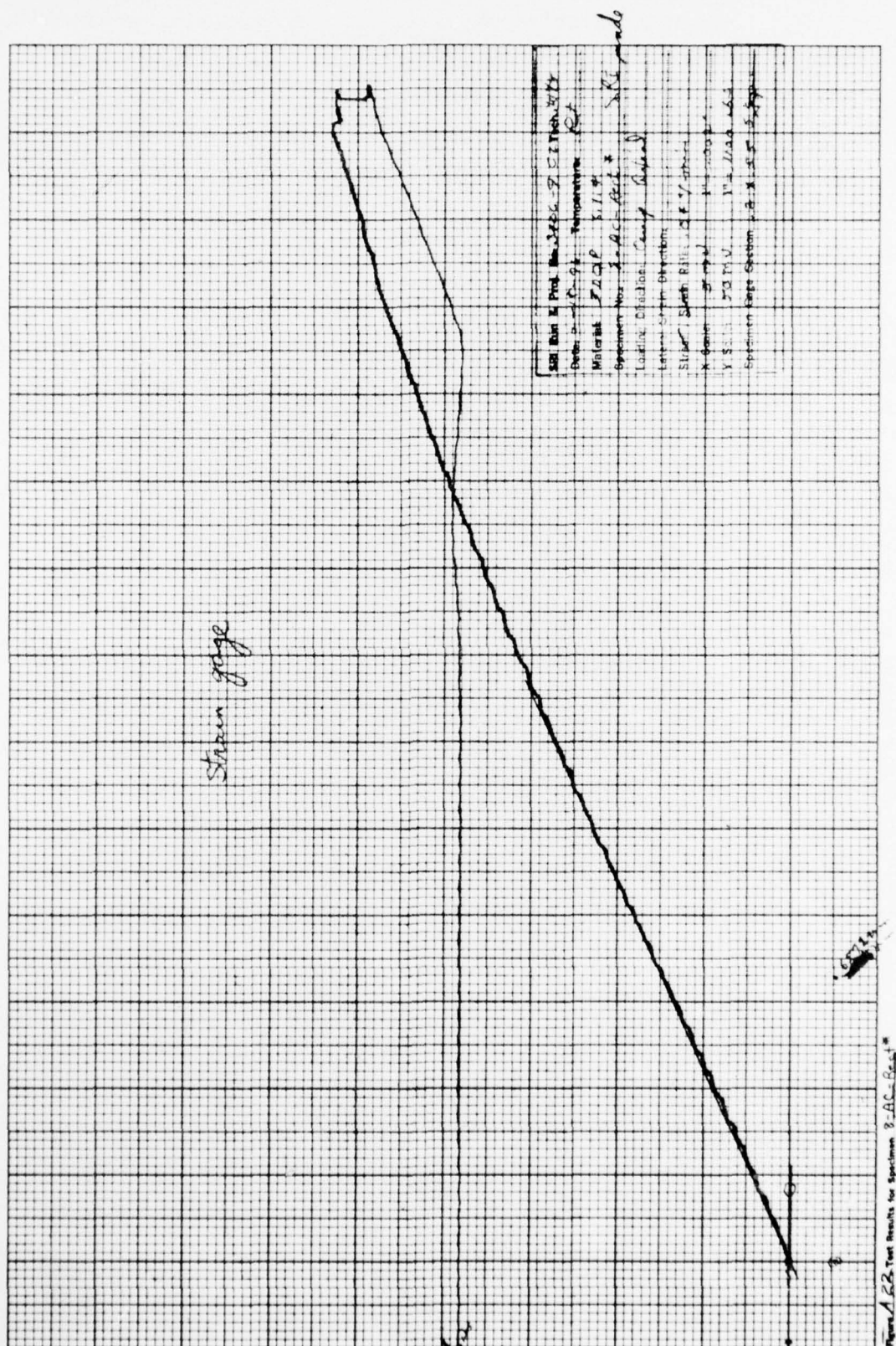








AC-825 Test results for Reaction 8-AC-825



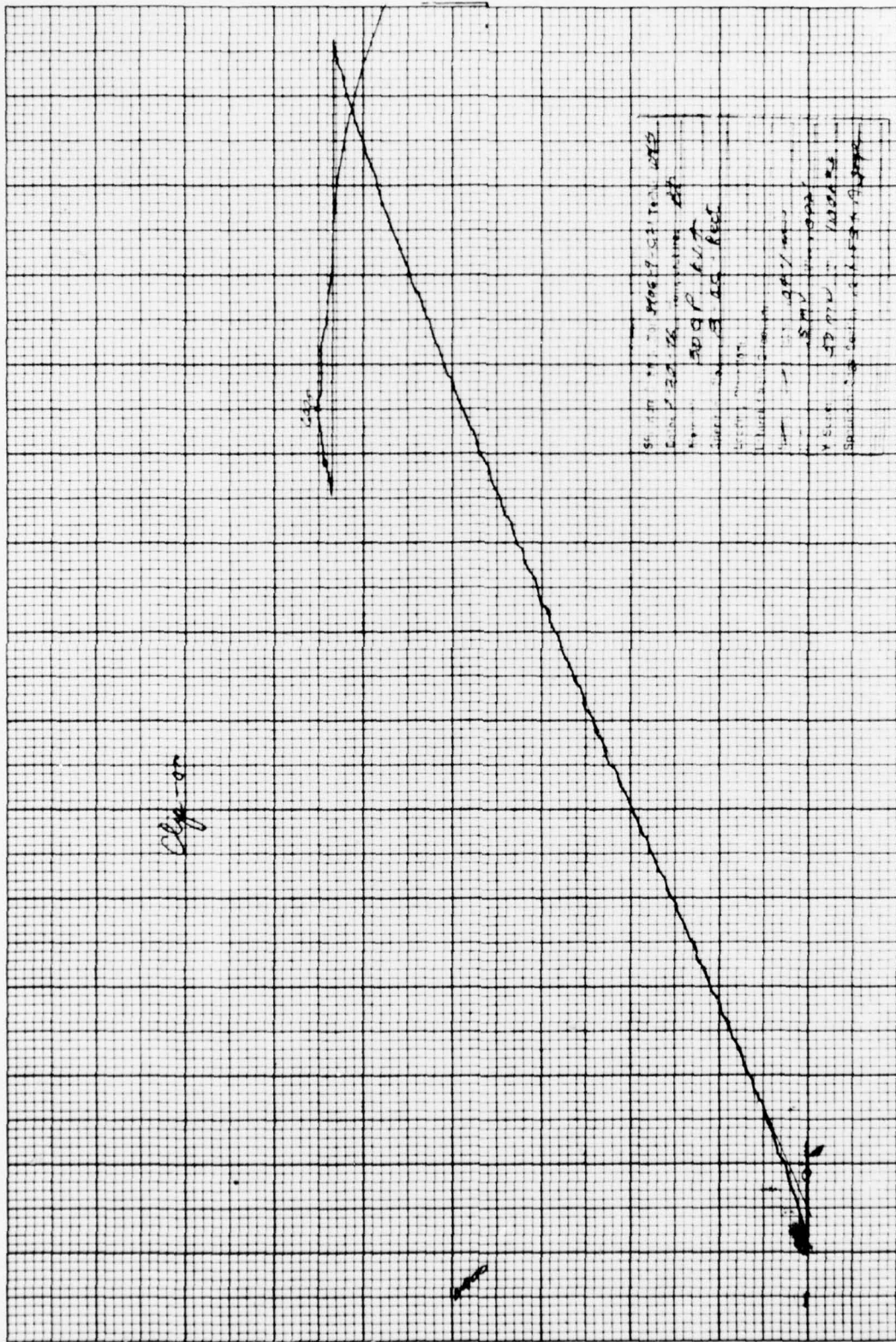


Figure A23 Test Results for Specimen 8, AC-1192

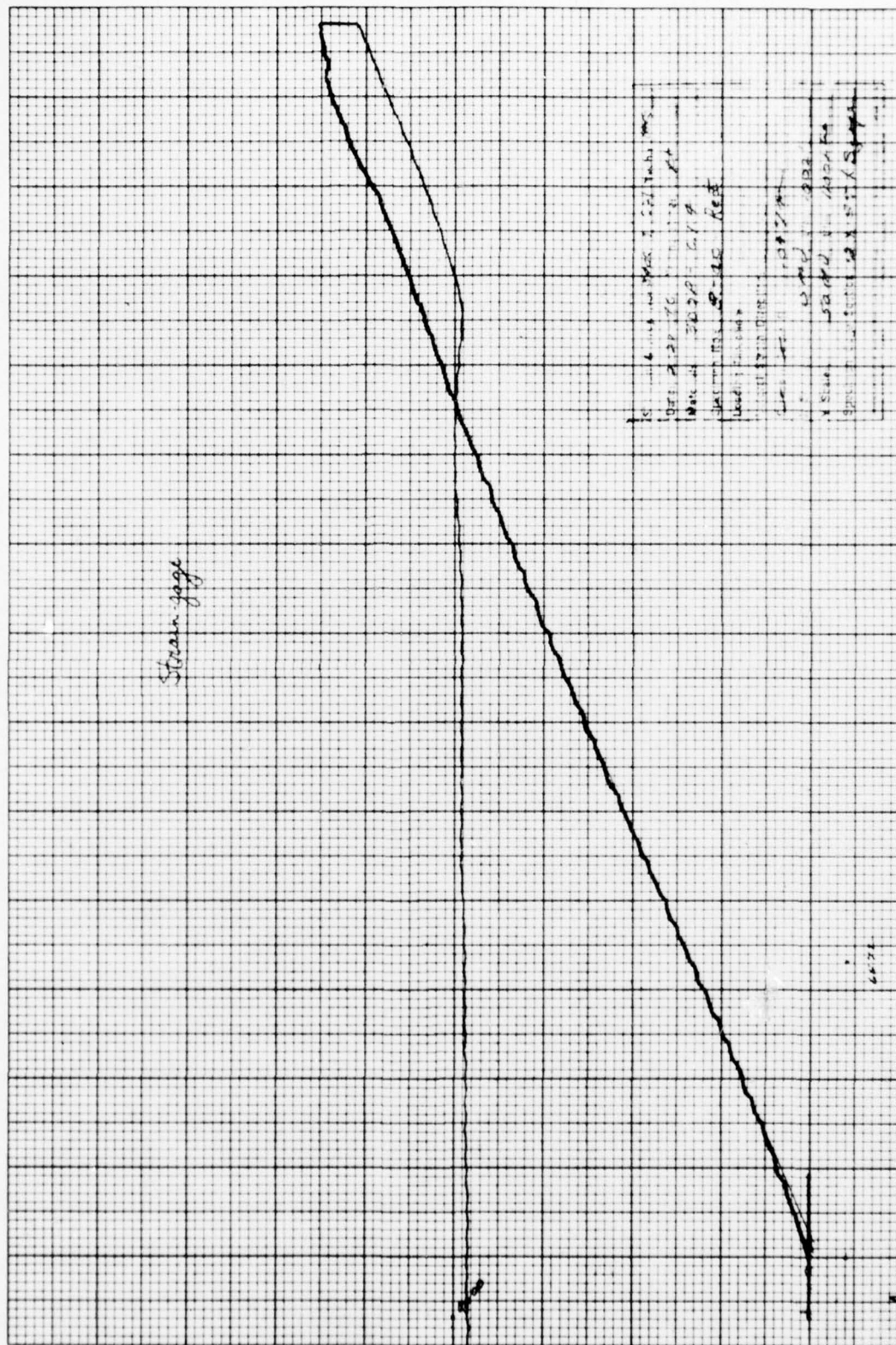
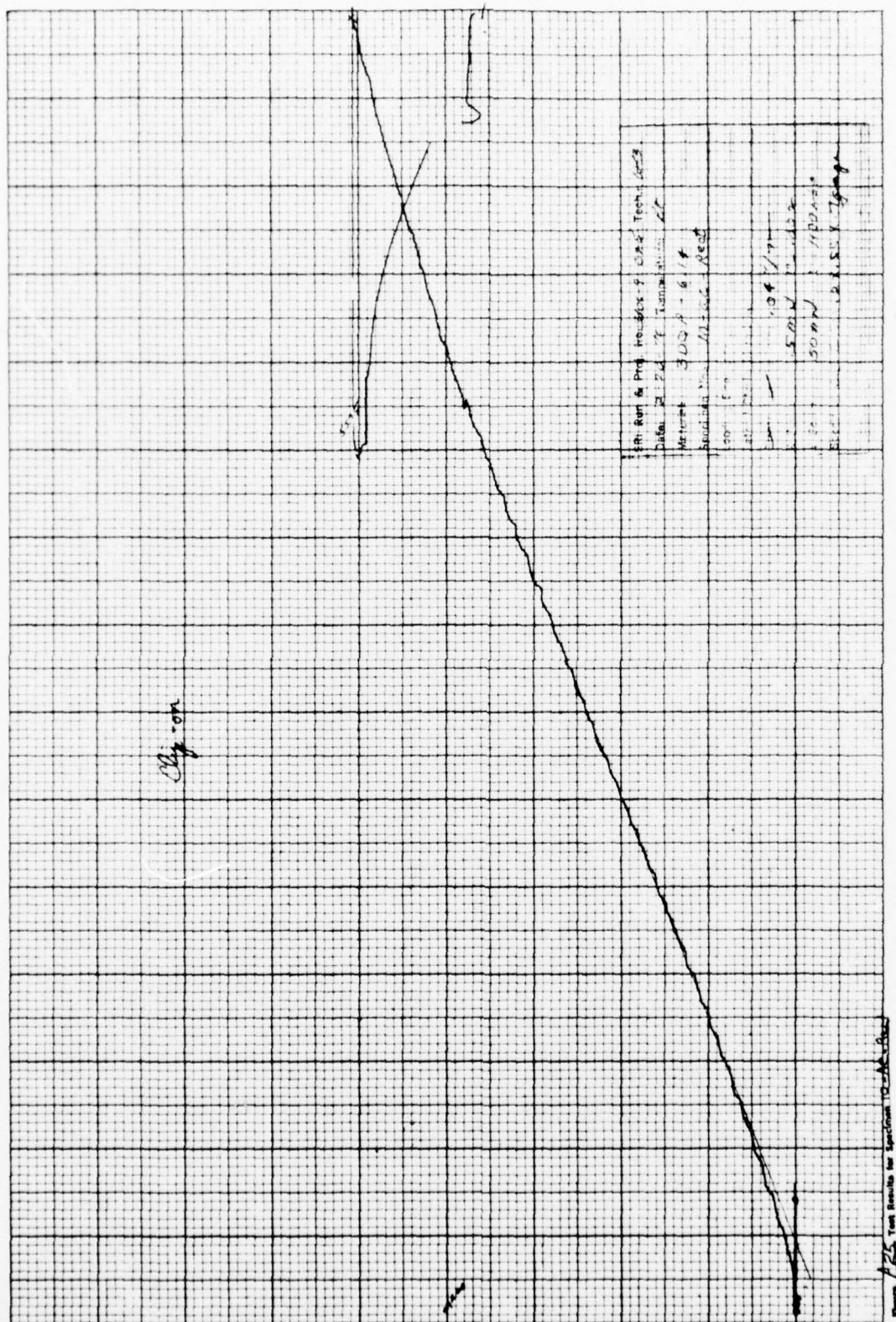
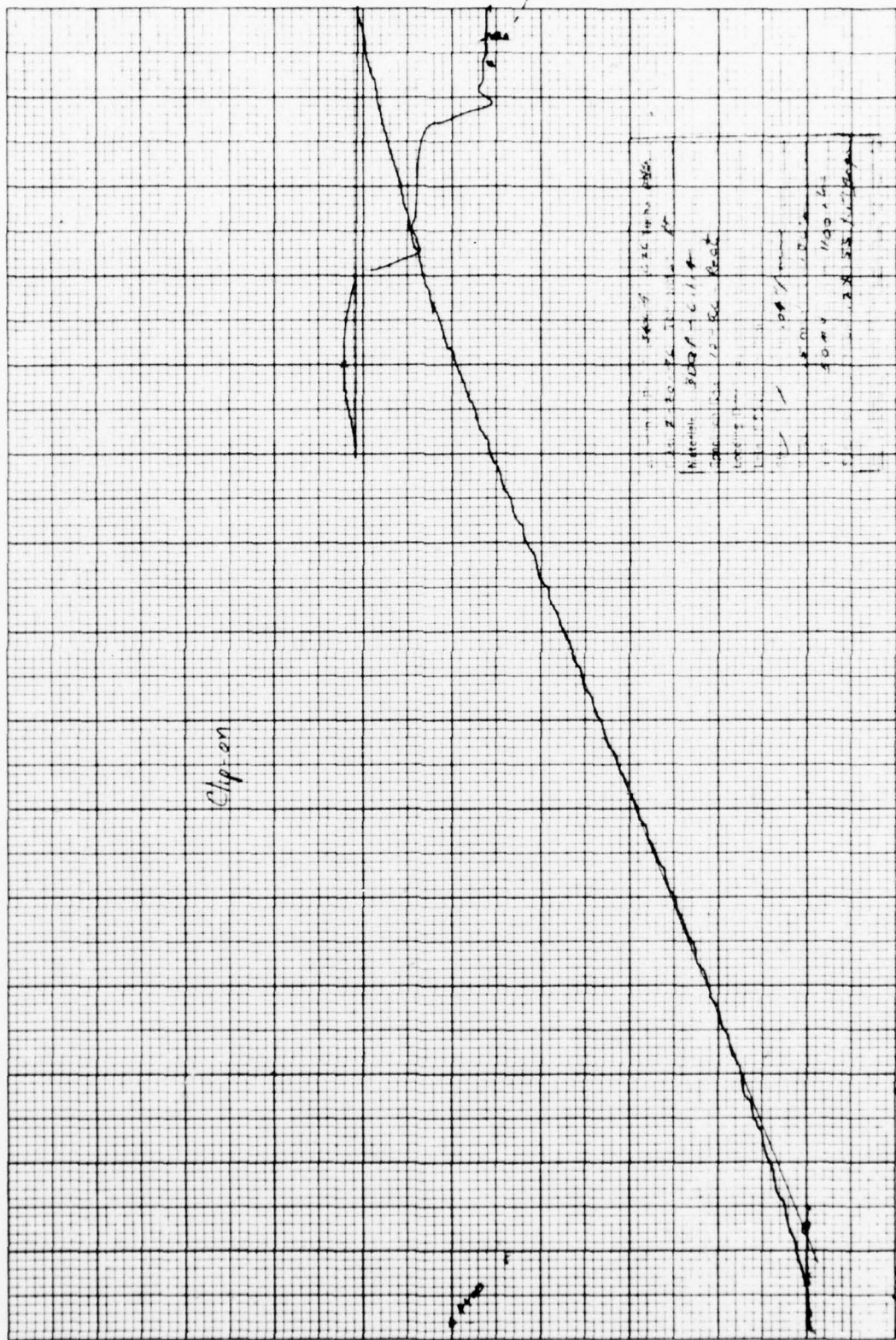


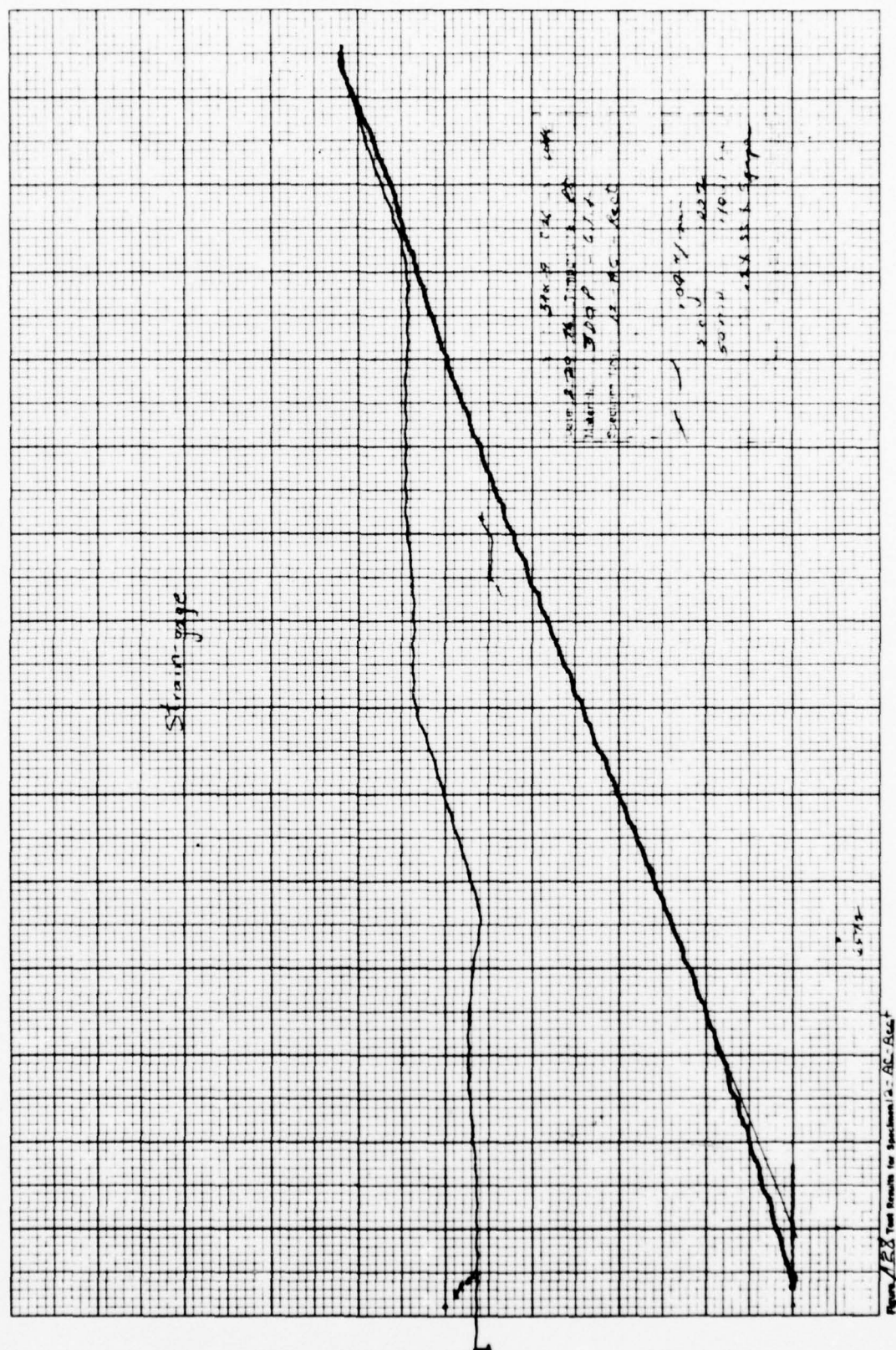
Figure 1. Stream Profile for Station 100





Clip on

From 12.1. That is the end of the record 12. AR-Beet

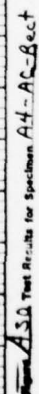


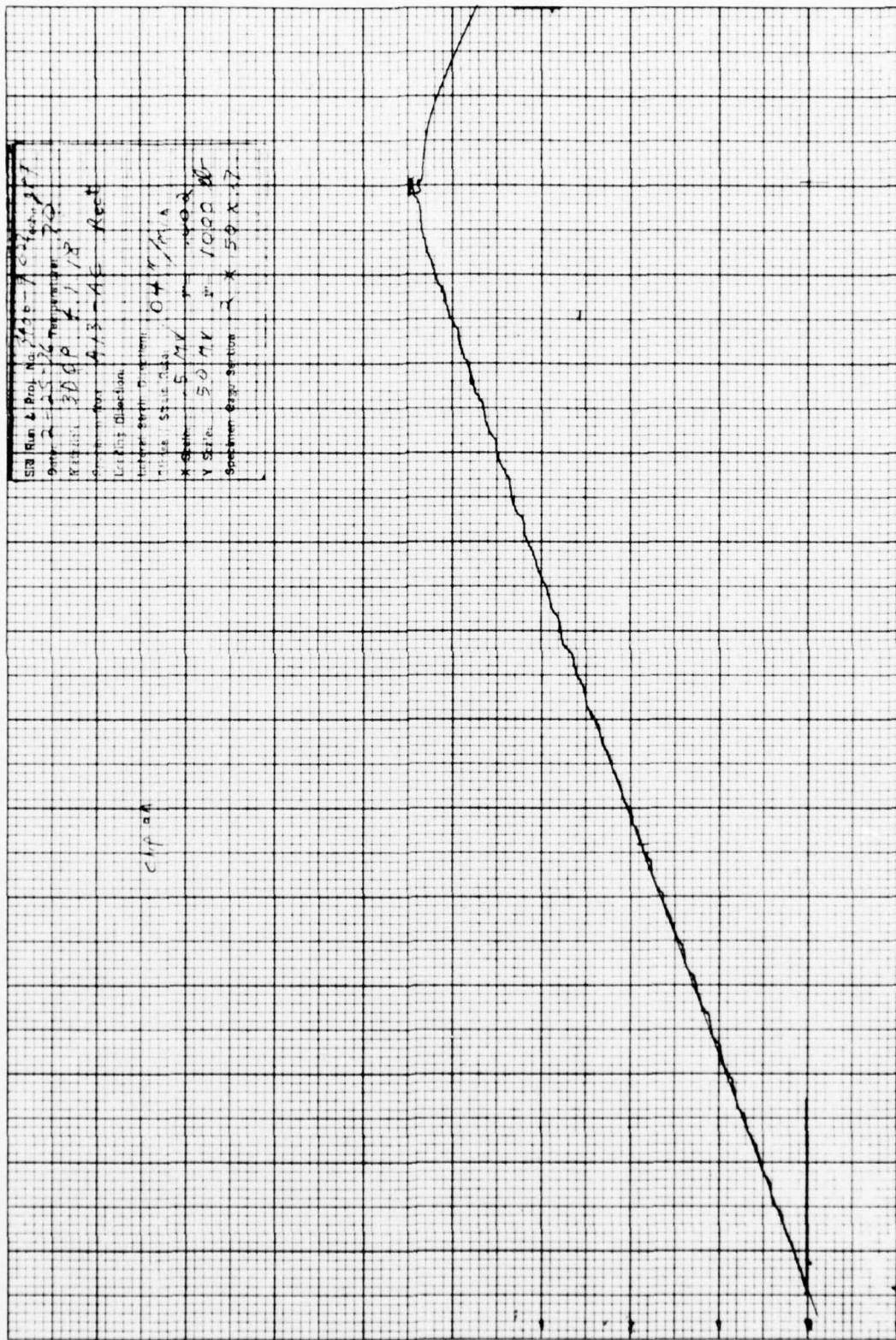
A3

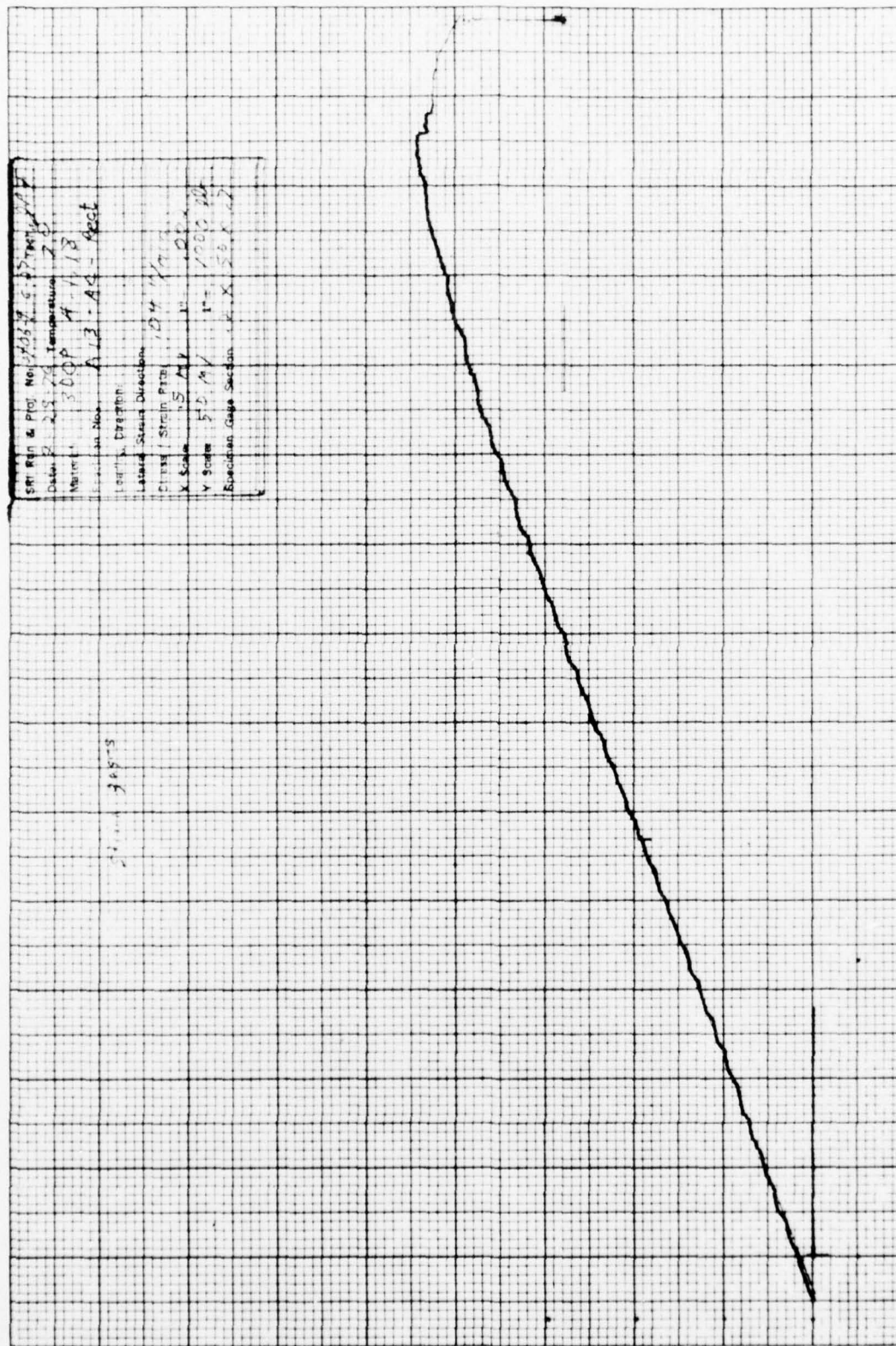
Axial Compressive Tests
Rectangular Specimen Configuration

