01 Dec 1966

Tests on light gage steel diaphragms

George Winter

T. V. S. R. Apparao

Department of Structural Engineering

School of Civil Engineering

Cornell University

Report No. 328

TESTS ON LIGHT GAGE STEEL DIAPHRAGMS

by

T.V.S.R. Apparao

George Winter

Project Director

A Research Project Sponsored by the

American Iron and Steel Institute

Ithaca, New York December, 1966

TABLE OF CONTENTS

ABSTRACT

This report supplements and extends the scope of Report No. 319, "Structural Performance of Light Gage Steel Diaphragms", by Dr. Larry D. Luttrell.

Eleven static load tests were conducted on 22 gage narrow rib roof decks to investigate the effect of length of the diaphragm, type of welding, and diaphragm material tensile properties on the shear stiffness and strength of the diaphragm. The behavior of a diaphragm under reversed load at two different levels, one at 0.4 x ultimate static load and the other at 0.6 x ultimate static load was explored by conducting five tests. The tests at a high level of reversed load (0.6 x P_u) were motivated by the fact that during earthquakes and blasts structures are subjected to high levels of reversed load for a few cycles. Three static load tests were performed on standard corrugated diaphragms to supplement the tests done by Dr. Luttrell and reported in Report No. 319 so as to formulate the strength (Plf.) of a diaphragm without <u>intermediate fasteners</u>* as a function of its thickness.

It is confirmed by the above investigations that the shear stiffness of a diaphragm is dependent mainly on the length of the diaphragm, and the type and spacing of fasteners. The strength of a diaphragm is seen to be dependent mainly on the thickness of the diaphragm, and the type and spacing of the

* The definition is the same as in Report 319.

fasteners. Five cycles of reversed load at ±0.6 x ultimate load of an identical diaphragm under static load resulted in a maximum reduction of 25% in strength of the diaphragm.

INTRODUCTION

It is well known that light gage steel diaphragms are very effective in bracing structural members. In order to use a diaphragm to its maximum capacities the designer wants to know its stiffness and strength. These two characteristics of a diaphragm are found to be dependent mainly on its length and the thickness, the type and spacing of the fasteners, and the type of loading.

This report describes the investigations conducted to determine the strength and stiffness characteristics of narrow rib roof decks and the strengths of standard corrugated diaphragms of different thicknesses.

2. TESTING APPARATUS AND PROCEDURE

All the tests mentioned above were made on the light frame which is made of cold formed 6" x 1 1/2" channels. Fourteen gage material was used for the marginal members and sixteen gage for the purlins. Three nominal sizes, 72" x 72", 120" x 72", 144" x 120", of diaphragms were used for the tests on narrow rib roof decks whereas 144" x 120" (nominal size) diaphragm was used for the standard corrugated diaphragms The centerline dimensions of the frames were the same as the nominal sizes of the diaphragms for the tests on narrow rib roof decks. But the centerline size of the frame was 141" x 120" for the tests on standard corrugated panels because the length of the panels was 144" and the edge fasteners were approximately 1 1/2" from the edges of the panels. The purlin arrangement, along with the nominal size of the diaphragm are shown in the figures for each test at the end of this report. A typical line diagram for a test is shown in Fig. 1a. All the internal connections in the frame were considered as pinned since they offered negligible resistance to frame deformation prior to attaching to the diaphragm. The plane of the diaphragm was horizontal. Vertical support was provided by rollers, one near each corner, along the edge DE. The wall connections consisted of a pin on the south-east corner and a doubly pinned link on the north-east corner. The details of the connections at the corners of the light frame are shown in Fig. 1a.

The loading apparatus for the above diaphragms consisted of two 50 ton hydraulic jack and load cell arrangements in line with and at the ends of the west perimeter member, one being for the direct loads and the other for the reversed loads (Fig. 1a). Loads were applied, in suitable increments, at the level where the diaphragm was attached to the frame. Loads were applied by the direct load jack (south jack) in static load tests. Reversed load tests were conducted by using south and north jacks alternatively to obtain the load levels desired.

Deflections were measured in the plane of the diaphragm with the dial gages 1, 2, 3, and 4 at corners C, E, and G in the directions indicated in Fig. 1a. From these measurements it was possible to correct for the support movement and arrive at the true diaphragm deflection, Δ, according to the formula

$$\Delta = D_3 - \{ D_1 + \frac{a}{b} (D_2 + D_4)\}$$

where D_1, D_2, D_3, and D_4 are the measured movements of the corners indicated by the dial gages 1, 2, 3, and 4 respectively, and the dimensions a and b are shown in Fig. 1a.

Standard tension coupons were taken from each panel of a diaphragm for the tests 1-B through 8 and were tested using a 2" extensometer and a drum recorder to plot the load-deformation curves. Tension coupons were taken randomly from one panel for each one of the tests 9 through 17 and SC-1 through SC-3 and were tested in order to check that all the panels from the shipments had approximately the same material properties. Thickness was measured before and after removing the paint, for each tension test of the coupons, in the case of narrow rib roof decks. Galvanized and uncoated thicknesses were measured in the case of standard corrugated diaphragms.

3. FASTENERS

Welding was used for all the tests on the narrow rib roof decks. The panel to frame welds, excluding the welds on the longitudinal edge of the panel at the marginal members, were puddle welds. These were not radically different from conventional plug welds, one difference being that the hole was burned and the weld made in one continuous operation. The seam welds (or fillet welds) used at the longitudinal edge of the diaphragm and at the interior sidelaps, were similar to the ordinary fillet welds except more care was required to prevent burning holes in the panels. Two types of welding, light welding and heavy welding, were adopted to investigate the behavior of the diaphragms with the two different types of connections. The terms light welding and heavy welding can be understood by referring to the figures, in which fastener details of the diaphragms are given, and the corresponding tests.

Number 14 type B self threading screws with aluminum backed neoprene washer assemblies were used in all the tests on corrugated sheets. These screws were used in predrilled holes which were slightly less than the minimum throat diameter of the threads. No intermediate fasteners were used in all the three tests. Fastener details are given in Fig. 16.

4. TEST RESULTS

Details and results of the tests are presented in Figures 1b through 17 and in Tables 1 through 4. Results of some of the previous tests done by Dr. Luttrell and reported in Report #319 are also given for the purpose of comparison. The arrangement of the test results in Tables 4 through 8 helps to compare and draw conclusions on the behavior of the particular shear diaphragms depending on their length, type of connection, material properties in tension and under reversed loads. A brief description of each test follows.

4.1. 22 Gage Narrow Rib Roof Decks

Static load tests were conducted on three nominal sizes of the diaphragms as mentioned in Section 2. Seam welds and puddle welds used were 3/4" in size and the details of the connections varied depending on the size of the diaphragm and the type of welding. Reversed load tests were conducted on diaphragms at levels of 0.4 P_u and 0.6 P_u, where P_u is the ultimate static load for an identical diaphragm. In all the tests, in which load was applied by the south jack, the diaphragm corner at the north jack started lifting above the roller support at a load of approximately 1200 lbs. This corner was held down by loading with a sufficient number of metal bricks just to hold this corner in plane with the other three corners. Similarly, when the load was appled by the north jack the corner of the diaphragm at the south jack was held down properly as described above. Material properties in tension for different tests are listed in Table 1.

<u>Test 1-B.</u> Fig. 1b. Light welding. Ave. yield strength = 26.2 ksi. P_u = 1700 lbs. In this static load test large deformations were observed at the ends of the diaphragm at about 2/3 of the ultimate load. Ribs of the diaphragm were no longer vertical. The flat portion of the diaphragm panels was bent considerably. This type of large deformation was typical of all the diaphragm tests with light welding. At ultimate load the deformations became larger and eventually welds broke along a seam.

<u>Test 2-B.</u> Fig. 2. Heavy welding. Ave. yield strength = 25.8 ksi. P_u = 2630 lbs. The deformation at the ends of the diaphragm was much smaller compared to that in Test 1-B at the same load level. Even at ultimate load the end deformation was not large. This was typical of the tests with heavy welding. The ultimate load was reached when one of the puddle welds along the end CG failed. There was a 55% increase in strength over that in Test 1-B.

<u>Test 3.</u> Fig. 1b. Light welding. Ave. yield strength = 37.3 ksi. P_u = 1880 lbs. The deformation pattern during the loading and at ultimate load was typical of a diaphragm with light welding. Failure occurred when one of the puddle welds failed. There was an 11% increase in strength over that in Test 1-B due to a 42% increase in yield strength.

<u>Test 4.</u> Fig. 2. Heavy welding. Ave. yield strength = 36.5 ksi. P_u = 2680 lbs. Ultimate load was reached when a puddle weld along the end CG failed. There was a 43% increase in strength over that in Test 3 due to heavy welding. Also,

there was a 2% increase in strength compared to that in Test 2-B due to 42% increase in yield strength.

Test 5. Fig. 3. Light welding. Ave. yield strength = 25.8 ksi. P_u = 2550 lbs. Larger distortion was noted at the ends than was typical of a diaphragm with light welding. A puddle weld along the end CG failed at the ultimate load. The strength of the diaphragm was much higher than one would expect of a typical diaphragm with light welding, probably indicating higher quality welds.

Test 6. Fig. 3. Light welding. Ave. yield strength = 35 ksi. P_u = 1980 lbs. At ultimate load, a puddle weld along the end CG failed. Distortion at ends was typical of a diaphragm with light welding. The strength of this diaphragm was smaller than that in test 5, even though the yield strength of the material was greater.

Test 7. Fig. 4. Heavy welding. Ave. yield strength = 26.3 ksi. P_u = 3200 lbs. At ultimate load there was a buckle of the sheet at one of the welds, failure of a seam weld along the purlin and a puddle weld failure along the edge GE. Distortion at the ends was more than usual for a heavy welded diaphragm. There was a 22% increase in strength over that in Test 5 due to heavy welding.

Test 8. Fig. 4. Heavy welding. Ave. yield strength = 36.6 ksi. P_u = 4050 lbs. A puddle weld broke and the sheet tore at a weld on the edge GE. The distortion at the ends was larger than usual for a heavy welded diaphragm. The large increase in strength compared to that in Test 6 is due to the difference in the states of failure. There was a 27% increase in strength over that in Test 7 due to an increase of 39% in yield strength of the diaphragm material.

Test 9. Fig. 5. Light welding. P_u = 4100 lbs. Static load test. In this test, one of the 18" wide panels was cut along the rib to obtain 12" wide panel to make up a 10' wide diaphragm. The cut edge of this panel was less stiff than the edge of a panel 18" wide. There was a buckle along the cut edge near a weld and at ultimate load a seam weld and a puddle weld failed along the cut edge seam.

Test 10. Figs. 9 and 10. Light welding. P_u = 3620 lbs. Reversed load test. 5cy. to 0.4 x 4100 (= 1640 lbs.). There was no noticeable damage of the diaphragm after five complete cycles of load at ± 1640 lbs. Later it was loaded from zero to failure. One seam weld broke at a load of about 2400 lbs.; but still the diaphragm could take additional load. Complete failure occurred at 3620 lbs. when one more seam weld and a puddle weld broke along the same seam. There was a 13% reduction in strength due to reversed loading, compared to that in Test 9.

Test 11. Fig. 6. Heavy welding. P_u = 5700 lbs. Static load test. A puddle weld failed along the edge CD at a load of about 4100 lbs. and another puddle weld failed along the edge DE at a load of about 4800 lbs. Still, the diaphragm could take additional load. Two seam welds along a seam failed which brought about the complete failure at 5700 lbs. There was a 39% increase in strength over that in Test 9 due to heavy welding.

Test 12. Figs. 11 and 15. Heavy welding. P_u = 3850 lbs. Reversed load test. 5 cy. to 0.4 x 5700 (= 2280 lbs.). There was no noticeable damage of the diaphragm after five complete cycles of load at ± 2280 lbs. There was a buckle along the cut edge and near the end GE before failure occurred. Three seam welds and a puddle weld broke along the seam of the cut edge at ultimate load. There was a 32% reduction in strength due to reversed loading compared to the strength of an identical diaphragm (Test 11) under static load.

Test 13. Figs. 7 and 12. Light welding. P_u = 4300 lbs. Reversed load test. 5cy. to 0.6 x 4100 (= 2460 lbs.). The cut edge of the 12" wide panel was stiffened by folding back to the rib a small width of the edge so that the edge will be as stiff as the edge of the original 18" wide panel and the edge does not buckle prematurely. A puddle weld on the end GE failed at a load of 1900 lbs. during the direct loading of the second cycle. It was decided that the weld failed prematurely and it was welded again. Some distortion at the ends was noted after five complete cycles of the reversed load. A puddle weld along the edge CD broke at ultimate load of 4300 lbs. Large distortion of the diaphragm and bending of the perimeter member of the frame GE were noted at failure.

Test 14. Heavy welding. Reversed load test. 5 cy. to 0.6 x 5700 lbs. The cut edge stiffened. The diaphragm completely failed during the direct loading of the fourth cycle at about 2000 lbs. Two seam welds failed during the direct loading of the second cycle at 3400 lbs. This failure was considered premature for this diaphragm and they were re-welded. Later, some more welds failed along the same seam during the third cycle and the diaphragm completely failed during the fourth cycle. This illustrates convincingly that quality of the welding is an important factor which determines the strength of the diaphragm.

Test 15. Figs. 13 and 15. Details of the test were the same as in Test 14. There was no noticeable damage of the diaphragm after five cycles of reversed load at ± 3420 lbs. Later it was loaded from zero to failure. Two welds broke and there was a local buckle along a seam at ultimate load. There was a 25% reduction in strength due to reversed loading compared to that in Test 11.

Test 16. Fig. 7. Light welding. P_u = 4400 lbs. Static load test. The cut edge stiffened. The aim of the test was to determine the increase in strength due to stiffening of the edge by comparing with that in Test 9. The distortion of the diaphragm was typical of its kind. One seam weld broke at ultimate load. There was a 7% increase in strength due to stiffening of the edge.

Test 17. Figs. 14 and 15. Heavy welding. P_u = 4300 lbs. Reversed load test. 5cy. to 0.4 x 5700 (= 2280 lbs.). The cut edge stiffened. There was no noticeable damage after five cycles of reversed loading at ± 2280 lbs. Two seam welds and a puddle weld failed at ultimate load and also a local buckle of the edge of a panel was noted at a puddle weld. There was a 25% reduction in strength due to reversed loading, compared to that in Test 11.

