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REPORT OF TESTS OF STABILITY OF STIFFENED PLATES

BY

ANDREW BRODSKY* AND PAUL H. KAAR**

Foreword

These tests on the behavior of stiffened plate elements loaded in compression were started in 1941. Mr. Brodsky worked on this project until 1943 when the war put a stop to the work. In 1947 the study was resumed by Dr. Johnston and Mr. Kaar. The project was under the sponsorship of the American Institute of Steel Construction.

Introduction

The program for the A.I.S.C. research fellowship was outlined as follows:

> "Tests of plate elements in compression, with both longitudinal and lateral stiffeners. This program would consider some of the fundamental analytical problems in Chapters 4 and 5 of the paper on Elastic Stability by Messrs. Moisseiff and Lienhard[1], and would include experimental corroboration of the stability problems involved. Variations in plate thickness ratios and in

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[1] Transactions ASCE, 1941 p. 1052 to p. 1088

the relative size and spacing of the stiffener elements would be considered."*

The tests were to deal primarily with the fundamental plate elements for cellular tower construction. Previous tests on the behavior of plates reinforced by stiffeners, especially those made in Europe, have been limited in their scope. Theoretical investigations of the problem have been made by several authors. These studies have been general in scope and have furnished no practical results.

Program

It was the intention of these tests to simulate the vertical edge conditions of a cellular tower. The scope of the tests was limited by the capacity of the ~~seven~~ eight hundred thousand pound capacity testing machine at the Fritz Engineering Laboratory. Eleven pilot tests were made to perfect the test procedure to be used on larger specimens. Four large specimens were tested in the main program.

The number of stiffeners and the thickness of the plates were both varied. The test specimens were based on Mr. Moisseiff's design using the equation

$$d/t = 50(N+1) \qquad (1)$$

where d = total width of plate
t = thickness of plate
N = number of longitudinal stiffeners

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*Letter from Bruce Johnston to Mr. Moisseiff, July 3, 1941.

Test Procedure of Pilot Tests

In the following description of each pilot test all test plate specimens are of a size 25 inches by $\frac{1}{4}$ inch by 4 feet 4 inches with a clear length of 4 feet $\frac{1}{2}$ inch unless otherwise noted. The two 25 inch edges were perpendicular to the load line and were clamped. Unless otherwise stated lateral deflection measurements were made. Unit stresses mentioned are average over the area of the plate. All welding and riveting were done by expert workmen.

The following is a description of each pilot test:

The buckling load of both these and the main test specimens was determined by the formula:

$$\sigma_{cr} = K \frac{E \pi^2 \zeta}{12\ (1-v^2)} \left(\frac{t}{d}\right)^2 * \qquad (2)$$

where t = thickness of plate
d = width of plate
E = modulus of elasticity of plate
v = Poisson's ratio
σ_{cr} = critical buckling stress
K = coefficient dependent on end conditions & conditions of plate
ζ = modulus factor equal to 1 below yield point

Test 1:- An unstiffened plate with the two vertical edges unsupported was loaded to a total load of 14,000 pounds with an average stress of 2,800 psi. The critical Euler buckling load for this plate was 20,850 pounds. The plate deflected in a half wave.

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* Elastic Stability by Moisseiff and Lienhard Transactions ASCE, 1941 p. 1054

Test 2:- The plate used in Test 1 was used again in this test. The plate was unstiffened and the two vertical edges were unsupported. Horizontal bars $\frac{1}{4}$ inch diameter by 8 inches long were placed perpendicular to the faces of the plate at the vertical edges and were 3 inches on center. These bars, the ends of which were 3/8 inches from the faces of the plate, were designed to give lateral support to the vertical plate edges when the plate deflected. The theoretical buckling load computed from equation (2) was 102,895 pounds. At 103,000 pounds, 15,600 psi, the plate buckled into a full wave. At a load of 122,500 pounds, 18,560 psi, the $\frac{1}{4}$ inch diameter bars buckled from the plate load and the plate deflected into a half wave.

Test 3:- This test was identical to Test 2 except timber backing-up strips were used in an effort to prevent buckling of the $\frac{1}{4}$ inch diameter bars. At a load of 110,800 pounds, 16,790 psi, the strips slid and the plate buckled into a half wave.

Test 4:- This test was identical to Test 3 except ties were used between the plate and the timber strips. At a load of 125,100 pounds, 18,950 psi the $\frac{1}{4}$ inch diameter bars buckled and the plate showed a permanent deflection. The plate had yielded at many points.

Because the actual buckling load always exceeded the theoretical critical buckling load of 102,895 pounds and because the lateral support bars buckled this test method was abandoned. It was felt that the bars took too large a percentage of the axial load for good test results.

It was decided to weld flanges to vertical edges of the plates and to apply the load to this built-up column.

Test 5:- A plate 4 inches by $\frac{1}{4}$ inch by 4 feet $\frac{1}{2}$ inch was welded perpendicular to both vertical edges of this plate. These four inch plates were made to bear against the plate clamping angles so that they took their proportionate share of the load. The theoretical critical load was 134,000 pounds. At 135,000 pounds, 15,700 psi the plate buckled into a half wave. The maximum load sustained was 143,000 pounds, 16,630 psi.

Test 6:- A plate $2\frac{1}{2}$ inches by $\frac{1}{4}$ inch by 4 feet $\frac{1}{2}$ inch was welded to one face of the plate at the center line and identical sized plates were welded to the vertical edges of the test plate. All stiffeners were made to bear against the loading blocks. In order to prevent the flanges from bending excessively steel strips 1 inch by $\frac{1}{4}$ inch by 7 inches were welded to the flanges at the mid height of the plate and three inches from either end. One end of the strip was welded to the plate edge stiffeners, the other to the vertical support beams. The thickness of the strips was reduced to 1/8 inch at the beam end to lessen the vertical load they might absorb during the test. A preliminary test was made to see the amount of load the strips would possibly absorb. It was obvious that these strips would not take more than one percent of the load.

Connection angles were bolted to the supporting beams and a reference plate of the same size as the test plate was bolted to the angles. This plate was at a distance of about 16 inches from the test plate and it was necessary to design a special deflectometer for reading lateral deflections. An extension was made for a 1/1000 inch dial gage. Gage holes were drilled into the reference plate and punch marks were made in the test plate. Deflection readings were taken along a number of points at different loads.

At a load of 240,000 pounds, 28,070 psi there was general yielding of the plate. The maximum load sustained was 260,000 pounds, 30,410 psi. Fig. 1 shows the general test set-up and Fig. 2 shows the set-up after the supporting beam on one side had been removed.

Test 7:- The set-up was identical to Test 6 except that an angle 2½ inches by 2 inches by 3/16 inches by 4 feet ½ inch was riveted to the plate at the center line. At a load of 240,000 pounds, 27,550 psi there was general yielding. The maximum load sustained was 275,000 pounds, 31,570 psi. Figs. 3 and 4 show the specimen after removal from the testing machine.

Test 8:- A plate 22 inches by ¼ inch by 4 feet 4 inches was used the width of which was below the maximum as provided by Equation (1). Plates 2½ inches by ¼ inch by 4 feet ½ inch were welded to the vertical edges of the plate and a plate 2½ inches by ¼ inch by 4 feet 6 inches was welded as a center stiffener.

The center stiffener was longer than those used in the other tests. It was cut to fit the clamping angles and was partly bearing against the loading blocks. This was to prevent the plate from bending in the direction of the stiffener. The plate did deflect in the opposite direction. At 140,000 pounds, 18,490 psi there were strain lines throughout the plate and on the center stiffener. The maximum load sustained was 241,000 pounds, 31,840 psi, when the stiffener buckled and then the plate buckled in a half wave. Fig. 5 shows the specimen after the test was completed.

Test 9:- A plate 28 inches by ¼ inch by 4 feet 4 inches was used the width of which was above the maximum width as provided in Equation (1). Plates 2½ inches by ¼ inch by 4 feet ½ inch were welded to the vertical edges and a plate 2½ inches by ¼ inch by 4 feet 2 3/4 inches was welded as a center stiffener. This stiffener was cut to bear closely against the clamping angles. In addition a steel strip 2½ inches by ¼ inch by 4 inches was welded to the test specimen both on top and bottom in back of the center stiffener. These pieces were also made to fit the clamping angles. The purpose of these plates was to give the test plate added rigidity. At a load of 250,000 pounds, 27,170 psi the center line stiffener began to yield rapidly and it buckled at a load of 261,000 pounds, 28,370 psi. The steel of the center line stiffener had a lower proportional limit than that of the main plate. Figs. 6 and 7 show the specimen after testing.

Test 10:- A standard size plate was used for this test. Plates 4 inches by ¼ inch by 4 feet ½ inch were welded to the vertical edges of the test plate. The wider flanges would add to the rigidity of the built-up column and it was hoped would allow the full strength of the plate to be utilized. A plate 2½ inches by ¼ inches by 4 feet 2 3/4 inches was welded along the center line. Strips 2½ inches by ¼ inch by 4 inches were welded to the plate in back of the center line stiffener on the top and bottom to increase the rigidity.

Lateral support for the plate was provided by steel strips 1 inch by ¼ inch by 6½ inches welded at one end to the flange plates, and at the other end to flanges of WF sections. These lateral supports were located three inches from the top and bottom and at the center of the flanges. The maximum load sustained was 309,000 pounds, 33,590 psi at which time the plate buckled in a half wave with at least two smaller full waves in each panel. Figs. 8 and 9 show the specimen after the test had been completed. Fig. 10 shows a contour plot of lateral deflection of this plate. Fig. 11 shows a load deflection curve for this plate.

Plates, in some of the pilot tests, were welded to the unloaded vertical edges of the plates as flanges. Horizontal steel strips were welded to these flanges to tie the plate to columns which were in turn fixed. It was the original intention to use this arrangement in the tests of the large plates with the horizontal tie plates being spaced six inches on center.

In a letter to Mr. F. H. Frankland dated December 22, 1942, Mr. Brodsky proposed that the system for supporting the unloaded vertical edges of the plates be revised. He proposed the method of support which was adopted and is described on Page 11 of this report. The majority of the Committee on Technical Research of the American Institute of Steel Construction agreed to Mr. Brodsky's proposal. Dr. Bruce Johnston, who was away from the University on war leave at the time, approved of the suggestion "to speed up production", with the supposition that the originally planned test method could be used if difficulties arose with the new method.

Test 11:- In this test was tried the entirely different support method which Mr. Brodsky proposed. On a normal sized plate 5/8 inch diameter bars 5/8 inches long were welded to the vertical edges of the plate 6 inches on center. The only stiffener used was a $2\frac{1}{4}$ inch by $\frac{1}{4}$ inch by 4 feet 3/4 inch long plate welded to the test plate along the center line. The rounds fitted into guide slots made by welding plates to a column. The guides and plates were greased before the test began. There was free vertical movement of the plate in the slots before the plate was clamped for the test.

Near the ultimate load one of the guide plates broke away from the column thus freeing the plate. Because of this breaking deflection notes could not be made for all points. The ultimate load was 183,700 pounds, 25,550 psi.

The results of the eleven pilot tests are summarized in Table I.

On the basis of pilot test eleven procedure for testing the four main plates was formulated.

Discussion of Test Data - Pilot Tests

Table I shows in tabular form, the results of the pilot tests and the characteristics of the plates. Critical buckling loads are computed by Equation (2), by Southwell's Method*, and by "top-of-the-knee method"**. As can be observed by comparison of values obtained as above with testing machine loads required to buckle the plates there is some agreement but seldom do all methods agree closely. Agreement of the testing machine buckling load and the critical load as determined by Equation (2) is evidence of the correctness of the subject paper.

Transverse stiffeners were not used in these tests so the theory concerning the action of these stiffeners could not be checked.

The writer does not believe the pilot tests were of large enough size. Handling of the main test specimens presented such a number of new problems that it was almost like an entirely new research project.

