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A FOUR POINT BENDING EXPERIMENT

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This report presents data obtained in a four point bend experiment on a 105 mm M68 rotary forged gun tube. The four point bending was accomplished using a standard hydraulic straightening press fitted with a two point loading device designed and fabricated by the Benet Weapons Laboratory Engineering Support Branch. Strains were measured at several points on the surface in a circumferential plane using standard foil type resistance gages and standard strain
(CONT'D ON REVERSE)

20. ABSTRACT (CONT'D)

readout equipment. Deflections at mid-span were measured with a rotary ten turn potentiometer. Load strain and load deflection curves are presented and compared with theory. The agreement is quite good. The difference between theory and experiment probably can be attributed to the larger diameter of the tube nearer the breech end which could contribute to greater stiffness. Maximum strains were less than 1.4 percent and are quite low compared to those expected in three point bending. The experiment shows a good possibility of using four point bending to eliminate the need for hot straightening.

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ACKNOWLEDGMENTS

Appreciation is extended to Leo Szymanski and W. Wiley in carrying out the experiment.

INTRODUCTION AND OBJECTIVE

Gun tube forgings are presently straightened using a three point bending method. Forgings which do not exceed an established straightness criteria are straightened cold. Tubes exceeding the criteria are straightened hot in order to prevent excessive inelastic straining of the gun tube material. The requirement for the costly and time consuming hot straightening process can be obviated if a straightening method is incorporated which reduces the magnitude of strain during the straightening process.

Theoretical calculations show that the magnitude of strains can be reduced by a factor of two or more when a four point bending method is employed.[1] This experiment was performed to compare the theoretical strain to the actual measured strain in a 105 mm M68 gun tube forging during press straightening using a four point bending procedure. The four point bending was accomplished with a hydraulic press fitted with a two point loading device, which was designed and fabricated by the Engineering Support Branch of Benet Weapons Laboratory.

EXPERIMENTAL BACKGROUND AND PROCEDURE

A 105 mm M68 rotary forged gun tube forging #2160 was selected for straightening. This tube was selected primarily because it possessed a singular large bow. Figure 1 shows a profile of the major bow showing the deviation from straightness as measured by deflection (bow) and total

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[1]Milligan, R. V., "A Comparison of Three Point and Four Point Loading in Elastic-Plastic Bending of Beams," ARRADCOM Technical Report, to be published.

indicator readings (TIR) as a function of length. The reported TIR values and corresponding clock positions are given in Table I.

The gun tube forging was straightened using a four point bending method. The four point bending was accomplished with a 1500 ton hydraulic press #WV11023 fitted with a two point loading device. The device has a load spacing of 20 inches as shown in Figure 2. The tube was positioned on the two tube supports as indicated in Figure 3. The support spacing was 11 feet. The two point load was situated midway between the two supports.

Deflection was measured at a point on the tube located midway between the two loading points. The deflection measuring equipment consisted of a dry cell battery, ten turn potentiometer with pulley, a voltmeter, music wire, lead weight, and a hose clamp. The weighted music wire was attached to the tube by means of a hose clamp. The wire was wrapped three times around the pulley attached to the potentiometer. The potentiometer was fixed relative to the tube so that as the tube deflected under load, the wire caused the pulley, and hence the potentiometer shaft, to rotate. The voltmeter was used to measure the variable voltage output. The deflection of the tube due to a given load was determined from the voltage change and the calibration curve shown in Figure 4.

The strain values measured during straightening were obtained from nine strain gages mounted on the O.D. surface of the tube. The gages were the FAE type having a 0.25 inch gage length, a resistance of 120 ohms, and a gage factor equal to 2.04. Eastman 910 adhesive was used to attach the gages to the tube surface. The strains were measured using a 10 channel switching and balancing unit, BLH Model 225, and a digital strain indicator, BLH Model 2000A.

TIR VALUES

105mm M68 TUBE SHOP #2160

Location from Breech End (ft)	Total Indicator Readings (TIR) (in)	Clock Position
4	.220	3
5	.260	3
6	.250	2
7	.300	1
8	.360	12
9	.530	12
10	.790 } .260	12
11	1.090 } .300	12
12	1.210	12
13	1.100	12
14	.790 } .310	12
15	.550	11
16	.400	10
17	.180	11

(Table I)

The strain gages were located in a vertical plane three inches from the deflection measurement location. The gages were mounted on one half the tube circumference as shown in Figure 5. After the gages were mounted on the tube, it was discovered that the 12 o'clock position stamped on the tube which was used to orient the gages was different from the TIR report 12 o'clock position. In order to compensate for the difference, the plane of bending changed by what amounted to a 45 degree clockwise rotation of the tube. Figure 6 shows the gage locations as they were finally oriented during pressing. The numbers adjacent to the gage numbers refer to the gage distances to the neutral axis.

The straightening loads applied to the tube by the hydraulic press were measured indirectly by a 1500 psi max. pressure gage. The pressure gage had a sensitivity of ± 10 psi. The total loads were determined by the product of the hydraulic pressure reading and the press cylinder area, 1256 square inches, plus the dead weight of the press ram estimated at seven tons.

RESULTS AND DISCUSSION

The strain and deflection data recorded during press straightening of the tube forging are shown in Tables II and III respectively. Note that the maximum strain measured (gage 8) was slightly less than 1.4 percent strain. The maximum permanent deflection measured was 1.05 inches. A discrepancy between the strain and deflection data exists. No permanent strain was detected after the 82.4 ton load was released, but a 0.25 inch permanent deflection was recorded. The permanent deflection is most likely in error due to slippage of the weighted wire relative to the tube and clamp. The wire was reattached and the voltage rezeroed at this point for subsequent readings.

