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20 September 1961

INVESTIGATION OF THE STRUCTURAL
INTEGRITY OF SECOND-STAGE
MINUTEMAN CHAMBERS
OF LADISH D-6ac STEEL

AFBSD TECHNICAL NOTE 61-16
Contract NO. AF 33(600)-36610
and Supplemental Agreement No. 14



Aerojet-General CORPORATION

A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY
AZUSA, CALIFORNIA • SACRAMENTO, CALIFORNIA



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TECHNICAL NOTE
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20 September 1961

INVESTIGATION OF THE STRUCTURAL INTEGRITY OF
SECOND-STAGE MINUTEMAN CHAMBERS
OF LADISH D-6ac STEEL

Prepared by

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Sacramento, California

AFBSD TECHNICAL NOTE 61-16
Contract No. AF 33(600)-36610
and Supplemental Agreement No. 14

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ABSTRACT

Second-stage Minuteman chambers fabricated of Ladish D-6ac steel were subjected to hydrostatic tests to investigate the structural soundness of the cases. The test series was conducted in four phases in accordance with Aerojet-General Test Plans 398, 406, and 458.

Test data obtained at pressures ranging from 0 to 600 psig indicated that chambers fabricated of this material meet specifications pertaining to structural integrity.

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I. INTRODUCTION

Detailed data were obtained during hydrostatic tests of second-stage Minuteman chambers fabricated of Ladish D-6ac steel. Test data obtained consist of stress, strain, and deflection measurements plotted for pressures ranging from 0 to 600 psig. In addition, failure stresses are shown for a chamber tested at 340°F.

The purpose of this program was to obtain stress, strain, and deflection data for a typical second-stage Minuteman chamber. The data obtained, together with measurements of thickness and radii of curvature, substantiated the structural integrity of the second-stage Minuteman engine cases.

II. TECHNICAL DISCUSSION

The components that were tested, and test plans and sequences, are shown in Table 1.

A. PHASE I: AFT CLOSURE STRAIN

Strain gages were used to determine the magnitude of the stresses in the aft closure at design load and ambient temperature. Phase I data, shown in Appendix A, provide experimental strain and calculated stress values plotted against loading pressure. The test equipment, loads, and instrumentation used are shown in Test Plan No. 398. Rosette and biaxial gages were used inside and outside the aft closure, as shown in Figure 1. Strains at the closure joint were measured with five pairs of gages located internally and externally at five different positions (Figure 2).

Vidigage measurements are shown in Figures 1 and 2. The data were obtained from points on the closure where strain gages were located. Figure 3 shows stress values at each gage location at a chamber pressure of 600 psi.

II, Technical Discussion (cont.)

B. PHASE II: STRESSCOAT DATA

Stresscoat tests were made in accordance with Magnaflux Corp. specifications. Under ambient conditions of temperature and humidity, the coating was expected to withstand a threshold strain between 700 and 900 microin./in. An undercoat and a coating of stresscoat were applied and cured at $85 \pm 5^{\circ}\text{F}$ for 18 hr.

The Stresscoat-cracking pressure at a threshold strain of 700 microin./in. was predicted with calculations of chamber and closure thicknesses. Prior to the test, a calibration bar was tested and the threshold strain was determined. The predicted cracking pressure was corrected relative to the calibration bar threshold strain. The specimen was pressurized in increments of 10, 20, 30, or 50 psi. Duration of the pressurization periods was measured so that corrections for threshold strain creep could be made.

Correlation strain gages (Figure 4) located at points 52 through 60 were used to obtain measured strain data.

Strains and stresses were calculated from Stresscoat and strain gage data. By the use of threshold strain and cracking pressure, strains and stresses were extrapolated to 600 psi. Depending on the pressure increments, each zone had a range of stress values varying from 10 to 25%. The only area where strain and stress could be calculated directly was on the isoeutatic lines between cracking zones where the lowest pressure recorded was the actual cracking pressure. Correlation between strain gage and Stresscoat data was within 25%. The data are tabulated in Appendix B.

II, Technical Discussion (cont.)

C. PHASE III: CHAMBER DEFLECTION AND EXPANSION AND
BLAST TUBE ROTATION

The purpose of the Phase III tests was to determine the deflection and rotation of the blast tube axis relative to the chamber longitudinal axis, and the longitudinal and radial expansion of the chamber. The test setup and methods are described in Test Plan No. 398.

Data obtained for blast tube rotation were inconclusive. Deflection measurements of blast tube rotation were of small magnitude and caused inconsistencies in data analysis.

Chamber deflections resulting from internal pressurization were measured with deflection beams. Chamber deflections were also of small magnitude, causing a 10% error in data reduction. Deflection data are shown in Figure 5 and in Appendix C.

D. PHASE IV: DETERMINATION OF STRESSES IN THE CHAMBER
JOINTS AND IN THE FORWARD HEAD

The purpose of the Phase IV tests was to determine the magnitude of stresses at limit load and ambient temperature by the use of strain gages in the forward and aft chamber joints and in the forward head. The test specimens, test setup, and gage locations are as described in Test Plan No. 398.

Figures 4, 6, 7, and 8 show the measured thickness of the test specimens at gage locations and at the forward head. Figures 9 and 10 show stress values at 600 psi. Appendix D shows experimental strain and calculated stress values plotted against loading pressure.

II, Technical Discussion (cont.)

E. PHASE V: BURST TEST

A second-stage Minuteman chamber was tested to failure at a temperature of 340°F in accordance with Test Plan No. 406. The deflection beam, high-temperature strain-gage location, and thicknesses at each location are shown in Figure 11.

Appendix E shows strain and deflection measurements obtained at elevated temperature plotted against loading pressure.

F. INTERPRETATION OF TEST DATA

Accuracy of reduced data depends on the magnitude of the recorded strain. Low strain values (up to 1000 microin. /in.) have an accuracy of only 5%, but relatively high strain values (4000 microin. /in. and above) can be reduced with an accuracy of $\pm 1\%$. The overall accuracy of the strain gages, lead wires, and recording instruments is $\pm 1.5\%$. Data obtained at ambient temperature can be expected to have an accuracy of ± 2.5 to $\pm 6.5\%$, depending on the magnitude of the measured strain. Data taken at elevated temperatures is 15% low, due to the gage factor shift at elevated temperature and must be increased by this amount.

Test data are in the form of strain- and stress-vs-pressure curves, deflection-vs-pressure curves, and stress vs location at 600 psig. In addition, the results of a posttest dimensional survey are presented. Radii of curvature variation in the aft closure are shown in Figures 12 and 13.

Figures 14 through 36 provide supplementary data and show the test setup, strain gage layout and installation, the ruptured engine case, Stress-coat crack patterns, and the test cell hydraulic system. Further data are presented in the appendixes.

TABLE 1

TEST ARTICLES AND SEQUENCE

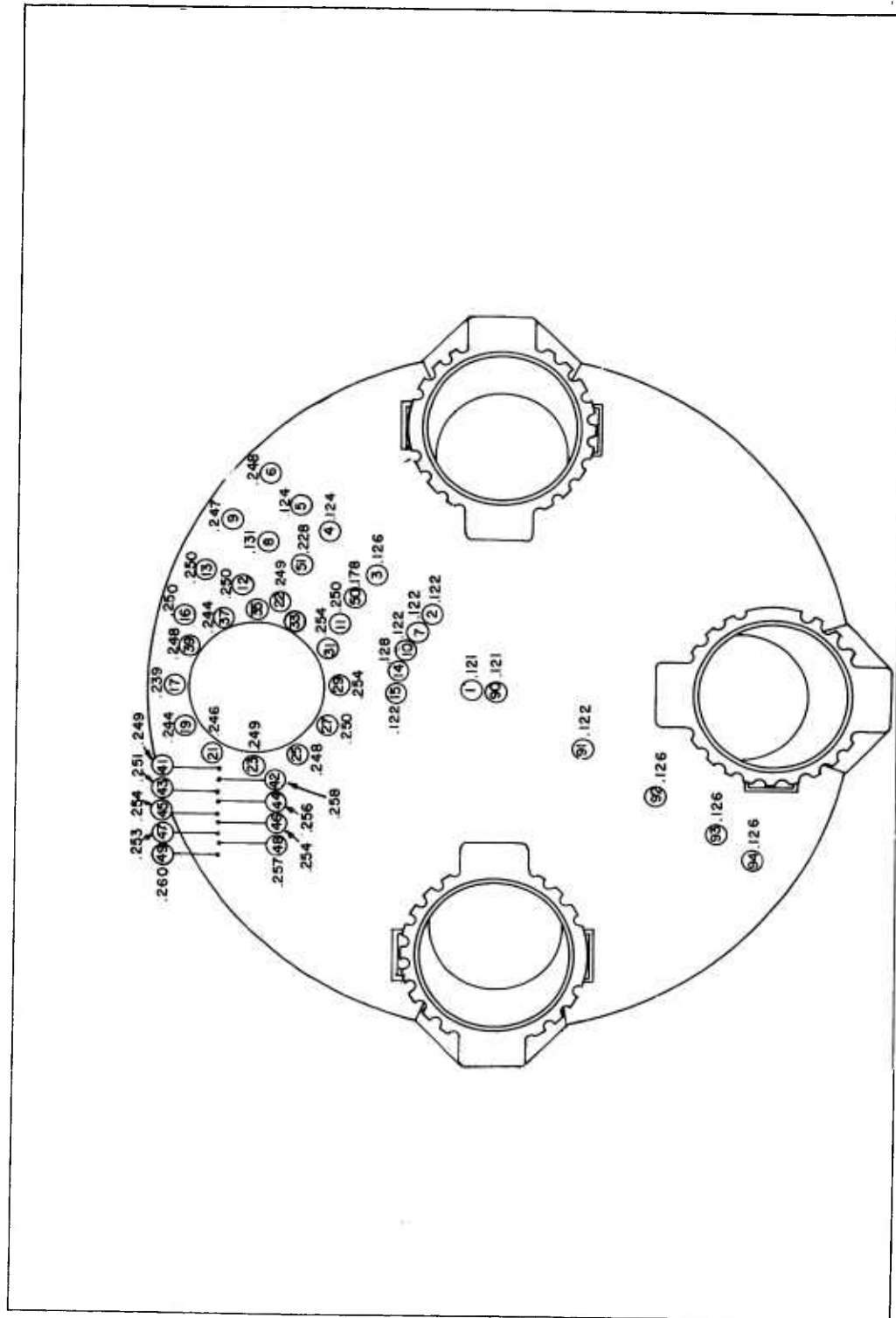
Engine Case S/N 519564
Aft Closure S/N 522244

<u>Test Plan</u>		<u>Cycles</u>	<u>Pressure, psi</u>
Reference Test Plan No. 398	Phase I Test	2	600
	Phase II Test	8	*
	Phase III Test	1	600
Reference Test Plan No. 406	Hot Burst Test		
	Phase V	1	750

Engine Case S/N 519576
Aft Closure S/N 522244

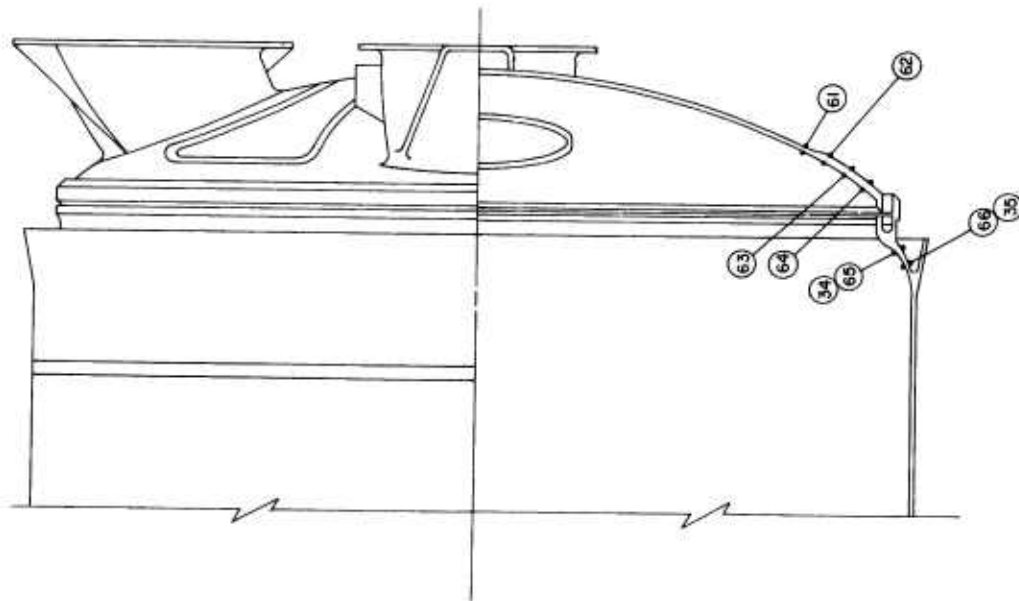
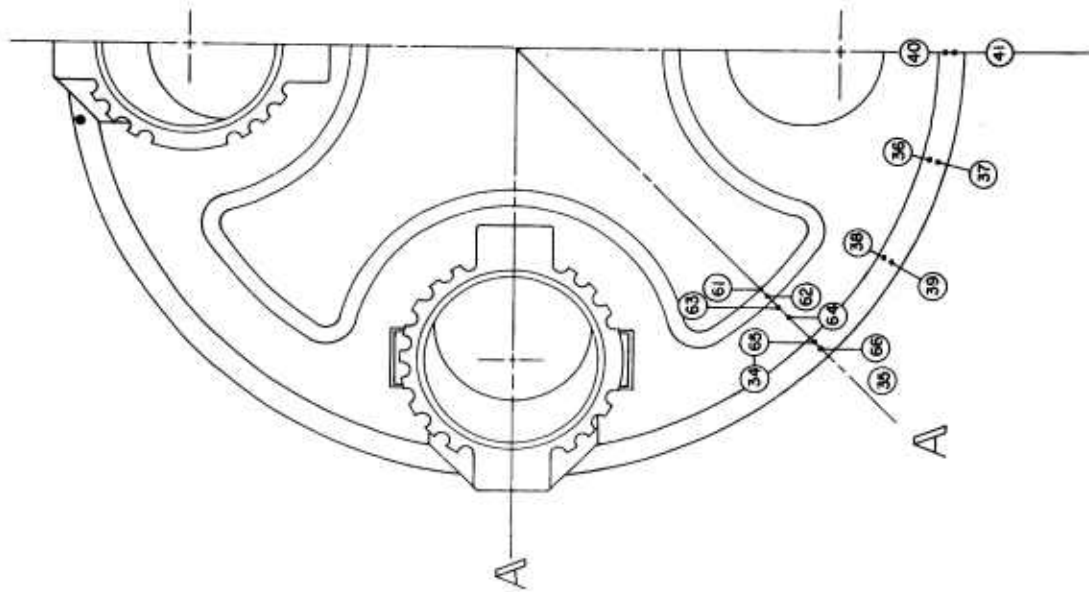
<u>Test Plan</u>		<u>Cycles</u>	<u>Pressure, psi</u>
Reference Test Plan No. 398	Phase IV Test	1	600
	Aft Closure Stiffness	4	600

* Phase II - Test cycles were to 60,80,100,120,
175,270,370, and 600 psig



Aft Closure Gage Locations and Thickness Measurements
at Gages

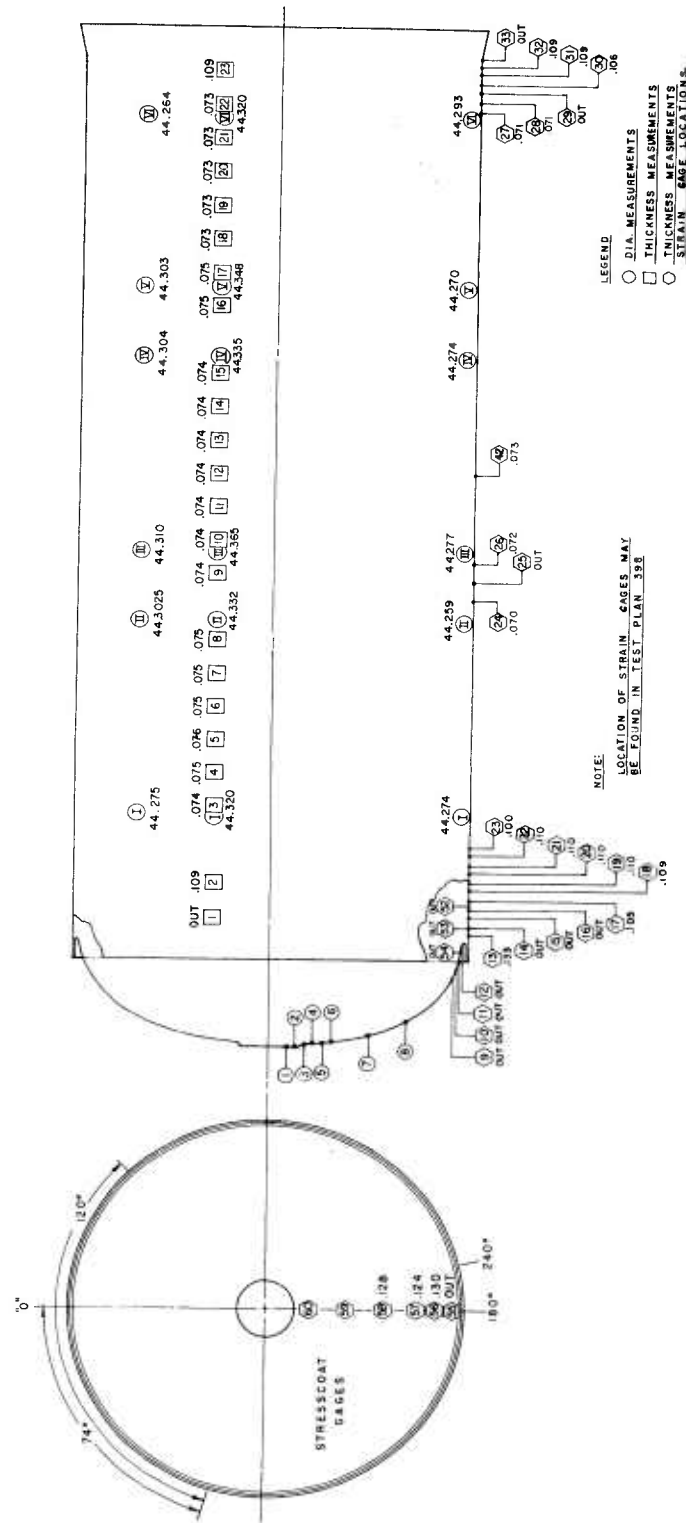
Figure 1



SECTION A-A

Aft Joint and Aft Closure Joint Strain Gage Location

Figure 2



Chamber and Forward Closure Gage Locations and Thickness Measurements

Figure 4

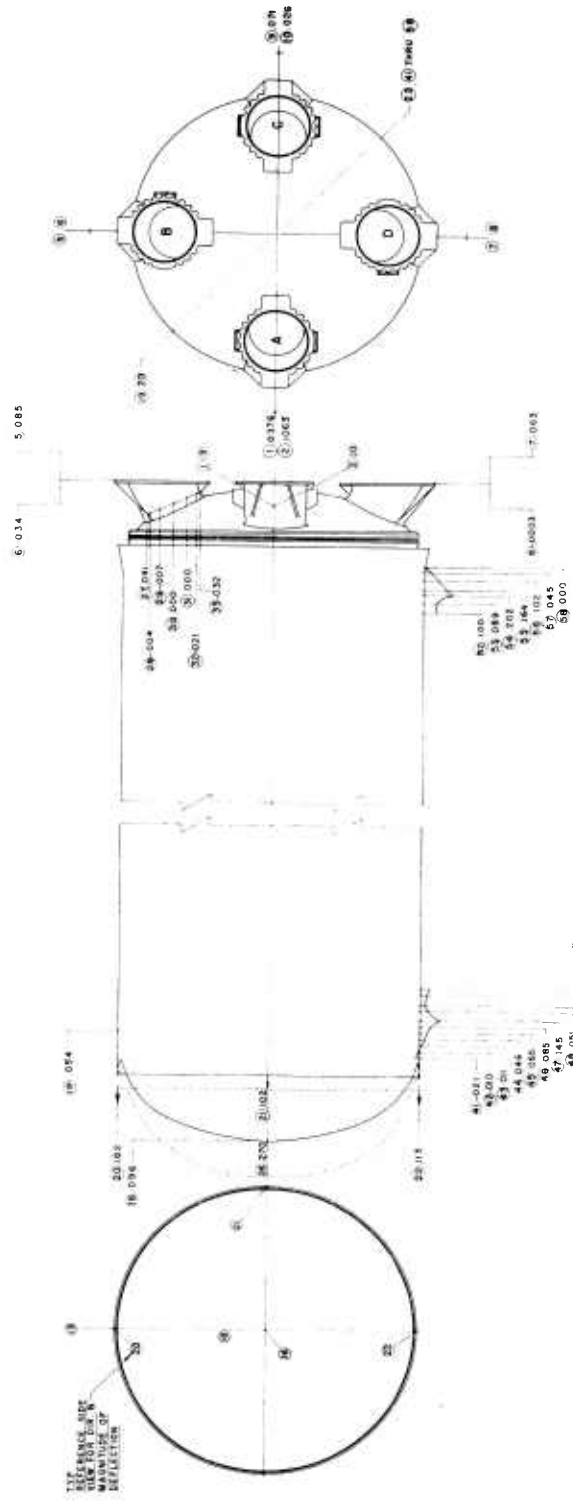
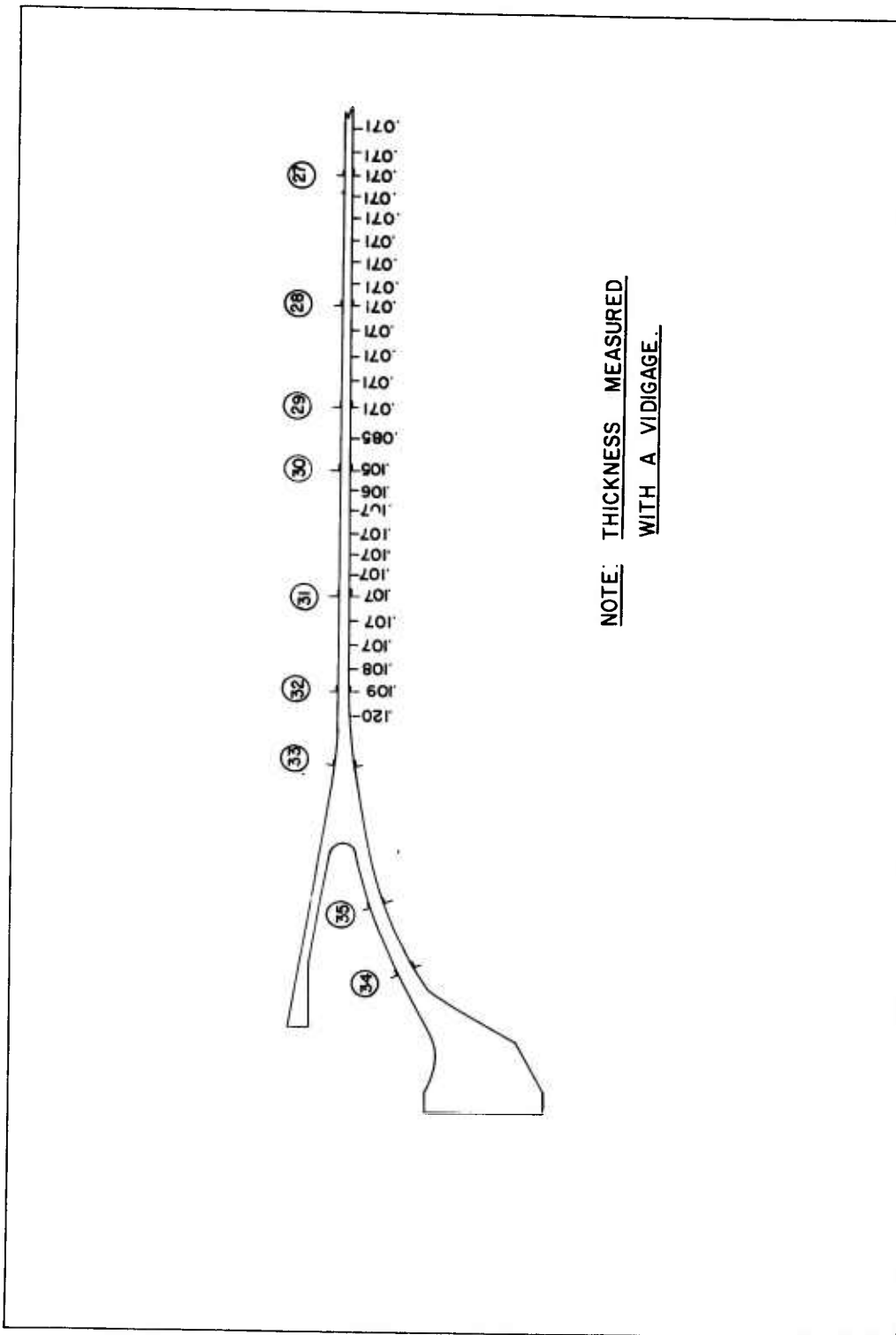


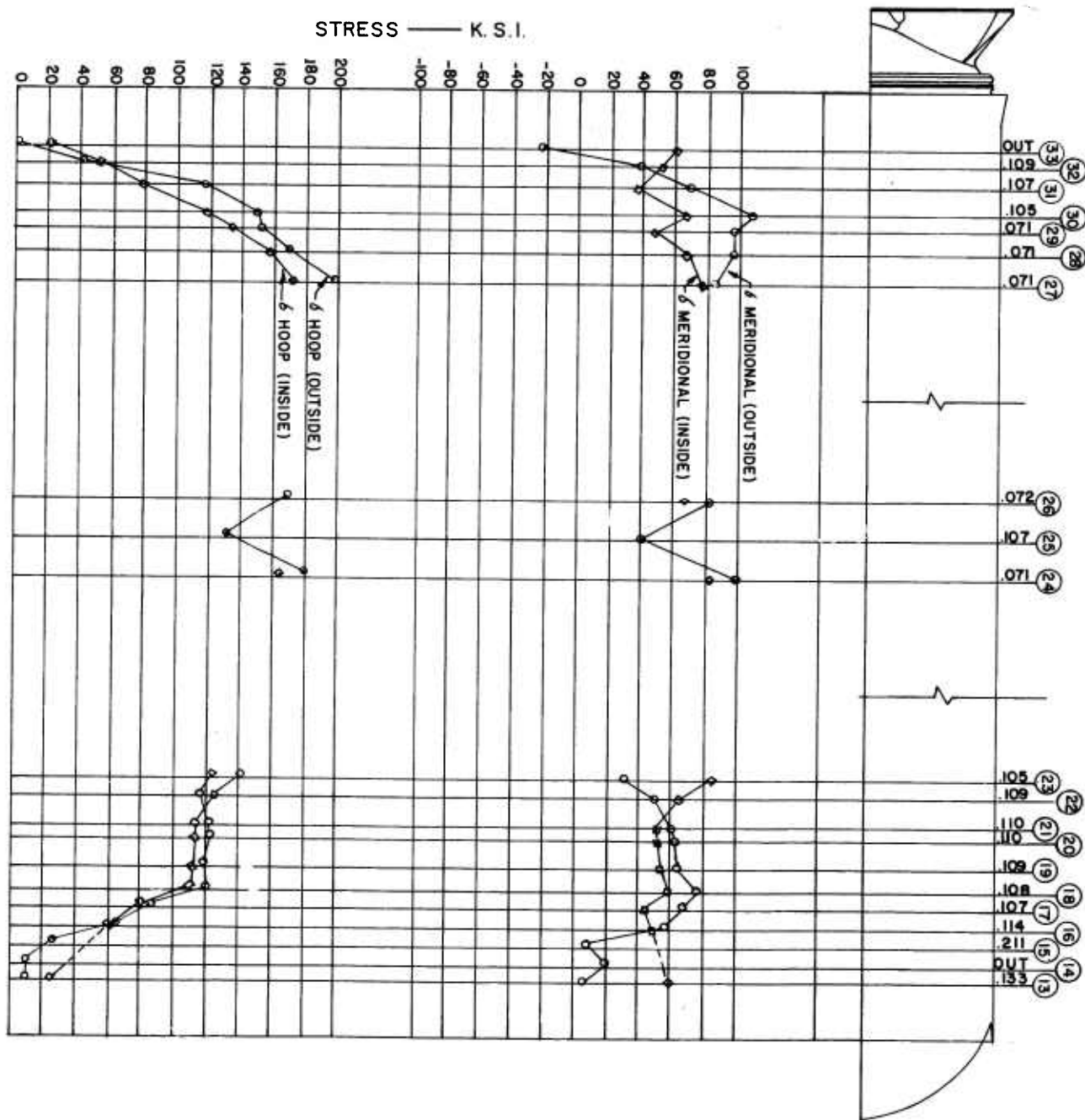
Figure 5

Deflection Measurements



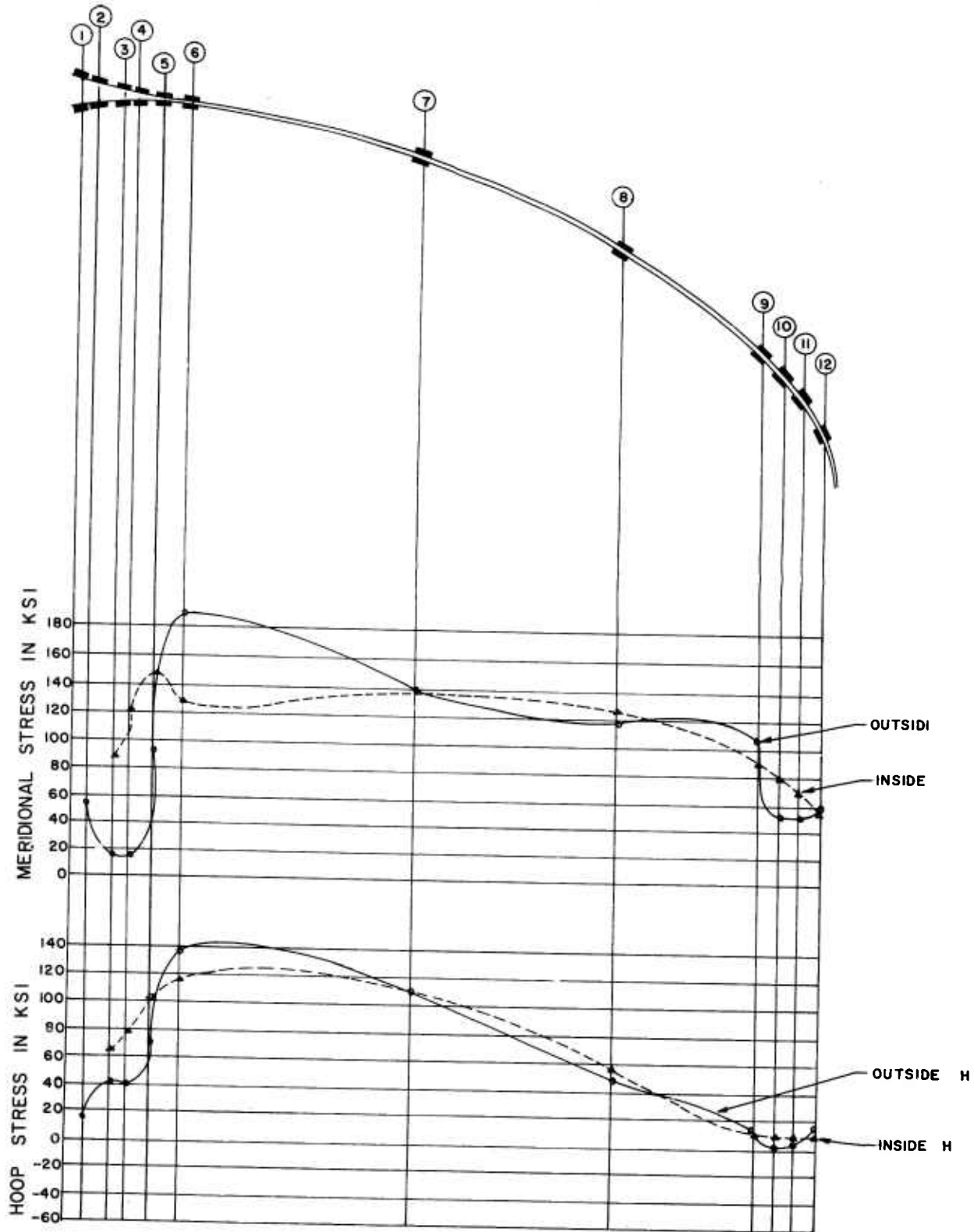
Chamber Thickness Measurements, Aft End of Chamber

Figure 7



Chamber Gage Locations and Stress Values at 600 psi

Figure 9



Forward Closure Gage Locations and Stress Values at 600 psi

Figure 10

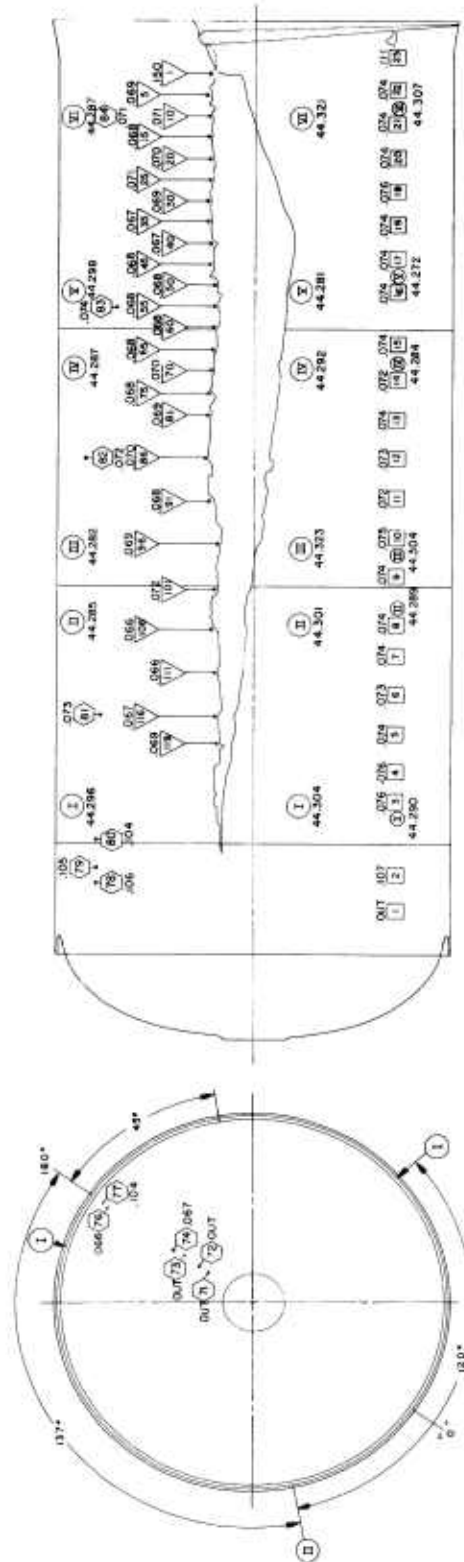


Figure 11

RUPTURE MEASUREMENTS											
1	.150	.21	.070	.41	.068	.61	.076	.81	.063	.071	.072
2	.150	.22	.071	.42	.068	.62	.076	.82	.063	.102	.072
3	.160	.23	.071	.43	.068	.63	.077	.83	.063	.103	.068
4	.069	.24	.071	.44	.068	.64	.068	.84	.068	.044	.067
5	.069	.25	.071	.45	.068	.65	.068	.85	.069	.065	.066
6	.070	.26	.071	.46	.068	.66	.068	.86	.069	.106	.066
7	.070	.27	.071	.47	.067	.67	.070	.87	.069	.107	.068
8	.071	.28	.070	.48	.068	.68	.070	.88	.069	.108	.066
9	.071	.29	.070	.49	.068	.69	.070	.89	.069	.099	.066
10	.071	.30	.070	.50	.068	.70	.070	.90	.075	.110	.066
11	.069	.31	.069	.51	.068	.71	.069	.91	.067	.111	.066
12	.069	.32	.069	.52	.068	.72	.069	.92	.067	.112	.066
13	.068	.33	.069	.53	.068	.73	.068	.93	.068	.113	.066
14	.069	.34	.067	.54	.068	.74	.068	.94	.067	.114	.066
15	.068	.35	.067	.55	.068	.75	.068	.95	.068	.115	.066
16	.068	.36	.067	.56	.068	.76	.068	.96	.068	.116	.066
17	.069	.37	.067	.57	.068	.77	.070	.97	.069	.117	.068
18	.069	.38	.067	.58	.069	.78	.069	.98	.067	.118	.066
19	.070	.39	.068	.59	.071	.79	.069	.99	.068	.119	.069
20	.070	.40	.067	.60	.068	.80	.068	.100	.068	.100	.066

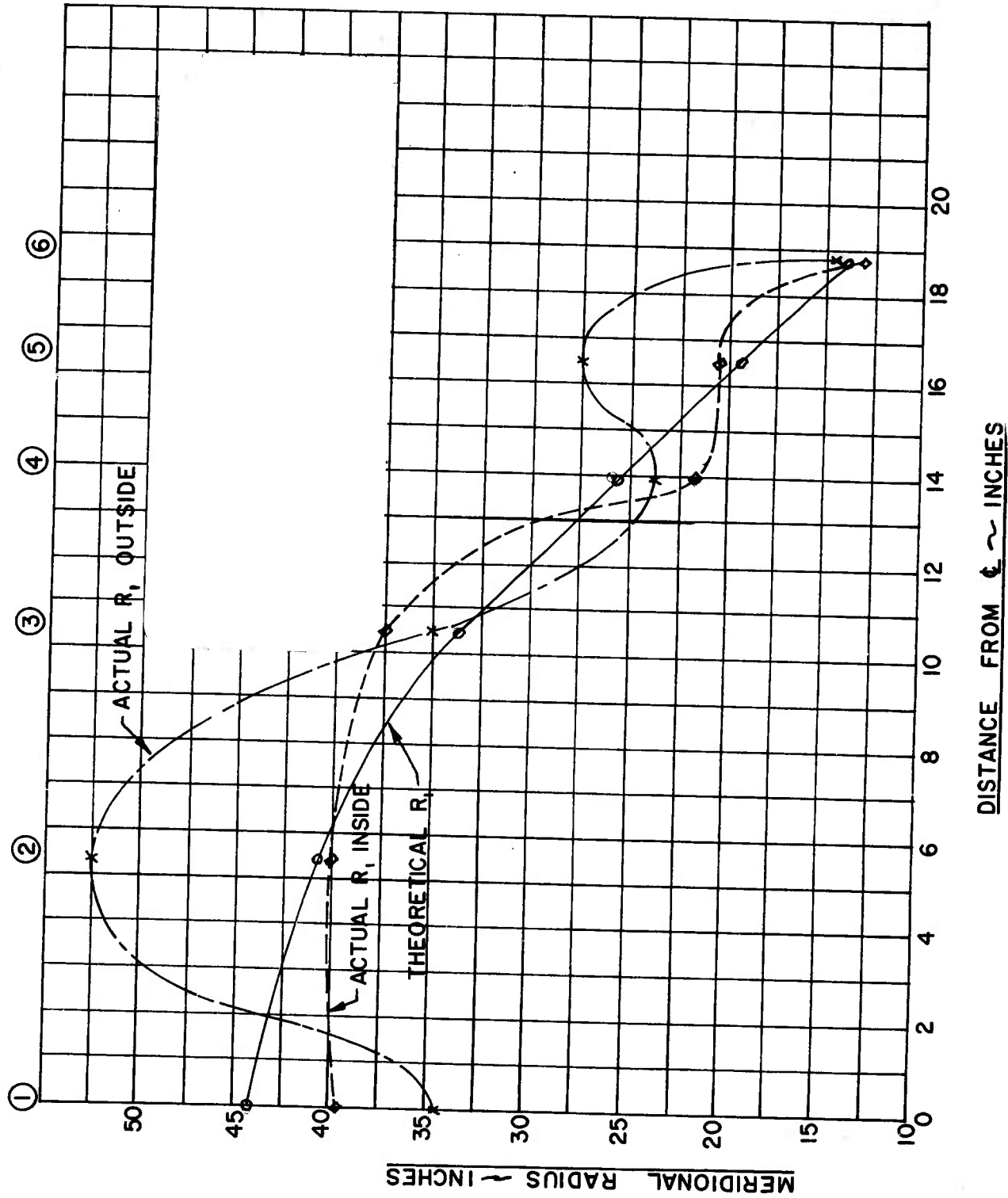
NOTE:

LOCATION OF STRAIN GAGES MAY BE FOUND IN TEST PLAN 398.

LEGEND

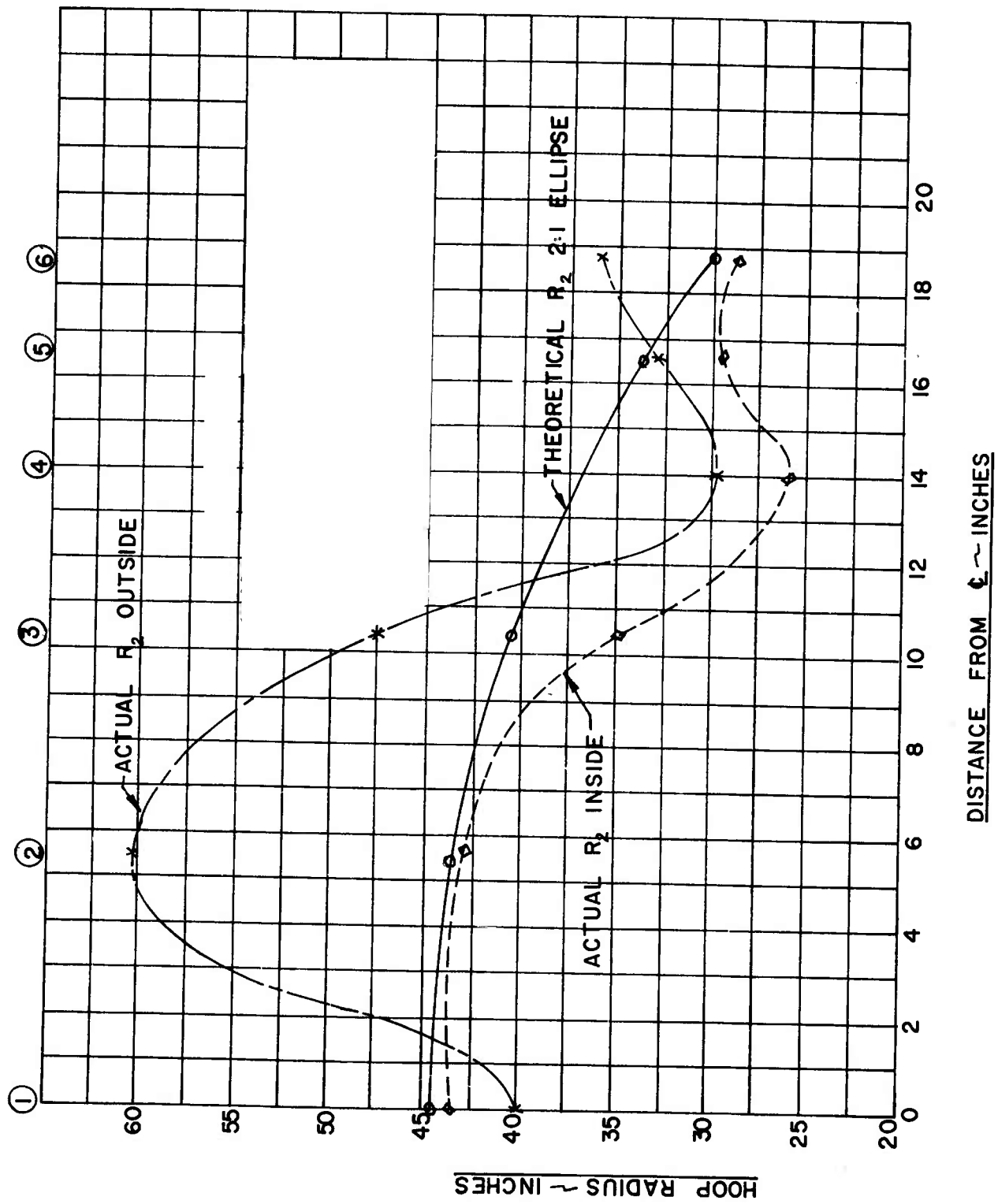
- DIA. MEASUREMENTS
- THICKNESS MEASUREMENTS
- ◇ THICKNESS MEASUREMENTS ALONG RUPTURE
- ▽ STRAIN GAGE LOCATIONS
- △ THICKNESS MEASUREMENTS ALONG RUPTURE

Burst Chamber Data



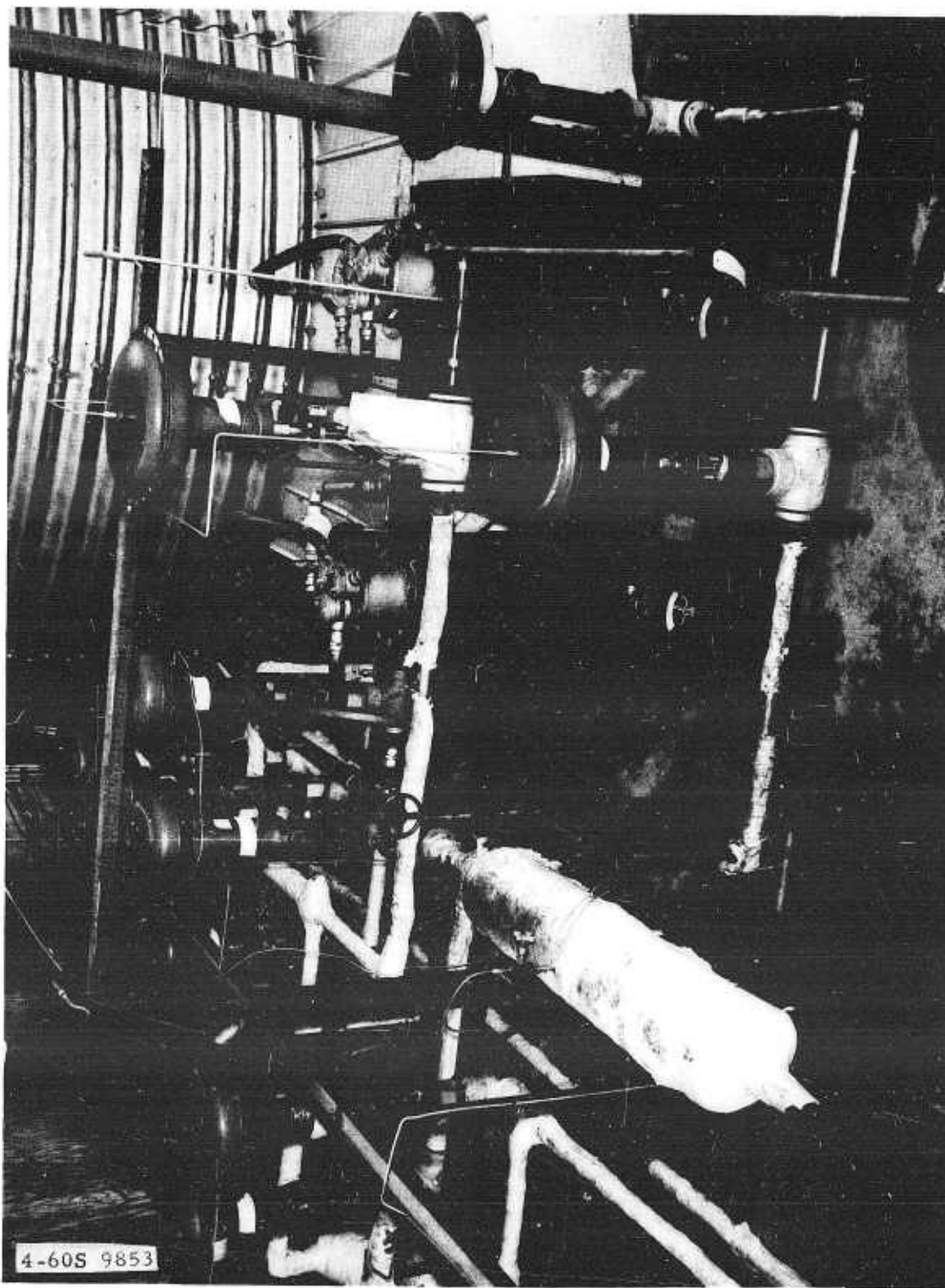
Actual vs Theoretical Meridional Radius of Curvature,
Aft Closure

Figure 12



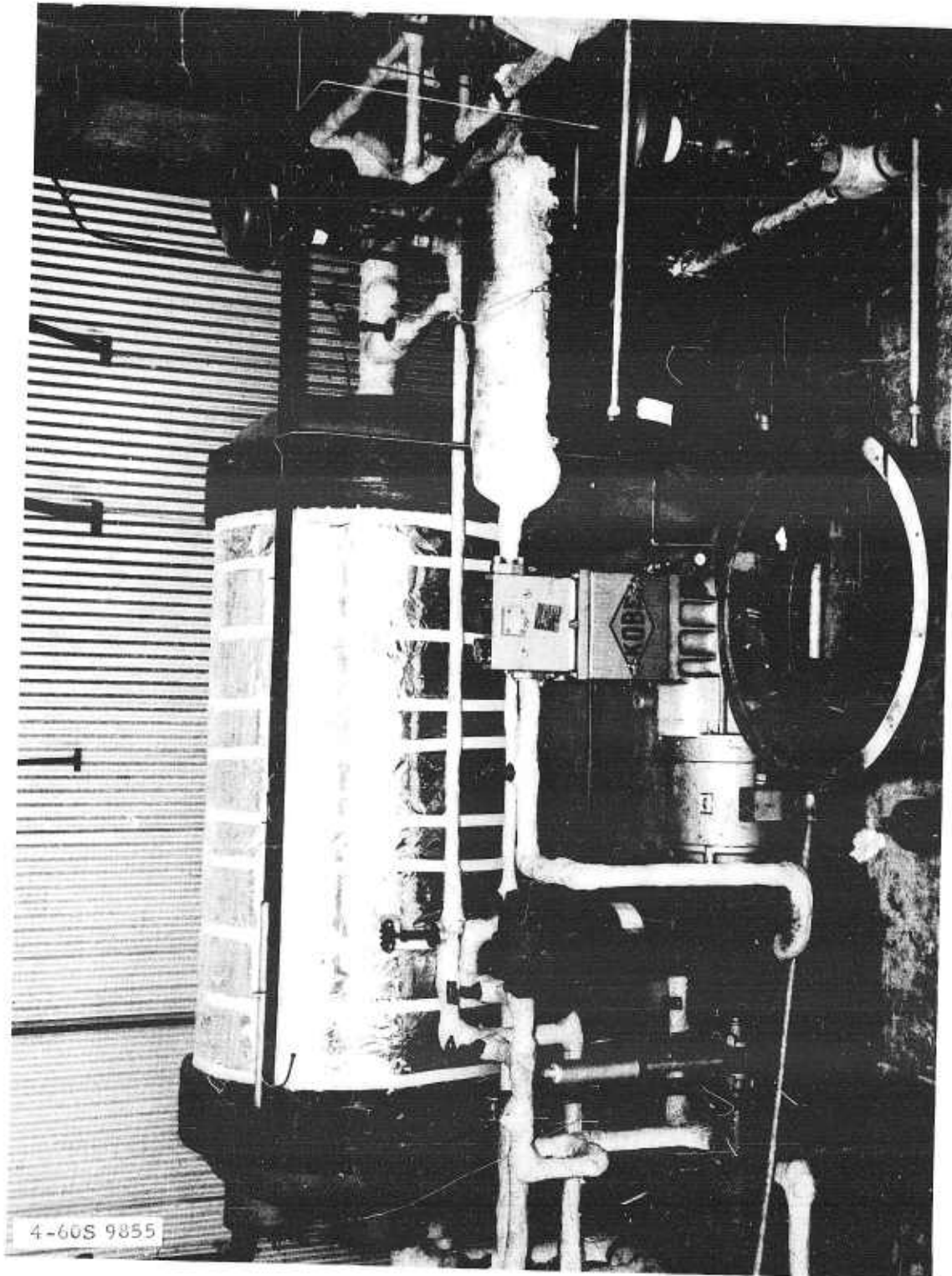
Actual vs Theoretical Hoop Radius of Curvature, Aft Closure

Figure 13



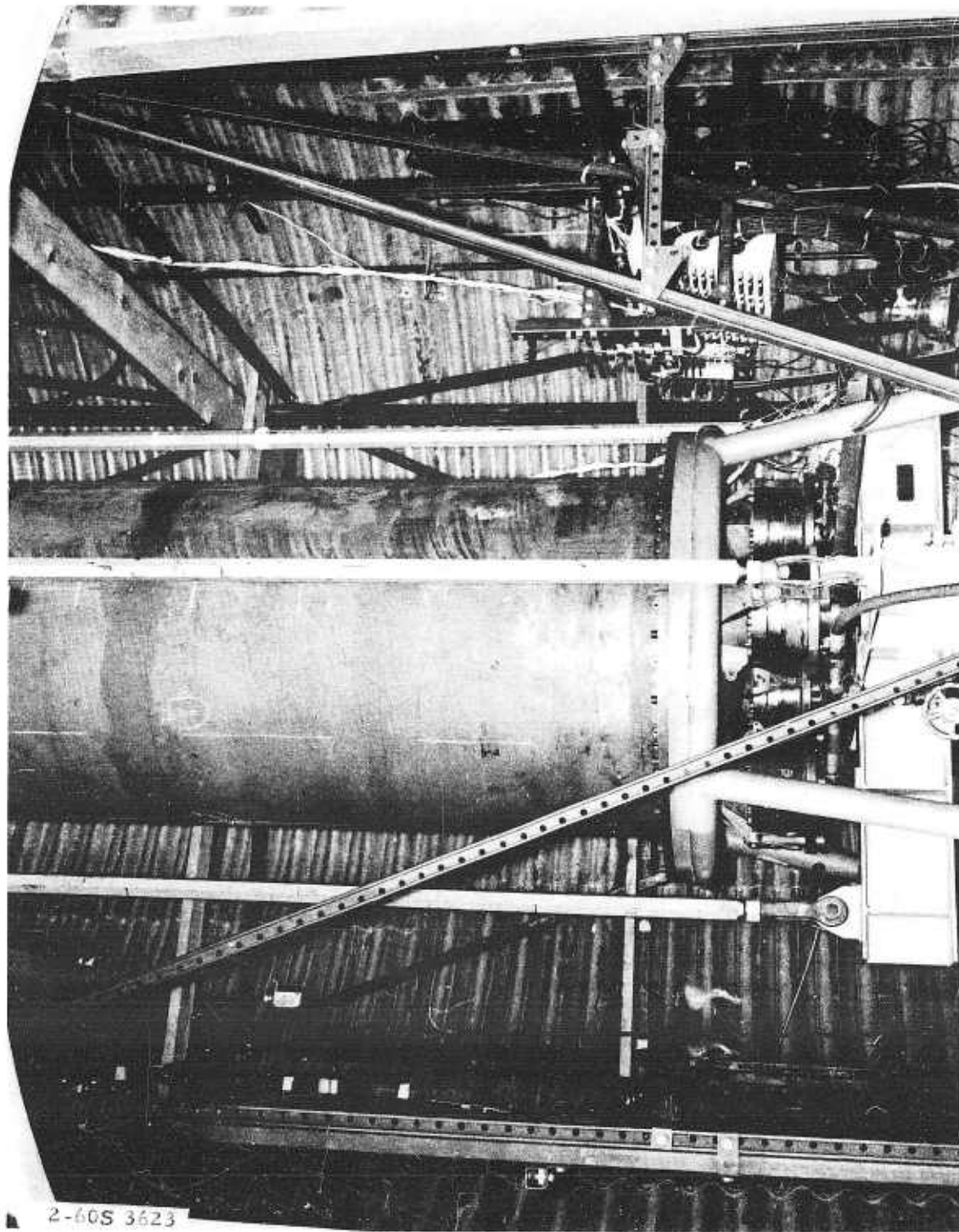
Hydraulic Valves and Heating System

Figure 14



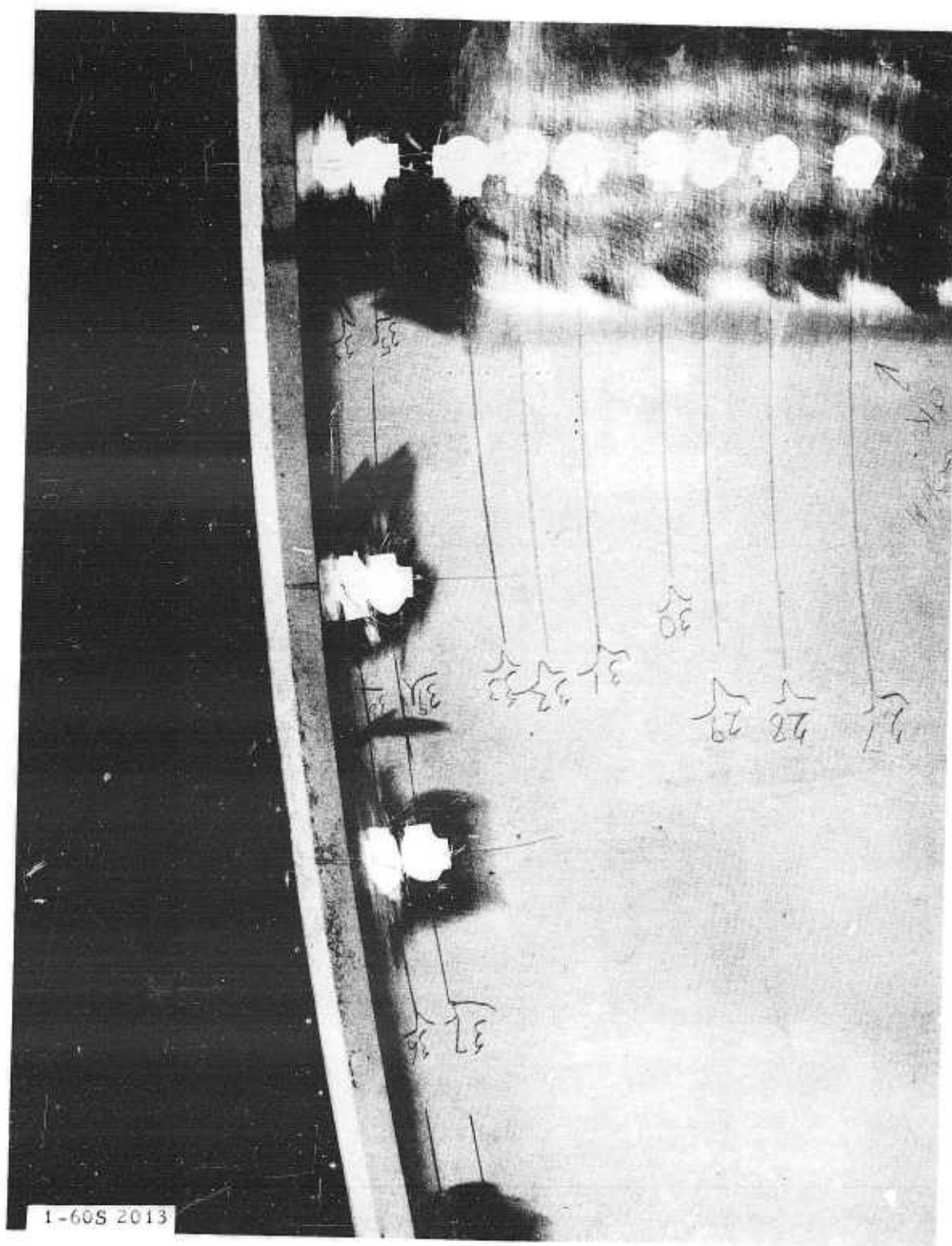
Hydraulic Pumps and Reservoir

Figure 15



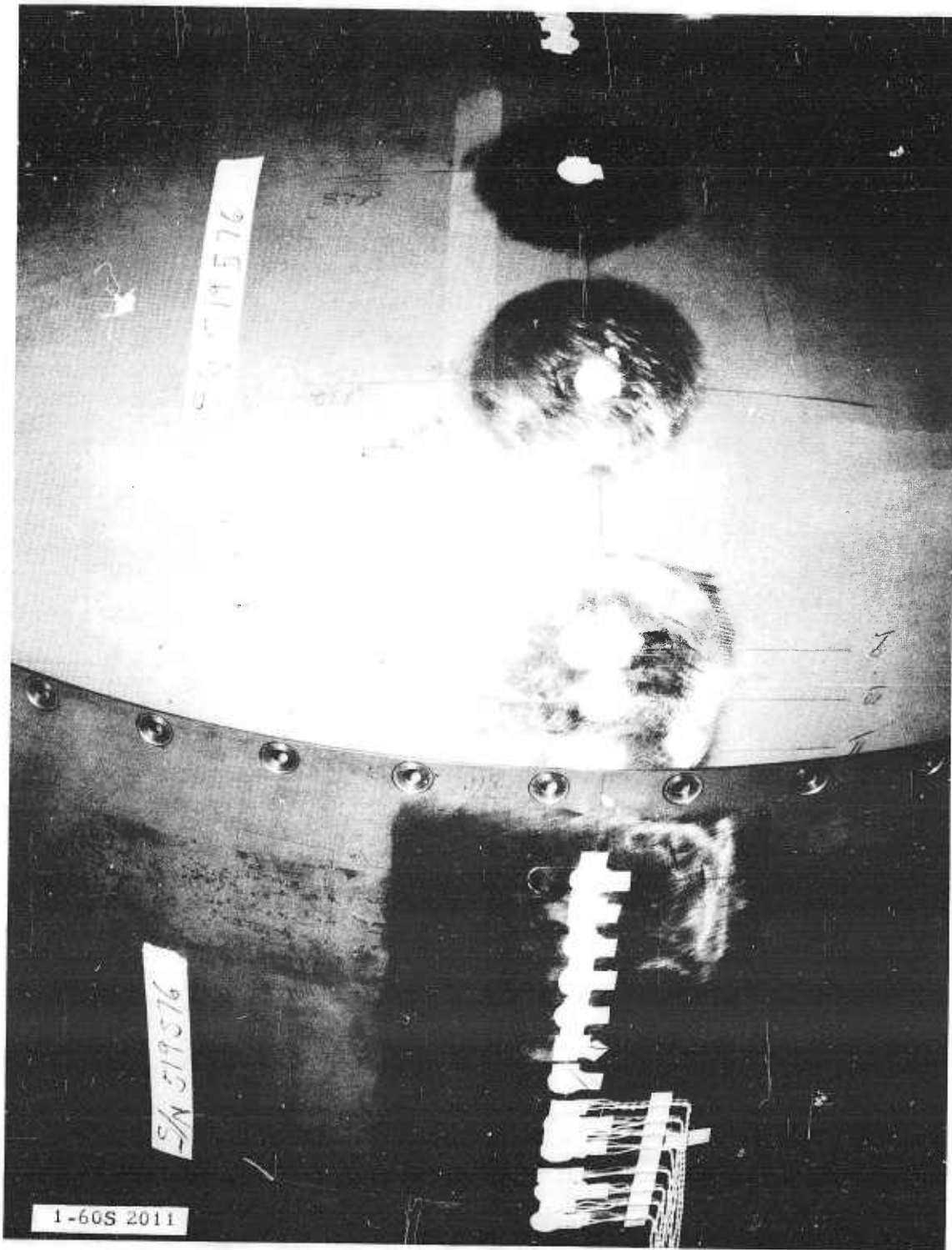
Typical Test Setup, 15-ft-dia Test Cell

Figure 16



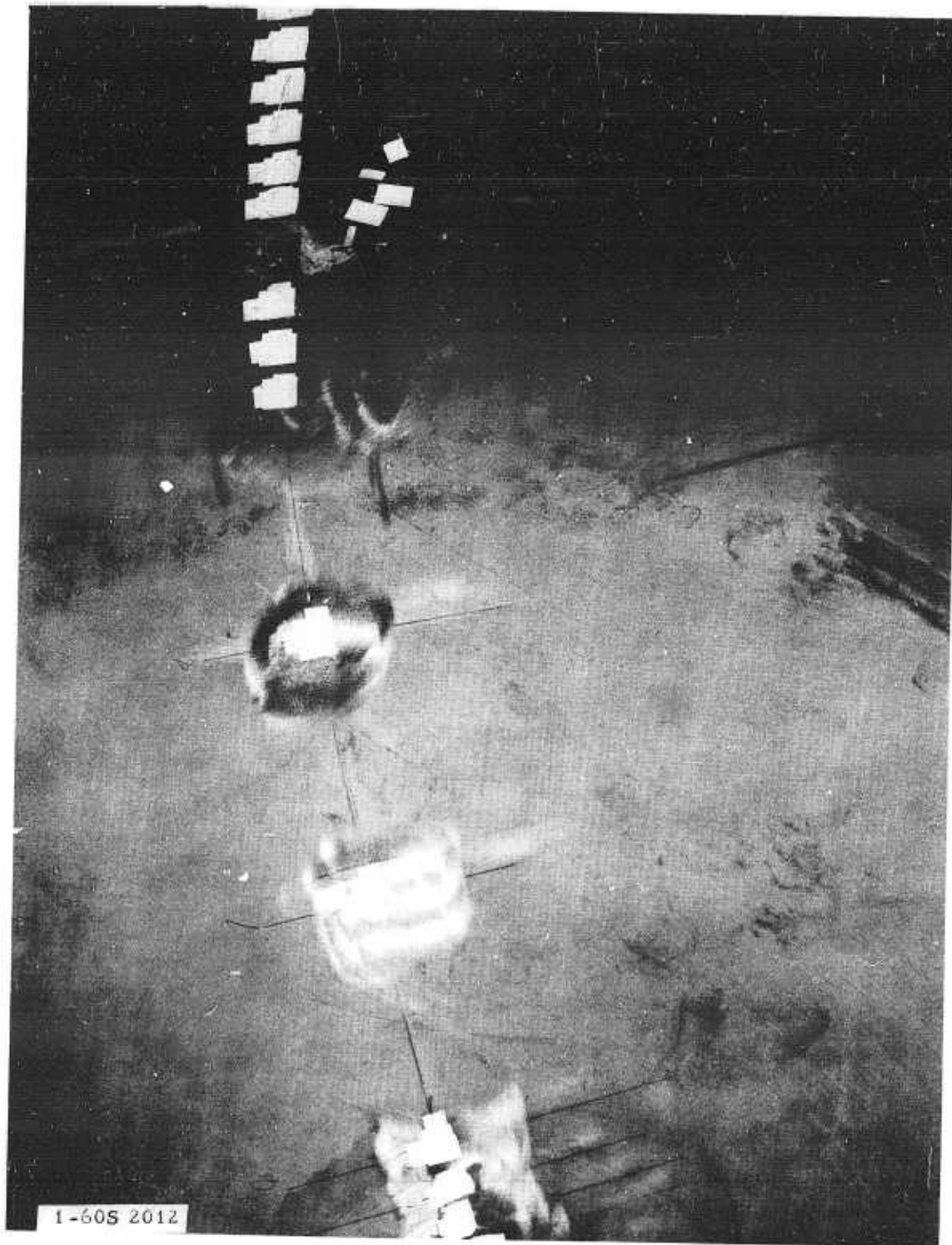
Inside Strain Gages at Aft Joint and Cylinder

Figure 17



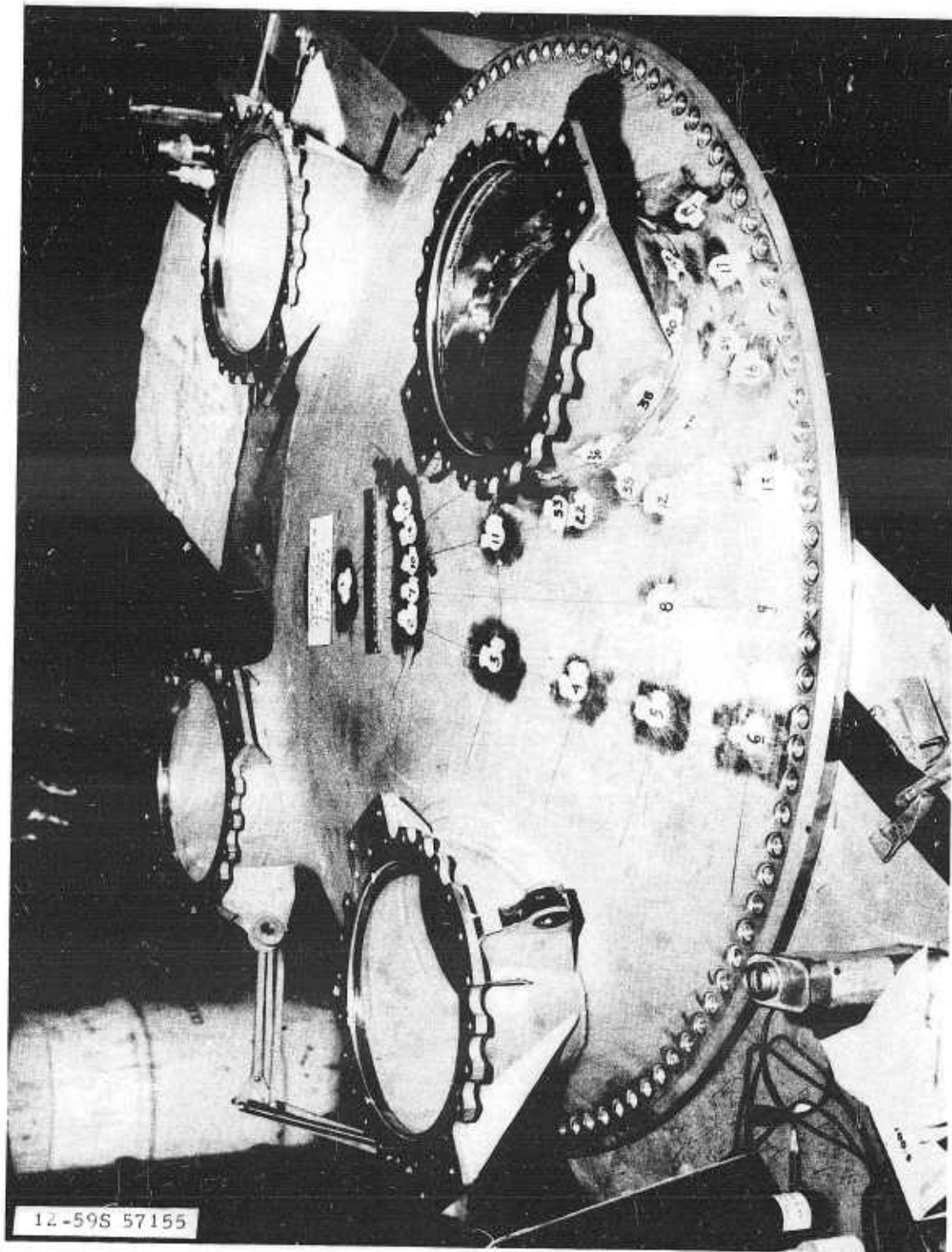
Outside Strain Gages, Forward Head and Joint

Figure 18



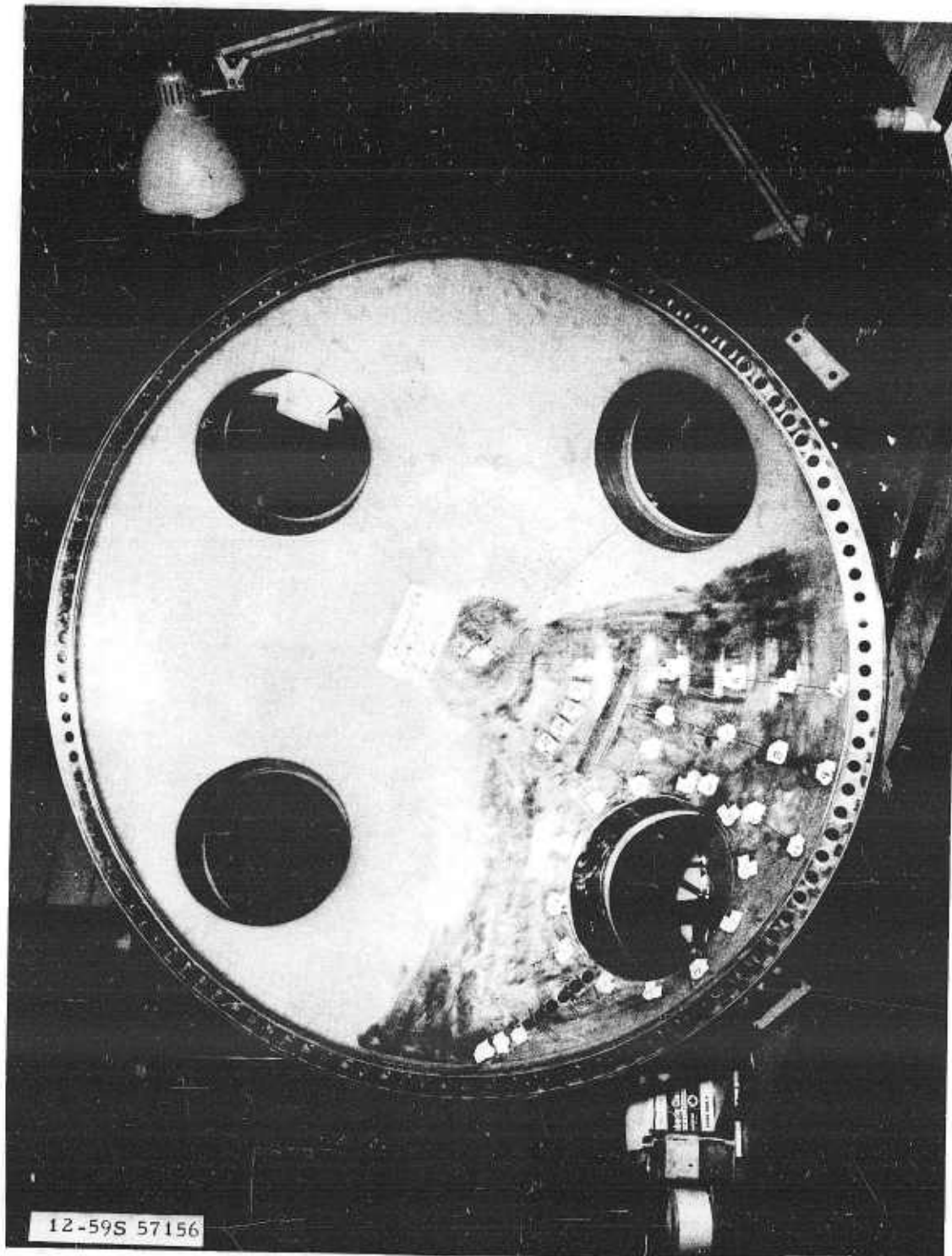
Inside Strain Gages, Forward Head and Joint

Figure 19



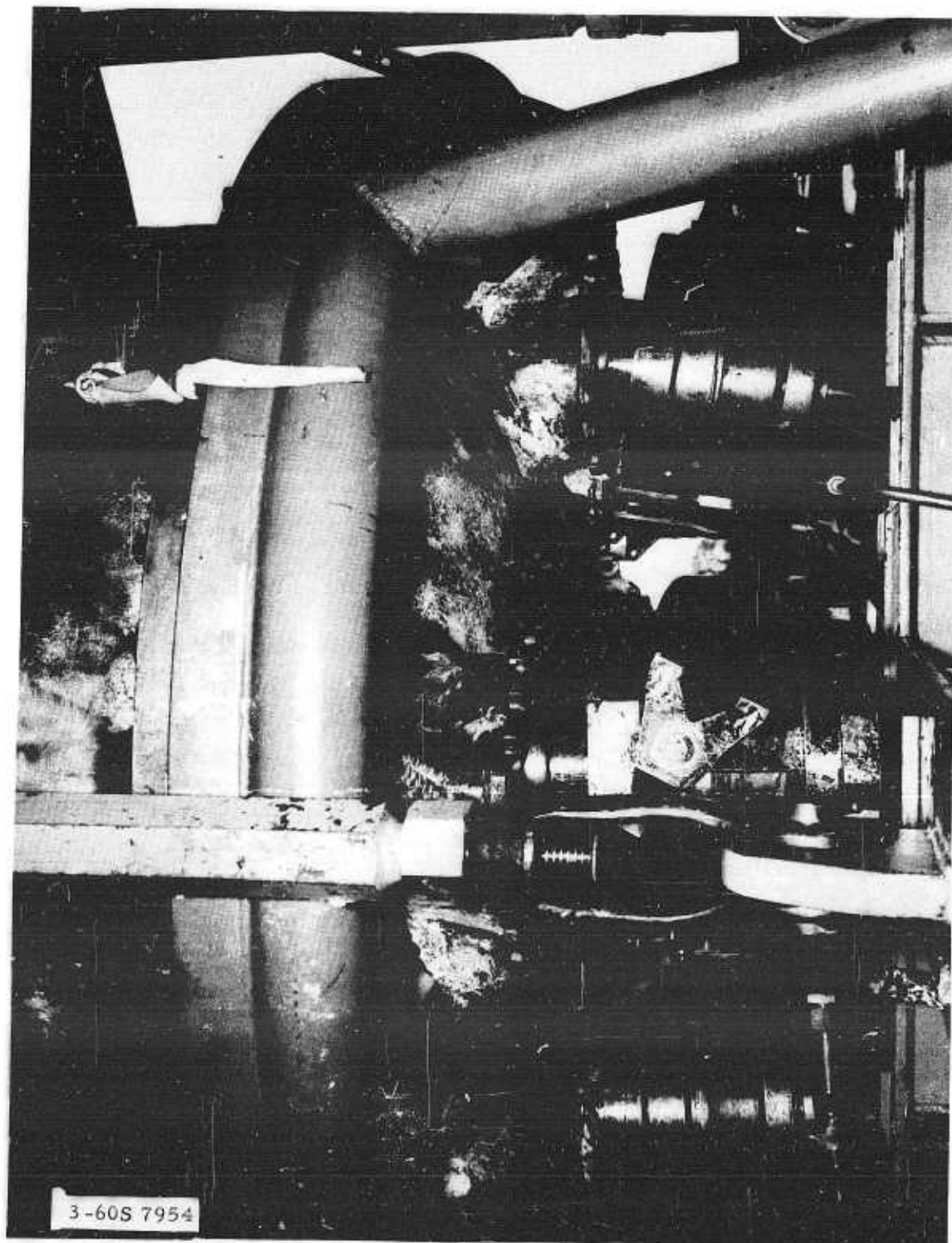
Outside Strain Gages, Aft Closure

Figure 20



Inside Strain Gages, Aft Closure

Figure 21



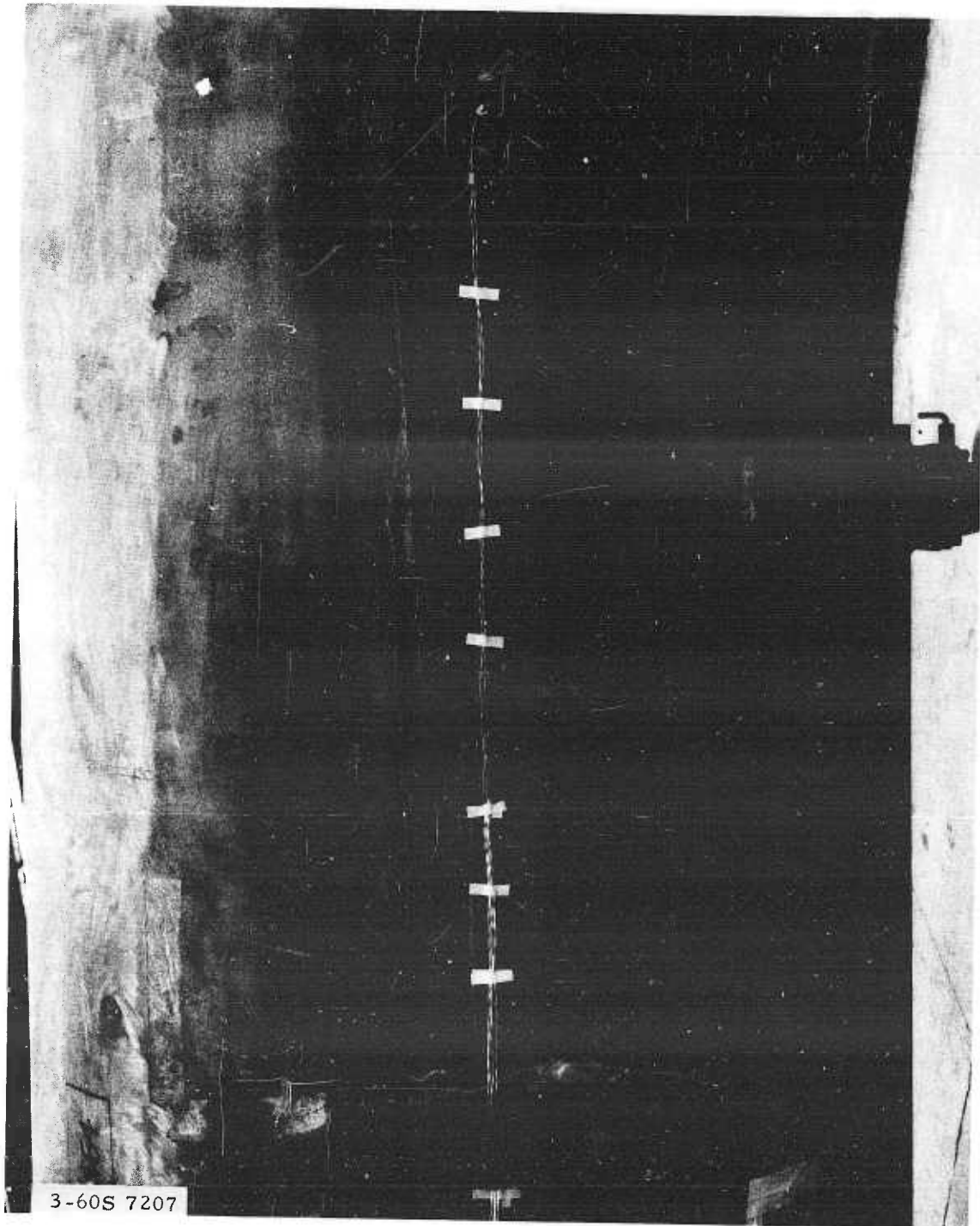
Nozzle Piston Arrangement, Aft Closure

Figure 22



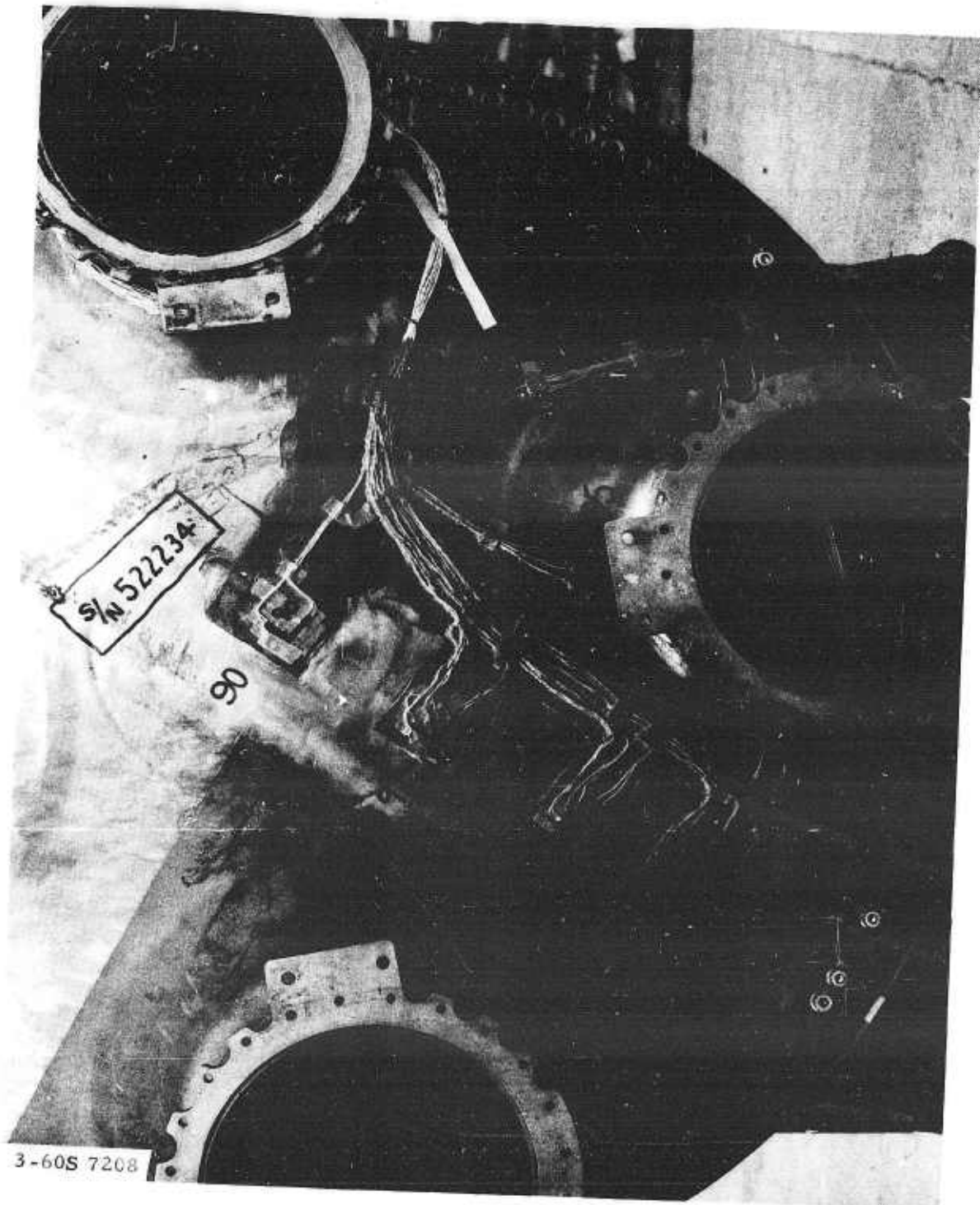
Strain Gages, Burst Test, Forward Head

Figure 23



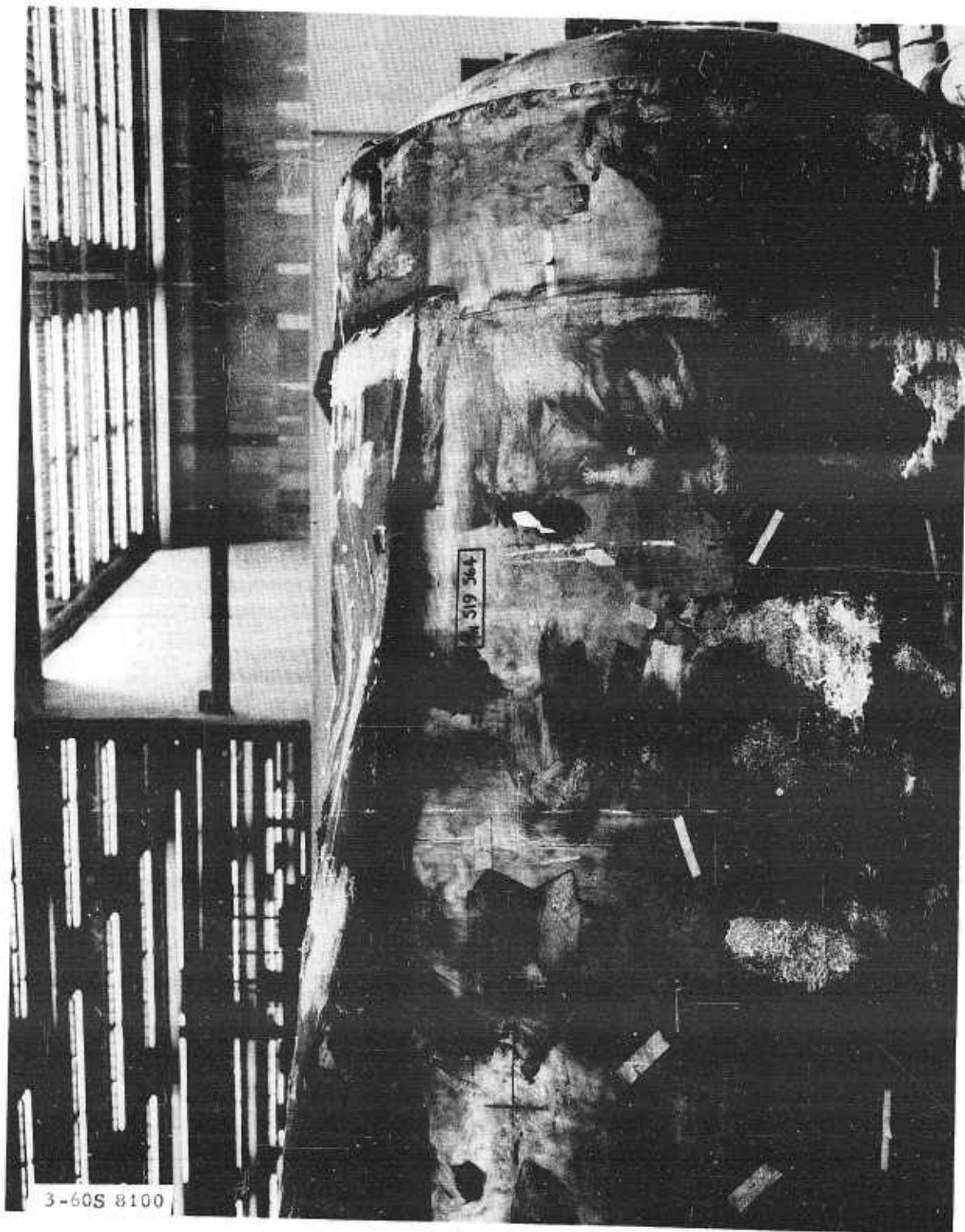
Strain Gages, Burst Test, Chamber

Figure 24



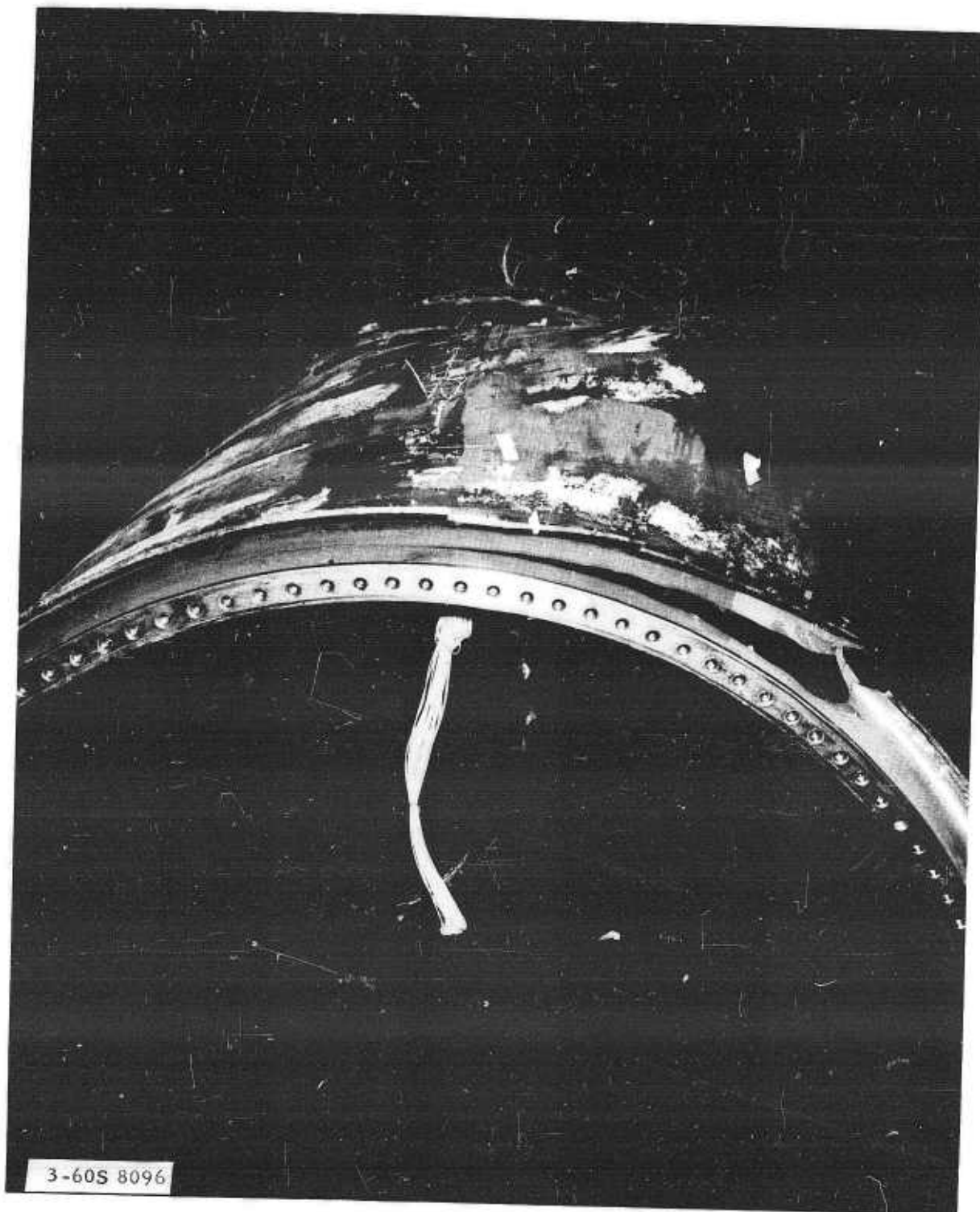
Strain Gages, Burst Test, Aft Closure

Figure 25



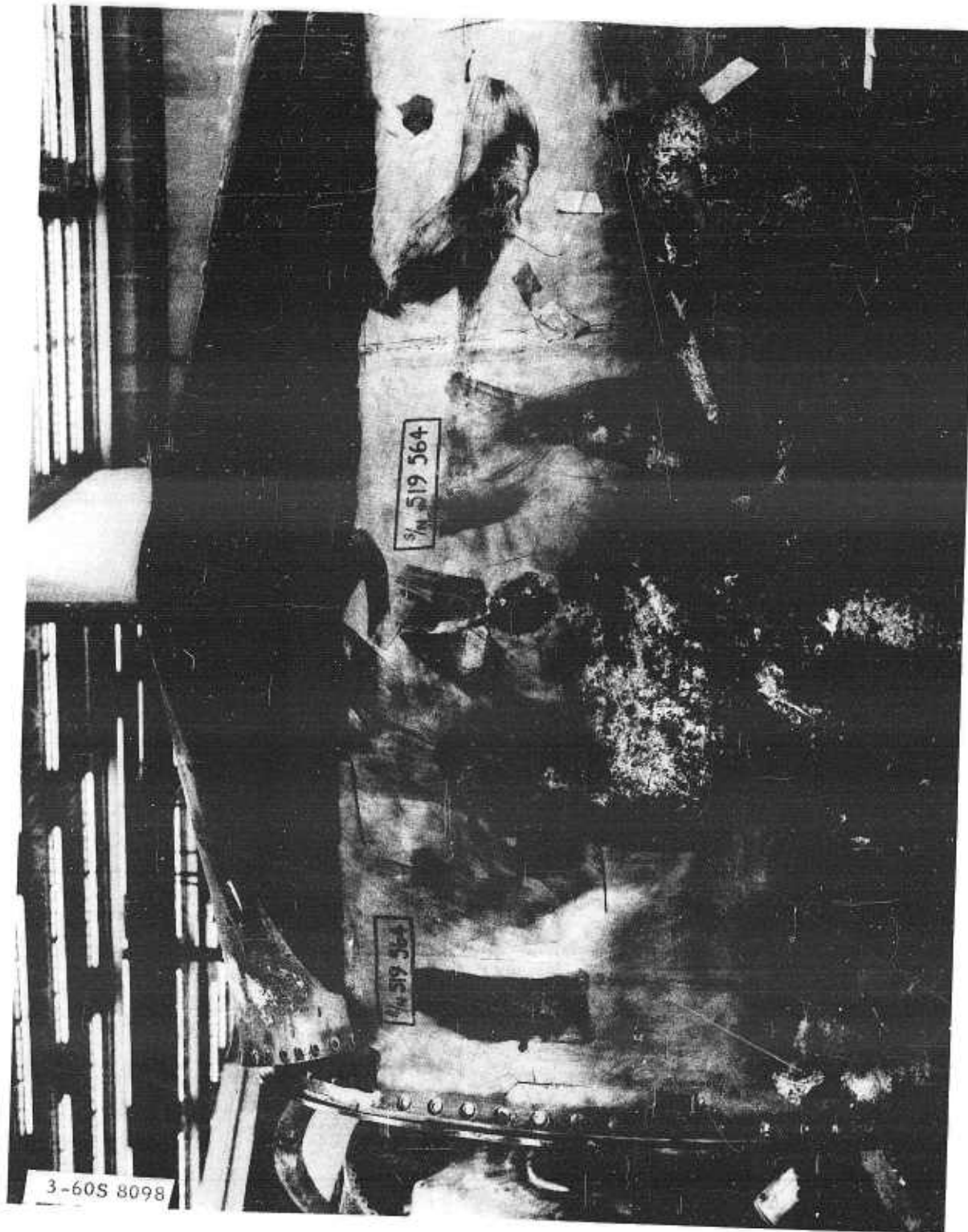
Forward End of Failed Second-Stage Minuteman Chamber

Figure 26



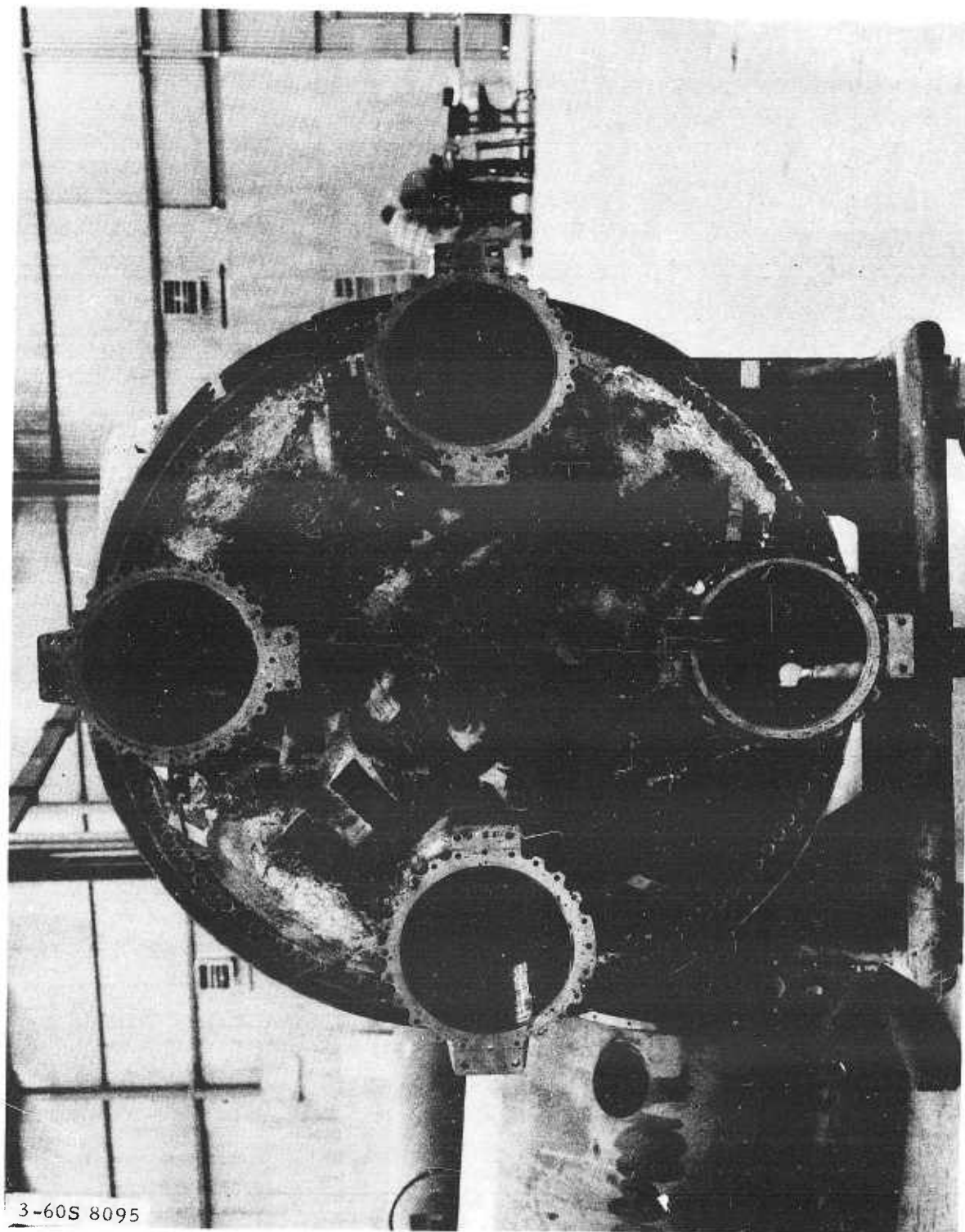
Aft End of Failed Second-Stage Minuteman, Closure Removed

Figure 27



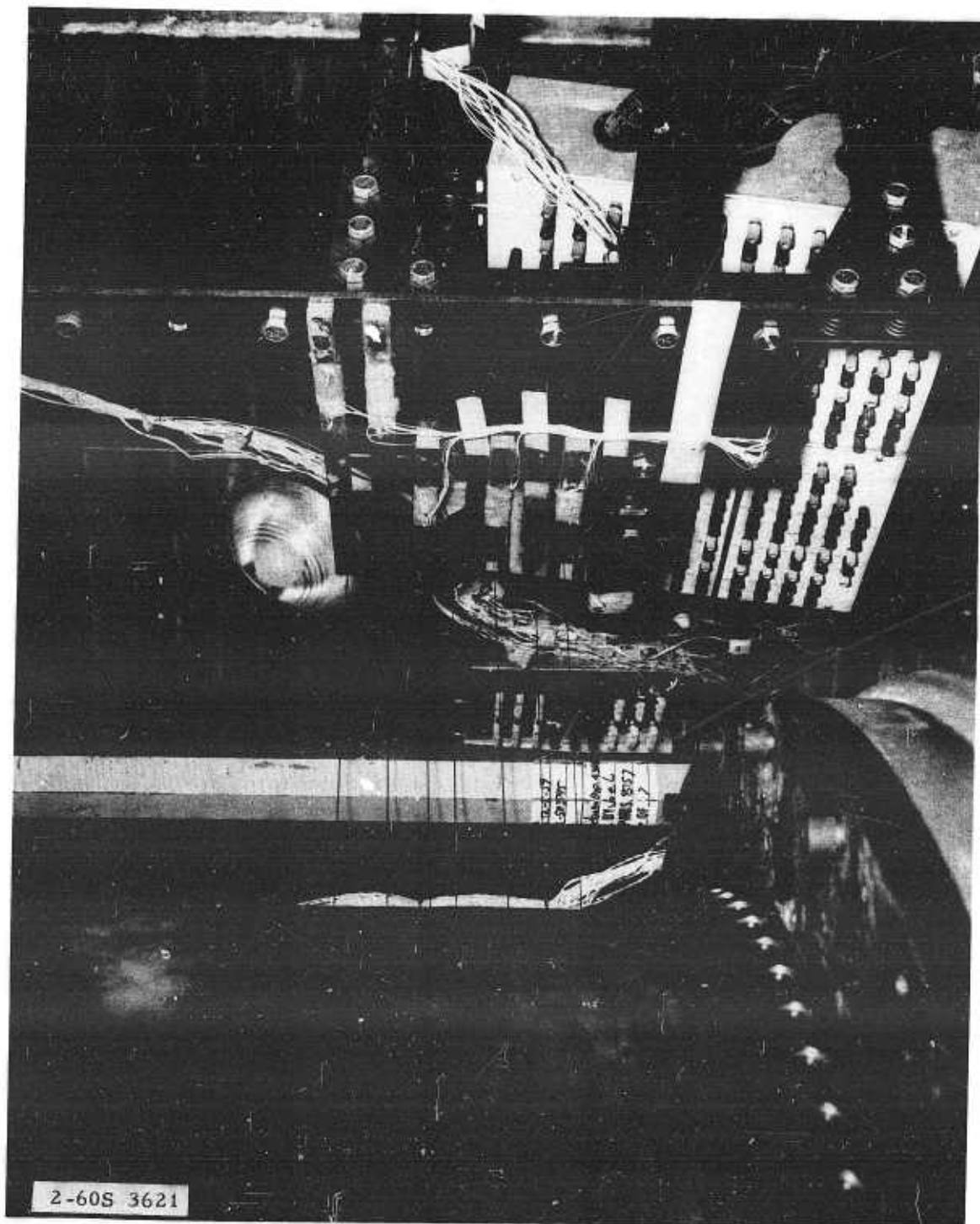
Aft End of Failed Second -Stage Minuteman Chamber

Figure 28



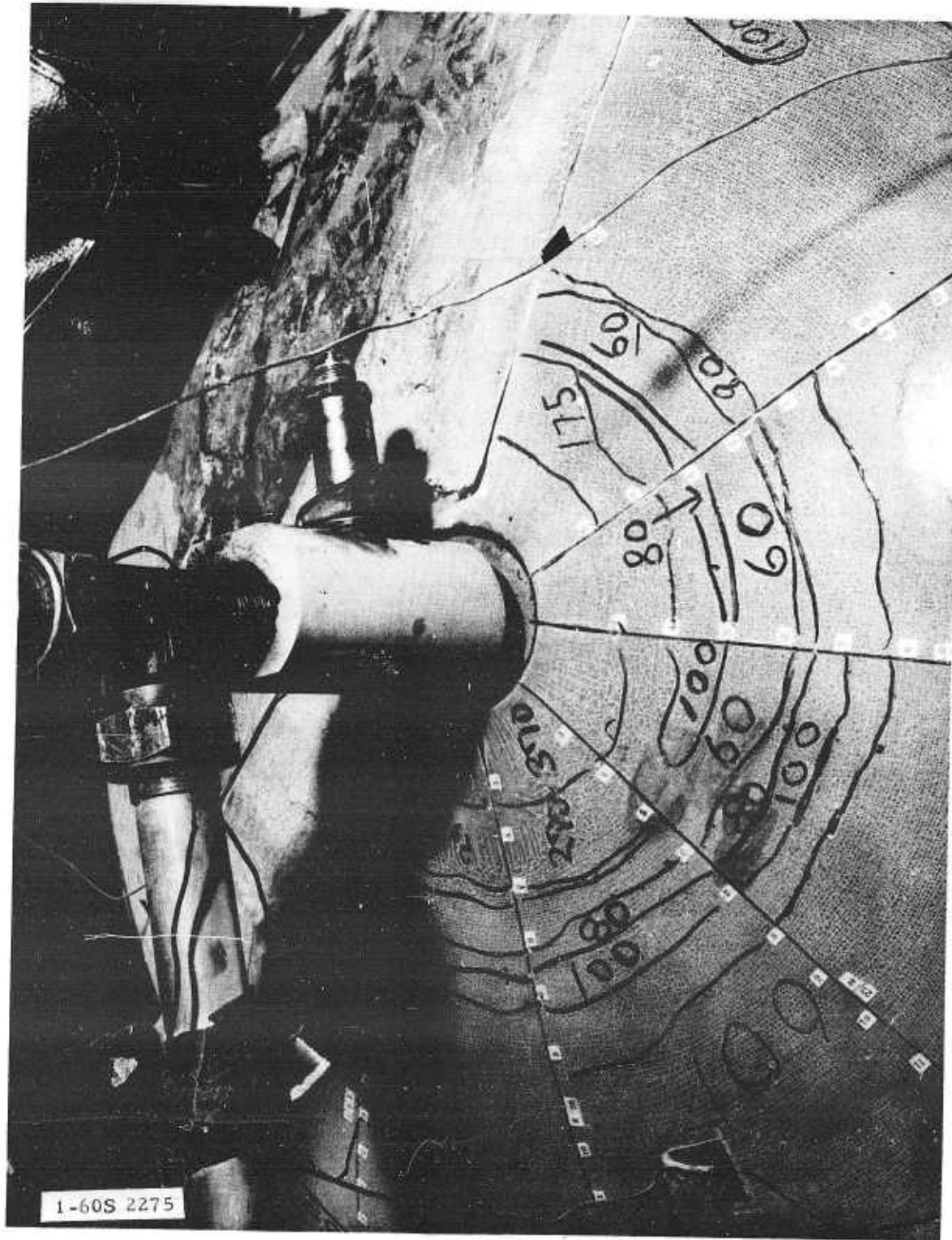
Art Closure of Failed Second-Stage Minuteman Chamber

Figure 29



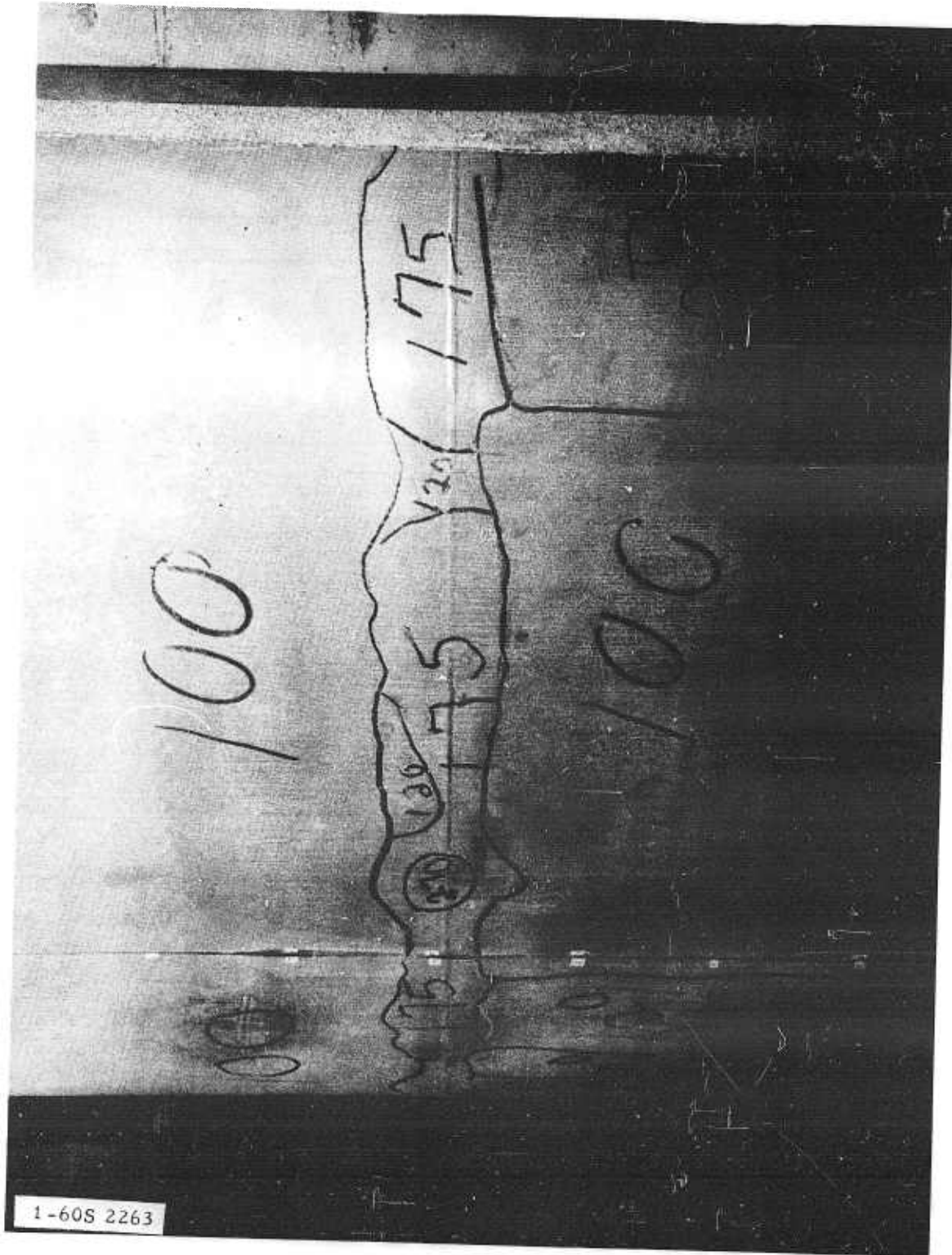
Deflection Measurement Arrangement

Figure 30



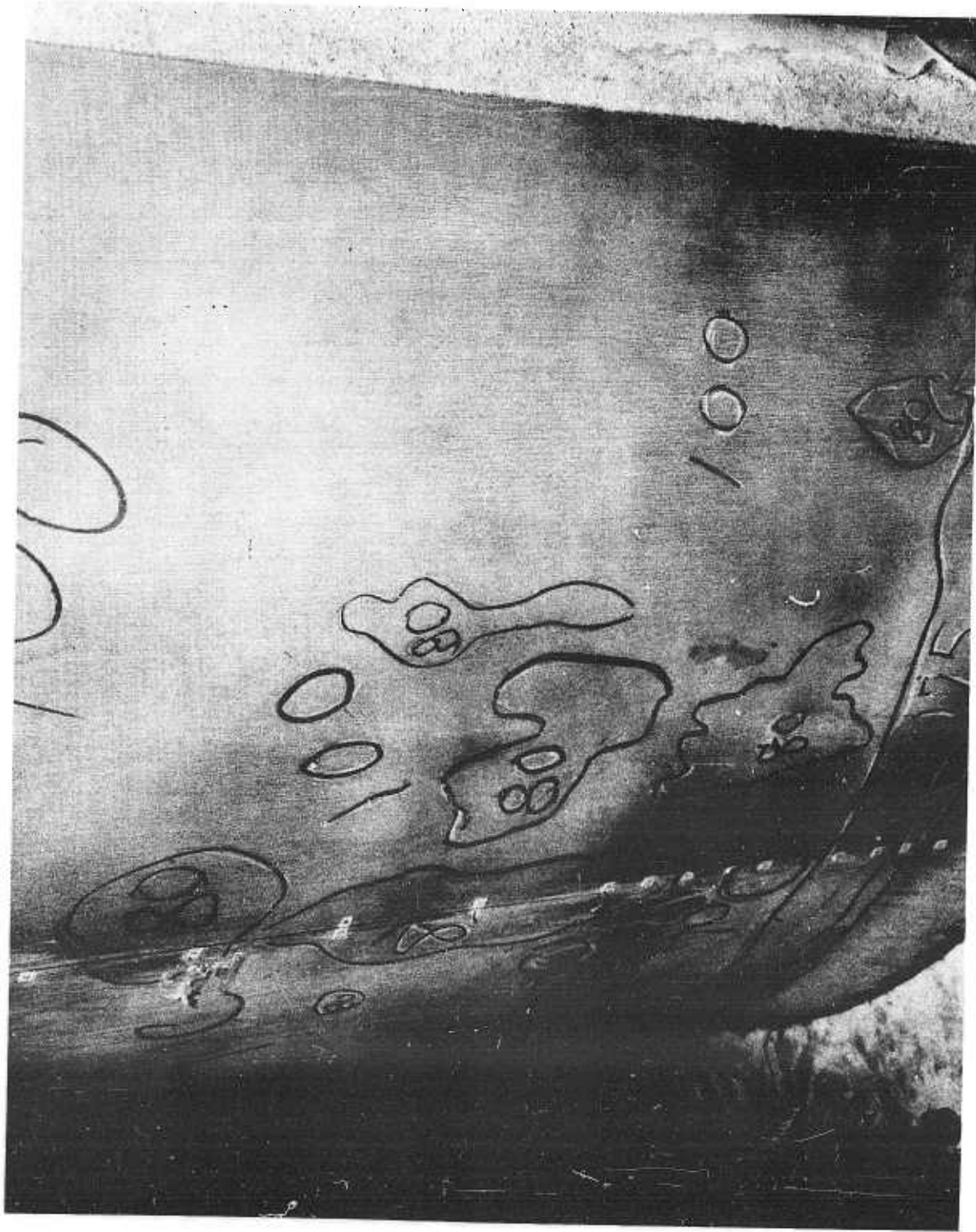
Stresscoat, Forward Head

Figure 31



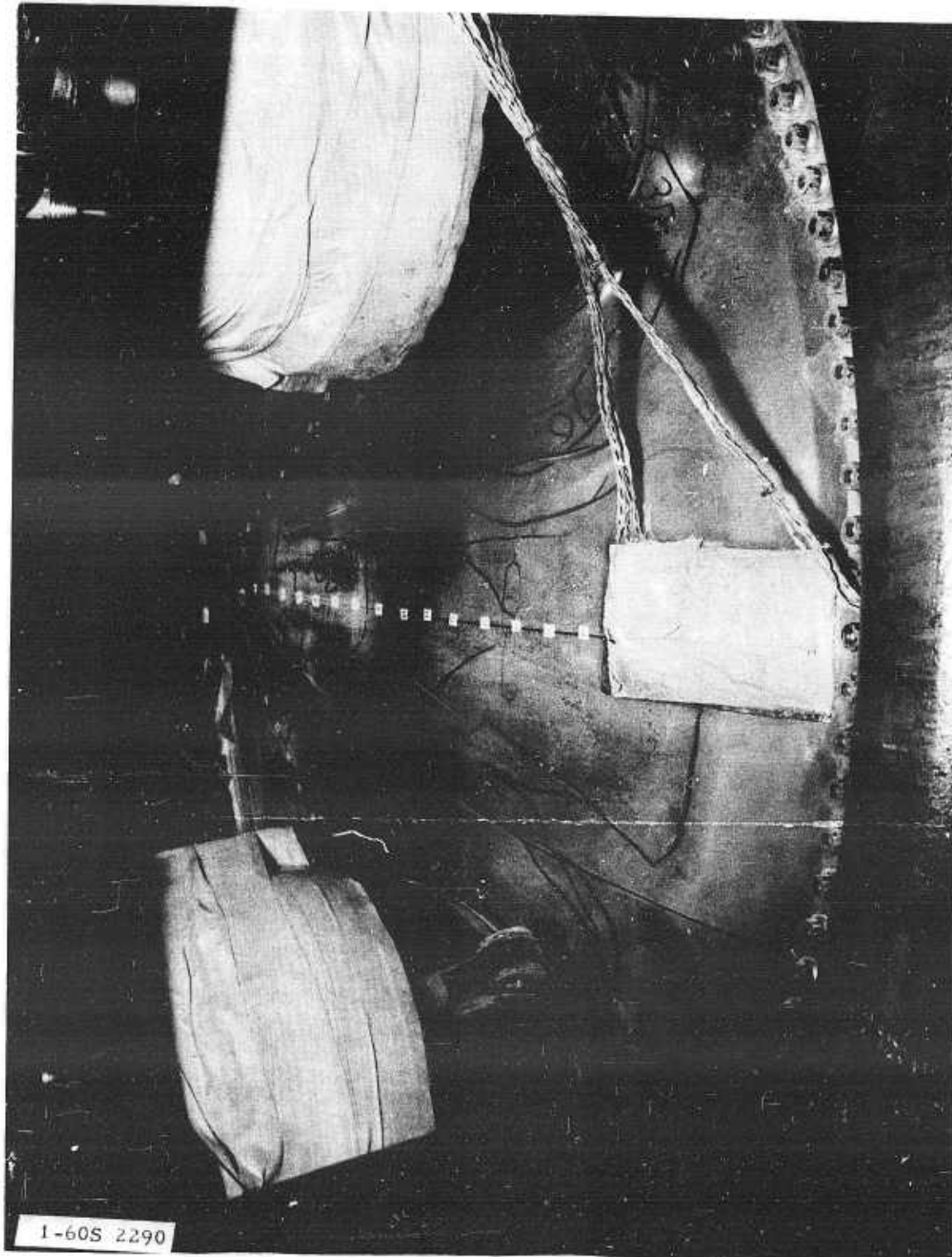
Stresscoat, Chamber

Figure 32



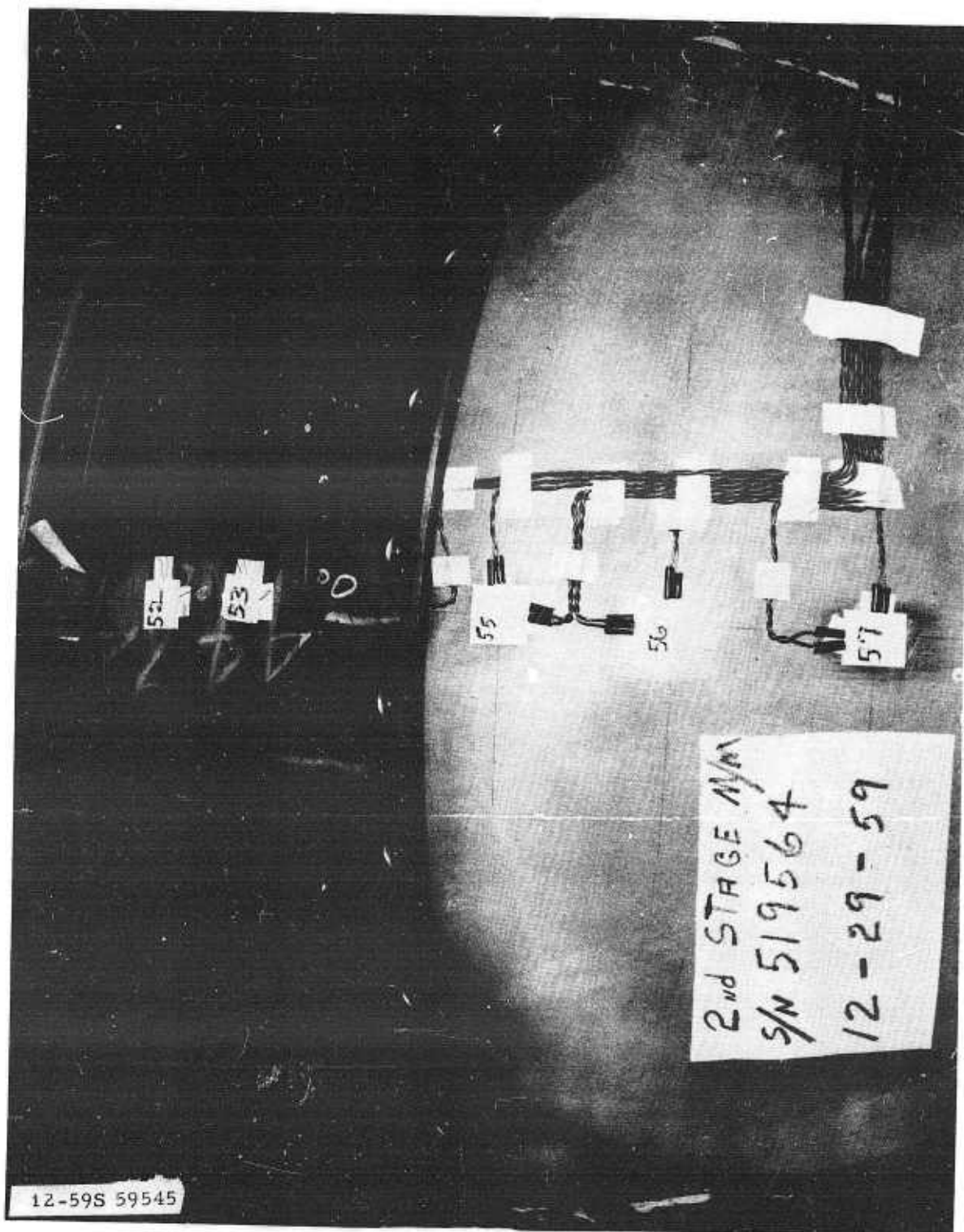
Stresscoat, Aft End of Chamber

Figure 33



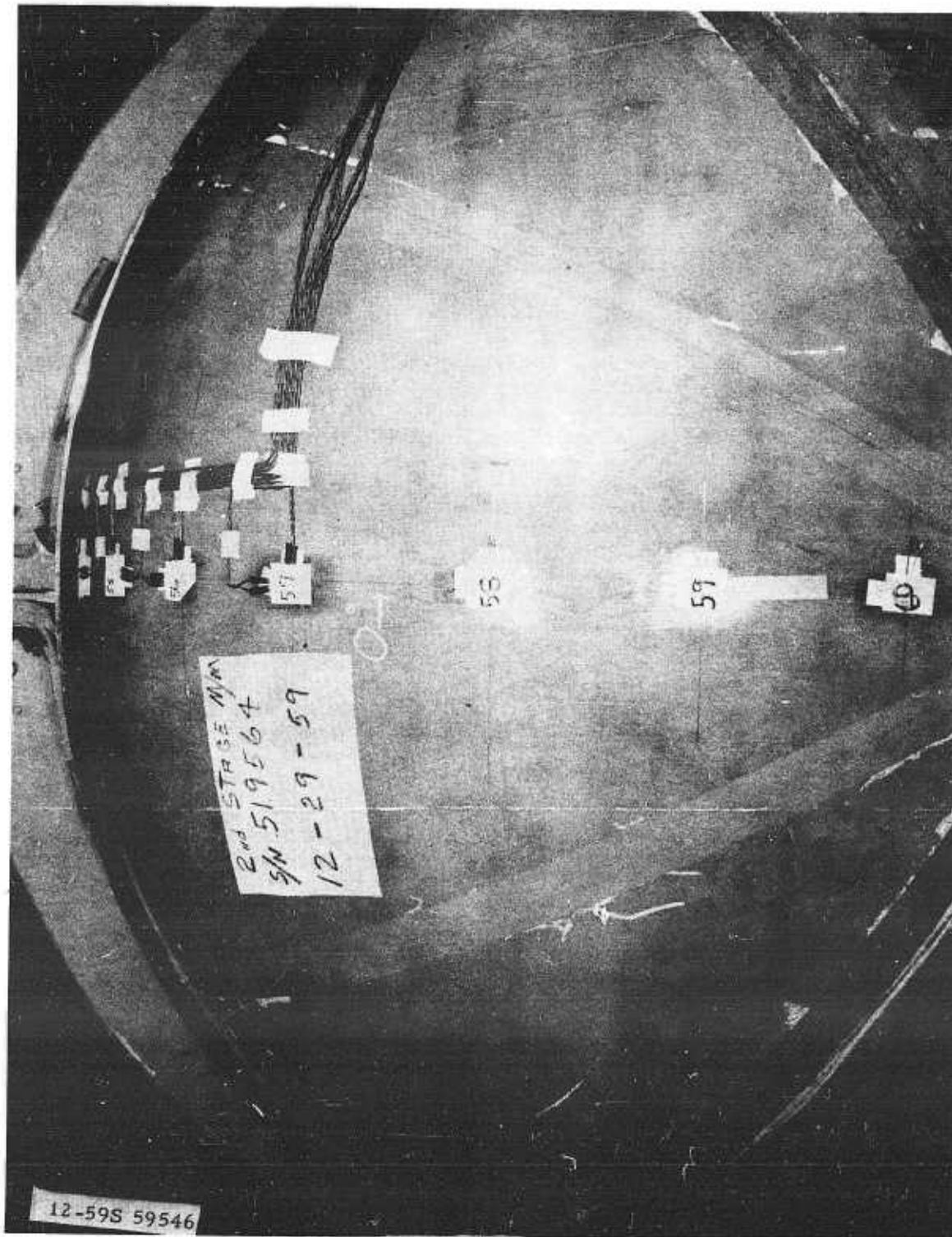
Stresscoat, Aft Closure

Figure 34



Strain Gage Locations, Forward Head, Stresscoat Pin.