Test Procedure for Main Plates

Two bearing blocks 5 inches by 8 inches by 2 inches

** NACA TN No. 1124, 1946

* R. V. Southwell, Proceedings Royal Society Series A, Vol. 135, p. 601

thick were tack-welded to a load-bearing-block 4 feet 2 inches by 4 inches by 9 inches deep. The load was applied to the smaller bearing blocks which, in turn, transmitted the load through the large bearing block to the plate specimen. Fixed-end conditions along the top and bottom of the plate were established by bolting the specimen to the large bearing blocks. The connection was made in the following manner: two 2 inch by 5/8 inch angles were bolted to the large bearing block, back to back, spaced far enough apart to permit insertion of the end of the plate. Bolts, three inches on center , passing through the plate and the angles fastened the plate specimen securely to the bearing block. A bearing plate 4 feet 2 inches by 8 inches by 3 inches deep with the identical plate fastening arrangement was used to secure the bottom of the plate specimen.

The following method of securing the vertical edges of the plate was used: Round bars 5/8 inches in diameter by ½ inch long were welded to the vertical edges of the plate specimens 2 inches on center. Each vertical edge of the plate test specimen with the rounds attached was inserted between two 3 inch by 3 inch by 5/8 inch angles welded back to back to a column. The column was fixed against lateral deflection (but not against twisting as later developed) and raised above the table of the testing machine. In this manner, it was thought, the vertical edges of the plate specimen were free to rotate or to move up and down, but not free to move laterally. The angle backs and the rounds on the vertical edges of the plate

The angle backs and the rounds on the vertical edges of the plate were greased before the test so there would be a minimum of friction. Since the columns were clear of the testing machine table, no load could be transmitted by them to the load weighing mechanism. A cross-section of the plate and supports is shown in Fig. 12.

At the beginning of each test vertical strain measurements were taken with a Whittemore Strain Gage along the vertical edges of the plate at various load intervals within the elastic range. If there was a difference in the amount of strain, the loading head was adjusted by means of shims until the strain was nearly equal at both edges.

Description of Main Test Specimens

Test No.	Plate Size	Calipered Plate Thickness	Plate Area	Long. Stiffener	Trans. Stiffener
1	36½"x3/8"x19'	0.3735"	15.11sq.in.	1	1
2	38"x 3/8"x19'	0.374	15.14	1	4
3	48½"x5/16"x17'	0.313	18.10	2	1
4	48"~~x~~7/16"x5/16"x17'	0.324	17.97	2	3

7 48 7/16"

The main plate material was purchased from the Bethlehem Steel Company, Bethlehem, Pennsylvania. The 3/8" plates were from the same heat as were the 5/16" plates. The physical and chemical properties are as follows:

Pl. No.	T'ness	Yield Point p.s.i.	Tensile Strength psi	Elongation %	Reduction of area %	Chemical		Analysis	
						C. %	Mn. %	P. %	S. %
1&2	3/8"	37,900	61,700	26.0	56.5	.18	.51	.020	.032
3&4	5/16"	38,800	64,100	31.0	59.5	.16	.46	.011	.033

In each case the stiffeners were welded so that the plate was divided into equal sized panels. The stiffeners were cut in such a manner that neither end contacted the bearing blocks. This procedure kept the stiffeners from taking any of the testing machine load in direct compression.

Plate 1:- This plate had been fabricated with welded flanges and single transverse and vertical stiffeners. After round edge supports had been selected, the flanges were burned off. The plate was then only 36½ inches wide.

Seven horizontal strain gage lines were laid out on the plate at the top and bottom ends and approximately at the sixth points. Each gage line was divided into five gage sets - one close to each end and the others at quarter points along the plate width. Gage lines were also laid out on the stiffener.

Twenty-six horizontal deflection gage lines were laid on the plate at the top and bottom and spaced at equal intervals of 4½ inches along the vertical edge of the plate in the same manner as the strain gages.

The plate was not of uniform length and one side took more load than did the other. An attempt was made to shim the bottom loading block up. Strain and deflection readings were taken at 75,000 pound intervals on plate and stiffener.

The first strain lines appeared at a lower corner at 144,000 pounds load, 9,530 psi. At 300,000 pounds, 19,850 psi there was much yielding at this corner.

The strain measurements at the lower end frequently showed a variation from tension to compression along a straight horizontal line perpendicular to the face of the plate. At the maximum load the strain had become almost constant throughout the middle of the plate.

A reference plate was fastened to the testing machine parallel to the specimen plate for deflection measurements.

A drawing of this plate is shown in Fig. 14.

Plate 2:- This plate was 38 inches wide. A single vertical stiffener and 4 transverse stiffeners whre welded to the plate making equal sized panels.

Eight horizontal strain gage lines were laid out on the plate at the top and bottom and at 9 inch intervals at the center of the plate in the same manner as described for Plate 1.

At 225,000 pounds, 14,860 psi strain lines showed behind all horizontal stiffeners. At 300,000 pounds, 19,820 psi strain lines appeared on the vertical stiffeners about $\frac{1}{4}$ of the plate length up from the bottom. At 375,000 pounds, 24,770 psi there were strain lines generally all over the plate and stiffeners.

The variation of strain measurement along horizontal lines perpendicular to the face of the plate described in Plate 1 was found in Plate 2.

A drawing of this plate is shown in Fig. 15.

Plate 3:- This plate was 48¼ inches wide.

Four horizontal strain gage lines were laid out on the plate at the top, bottom, middle, and lower quarter point. Each gage line was divided into eleven gage sets two each in two of the three panels and one in the remaining panel. The remaining six gage lines were located on the vertical stiffeners, three lines on each.

Deflection gage lines were laid out similar to those in Plate 1.

At 180,000 pounds, 9,940 psi. strain lines were observed in one vertical stiffener at the top of the plate. At 270,000 pounds, 14,920 psi. strain lines appeared in one bottom corner. At 360,000 pounds, 19,890 psi. strain lines appeared behind the two vertical stiffeners the entire length of the plate. At 450,000 pounds, 24,860 psi. the load dropped off to 443,000 pounds, 24,480 psi. At 475,500 pounds, 26,270 psi. the plate buckled in the bottom quarter. The final form of the plate was 1½ waves.

A drawing of the plate is shown in Fig. 16.

Plate 4:- Strain gage lines were laid out as described in Plate 3. Deflection gage lines were laid out similar to those in Plate 1.

At 180,000 pounds, 10,020 psi. strain lines appeared in the upper corner of the plate. At 270,000 pounds, 15,030 psi. strain lines appeared at the lower edge of the plate and below the bottom transverse stiffeners. At 360,000 pounds strain lines appeared on the edges of the vertical stiffener, in the upper quarter of the plate. At 450,000 pounds, 25,040 psi the plate buckled. The ultimate load was 465,000 pounds, 25,880 psi.

Discussion of Test Data - Main Tests

Plates 1 and 2:- When the original test data was re-examined in 1947, it became apparent that the upper head of the testing machine and the bottom of the plate and fixture must have moved laterally. This movement was probably due to "play" be- the screws and nuts of the machine. This condition was shown by the lateral deflections which were measured at the top and bottom of the plate which should have remained fixed. Correction of the lateral deflection data was affected by applying a corrective factor equal to the measured deflection at the two ends of the plate. This correction factor was proportioned throughout the length of the plate.

Plots of the deflected surfaces of the plates are shown in Figs. 18 and 19.

Plate 3:- Some of the deflection data for this sheet was not recorded. Data for areas along the edges of the plate is sketchy and there is little available data for deflections of the top one-third of the plate. On only the middle two of the five gage lines was a deflection measurement made for the top of the plate. These two available measurements indicated that the same thing had happened on Plate 3 that had happened to Plates 1 and 2 - i.e., the plate top and bottom had moved laterally during loading . Corrections similar to those outlined in the discussion

of Plates 1 and 2 were made in the case of gage lines 3 and 4, the gage lines having a recorded end lateral deflection. Corrections for gage lines 1, 2, and 5 were made in the following manner. There were no measured deflections (head movement) at the top of the plate along these gage lines. It was assumed that the movement would be proportional to the distance from gage lines where the measurements were made; i.e., assuming the top of the plate to be a straight line, two points would determine the line. After the movement of the upper head had been determined in this fashion, proportional corrections along the vertical length of the gage lines were made as had been done in Plates 1 and 2.

Mr. Brodsky observed and recorded in the data that the supports of the vertical edges of both Plates 3 and 4 deflected during the test. Because the function of the columns was to furnish an unyielding support, and since the supports failed to function in this fashion, the usefulness of the test data is questionable.

It is the writer's belief that the deflection and twisting was due to the weakness of the open wide flange support sections in torsional resistance. There is no mention of this lateral deflection in the data of Plates 1 and 2, but since the maximum loads are in the same general range, and since the deflections are similar, it is probable that it existed during these tests and was not discovered until the third plate was tested.

A plot of the deflected surface of the plate is shown in Fig. 20.

Plate 4:- Some of the deflection data, as in the case of Plate 3, was not recorded. There is no recorded data for de-deflections of the vertical edges of the top three-quarters of the plate. As in Plates 1 and 2 it is evident that the upper head of the testing machine must have slipped laterally, and the bottom of the plate and fixture must have slipped a slight amount. Corrections were applied exactly as in the case of Plates 1, 2, and 3.

A plot of the deflected surface is shown in Fig. 21.

The machine load on some plates was compared with the product obtained by multiplying the plate strain times the modulus of elasticity of the plate material times the area. In very few cases did these two values agree closely, There is a general trend for the percentage difference between the two values to increase toward the bottom of the plate. This was to be expected because once the vertical supports had twisted or deflected the plate could not slide freely in the vertical slots. The vertical columns probably took load from the plate. The maximum difference was 80% and the minimum difference was 10%.

Determinations of the modulus of elasticity of the plate steel were carefully made. Five coupon tests were made of material from each plate. Each of the five tests was made by the use of a different gage. The gages used were: Huggenberger, Whittemore, and Moore. The average of the five separate modulus determinations was used as the modulus of elasticity of that plate. The modulus determination of Plates 1 and 2 was 30,100,000 psi and that of Plates 3 and 4 was 30,000,000 psi. In order to test the difference of individual interpretation of data two different engineers examined the stress-strain data and independently computed the modulus values. While the individual values assigned to the modulus value for the five separate tests varied, the average of the five values was the same for each man.

Discussion of Theory

The following quotations are taken directly from the paper Elastic Stability by Moisseiff and Lienhard:

> "The principal function of stiffeners consists in increasing the buckling resistance of the plates to which they are attached. The stiffeners divide the plates or webs into panels, and it is evident that their economical usefulness demands such proportioning that the critical stress of the entire structure is equal to the critical stress of the most stressed panel. The dimensioning of the stiffeners must be such that they form nodal lines at their locations when the critical stress is reached."
>
> "The proper spacing and proportioning of longitudinal stiffeners increase the allowable plate slenderness to multiples of the unreinforced column plate, depending on the number of stiffeners used."

"An unreinforced plate subject to uniform compressive stresses will buckle into waves; the number of these waves depends on the ratio of length to width of plate. It is evident that if a transverse stiffener is placed at the nodal line of the plate the latter will not increase its buckling strength. However, should transverse stiffeners be placed in such a manner that they will shorten the length of each half wave, the buckling stability will be increased."

The size of the plates is covered by Equation (1), $\frac{d}{t} = 50\,(N+1)$. The terms of this equation are defined on page 2 of this report.

The size of the longitudinal stiffeners required is taken from design tables in the paper <u>Elastic Stability</u>, and the design procedure is also outlined in that paper on page 1066.