STRAIN DATA

(Table II)

Pressure Gage (psi)	Total Load (tons)	Load "P" (kips)	Strain ($x10^{-5}$ in/in)								
			G1	G2	G3	G4	G5	G6	G7	G8	G9
0	0.0	0.0	+12	+7	+4	+1	−3	−3	−4	−4	−2
50	38.4	38.4	+231	−2	−122	−173	−218	−254	−281	−313	−226
90	63.5	63.5	+298	−15	−173	−239	−298	−344	−379	−417	−294
100	69.8	69.8	+343	−17	−199	−275	−342	−396	−436	−479	−340
110	76.1	76.1	+372	−18	−215	−299	−370	−429	−472	−520	−369
120	82.4	82.4	+407	−19	−236	−325	−406	−470	−518	−570	−406
0	PR	PR	+8	+7	+5	+3	−2	−2	−2	−2	+2
130	88.7	88.7	+407	−31	−232	−344	−426	−491	−540	−593	−422
145	98.1	98.1	+461	−34	−283	−388	−482	−556	−614	−674	−479
150	101.2	101.2	+483	−35	−327	−407	−505	−584	−644	−707	−503
160	107.5	107.5	+550	−40	−340	−466	−581	−670	−741	−811	−582
170	113.8	113.8	+603	−46	−378	−517	−646	−743	−822	−899	−648
0	PR	PR	+74	−12	−57	−77	−99	−111	−124	−131	−95
160	107.5	107.5	+594	−62	−389	−524	−647	−803	−878	−890	−632
170	113.8	113.8	+612	−64	−402	−540	−668	−828	−905	−919	−652
180	120.1	120.1	+636	−68	−420	−565	−678	−861	−942	−958	−681
190	126.4	126.4	+759	−88	−543	−689	−850	−1034	−1133	−1164	−835
200	132.7	132.7	+872	−109	−602	−807	−994	−1196	−1311	−1356	−980
0	PR	PR	+272	−49	−209	−277	−342	−448	−489	−459	−341

PR – Pressure Released

DEFLECTION DATA

(Table III)

Force "P" (kips)	Voltage (volts)	Deflection (inches)
0.0	0.00	0.00
38.4	0.88	1.71
63.5	1.12	2.17
69.8	1.26	2.45
76.1	1.35	2.62
82.4	1.47	2.85
Pressure Released	0.13	0.25 *
88.7	1.39	2.70
95.1	1.58	3.07
101.2	1.65	3.20
107.5	1.96	3.61
113.8	2.01	3.90
Pressure Released	0.12	0.23
107.5	1.92	3.73
113.8	1.98	3.84
120.1	2.04	3.96
126.4	2.32	4.50
132.7	2.57	4.99
Pressure Released	0.54	1.05

* Strain gage readings at this point indicate no permanent strain hence no permanent deflection. The wire may have slipped relative to the tube. The voltage was rezeroed at this point.

Plots of strain vs. distance from the neutral axis for three different loads, corresponding to three different runs are shown in Figure 7. In addition, Figure 8 shows the residual or permanent strains after unloading vs. the distance from the neutral axis. Both plots verify the concept of planes remaining plane even after elastic/plastic deformation.

A comparison of the experimental and theoretical load vs. strain curves is shown in Figure 9. The difference in the elastic/plastic regime is most likely due to the fact that the theory is based on a tube with a constant cross section throughout the entire tube length, whereas the sketch in Figure 3 shows that the diameter was larger on the breech end of the tube.

The experimental and theoretical load vs. deflection curves are shown in Figure 10. The comparison shows that a greater load was required to produce a given deflection than theoretically predicted. Here again a stiffer tube, as was actually tested, would be expected to behave in this manner. Note that the first five data points are shown shifted 0.25 inch to the left. The fact that the five data points fall on the experimental curve further supports the belief that the wire slipped relative to the tube.

Figure 11 shows a comparison of the experimental and theoretical curves of strain vs. deflection. Again, the experimental strain for a given deflection is slightly greater than predicted, but generally is in good agreement with the theoretical calculations.

CONCLUSIONS AND RECOMMENDATIONS

1. The strains measured during straightening are in good agreement with theoretically predicted values. The slight difference is likely due to the non-uniform cross section which existed in the actual tube. The actual tube was in effect slightly stiffer than the assumed uniform diameter tube used for theoretical calculation.

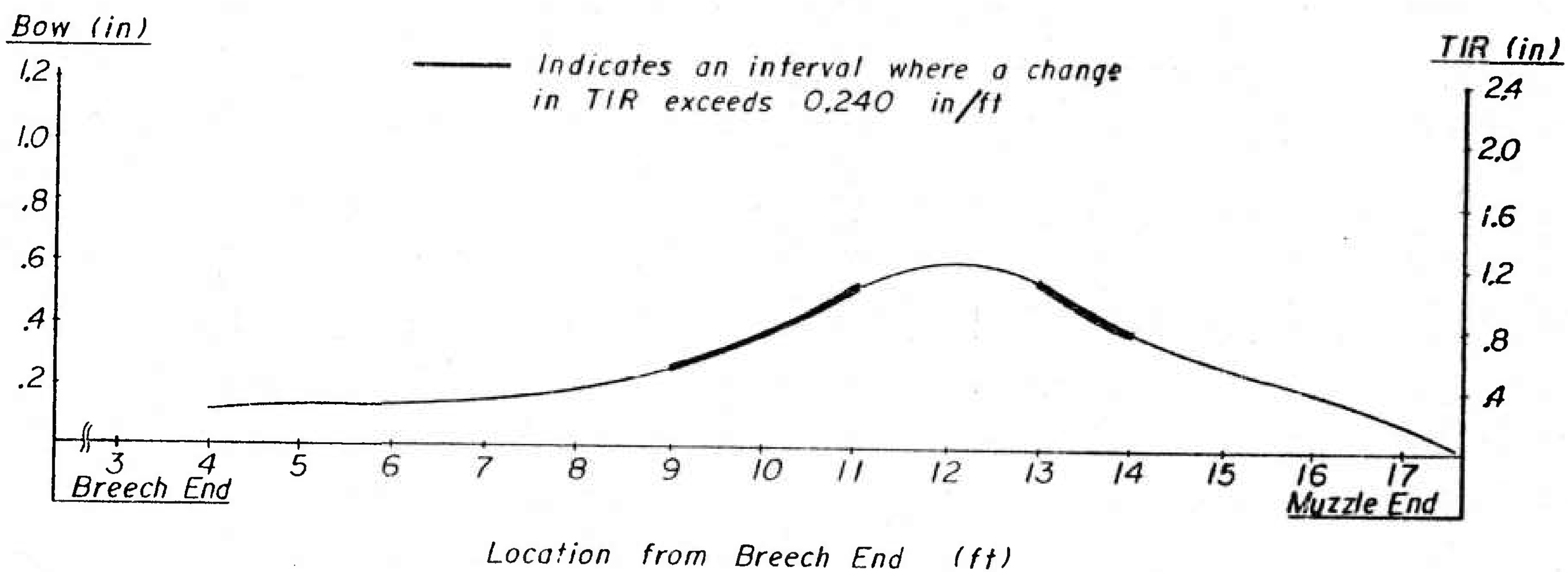
2. The maximum experimental strain was approximately 1.4 percent compared to a theoretical value of 1.2 percent based on a constant outside diameter tube in four point bending. Comparing this with the theoretical three point strain of 1.9 percent associated with removing the same amount of permanent deflection we would estimate that the maximum experimental strain for the same tube tested in three point bending would be 2.3 percent. This is nearly a factor of two larger.