Figure 35



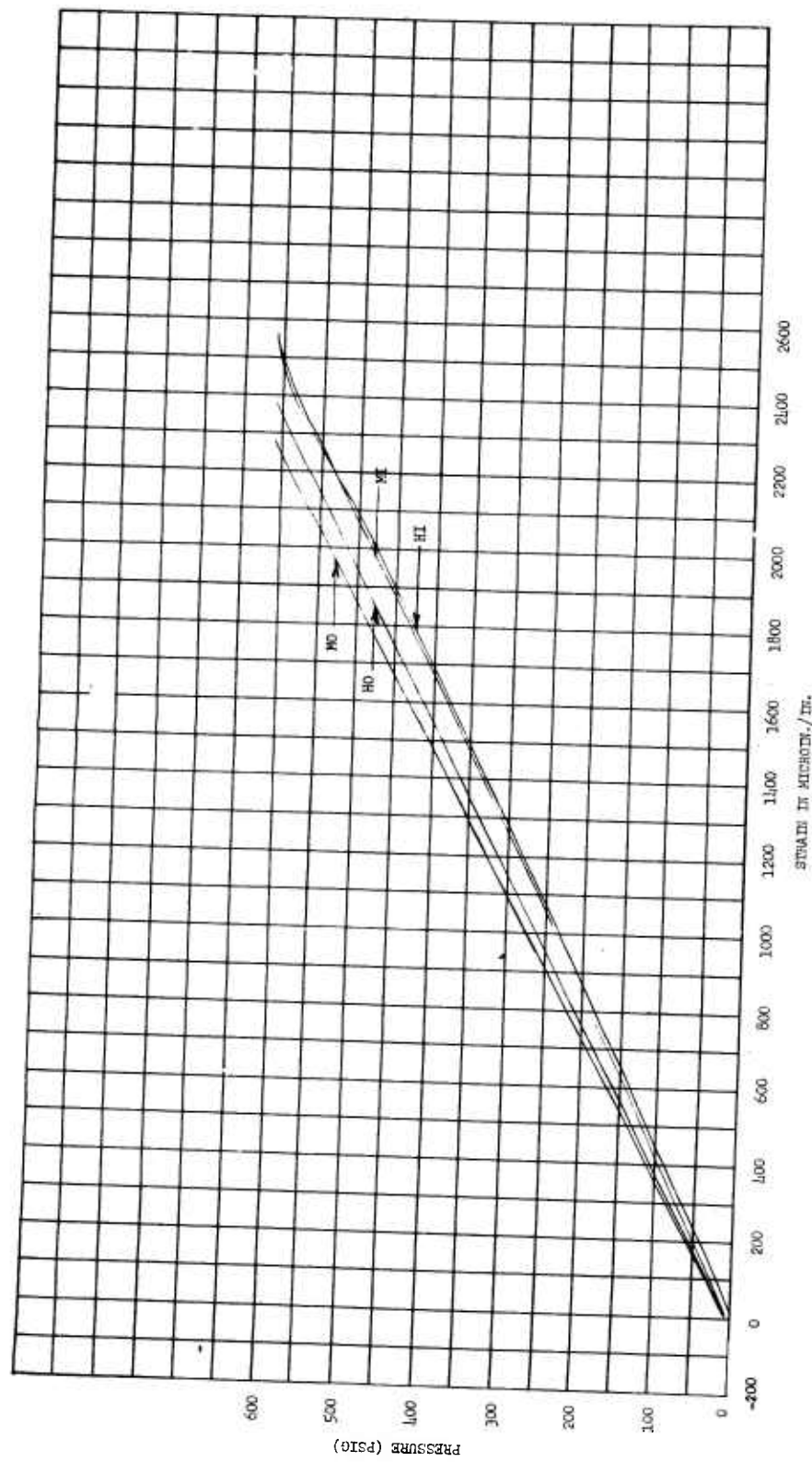
Strain Gage Locations, Forward Head, Stresscoat Phase

Figure 36

APPENDIX A: PHASE I

STRESS AND STRAIN CURVES
FOR AFT CLOSURE, POINTS
1 TO 51 AND 61 TO 66

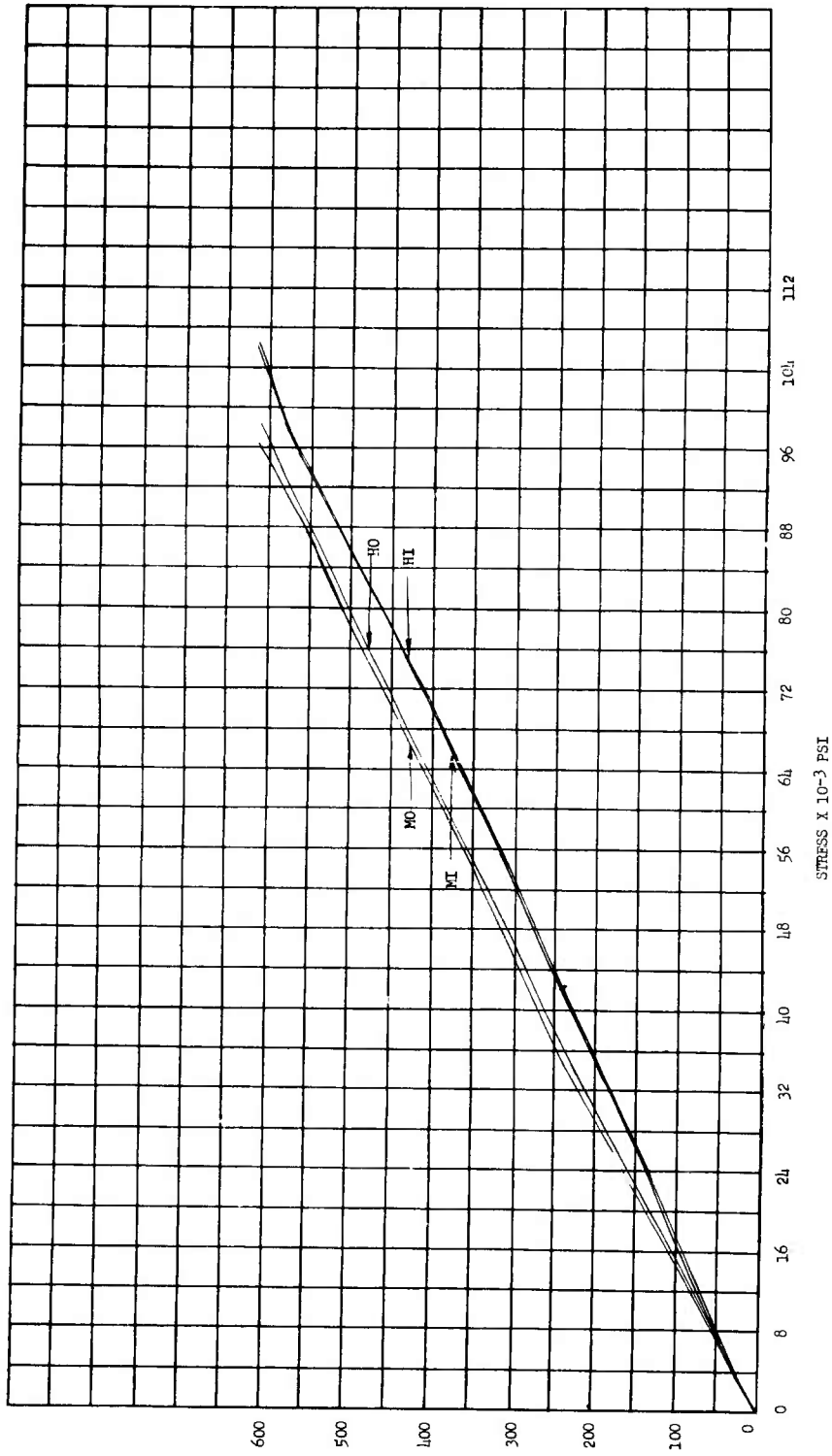
Appendix A



Pressure vs Strain, Gage Point 1

Figure 1

Appendix A



Pressure vs Stress, Gage Point 1

Figure 2

Appendix A

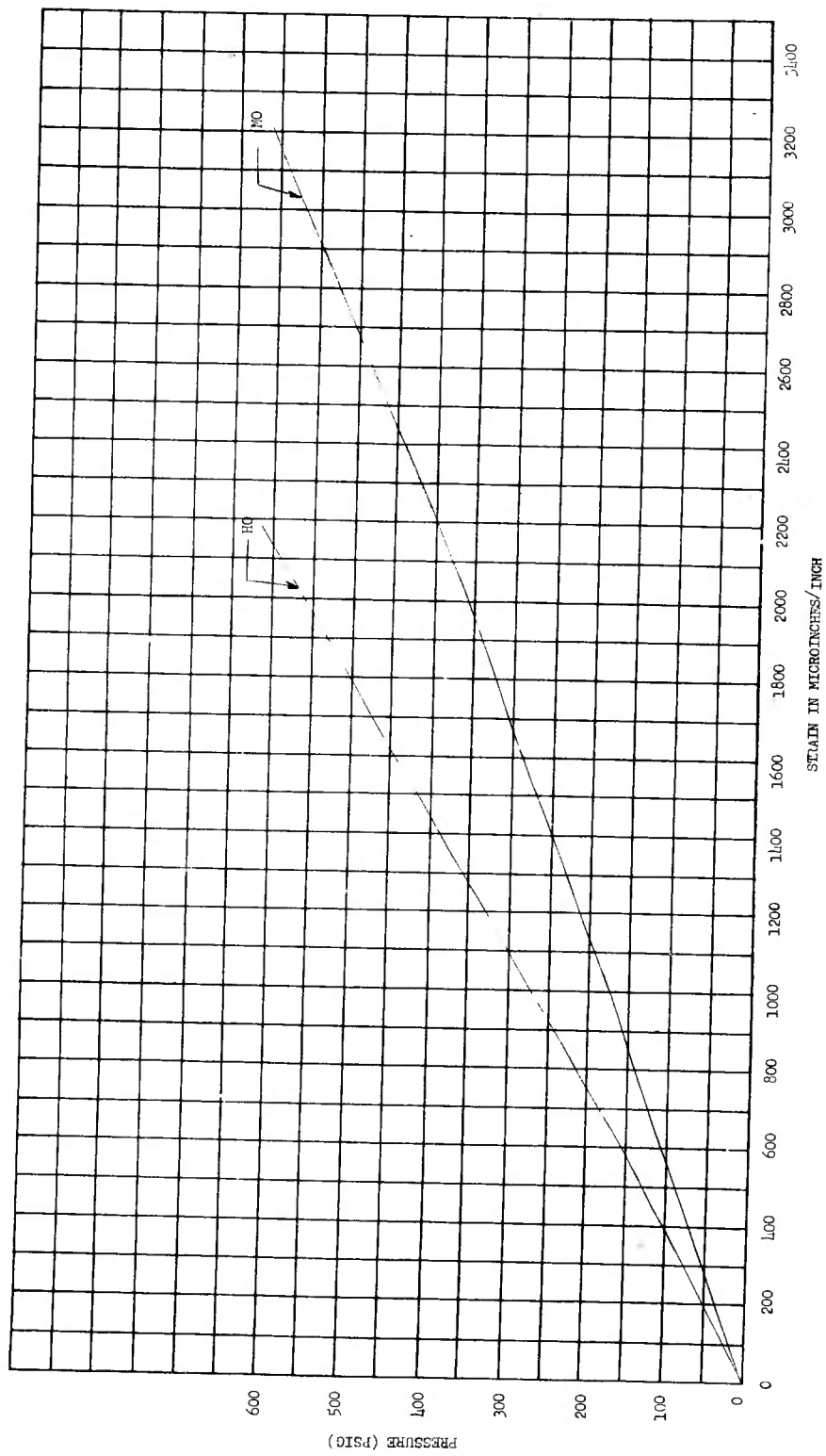
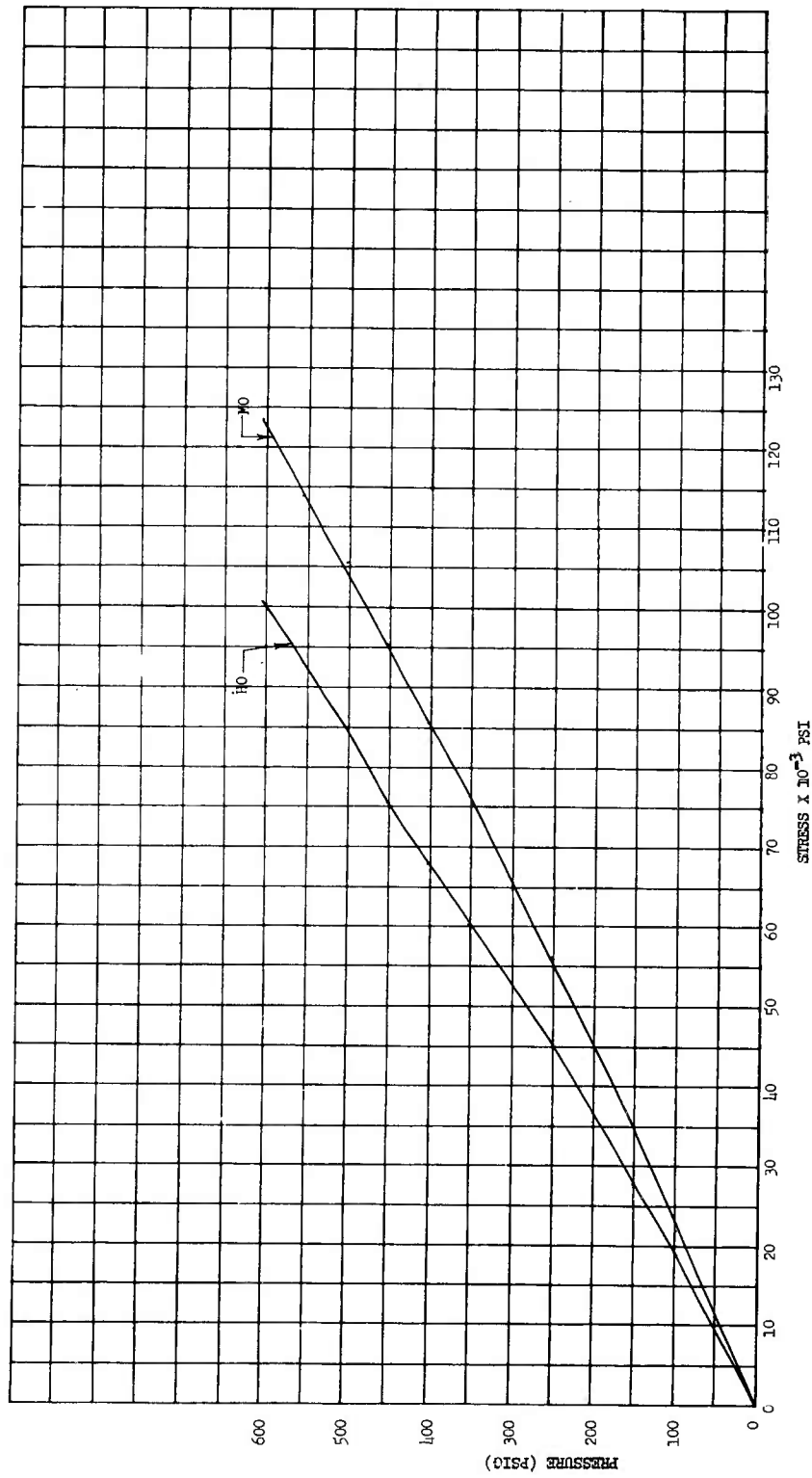


Figure 3

Pressure vs Strain, Gage Point 2

Appendix A



Pressure vs Stress, Gage Point 2

Figure 4

Appendix A

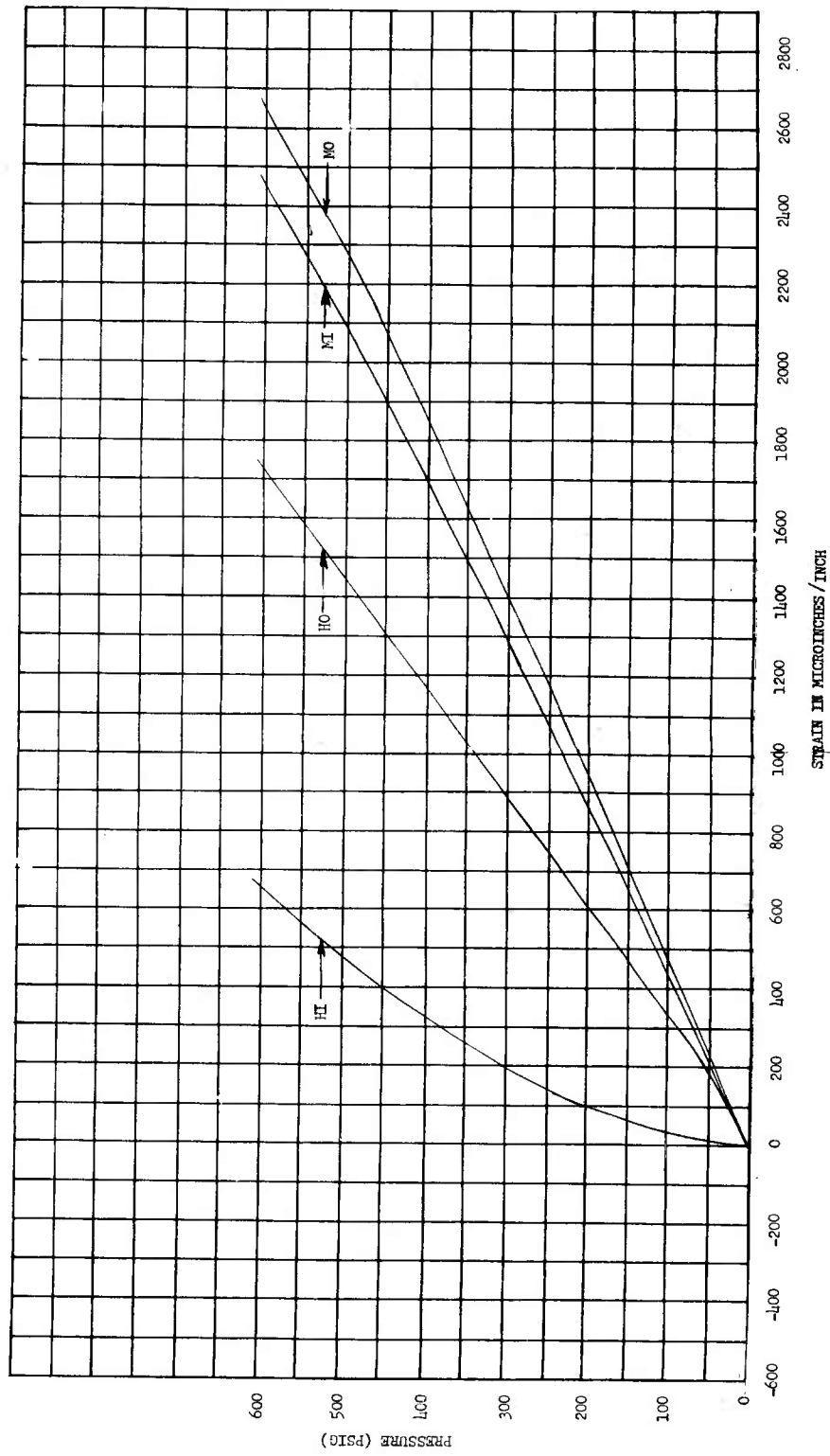


Figure 5

Pressure vs Strain, Gage Point 3

Appendix A

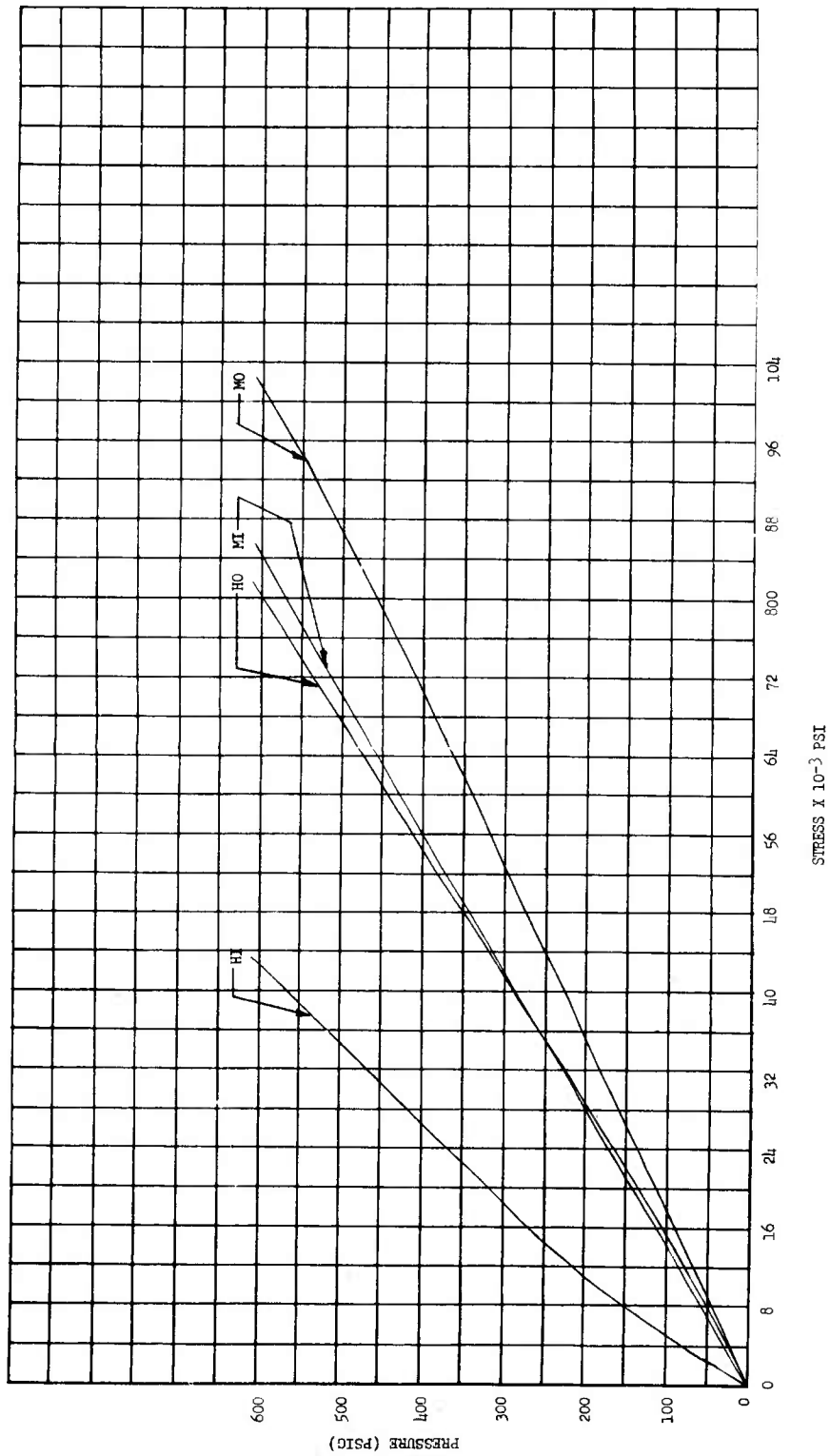


Figure 6

Pressure vs Stress, Gage Point 3

Appendix A

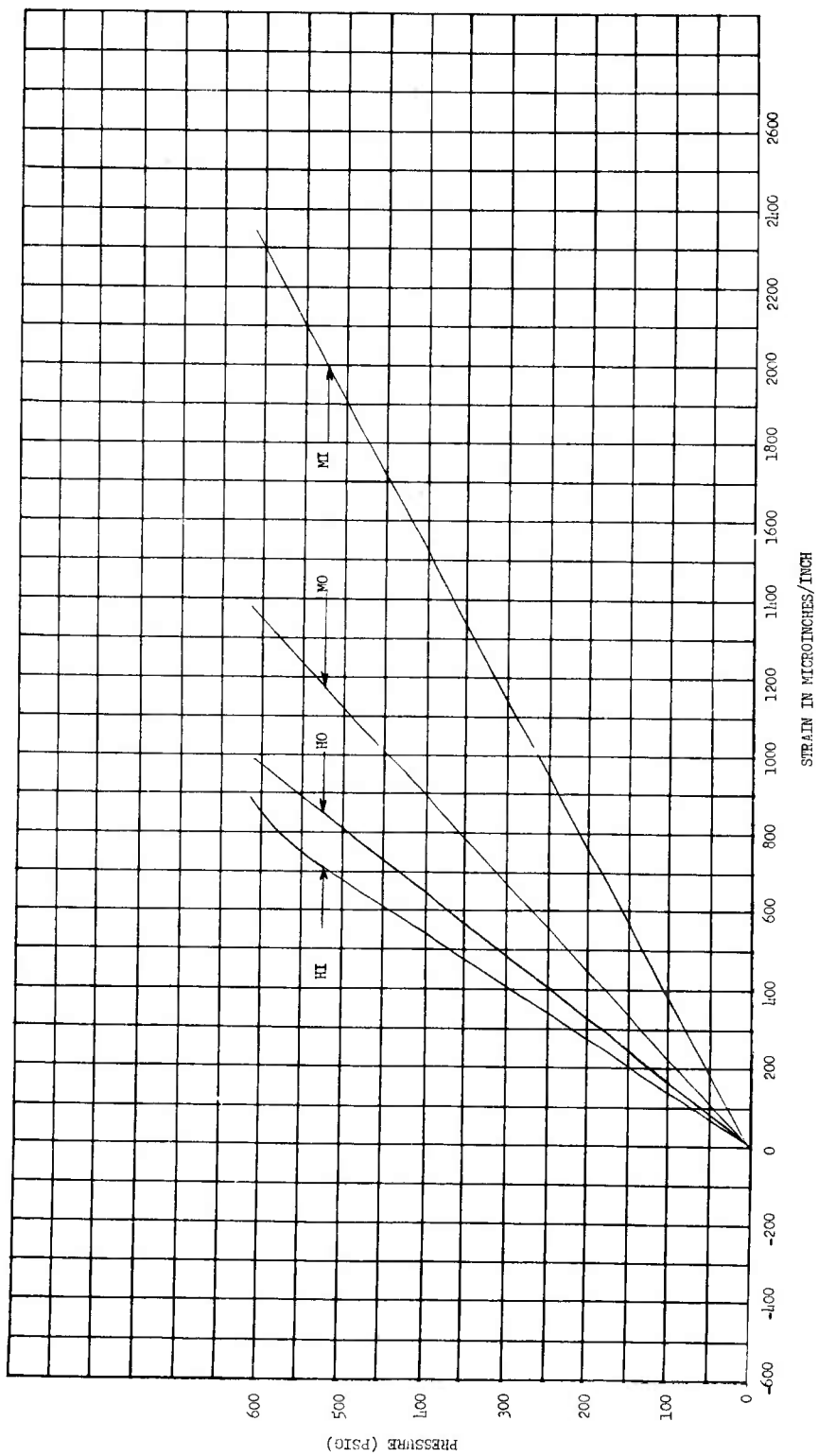


Figure 7

Pressure vs Strain, Gage Point 4

Appendix A

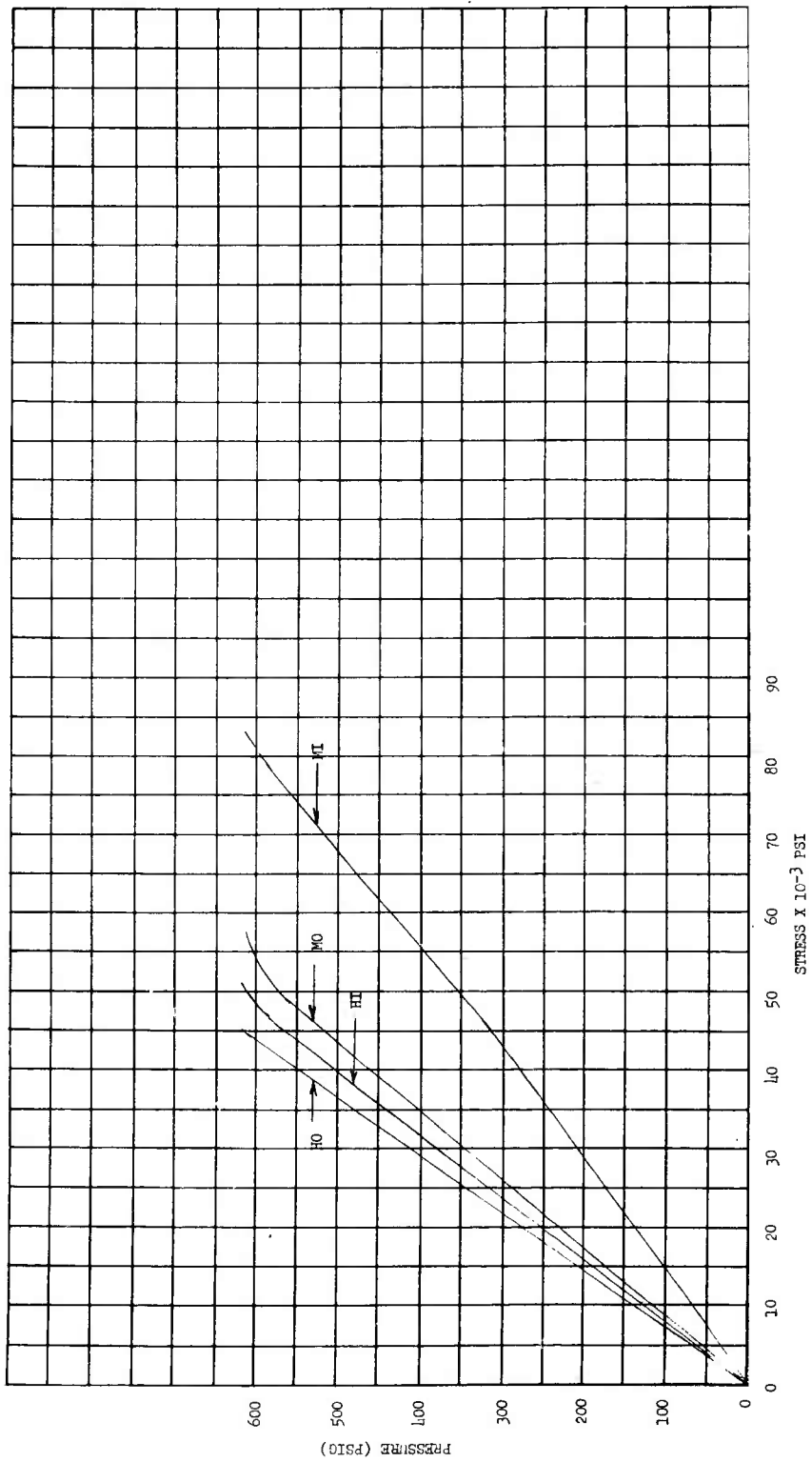


Figure 8

Pressure vs Stress, Gage Point 4

Appendix A

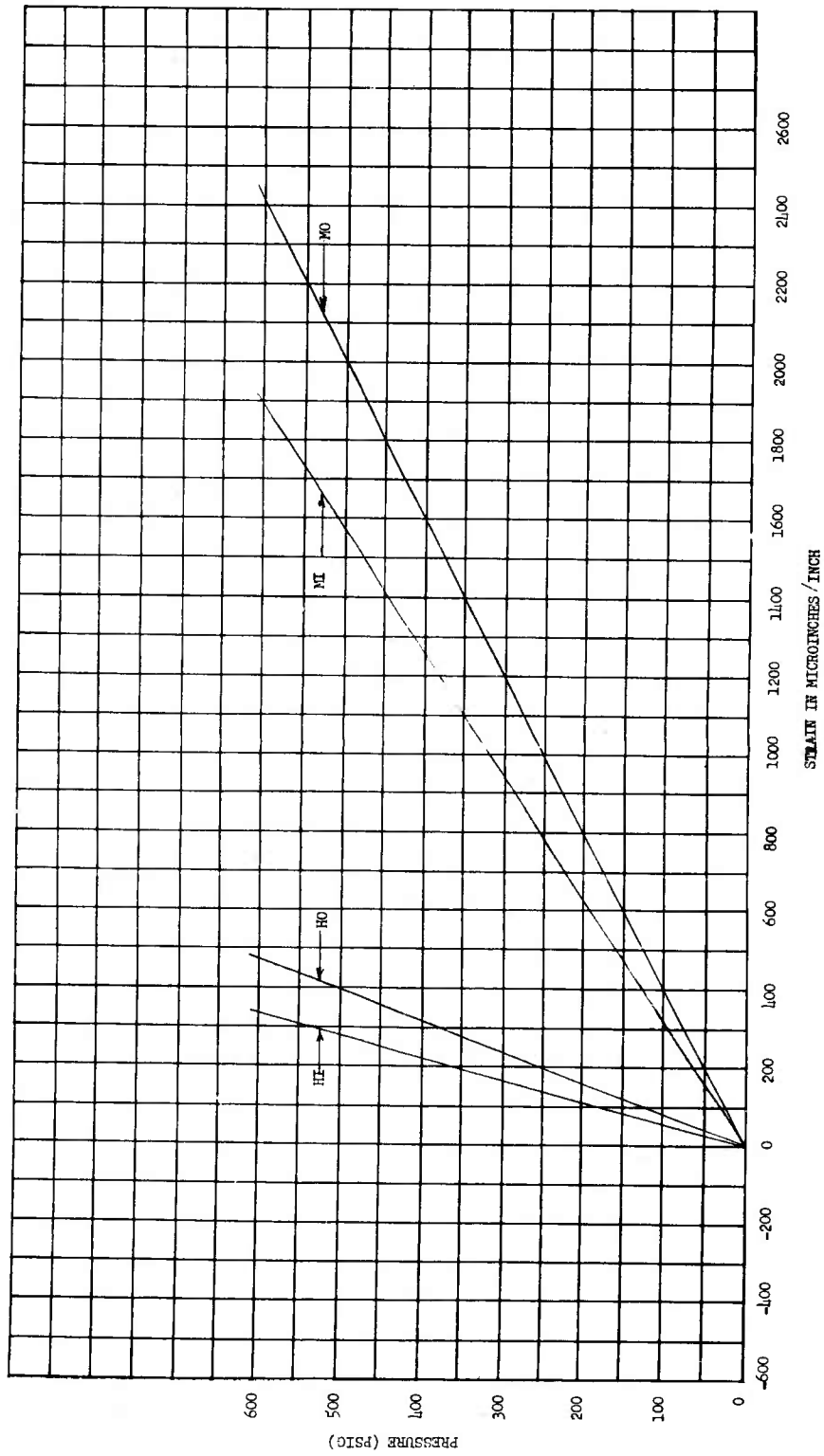


Figure 9

Pressure vs Strain, Gage Point 5

Appendix A

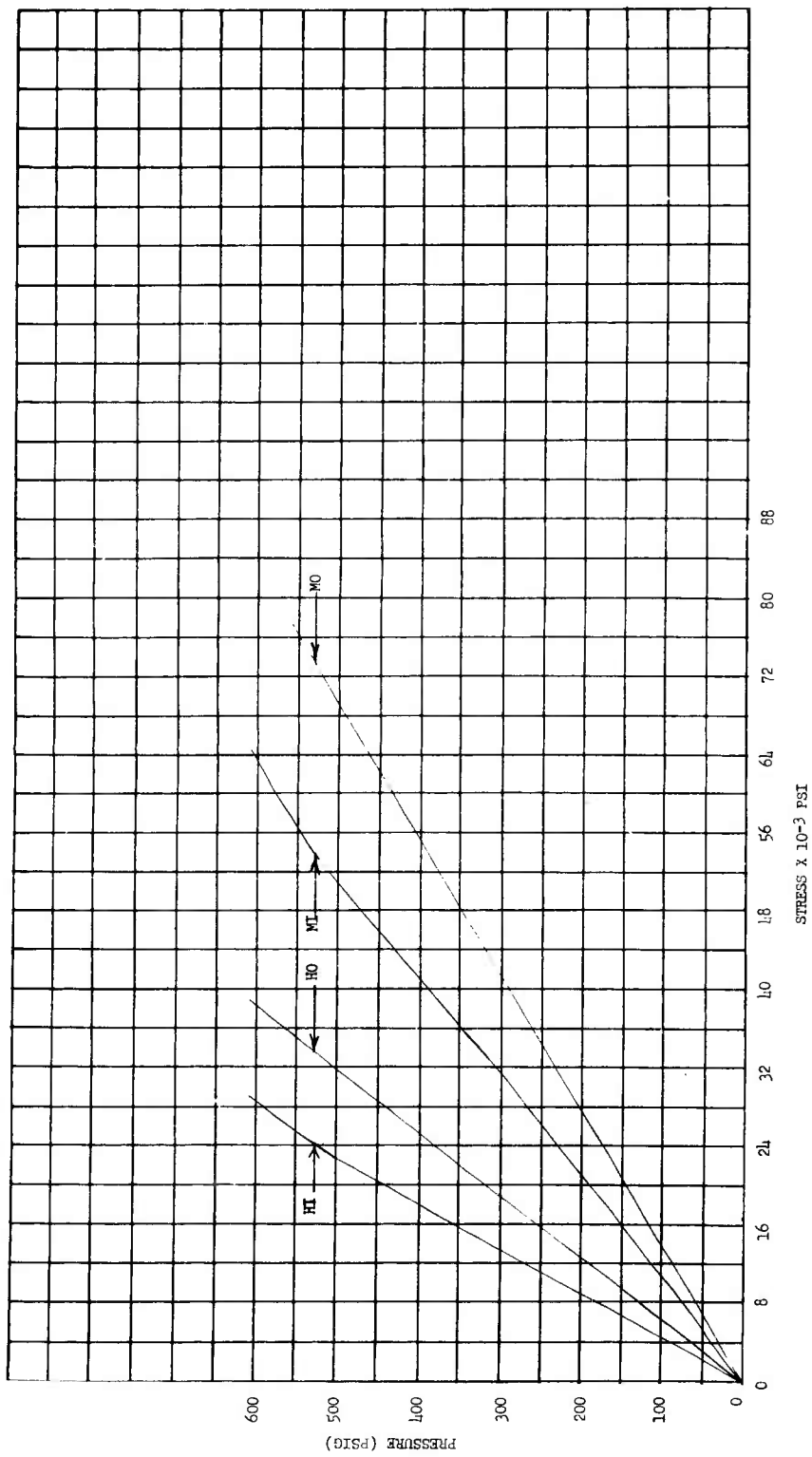


Figure 10

Pressure vs Stress, Gage Point 5

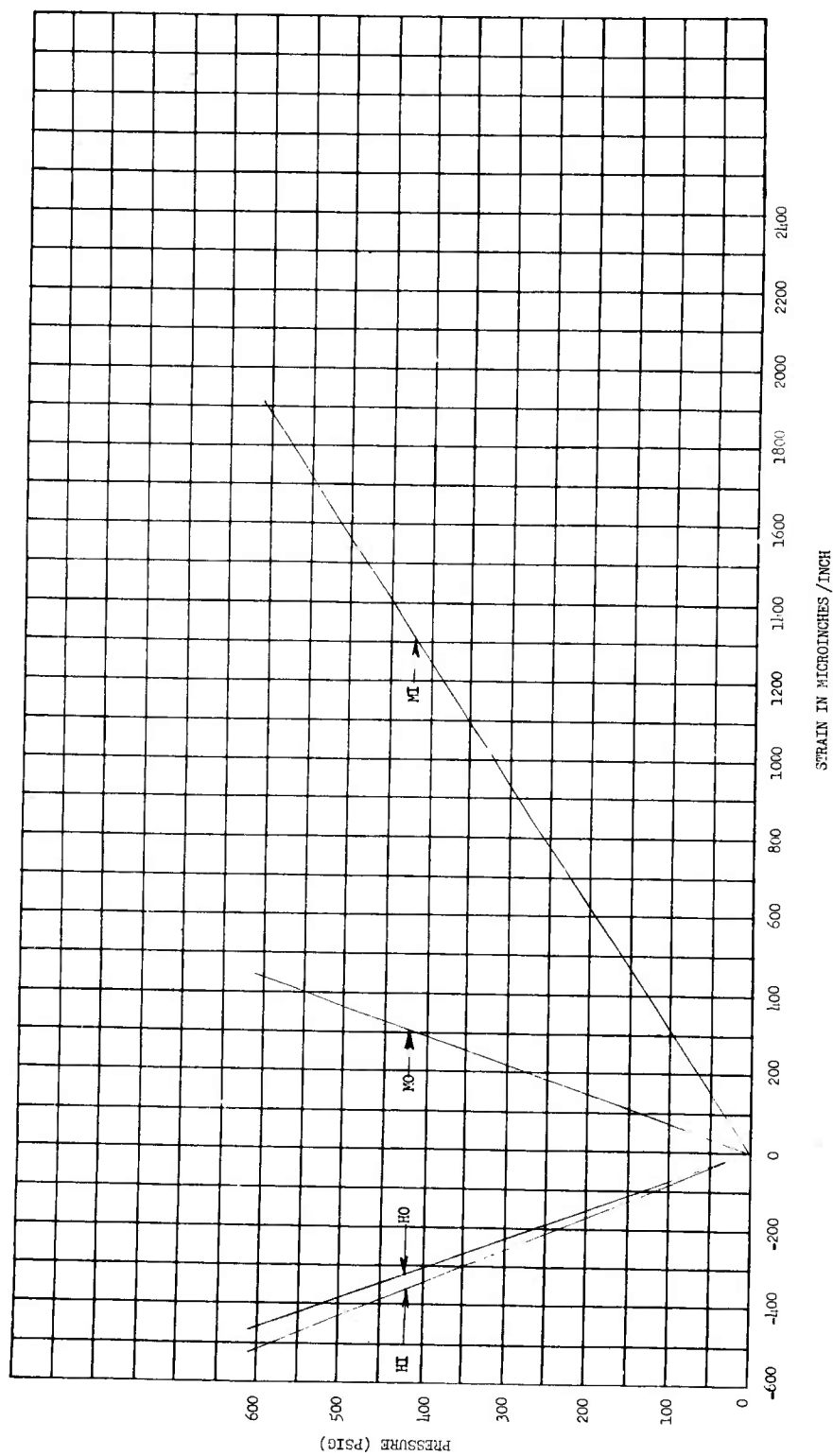


Figure 11

Pressure is Strain, Gage Point 6

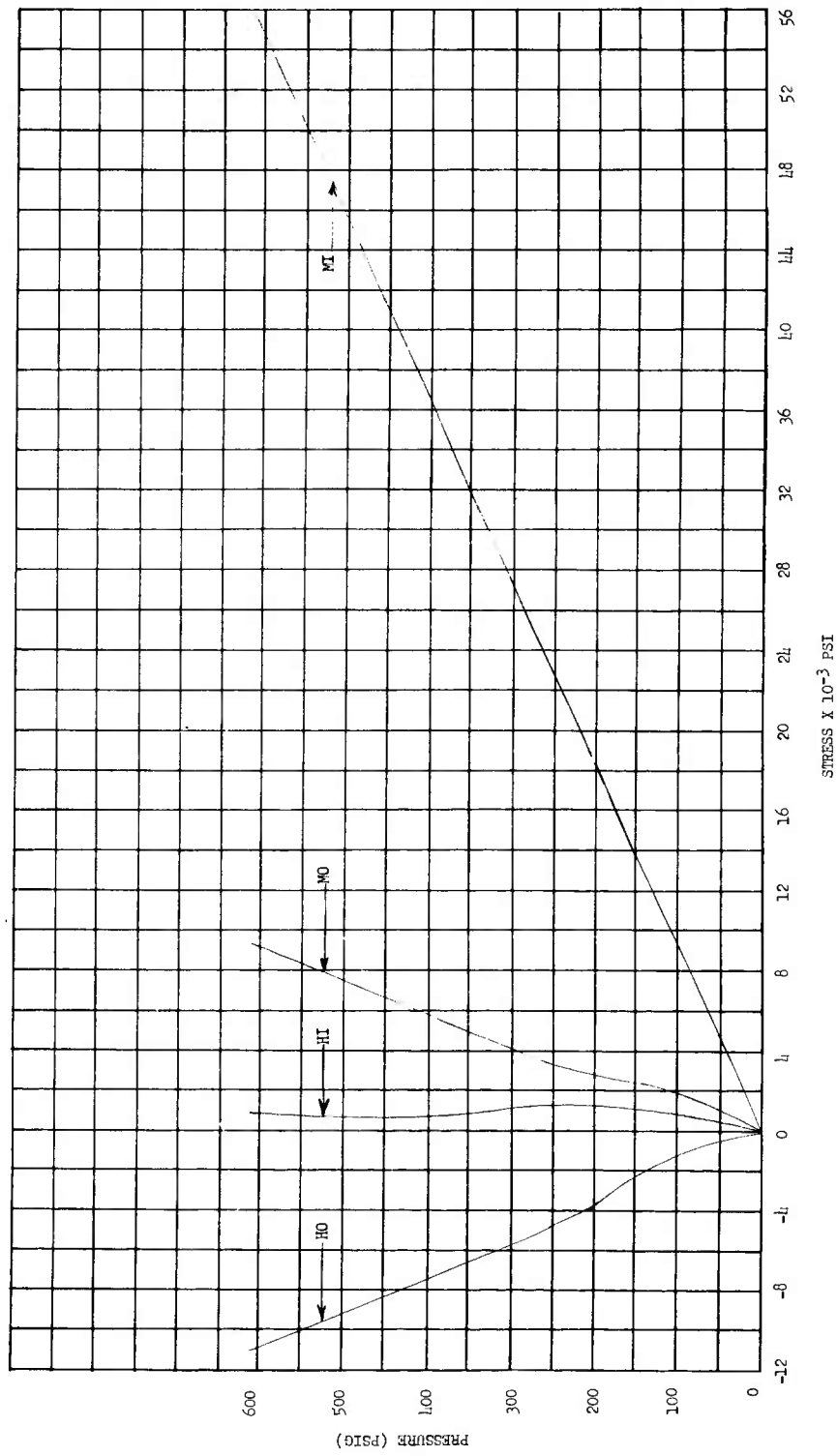
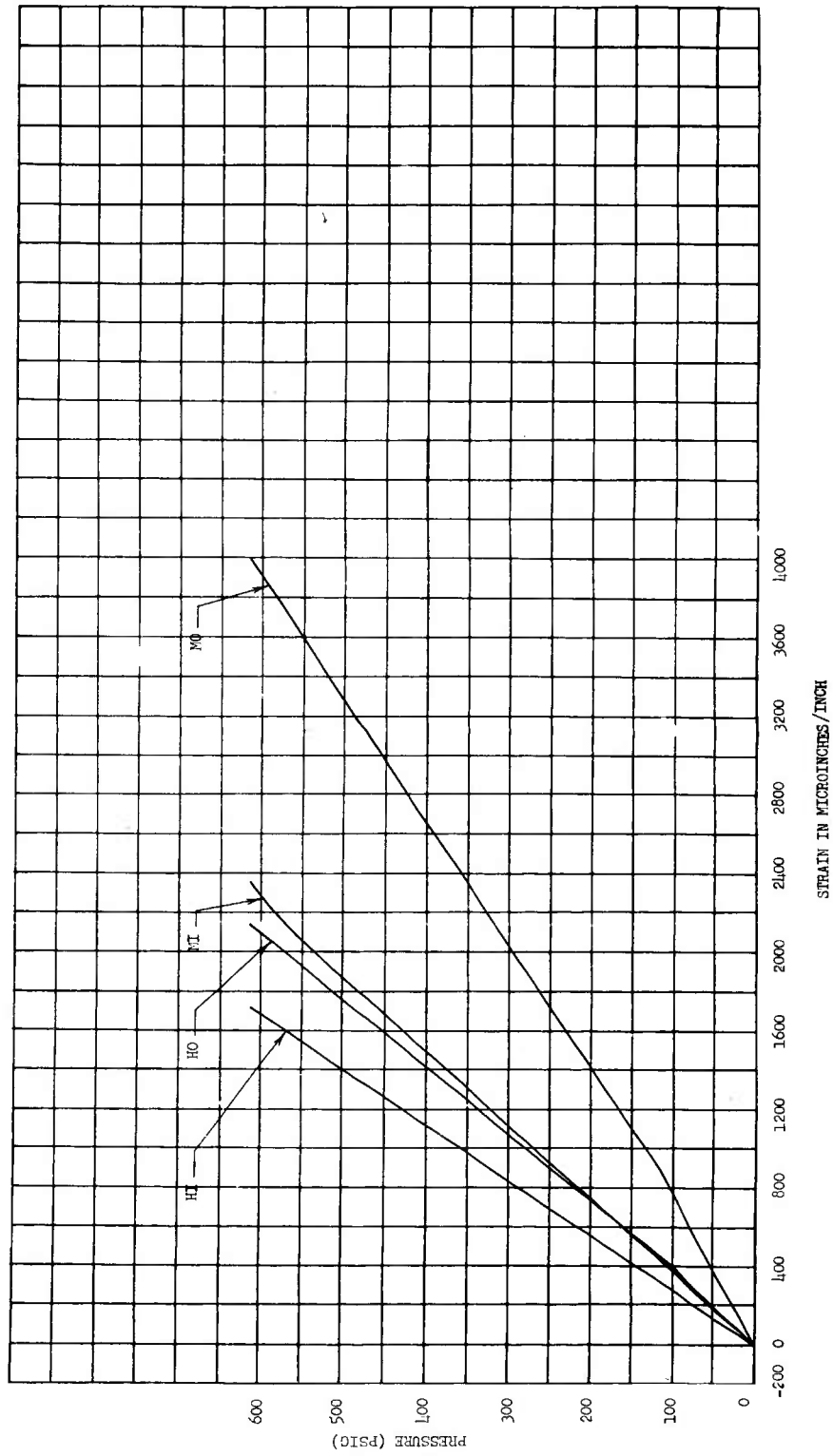


Figure 12

Pressure vs Stress, Gage Point 6



Pressure vs Strain, Gage Point 7

Figure 13

Appendix A

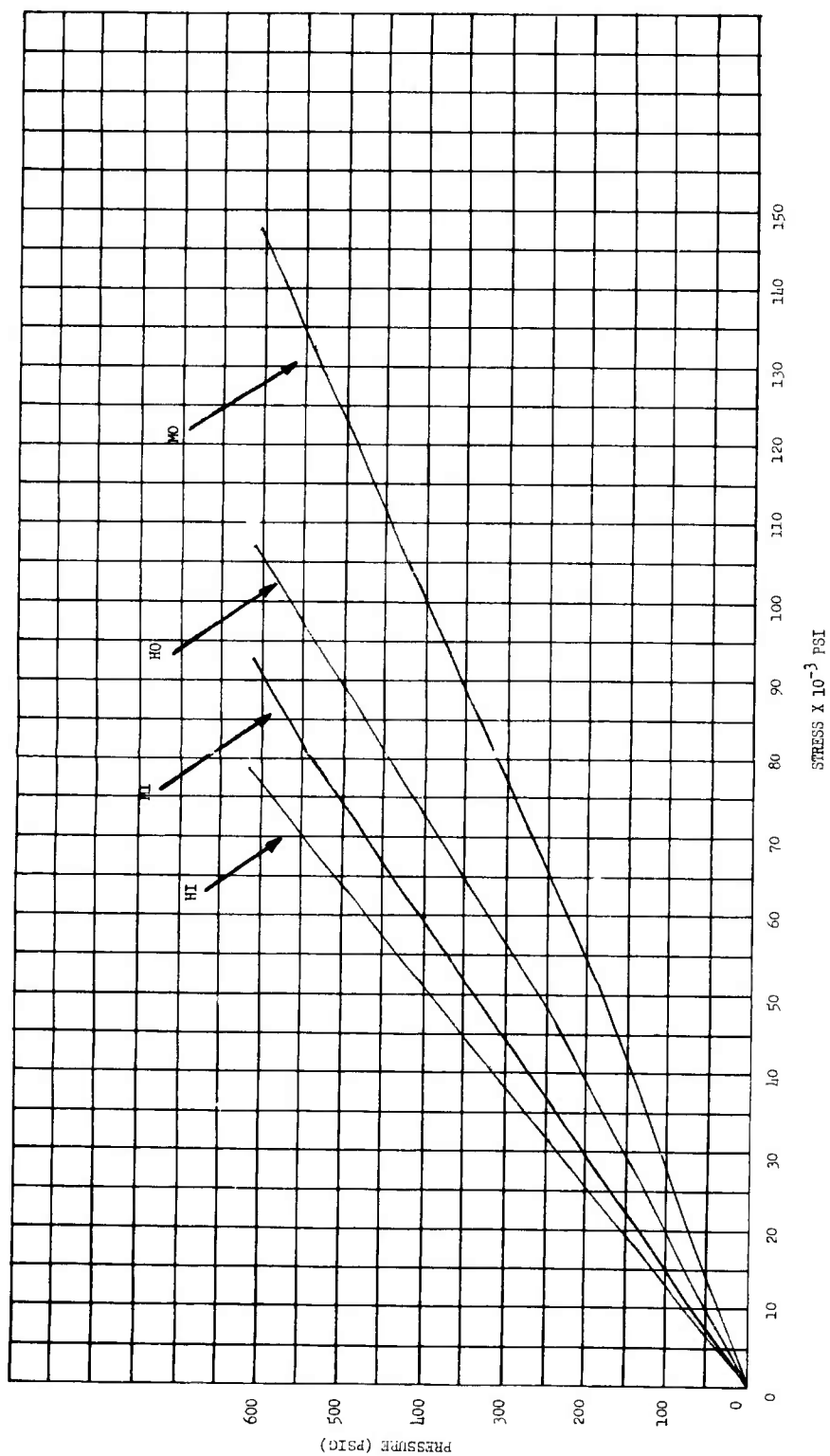
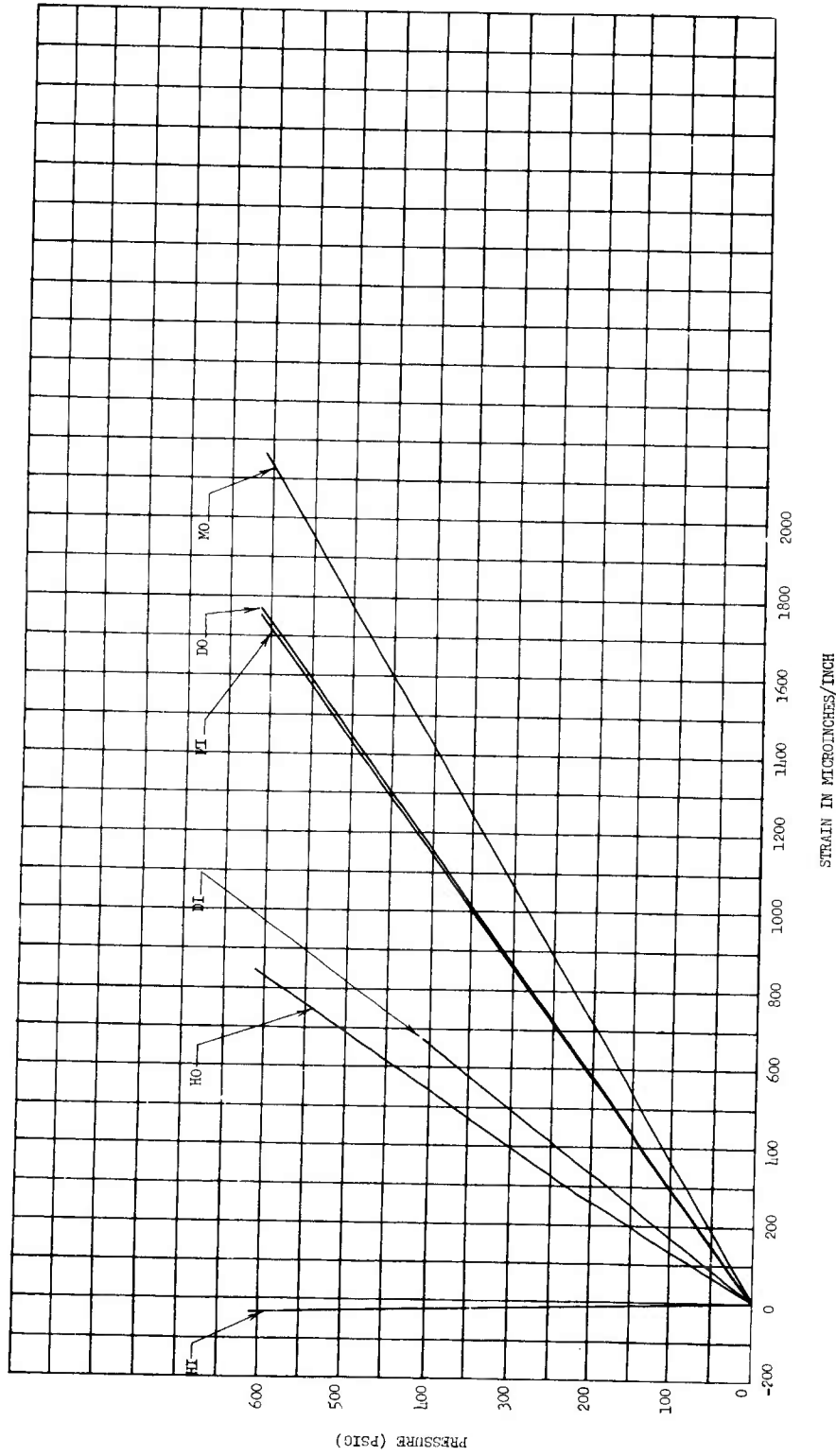


Figure 14

Pressure vs Stress, Gage Point 7

Appendix A



Pressure vs Strain, Gage Point 8

Figure 15

Appendix A

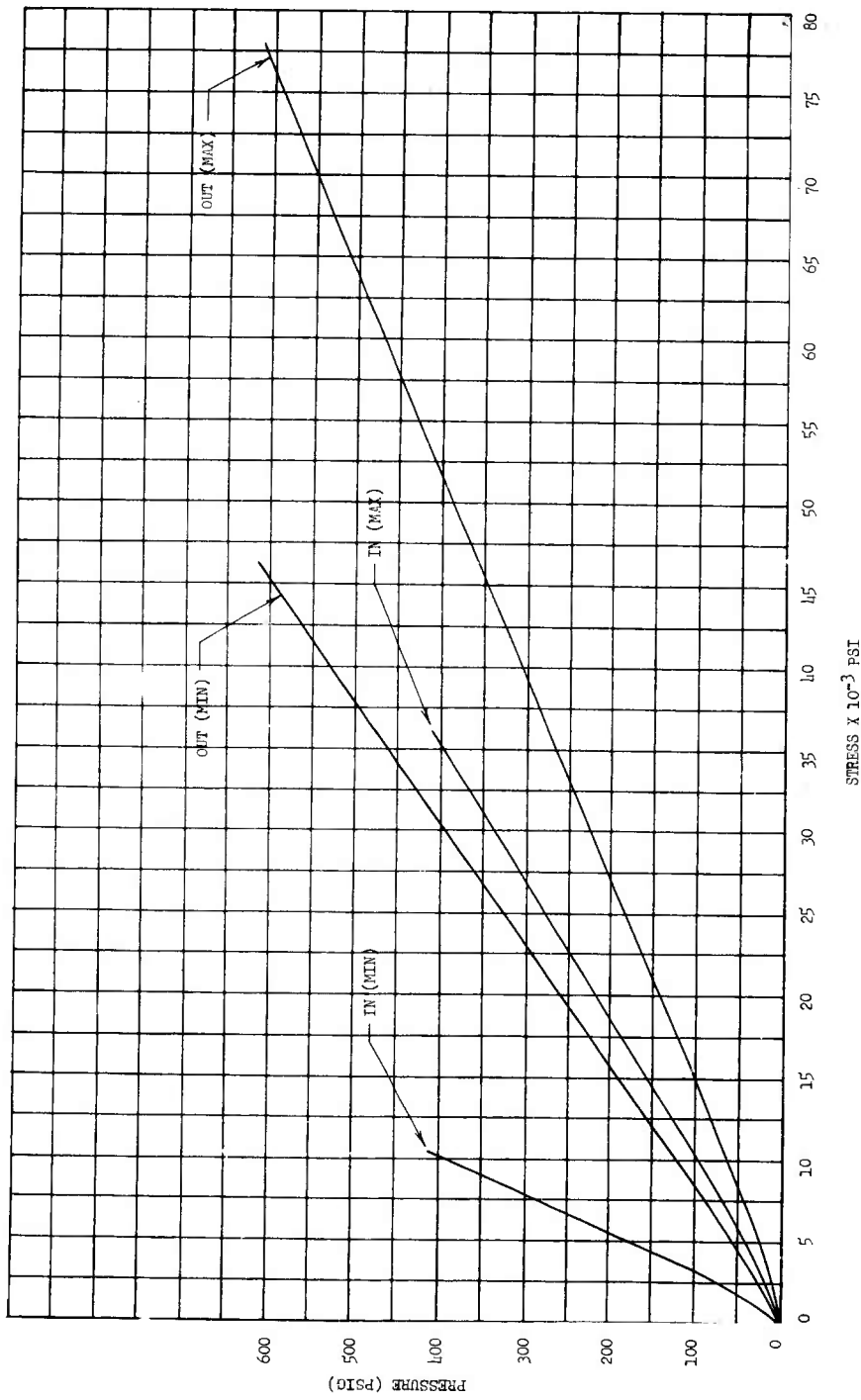
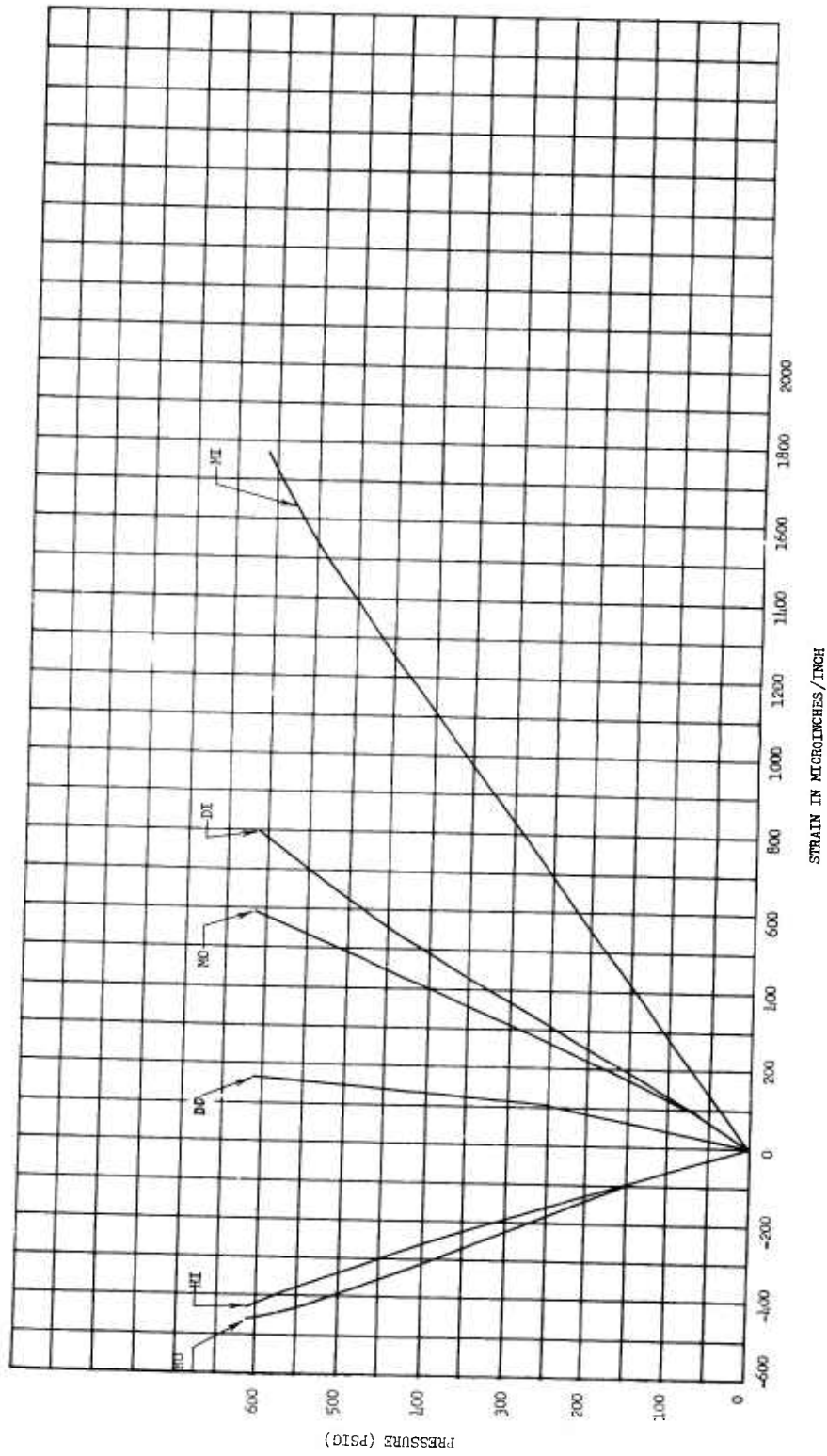


Figure 16

Pressure vs Stress, Gage Point 8

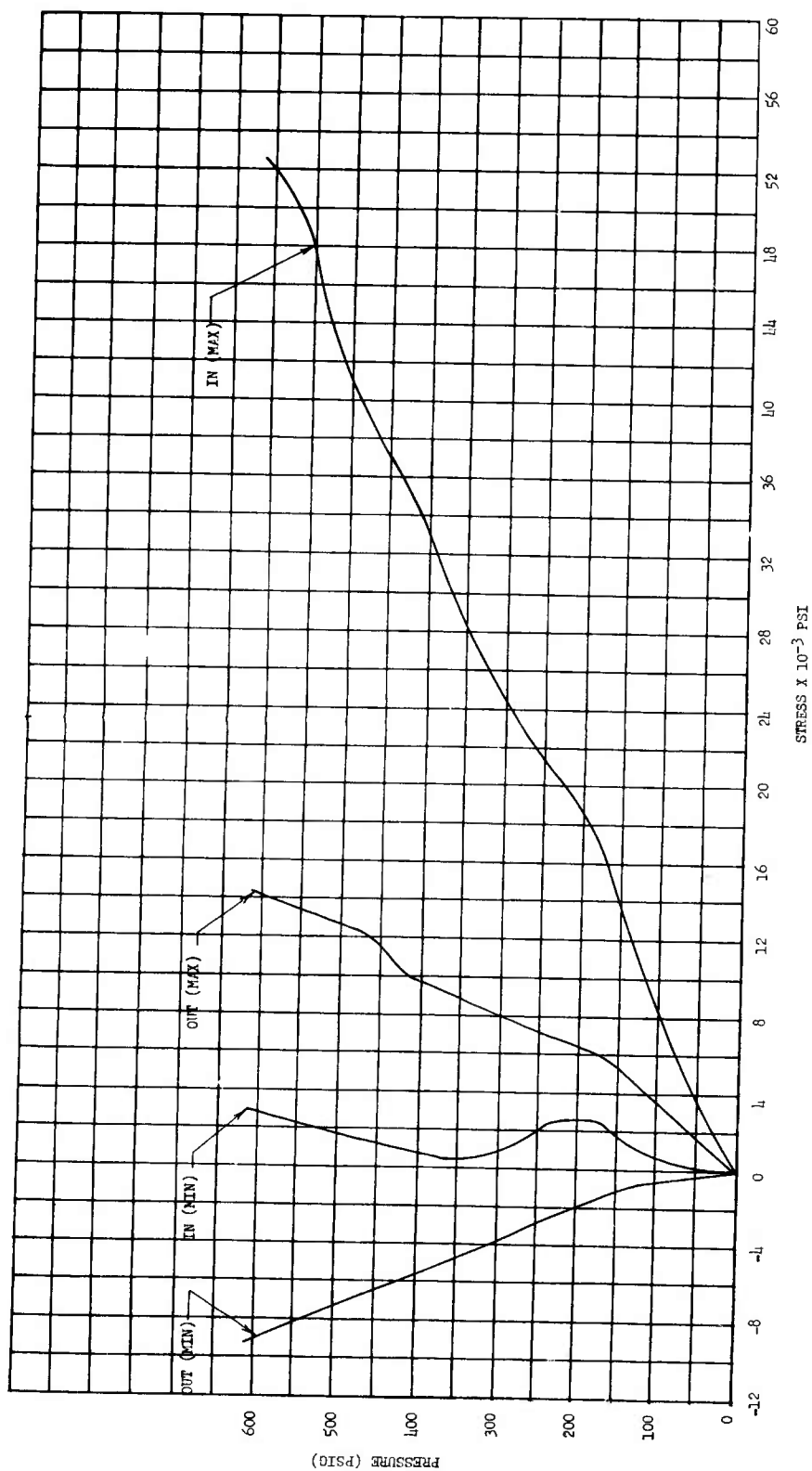
Appendix A



Pressure vs Strain, Gage Point 9

Figure 17

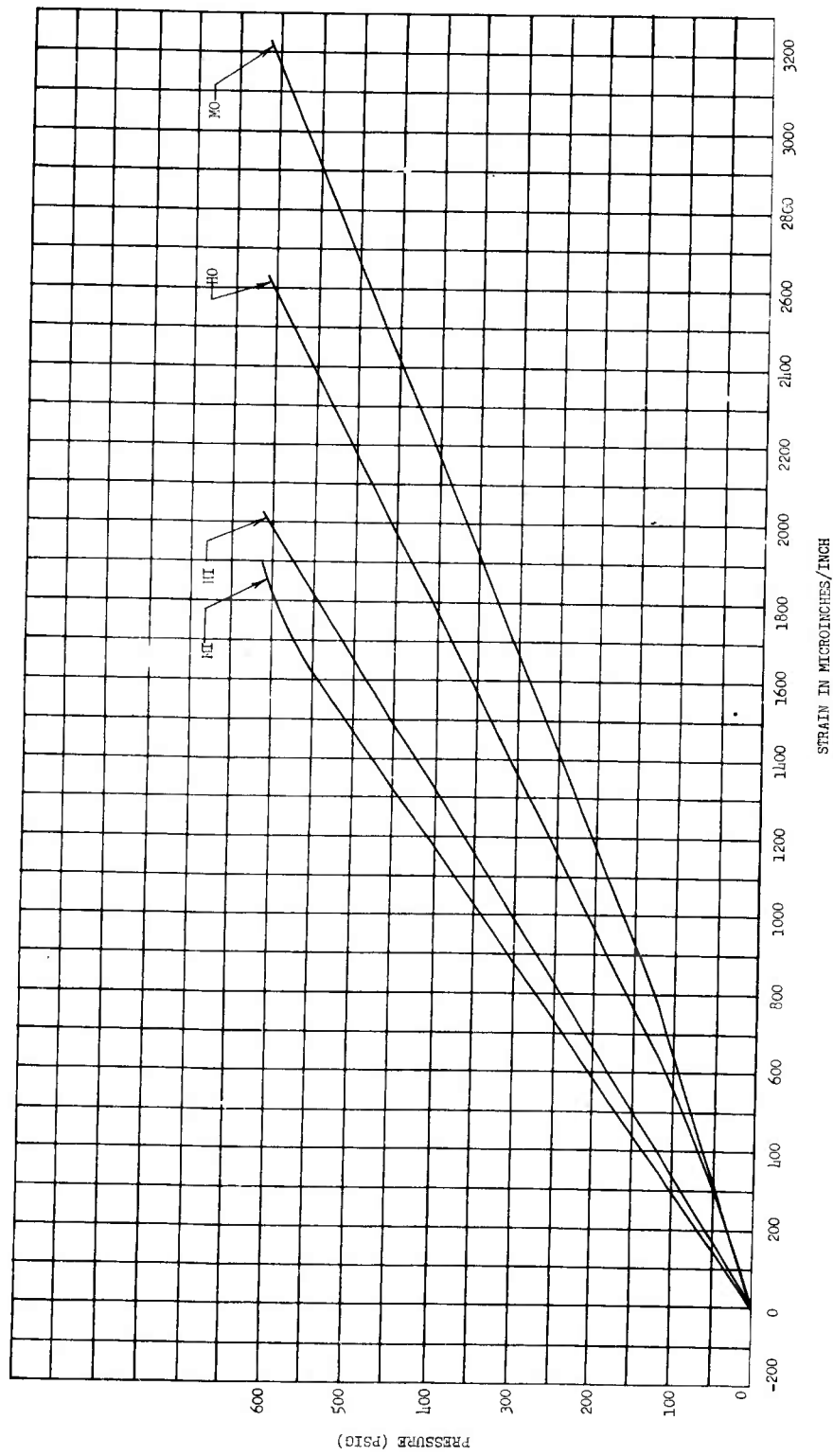
Appendix A



Pressure vs Stress, Gage Point 9

Figure 18

Appendix A



Pressure vs Strain, Gage Point 10

Figure 19

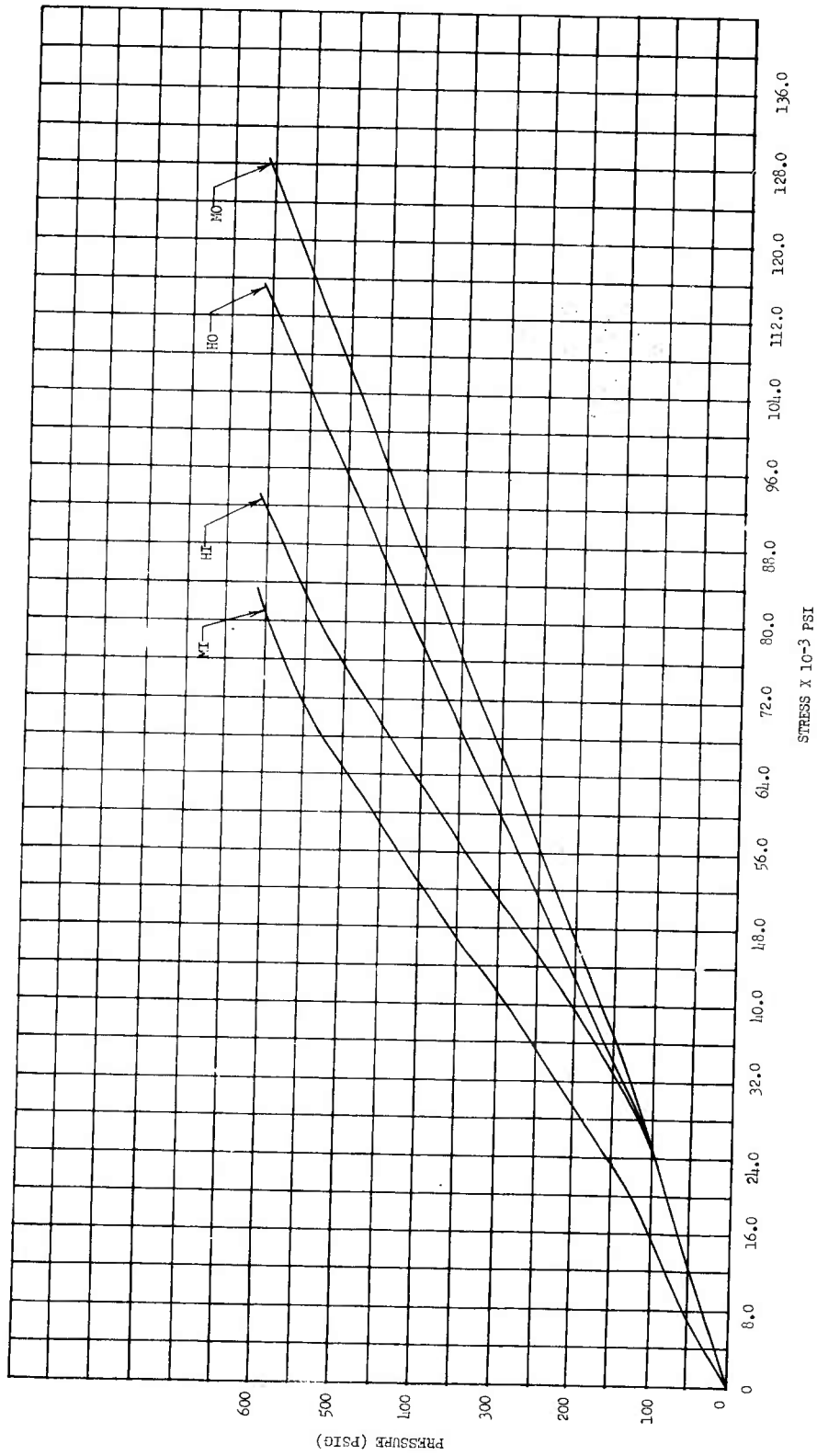


Figure 20

Pressure vs Stress, Gage Point 10

Appendix A

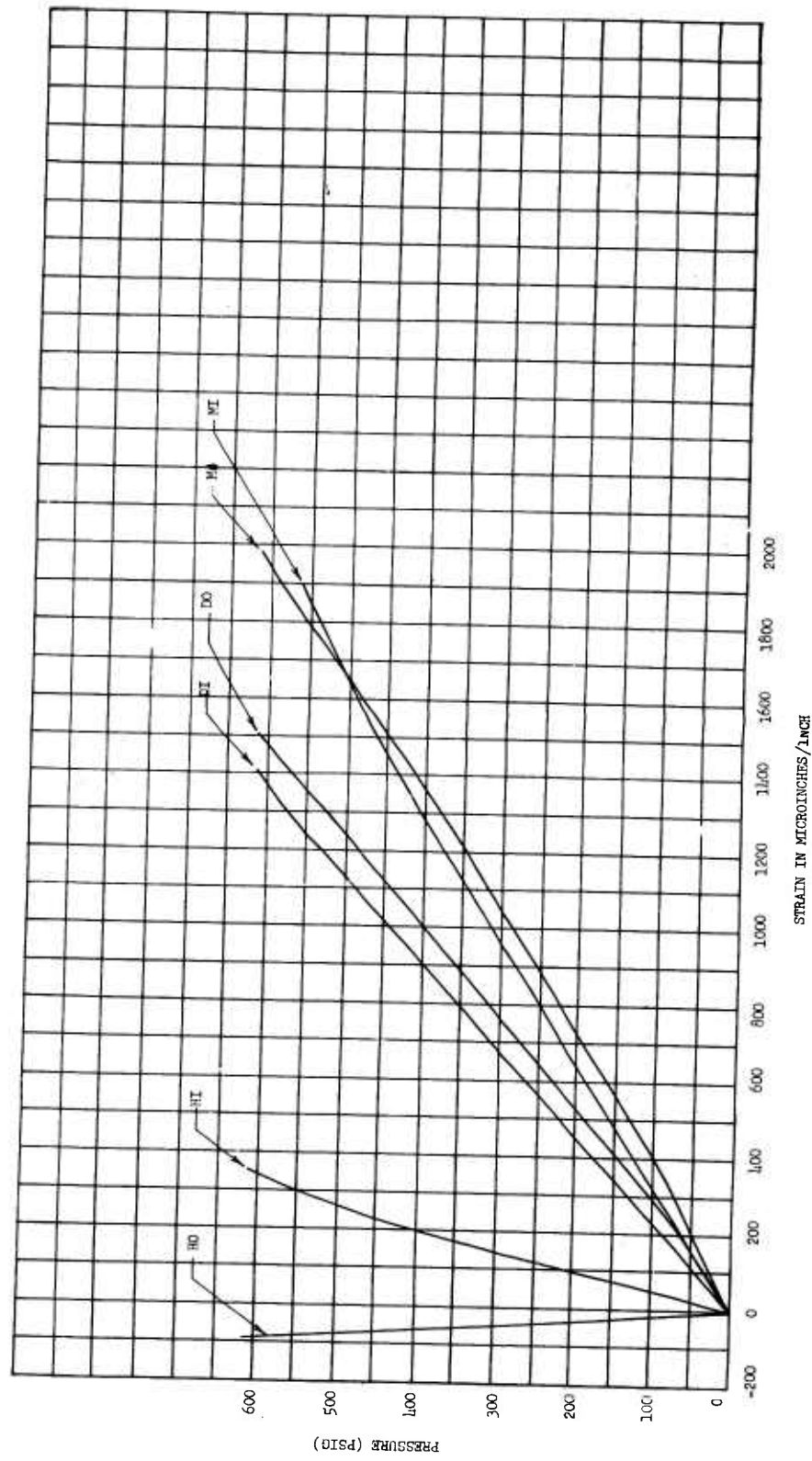


Figure 21

Pressure vs Strain, Gage Point 11

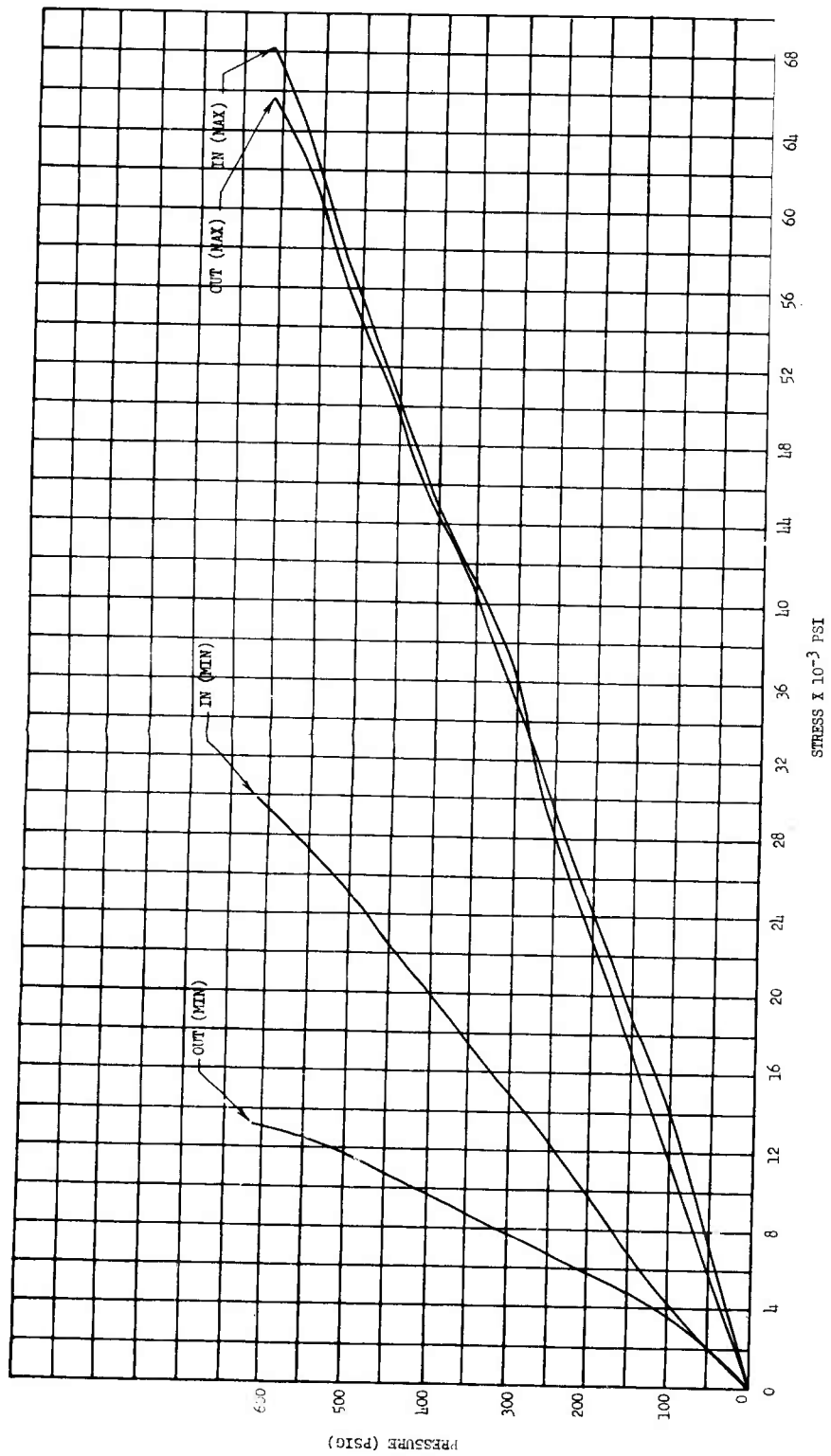


Figure 22

Pressure vs Stress, Gage Point 11

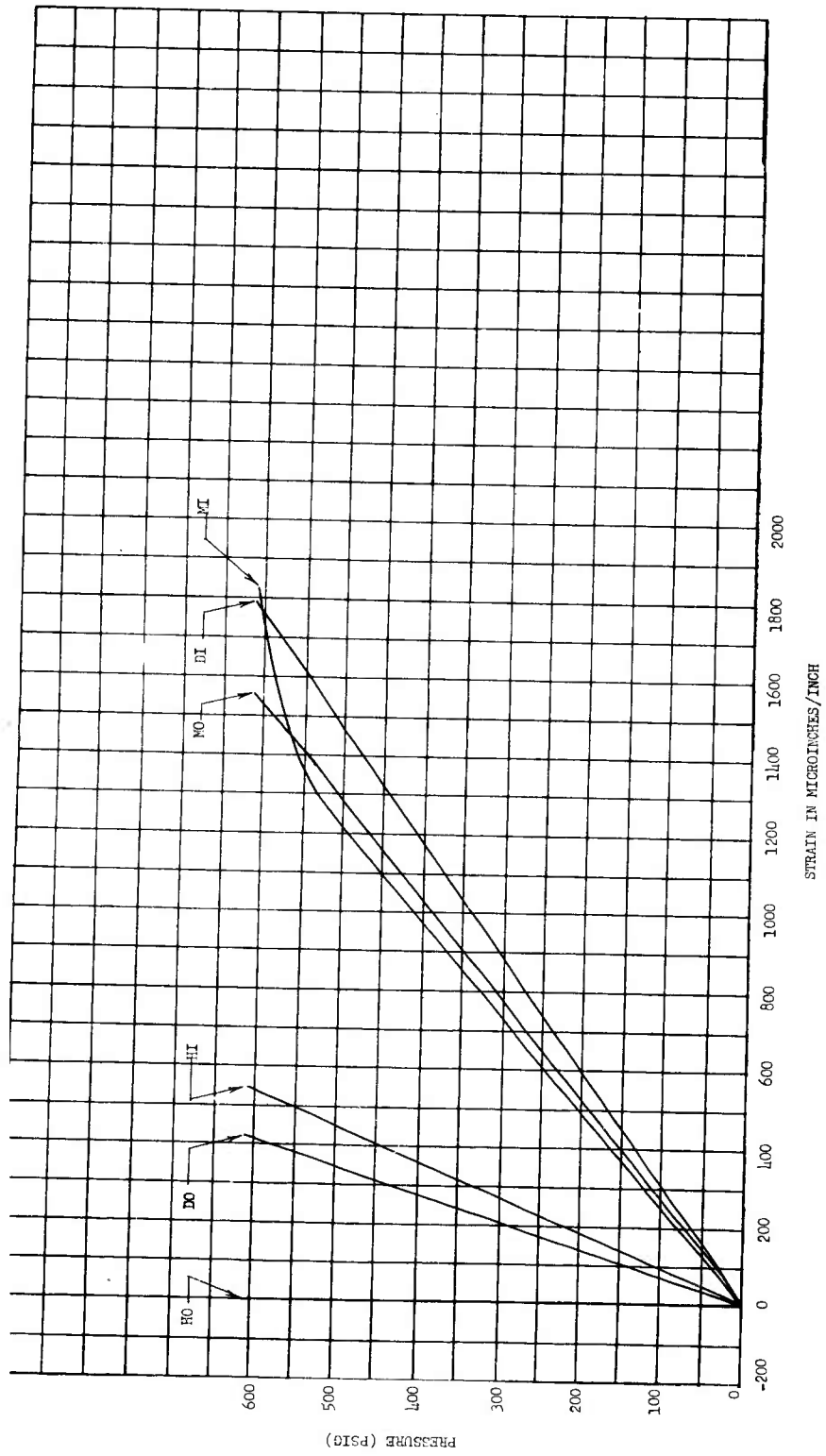


Figure 23

Pressure vs Strain, Gage Point 12

Appendix A

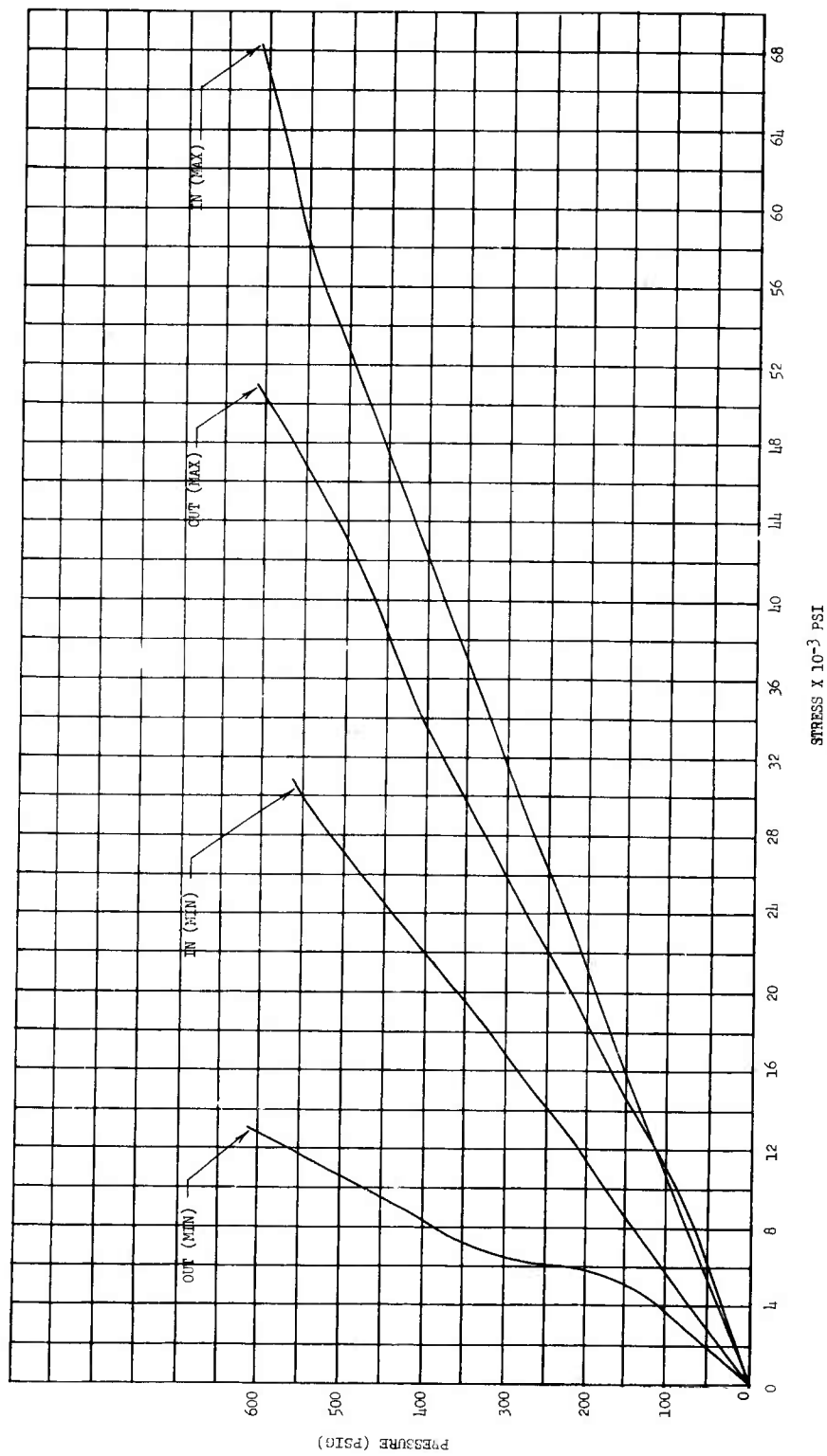


Figure 24

Pressure vs Stress, Gage Point 12

Appendix A

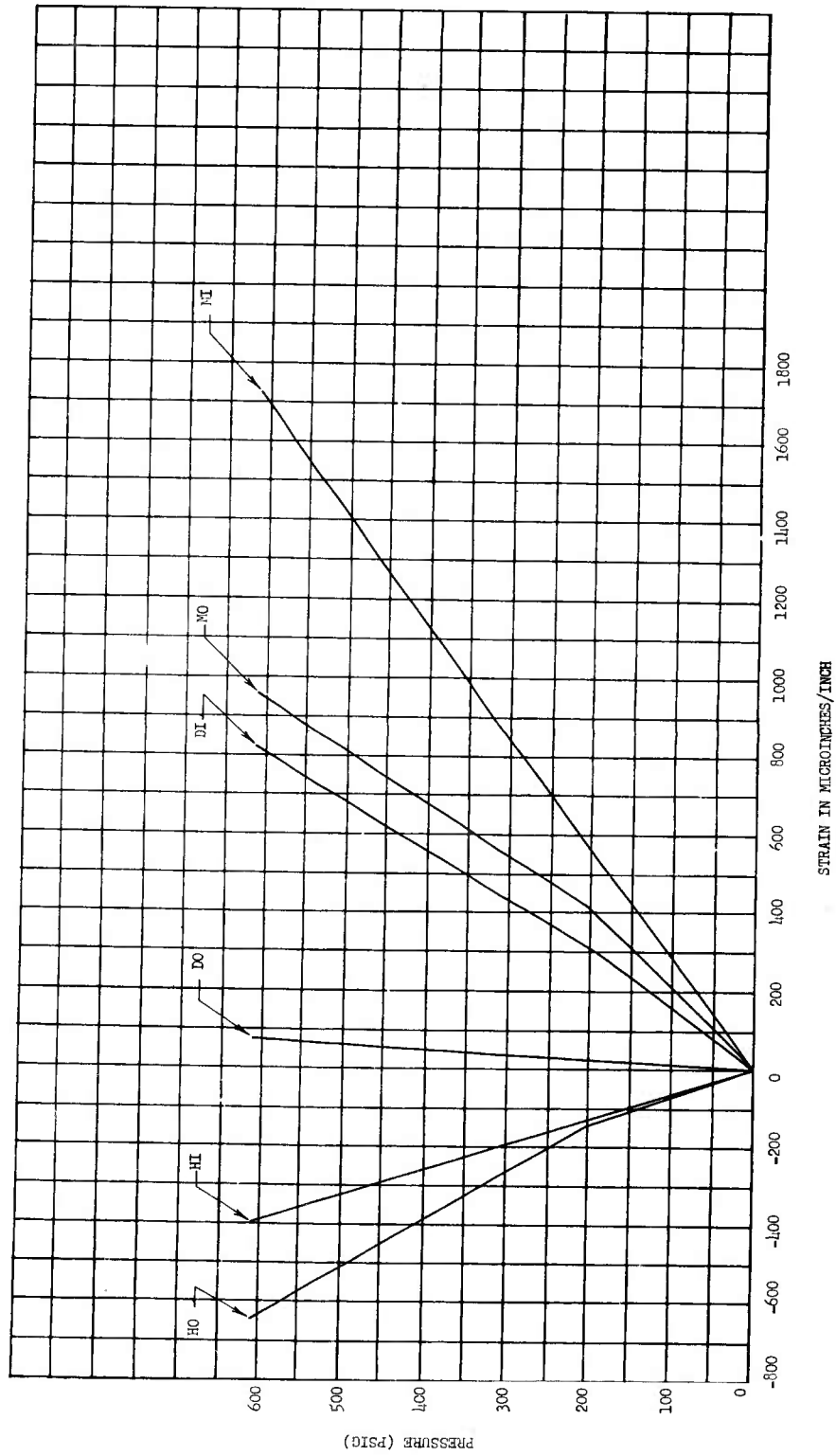


Figure 25

Pressure vs Strain, Gage Point 13

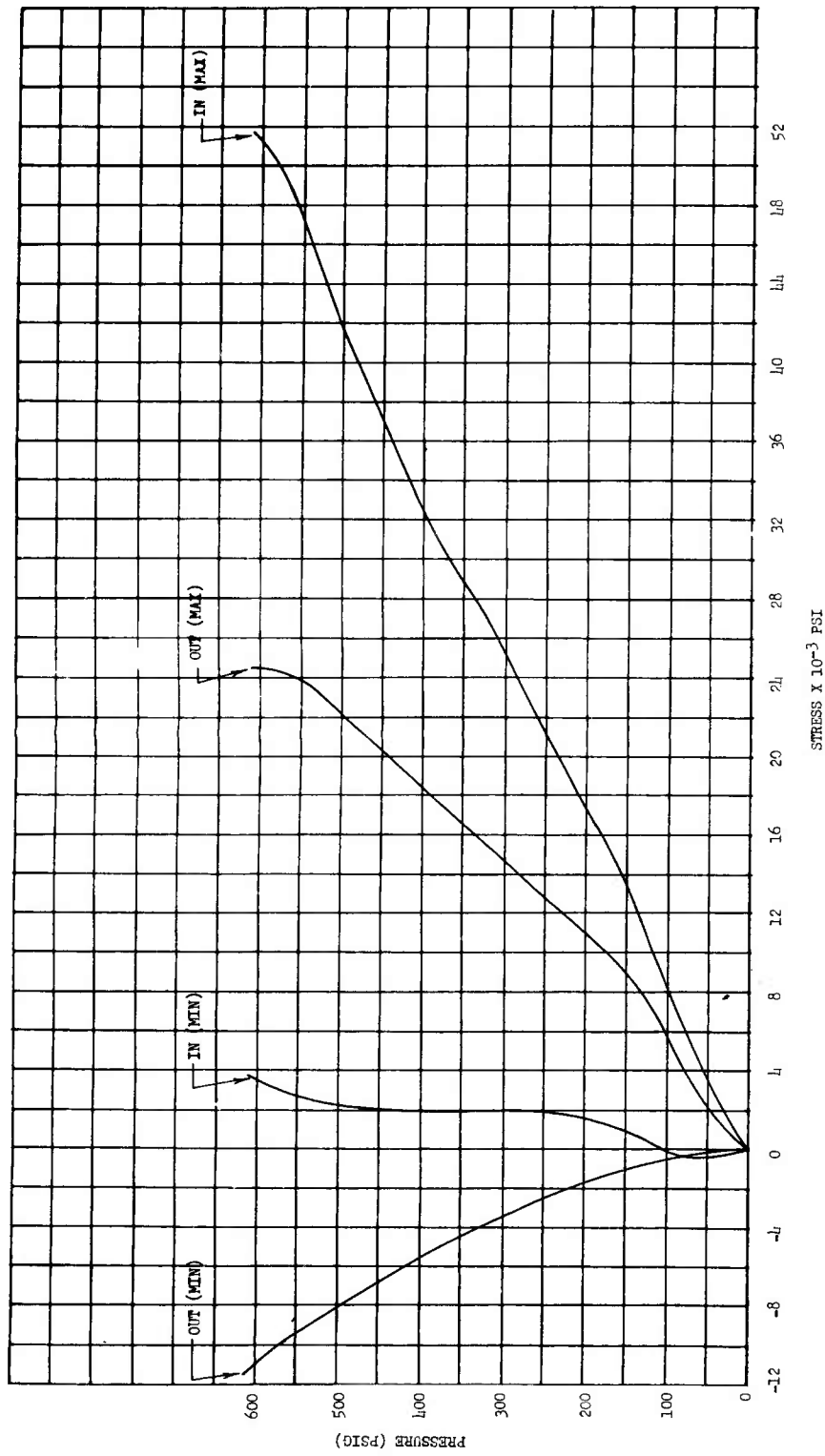


Figure 26

Pressure vs Stress, Gage Point 13

Appendix A

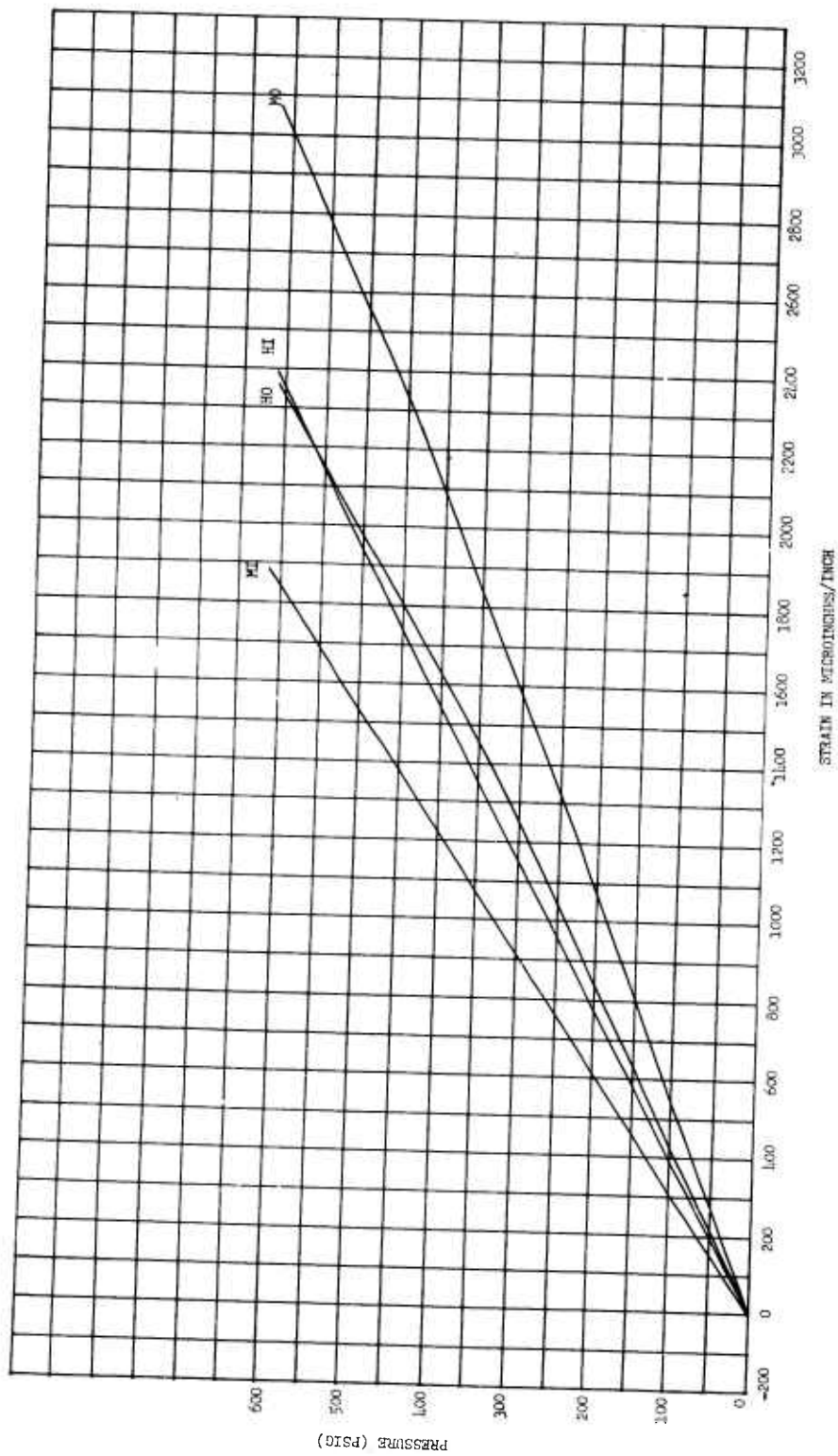


Figure 27

Pressure vs Strain, Gage Point 14

Appendix A

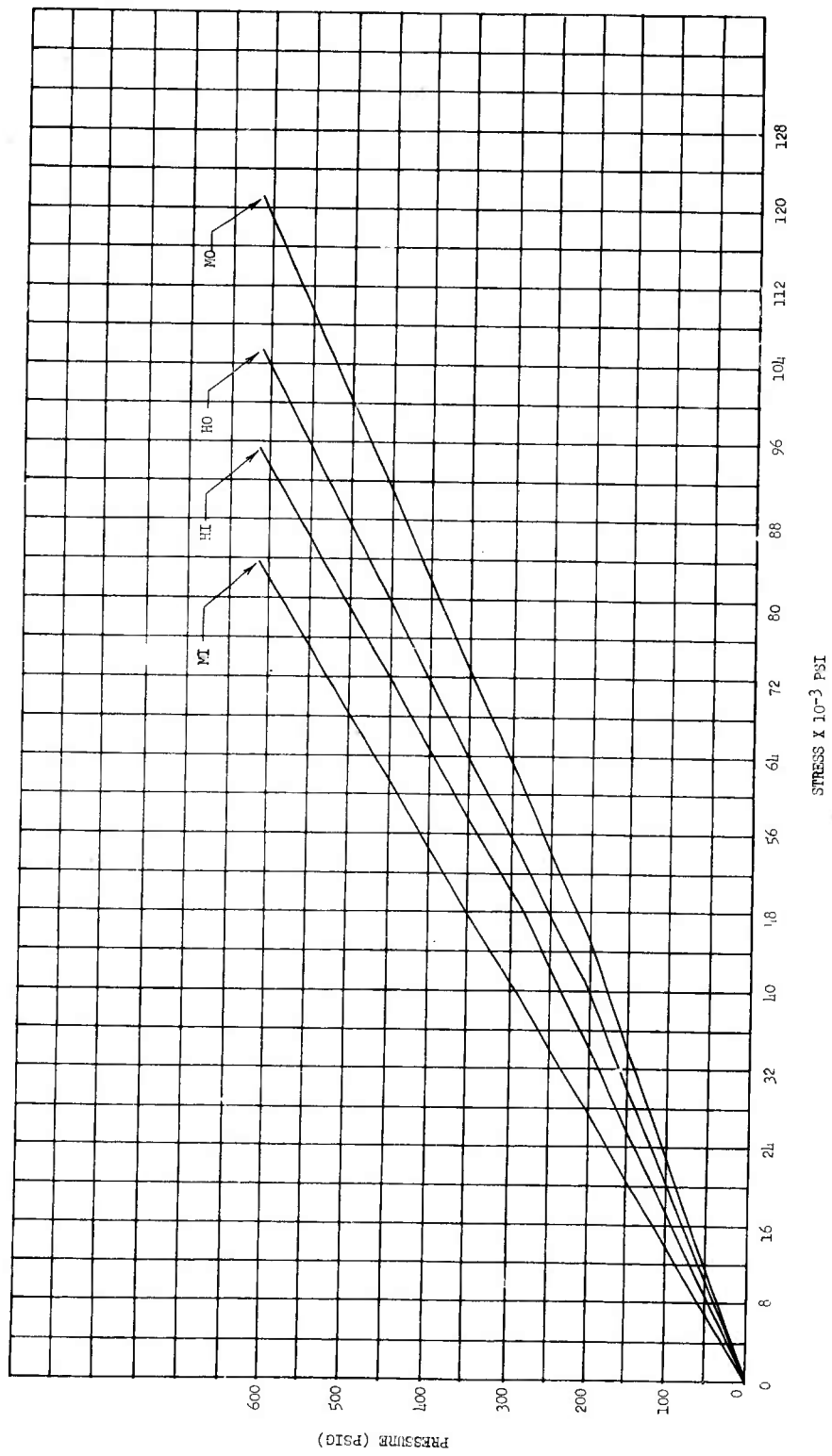


Figure 28

Pressure vs Stress, Gage Point 14

Appendix A

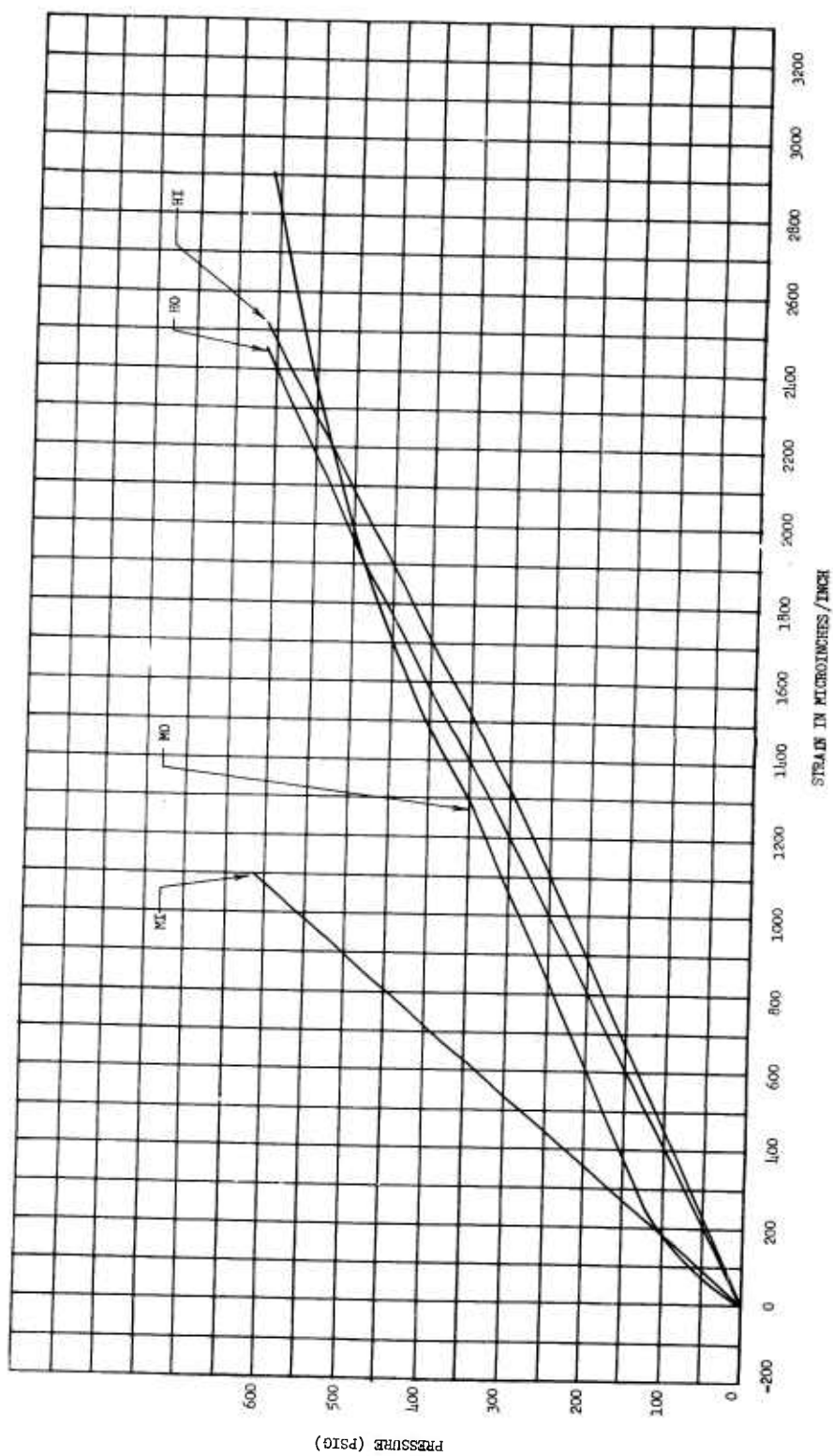
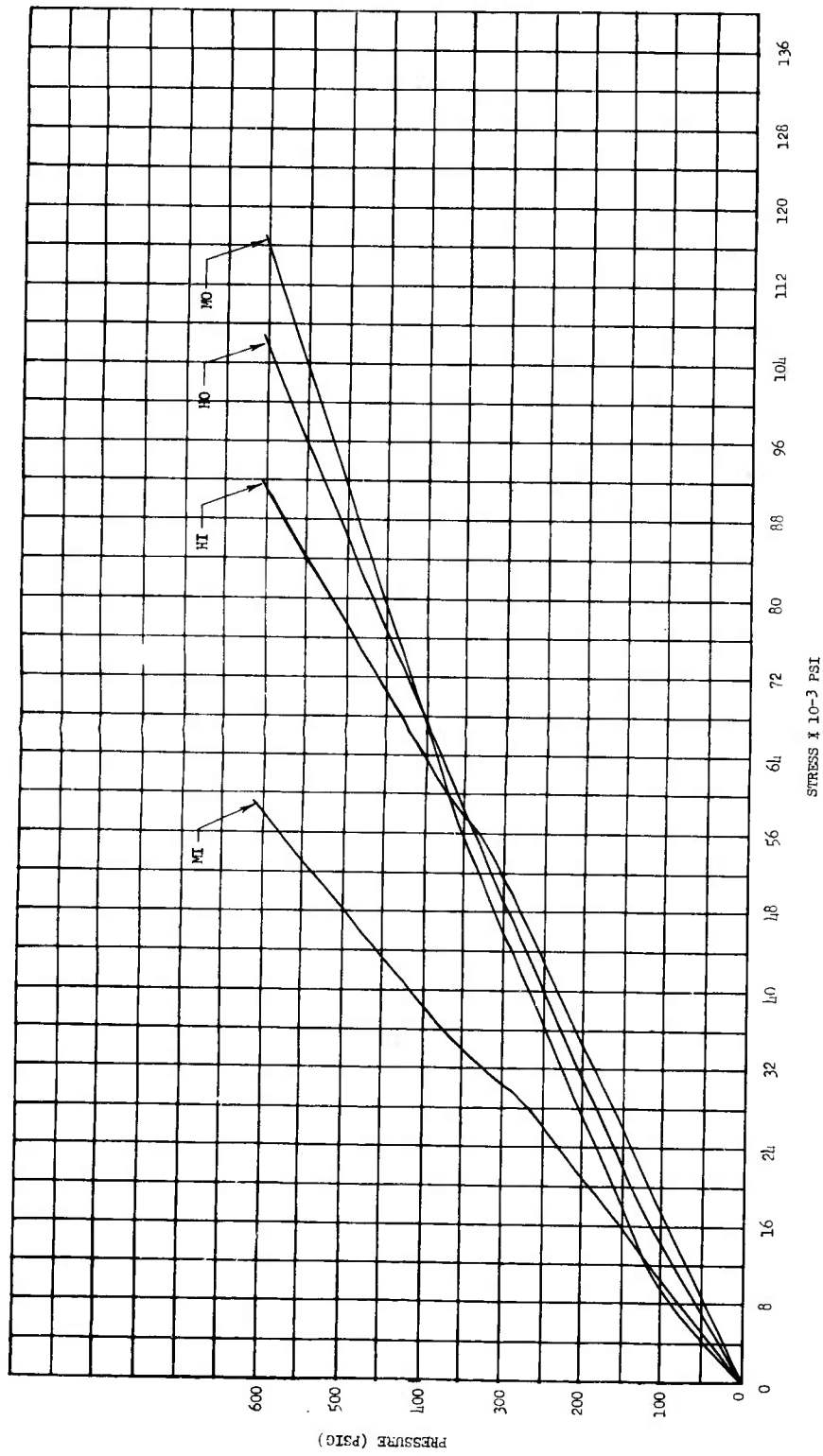


Figure 29

Pressure vs Strain, Gage Point 15

Appendix A



Pressure vs Stress, Gage Point 15

Figure 30

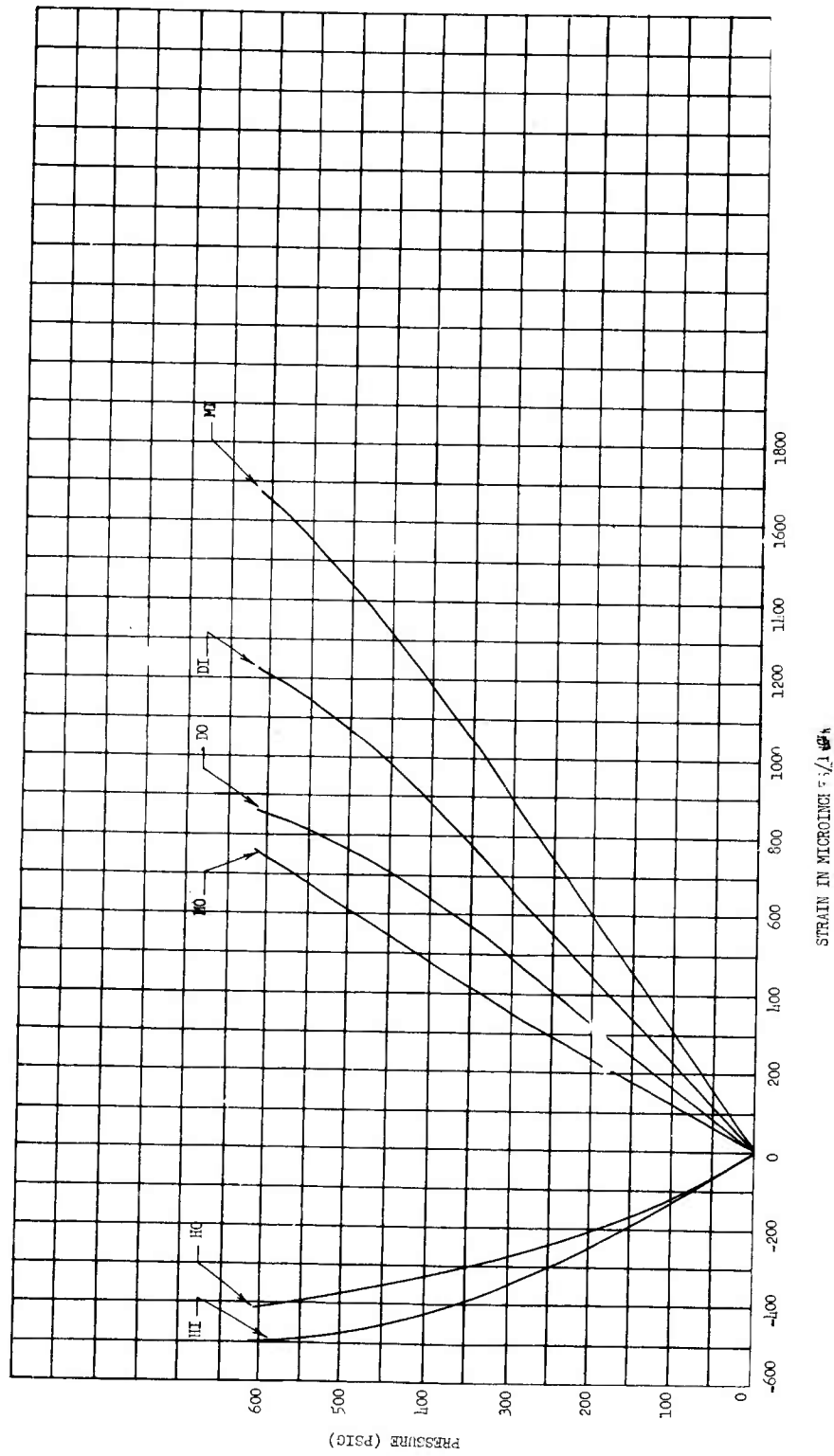


Figure 31

Pressure vs Strain, Gage Point 16

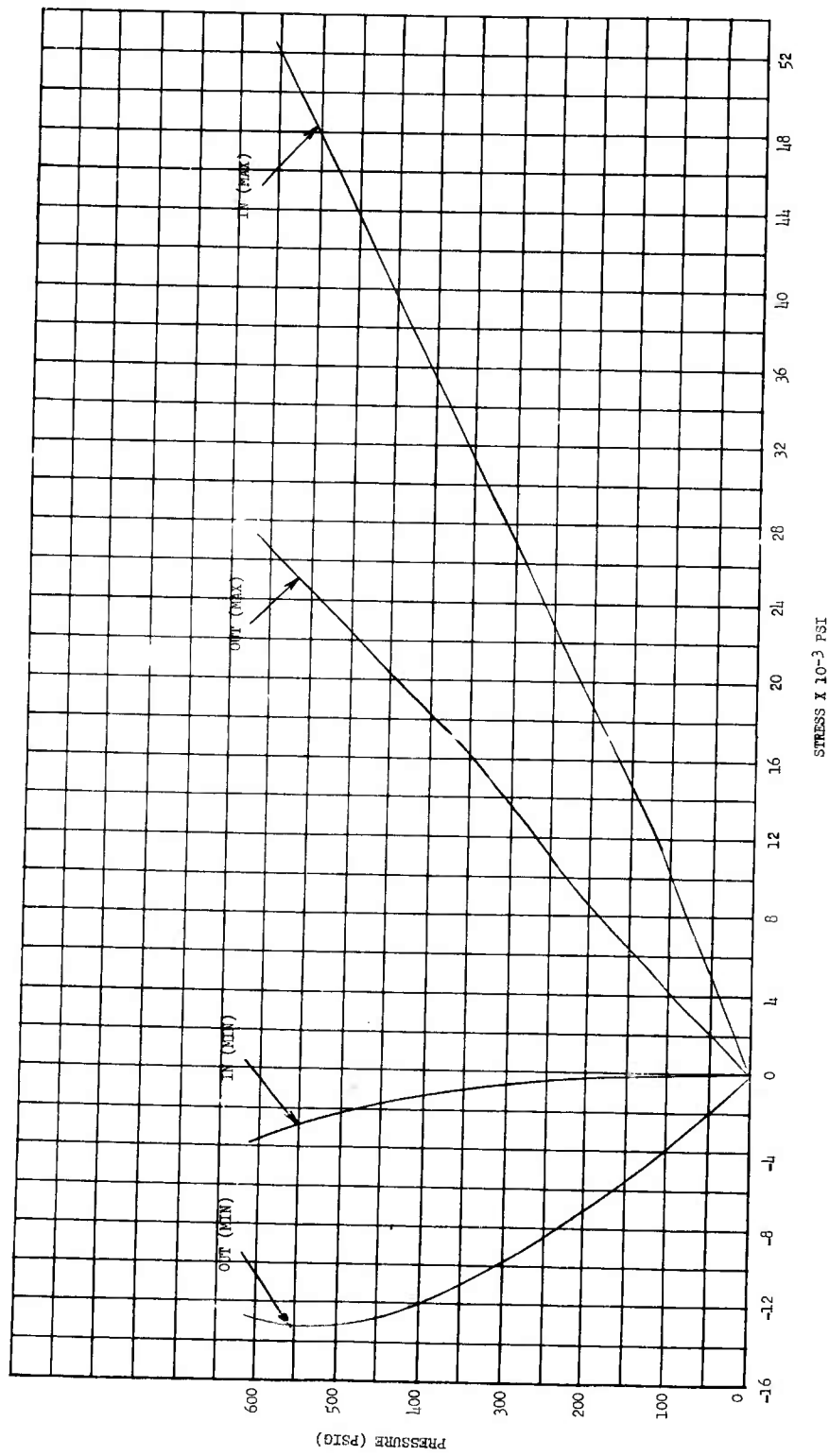
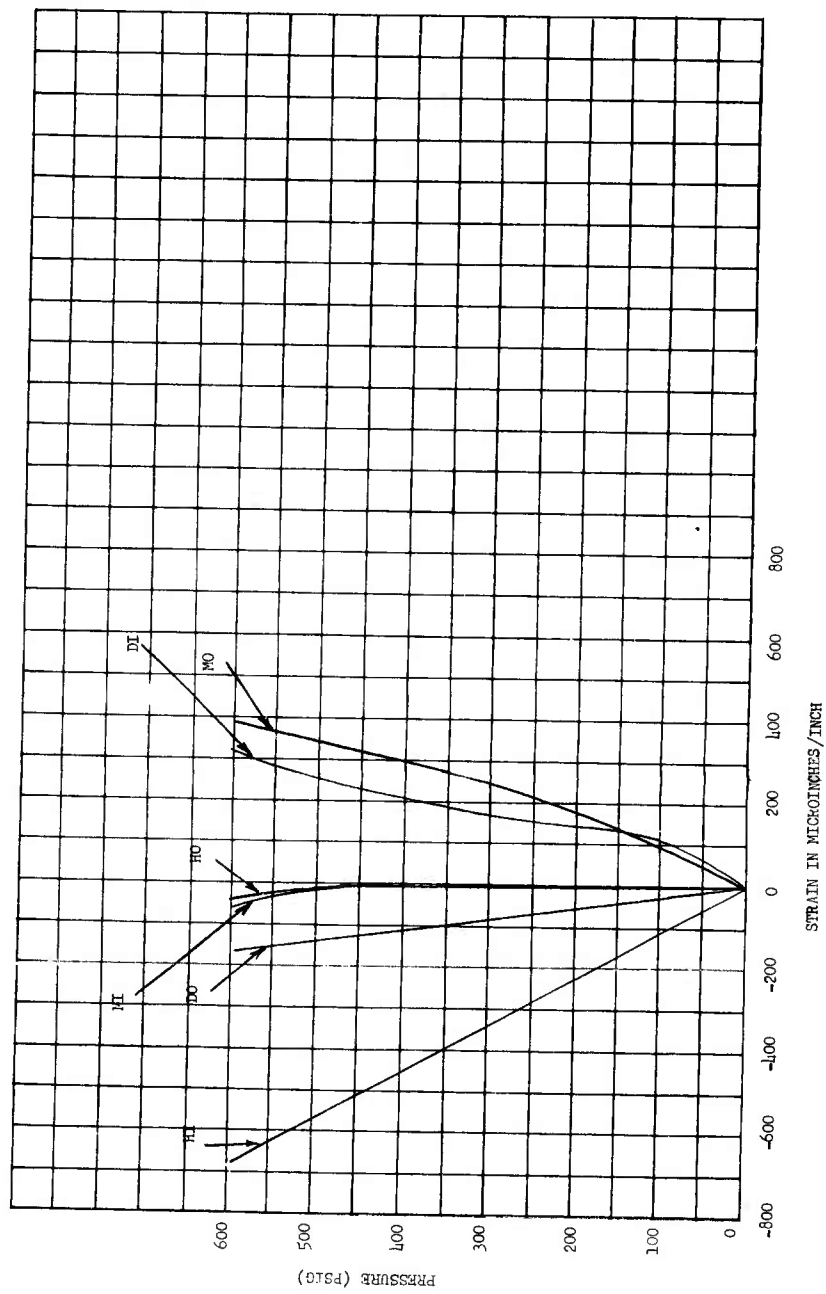


Figure 32

Pressure vs Stress, Gage Point 16



Pressure vs Strain, Gage Point 17

Figure 33

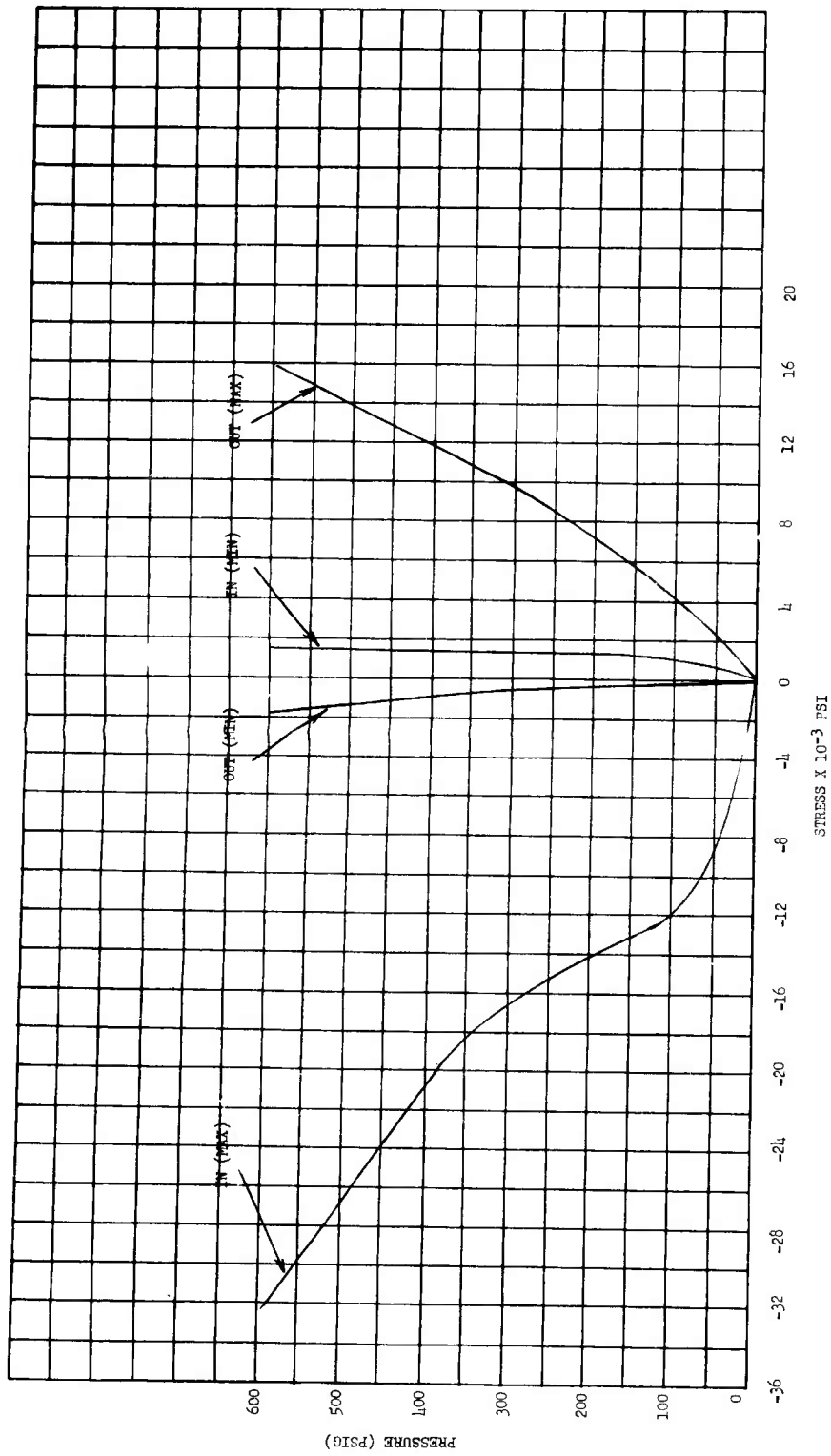


Figure 34

Pressure vs Stress, Gage Point 17

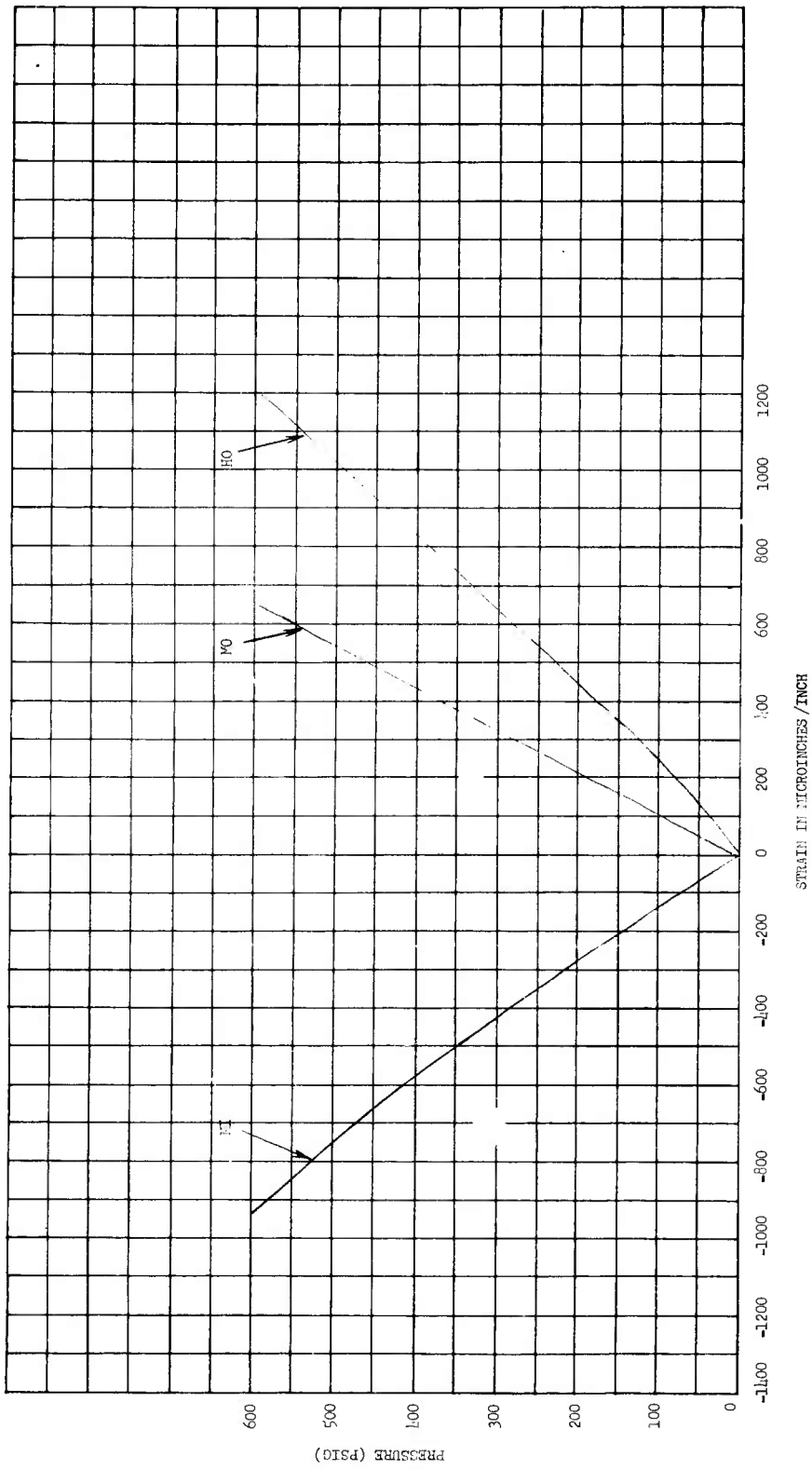
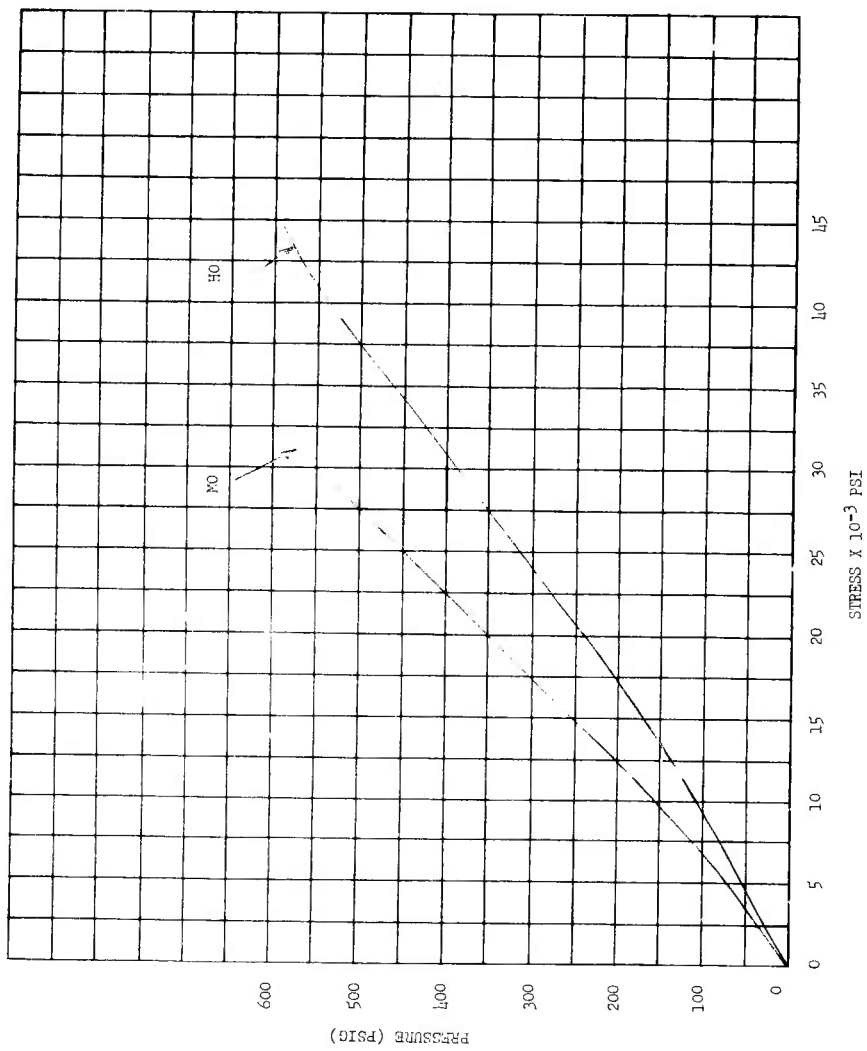


Figure 35

Pressure vs Strain, Gage Point 18

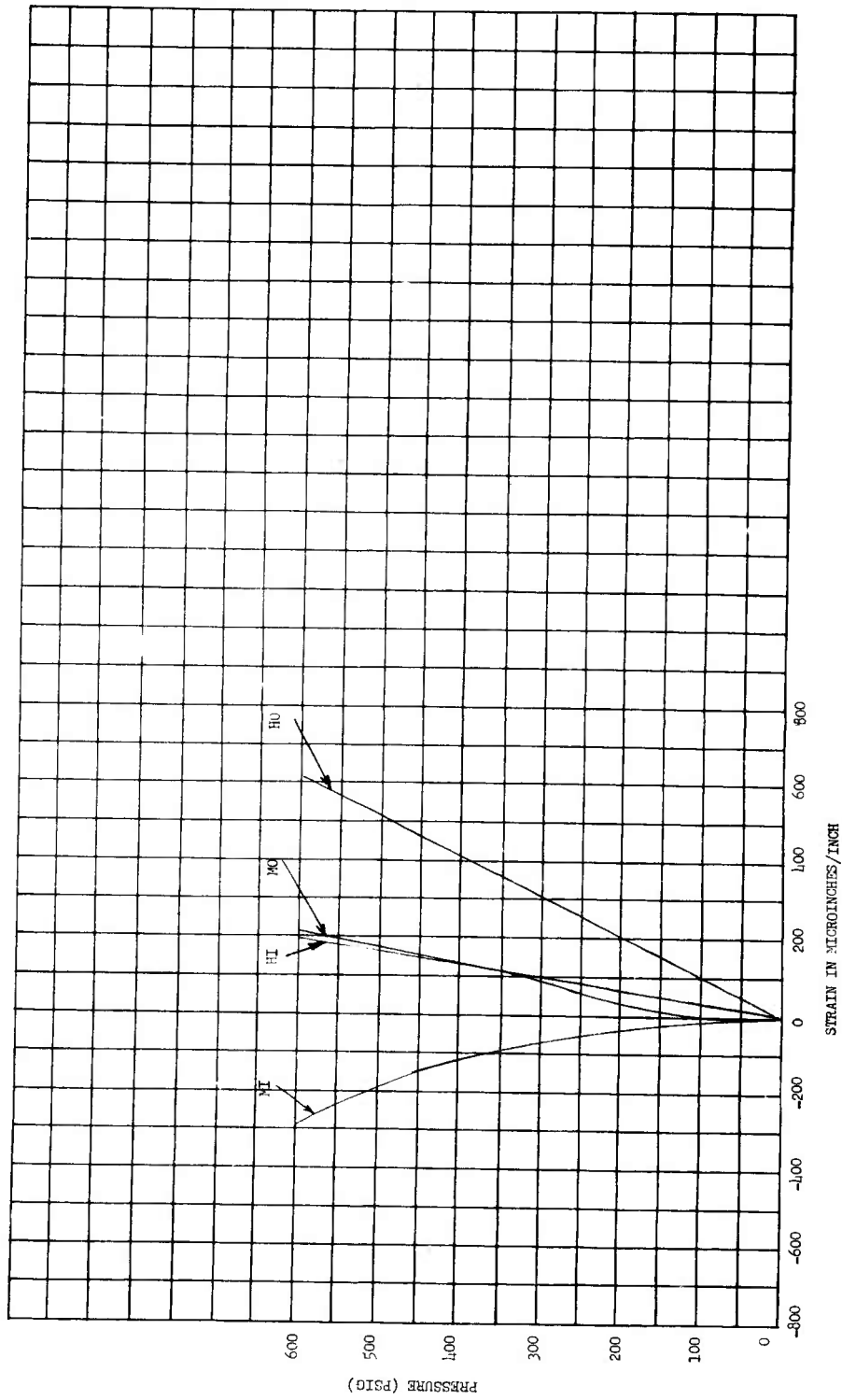
Appendix A



Pressure vs Stress, Gage Point 18

Figure 36

Appendix A



Pressure vs Strain, Gage Point 19

Figure 37

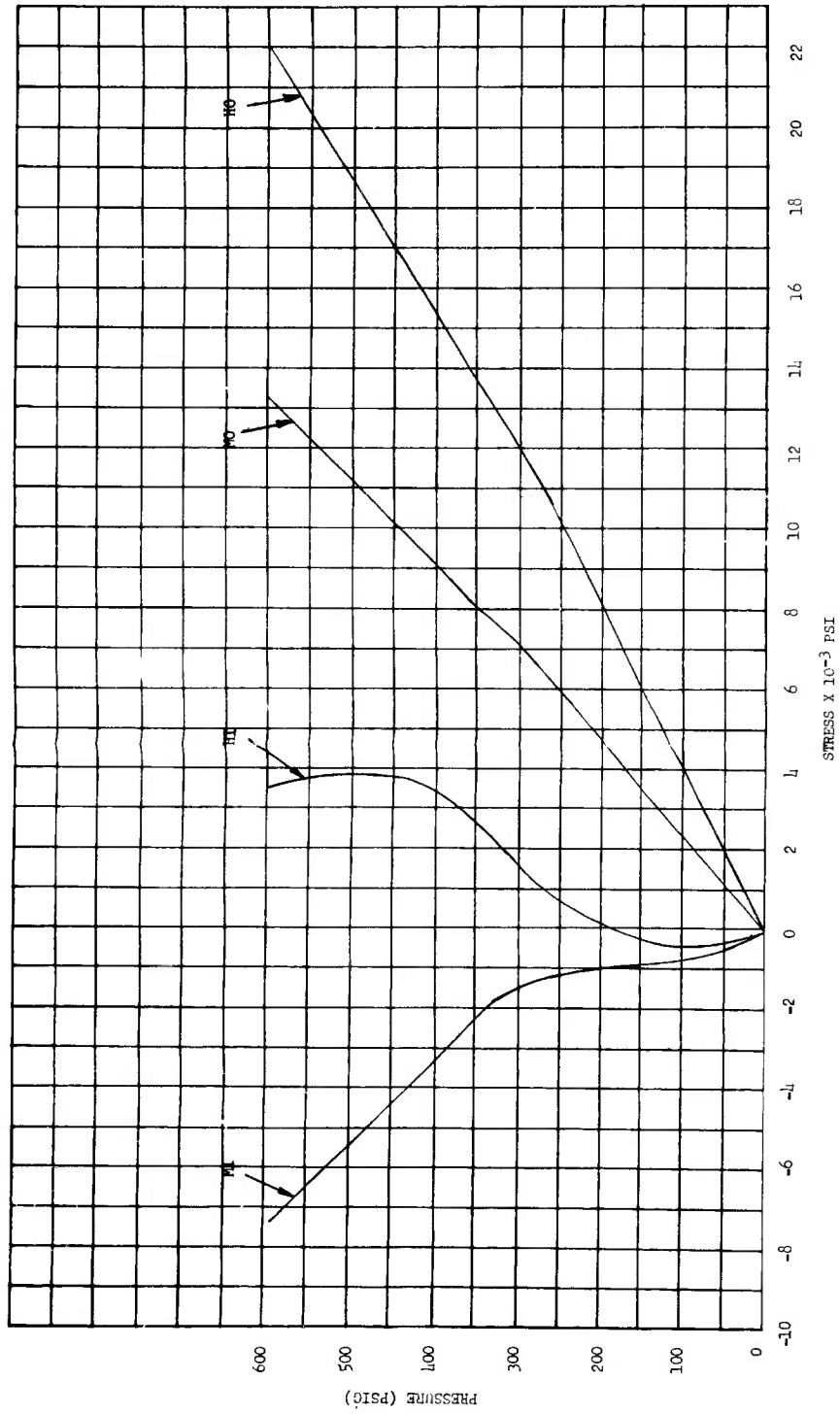
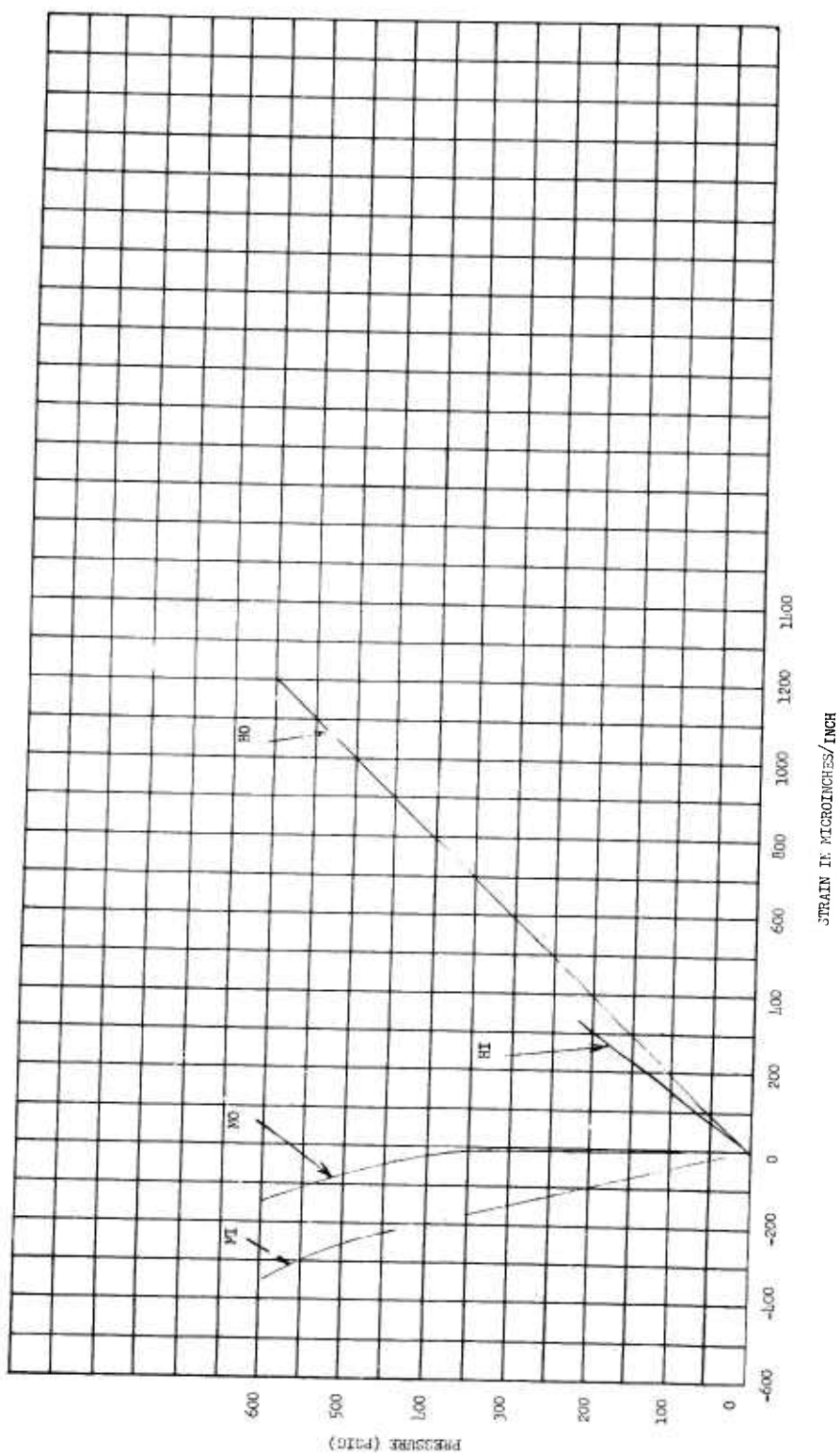