The size of the transverse stiffeners is governed by the equation:

$$I_t = 0.58\sqrt{\frac{N'^5}{\beta}}\,t^3\,d\,\sqrt{N'} = Tt^3\,d\,\sqrt{N'}$$

where I_t = moment of inertia of the transverse stiffener
N' = number of stiffeners
T = coefficient given in paper <u>Elastic Stability</u>
t = thickness of plate
d = width of plate

Had this series of tests been perfect, and if all material in the paper <u>Elastic Stability</u> is correct we would expect the test specimens to have the following characteristics:

(1) The buckling resistance of the most stressed panel to be the same as that of the whole plate

(2) The critical buckling load to be (N+1) times the critical buckling load of a similar plate unreinforced and one panel width wide. N = the number of longitudinal stiffeners.

(3) The buckled plate to be of such form that each transverse stiffener be at a node, i.e., the transverse to truly shorten the buckled wave length under that occurring in a plate with fewer or no transverse stiffeners than the specimen.

The main tests did not confirm any of our expectations. Since there was serious difficulty with the test set-up we cannot evaluate our agreement or disagreement with the theory of the paper Elastic Stability.

The pilot tests while not being similar in size to the main test specimens, did confirm some of the theory in the subject paper.

Recommendation

The writer recommends that if the tests are continued the two untested plates be used as pilot test plates and new specimens be obtained for the new tests. The writer believes the best test set-up to be that developed and used in pilot test 10. He does not believe any value can be derived in merely testing the two remaining plates. If the two tests were entirely successful, a research project consisting of questionable value data on four tests and good data on two tests would still not be given much consideration.

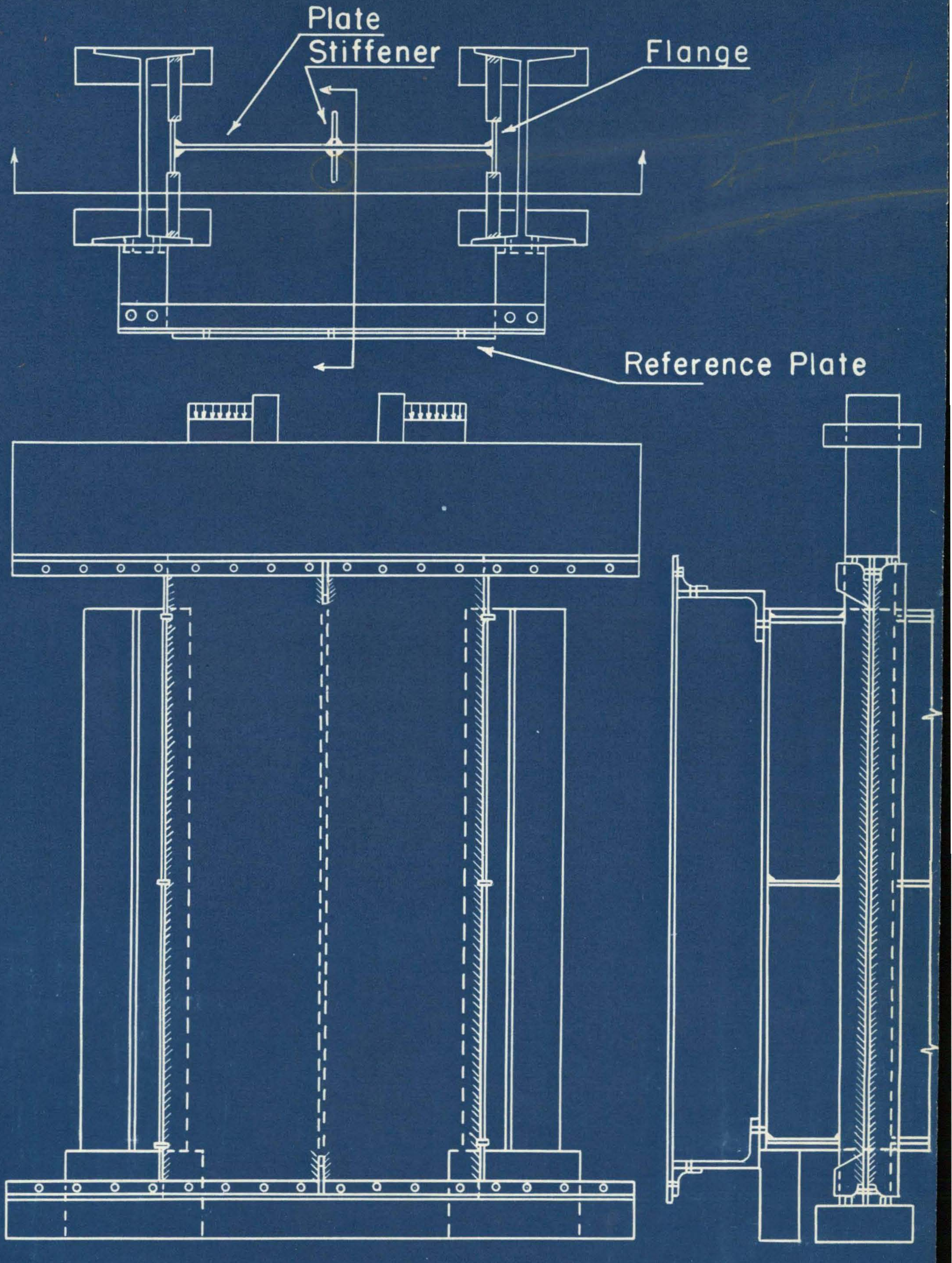


Fig. I. TYPICAL TEST SETUP

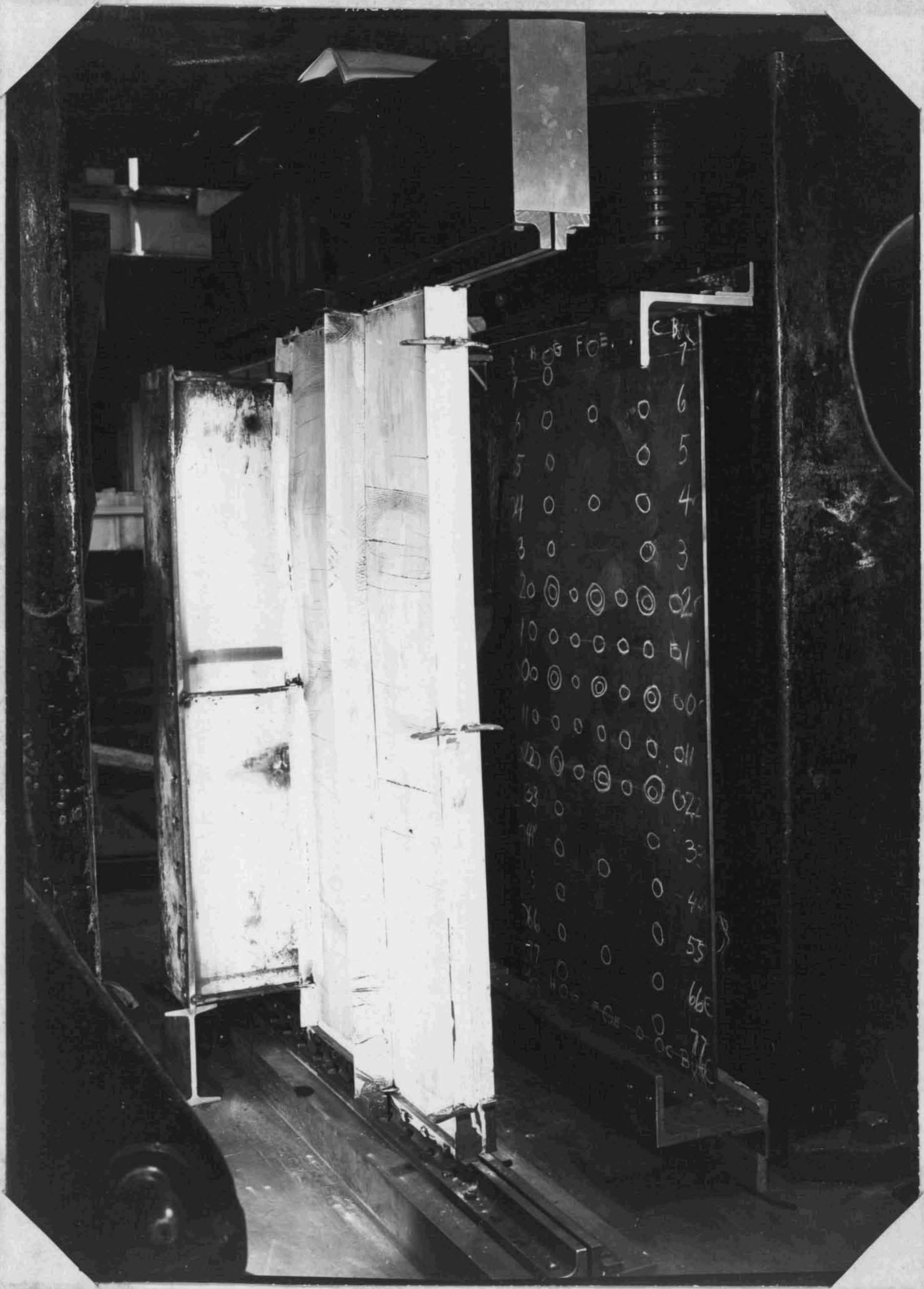


Fig. 2

General Test Set-Up - Pilot Tests 5 to 10
(Supporting beam on near side removed)