3. The experiment shows a good possibility of using four point bending to eliminate the need for hot straightening.

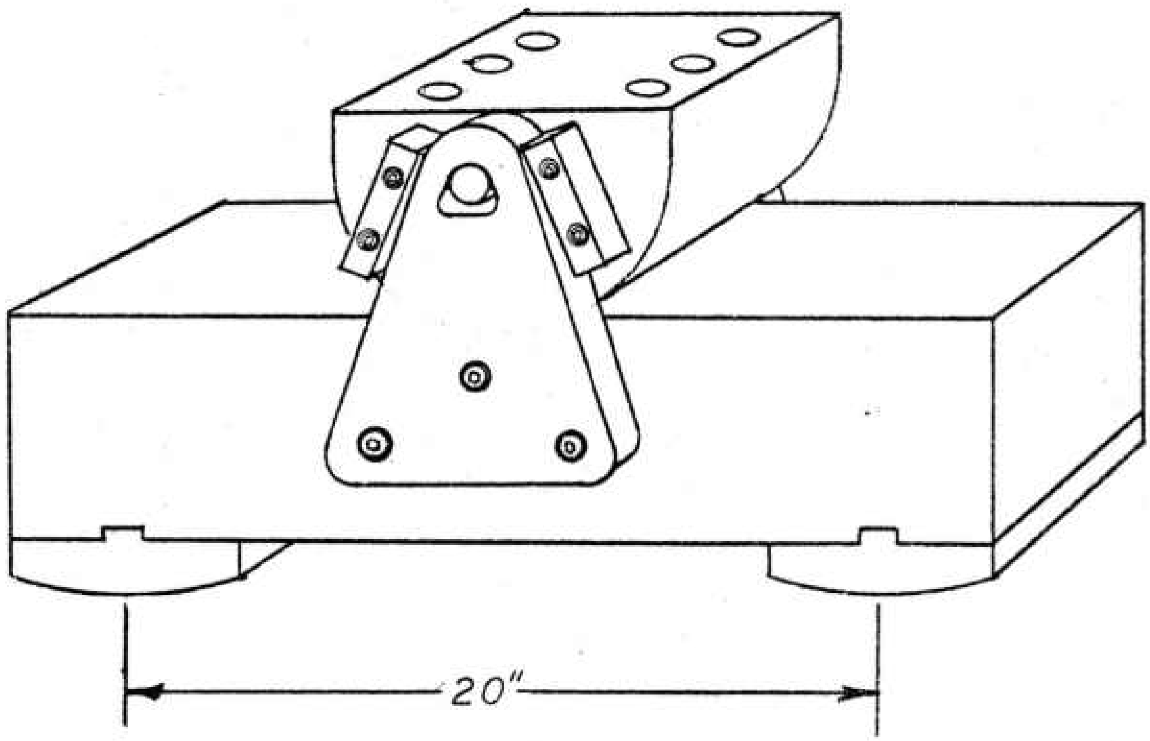
DEVIATION FROM STRAIGHTNESS

105 mm M68 TUBE SHOP #2160

(fig 1)



Note: This device bolts to the ram on the hydrolic press.