4.2. Static Load Tests on Standard Corrugated Diaphragms (galvanized) without Intermediate Fasteners

Test SC-1 Fig. 16. 24 Gage. P_u = 5000 lbs. Relative movement of the adjacent panels along the seams and tilting of the screws were first observed at a load of about 3000 lbs. This kind of phenomenon was typical of the standard corrugated diaphragm tests and was described in Report No. 319. At a load of about 4000 lbs. two adjacent panels got separated along the seam between the fasteners. There was a local buckle of the panel around a fastener along the edge CD at ultimate load. Considerable amount of relative displacement of adjacent panels was noted and there was slight tearing of the panels around fasteners at failure.

Test SC-2. Fig. 16. P_u = 5400 lbs. This test was an exact repetition of Test SC-1. Final failure was by tilting of a screw and tearing of the panel around the screw.

Test SC-3. Fig. 16. 26 Gage. P_u = 4650#. The deformation of the diaphragm was typical of the standard corrugated diaphragm tests. There was a local buckle of a panel at a seam around a screw at a load of about 3400 lbs. There was another local buckle at ultimate load around a fastener at a different seam.

5. DISCUSSION AND CONCLUSIONS

To facilitate the discussion of the test results, suitable comparison of the results was arranged in Tables 4 through 8.

5.1. Static Load Tests on 22 Gage Narrow Rib Roof Decks

a. Effect of Diaphragm Length on the Shear Stiffness, G'.

Light Welding. When the diaphragm length was increased from 6' to 10' (i.e. 67% increase), there was a 30% increase in G' whereas there was a 120% increase in G' for an increase of 100% in length, 6' to 12' (note that the width of the diaphragm is not an important factor compared to the length of the diaphragm while considering G' and strength).

Heavy Welding. Increase in length of the diaphragm from 6' to 10' (i.e. 67% increase) brought about 64% increase in shear stiffness. But 100% incrase in length, from 6' to 12', amounted to only 68% increase in shear stiffness.

Fig. 8 gives the graphical relationship between the length and the shear stiffness of a diaphragm.

It can be concluded from the above that the shear stiffness of a diaphragm increases with its length and the amount of increase depends on the type of connection and the length of the diaphragm.

b. Effect of Diaphragm Length on its Shear Strength, Plf.

Light Welding. It is seen from Table 5 that the average shear strength of the diaphragms of 10' length was 10% smaller than that of diaphragms of 6' length. There was an increase of 8% in strength due to 100% increase in length of a diaphragm (6' to 12').

Heavy Welding. There was some decrease in strength of the diaphragm when its length was increased from 6' to 10' or 12'. But if diaphragms of 10' and 12' lengths are considered, (Table 5) one finds some increase in strength. These differences are small and probably represent scatter.

In general, it can be said that the strength of a diaphragm is more or less independent of its length. The average strength of diaphragms with light welding was 384 Plf. and with heavy welding was 459 Plf.

c. Effect of Welding on the Shear Stiffness of a Diaphragm. (Refer to Table 6).

The increase in G' of a diaphragm with heavy welding compared to that of an identical diaphragm with light welding varied from 62% to 187%. It is seen from Table 6 that the amount of increase does not depend consistently either on the increase of the diaphragm length or on the increase in yield strength. So, the amount of this increase is attributed to the quality of the welding in each particular test.

The conclusion is that the heavier the welding the higher the G'. The amount of increase in G' due to heavier welding depends on the quality of the welding.

d. Effect of Welding on the Shear Strength (Plf). Refer to Table 6.

The increase in strength of diaphragms with heavy welding compared to those with light welding varied from 22% to 105%. As mentioned above, this increase does not depend on the size of the diaphragms or the yield strength.

It can be concluded that heavier welding increases the strength of a diaphragm and the amount of increase depends on the quality of welding.

e. Effect of Diaphragm Material Properties on Shear Stiffness and Strength (Plf).

It is seen from Table 7 that a considerable increase in yield strength amounted only to a small increase in shear stiffness and strength in most cases. But there was a decrease in shear stiffness and strength in a few cases due to increase in yield strength.

Therefore, it can be concluded that the yield strength of the diaphragm material has relatively little effect on its shear stiffness and strength.

5.2 Reversed Load Tests on 22 Gage Narrow Rib Roof Decks

f. Light Welding. It is seen from Table 8 that the reduction in strength (Plf) due to reversed loading of 5cy. to 0.6 x 4100 lbs. is smaller than that due to 5cy. to 0.4 x 4100 lbs. This is contrary to expectation. However, this discrepancy can be attributed to the quality of welding in those tests (refer to 5.1d, Section 6). Further, the reduction in strength is small (from 2% to 13%) for all practical purposes.

g. Heavy Welding. The reduction in strength was almost the same whether the reversed loading was 5cy. to 0.4 x 5700# or 5cy. to 0.6 x 5700#. It is seen that the reduction in strength was considerable, and varied from 25% to 32%.

One can conclude from the above that the percentage reduction in strength of a diaphragm under reversed load compared to the static ultimate load of an identical diaphragm is larger if the welding is heavier.

5.3 Static Load Tests on Standard Corrugated Diaphragms (Galvanized).

All the test data from this report and Report No. 319 on full size (12' x 10') standard corrugated diaphragms without intermediate fasteners have been presented in Table 4. It is intended to formulate a relationship between the strength of a diaphragm and its uncoated thickness. Average (Plf) vs. uncoated thickness (in) has been plotted in Fig. 17. It is seen that a linear relationship exists between the strength and the thickness of a diaphragm and is given by

$$\text{Strength (Plf.)} = 140 + 11562\, t$$

where t = uncoated thickness of the diaphragm material; the use of the above formula is restricted to the range of values of t in which the tests were conducted.

TABLE 1 - Diaphragm Material Properties

22 Gage Narrow Rib Roof Decks

Test No.	Painted Thickness (in.)	Thickness, paint removed (in.)	Tensile Strength (ksi) Yield at 0.2% off.	Tensile Strength (ksi) ult.	Elong. per 2" %
1-A, 2-A**	-	- (22 gage)	32.8	45.3	25
1-B***	0.0306	0.0289	26.2	51.2	44
2-B***	0.0310	0.0292	25.8	50.0	41
3	0.0317	0.0299	37.3	54.2	40
4	0.0314	0.0295	36.5	53.4	41
5***	0.0310	0.0292	25.8	50.9	41
6	0.0313	0.0296	35.8	50.8	38
7***	0.0307	0.0289	26.3	50.7	41
8	0.0324	0.0307	36.6	53.8	40
9	0.0301	0.0283	33.2	50.5	43
10	0.0298	0.0280	31.9	50.8	42
11	0.0300	0.0283	31.8	50.8	43
12	0.0299	0.0280	32.5	51.2	42
13*	0.0298	0.0280	32.1	50.6	41
14*	0.0281	0.0263	31.6	46.6	41
15*	0.0282	0.0263	30.9	46.4	41
16*	0.0283	0.0266	29.9	46.3	40
17*	0.0288	0.0270	30.6	46.3	40

* The cut edge of the 12" wide panel is properly stiffened.

** Tests conducted by Dr. Luttrell and reported in Report No. 319.

*** Proportional limit is nearly half of the yield strength.

TABLE 2. Diaphragm Material Properties

Standard Corrugated Diaphragms

Test No.	Gage	Galvanized Thickness (in.)	Uncoated Thickness (in.)	Tensile Strength (ksi) Yield at 0.2% off.	Ult.	Elong. per 2" %
SC-1	24	0.0270	0.0260	40.5	52.6	27
SC-2	24	0.0271	0.0259	41.7	54.0	25
SC-3	26	0.0210	0.0193	44.4	57.7	20
4AP, 4AP-2, & 4AP-3 **	22	0.0326	0.0310	33.4	45.4	30
4P**	26	0.0204	0.0188	58.7	63.3	25
6AP, 6AP-2 **	28	0.0200	0.0162	50.1	54.9	20

** Tests conducted by Dr. Luttrell and reported in Report No. 319.

TABLE 3. Summary of the Tests on 22 Gage Narrow Rib Roof Decks

Test No.	Diaphragm Size: length x width	Type of Welding	Shear Stiffness G' (lbs./in.)	Ult. Load (lbs.)	Strength in Plf.
			HEAVY FRAME		
1-A	12' x 10'	L.W. (no int.welds)	5000	3720	310
2-A	12' x 10'	L.W. (with int.welds)	5000	4968	414
			LIGHT FRAME		
1-B	10' x 6'	L.W.	2880	1700	283
2-B	10' x 6'	H.W.	8267	2630	438
3	10' x 6'	L.W.	3092	1880	313
4	10' x 6'	H.W.	7550	2680	447
5	6' x 6'	L.W.	2075	(2550)	(438)
6	6' x 6'	L.W.	2360	1980	330
7	6' x 6'	H.W.	4420	(3200)	(533)
8	6' x 6'	H.W.	5230	(4050)	(675)
9	12' x 10'	L.W.	5010	4100	342
16*	"	"	4750	4400	367
10 (5 cy. to 0.4 x 4100#)	"	"	--	3600	300
13* (5 cy. to 0.6 x 4100#)	"	"	--	4300	358
11	12' x 10'	H.W.	8120	5700	475
12 (5 cy. to 0.4 P_u)	"	"	--	3850	321
17* (5 cy to 0.4 P_u)	"	"	--	4300	358
15* (5cy. to 0.6 P_u)	"	"	--	4300	358

L.W. = Light Welding; H.W. = Heavy Welding
* The cut edge of 12" wide panel is properly stiffened.
( ) Very large deformation at ends was noted at failure.

TABLE 4. Tests on Standard Corrugated Diaphragms
(Light Frame, Size: 12' x 10')

Test No.	Gage	Uncoated Thickness (in.)	End Conn. Panel-Frame No./Panel	Intermediate Fasteners	Strength in Plf.	Ave. Strength in Plf.	Recommended Strength in Plf.
4AP	22	0.0310	3 - #14 Screws	No	512		
4AP-2	"	"	"	"	483	511	510
4AP-3	"	"	"	"	539		
SC-1	24	0.0260	"	"	417	434	435
SC-2	"	0.0259	"	"	450		
4P	26	0.0188	"	"	392	390	360
SC-3	"	0.0193	"	"	388		
6AP	28	0.0162	"	"	308	325	325
6AP-2	"	"	"	"	342		
5P	26	0.0188	"	Yes	600	600	600

TABLE 5. Comparison of G' and Plf. of the Diaphragms with Different Lengths.

Test No.	Size of the Diaphragm (length x width)	Yield Strength (ksi)	Average Yield Strength (ksi)	G' (lbs/in)	Average G' (lbs/in)	Increase in G' %	Str. (Plf)	Average Strength (Plf)	Increase in Strength %
				Light Welding					
5	6' x 6'	25.8		2075			(438)	(438)	
			30.8		2218				
6	6' x 6'	35.8		2360			330	330	
1-B	10' x 6'	26.2		2880			283		
			31.8		2886	30		298	-10
3	10' x 6'	37.3		3092			313		
2-A (H.F.)	12' x 10'	32.8	32.8	5000	5000		414		
9	12' x 10'	33.2	33.2	5010			342		
					4880	120		355	+8
16*	12' x 10'	29.9	29.9	4750			367		

Ave. Plf., (438) not included = 384

* The cut edge of the 12" panel was properly stiffened.
H.F. = Heavy frame test.
( ) Very large deformation at ends was noted at failure.

TABLE 5 (cont.)

Test No.	Size of the Diaphragm (length x width)	Yield Strength (ksi)	Average Yield Strength (ksi)	G' (lbs/in)	Average G' (lbs/in)	Increase in G' %	Strength (Plf)	Average Strength (Plf)	Increase in Strength %
				Heavy Welding					
7	6' x 6'	26.3	32.0	4420	4825		(533)		
8	6' x 6'	36.6		5230			(675)		
2-B	10' x 6'	25.8	31.2	8267	7908	64	438	443	
4	10' x 6'	36.5		7550			447		
11	12' x 10'	31.8		8120	8120	68	475	475	+7
							Ave.Plf., (533)&(675) not included	= 459	

* The cut edge of the 12" panel was properly stiffened
H.F. = Heavy frame test
( ) Very large deformation at ends was noted at failure.

TABLE 6. Comparison of G' and Plf. of the Diaphragms with Different Welding

Test No.	Size of the Diaphragm (length x width)	Yield Strength (ksi)	Type of Connection	G' (lbs/in)	Increase in G' (%)	Strength in Plf.	Increase in Strength, Plf. (%)
5	6' x 6'	25.8	L.W.	2075	113	(438)	(22)
7	6' x 6'	26.3	H.W.	4420		(533)	
6	6' x 6'	35.8	L.W.	2360	122	330	(105)
8	6' x 6'	36.6	H.W.	5230		(675)	
1-B	10' x 6'	26.2	L.W.	2880	187	283	55
2-B	10' x 6'	25.8	H.W.	8267		438	
3	10' x 6'	37.3	L.W.	3092	144	313	43
4	10' x 6'	36.5	H.W.	7550		447	
9	12' x 10'	33.2	L.W.	5010	62	342	39
11	12' x 10'	31.8	H.W.	8120		475	

L.W. = Light welding
H.W. = Heavy welding
( ) Very large deformation at ends was noted at failure.

TABLE 7. Comparison of G' and Plf. of the Diaphragms with Different Material Properties

Test No.	Size of the Diaphragm (length x width)	Yield Strength σ_y (ksi)	Increase in Yield Strength (%)	G' (lbs/in)	Increase in G' (%)	Strength in Plf.	Increase in Strength, Plf (%)
			Light Welding				
5***	6' x 6'	25.8	39	2075	14	(438)	(-25)
6	6' x 6'	35.8		2360		330	
1-B***	10' x 6'	26.2	42	2880	7	283	11
3	10' x 6'	37.3		3092		313	
			Heavy Welding				
7***	6' x 6'	26.3	39	4420	18	(533)	(27)
8	6' x 6'	36.6		5230		(675)	
2-B***	10' x 6'	25.8	42	8267	-9	438	2
4	10' x 6'	36.5		7550		447	

*** Proportional limit is nearly half of the yield strength

( ) Very large deformation at ends was noted at failure.

TABLE 8. Reversed Load Tests on 22 Gage Narrow Rib Roof Decks (Light Frame; size 12' x 10')

Test No.	Type of Load	Ultimate Load (lbs)	Strength in Plf.	% Reduction in Strength (Plf)
		Light Welding		
9	S.L.	4100	342	
16*	S.L.	4400	367	
10	5cy. to 0.4 x 4100#	3600	300	13
13*	5cy. to 0.6 x 4100#	4300	358	2
		Heavy Welding		
11	S.L.	5700	475	
12	5cy. to 0.4 x 5700#	3850	321	32
17*	5cy. to 0.4 x 5700#	4300	358	25
15*	5cy. to 0.6 x 5700#	4300	358	25

S.L. = Static load

* The cut edge of the 12" wide panel is properly stiffened.