Figure 38

Pressure vs Stress, Gage Point 19



Pressure vs Strain, Gage Point 20

Figure 39

Appendix E

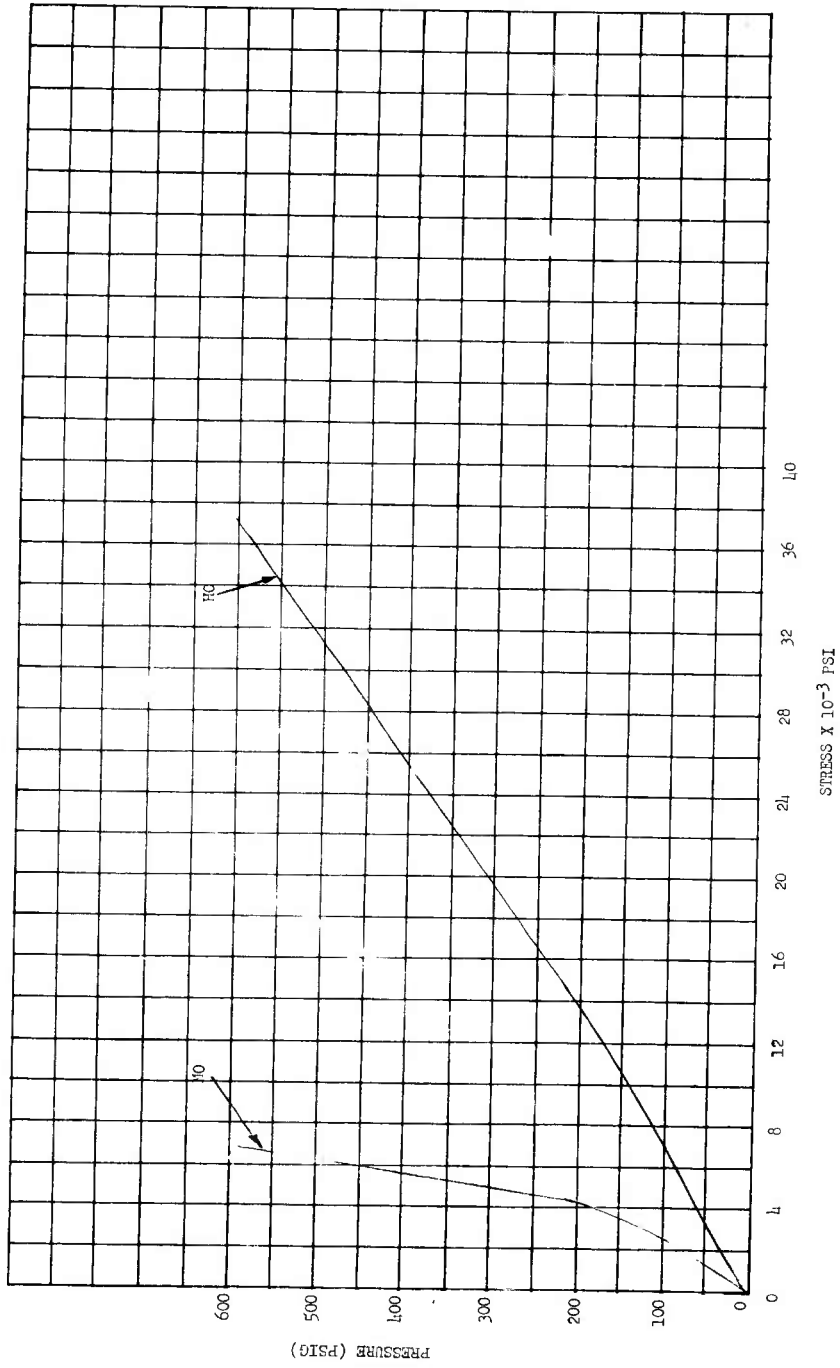


Figure 40

Pressure vs Stress, Gage Point 20

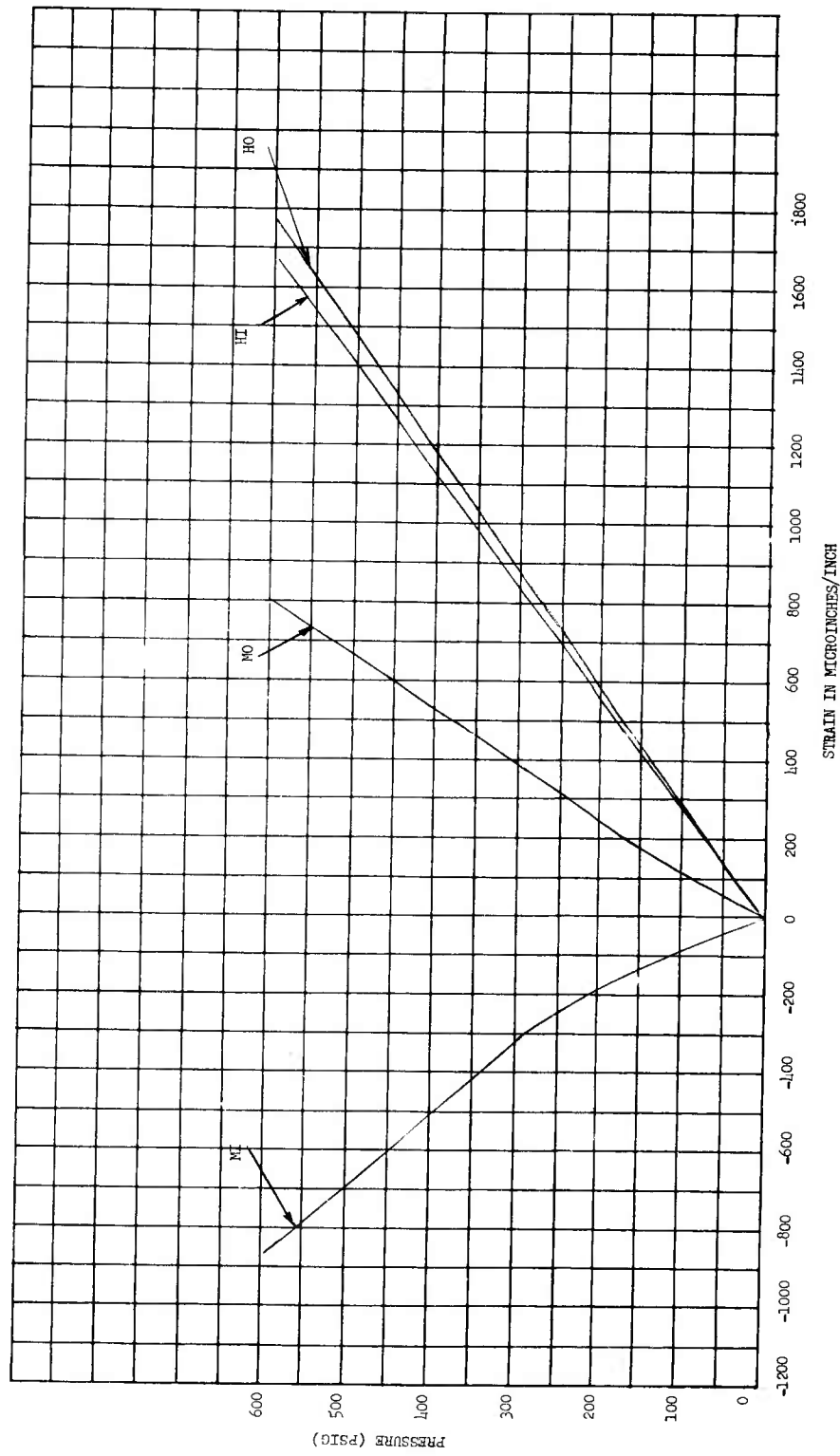
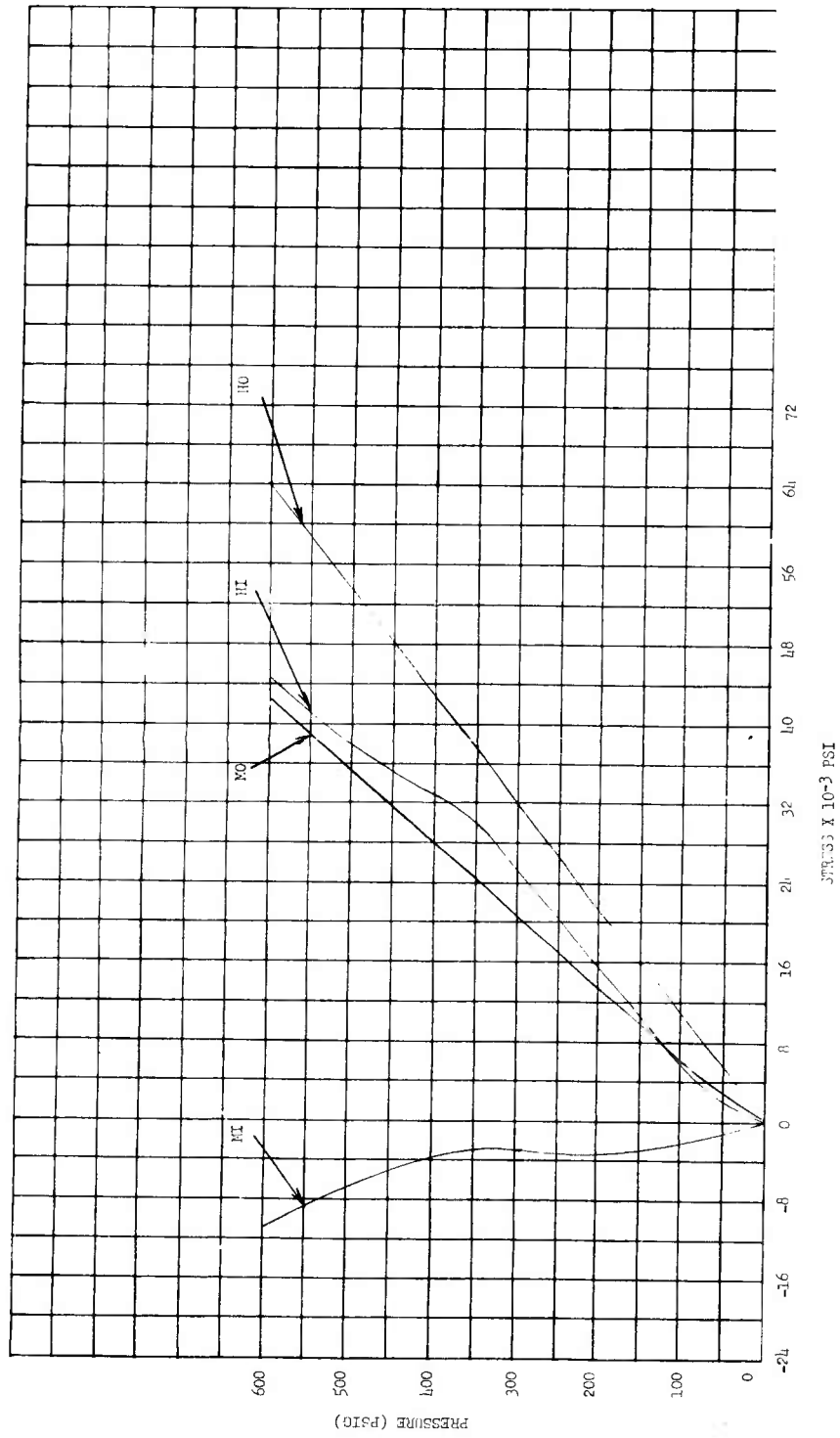


Figure 41

Pressure vs Strain, Gage Point 21

Appendix A



Pressure vs Stress, Gage Point 21

Figure 42

Appendix A

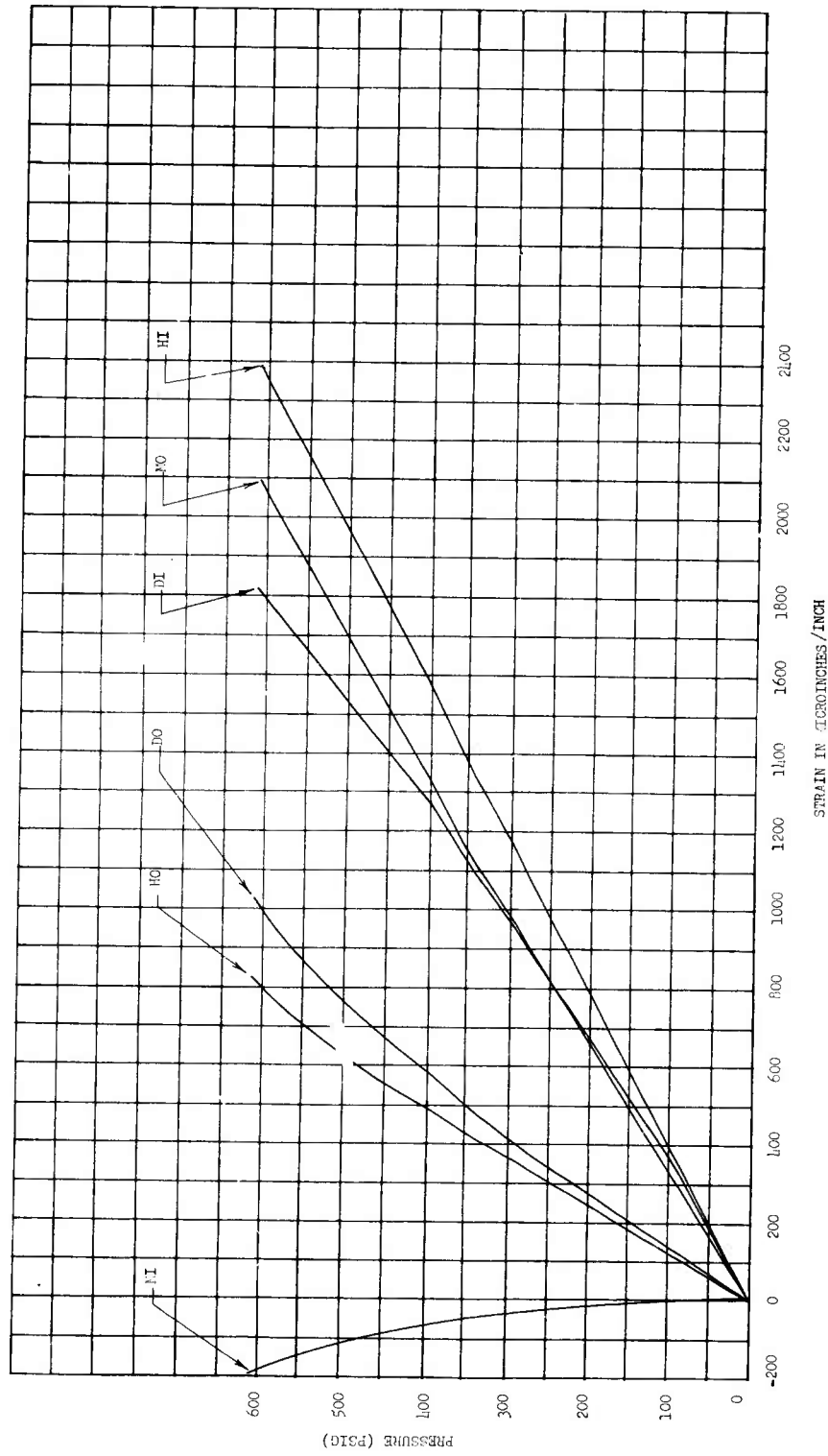


Figure 43

Pressure vs Strain, Gage Point 22

Appendix A

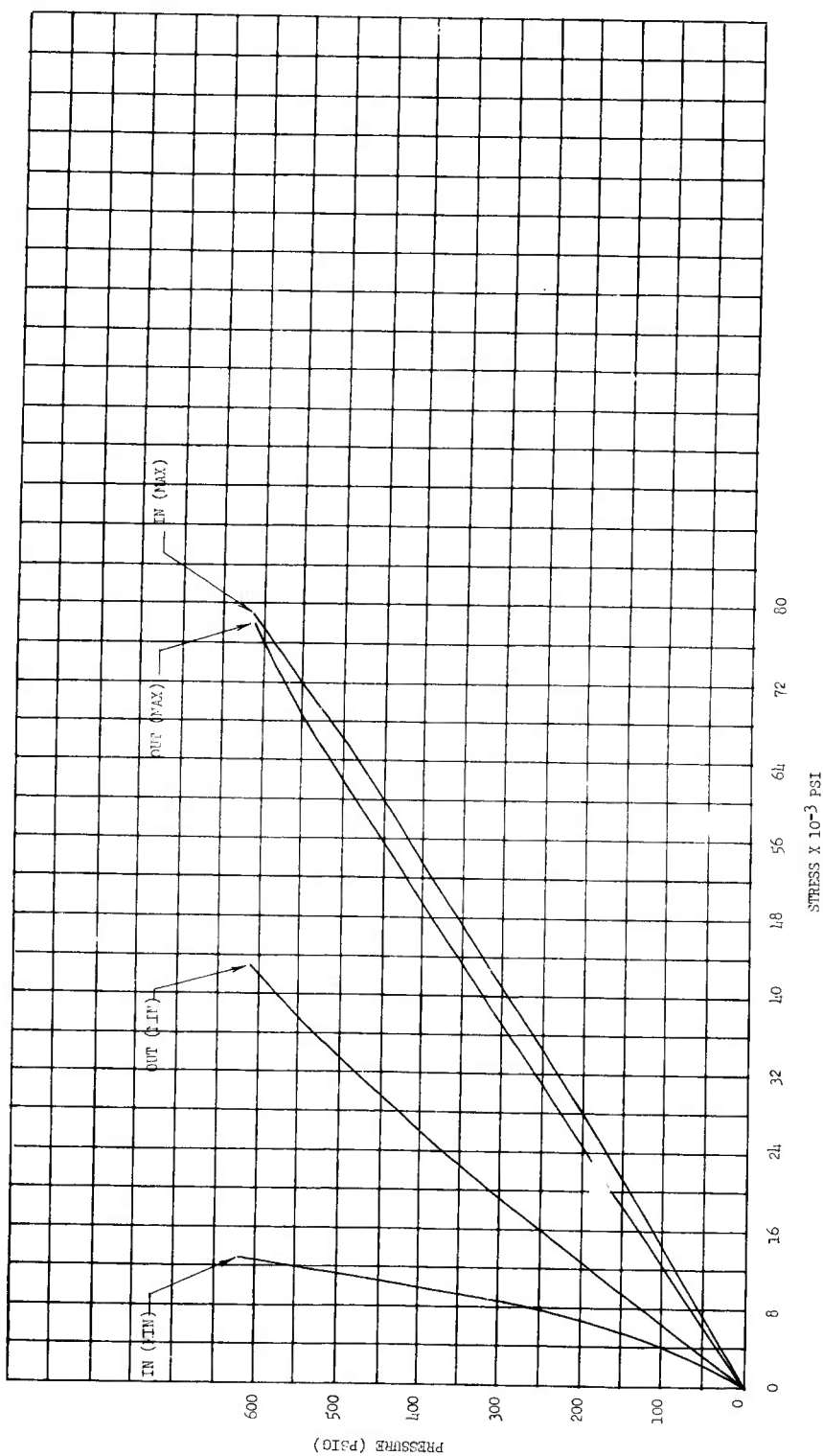
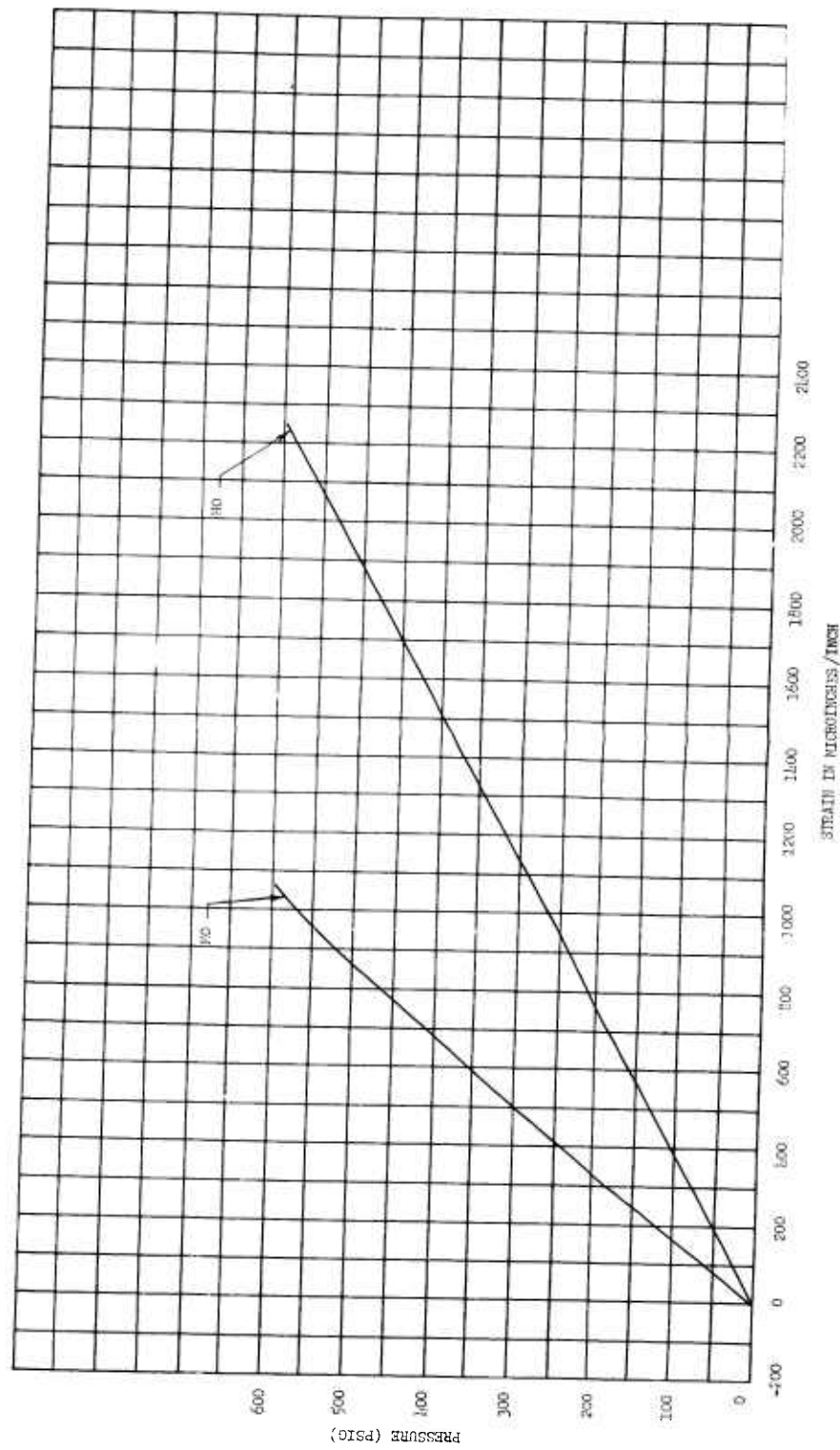


Figure 44

Pressure vs Stress, Gage Point 22

Appendix A



Pressure vs Strain, Gage Point 23

Figure 45

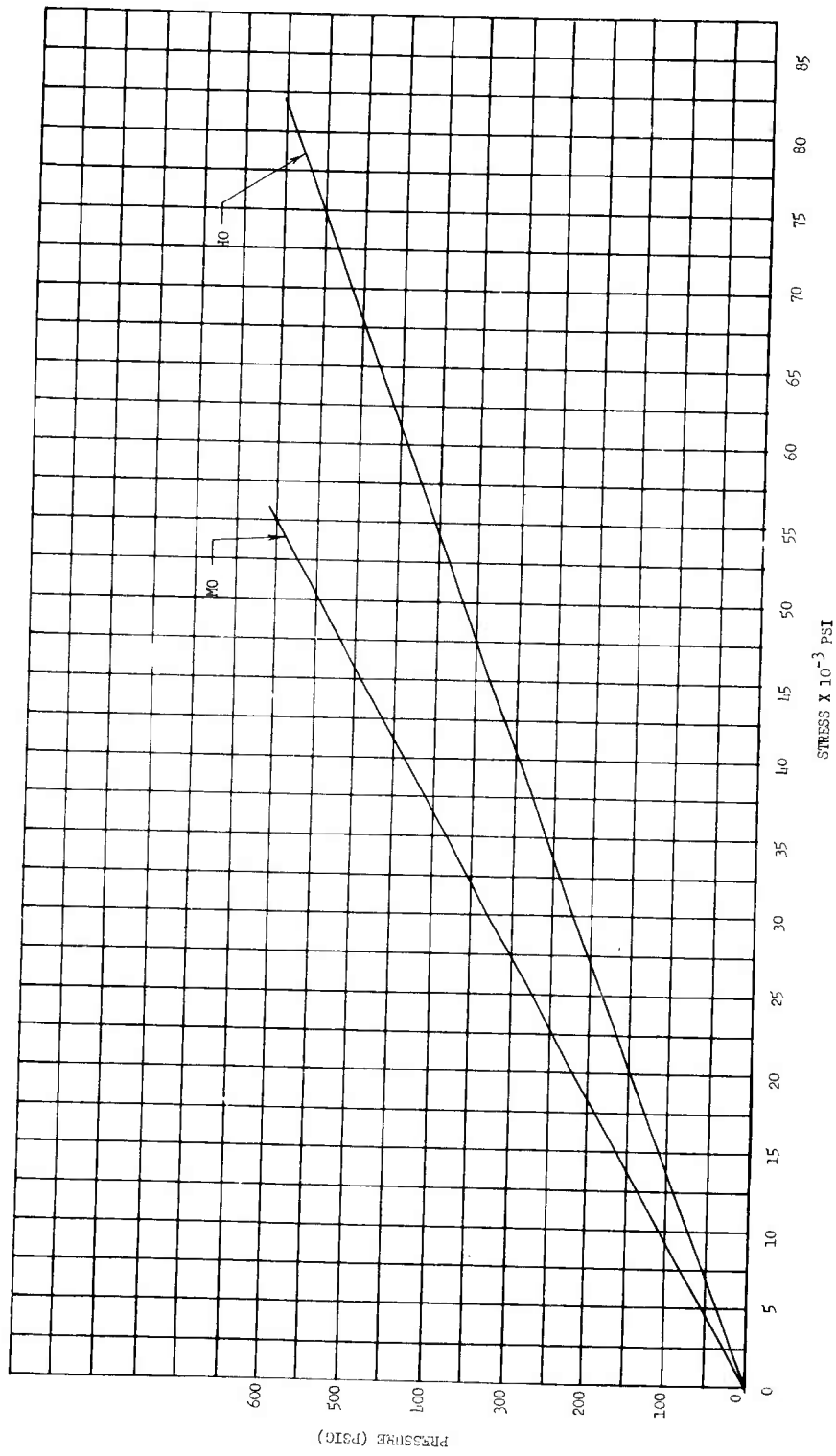
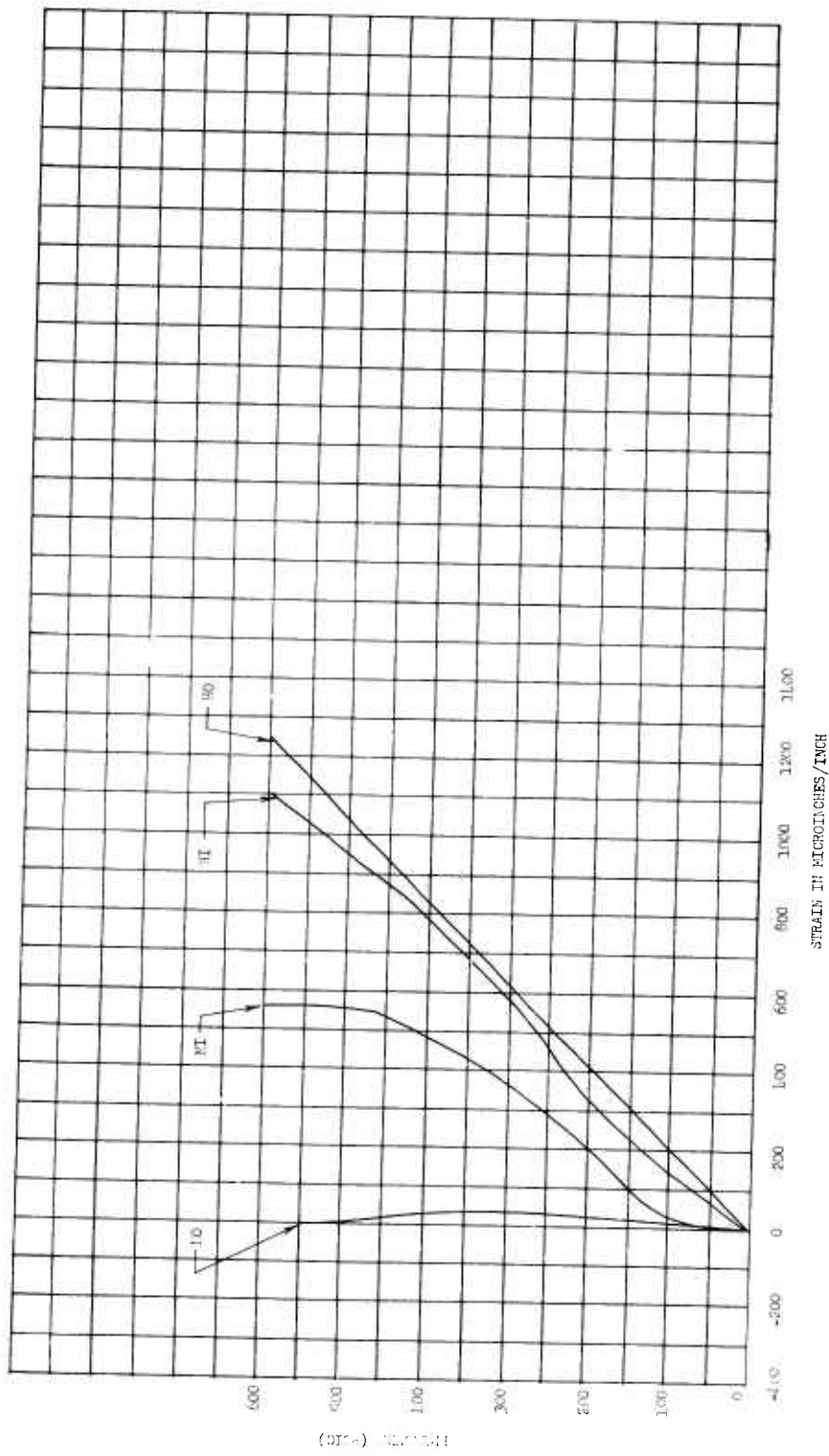


Figure 46

Pressure vs Stress, Gage Point 23



Pressure vs Strain, Gage Point 24

Figure 47

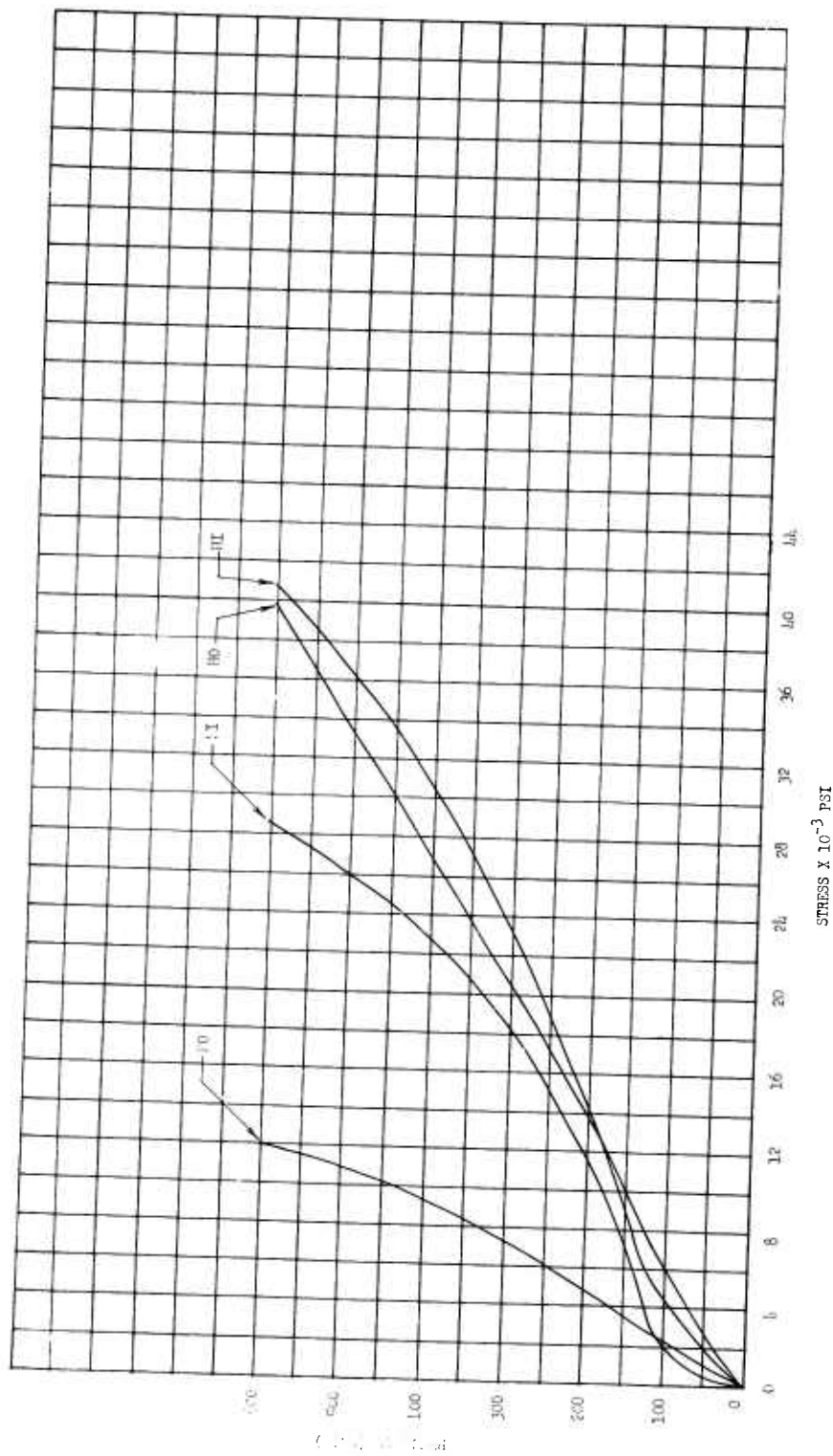


Figure 48

Pressure vs Stress, CAGE POINT 24

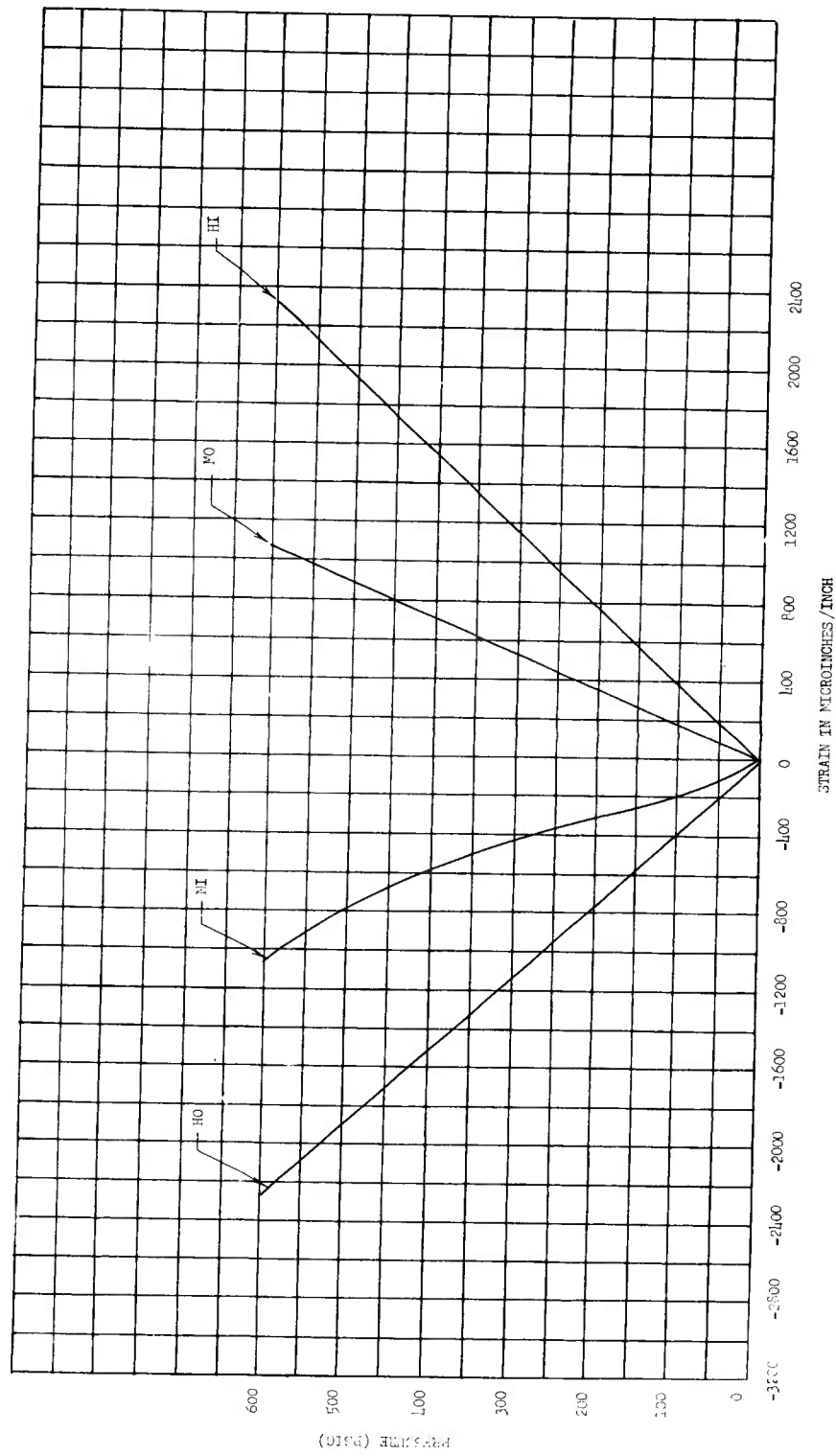


Figure 49

Pressure vs Strain, Gage Point 25

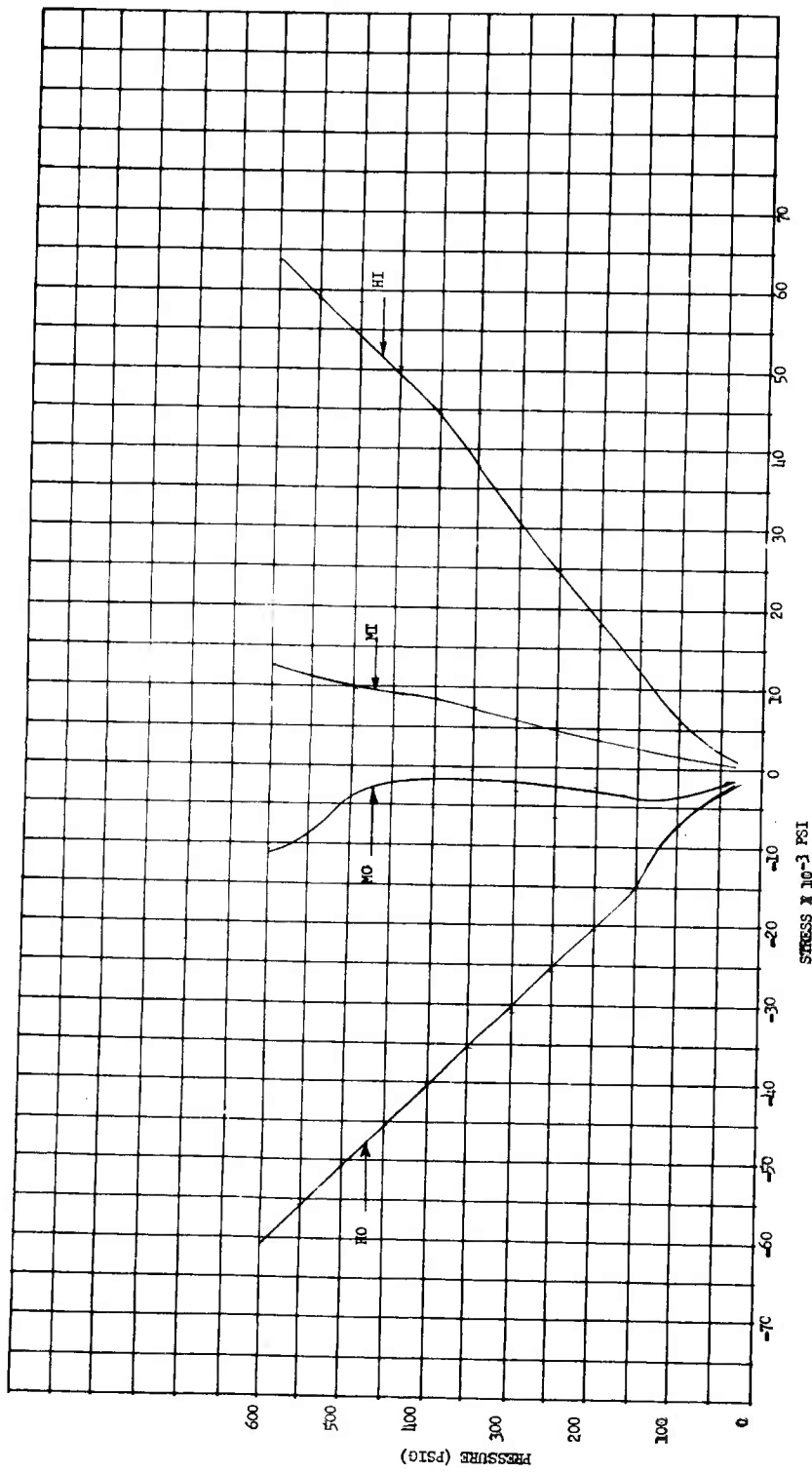


Figure 50

Pressure vs Stress, Gage Point 25

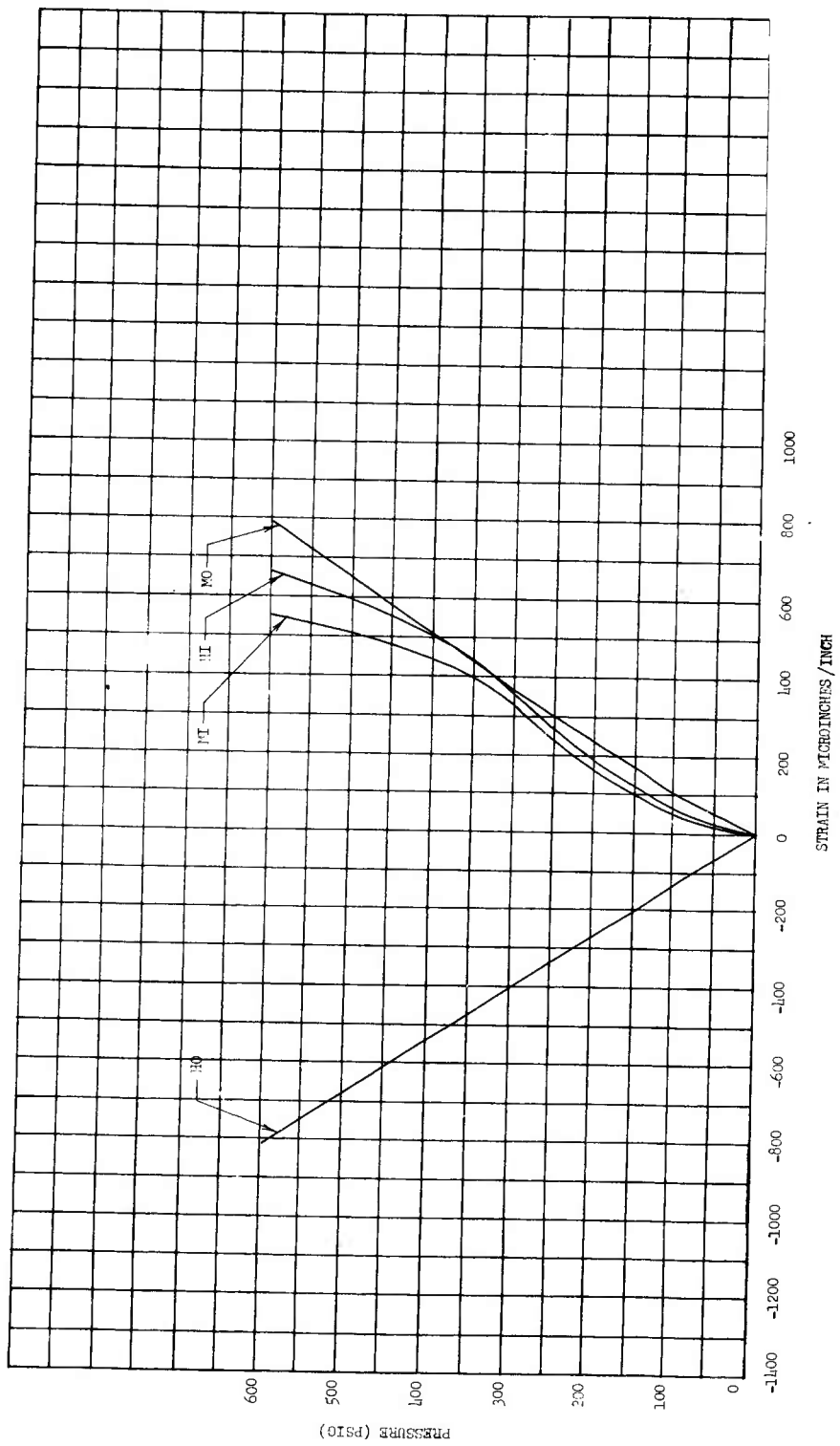


Figure 51

Pressure vs Strain, Gage Point 26

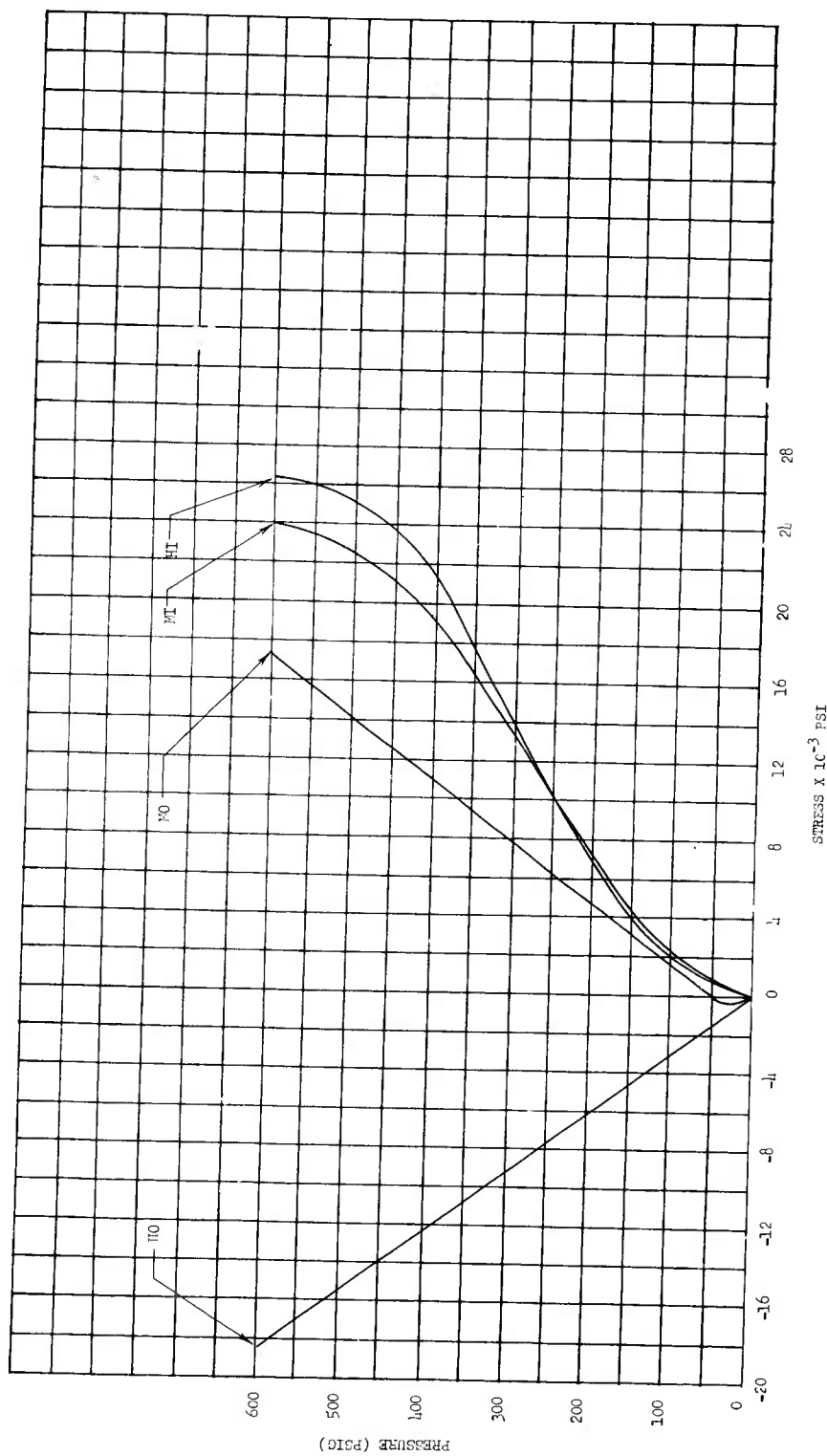


Figure 52

Pressure vs Stress, Gage Point 26

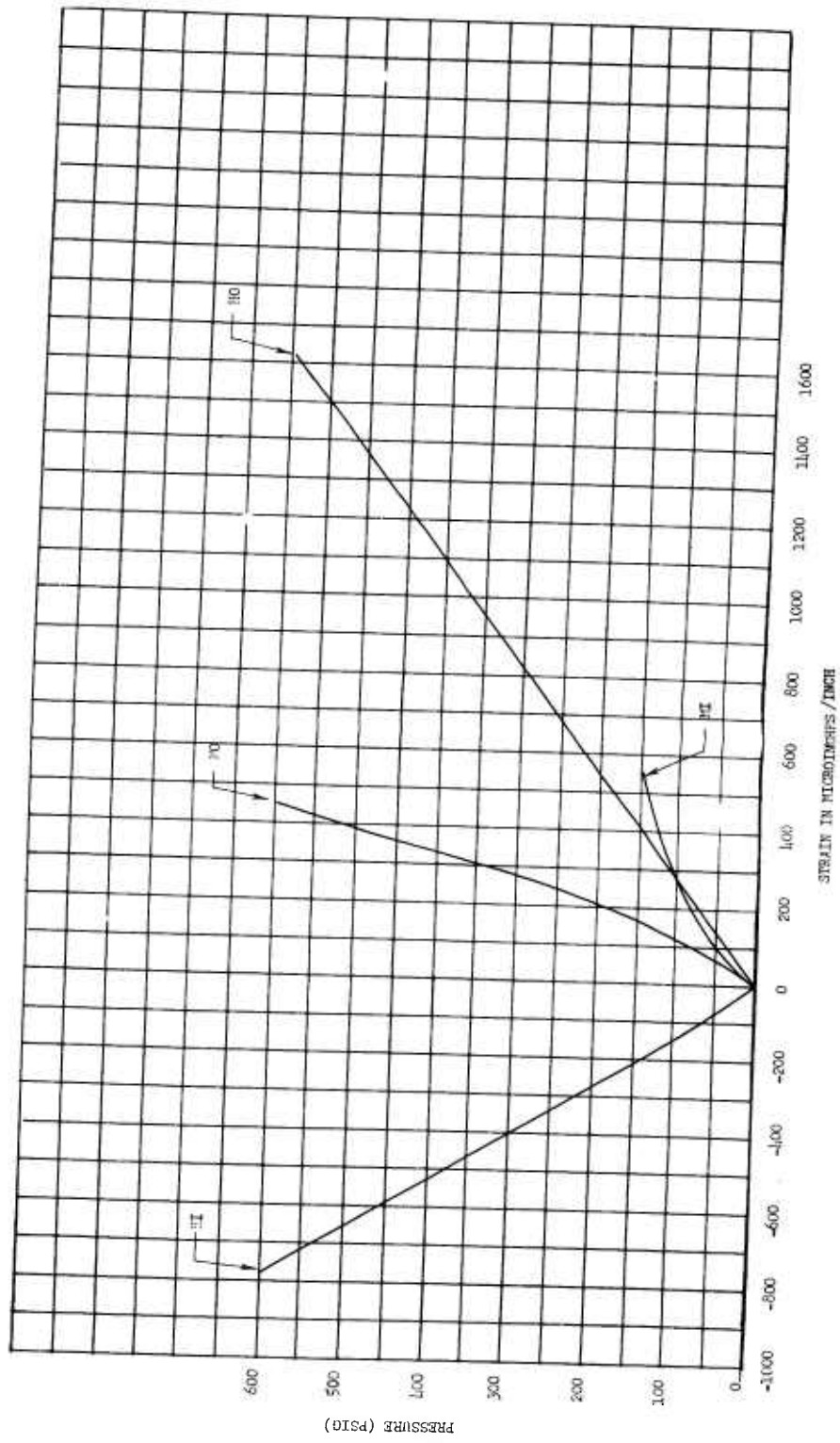


Figure 53

Pressure vs Strain, Gage Point 27

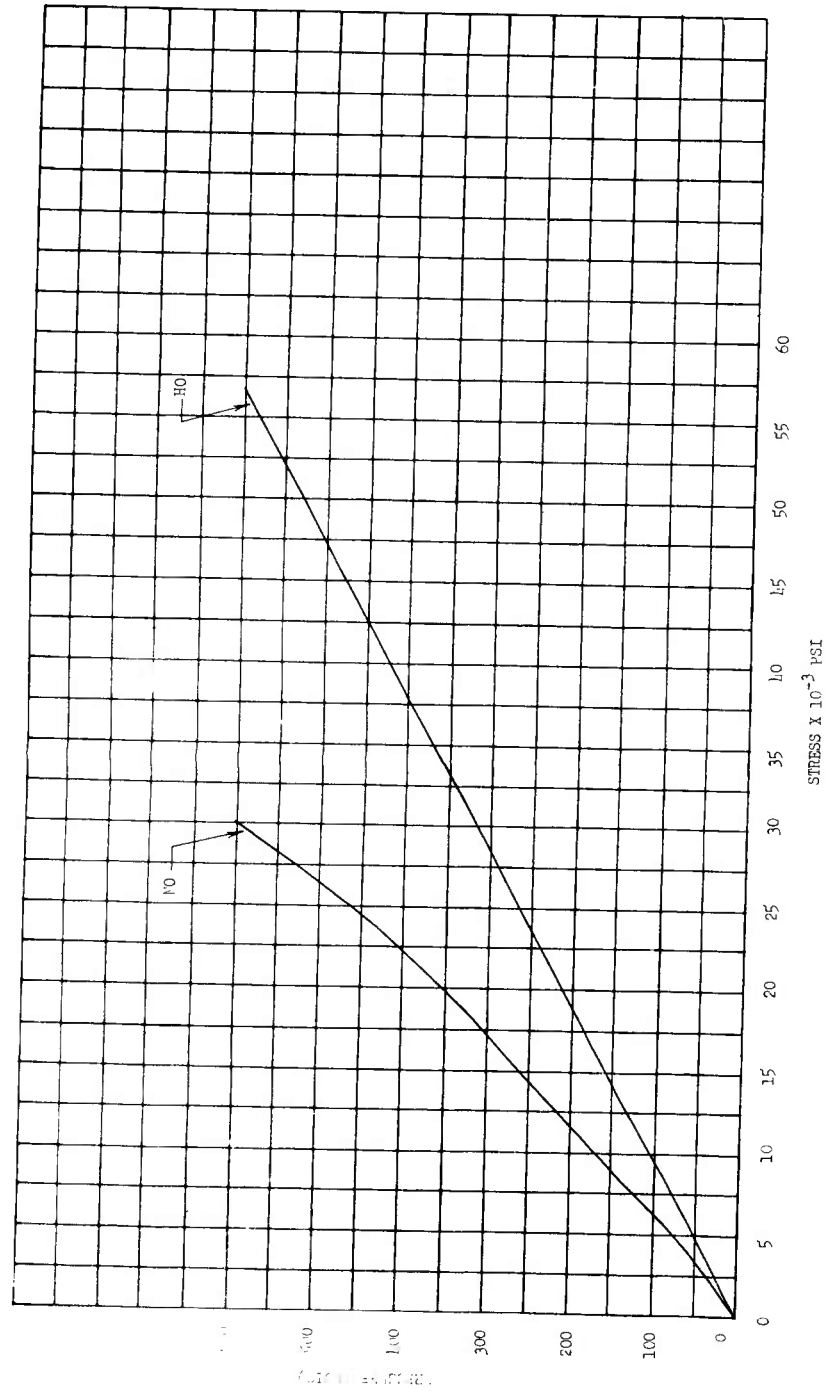
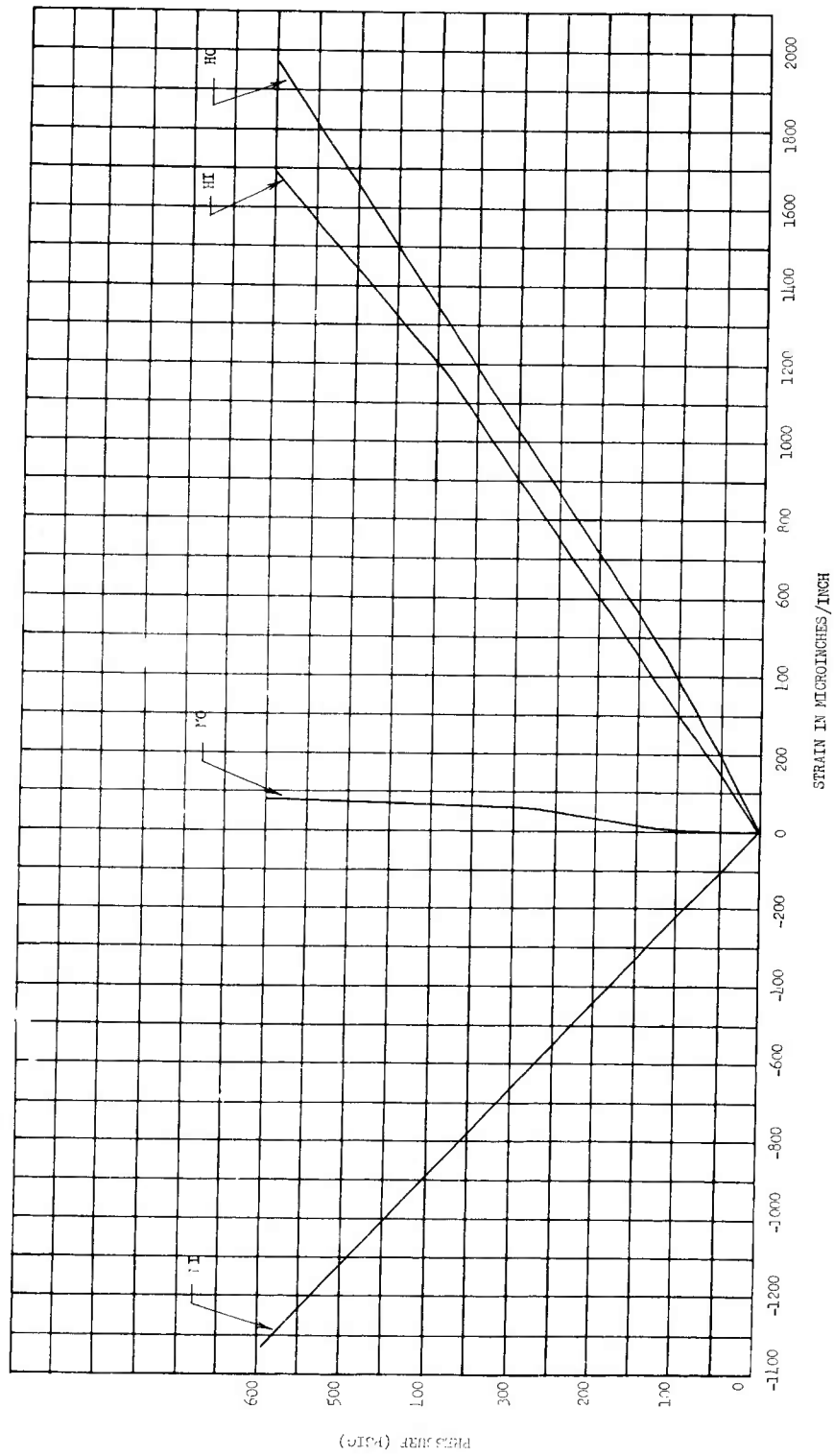


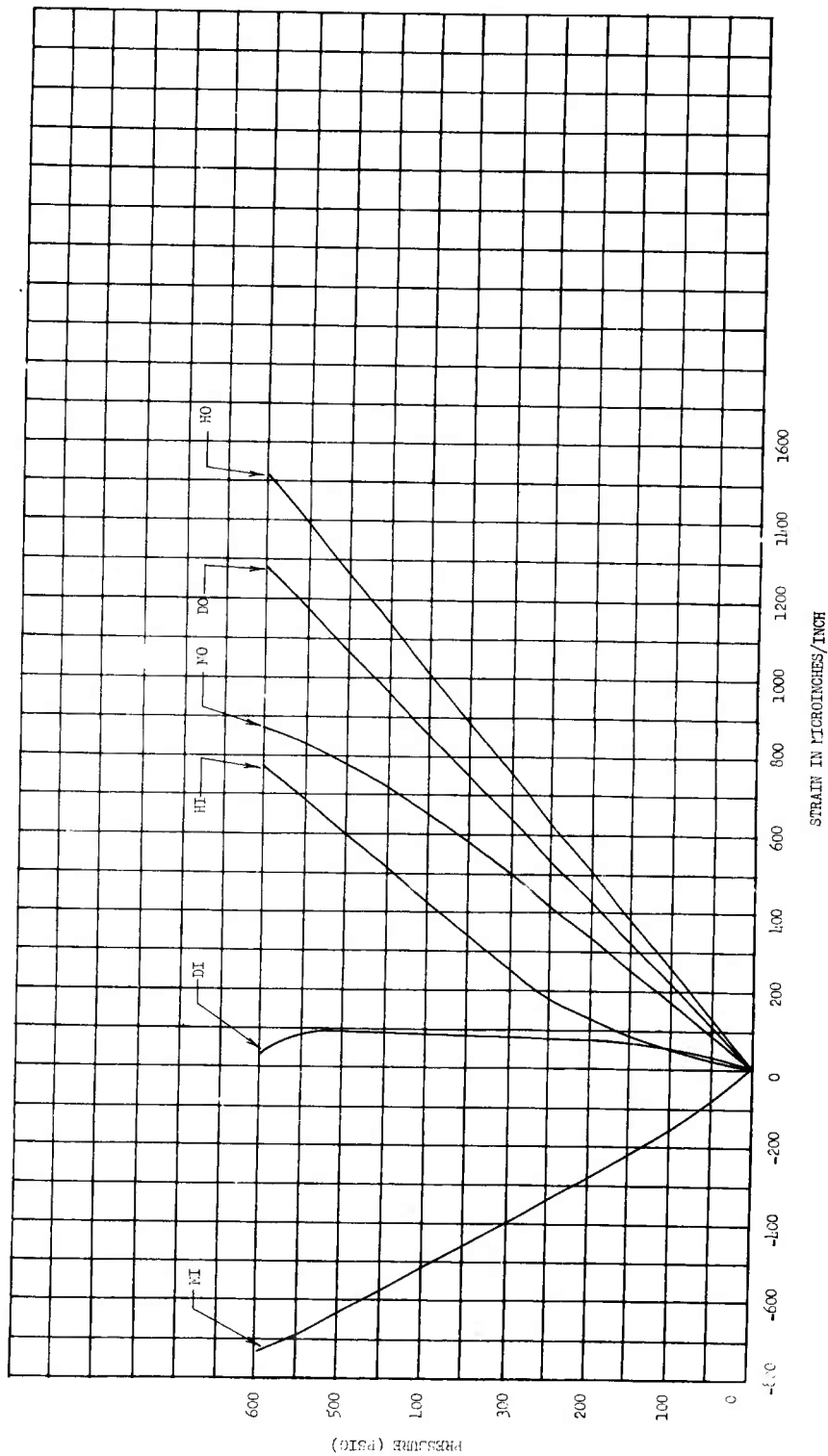
Figure 54

Pressure vs Stress, Gage Point 27



Pressure vs Strain, Gage Point 28

Figure 55



Pressure vs Stress, Gage Point 28

Figure 56

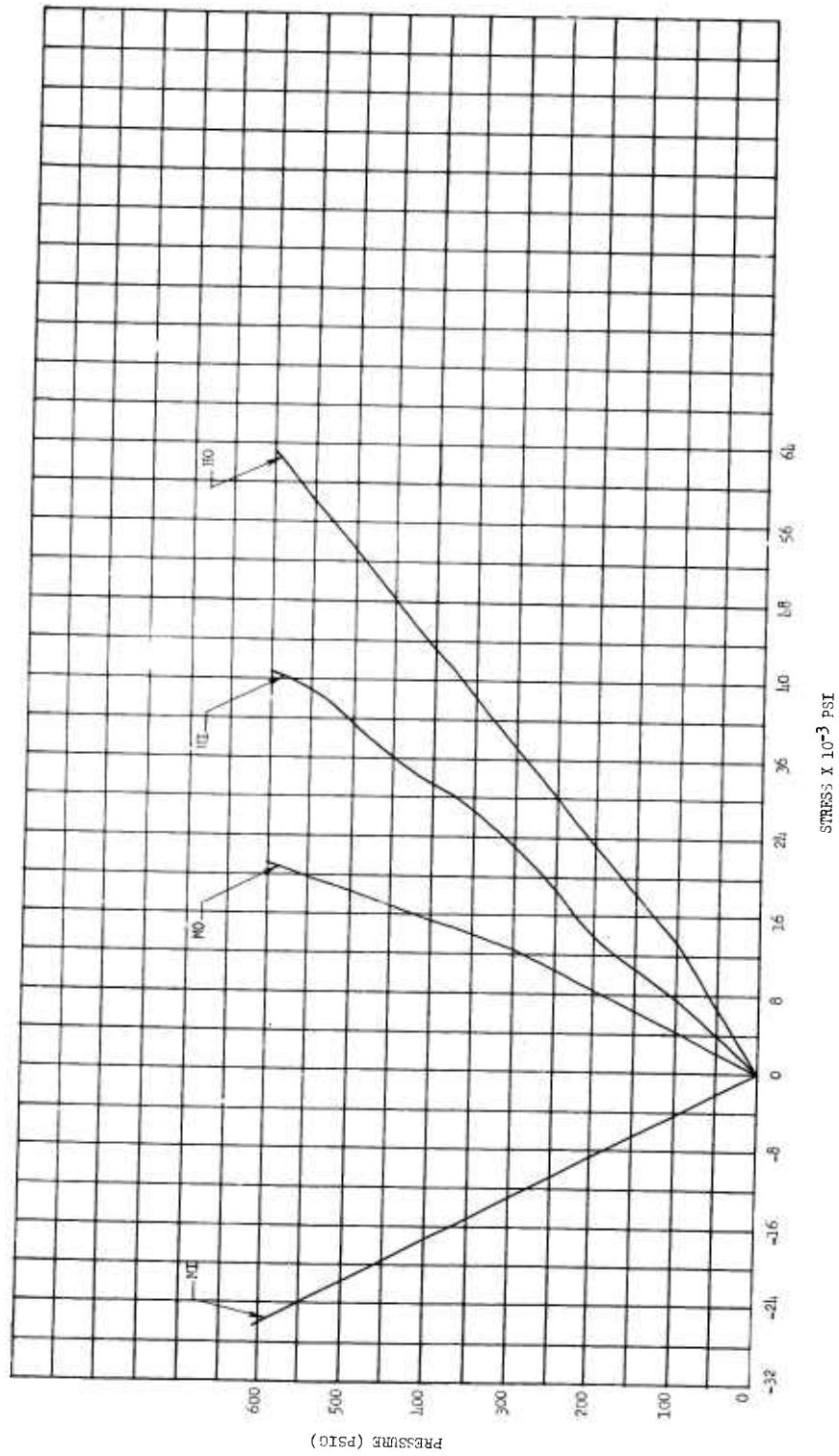


Figure 57

Pressure vs Strain, Gage Point 29

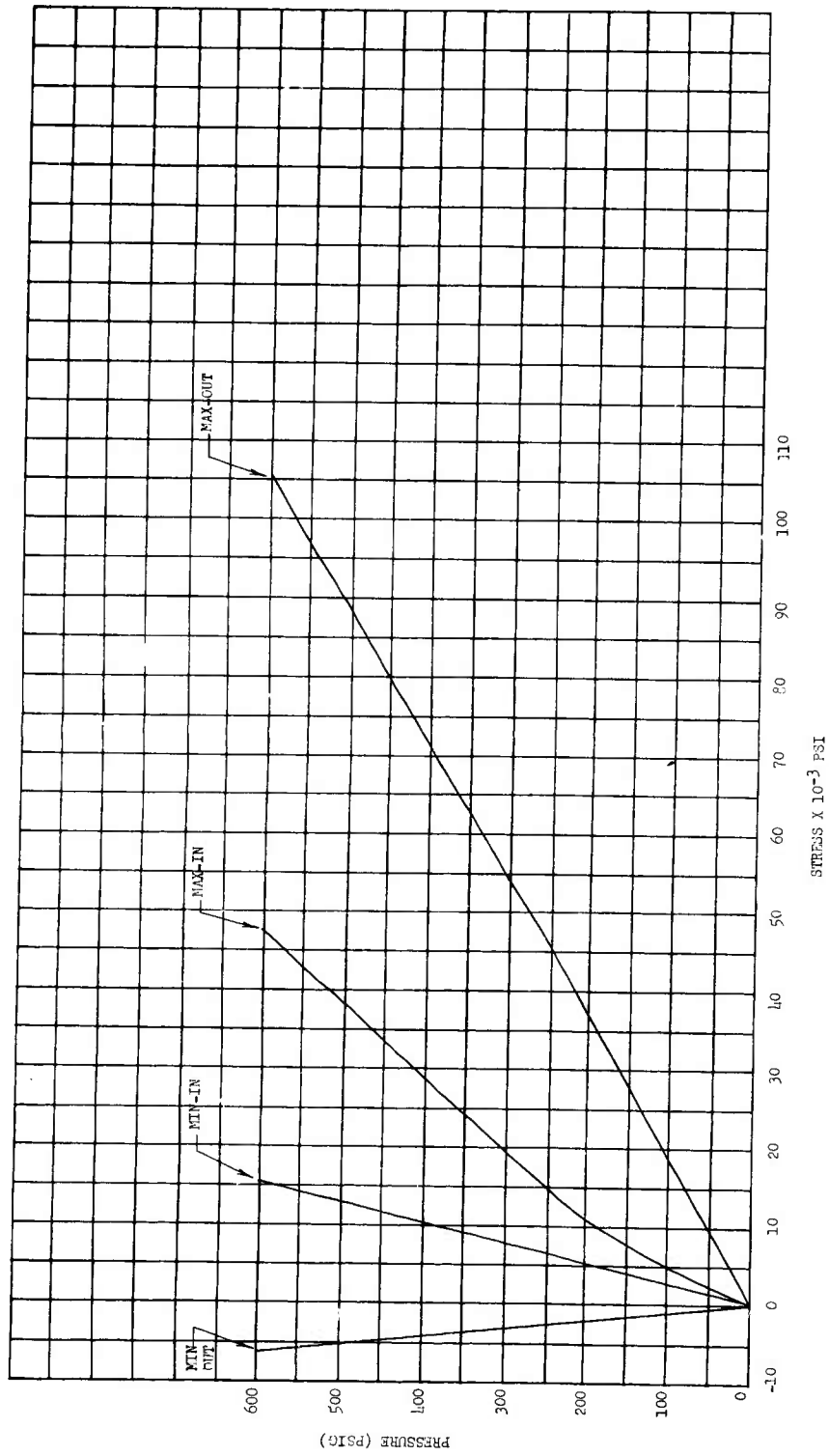


Figure 58

Pressure vs Stress, Gage Point 29

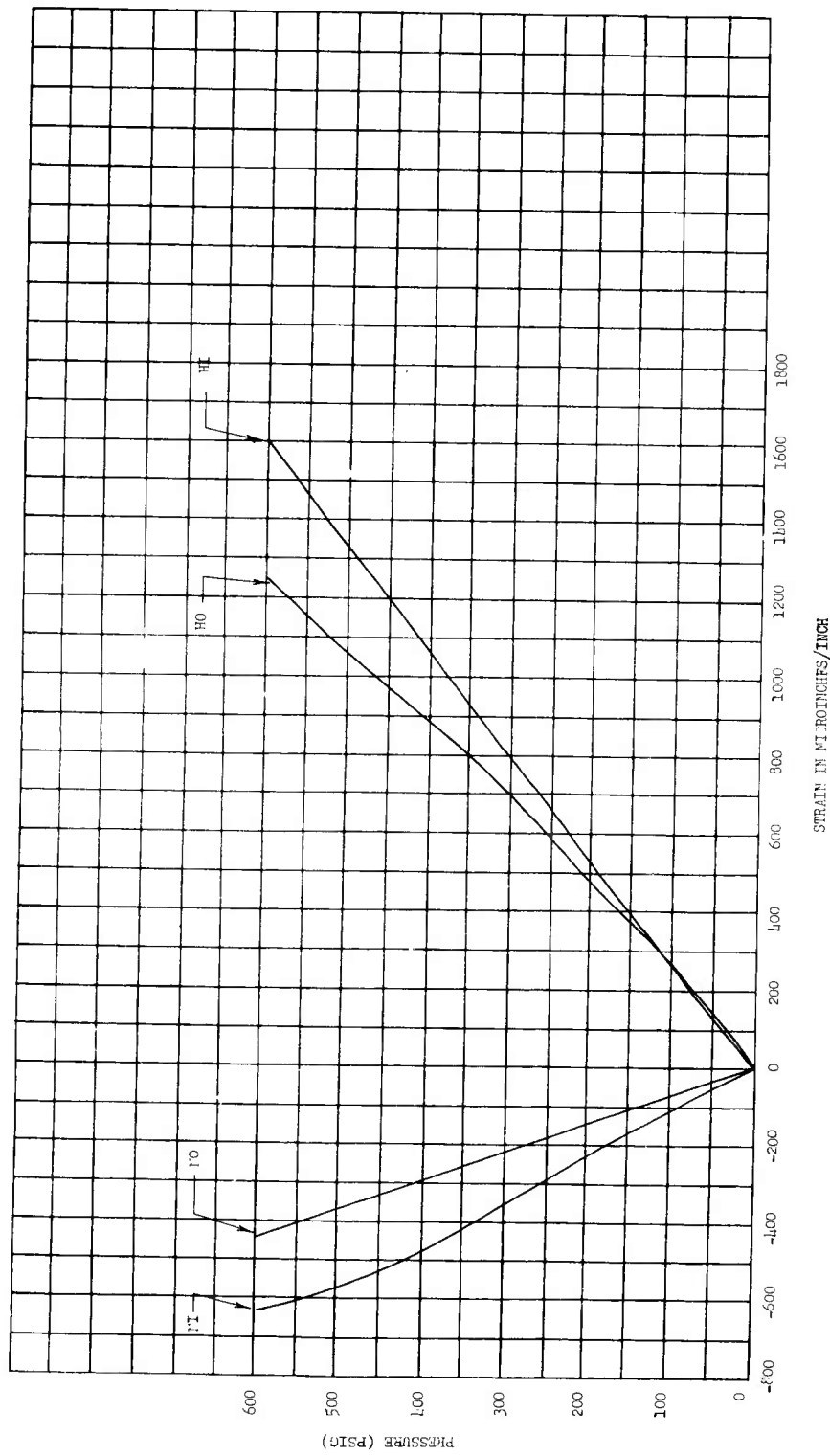
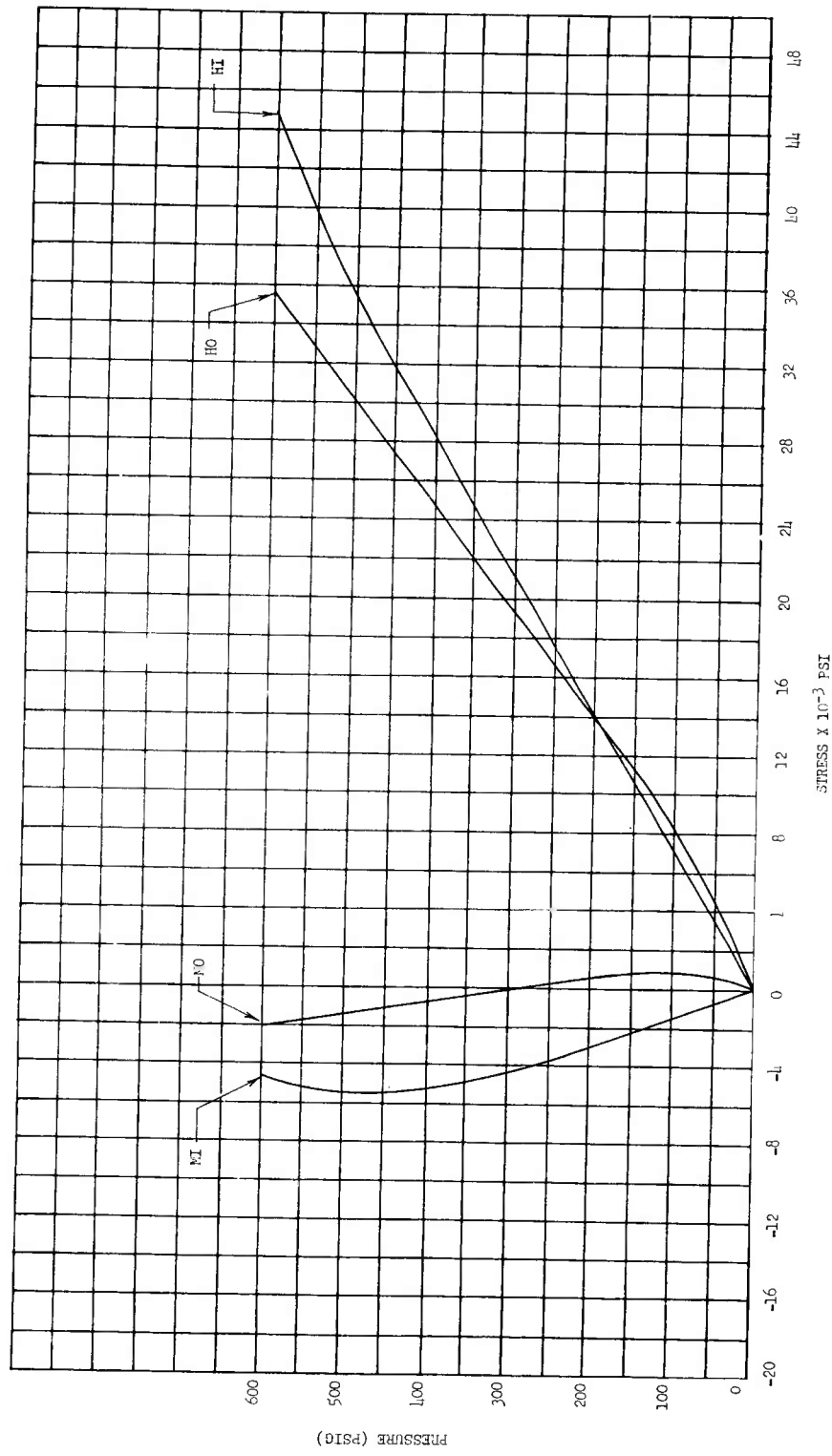


Figure 59

Pressure vs Strain, Gage Point 30



Pressure vs Stress, Gage Point 30

Figure 60

Appendix A

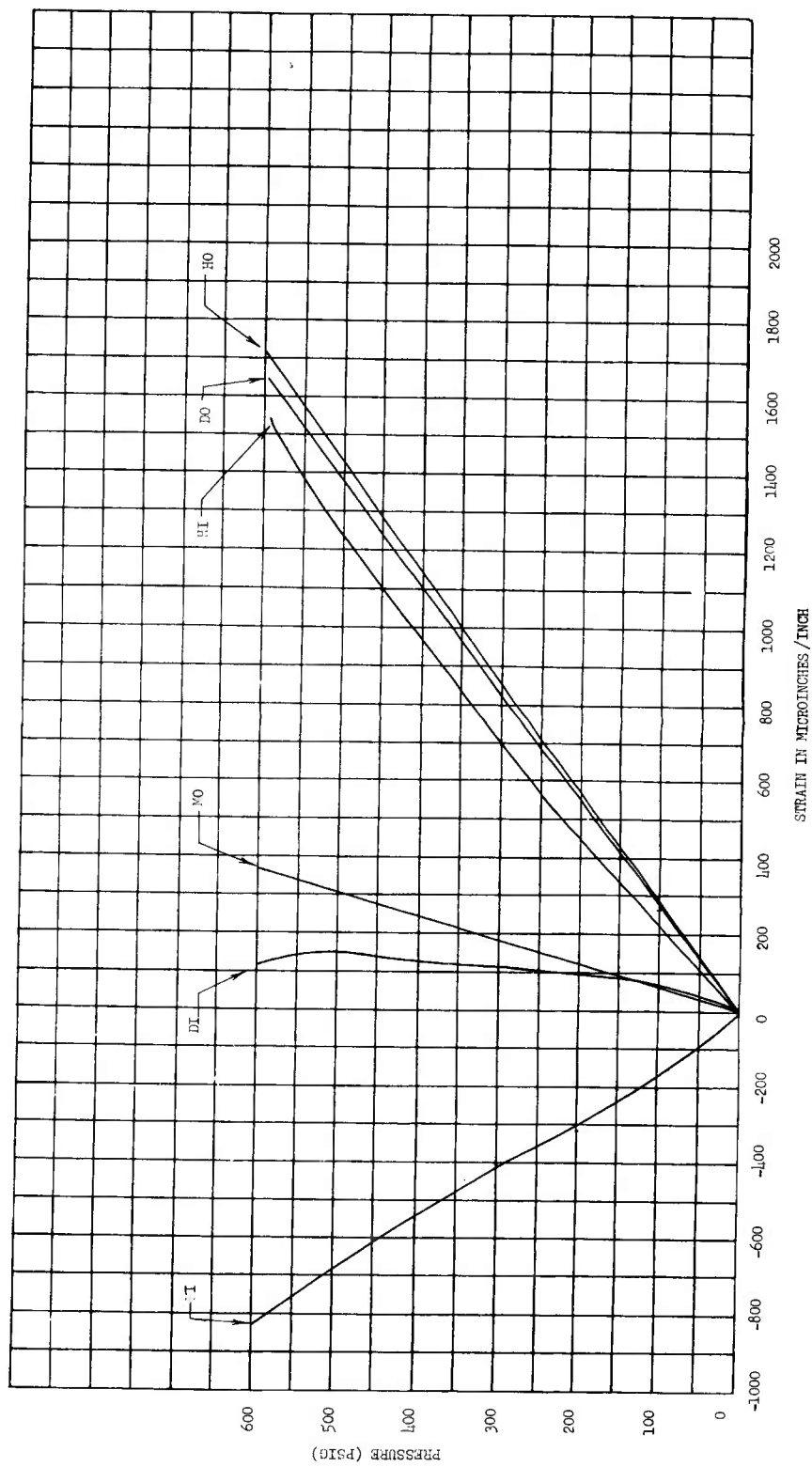
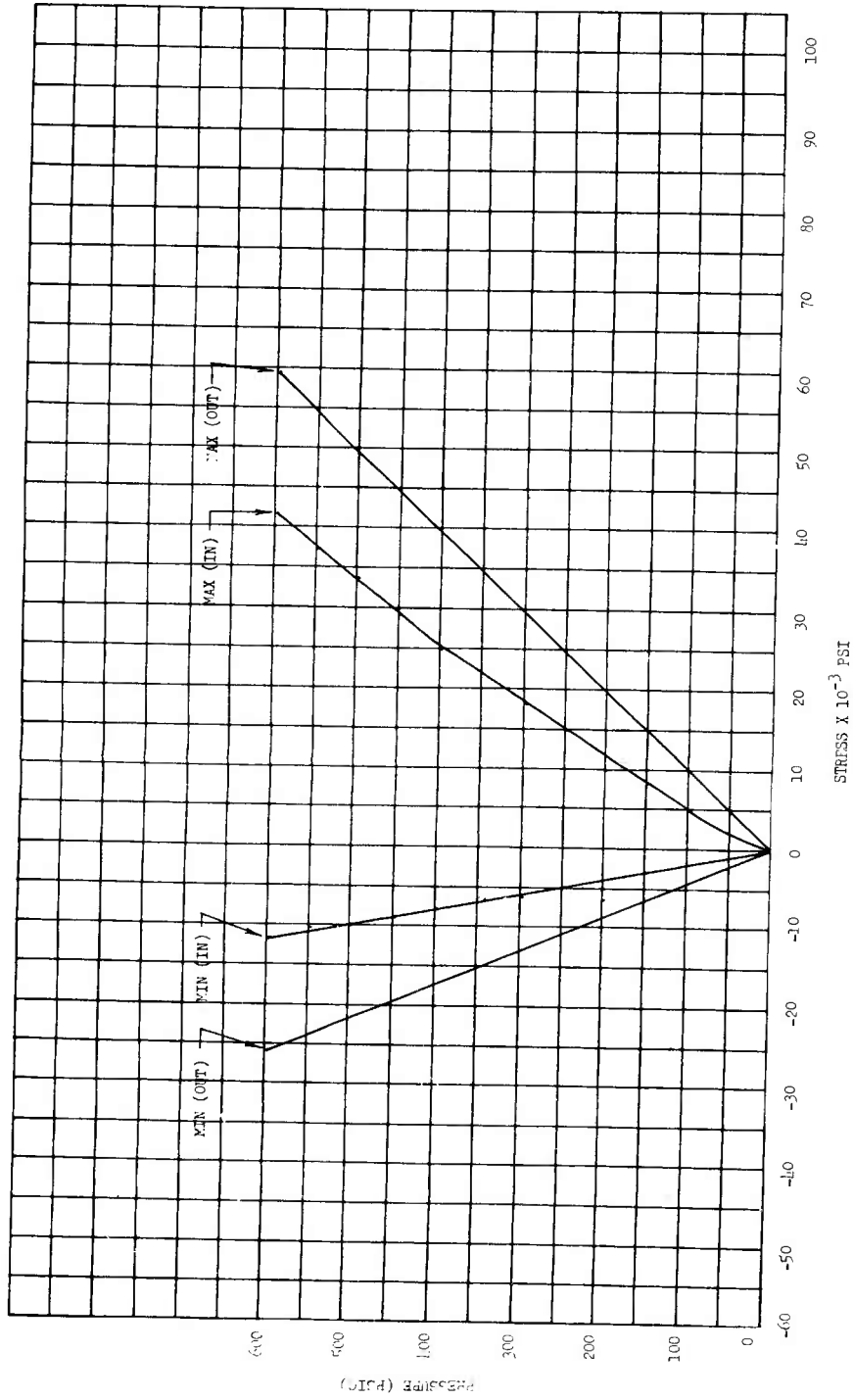


Figure 61

Pressure vs Strain, Gage Point 31

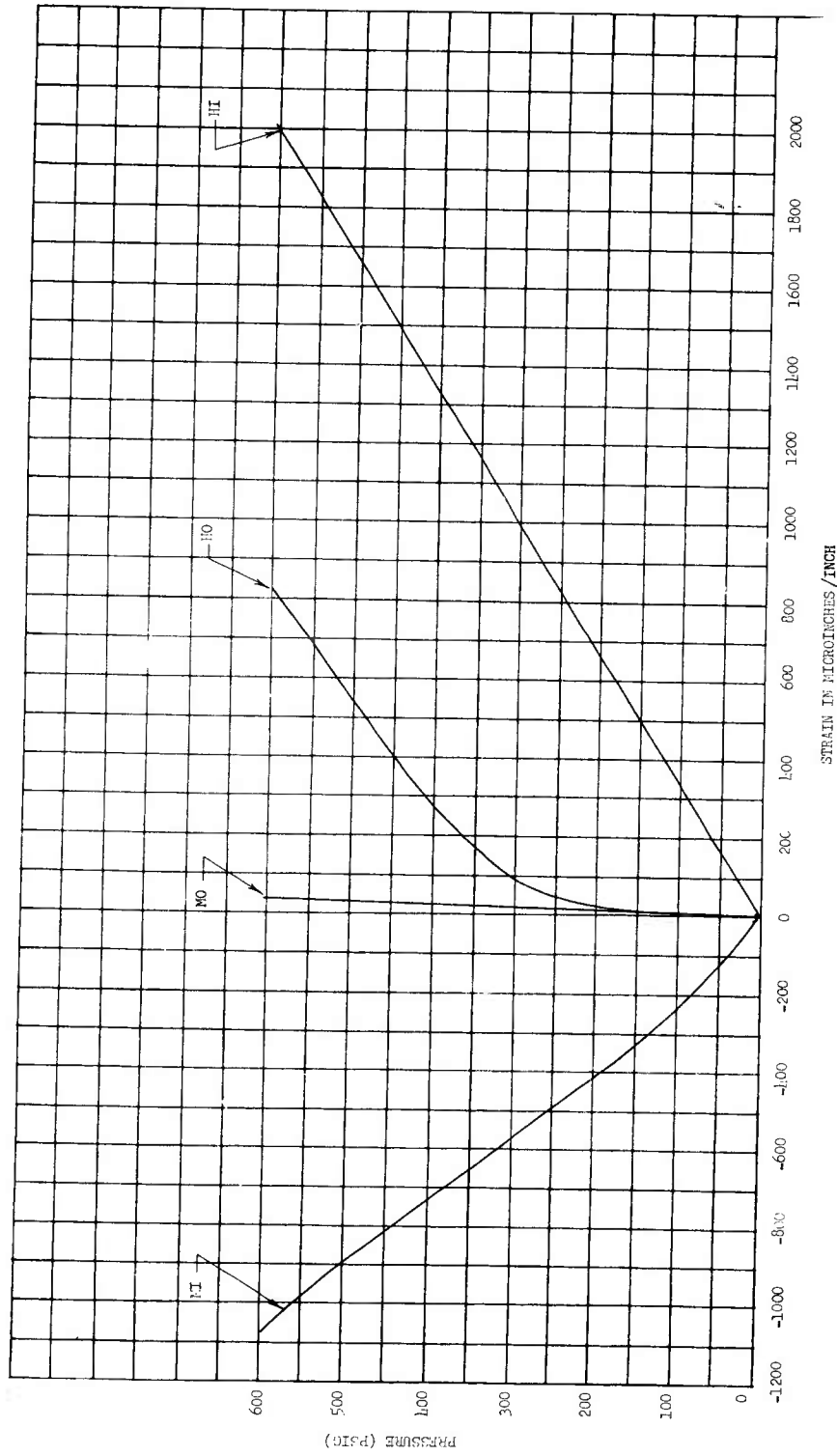
Appendix A



Pressure vs Stress, Gage Point 31

Figure 62

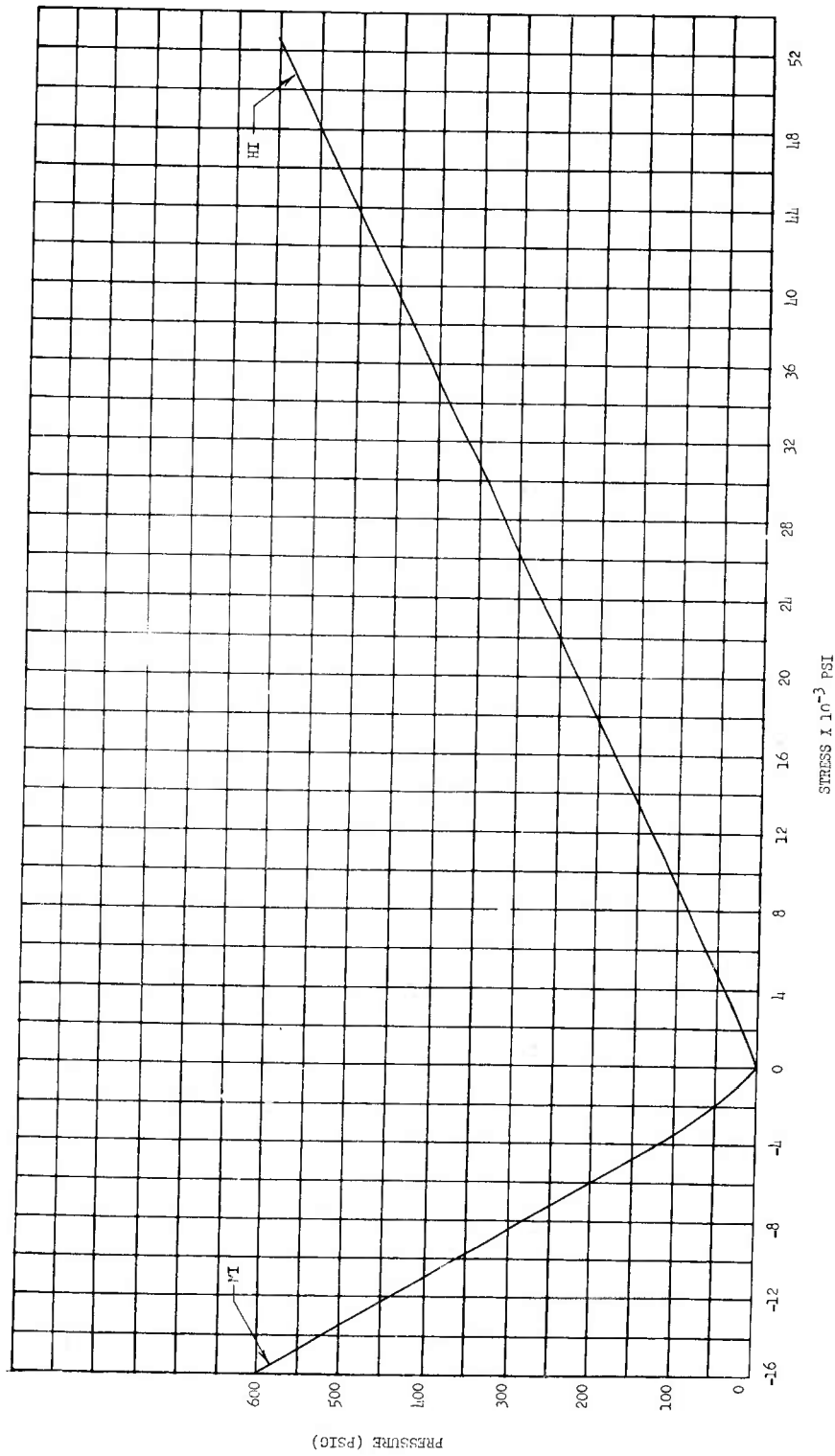
Appendix A



Pressure vs Strain, Gage Point 32

Figure 63

Appendix A



Pressure vs Stress, Gage Point 32

Figure 64

Appendix A

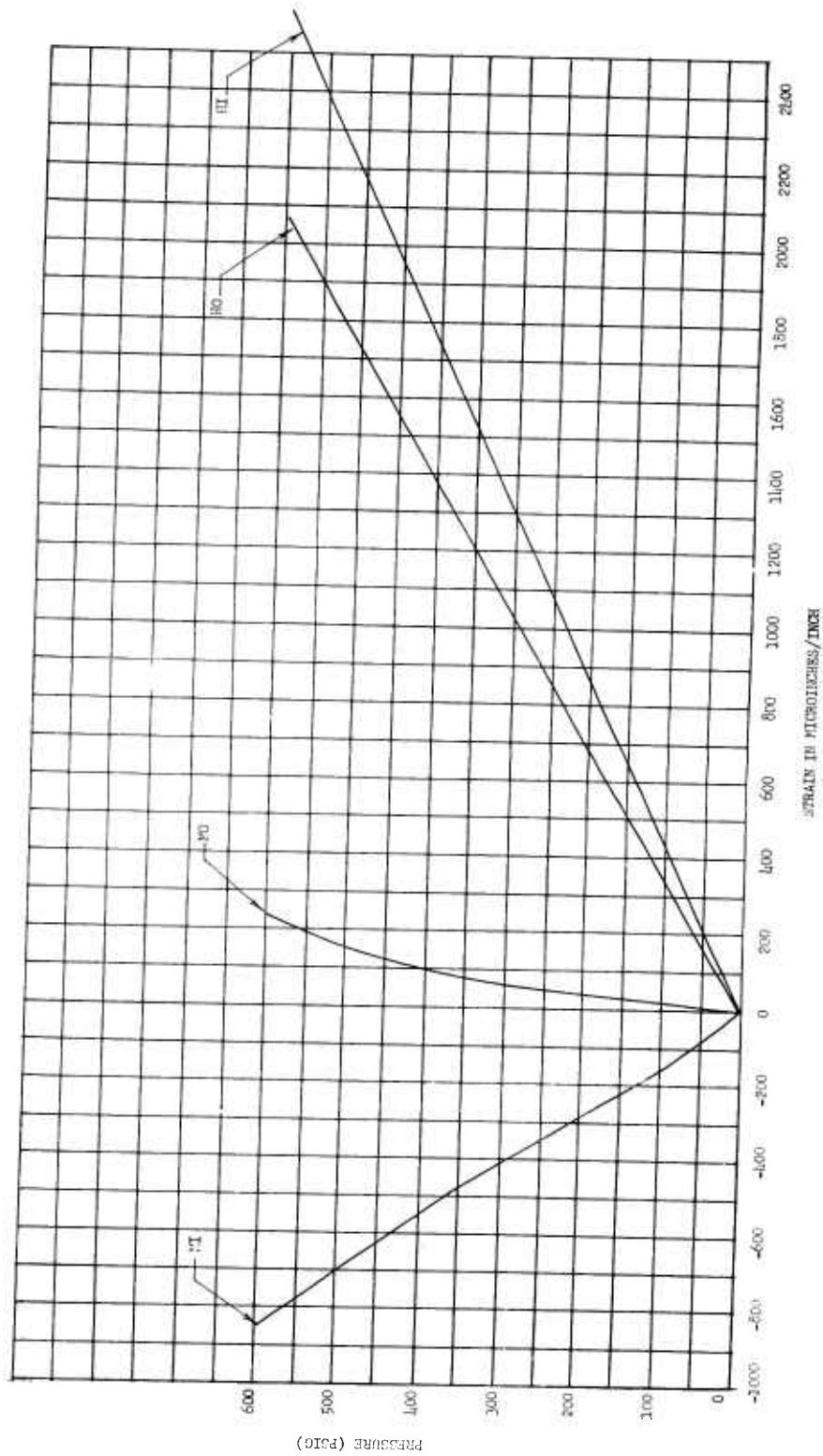


Figure 65

Pressure vs Strain, Gage Point 33

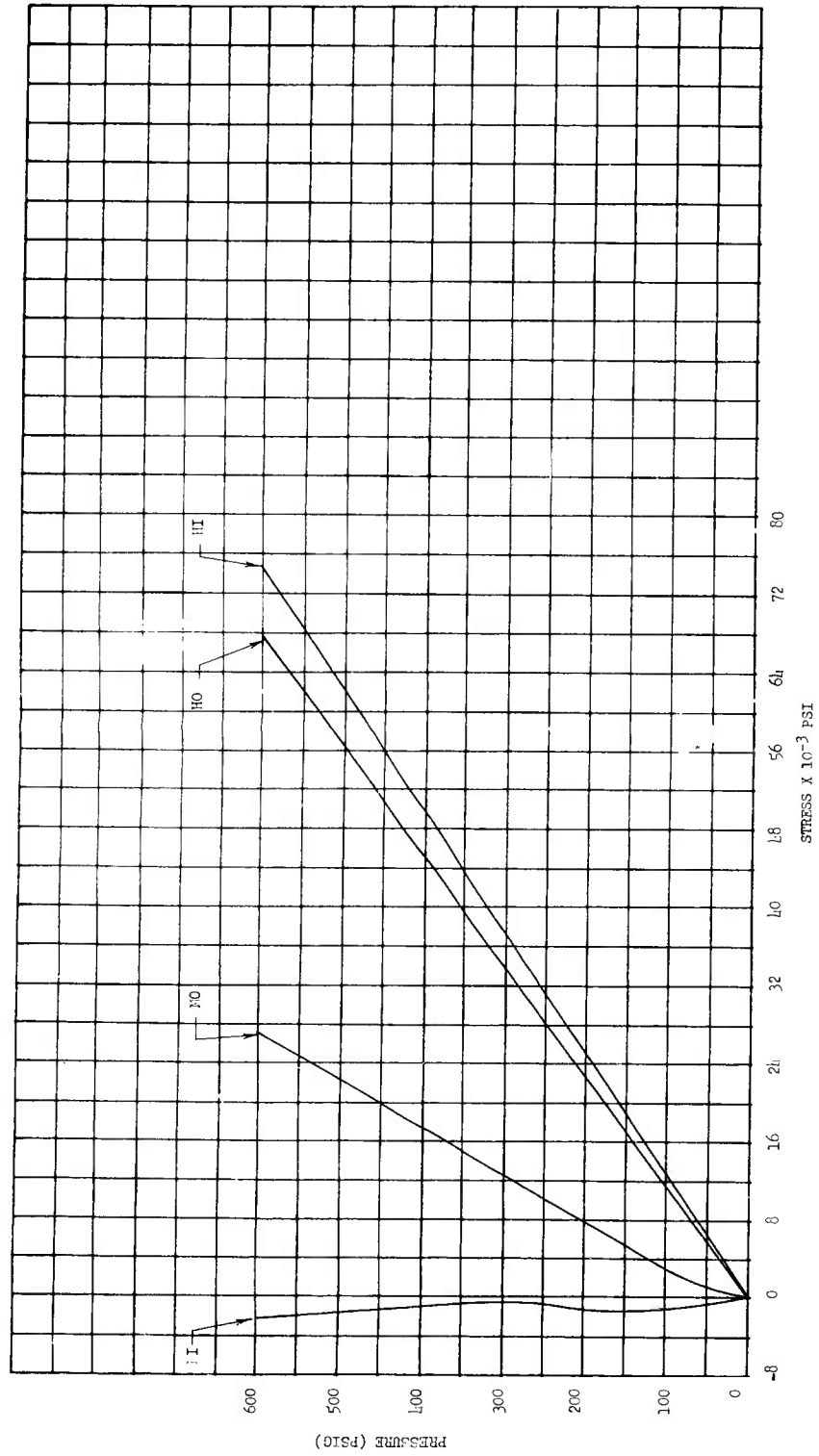
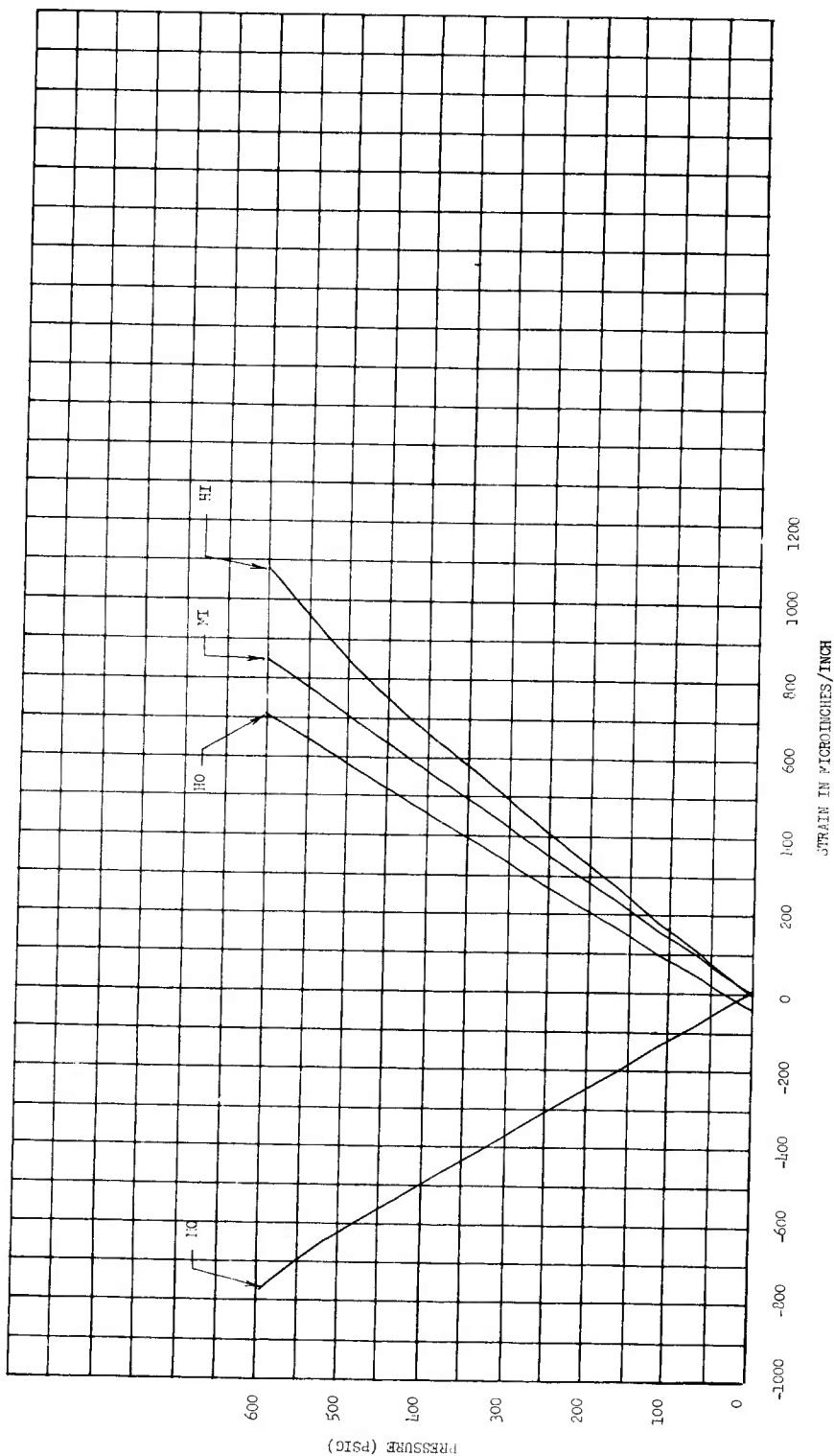


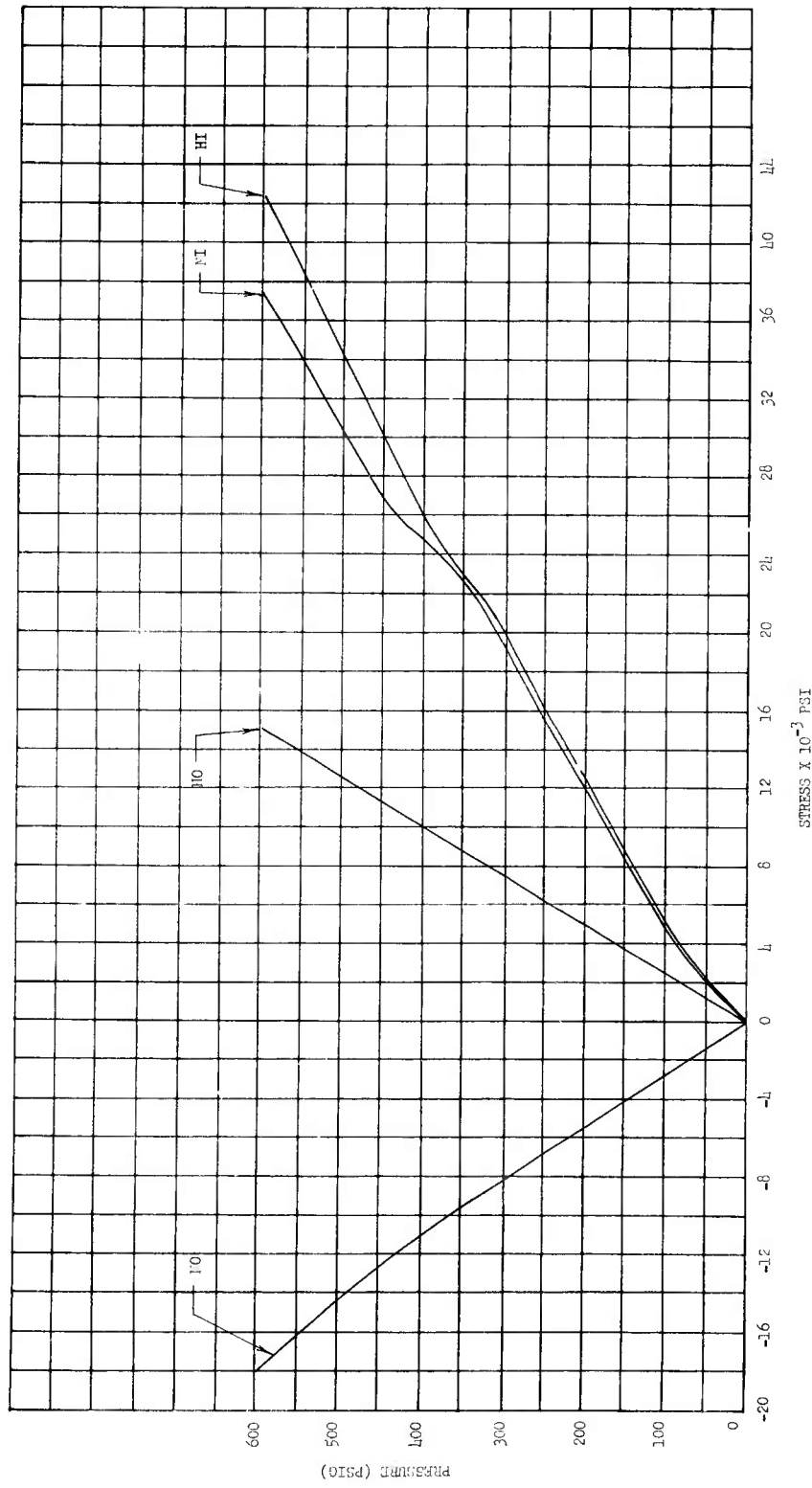
Figure 66

Pressure vs Stress, Gage Point 33



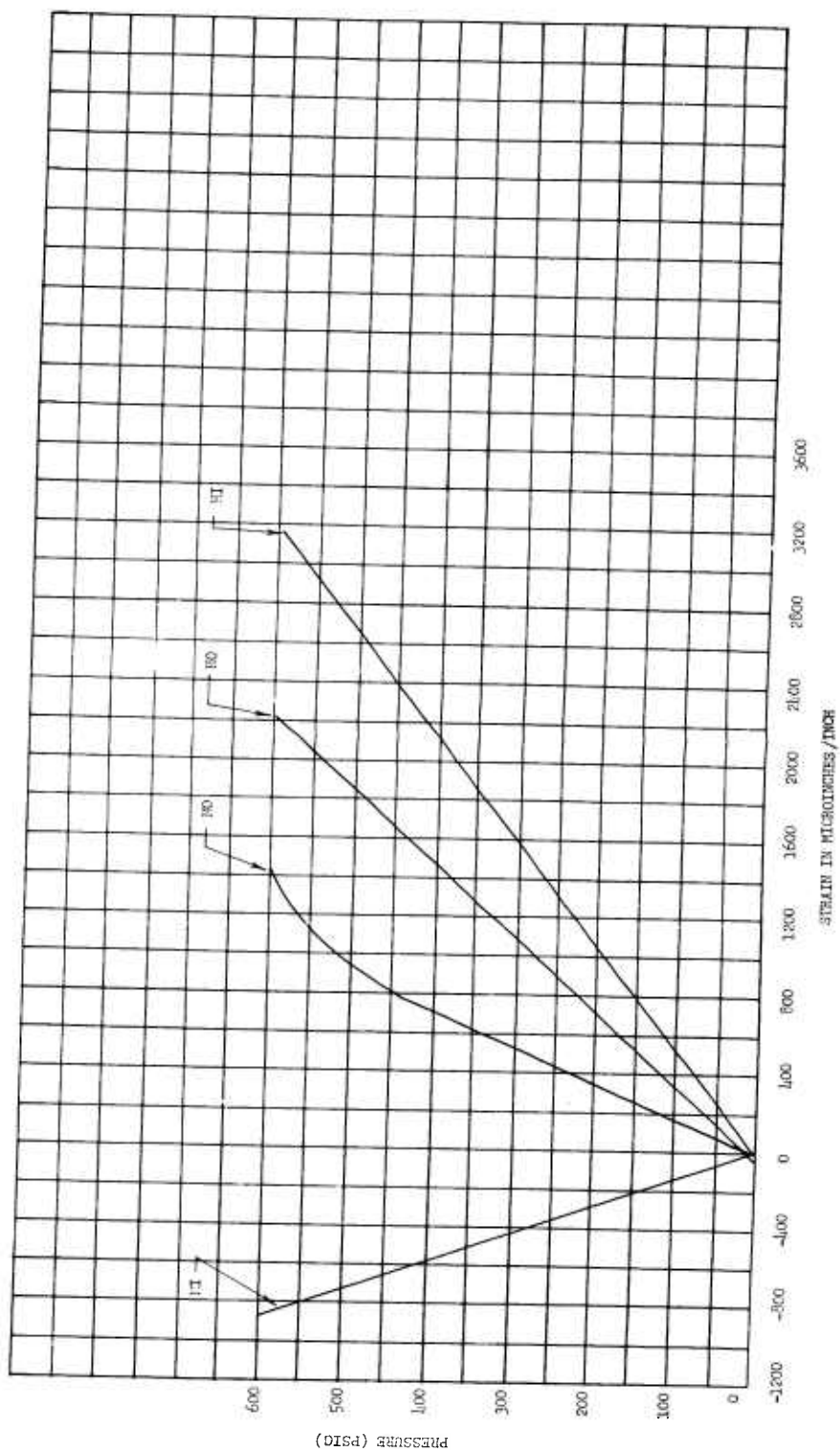
Pressure vs Strain, Gage Point 34

Figure 67



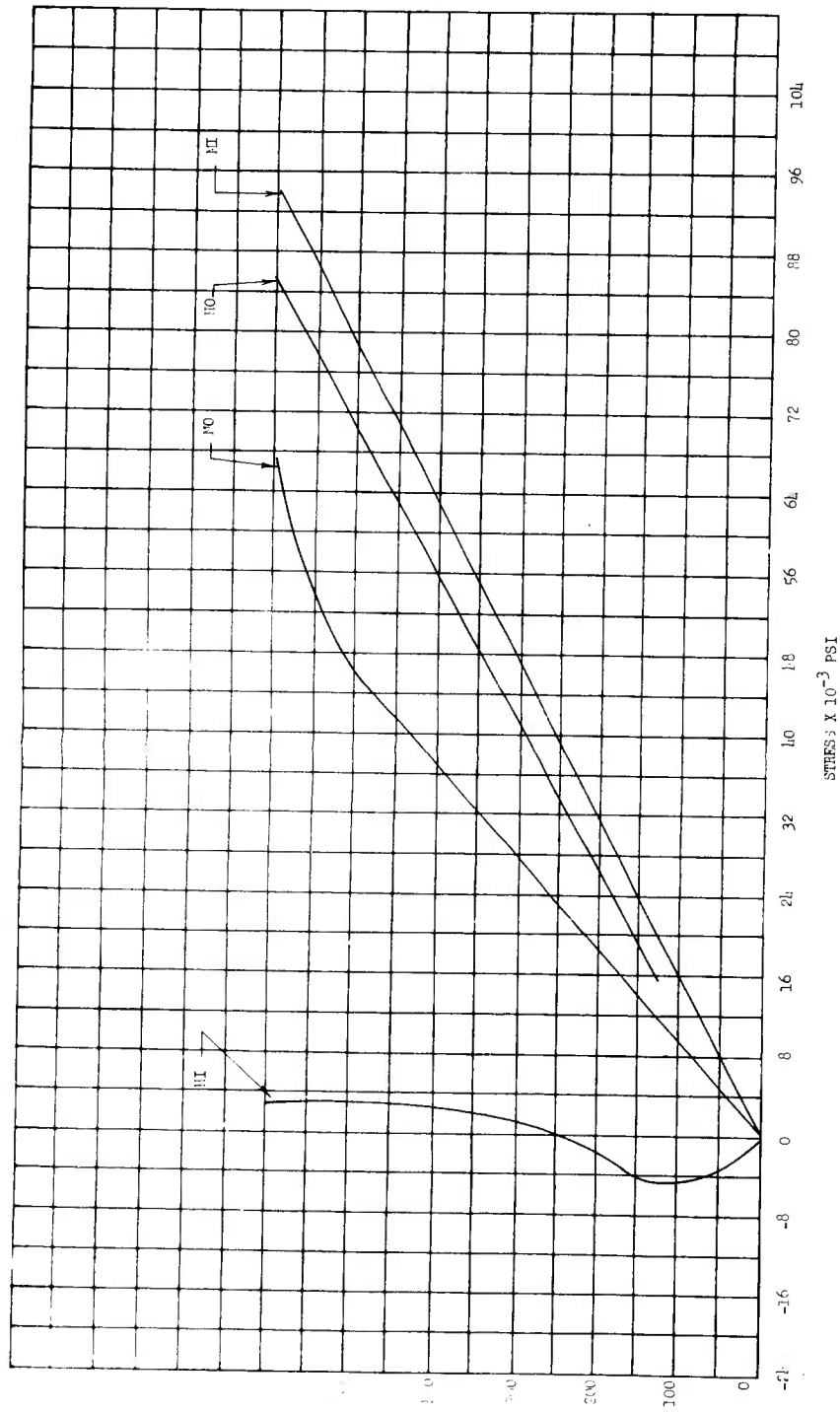
Pressure vs Stress, Gage Point 34

Figure 68



Pressure vs Strain, Gage Point 35

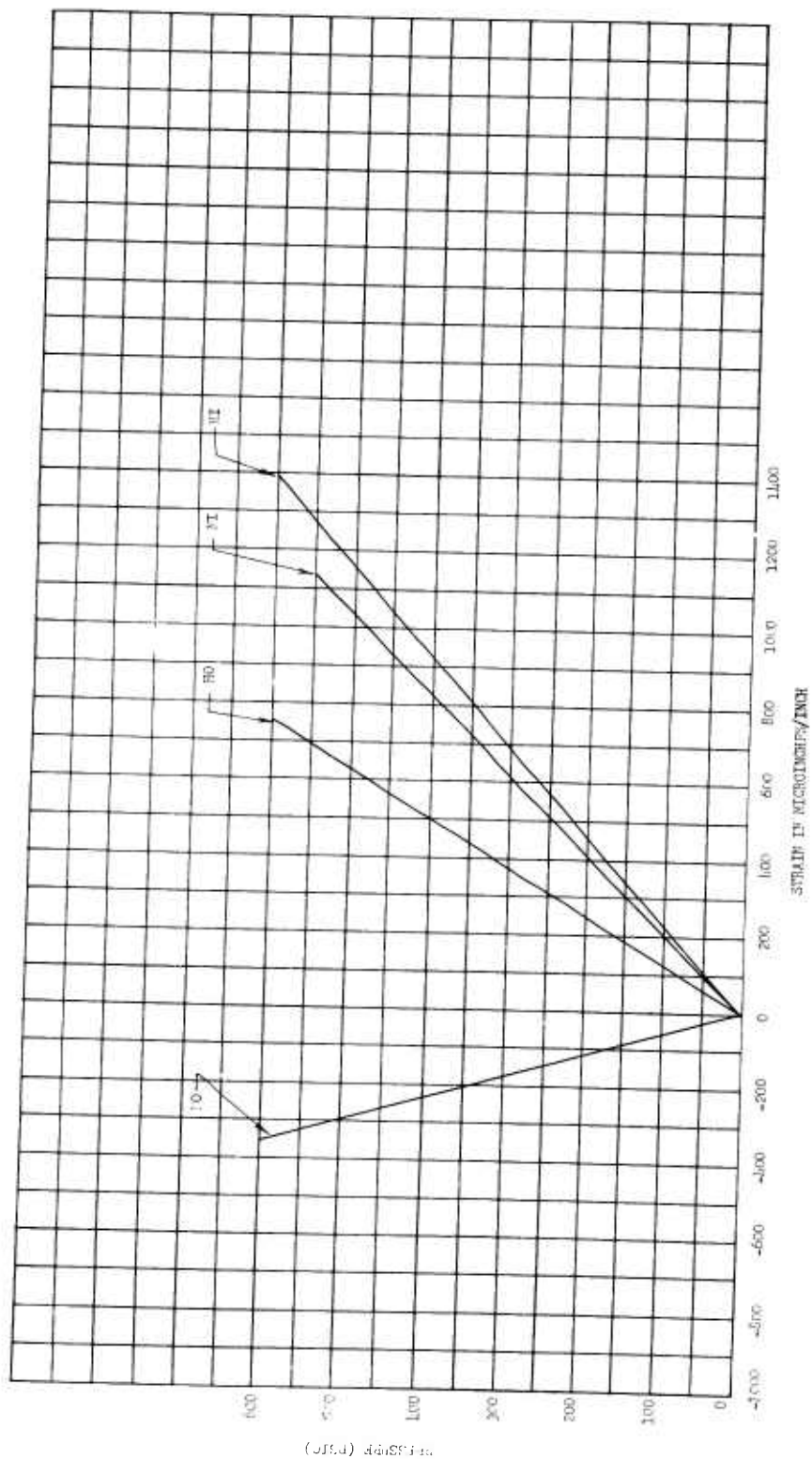
Figure 69



Pressure vs Stress, Gage Point 35

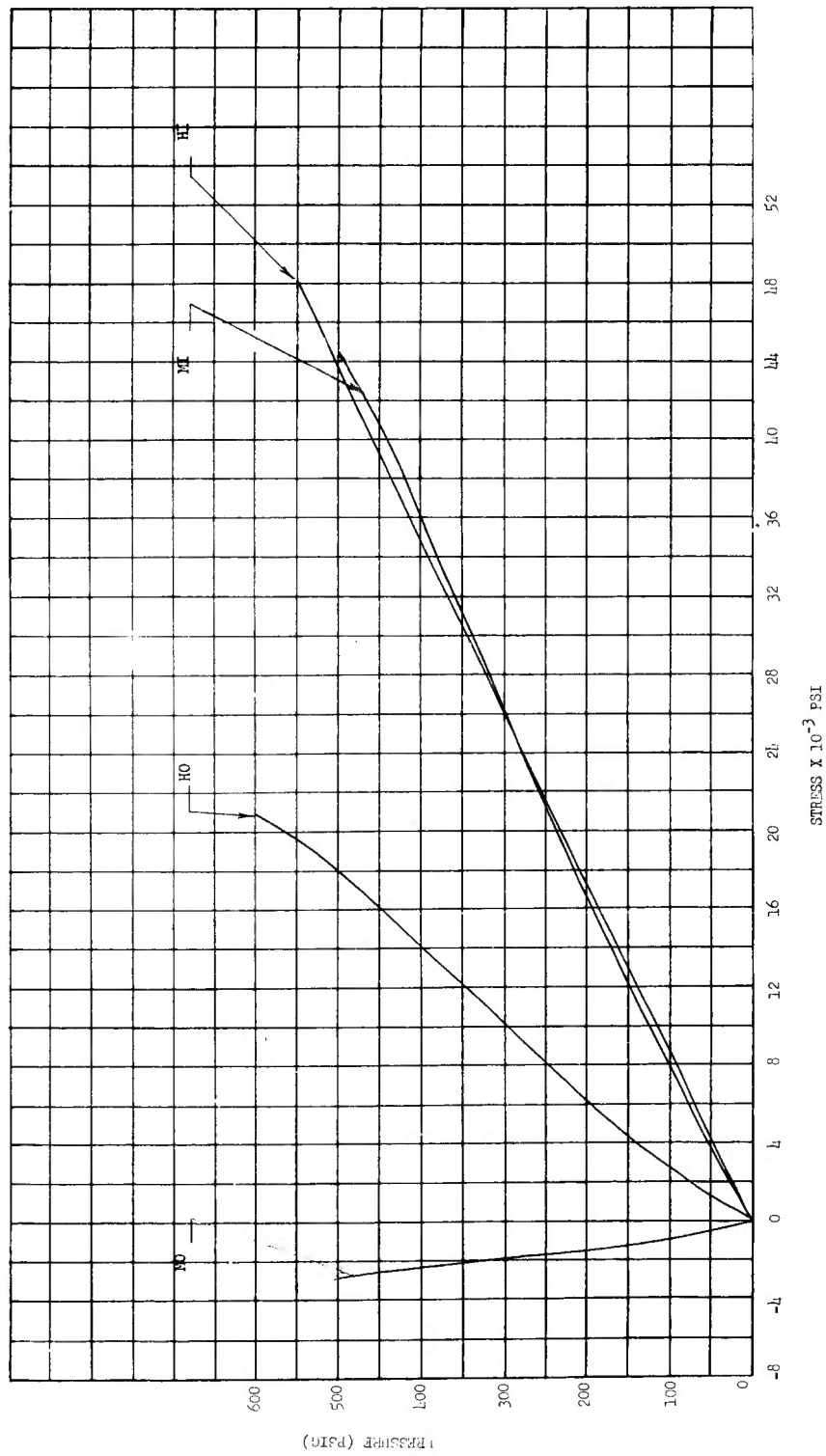
Figure 70

Appendix A



Pressure vs Strain, Gage Point 36

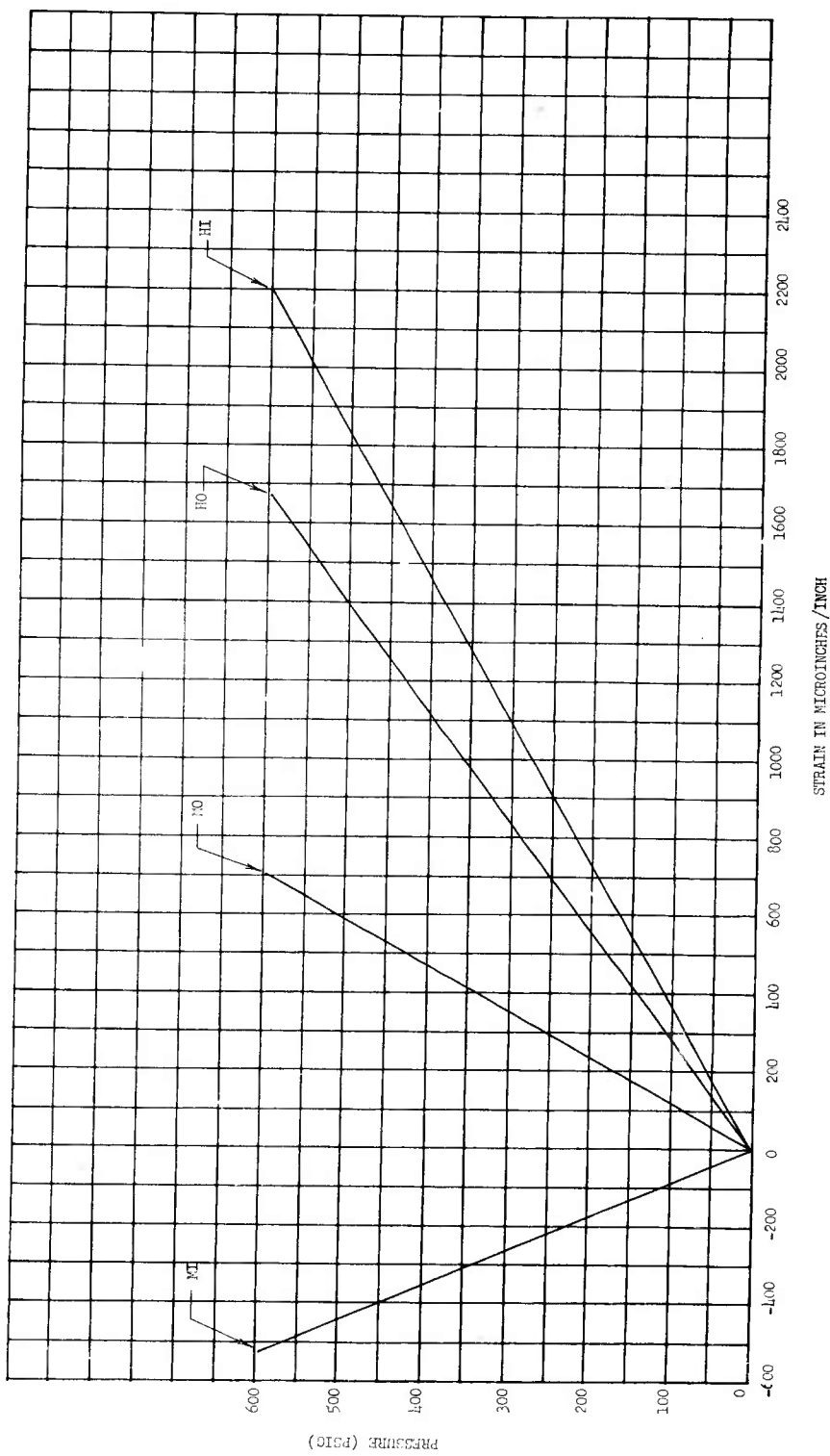
Figure 71



Pressure vs Stress, Gage Point 36

Figure 72

Appendix A



Pressure vs Strain, Gage Point 37

Figure 73

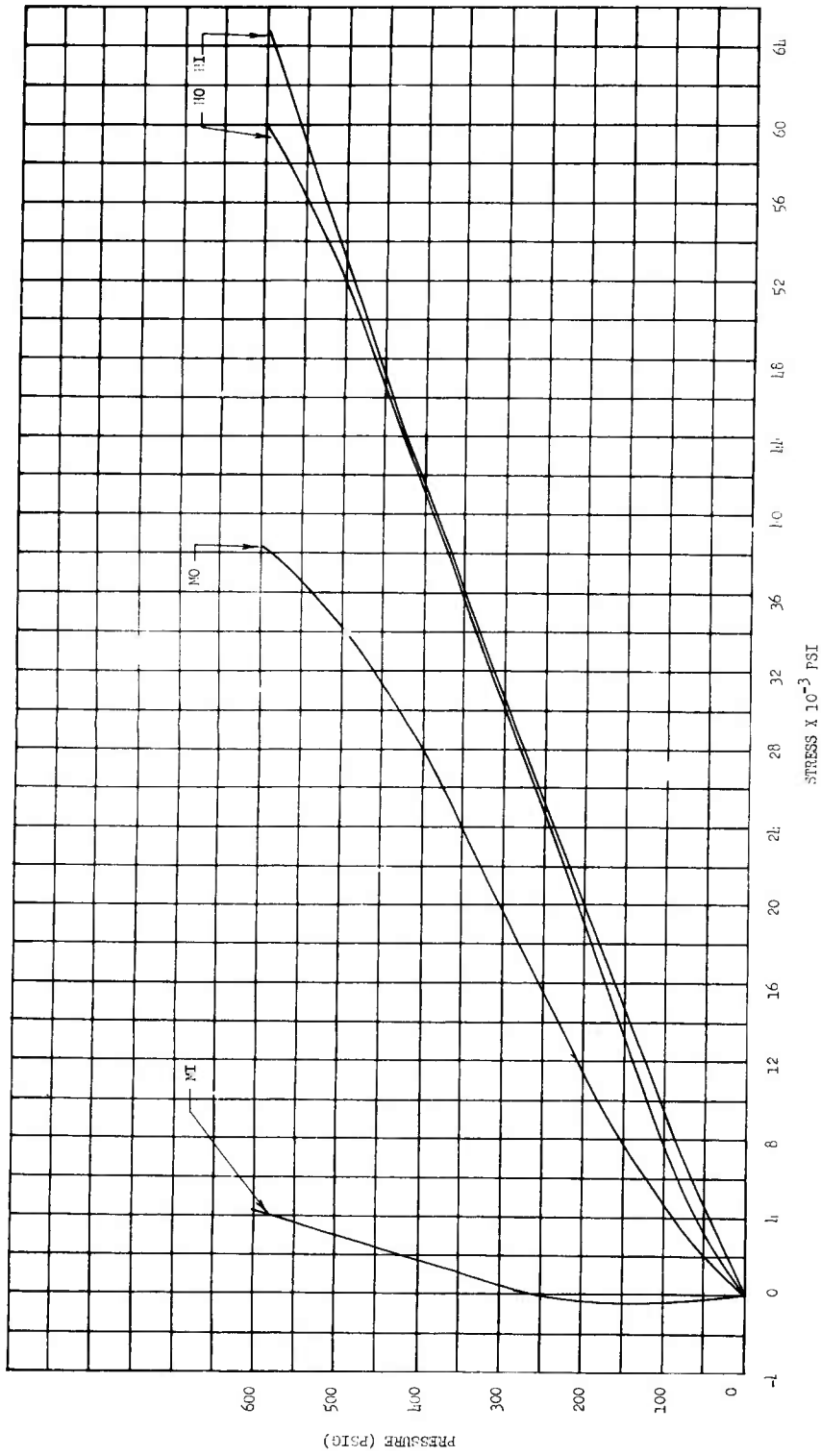
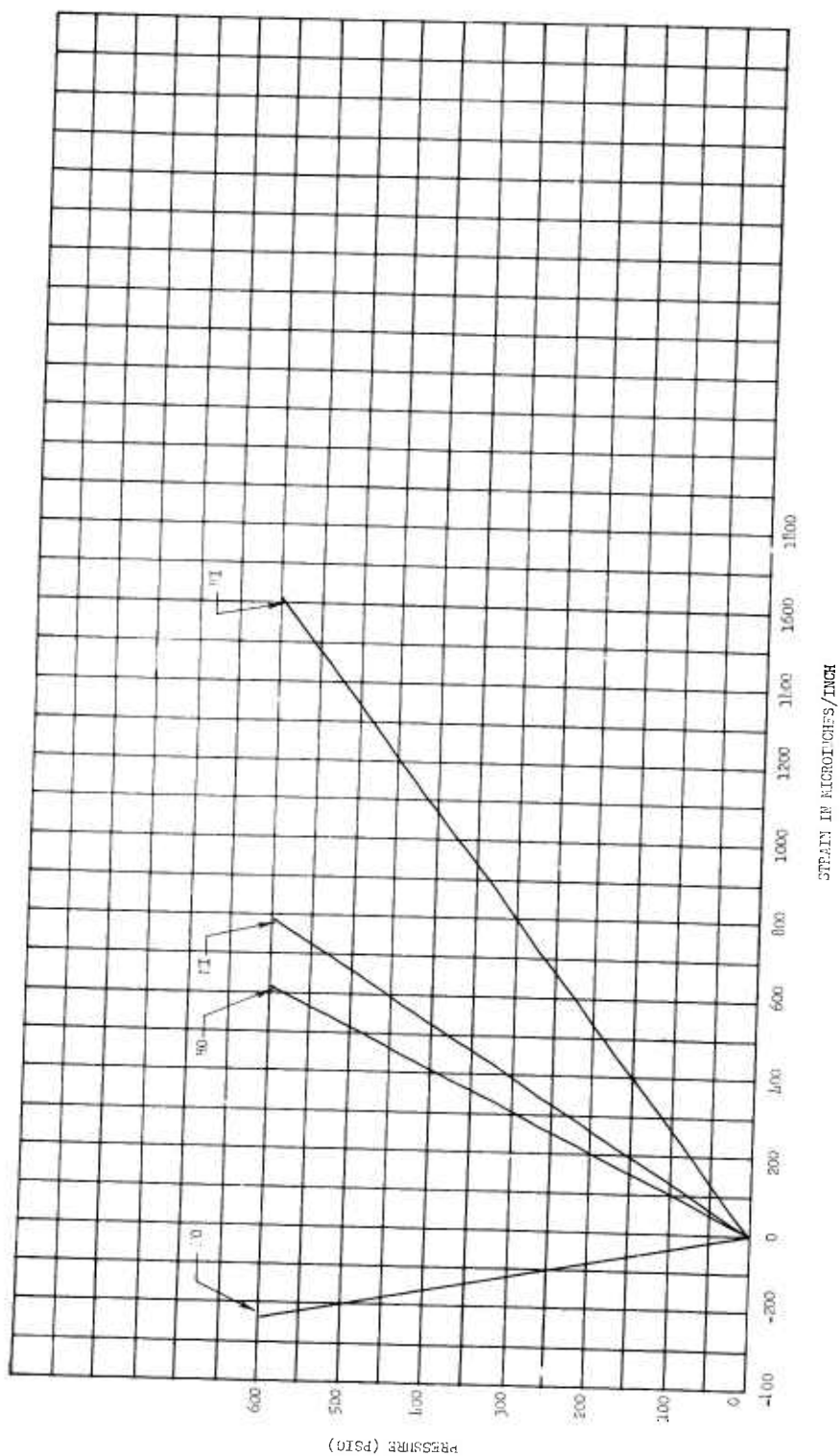