Fig. No 3
Pilot Test Specimen No. 7

Fig. No 4
Pilot Test Specimen No. 7

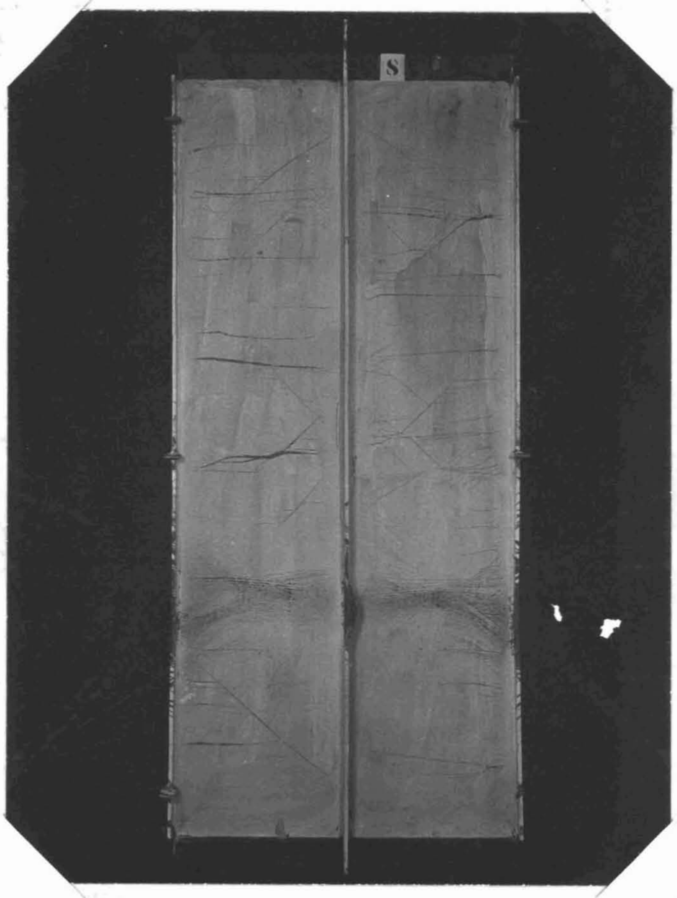


Fig 5

Pilot Test Specimen No. 8

Fig. No 6.
Pilot Test Specimen No. 9

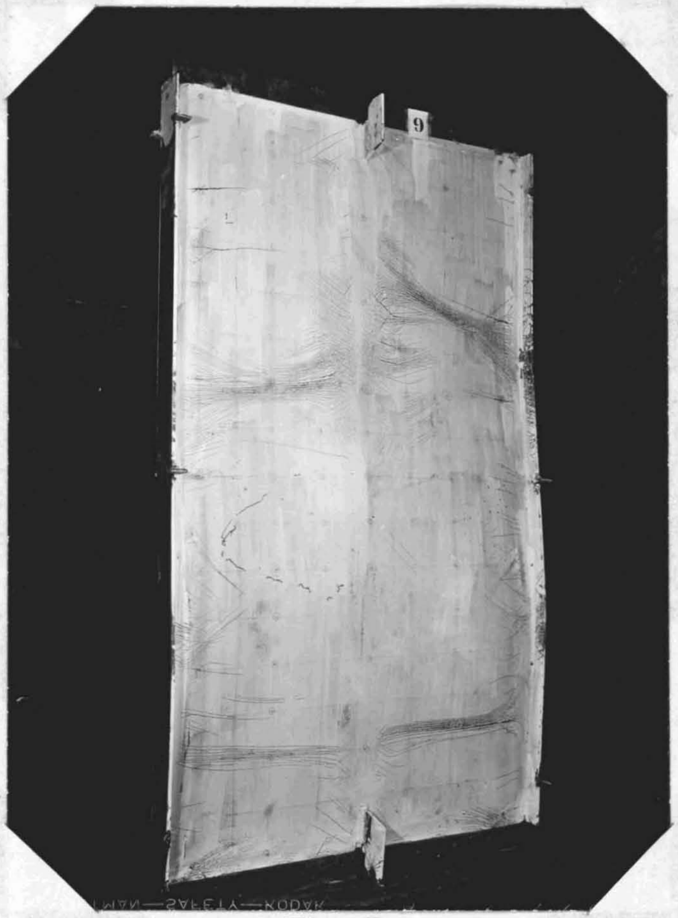


Fig 7.
Pilot Test Specimen No. 9

6+7

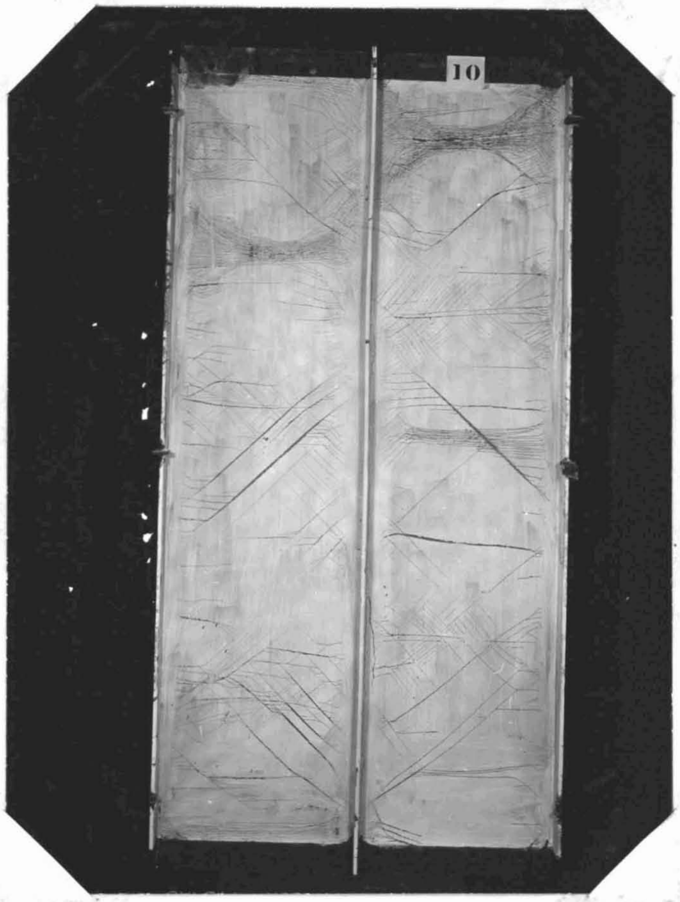


Fig. 8
Pilot Test Specimen No. 10

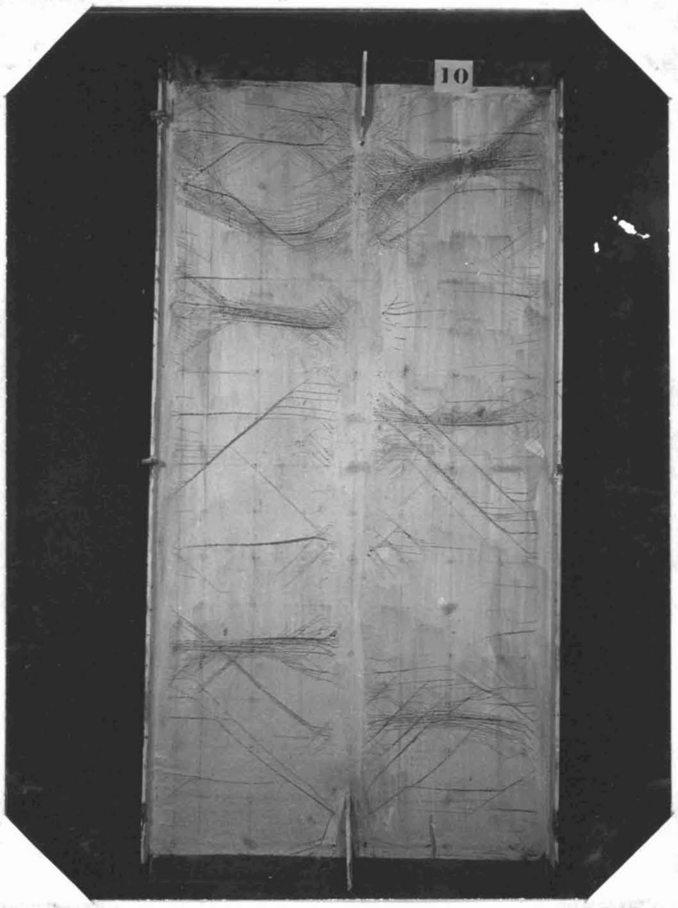


Fig. 9
Pilot Test Specimen No. 10

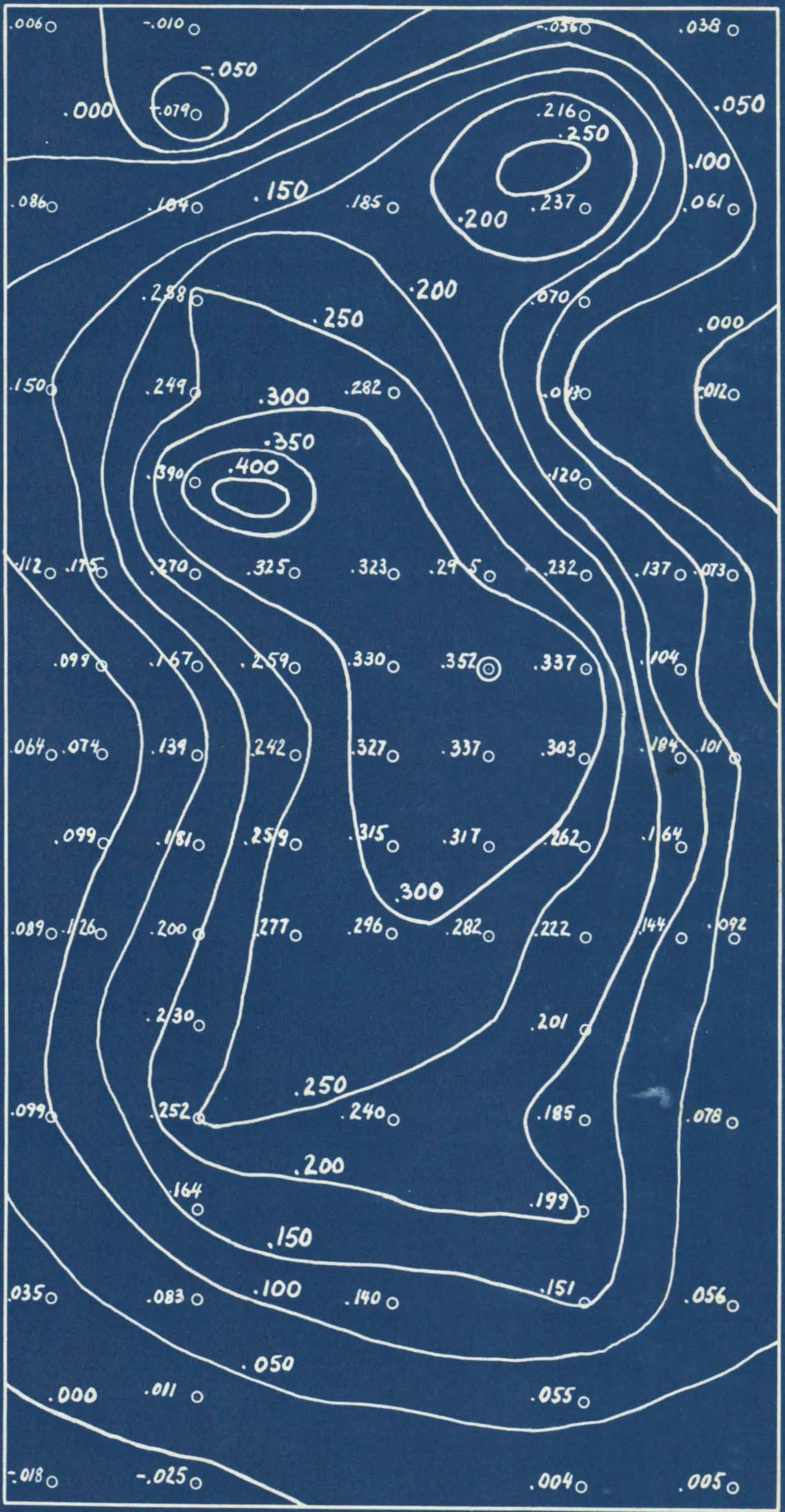


Fig. 10. DEFLECTION SURFACE PILOT TEST No. 10
DEFLECTIONS IN INCHES AFTER FAILURE

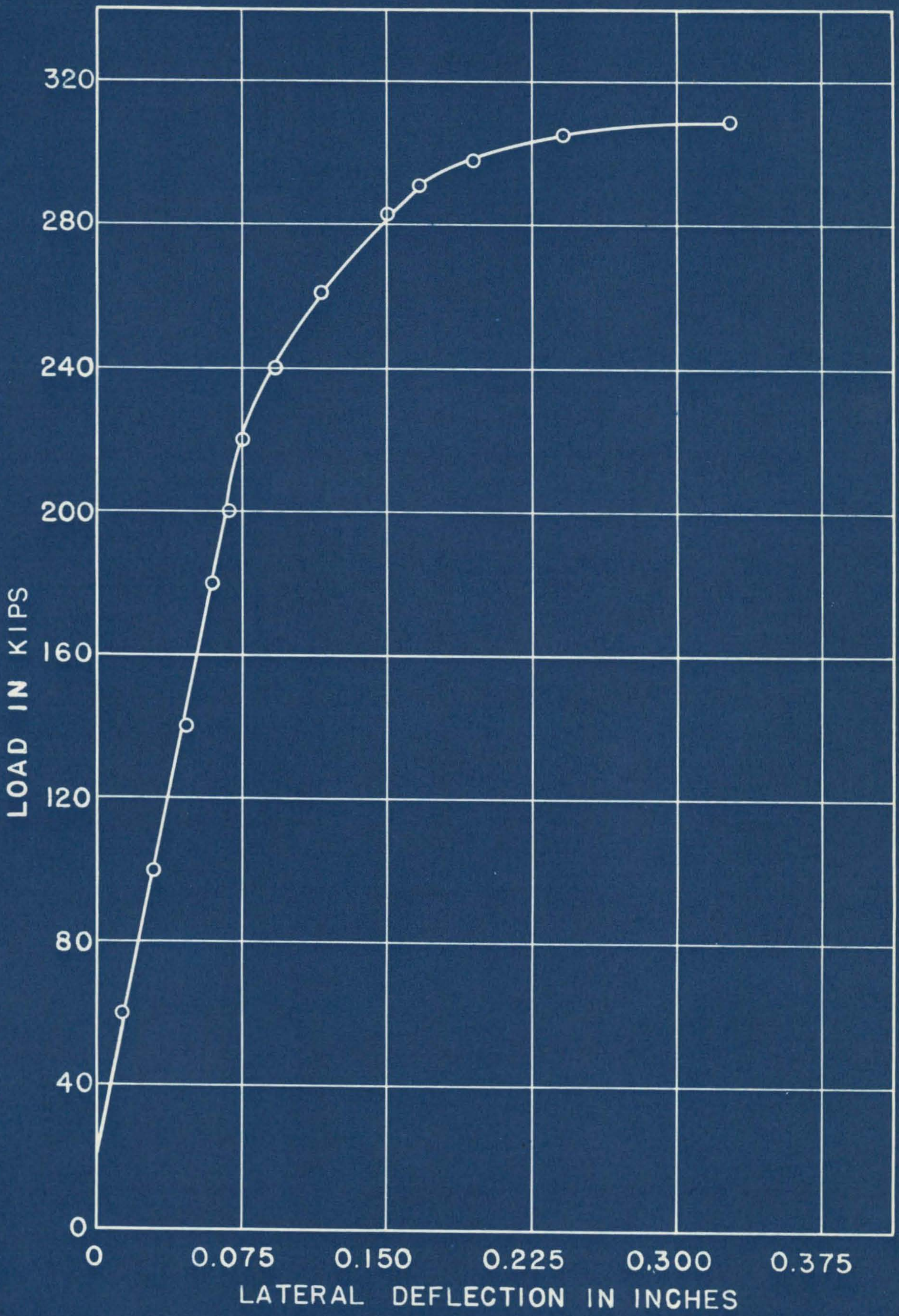
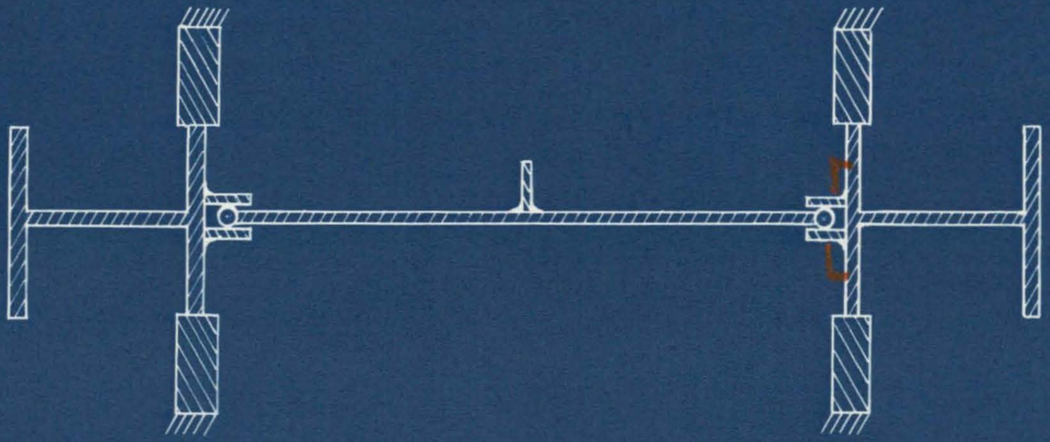