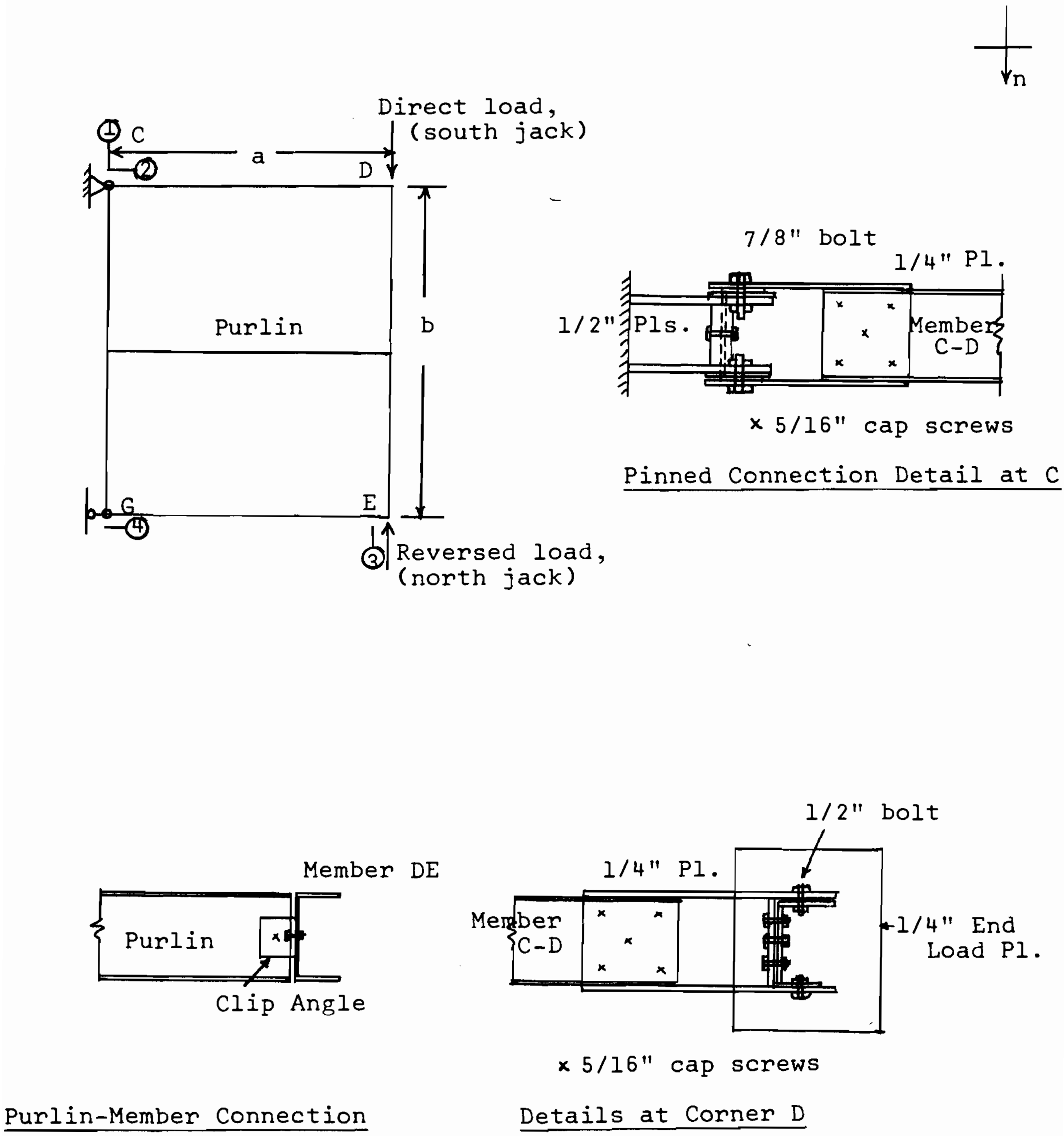


Fig. 1a. Light Frame Details.

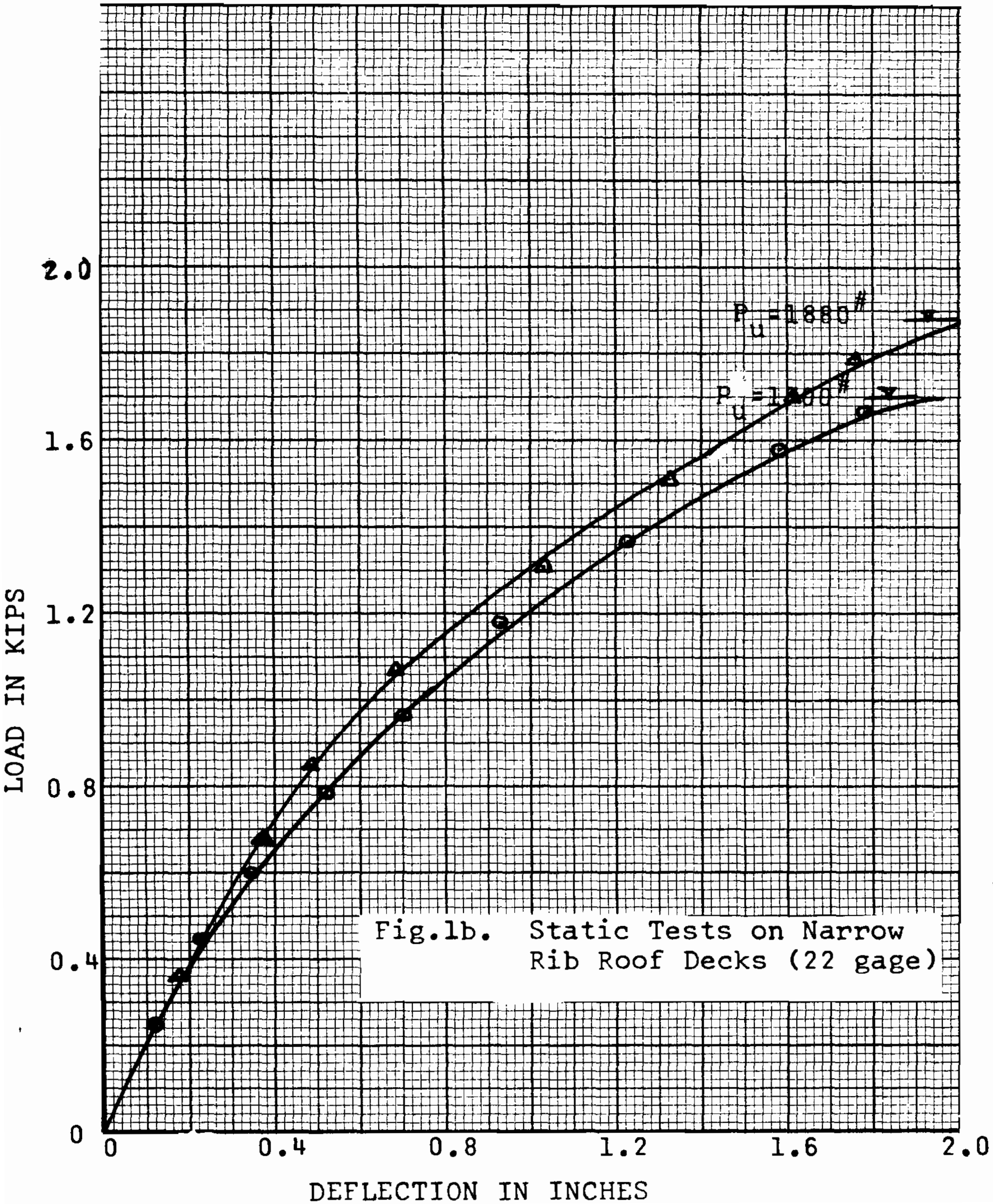
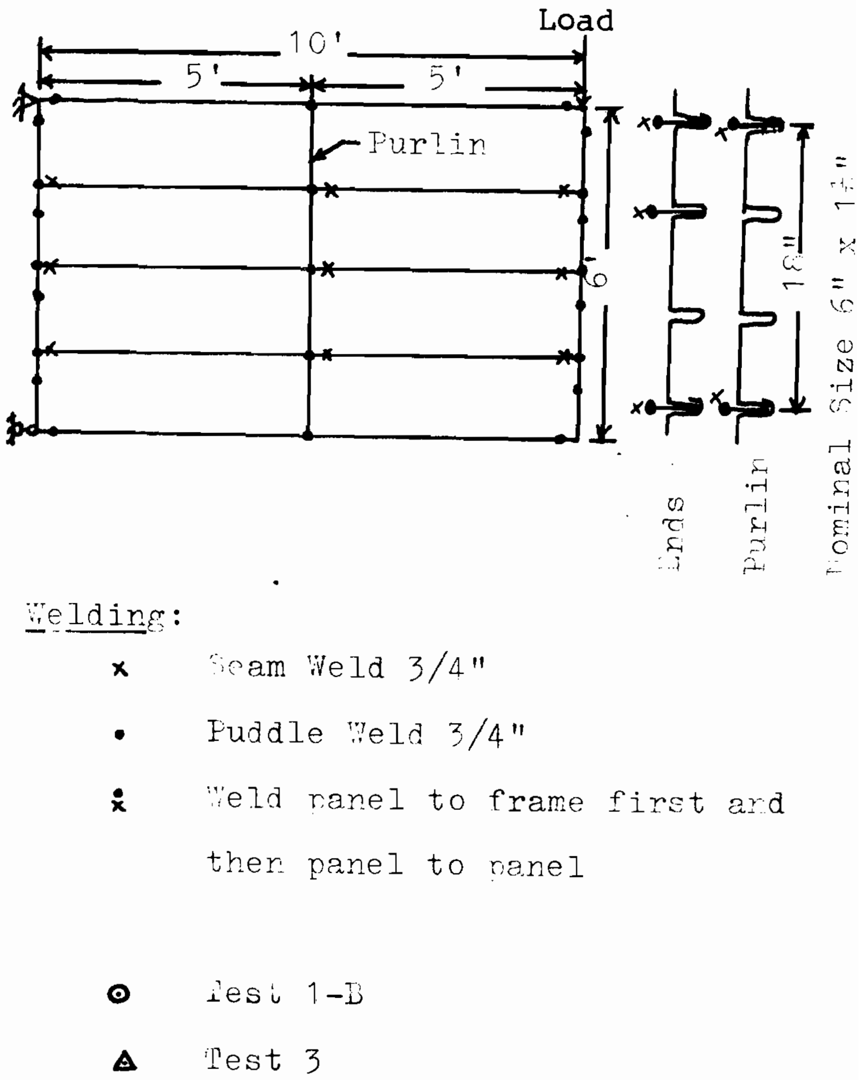


Fig.1b. Static Tests on Narrow Rib Roof Decks (22 gage)



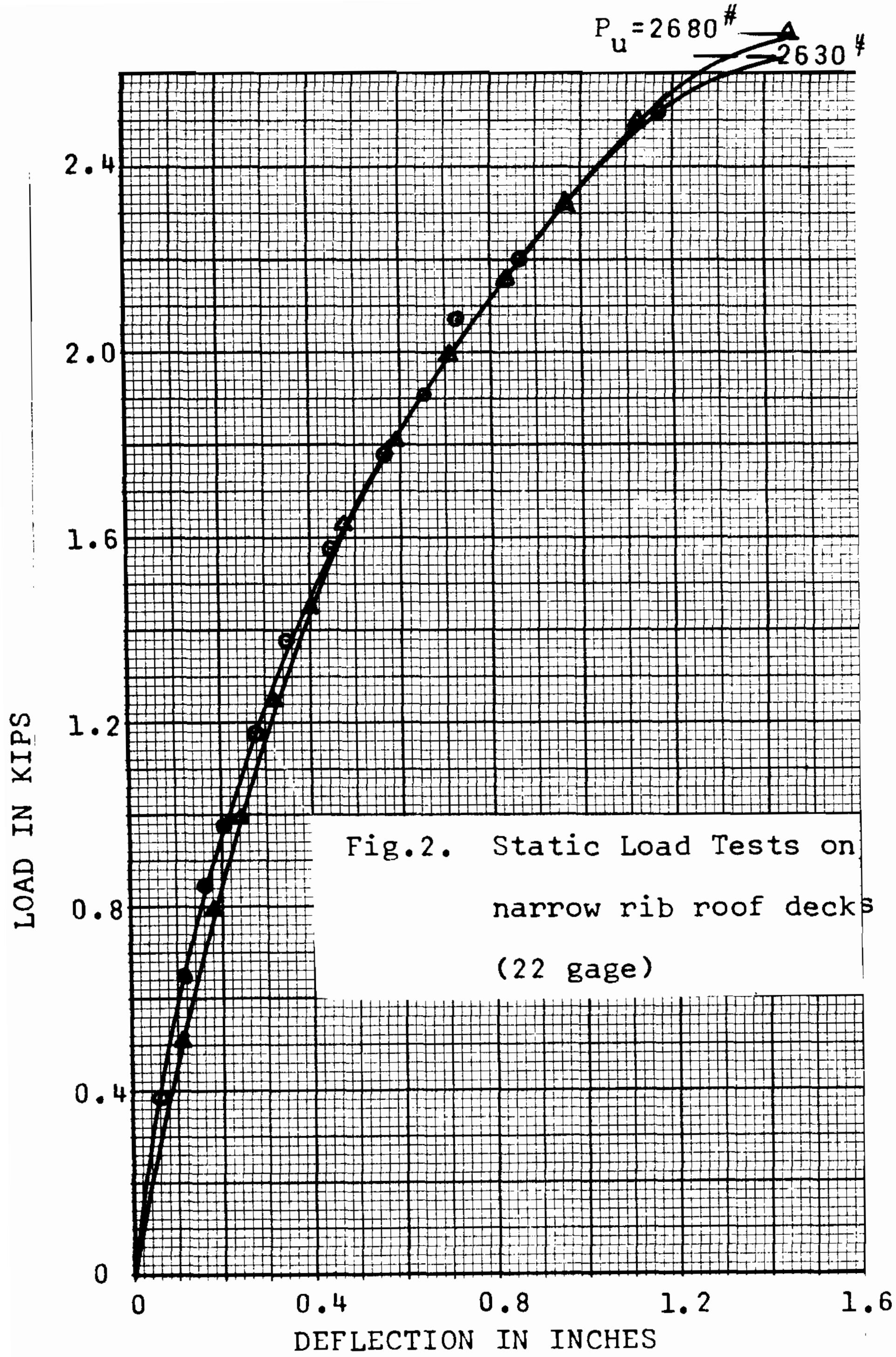
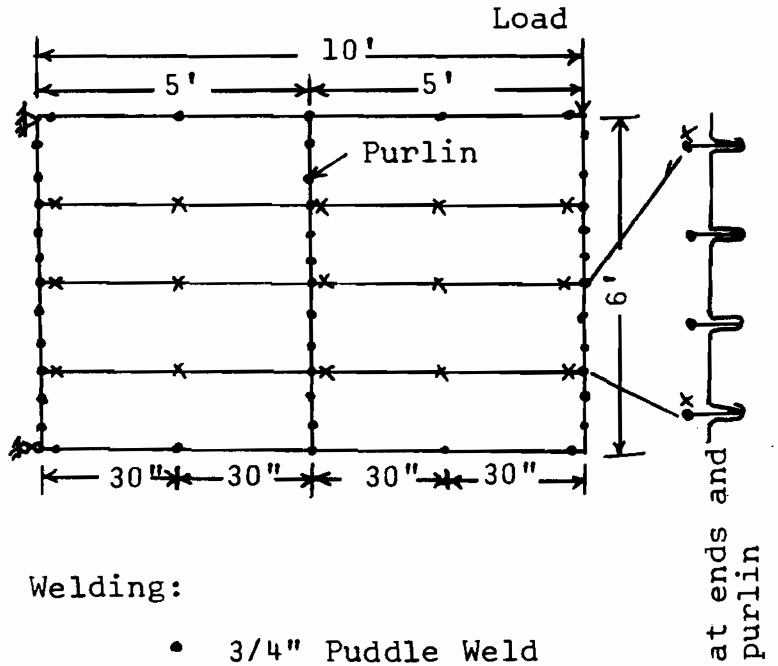