4.1.18

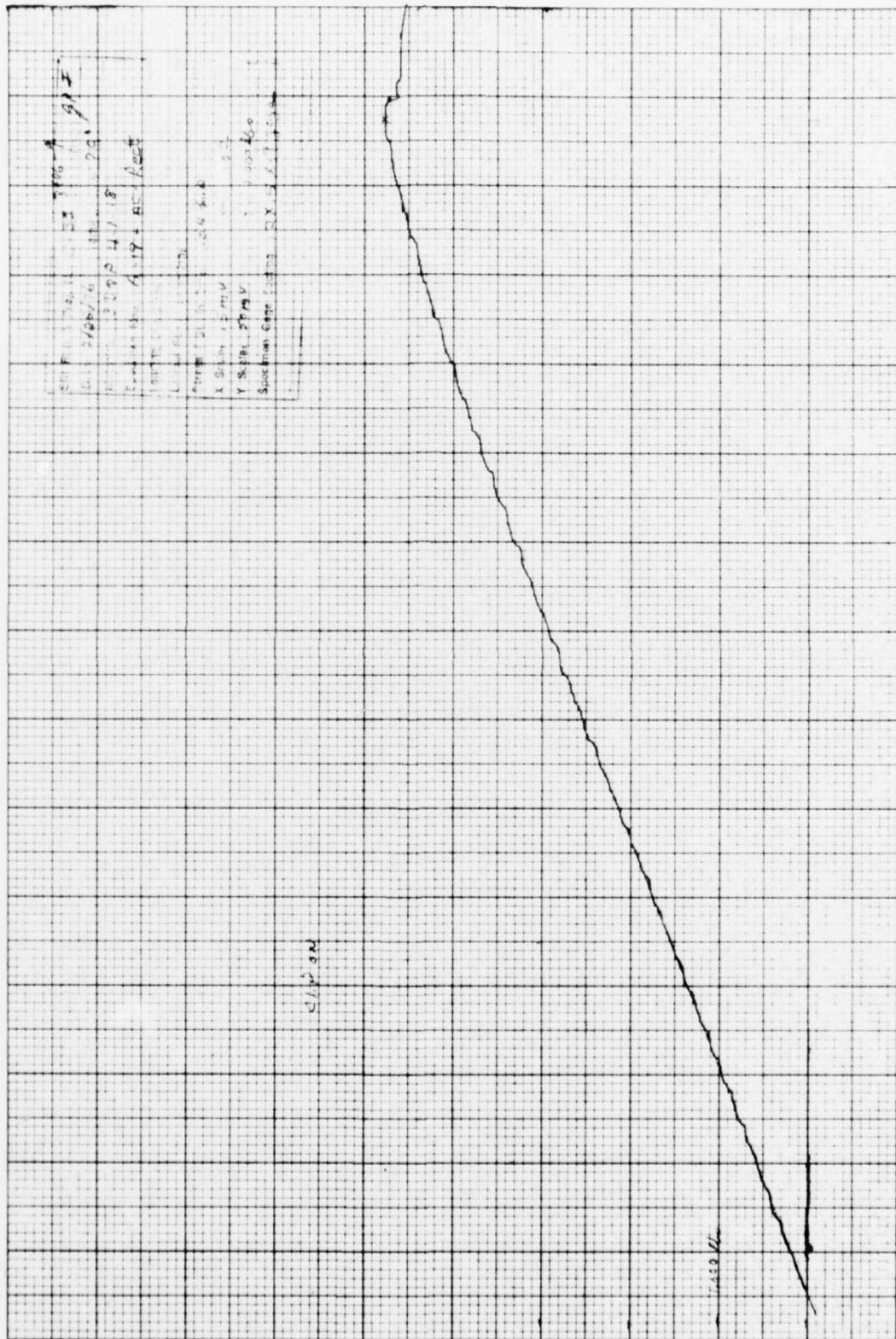
Strain gage

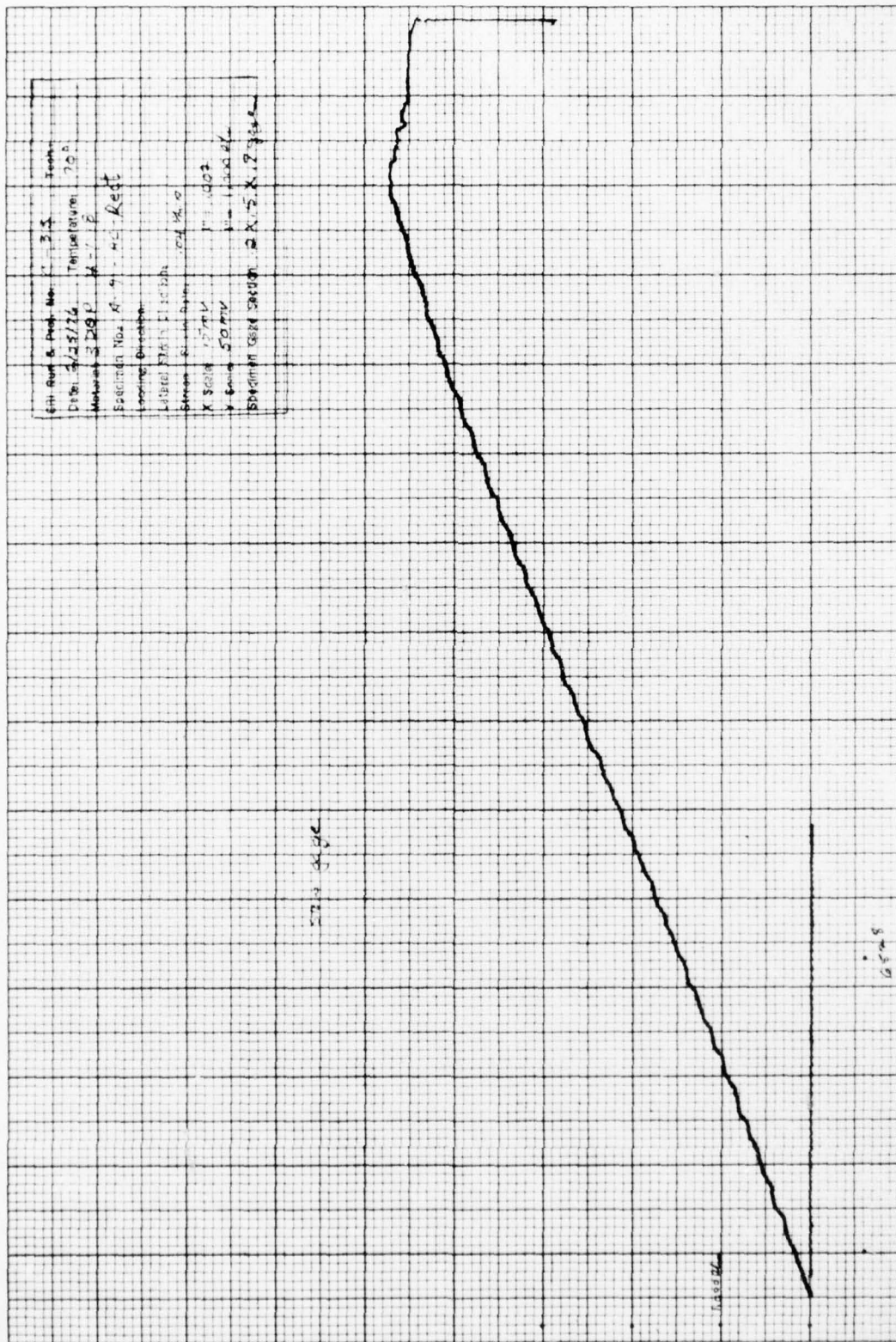


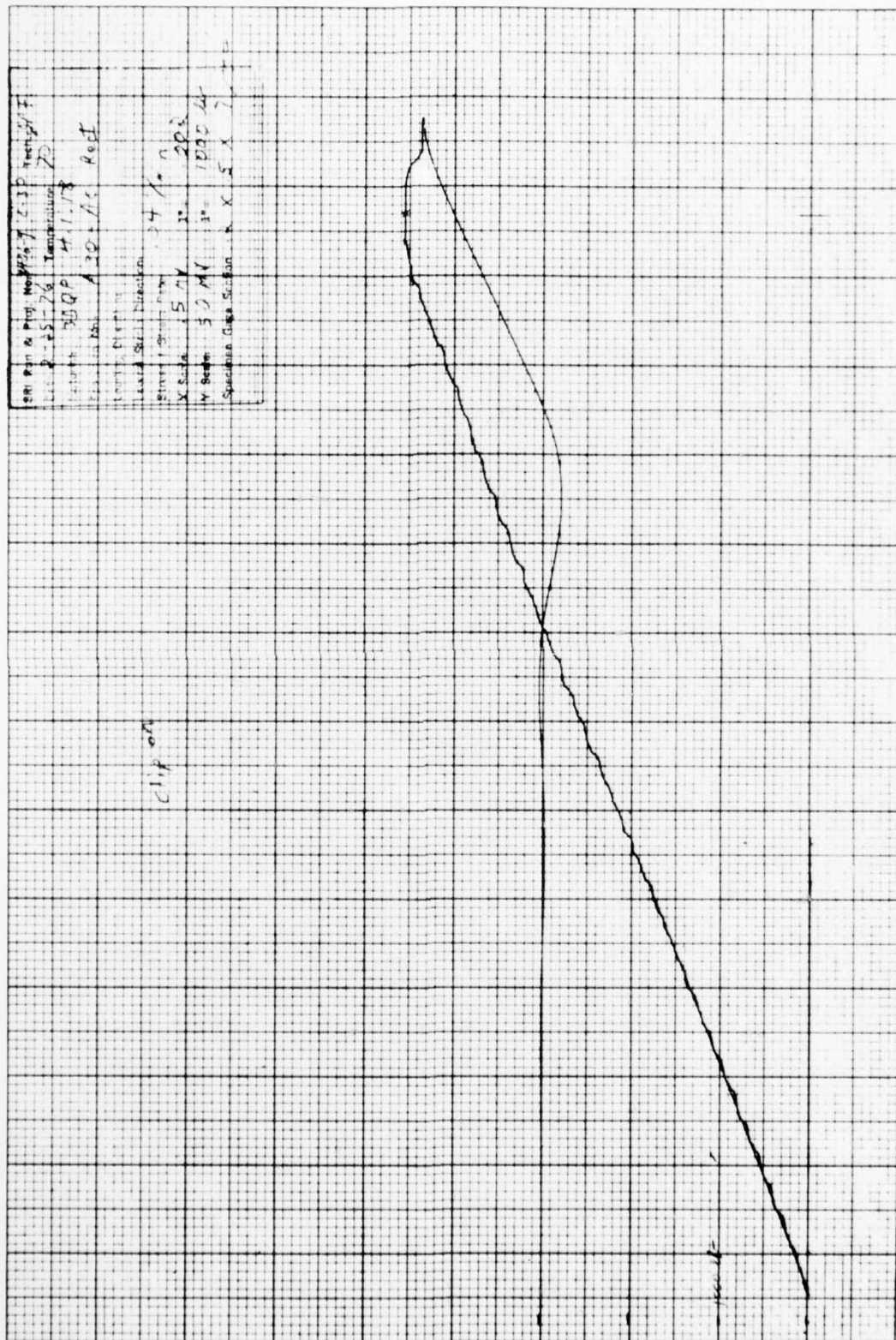




SPT Pen & Plot No. 2406-4 G. S. T. 13-14
 Date 2-13-74 Temperature 2.0
 Name 300P H-118
 Loc. in No. A.13-AC-Rect
 Loc. in Direction
 Latent Sound Direction
 First / Strain Plot 10M 17.2
 X Scale 5.0M 1.0
 Y Scale 5.0M 1.0
 Residual Gauge Section 1.0 X 5.0 1.0







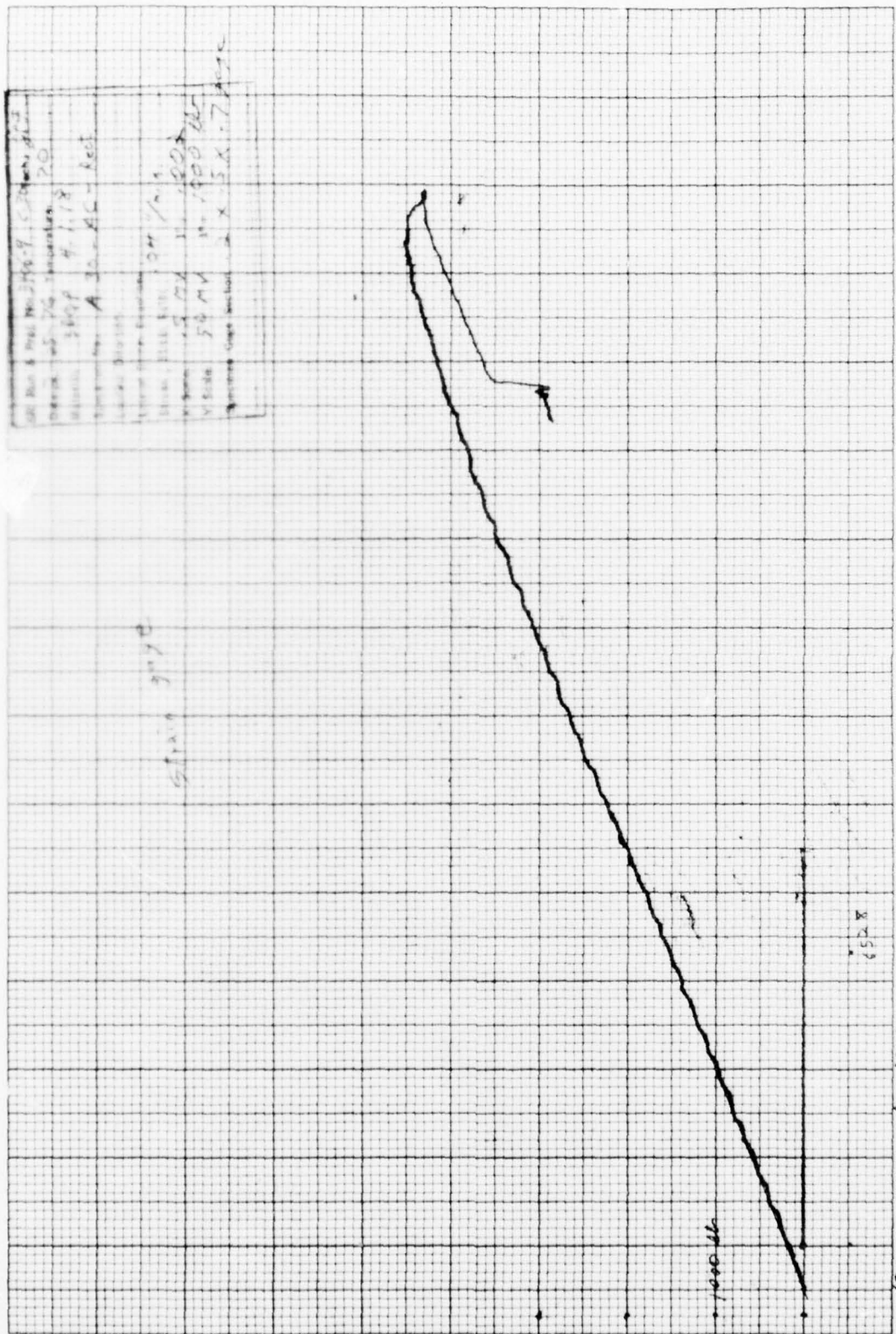
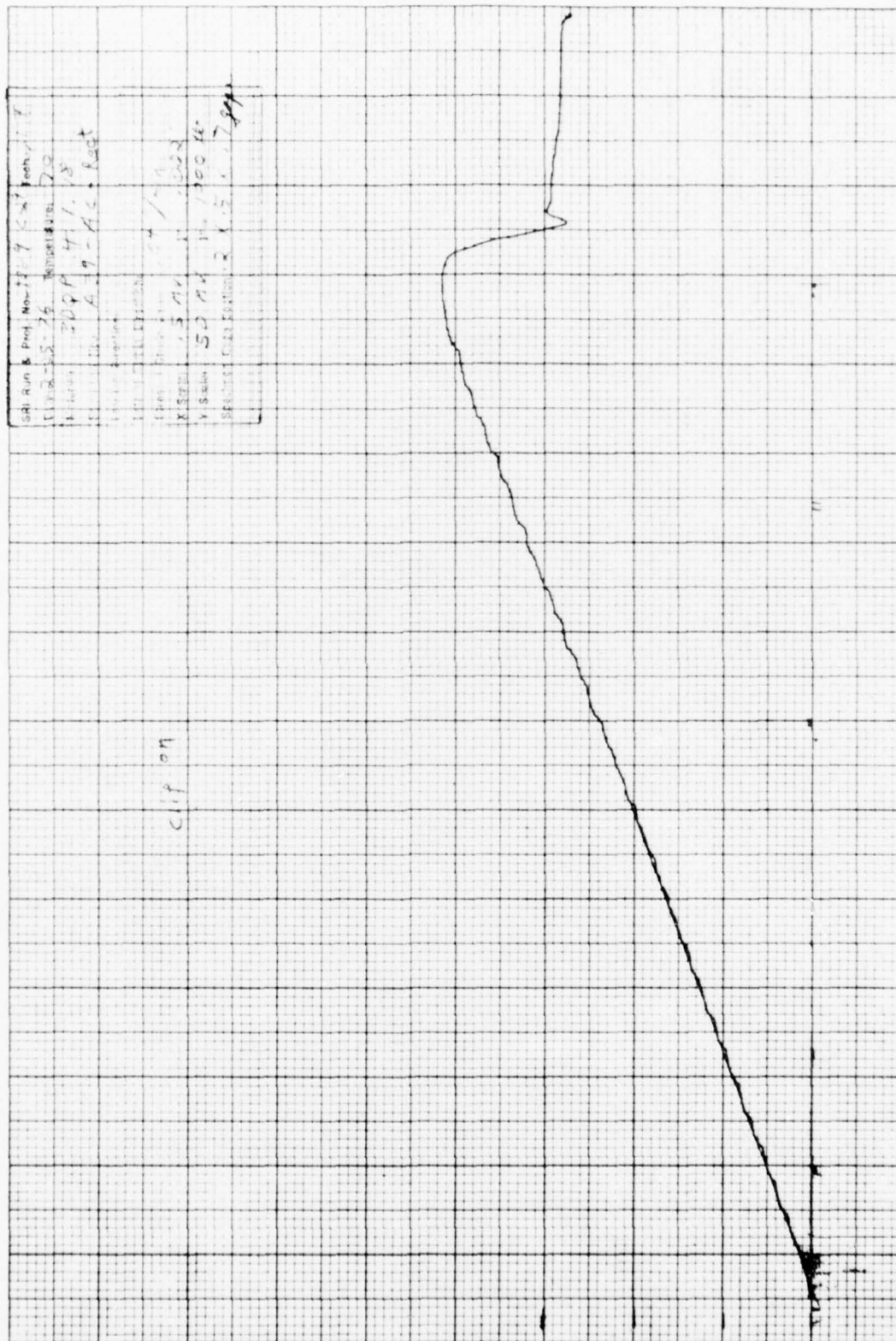


Figure 1. Test Results for Specimen A30-AC-Rect



From A37 Test Results for Specimen A39-AC-Rect

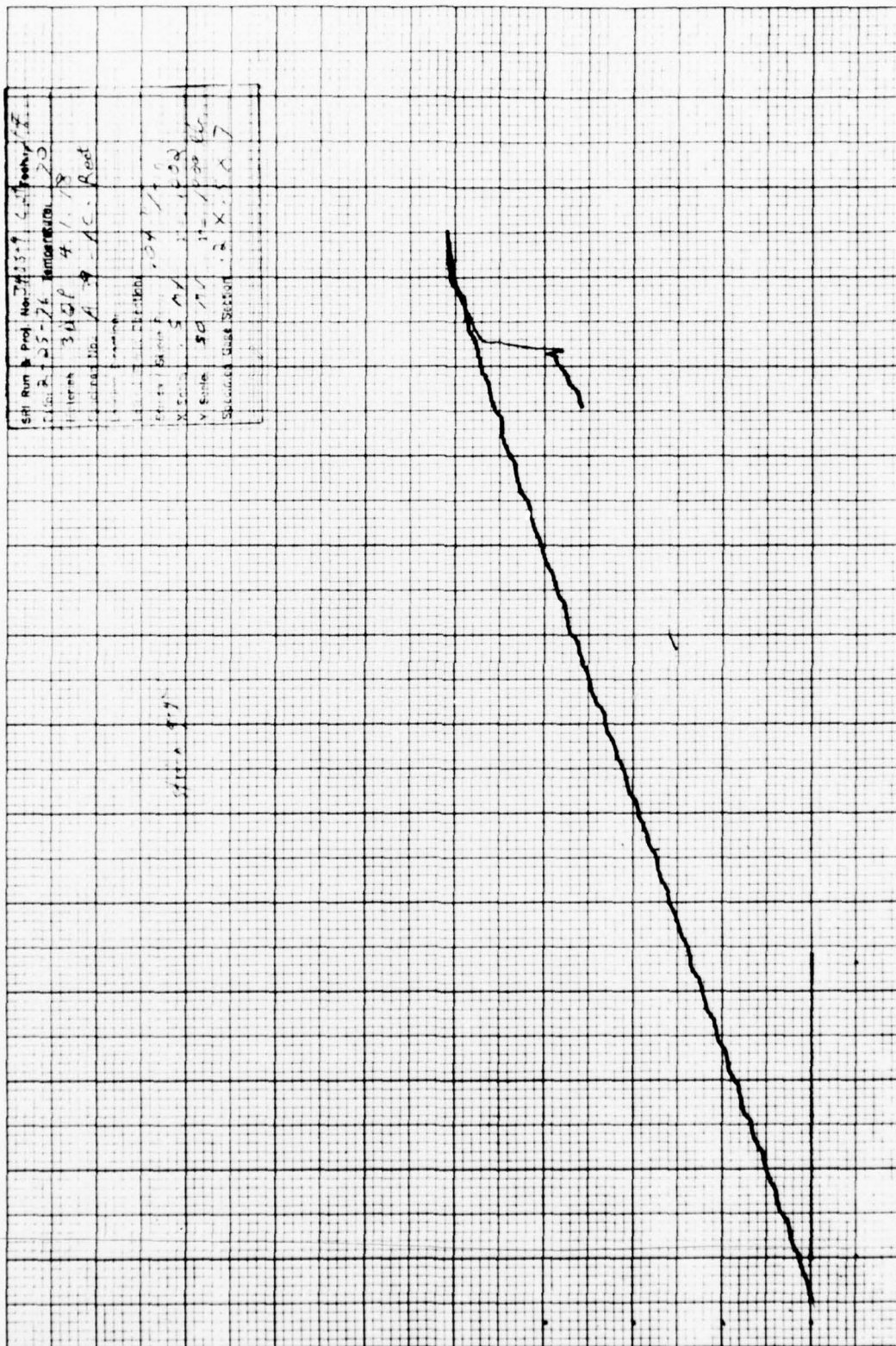
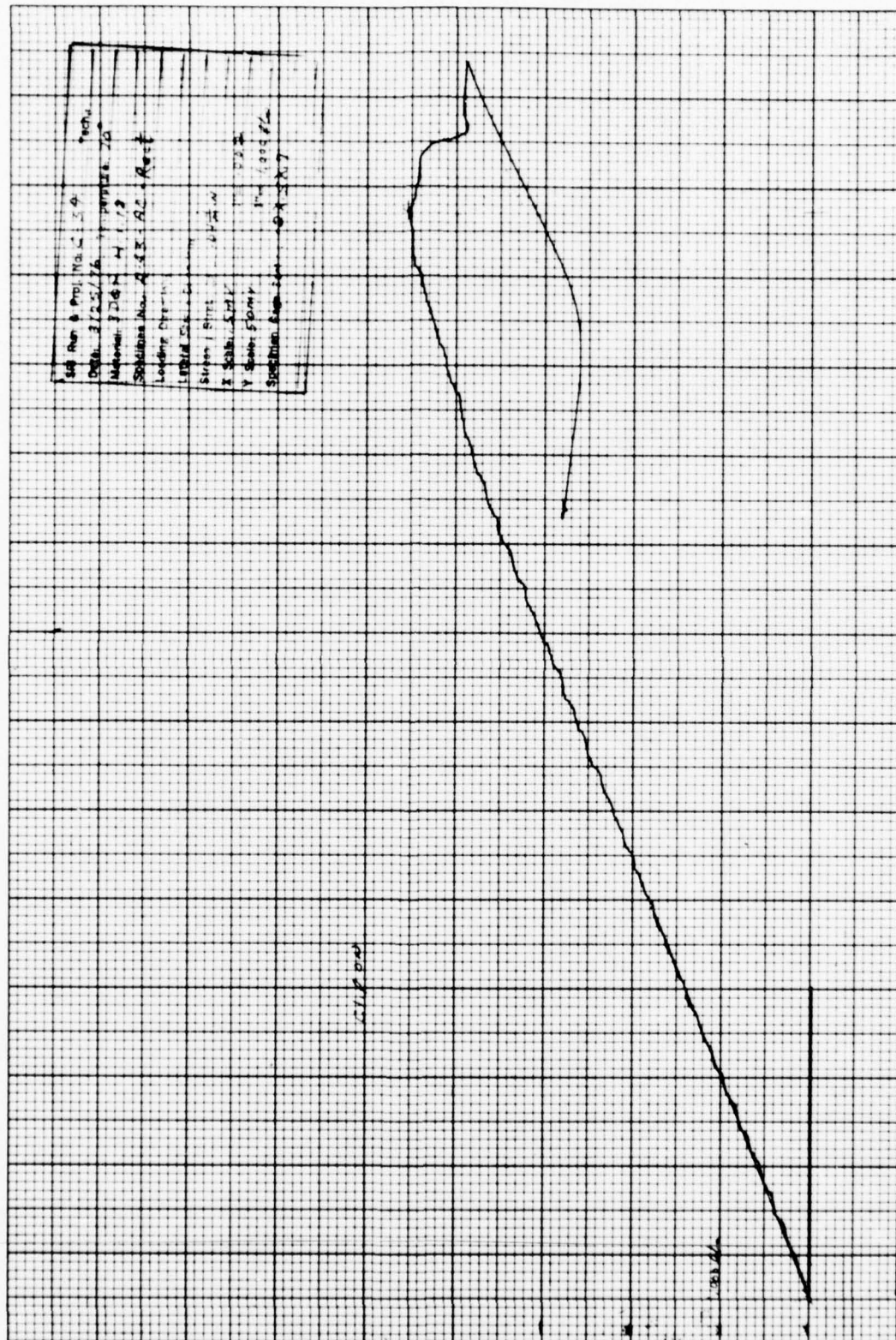
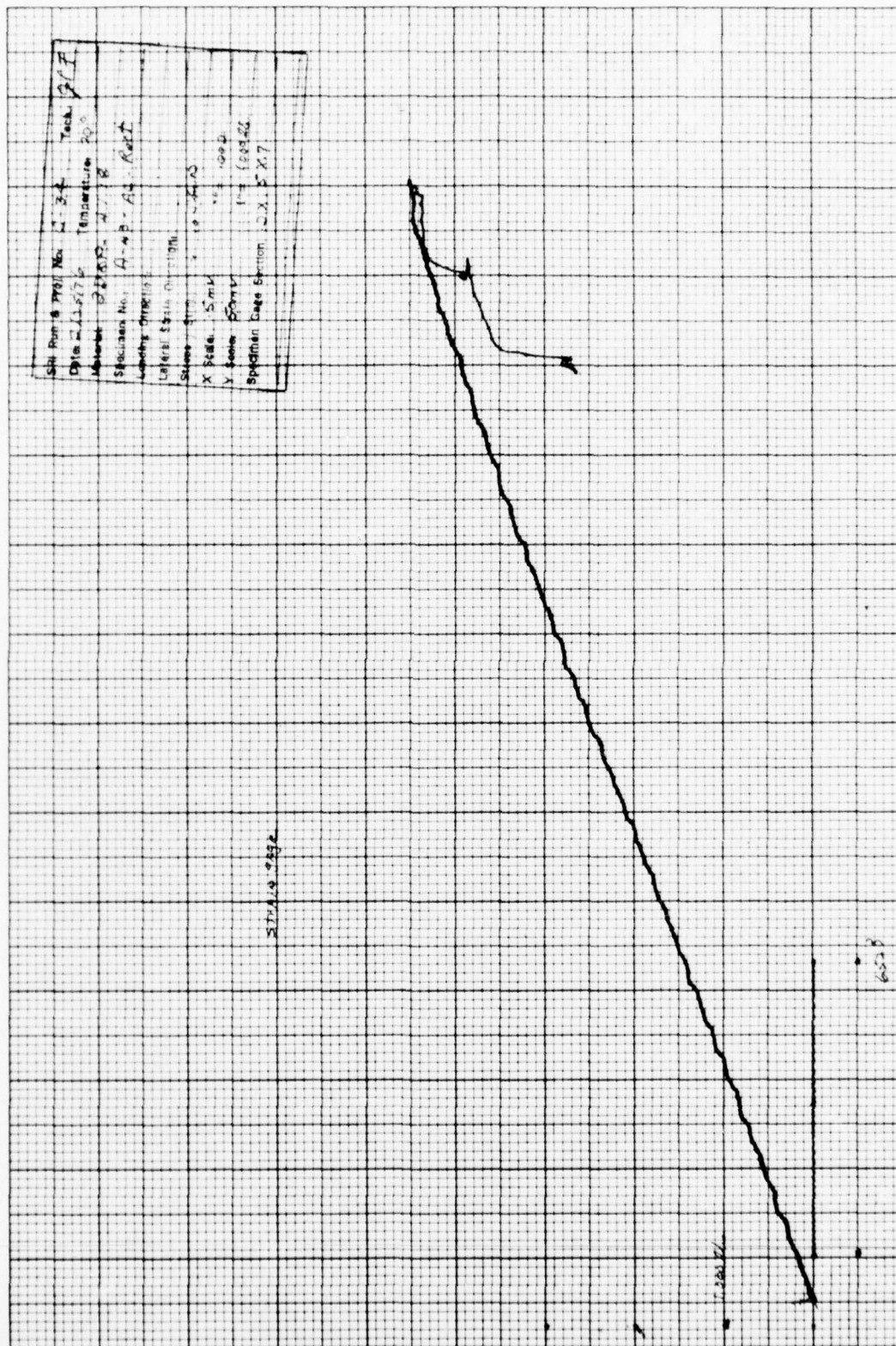