Figure 74

Pressure vs Stress, Gage Point 37

Appendix A



Pressure vs Strain, Gage Point 38

Figure 75

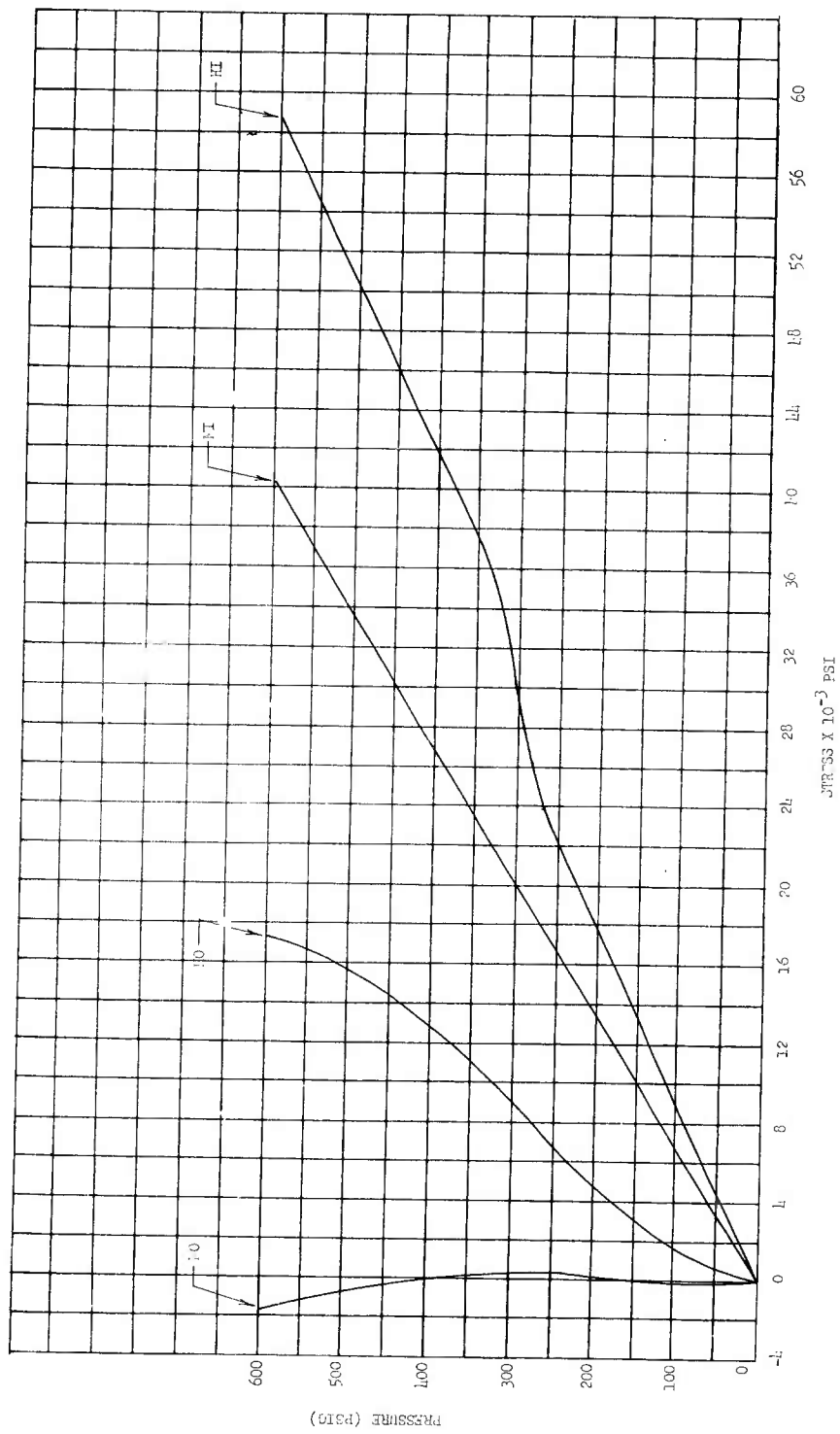
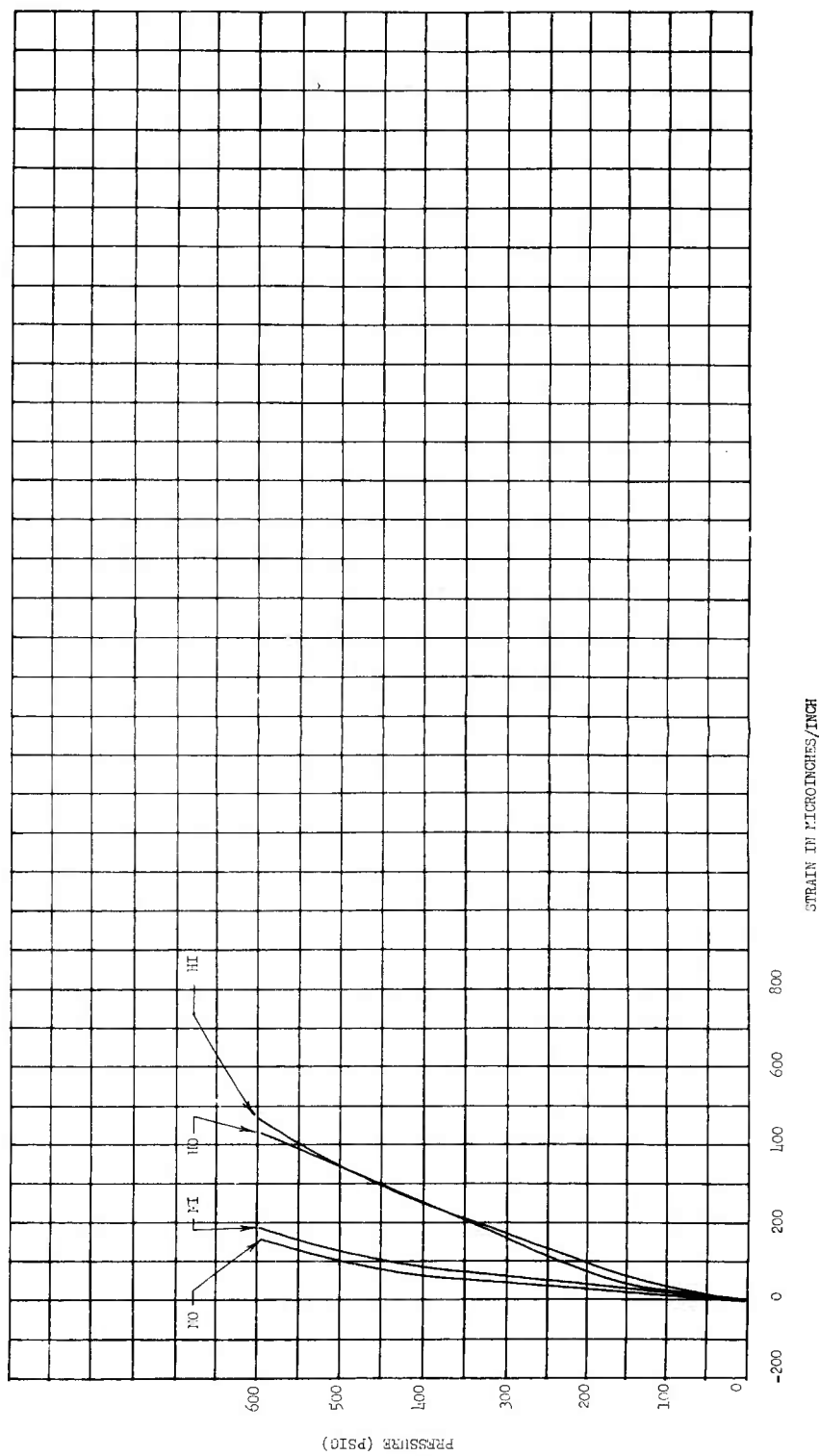


Figure 76

Pressure vs Stress, Gage Point 38



Pressure vs Strain, Gage Point 39

Figure 77

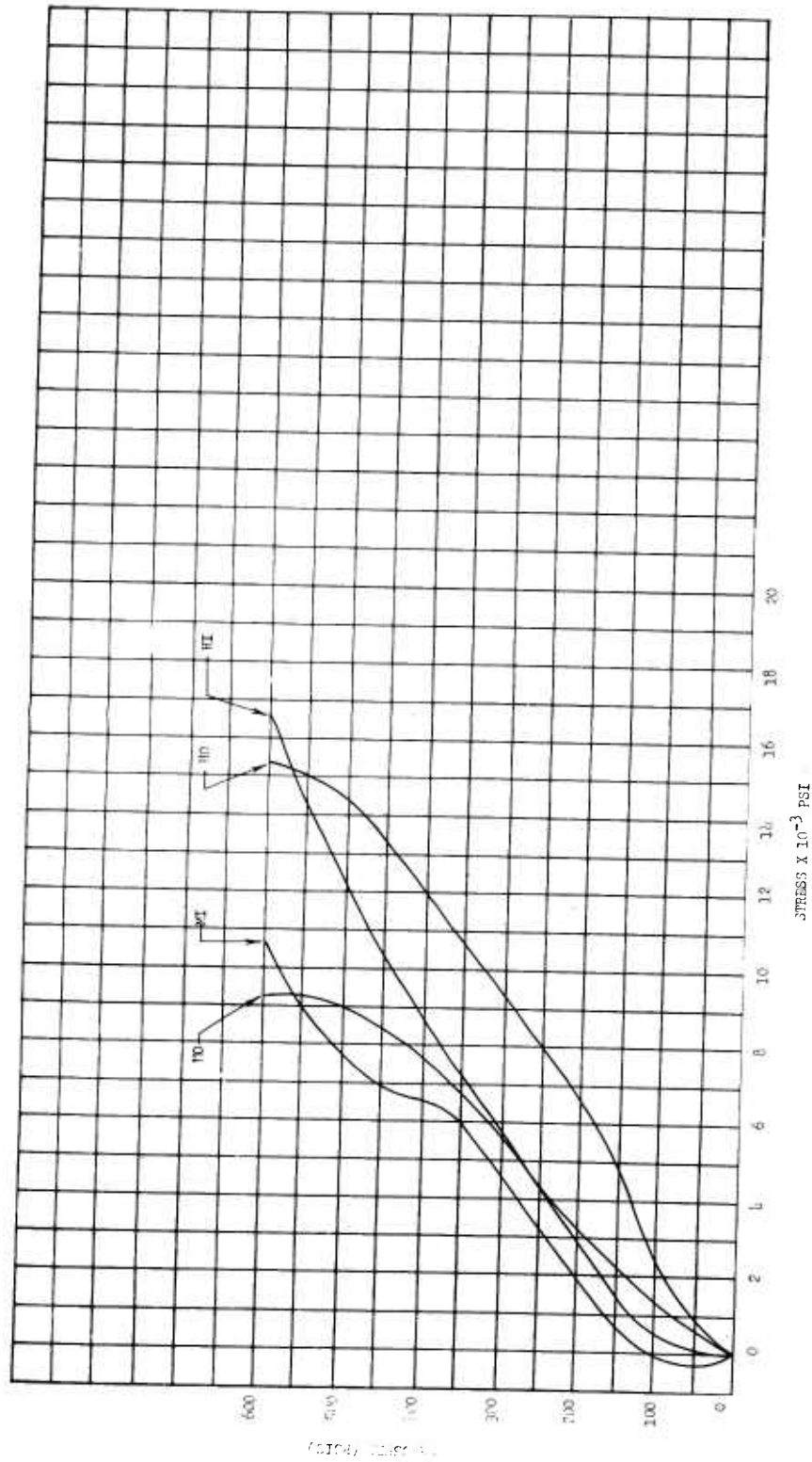
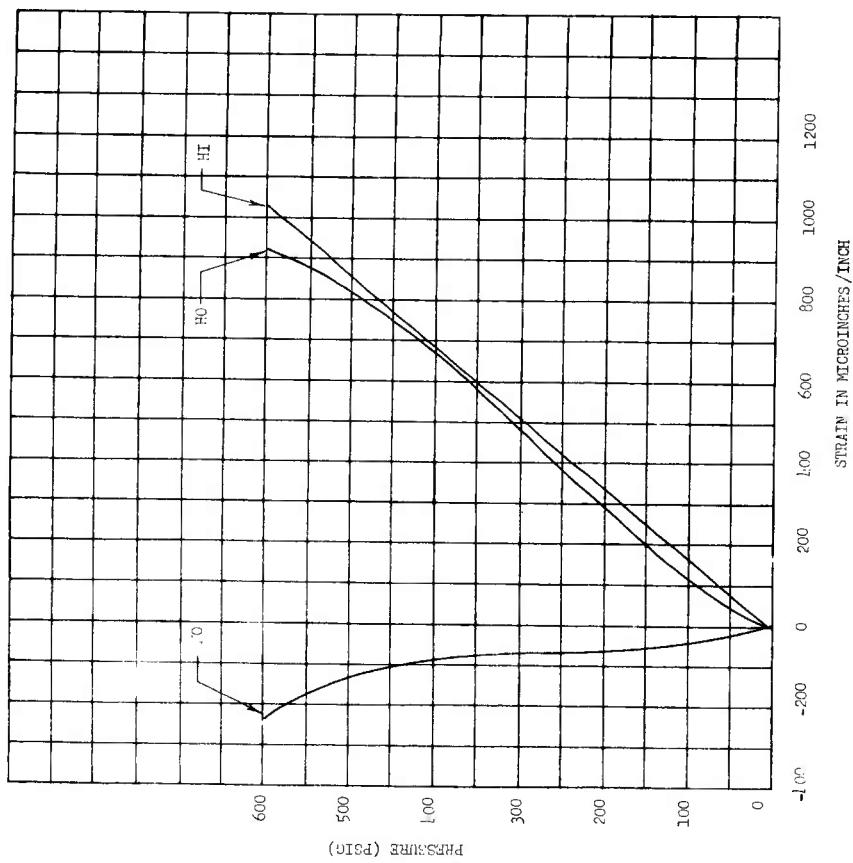


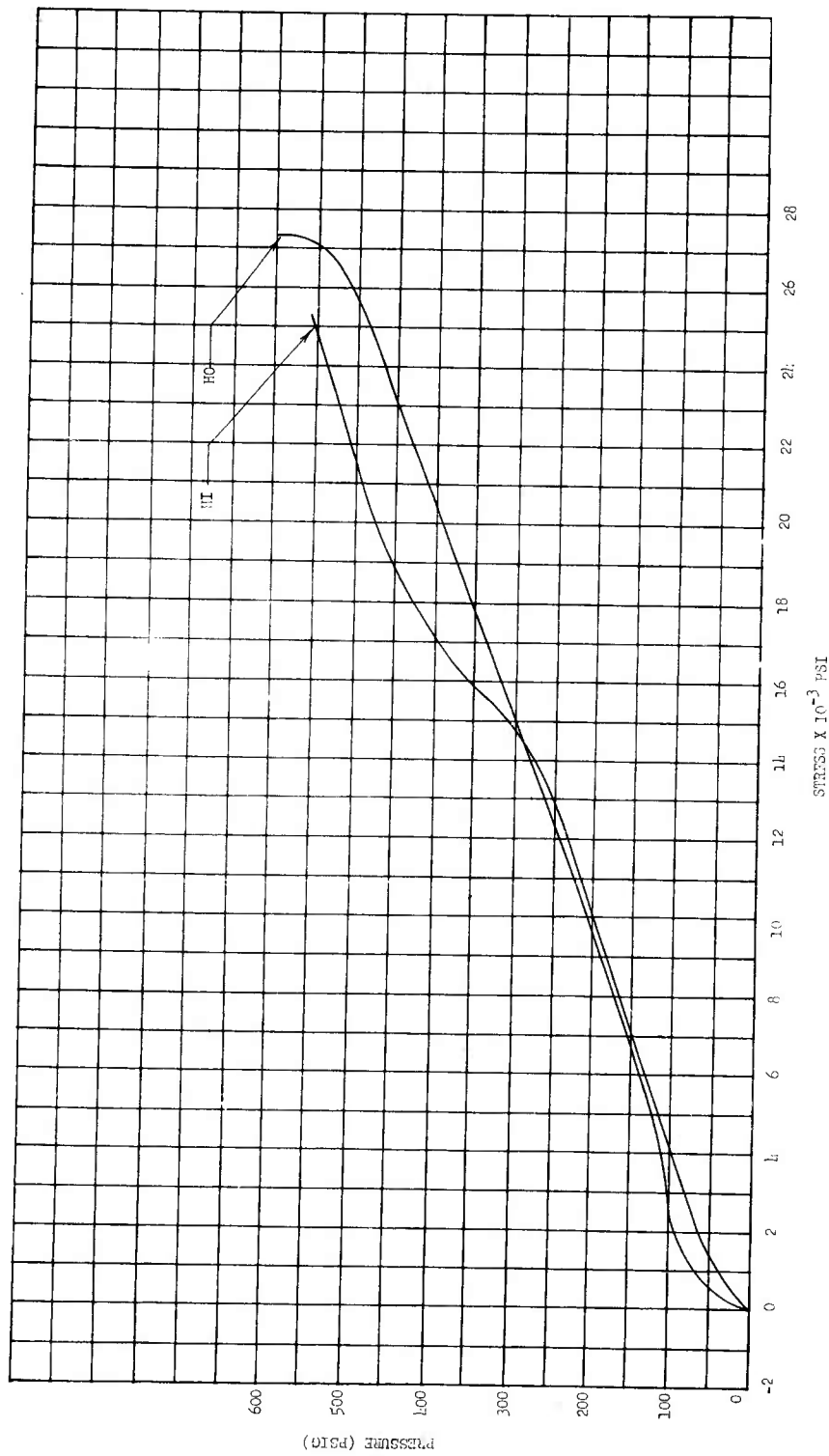
Figure 78

Pressure vs Stress, Gage Point 39



Pressure vs Strain, Gage Point 40

Figure 79



Pressure vs Stress, Gage Point 40

Figure 80

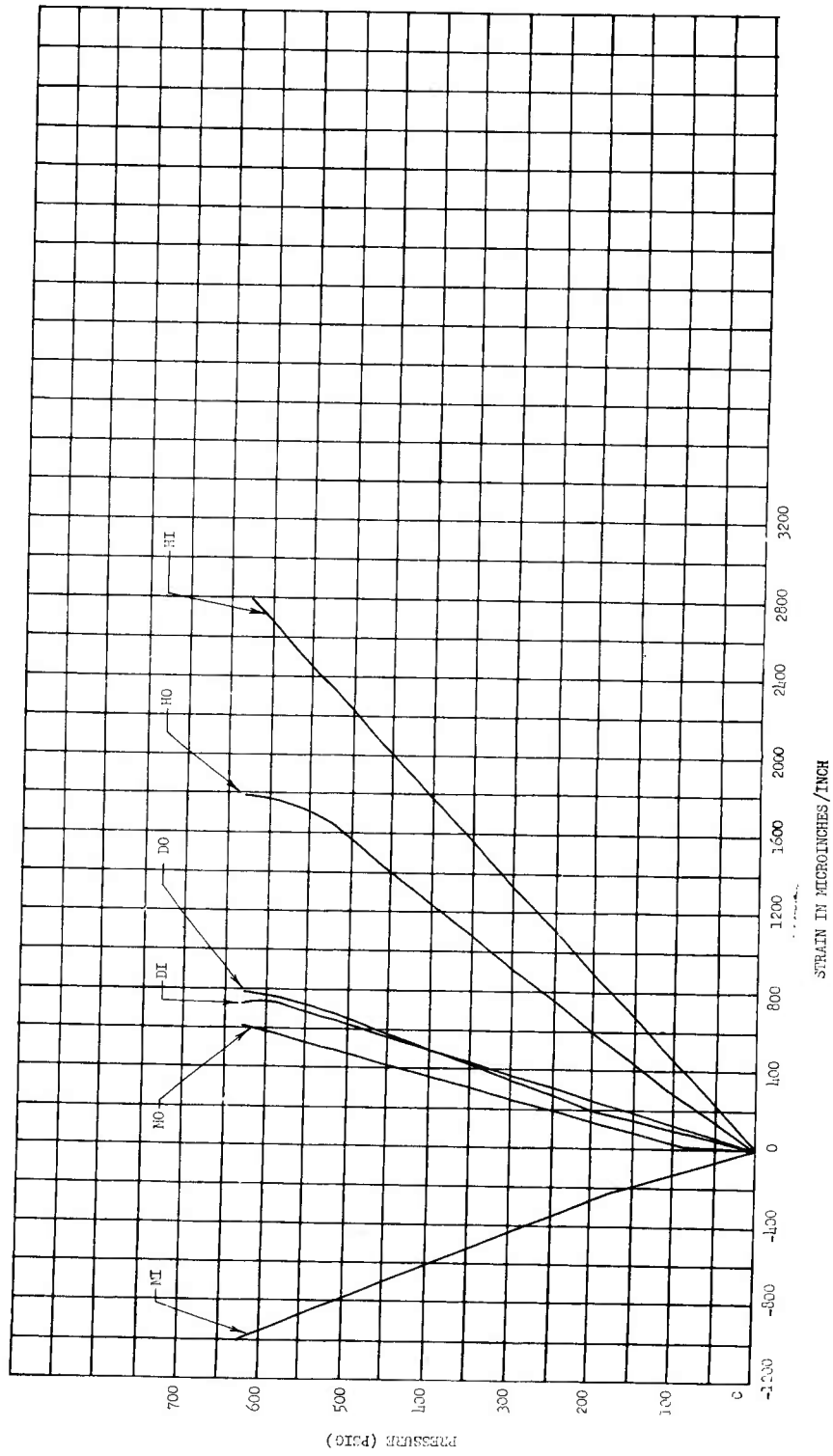
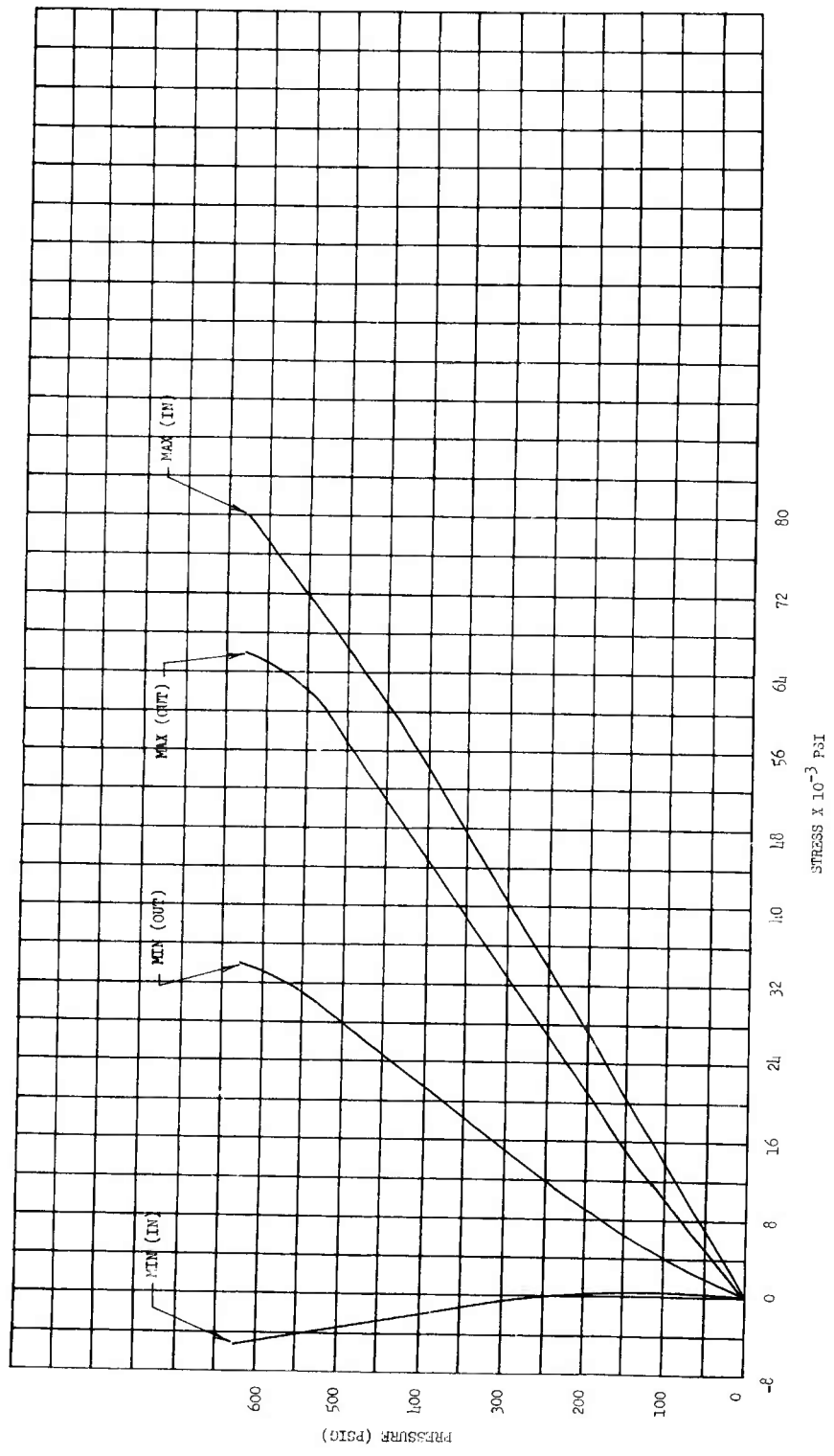


Figure 81

Pressure vs Strain, Gage Point 41

Appendix A



Pressure vs Stress, Gage Point 41

Figure 82

Appendix A

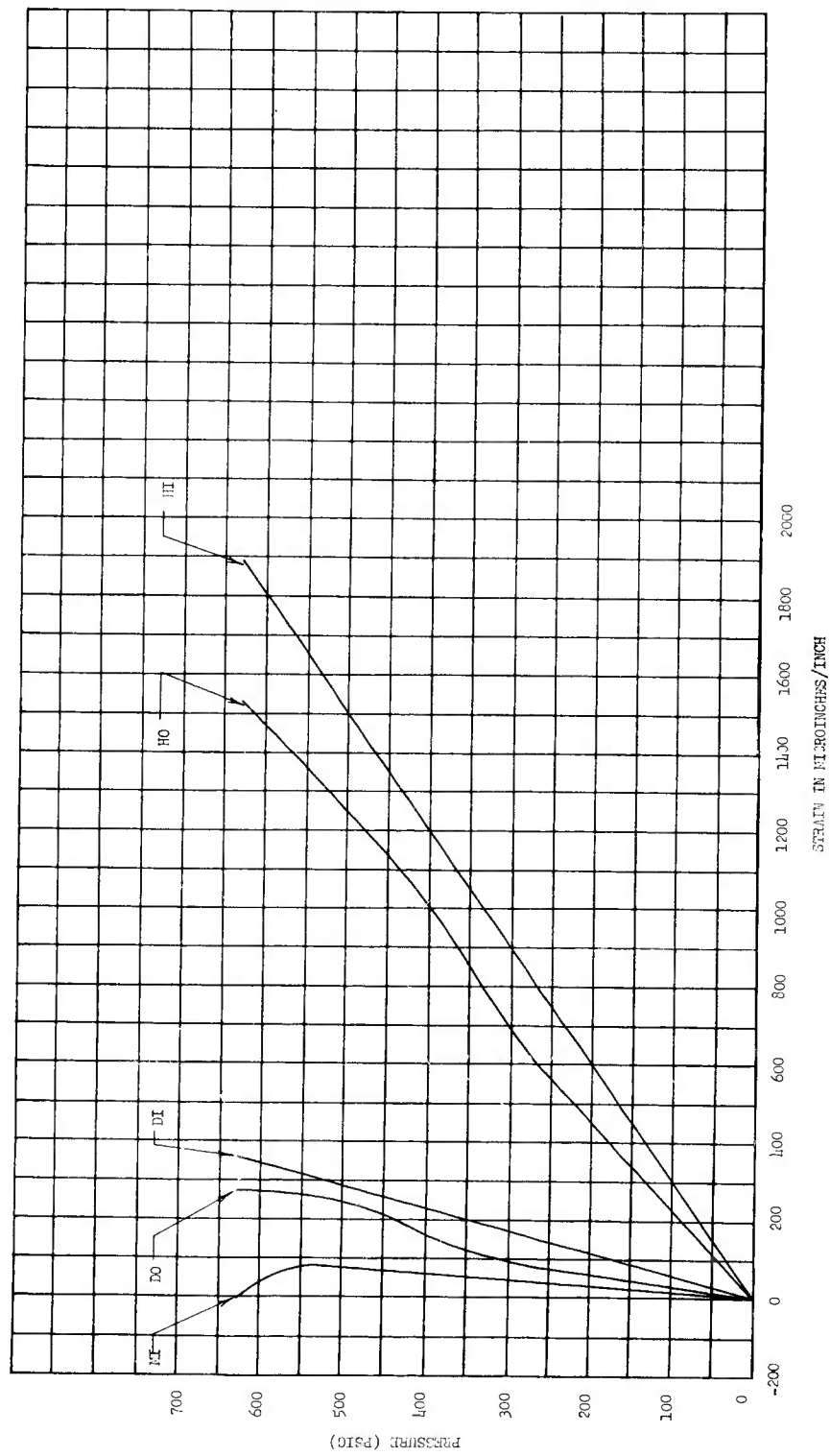
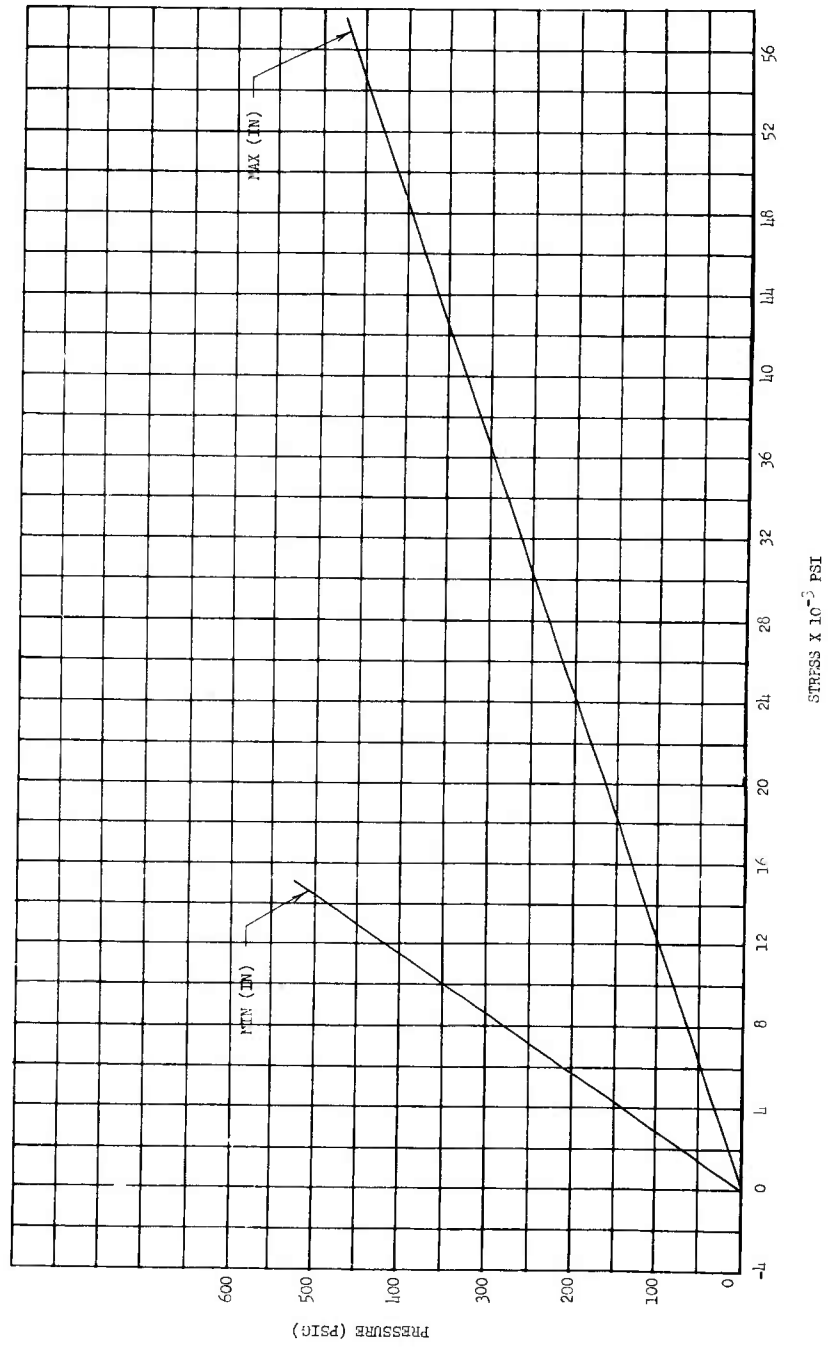


Figure 83

Pressure vs Strain, Gage Point 42

Appendix A



Pressure vs Stress, Gage Point 42

Figure 84

Appendix A

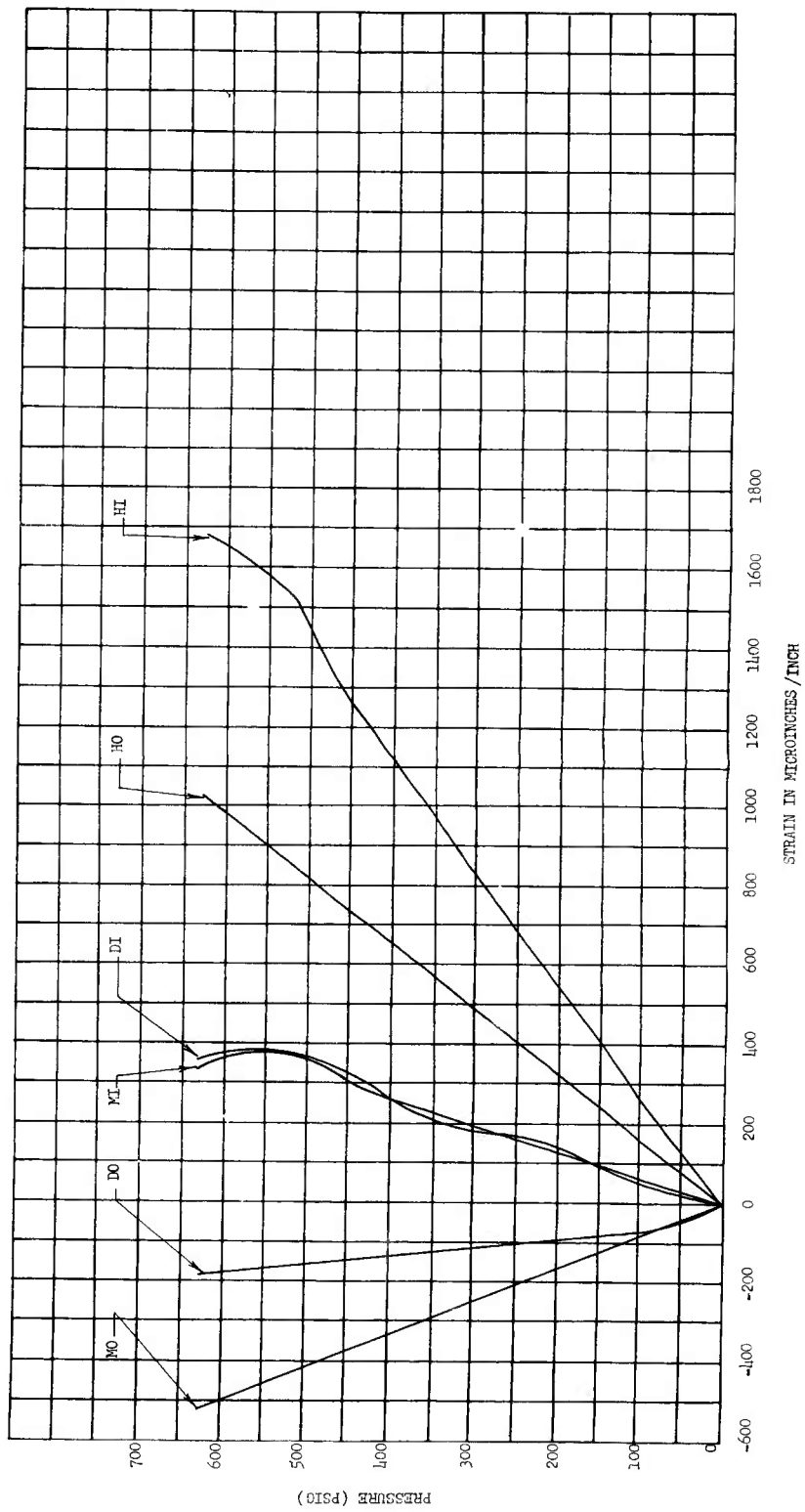


Figure 85

Pressure vs Strain, Gage Point 43

Appendix A

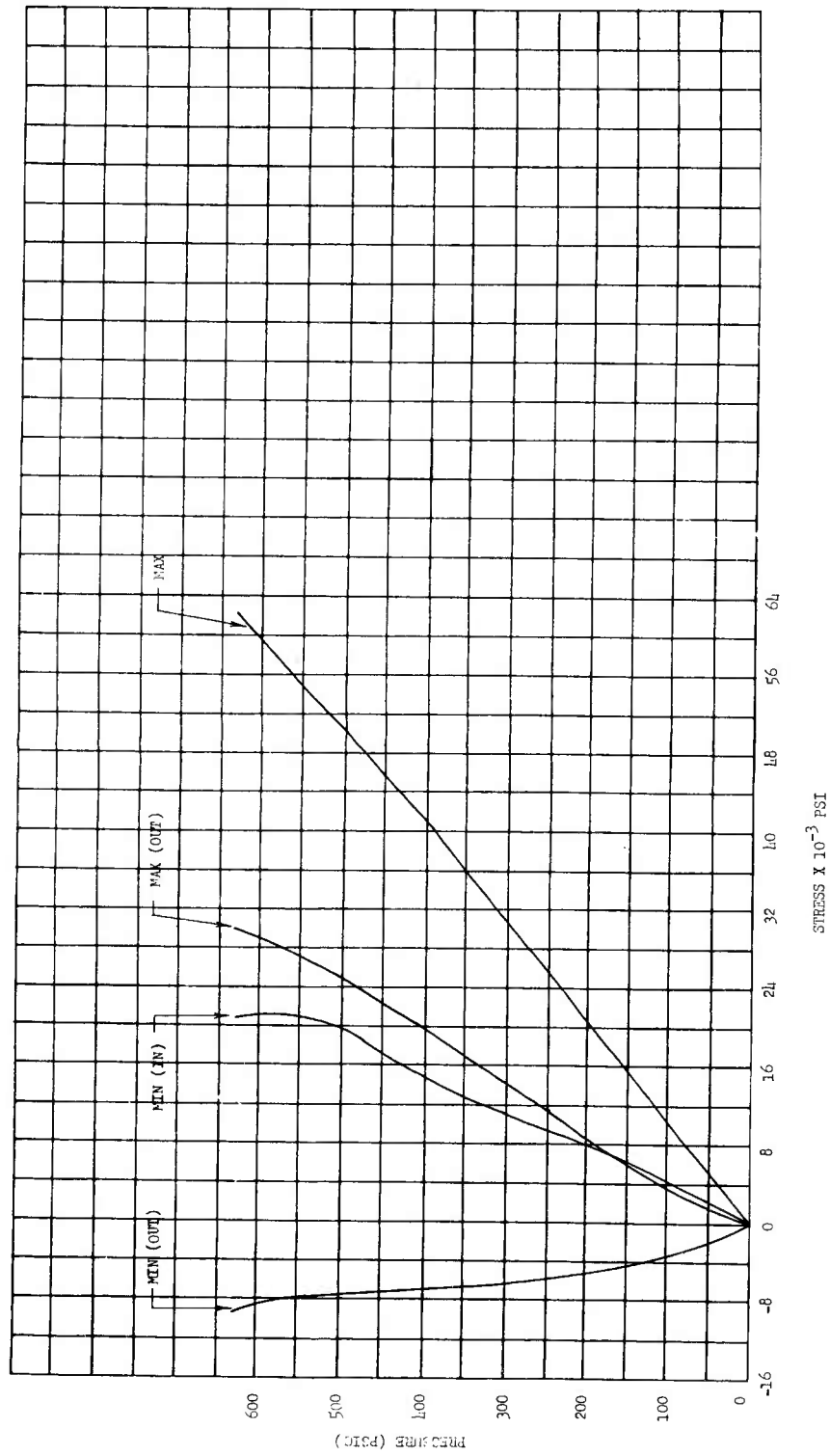


Figure 86

Pressure vs Stress, Gage Point 43

Appendix A

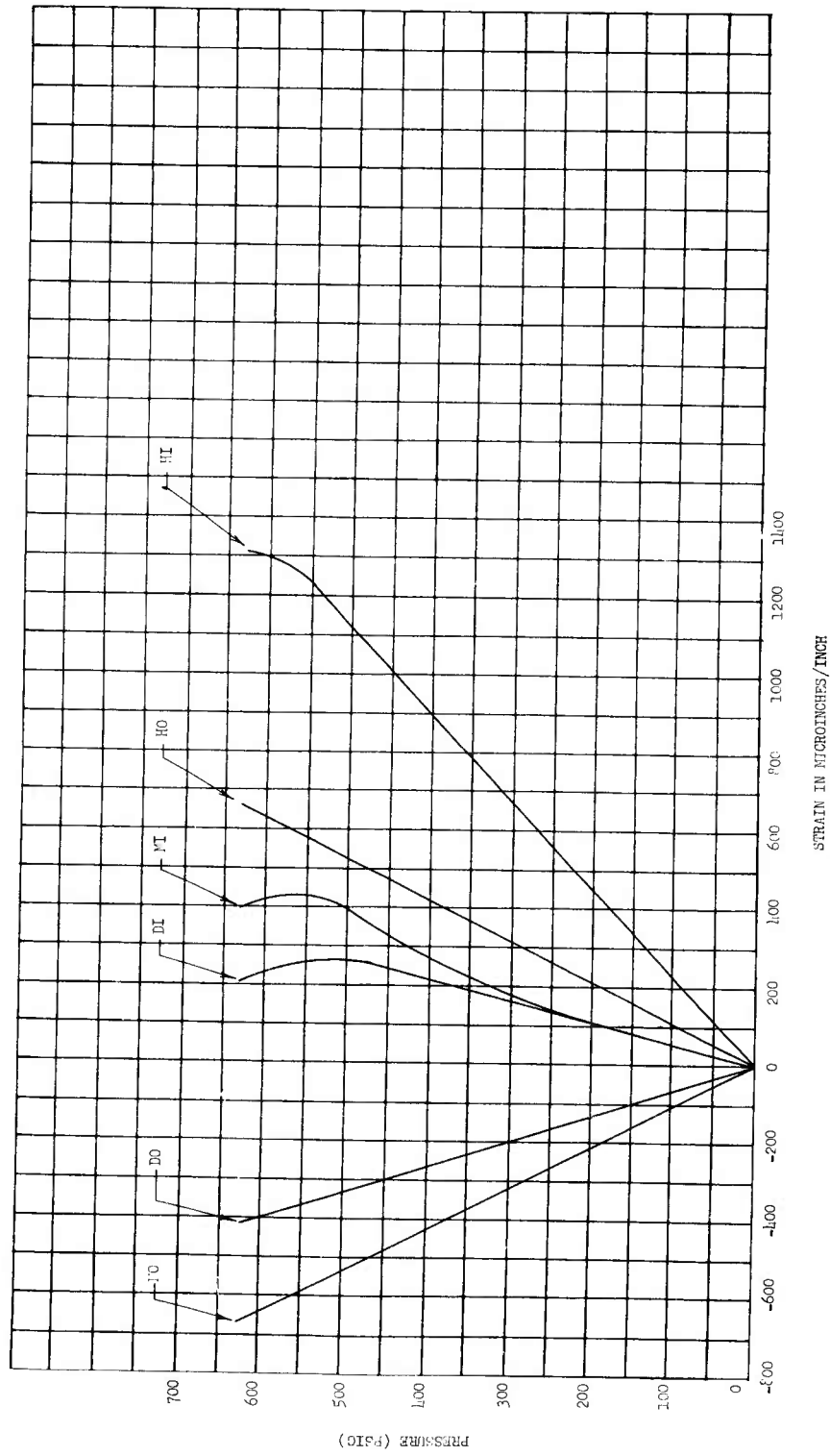


Figure 87

Pressure vs Strain, Gage Point 44

Appendix A

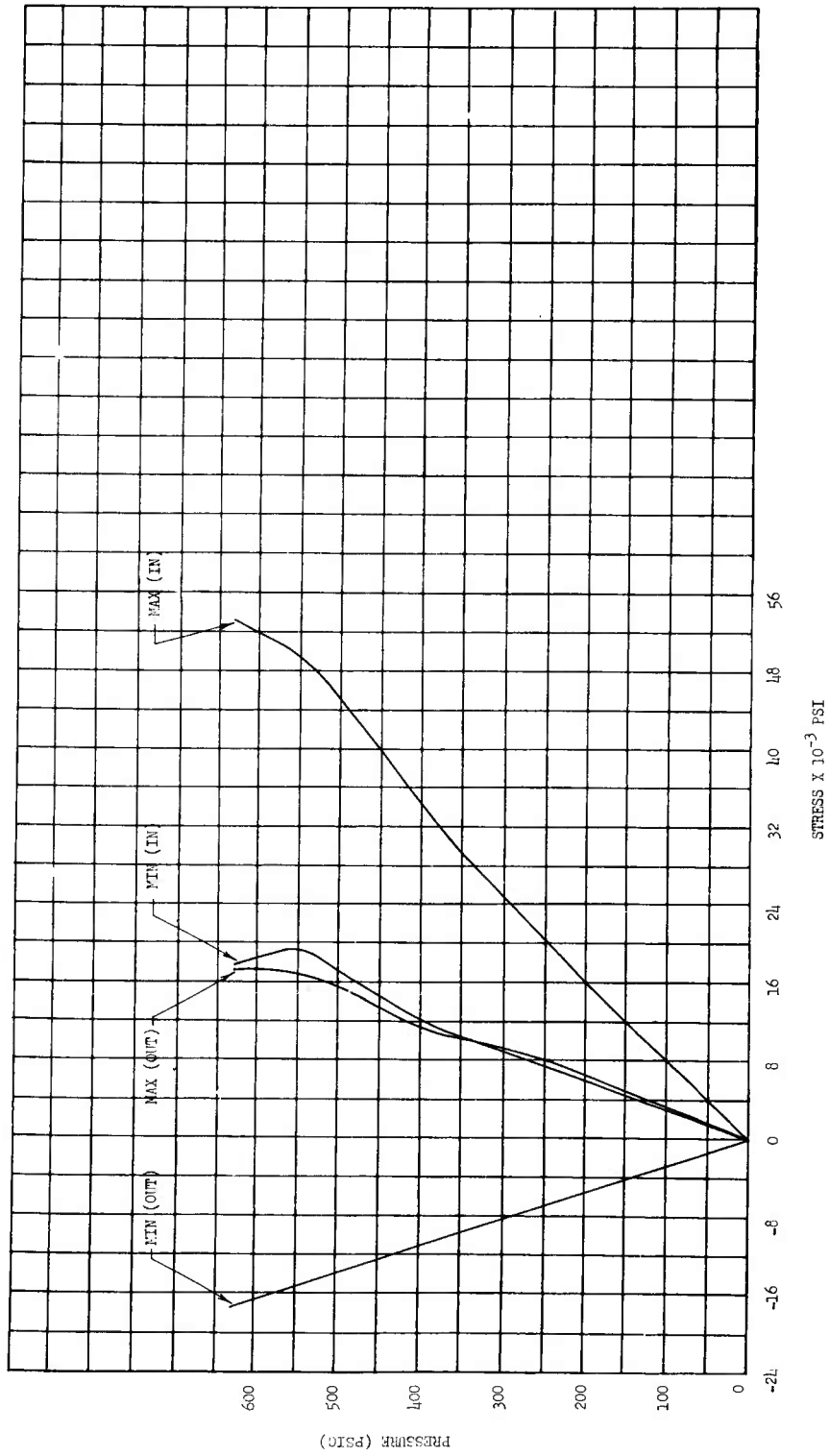


Figure 88

Pressure vs Stress, Gage Point 44

Appendix A

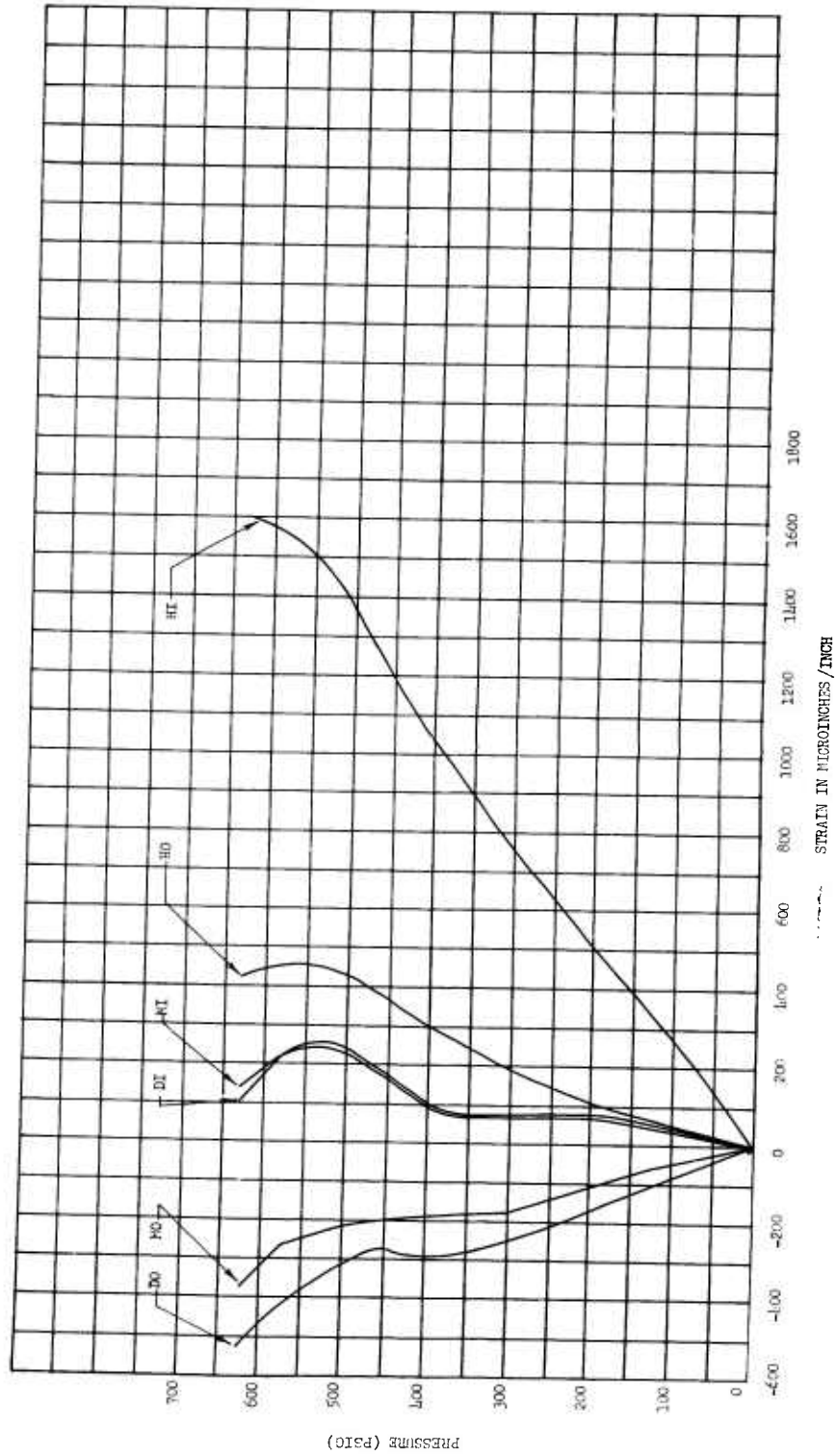


Figure 89

Pressure vs Strain, Gage Point 45

Appendix A

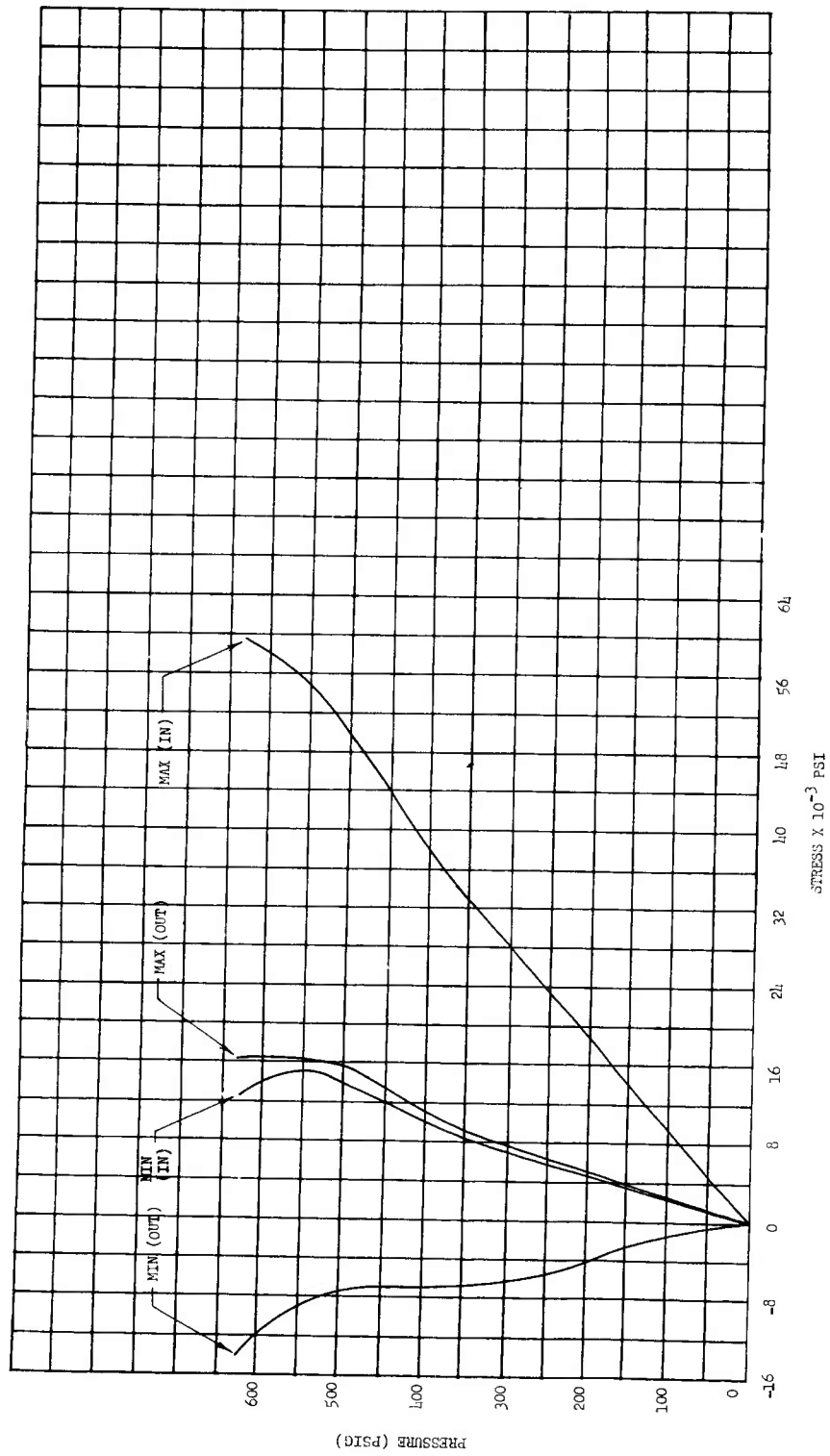


Figure 90

Pressure vs Stress, Gage Point 45

Appendix A

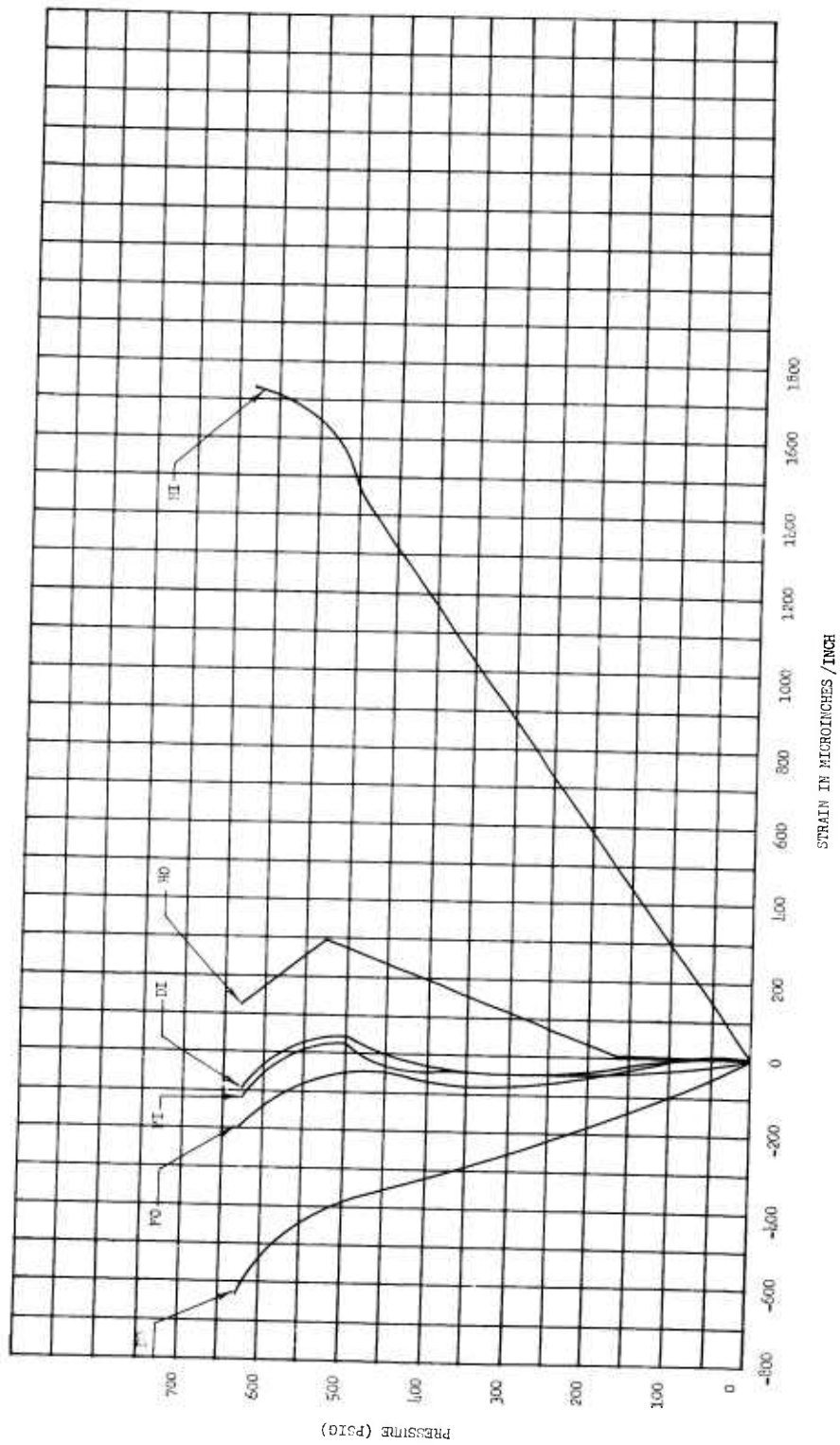


Figure 91

Pressure vs Strain, Gage Point 46

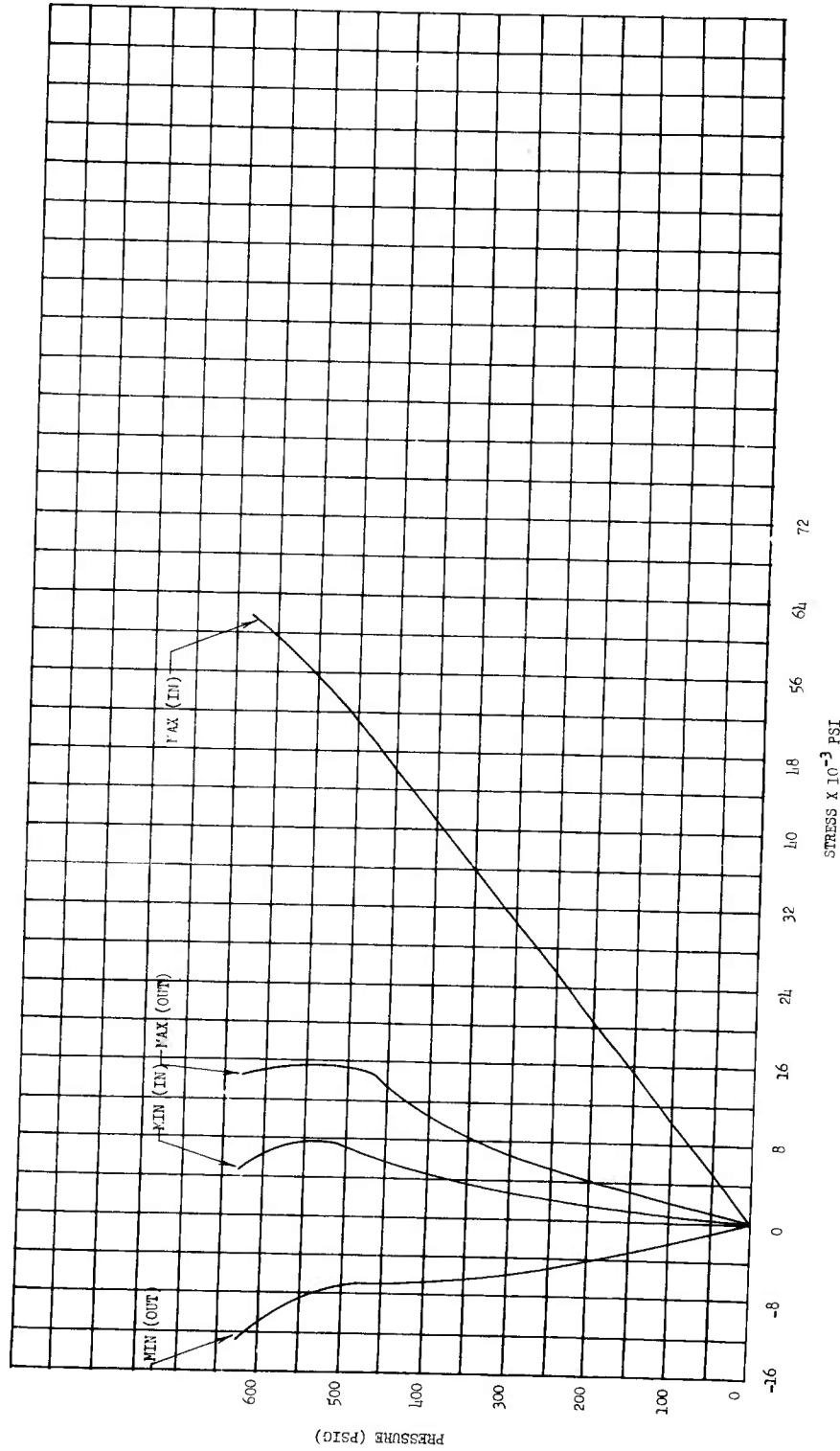


Figure 92

Pressure vs Stress, Gage Point 46

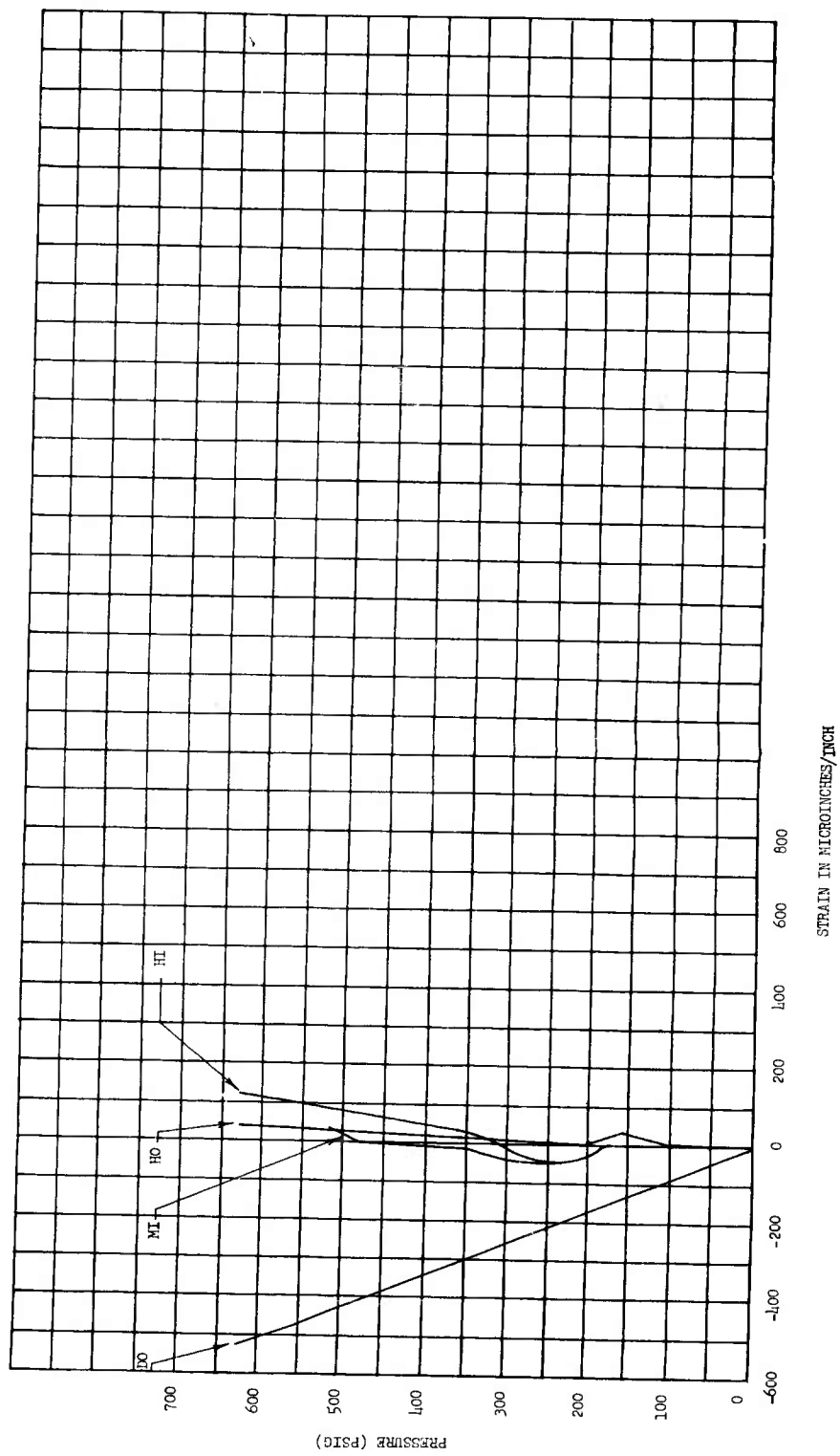
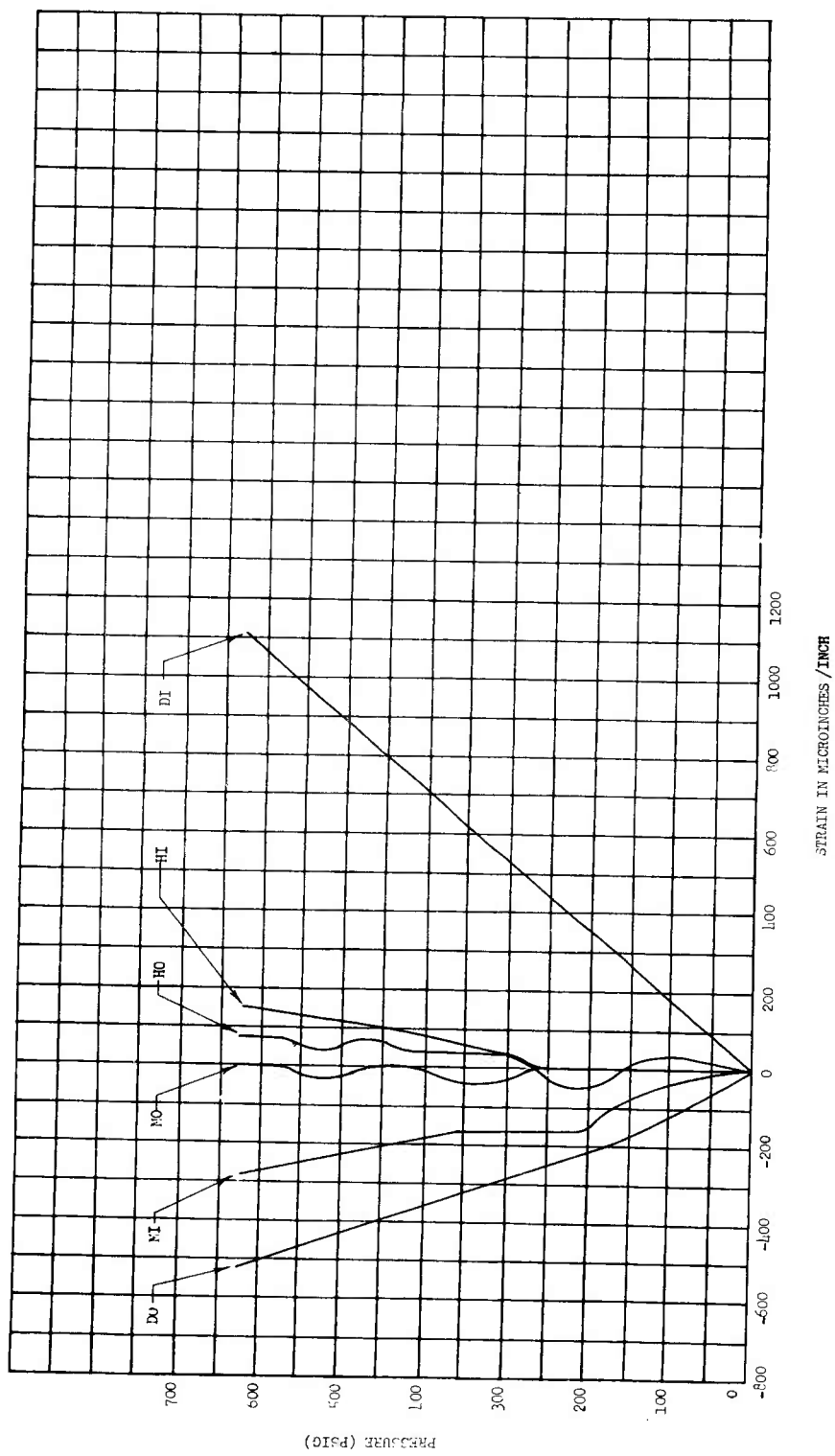


Figure 93

Pressure vs Strain, Gage Point 47



Pressure vs Strain, Gage Point 48

Figure 94

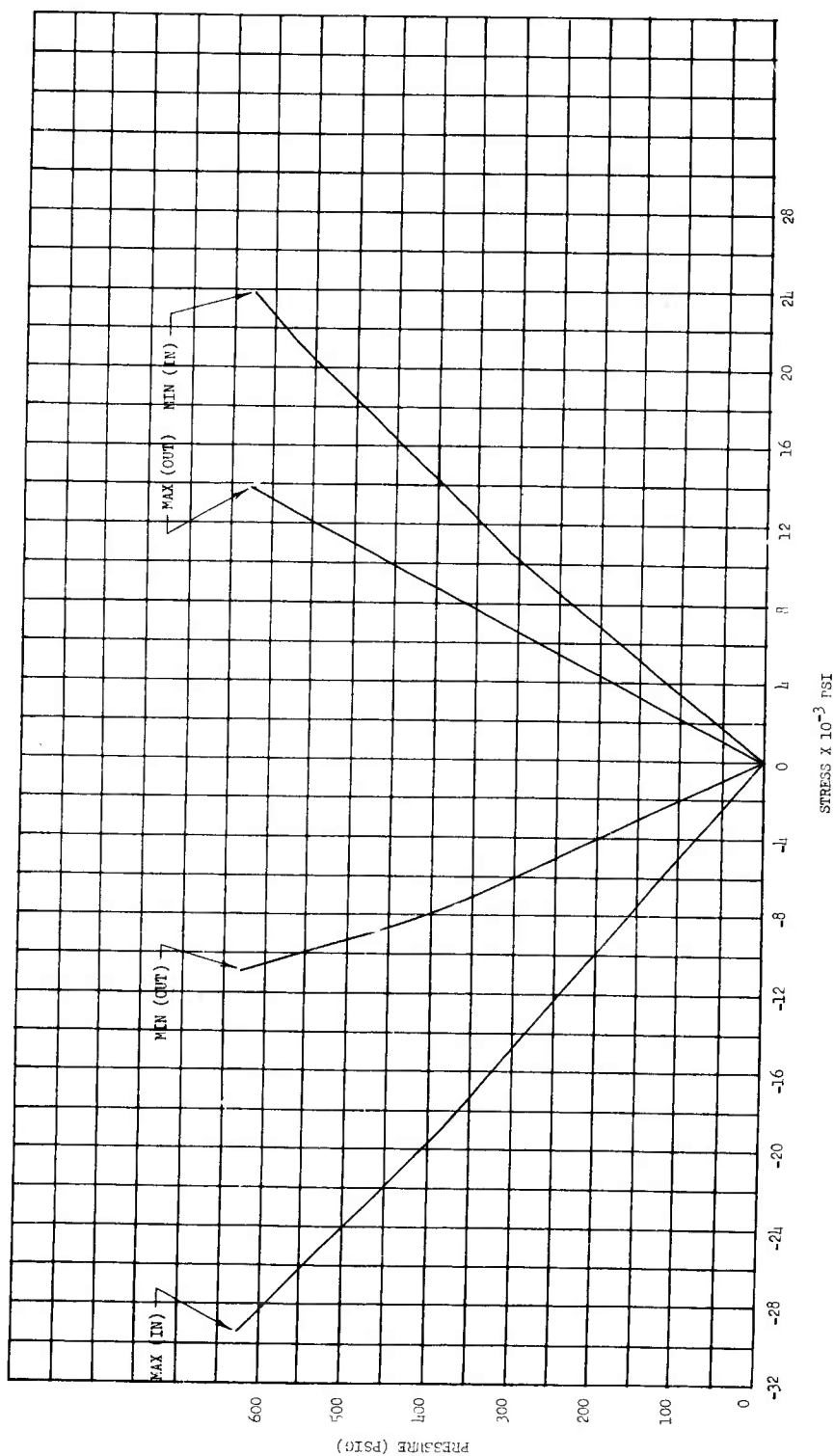
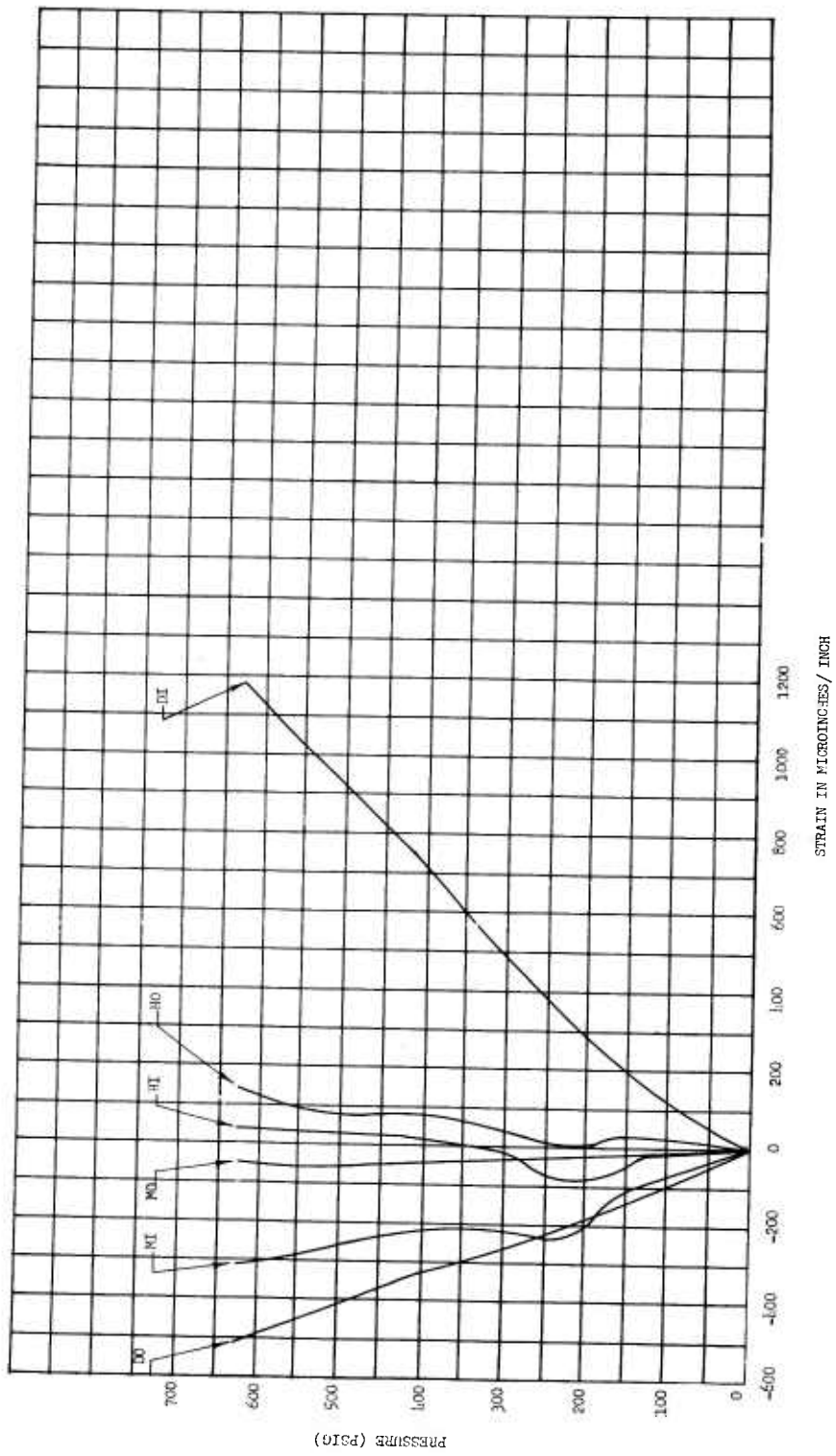


Figure 95

Pressure vs Stress, Gage Point 48



Pressure vs Strain, Gage Point 49

Figure 96

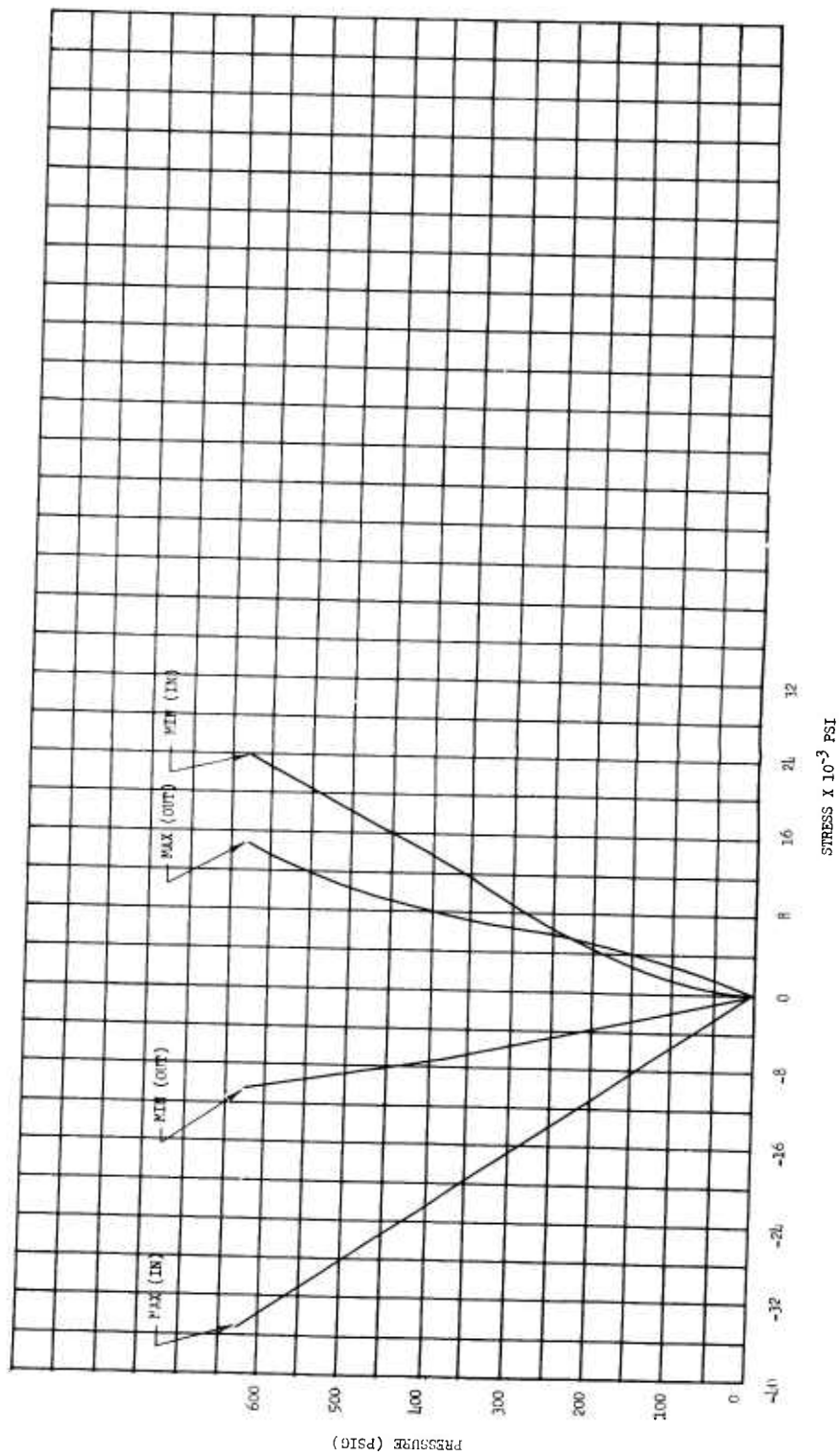
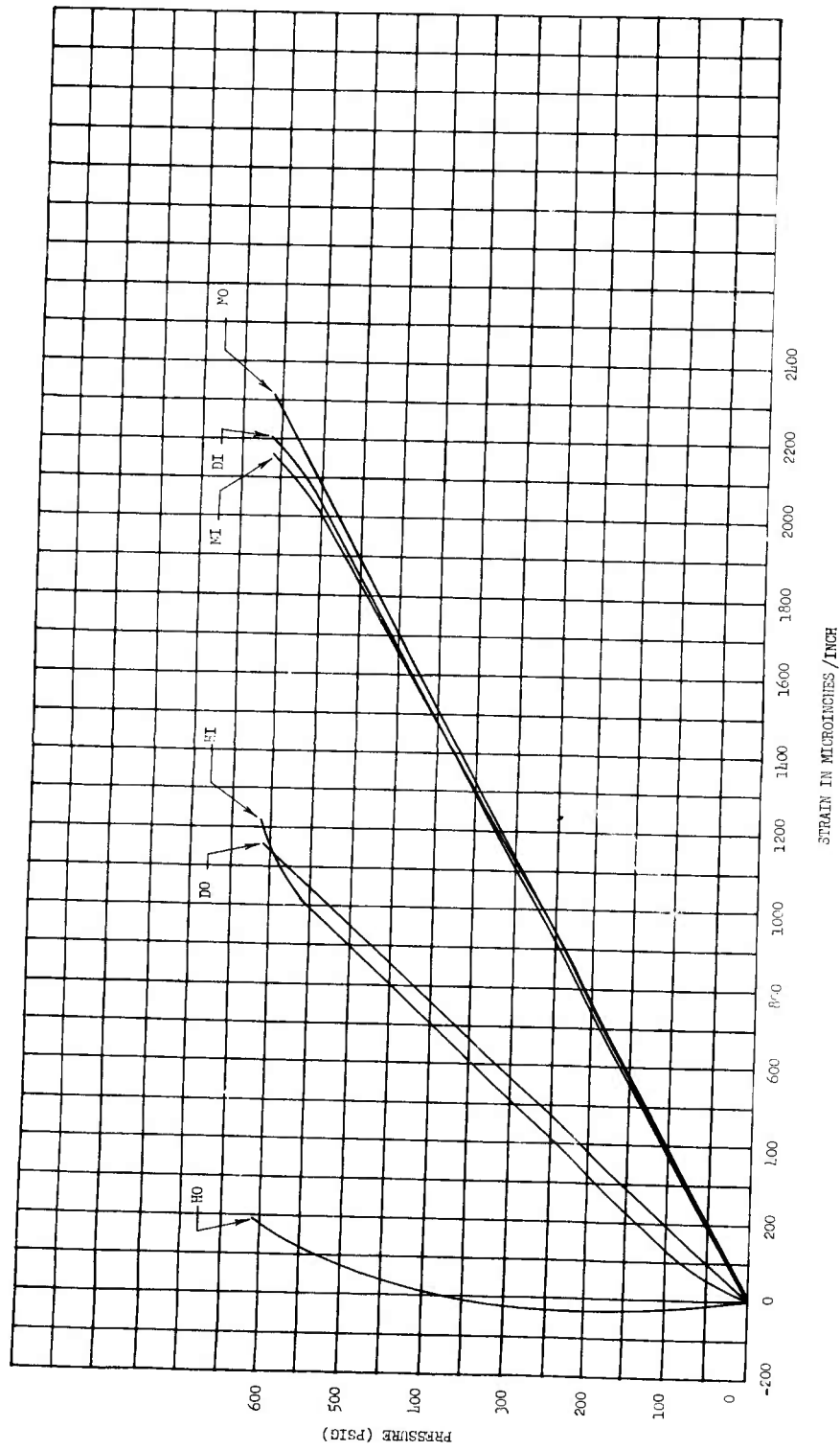


Figure 97

Pressure vs Stress; Gage Point 49



Pressure vs Strain, Gage Point 50

Figure 98

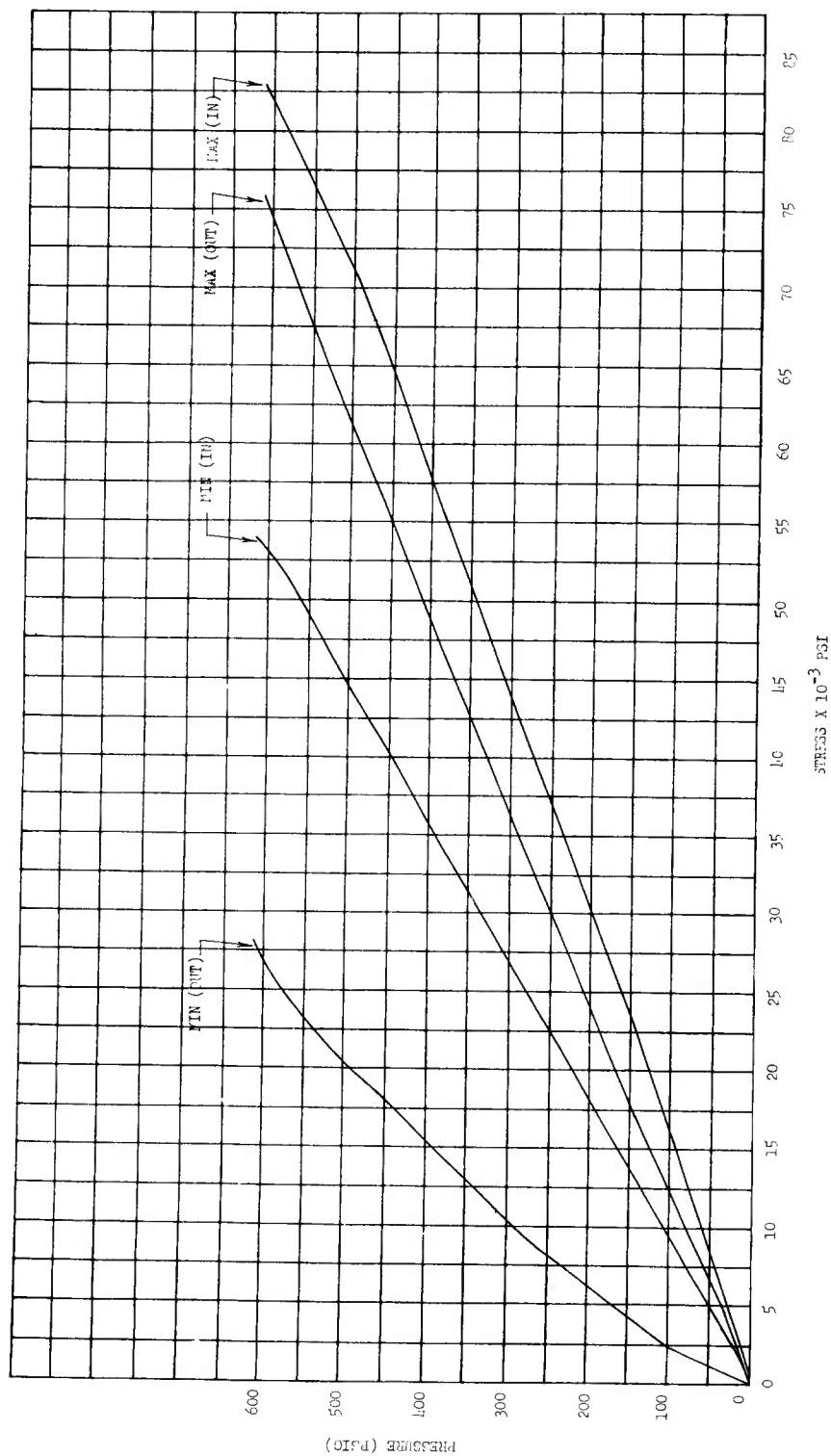
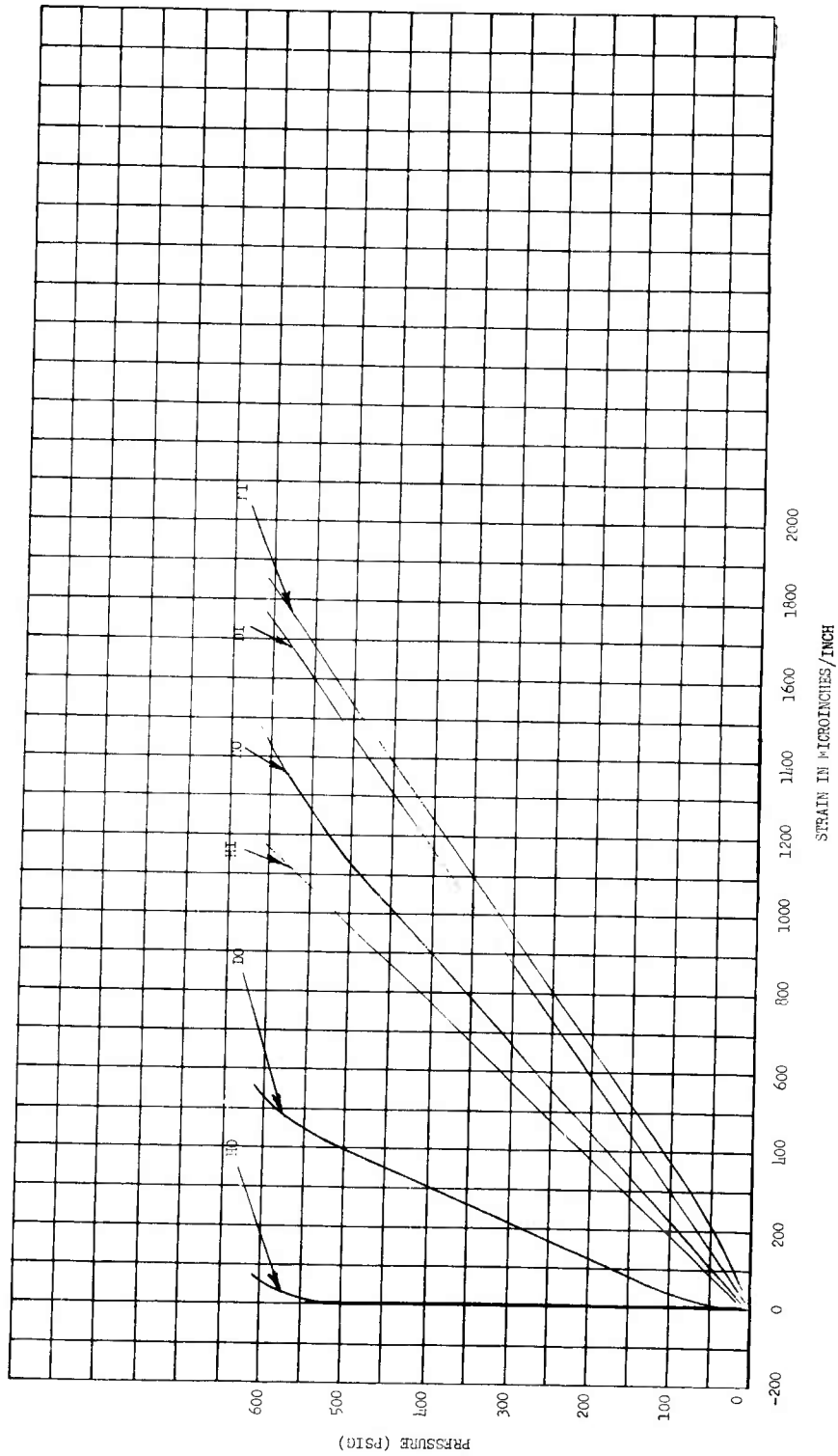


Figure 99

Pressure vs Stress, Gage Point 50



Pressure vs Strain, Gage Point 51

Figure 100

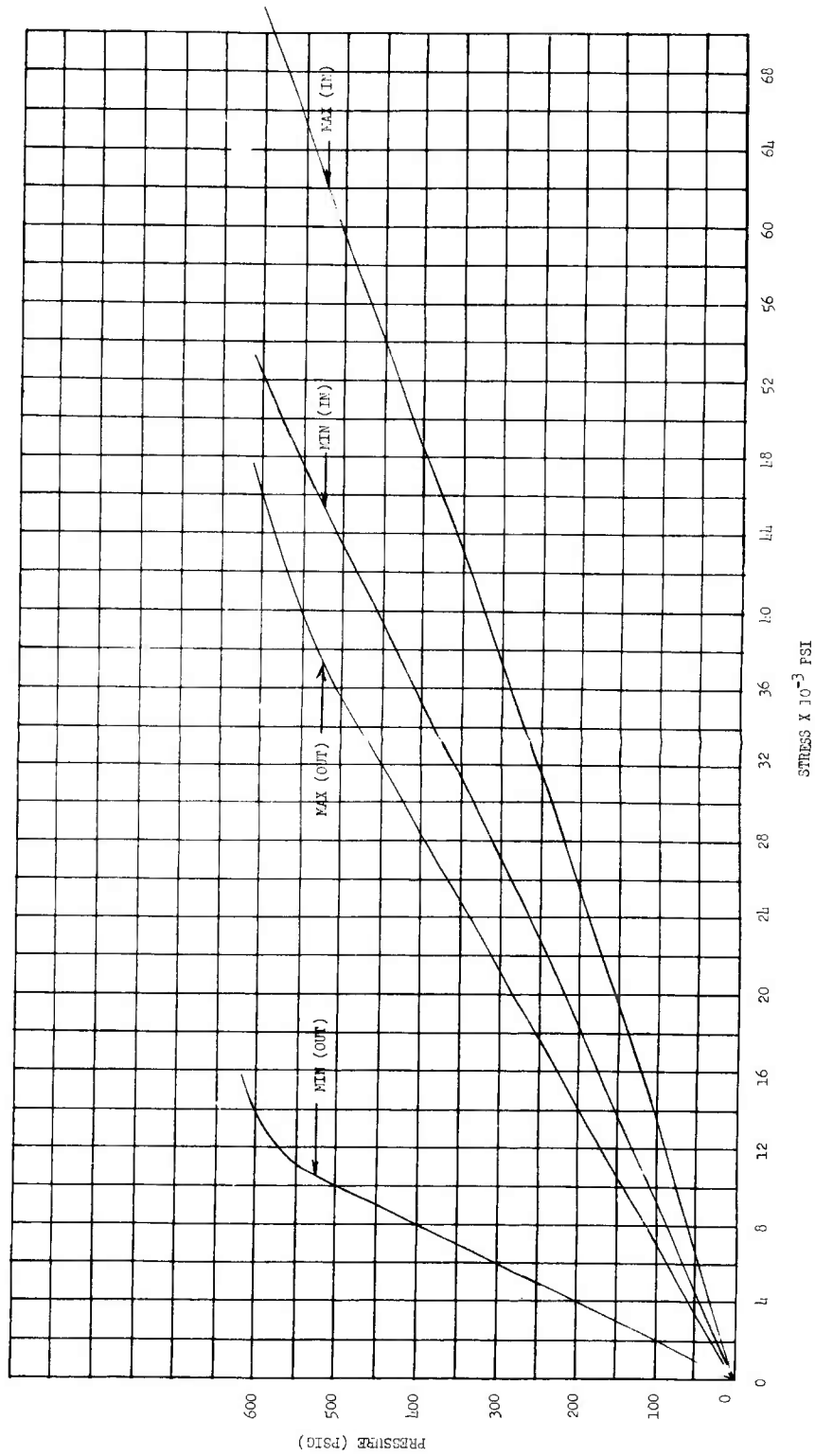
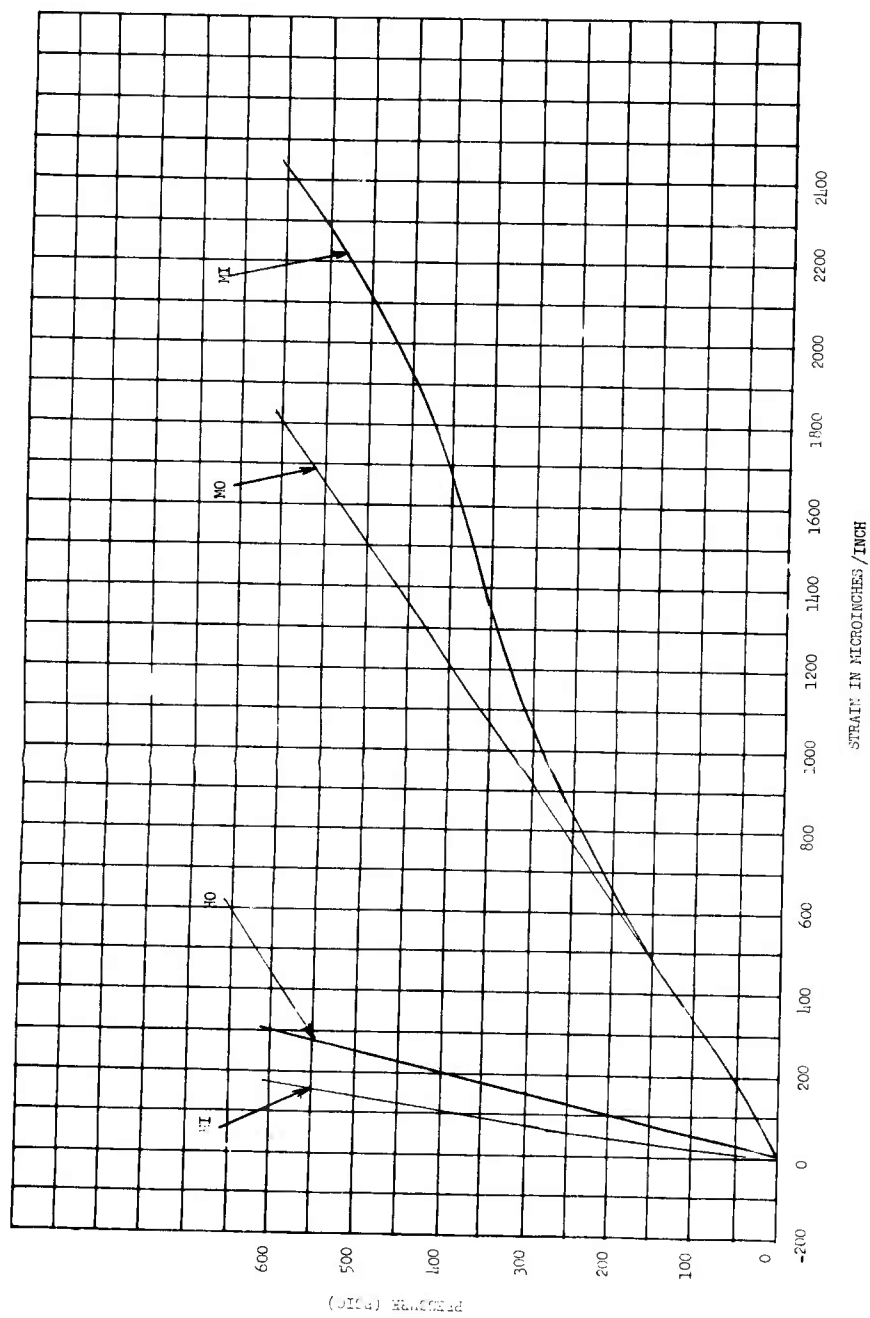


Figure 101

Pressure vs Stress, Gage Point 51



Pressure vs Strain, Gage Point 61

Figure 102

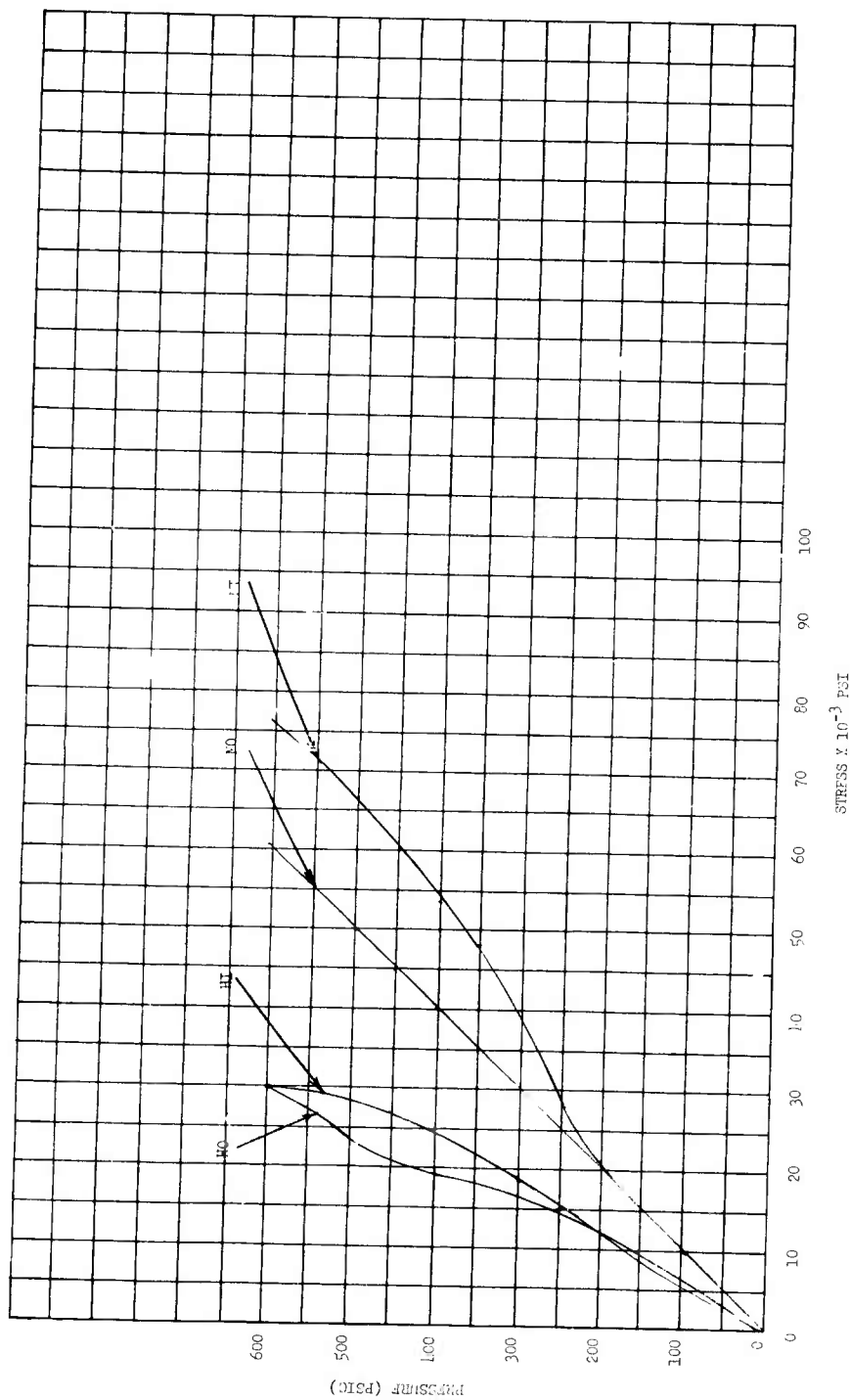
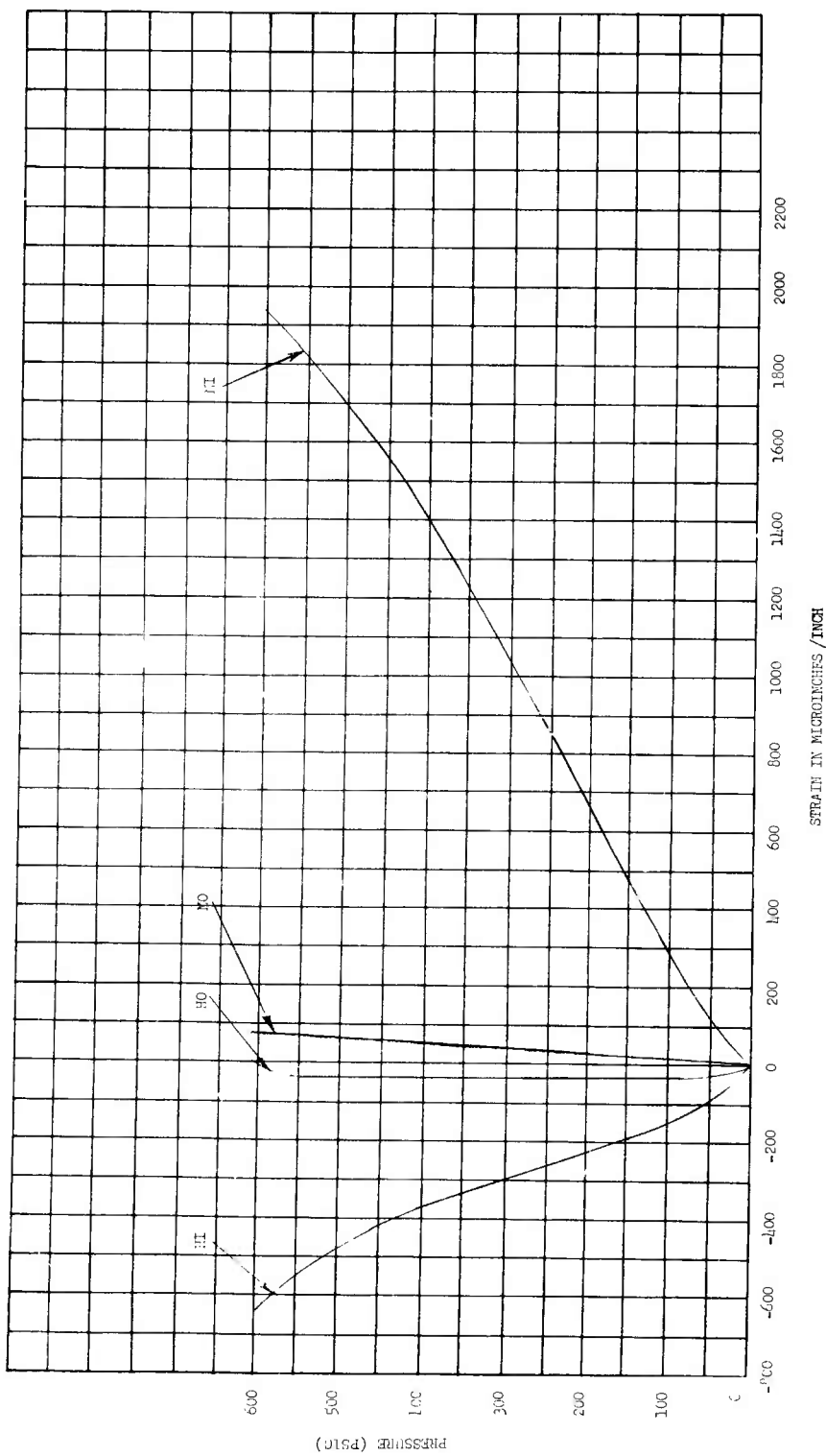


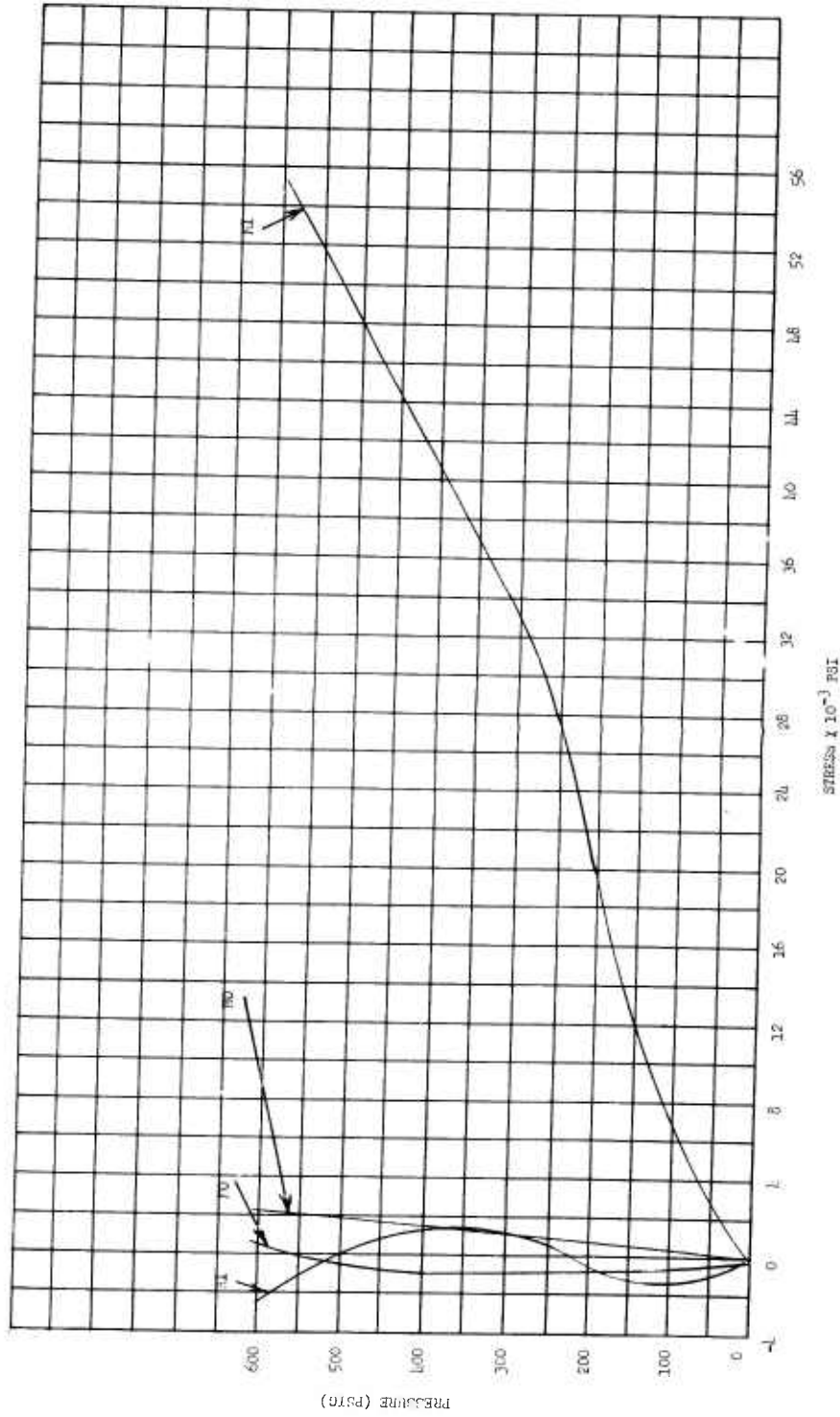
Figure 103

Pressure vs Stress, Gage Point 61



Pressure vs Strain, Gage Point 62

Figure 104



Pressure vs Stress, Gage Point 62

Figure 105

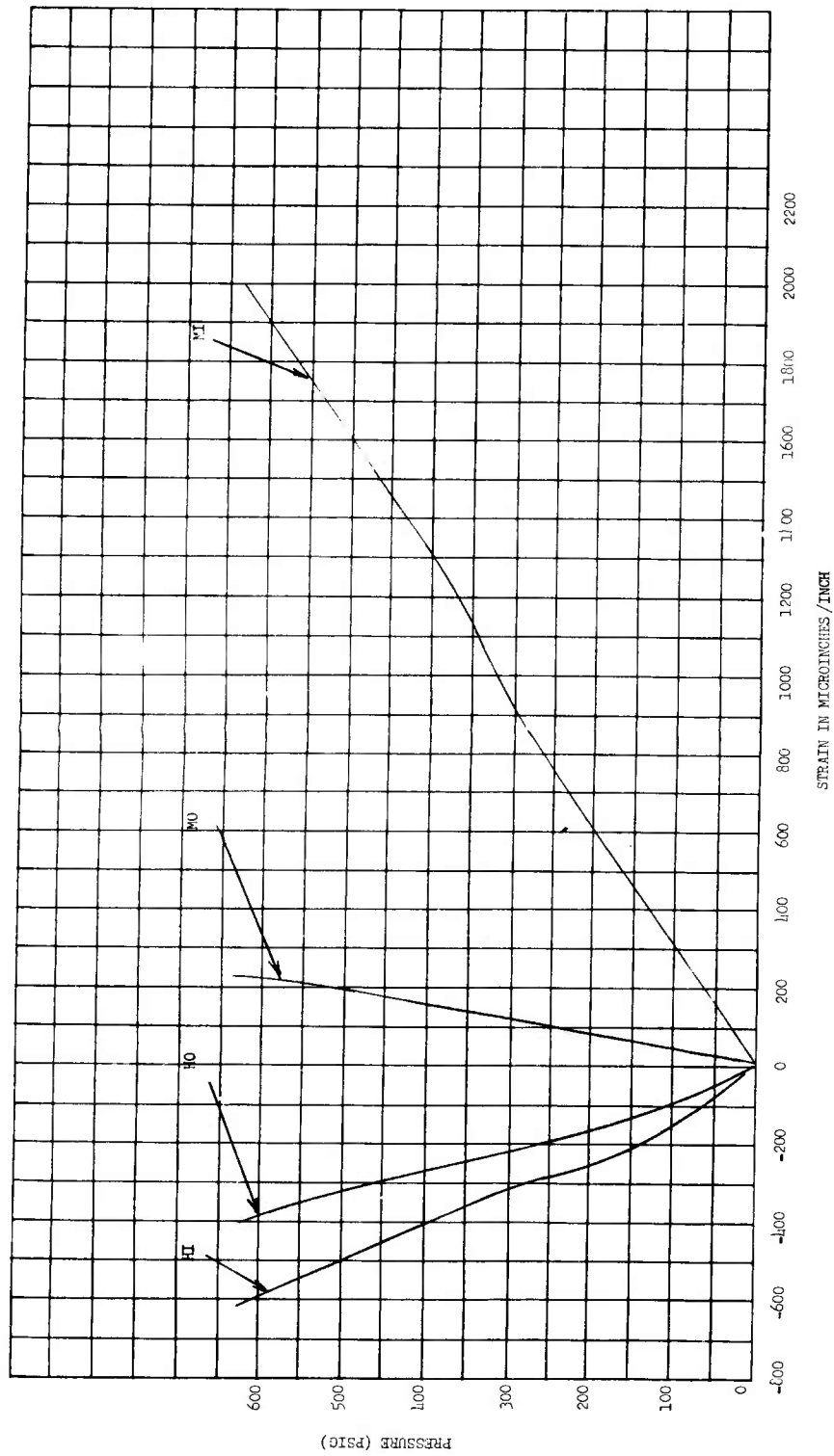


Figure 106

Pressure vs Strain, Gage Point 63

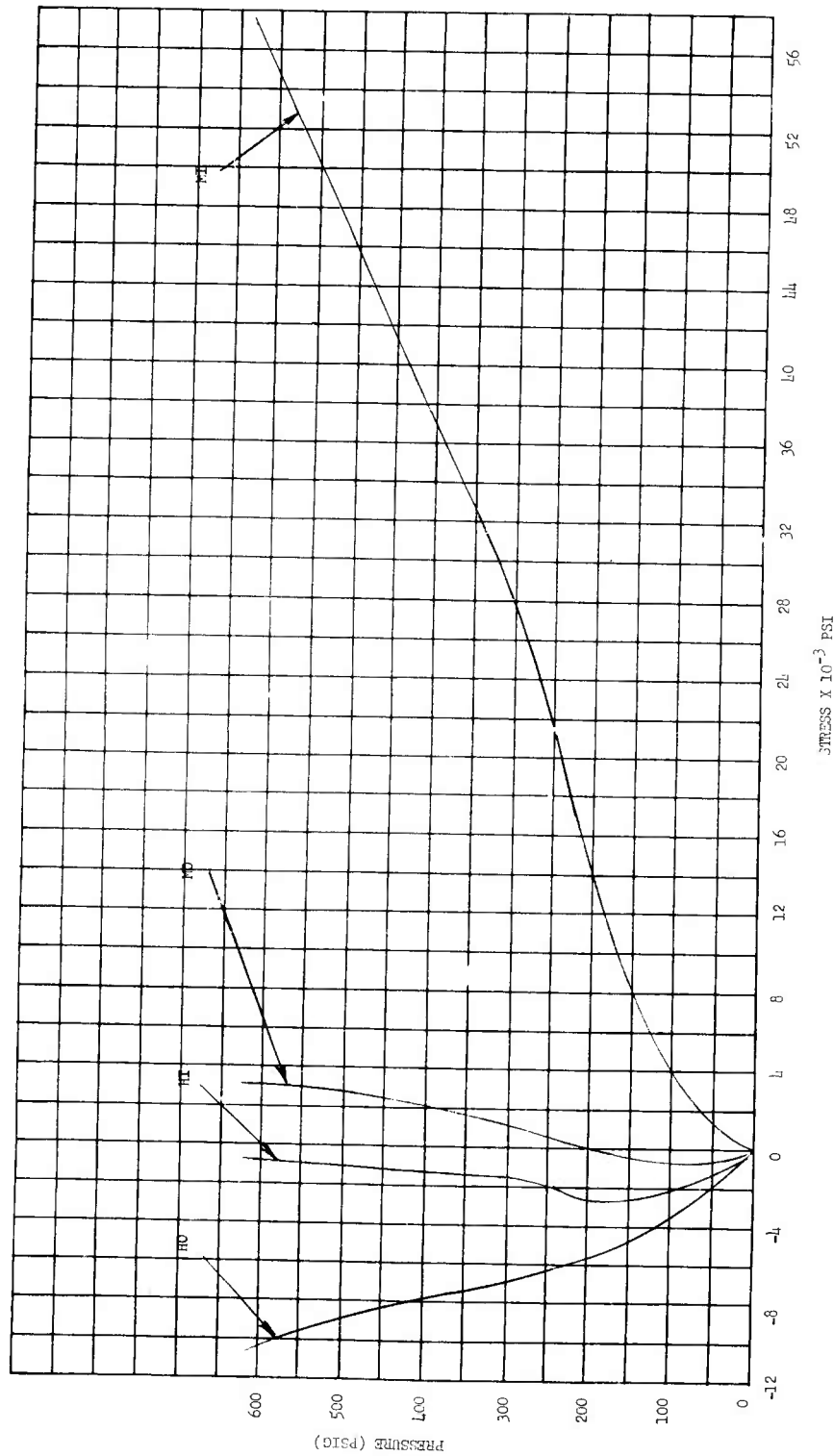
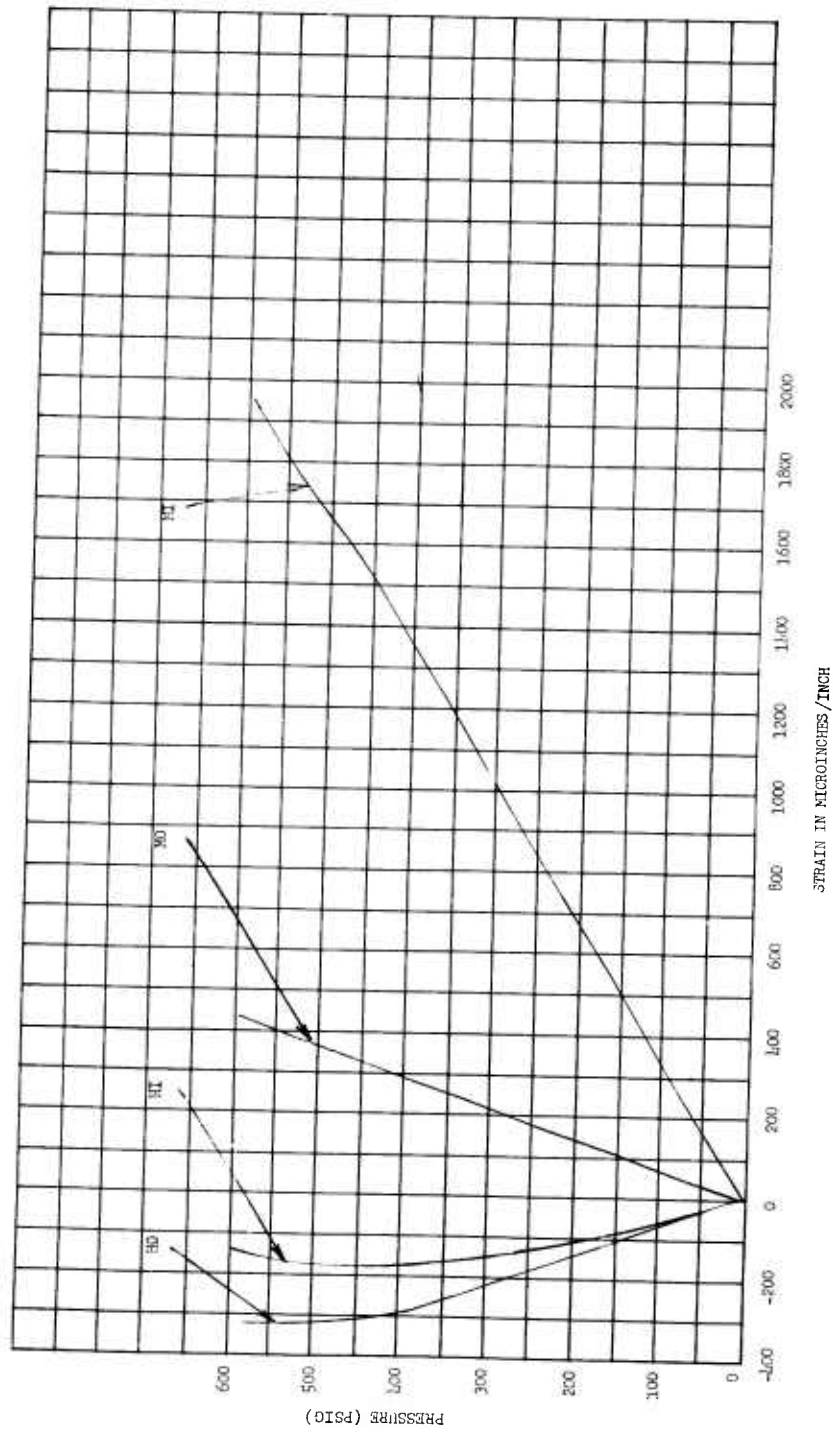


Figure 107

Pressure vs Stress, Gage Point 63



Pressure vs Strain, Gage Point 64

Figure 108

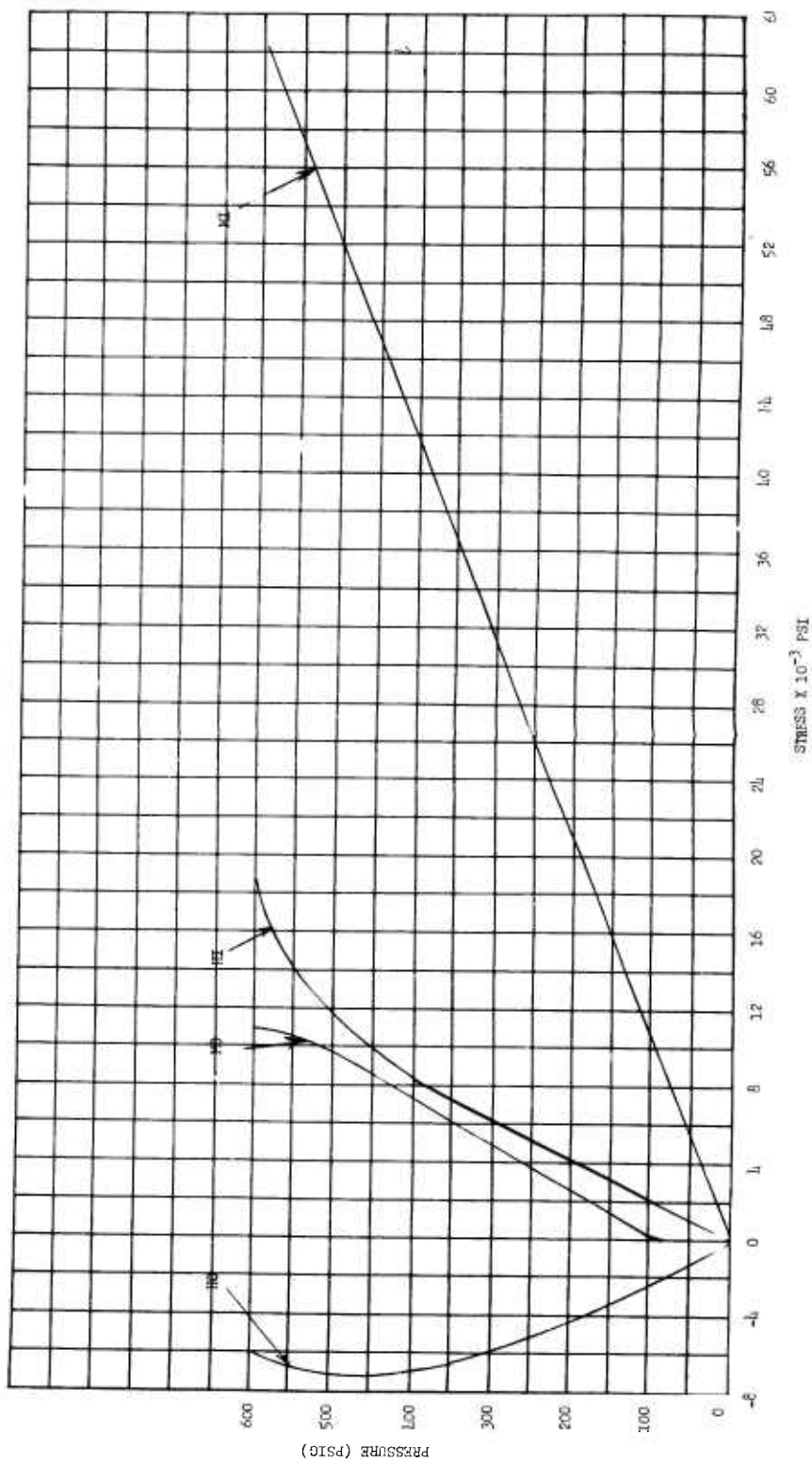
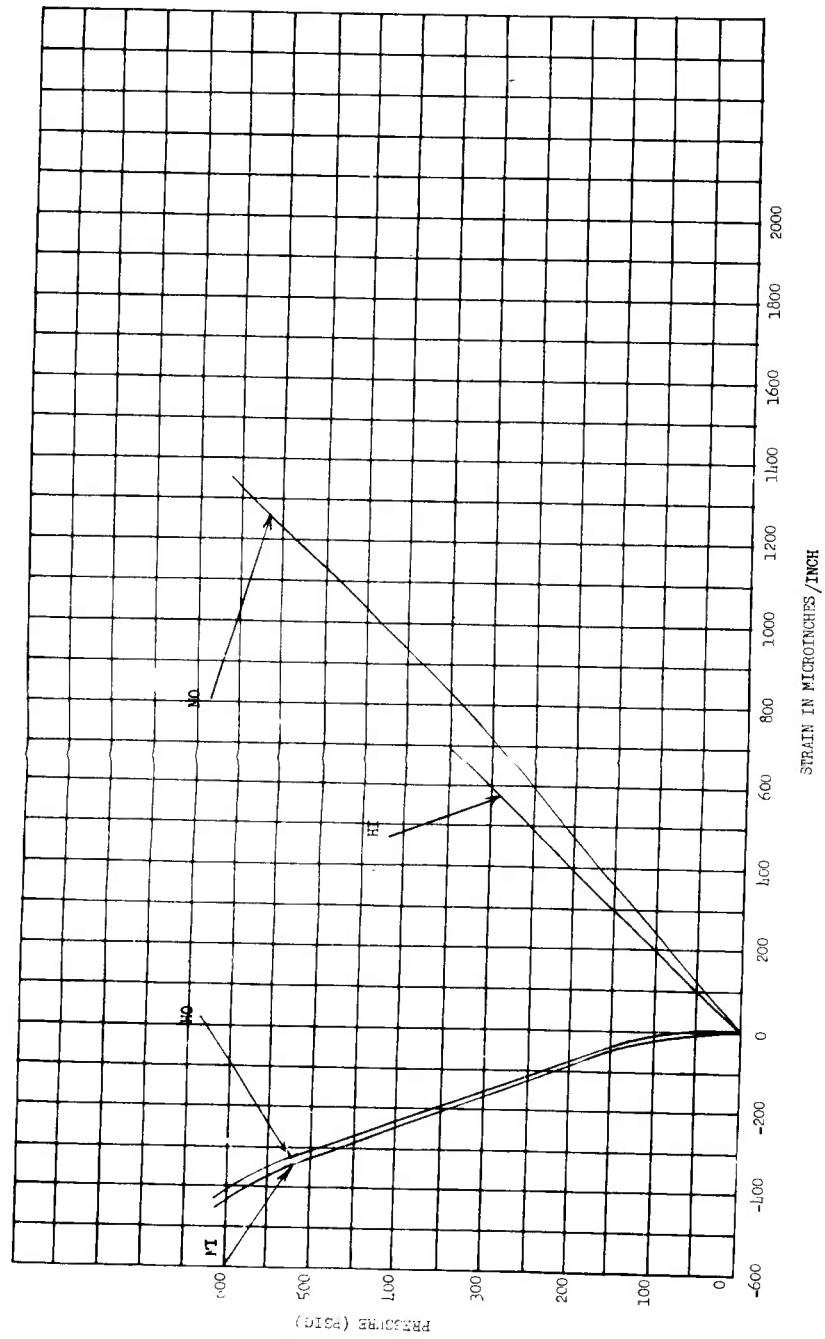


Figure 109

Pressure vs Stress, Gage Point 64



Pressure vs Strain, Gage Point 65

Figure 110

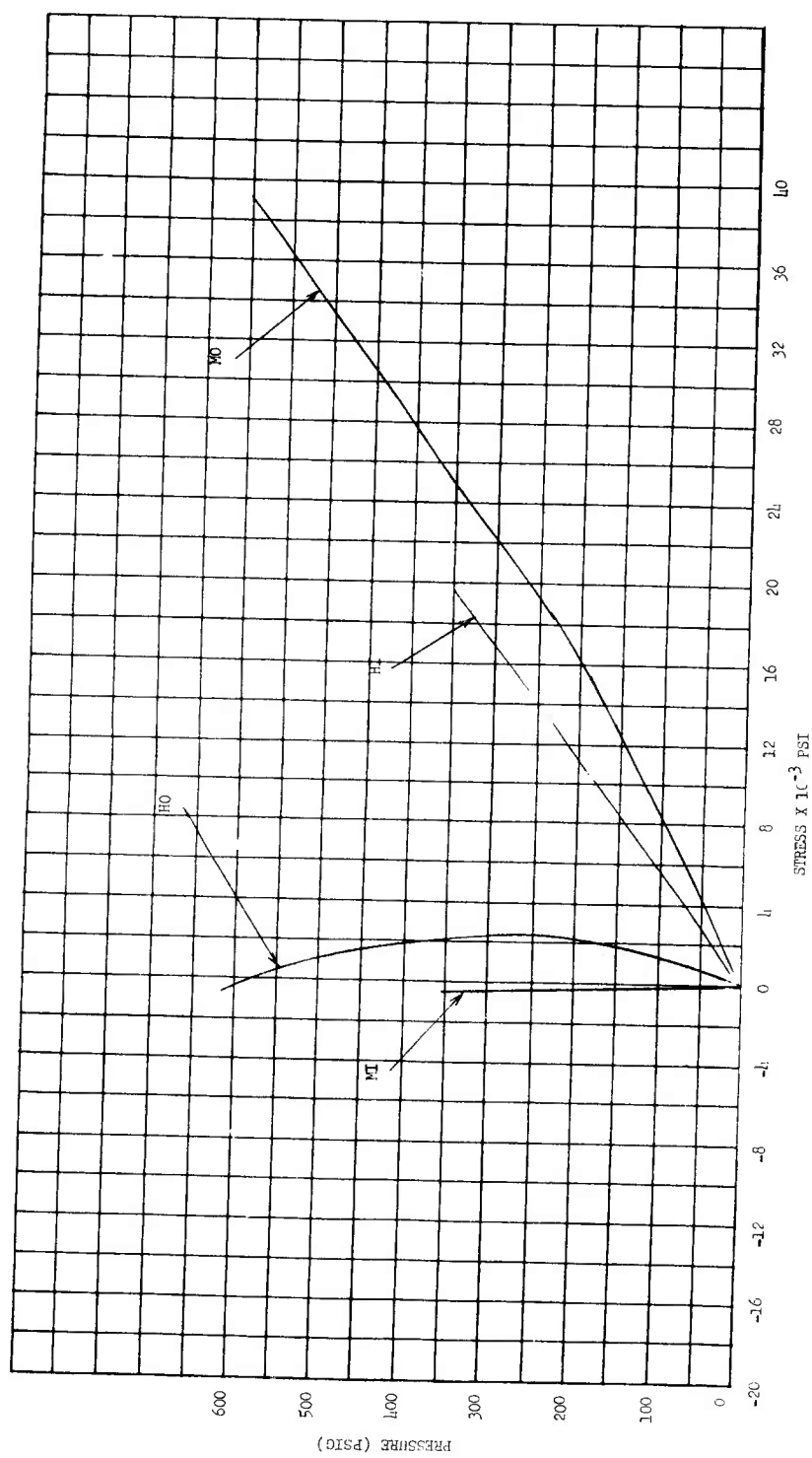
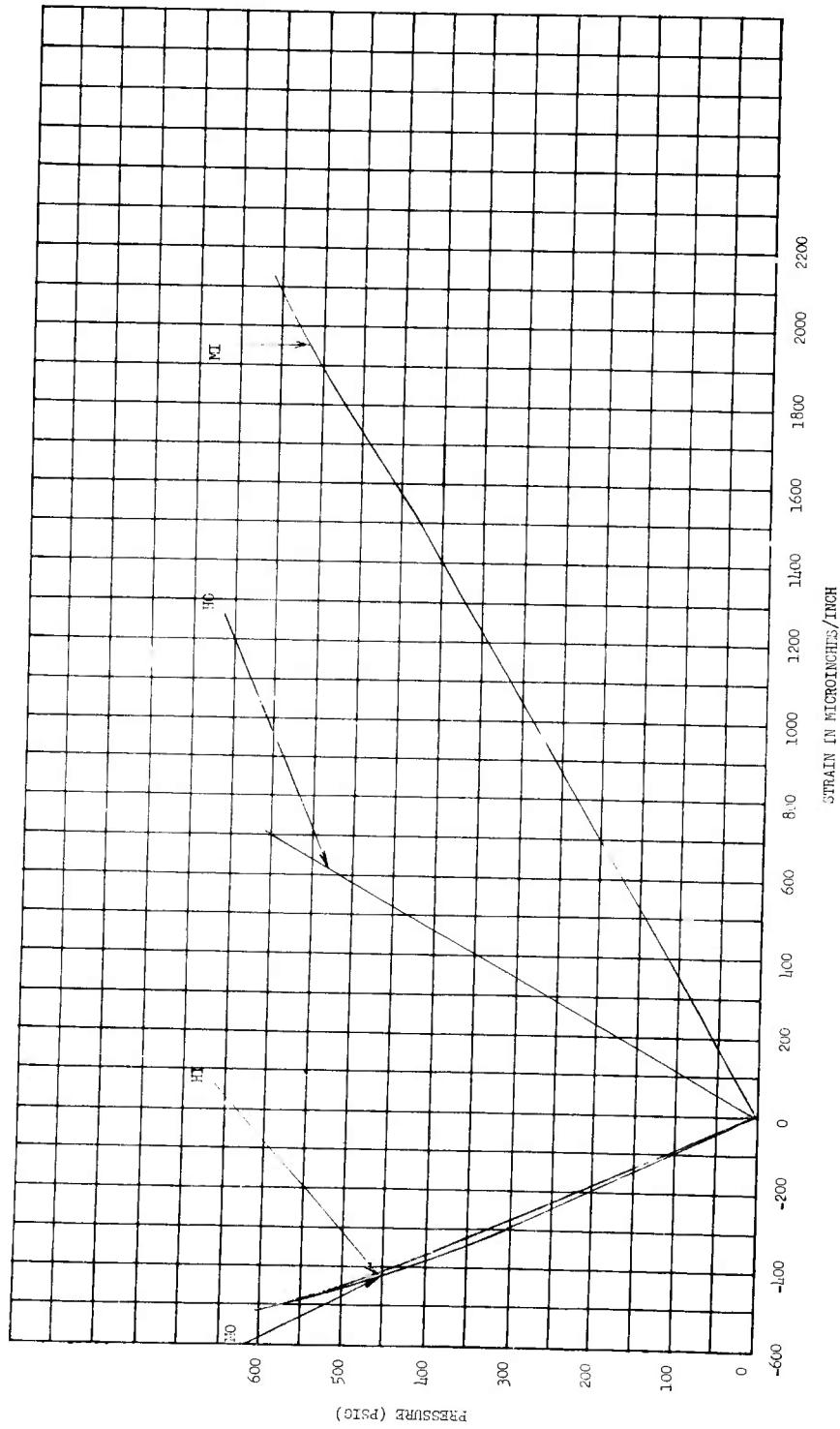