Fig.2. Static Load Tests on narrow rib roof decks (22 gage)



Welding:

- • 3/4" Puddle Weld
- × 3/4" Seam Weld
- •× Weld panel to frame first and then panel to panel

— —

- ⊙ Test 2-B
- △ Test 4

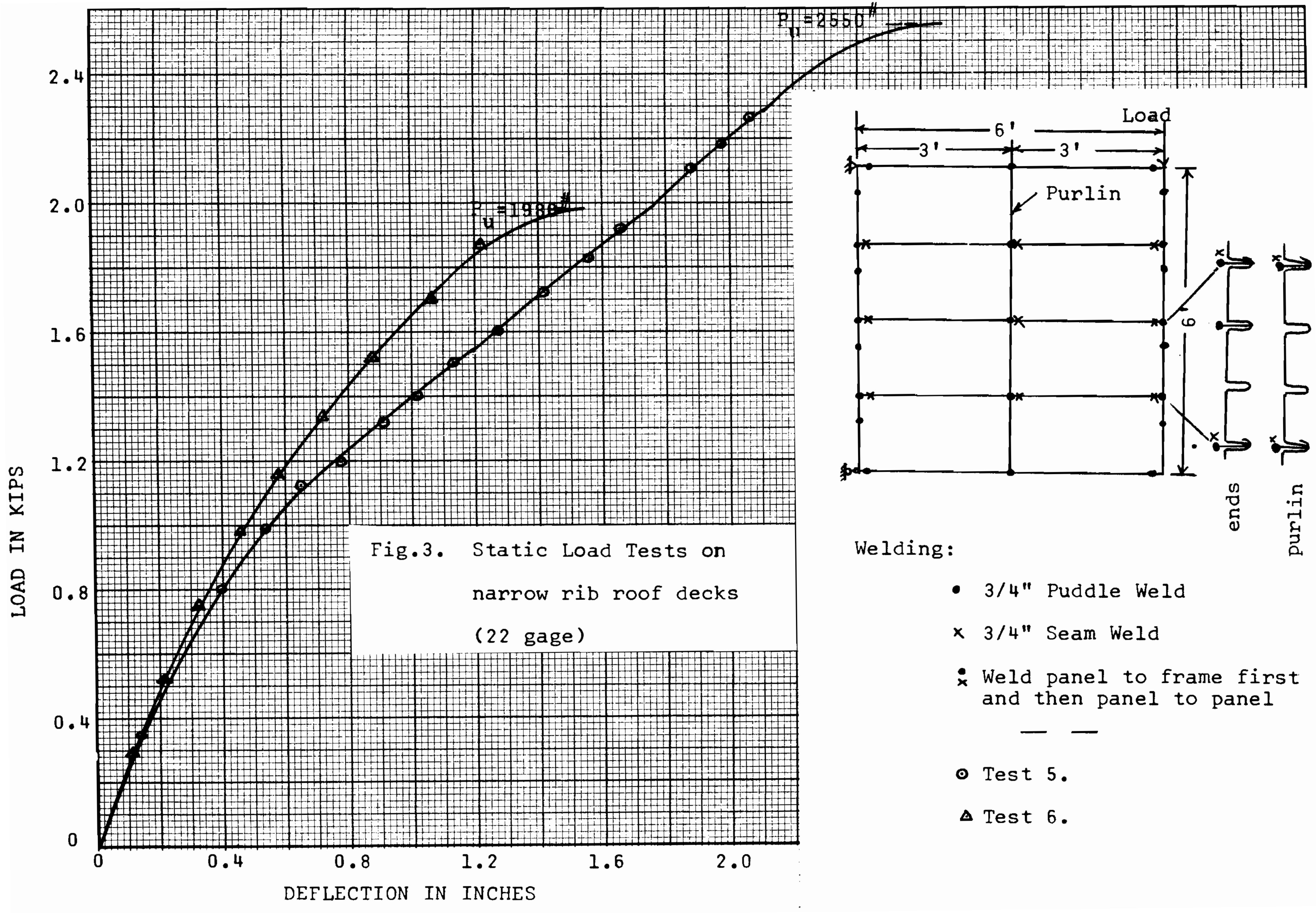


Fig.3. Static Load Tests on narrow rib roof decks (22 gage)

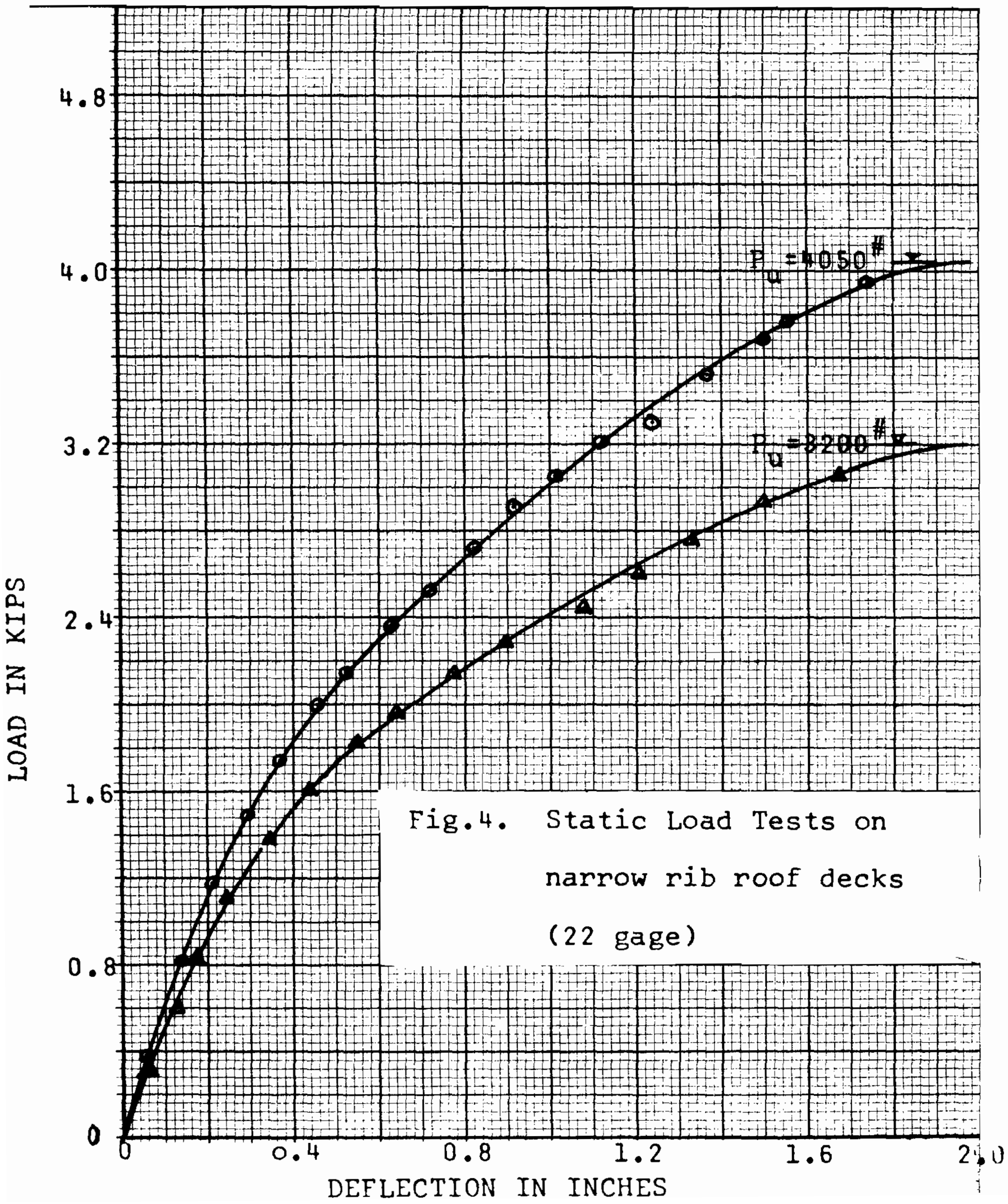
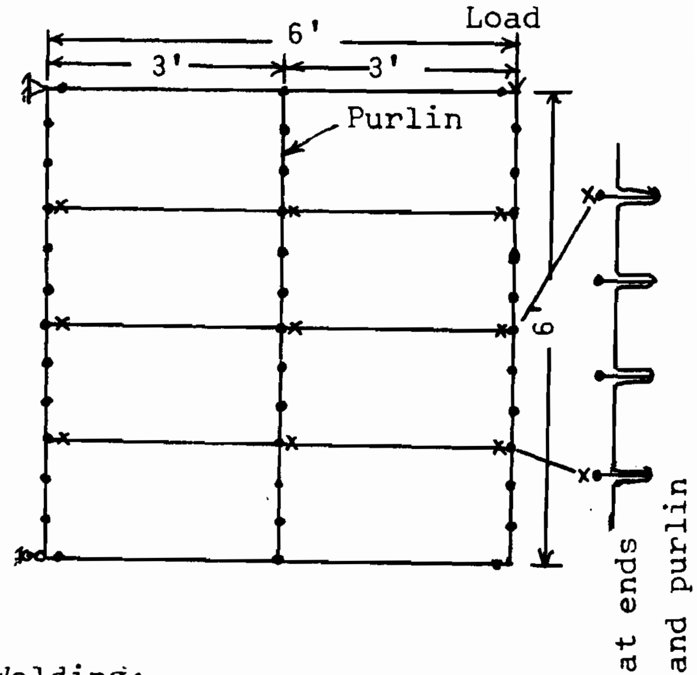


Fig.4. Static Load Tests on narrow rib roof decks (22 gage)



Welding:

- • 3/4" Puddle Weld
- x 3/4" Seam Weld
- •/x Weld panel to frame first and then panel to panel

— —

- △ Test 7.
- ⊙ Test 8.

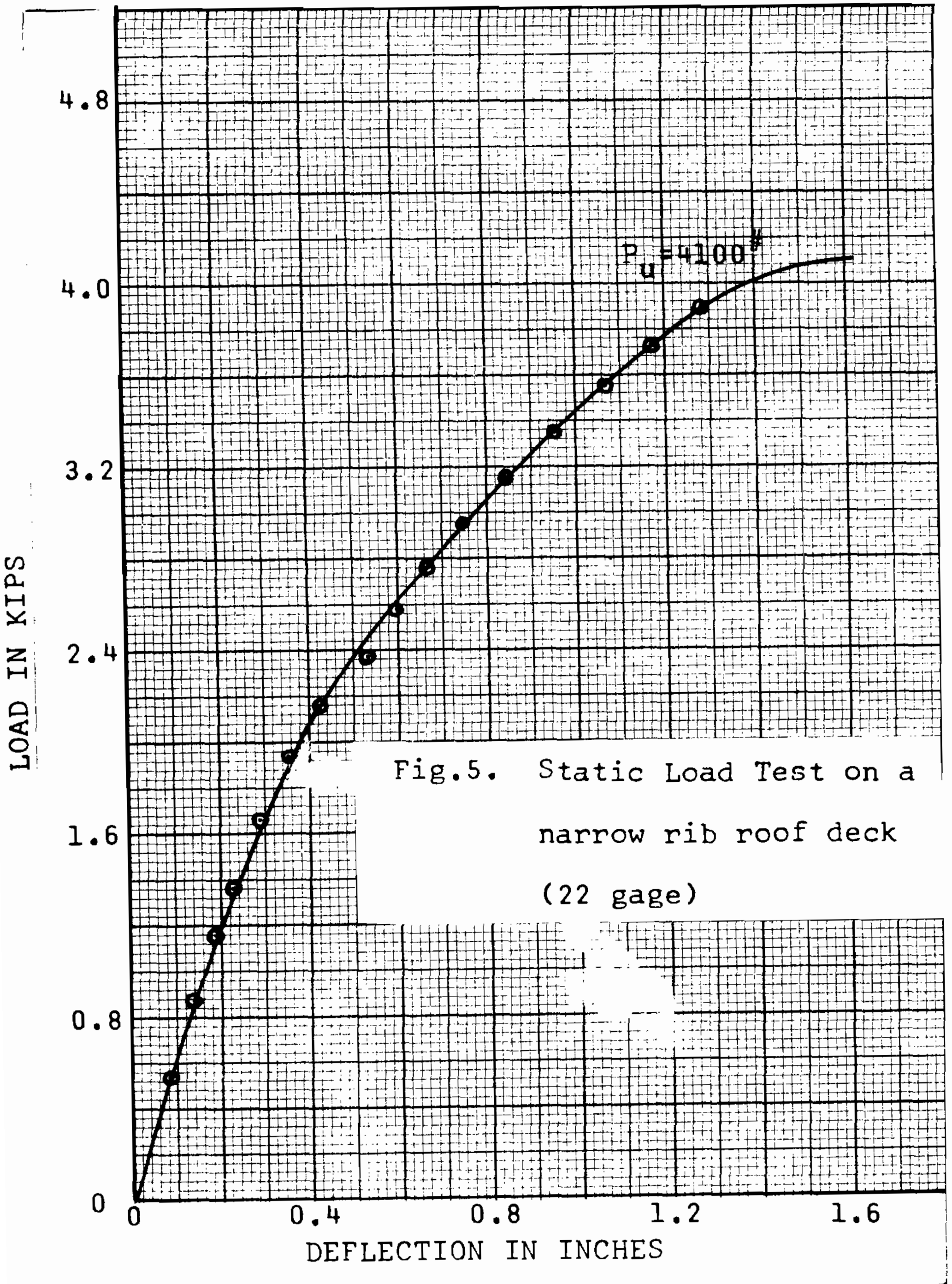
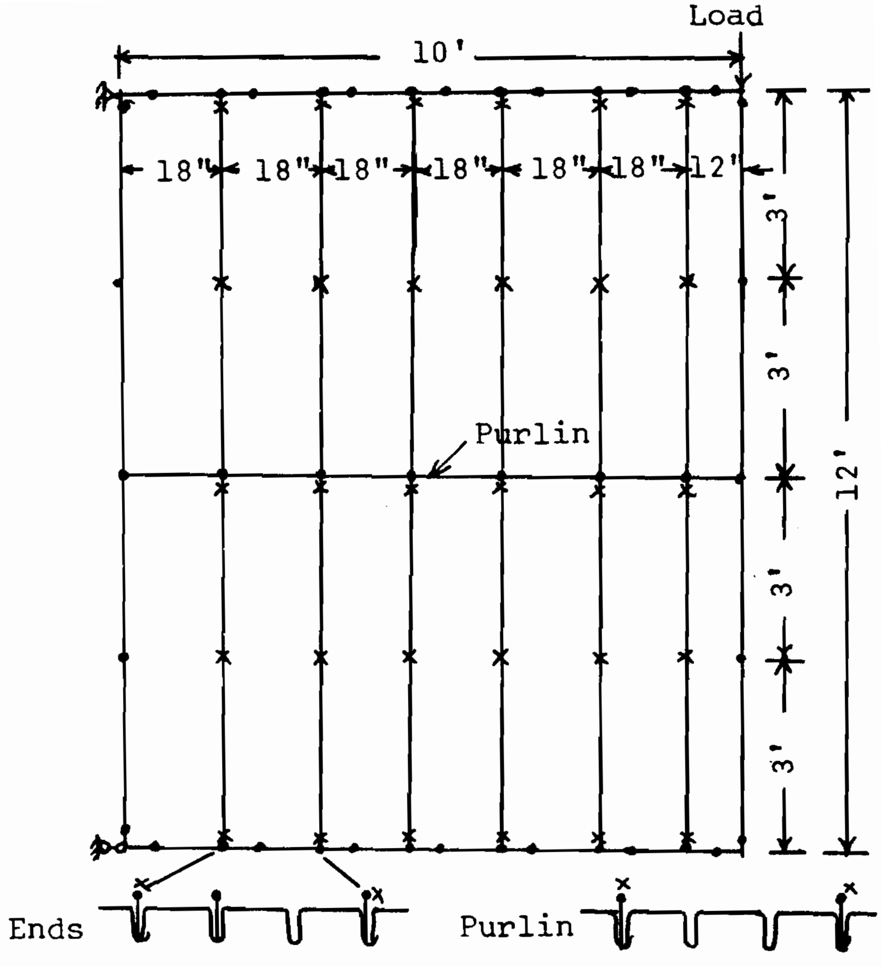