Figure 153. Test Results for Specimen AS9-AC-Aect



Sub Run 6 Proj. No. 54
 Date 3/25/76
 Location 126 M H 13
 Station No. A-43-AC-Rect
 Loading Diagram
 Lateral Displacement
 Sides 1 2 3 4 5 6 7 8 9 10
 X Scale 5000
 Y Scale 5000
 Station No. 1000 ft
 Station No. 1000 ft

A-43-AC-Rect



Soil Profile 1991 No. 1-3-1
 Date 11/17/76 Temperature 20°
 Moisture 28.8% Wt. %
 Specimen No. A-43-AC-Act
 Loading Direction
 Lateral Stress Direction
 Stress 100 kN
 X Scale 5 mm
 Y Scale 5 mm
 Spigot Base Section 10 X 5 X 7

A 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750, 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 990, 1000, 1010, 1020, 1030, 1040, 1050, 1060, 1070, 1080, 1090, 1100, 1110, 1120, 1130, 1140, 1150, 1160, 1170, 1180, 1190, 1200, 1210, 1220, 1230, 1240, 1250, 1260, 1270, 1280, 1290, 1300, 1310, 1320, 1330, 1340, 1350, 1360, 1370, 1380, 1390, 1400, 1410, 1420, 1430, 1440, 1450, 1460, 1470, 1480, 1490, 1500, 1510, 1520, 1530, 1540, 1550, 1560, 1570, 1580, 1590, 1600, 1610, 1620, 1630, 1640, 1650, 1660, 1670, 1680, 1690, 1700, 1710, 1720, 1730, 1740, 1750, 1760, 1770, 1780, 1790, 1800, 1810, 1820, 1830, 1840, 1850, 1860, 1870, 1880, 1890, 1900, 1910, 1920, 1930, 1940, 1950, 1960, 1970, 1980, 1990, 2000, 2010, 2020, 2030, 2040, 2050, 2060, 2070, 2080, 2090, 2100, 2110, 2120, 2130, 2140, 2150, 2160, 2170, 2180, 2190, 2200, 2210, 2220, 2230, 2240, 2250, 2260, 2270, 2280, 2290, 2300, 2310, 2320, 2330, 2340, 2350, 2360, 2370, 2380, 2390, 2400, 2410, 2420, 2430, 2440, 2450, 2460, 2470, 2480, 2490, 2500, 2510, 2520, 2530, 2540, 2550, 2560, 2570, 2580, 2590, 2600, 2610, 2620, 2630, 2640, 2650, 2660, 2670, 2680, 2690, 2700, 2710, 2720, 2730, 2740, 2750, 2760, 2770, 2780, 2790, 2800, 2810, 2820, 2830, 2840, 2850, 2860, 2870, 2880, 2890, 2900, 2910, 2920, 2930, 2940, 2950, 2960, 2970, 2980, 2990, 3000, 3010, 3020, 3030, 3040, 3050, 3060, 3070, 3080, 3090, 3100, 3110, 3120, 3130, 3140, 3150, 3160, 3170, 3180, 3190, 3200, 3210, 3220, 3230, 3240, 3250, 3260, 3270, 3280, 3290, 3300, 3310, 3320, 3330, 3340, 3350, 3360, 3370, 3380, 3390, 3400, 3410, 3420, 3430, 3440, 3450, 3460, 3470, 3480, 3490, 3500, 3510, 3520, 3530, 3540, 3550, 3560, 3570, 3580, 3590, 3600, 3610, 3620, 3630, 3640, 3650, 3660, 3670, 3680, 3690, 3700, 3710, 3720, 3730, 3740, 3750, 3760, 3770, 3780, 3790, 3800, 3810, 3820, 3830, 3840, 3850, 3860, 3870, 3880, 3890, 3900, 3910, 3920, 3930, 3940, 3950, 3960, 3970, 3980, 3990, 4000, 4010, 4020, 4030, 4040, 4050, 4060, 4070, 4080, 4090, 4100, 4110, 4120, 4130, 4140, 4150, 4160, 4170, 4180, 4190, 4200, 4210, 4220, 4230, 4240, 4250, 4260, 4270, 4280, 4290, 4300, 4310, 4320, 4330, 4340, 4350, 4360, 4370, 4380, 4390, 4400, 4410, 4420, 4430, 4440, 4450, 4460, 4470, 4480, 4490, 4500, 4510, 4520, 4530, 4540, 4550, 4560, 4570, 4580, 4590, 4600, 4610, 4620, 4630, 4640, 4650, 4660, 4670, 4680, 4690, 4700, 4710, 4720, 4730, 4740, 4750, 4760, 4770, 4780, 4790, 4800, 4810, 4820, 4830, 4840, 4850, 4860, 4870, 4880, 4890, 4900, 4910, 4920, 4930, 4940, 4950, 4960, 4970, 4980, 4990, 5000, 5010, 5020, 5030, 5040, 5050, 5060, 5070, 5080, 5090, 5100, 5110, 5120, 5130, 5140, 5150, 5160, 5170, 5180, 5190, 5200, 5210, 5220, 5230, 5240, 5250, 5260, 5270, 5280, 5290, 5300, 5310, 5320, 5330, 5340, 5350, 5360, 5370, 5380, 5390, 5400, 5410, 5420, 5430, 5440, 5450, 5460, 5470, 5480, 5490, 5500, 5510, 5520, 5530, 5540, 5550, 5560, 5570, 5580, 5590, 5600, 5610, 5620, 5630, 5640, 5650, 5660, 5670, 5680, 5690, 5700, 5710, 5720, 5730, 5740, 5750, 5760, 5770, 5780, 5790, 5800, 5810, 5820, 5830, 5840, 5850, 5860, 5870, 5880, 5890, 5900, 5910, 5920, 5930, 5940, 5950, 5960, 5970, 5980, 5990, 6000, 6010, 6020, 6030, 6040, 6050, 6060, 6070, 6080, 6090, 6100, 6110, 6120, 6130, 6140, 6150, 6160, 6170, 6180, 6190, 6200, 6210, 6220, 6230, 6240, 6250, 6260, 6270, 6280, 6290, 6300, 6310, 6320, 6330, 6340, 6350, 6360, 6370, 6380, 6390, 6400, 6410, 6420, 6430, 6440, 6450, 6460, 6470, 6480, 6490, 6500, 6510, 6520, 6530, 6540, 6550, 6560, 6570, 6580, 6590, 6600, 6610, 6620, 6630, 6640, 6650, 6660, 6670, 6680, 6690, 6700, 6710, 6720, 6730, 6740, 6750, 6760, 6770, 6780, 6790, 6800, 6810, 6820, 6830, 6840, 6850, 6860, 6870, 6880, 6890, 6900, 6910, 6920, 6930, 6940, 6950, 6960, 6970, 6980, 6990, 7000, 7010, 7020, 7030, 7040, 7050, 7060, 7070, 7080, 7090, 7100, 7110, 7120, 7130, 7140, 7150, 7160, 7170, 7180, 7190, 7200, 7210, 7220, 7230, 7240, 7250, 7260, 7270, 7280, 7290, 7300, 7310, 7320, 7330, 7340, 7350, 7360, 7370, 7380, 7390, 7400, 7410, 7420, 7430, 7440, 7450, 7460, 7470, 7480, 7490, 7500, 7510, 7520, 7530, 7540, 7550, 7560, 7570, 7580, 7590, 7600, 7610, 7620, 7630, 7640, 7650, 7660, 7670, 7680, 7690, 7700, 7710, 7720, 7730, 7740, 7750, 7760, 7770, 7780, 7790, 7800, 7810, 7820, 7830, 7840, 7850, 7860, 7870, 7880, 7890, 7900, 7910, 7920, 7930, 7940, 7950, 7960, 7970, 7980, 7990, 8000, 8010, 8020, 8030, 8040, 8050, 8060, 8070, 8080, 8090, 8100, 8110, 8120, 8130, 8140, 8150, 8160, 8170, 8180, 8190, 8200, 8210, 8220, 8230, 8240, 8250, 8260, 8270, 8280, 8290, 8300, 8310, 8320, 8330, 8340, 8350, 8360, 8370, 8380, 8390, 8400, 8410, 8420, 8430, 8440, 8450, 8460, 8470, 8480, 8490, 8500, 8510, 8520, 8530, 8540, 8550, 8560, 8570, 8580, 8590, 8600, 8610, 8620, 8630, 8640, 8650, 8660, 8670, 8680, 8690, 8700, 8710, 8720, 8730, 8740, 8750, 8760, 8770, 8780, 8790, 8800, 8810, 8820, 8830, 8840, 8850, 8860, 8870, 8880, 8890, 8900, 8910, 8920, 8930, 8940, 8950, 8960, 8970, 8980, 8990, 9000, 9010, 9020, 9030, 9040, 9050, 9060, 9070, 9080, 9090, 9100, 9110, 9120, 9130, 9140, 9150, 9160, 9170, 9180, 9190, 9200, 9210, 9220, 9230, 9240, 9250, 9260, 9270, 9280, 9290, 9300, 9310, 9320, 9330, 9340, 9350, 9360, 9370, 9380, 9390, 9400, 9410, 9420, 9430, 9440, 9450, 9460, 9470, 9480, 9490, 9500, 9510, 9520, 9530, 9540, 9550, 9560, 9570, 9580, 9590, 9600, 9610, 9620, 9630, 9640, 9650, 9660, 9670, 9680, 9690, 9700, 9710, 9720, 9730, 9740, 9750, 9760, 9770, 9780, 9790, 9800, 9810, 9820, 9830, 9840, 9850, 9860, 9870, 9880, 9890, 9900, 9910, 9920, 9930, 9940, 9950, 9960, 9970, 9980, 9990, 10000

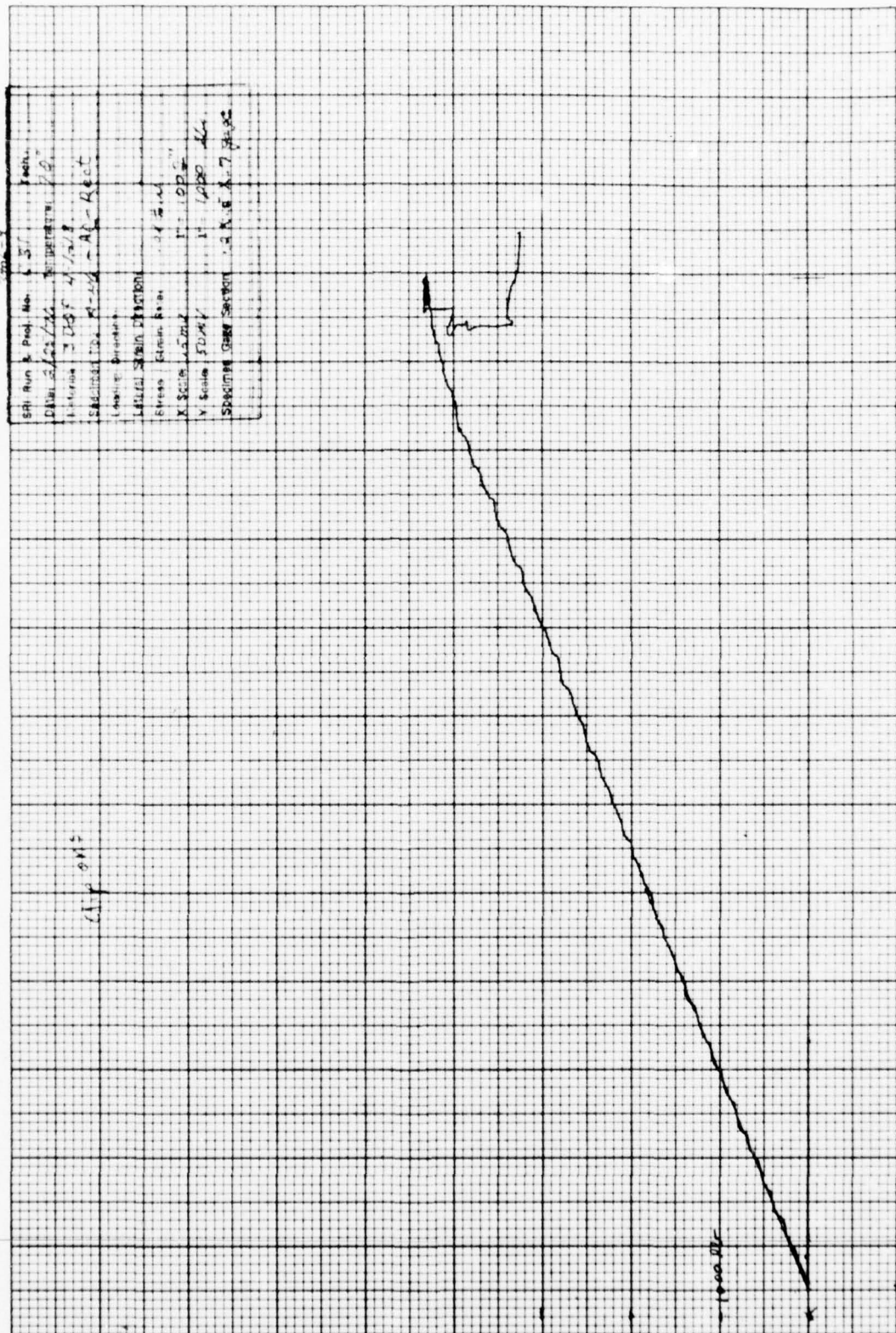
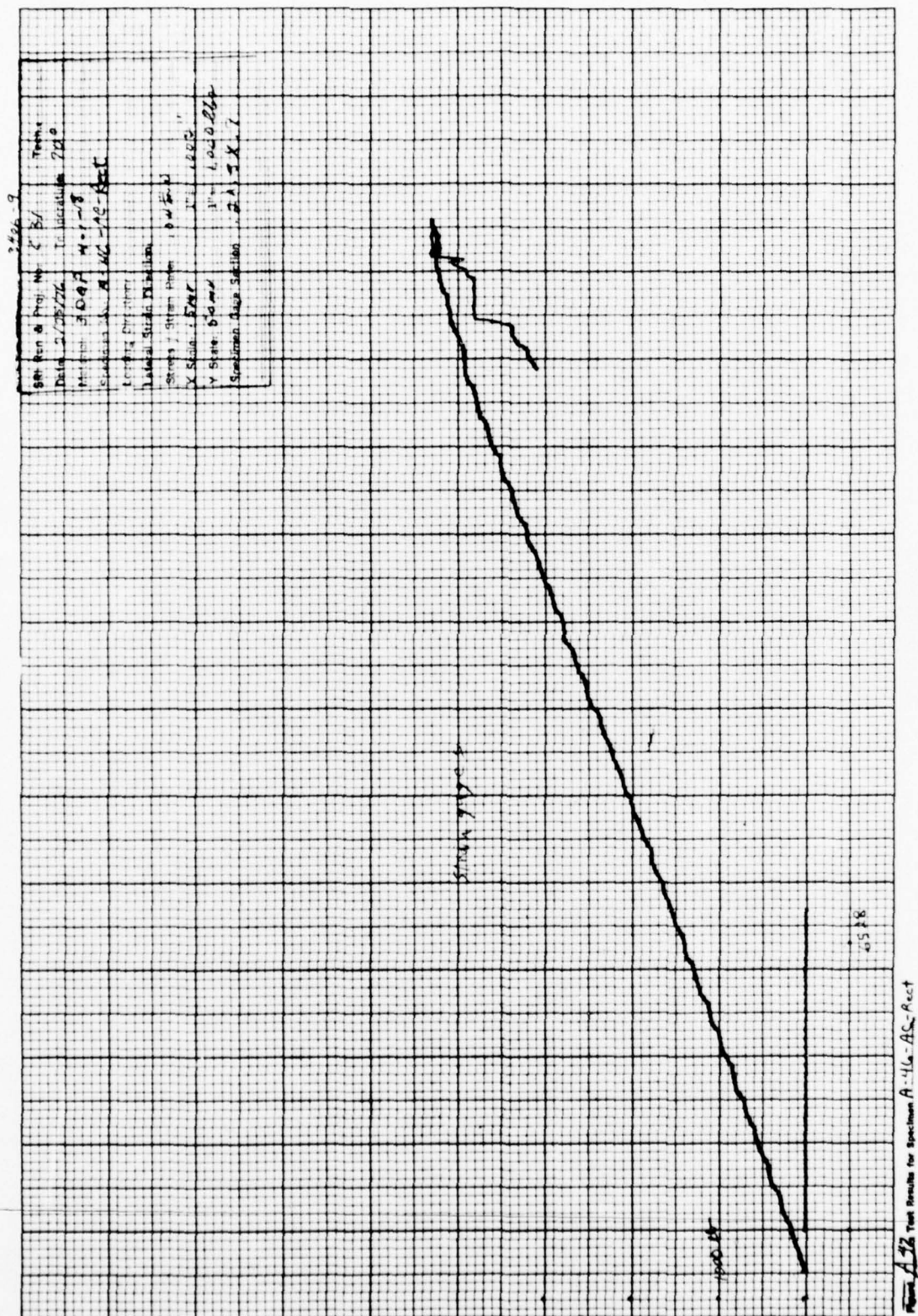
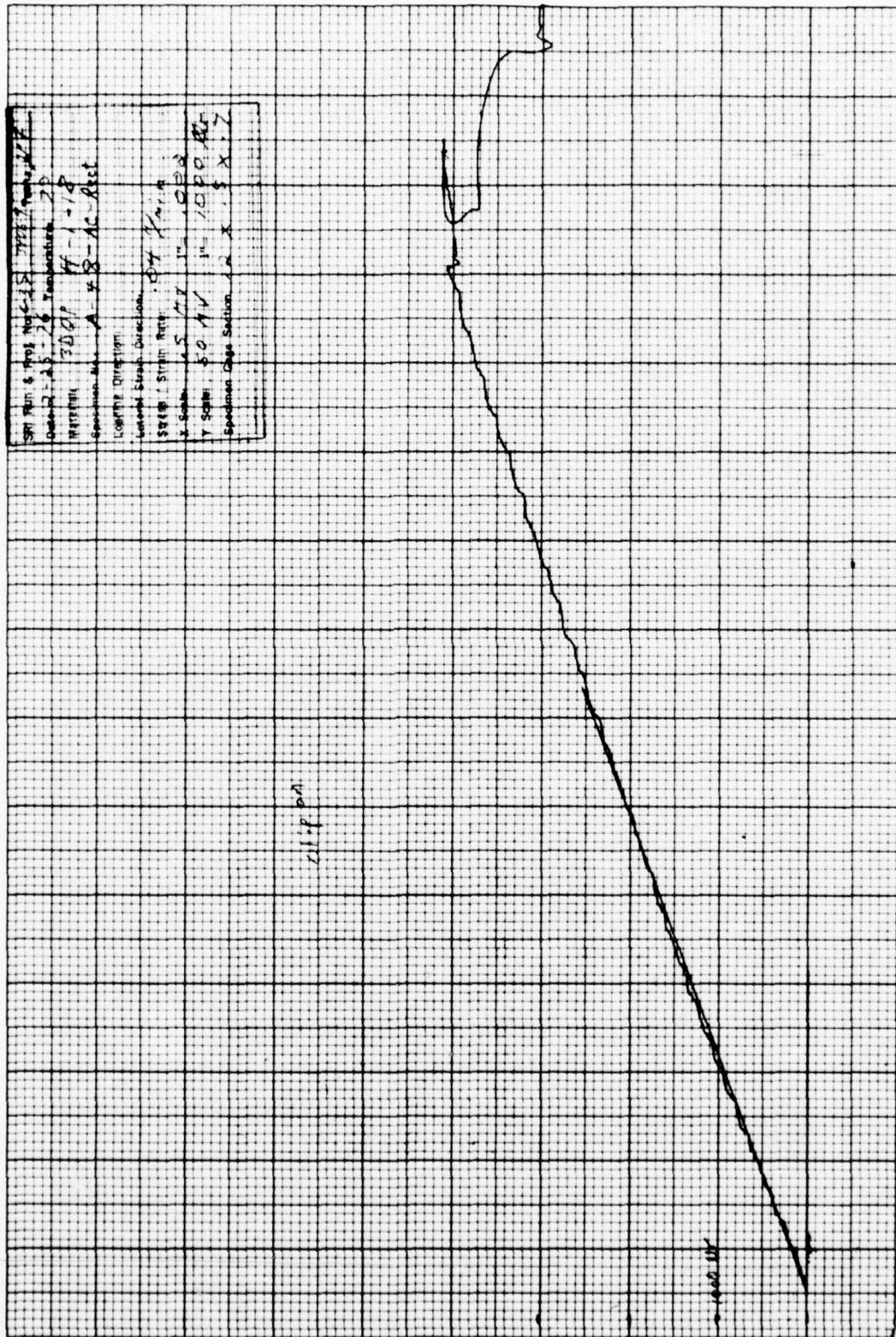


Figure 1. Test Results for Specimen A-46 AC-Rect





Specimen No. A-48-AC Rect
 Length Direction 1000
 Load Stress Direction 1000
 Specimen 1000
 Y Scale 1000
 X Scale 1000
 Specimen Case Section 1000

A-48-AC Rect

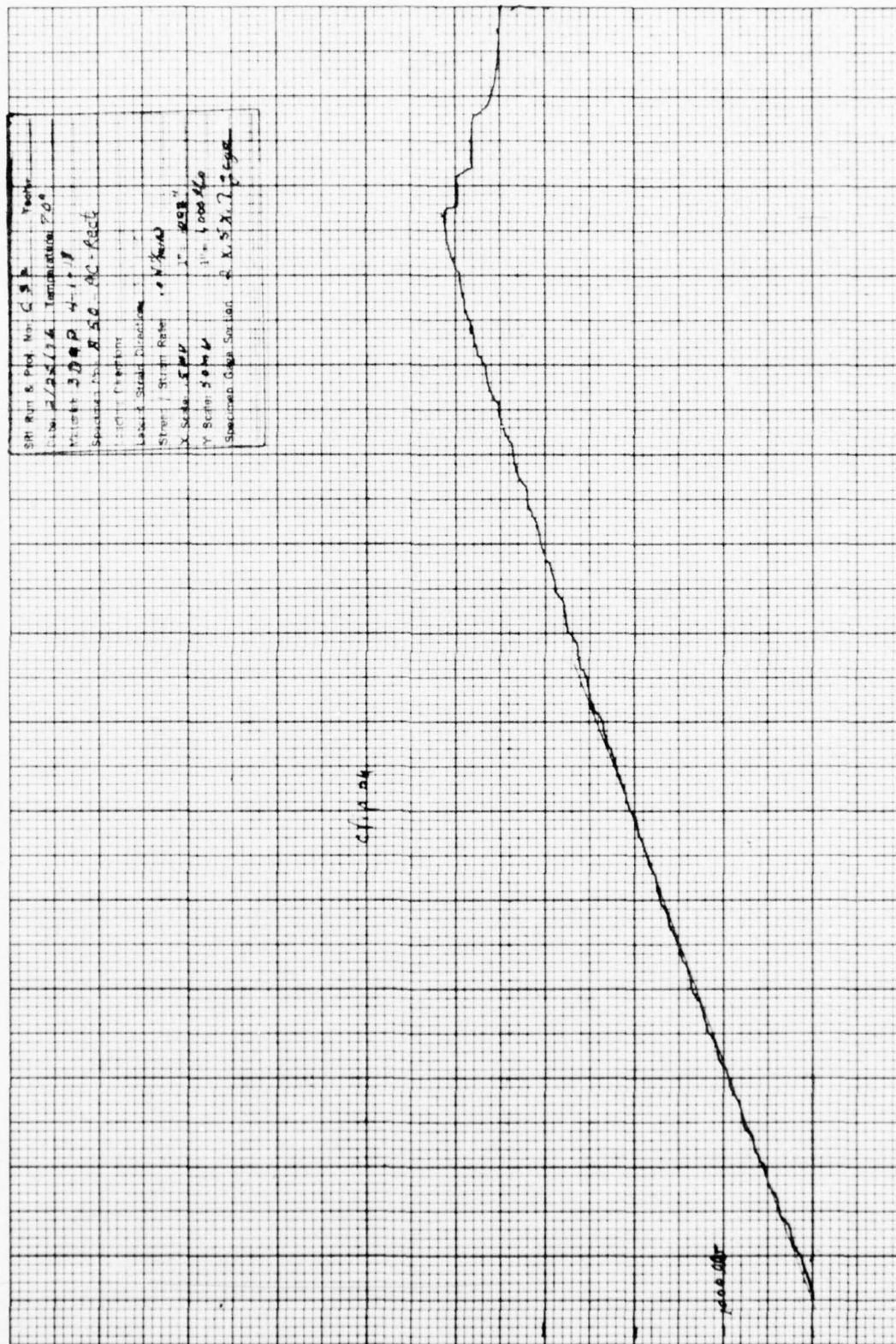
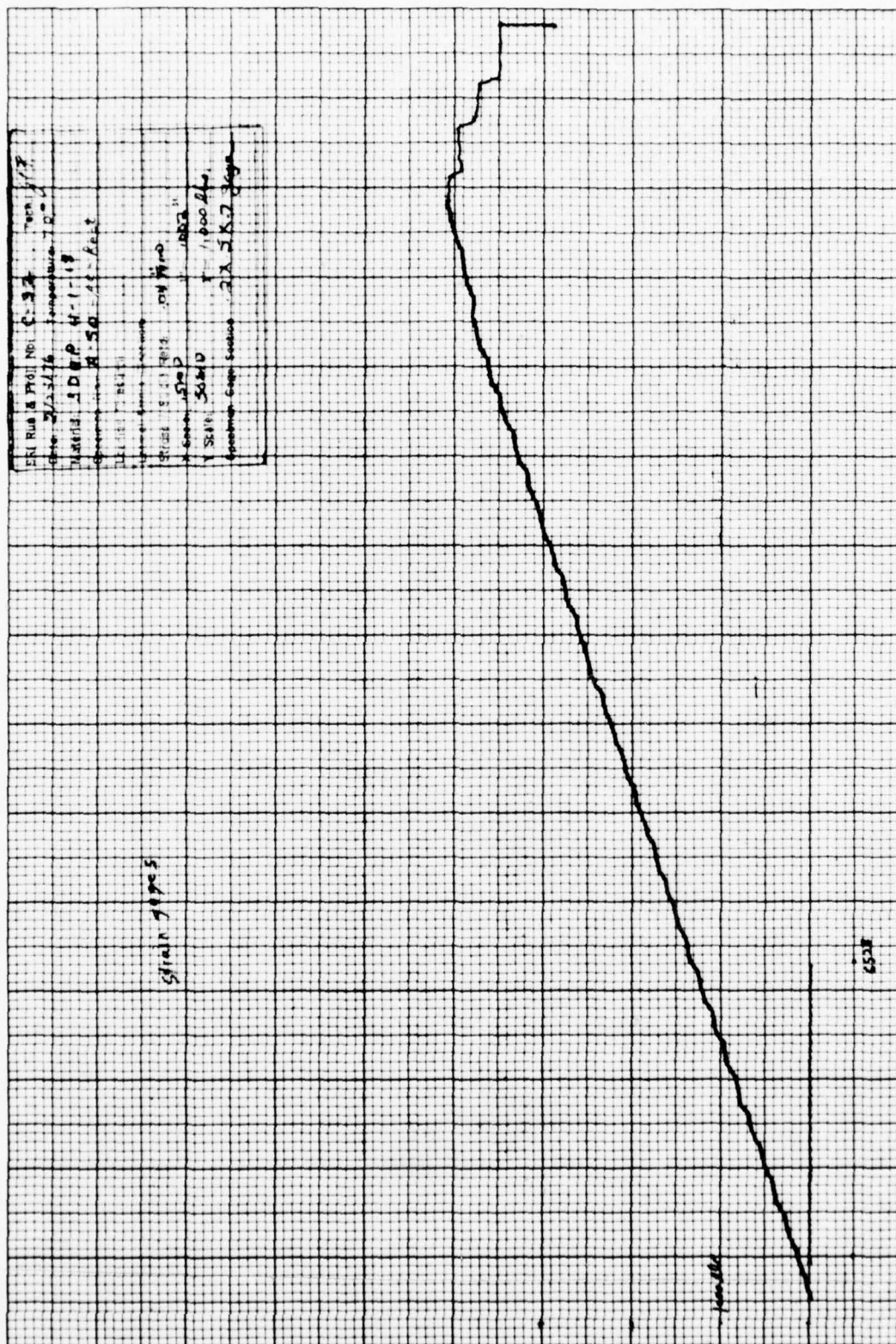