Figure 111

Pressure vs Stress, Gage Point 65

Appendix A



Pressure vs Strain, Gage Point 66

Figure 112

Appendix A

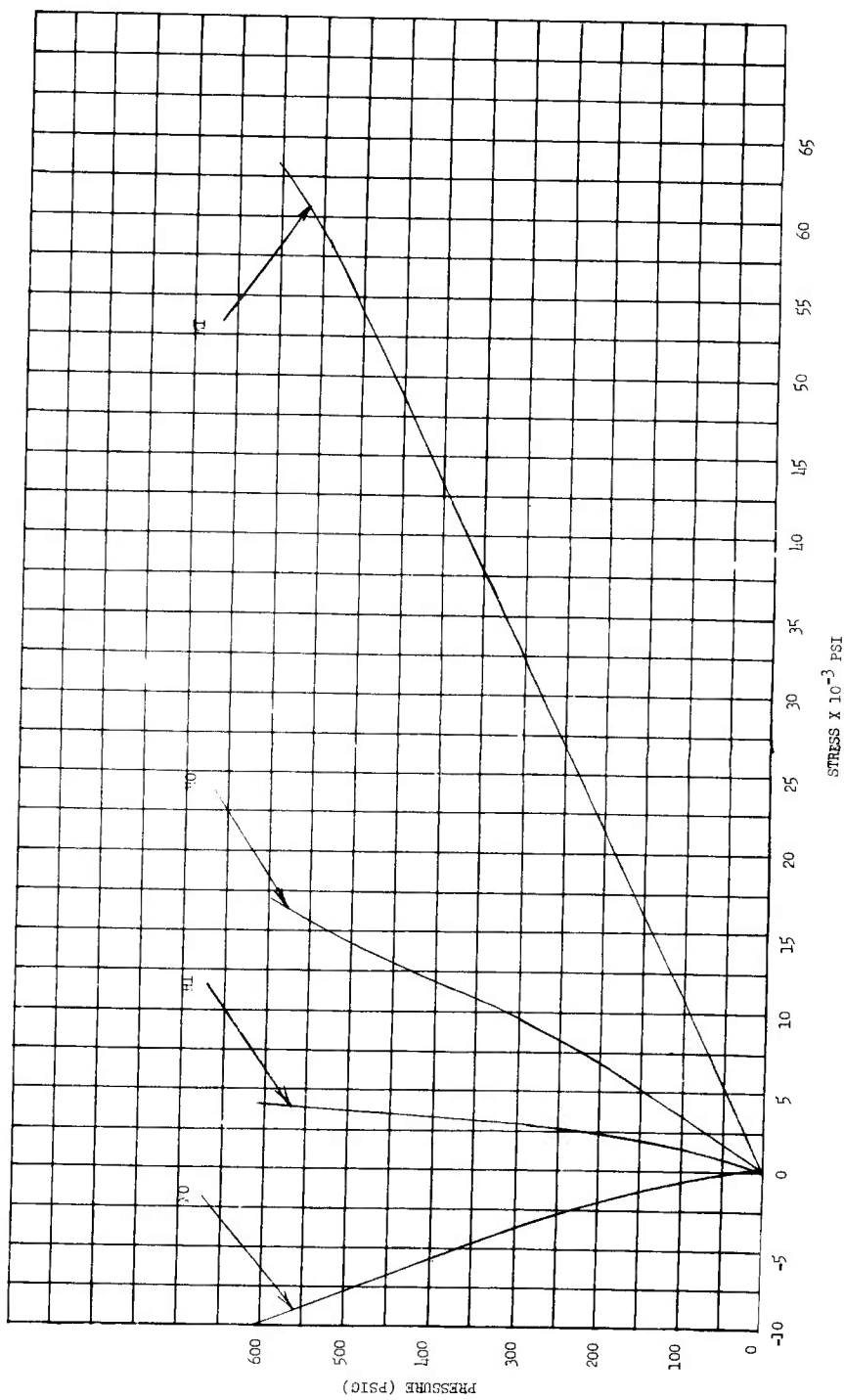


Figure 113

Pressure vs Stress, Gage Point 66

APPENDIX B: PHASE II

STRESS AND STRAIN
CURVES FOR STRESSCOAT,
POINTS 52 TO 60

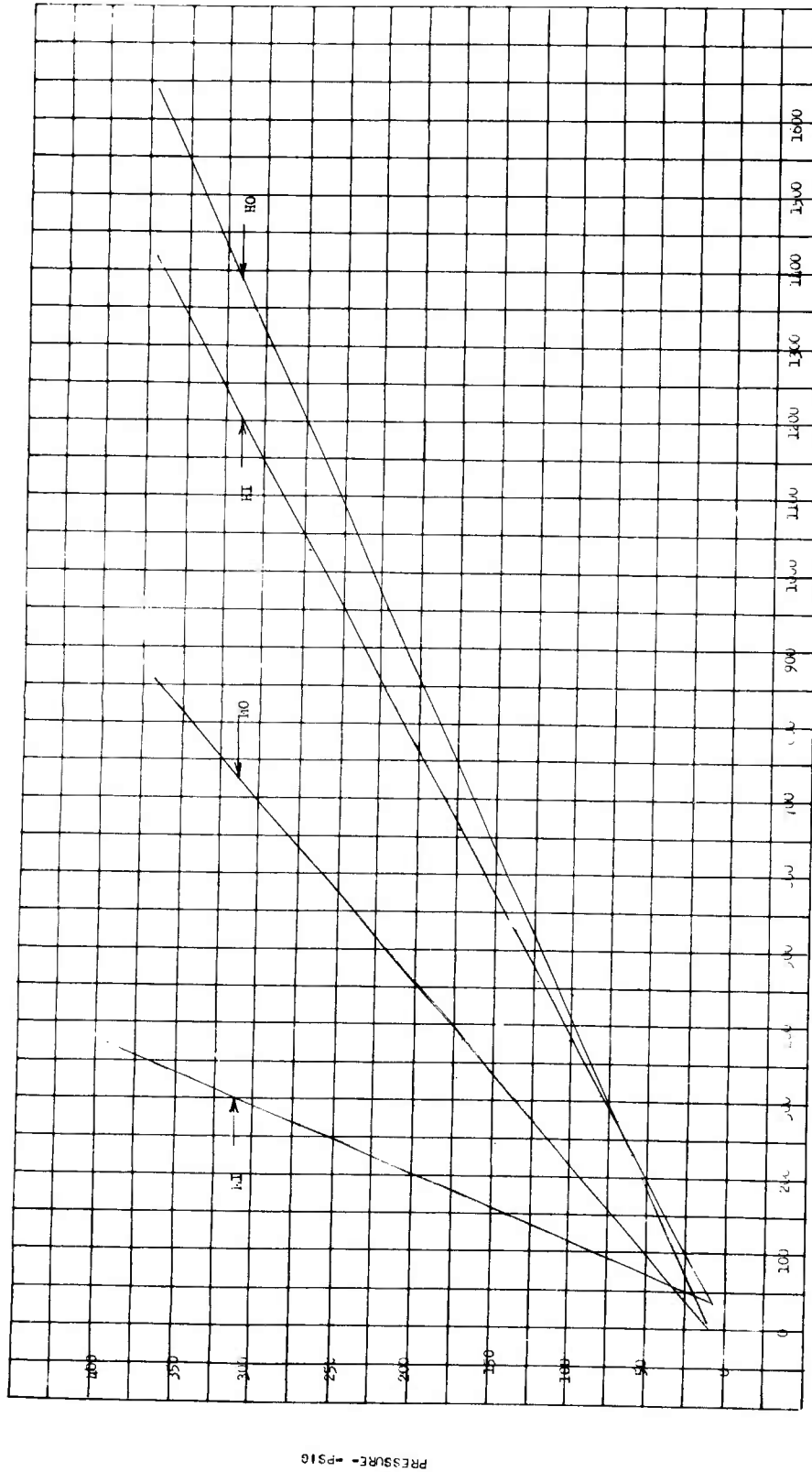


FIGURE 1

Pressure vs Strain, Gage Point 52

Figure 1

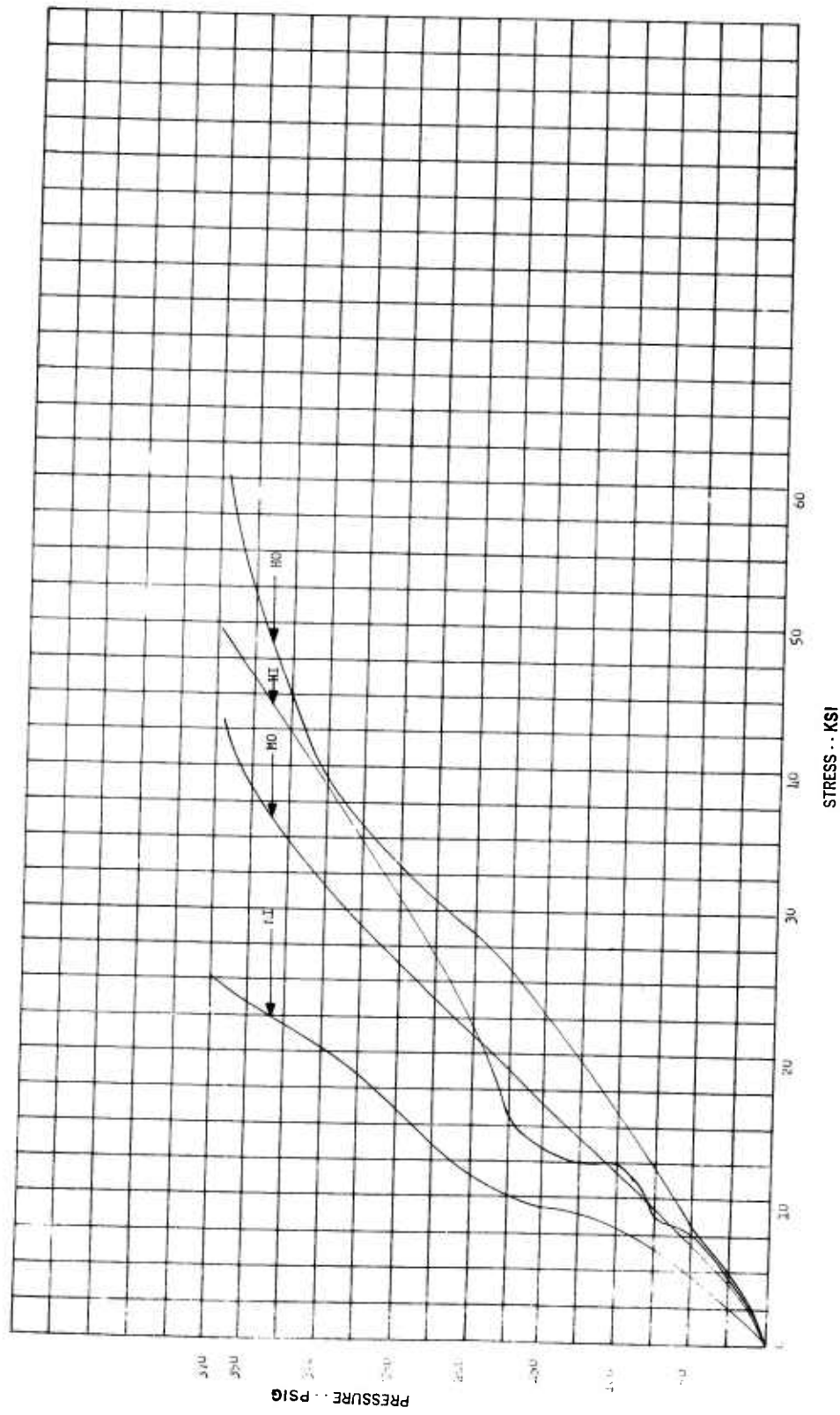
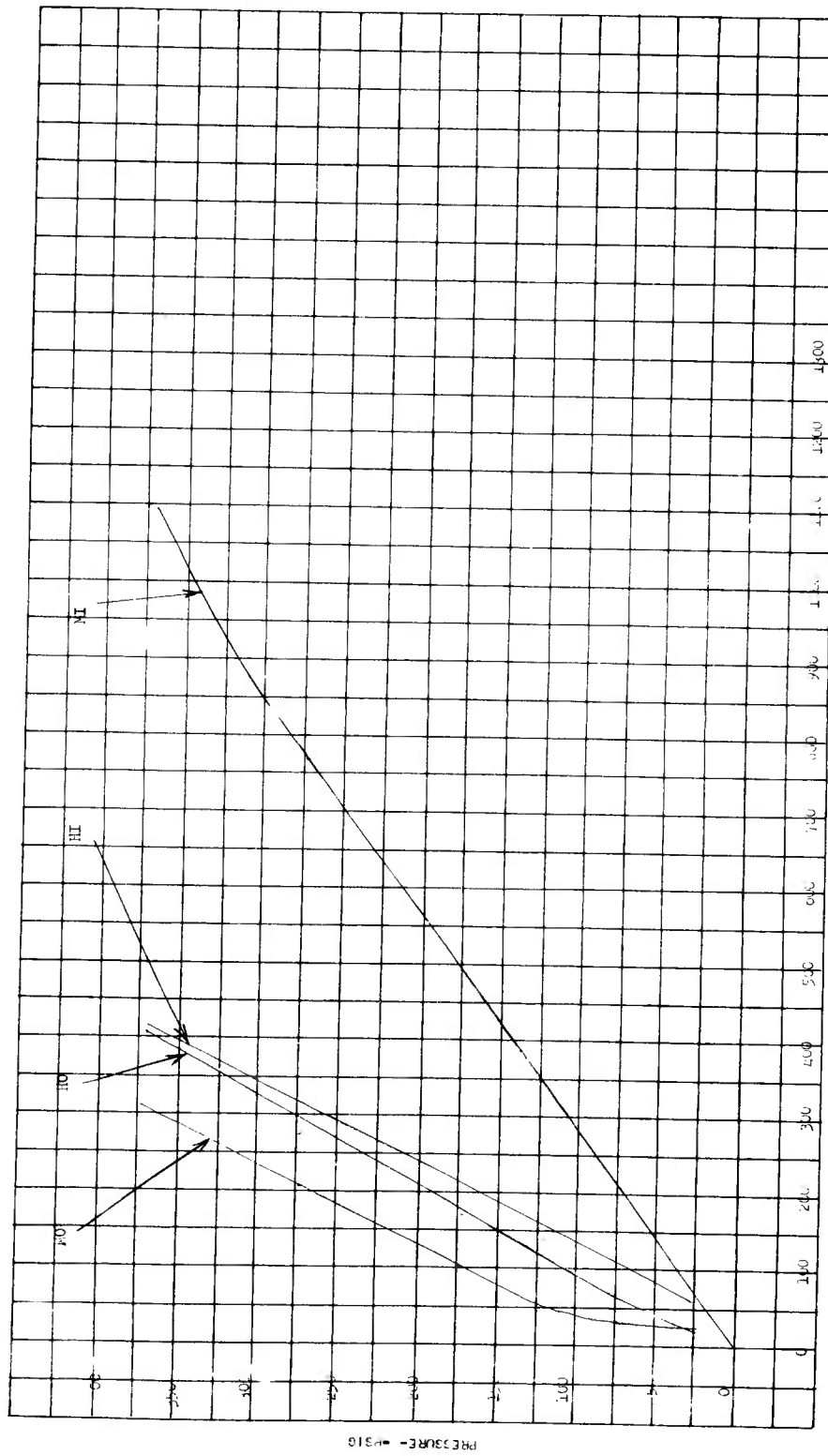


Figure 2

Pressure vs Stress, Gage Point 52



STRAIN PER CENT

Pressure vs Strain, Gage Point 53

Figure 3

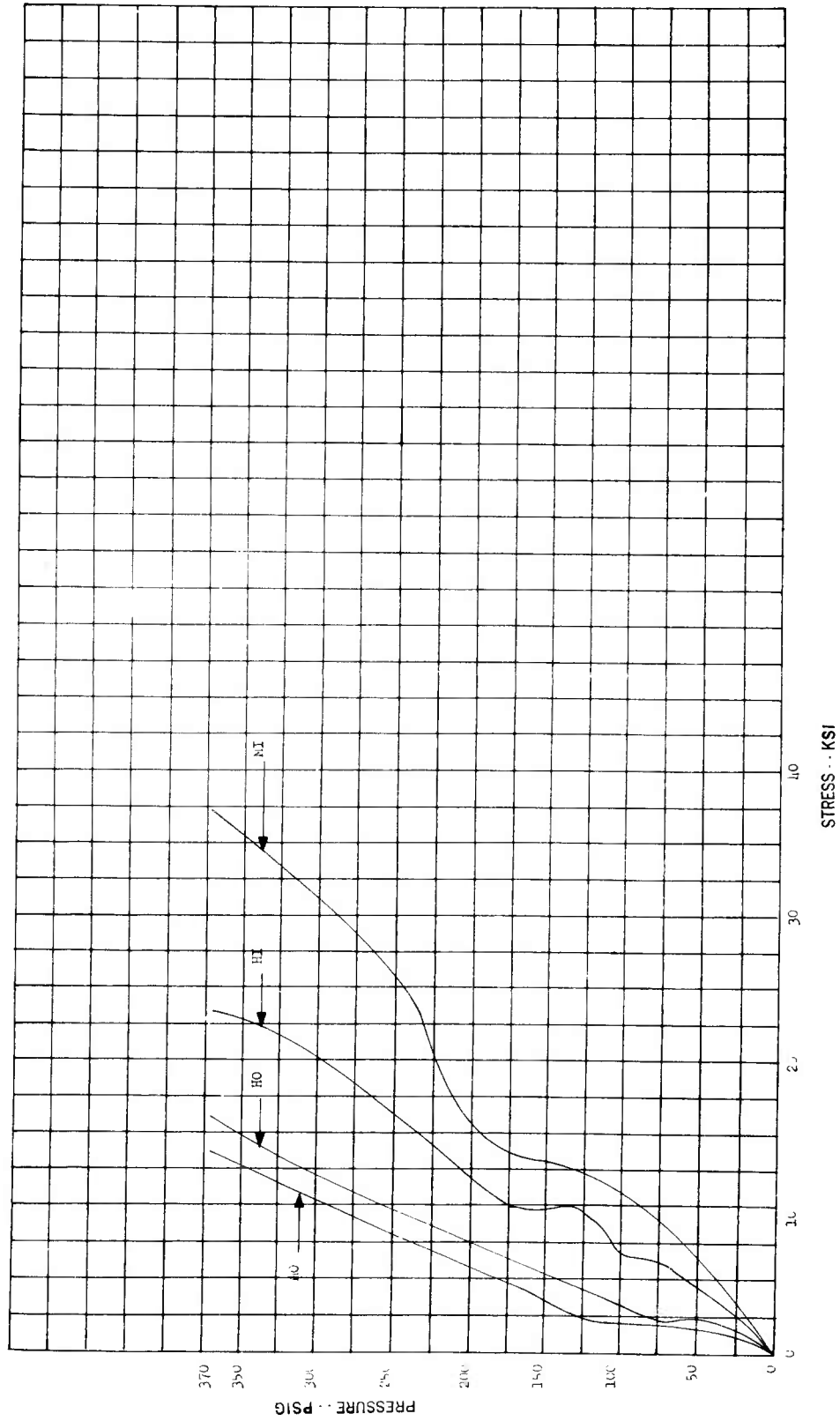
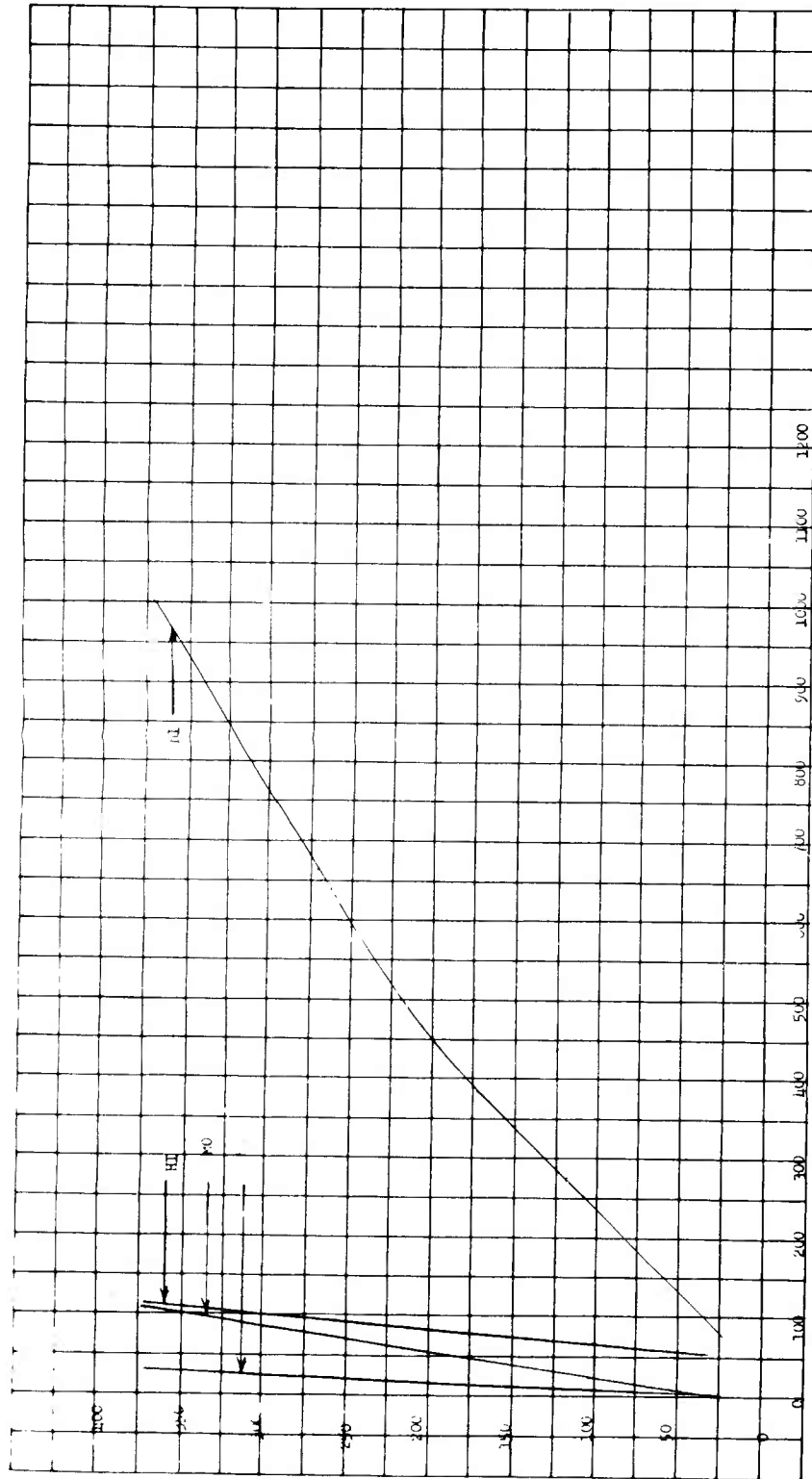


Figure 4

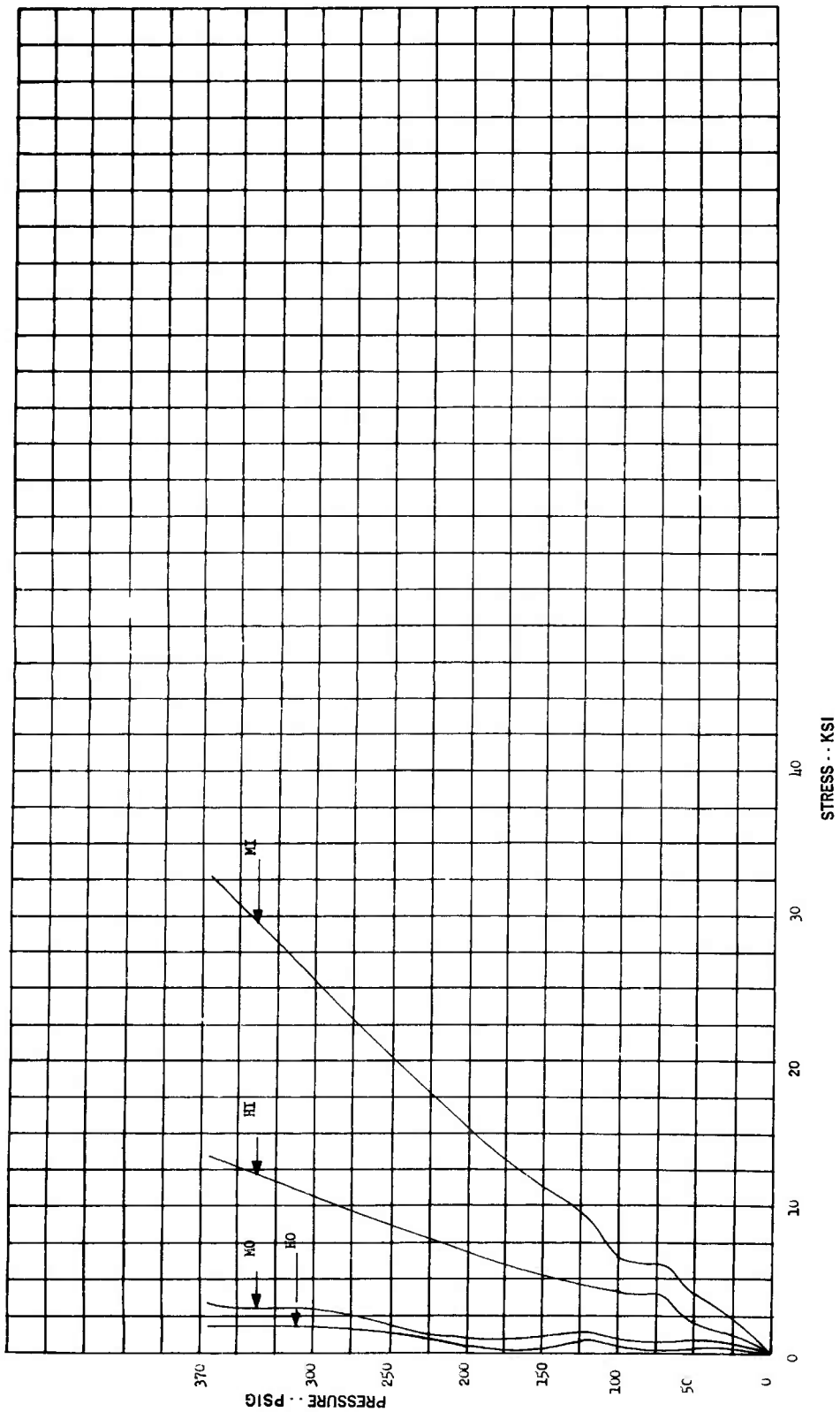
Pressure vs Stress, Gage Point 53



STRAIN IN HUNDREDS/IN.

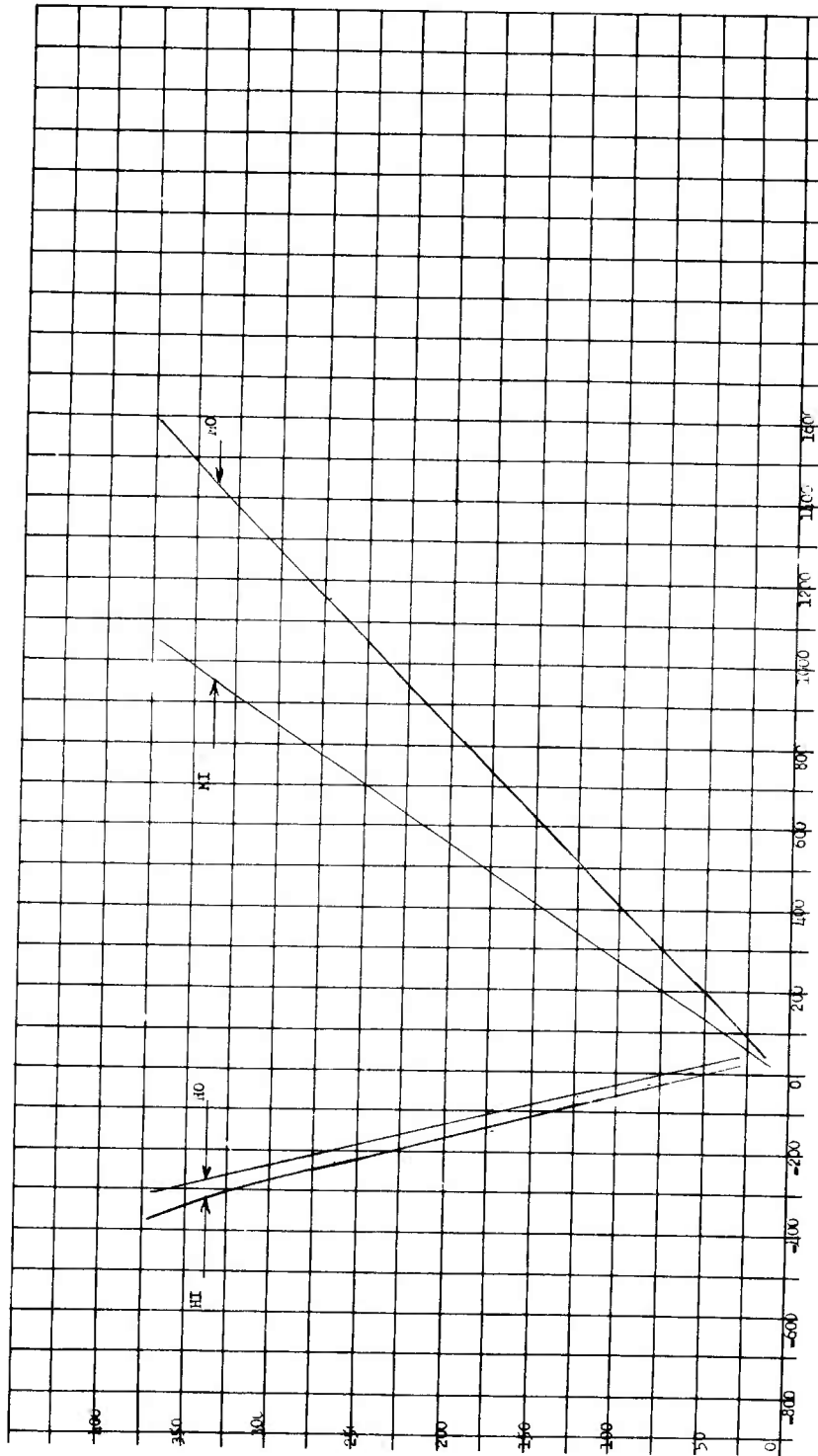
Pressure vs Strain, Gage Point 54

Figure 5



Pressure vs Stress, Gage Point 54

Figure 6



STRAIN IN MICROIN./IN.

Pressure vs Strain, Gage Point 55

PRESSURE - PSIG

Figure 7

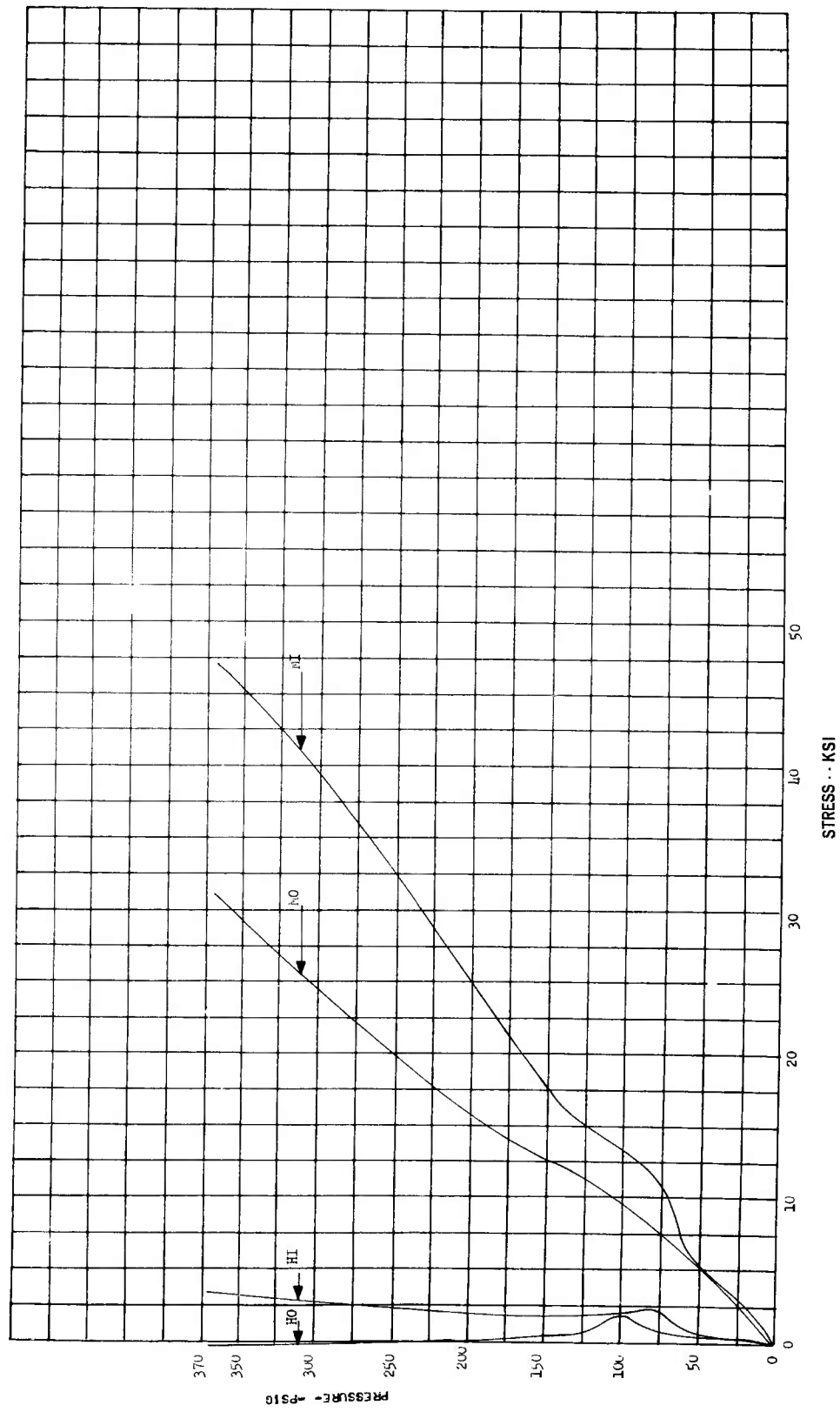


Figure 8

Pressure vs Stress, Gage Point 55

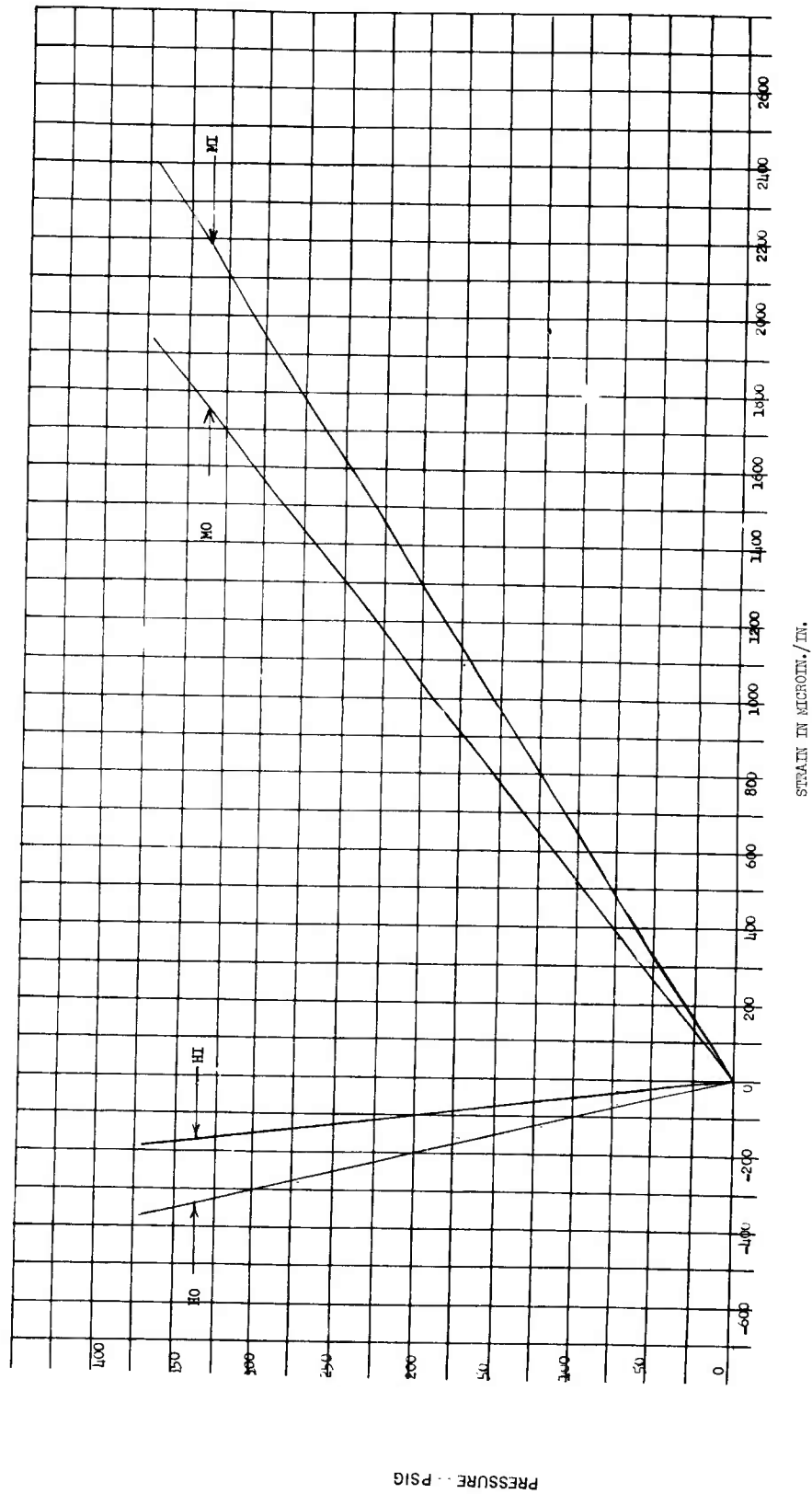
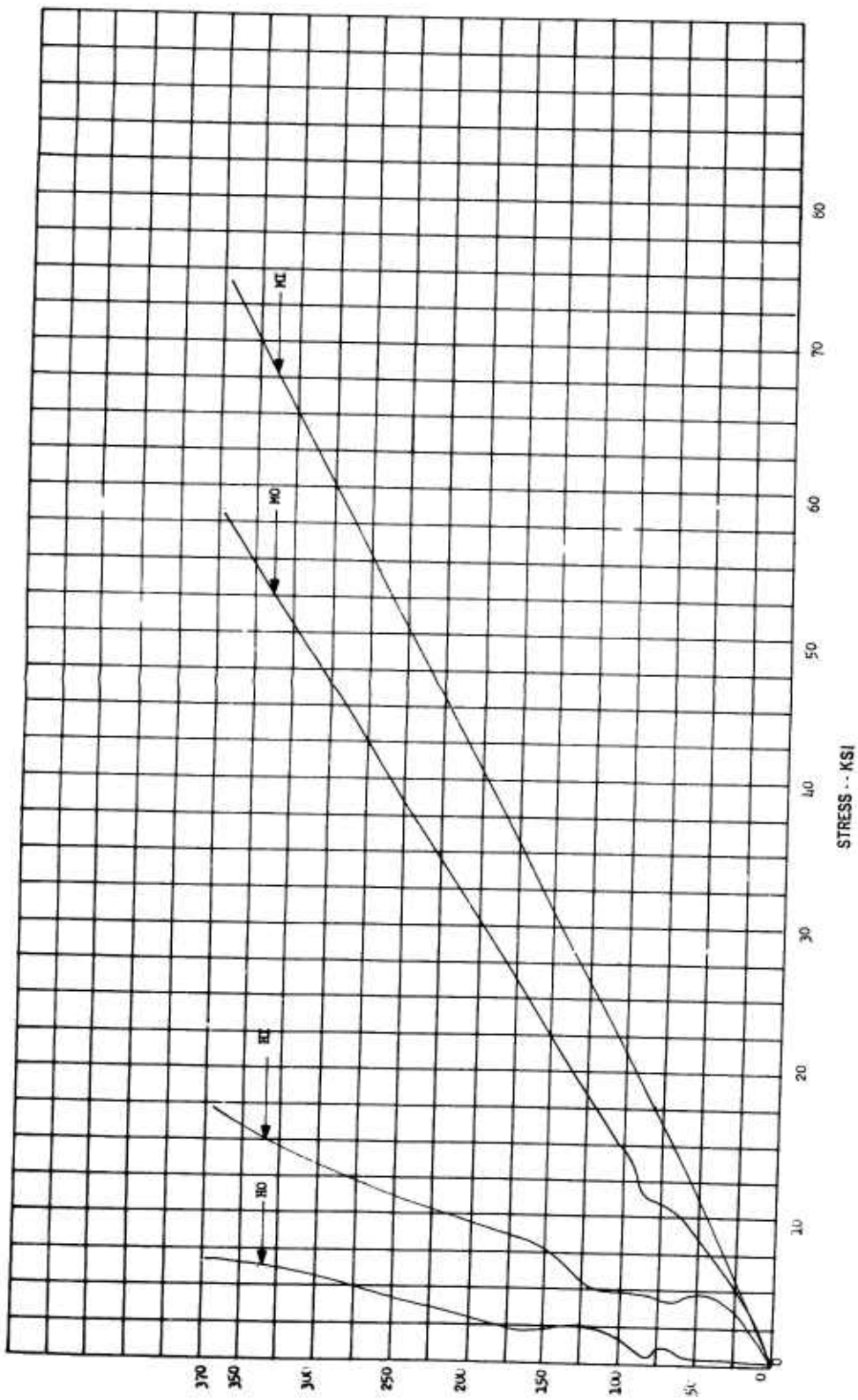


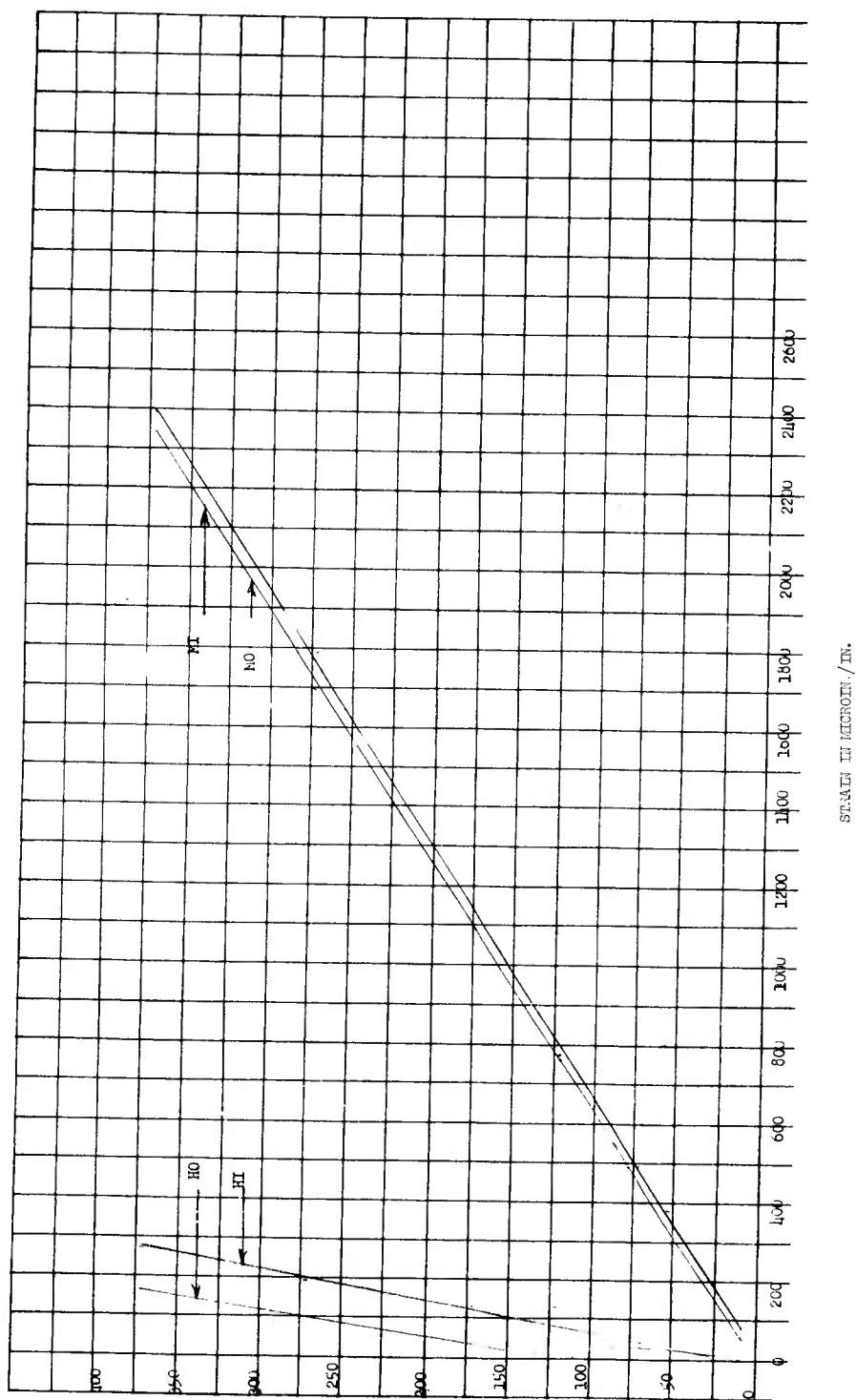
Figure 9

Pressure vs Strain, Gage Point 56



Pressure vs Stress, Gage Point 56

Figure 10



Pressure vs Strain, Gage Point 57

Figure 11

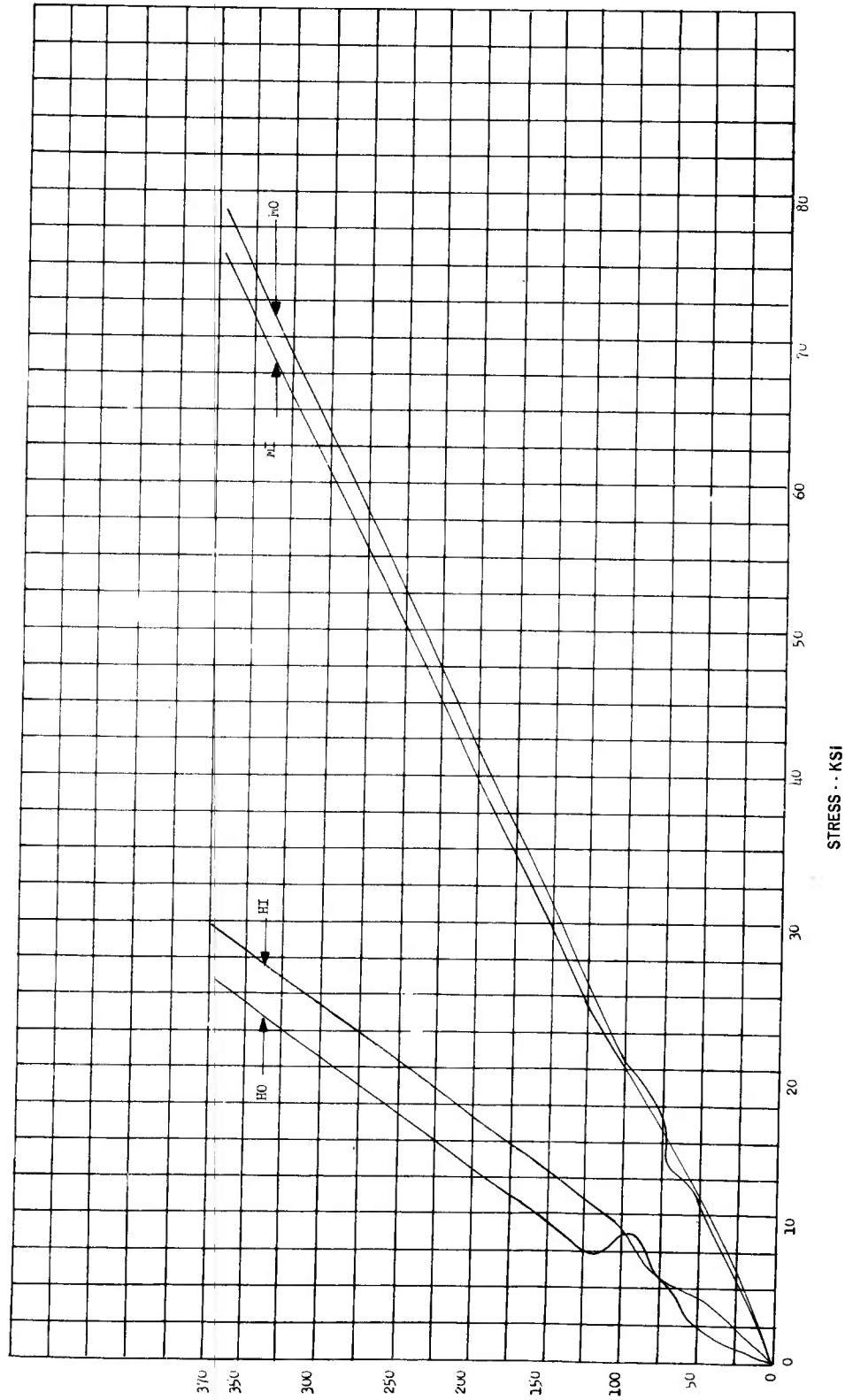
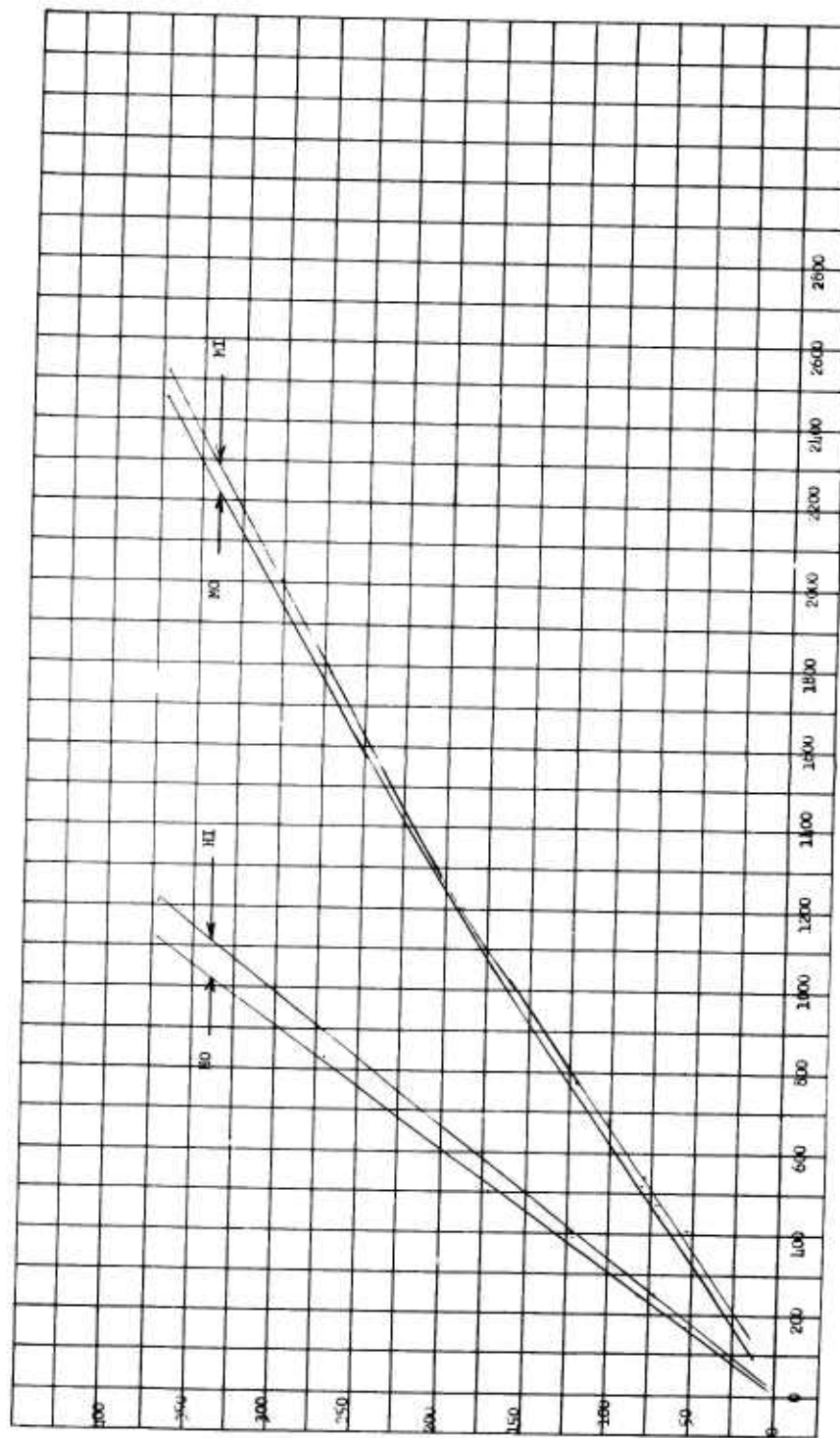


Figure 12

Pressure vs Stress, Gage Point 57



STRAIN IN MICROIN./IN.

Pressure vs Strain, Gage Point 58

Figure 13

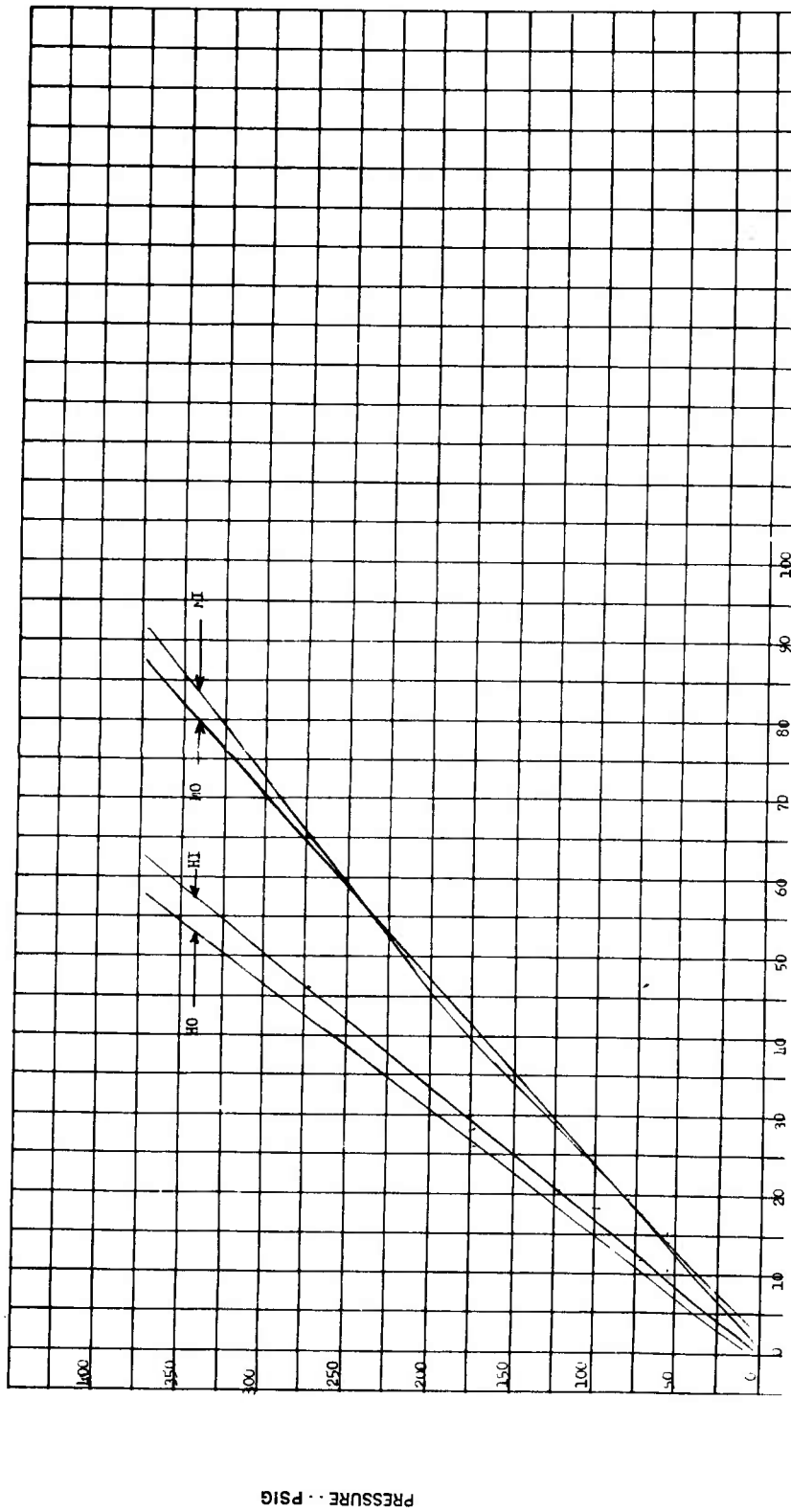


Figure 14

Pressure vs Stress, Gage Point 58

STRESS - KSI

PRESSURE - PSIG

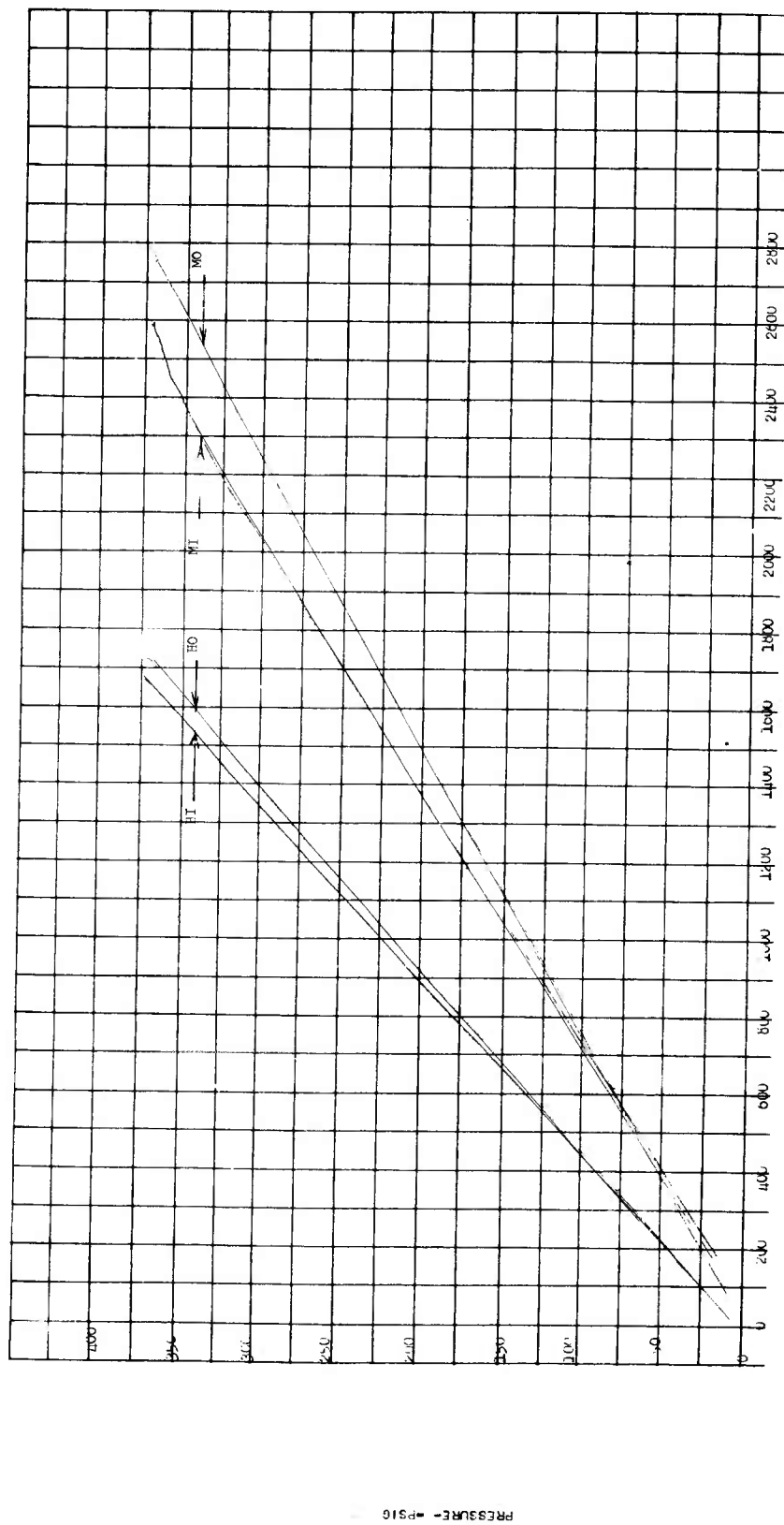


Figure 15

Pressure vs Strain, Gage Point 59

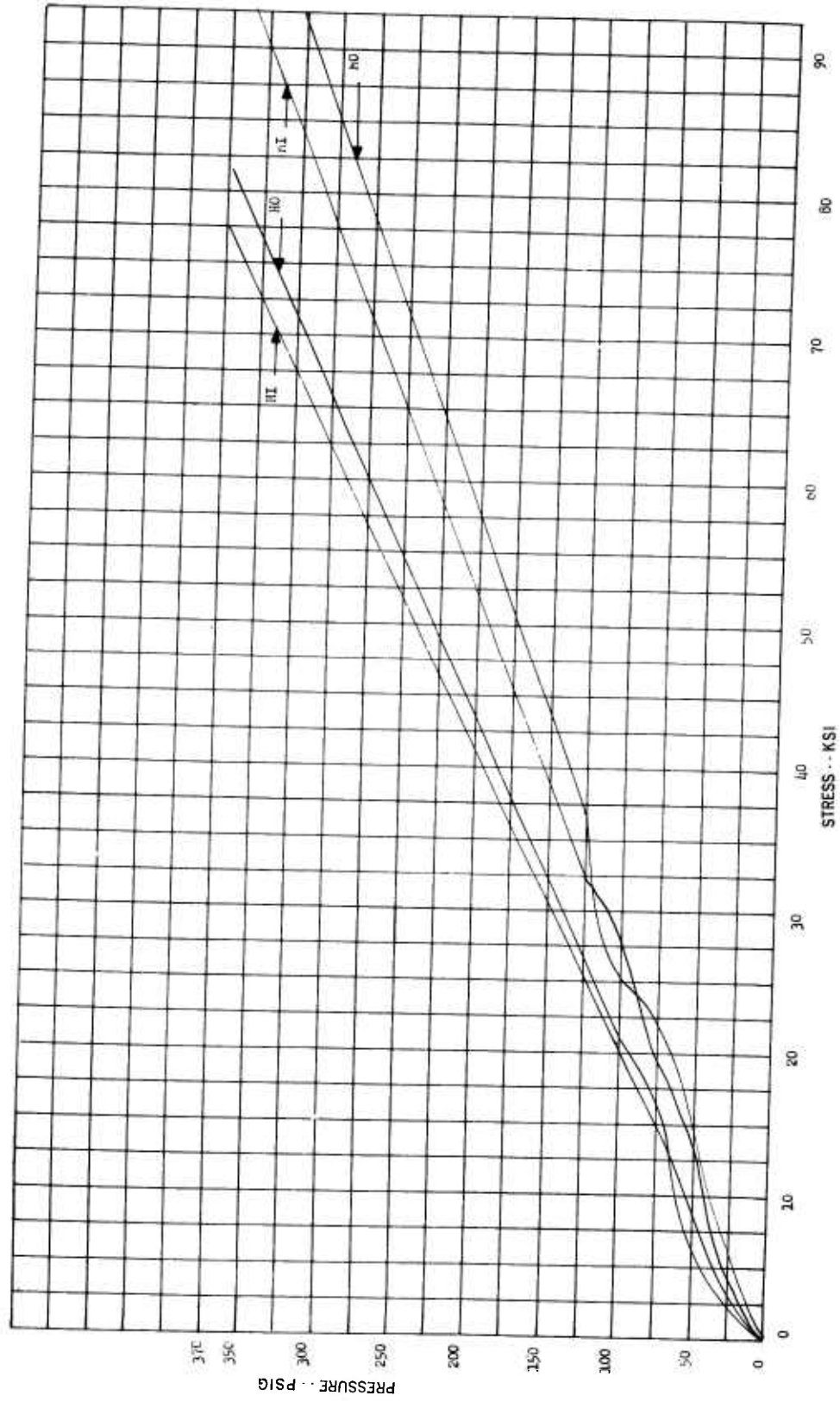
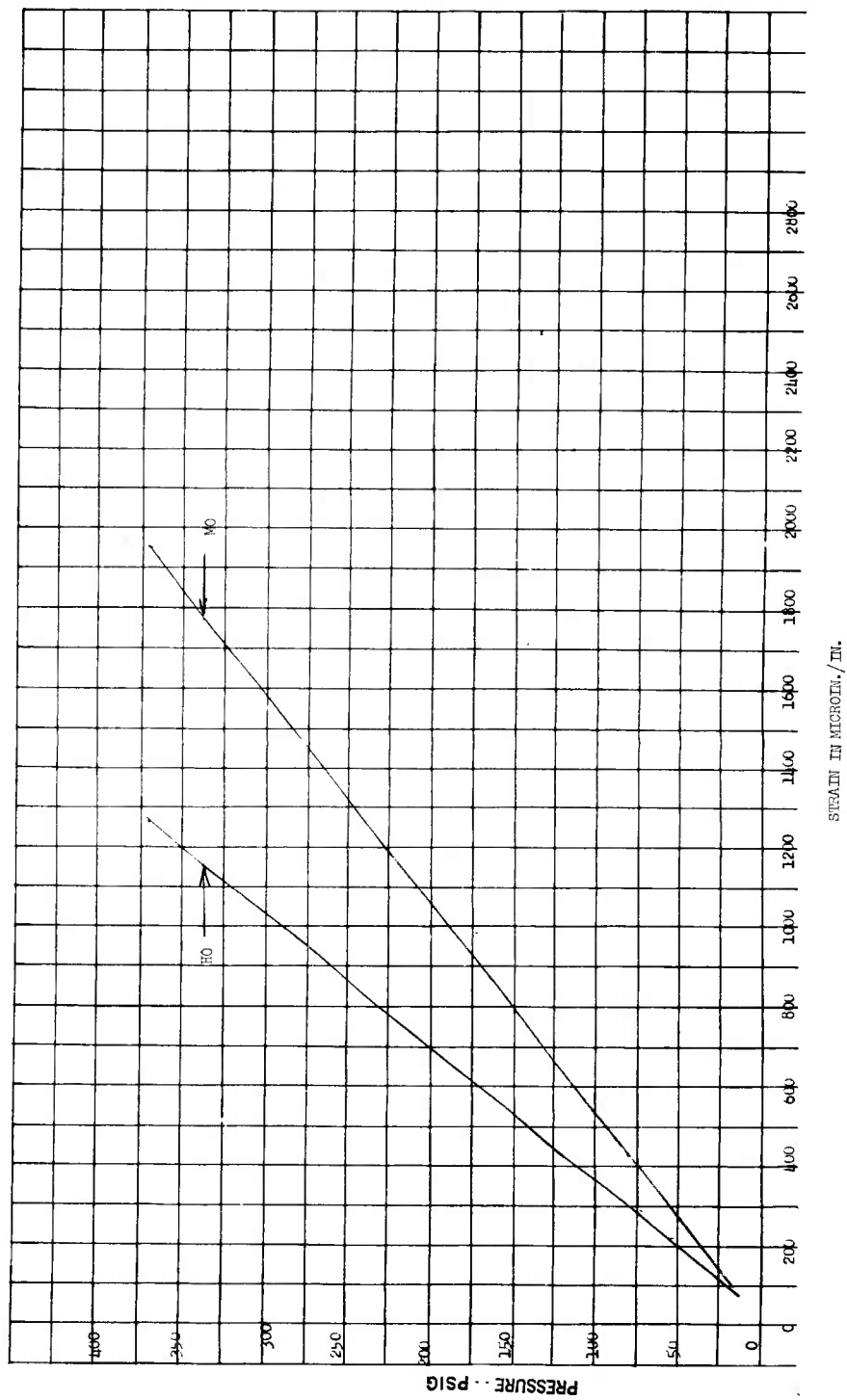


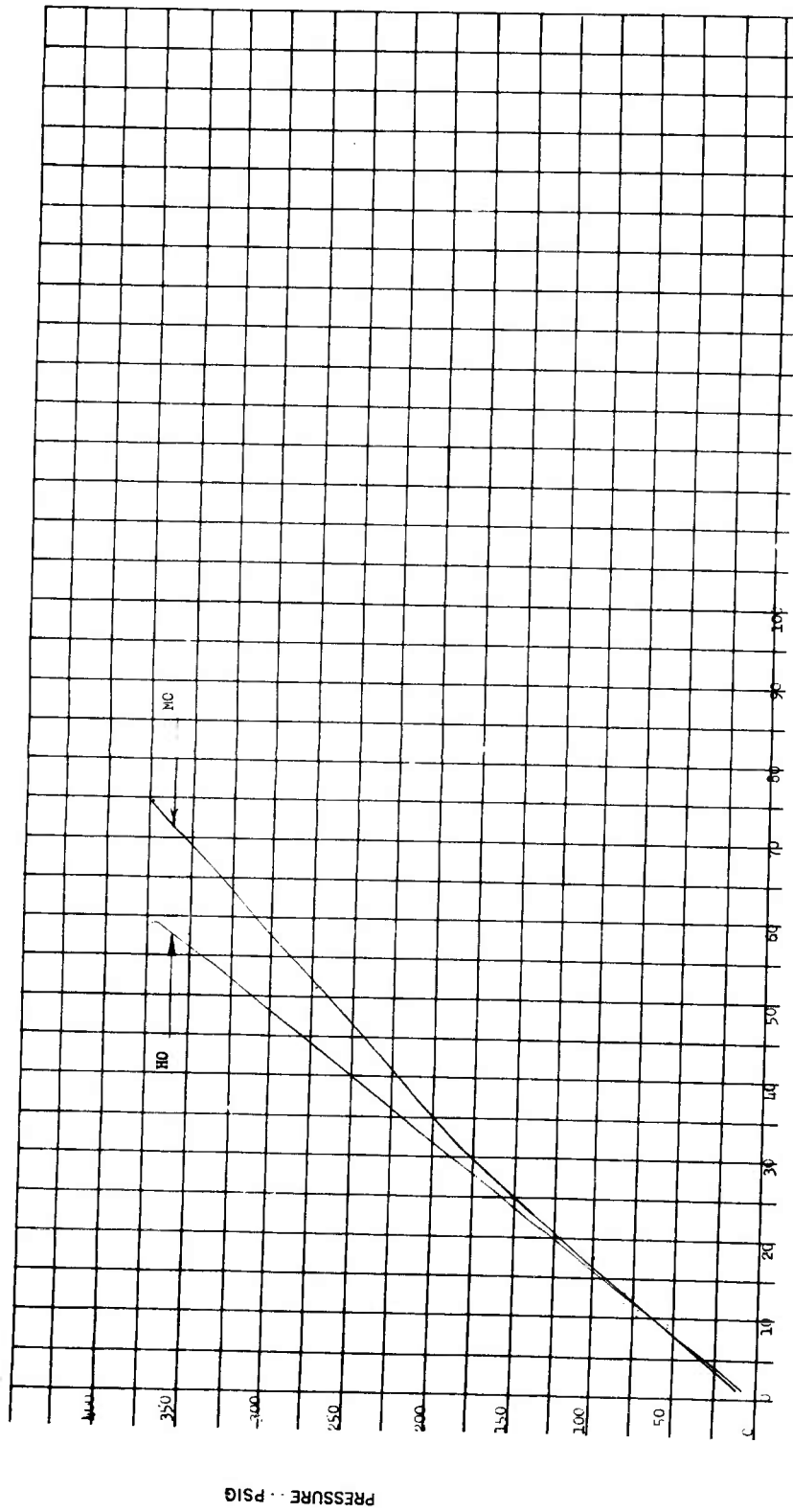
Figure 16

Pressure vs Stress, Gage Point 59



Pressure vs Strain, Gage Point 60

Figure 17



STRESS . . . KSI

Pressure vs Stress, Gage Point 60

Figure 18

APPENDIX C: PHASE III

DEFLECTION CURVES, POINTS 1 TO 50

Appendix C

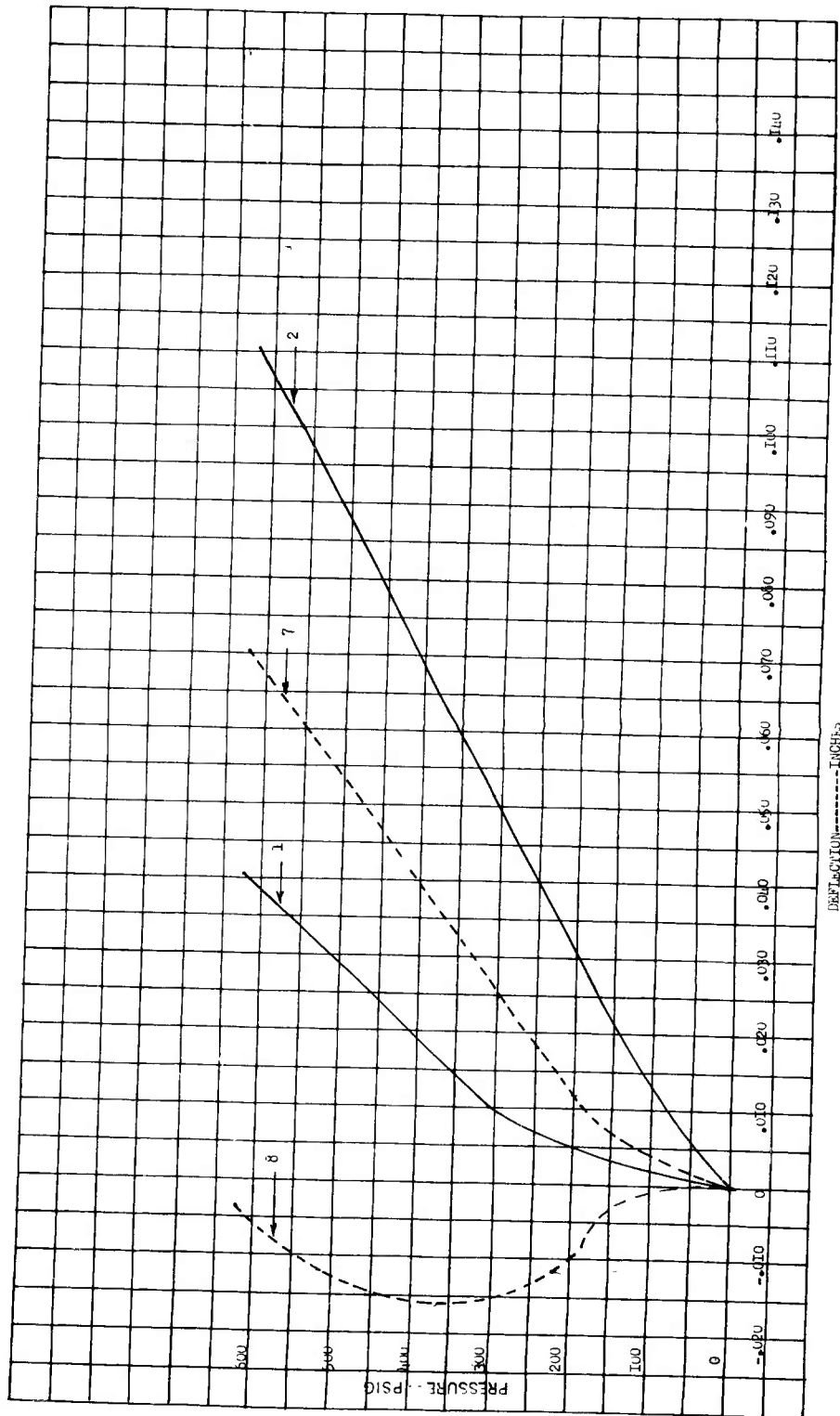
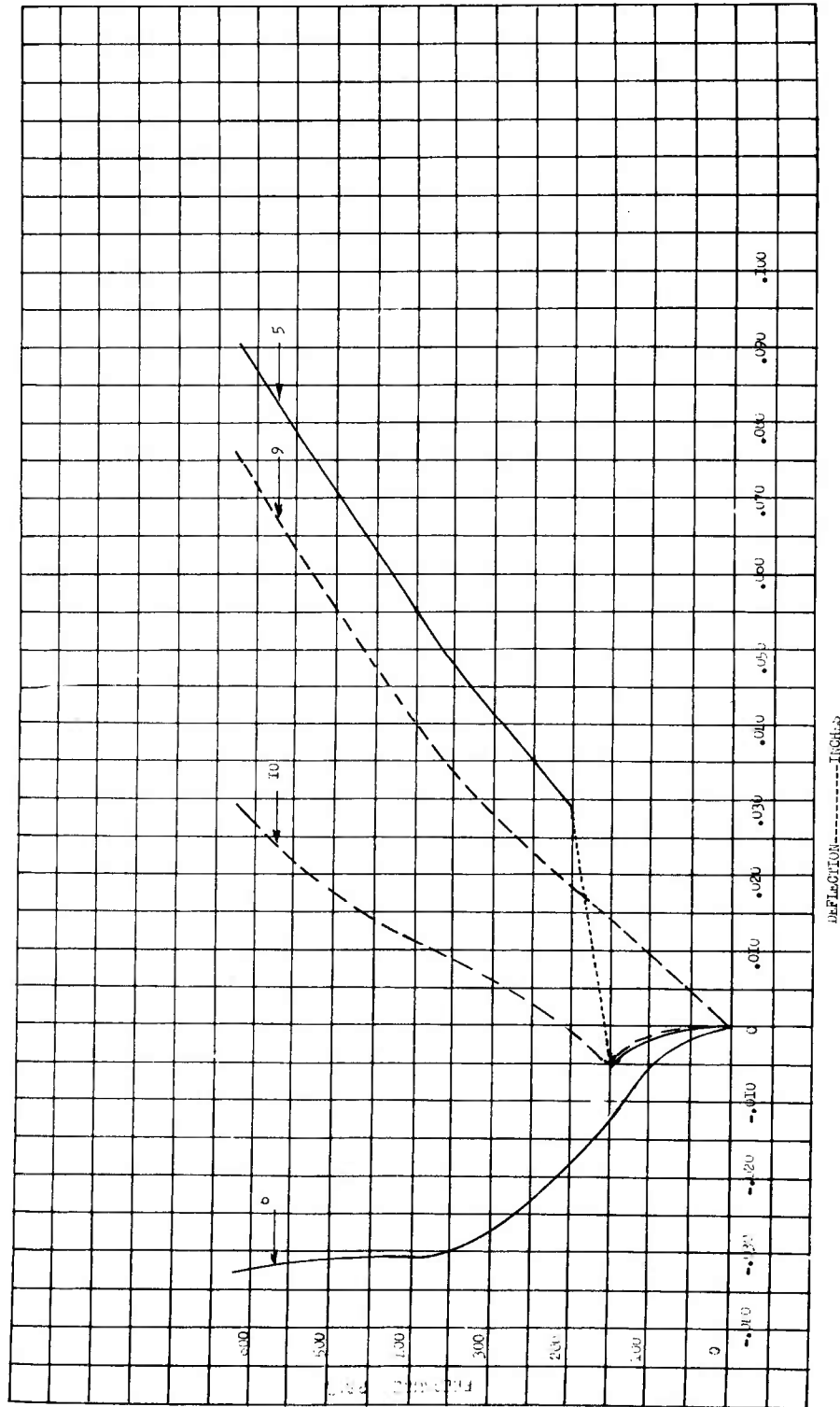


Figure 1

Pressure vs Deflection (-0.02 to 0.140 in.)

Appendix C



Pressure vs Deflection (-.04 to 0.100 in.)

Figure 2

Appendix C

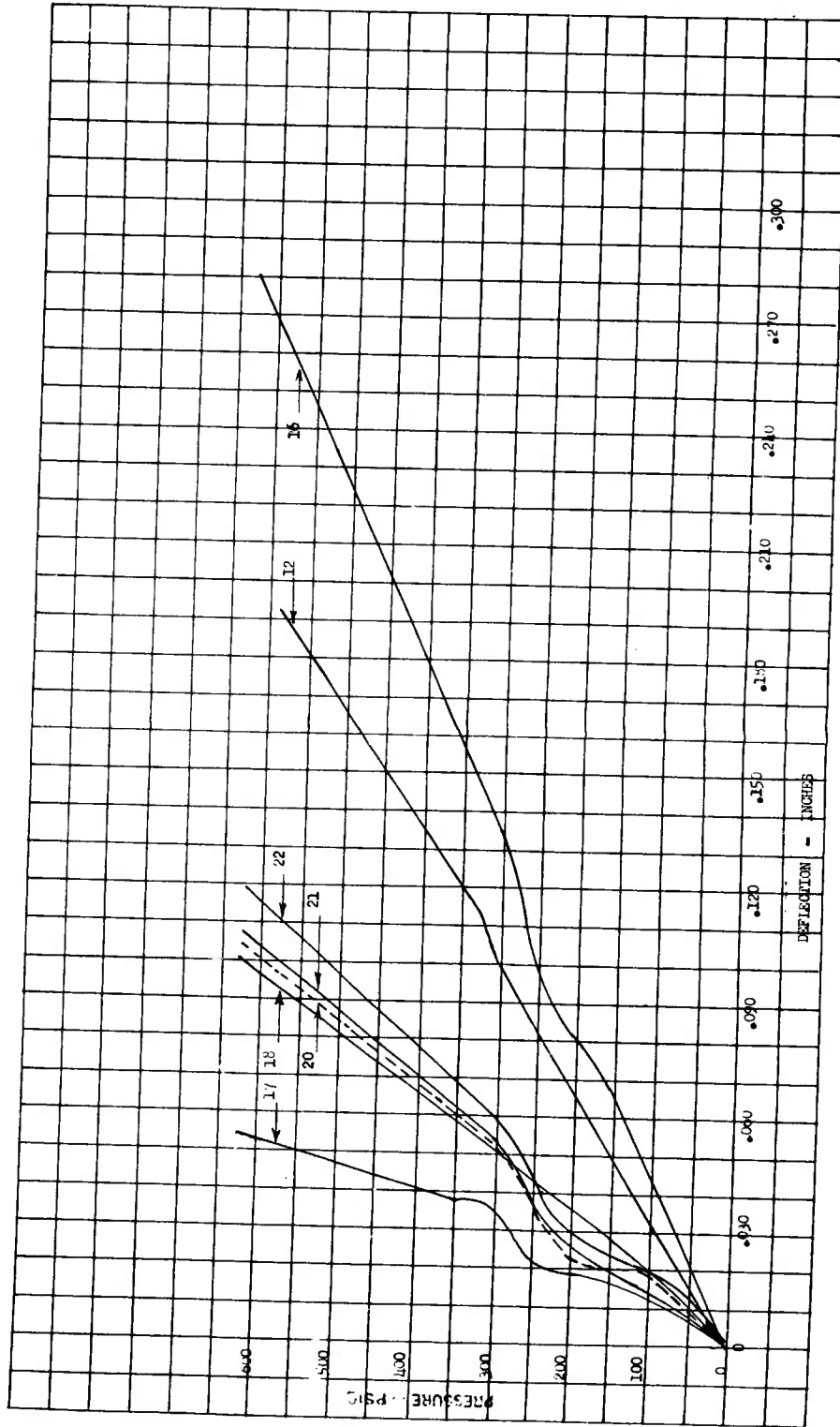
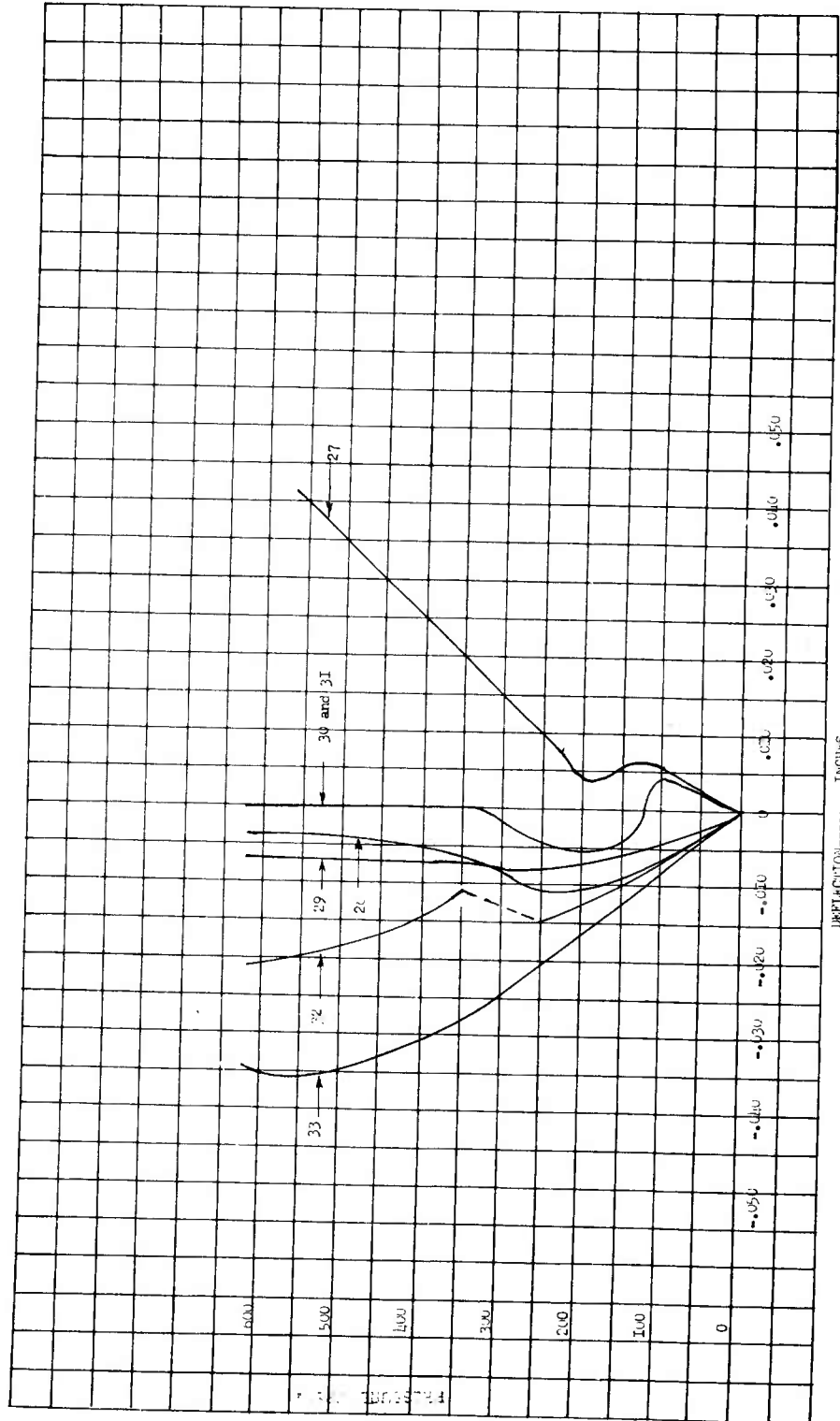


Figure 3

Pressure vs Deflection (0 to 0.300 in.)

Appendix C



Pressure vs Deflection (-0.05 to 0.050 in.)

Figure 4

Appendix C

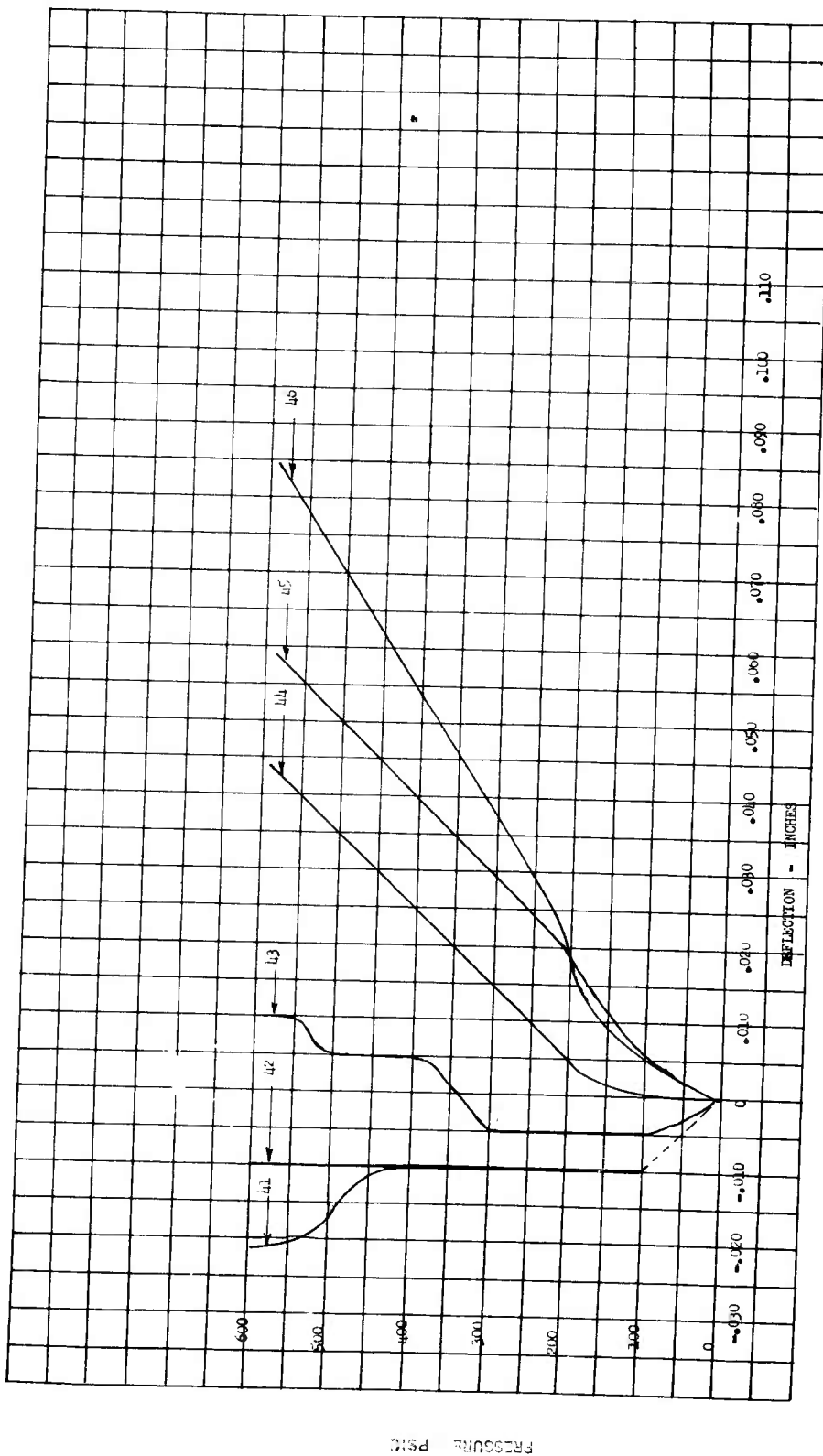
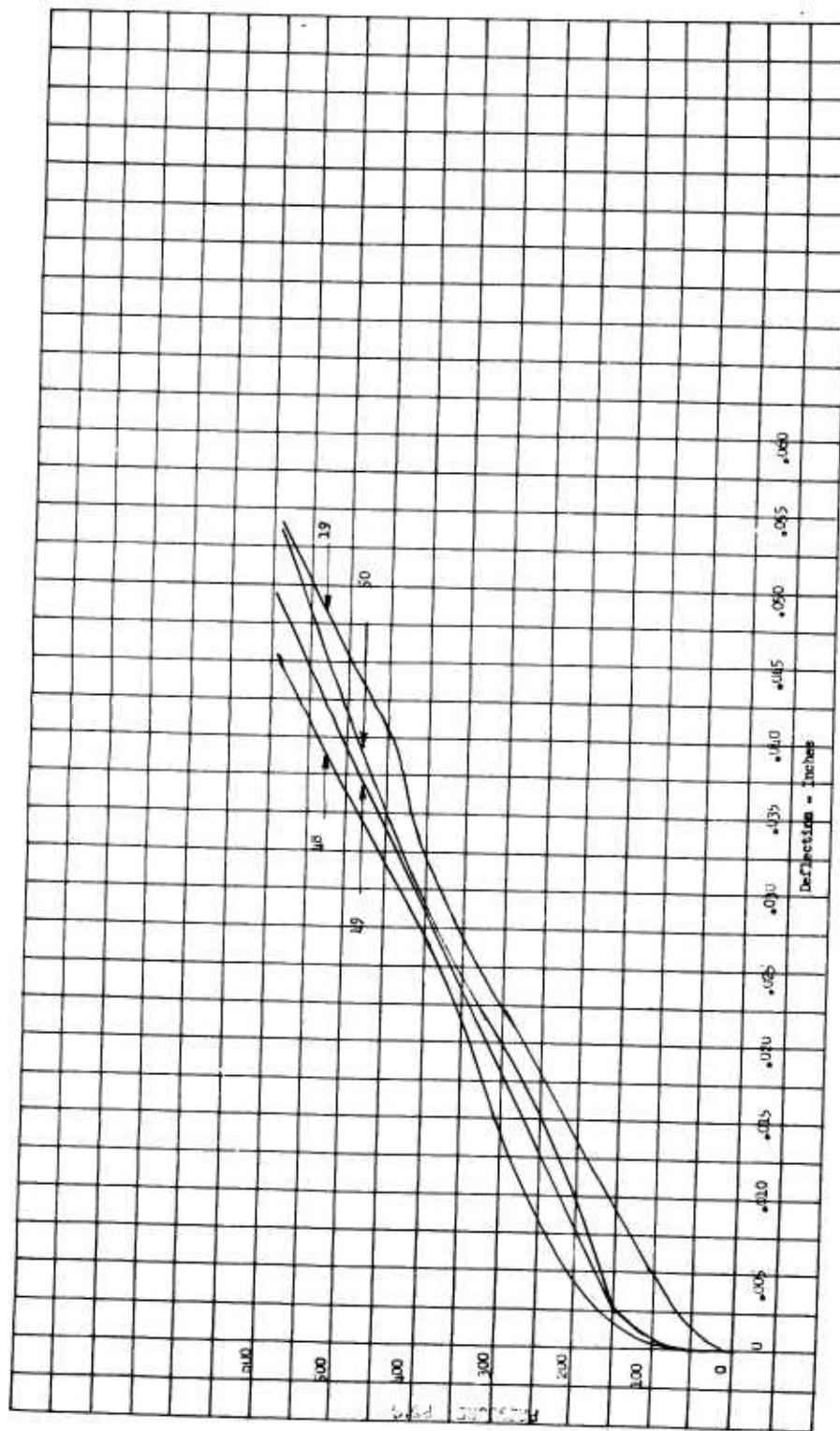


Figure 5

Pressure vs Deflection (-0.03 to 0.110 in.)



Pressure vs Deflection (0 to 0.060 in.)

Figure 6

APPENDIX D: PHASE IV

STRESS AND STRAIN CURVES FOR FORWARD
END OF CHAMBER, POINTS 2 TO 42

Appendix D

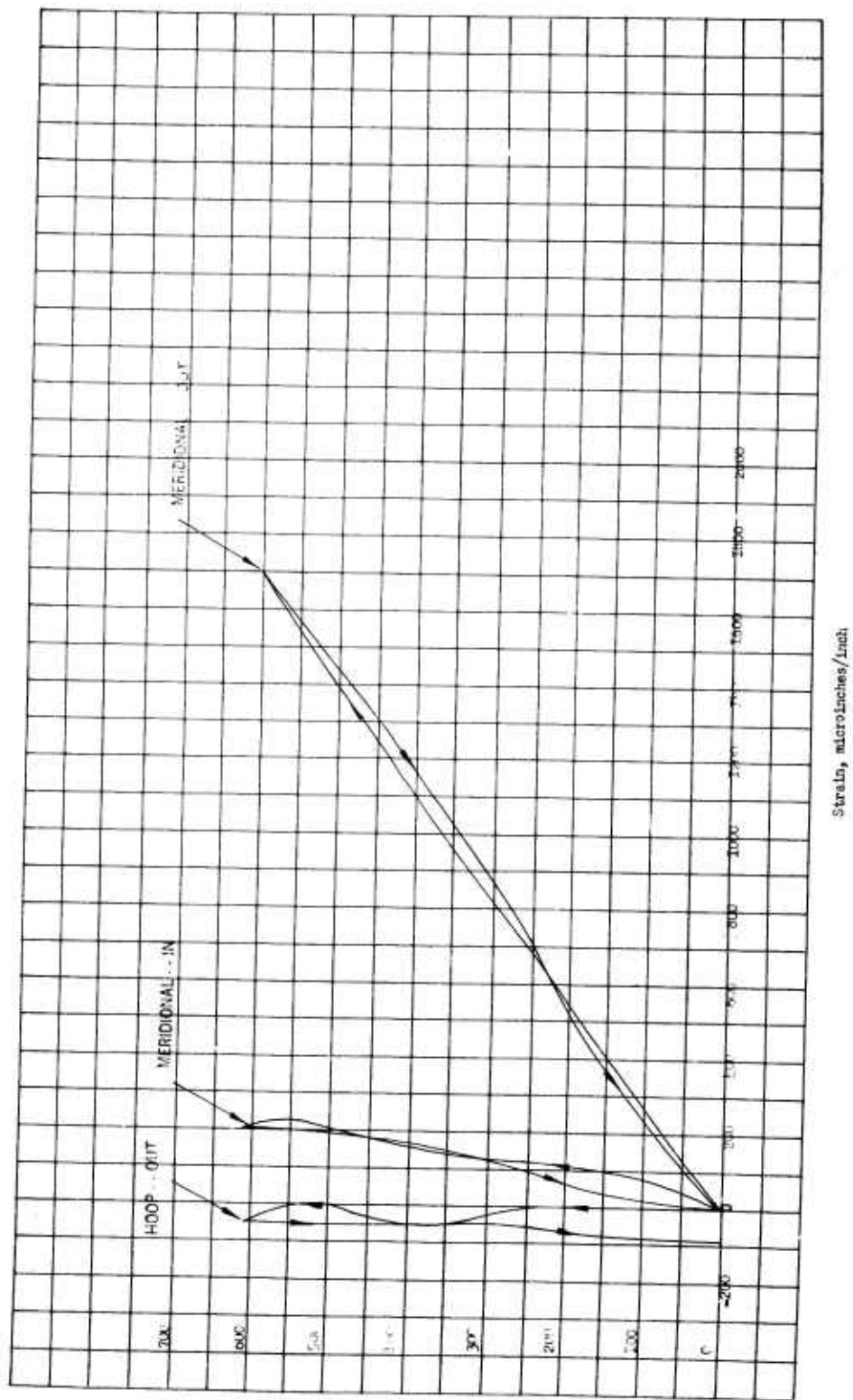


Figure 1

Pressure vs Strain, Cage Point 2

Appendix D

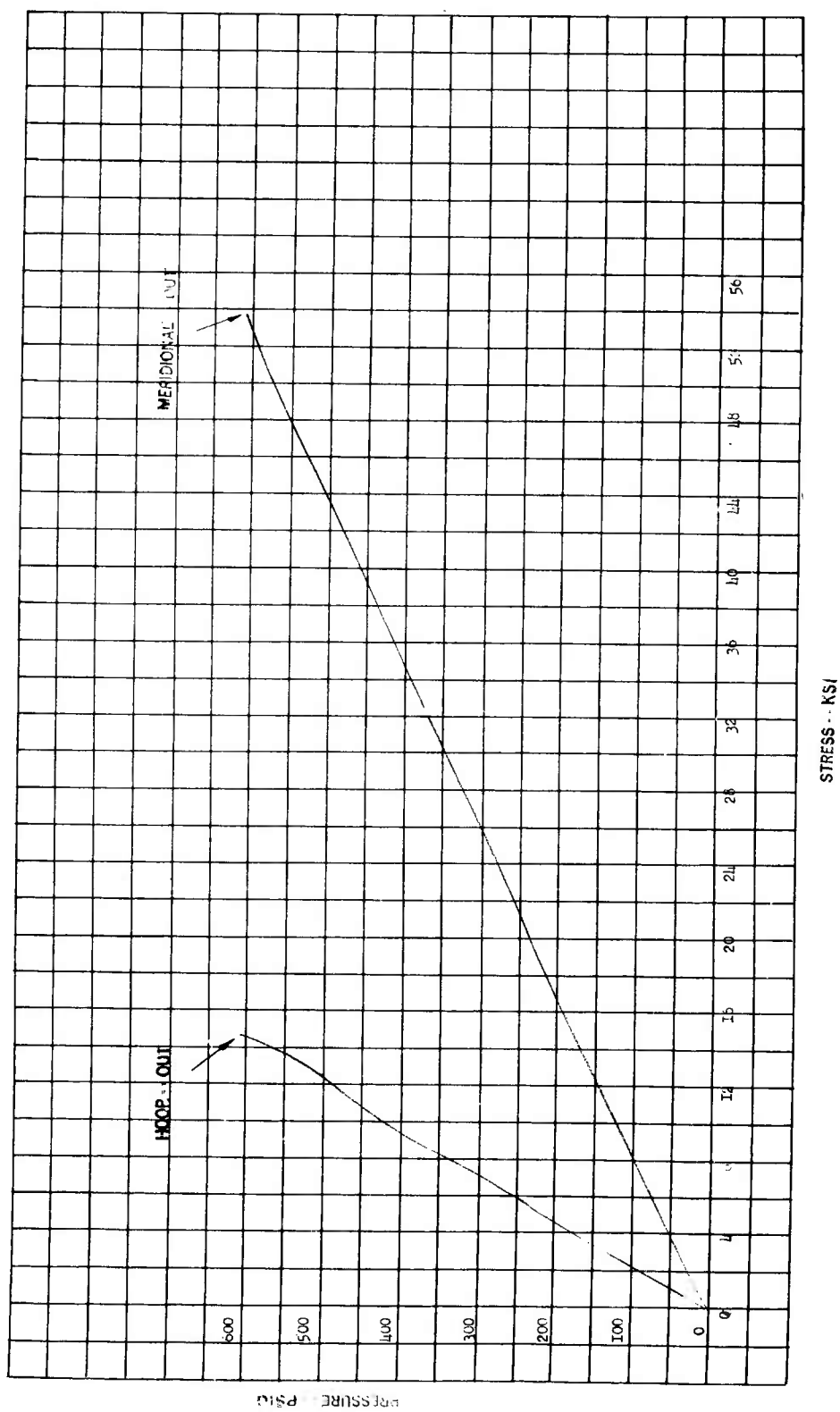


Figure 2

Pressure vs Stress, Gage Point 2

Appendix D

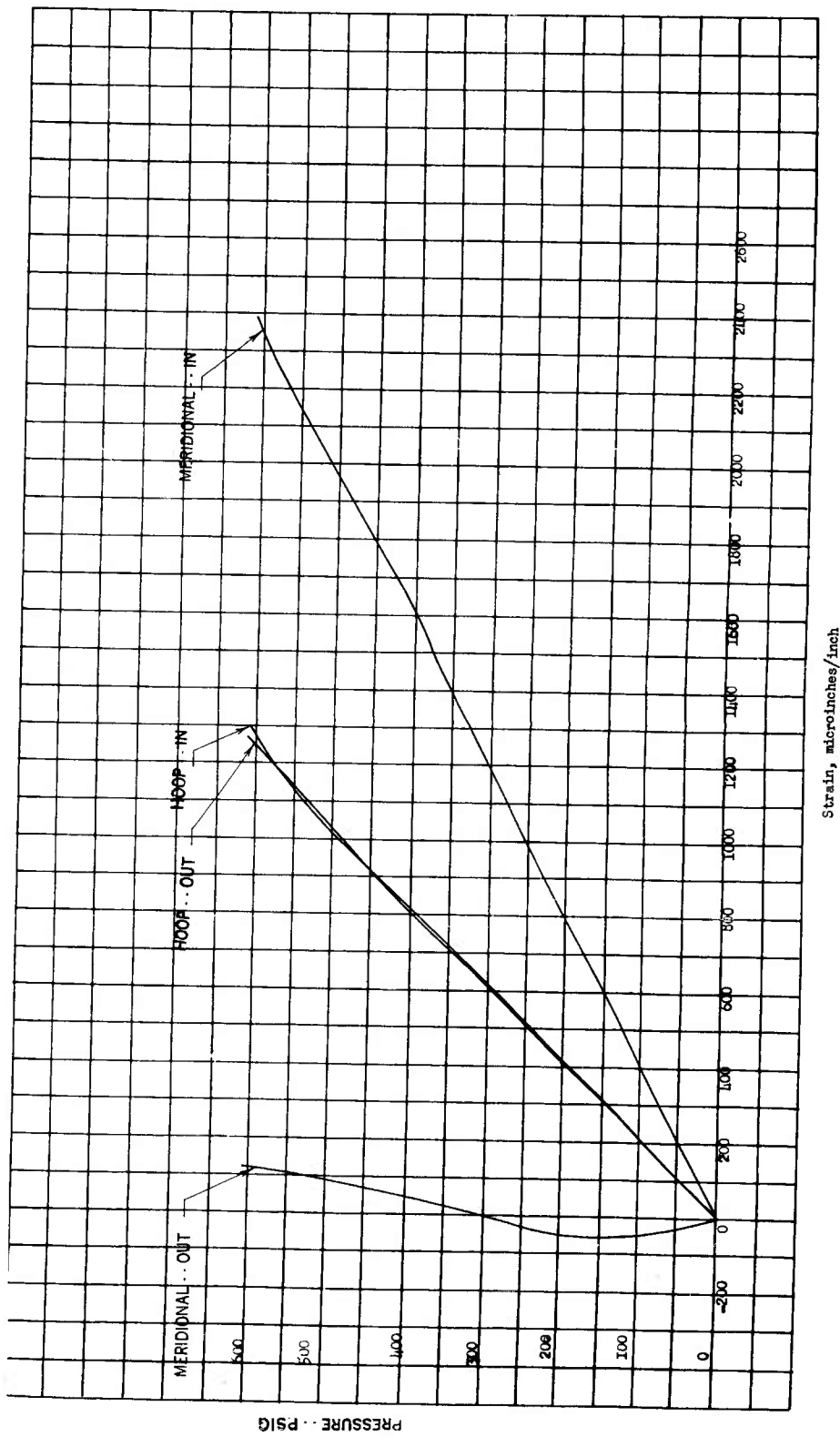
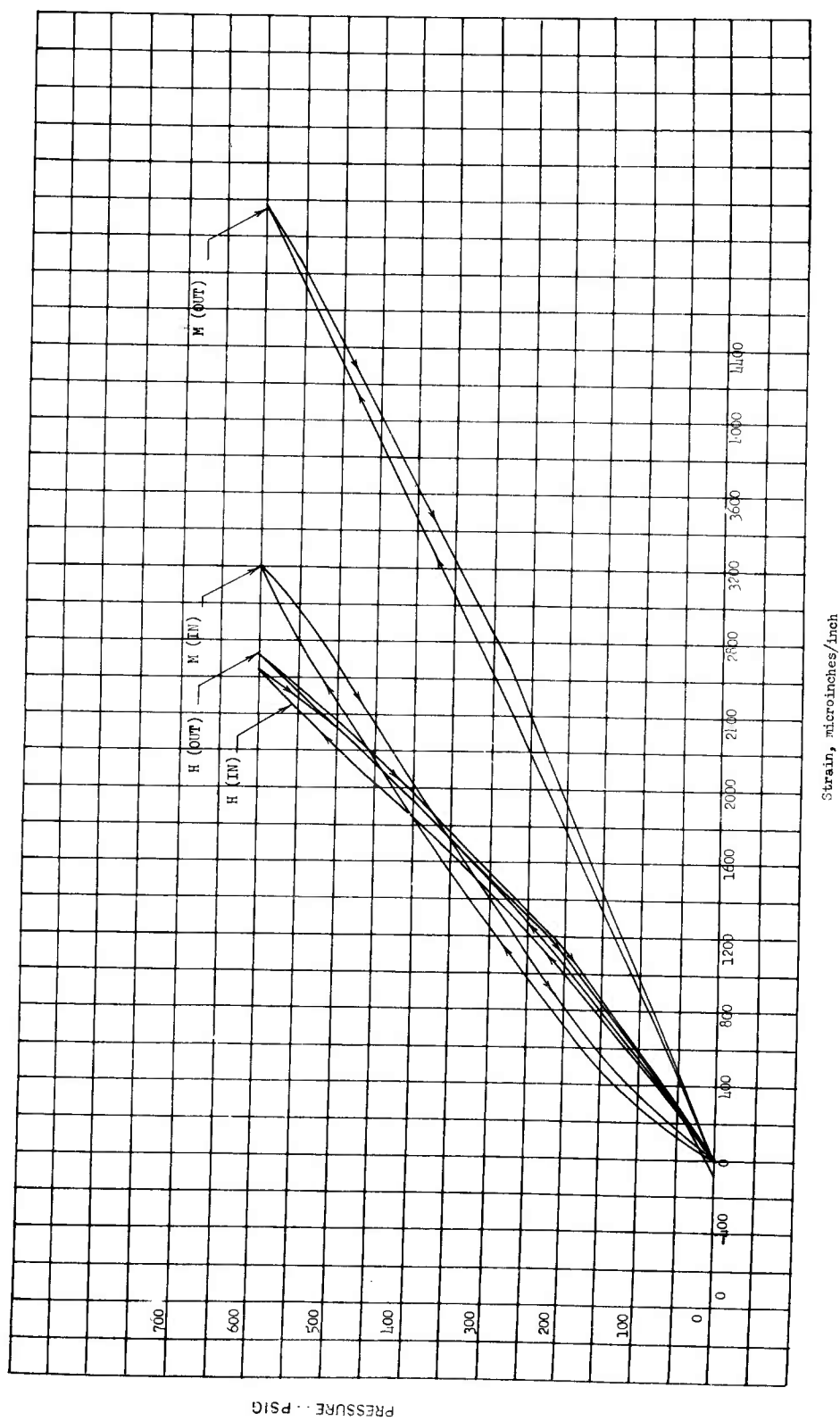


Figure 3

Pressure vs Strain, Gage Point 3

Appendix D



Strain, microinches/inch

Pressure vs Stress, Gage Point 3

Figure 4

Appendix D

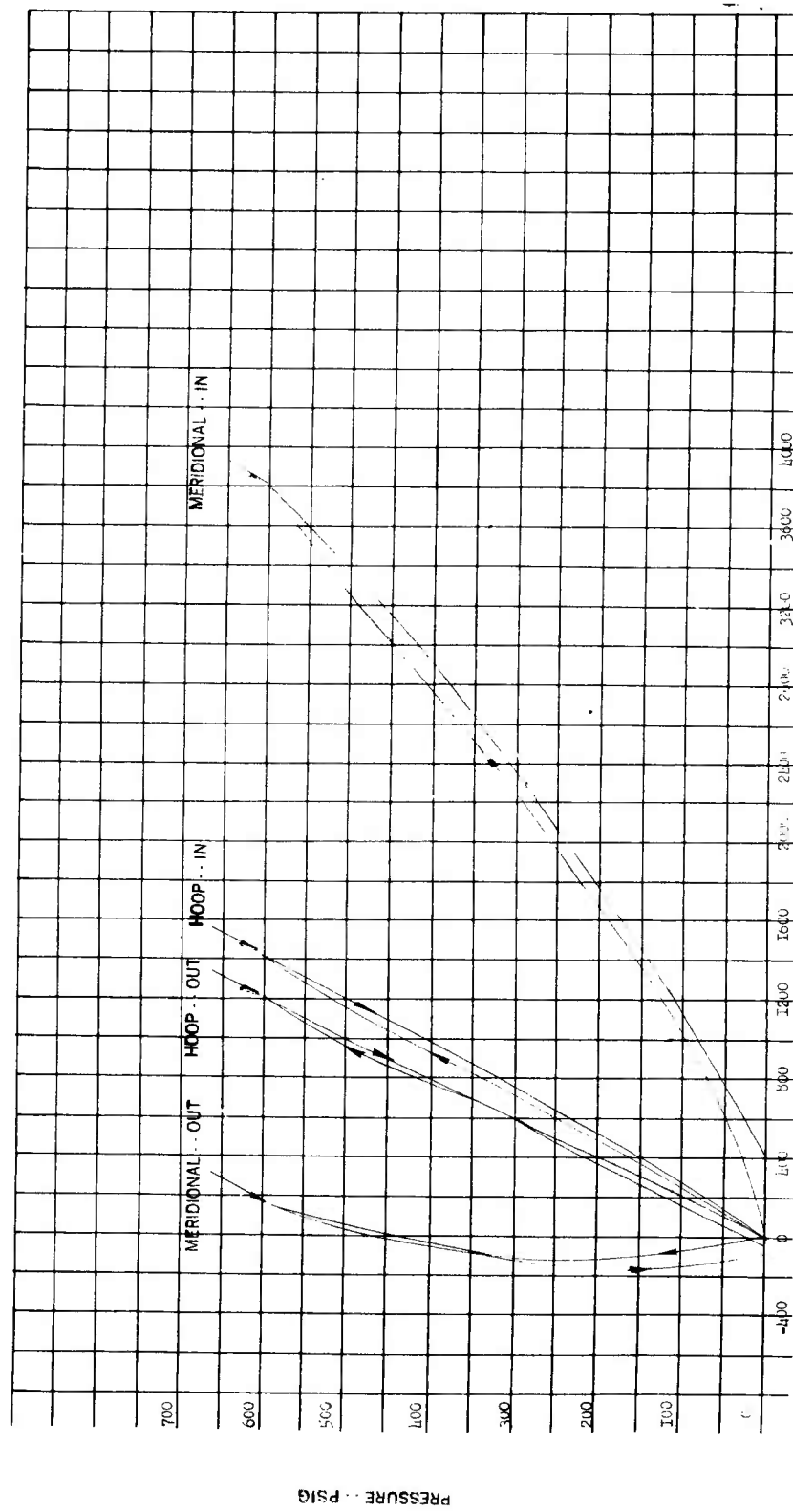
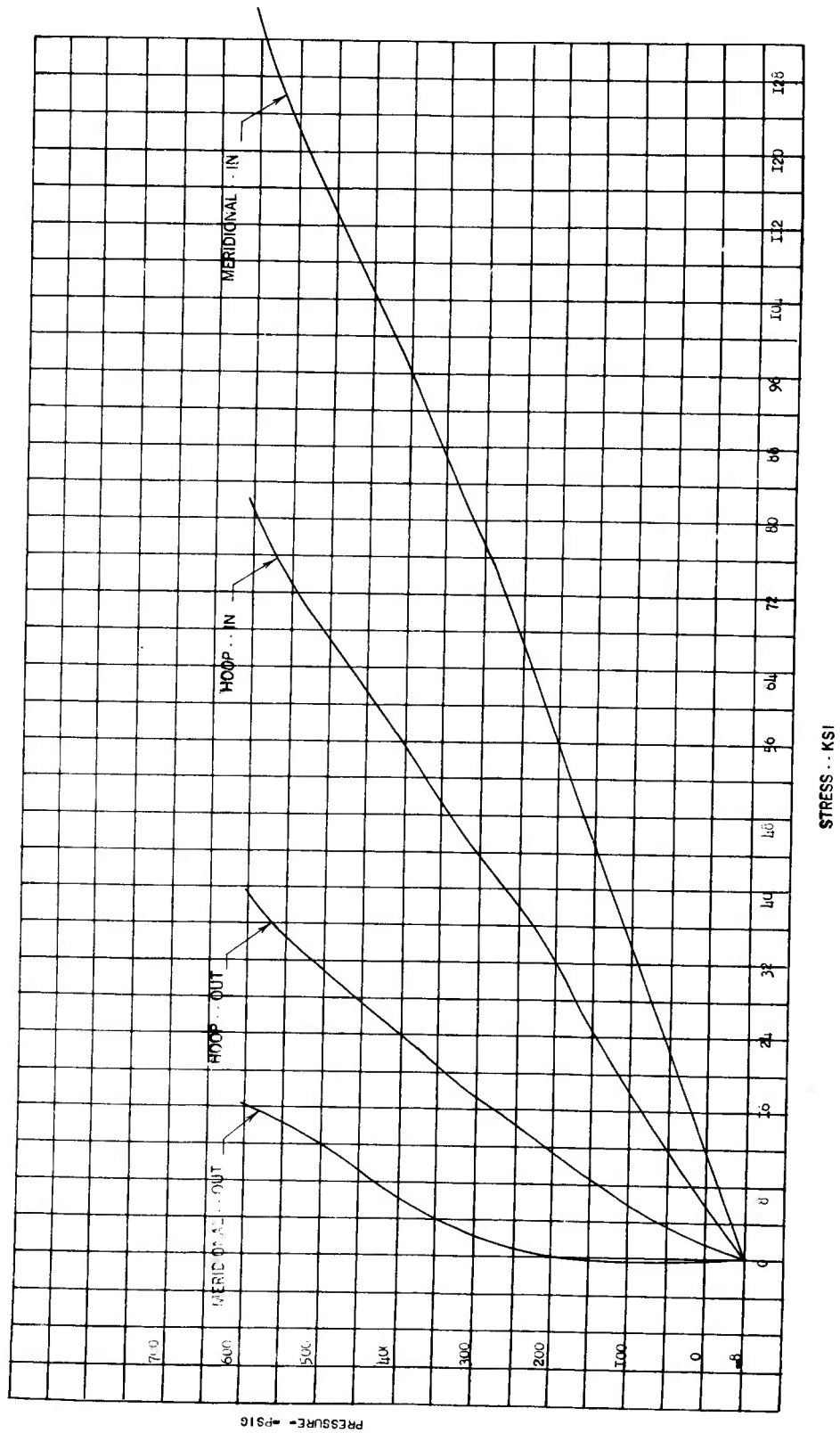


Figure 5

Strain, microinches/inch

Pressure vs Strain, Gage Point 4



Pressure vs Stress, Gage Point 4

Figure 6

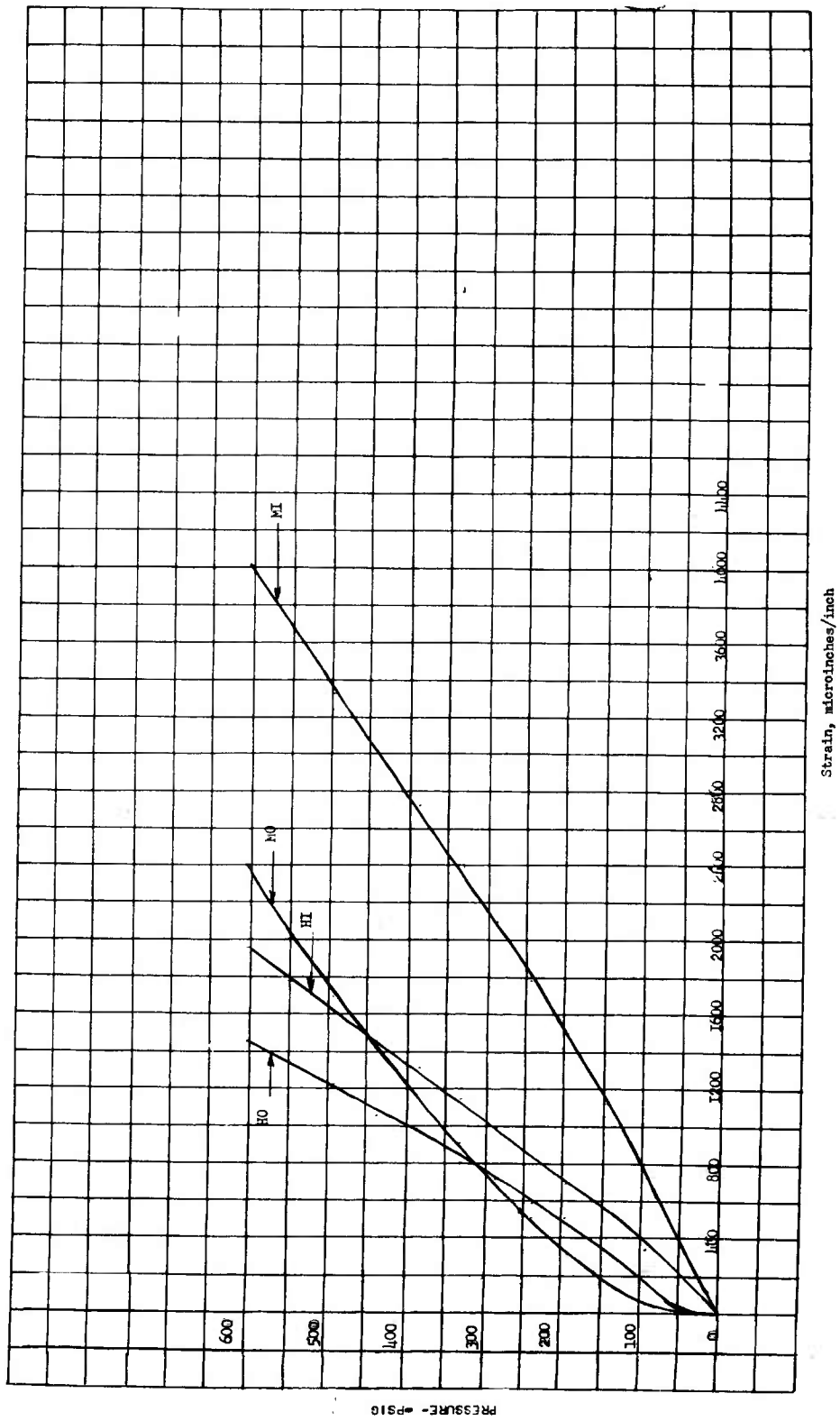
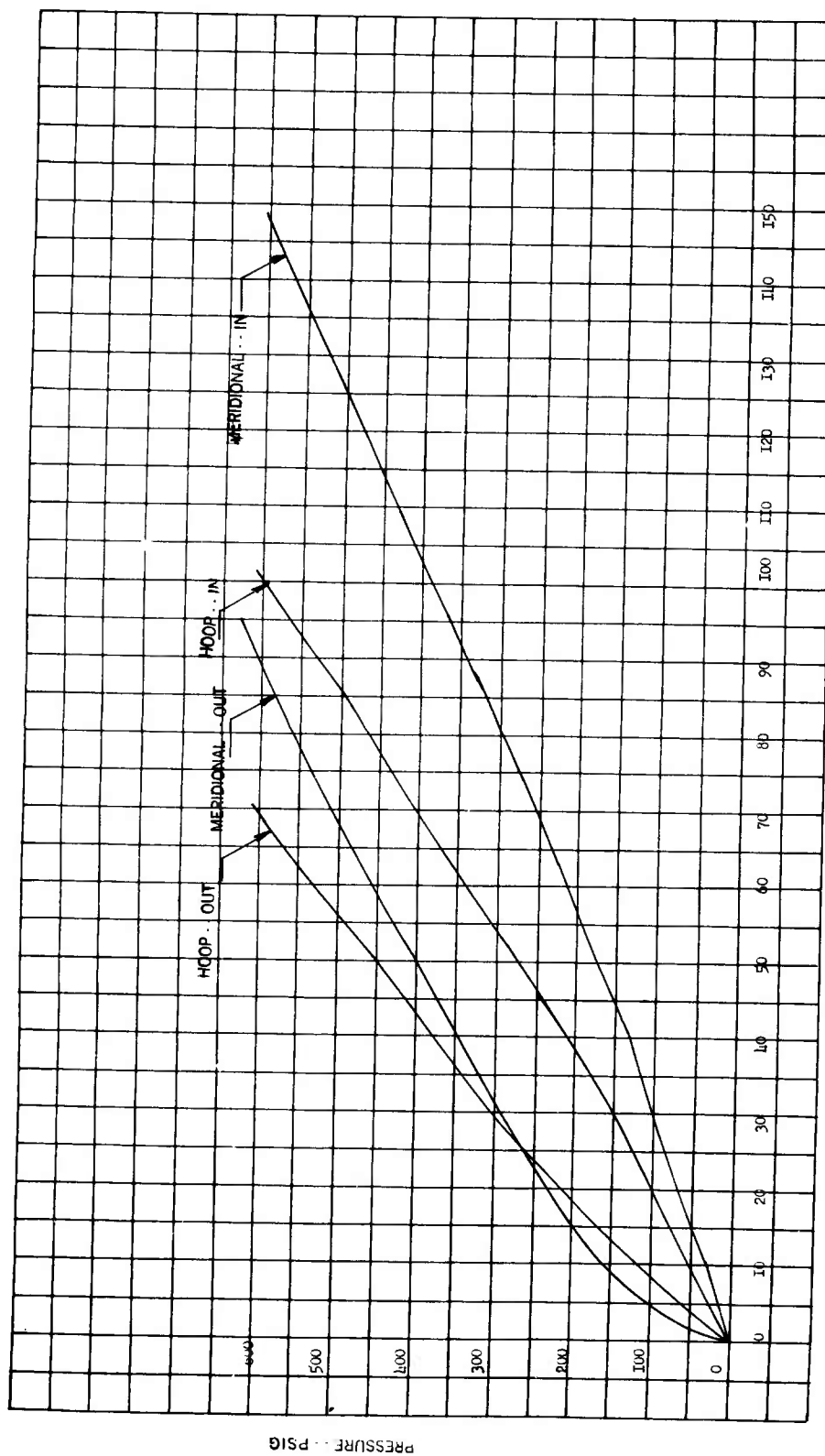


Figure 7

Pressure vs Strain, Gage Point 5



STRESS . . . KSI

Pressure vs Stress, Gage Point 5

Figure 8

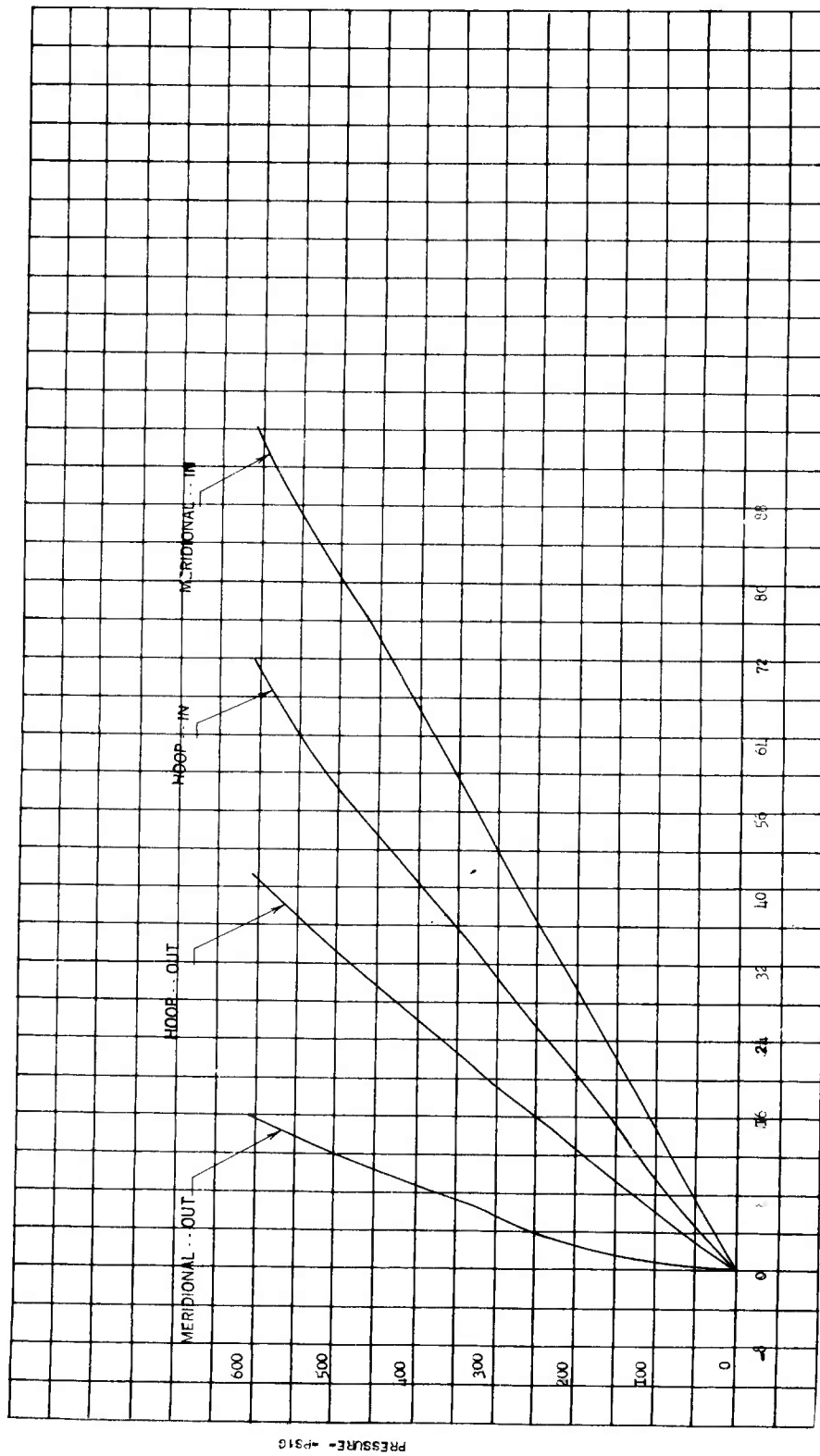


Figure 9

Pressure vs Strain, Gage Point 6

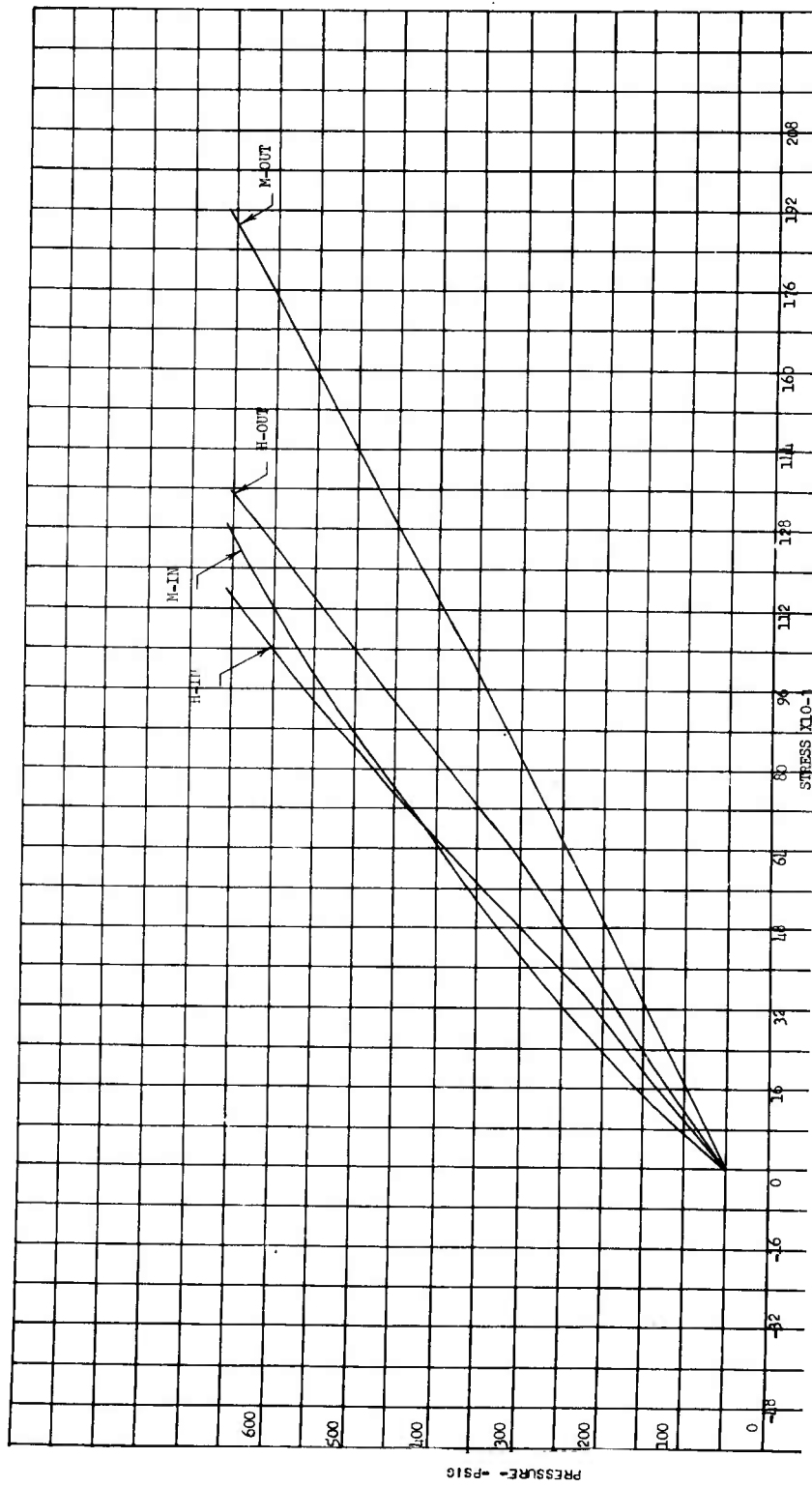
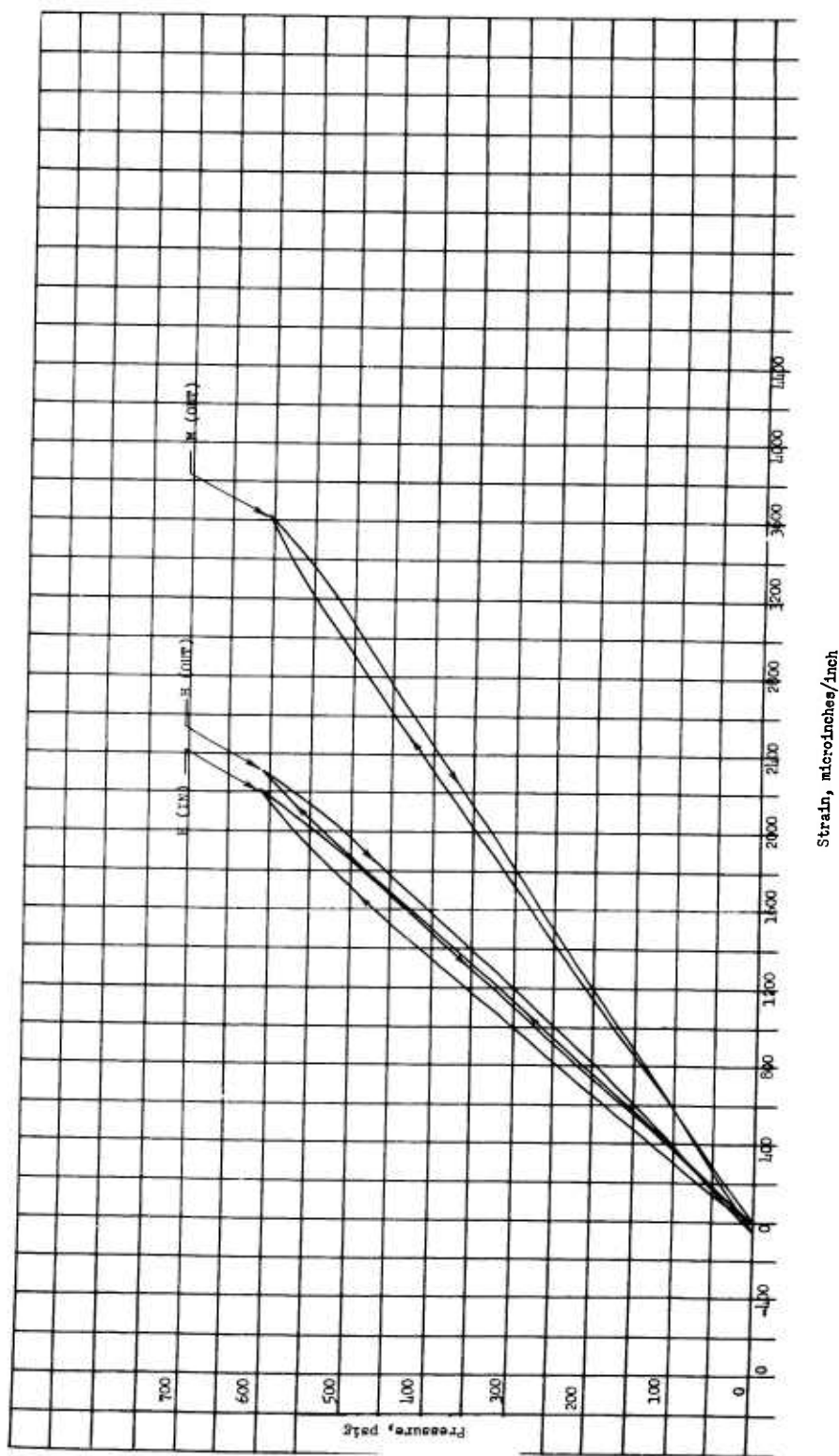