Fig. 11. PILOT TEST NO. 10
LOAD - DEFLECTION CURVE FOR
CENTER POINT OF PLATE



TEST SET-UP

Crossectional View-Pilot Test No. 11 - And All Main Tests

FIG. 12

Fig. 13

Pilot Test Specimen No. 11 After Testing

Fig. 13A

Pilot Test Specimen No. 11 After Testing - Reverse Side

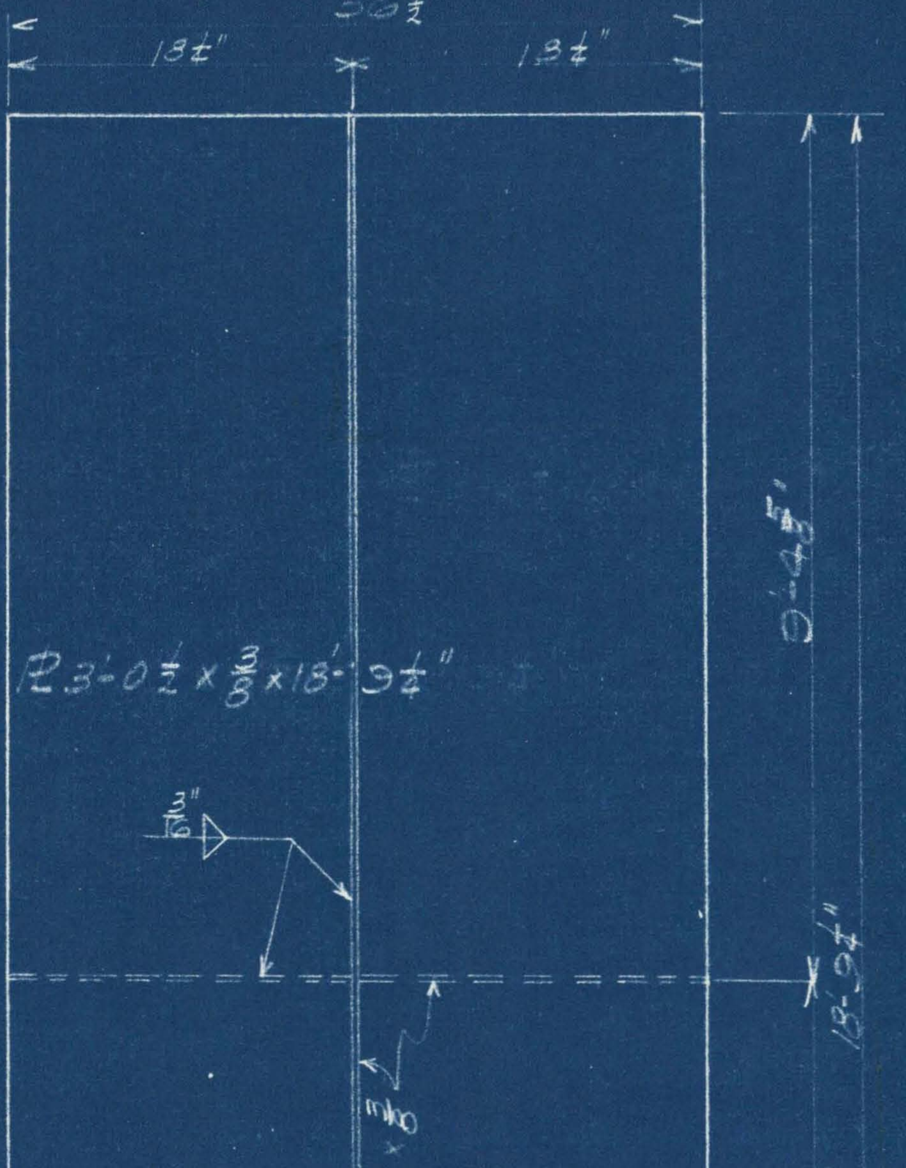


PLATE 1.
No Scale

Fig 14

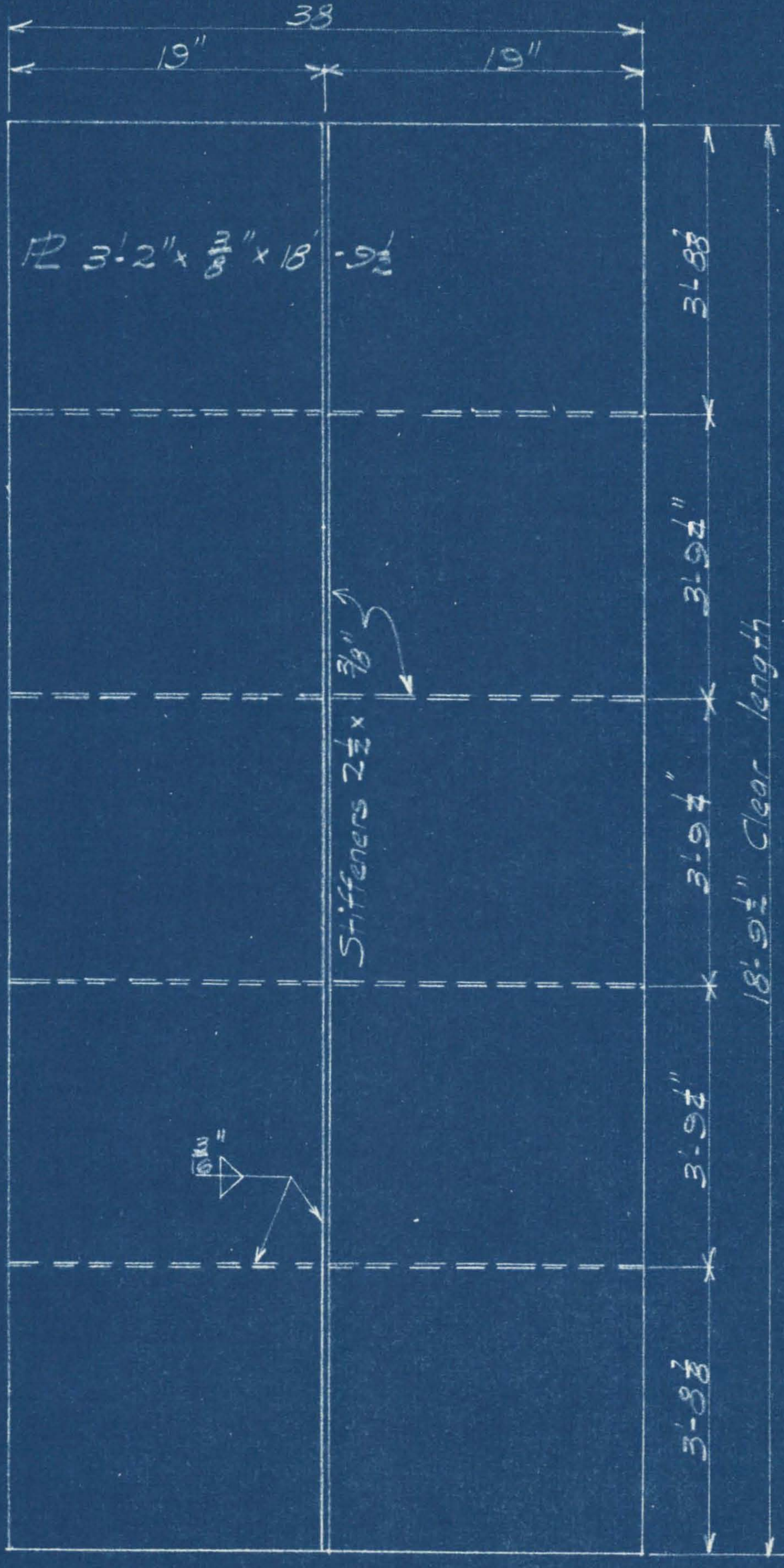


PLATE 2
No Scale

Fig 15

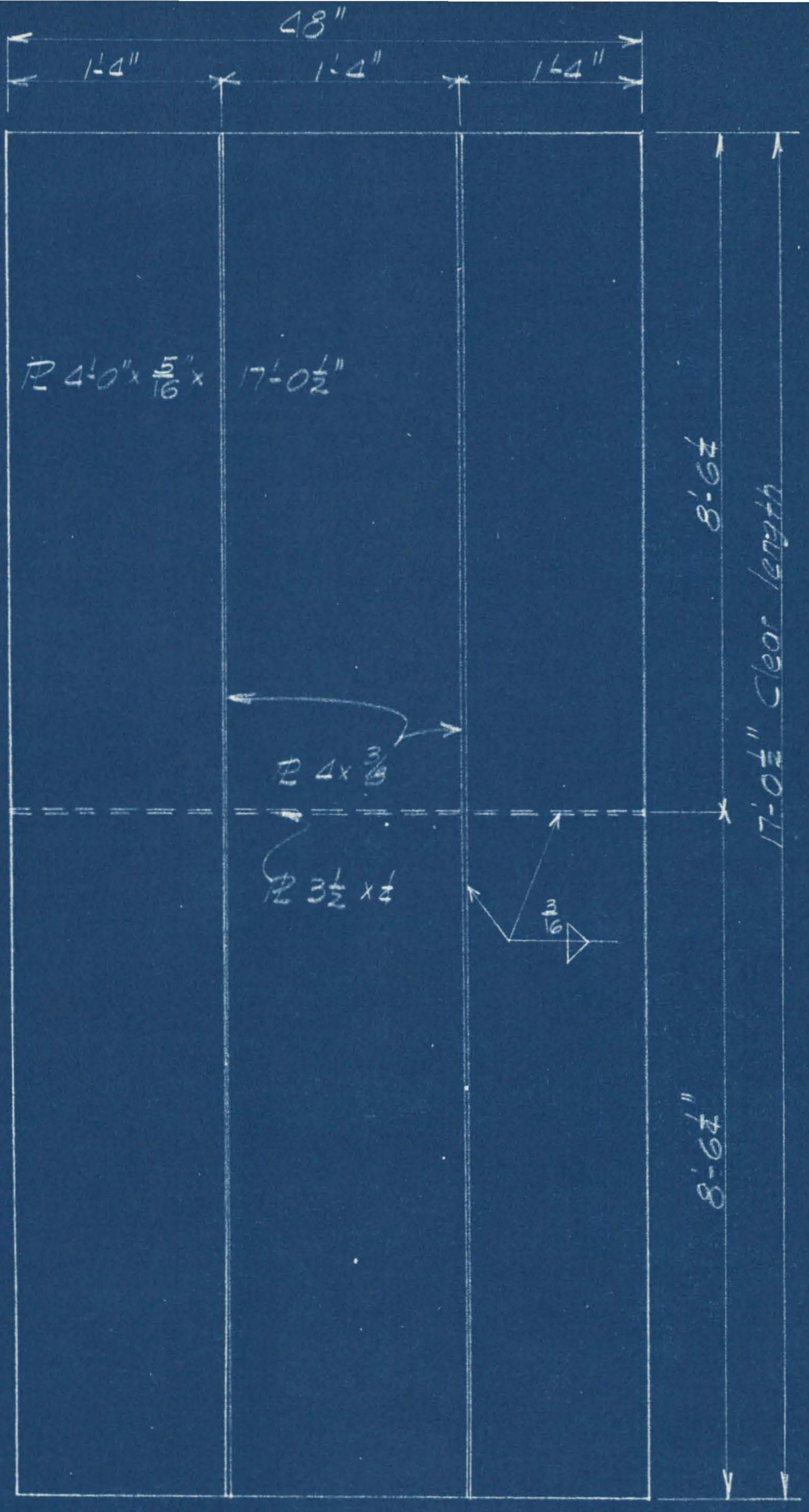


PLATE 3
No Scale

Fig 16

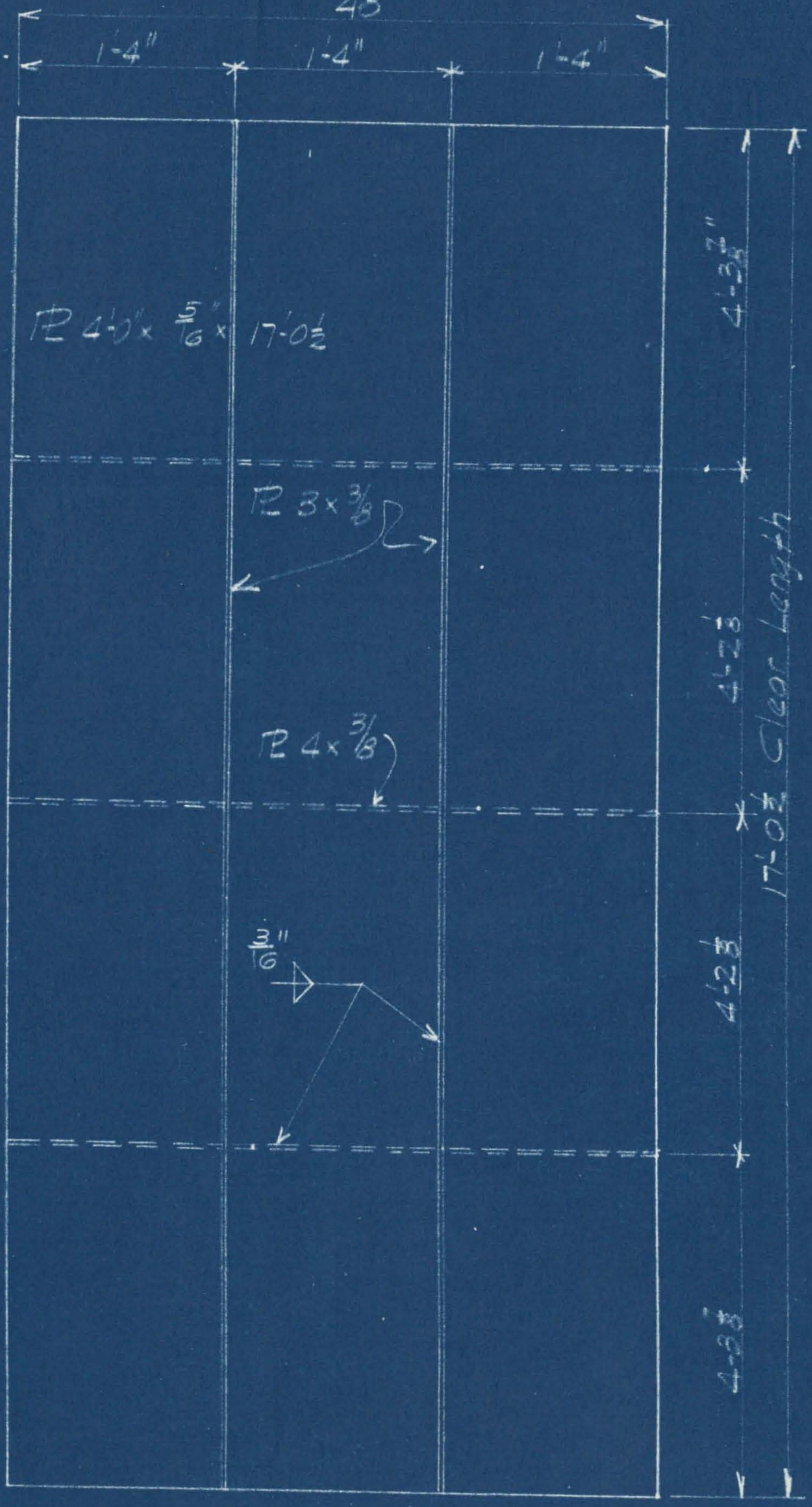
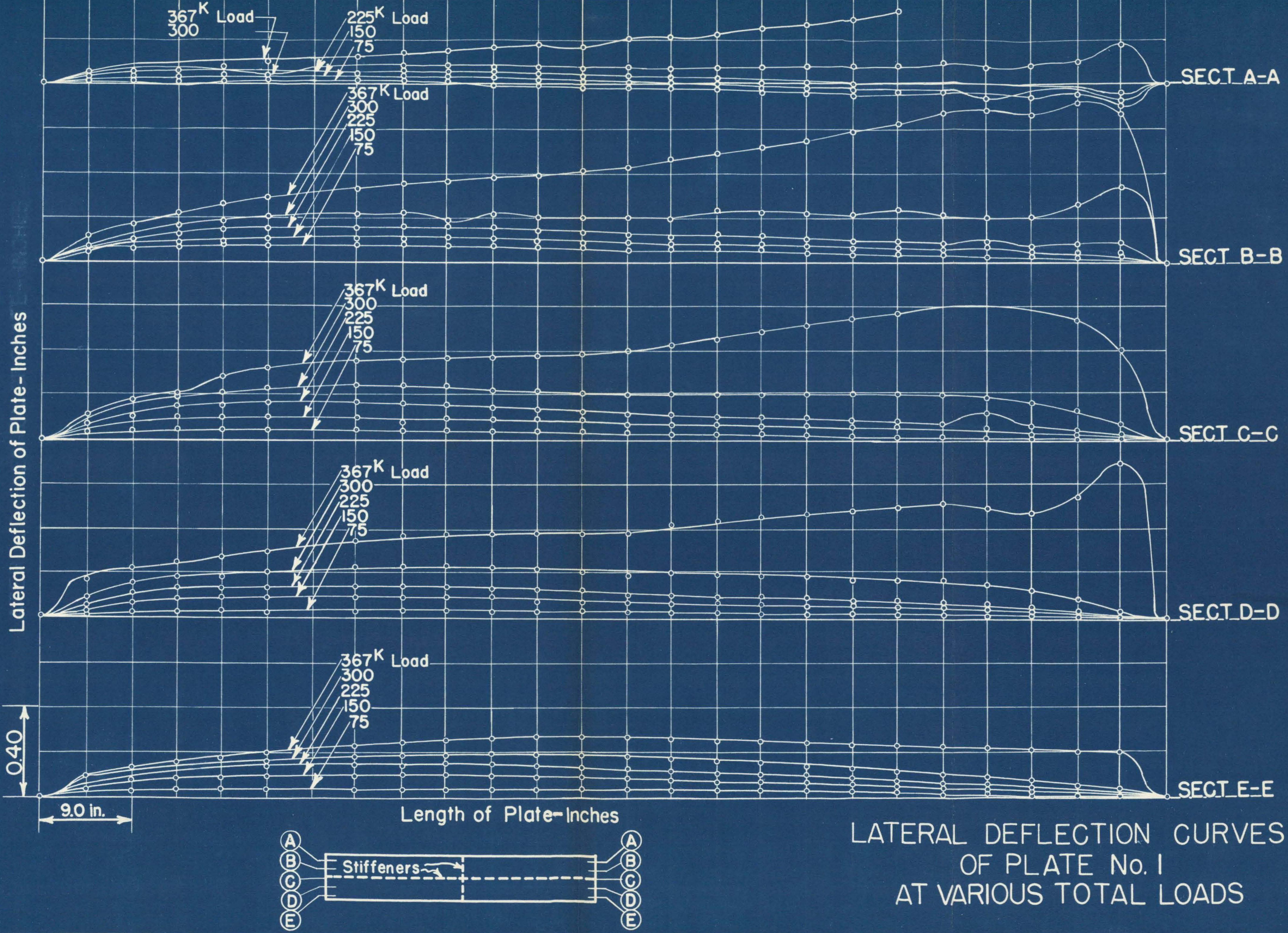