Figure A 95 Test Results for Specimen A 50-AC Act



A4

Circumferential Compressive Tests
SoRI Specimen Configuration

6.1.4

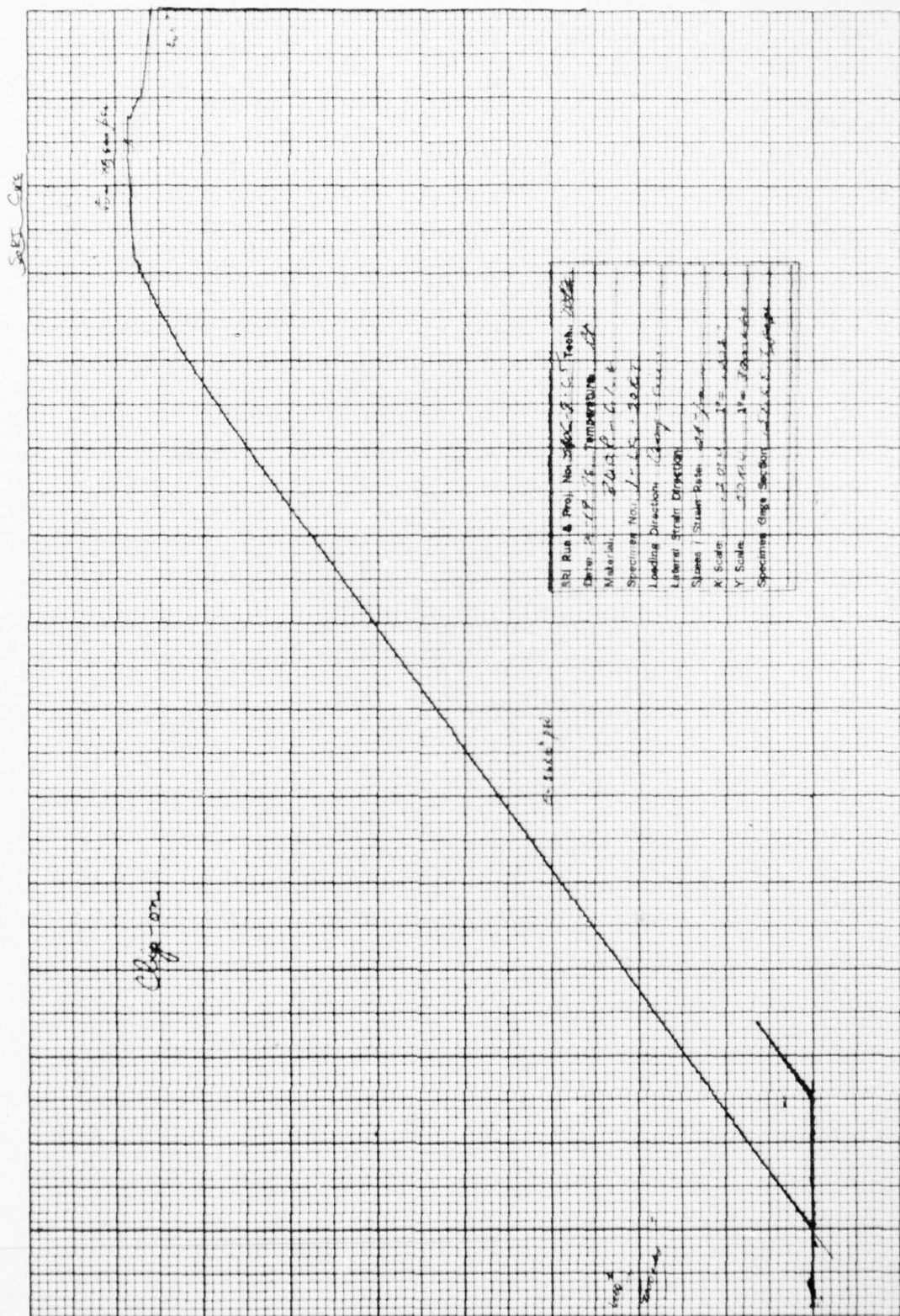
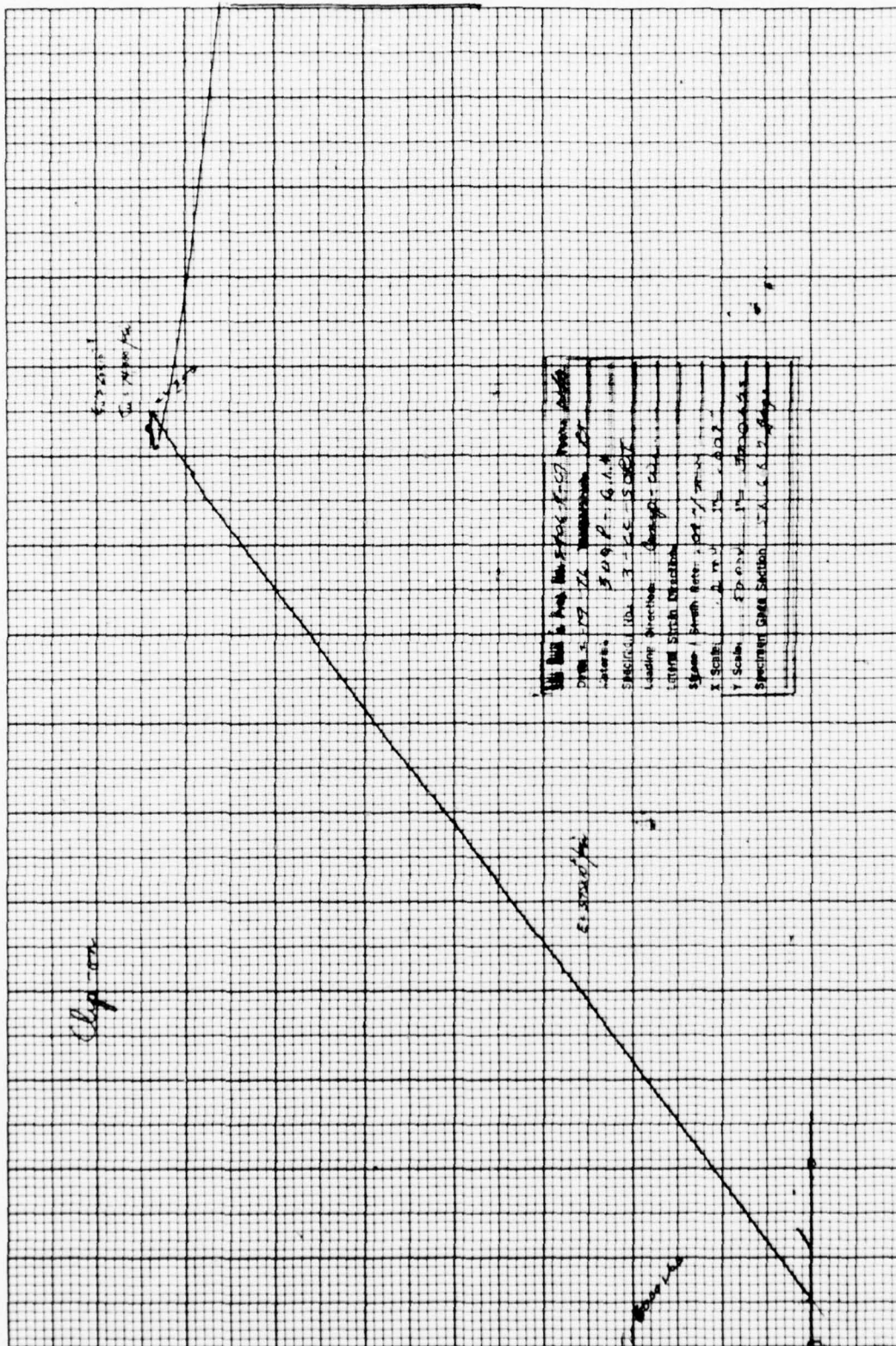
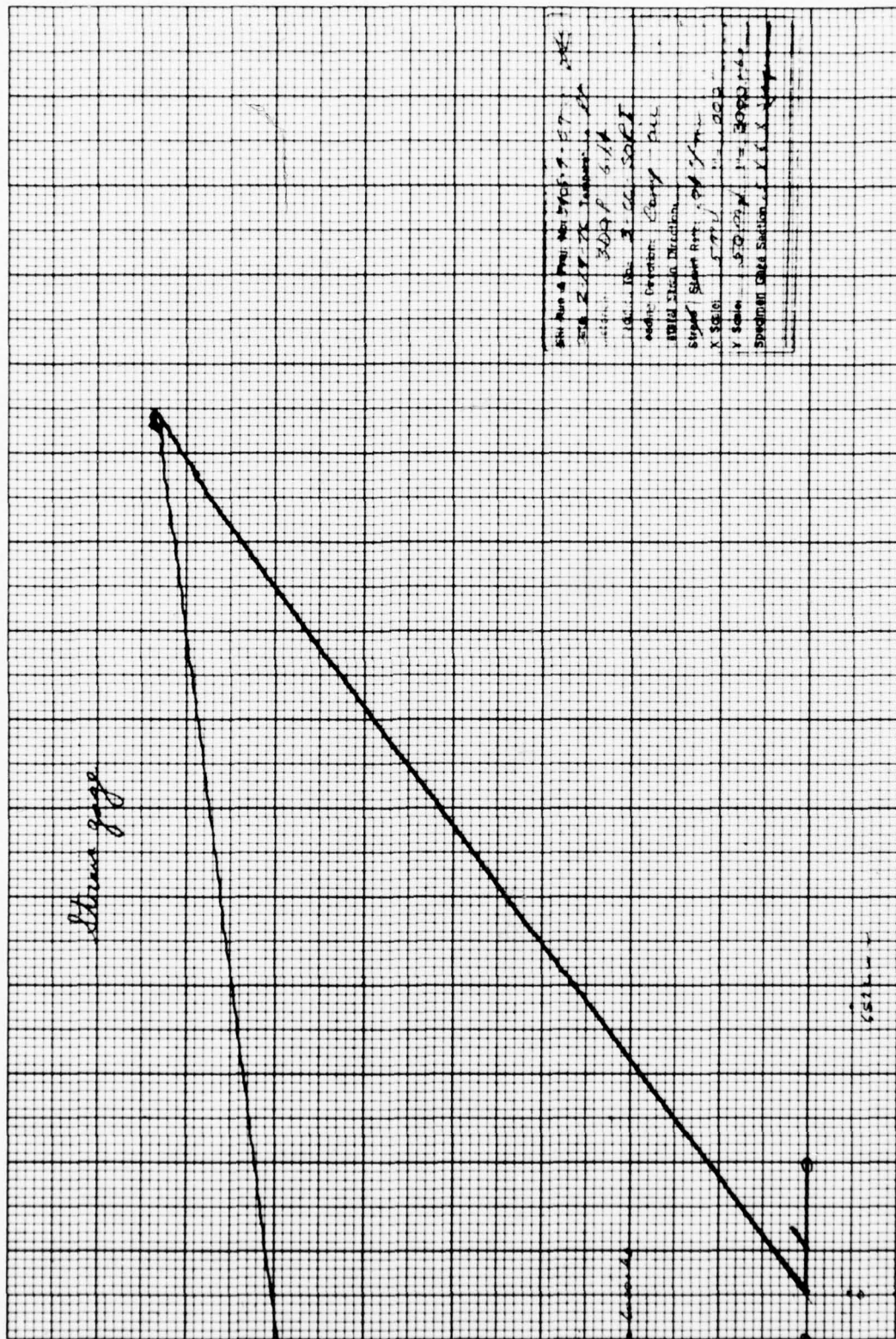


Figure 47. Test Results for Specimen 1-65-1000

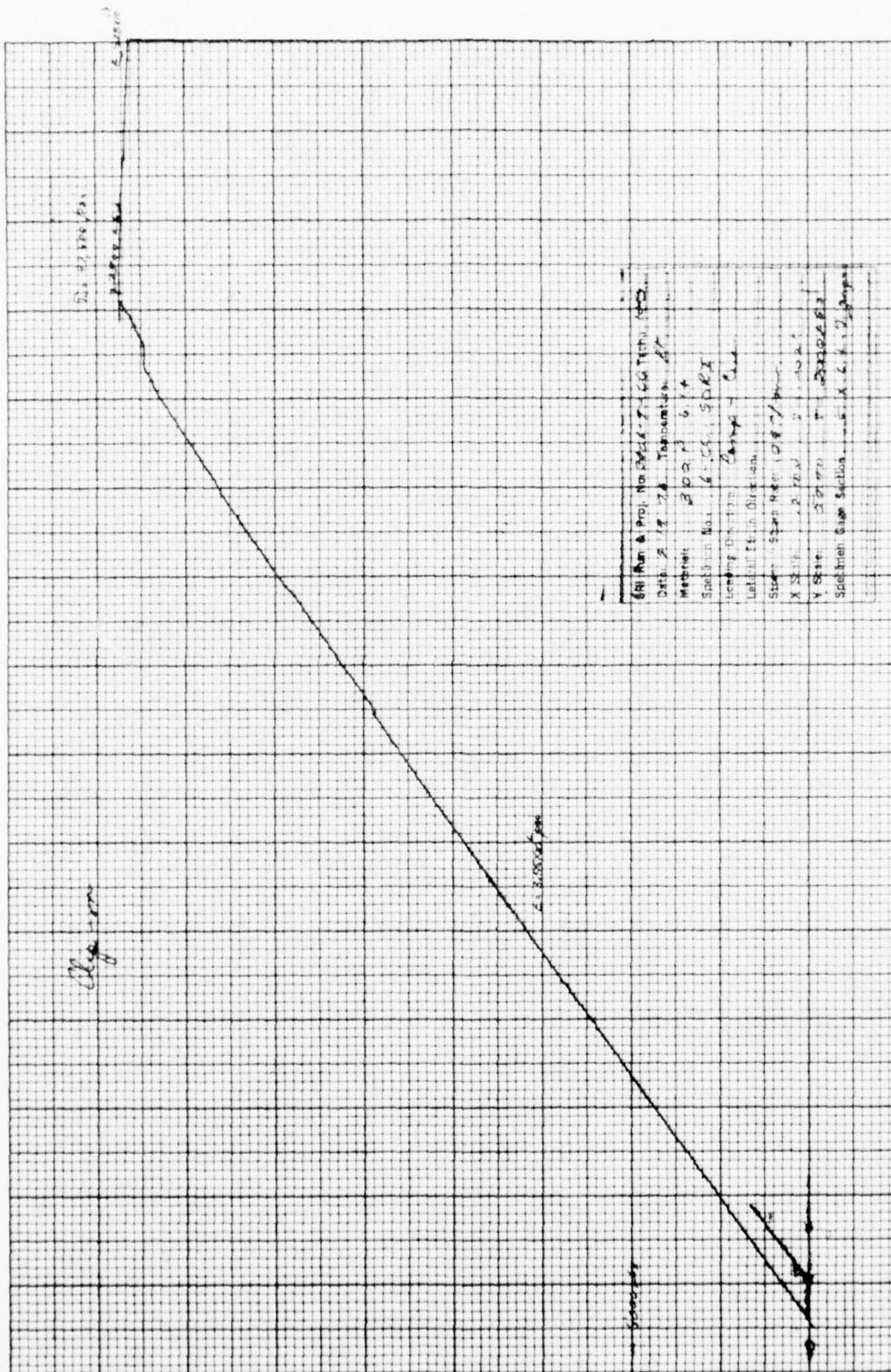


Test No.	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519	1520	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	1544	1545	1546	1547	1548	1549	1550	1551	1552
----------	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------



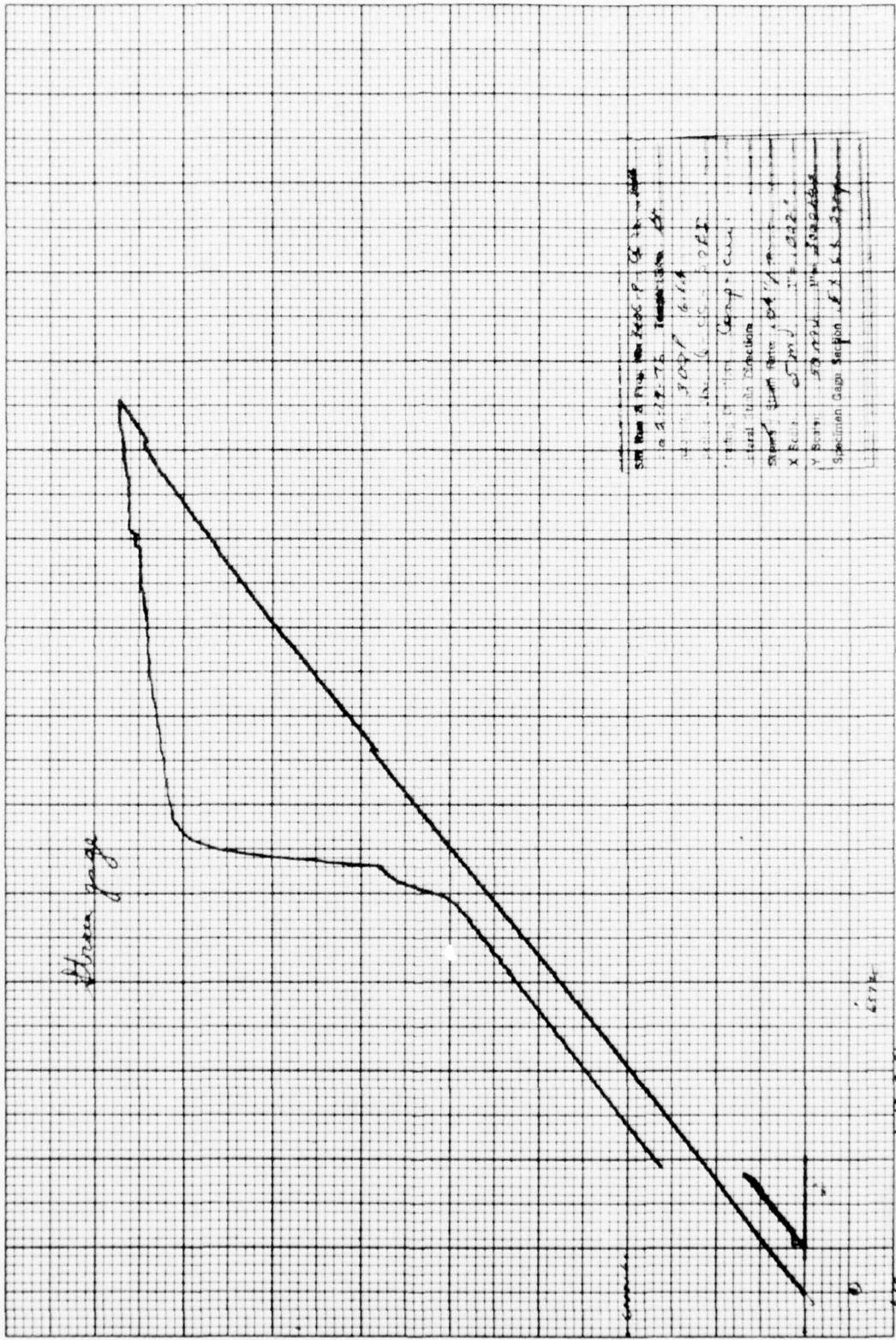
Soil Name: *Red Clay*
 Test No: *3027*
 Date: *3/1/64*
 Location: *3.00 SOFT*
 Moisture Content: *60%*
 Liquid Limit: *60%*
 Plastic Limit: *20%*
 Shrinkage: *15%*
 X Scale: *5000*
 Y Scale: *5000*
 Specimen Size: *1.5 x 1.5 x 1.5*

Figure ASD Test Results for Specimen 3.00-3.00



GRAIN & PROJ. NO. 54-6-7-100 TYP. 100
 DATE 2-12-78 TYP. 100
 METHOD 300 6 1 1
 SECTION NO. 6-55-50R
 LENGTH 0.5 ft. 100
 UNIT 1 ft. 100
 STATE 100 100 100
 X 100 100 100
 Y 100 100 100
 SECTION 100 100 100

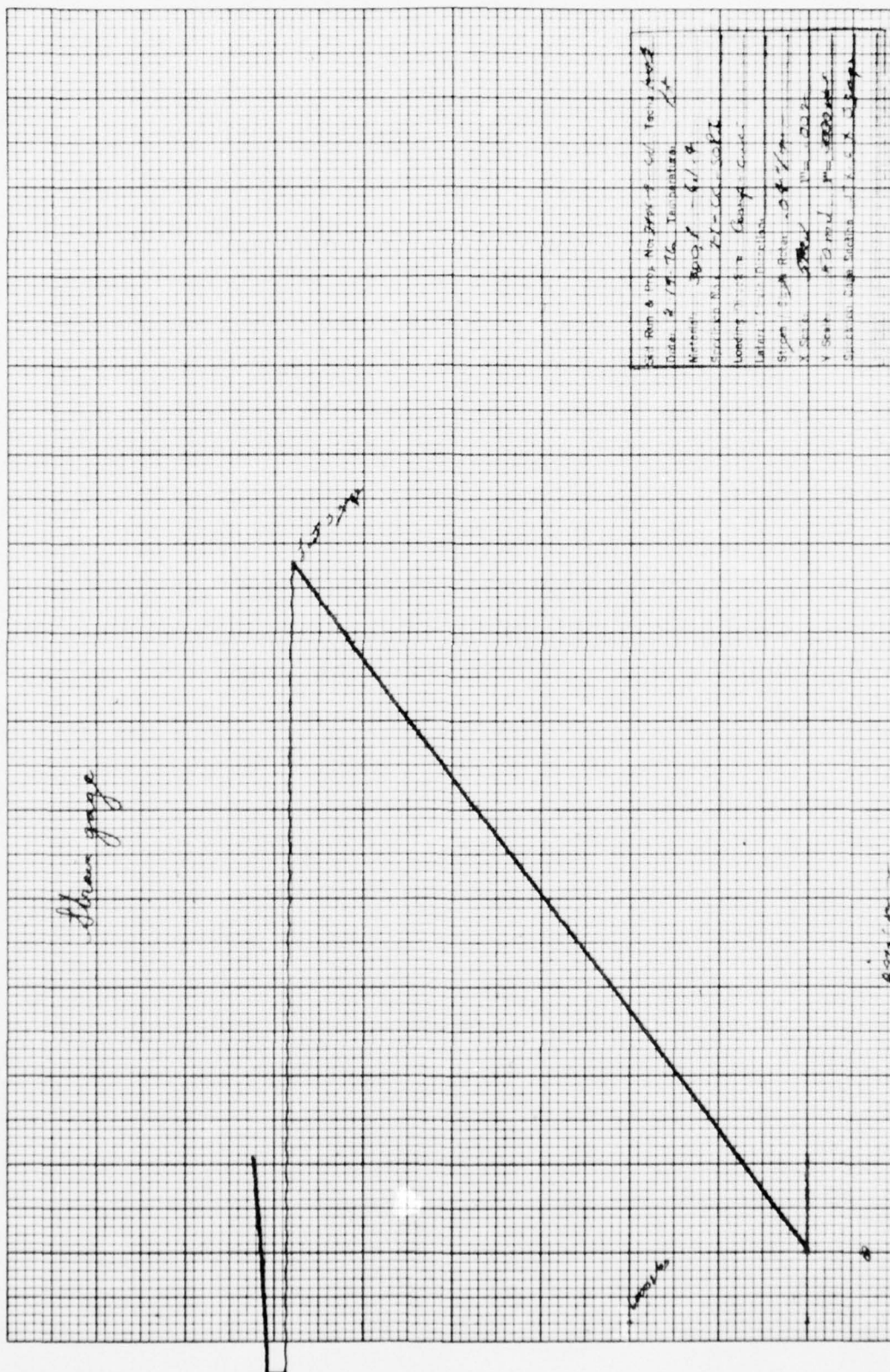
Page 251 Test Results for Specimens G-CC-50R



Stress vs. Strain

Specimen No. 1000-1000
 Date 10-10-75
 Test No. 1000-1000
 X Axis 1000
 Y Axis 1000
 Specimen Data Section 1000-1000

Figure 1.3.2 Test Results for Specimen 1000-1000



Set Run 6 mps. No. 1000-9-61. Tens. 1000
 Date: 8/18/76. Tens. 1000
 Name: 1000-9-61-9
 Size: 1000-9-61-9
 Location: 1000-9-61-9
 Notes: 1000-9-61-9
 X: 1000-9-61-9
 Y: 1000-9-61-9
 Z: 1000-9-61-9
 W: 1000-9-61-9
 V: 1000-9-61-9
 U: 1000-9-61-9
 T: 1000-9-61-9
 S: 1000-9-61-9
 R: 1000-9-61-9
 Q: 1000-9-61-9
 P: 1000-9-61-9
 O: 1000-9-61-9
 N: 1000-9-61-9
 M: 1000-9-61-9
 L: 1000-9-61-9
 K: 1000-9-61-9
 J: 1000-9-61-9
 I: 1000-9-61-9
 H: 1000-9-61-9
 G: 1000-9-61-9
 F: 1000-9-61-9
 E: 1000-9-61-9
 D: 1000-9-61-9
 C: 1000-9-61-9
 B: 1000-9-61-9
 A: 1000-9-61-9

Figure A.5. Strain Results for Experiment 7-1-CL-3-R1

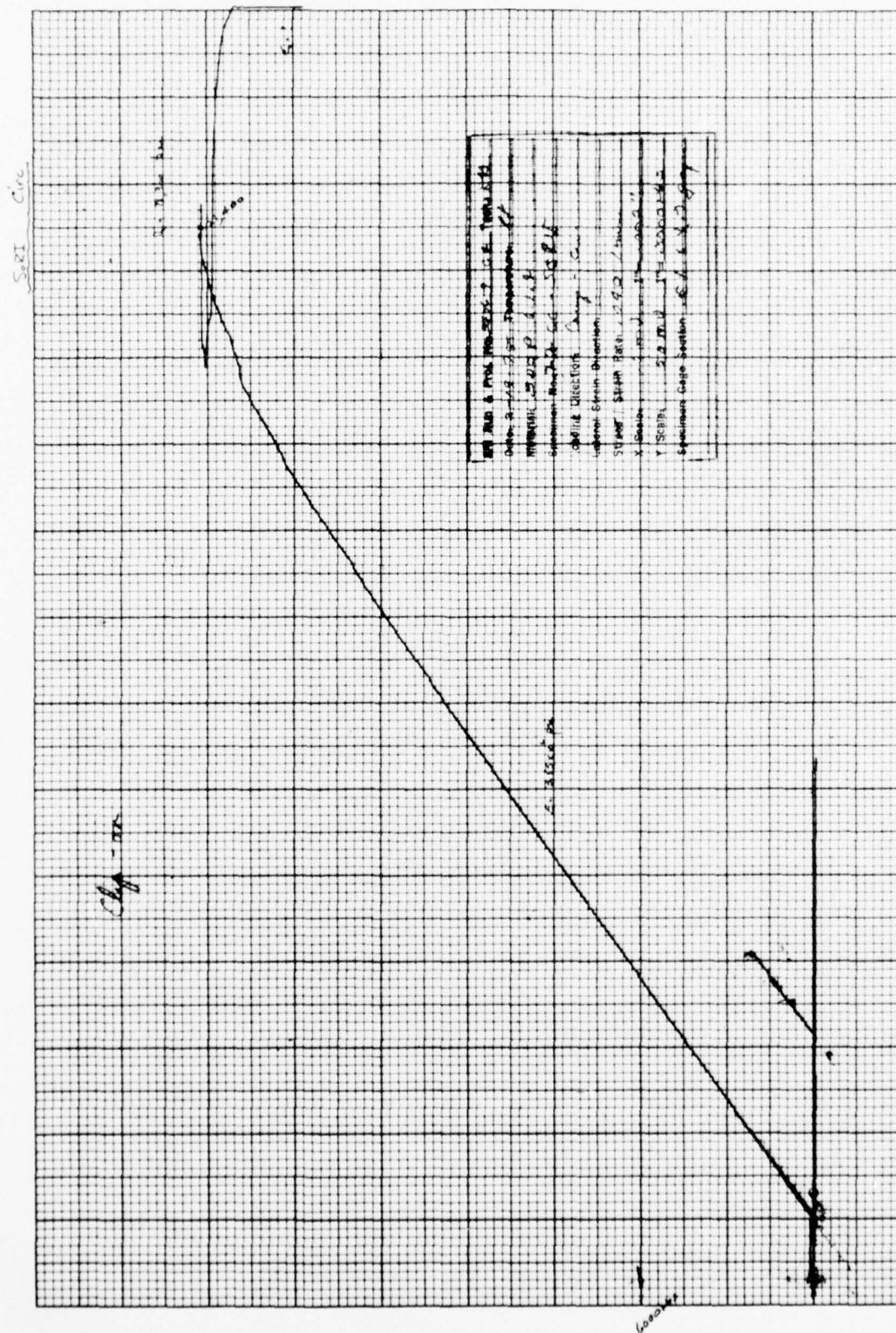
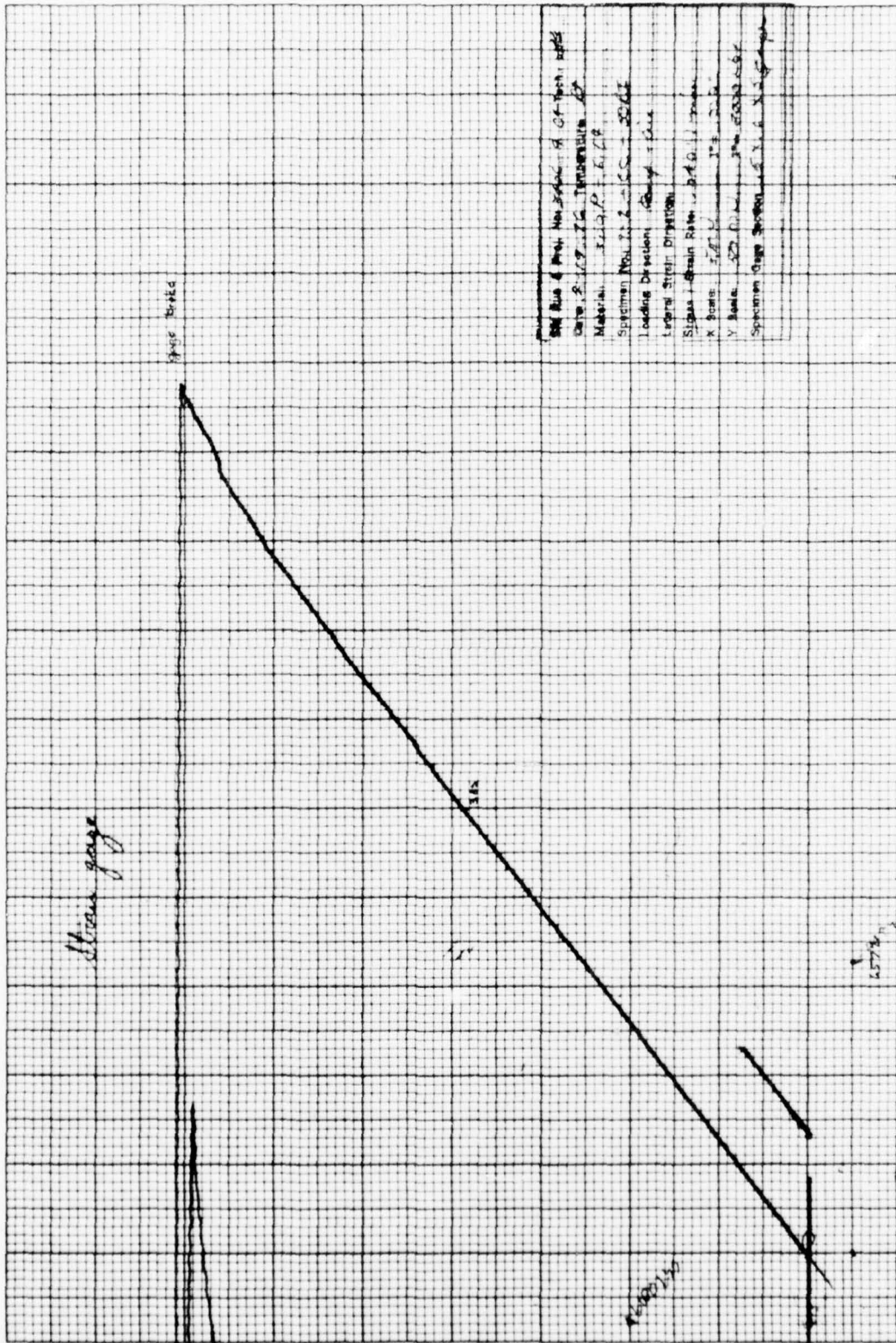