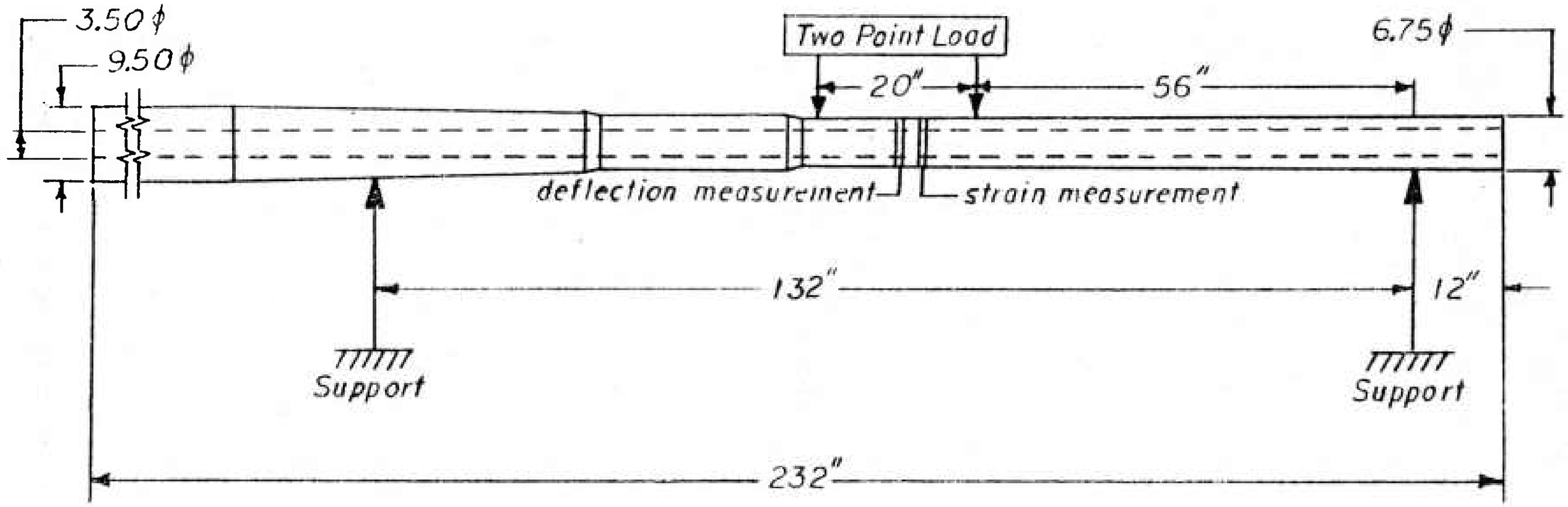


LOADING DEVICE

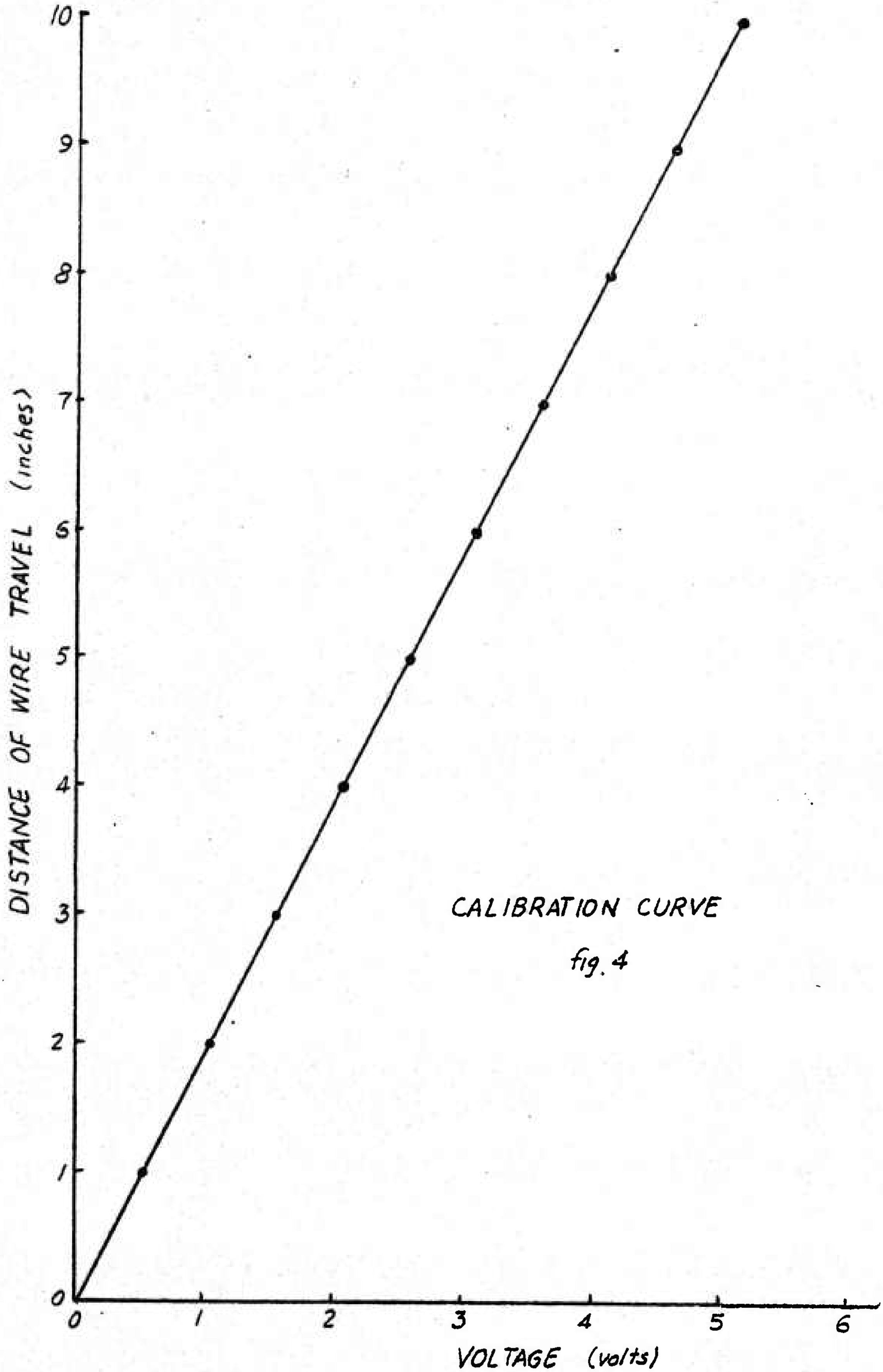
(fig 2)

LOCATION OF SUPPORTS & TWO POINT LOAD

105 mm M68 TUBE SHOP #2160



(fig 3)