Fig.5. Static Load Test on a narrow rib roof deck (22 gage)



• 3/4" Puddle Weld

× 3/4" Seam Weld

•× Weld panel to frame first and then panel to panel

<u>Test 9</u>.

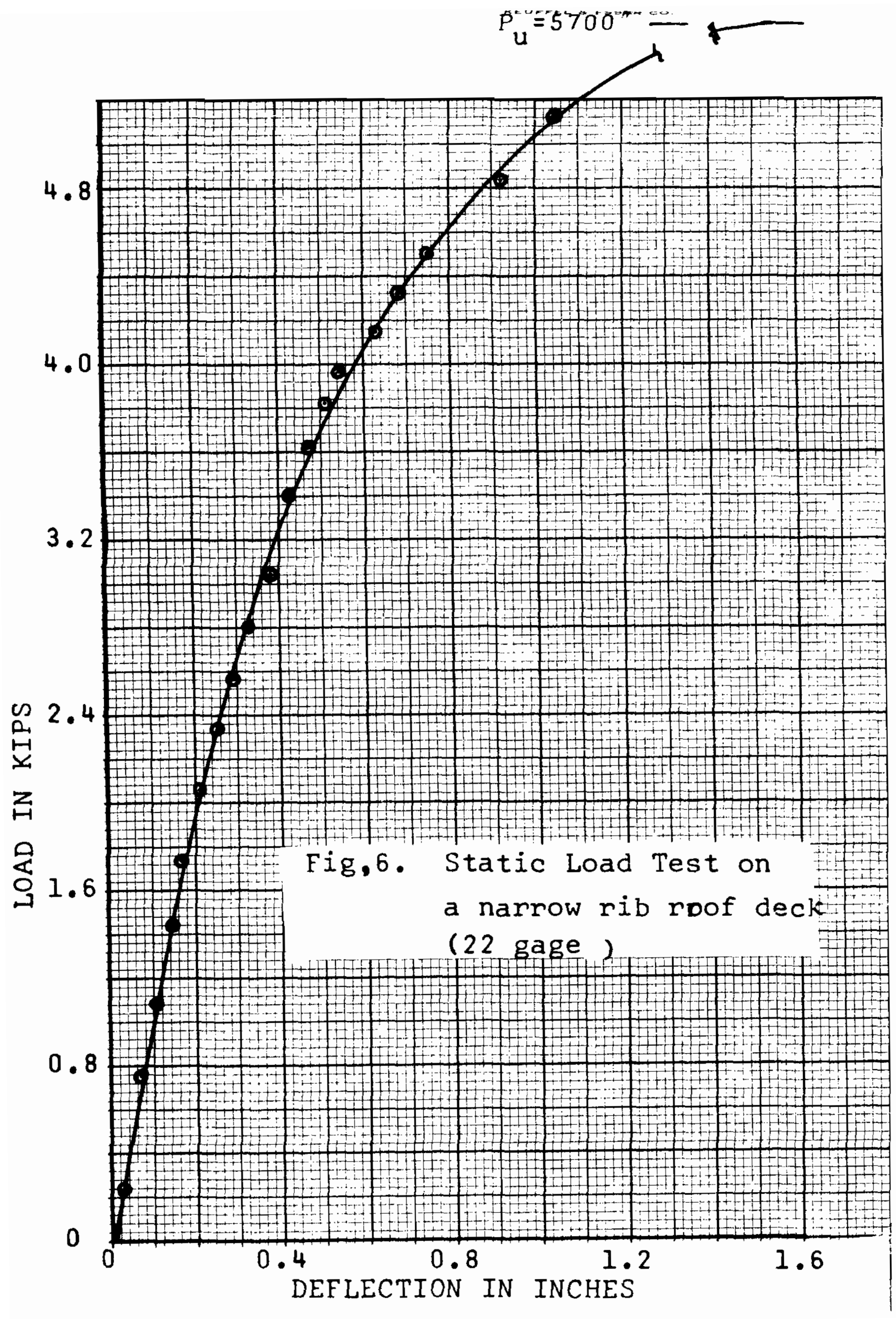
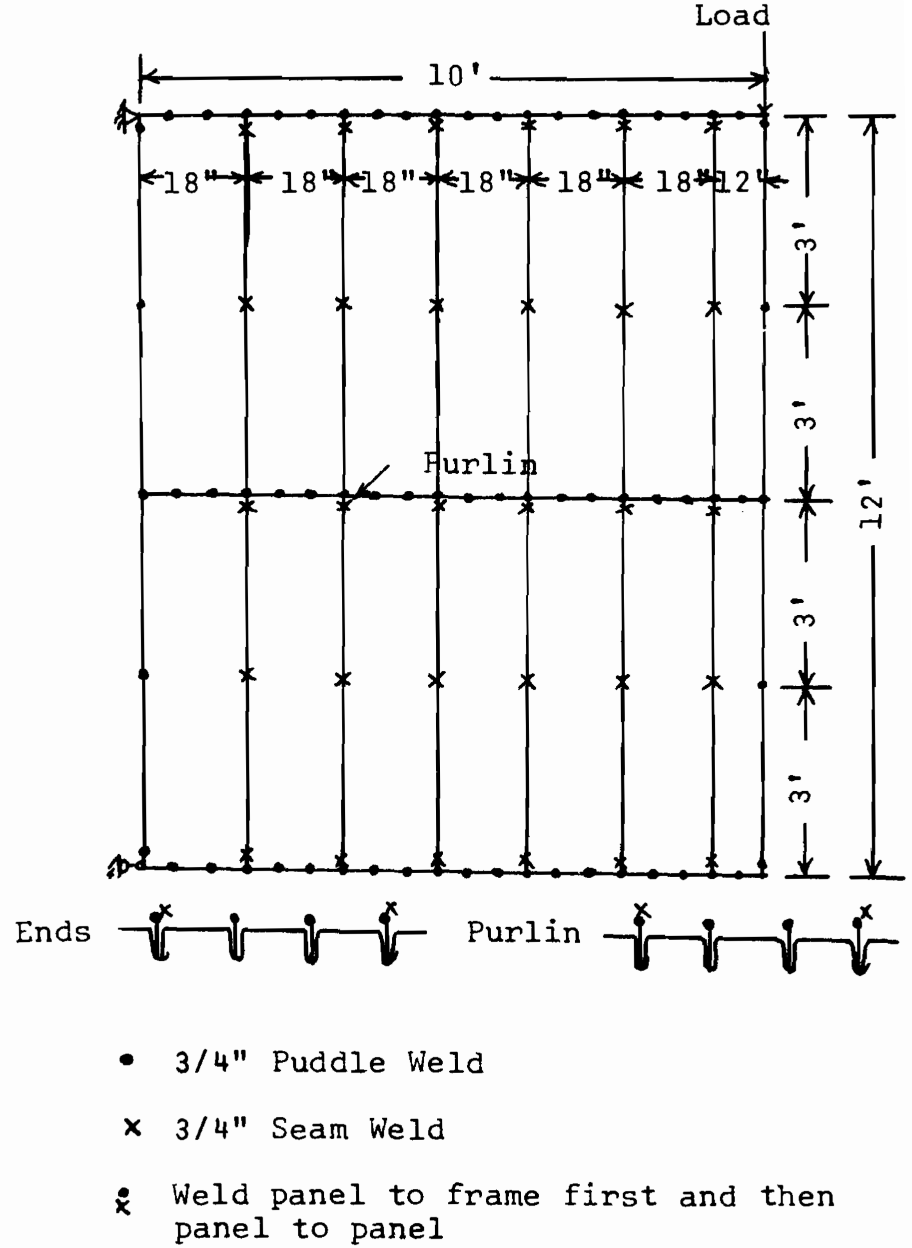


Fig.6. Static Load Test on a narrow rib roof deck (22 gage)



Test 11.

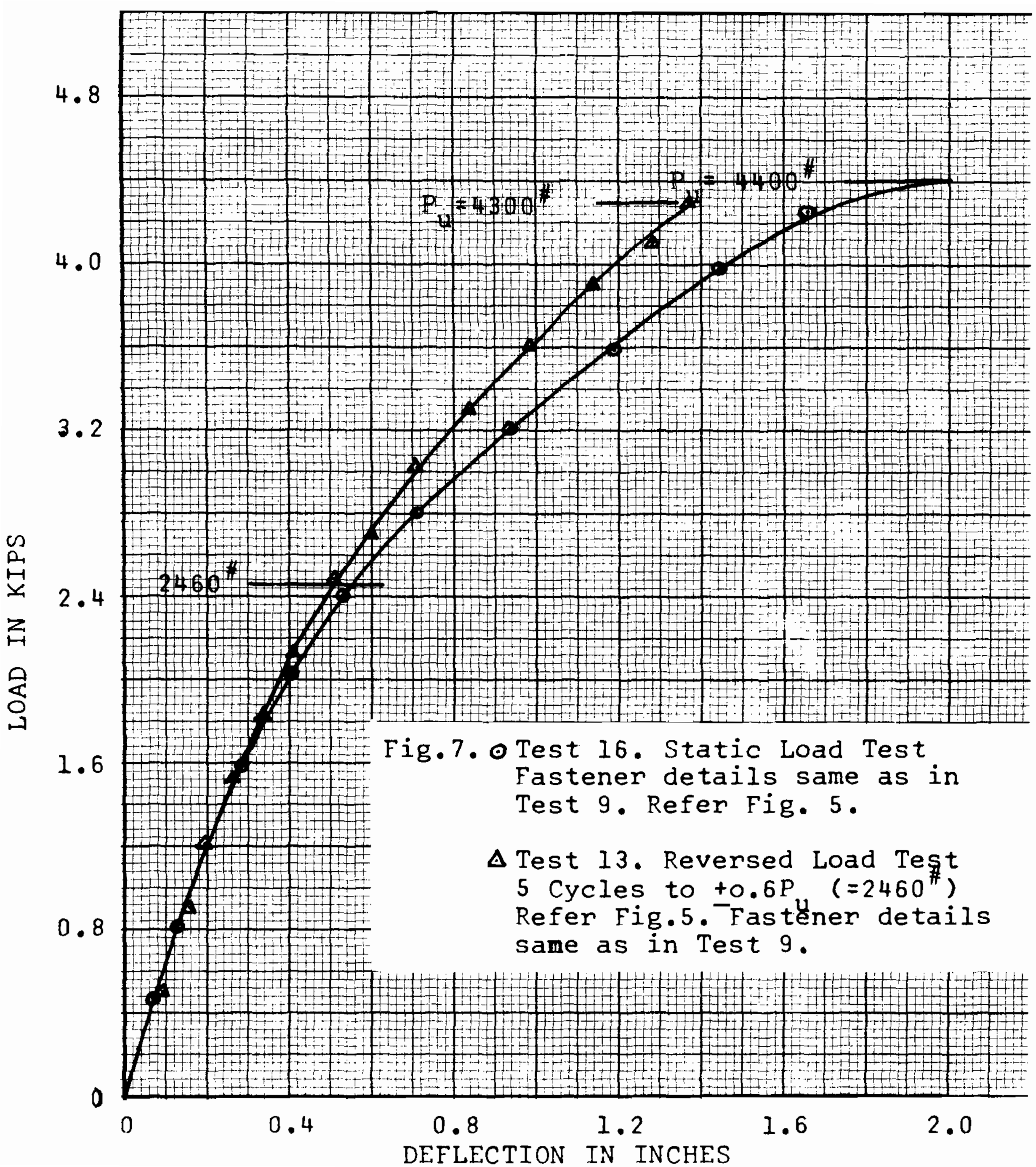


Fig.7. ⊙ Test 16. Static Load Test Fastener details same as in Test 9. Refer Fig. 5.