Figure 155 Test Results for Specimen 7-2-S-S-S-A1



Test Run & Test No. 20000 of 20-Test, 1000
 Date: 8-1-78, 10-Test, 1000000000
 Material: 5000, 10-Test, 1000000000
 Specimen No. 10-Test, 1000000000
 Loading Direction: 1000000000
 Legend: Stress Direction
 Stress: 1000000000, 1000000000
 X Points: 1000000000, 1000000000
 Y Points: 1000000000, 1000000000
 Specimen Gauge: 1000000000, 1000000000

A567 Test Results for Specimen 7-2-CC-SOAI
 1000000000

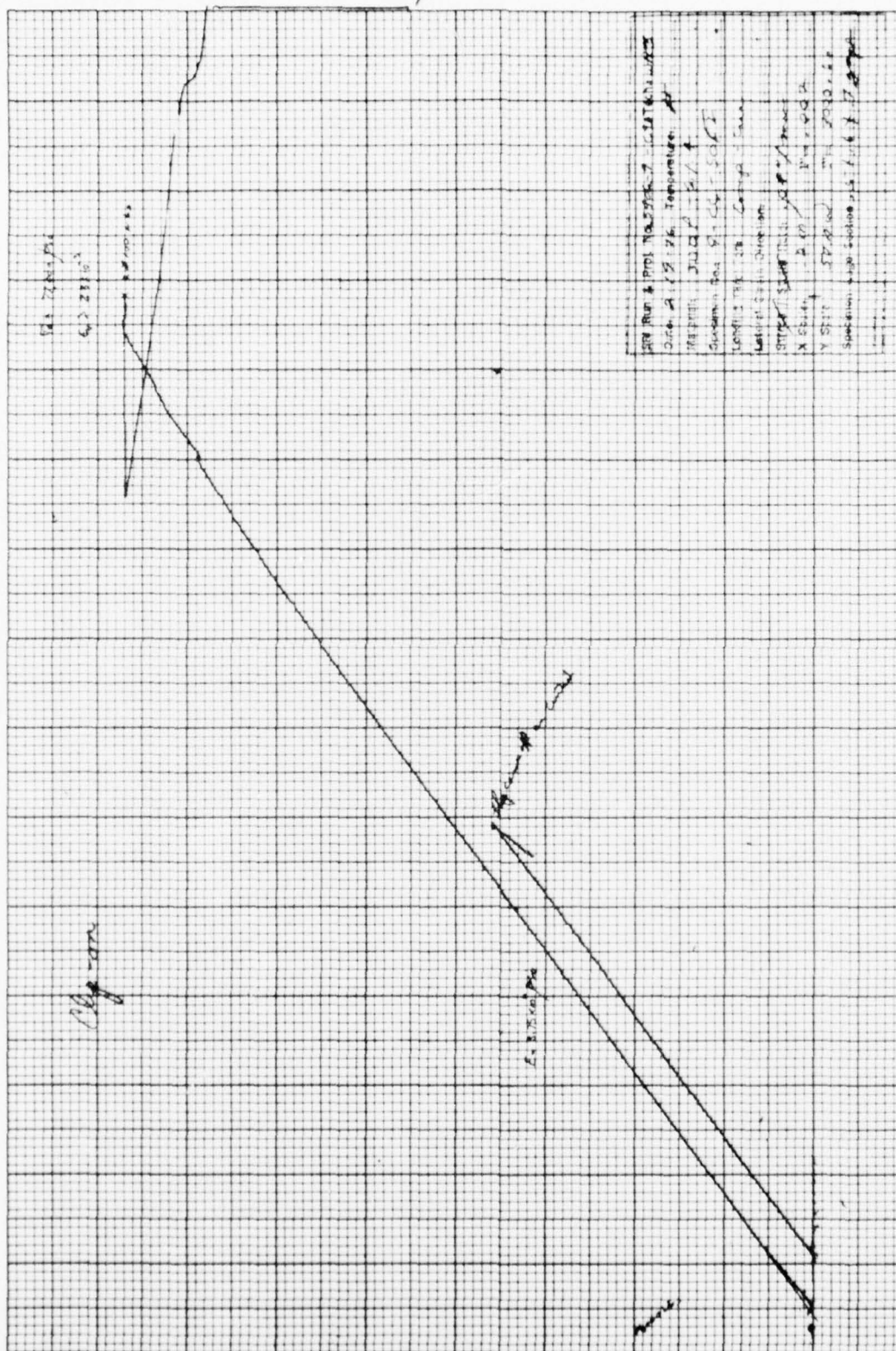
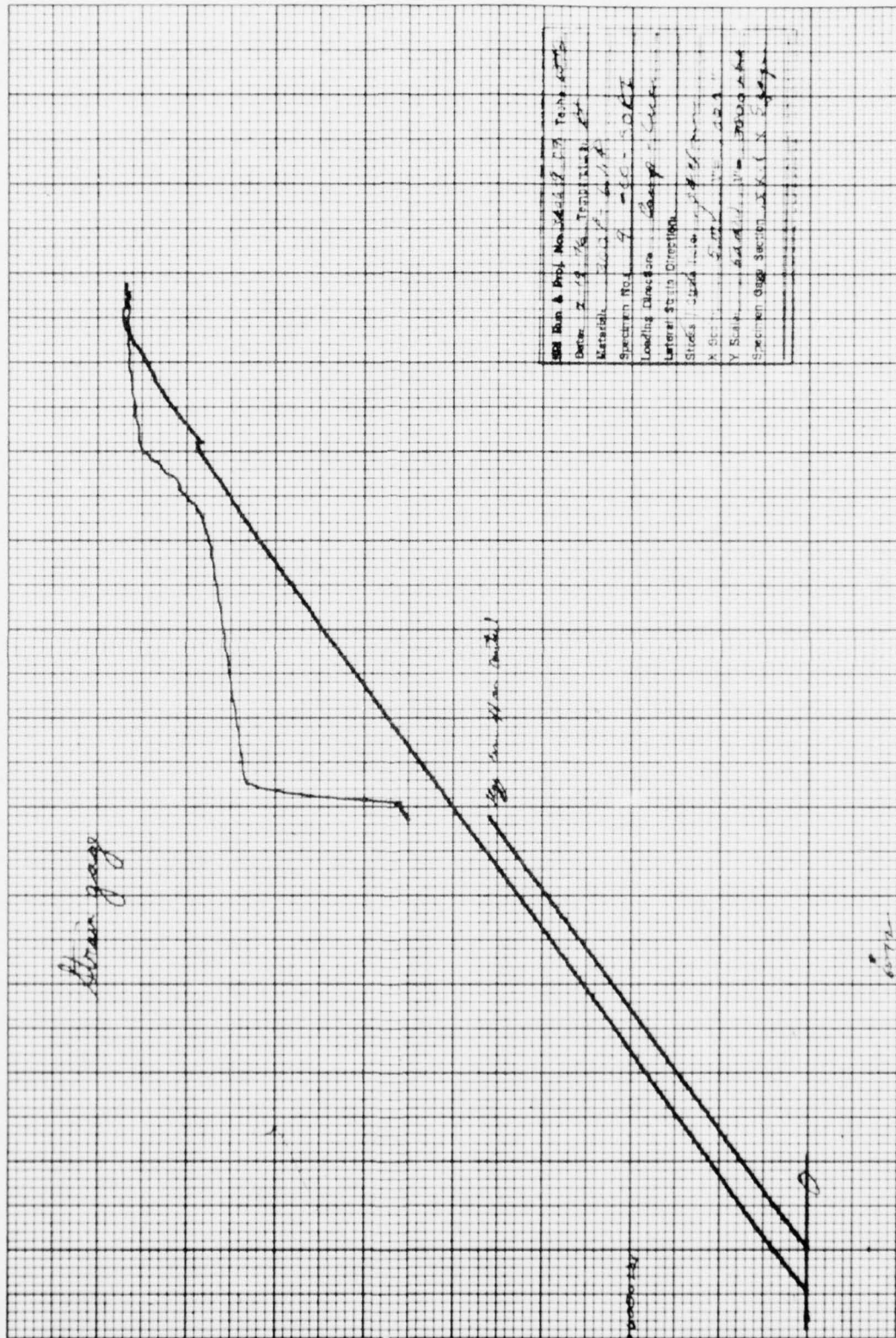
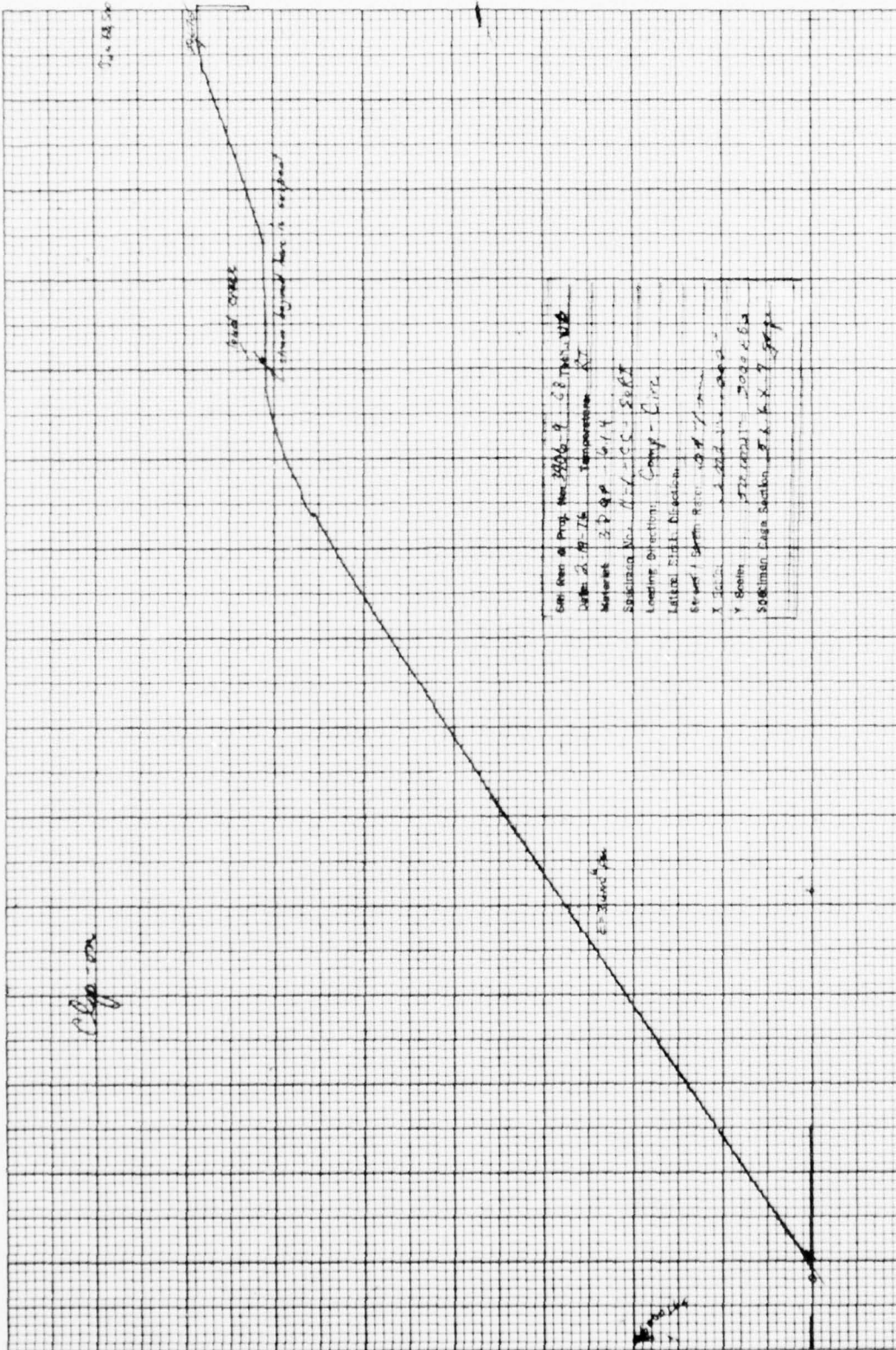


Figure 1.57 Test Results for Specimen 9-CC-SaR1



Specimen No. 91 - 50 - 5000
 Loading Direction: Tension
 Initial Stress Direction: Tension
 Strain Gage Section: X-X
 Y Strain: 0.001 in/in
 Specimen Gage Section: X-X
 Y Strain: 0.001 in/in

Figure A-58 Test Results for Specimen 91-50-5000



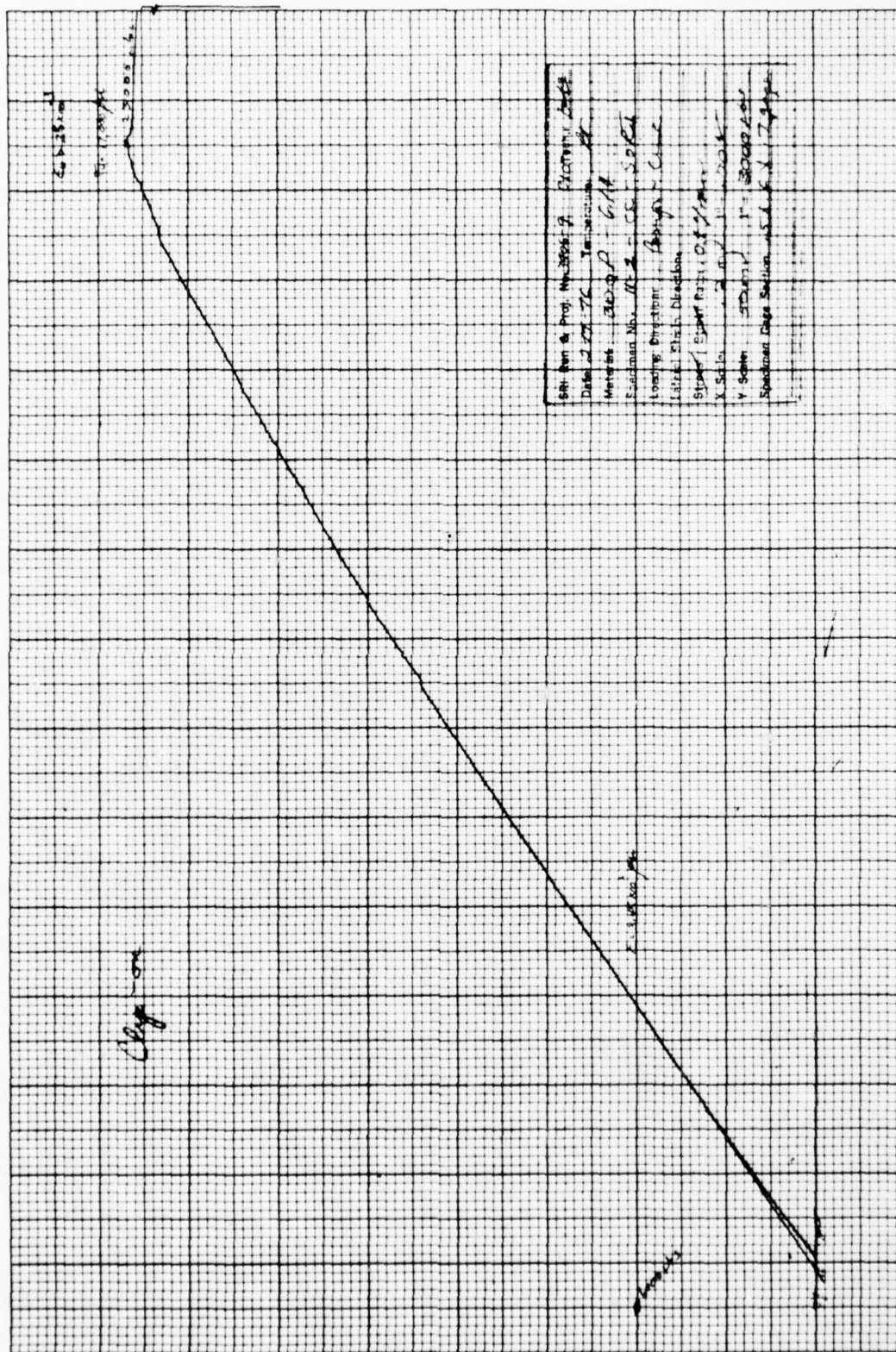


Figure 1. Absolute number of specimens (1 = 2.5 cm x 5.0 cm)

strain gage

SEA Run & Proj No.	2004-2	Stretch	100%
Date	1/17/74	Temperature	8°
Method	3-D-2	1-1-1	
Section No.	11-2	1-1-1	
Leading Direction	East	Line	
Lateral Strain Direction			
Strain / Speed Rate	2.5	1	
X Scale	5	1	
Y Scale	5	1	
Section No.	11-2	1-1-1	

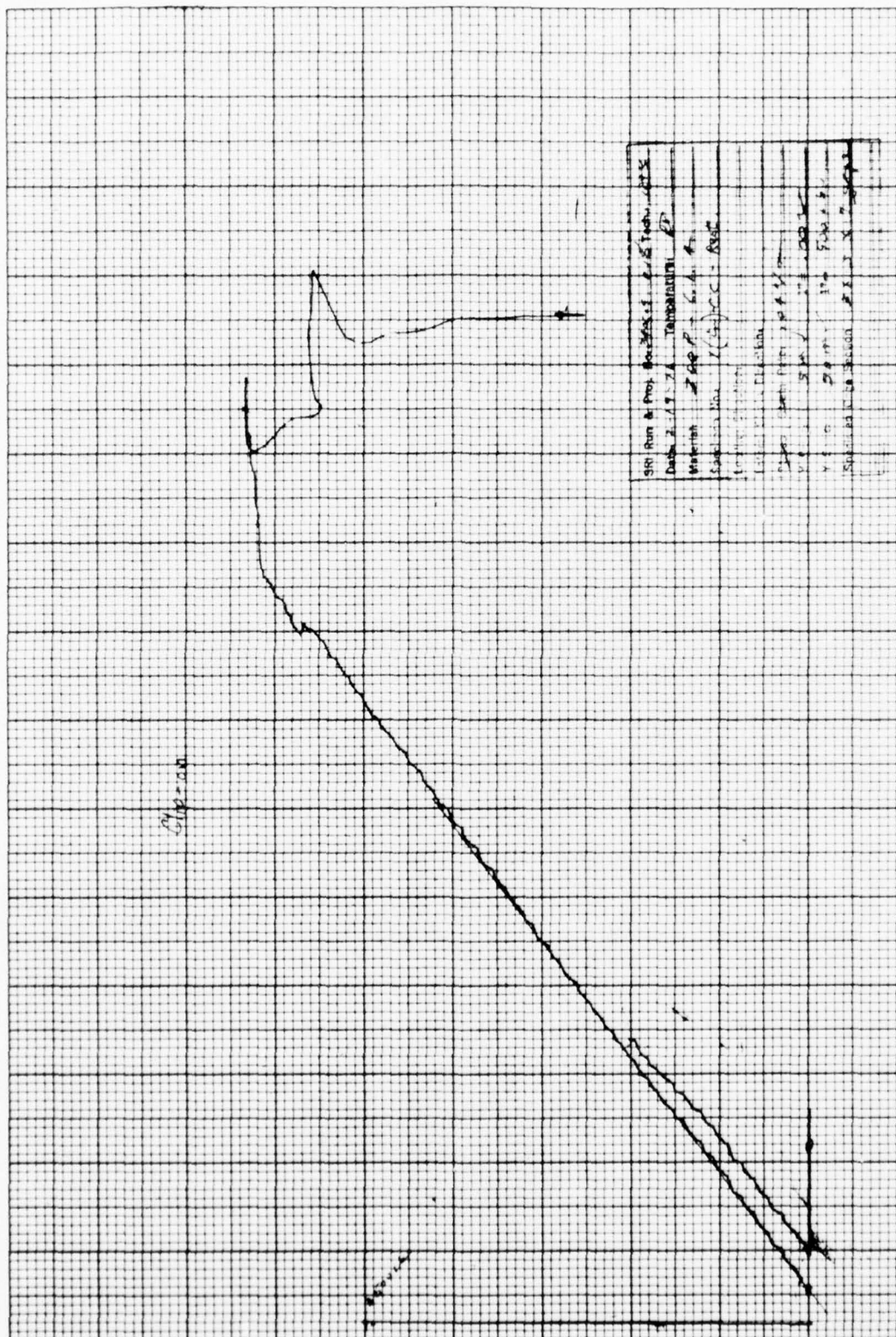
SEA 74

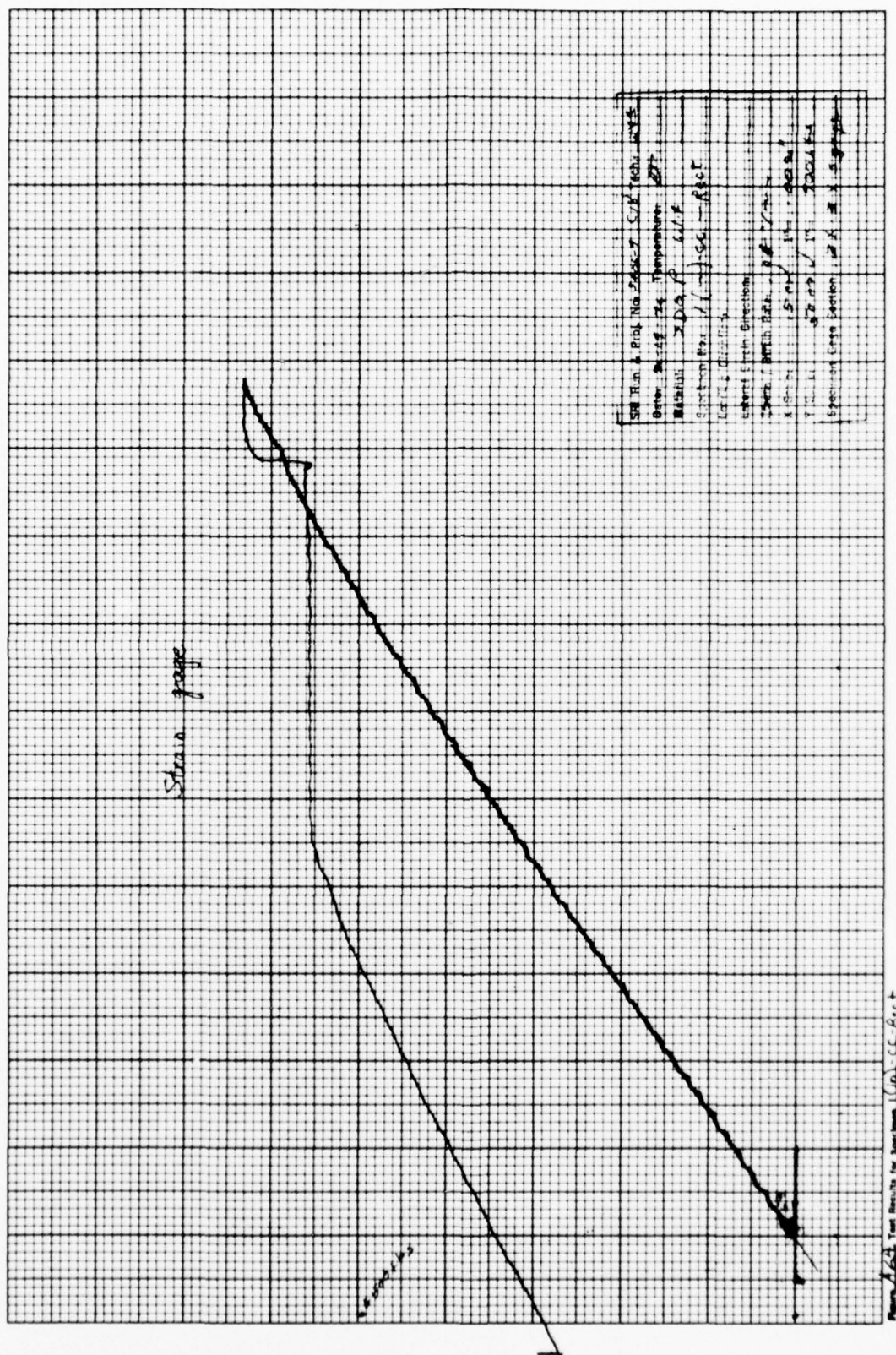
Fig. 2. Test Results for Specimen 11-2-CC-S. R. I

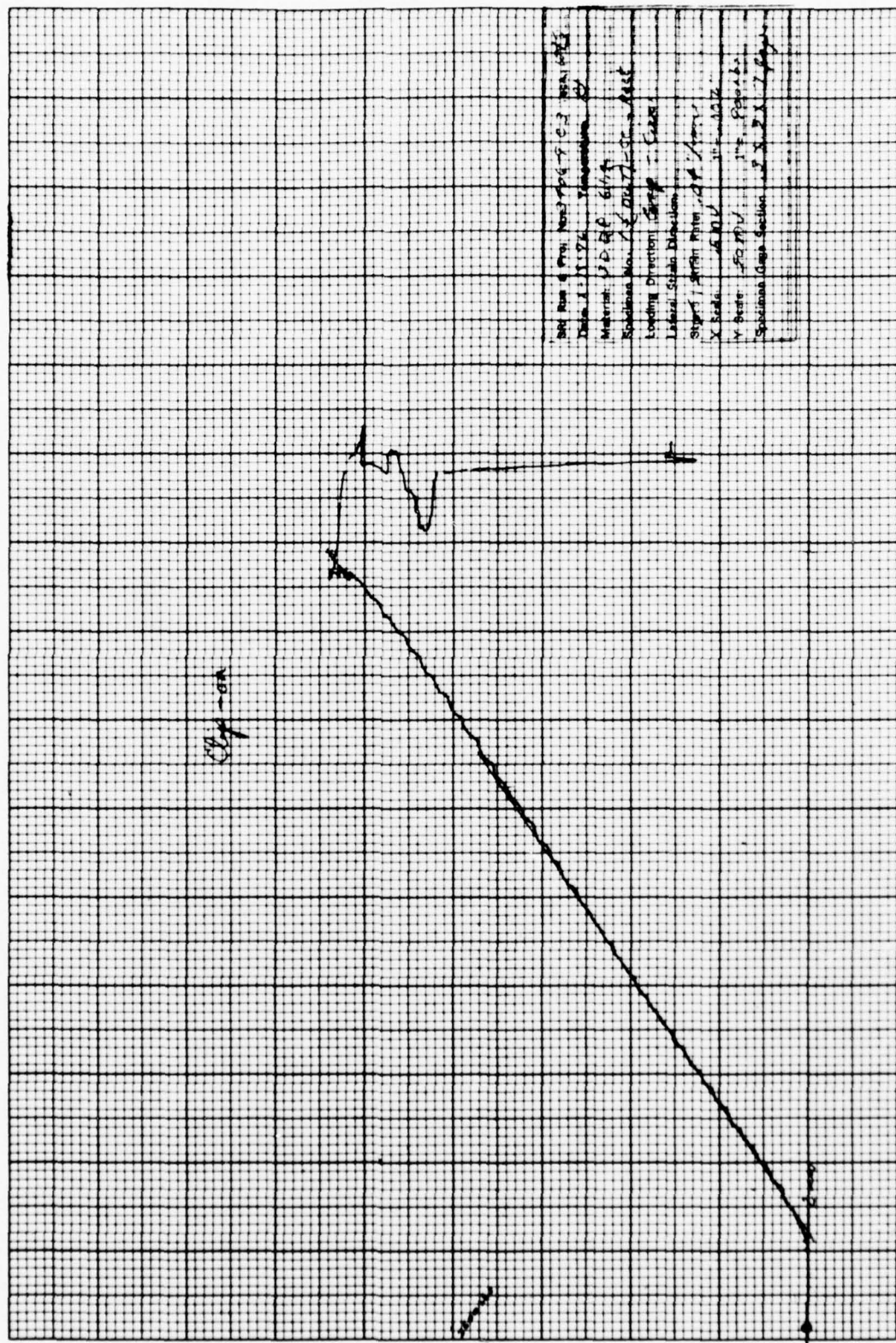
A5

Circumferential Compressive Tests
Rectangular Specimen Configuration

6.1.4







Test Run 4 9/10/68 10:00 AM 9 0.2 1000 1000
 Test 1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1
 Material: 1018 61/68
 Specimen No. 1018 61/68
 Loading Direction: Tension - 1000
 Lateral Strain Direction: 1000
 Speed: 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
 X Scale: 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
 Y Scale: 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000
 Specimen Data Section: 1000 1000 1000 1000 1000 1000 1000 1000 1000 1000