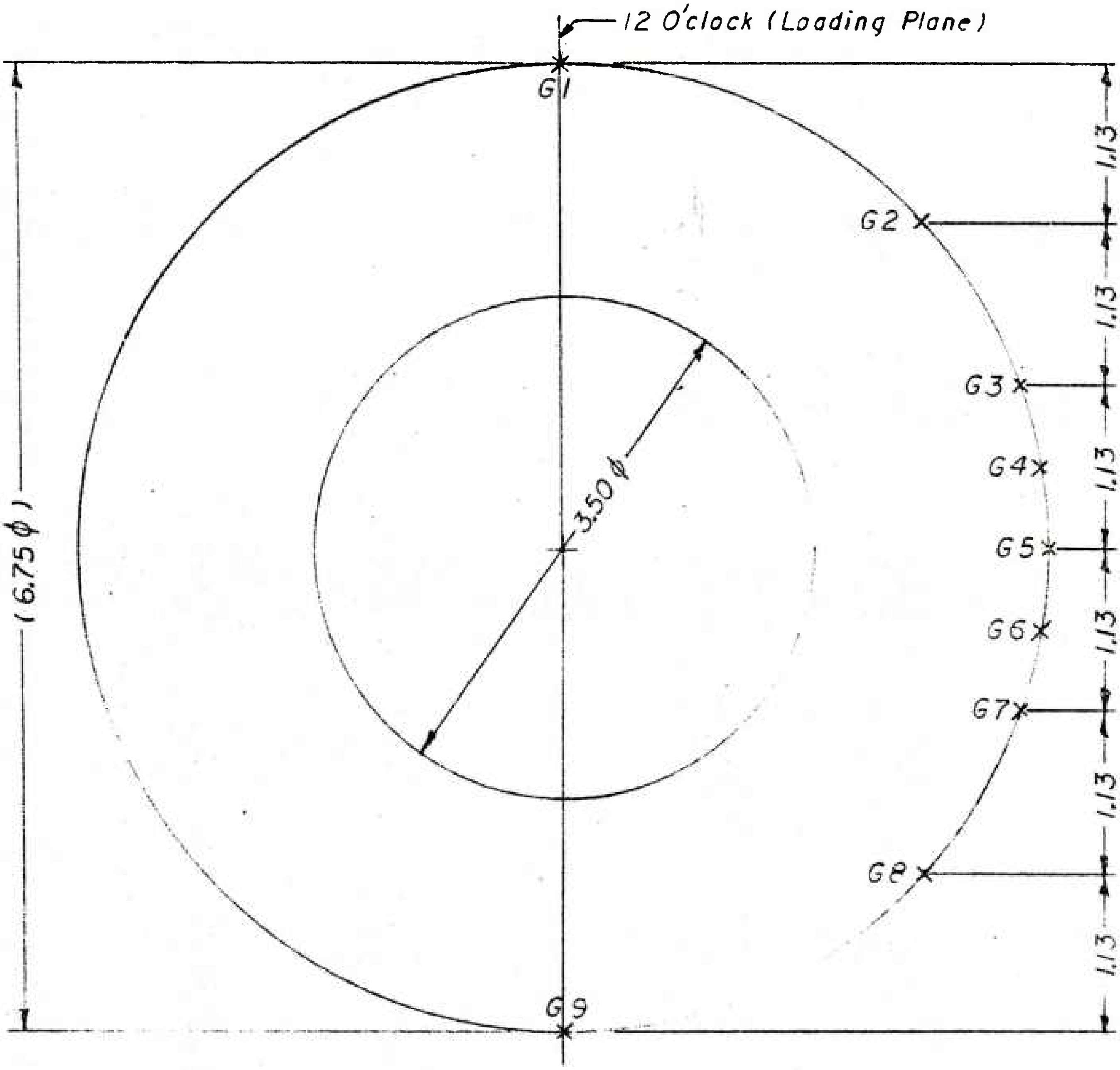


CALIBRATION CURVE

fig. 4

INITIAL GAGE LAYOUT

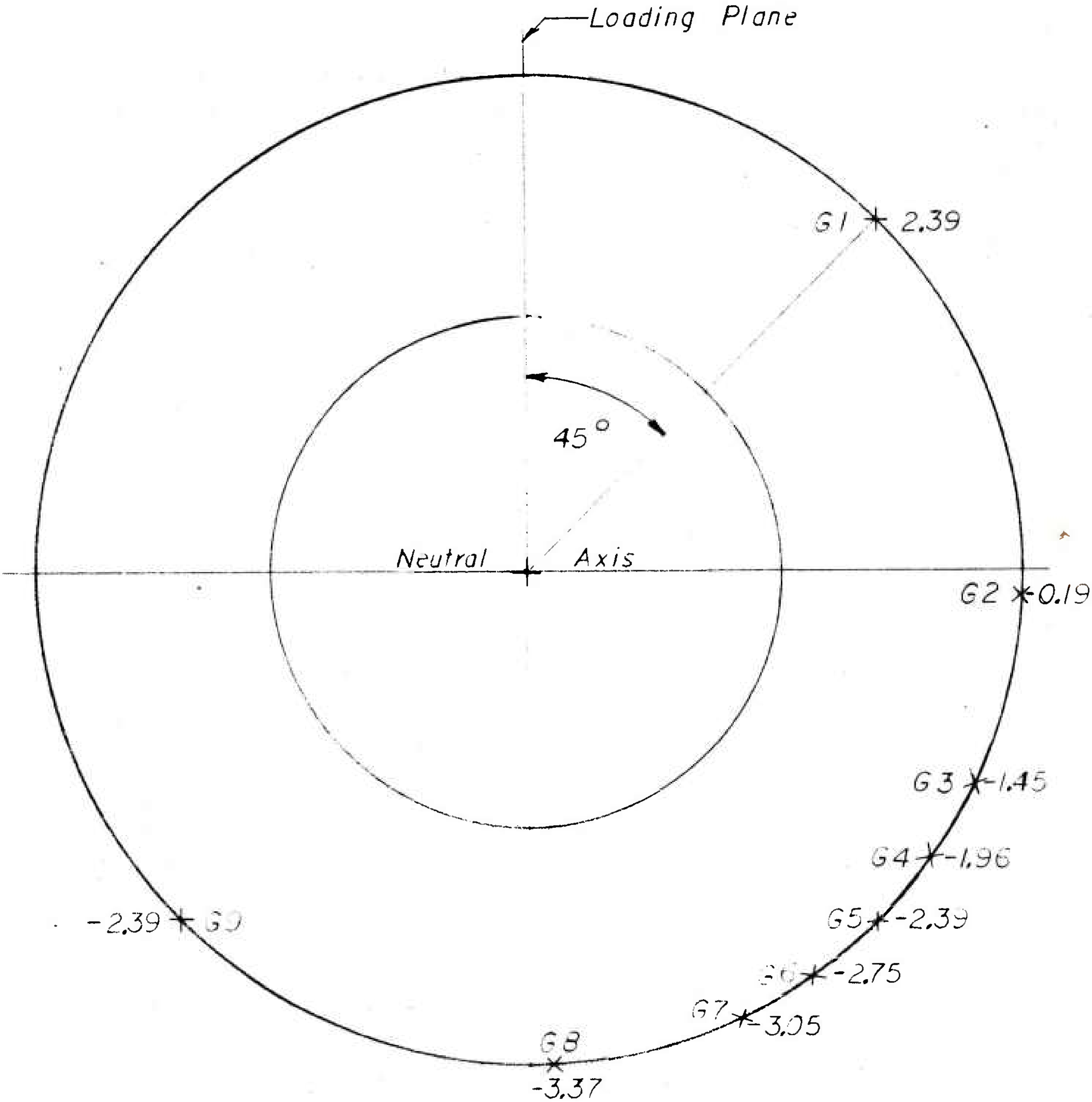
105 mm M68 TUBE SHOP # 2160



Section of Tube Located 157" from Breech End

(fig 5)