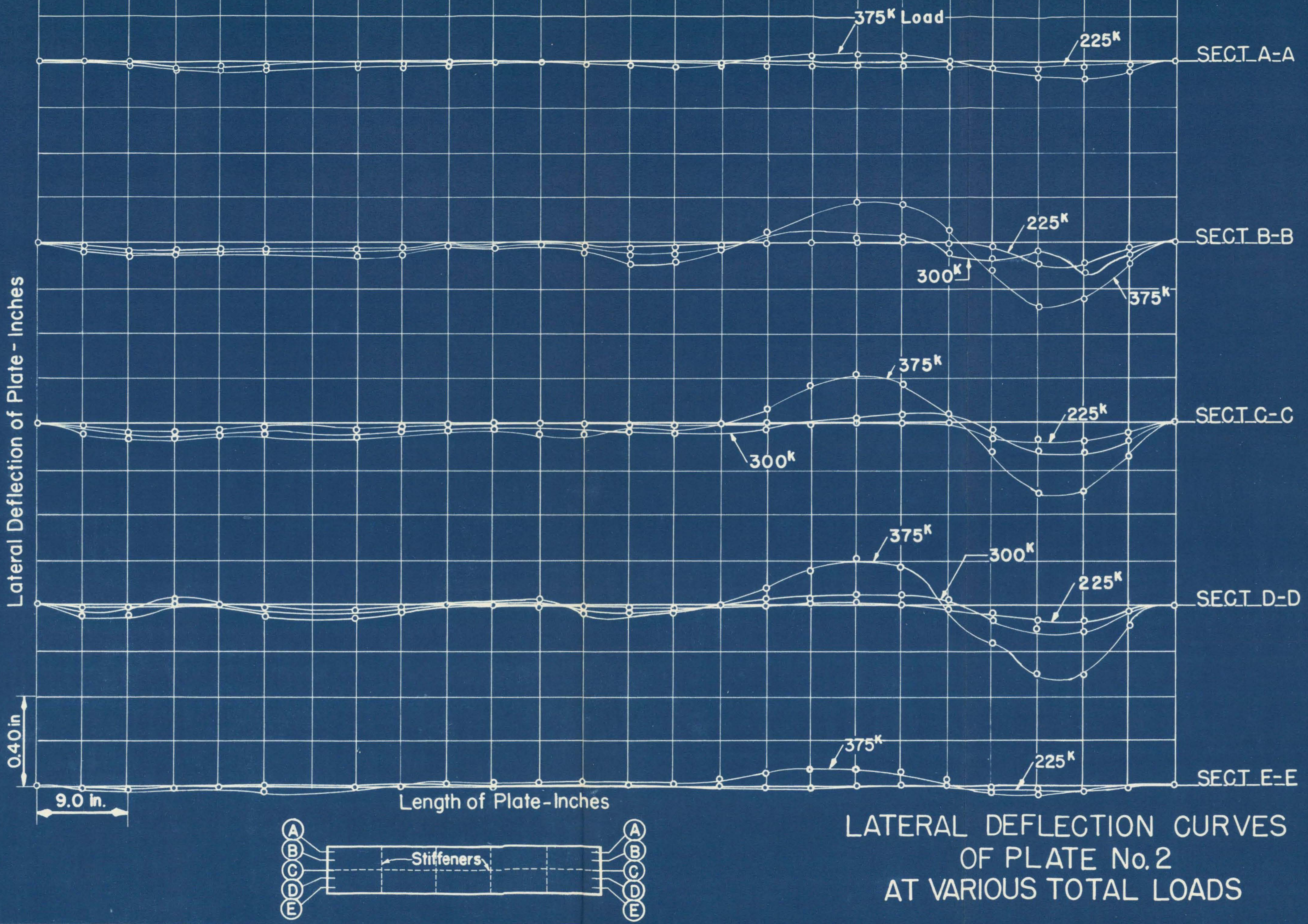
PLATE 4
(No Scale)