1000 1000 1000 1000 1000 1000 1000 1000 1000 1000

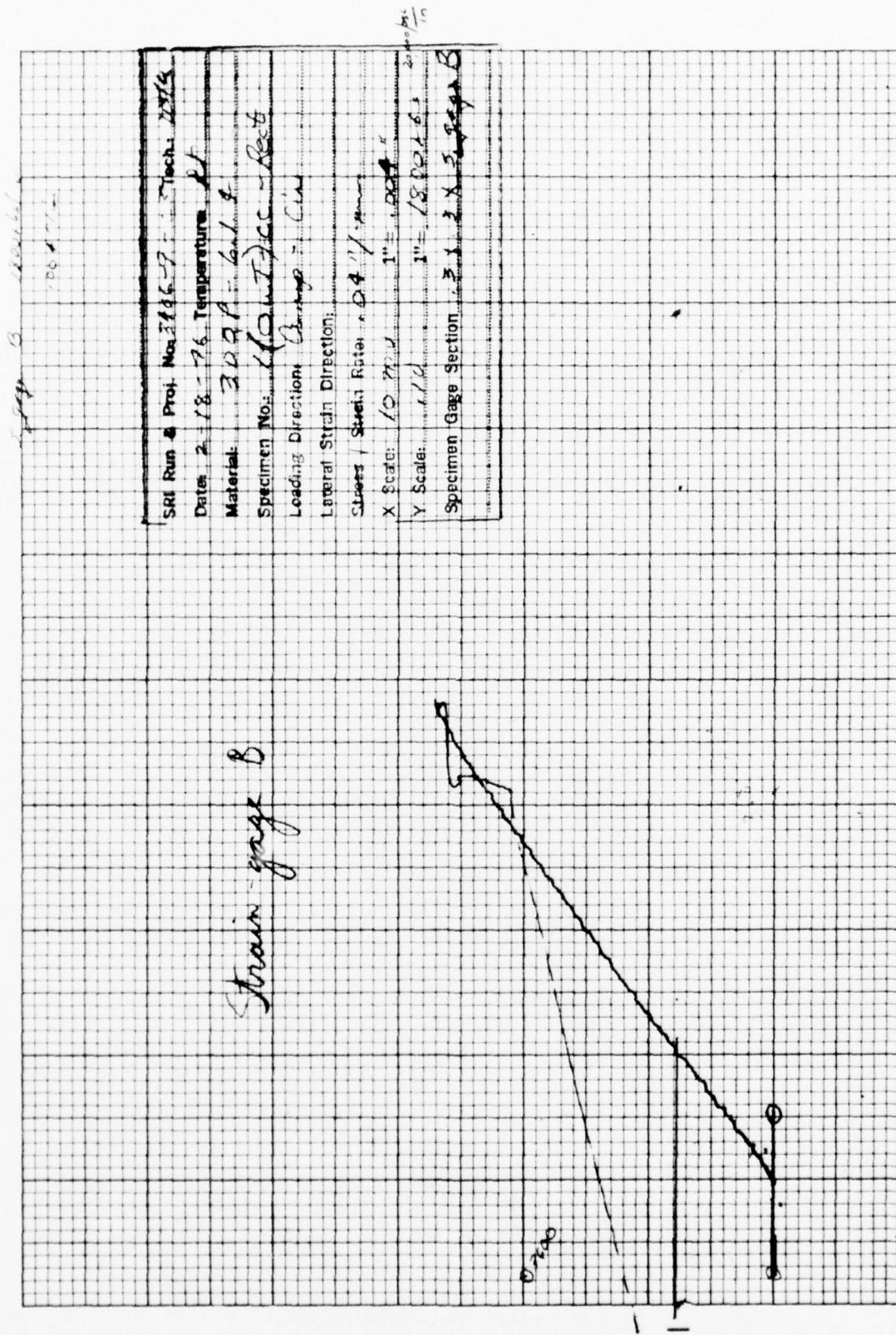


Figure A-6a Test Results for Specimen 1(COUT)-CC-Rect

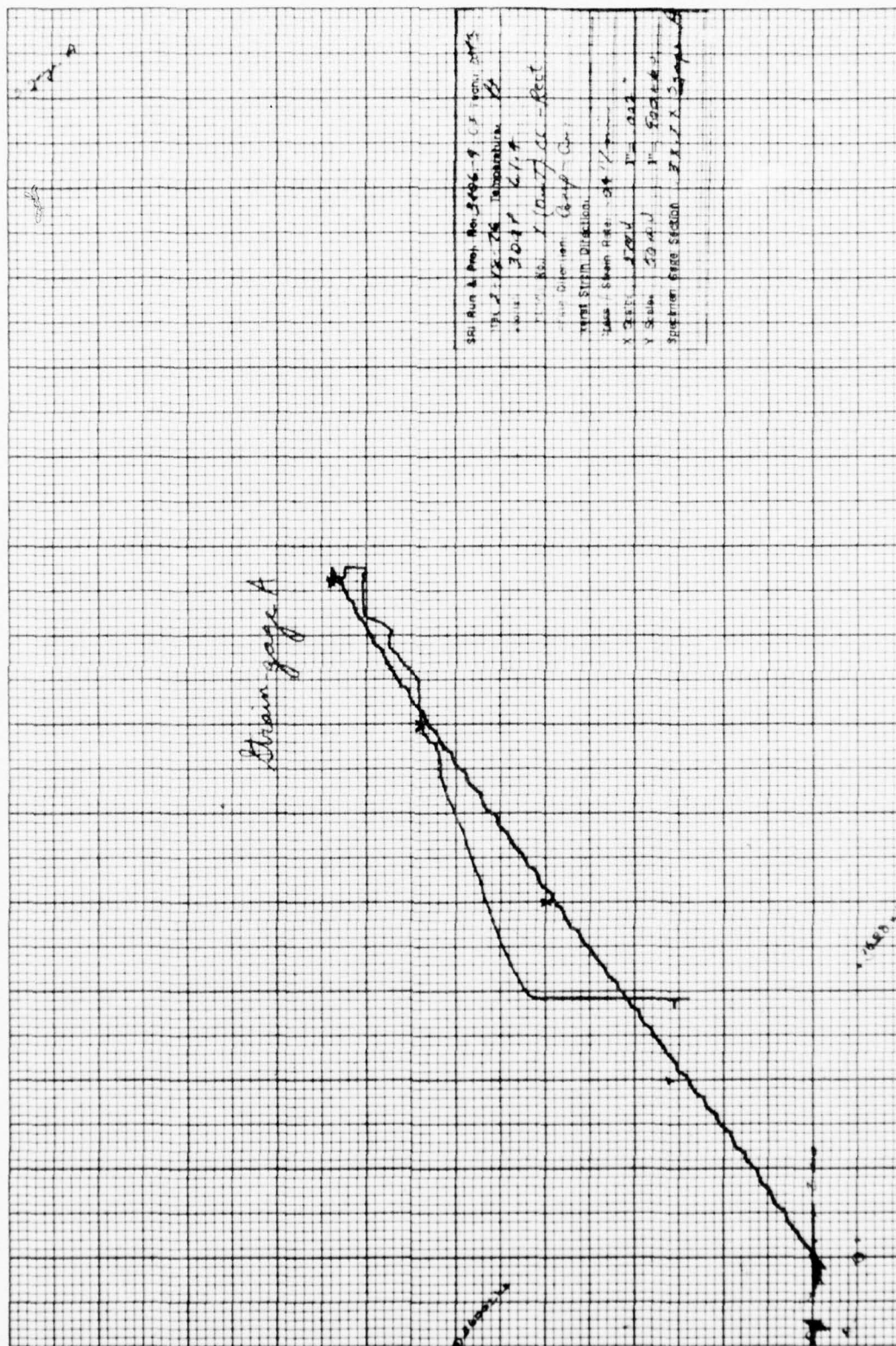


Figure A.6.7 Test Results for Specimens (GV1)-SC-Rect

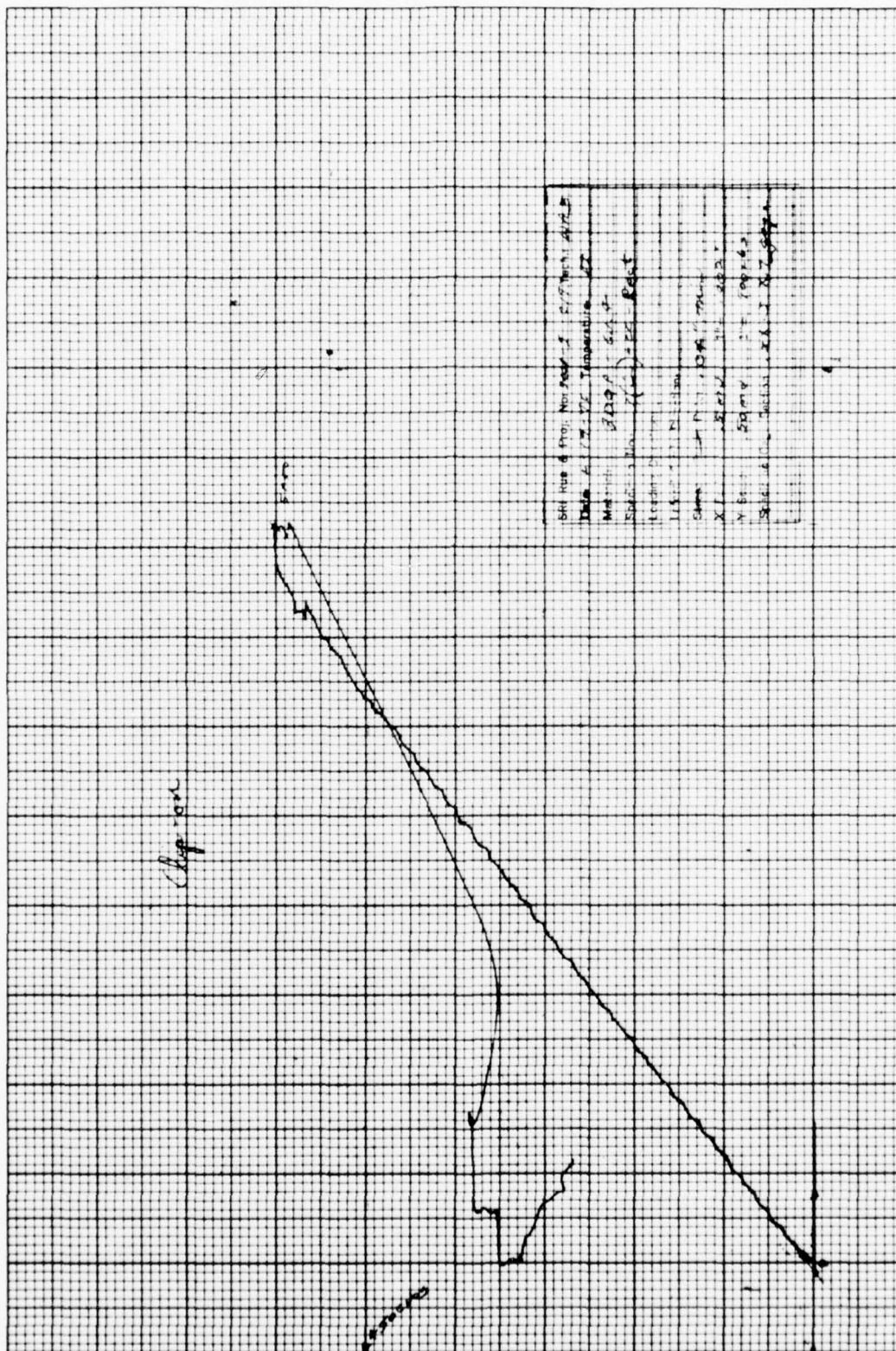
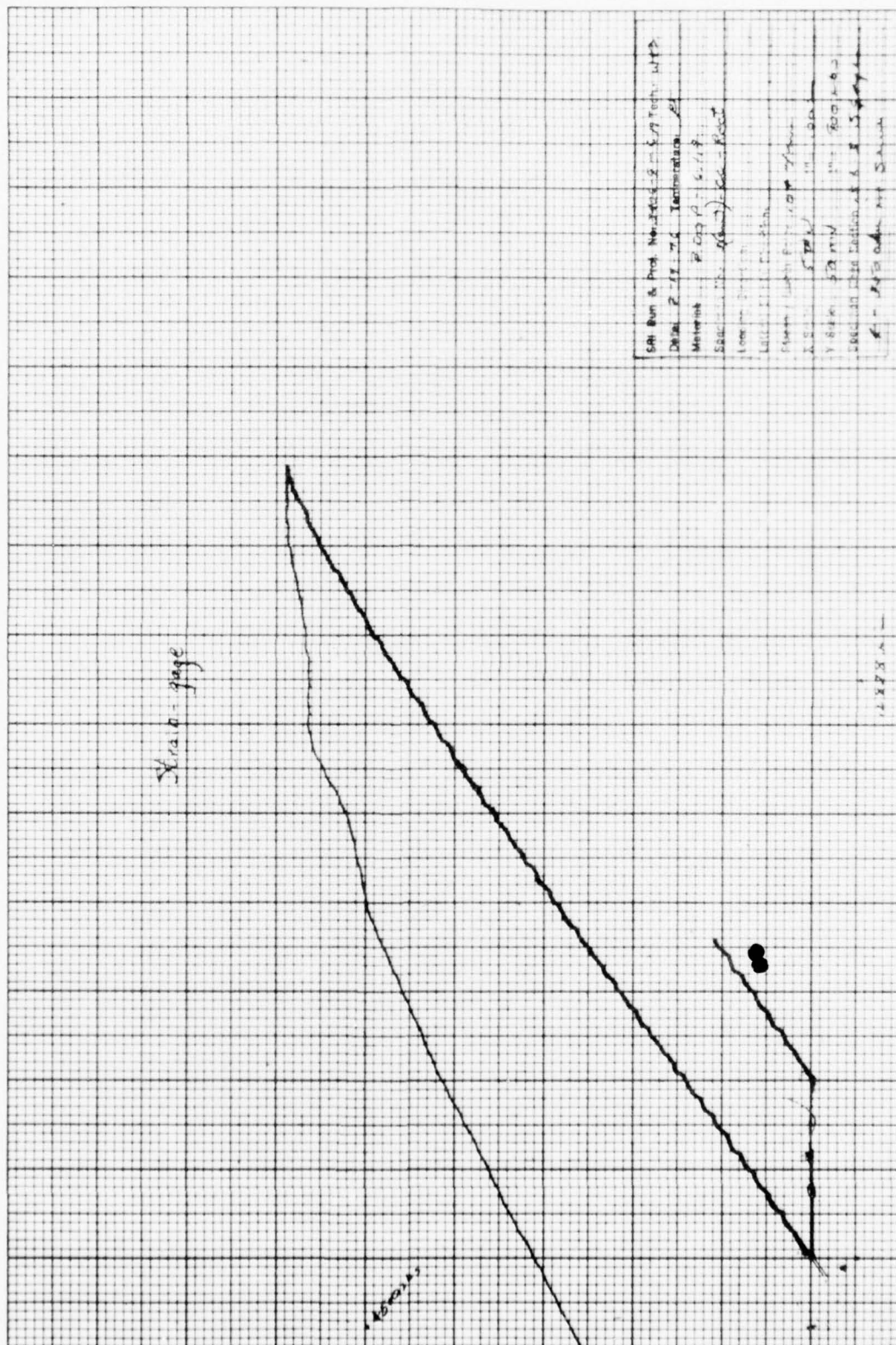


Figure 1.6.8. Plot Results for Spectrum 3(n) - 00-00-00

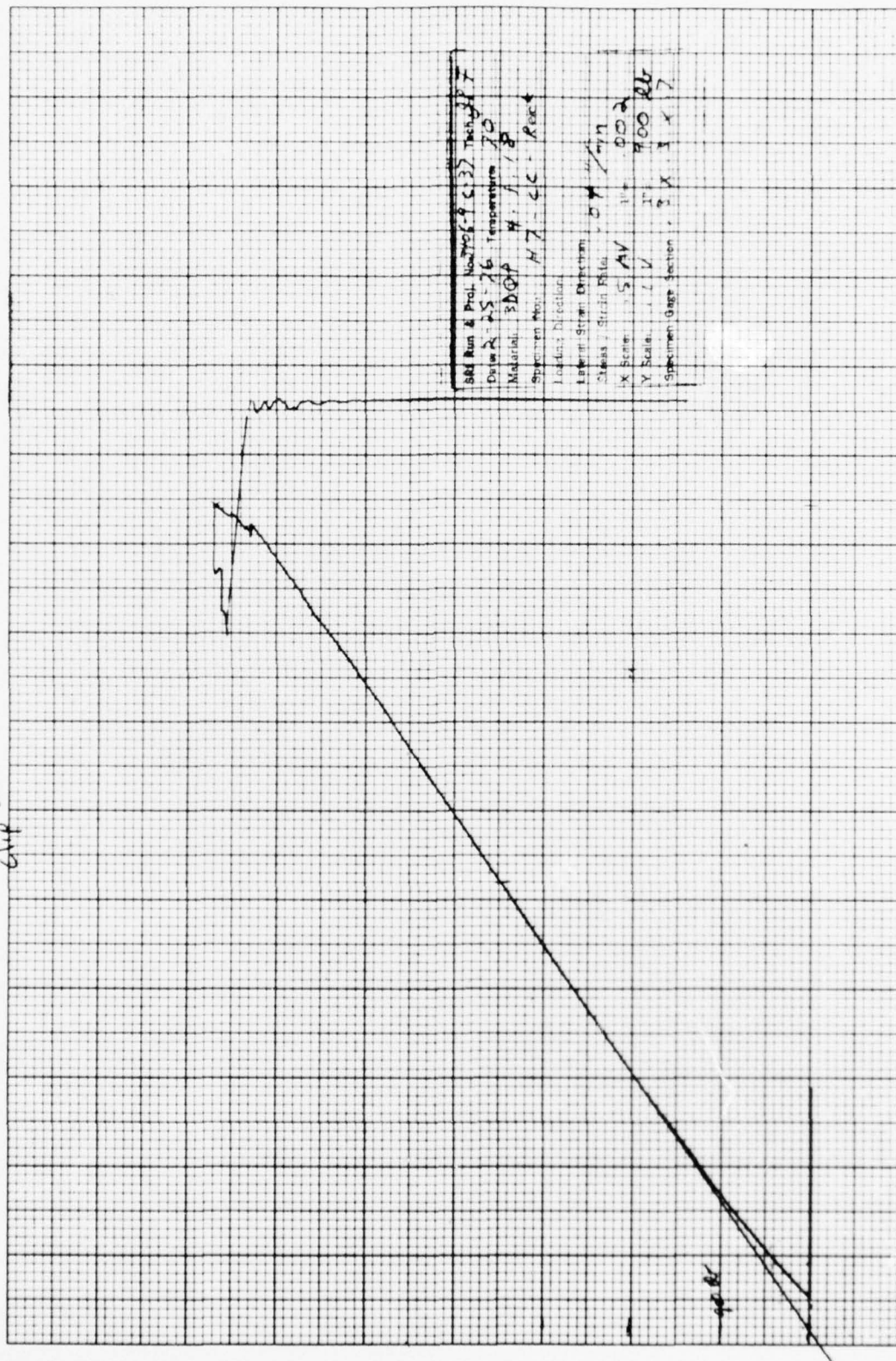


A6

Circumferential Compressive Tests
Rectangular Specimen Configuration

4.1.18

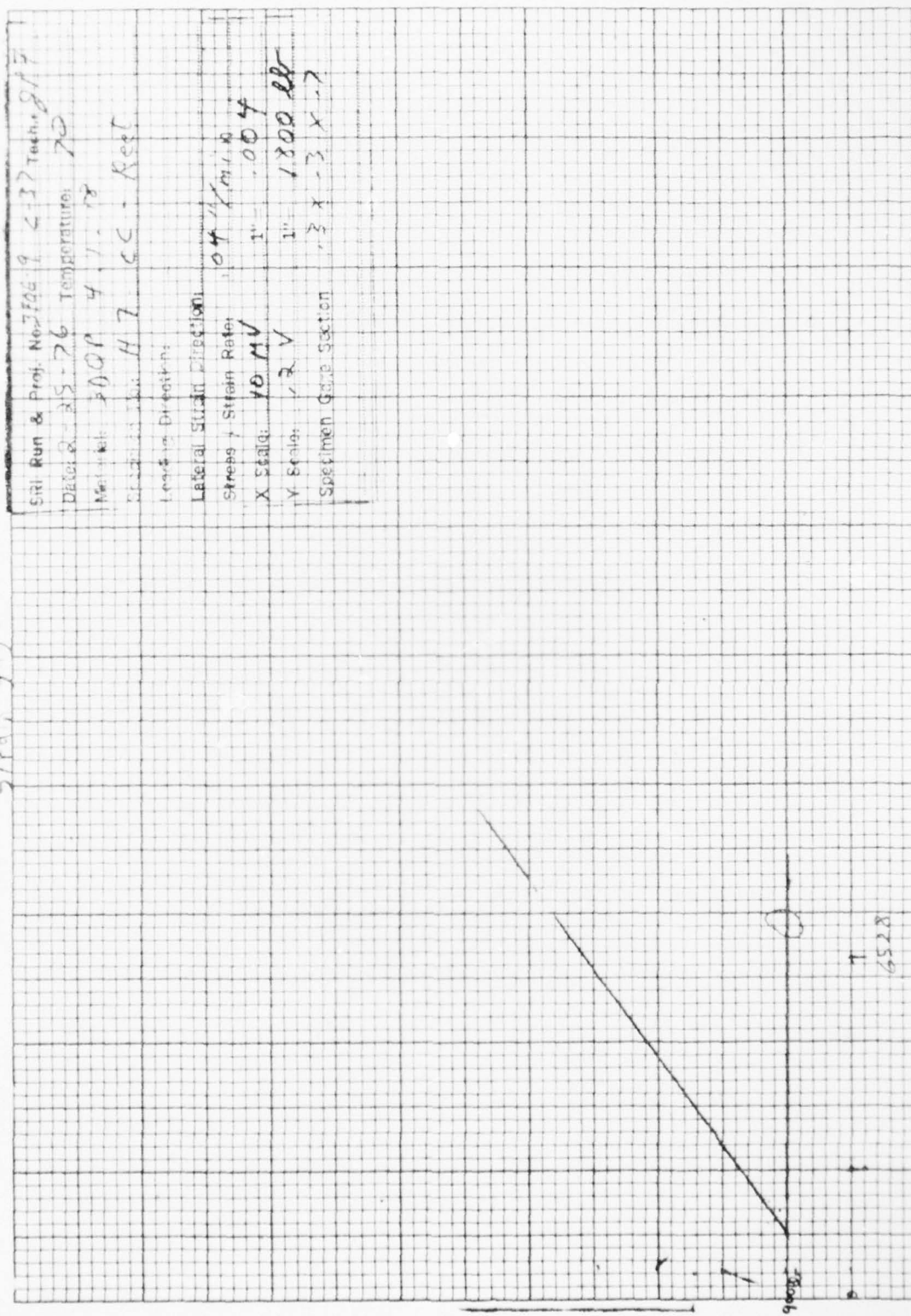
clips on



S&S Run & Prod. No. 206-9 C-37 Tech. 17
 Date 2-25-76 Temperature 70
 Material 300P H-1-18
 Specimen No. H7-CC-Rec-4
 Loading Direction
 Loading Strain Direction
 Stress - Strain Rate 5000 in
 X Scale 5 MV 1000
 Y Scale 10 V 1000
 Specimen Gauge Section 3 X 1 X 7

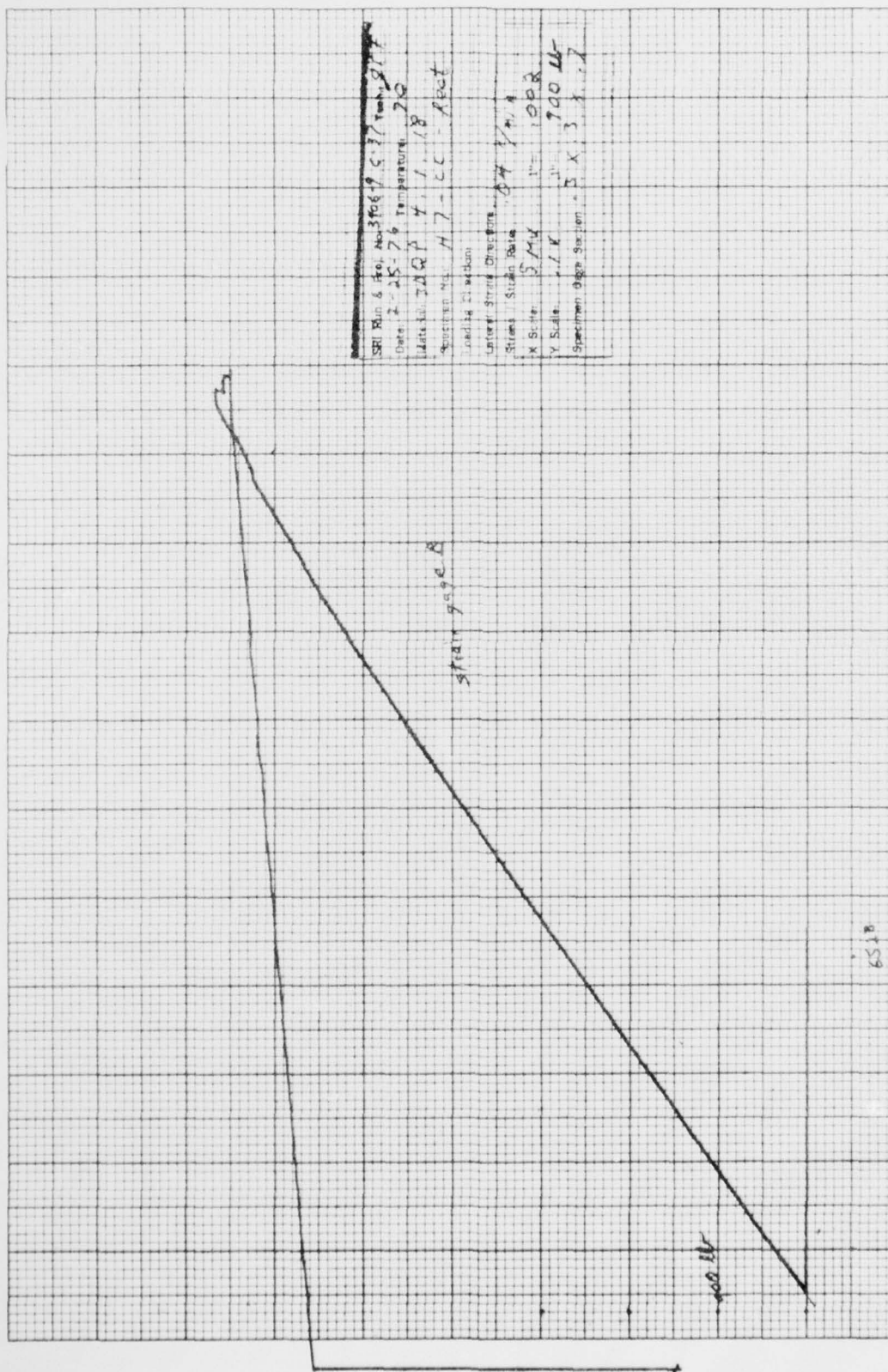
Figure A7a Test results for Specimen H7-CC-Rec-4

Strain gauge



Soil Run & Proj. No: 7269 < 37 Tech. 817
 Date: 2-25-76 Temperature: 70
 No. of: 300P 4 1-18
 Specimen: H7 CC - Keel
 Lateral Strain Direction: 04' 1' 1' 0
 Strips & Strain Rate: 1" .004
 X Scale: 10 MV
 Y Scale: 12 V
 Specimen Gauge Section: 3 X 3 X 7

Figure 6.73. Test Results for Specimen H7-CC-Bect



SRI Run & No. A037069 C-37 10/1/51
 Date 2-25-76 Temperature 72
 Adhesive JAGP 4.1.1.18
 Specimen No. H7-CC-Rect
 Loading Condition
 Uniaxial Stress Direction
 Stress Strain Rate 0.4 1/min
 X Scale 5 M 1" = 100 lb
 Y Scale 1 K 1" = 700 lb
 Specimen Gage Section 3 X 3 X 1/2