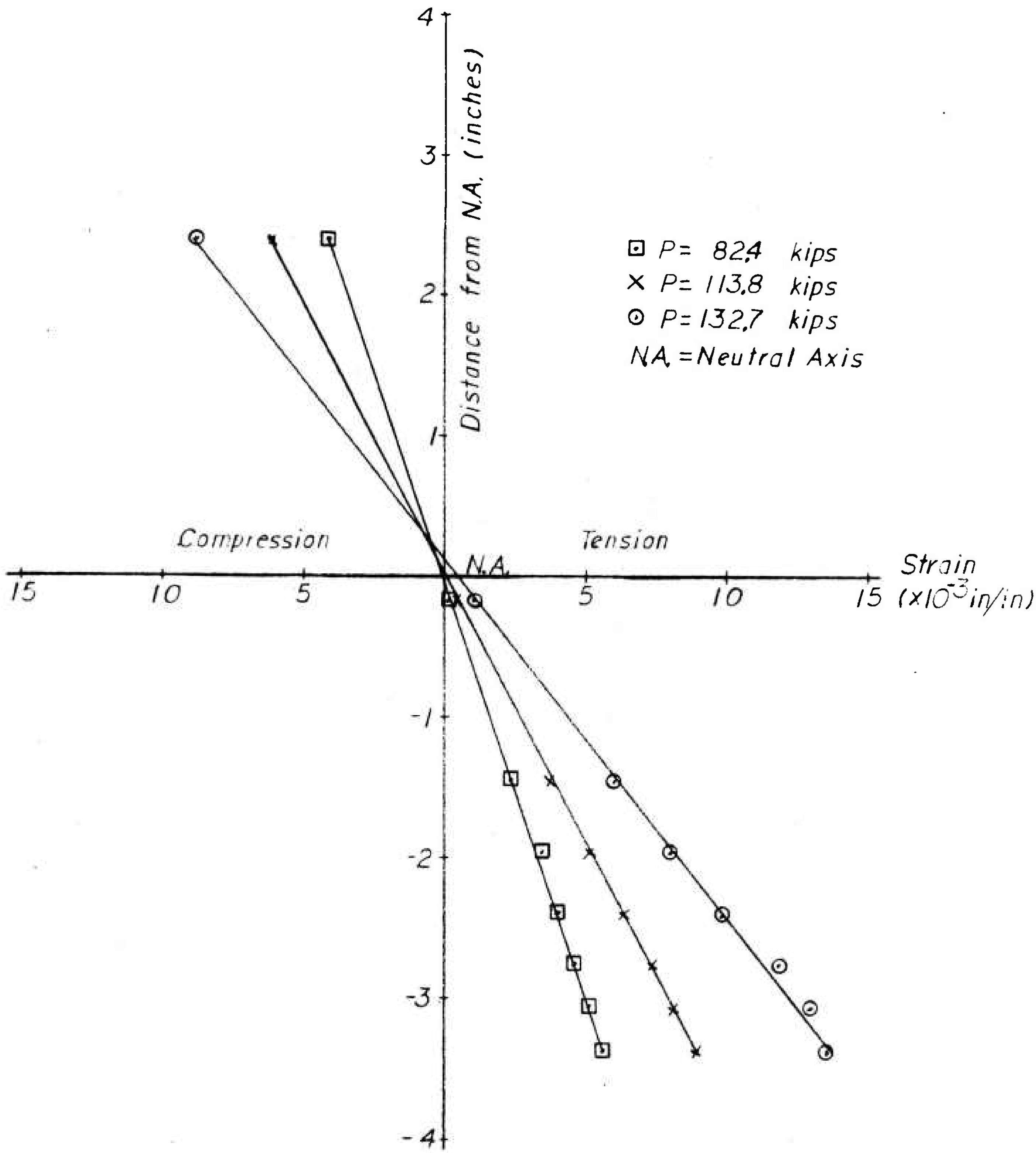
GAGE LOCATIONS AFTER 45° SHIFT



Section of Tube Located 157" from Breech End

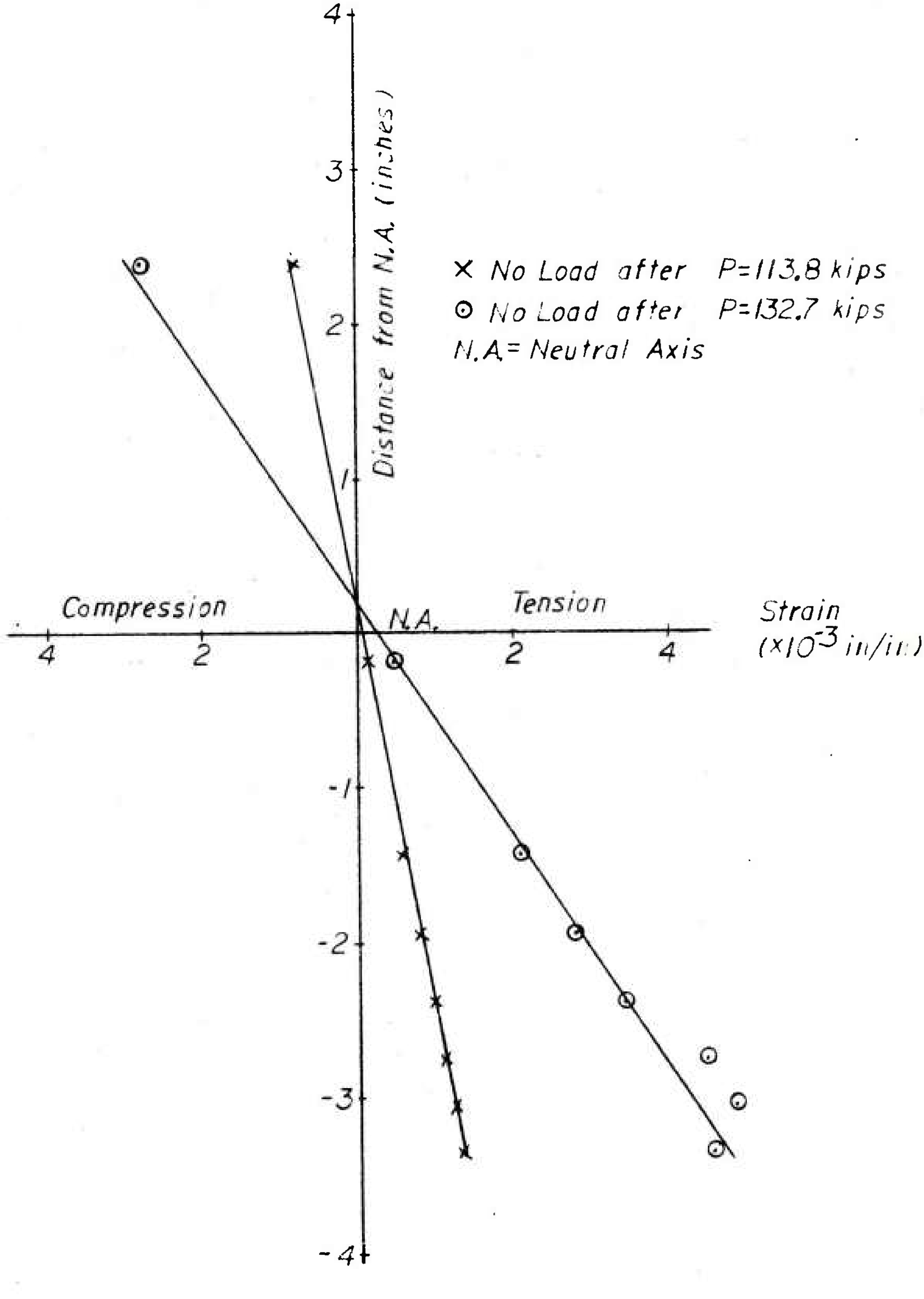
(fig 6)

STRAIN vs DISTANCE FROM N.A.