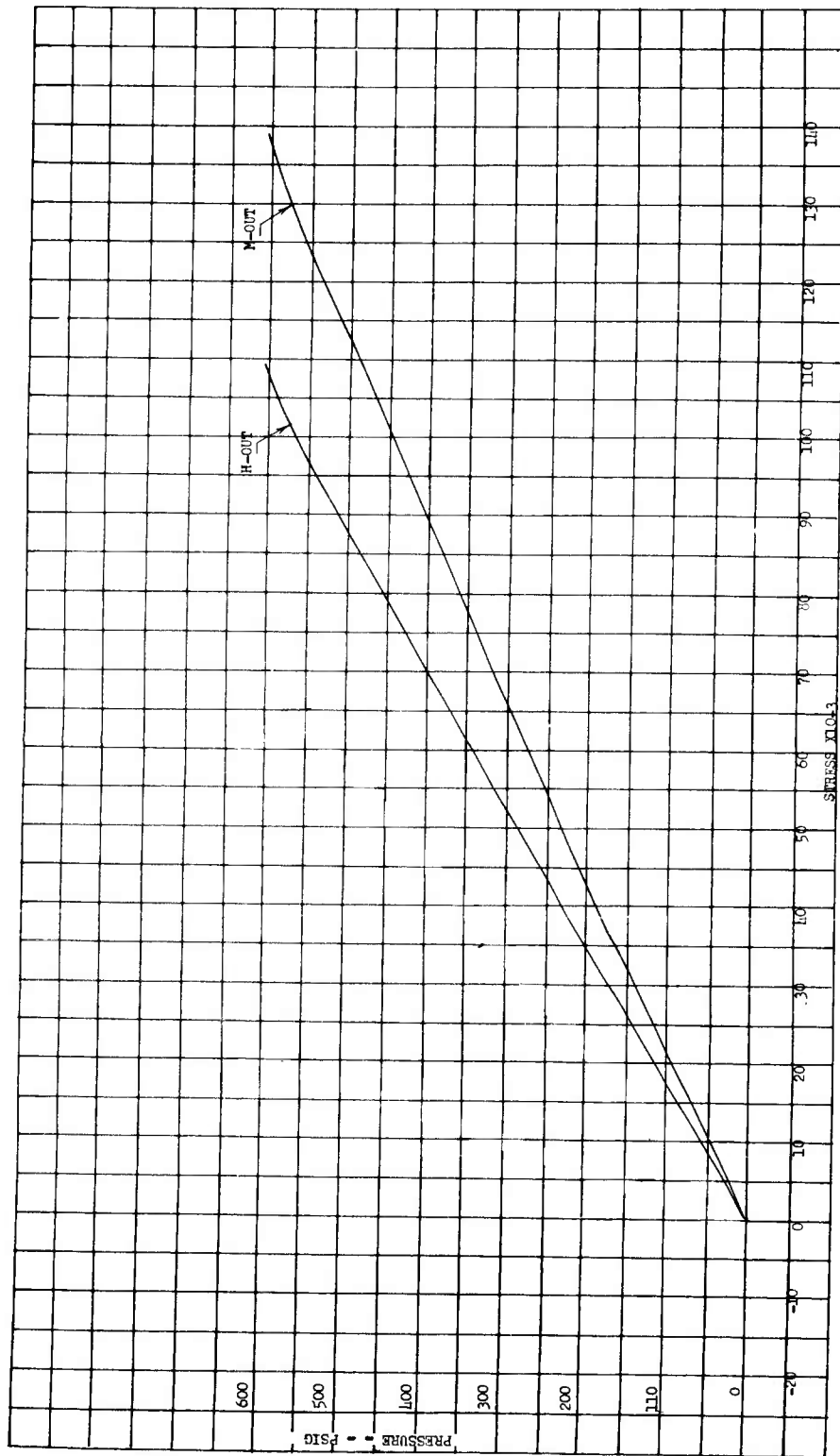
Figure 10

Pressure vs Stress, Gage Point 6



Pressure vs Strain, Gage Point 7

Figure 11



Pressure vs Stress, Gage Point 7

Figure 12

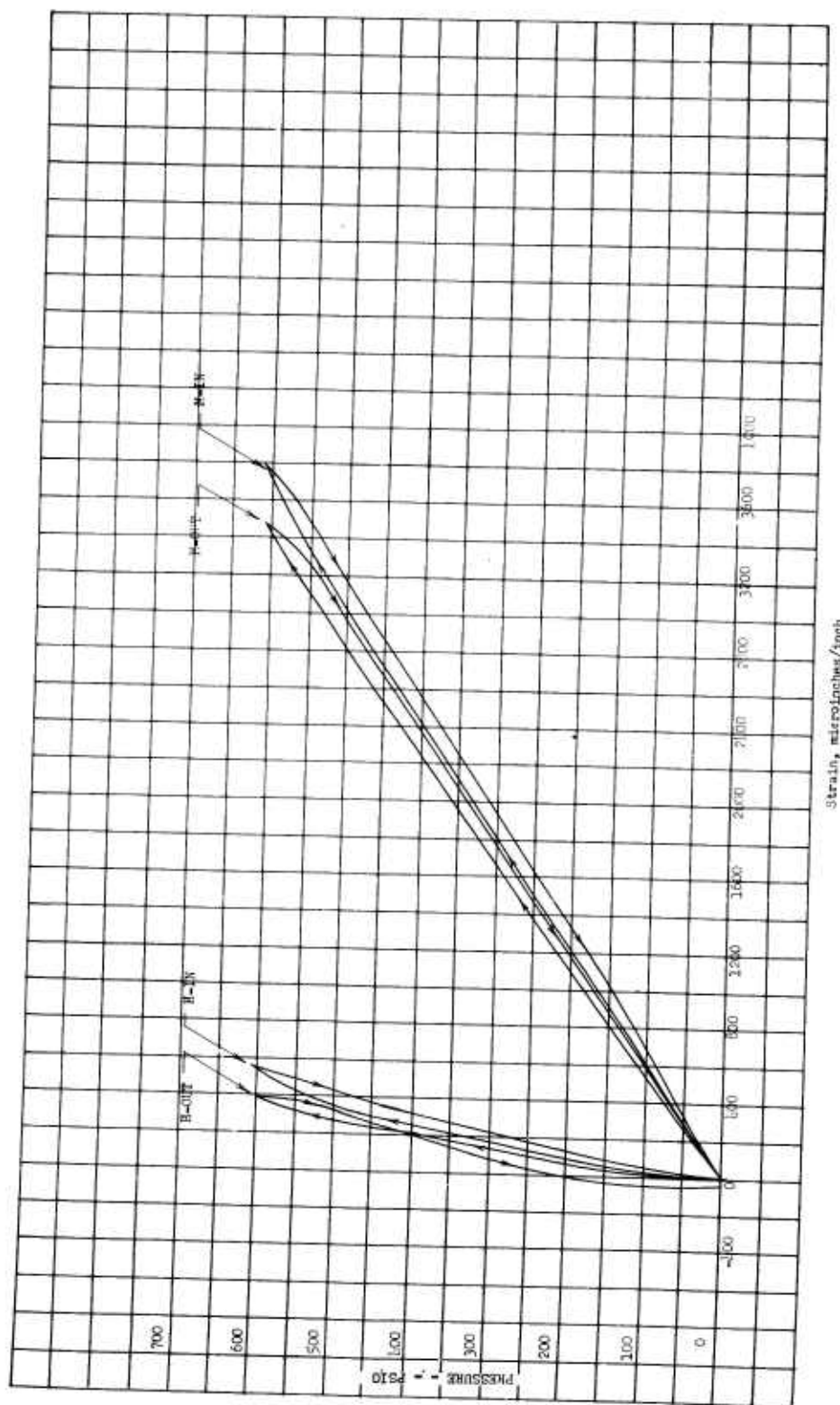
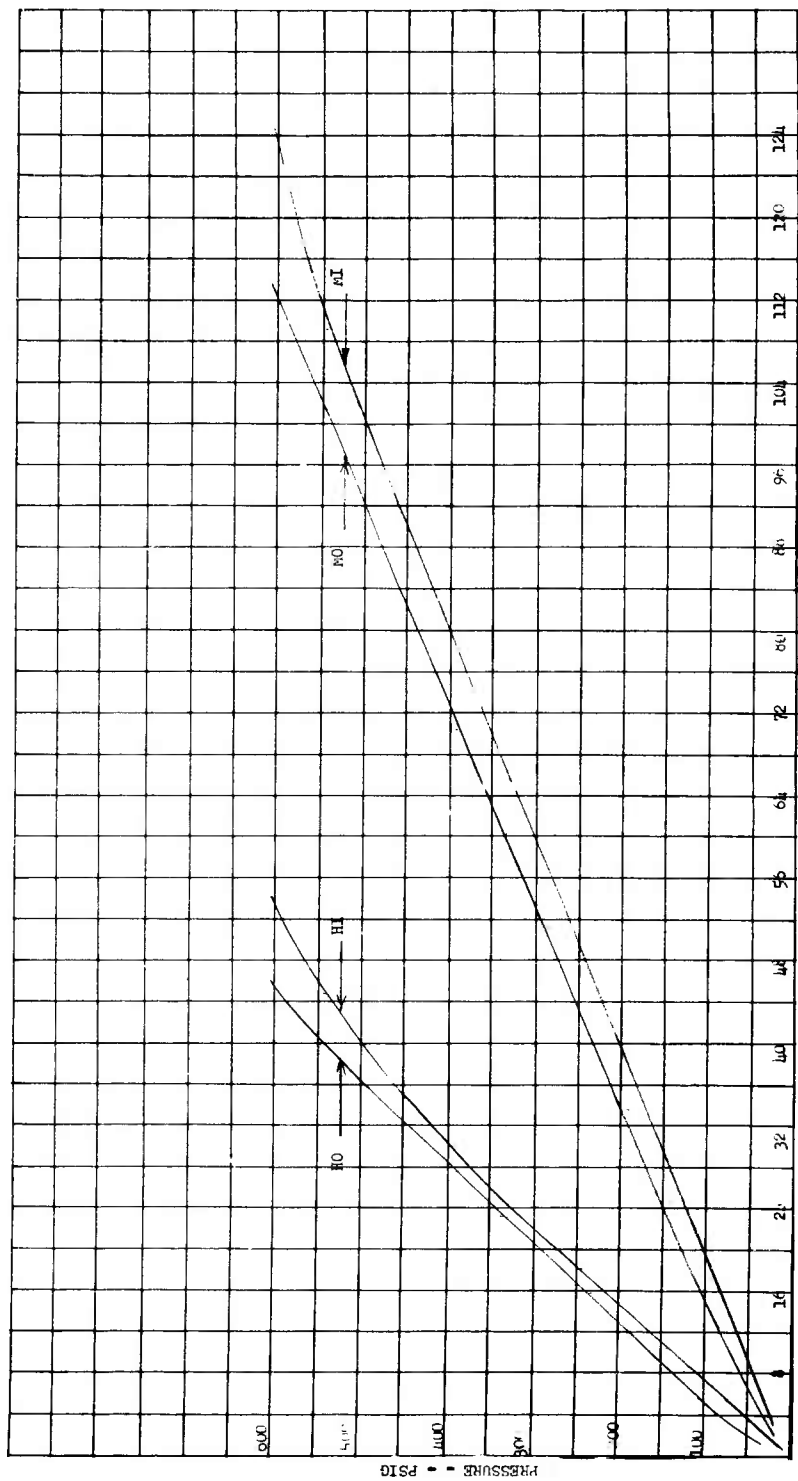


Figure 13

Pressure vs Strain, Gage Point 8



STRAIN, KSI

Pressure vs Stress, Gage Point 8

Figure 14

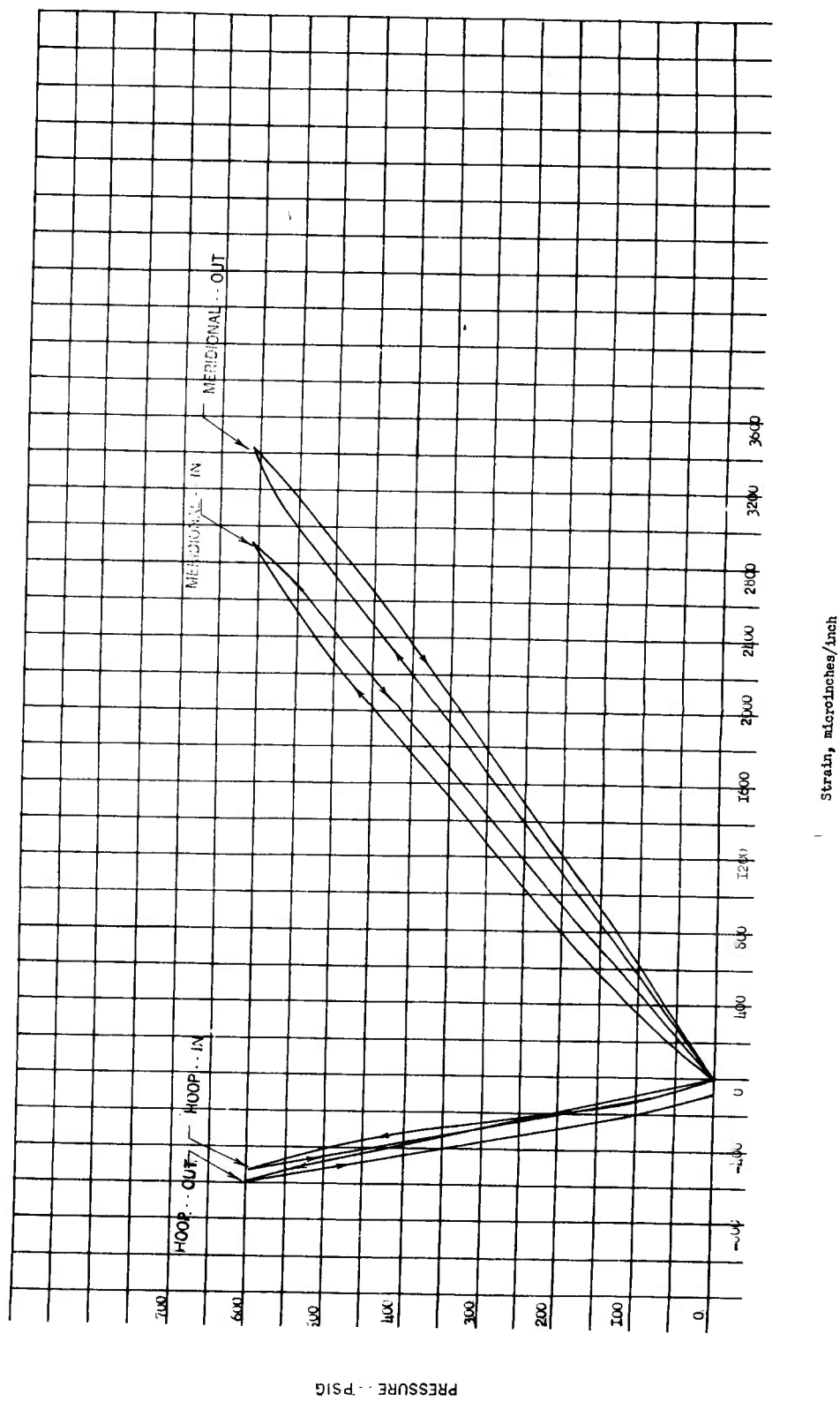
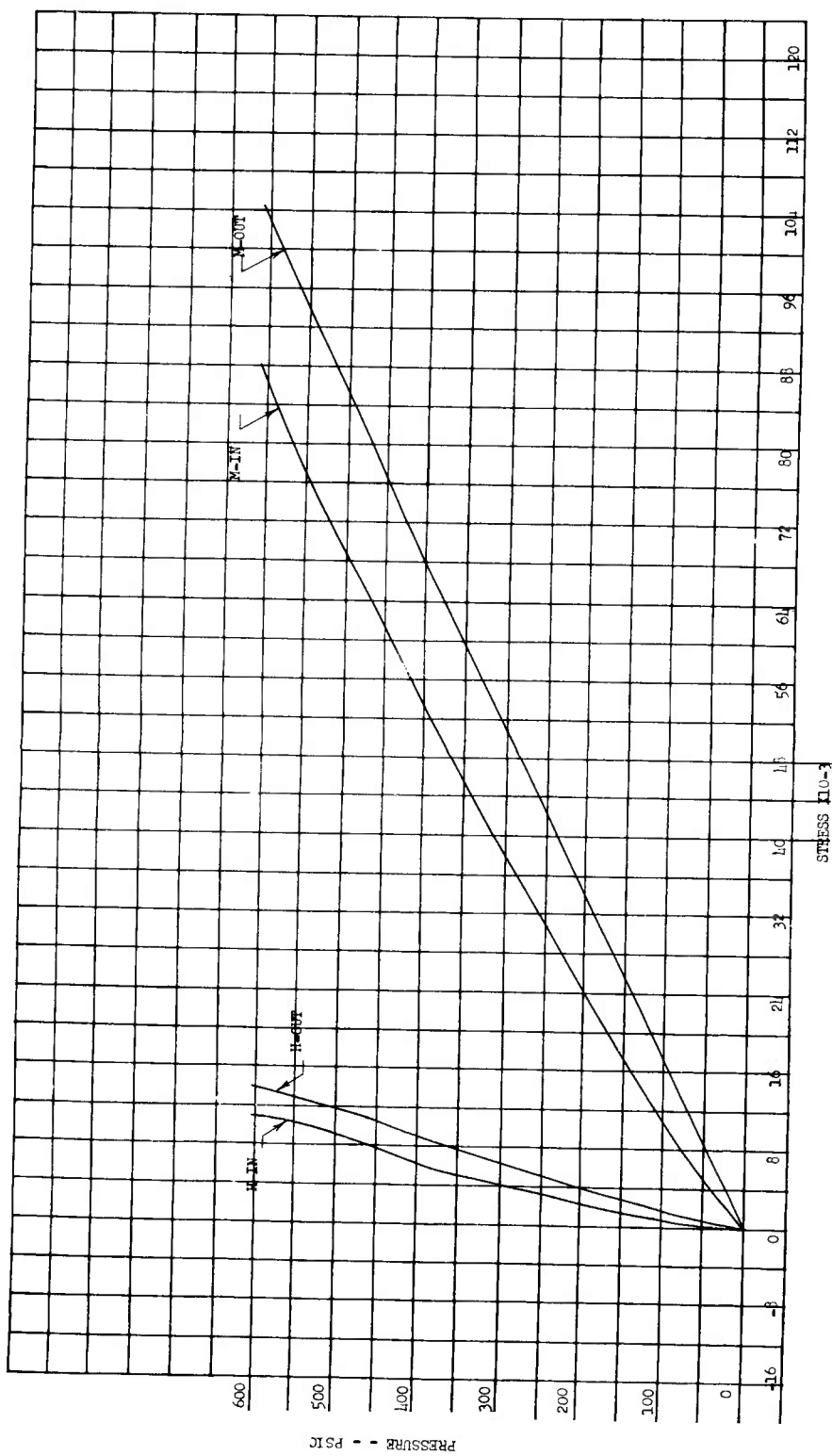


Figure 15

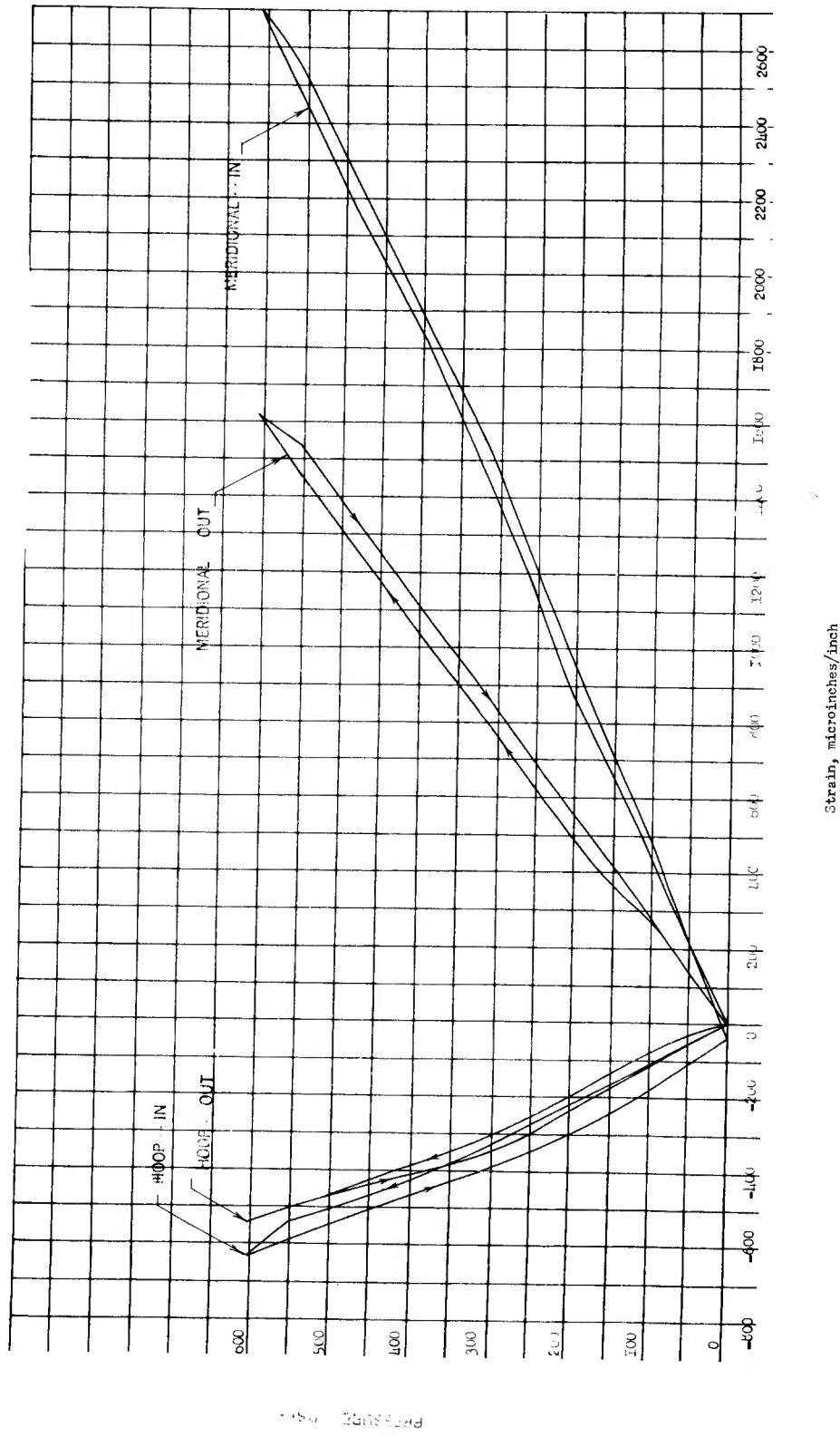
Pressure vs Strain, Cage Point 9

Appendix D



Pressure vs Stress, Gage Point 9

Figure 16



Pressure (psi)

Strain, microinches/inch

Figure 17

Pressure vs Strain, Gage Point 10

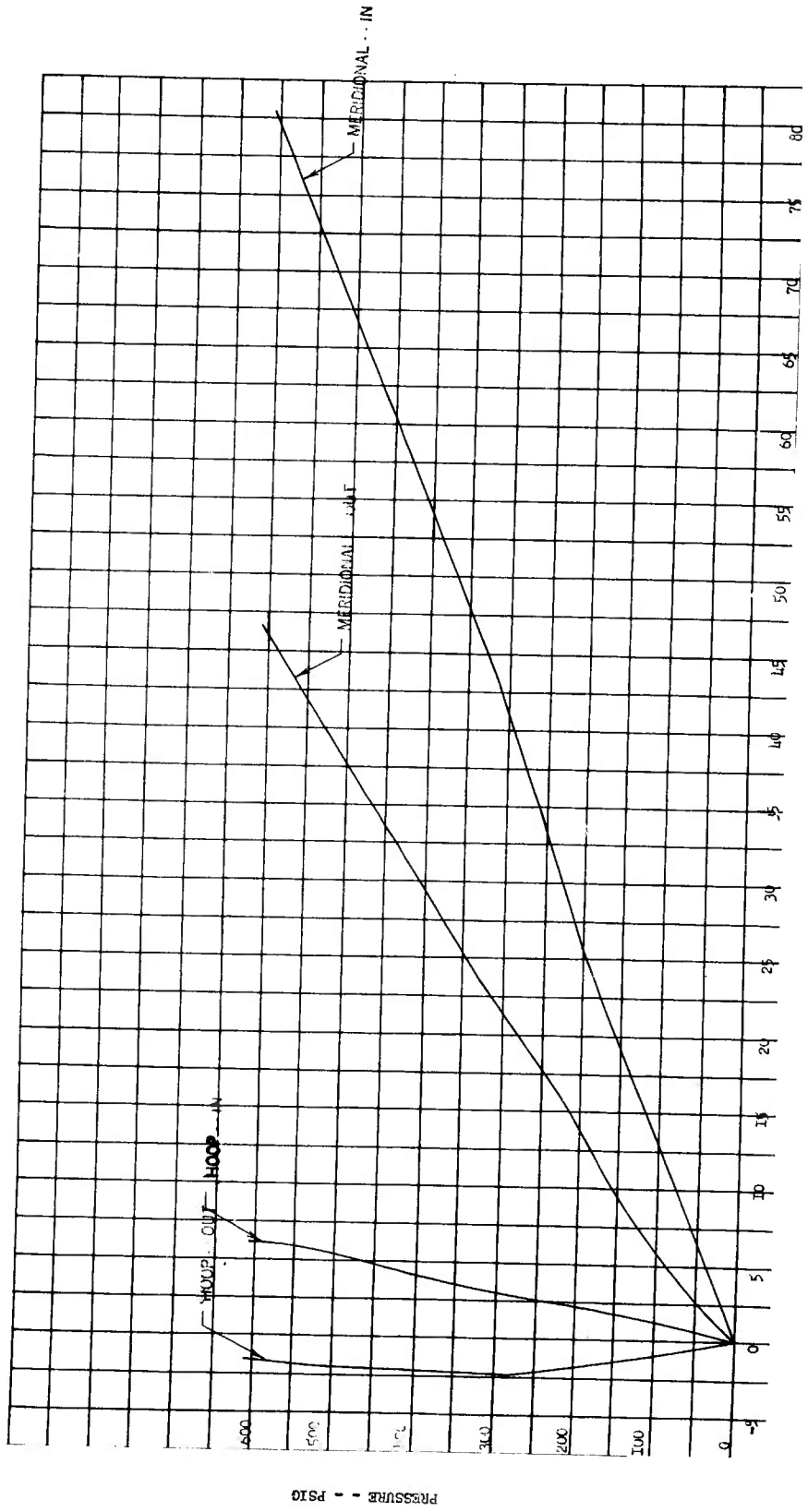
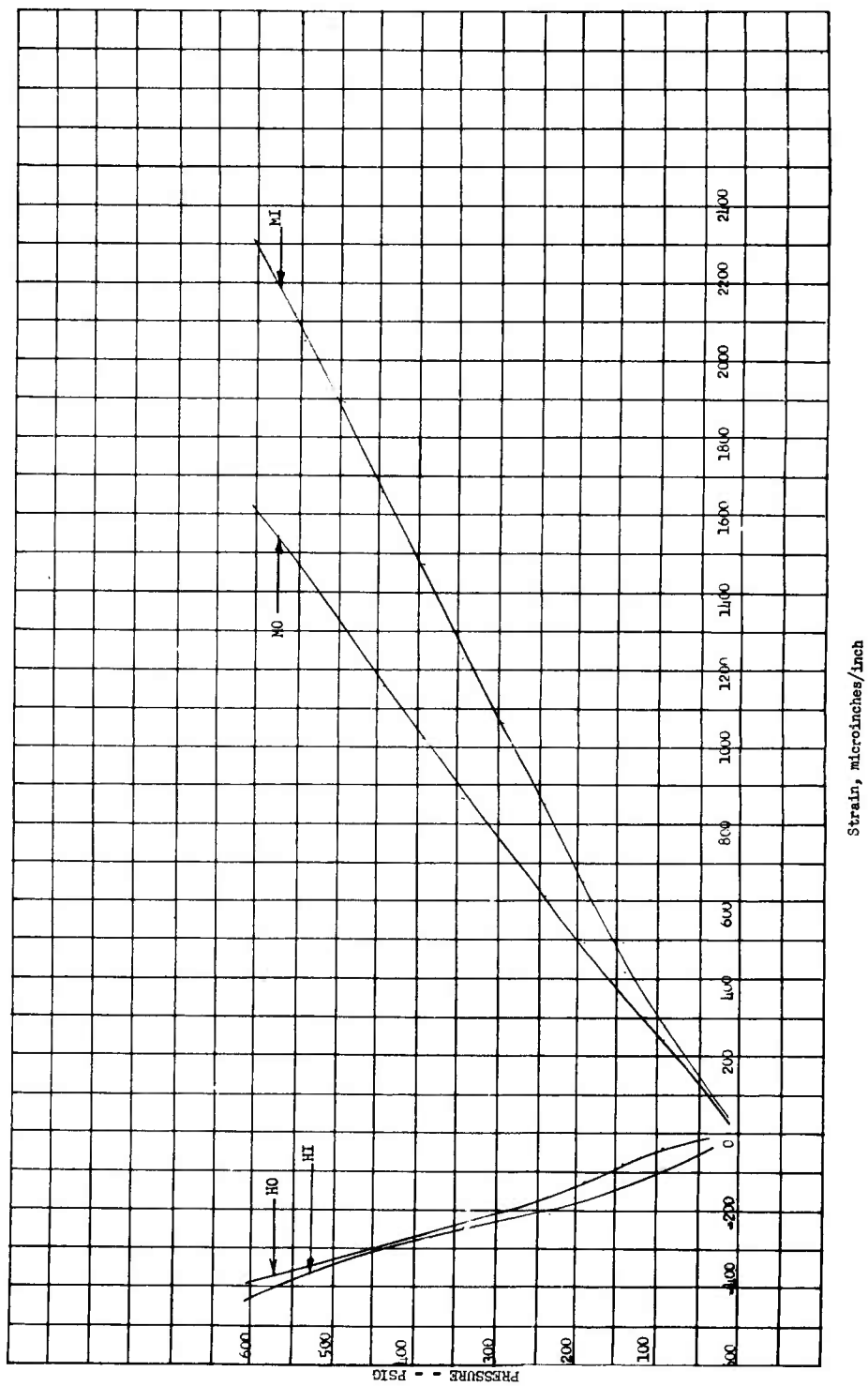


Figure 18

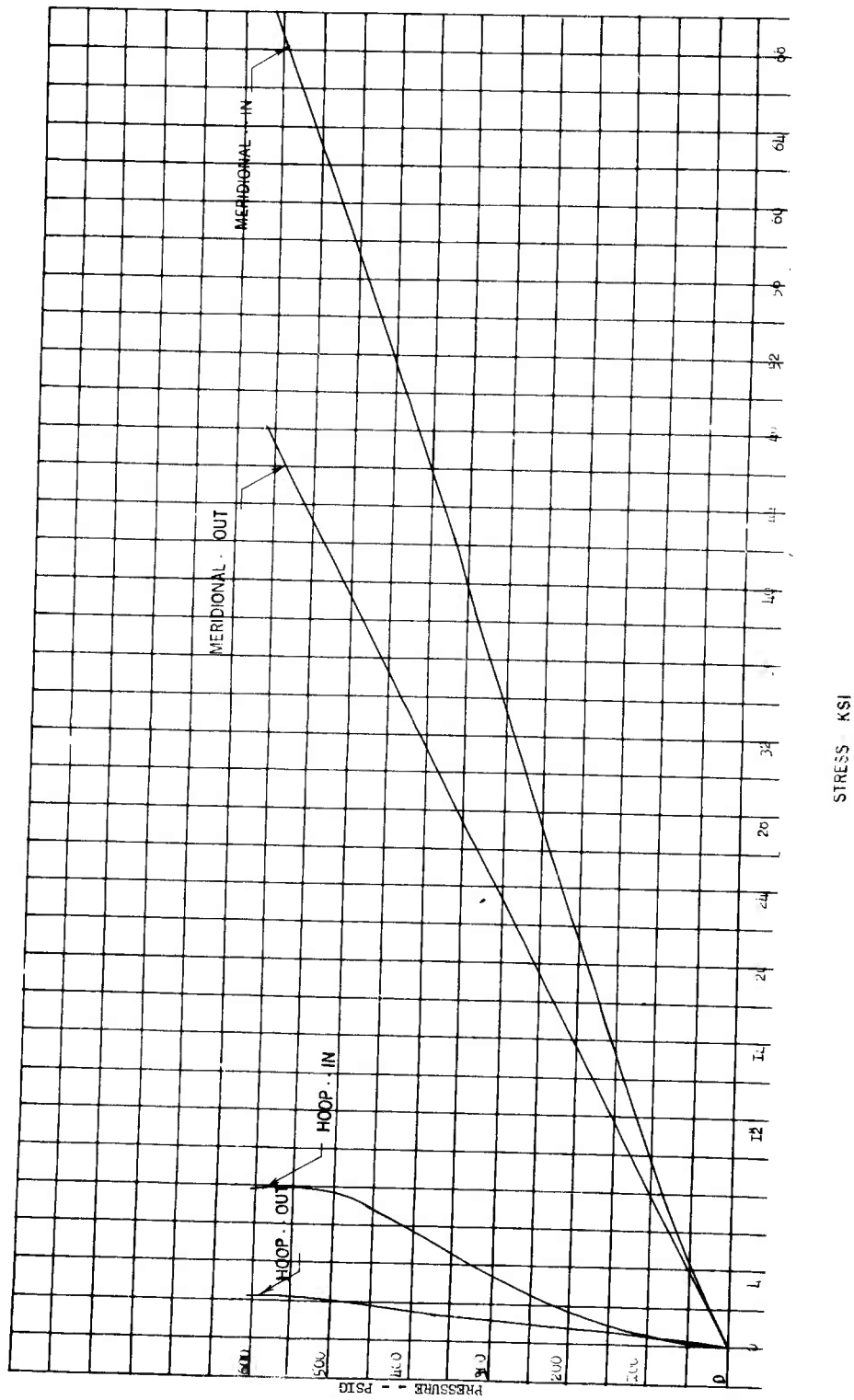
Pressure vs Stress, Gage Point 10

Appendix D



Pressure vs Strain, Gage Point 11

Figure 19



Pressure vs Stress, Gage Point 11

Figure 20

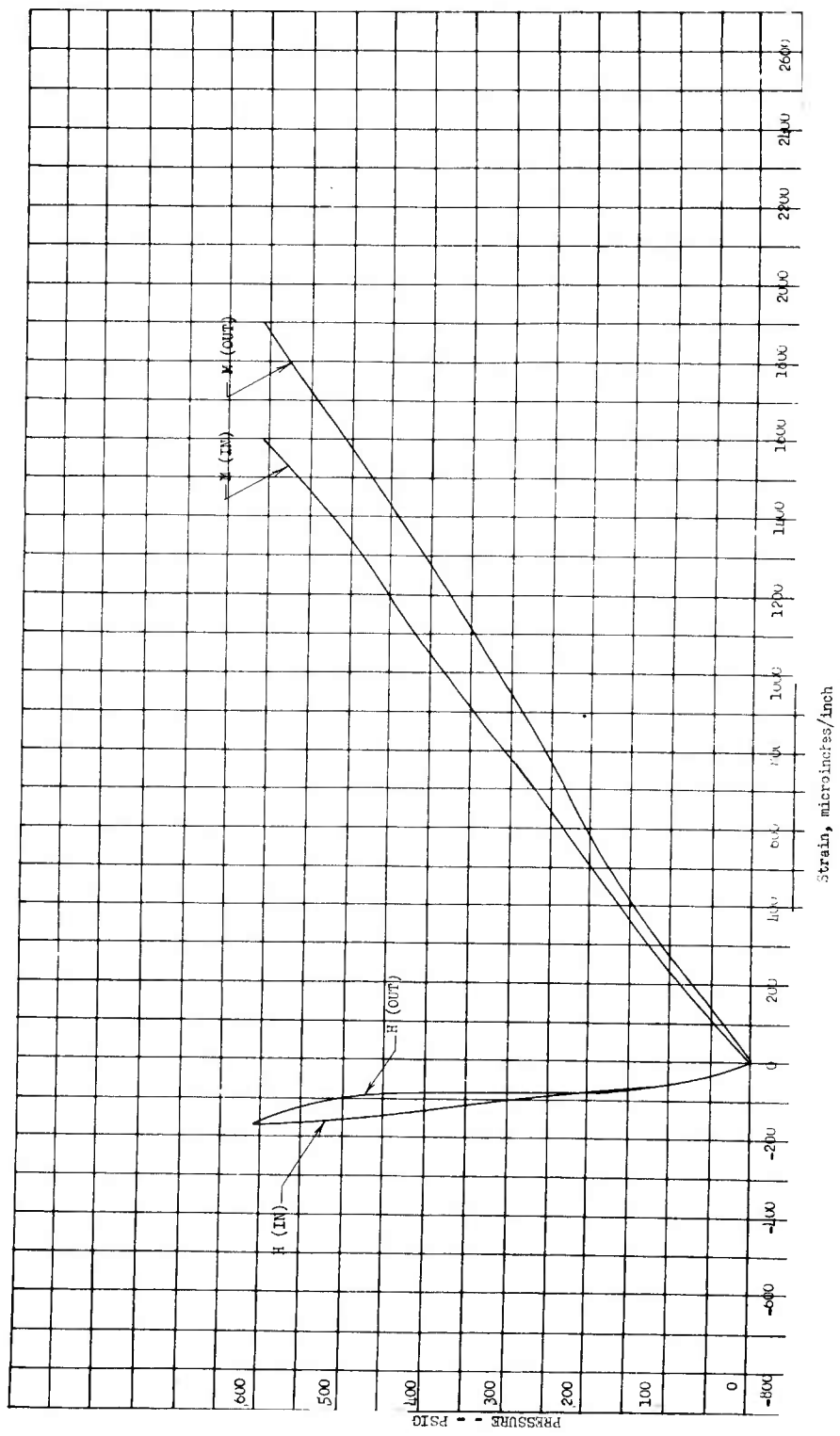


Figure 21

Pressure vs Strain, Gage Point 12

Appendix D

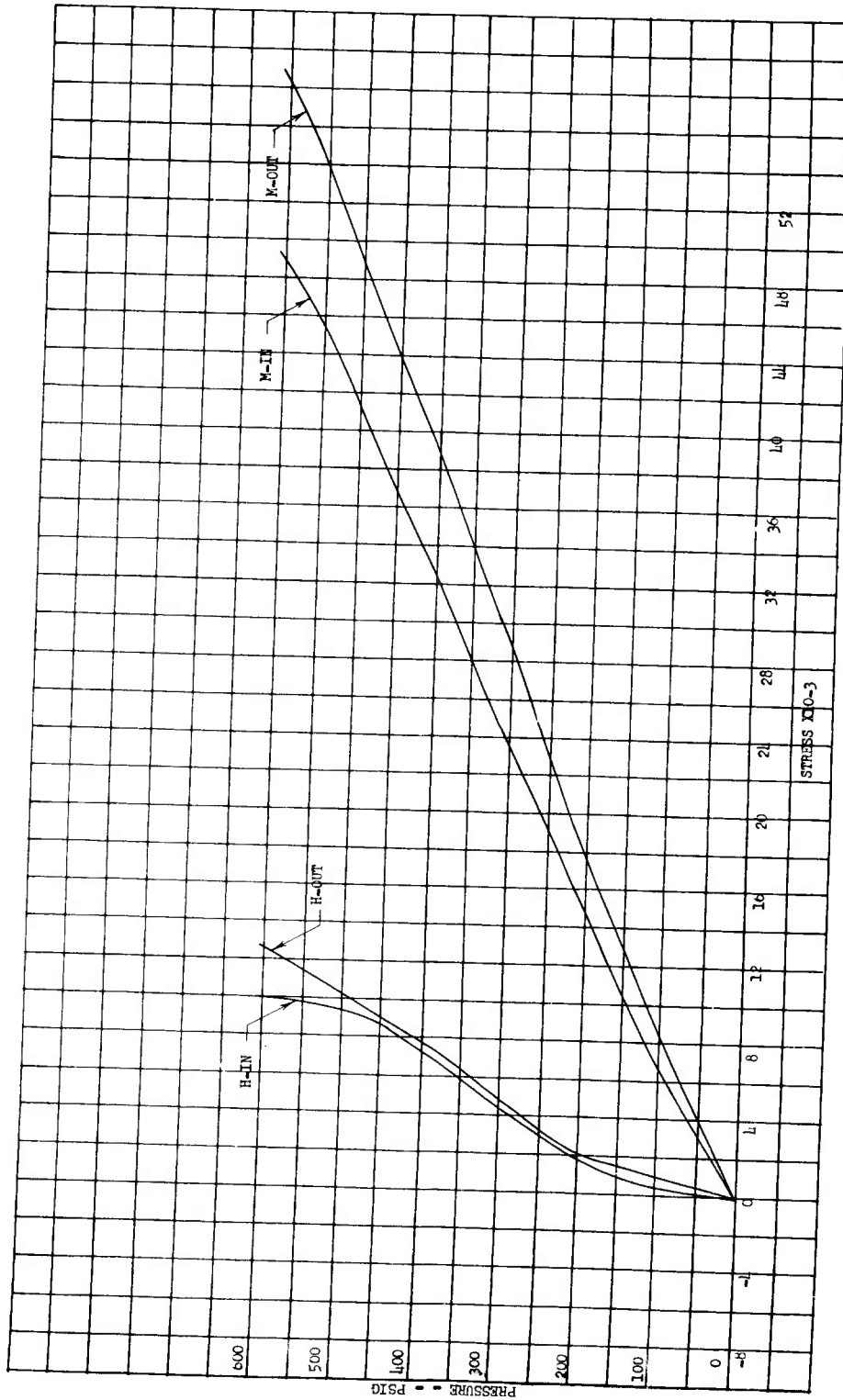


Figure 22

Pressure vs Stress, Gage Point 12

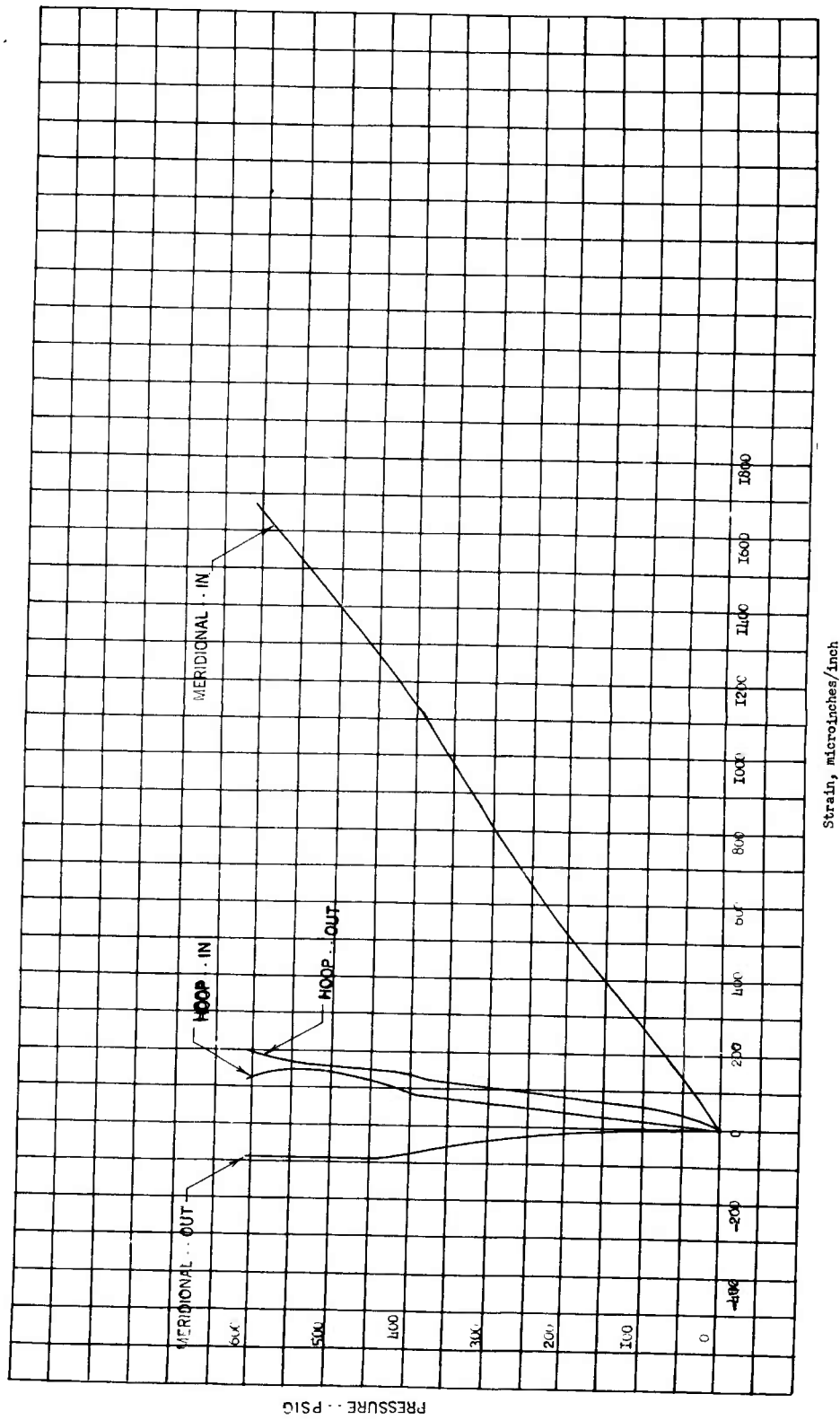


Figure 23

Pressure vs Strain, Gage Point 13

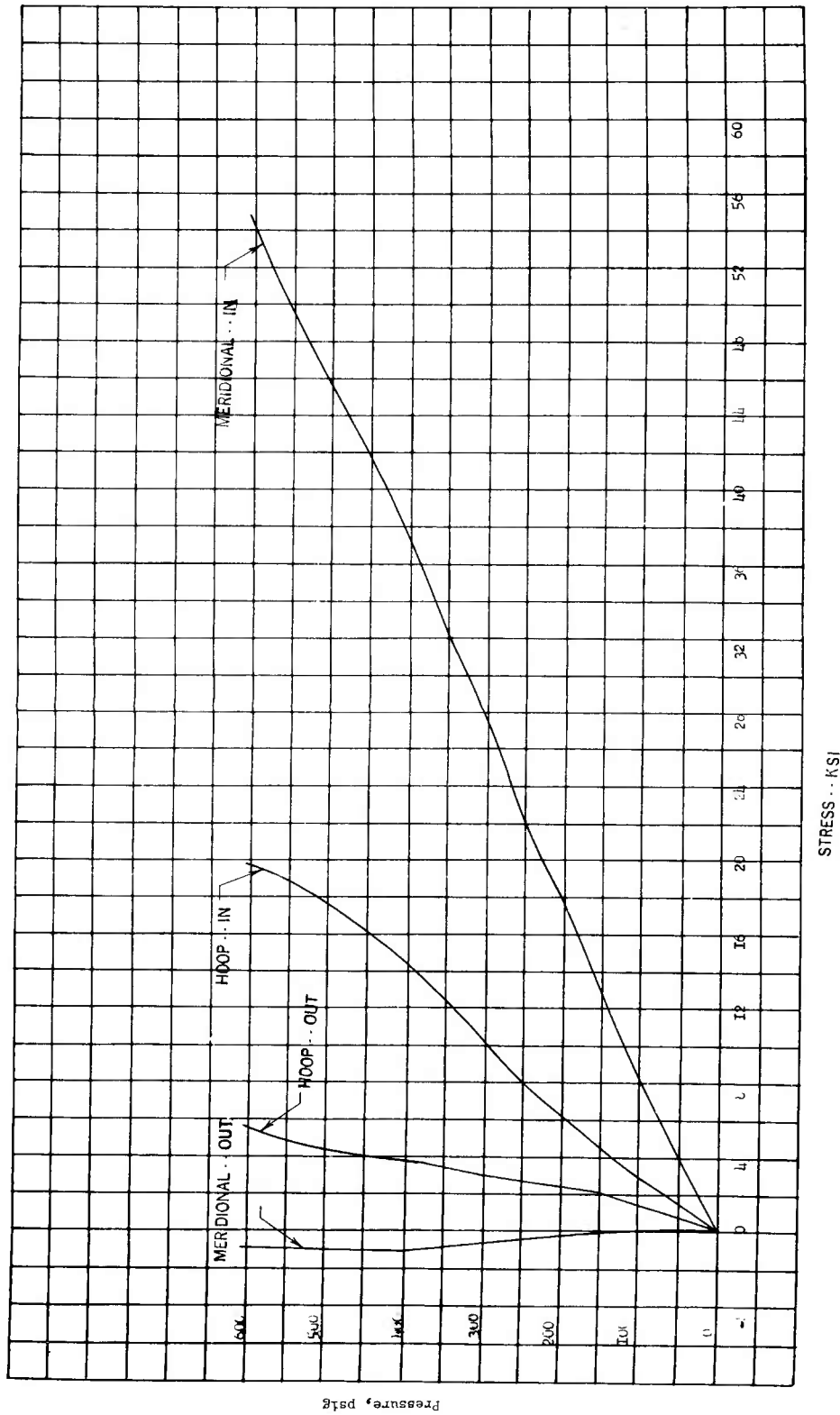


Figure 24

Pressure vs Stress, Gage Point 13

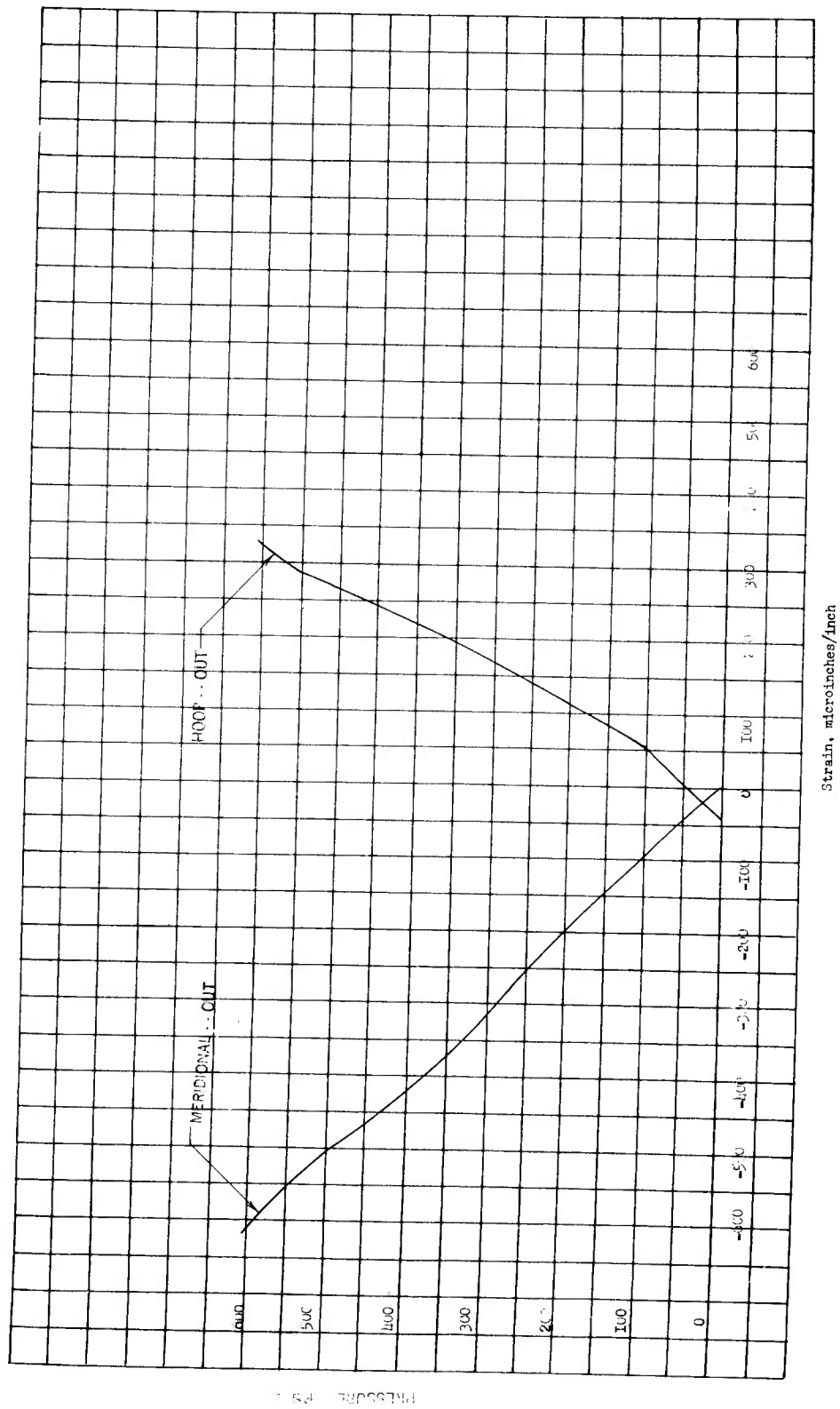
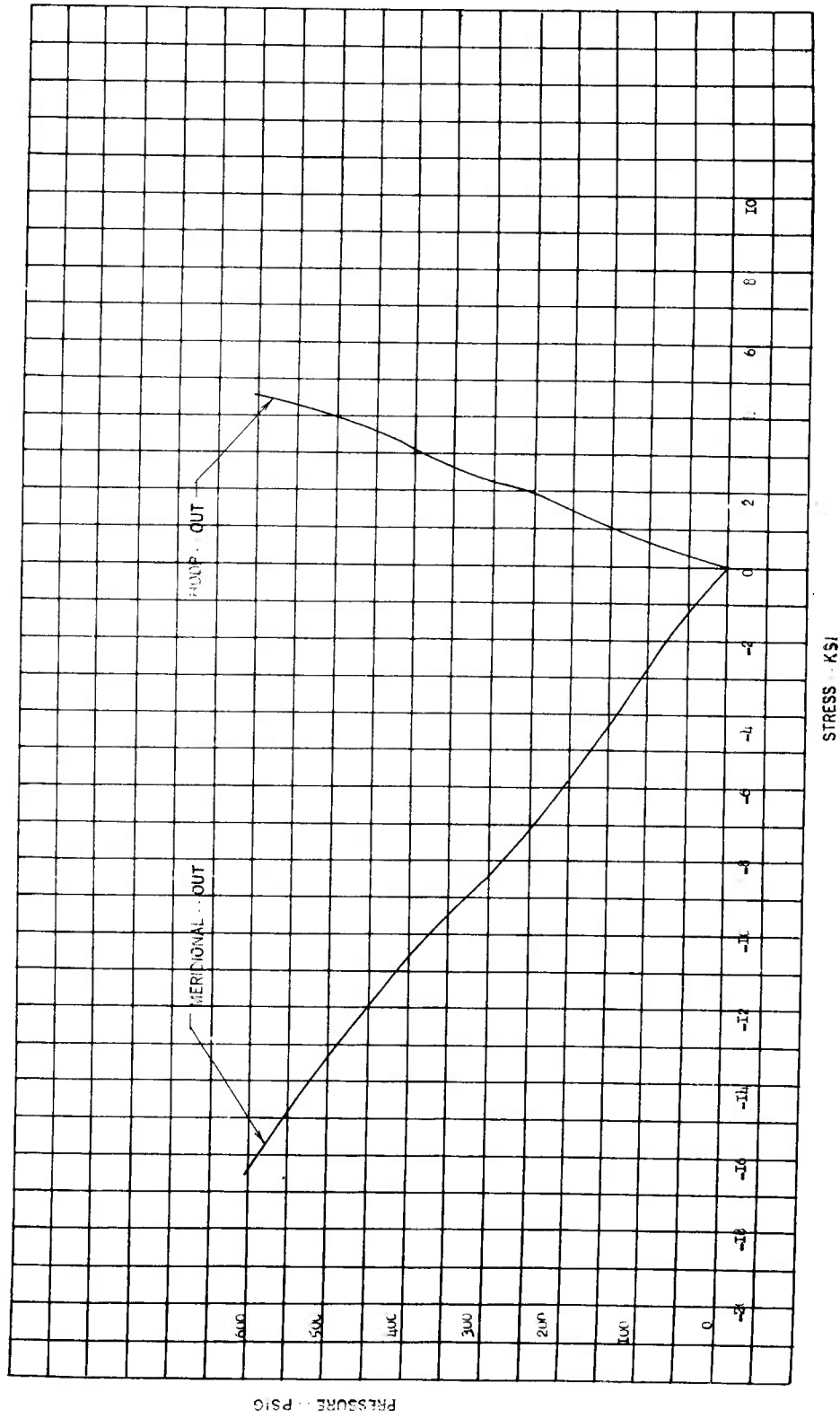


Figure 25

Pressure vs Strain, Gage Point 14



Pressure vs Stress, Gage Point 14

Figure 26

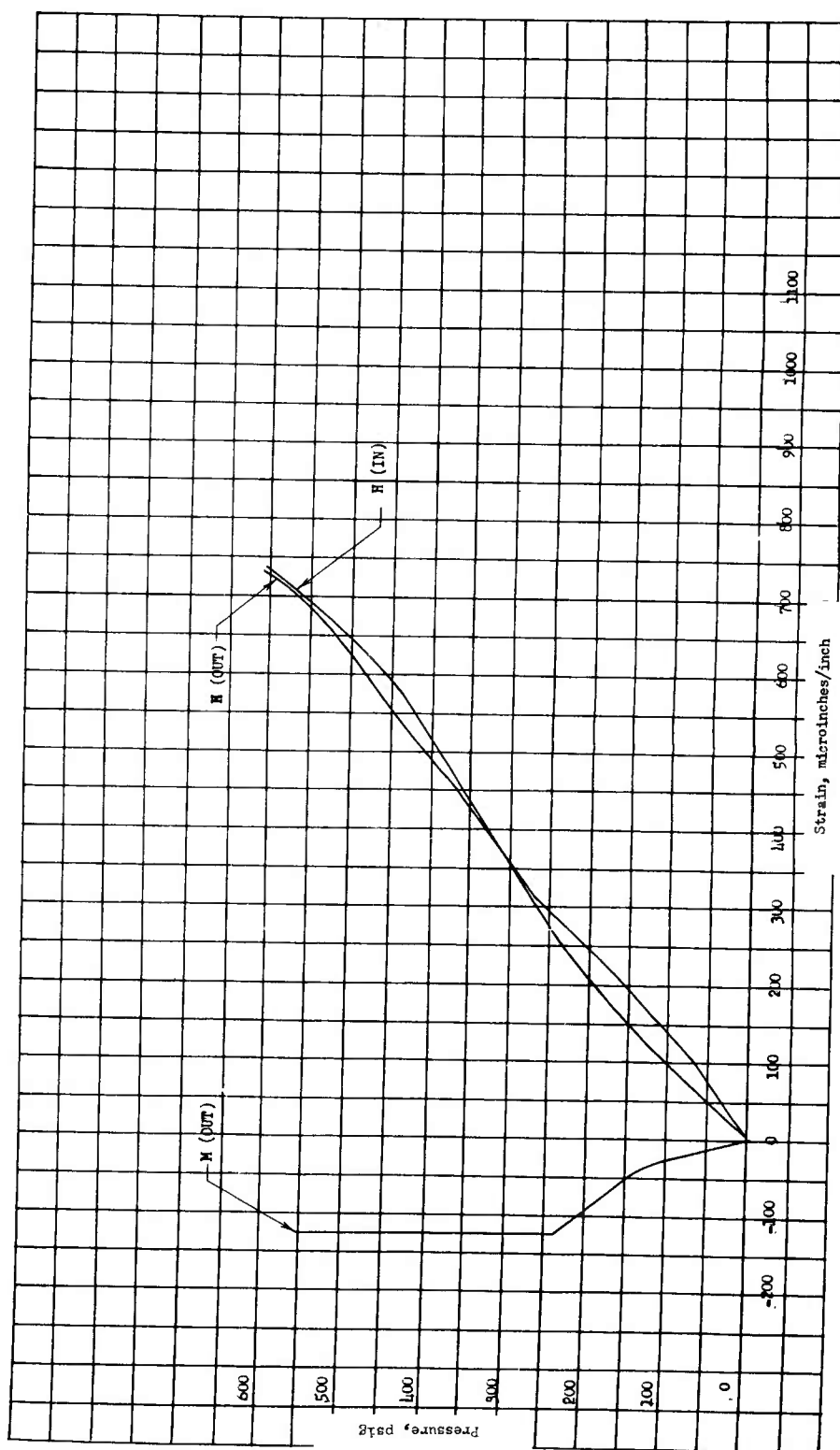


Figure 27

Pressure vs Strain, Gage Point 15

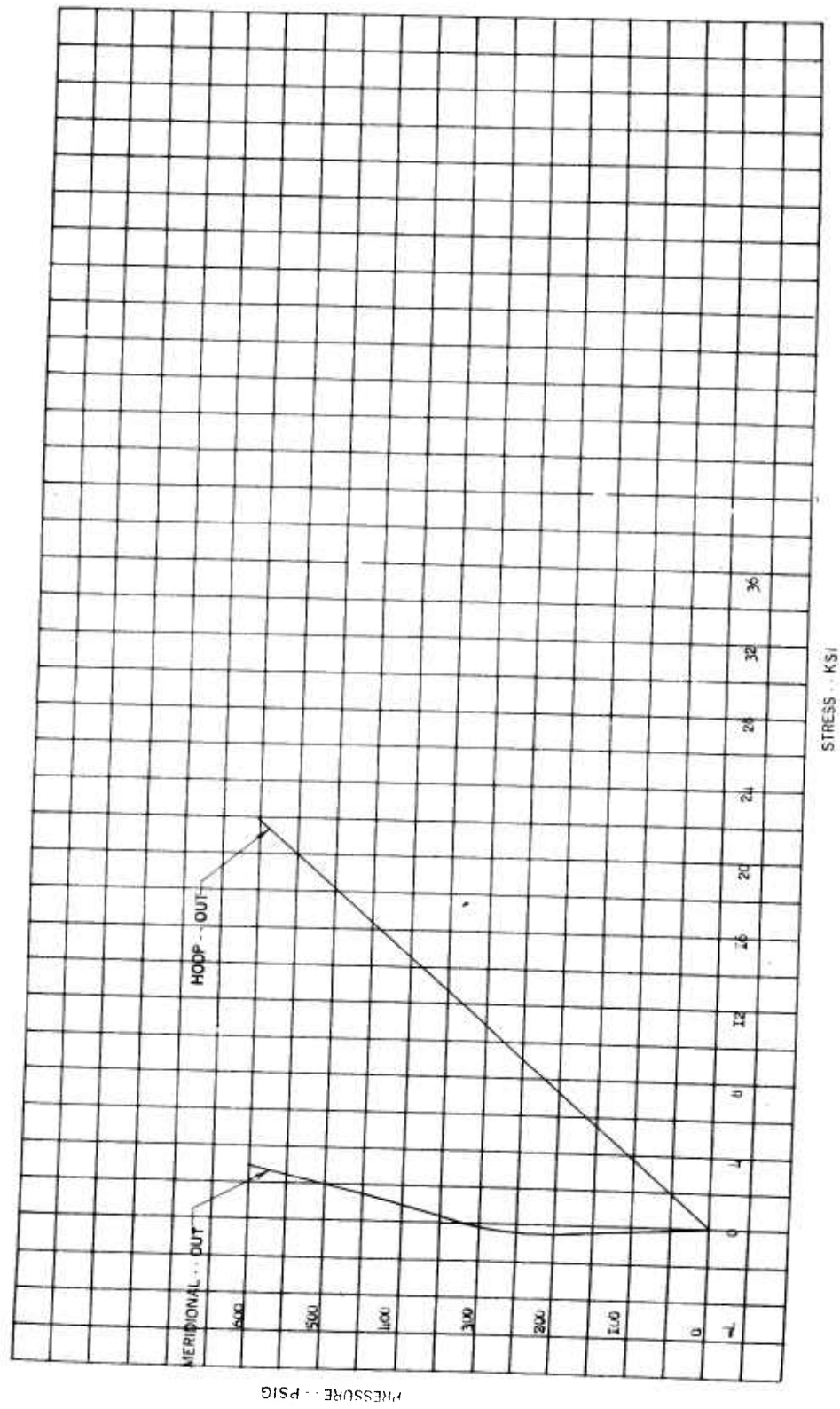


Figure 28

Pressure vs Stress, Gage Point 15

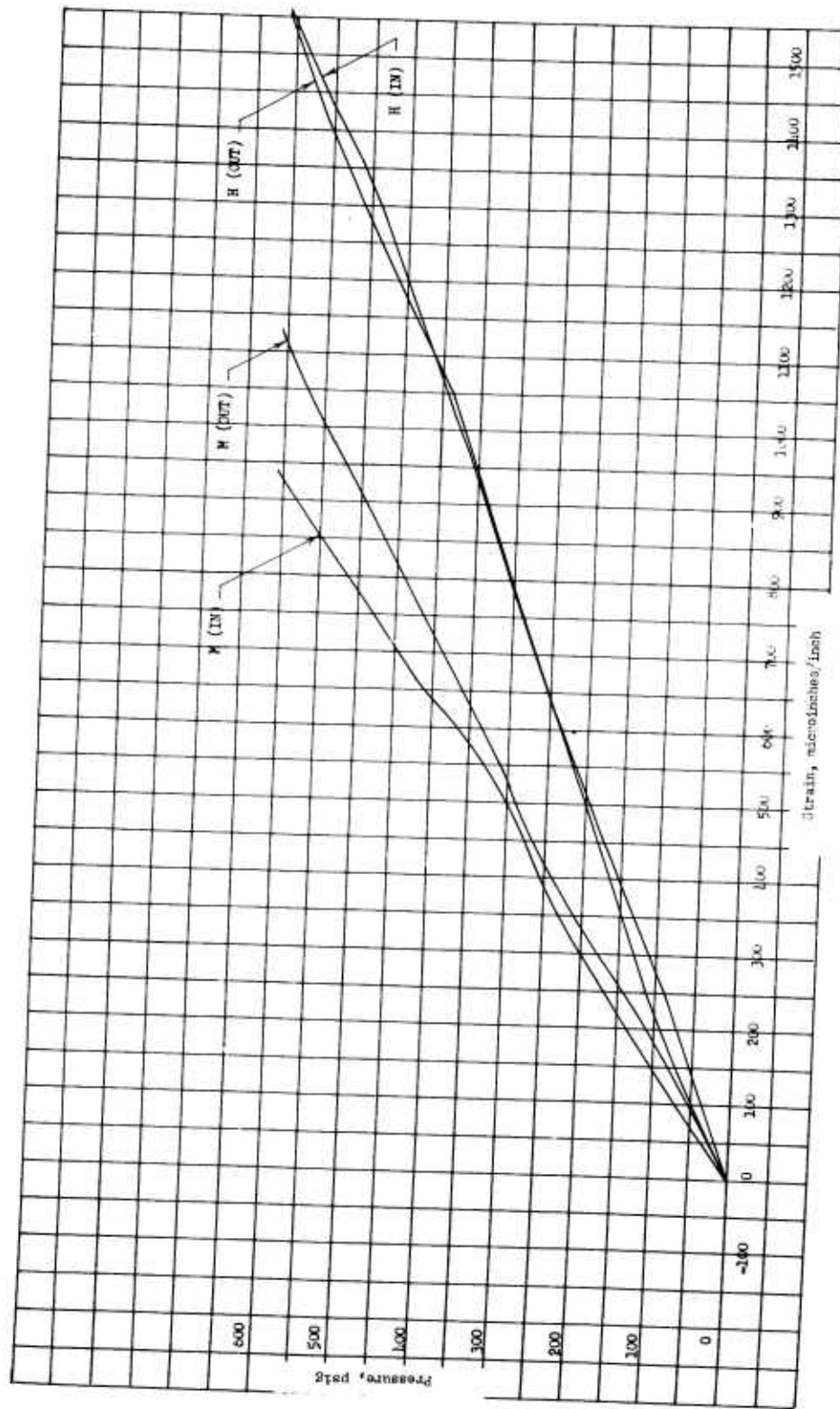


Figure 29

Pressure vs Strain, Gage Point 16

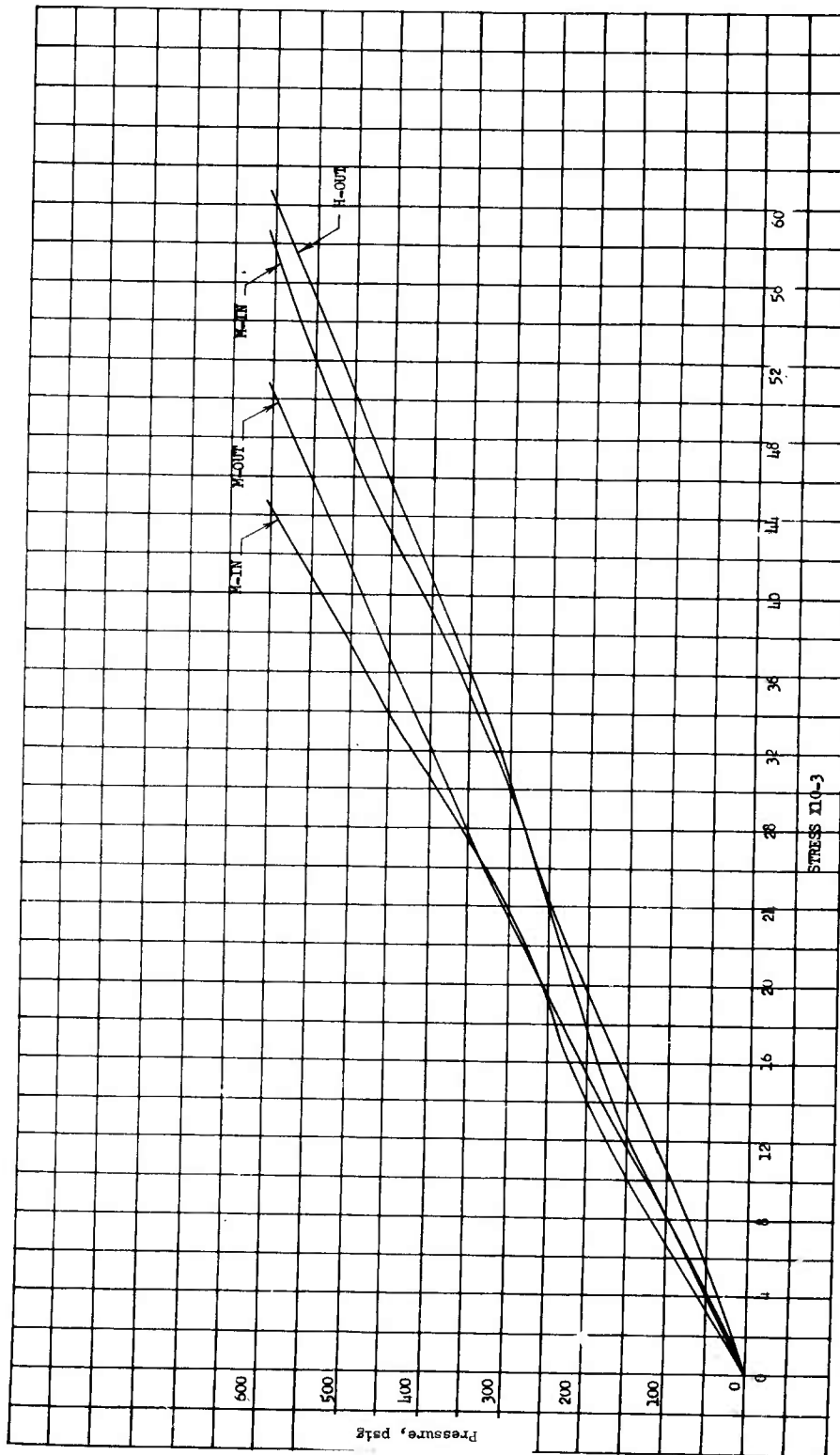


Figure 30

Pressure vs Stress, Gage Point 16

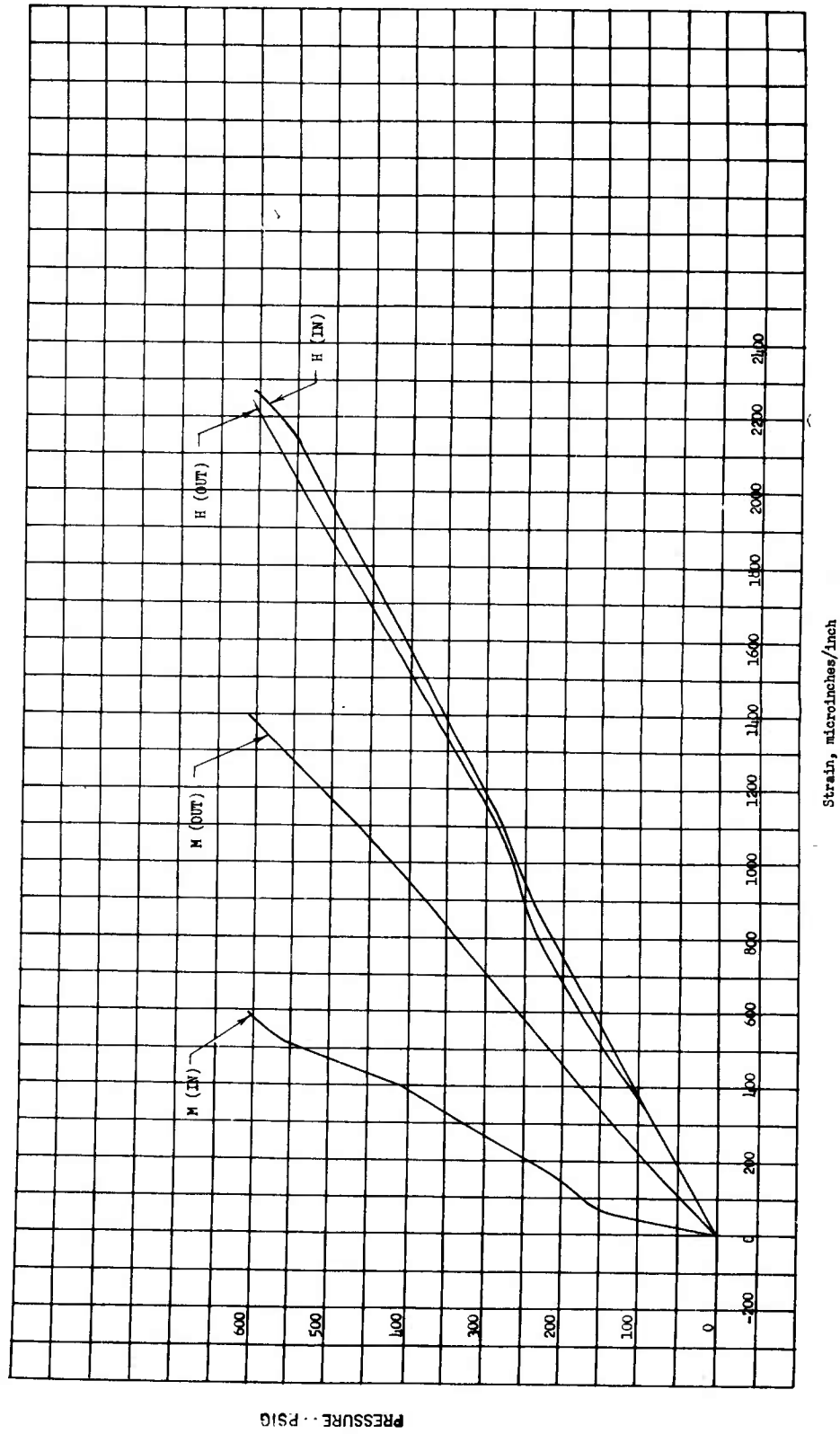
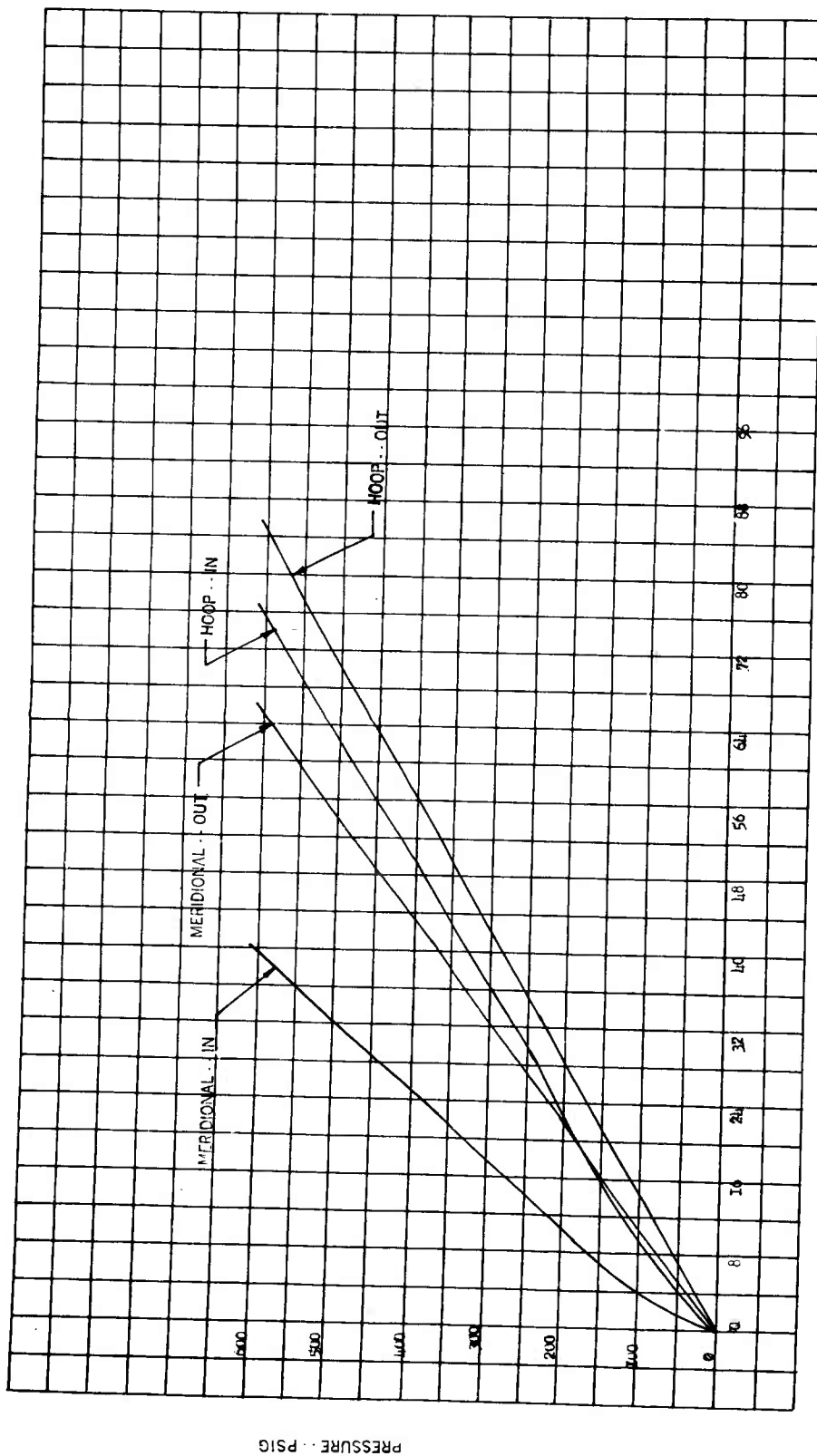


Figure 31

Pressure vs Strain, Gage Point 17

Appendix D



PRESSURE · PSIG

STRESS · KSI

Figure 32

Pressure vs Stress, Gage Point 17

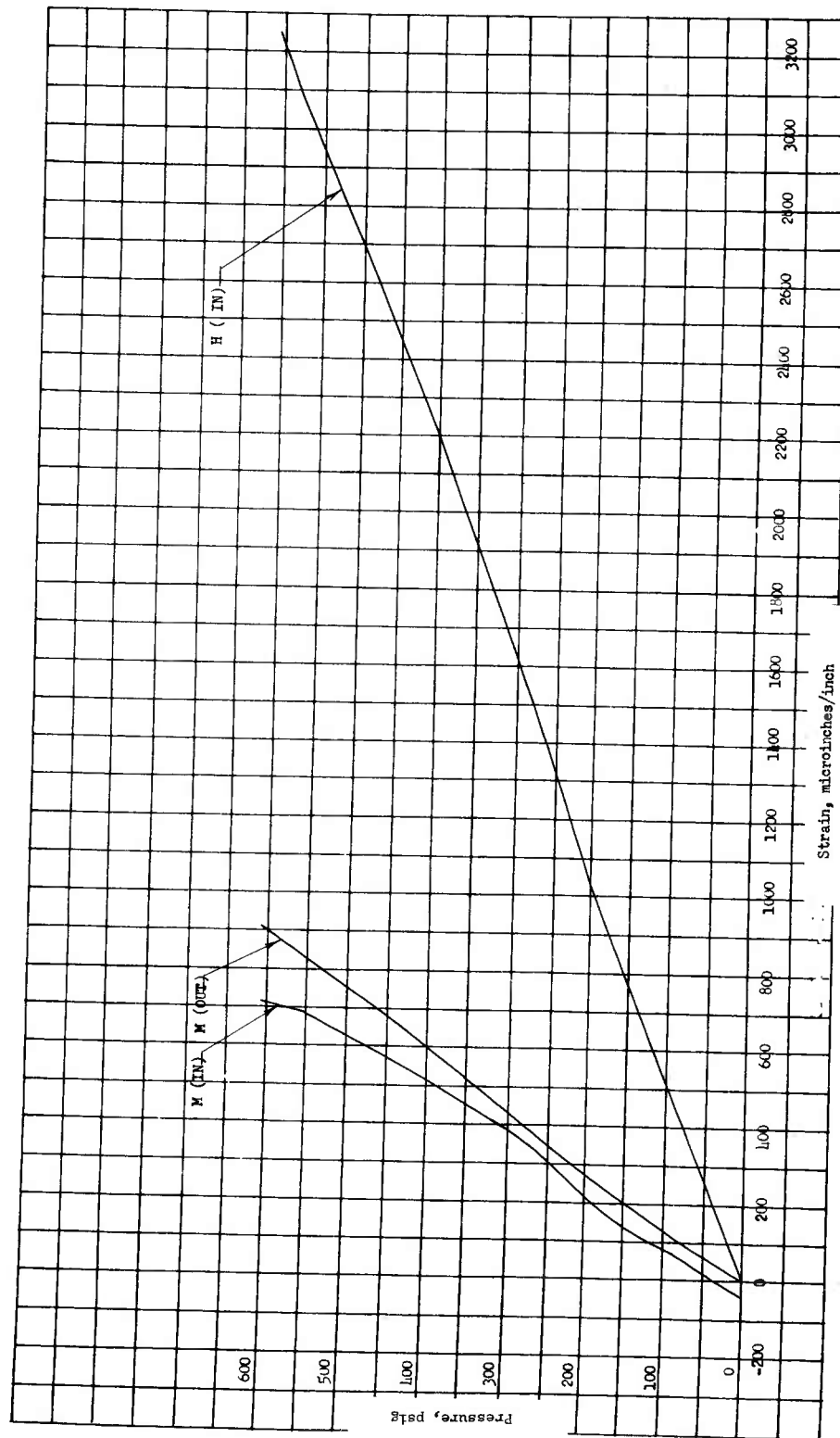


Figure 33

Pressure vs Strain, Gage Point 18

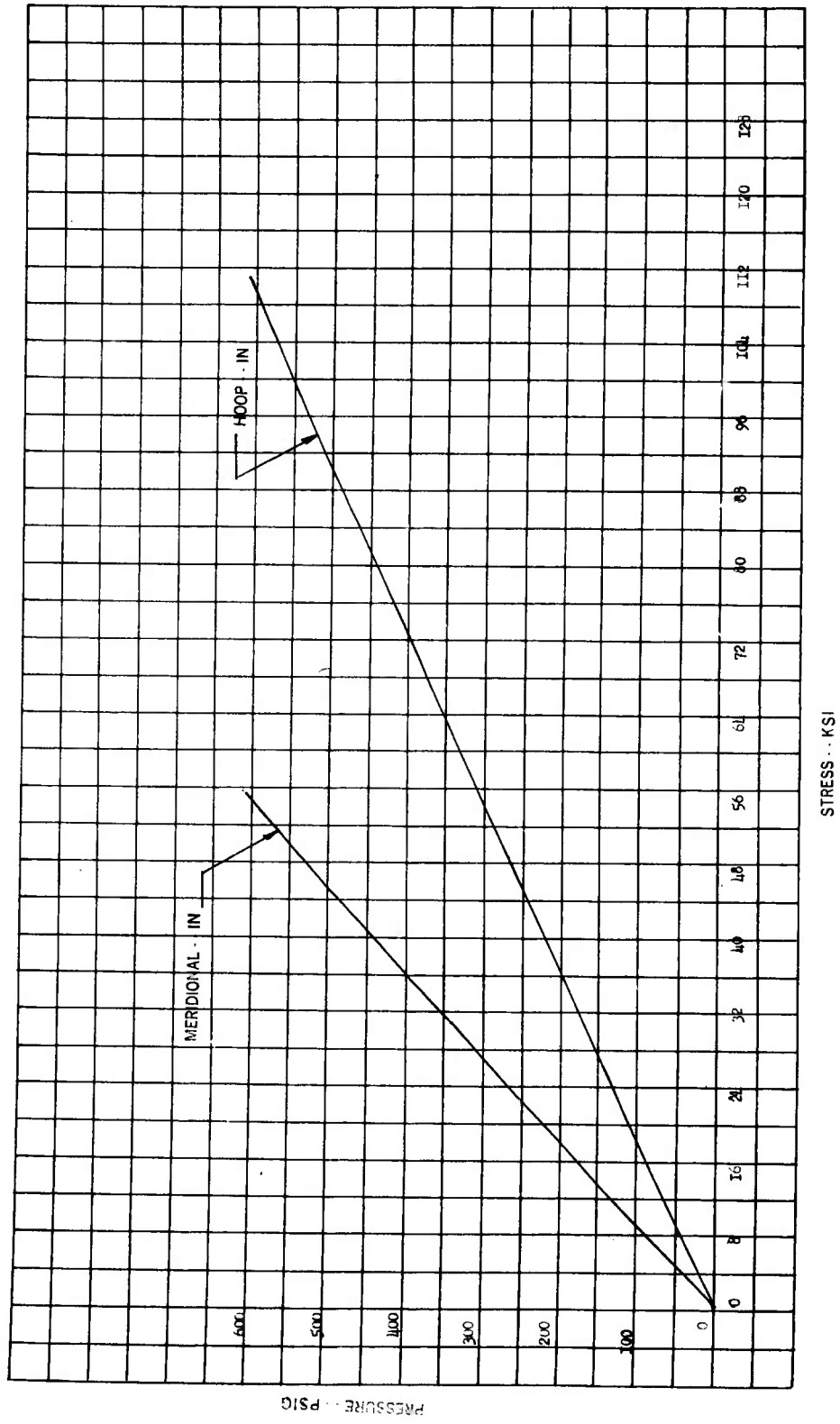
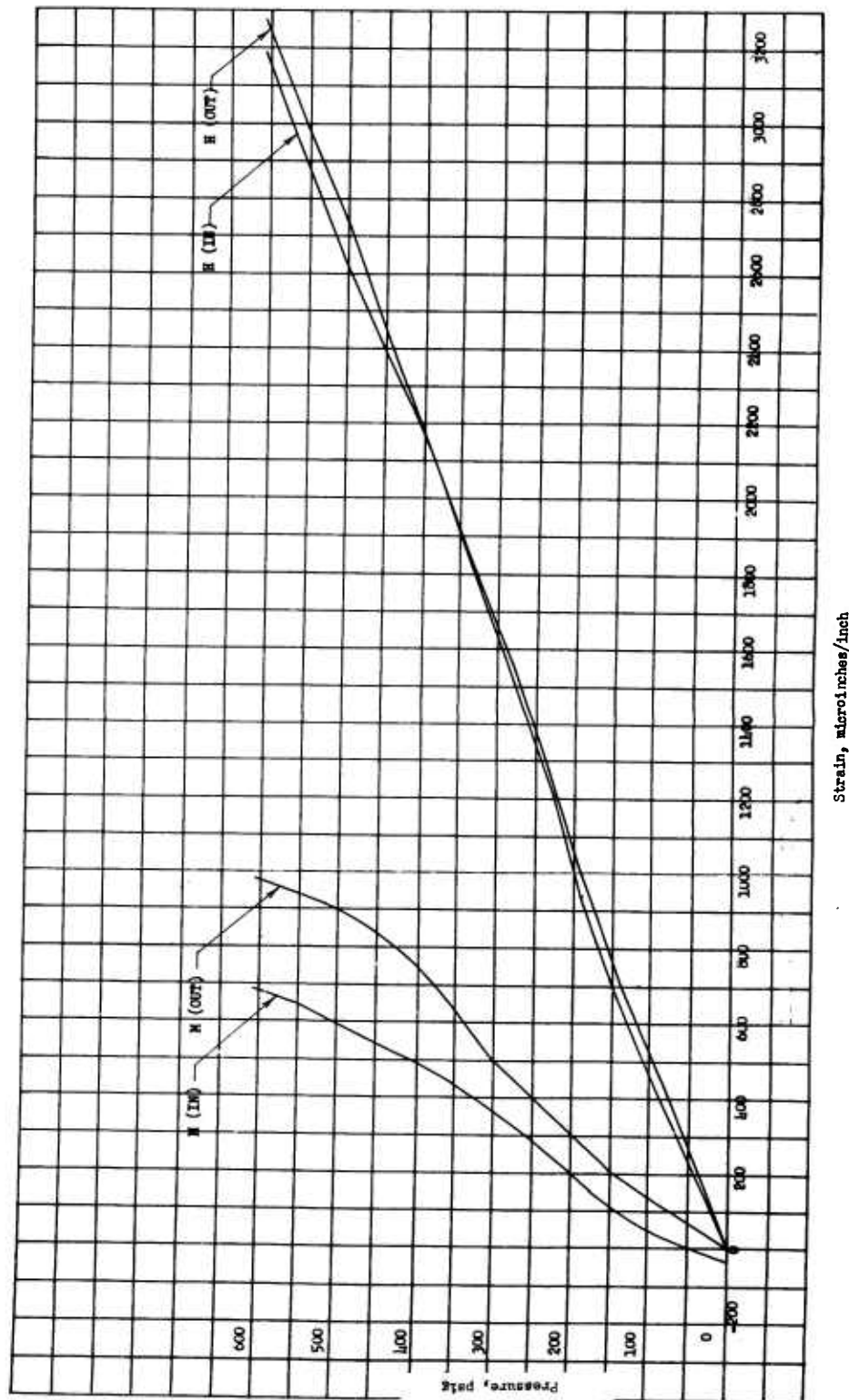