Figure A74 Test Results for Specimen H7-CC-Rect

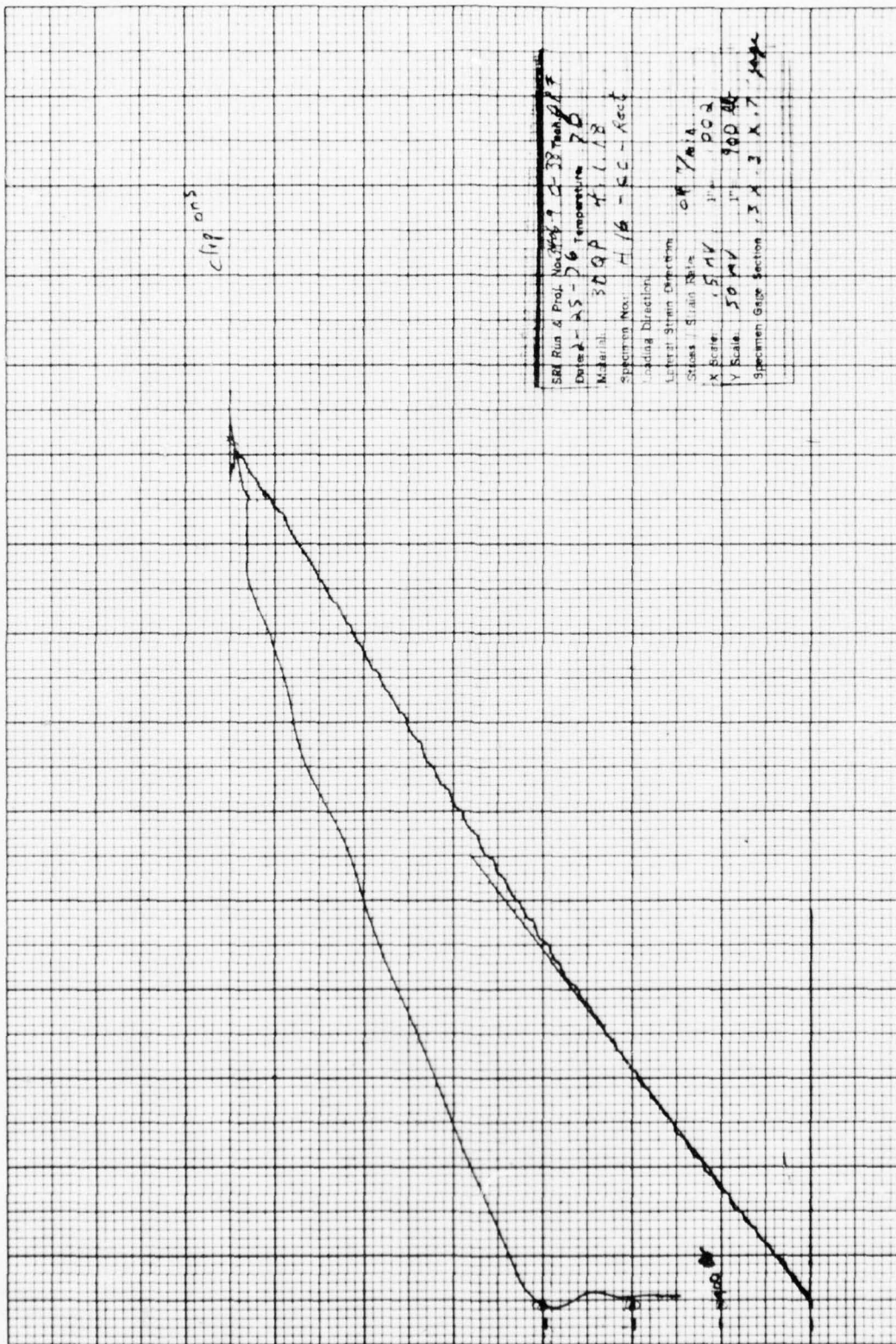


Figure A75 Test Results for Specimen H16-KC-Rect

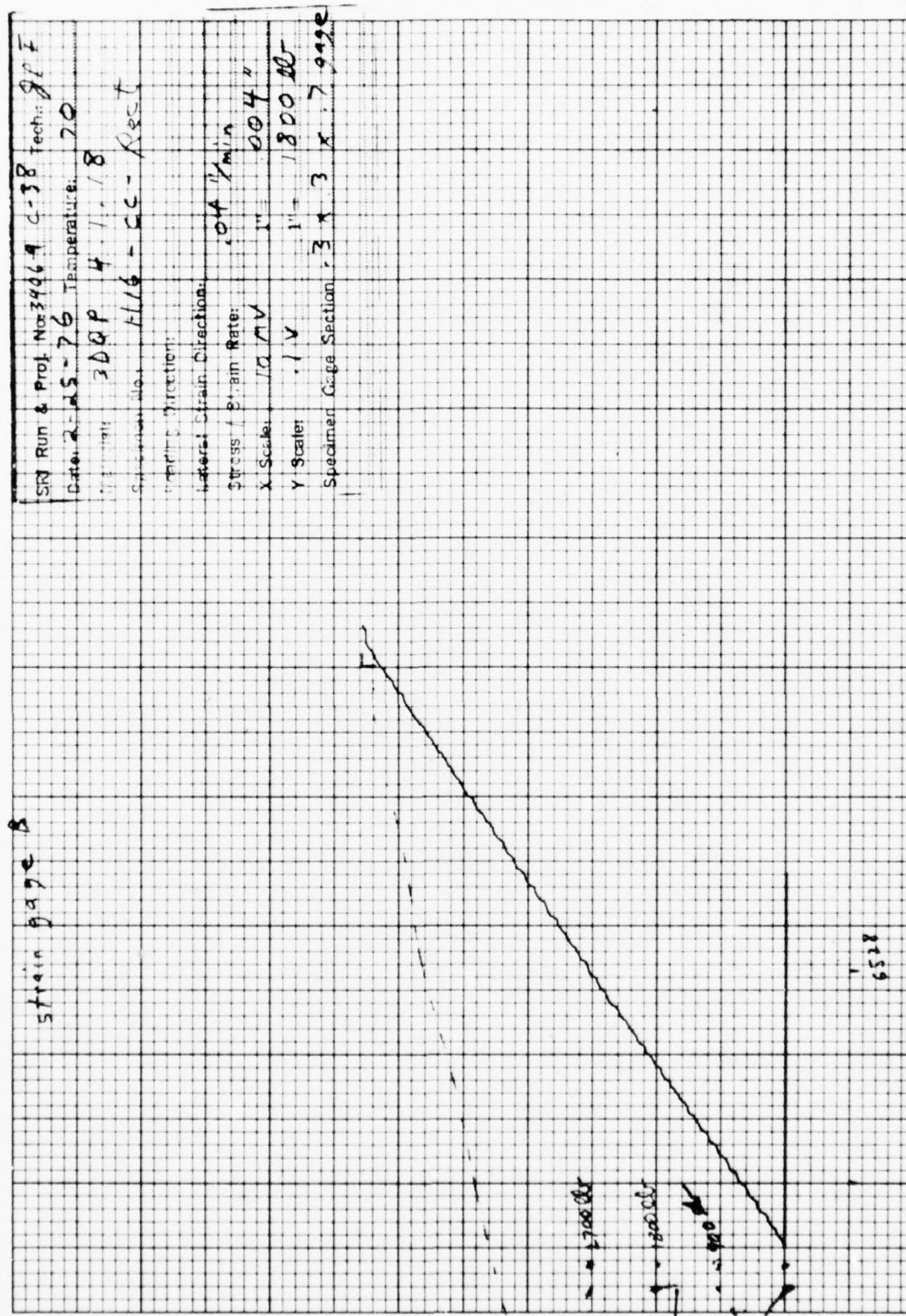
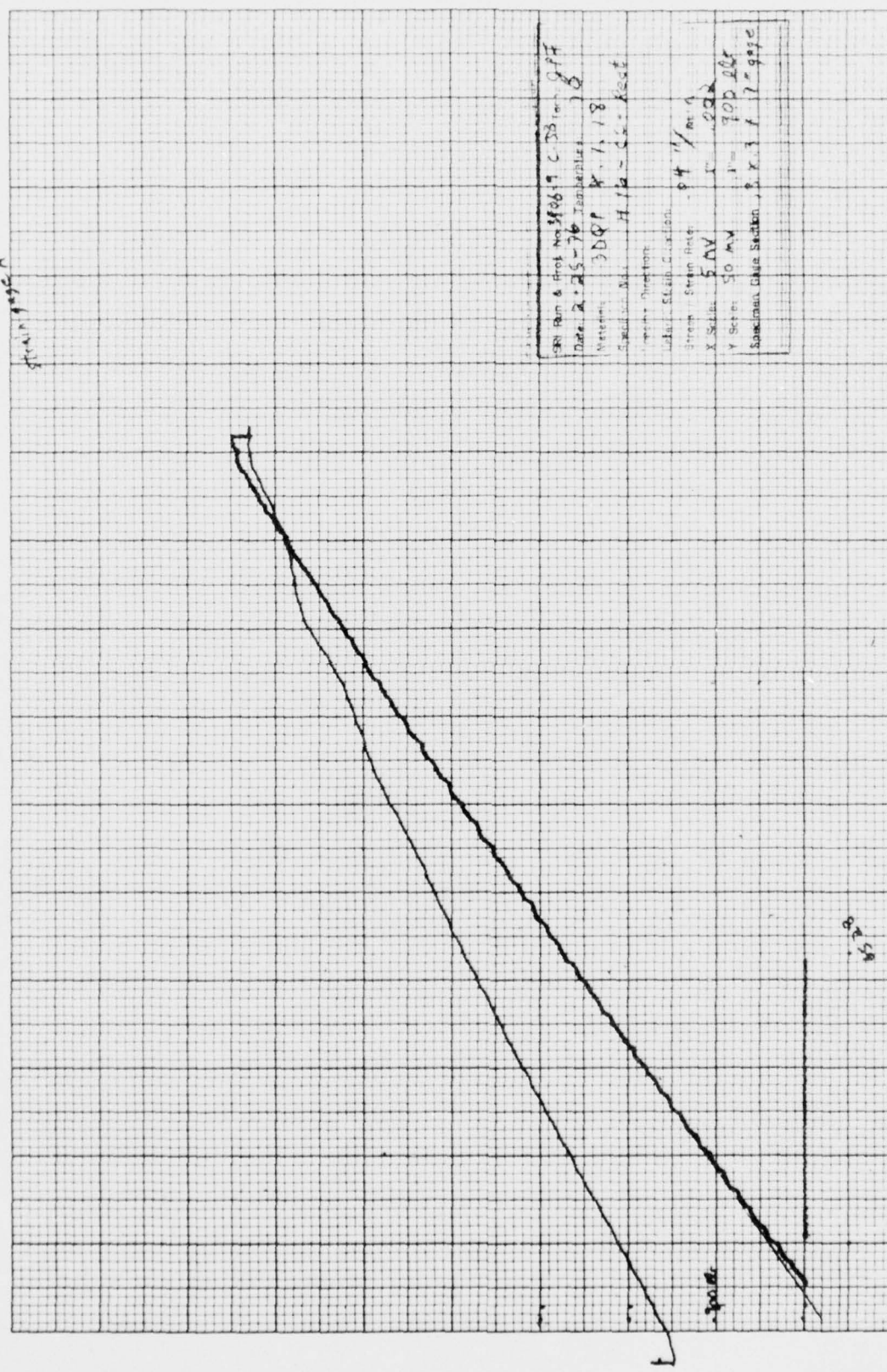


Figure A76 Test Machine for Specimen H16-CC-React

SN Run & Proj No: 346A C-38 Tech: JPF
 Date: 2-25-76 Temperature: 70
 Specimen: 300P 4-1-18
 Specimen No: H16-CC-React
 Loading Direction:
 Lateral Strain Direction: 0.4 in/min
 Stress / Strain Rate: 0.04
 X Scale: 10 MV
 Y Scale: 1 V
 Specimen Gage Section: 3 x 3 x 7.992

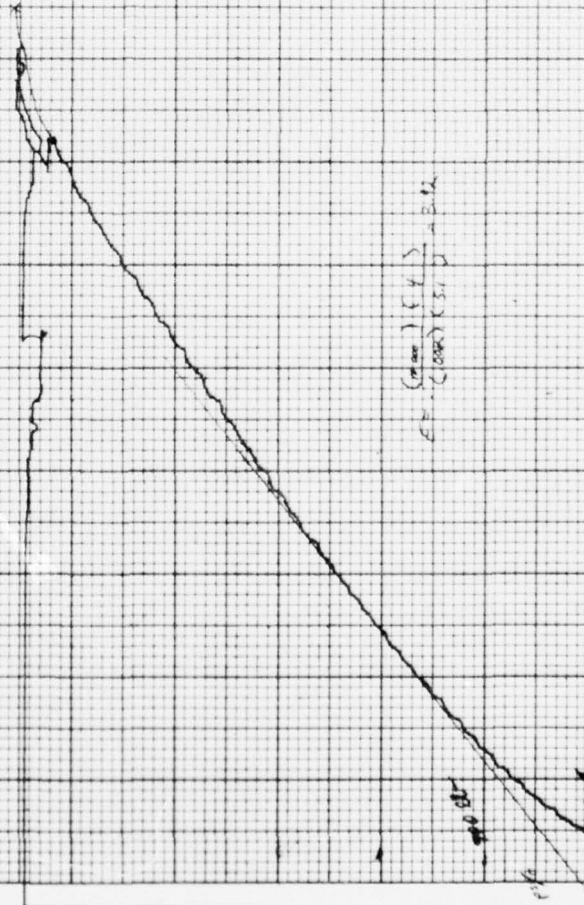
strain gauge A



FBI Lab & Prof. No. 58619 C-33 100 8.4
 Date: 2-25-76 Jambler 18
 Method: 300P W. 1. 18
 Sample No. H. 16 - 55 - Rec 6
 Machine: Spectrophotometer
 Scale: 5.0V 1" = 200 200
 Y Scale: 50 mm 1" = 100 200
 Spectrophotometer Data Section, 8. 2. 3 1 1" 999

Figure A77 Test Results for Specimen H16-55-Rec 6

Clip-on



$$E = \frac{(10000 - 0)}{(0.001 - 0)} = 10,000,000 \text{ psi}$$

10000 psi

S&T Run #	Prod. No.	3006	C. 10	Test #	78
Date	2	5	78	Temperature	20
Material	300A	4	1	8	
Specimen No.	H	24	54	Recd	
Loading Direction					
Support Strain Direction					
Strain / Strain Rate					
X Scale	5	MM			00
Y Scale	50	MM			00
Specimen Gauge Section	1.3	A	2	X	7

Figure 78. Test Results for Specimen H24-SC-Recd

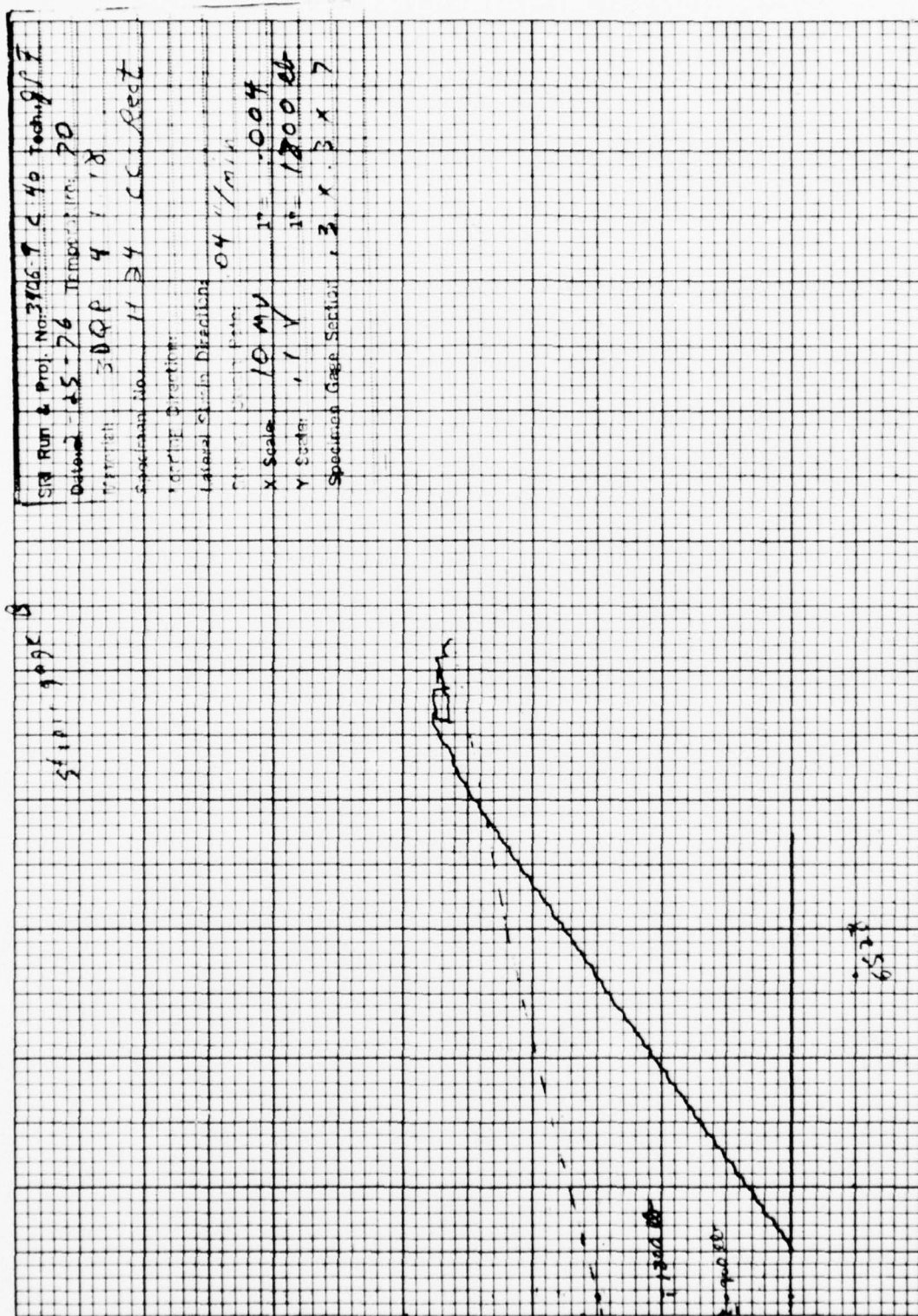


Figure A79 Test Results for Specimen

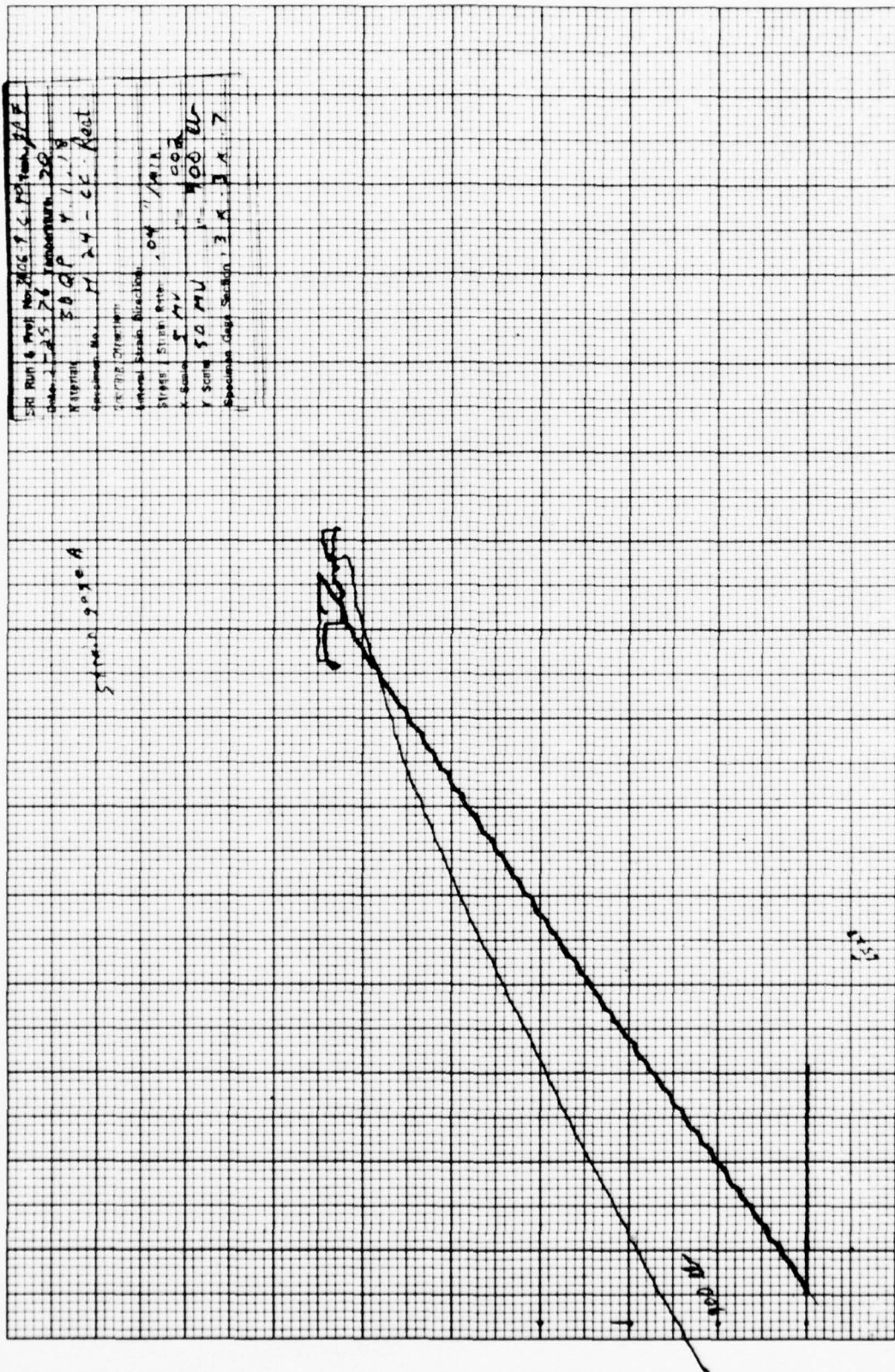
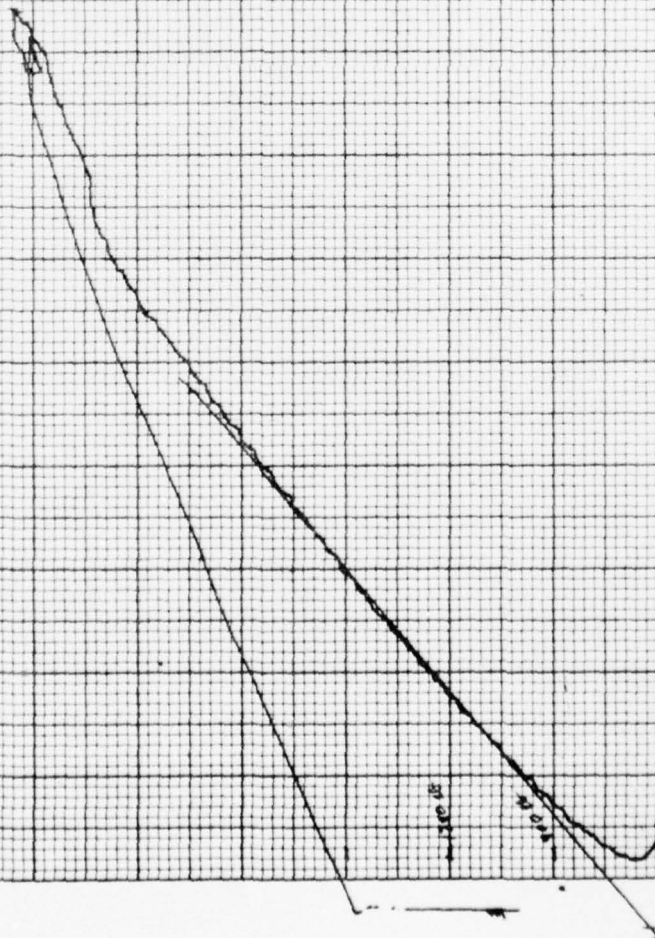


Figure A 80 Test Results for Carbon H2H-CC-Rect

2.1.2



APR 1, That Records for Suburban H32-CL-Res +

[illegible]

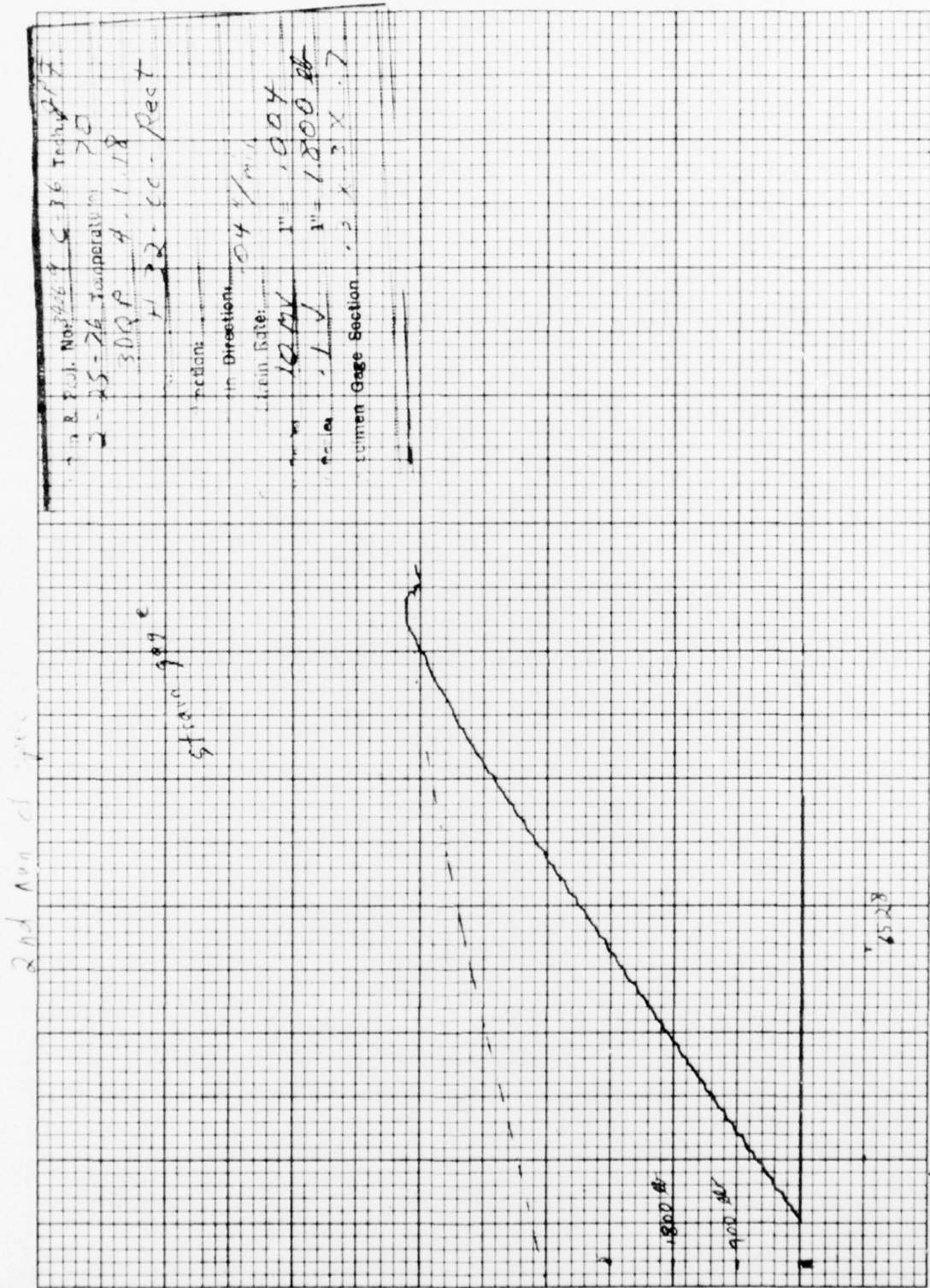
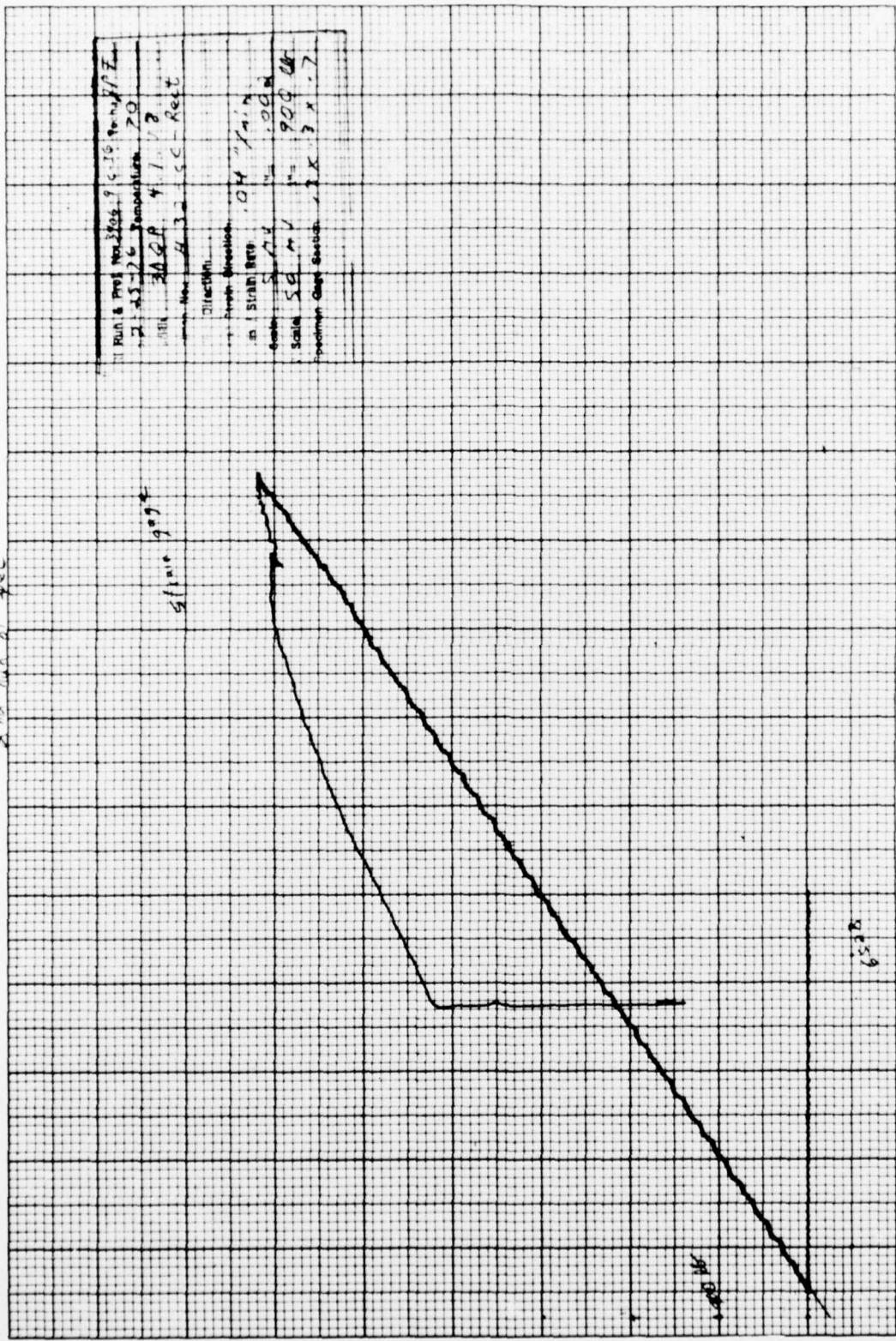