(fig 7)

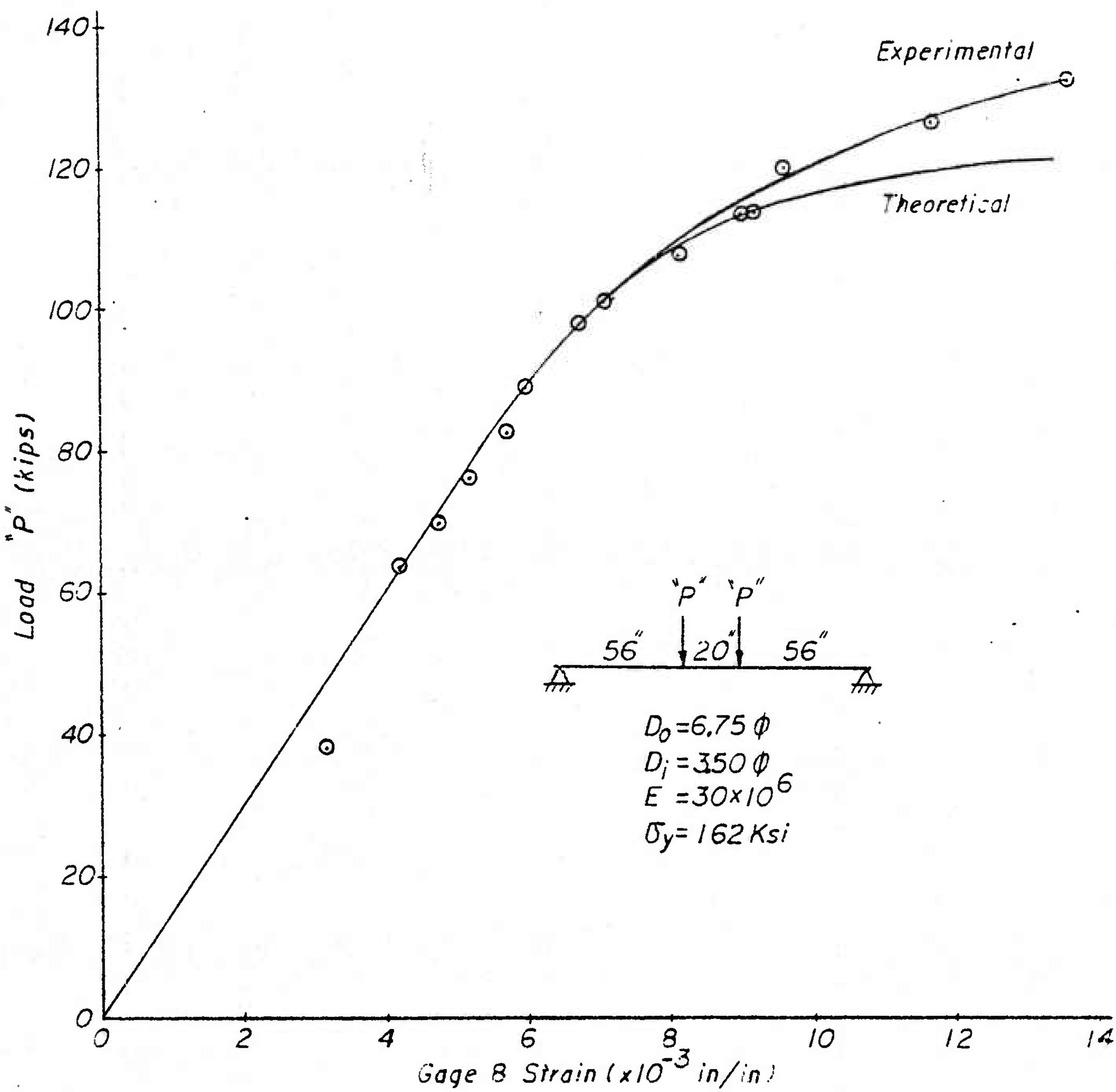
PERMANENT STRAIN vs DISTANCE FROM N.A.



(fig 8)