△ Test 13. Reversed Load Test 5 Cycles to $\pm 0.6P_u$ ($=2460^{\#}$) Refer Fig.5. Fastener details same as in Test 9.

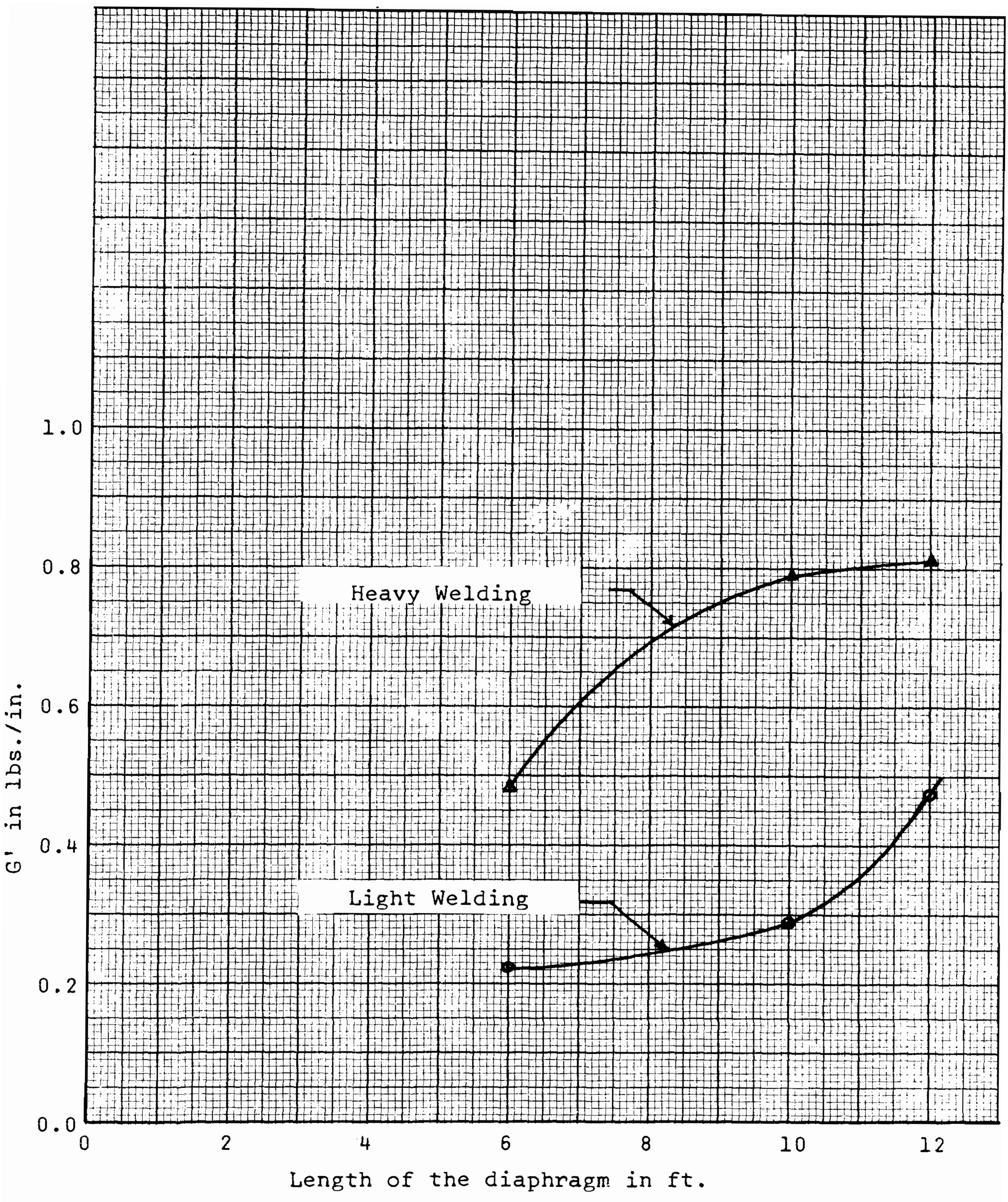


Fig. 8. Refer Table 5.

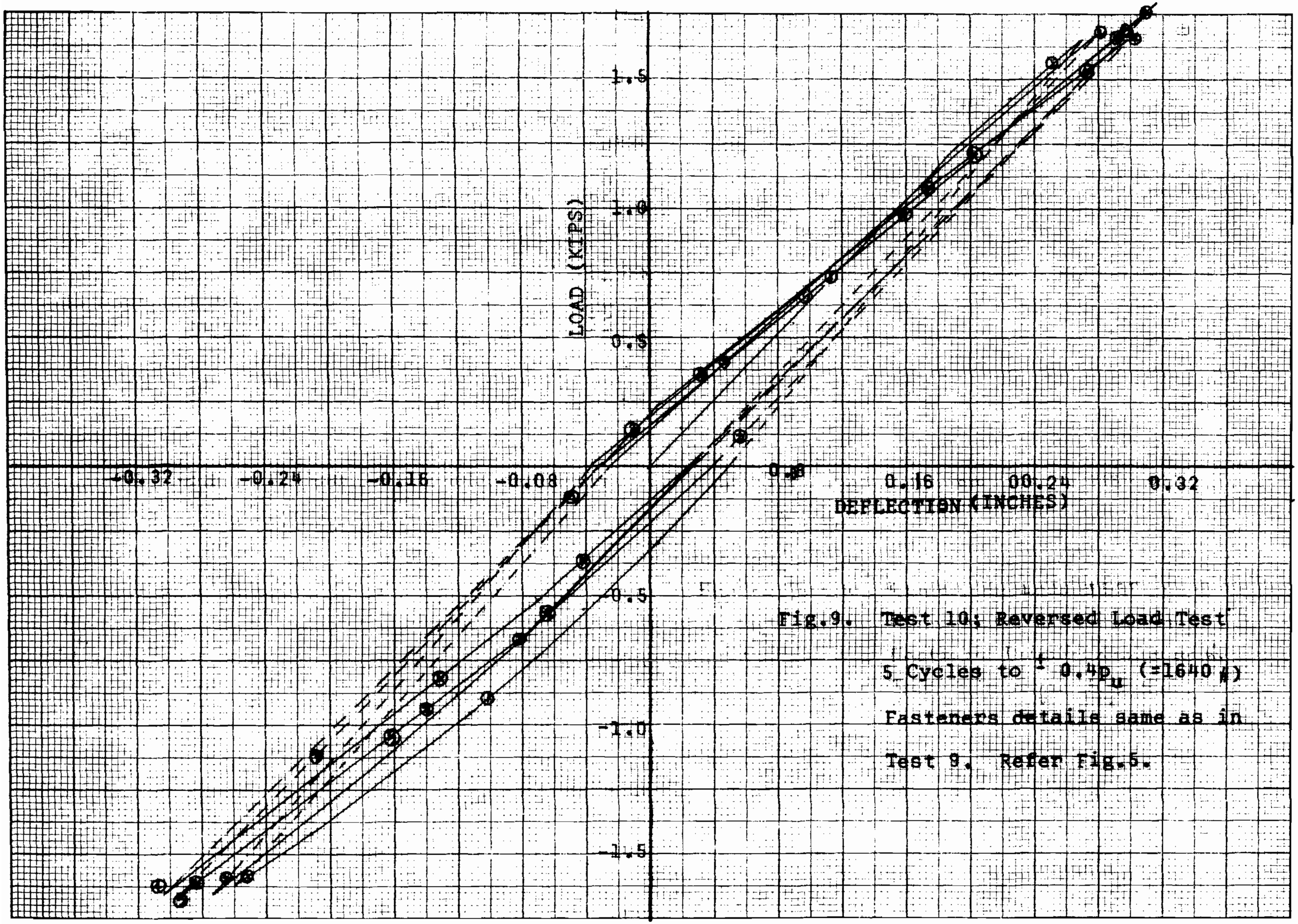


Fig.9. Test 10; Reversed Load Test

5 Cycles to ± $0.4p_u$ (=1640 #)

Fasteners details same as in

Test 9. Refer Fig.5.

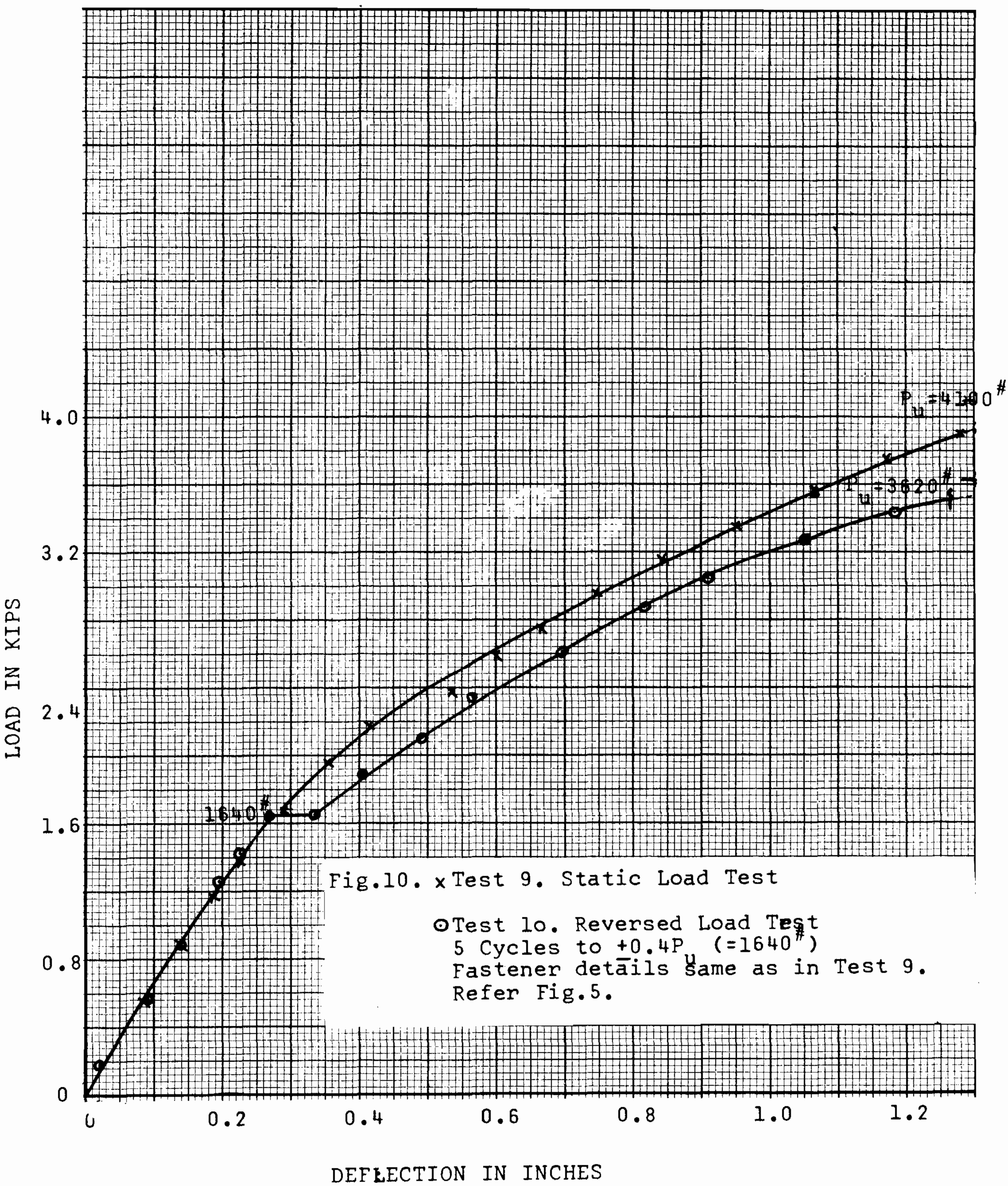


Fig.10. x Test 9. Static Load Test

⊙ Test 10. Reversed Load Test
5 Cycles to $\pm 0.4P_u$ (=1640#)
Fastener details same as in Test 9.
Refer Fig.5.

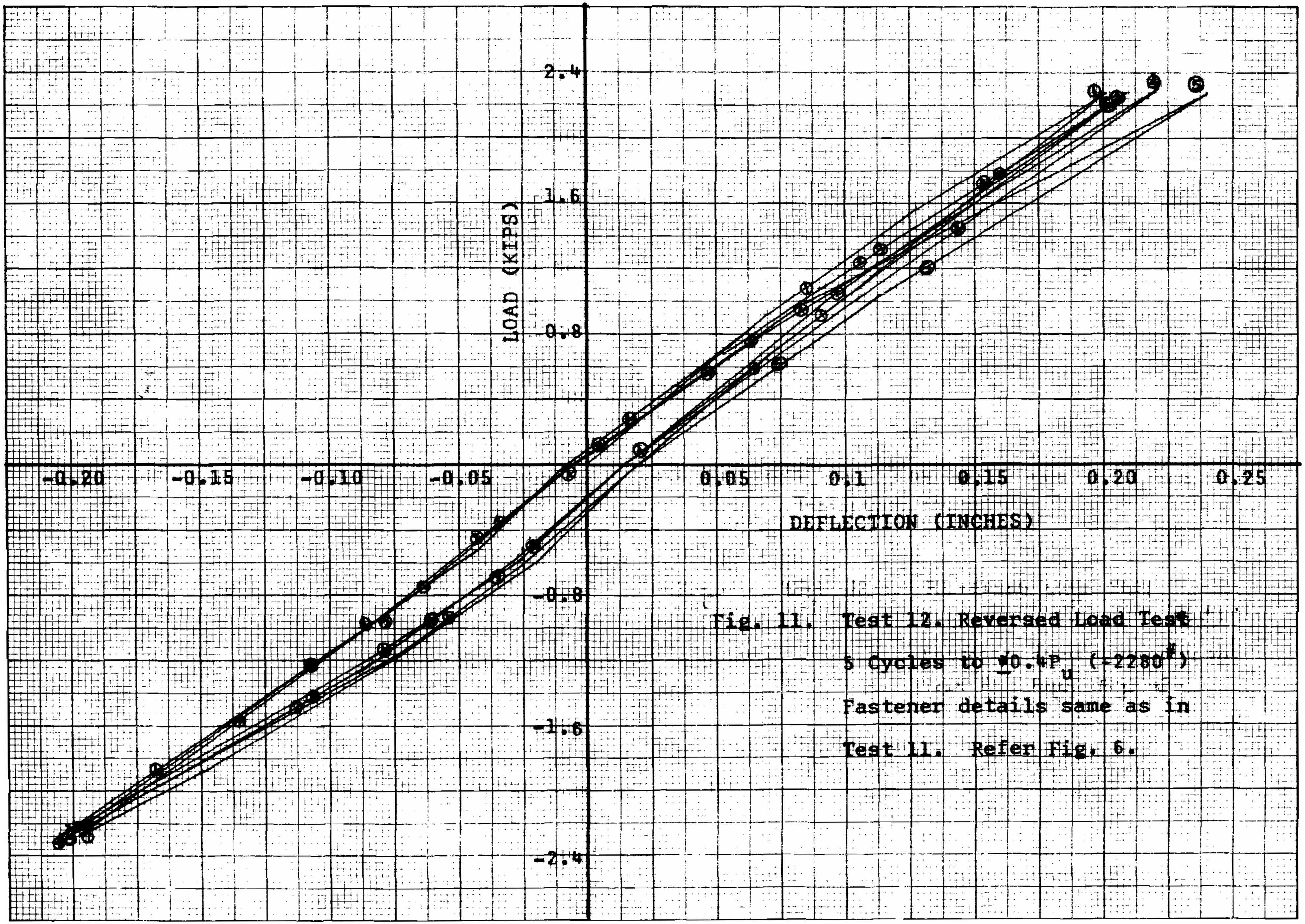


Fig. 11. Test 12. Reversed Load Test

5 Cycles to $\pm 0.4 P_u$ ($\pm 2280^{\#}$)

Fastener details same as in

Test 11. Refer Fig. 6.