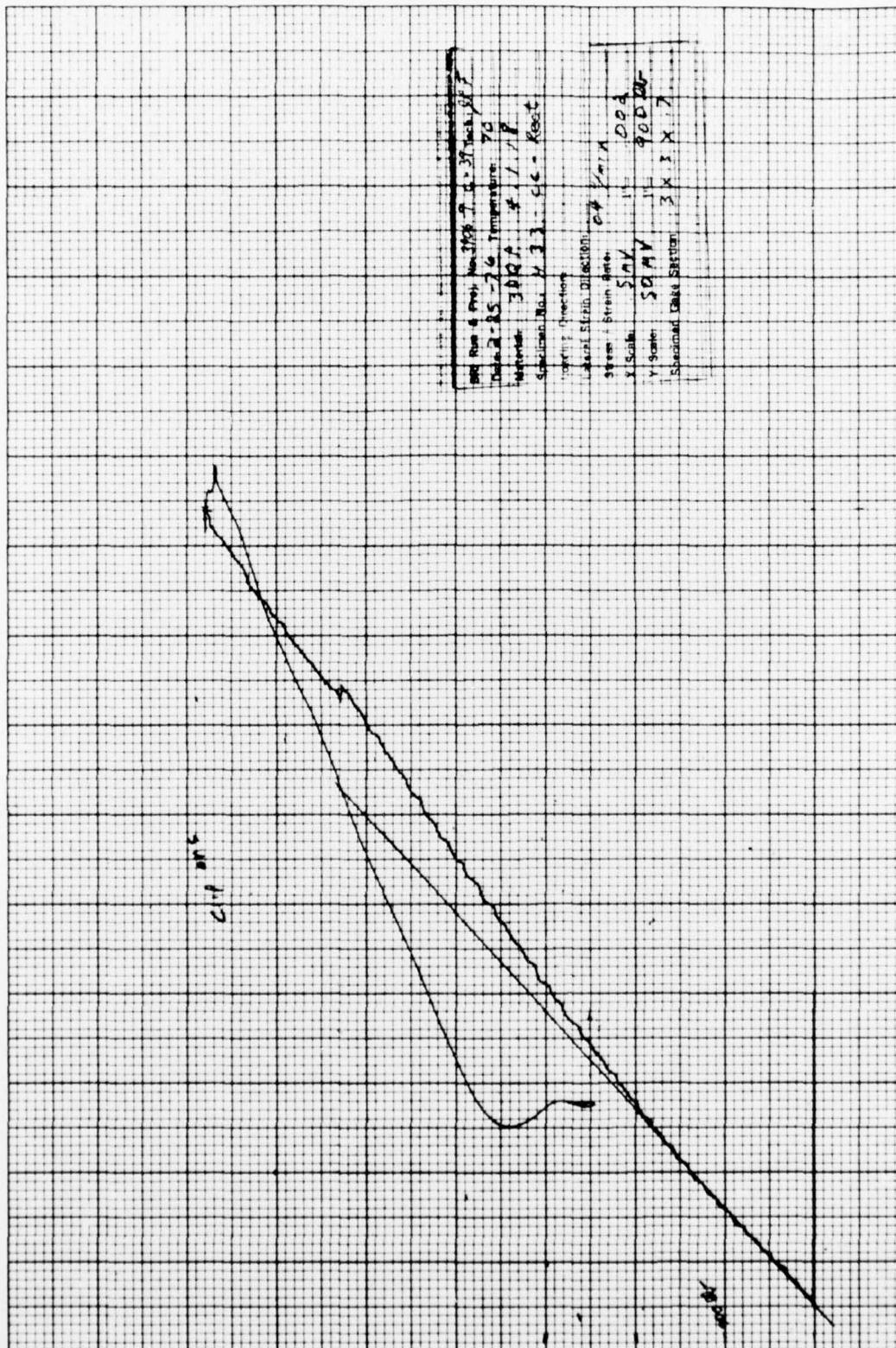
Figure A82. Test Results for Specimen H32-CC-Rect

2nd Run of Spec



Run & Prod No.	200-9	6-16	9-10-77
AS-26	Temperature	20	
30	4	1	2
30	32	5	Rect
Direction			
Start Date	10-4	1-1-77	
Scale	50	100	900
Reading	50	100	900
Reading	50	100	900

Fig. A83 Test Results for Specimen H 32-55-Rect



APL Test Results for Specimen H33-CC-Rect

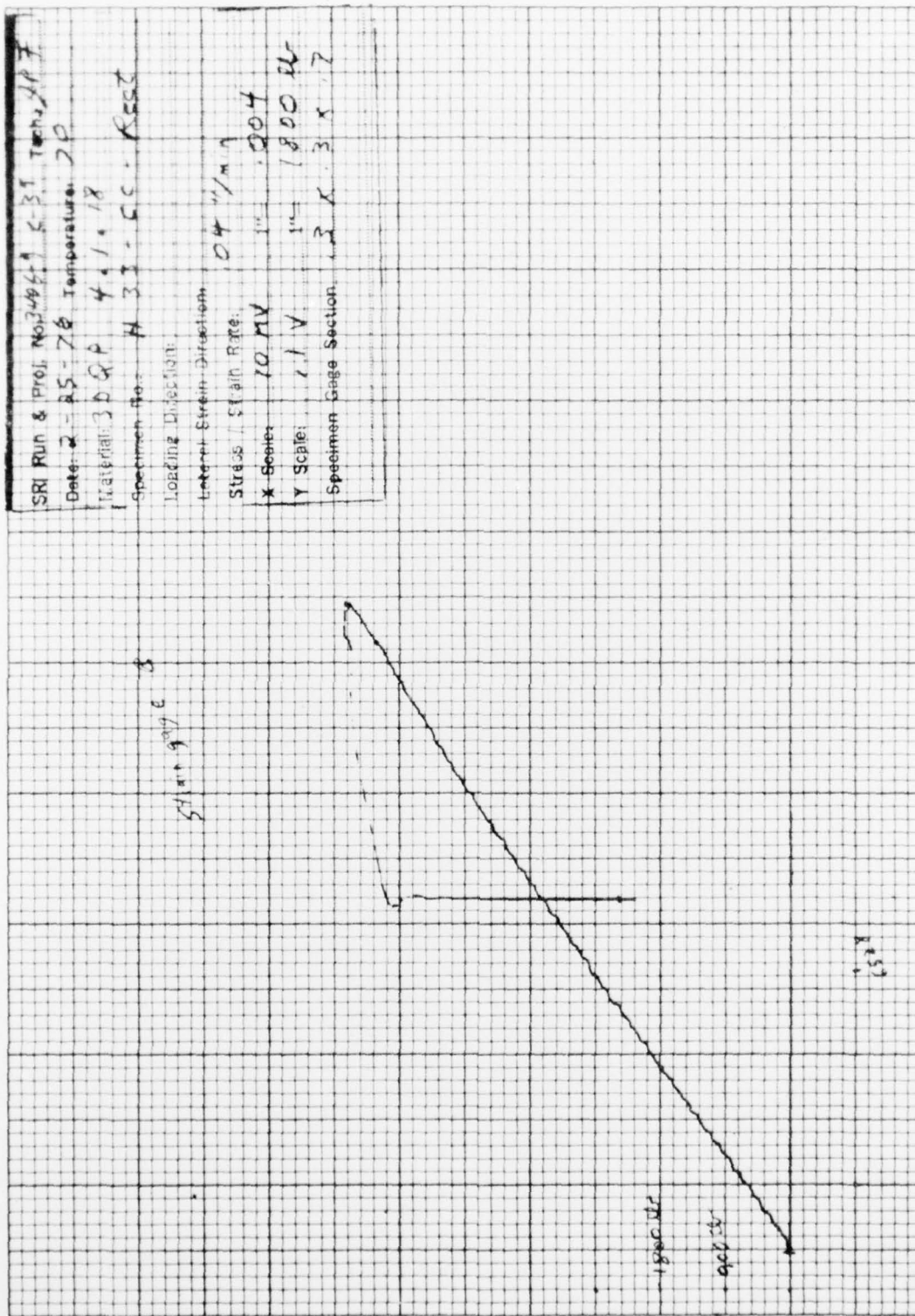


Figure A 85 Rest Results for Specimen H 33-CC-Rect

APPENDIX B

Ultrasonics

ULTRASONICS

The classical theory of the propagation of waves in elastic solid media describes the longitudinal motion of an element between two adjacent cross sections in a long prismatical bar by the equation

$$\frac{\partial^2 u}{\partial t^2} = V_0^2 \frac{\partial^2 u}{\partial x^2}$$

where

u = longitudinal displacement
 x = distance along the longitudinal axis of the bar
 t = time
 $V_0 = (E/\rho)^{1/2}$
 E = modulus of elasticity, and
 ρ = mass per unit volume

The general solution to the equation of motion can be written in the form

$$u = f(x + V_0 t) + g(x - V_0 t)$$

and is seen to represent two waves traveling in opposite directions along the longitudinal axis of the bar with constant velocity V_0 . Thus V_0 is the velocity of wave propagation and depends only on the modulus of elasticity and the density. It must be kept in mind, of course, that the assumption of a long prismatical bar infers that the transverse dimensions of the bar are small when compared to the length, and it is also assumed that the cross sections of the bar remain plane during deformation.

Sound transmission measurements for flaw detection and velocity are made utilizing a Sperry UM721 reflectoscope. The pulsed echo, reflection technique is used for detecting flaws. At 1 MHz, propagation is limited to a distance of approximately 12 inches -- or to state it another way -- a discontinuity at a depth below 6 inches of the surface is out of range. Sound velocity is determined by the through-transmission, elapsed-time method using the Sperry UM721 as a pulser unit and a Tektronix 564 oscilloscope complete with a 3B3 time base unit (time base precision of 1%) and a 3A3 vertical amplifier as measuring devices. Using this

method, a short pulse of longitudinal mode sound is transmitted through the specimen. An electrical pulse originates in a pulse generator and is applied to a ceramic piezoelectric crystal (SFZ). The pulse generated by this crystal is transmitted through a short delay line and inserted into the specimen. The time of insertion of the leading edge of this sound beam is the reference point on the time base of the oscilloscope which is used as a "high-speed stop watch". When the leading edge of this pulse of energy reaches the other end of the specimen, it is displayed on the oscilloscope. The difference between the entrance and exit times is used with the specimen length in calculating ultrasonic velocity. A short lucite delay line is used to allow time isolation of the sound wave from electrostatic coupling and to facilitate clear presentation of the leading edge of the entrant wave resulting in a more accurate "zero" in time. Reading time to initial rise portion of the sound wave gives some freedom from frequency distortion. This ultrasonic test system utilizes a longitudinal wave motion at frequencies near 1 MHz for graphites. A block diagram of the ultrasonic velocity measuring apparatus is shown in Figure B-1.

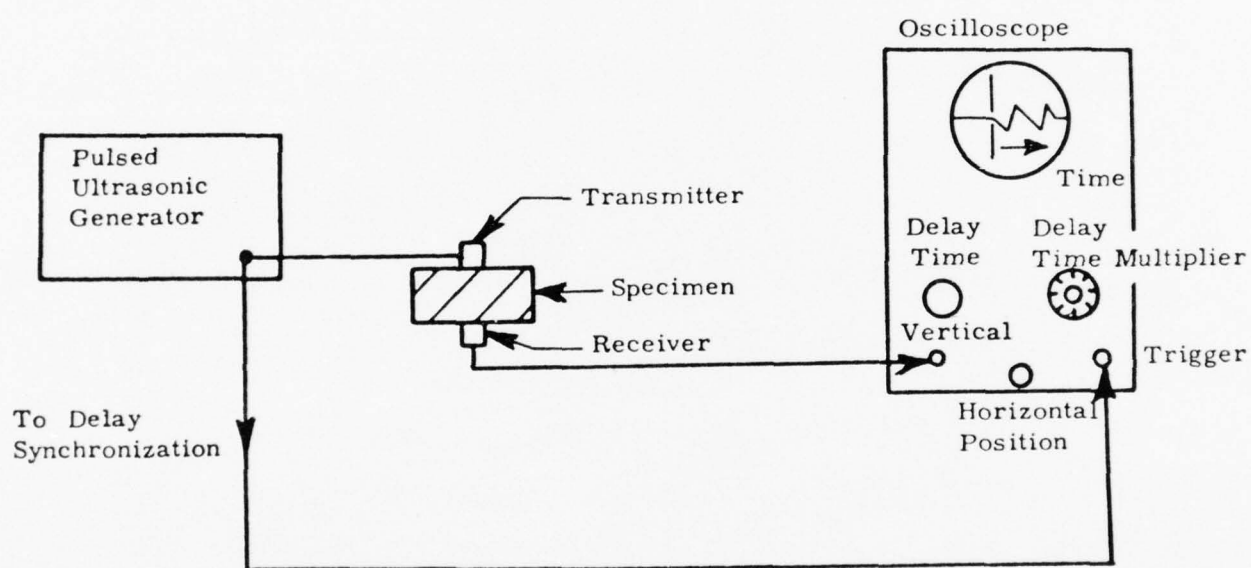


Figure B-1. Block Diagram of Ultrasonic Velocity Measuring Apparatus

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Director
 Defense Advanced Rsch. Proj. Agency
 ATTN: Strategic Tech. Office

Defense Communication Engineer Center
 ATTN: Code 720, John Worthington

Director
 Defense Communications Agency
 ATTN: NMCSSC Code 510

Defense Documentation Center
 12cy ATTN: TC

Director
 Defense Intelligence Agency
 ATTN: DT-1C, Nuc. Eng. Branch
 ATTN: DIA-DT-2, Tony Dorr
 ATTN: DI-7D
 ATTN: DT-2, Wpns. & Sys. Division

Director
 Defense Nuclear Agency
 ATTN: STSI, Archives
 3cy ATTN: STTL, Tech. Library
 ATTN: SPSS
 ATTN: SPAS
 ATTN: DDST
 ATTN: STSP
 ATTN: SPTD

Director of Defense Rsch. & Engineering
 ATTN: George R. Barse
 ATTN: DD/S&SS, John B. Walsh
 ATTN: AD/ET, J. Persh
 ATTN: AD/ET
 ATTN: AD/OS
 ATTN: DD/S&SS
 ATTN: DD/R&AT
 ATTN: AD/DS

Commander
 Field Command, Defense Nuclear Agency
 ATTN: FCTMOF
 ATTN: FCPR
 ATTN: FCTMD
 ATTN: FCTMOT, Lieutenant Commander Strobe

Director
 Joint Strat. Tgt. Planning Staff, JCS
 ATTN: JPTP
 ATTN: JPTM
 ATTN: JLTW-2
 ATTN: JPST

Chief
 Livermore Division, Field Command, DNA
 ATTN: FCPRL

OJCS/J-5
 ATTN: J-5, Plans & Policy, R & D Division

Studies Analysis and Gaming Agency
 Joint Chiefs of Staff
 ATTN: SDEB

DEPARTMENT OF THE ARMY

Director
 BMD Advanced Tech. Center
 ATTN: CRDABH-S, William C. Loomis
 ATTN: ATC-T, Melvin T. Capps
 ATTN: Marcus Whitfield

Program Manager
 BMD Program Office
 ATTN: DACS-BMT, John Shea
 ATTN: DACS-BMT, Clifford E. McLain
 ATTN: Technology Division
 ATTN: DACS-BMZ-D, Julian Davidson
 ATTN: DACS-BMZ

Commander
 BMD System Command
 ATTN: BDMSSC-TEB, R. Simpson
 ATTN: BDMSC-TEN, Noah J. Hurst

Deputy Chief of Staff for Rsch. Dev. & Acq.
 ATTN: NCB Division

Deputy Chief of Staff for Ops. & Plans
 ATTN: Director of Nuc. Plans & Policy

Commander
 Harry Diamond Laboratories
 ATTN: DRXDO-NP, Francis N. Wimenitz
 ATTN: DRXDO-NP, Louis J. Belliveau
 ATTN: DRXDO-RBH, James H. Gwaltney
 ATTN: DRXDO-RC, Robert B. Oswald, Jr.

Commander
 Picatinny Arsenal
 ATTN: SARPA-FR-E, Louis Avrami
 ATTN: SARPA-ND-C-T, Donald Miller
 ATTN: Al Loeb
 ATTN: SMUPA-MD, Henry Opat
 ATTN: F. Cotton

Director
 TRASANA
 ATTN: R. E. DeKinder, Jr.

Director
 U.S. Army Ballistic Research Labs.
 ATTN: DRXBR-TB, J. T. Frasier
 ATTN: DRXRD-BVL, William J. Schuman, Jr.
 ATTN: DRXBR-TL-IR, J. H. Keefer
 ATTN: Robert E. Eichelberger
 ATTN: DRXBR-X, Julius J. Meszaros
 ATTN: Richard Vitali

Commander
 U.S. Army Mat. & Mechanics Rsch. Center
 ATTN: DRXMR-HH, John F. Dignam

Commander
 U.S. Army Missile Command
 ATTN: DRSMI-XS, Chief Scientist
 ATTN: DRSMI-RRR, Bud Gibson
 ATTN: DRCPM-PE-EA, Wallace O. Wagner
 ATTN: Troy Smith
 ATTN: DRS-RKP, W. B. Thomas

DEPARTMENT OF THE ARMY (Continued)

Commander
U.S. Army Materiel Dev. & Readiness Command
ATTN: DRCDE-D, Lawrence Flynn

Commander
U.S. Army Nuclear Agency
ATTN: COL Deverill
ATTN: ATCA-NAW
ATTN: MONA-WE
ATTN: CDC-NVA
ATTN: MAJ J. Vecke
ATTN: MONA-SA

Chief
U.S. Army Research Office
ATTN: Technical Library

DEPARTMENT OF THE NAVY

Chief of Naval Material
ATTN: MAT 0323, Irving Jaffe

Chief of Naval Operations
ATTN: OP 62
ATTN: Robert A. Blaise
ATTN: OP 981
ATTN: Code 604C3, Robert Piacesi
ATTN: OP 981

Chief of Naval Research
ATTN: Code 464, Thomas P. Quinn

Director
Naval Research Laboratory
ATTN: Code 7770, Gerald Cooperstein
ATTN: Code 2600, Tech. Library
ATTN: Code 5180, Mario A. Persechino

Commander
Naval Sea Systems Command
ATTN: ORD-0333A
ATTN: 0333A, Marlin A. Kinna
ATTN: Code 0351

Commander
Naval Surface Weapons Center
ATTN: Code 2302, Leo F. Gowen
ATTN: Code 322, Victor C. Dawson
ATTN: Code WA501, Navy Nuc. Prgms. Off.
ATTN: Code 323, W. Carson Lyons
ATTN: Code 241, Joseph Petes

Commanding Officer
Naval Weapons Evaluation Facility
ATTN: Peter Hughes
ATTN: Lawrence R. Oliver

Director
Strategic Systems Project Office
ATTN: NSP-272
ATTN: NSP-273

DEPARTMENT OF THE AIR FORCE

Commandant
AF Flight Dynamics Laboratory, AFSC
ATTN: FXG

DEPARTMENT OF THE AIR FORCE (Continued)

AF Geophysics Laboratory, AFSC
ATTN: Chan Touart

AF Materials Laboratory, AFSC
ATTN: MBC, Donald L. Schmidt
ATTN: MAS
ATTN: MBE, George F. Schmitt
ATTN: LPH, Gordon Griffith
ATTN: T. Nicholas
ATTN: LTM
ATTN: Bill Kessler

AF Rocket Propulsion Laboratory, AFSC
ATTN: RTSN, G. A. Beale

AF Weapons Laboratory, AFSC
ATTN: ALO, Maj Lawrence T. James
ATTN: SUL
ATTN: SAB
ATTN: Al Sharp
ATTN: Dr. Minge
2cy ATTN: NTO
ATTN: Tech. Review
ATTN: DYS, Lt E. J. Burns
ATTN: DYT
ATTN: DYV

AFTAC
ATTN: Col Earnest F. Dukes, Jr.

Headquarters
Air Force Systems Command
ATTN: SOSS
ATTN: XRTO

Commander
Arnold Engineering Development Center
ATTN: XOA

Commander
ASD
4cy ATTN: EWES, D. Ward

Commander
Foreign Technology Division, AFSC
ATTN: TDPTN
ATTN: TDFBD, J. D. Pumphrey
ATTN: PDBG

HQ USAF/RD
ATTN: RDQSM
ATTN: RDPM
ATTN: RDQ
ATTN: RDQSM
ATTN: David S. Hyman
ATTN: RD

HQ USAF/XO
ATTN: XOSS

SAMSO/DY
ATTN: DYS

SAMSO/RS
ATTN: RSSE
ATTN: RSS
ATTN: RST

DEPARTMENT OF THE AIR FORCE (Continued)

SAMSO/ MN

ATTN: MNMR

Commander in Chief
Strategic Air Command

ATTN: XPFS
ATTN: DOXT
ATTN: XPQM
ATTN: XOBM
ATTN: NRI

ENERGY RESEARCH AND DEVELOPMENT ADMIN

Division of Military Application

ATTN: Doc. Con. for Res. & Dev. Branch

University of California

ATTN: G. Staihle, L-24
ATTN: Joseph B. Knox, L-216
ATTN: C. Joseph Taylor, L-92
ATTN: Larry W. Woodruff, L-96
ATTN: Joseph E. Keller, Jr., L-125

Los Alamos Scientific Laboratory

ATTN: Doc. Con. for J. W. Taylor
ATTN: Doc. Con. for Richard A. Gentry
ATTN: Doc. Con. for T. Talley
ATTN: Doc. Con. for John McQueen
ATTN: Doc. Con. for Donald Kerr
ATTN: Doc. Con. for R. S. Thurston

Sandia Laboratories

ATTN: Doc. Con. for T. Gold
ATTN: Doc. Con. for C. S. Hoyle
ATTN: Raymond Ng
ATTN: Doc. Con. for 8131, H. F. Norris, Jr.

Sandia Laboratories

ATTN: Doc. Con. for B. Caskey
ATTN: Doc. Con. for A. W. Snyder
ATTN: Doc. Con. for Albert Chabai
ATTN: Doc. Con. for Thomas B. Cook
ATTN: Doc. Con. for R. R. Boade
ATTN: Doc. Con. for Walter Herrmann
ATTN: Doc. Con. for D. McCloskey
ATTN: Doc. Con. for M. L. Merritt

DEPARTMENT OF DEFENSE CONTRACTORS

Acurex Corporation

ATTN: J. Huntington
ATTN: C. Nardo
ATTN: Robert M. Kendall
ATTN: J. Courtney

Aeronautical Rsch. Assoc. of Princeton, Inc.

ATTN: Coleman Donaldson

Aerospace Corporation

ATTN: J. McClelland
ATTN: W. Barry
ATTN: R. Allen
ATTN: R. Mortensen
ATTN: Richard Crolus, A2-Rm1027
ATTN: W. Mann
ATTN: R. Strickler

Analytic Services, Inc.

ATTN: Jack Selig

DEPARTMENT OF DEFENSE CONTRACTORS
(Continued)

Aro, Incorporated

ATTN: John C. Adams

Avco Research & Systems Group

ATTN: John E. Stevens, J100
ATTN: S. Skemp, J200
ATTN: George J. Davis
ATTN: George Weber, J230
ATTN: Doc. Control
ATTN: William G. Reinecke, K100
ATTN: J. Patrick
ATTN: John Gilmore, J400

Battelle Memorial Institute

ATTN: E. Unger
ATTN: W. Pfeifer
ATTN: Richard Castle
ATTN: Merwyn R. Vanderlind

The Boeing Company

ATTN: Brian Lempriere
ATTN: Ed York
ATTN: William Crist
ATTN: Robert Dyrdaahl
ATTN: Robert Holmes

The Boeing Company

ATTN: T. Swaney

Brown Engineering Company, Inc.

ATTN: Ronald Patrick

California Research & Technology, Inc.

ATTN: Ken Kreyenhagen

Calspan Corporation

ATTN: M. S. Holden
ATTN: M. G. Dunn
ATTN: Romeo A. Deliberis

University of Dayton

Industrial Security Super KL-505

ATTN: D. Gerdiman
ATTN: Hallock F. Swift

Effects Technology, Inc.

ATTN: Robert Wengler
ATTN: Richard Parise

Ford Aerospace & Communications Operations

ATTN: P. Spangler

General American Transportation Corp

General American Research Division

ATTN: Marion J. Balcerzak
ATTN: W. F. Byrne

General Dynamics Corp.

Convair Aerospace Division

ATTN: R. Shemensky

General Electric Company

ATTN: Phillip Cline
ATTN: Carl Anderson
ATTN: C. Kyriss
ATTN: B. M. Maguire
ATTN: A. Martellucci
ATTN: G. Harrison
ATTN: Daniel Edelman

DEPARTMENT OF DEFENSE CONTRACTORS
(Continued)

General Electric Company
TEMPO-Center for Advanced Studies
ATTN: DASIAC
ATTN: B. Gambill

General Research Corporation
ATTN: T. Stathacopoulos
ATTN: John Ise, Jr.
ATTN: Robert E. Rosenthal

Institute for Defense Analyses
ATTN: IDA Librarian, Ruth S. Smith
ATTN: Joel Bengston

Ion Physics Corporation
ATTN: Robert D. Evans

Kaman Avidyne
Division of Kaman Sciences Corp.
ATTN: Ray Reutinick
ATTN: E. S. Criscione
ATTN: Norman P. Hobbs

Kaman Sciences Corporation
ATTN: R. Keefe
ATTN: John Keith
ATTN: John R. Hoffman
ATTN: Thomas Meagher
ATTN: Donald C. Sachs
ATTN: Frank H. Shelton

LFE Corporation
Environmental Analysis Lab. Division
ATTN: Marcel Nathans

Lockheed Missiles & Space Co., Inc.
ATTN: Gerald T. Chrusciel
ATTN: Charles M. Lee
ATTN: Arthur Collins, Dept. 81-14
ATTN: Art Thomas, Dept. 85-85
ATTN: L. D. Hull

Lockheed Missiles and Space Co.
ATTN: T. R. Fortune

Lockheed Missiles and Space Company
ATTN: F. G. Borgardt
ATTN: Raymond R. Capioux

Martin Marietta Aerospace
ATTN: Laird Kinnaird
ATTN: G. Fotieo
ATTN: William A. Gray, MP-61
ATTN: Joyce Legare, MP-328
ATTN: H. Rosenthal
ATTN: James M. Potts, MP-61
ATTN: Gene Aiello

McDonnell Douglas Corporation
ATTN: Robert W. Halprin
ATTN: L. Cohen
ATTN: R. J. Reck
ATTN: Ken Kratch
ATTN: J. Kirby
ATTN: J. F. Garibotti
ATTN: H. Hurwicz

DEPARTMENT OF DEFENSE CONTRACTORS
(Continued)

McDonnell Douglas Corporation
ATTN: Jean McGrew

National Academy of Sciences
ATTN: Nat. Mat. Advisory Board for
Donald G. Groves
ATTN: Nat. Mat. Advisory Board for
Edward R. Dyer

Northrop Corporation
ATTN: Don Hicks

Pacific-Sierra Research Corp.
ATTN: Gary Lang

Physical Sciences, Inc.
ATTN: M. S. Finson

Physics International Company
ATTN: Doc. Con. for James Shea

Prototype Development Associates, Inc.
ATTN: John McDonald
ATTN: John Slaughter

R & D Associates
ATTN: Jerry Carpenter
ATTN: F. A. Field
ATTN: Harold L. Brode
ATTN: Albert L. Latter
ATTN: Cyrus P. Knowles

The Rand Corporation
ATTN: R. Robert Rapp

Raytheon Company
ATTN: Library

Science Applications, Inc.
ATTN: R. Fisher
ATTN: G. Ray
ATTN: John Warner
ATTN: Dwane Hove

Science Applications, Inc.
ATTN: Carl Swain
ATTN: Lyle Dunbar

Science Applications, Incorporated
ATTN: William M. Layson
ATTN: William R. Seebaugh

Southern Research Institute
ATTN: C. D. Pears
ATTN: J. R. Koenig
ATTN: G. F. Fornaro

Stanford Research Institute
ATTN: D. L. Huestis
ATTN: George R. Abrahamson
ATTN: Donald Curran
ATTN: Herbert E. Lindberg
ATTN: OAI
ATTN: Philip J. Dolan

DEPARTMENT OF DEFENSE CONTRACTORS
(Continued)

Stanford Research Institute
ATTN: Harold Carey
ATTN: W. B. Reuland

Systems, Science and Software, Inc.
ATTN: G. A. Gurtman
ATTN: Russell E. Duff

TRW Systems Group
ATTN: E. Y. Wong, 527/712
ATTN: William Polich
ATTN: Earl W. Allen, 520/141
ATTN: L. Berger
ATTN: V. Blankenship

DEPARTMENT OF DEFENSE CONTRACTORS
(Continued)

Terra Tek, Inc.
ATTN: Sidney Green

TRW Systems Group
ATTN: R. K. Plebuch, R1-2078
ATTN: Peter K. Dai, R1-2170
ATTN: Thomas G. Williams
ATTN: W. W. Wood
ATTN: D. H. Baer, R1-2136
2cy ATTN: I. E. Alber, R1-1008
ATTN: Peter Brandt, F1-2006