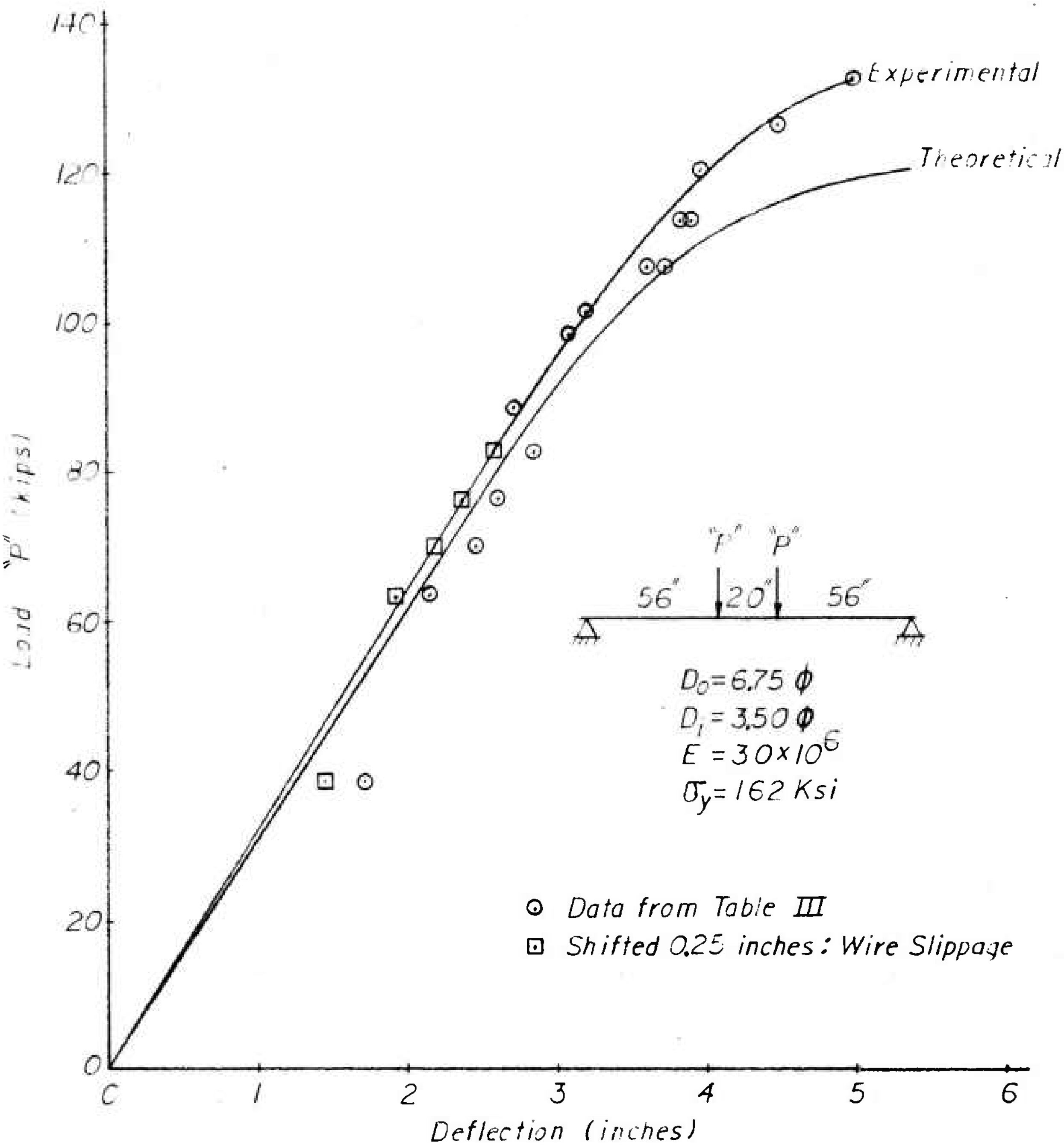
LOAD vs STRAIN

(fig 9)



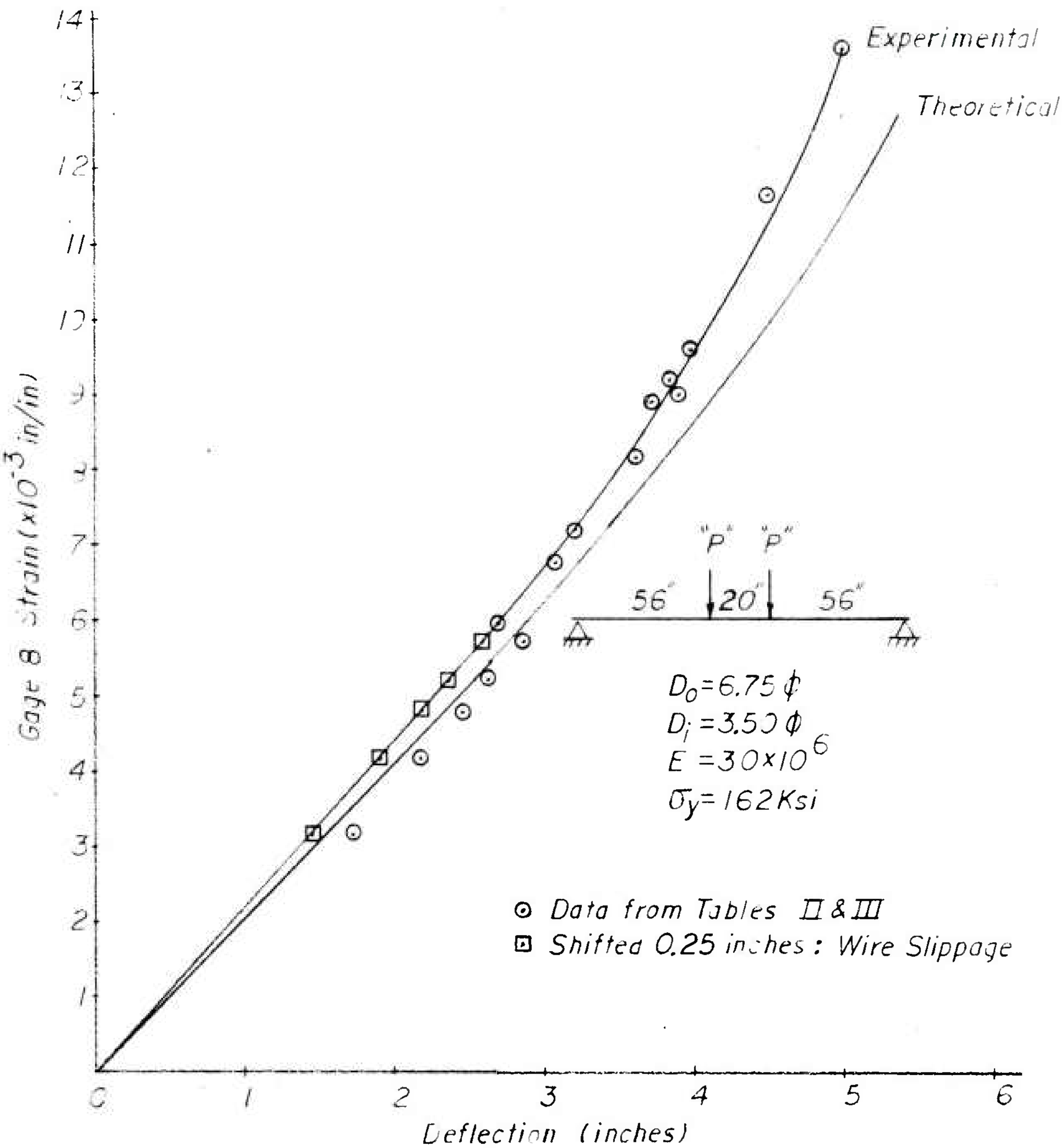
LOAD vs DEFLECTION

(fig 10)



STRAIN vs DEFLECTION

(fig II)



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