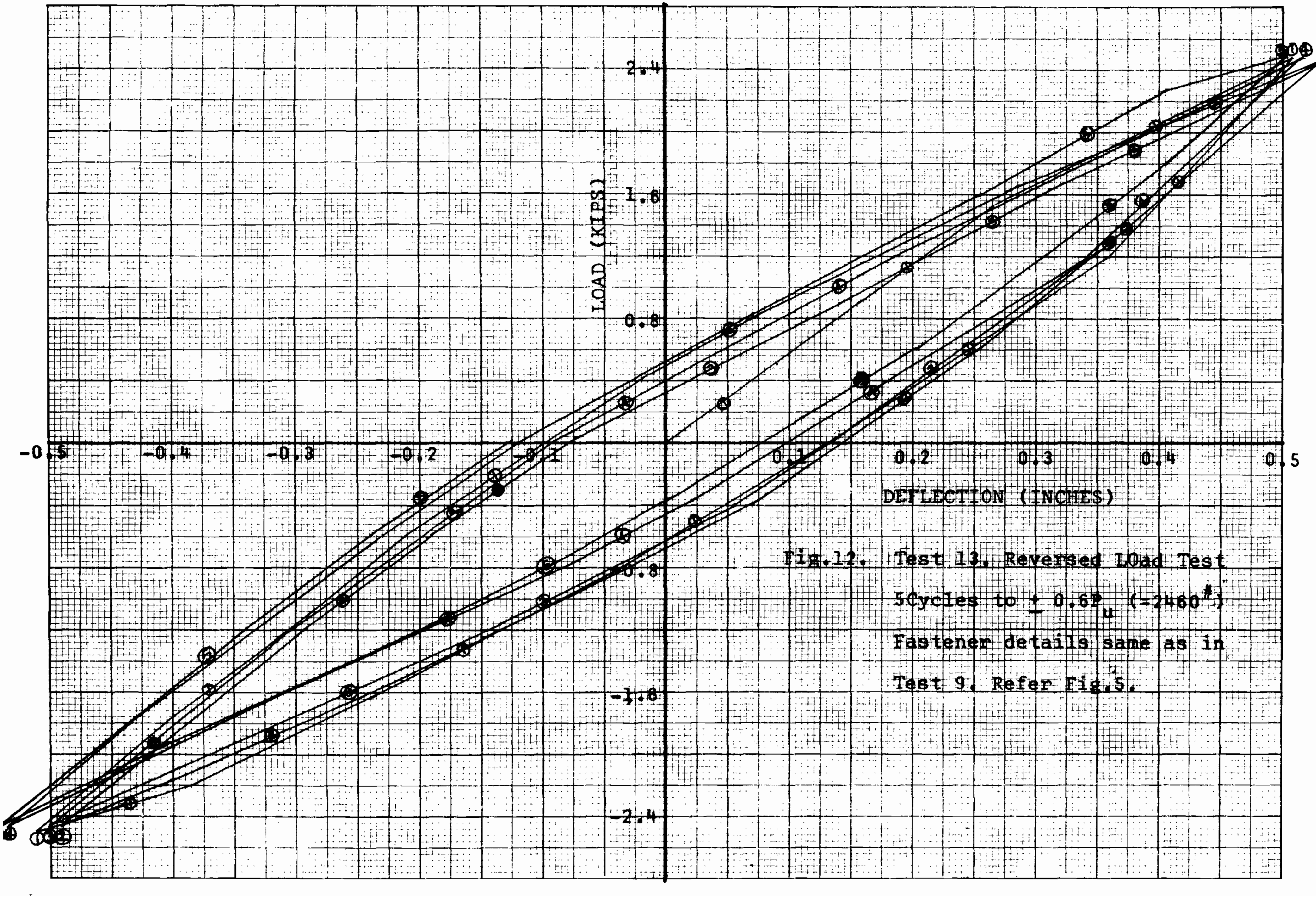


Fig.12. Test 13. Reversed LOad Test

5Cycles to $\pm$ 0.6P_u (=2460#)

Fastener details same as in

Test 9. Refer Fig.5.

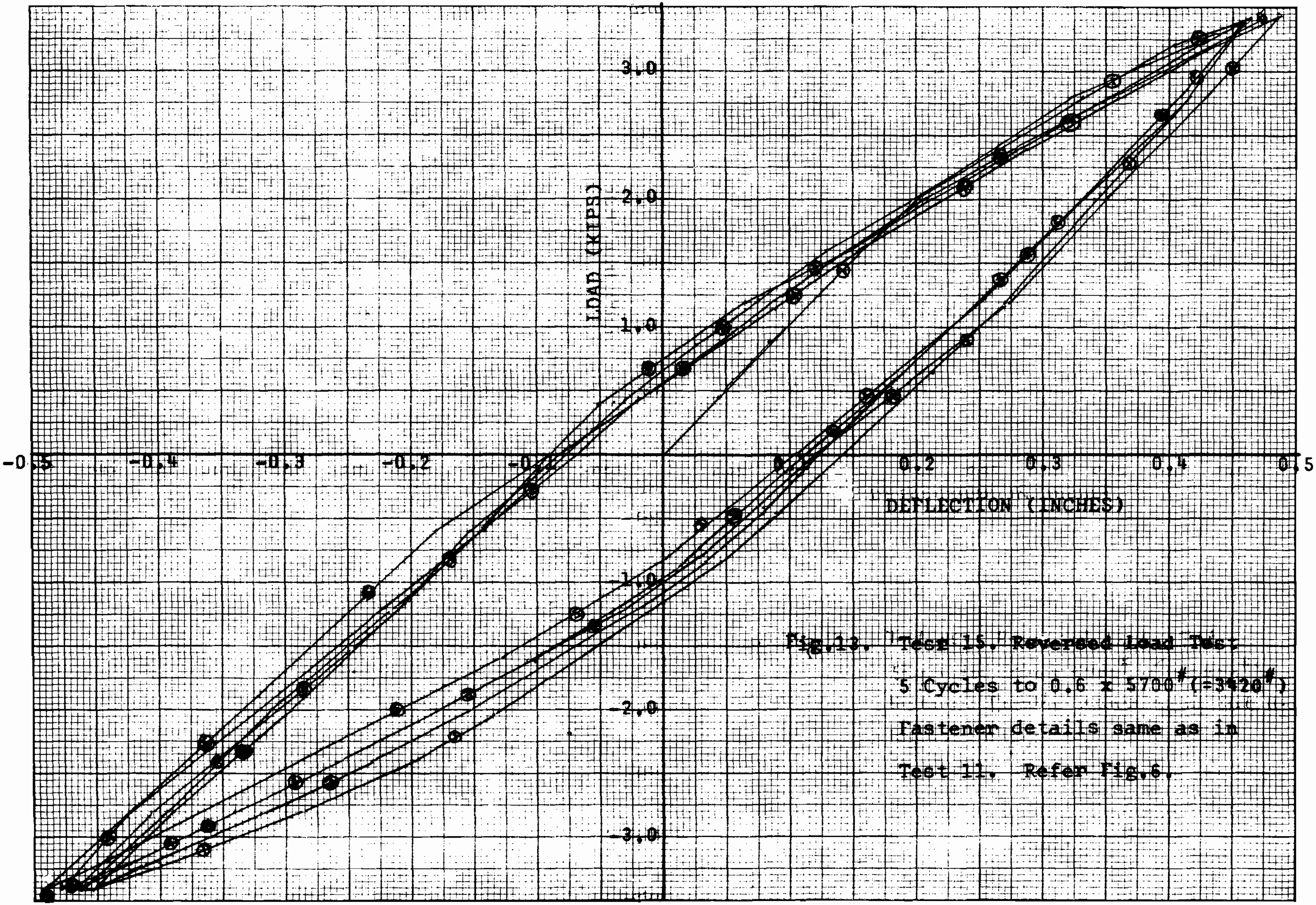


Fig.13. Test 15. Reversed Load Test
5 Cycles to 0.6 x 5700# (=3420#)
Fastener details same as in
Test 11. Refer Fig.6.

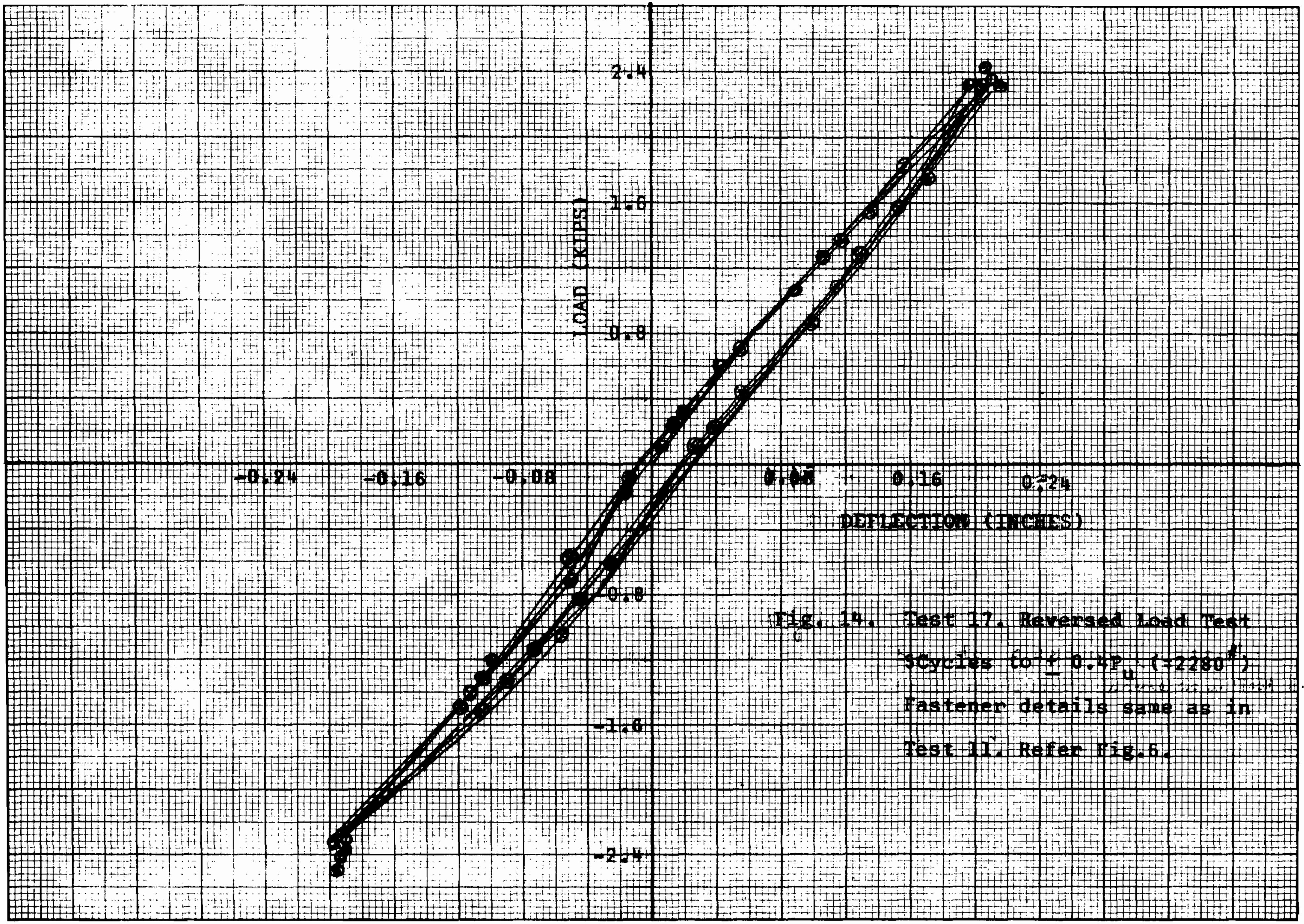


Fig. 14. Test 17. Reversed Load Test

5Cycles to $\pm$ 0.4P_u ($\pm$2280#)

Fastener details same as in

Test 11. Refer Fig.6.