Fig. 17



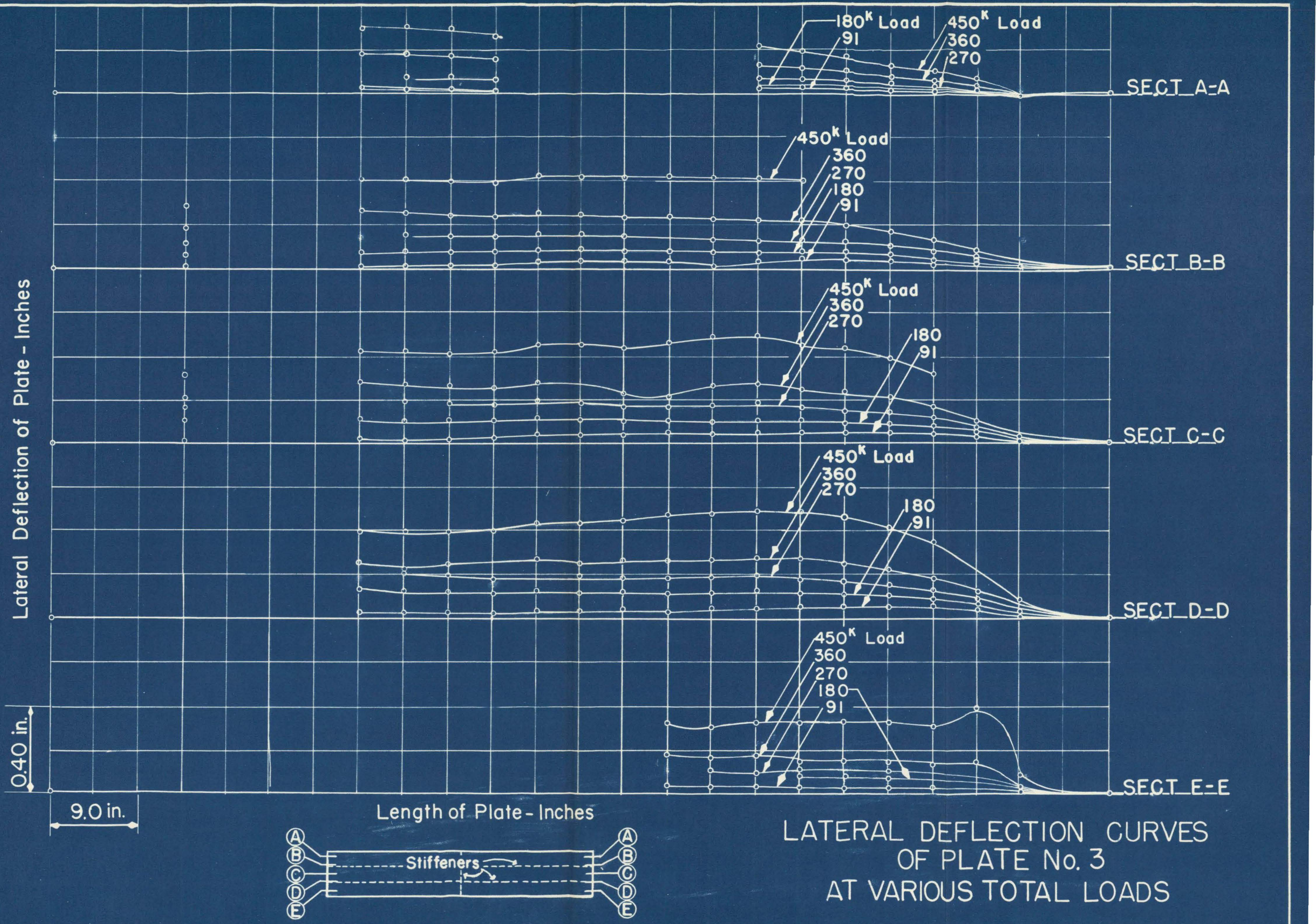
LATERAL DEFLECTION CURVES
OF PLATE No. I
AT VARIOUS TOTAL LOADS

FIG. 18



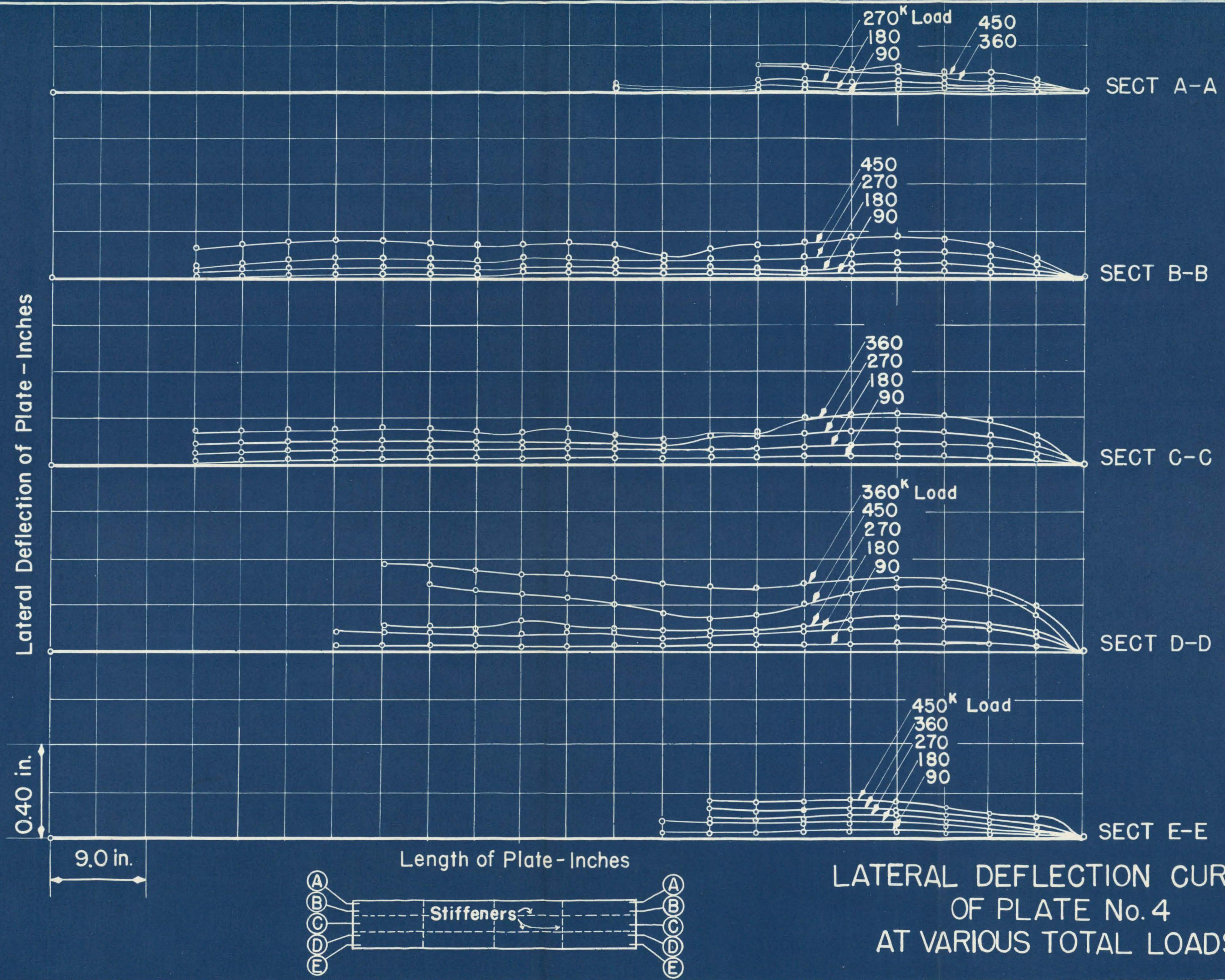
LATERAL DEFLECTION CURVES OF PLATE No. 2 AT VARIOUS TOTAL LOADS

FIG. 19



LATERAL DEFLECTION CURVES
OF PLATE No. 3
AT VARIOUS TOTAL LOADS

FIG. 20



LATERAL DEFLECTION CURVES
OF PLATE No. 4
AT VARIOUS TOTAL LOADS

FIG. 21

Fig. 22

Plates 1 to 4 - Main Test Specimens

TABLE I

SUMMARY OF PILOT TESTS

Test No.	PL Width	Avg. Thick.	PL Area	Stiffener Arrangement	Area		Machine Load at Time PL Buckled		Max. Load		P_{cr} by Formula 2++		P_{cr} by Southwell		P_{cr} by "Top of Knee Method"		Remarks
					Stiff.	Total	Load	Avg. Stress	Load	Avg. Stress	Load	Avg. Stress	Load	Avg. Stress	Load	Avg. Stress	
1	25.0"	0.264"	$6.60^{\square''}$	None	0	$6.60^{\square''}$	——	——	* ——	* ——	102.86^{k}	15.58^{ksi}	18.45^{k}	2.80^{ksi}	——	——	None
**2	25.0	0.264	6.60	None ■	0	6.60	103.0^{k}	15.60^{psi}	122.5	18.56	102.86	15.58	114.0	17.27	95	14.4	Restraining members buckled
3	25.0	0.264	6.60	None ■	0	6.60	110.8	16.79	110.8	16.79	102.86	15.58	120.0	18.18	85	12.9	Restraining members slipped
4†	25.0	0.264	6.60	None ■	0	6.60	125.1	18.95	125.1	18.95	102.86	15.58	133.3	20.20	124	18.8	Restraining members buckled
5	25.0	0.264	6.60	One bearing stiffener each vert. edge 4"x 1/4" Plate	2.0	8.60	135.0	15.70	143.0	16.63	134.02	15.58	198.5	23.08	138	16.05	None
6	25.0	0.264	6.60	One bearing stiffener each vert. edge. - One ℄ stiffener. All 2 1/2"x 1/4" Plate ■	1.95	8.55	260.0	30.41	260.0	30.41	276.60	32.35	275.0	32.16	240	28.07	None
7	25.0	0.264	6.60	One bearing stiffener 4"x 1/2" PL each vert. edge One ℄ stiffener 2 1/2" x 2" x 3/16" ■	2.11	8.71	275.0	31.57	275.0	31.57	281.80	32.35	378.0	43.40	250	28.70	None
8	22.0	0.262	5.76	One bearing stiffener 2 1/2"x 1/4" at each vert. edge and center line ■	1.81	7.57	241.0	31.84	241.0	31.84	257.60	34.03	375.0	49.54	235	31.04	Center stiffener buckled