Figure 34

Pressure vs Stress, Gage Point 18



Strain, microinches/inch

Pressure vs Strain, Gage Point 19

Figure 35

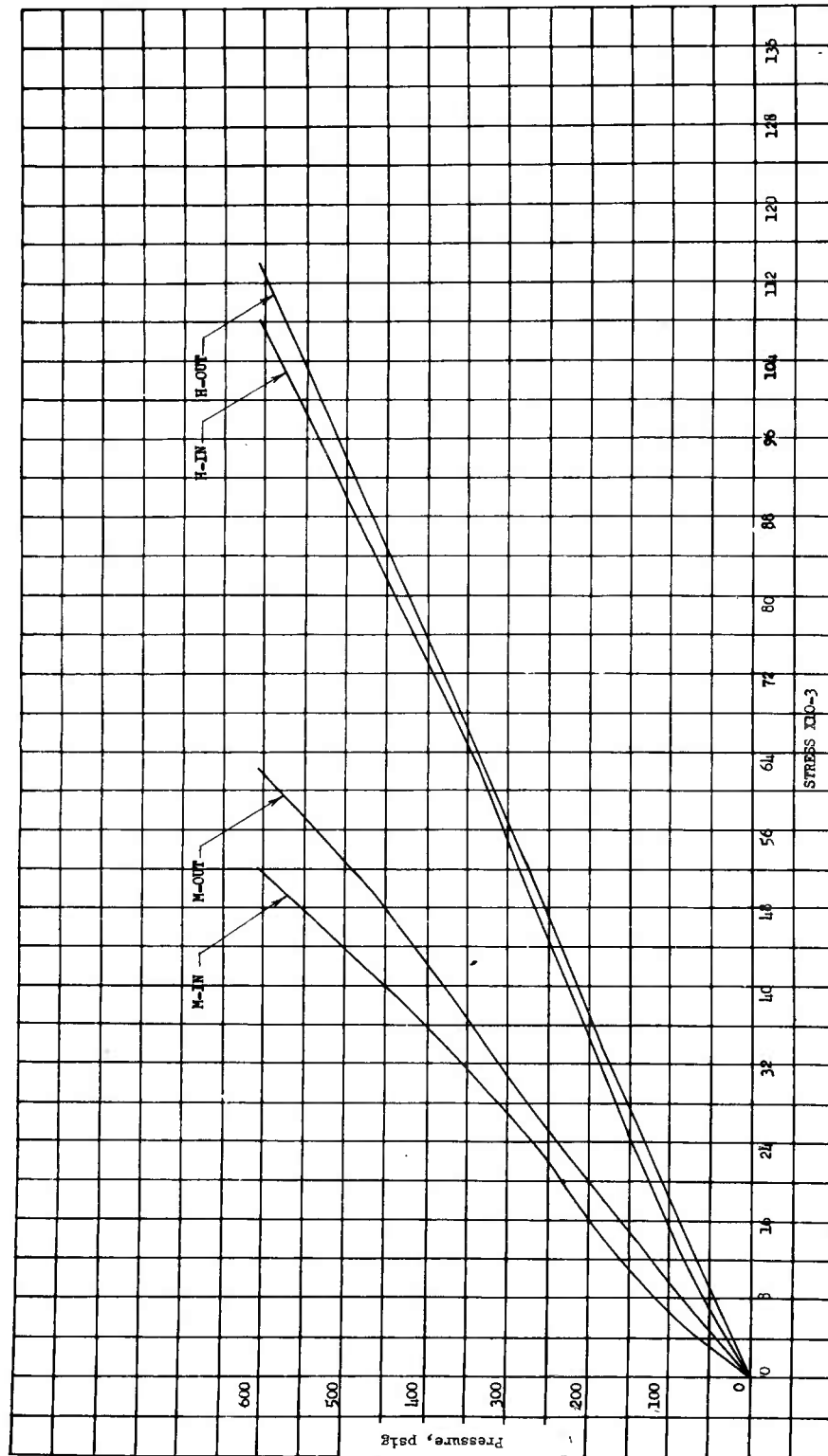


Figure 36

Pressure vs Stress, Gage Point 19

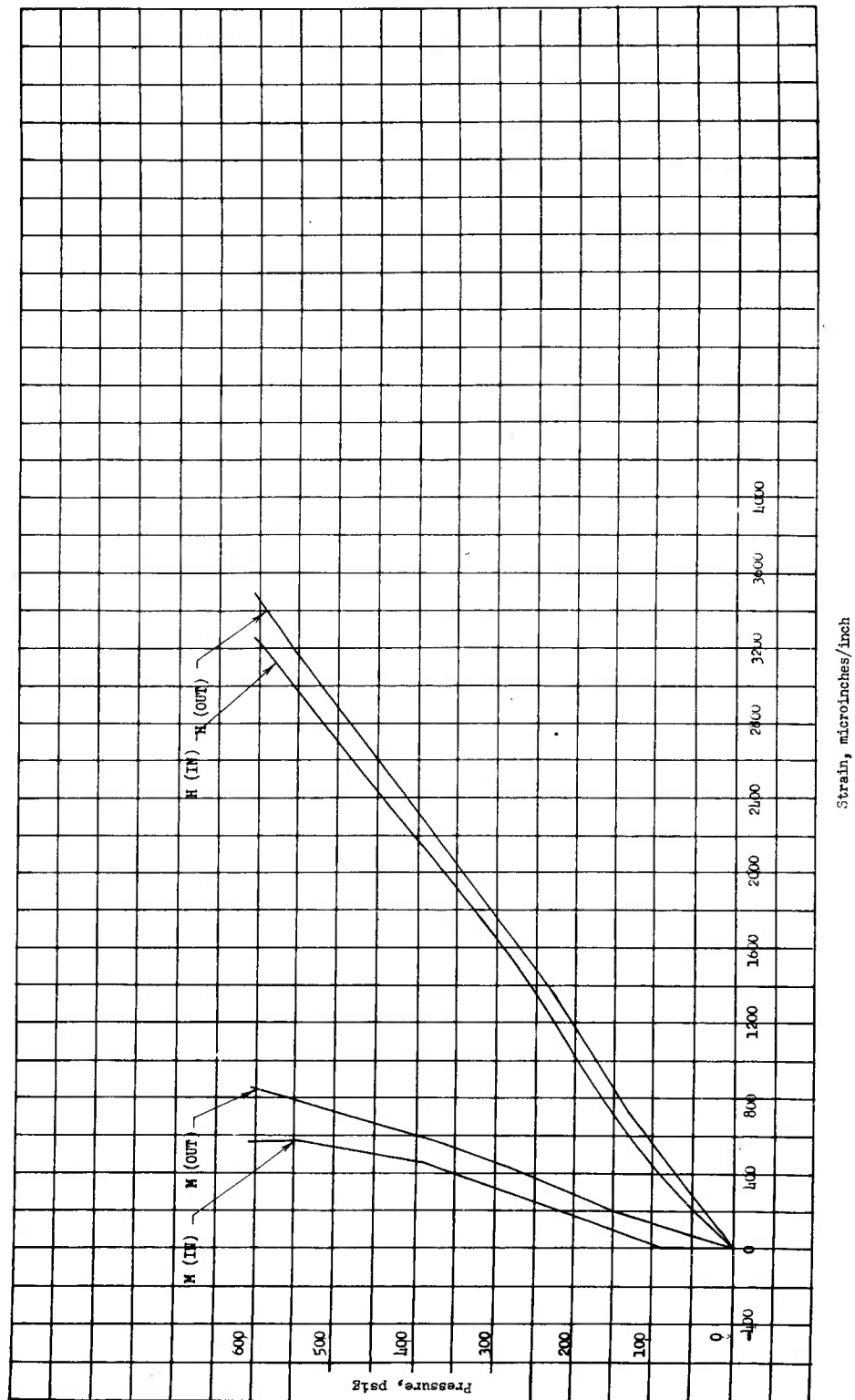


Figure 37

Pressure vs Strain, Gage Point 20

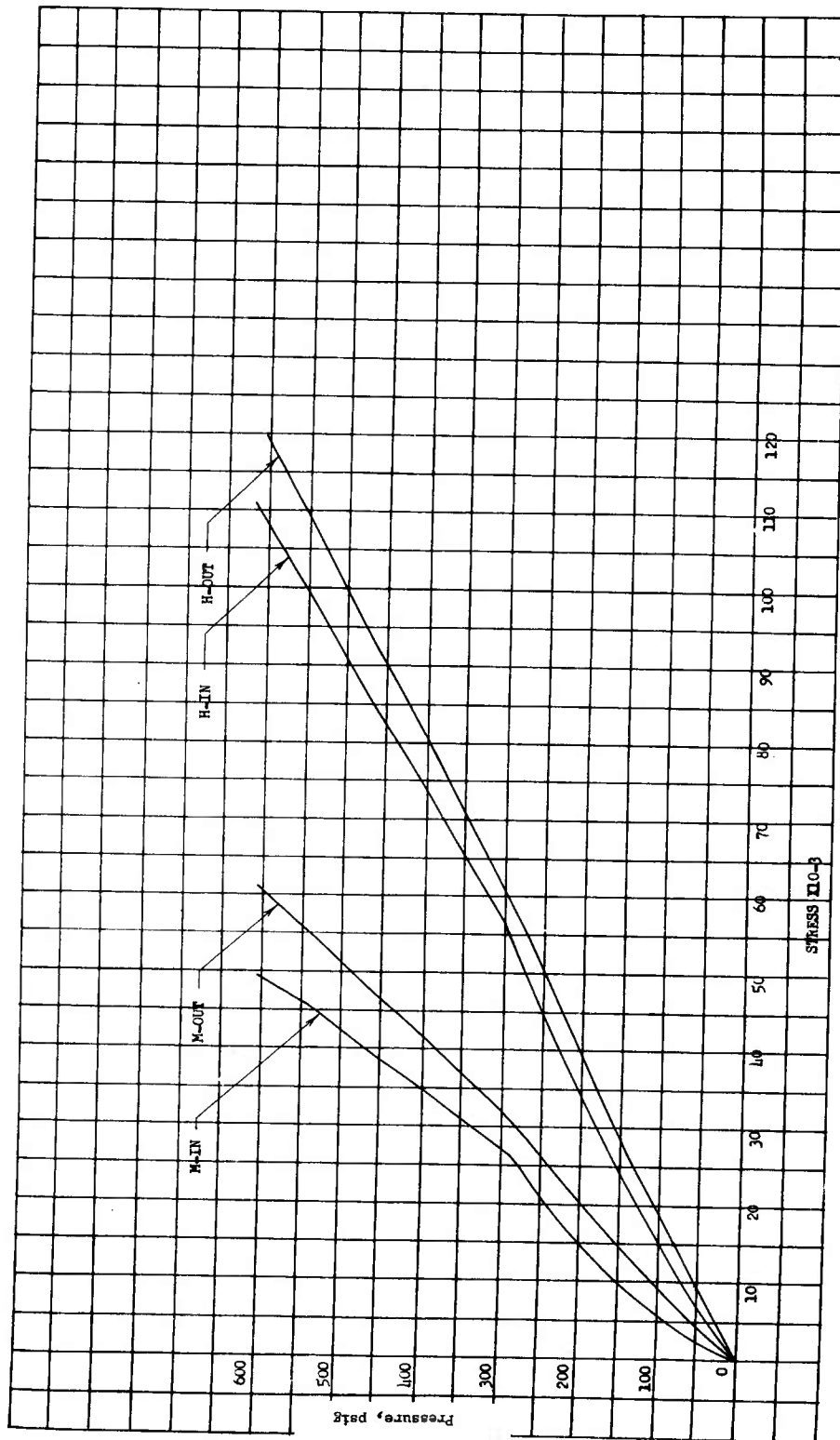


Figure 38

Pressure vs Stress, Gage Point 20

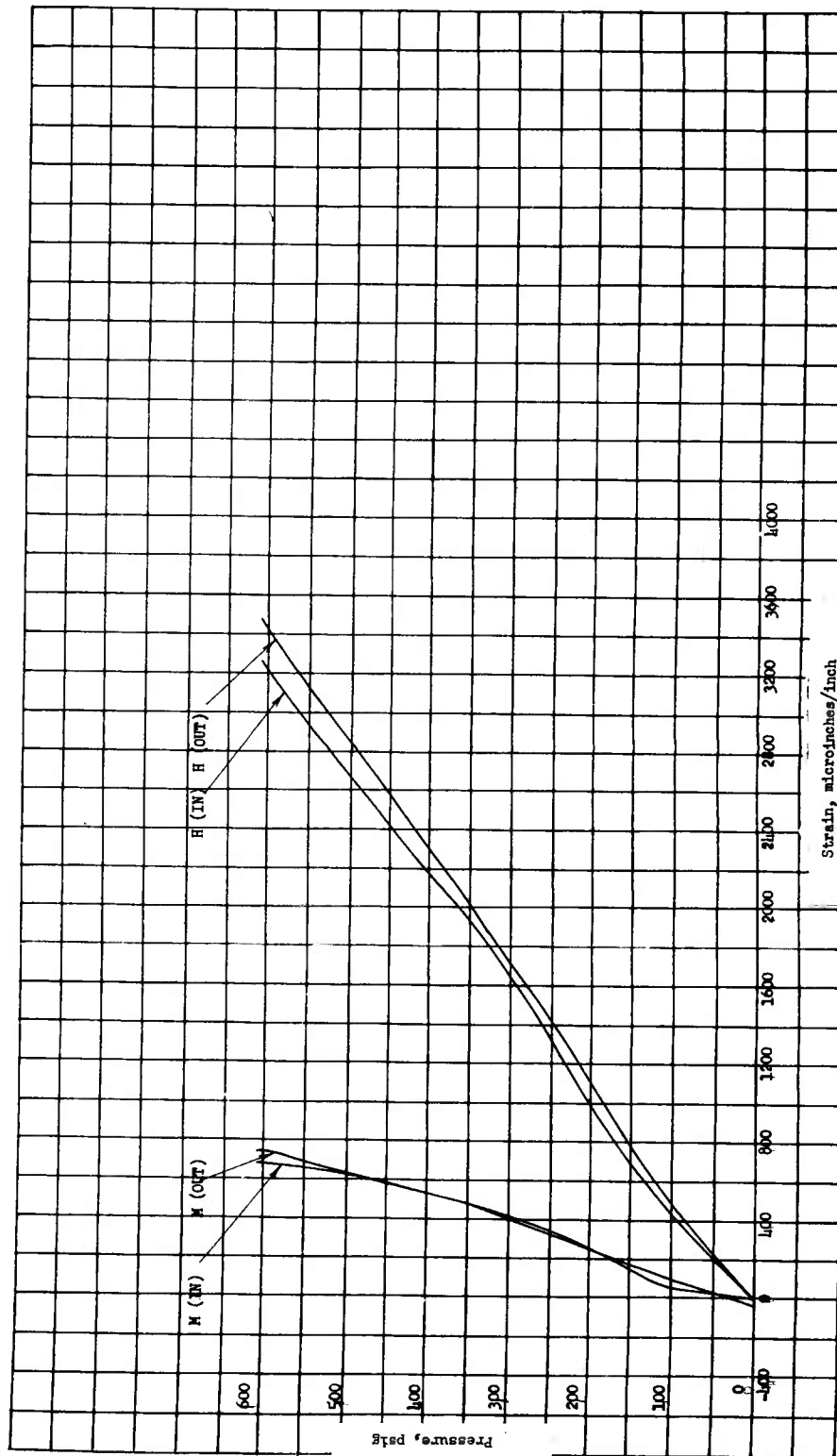


Figure 39

Pressure vs Strain, Gage Point 21

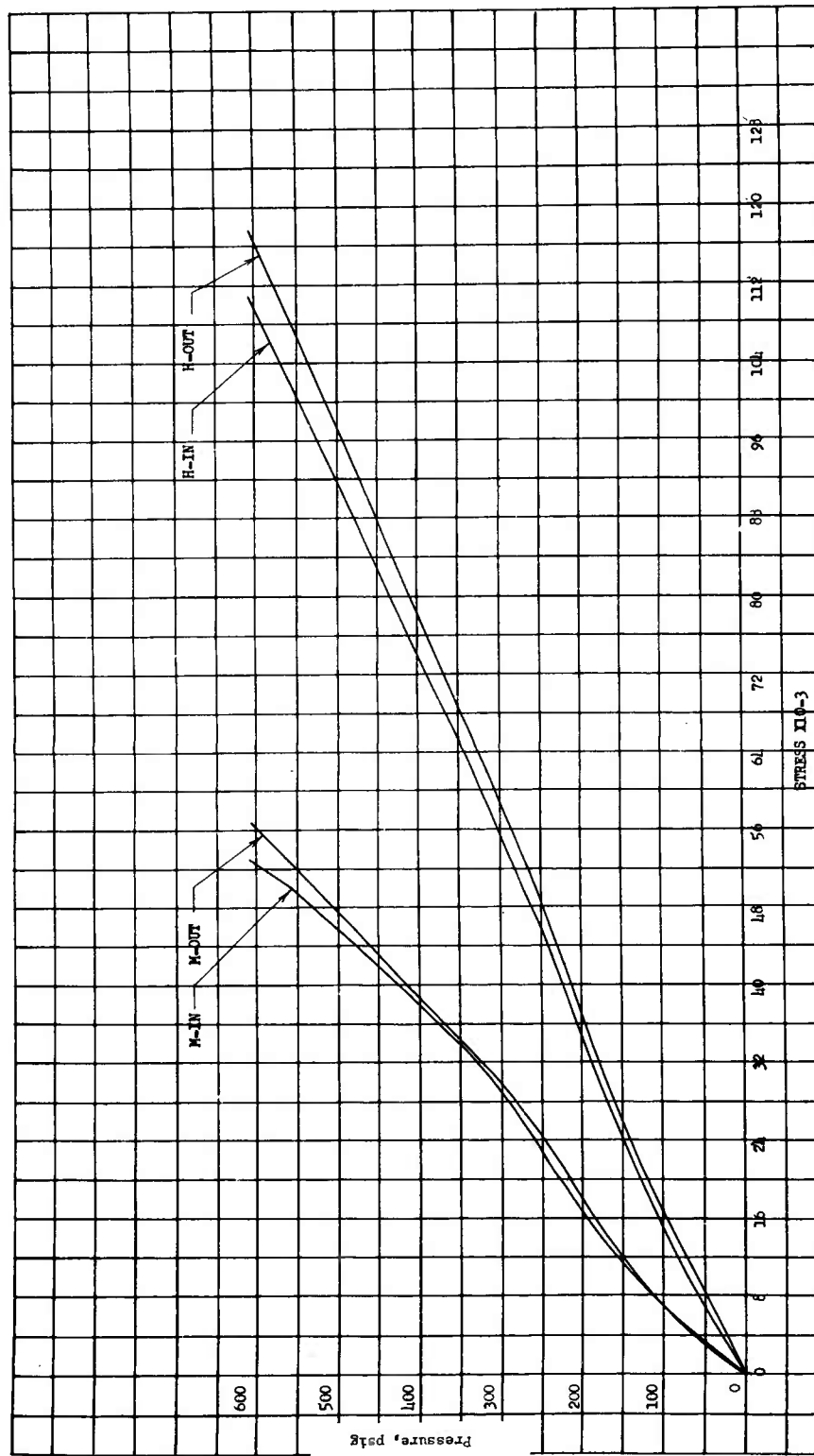


Figure 40

Pressure vs Stress, Gage Point 21

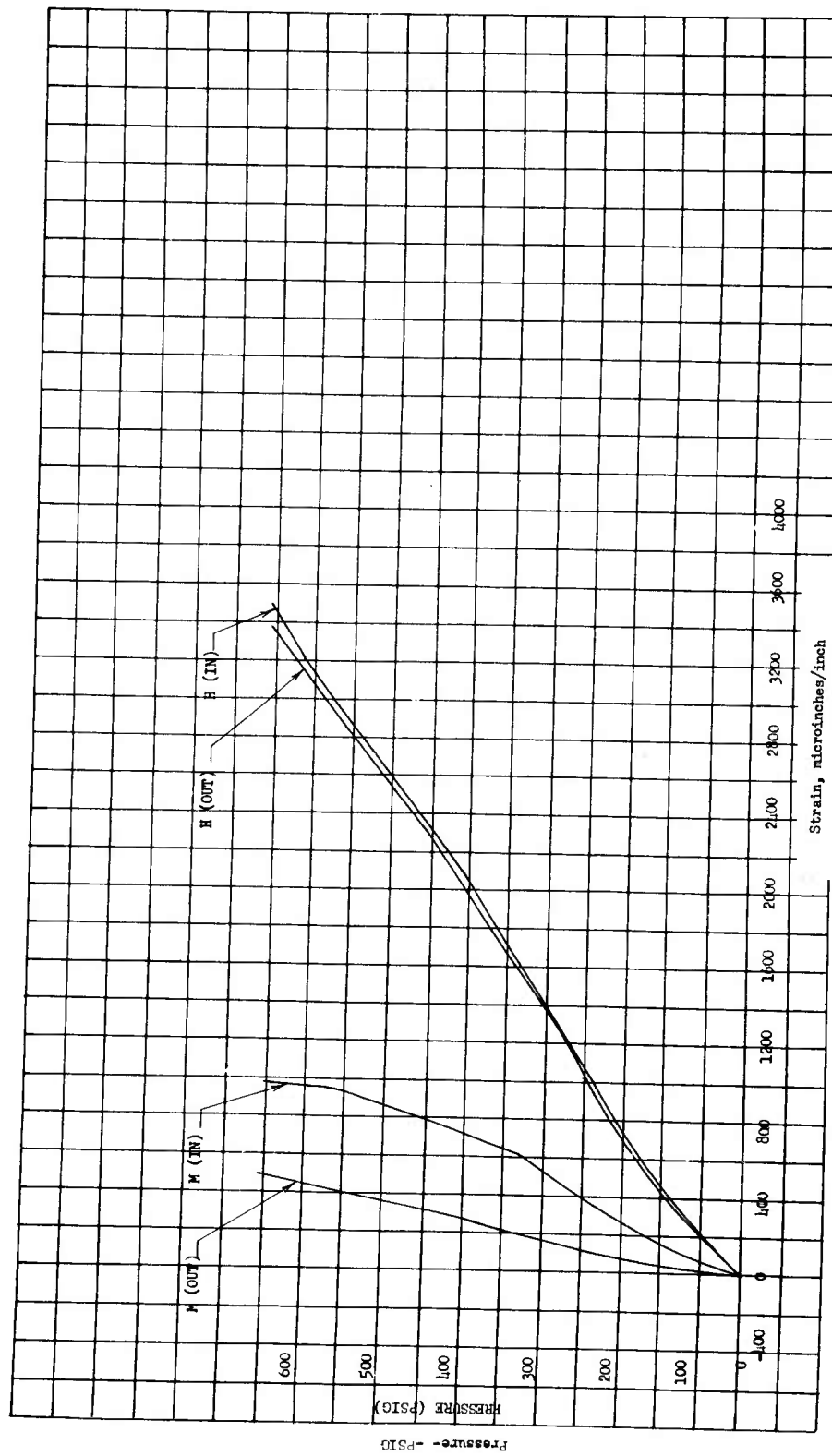


Figure 41

Pressure vs Strain, Gage Point 22

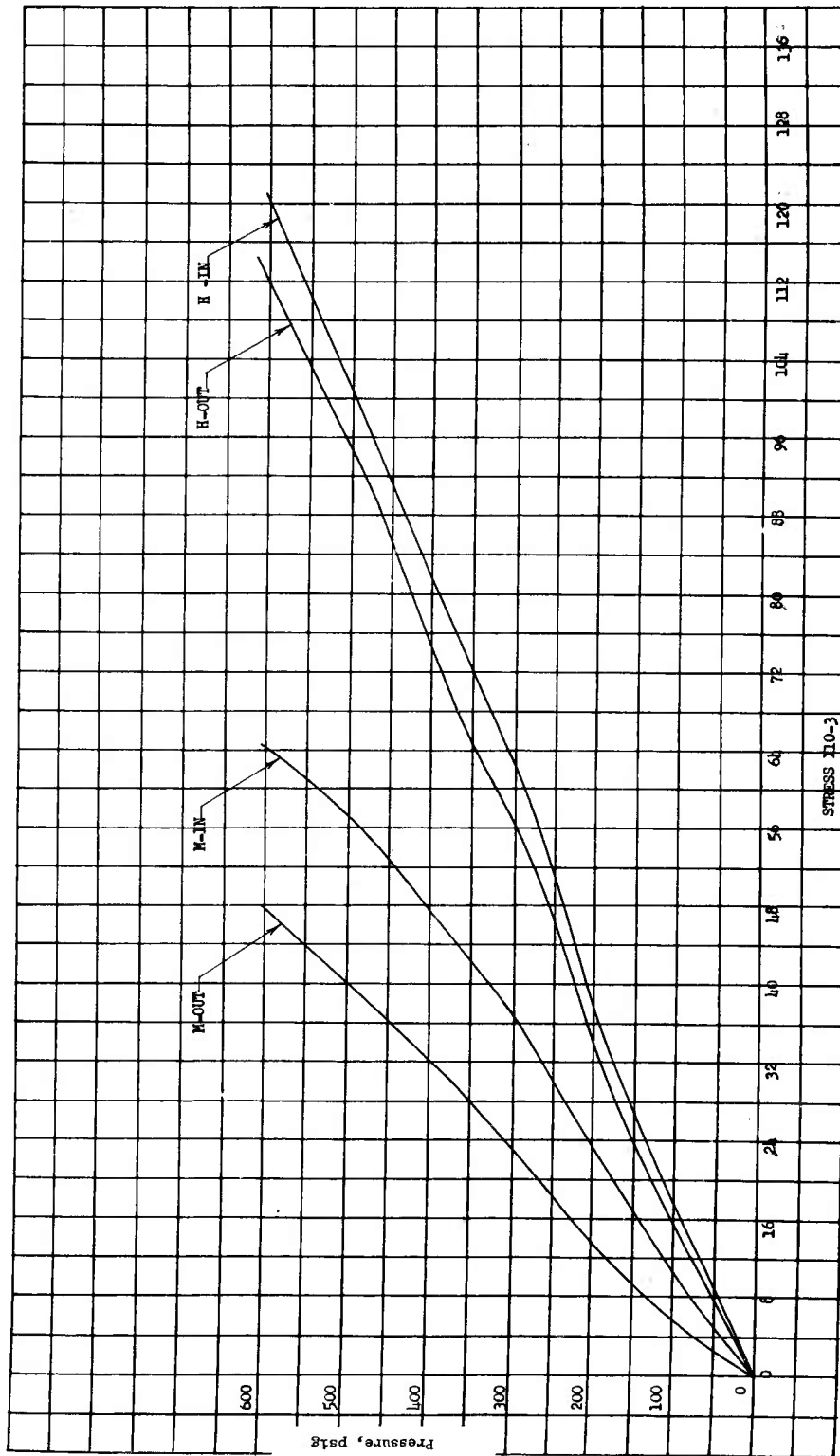


Figure 42

Pressure vs Stress, Gage Point 22

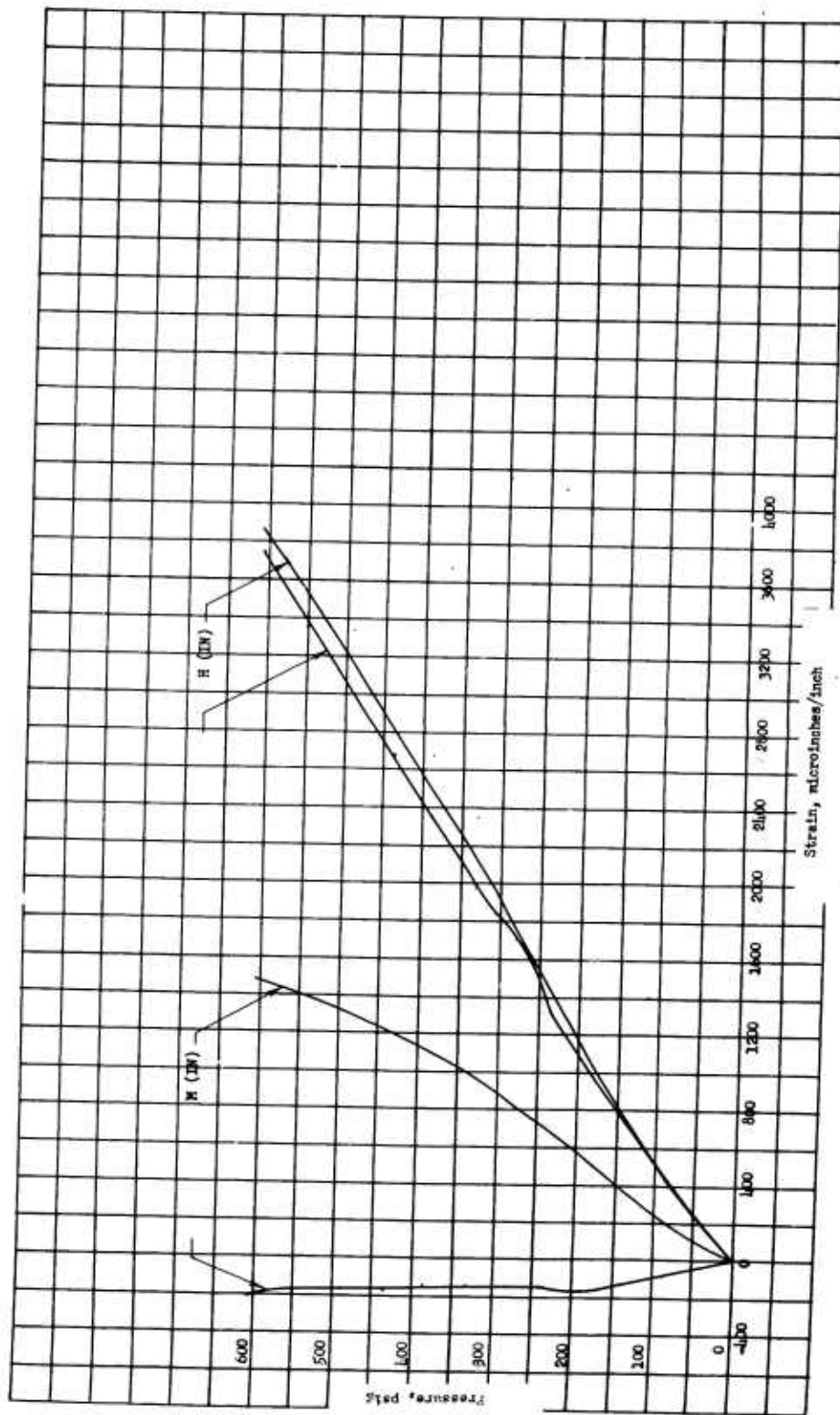


Figure 43

Pressure vs Strain, CAGE POINT 23

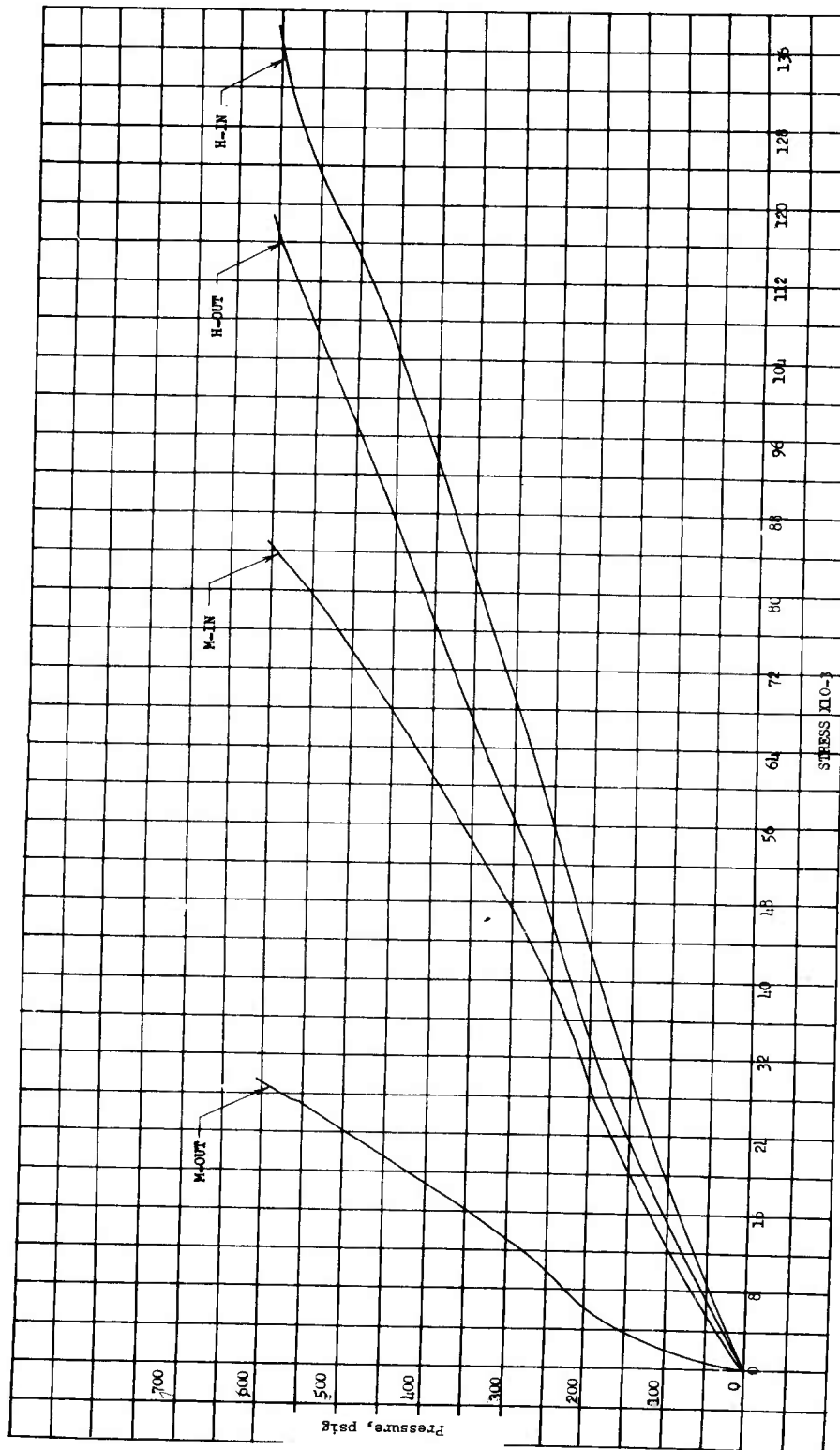


Figure 44

Pressure vs Stress, Gage Point 23

Appendix D

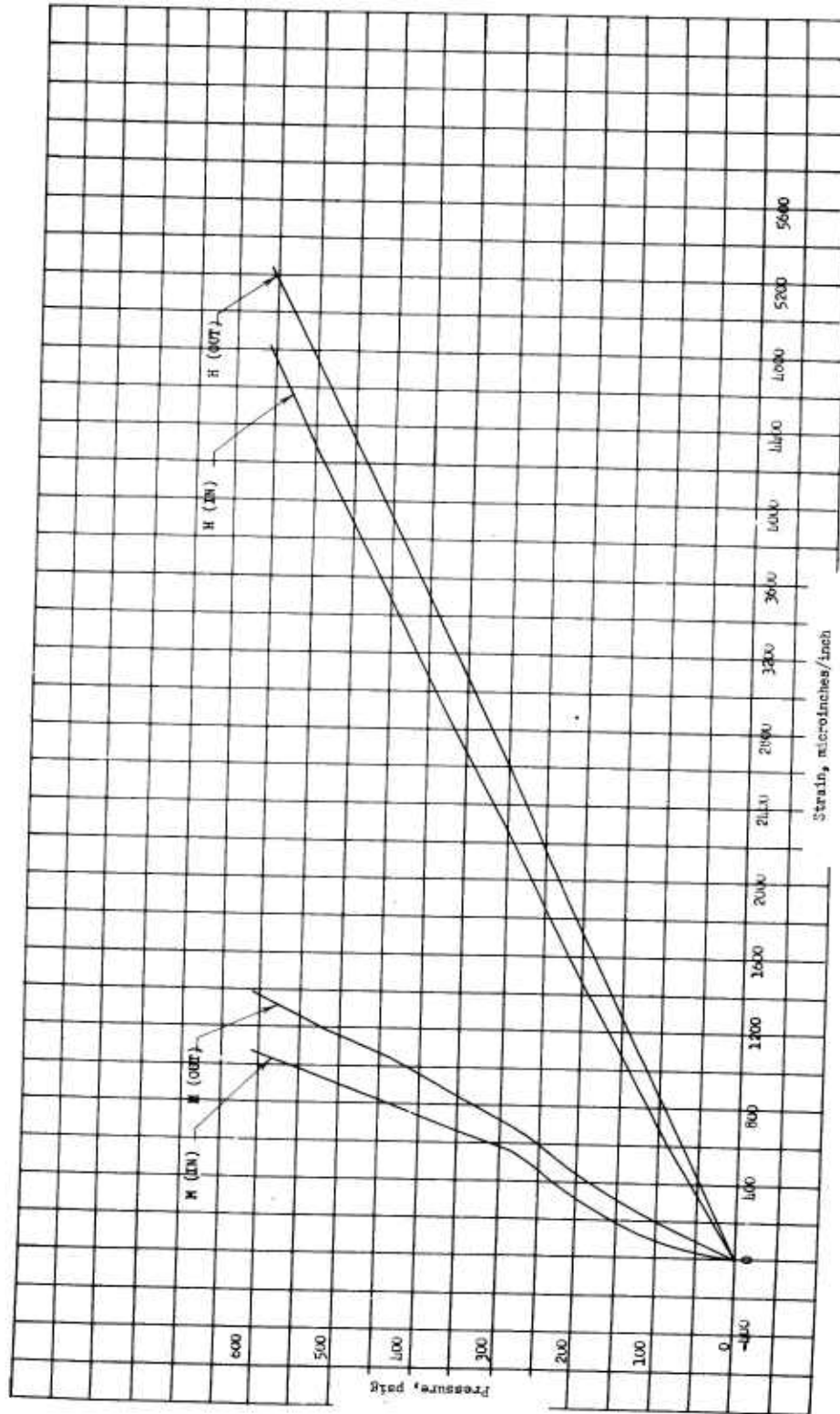


Figure 45

Pressure vs Strain, Gage Point 24

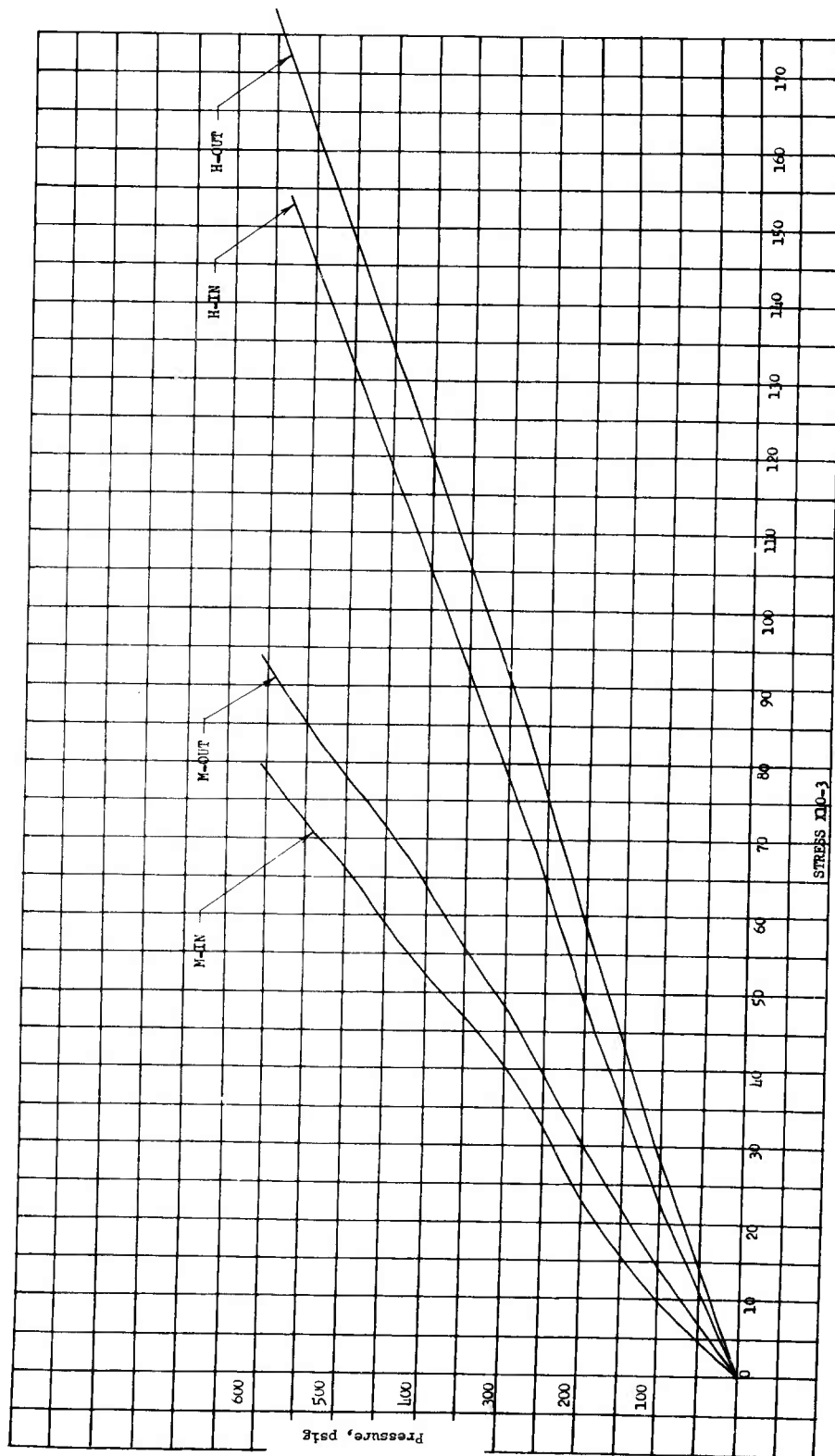


Figure 46

Pressure vs Stress, Gage Point 24

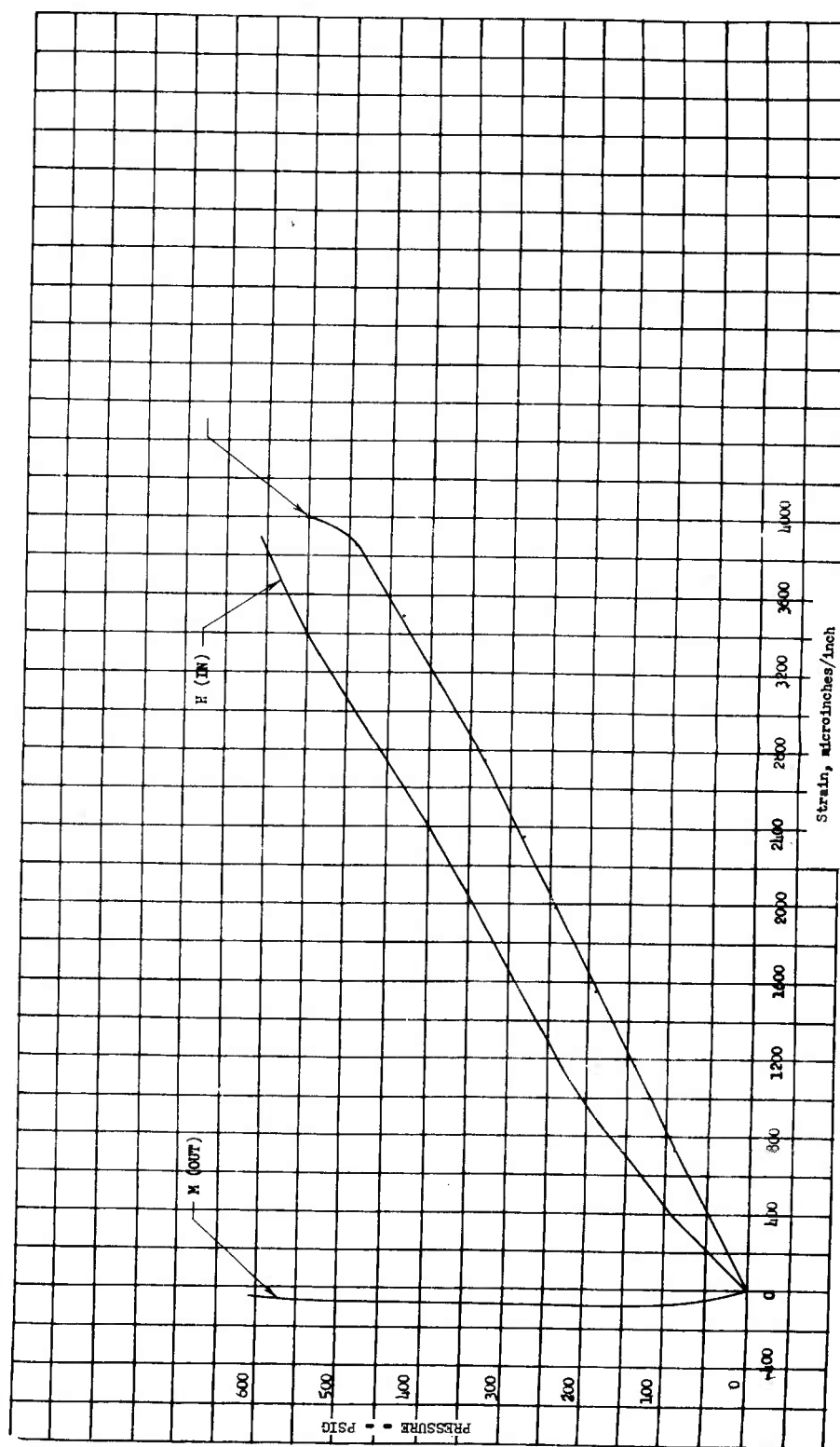


Figure 47

Pressure vs Strain, Gage Point 25

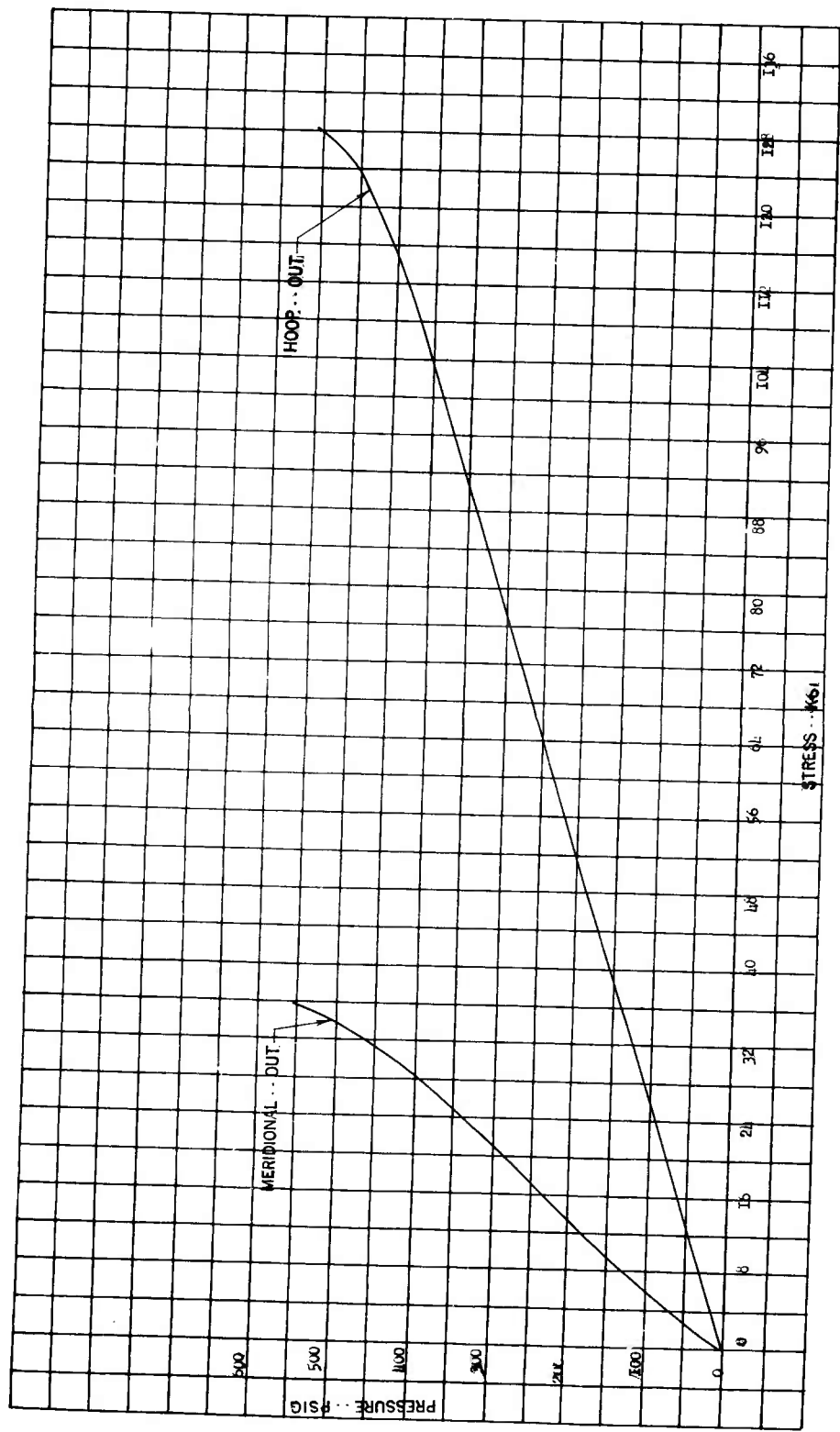


Figure 48

Pressure vs Stress, Gage Point 25

Appendix D

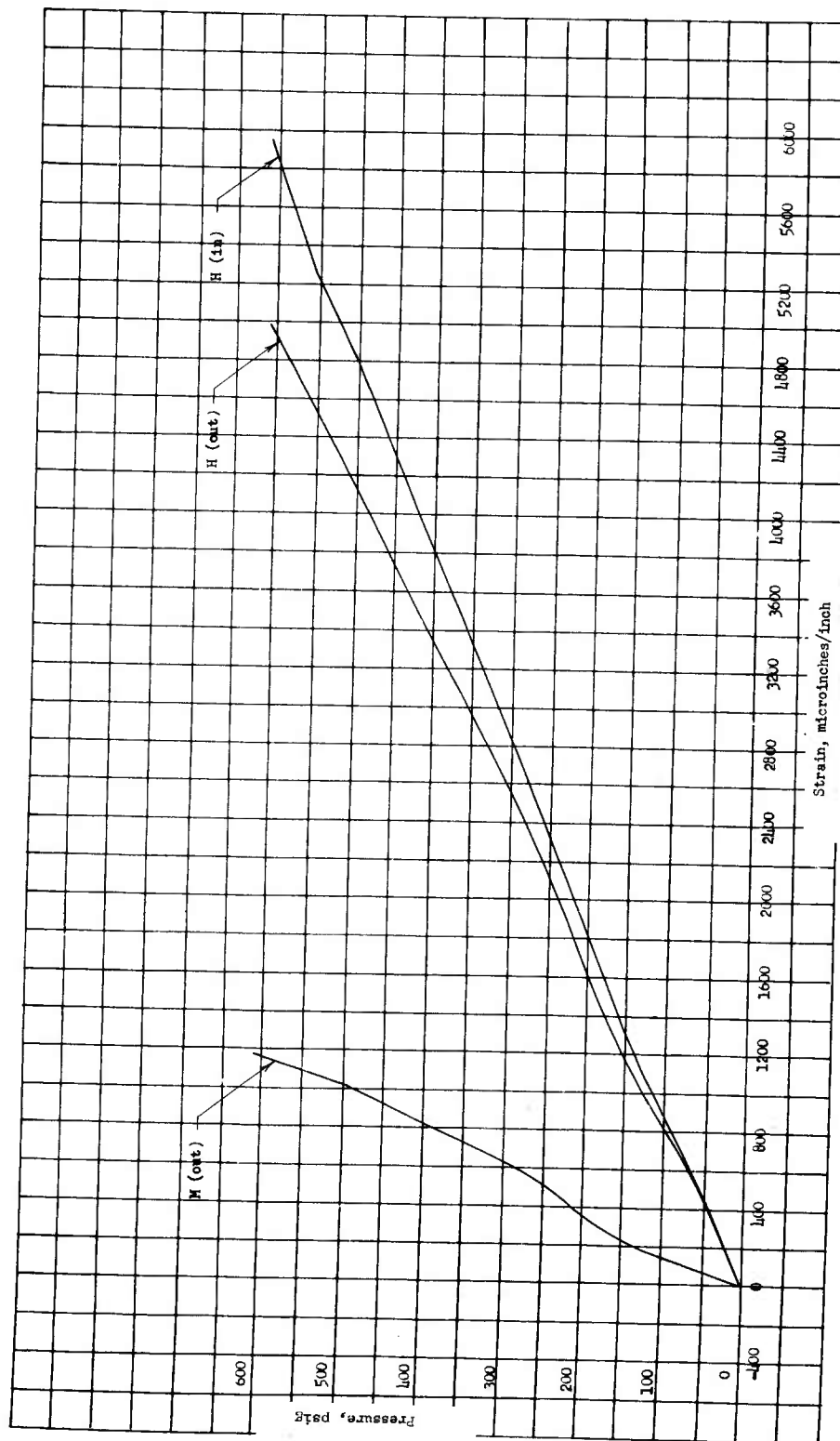


Figure 49

Pressure vs Strain, Gage Point 26

Appendix D

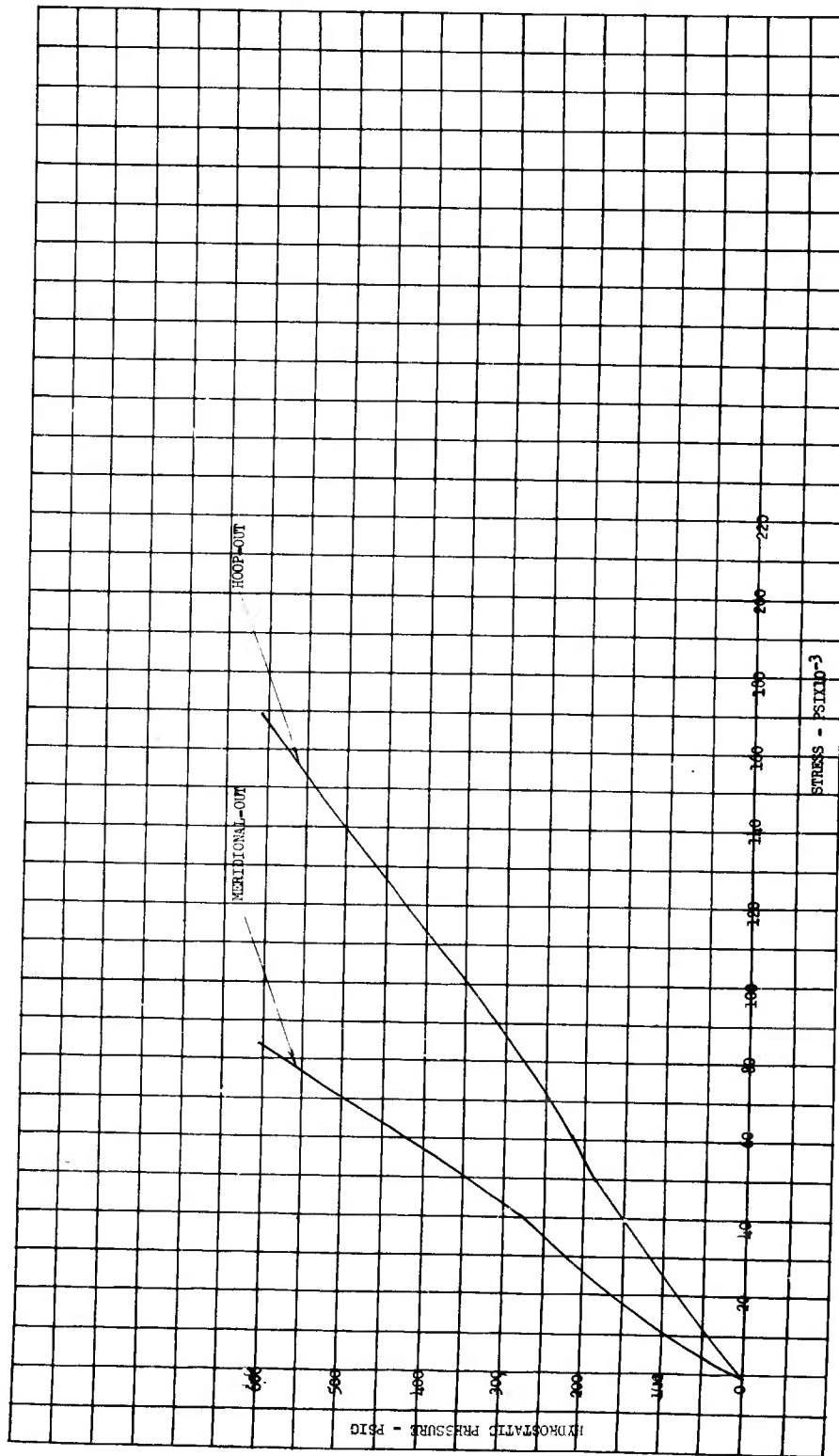


Figure 50

Pressure vs Stress, Gage Point 26

Appendix D

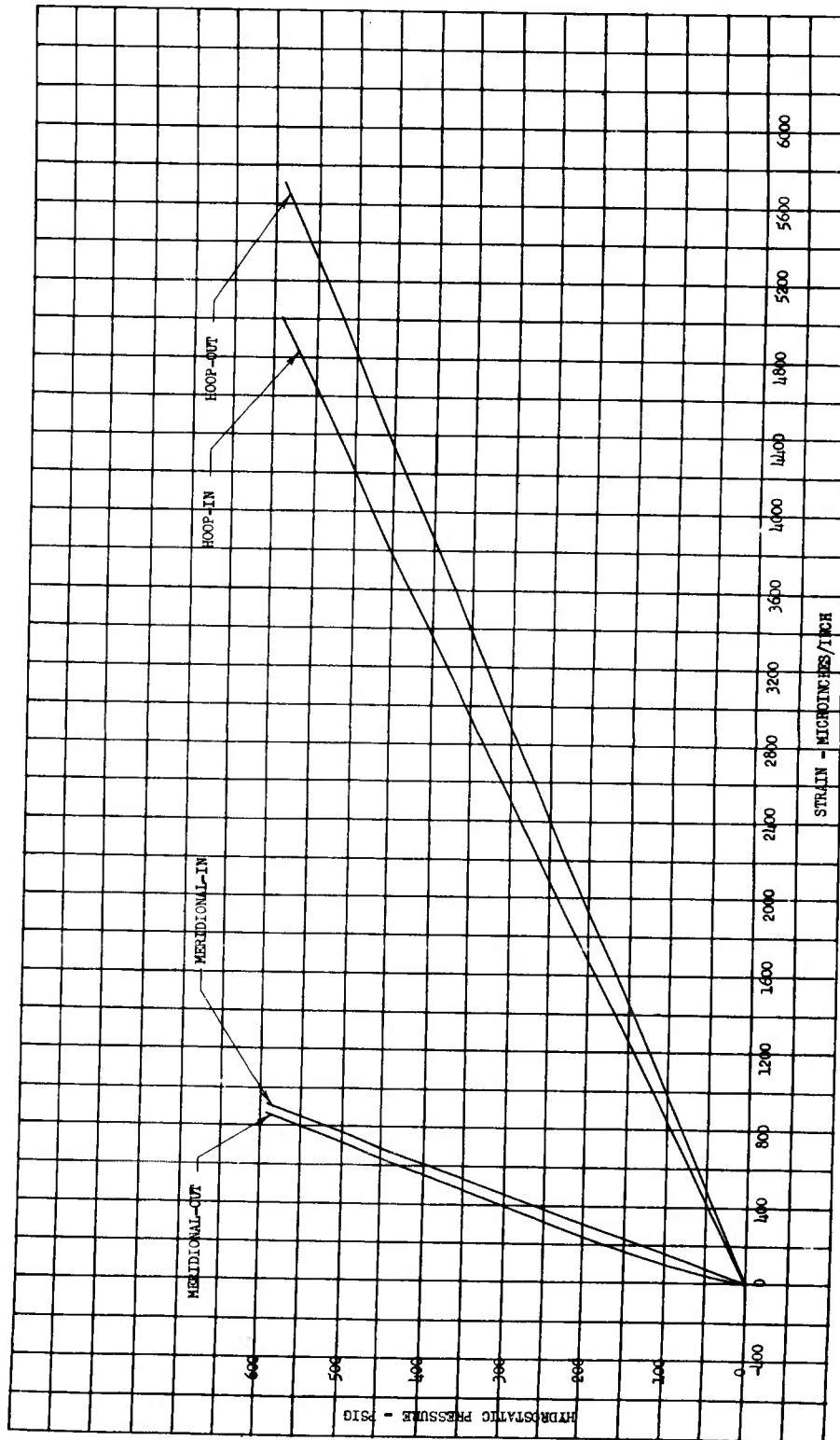


Figure 51

Pressure vs Strain, Gage Point 27

Appendix D

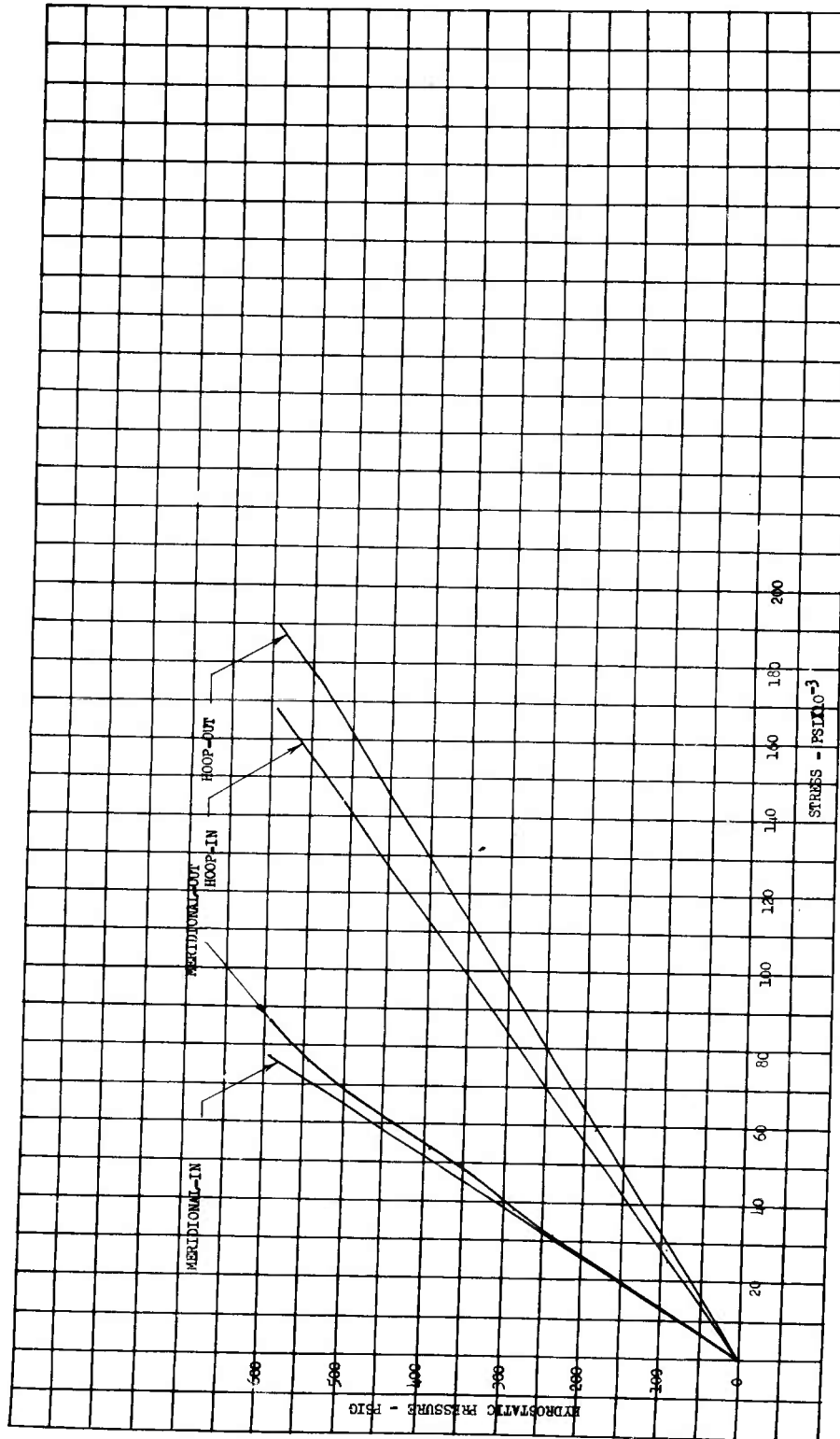


Figure 52

Pressure vs Stress, Gage Point 27

Appendix D

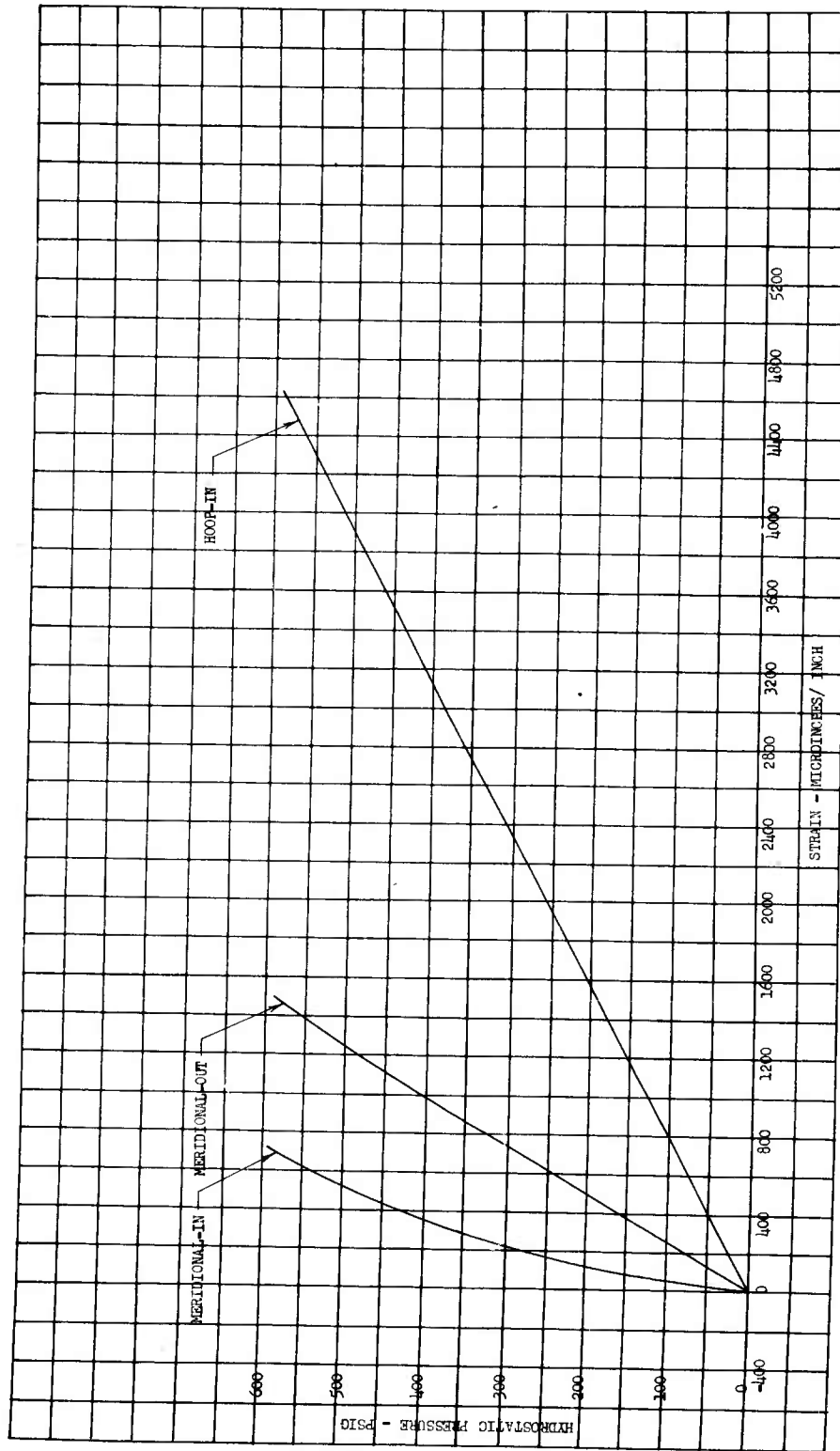


Figure 53

Pressure vs Strain, Gage Point 28

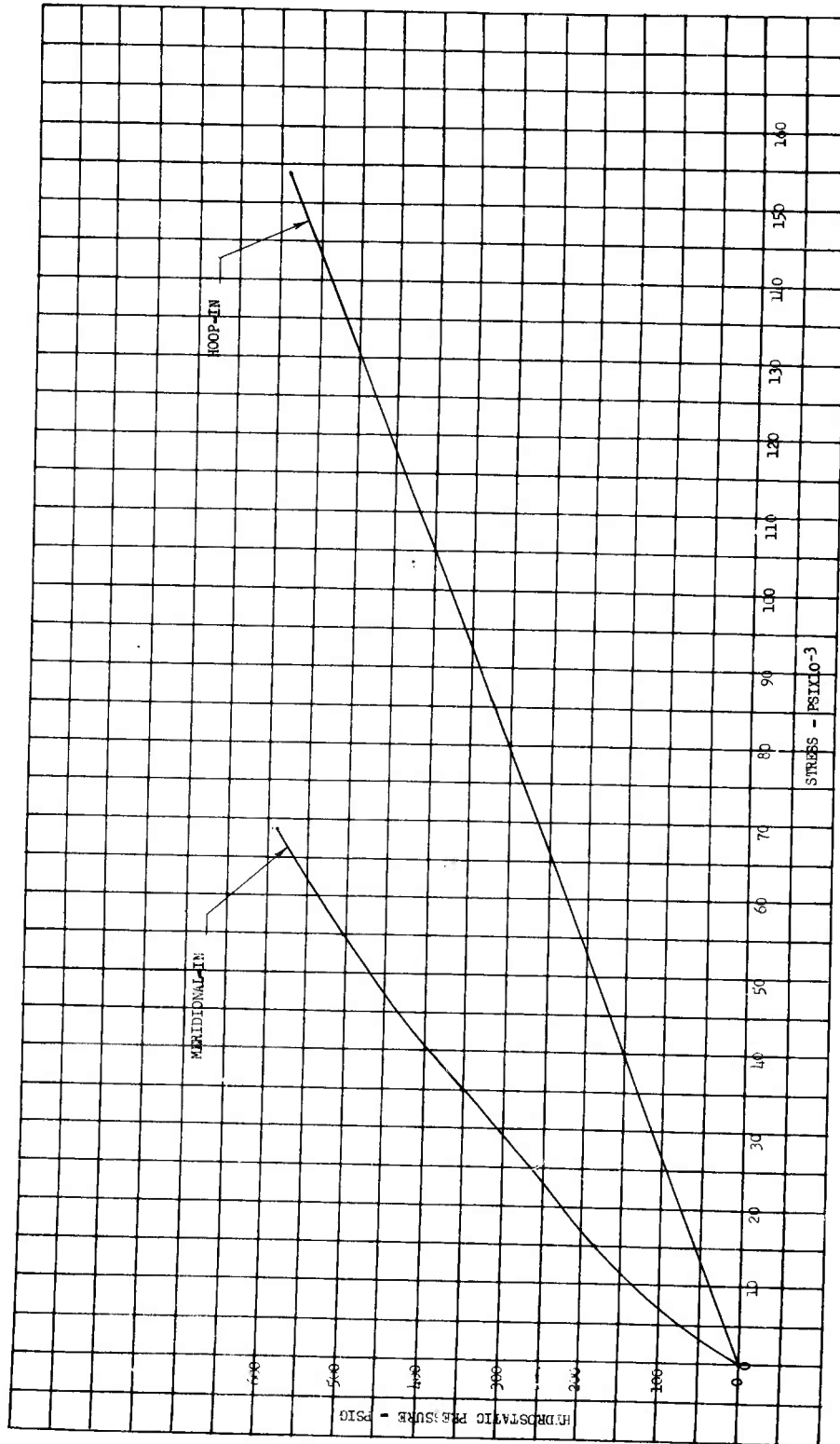
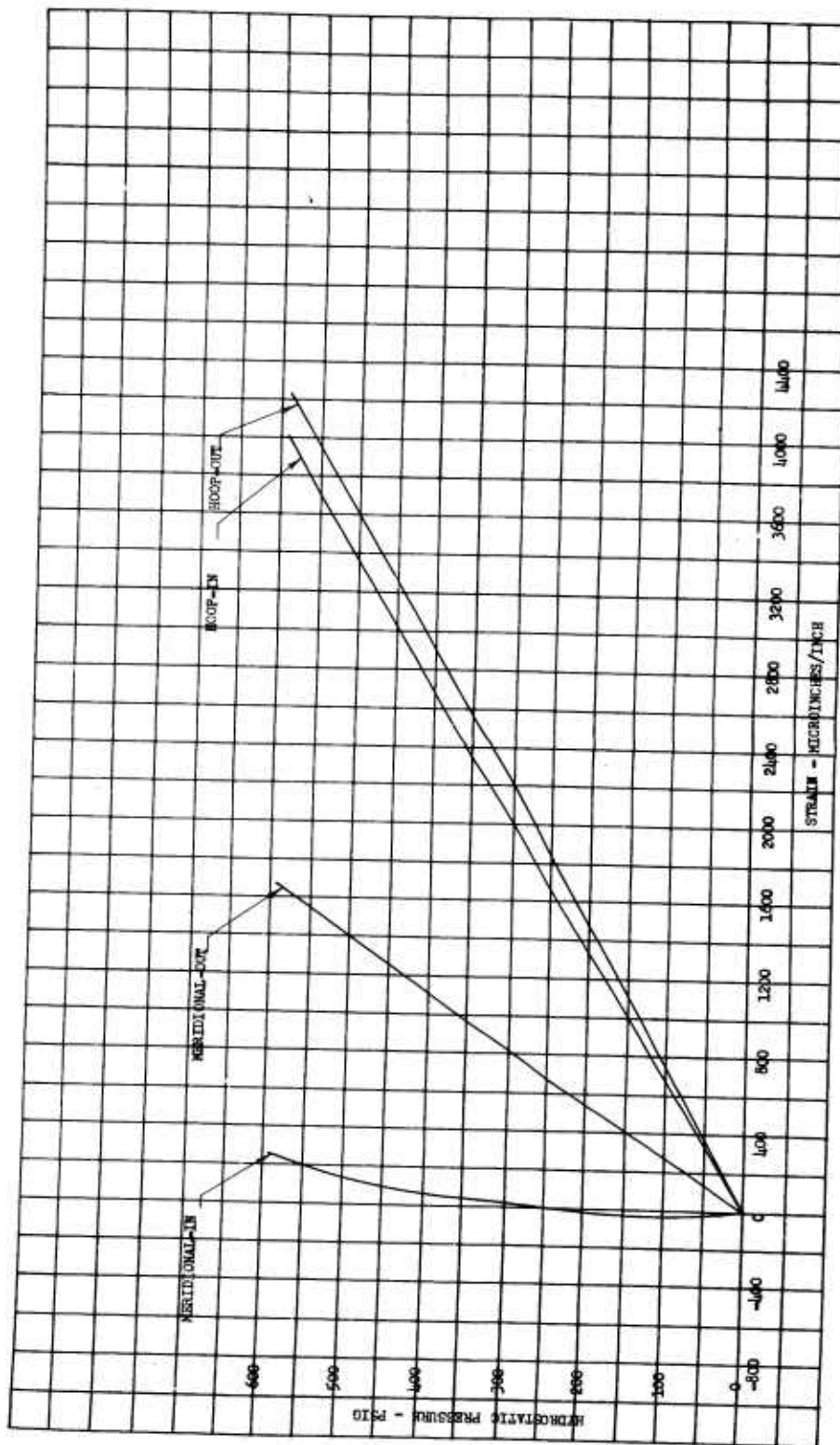


Figure 54

Pressure vs Stress, Gage Point 28



Pressure vs Strain, Gage Point 29

Figure 55

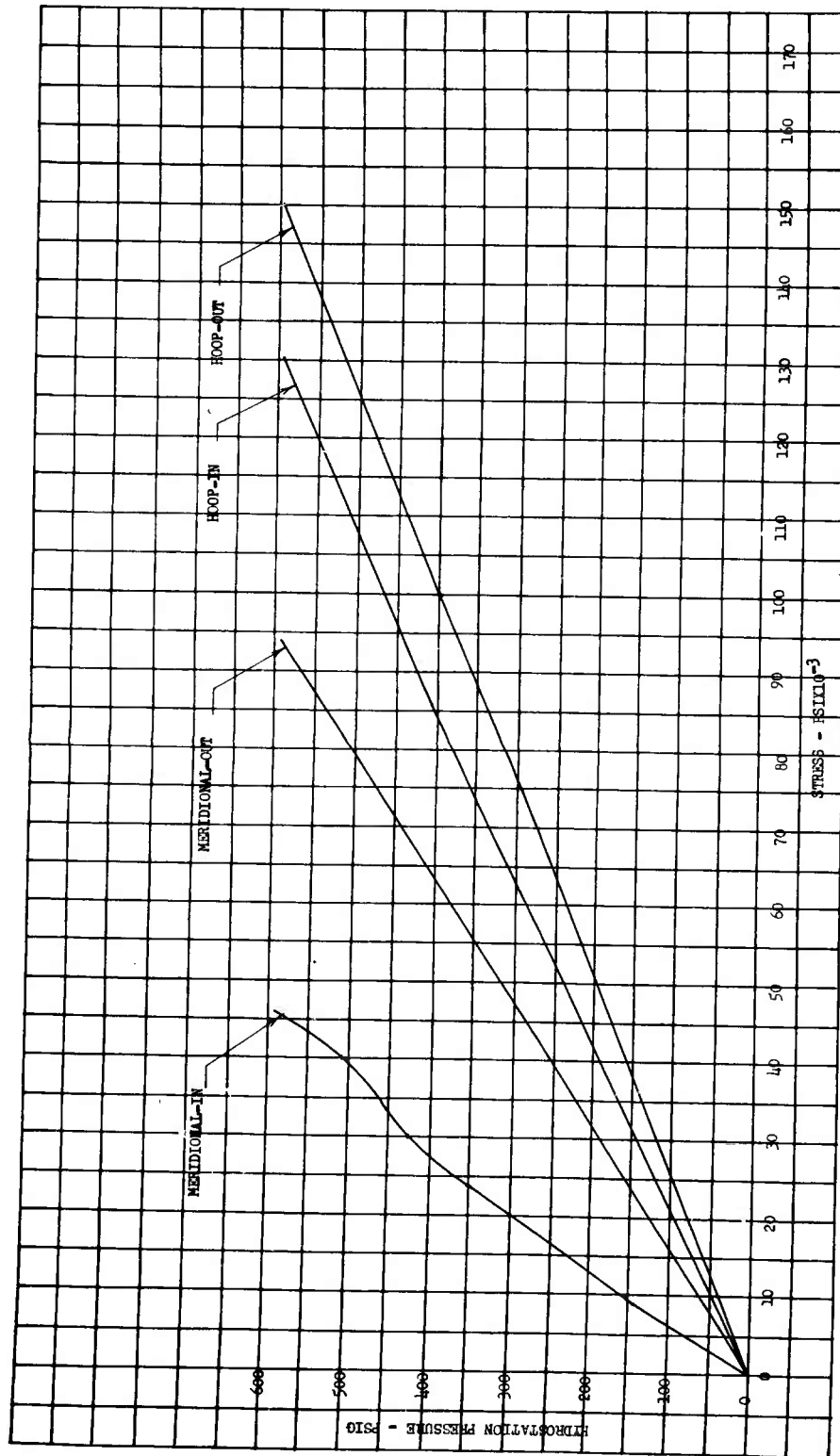


Figure 56

Pressure vs Stress, Gage Point 29

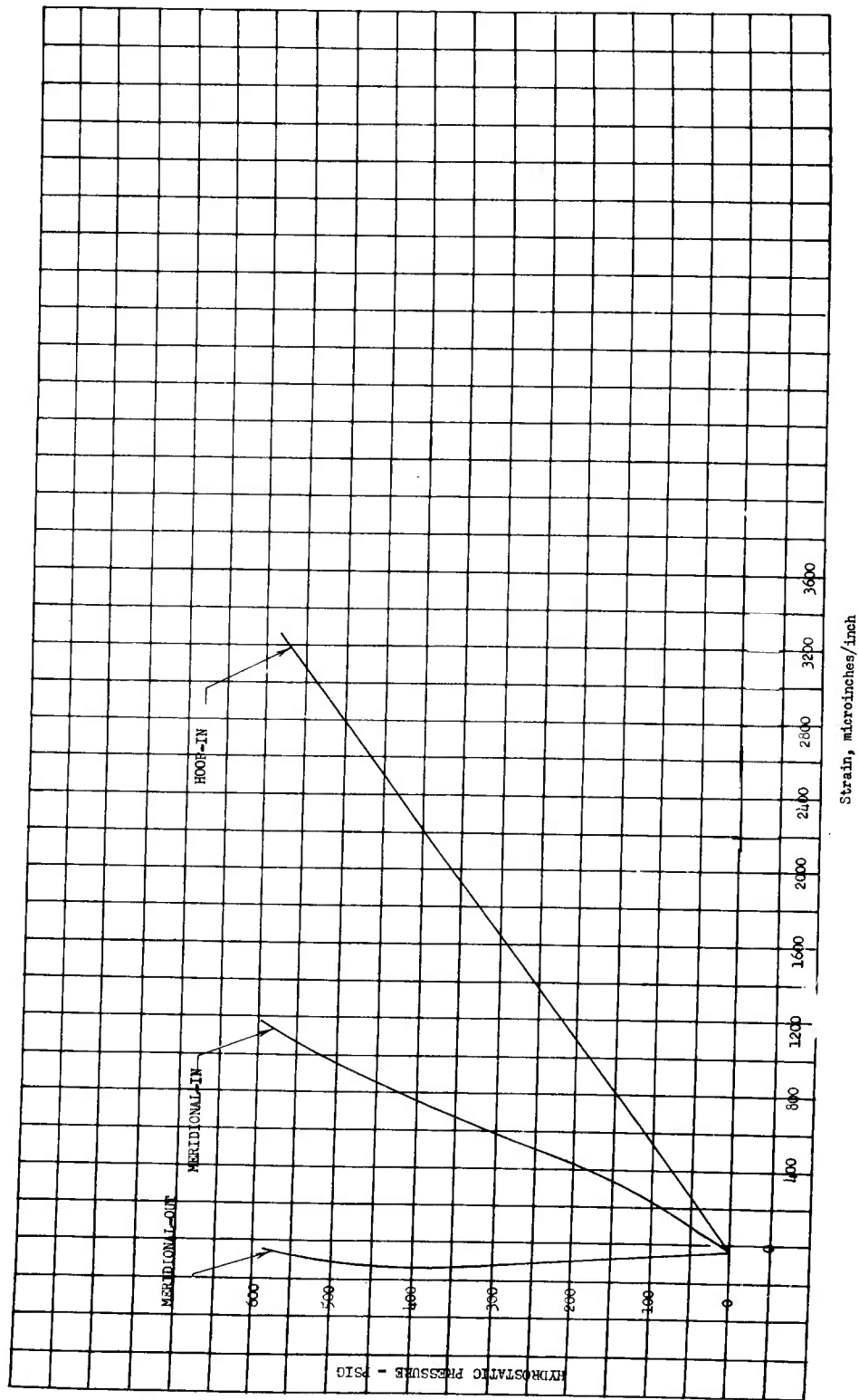


Figure 57

Pressure vs Strain, Gage Point 30

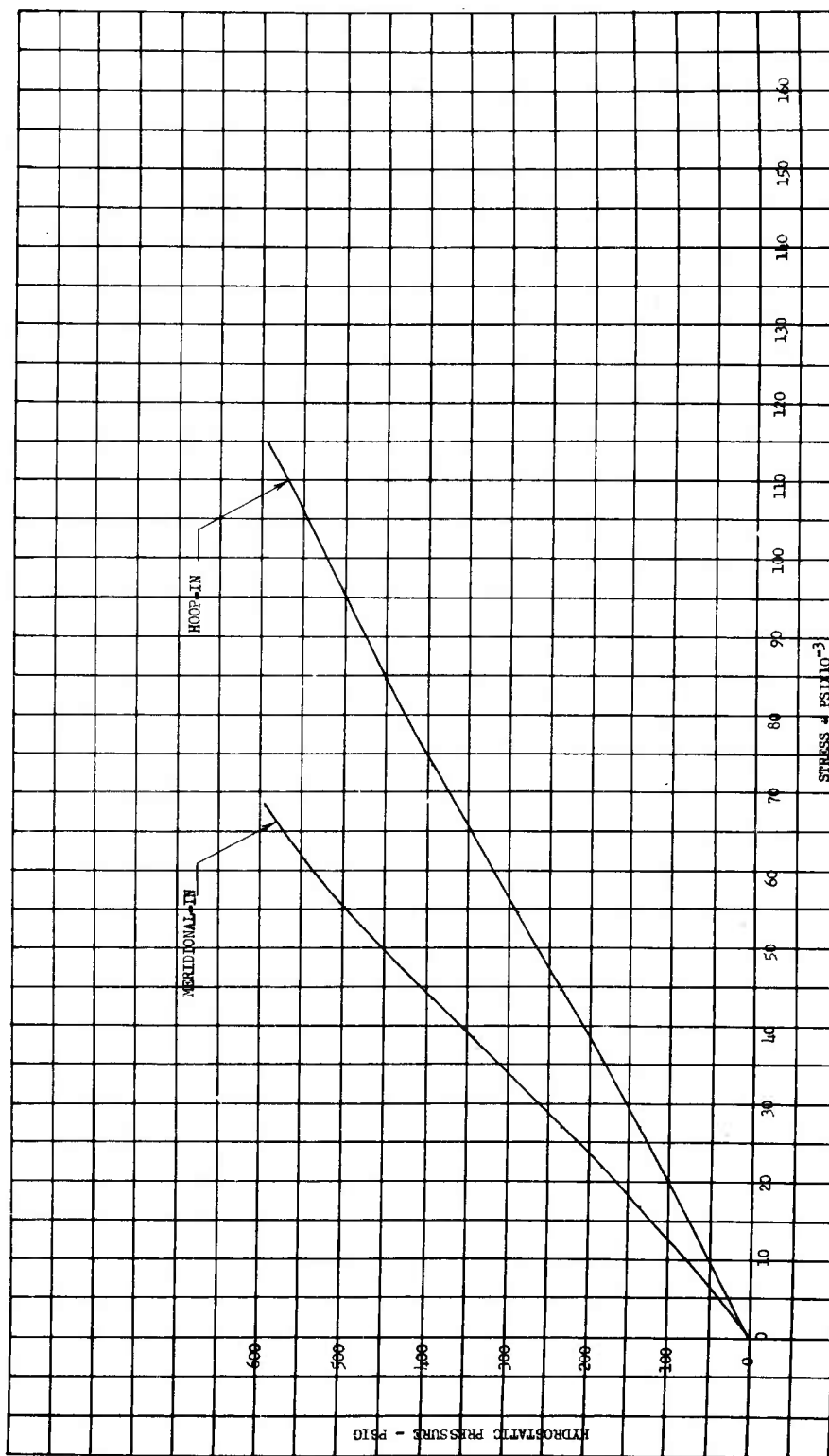


Figure 58

Pressure vs Stress, Gage Point 30

Appendix D

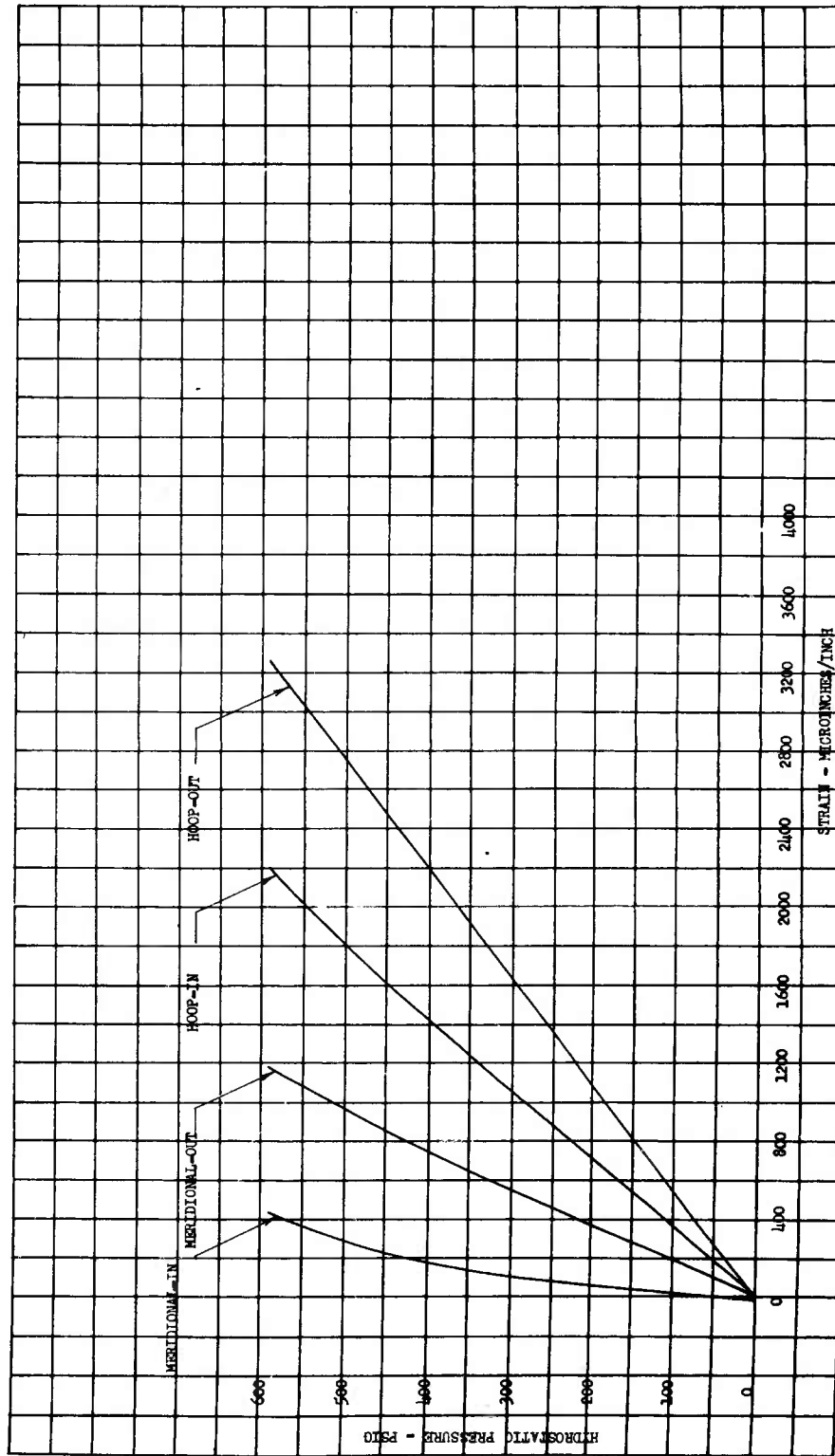


Figure 59

Pressure vs Strain, Gage Point 31

Appendix D

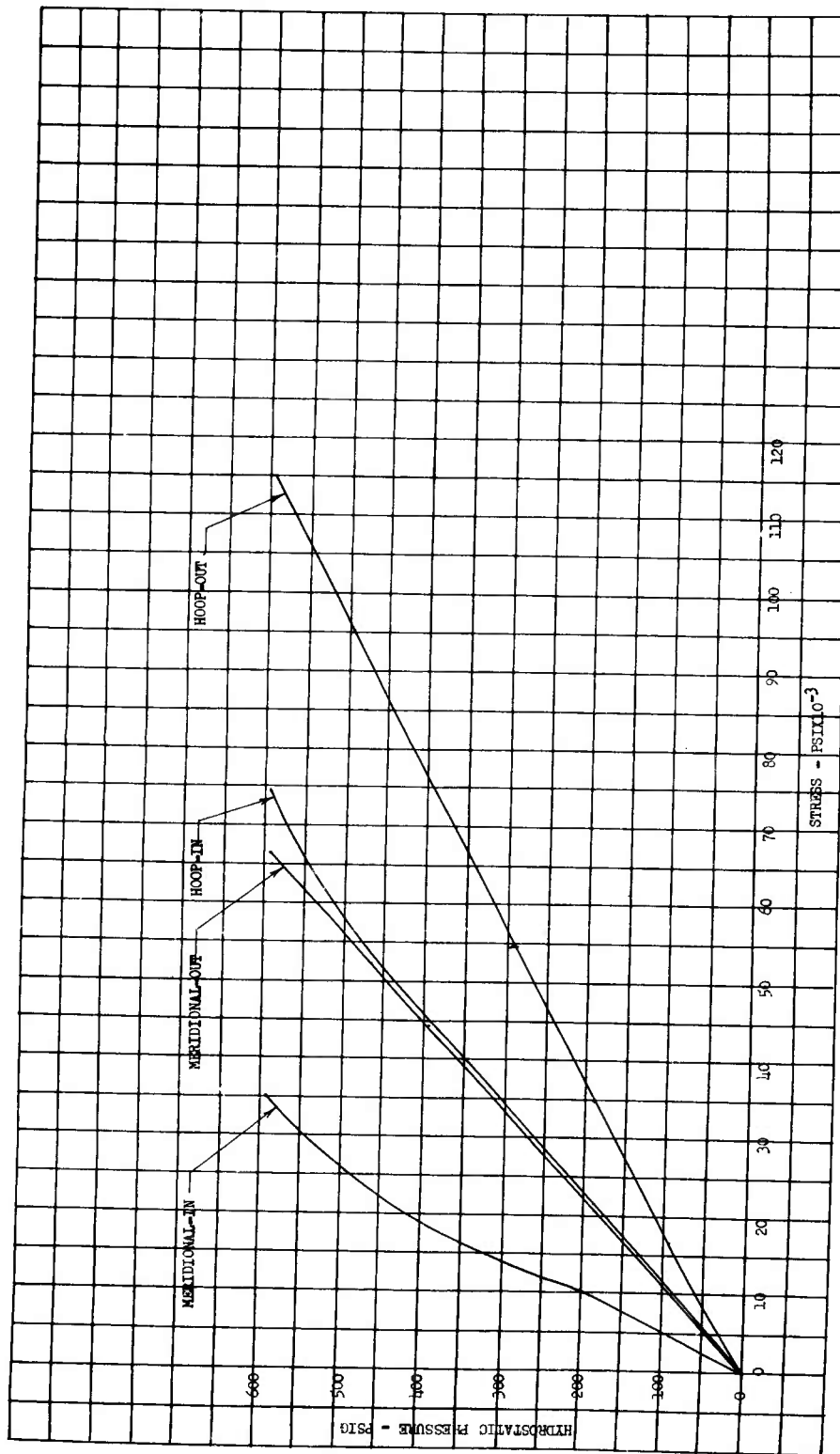


Figure 60

Pressure vs Stress, Gage Point 31

Appendix D

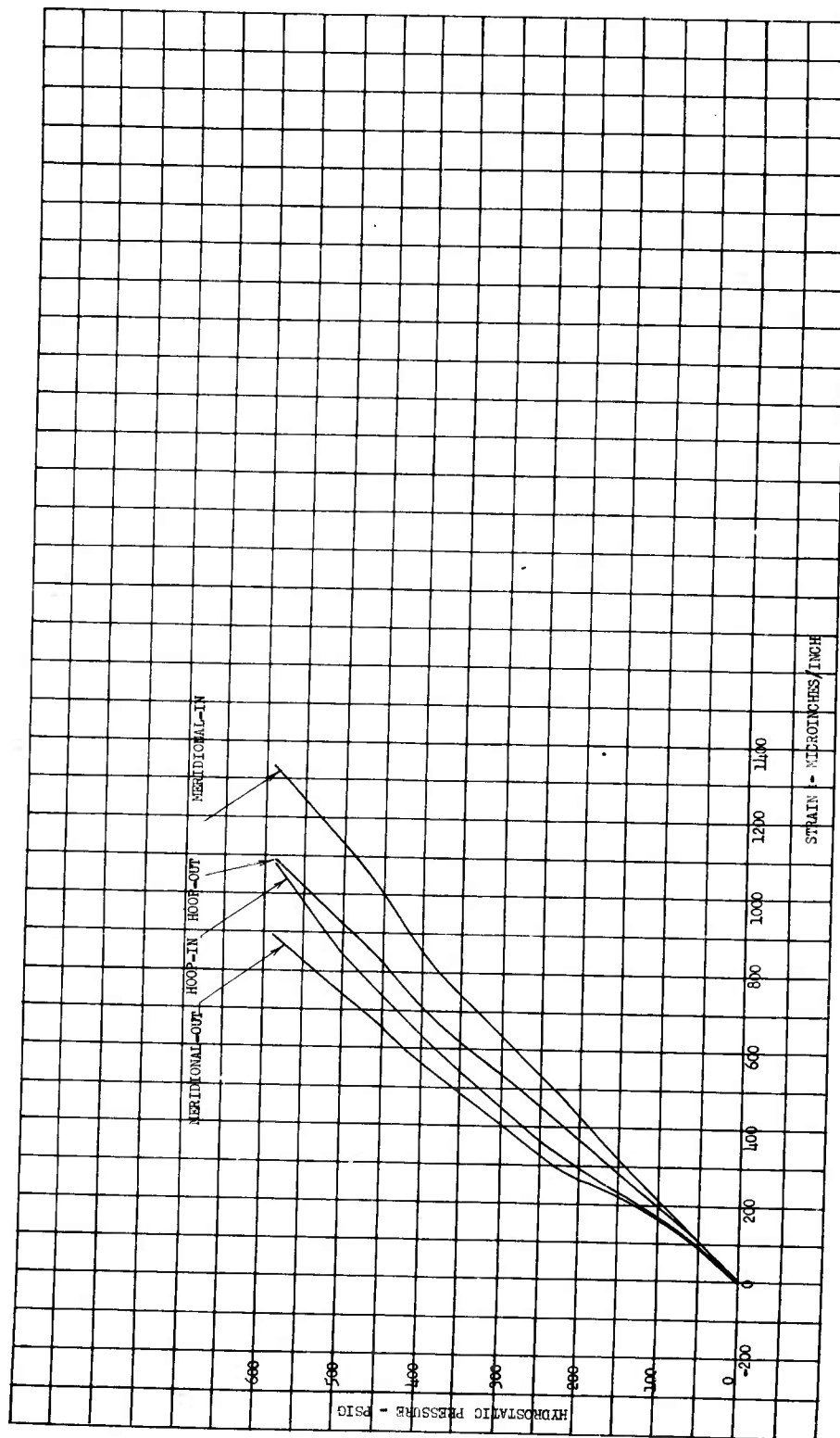


Figure 61

Pressure vs Strain, Gage Point 32

Appendix D

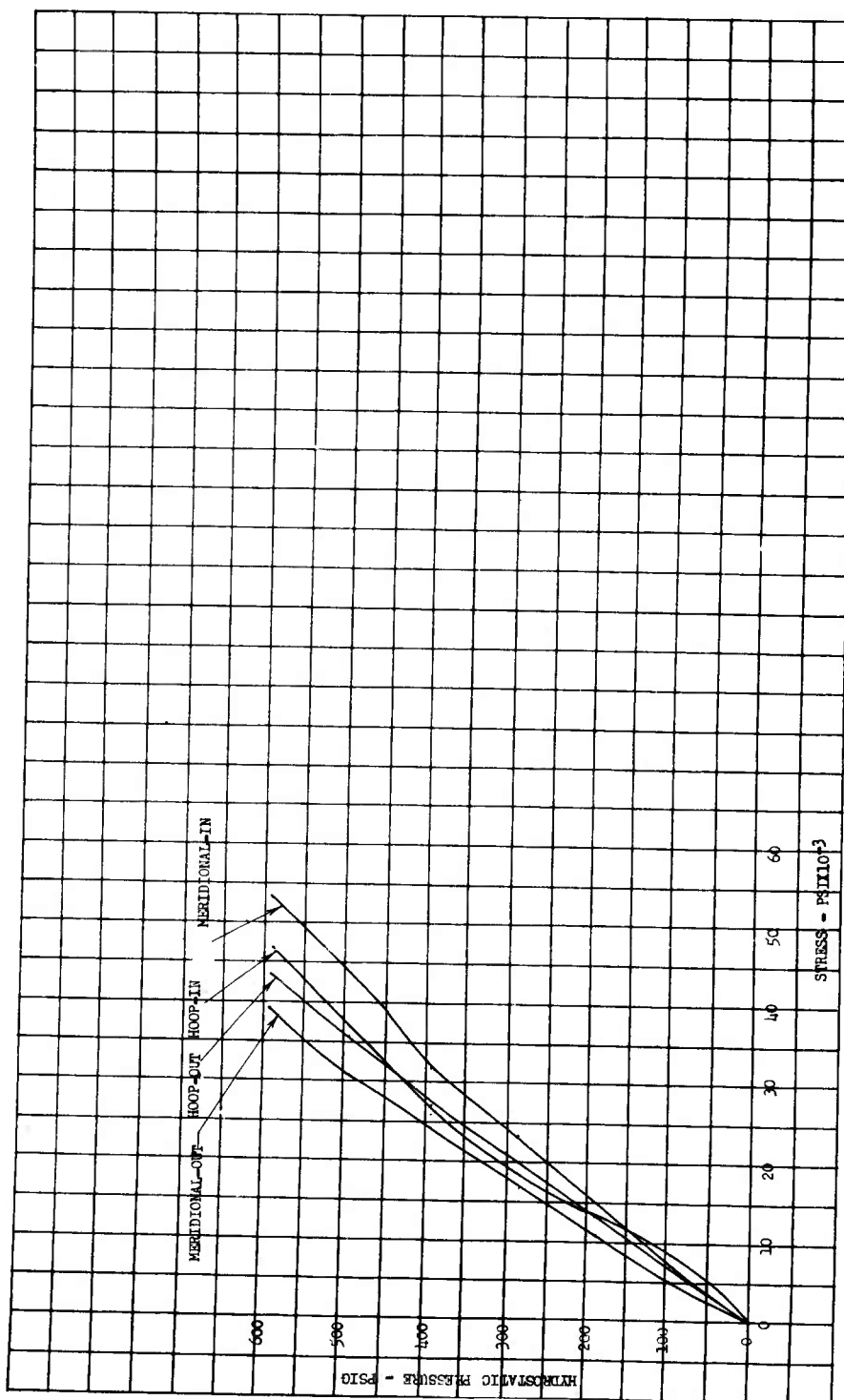


Figure 62

Pressure vs Stress, Gage Point 32

Appendix D

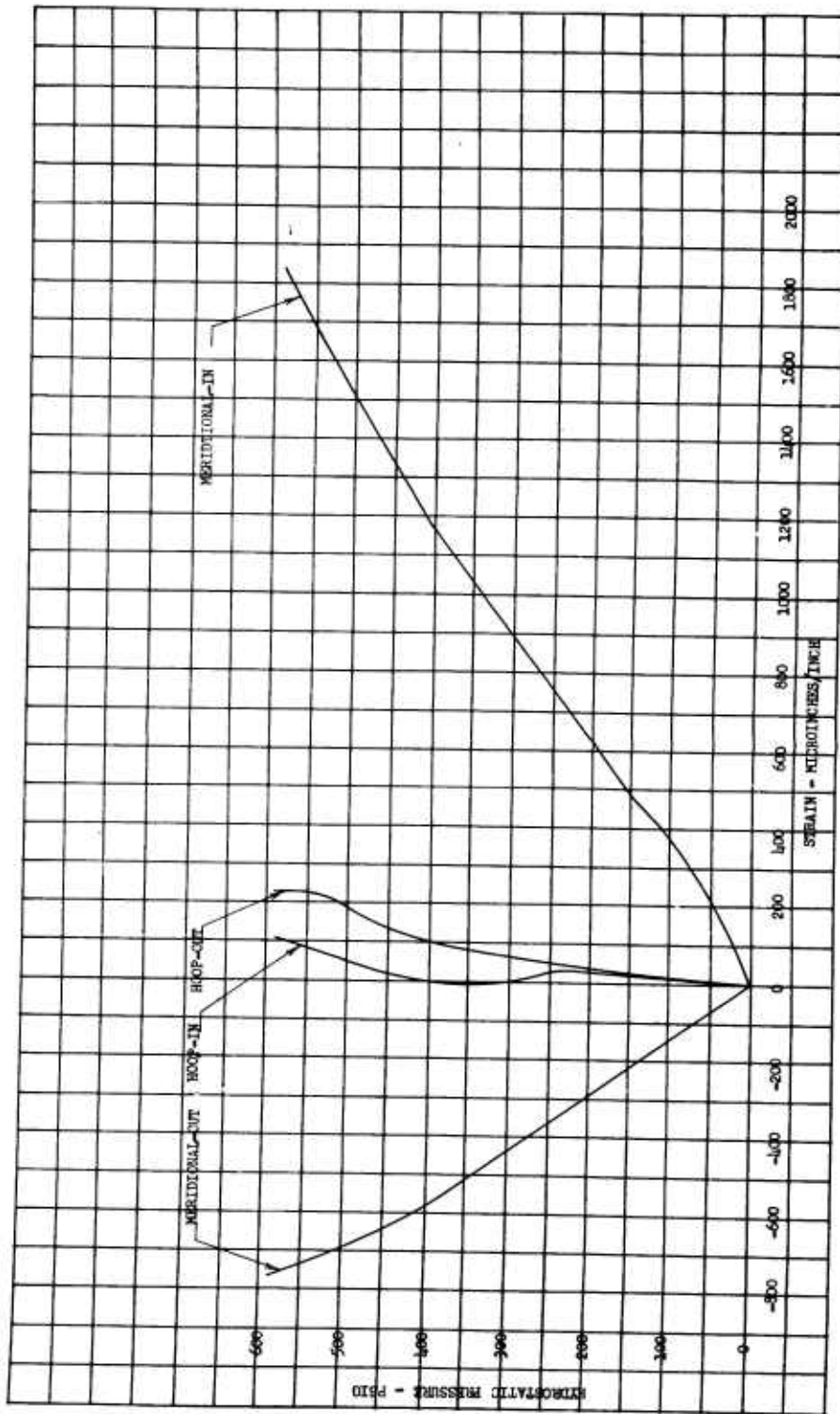


Figure 63

Pressure vs Strain, Gage Point 33

Appendix D

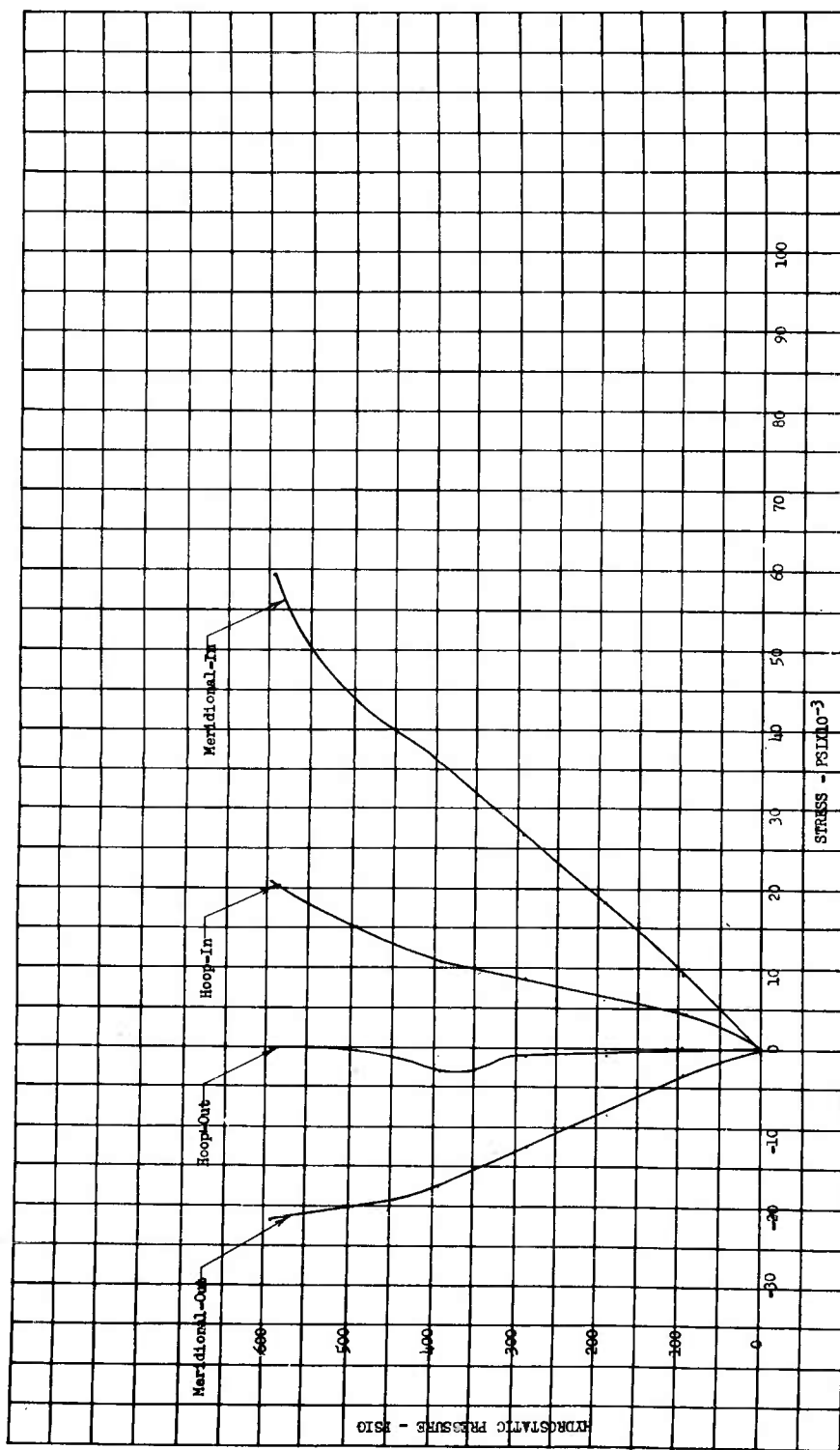


Figure 64

Pressure vs Stress, Gage Point 33

Appendix D

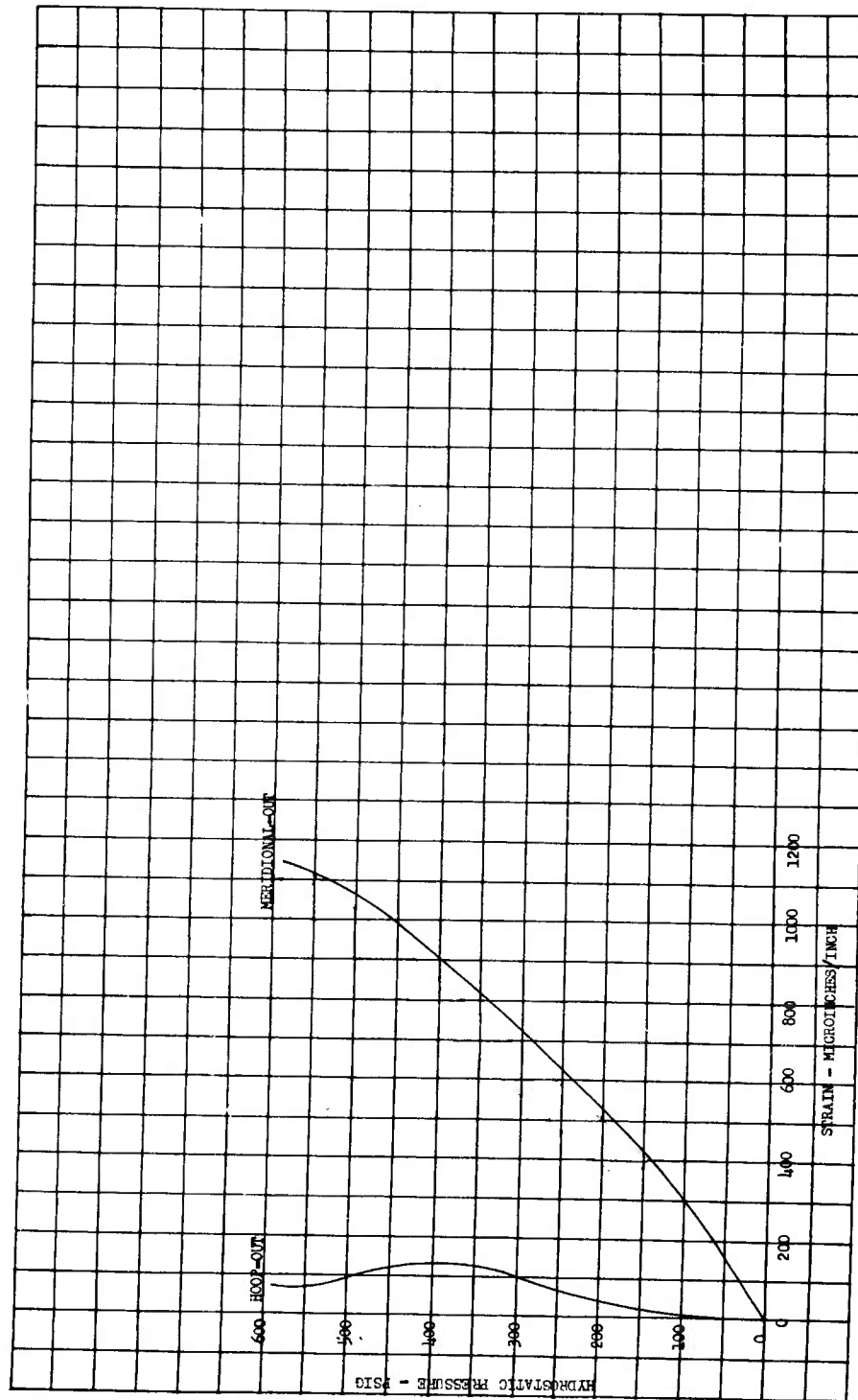


Figure 65

Pressure vs Strain, Gage Point 34

Appendix D

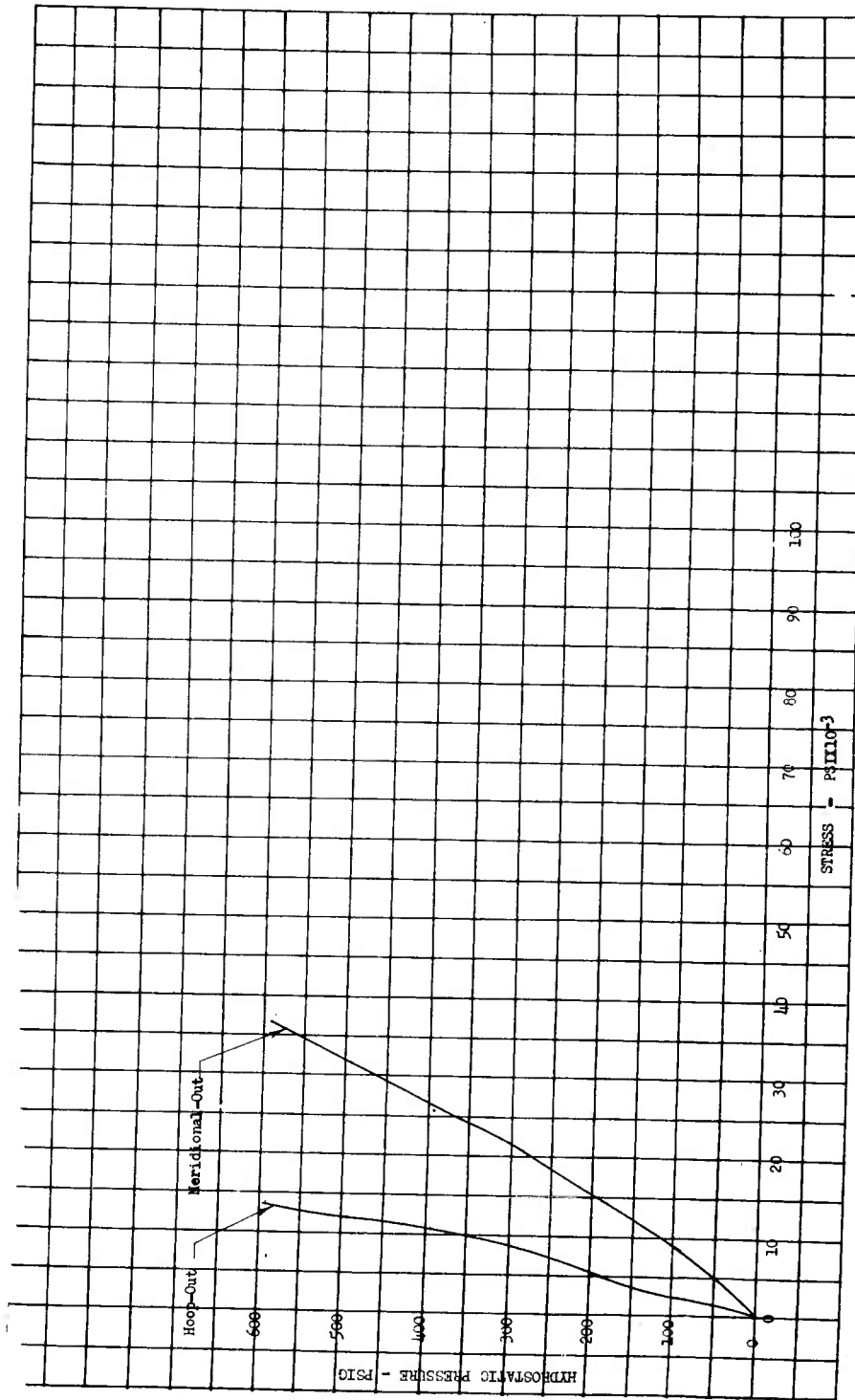


Figure 66

Pressure vs Stress, Gage Point 34

Appendix D

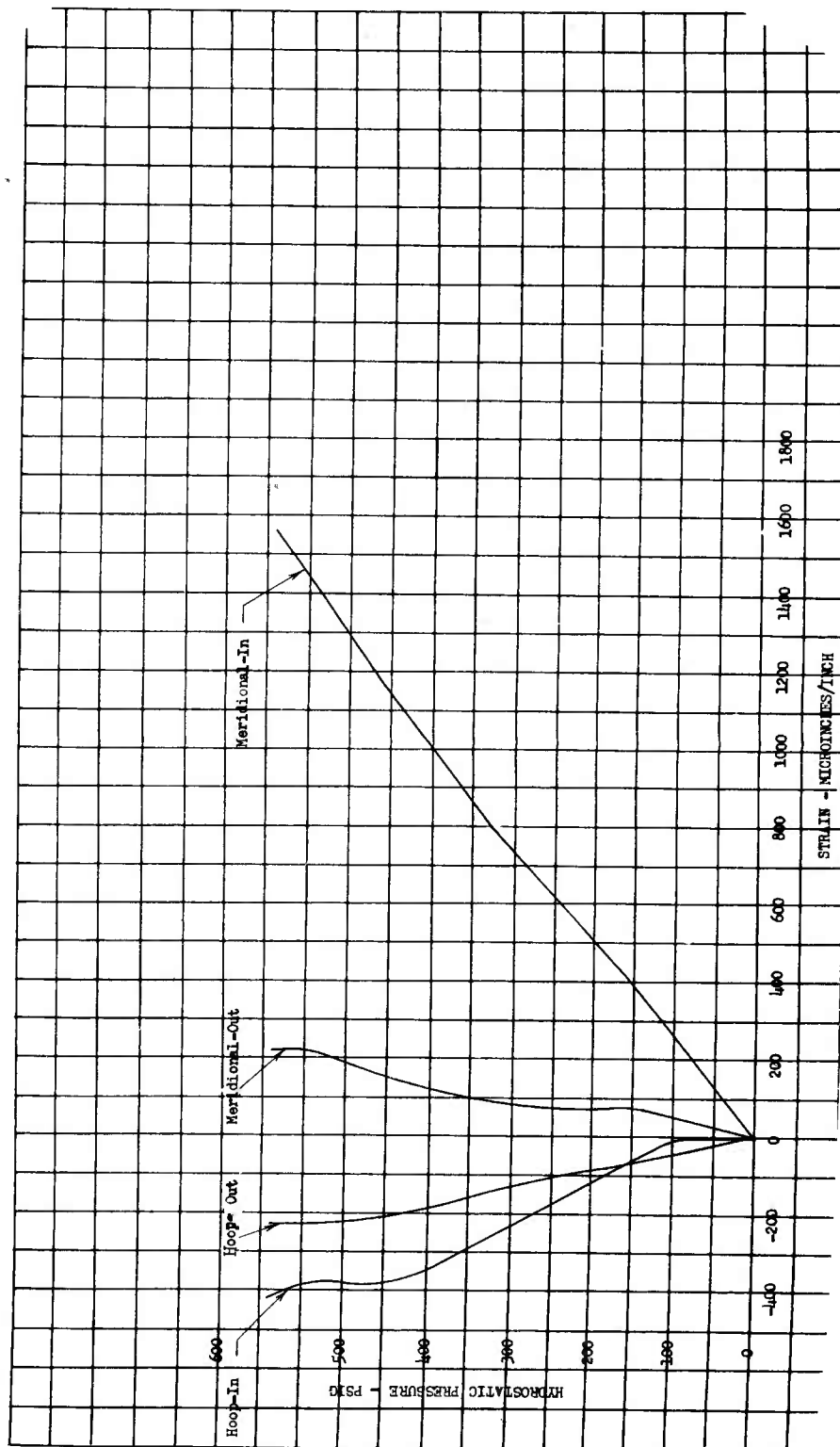


Figure 67

Pressure vs Strain, Gage Point 35

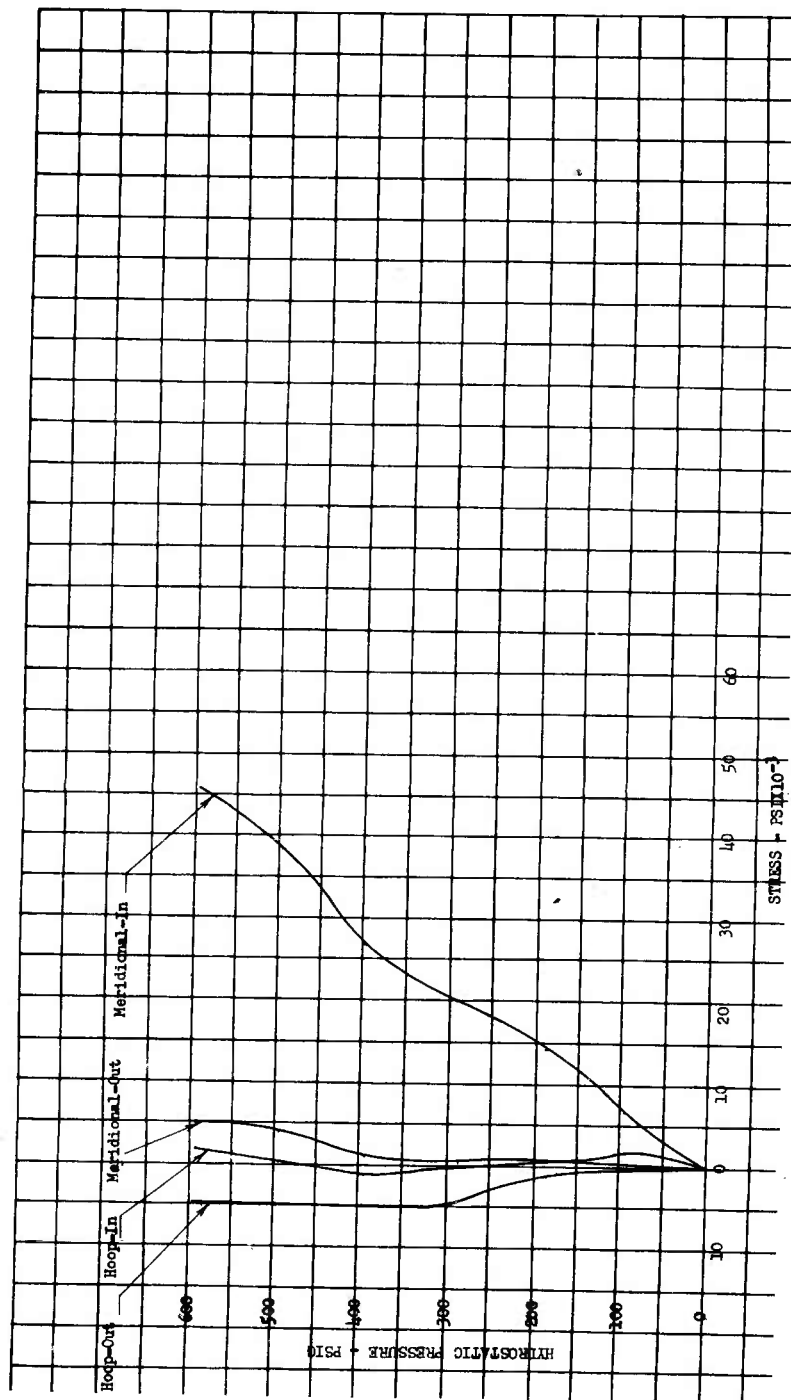


Figure 68

Pressure vs Stress, Gage Point 35

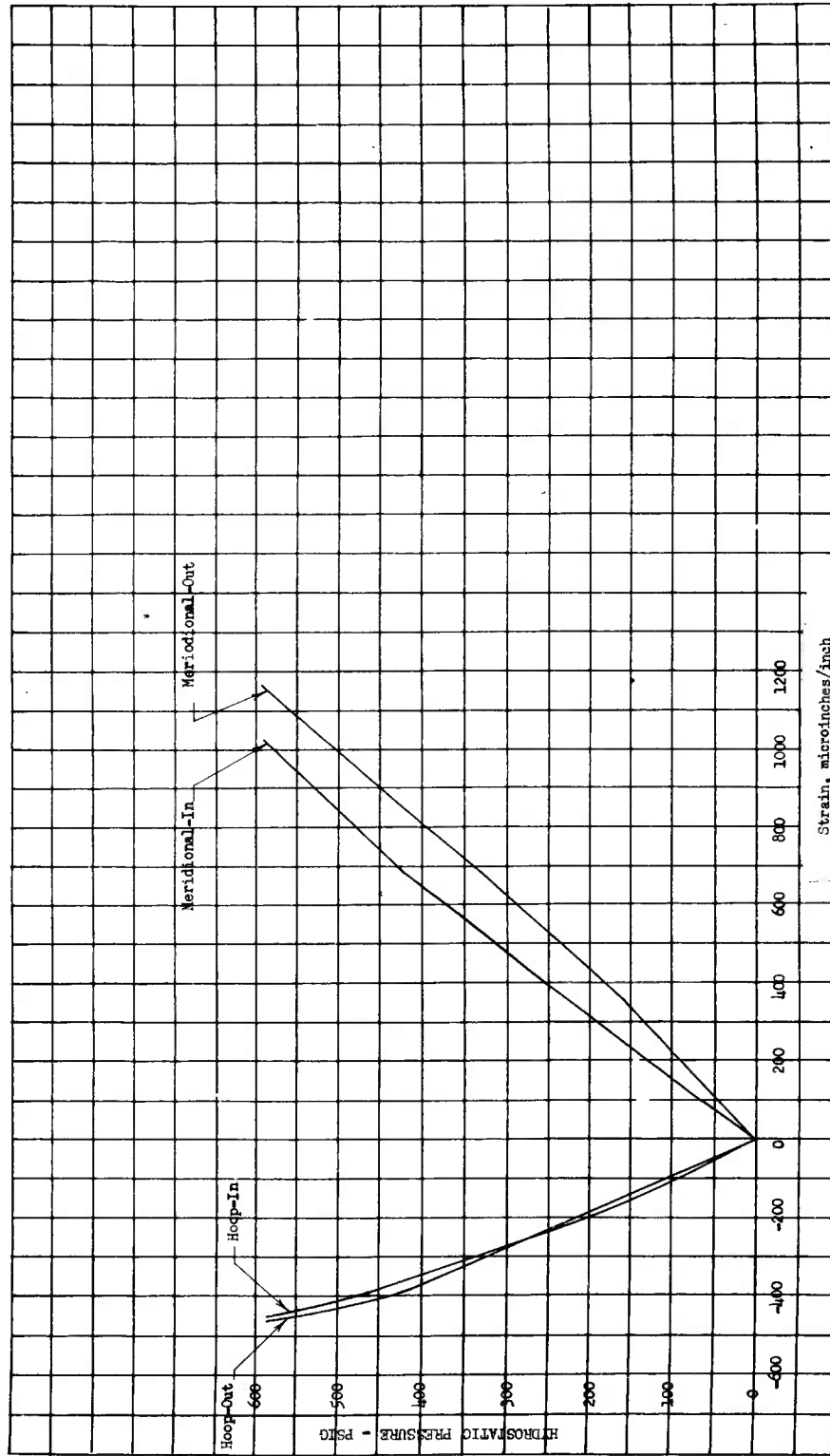


Figure 69

Pressure vs Strain, Gage Point 36

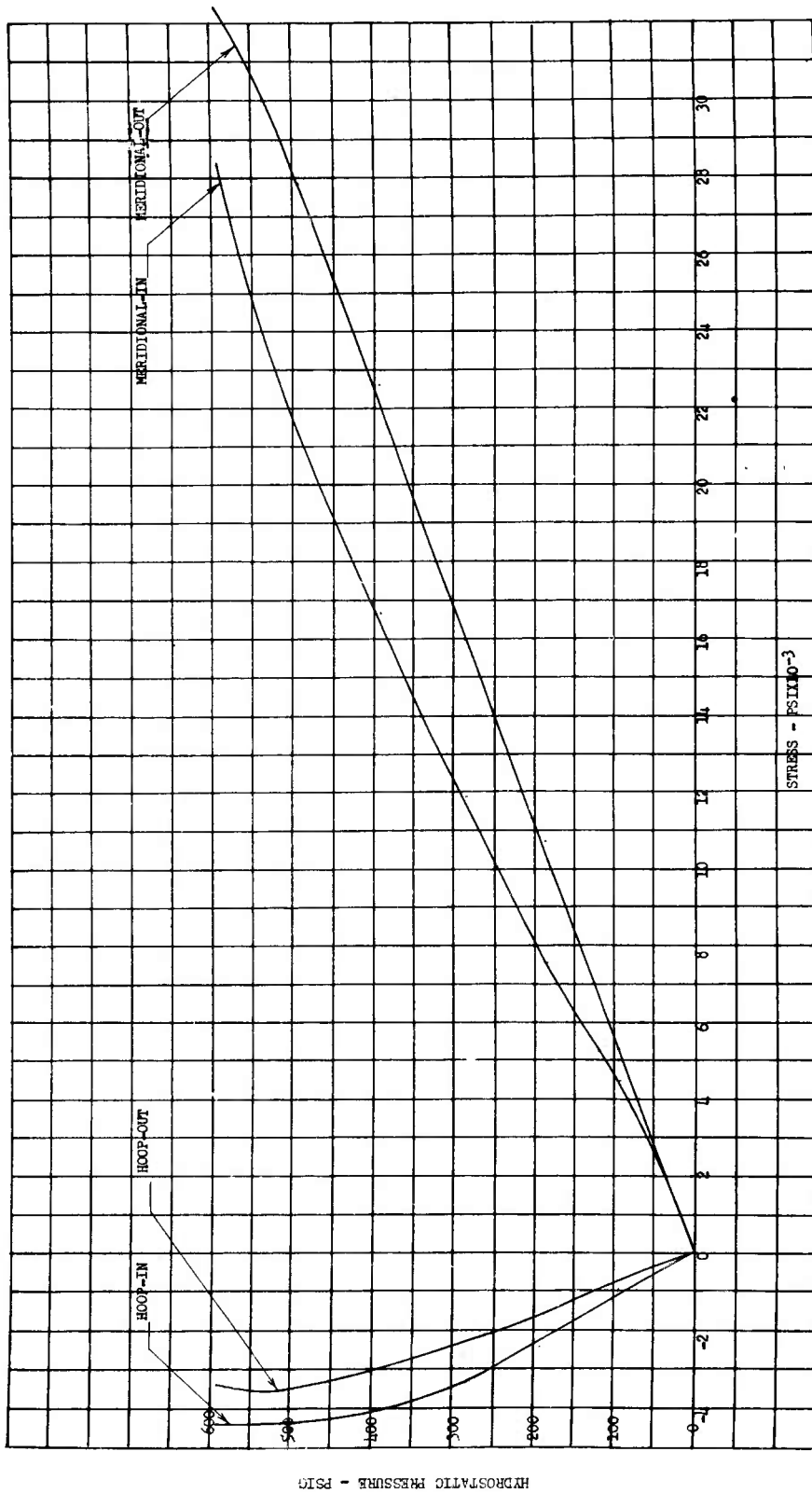


Figure 70

Pressure vs Stress, Gage Point 36

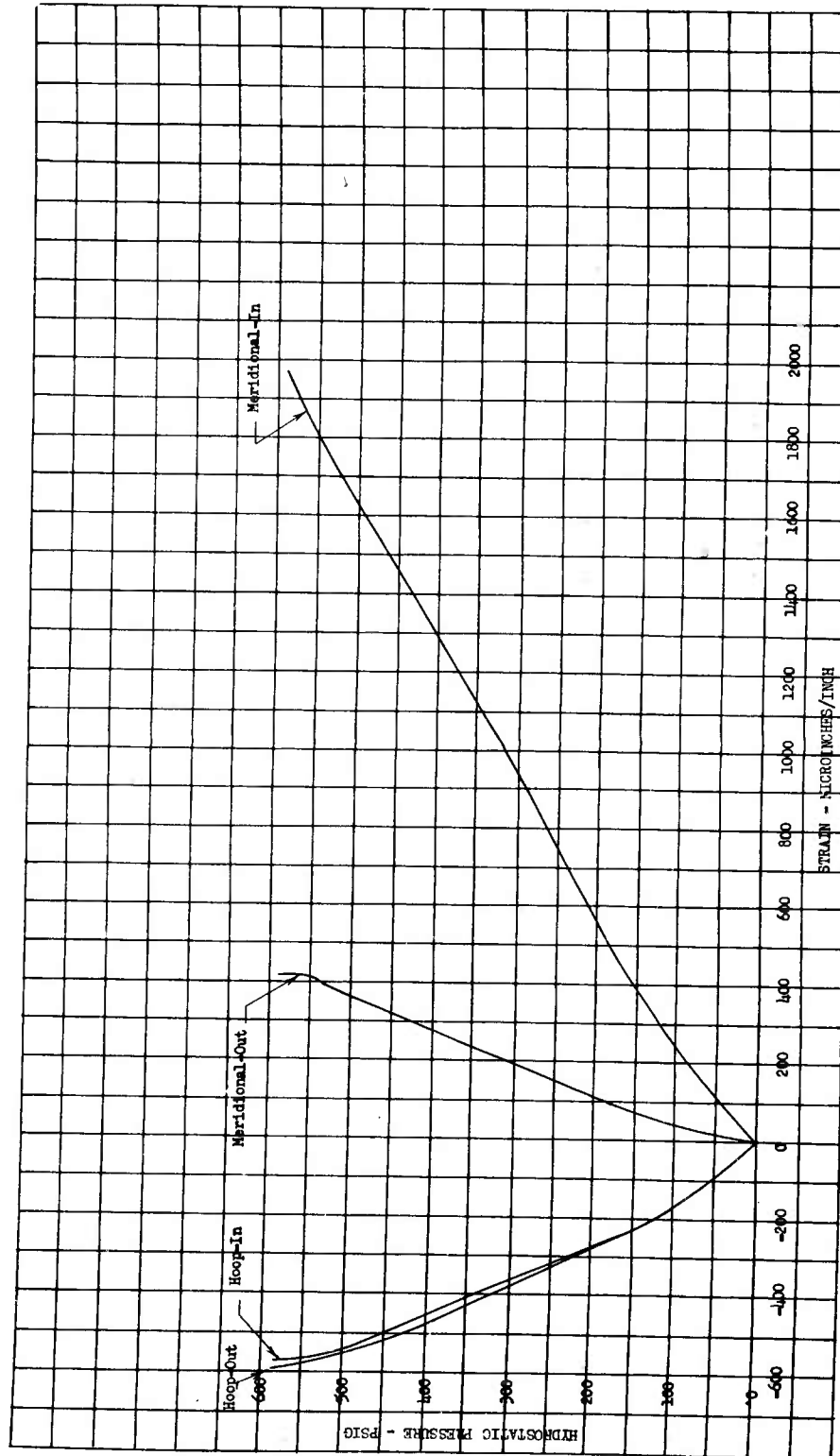


Figure 71

Pressure vs Strain, Gage Point 37

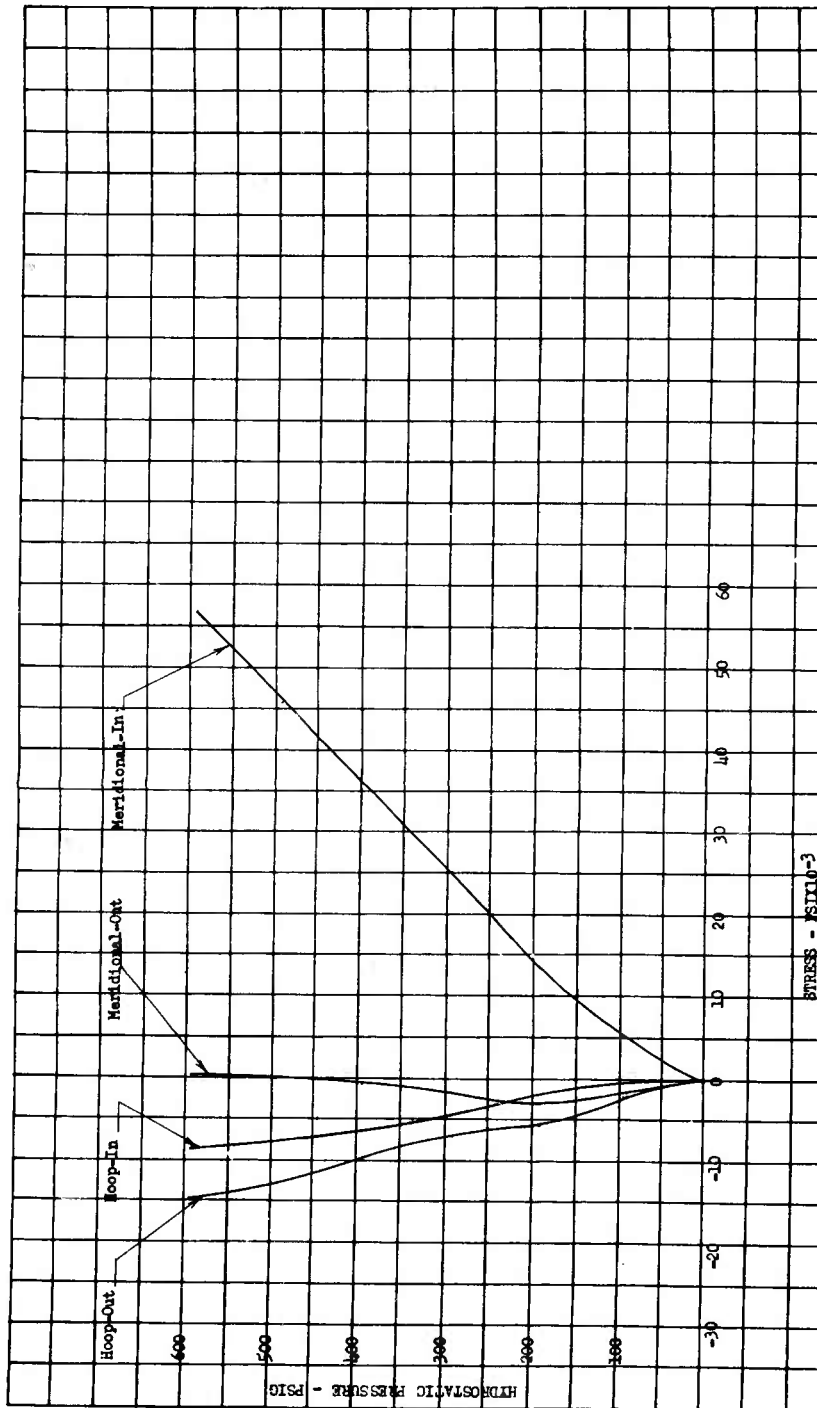


Figure 72

Pressure vs Stress, Gage Point 37

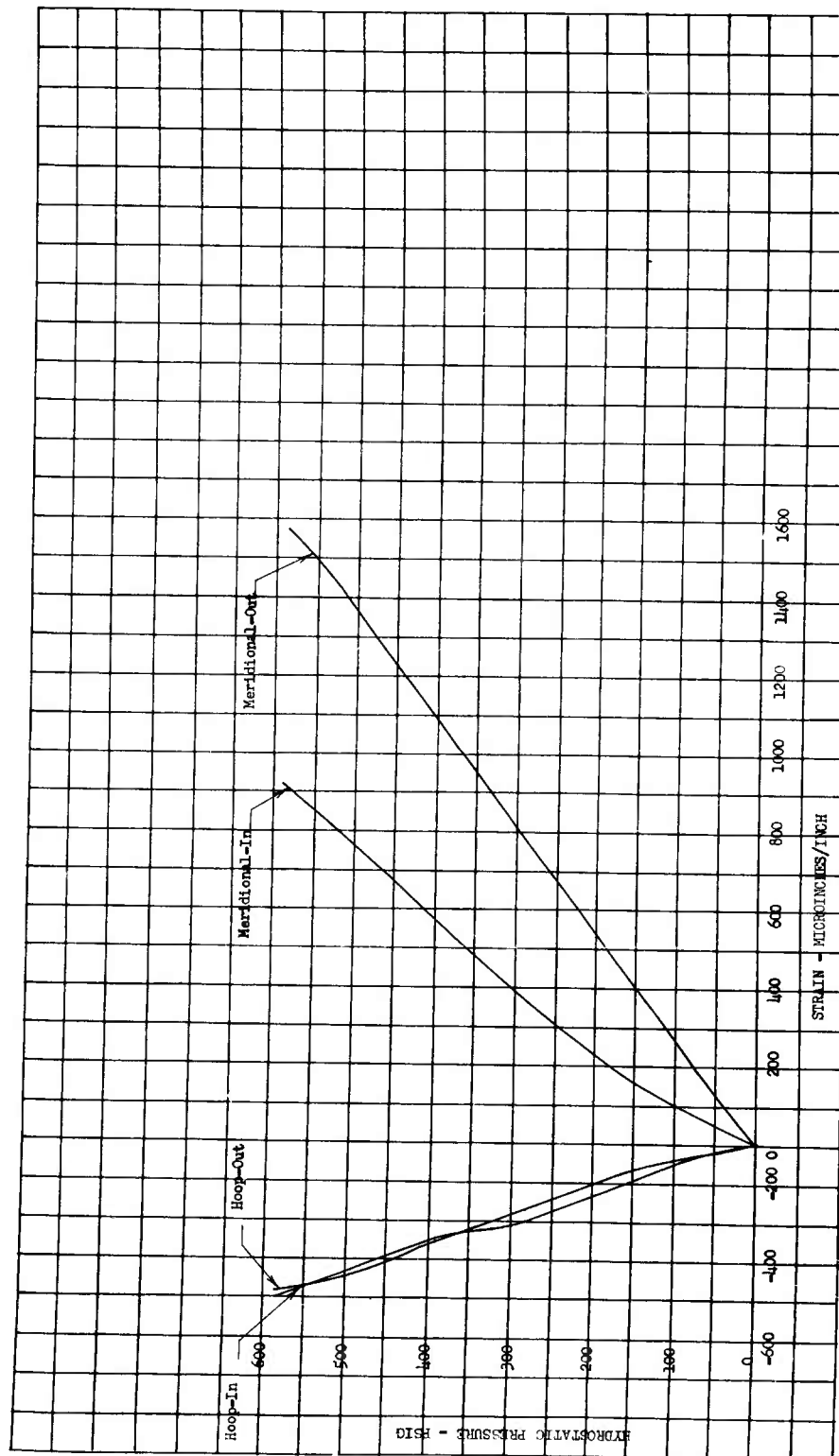


Figure 73

Appendix D

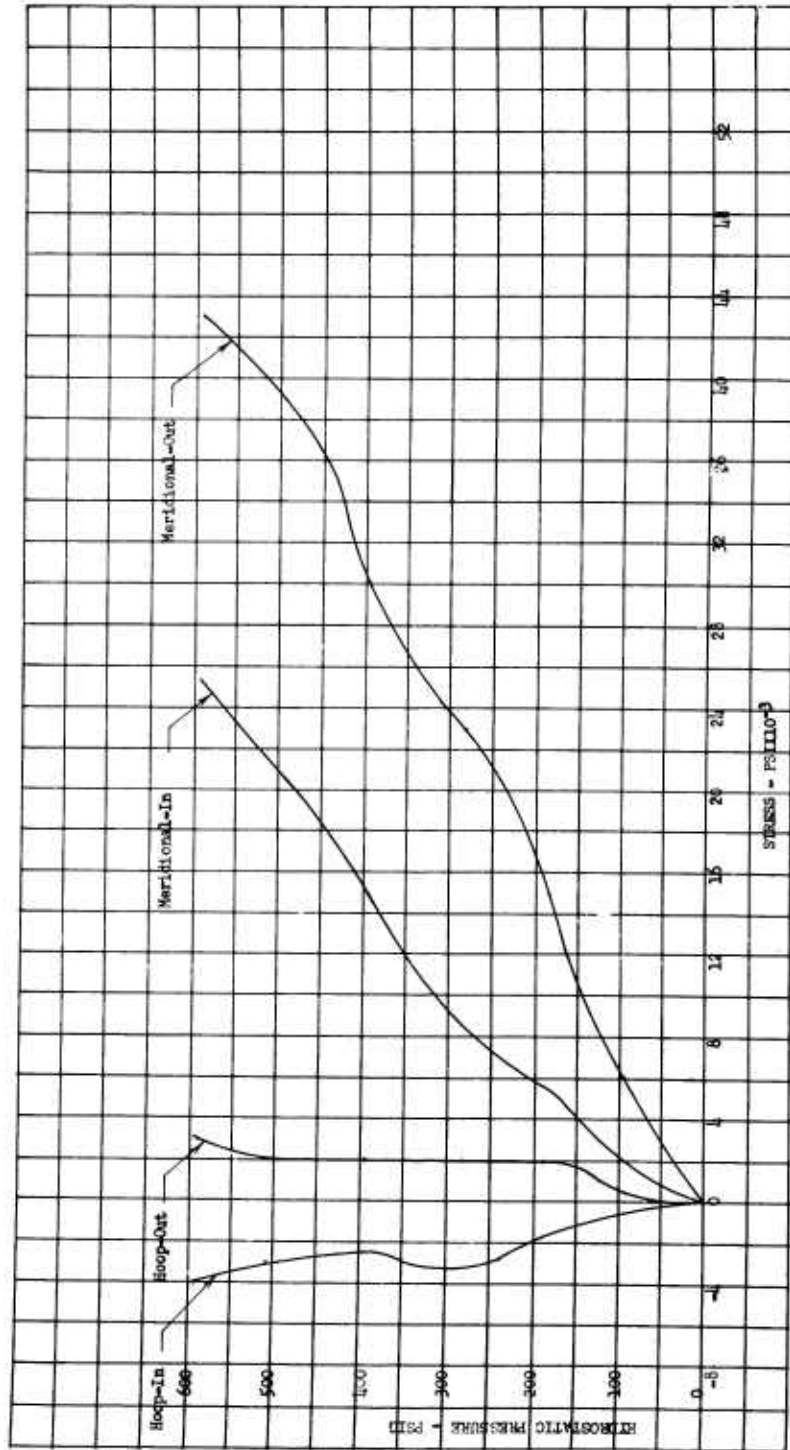


Figure 74

Pressure vs Stress, Gage Point 38

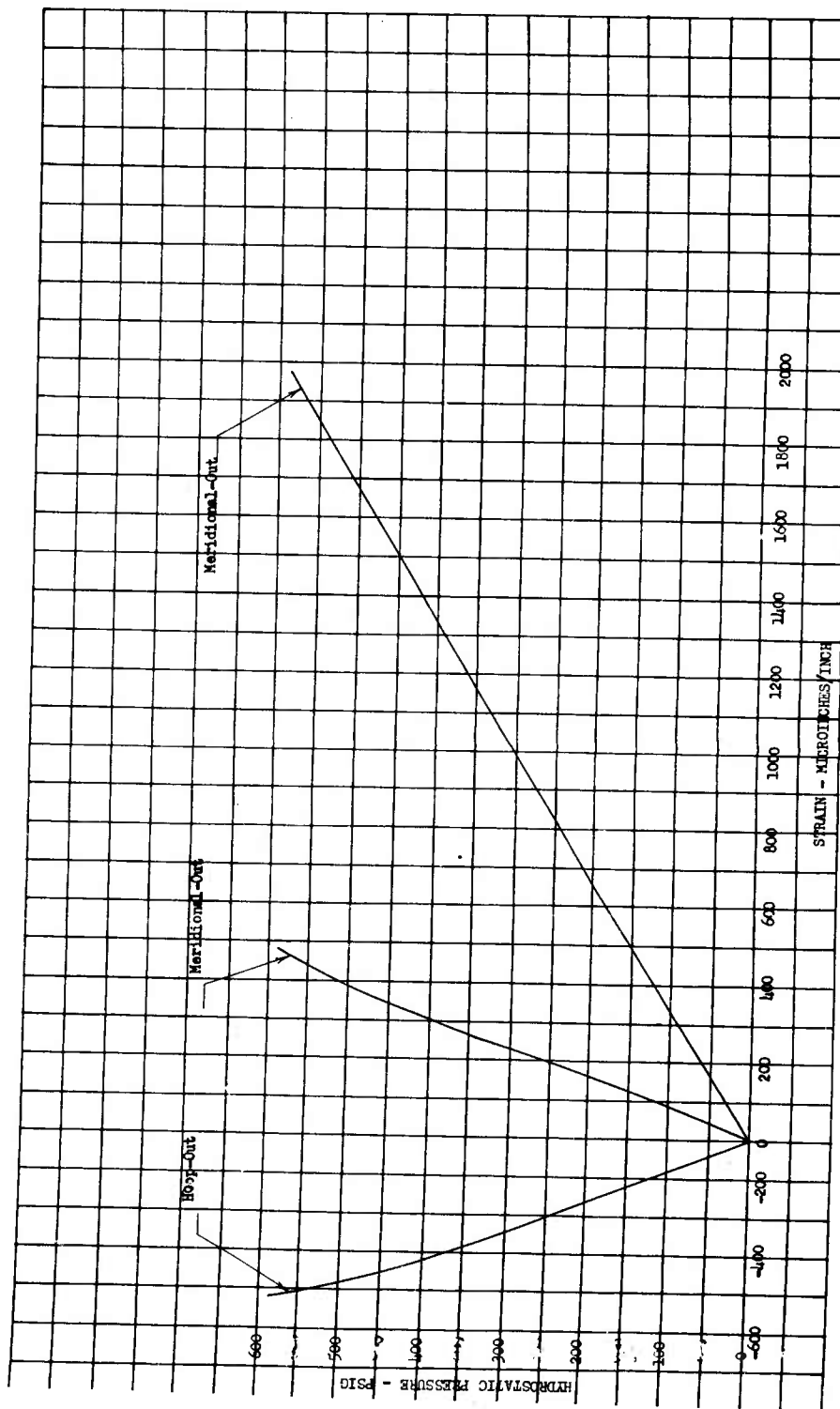


Figure 75

Appendix D

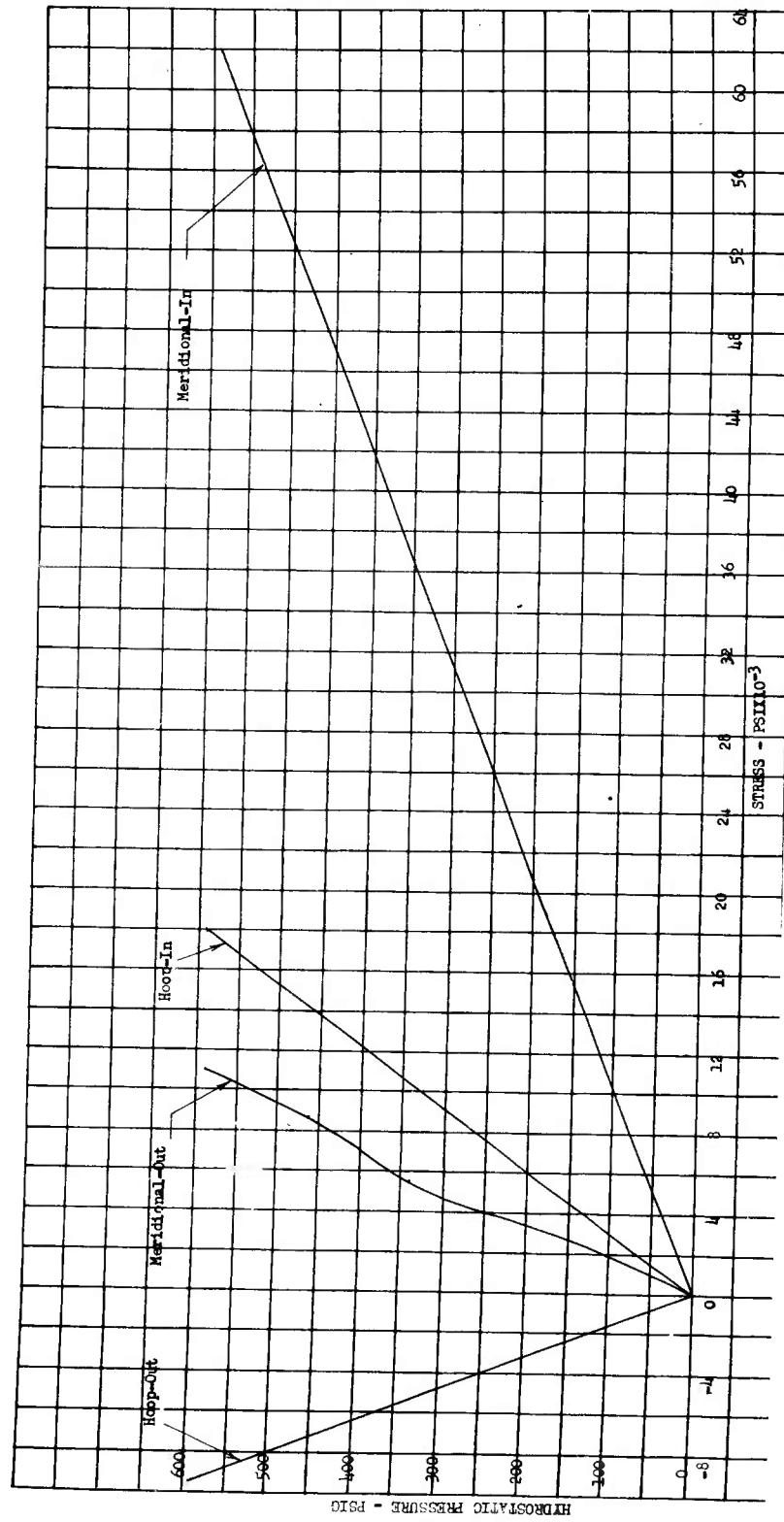


Figure 76

Pressure vs Stress, Gage Point 39

Appendix D

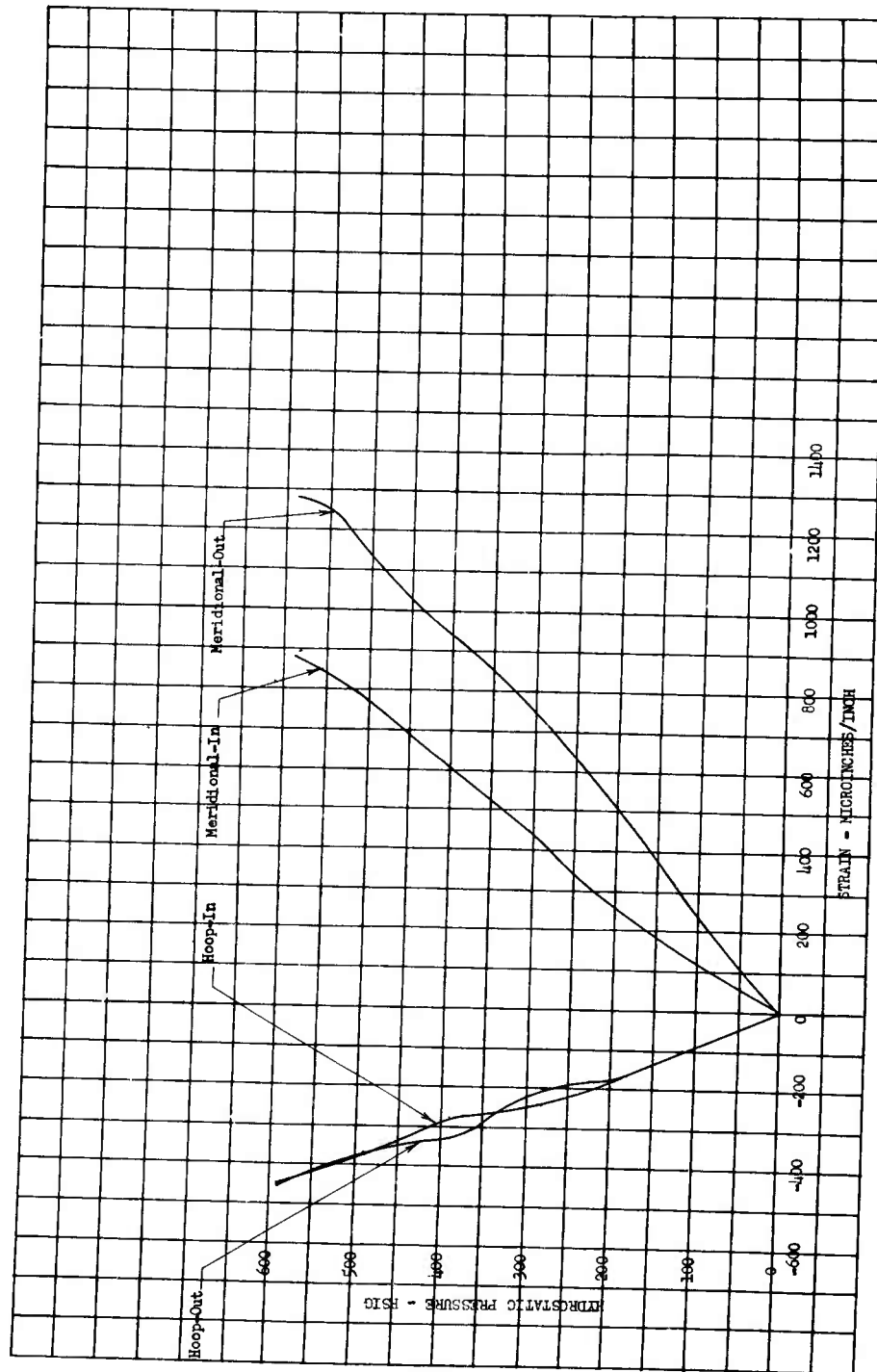


Figure 77

Pressure vs Strain, Gage Point 40

Appendix D

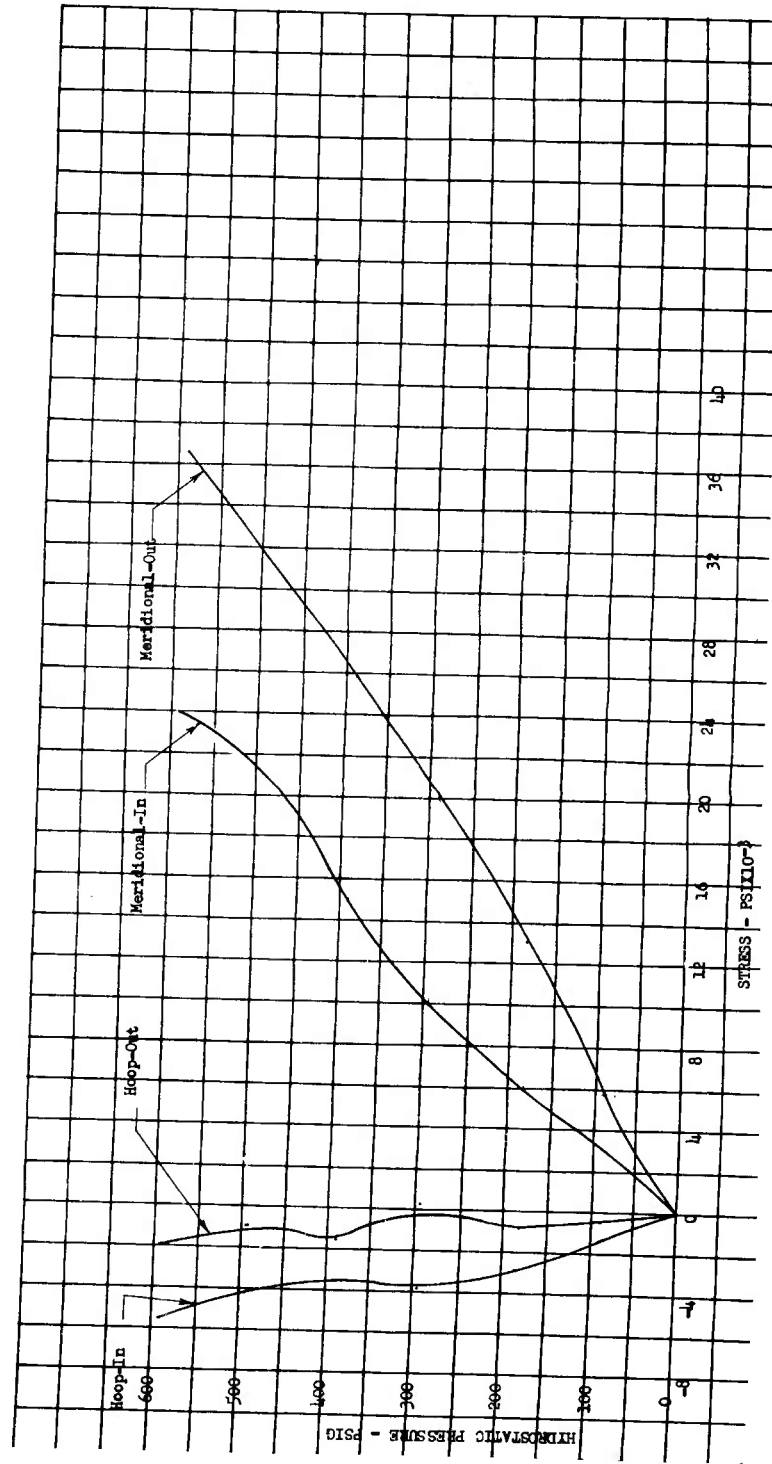


Figure 78

Pressure vs Stress, Gage Point 40

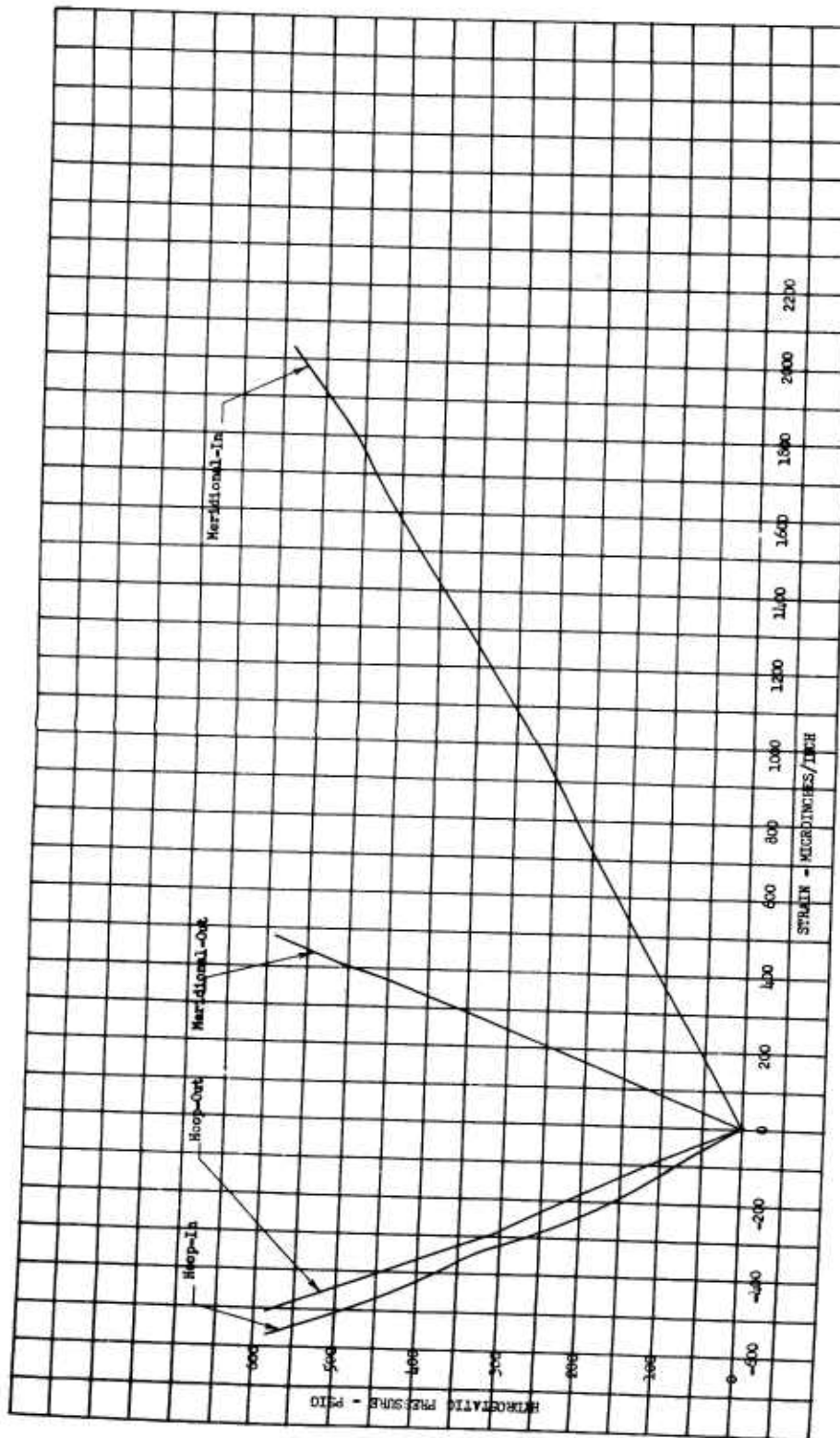


Figure 79

Pressure vs Strain, Gage Point 41

Appendix D

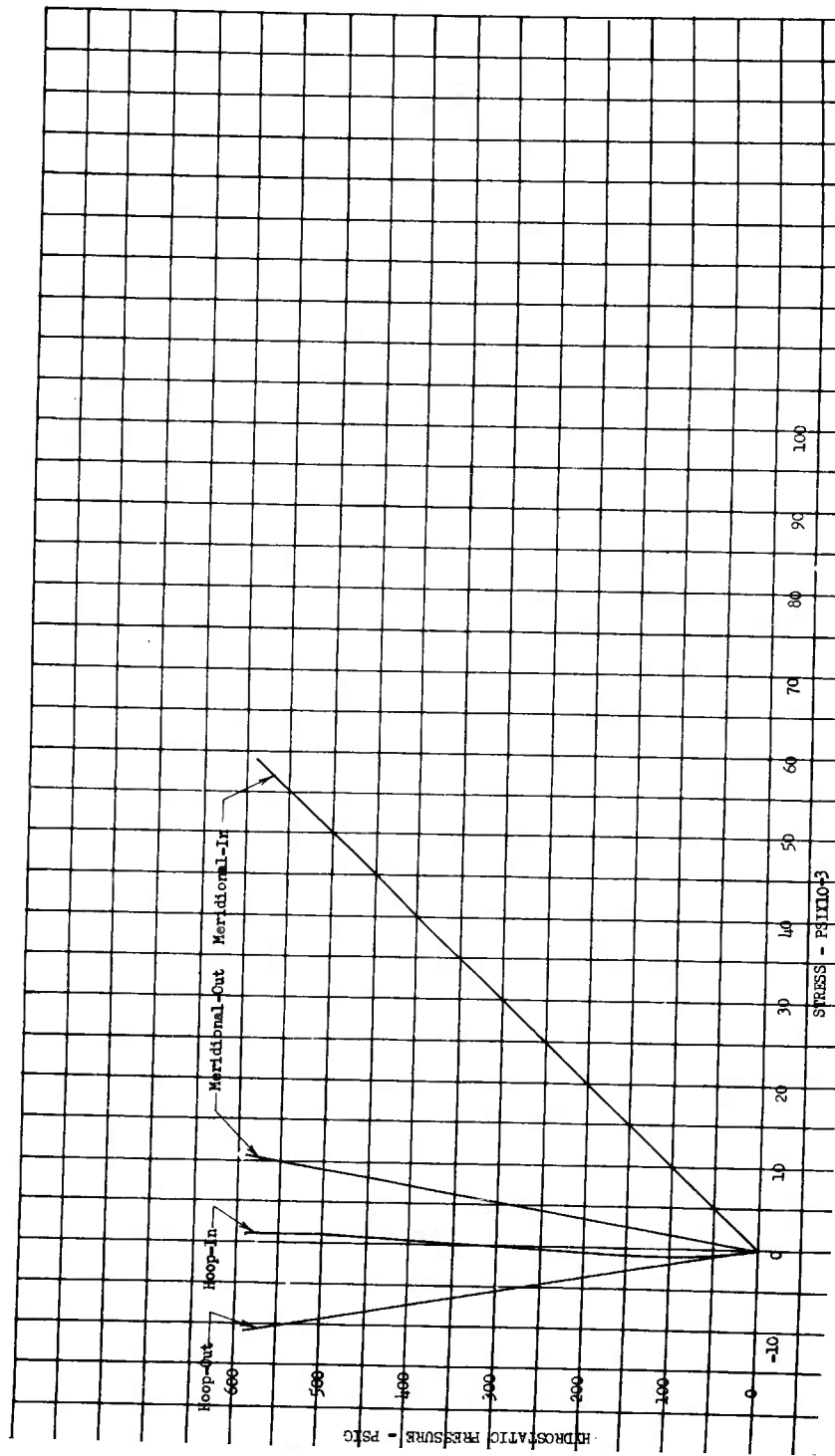


Figure 80

Pressure vs Stress, Gage Point 41

Appendix D

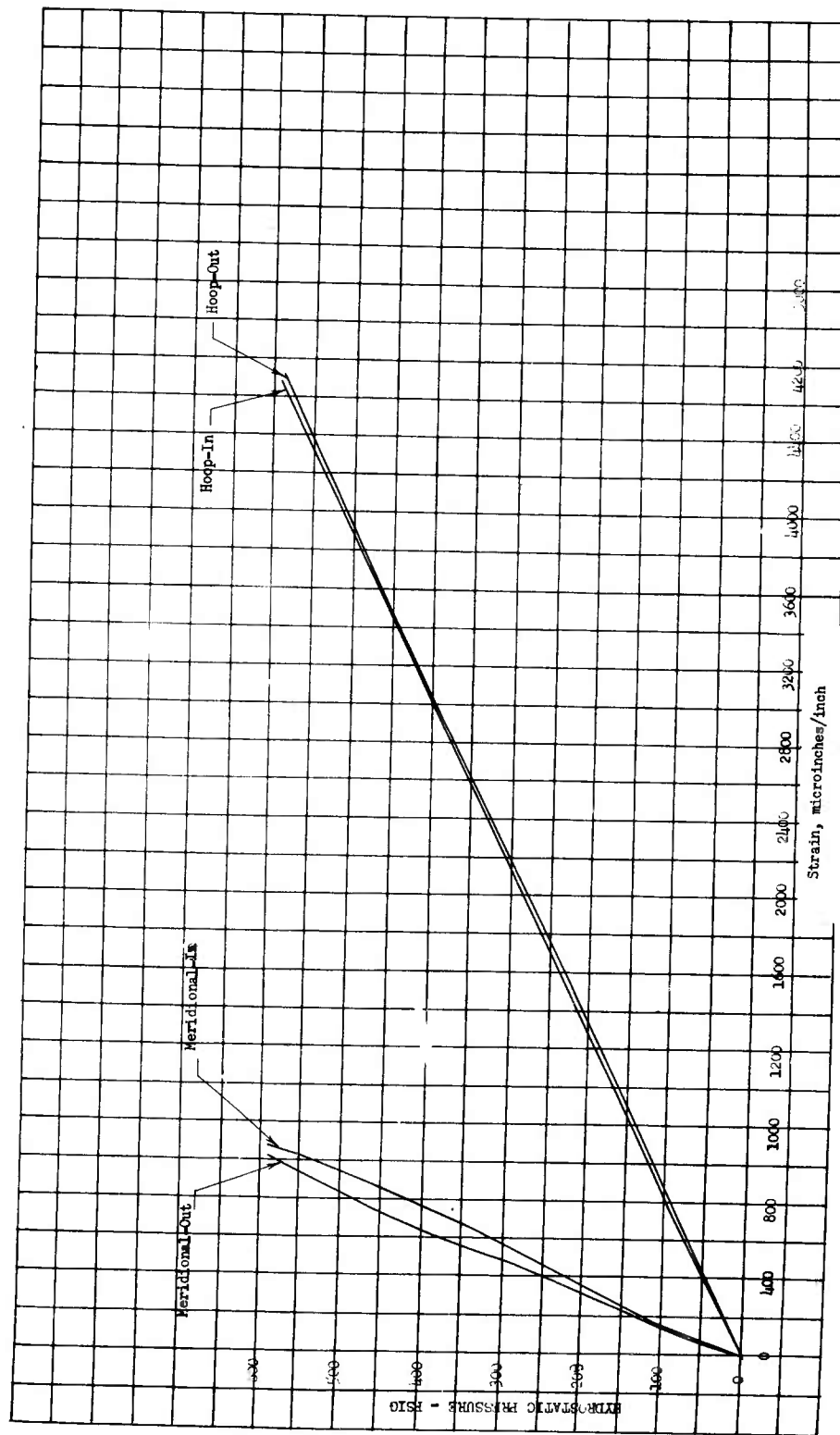


Figure 81

Pressure vs Strain, Gage Point 42

Appendix D

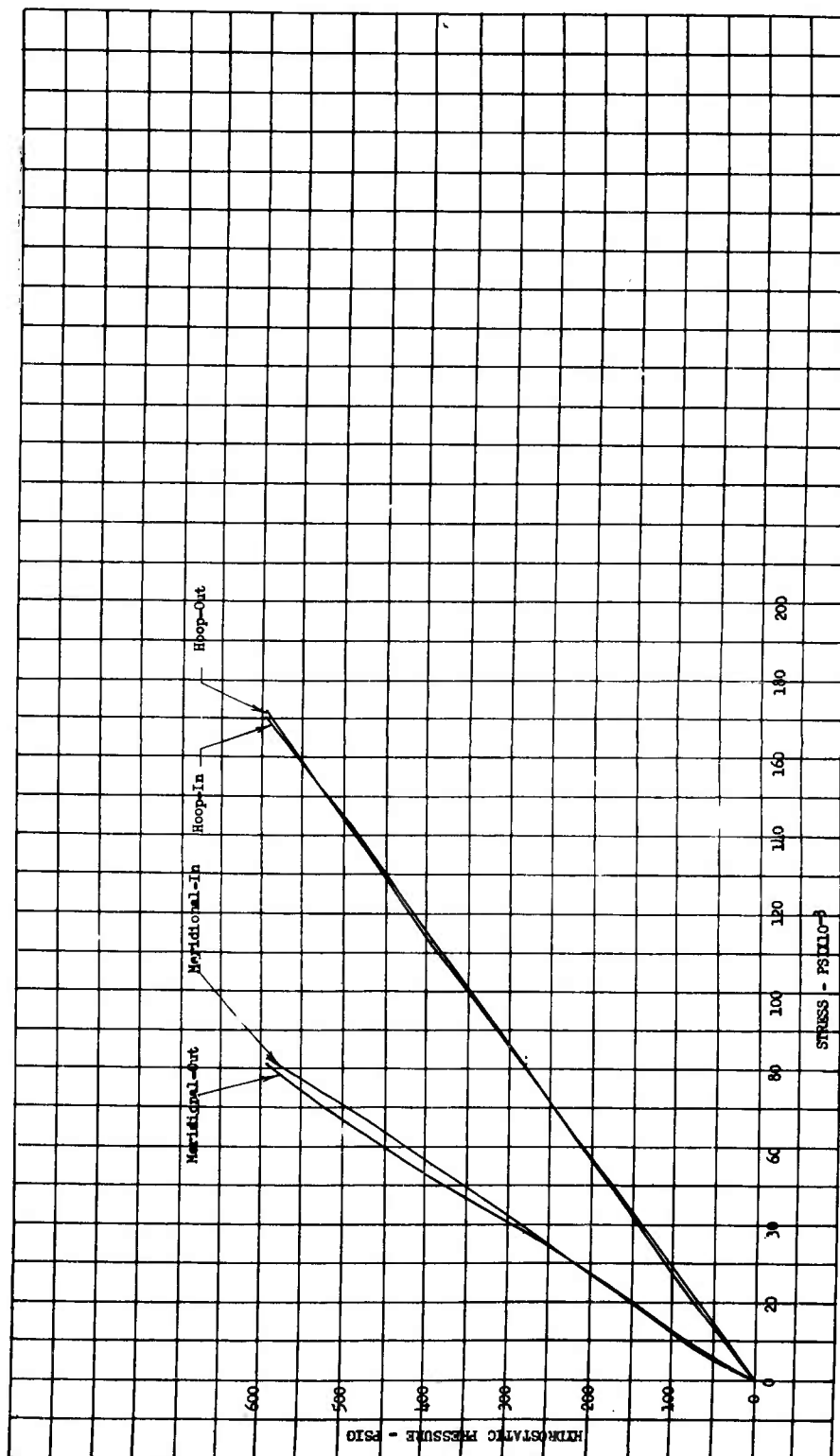


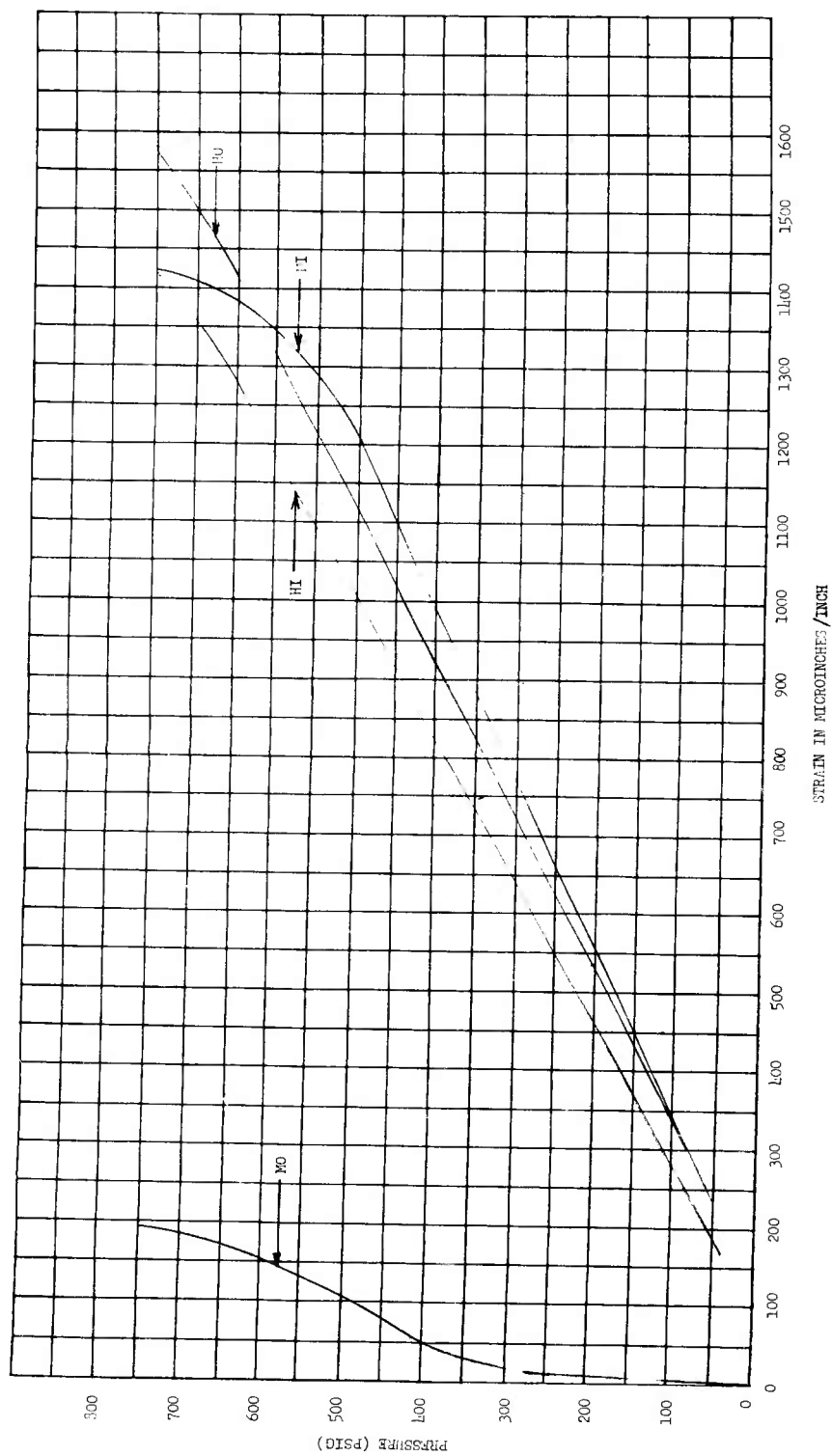
Figure 82

Pressure vs Stress, Gage Point 42

APPENDIX E: PHASE V

CIRCUMFERENTIAL GROWTH;
STRESS AND STRAIN PLOTS FOR POINTS
71 TO 74, 76 TO 78, 80, 82 TO 84, AND 90 TO 98

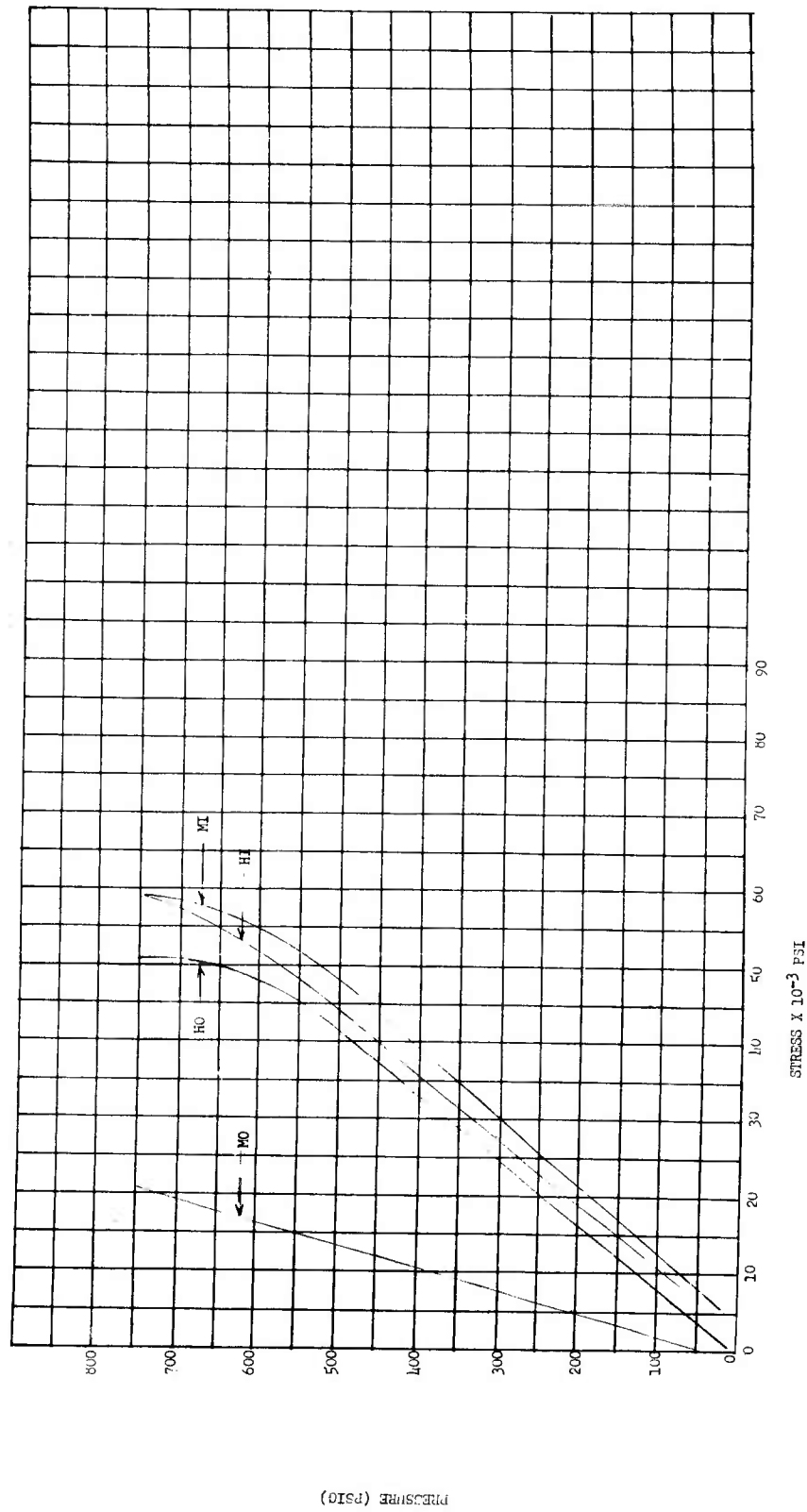
Appendix E



Pressure vs Strain, Gage Point 71

Figure 1

Appendix E



Pressure (PSID)