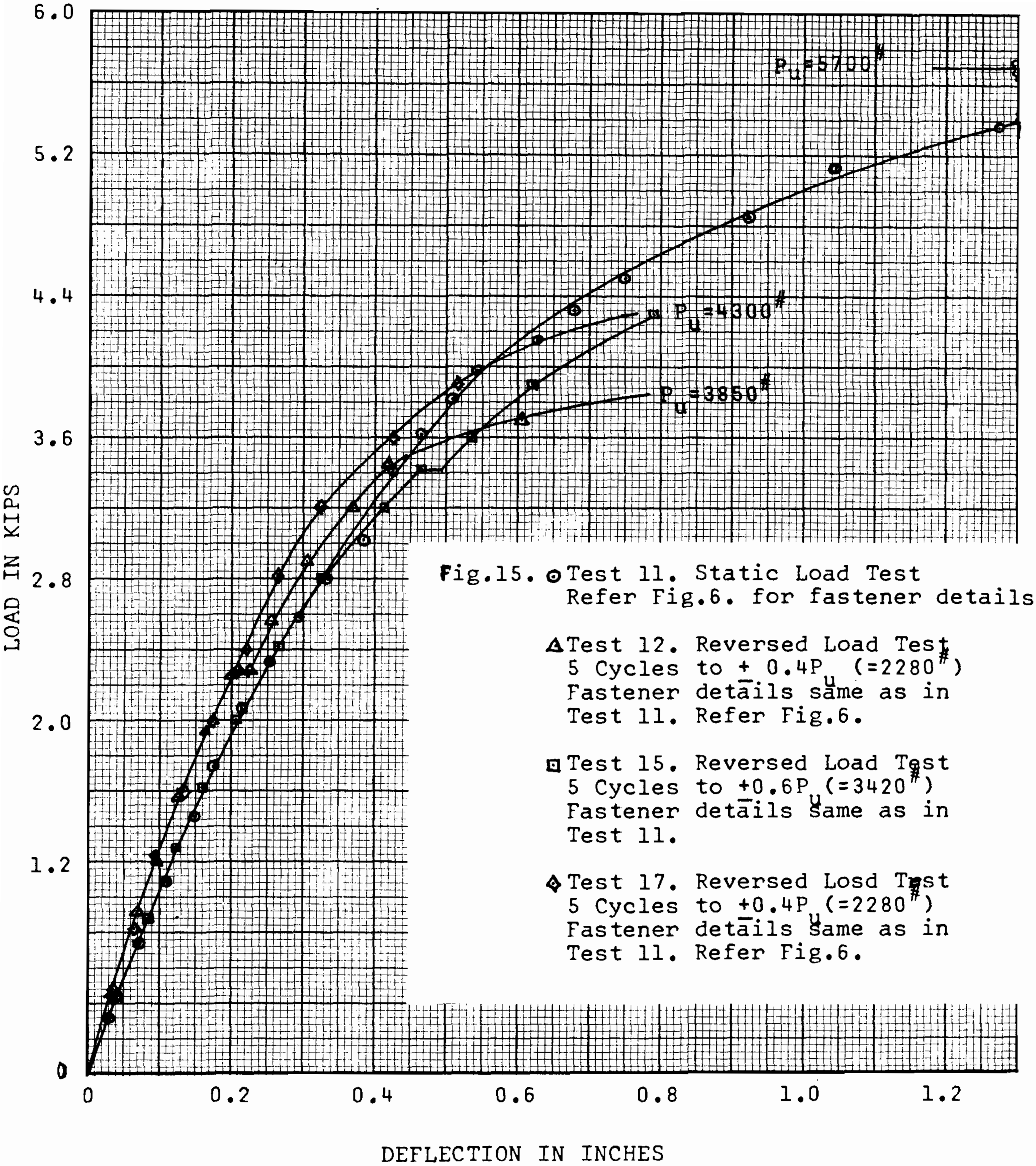


Fig.15. ⊙ Test 11. Static Load Test
Refer Fig.6. for fastener details

△ Test 12. Reversed Load Test
5 Cycles to $\pm$ $0.4P_u$ (=2280#)
Fastener details same as in
Test 11. Refer Fig.6.

⊡ Test 15. Reversed Load Test
5 Cycles to $\pm 0.6P_u$ (=3420#)
Fastener details same as in
Test 11.

◈ Test 17. Reversed Losd Test
5 Cycles to $\pm 0.4P_u$ (=2280#)
Fastener details same as in
Test 11. Refer Fig.6.

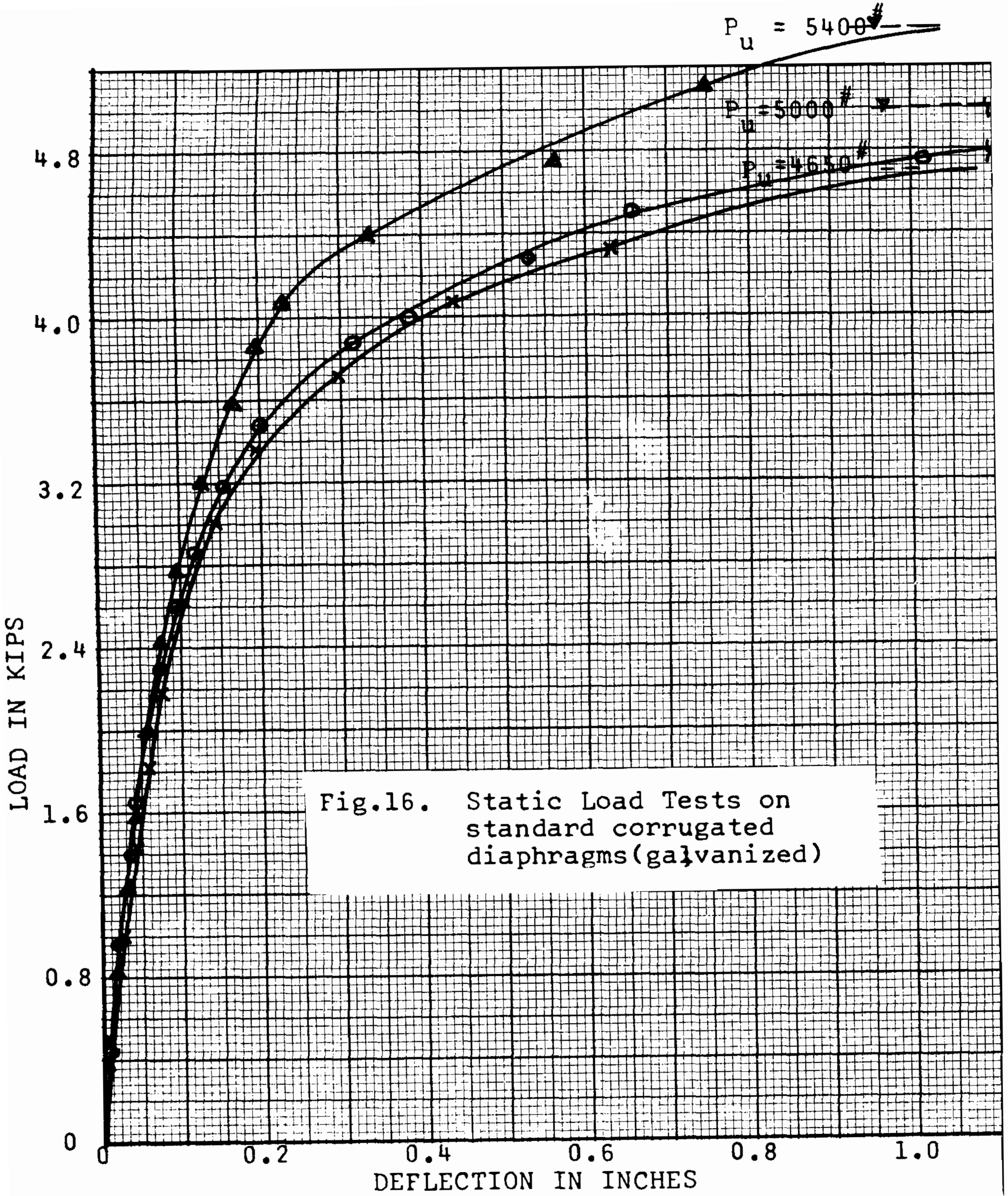
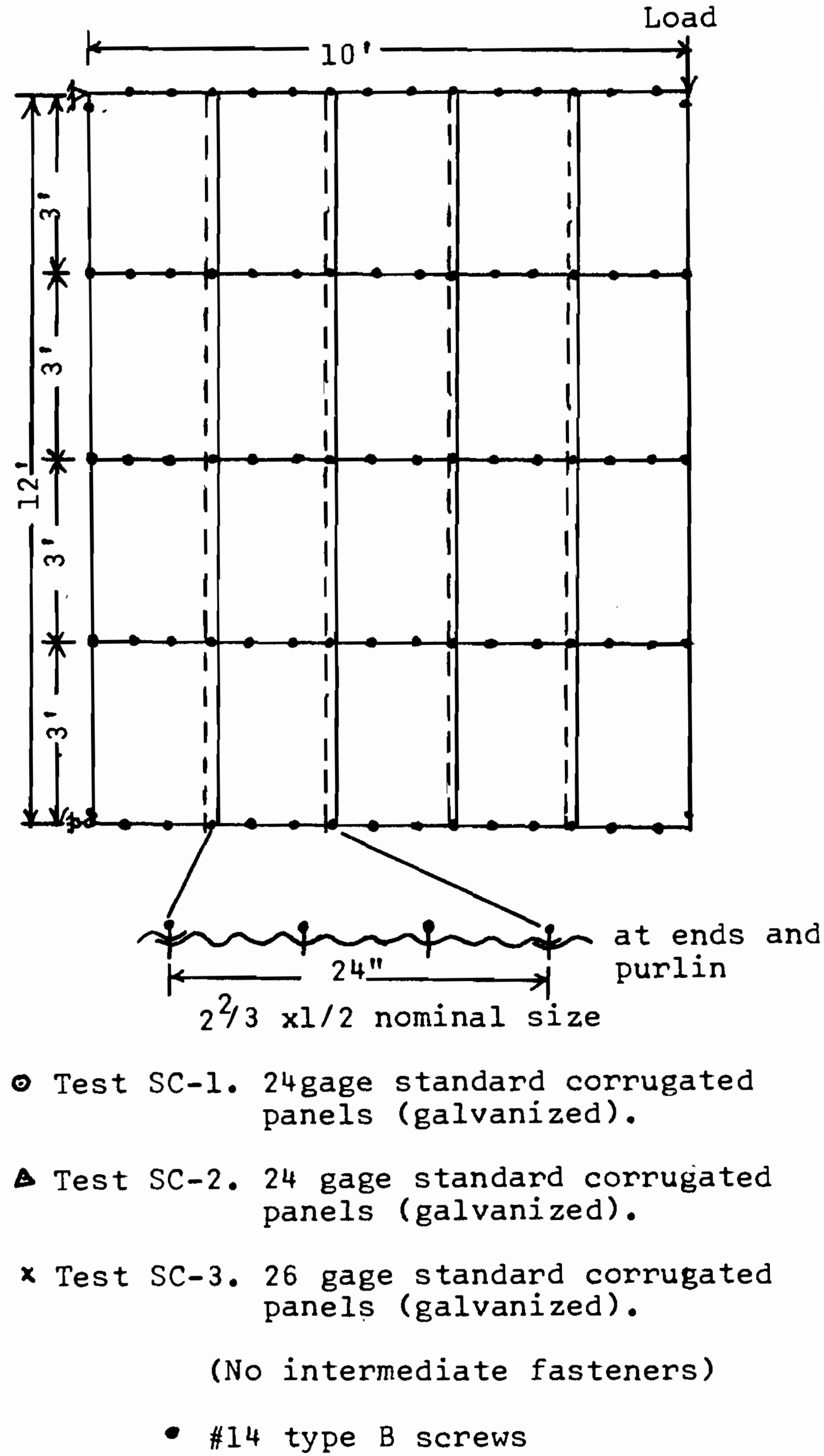


Fig.16. Static Load Tests on standard corrugated diaphragms(galvanized)



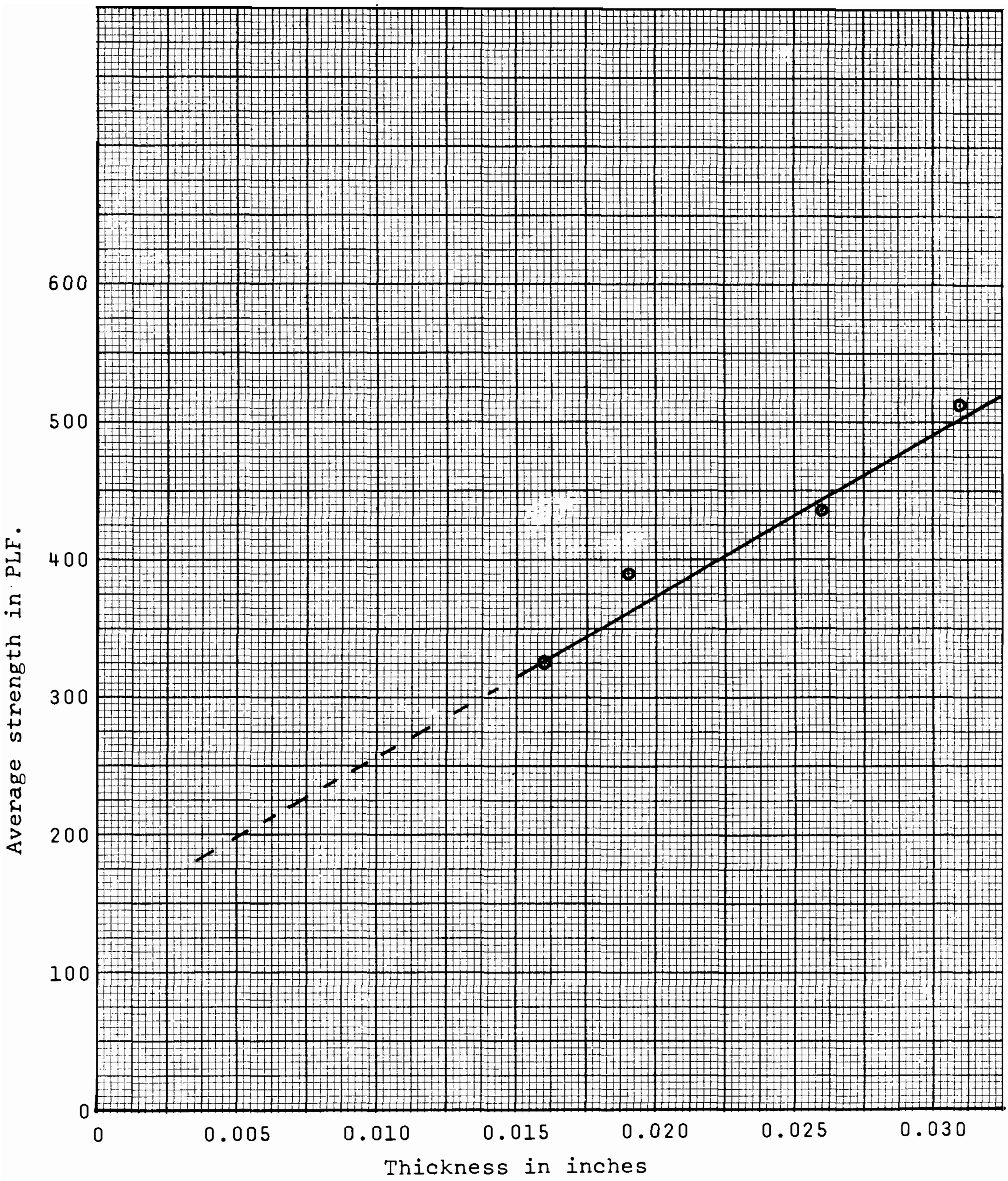


Fig.17. Tests on standard corrugated diaphragms

(22,24,26,28 gages; refer Table 4.)