Figure 2

Pressure vs Stress, Gage Point 71

Appendix E

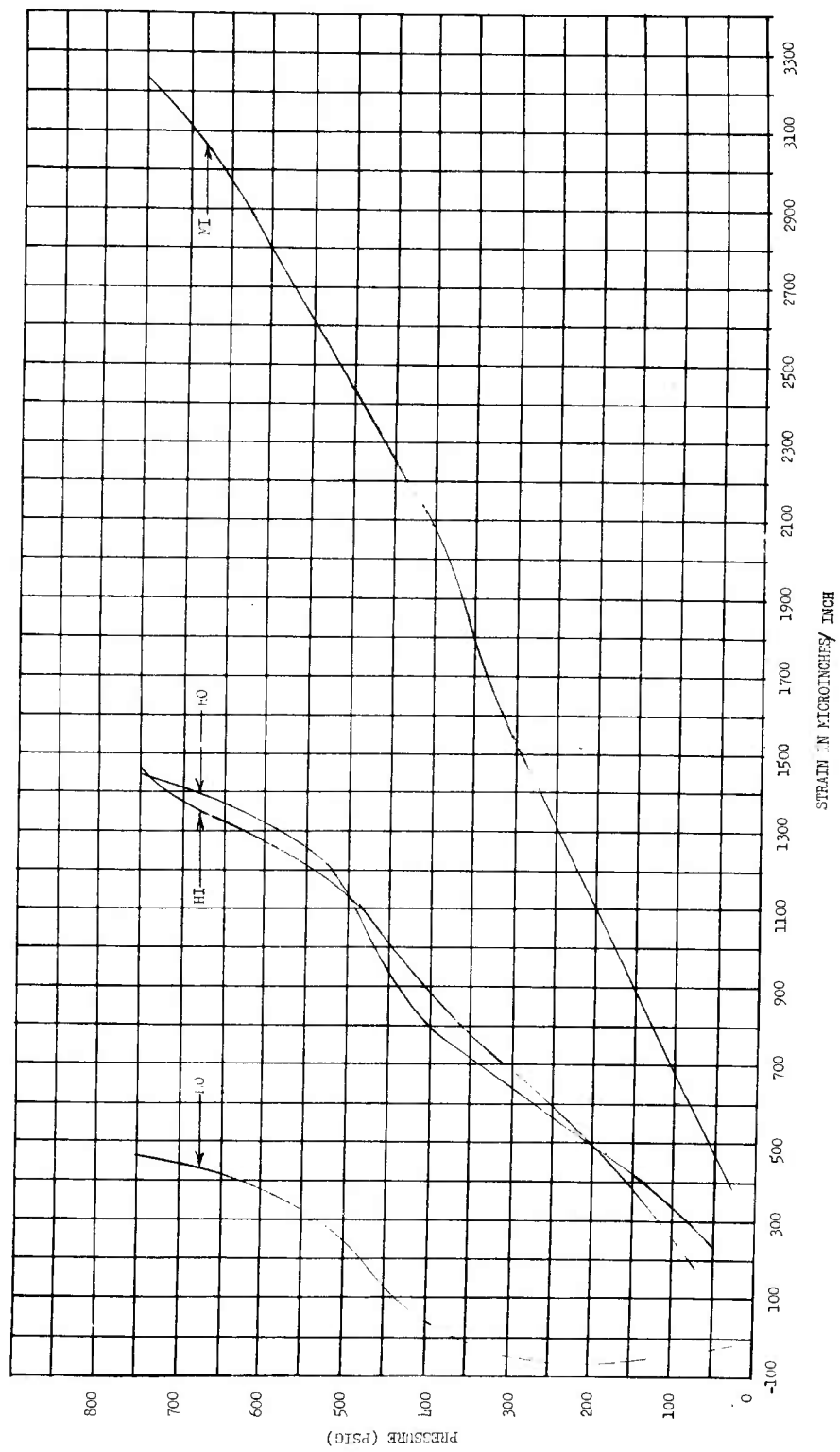
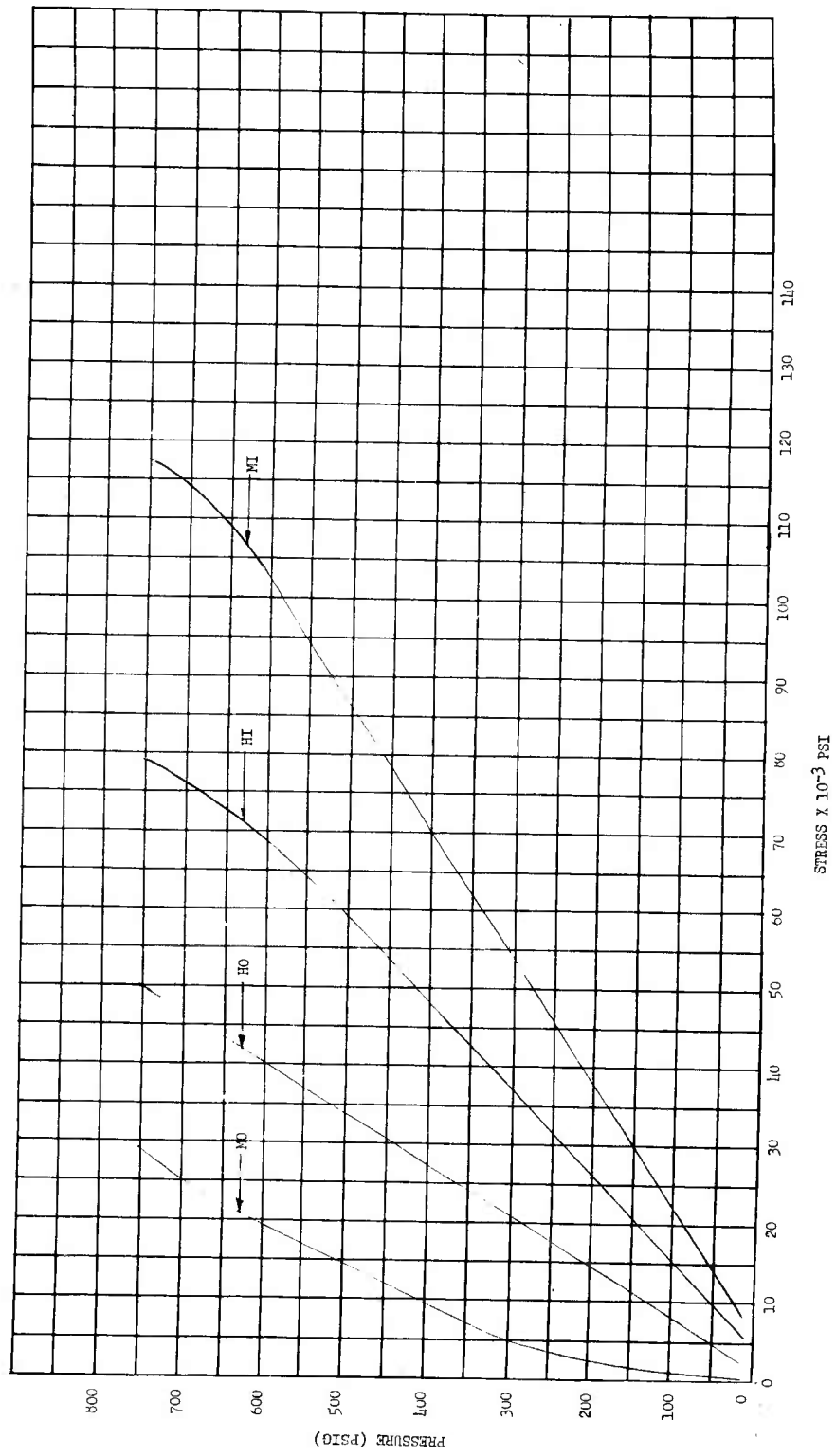


Figure 3

Pressure vs Strain, Gage Point 72

Appendix E



Pressure vs Stress, Gage Point 72

Figure 4

Appendix E

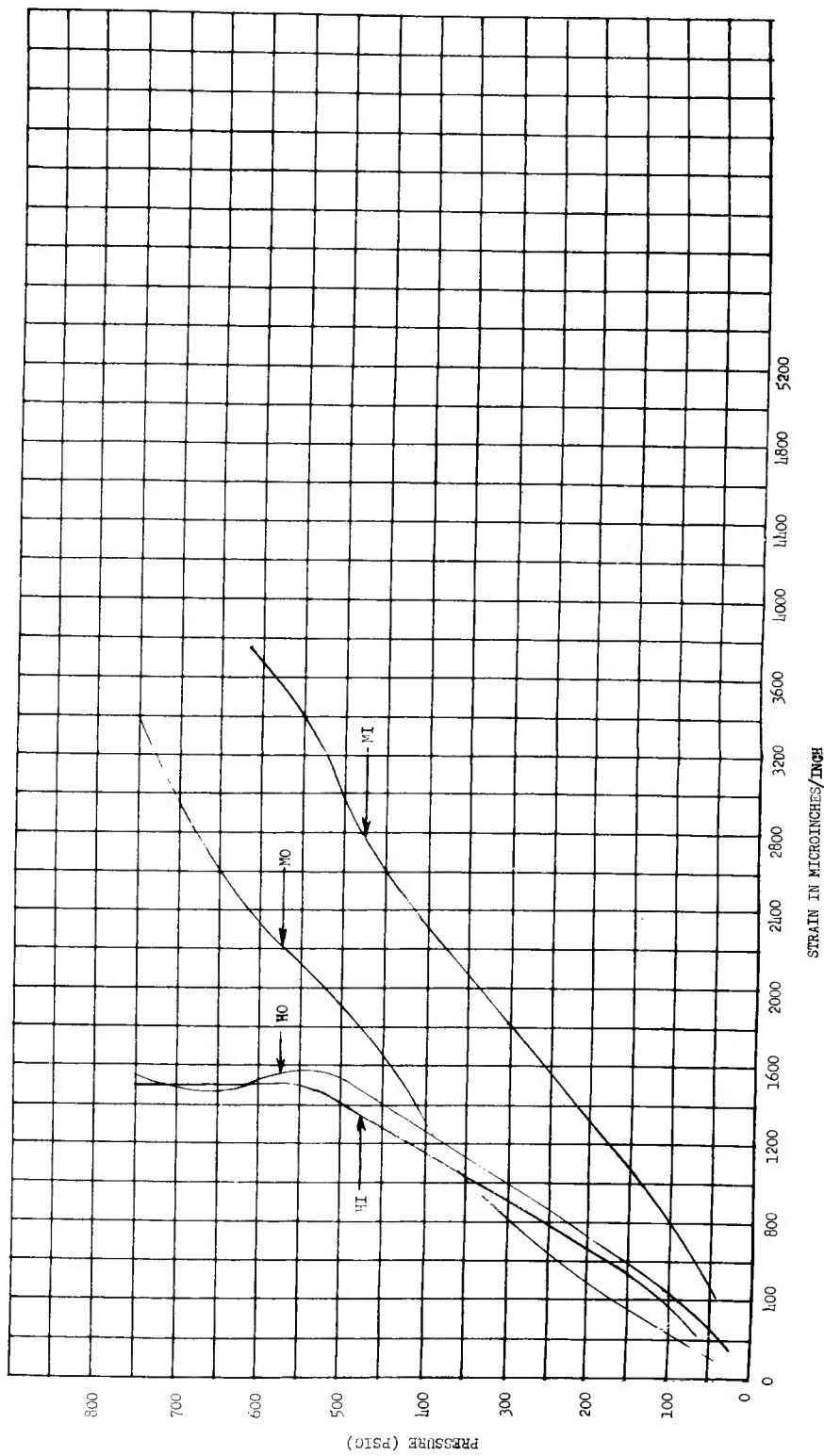


Figure 5

Pressure vs Strain, Gage Point 73

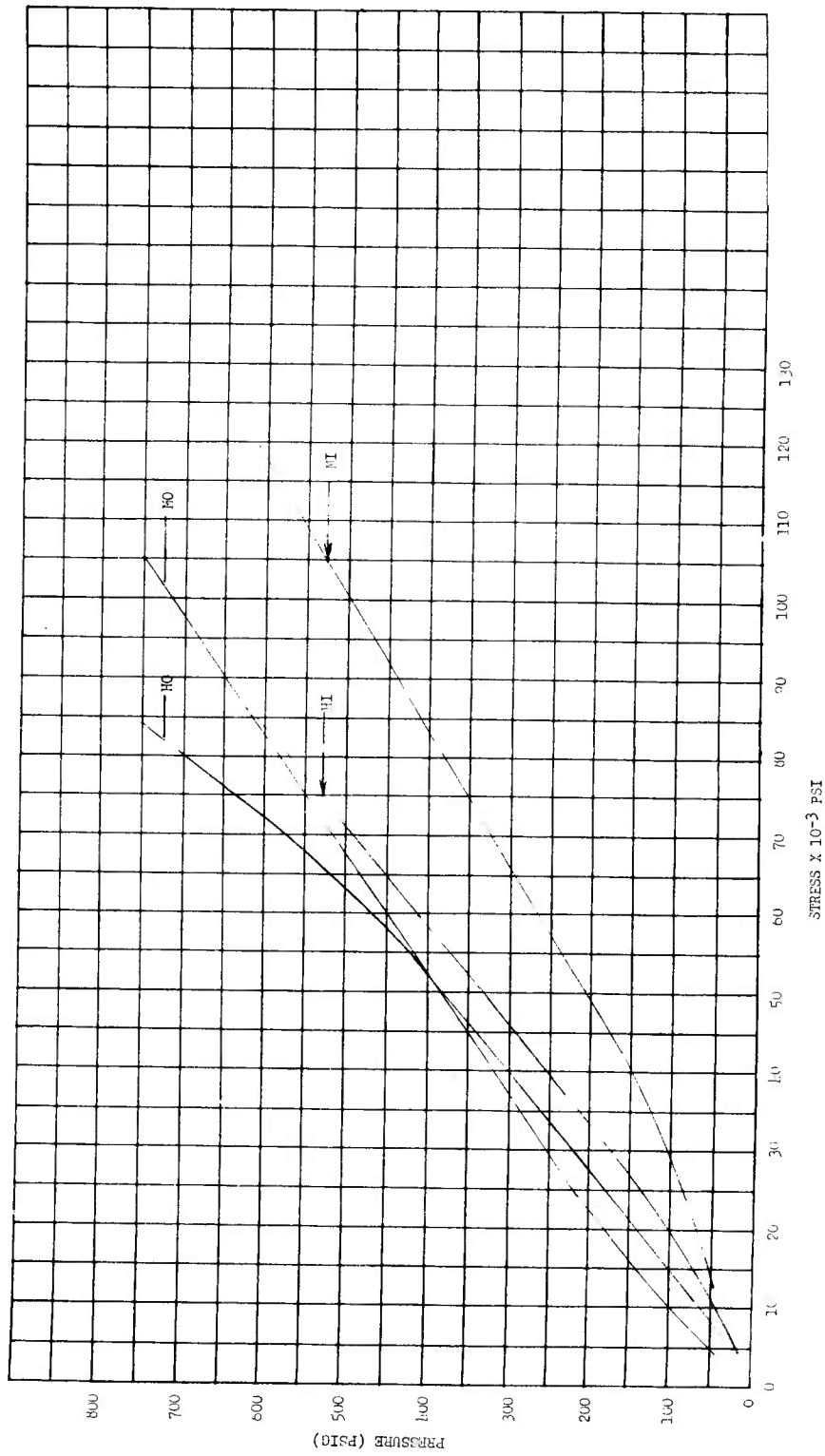


Figure 6

Pressure vs Stress, Gage Point 73

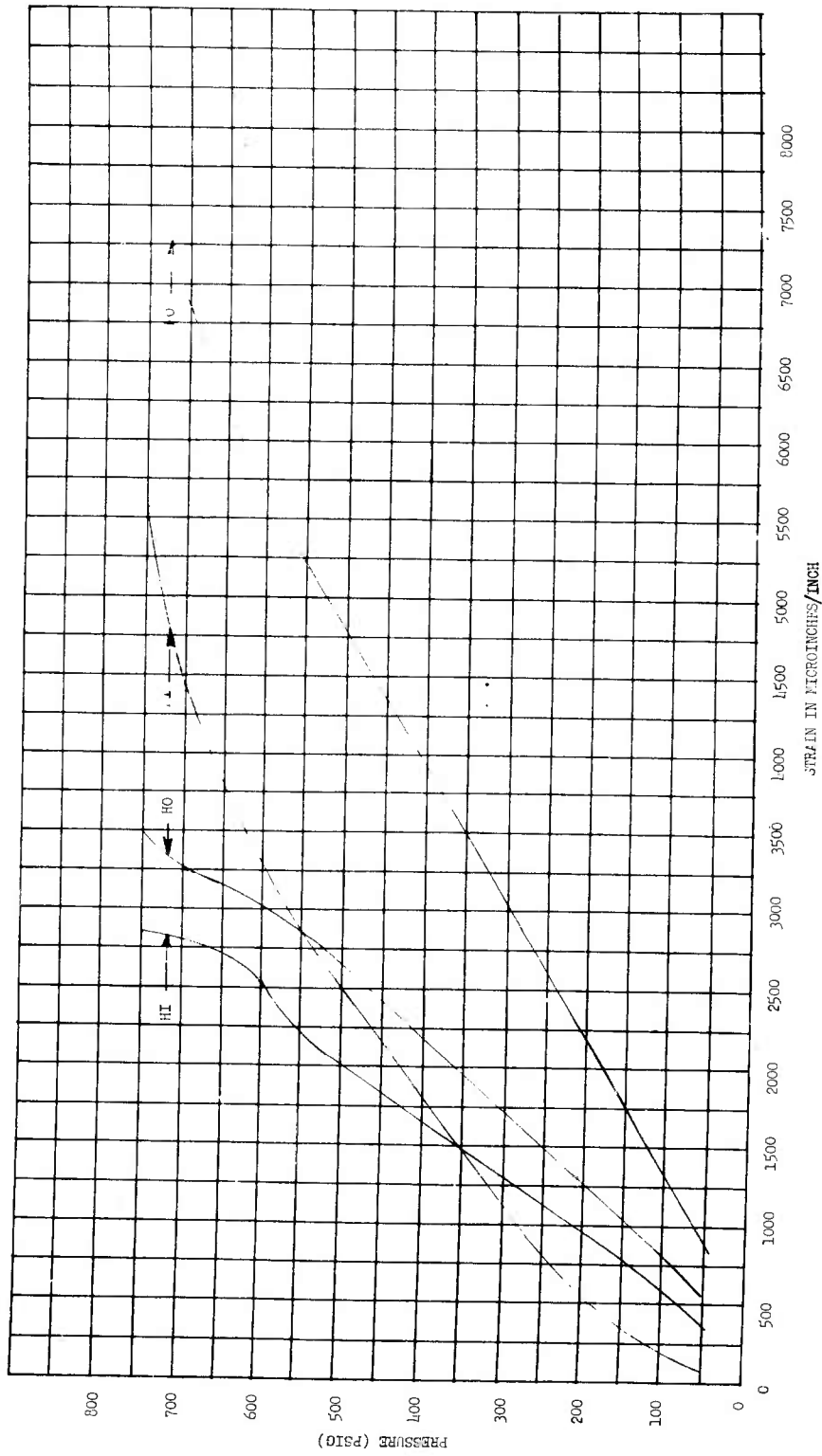


Figure 7

Pressure vs Strain, Gage Point 74

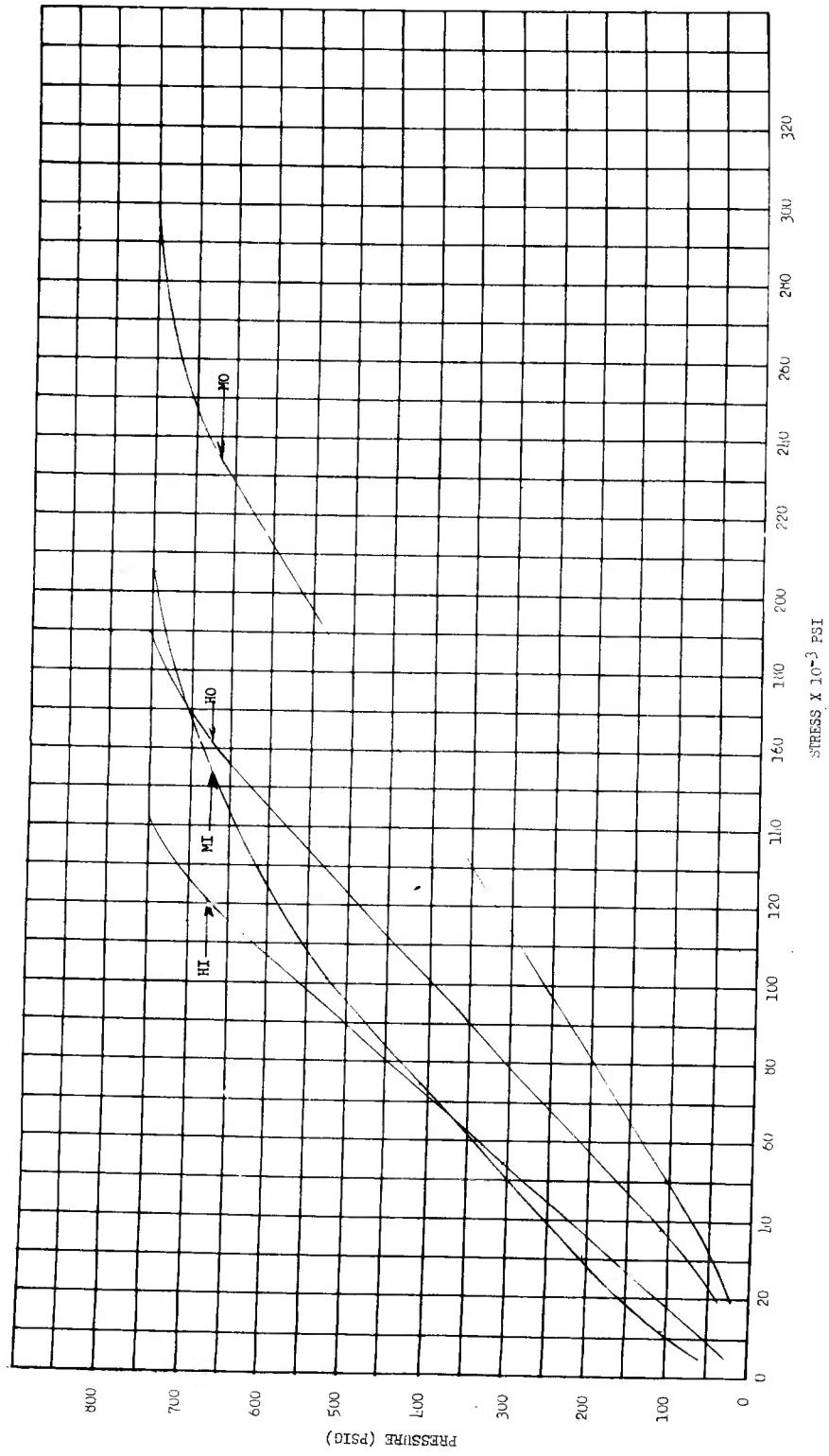


Figure 8

Pressure vs Stress, Gage Point 74

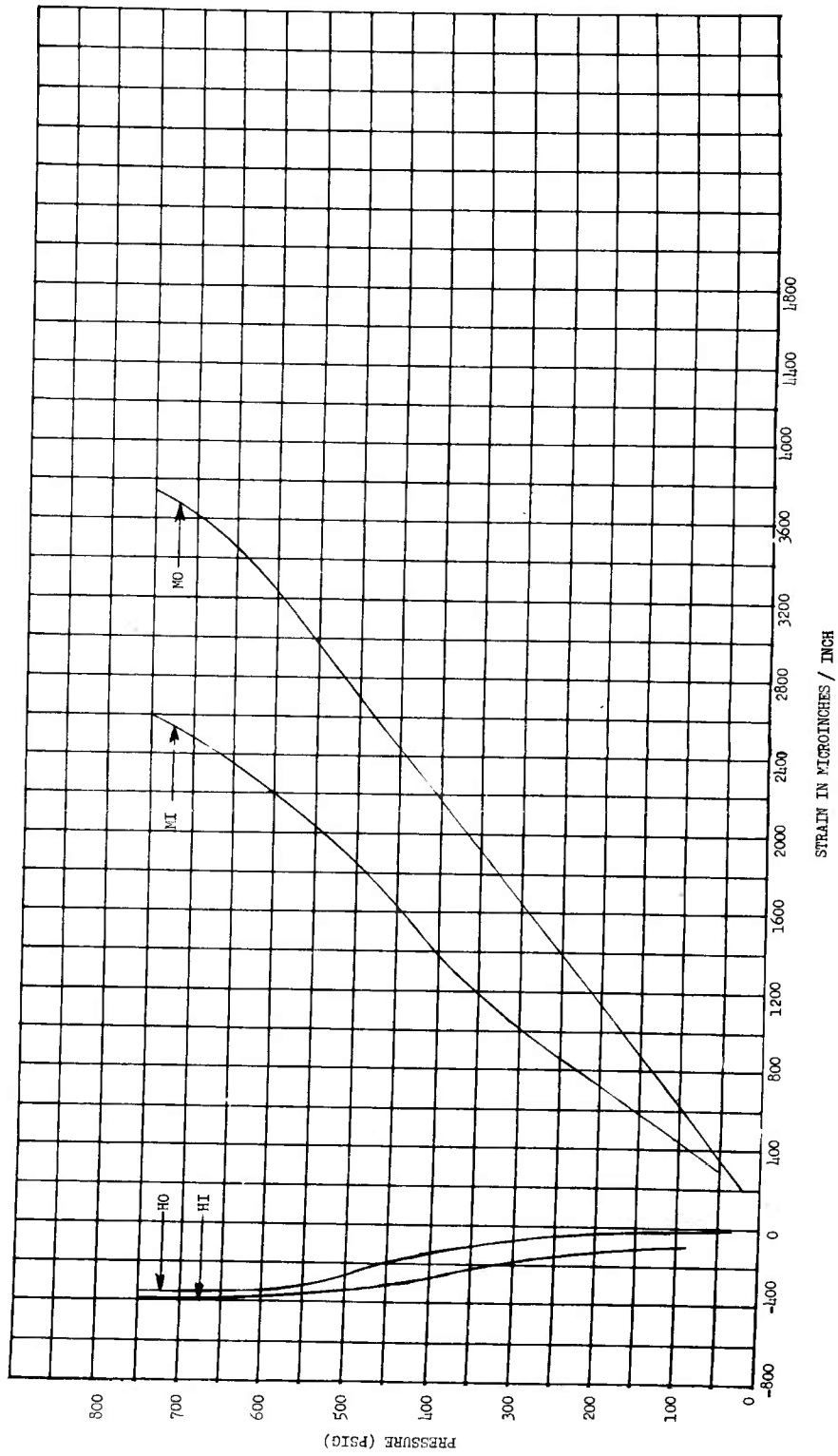


Figure 9

Pressure vs Strain, Gage Point 76

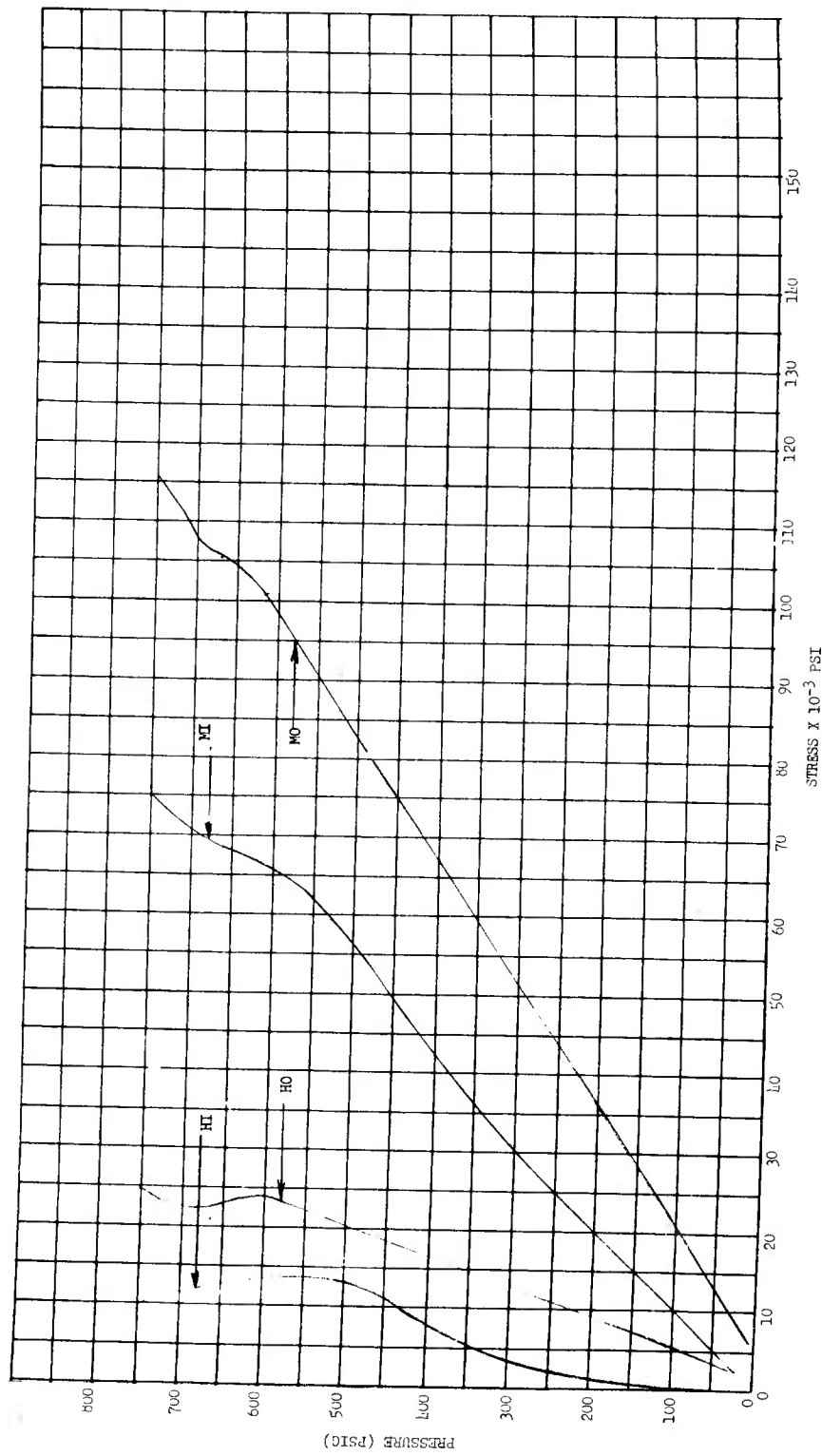
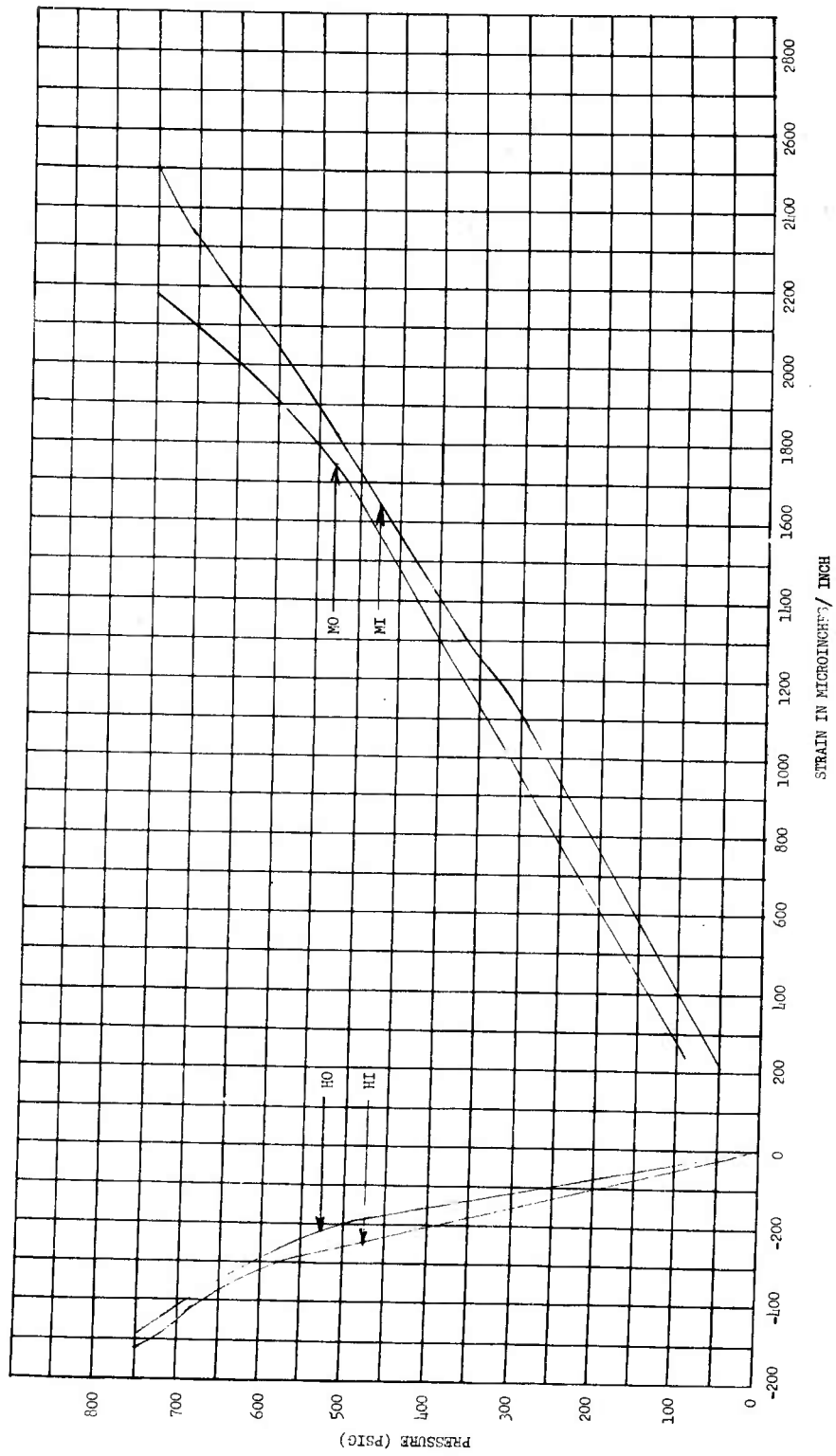


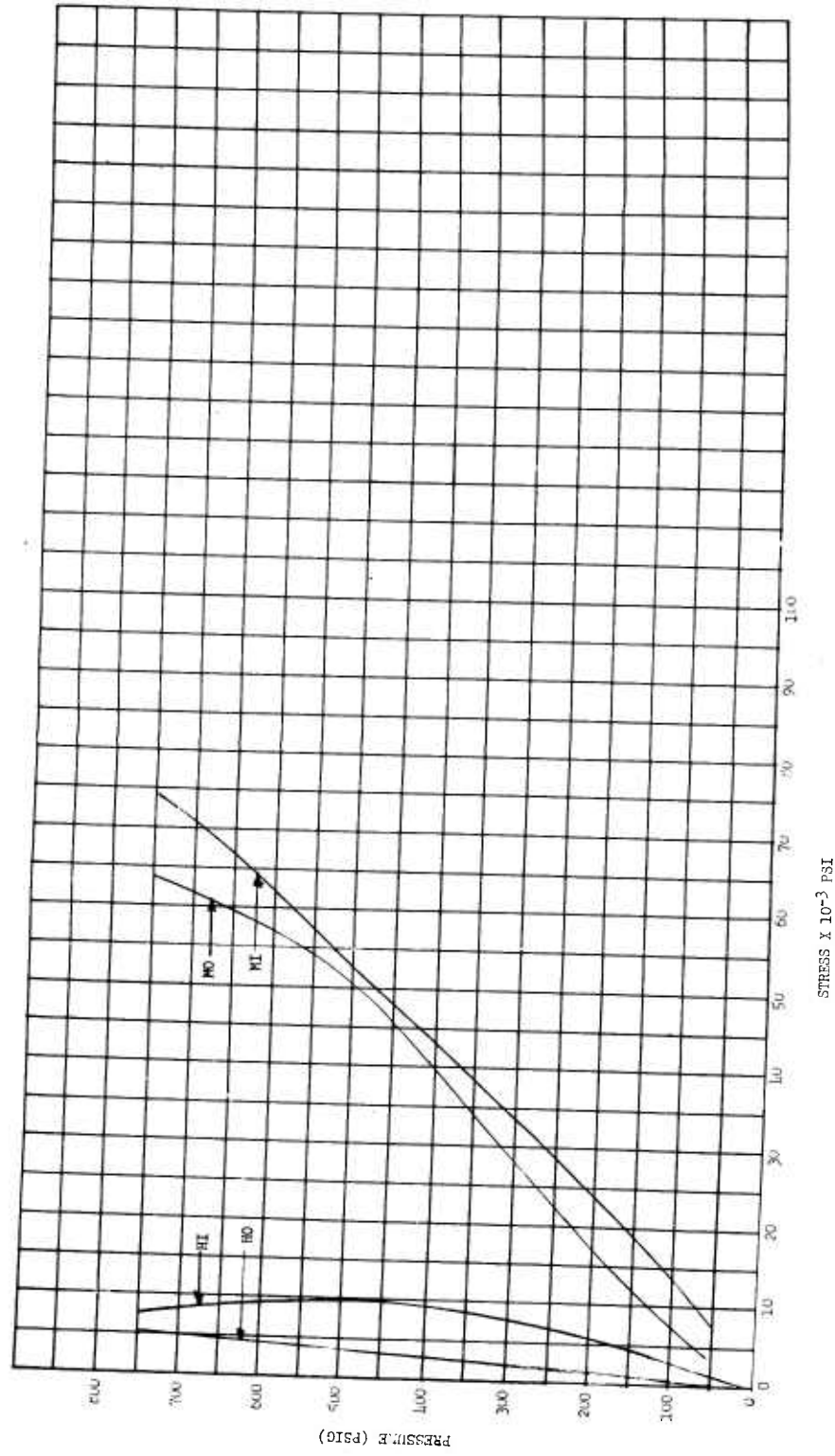
Figure 10

Pressure vs Stress, Gage Point 76



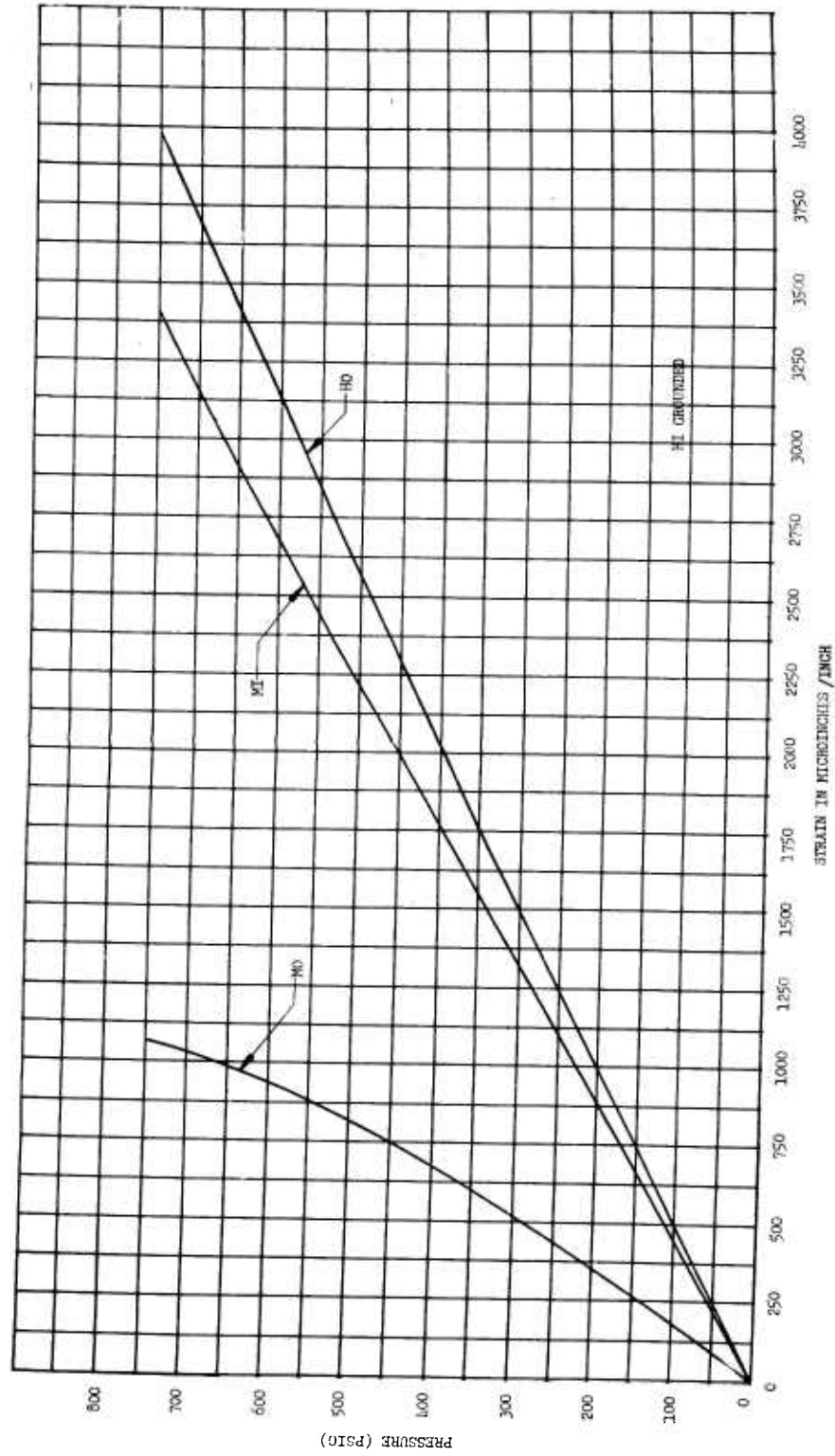
Pressure vs Strain, Gage Point 77

Figure 11



Pressure vs Stress, Gage Point 77

Figure 12



Pressure vs Strain, Gage Point 78

Figure 13

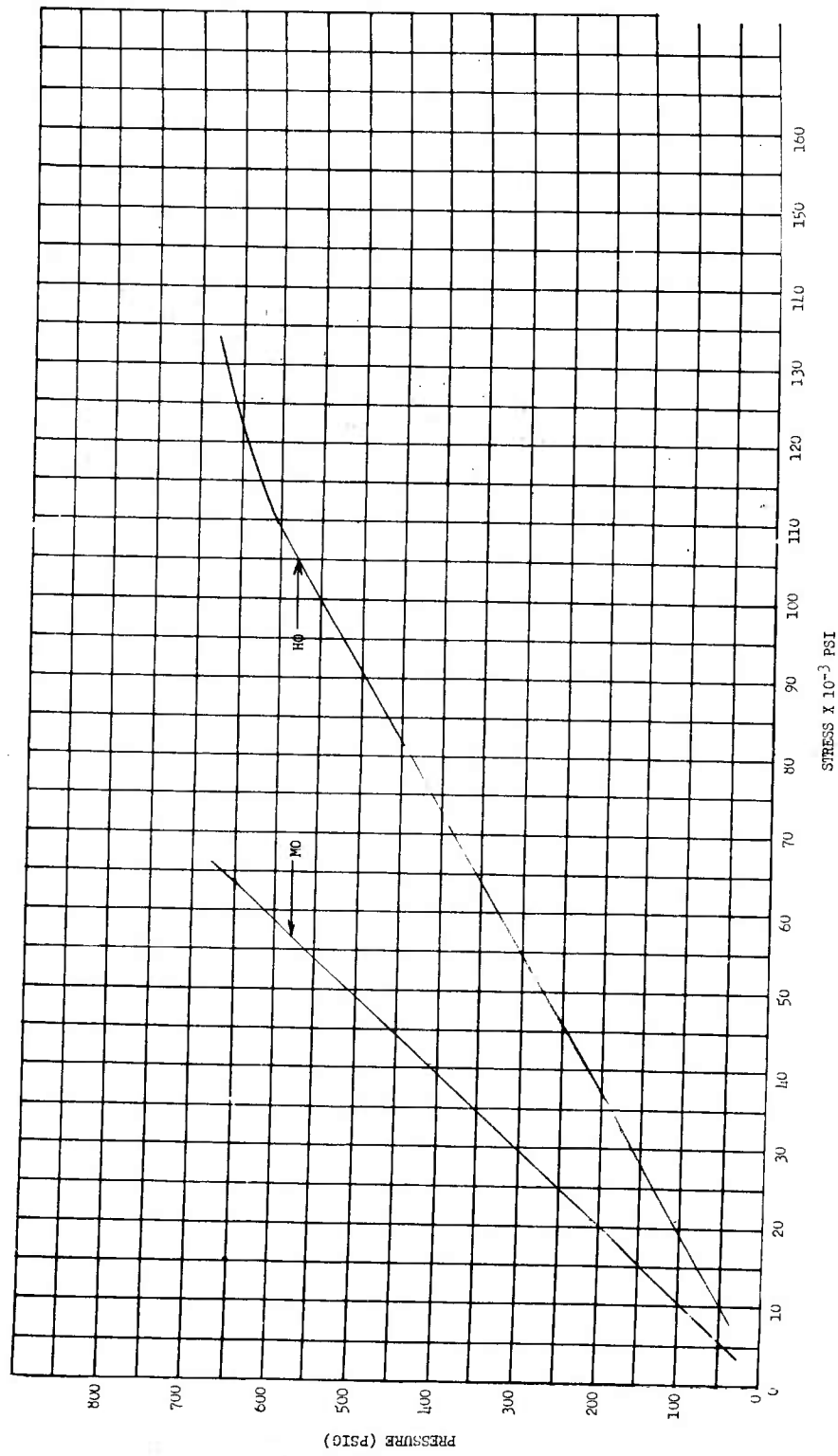


Figure 14

Pressure vs Stress, Gage Point 78

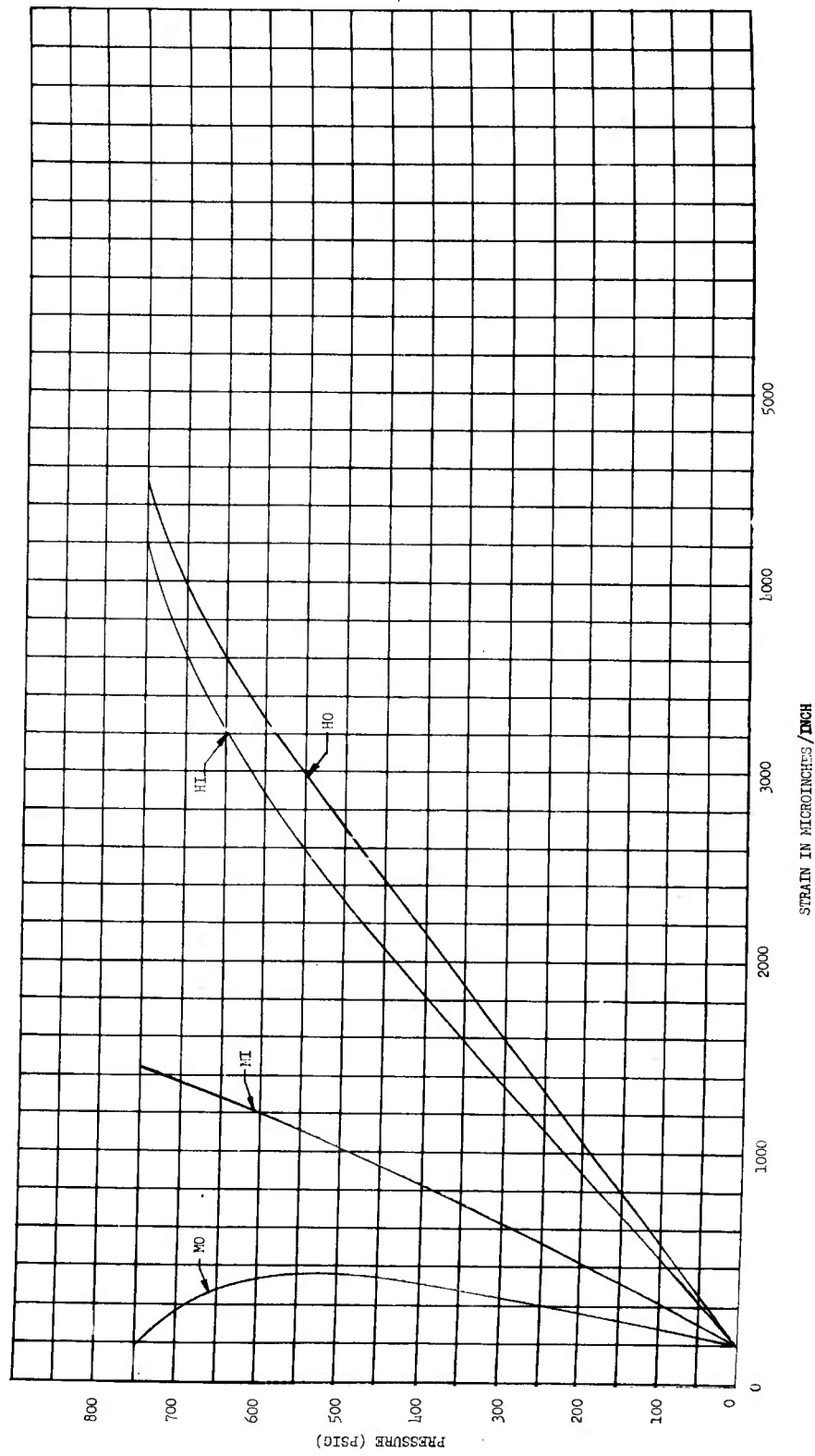


Figure 15

Pressure vs Strain, Gage Point 80

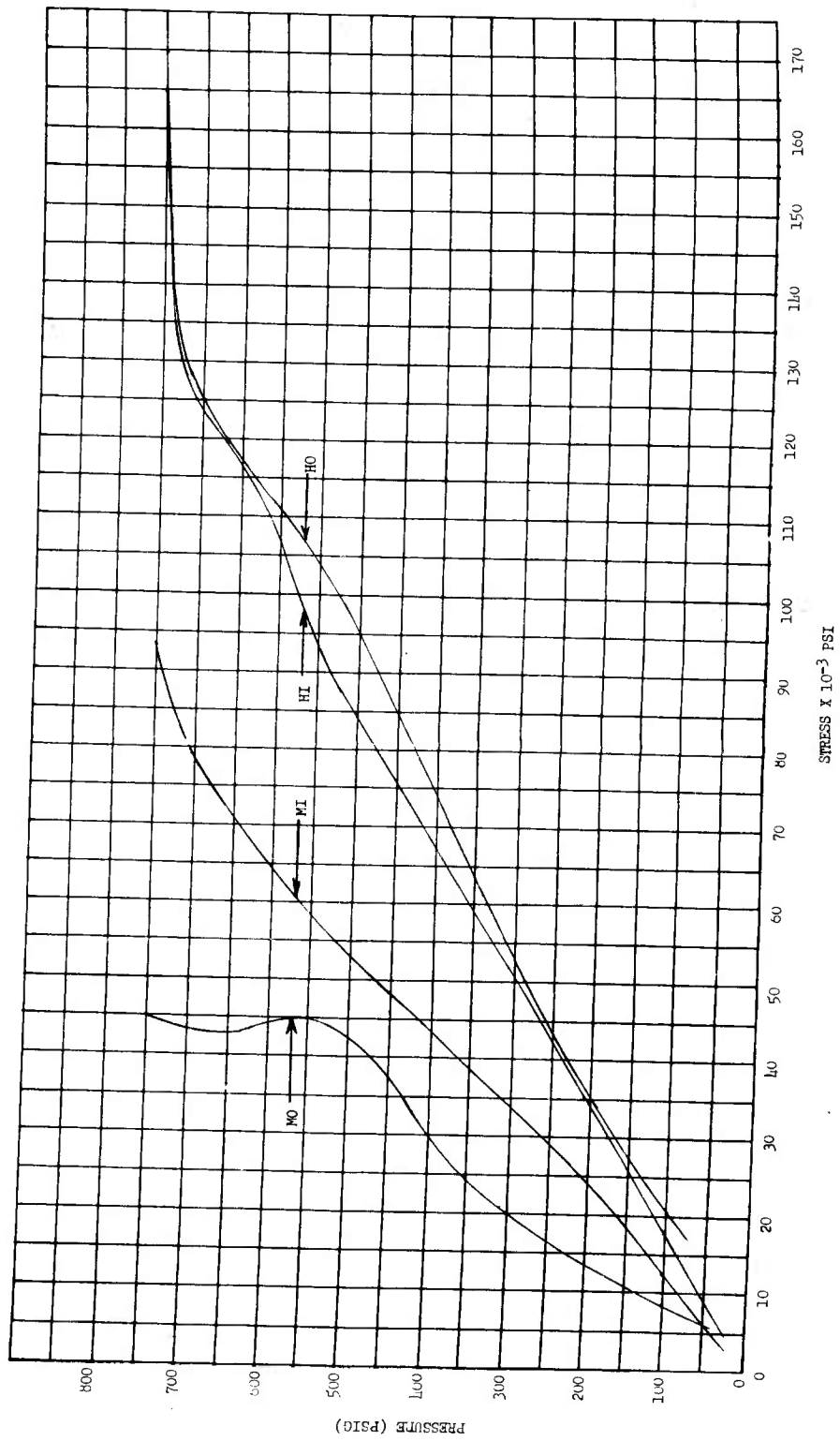


Figure 16

Pressure vs Stress, Gage Point 80

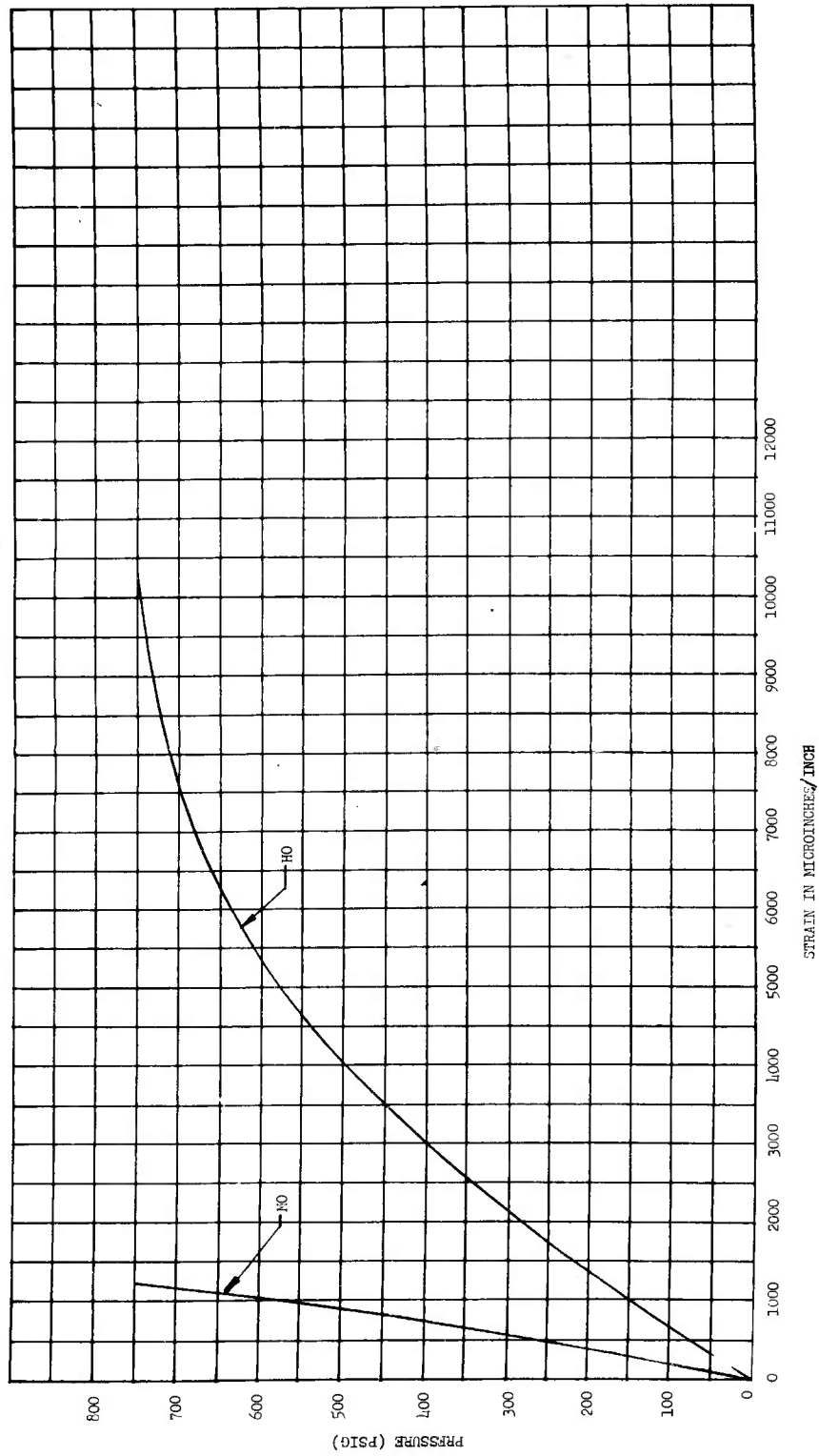


Figure 17

Pressure vs Strain, Gage Point 82

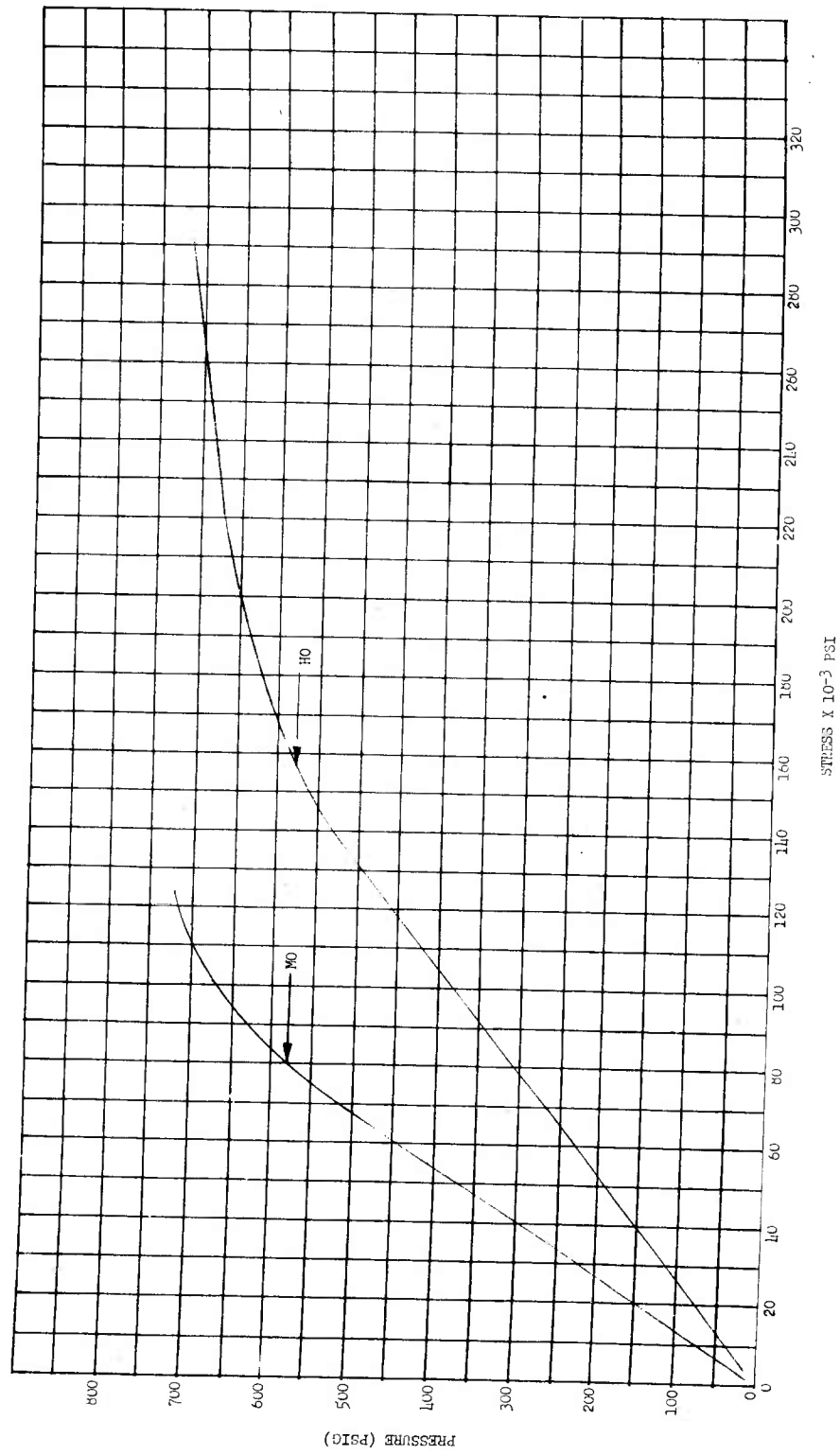


Figure 18

Pressure vs Stress, Gage Point 82

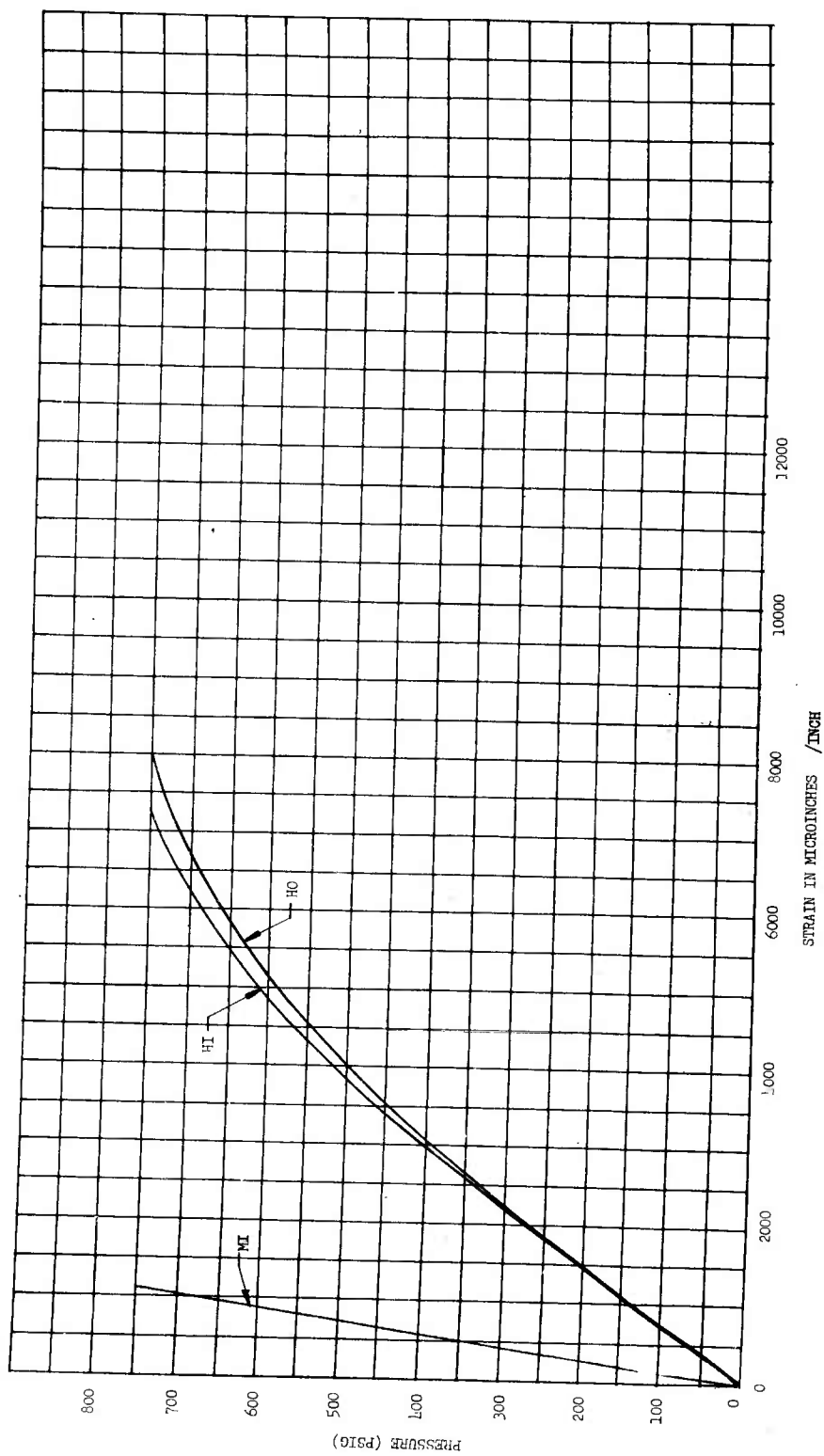


Figure 19

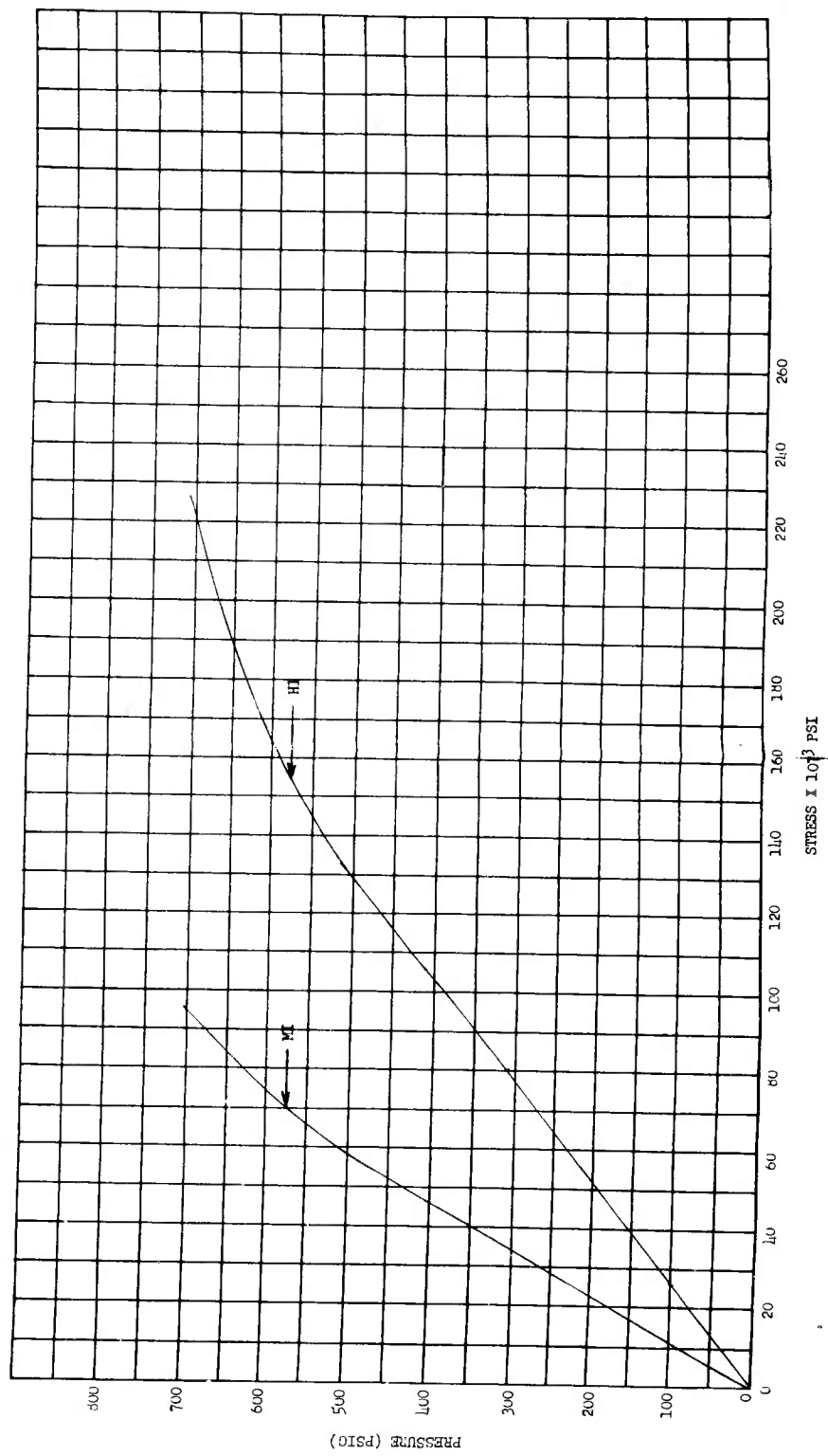


Figure 20

Pressure vs Stress, Gage Point 83

Appendix E

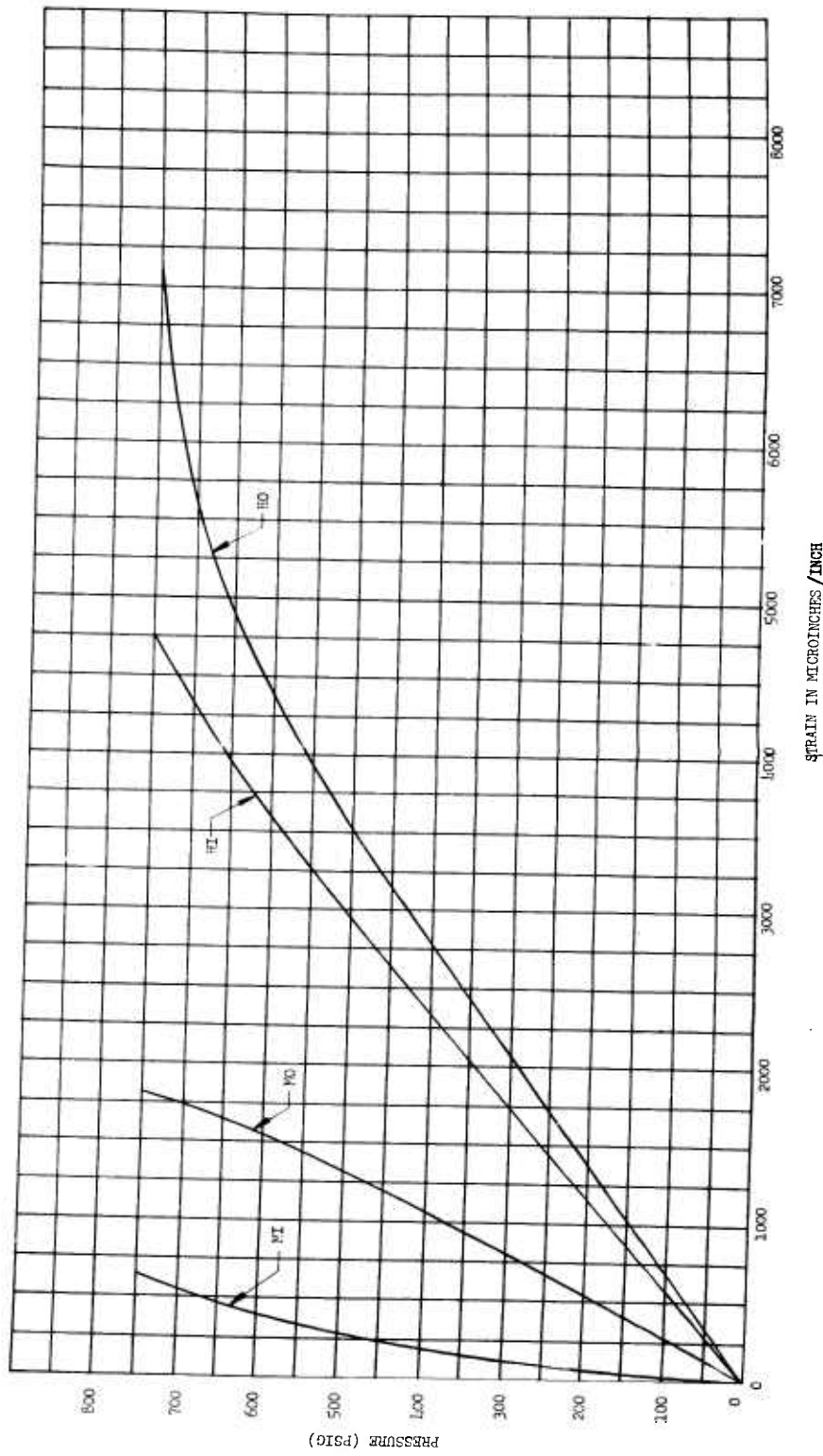
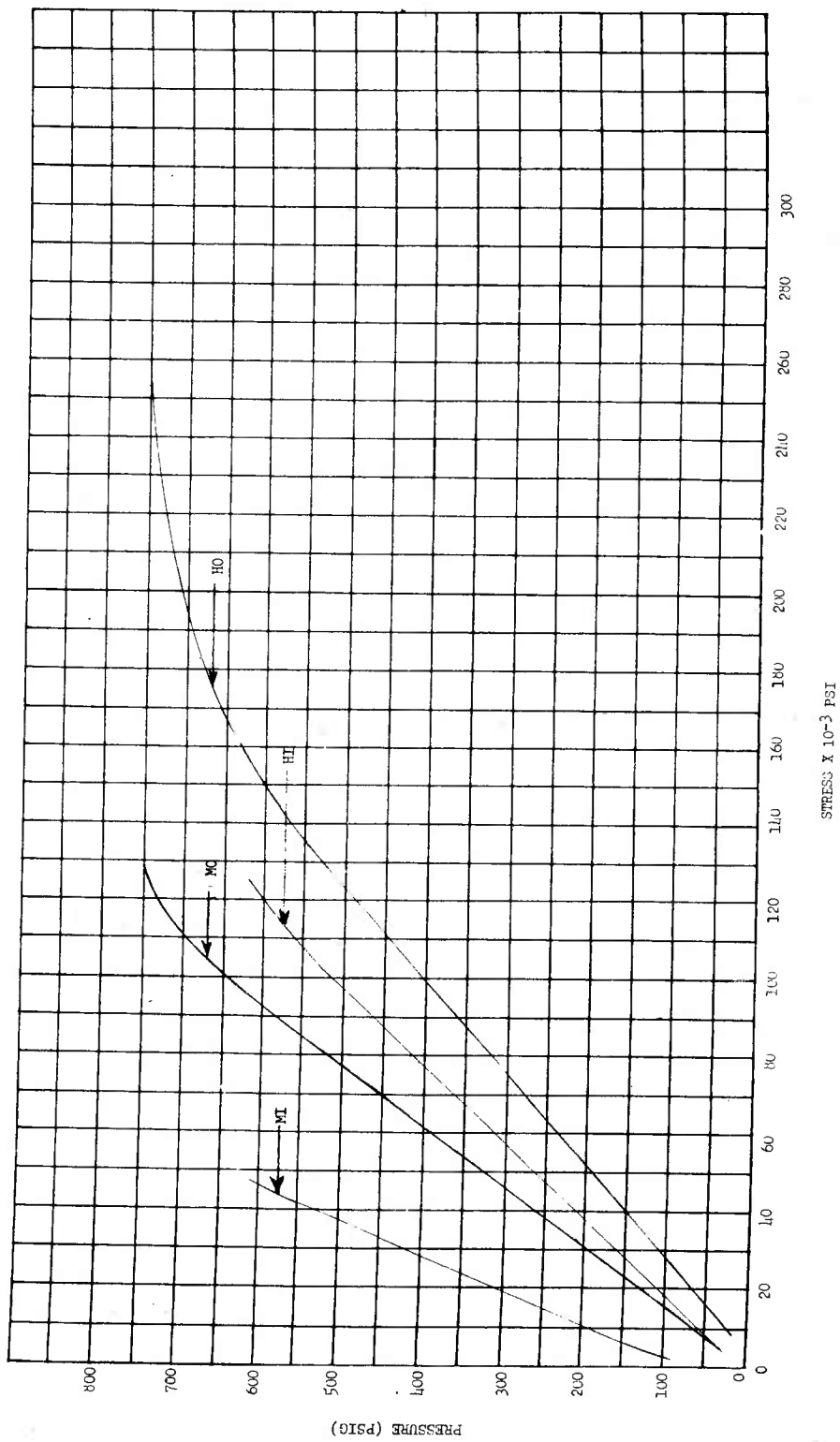


Figure 21

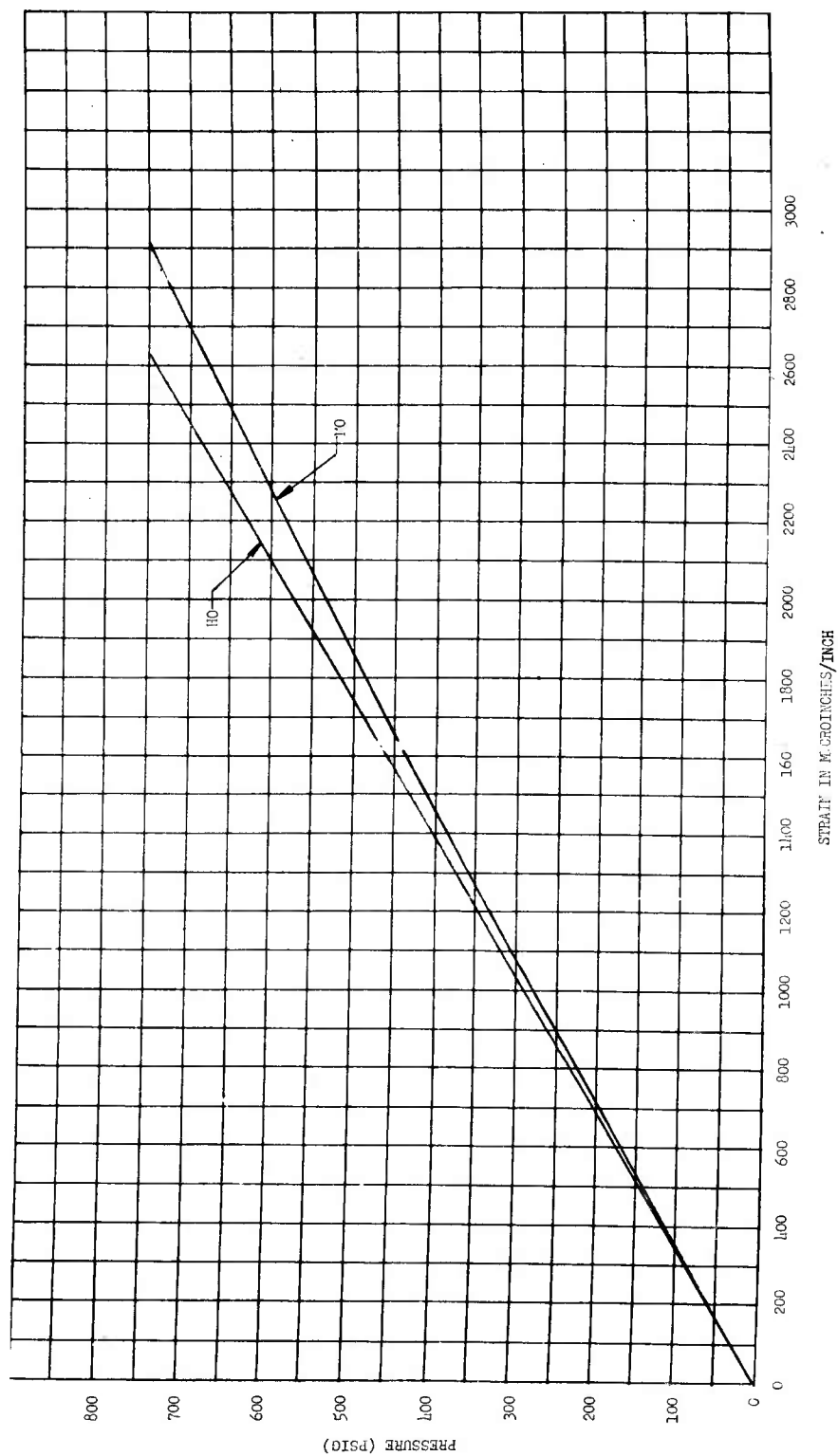
Pressure vs Strain, Gage Point 84



Pressure vs Stress, Gage Point 84

Figure 22

Appendix E



Pressure vs Strain , Gage Point 90

Figure 23

Appendix E

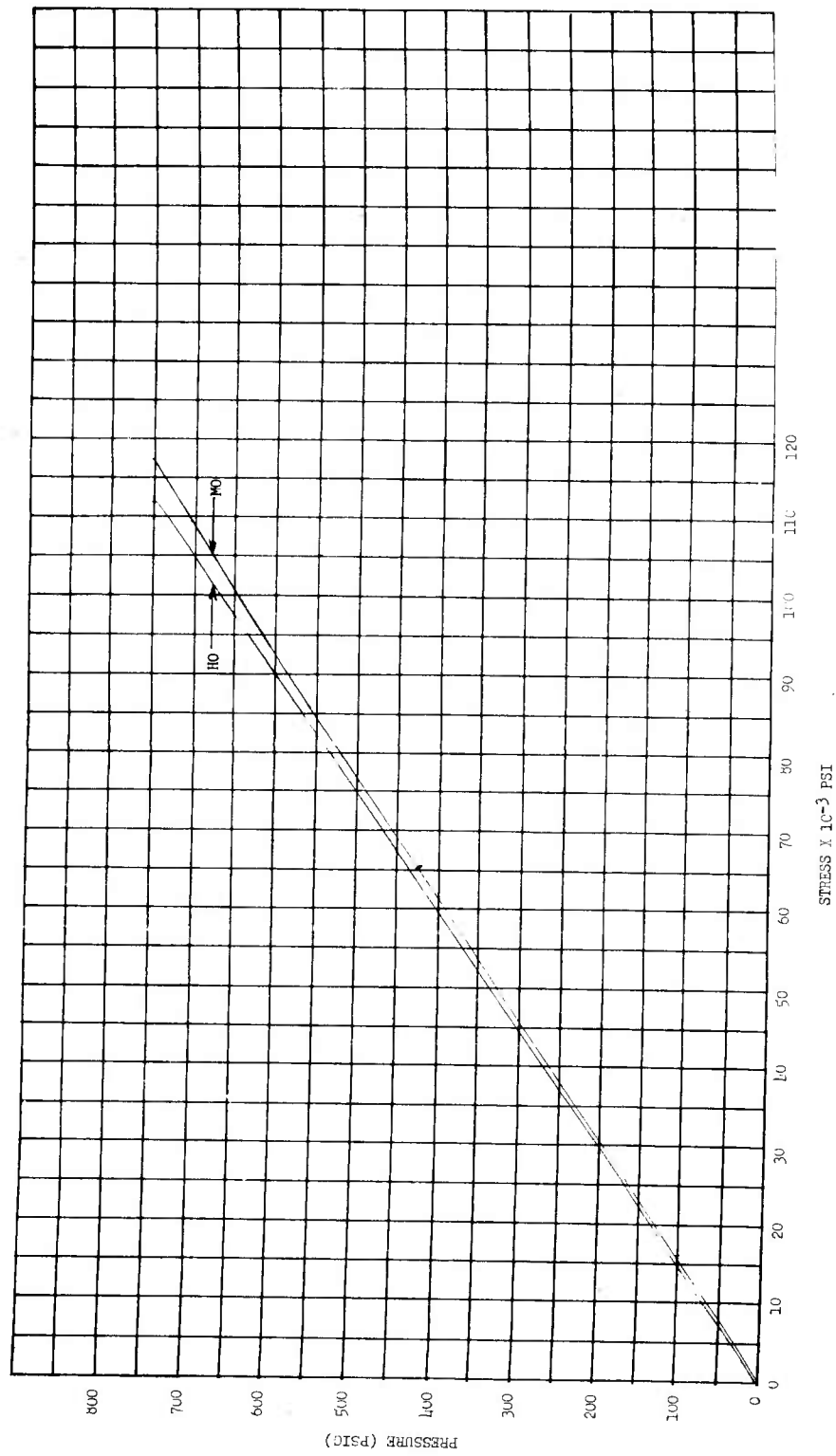
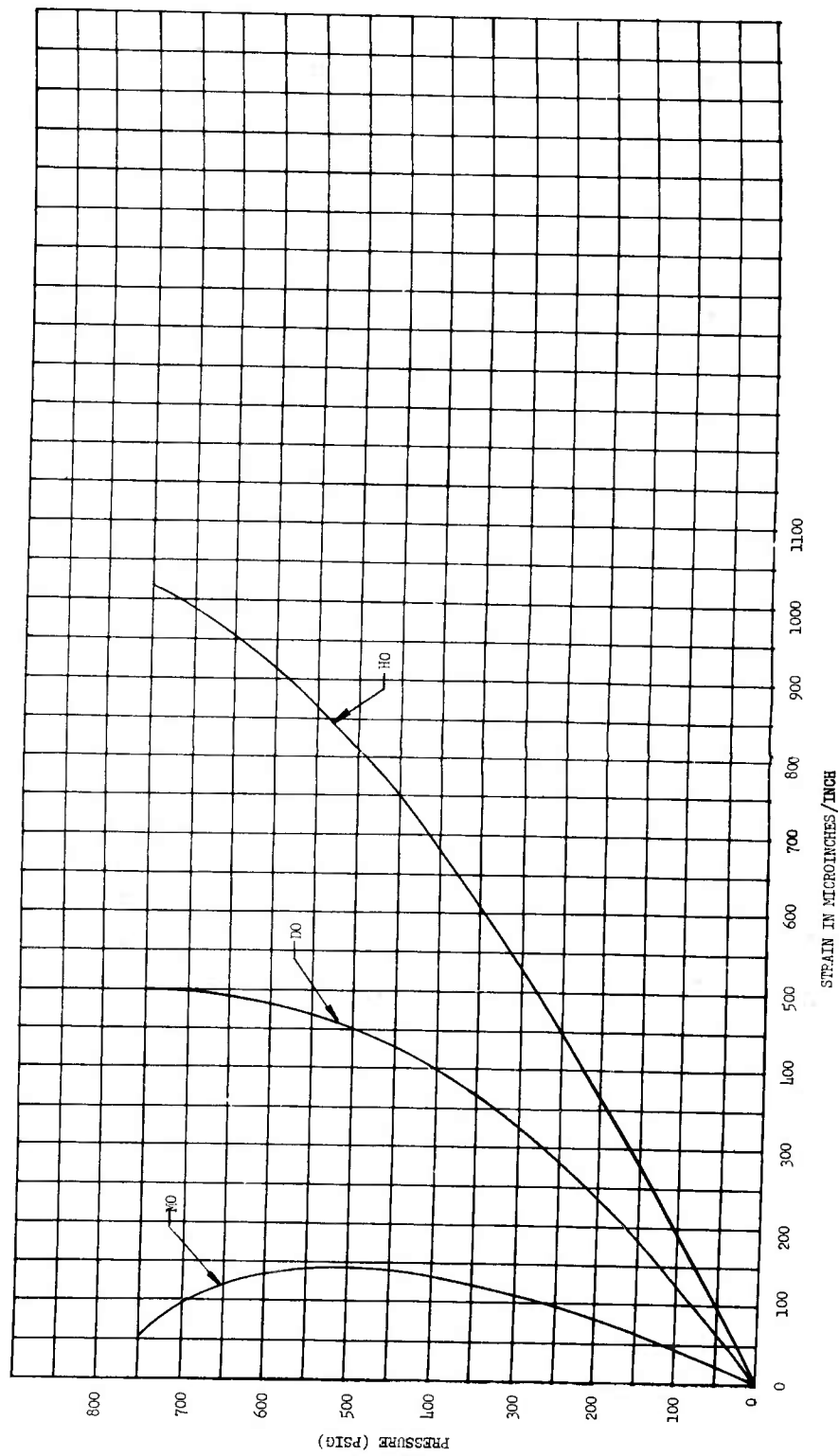


Figure 24

Pressure vs Stress, Gage Point 90

Appendix E



Pressure vs Strain, Gage Point 91

Figure 25

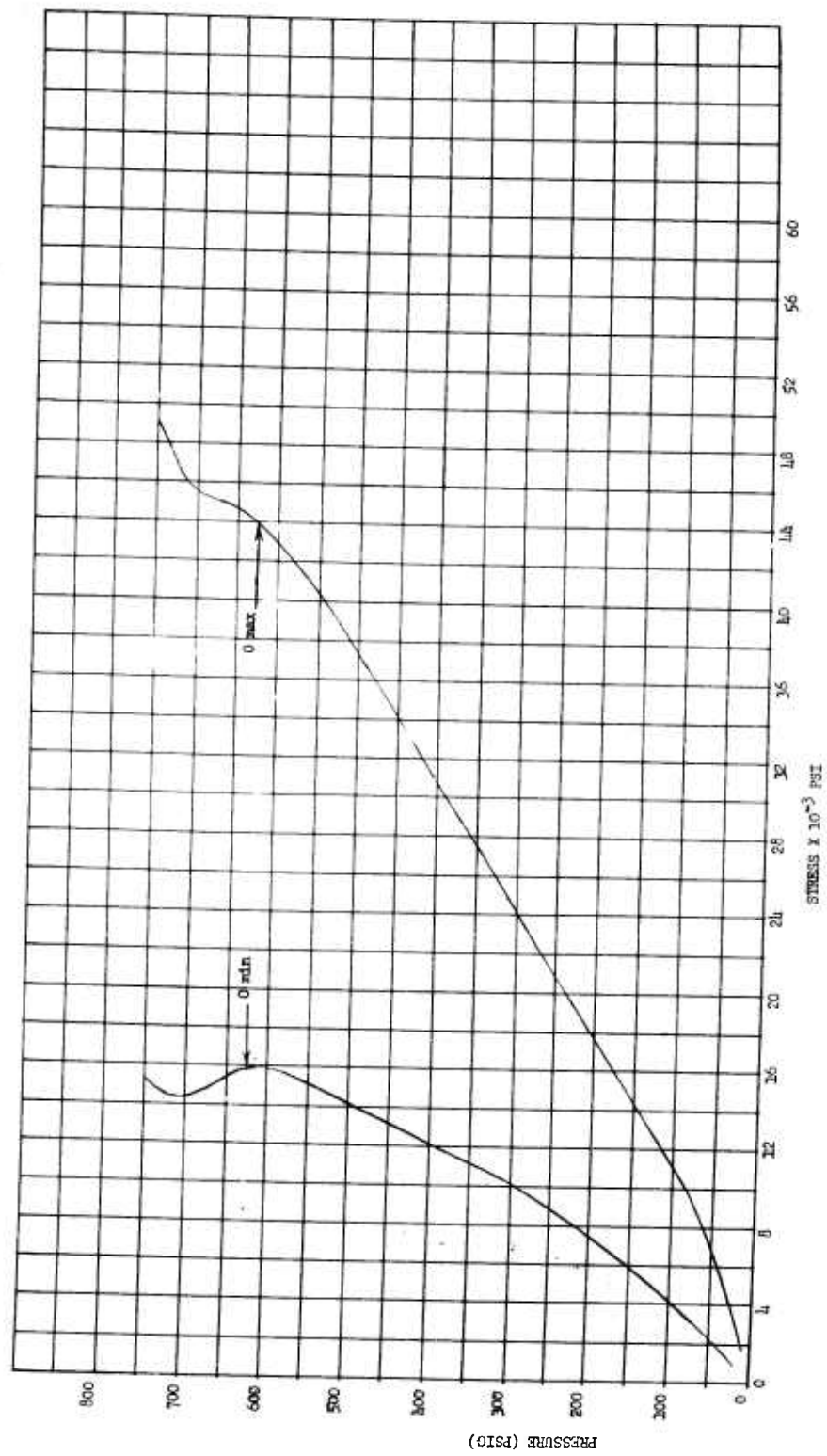


Figure 26

Pressure vs Stress, Gage Point 91

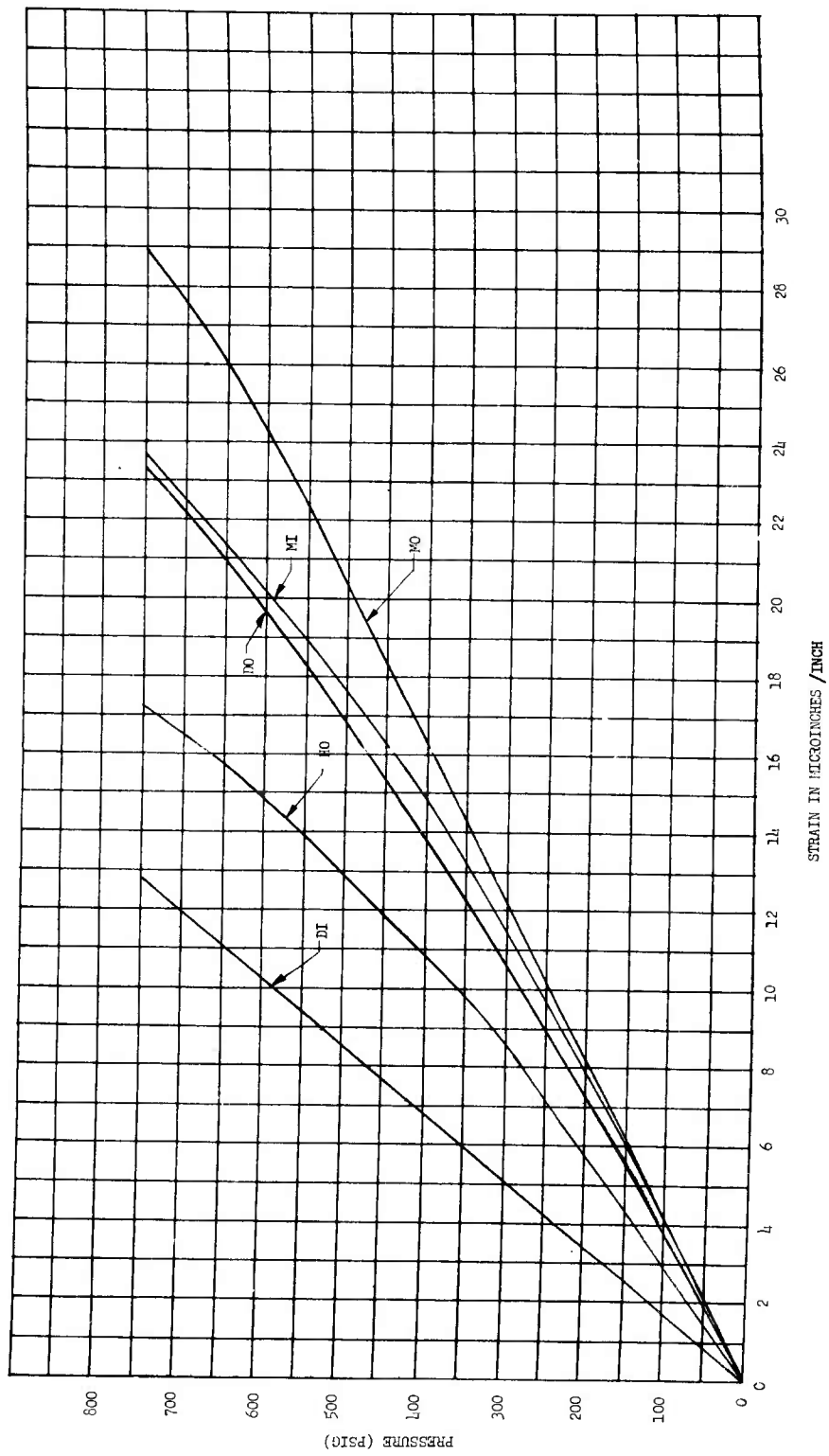
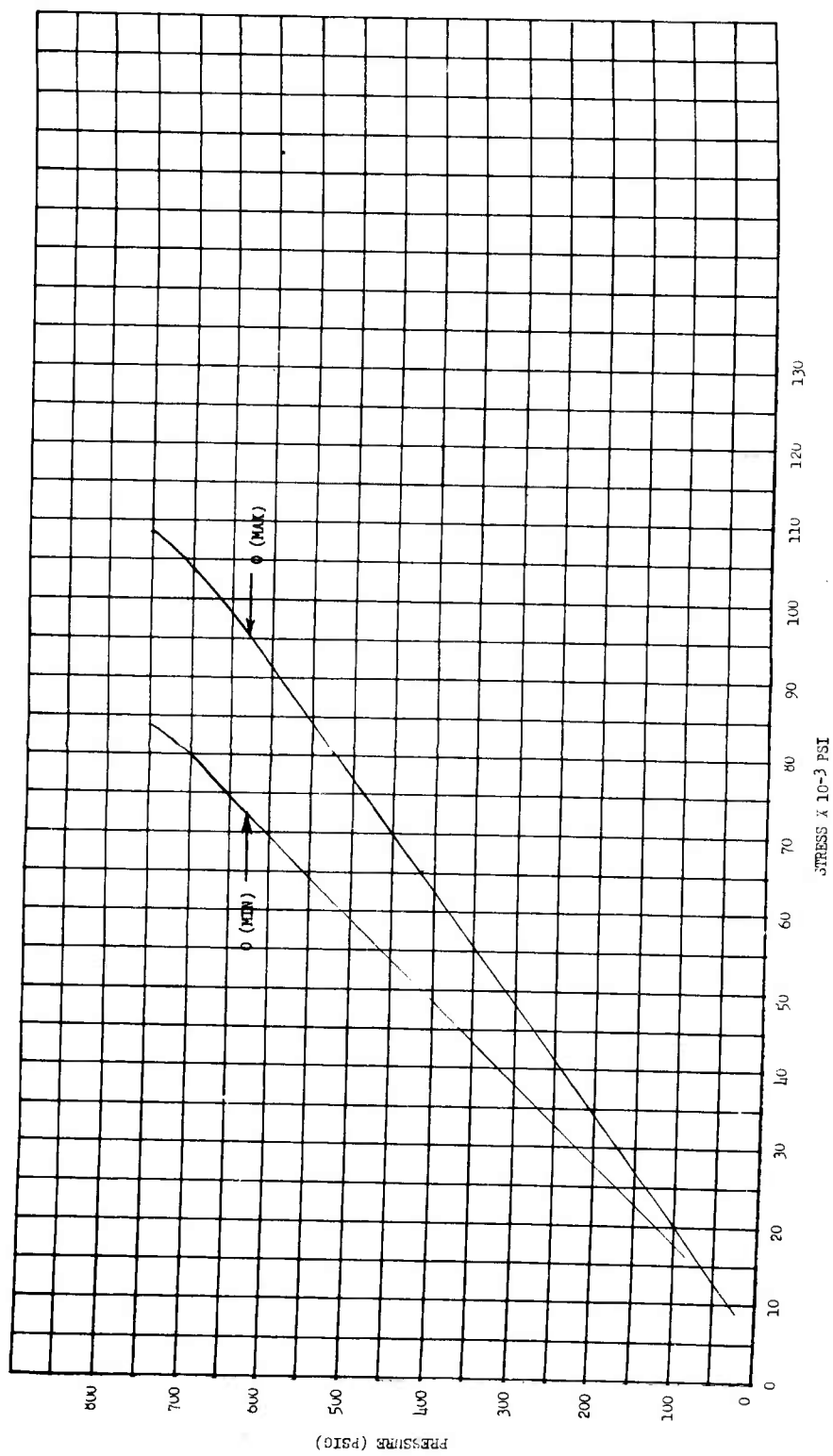


Figure 27

Pressure vs Strain, Gage Point 92



Pressure vs Stress, Gage Point 92

Figure 28

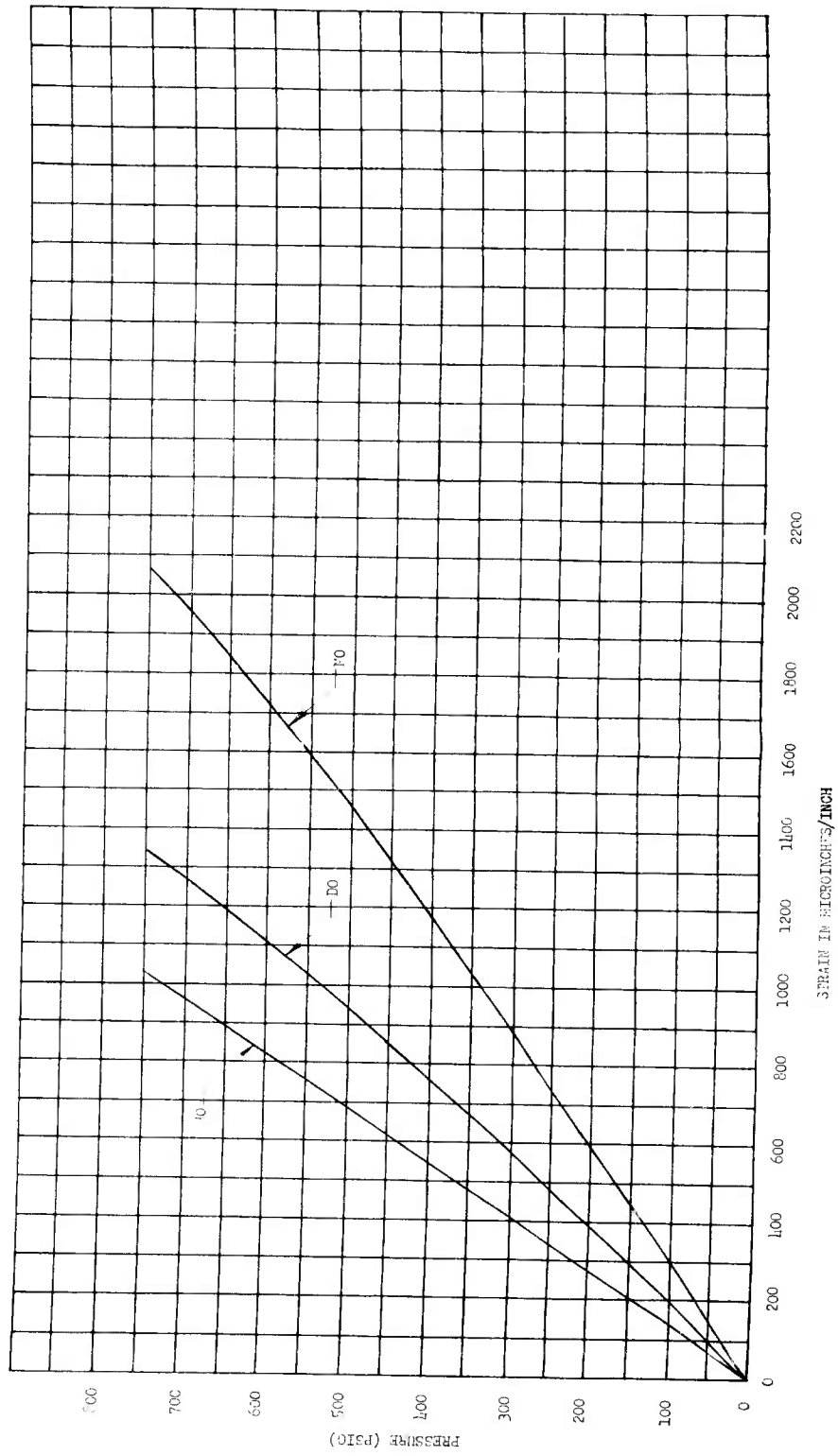


Figure 29

Pressure vs Strain, Gage Point 93

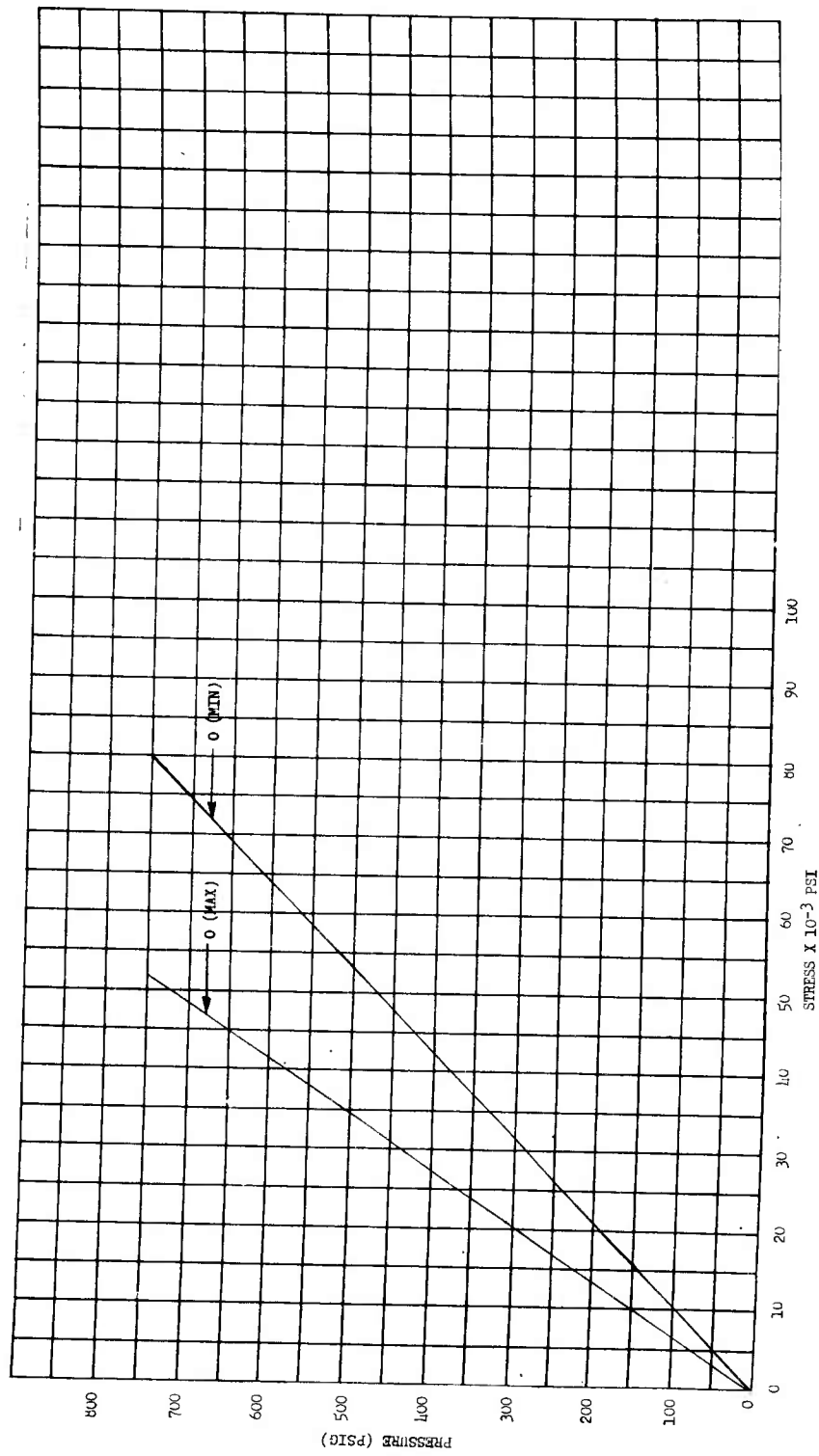
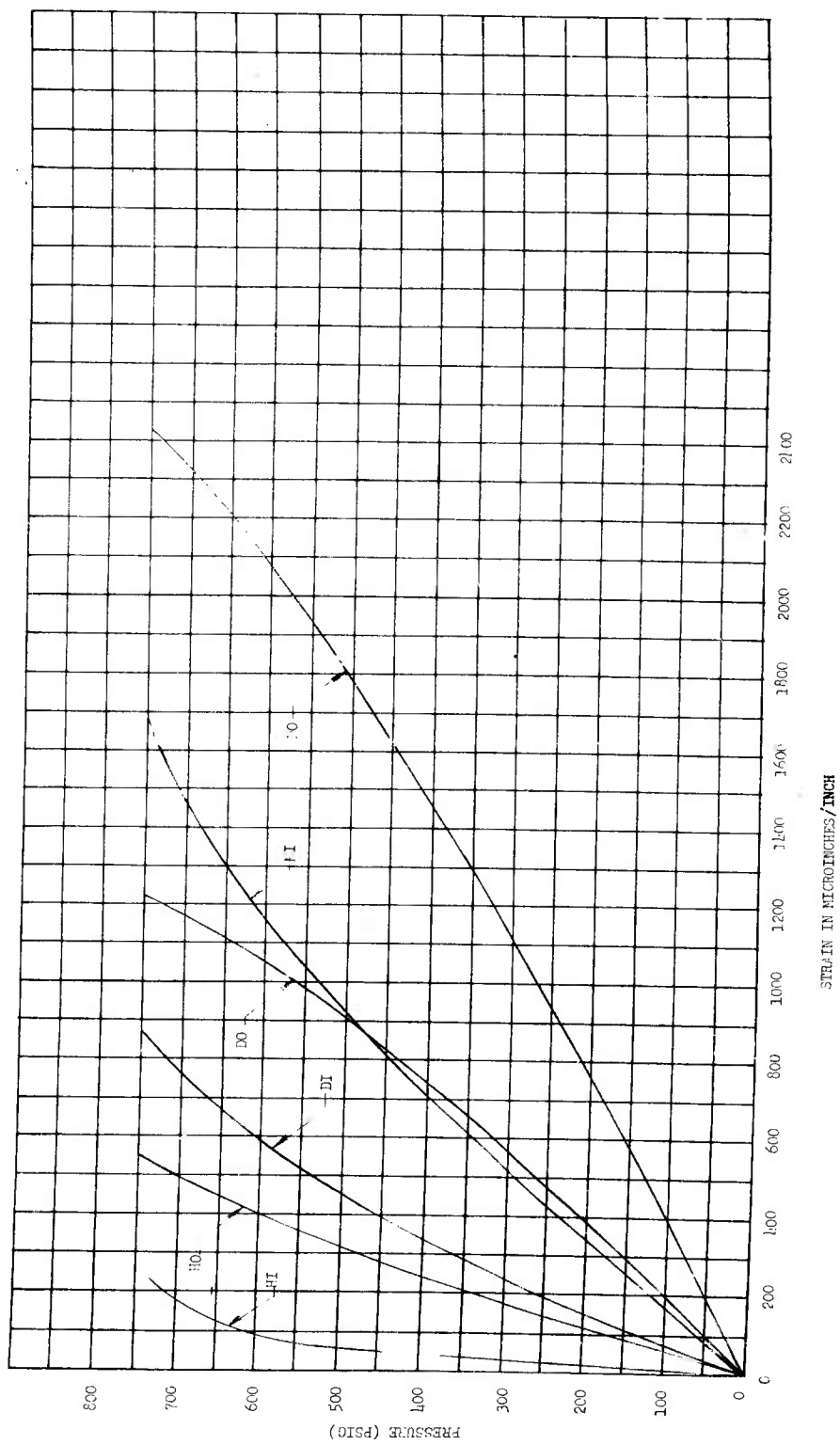


Figure 30

Pressure vs Stress, Gage Point 93



Pressure vs Strain, Gage Point 94

Figure 31

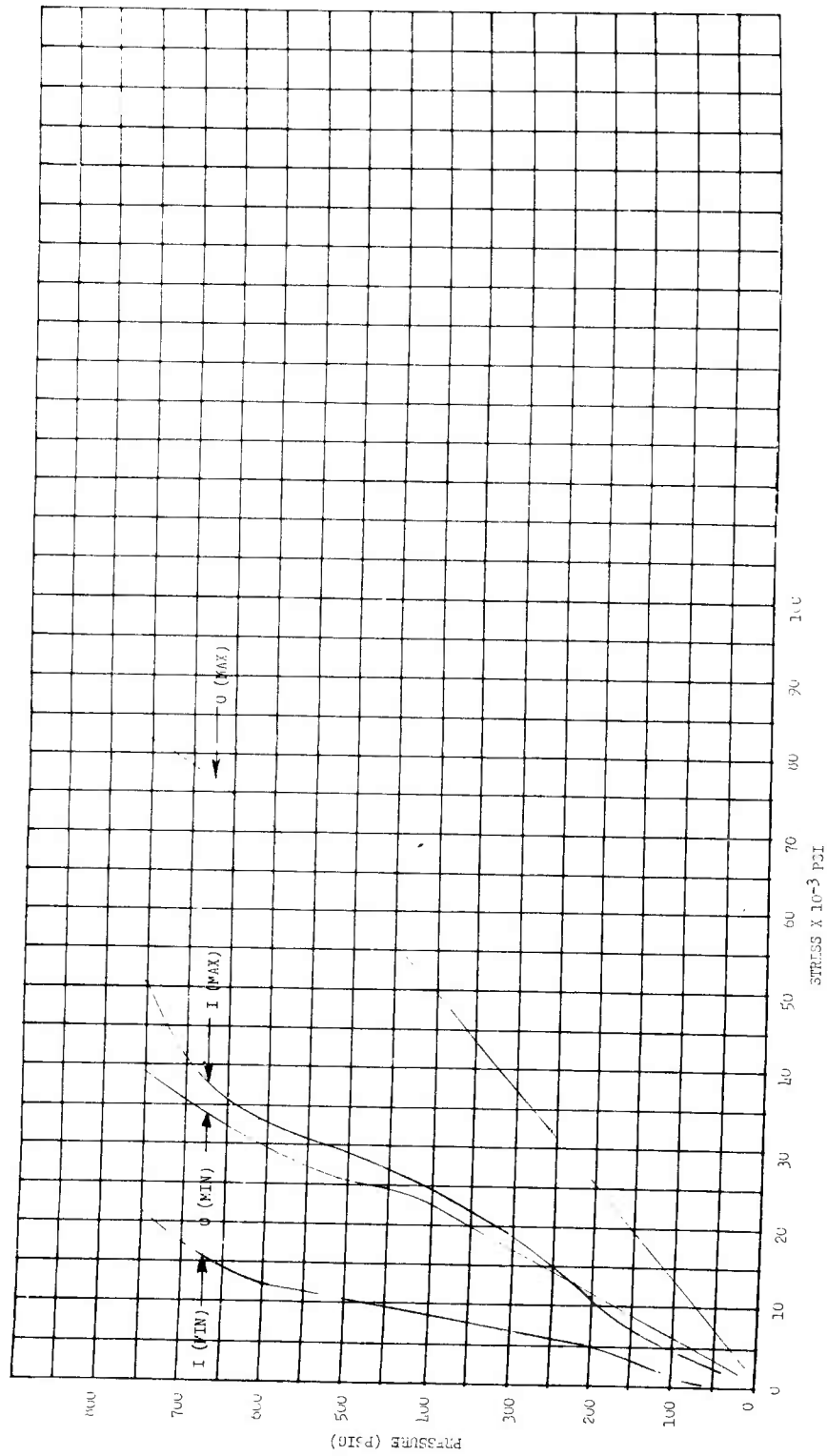
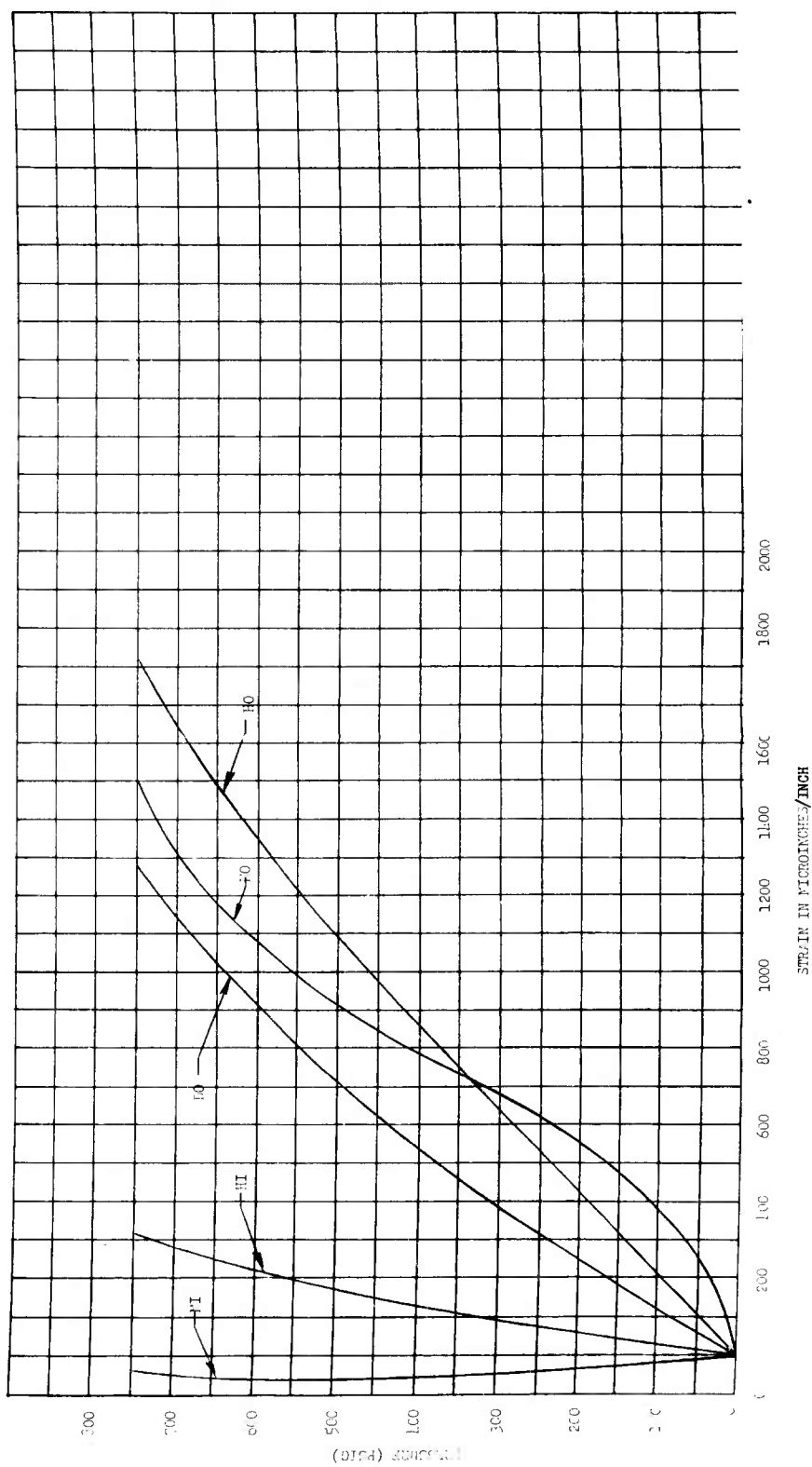


Figure 32

Pressure vs Stress, Gage Point 94

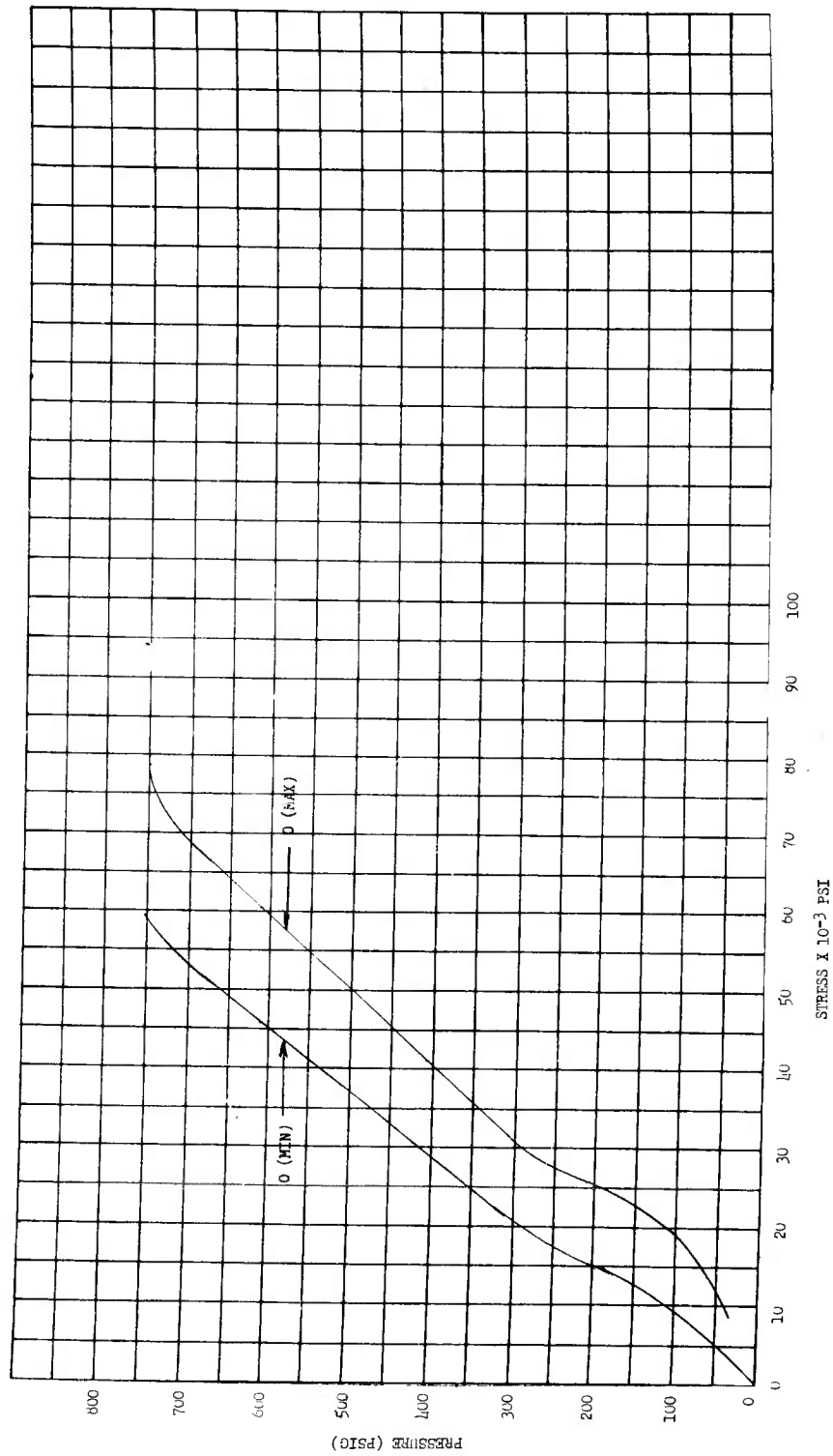
Appendix E



Pressure vs Strain, Gage Point 95

Figure 33

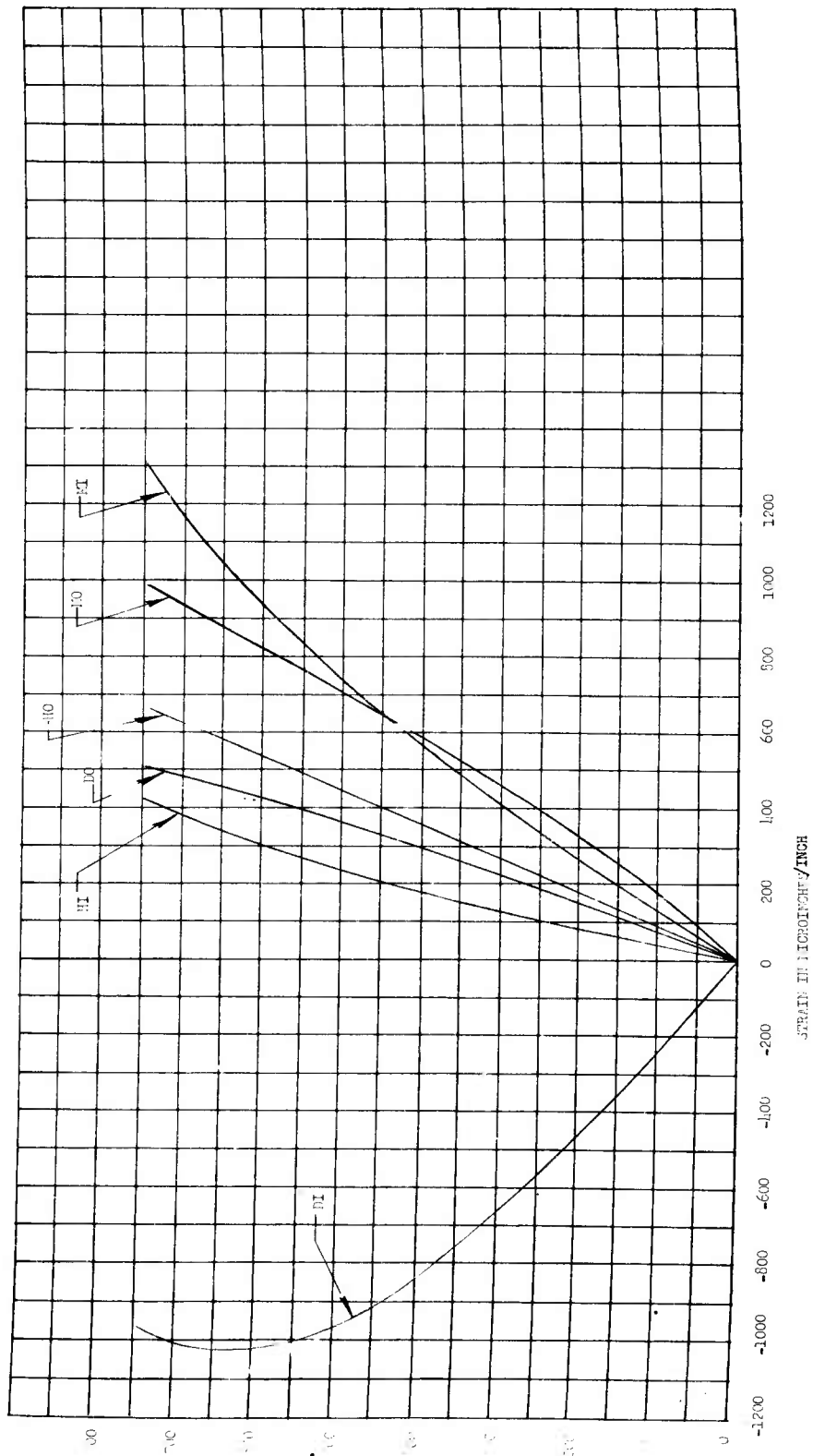
Appendix E



Pressure vs Stress, Gage Point 95

Figure 34

Appendix E



Pressure vs Strain, Gage Point 96

Figure 35

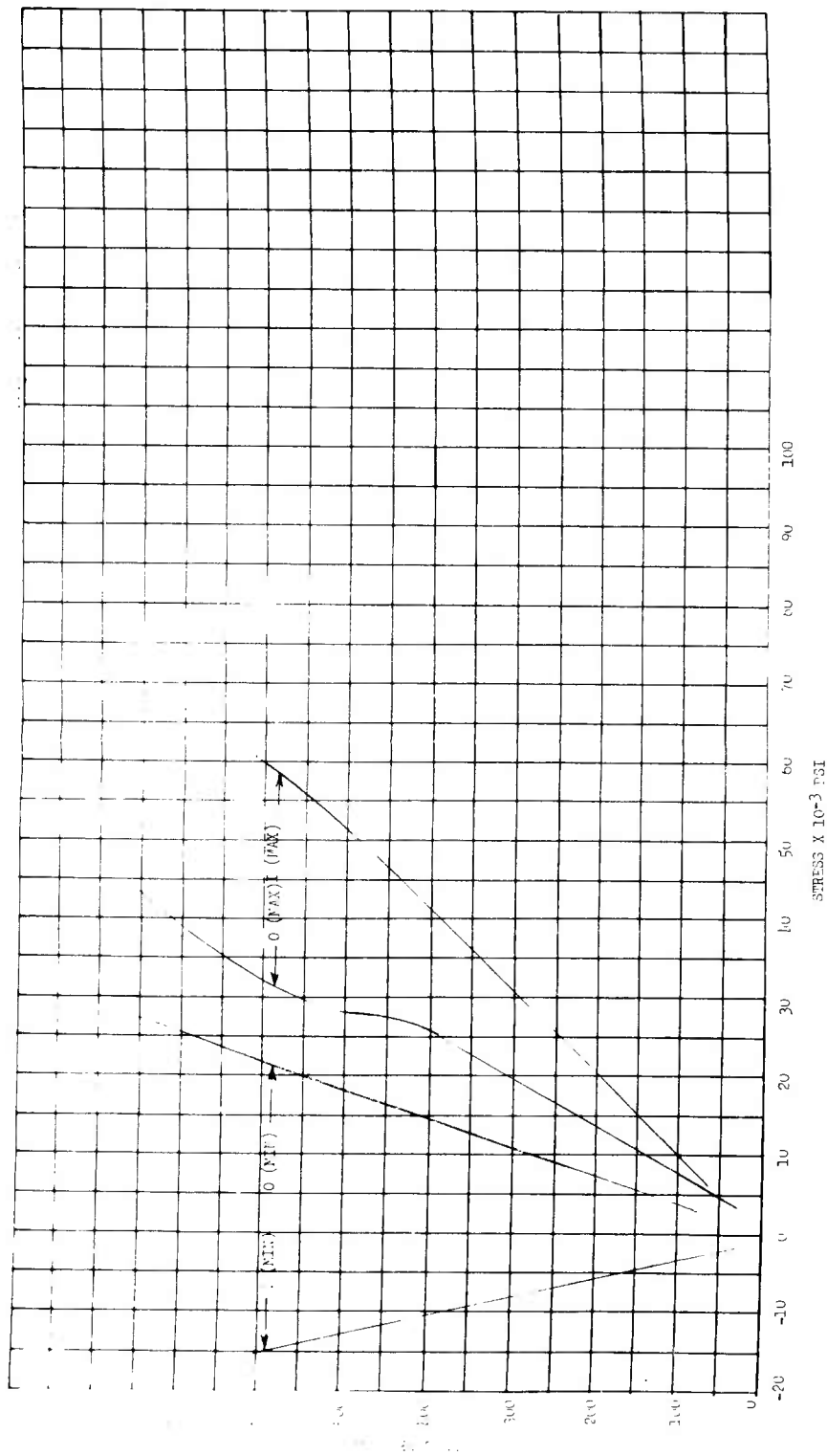


Figure 36

Pressure vs Stress, Gage Point 96

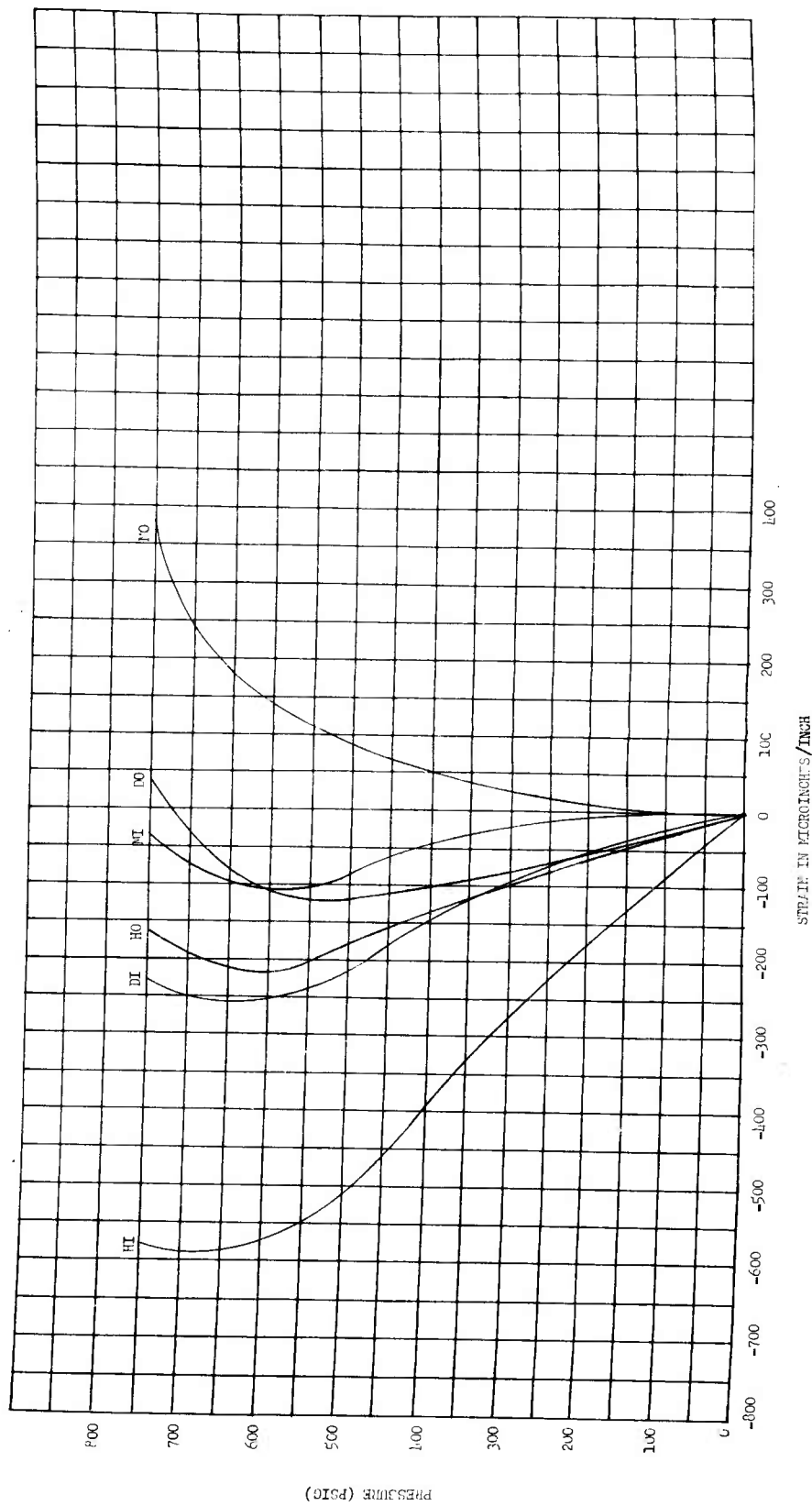
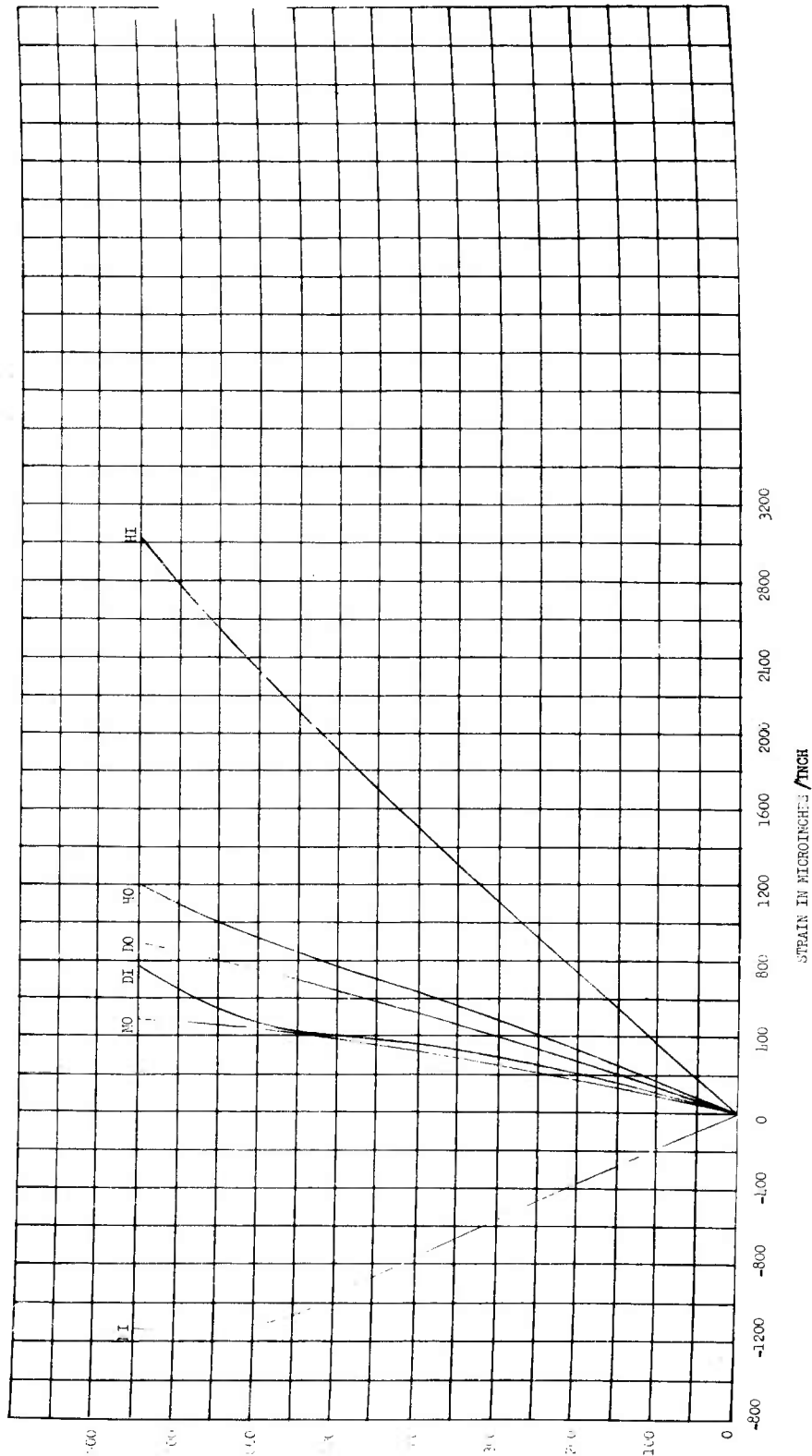


Figure 37

Pressure vs Strain, Gage Point 97



Pressure vs Strain, Gage Point 98

Figure 38

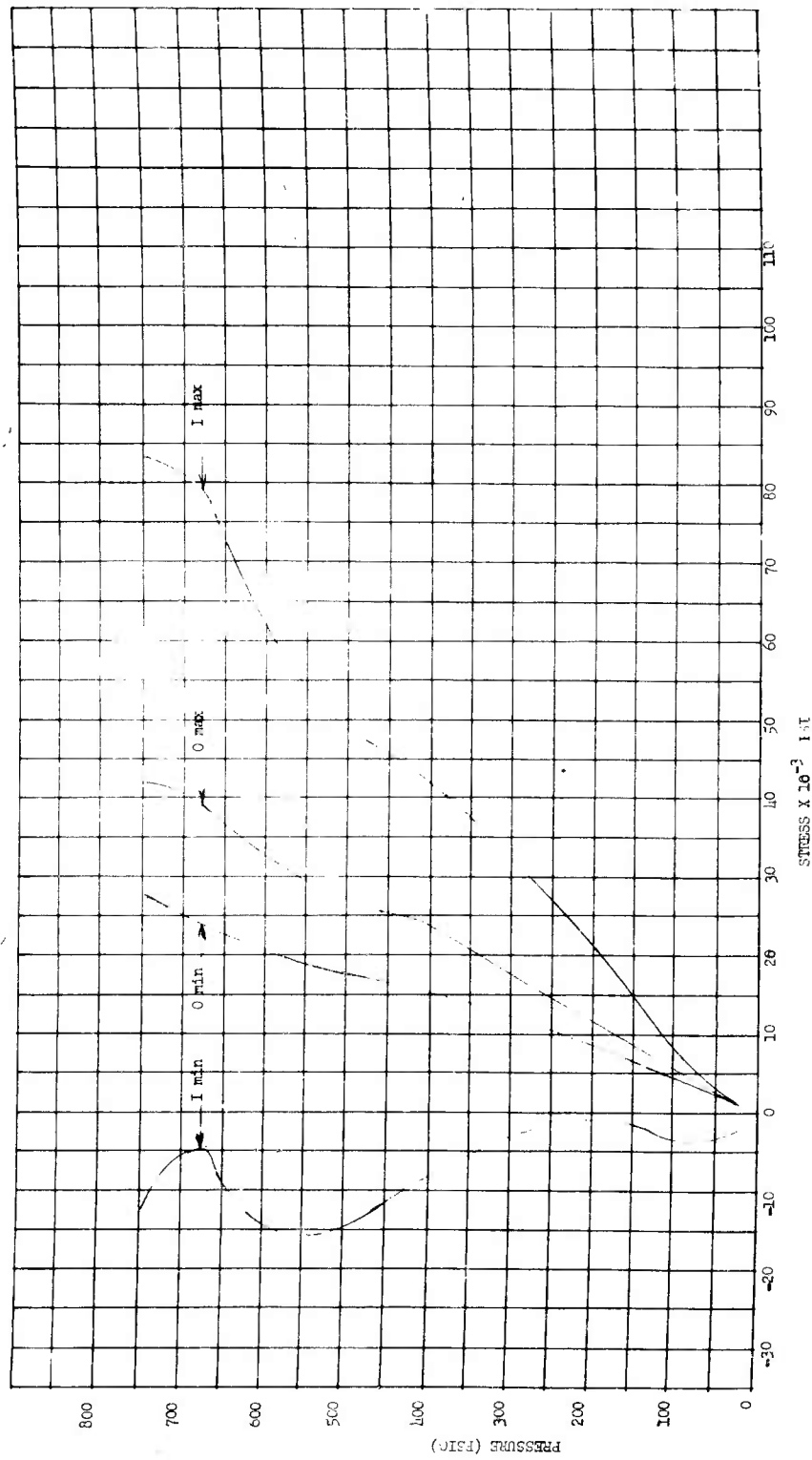


Figure 39

Pressure vs Stress, Gage Point 98