9	28.0	0.264	7.39	Same as above ▲ ■	1.81	9.20	261.0	28.37	261.0	28.37	280.70	30.51	260.0	28.26	240	26.09	Center stiffener buckled
10	25.0	0.263	6.58	One bearing plate 4"x 1/4" each vert. edge. ℄ stiffener 2 1/2" x 1/4" ▲ ■	2.62	9.20	309.0	33.59	309.0	33.59	297.6	32.35	331.0	35.98	290	31.52	None
11	25.0	0.263	6.58	One ℄ stiffener 2 1/4" x 1/4" ■	0.61	7.19	——	——	183.7	25.55	232.6	32.35	196.0	27.26	155	21.56	Guide plate broke away

* Not loaded to buckling load or to failure

▼ NACA TN No. 1124, 1946

** Same plate as used in test No. 1

++ See report - page 3

† Same plate as used in test No. 3

■ Vertical edges of plate restrained from lateral displacement

▲ Plate 2 1/2" x 1/4" x 4" welded on top and bottom plate opposite ℄ stiffener

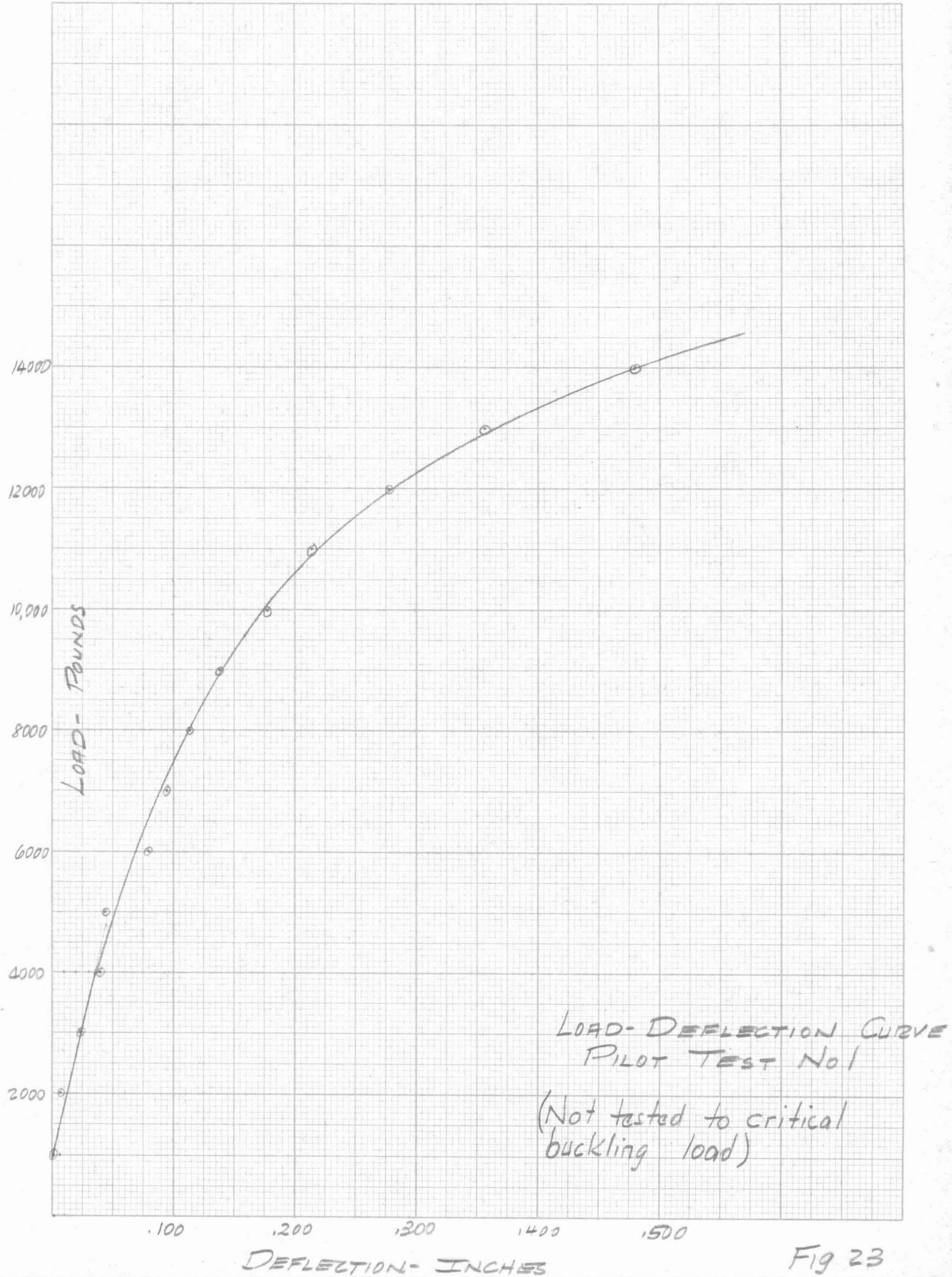
TABLE II

SUMMARY OF MAIN TESTS

Test No.	PL Width	Avg. Thick	PL Area	Stiffener Arrangement	Area		Machine Load at Time PL Buckled		Max. Load		P_{cr} by Formula		P_{cr} by Southwell		P_{cr} by "Top of Knee Method"		Remarks
					Stiff.	Total	Load	Avg. Stress	Load	Avg. Stress	Load	Avg. Stress	Load	Avg. Stress	Load	Avg. Stress	
1	36½"	0.373"	13.63□"	One vert. ℄ stiffener 4"x3/8" One horizontal ℄ stiffener	1.48□"	15.11□"	—	—	367.0^{k}	24.3^{ksi}	474.0^{k}	31.4^{ksi}	491.0^{k}	32.5^{ksi}	300^{k}	19.85^{ksi}	
2	38	0.374	14.21	One vert. stiffener 4"x3/8" Four horizontal stifener 3"x1/4"	0.93	15.14	375.0	24.77	387.0	25.6	465.0	30.7	* —	* —	330	21.80	
3	48¼	0.313	15.11	Two vert. stiffeners 4"x3/8" One horizontal stiffener 3½"x1/4"	2.99	18.10	450.0	24.86	475.5	26.2	552.0	30.5	* —	* —	412	22.76	
4	48 7/16	0.324	15.70	Two vert. stiffeners 3"x3/8" Three horizontal stiffeners 4"x3/8"	2.27	17.97	450.0	25.04	465.0	25.9	559.0	31.1	512.0	28.49	325	18.09	

*Results not reasonable.

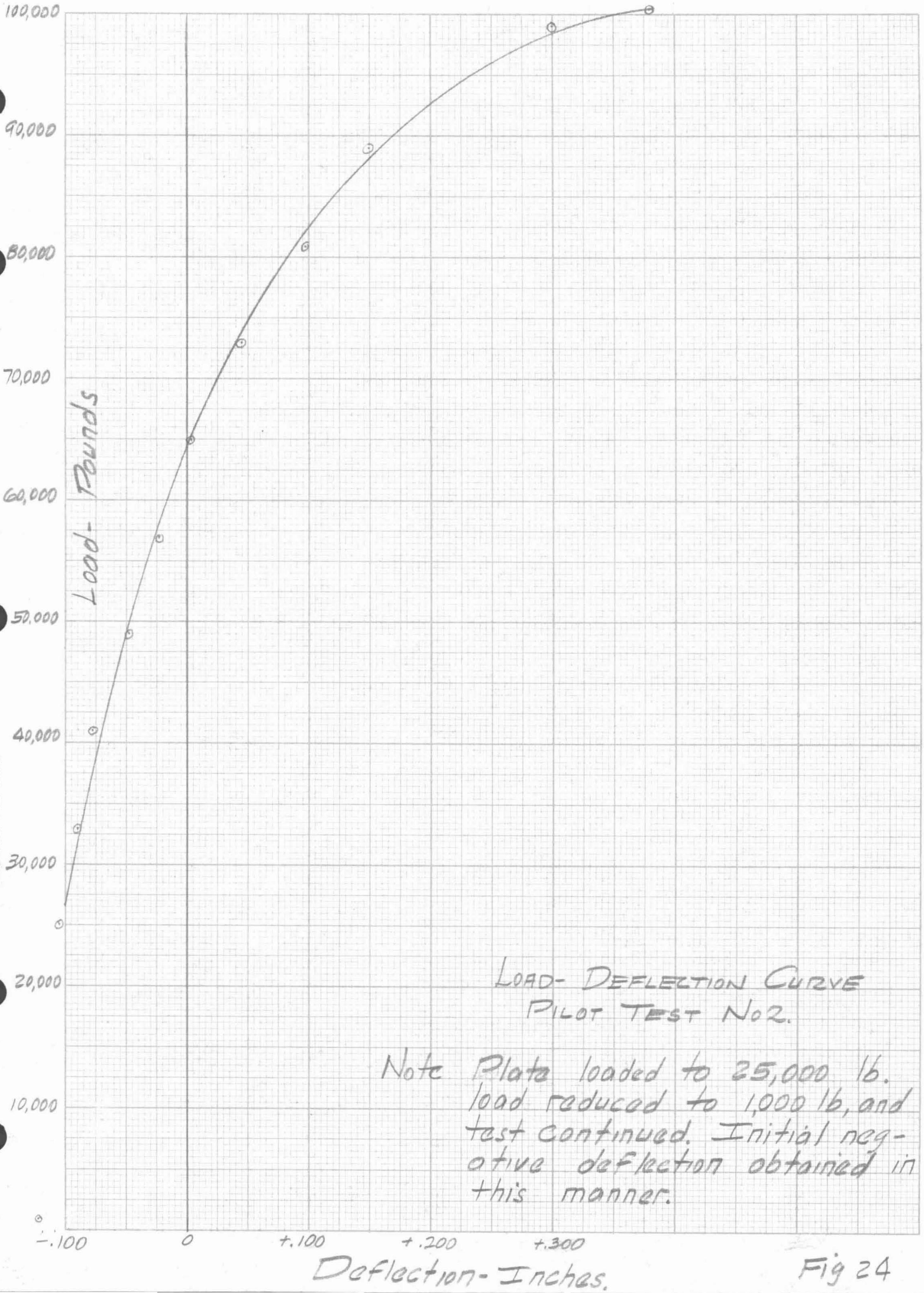
++ See report page 3.



LOAD-DEFLECTION CURVE
PILOT TEST No 1

(Not tested to critical
buckling load)

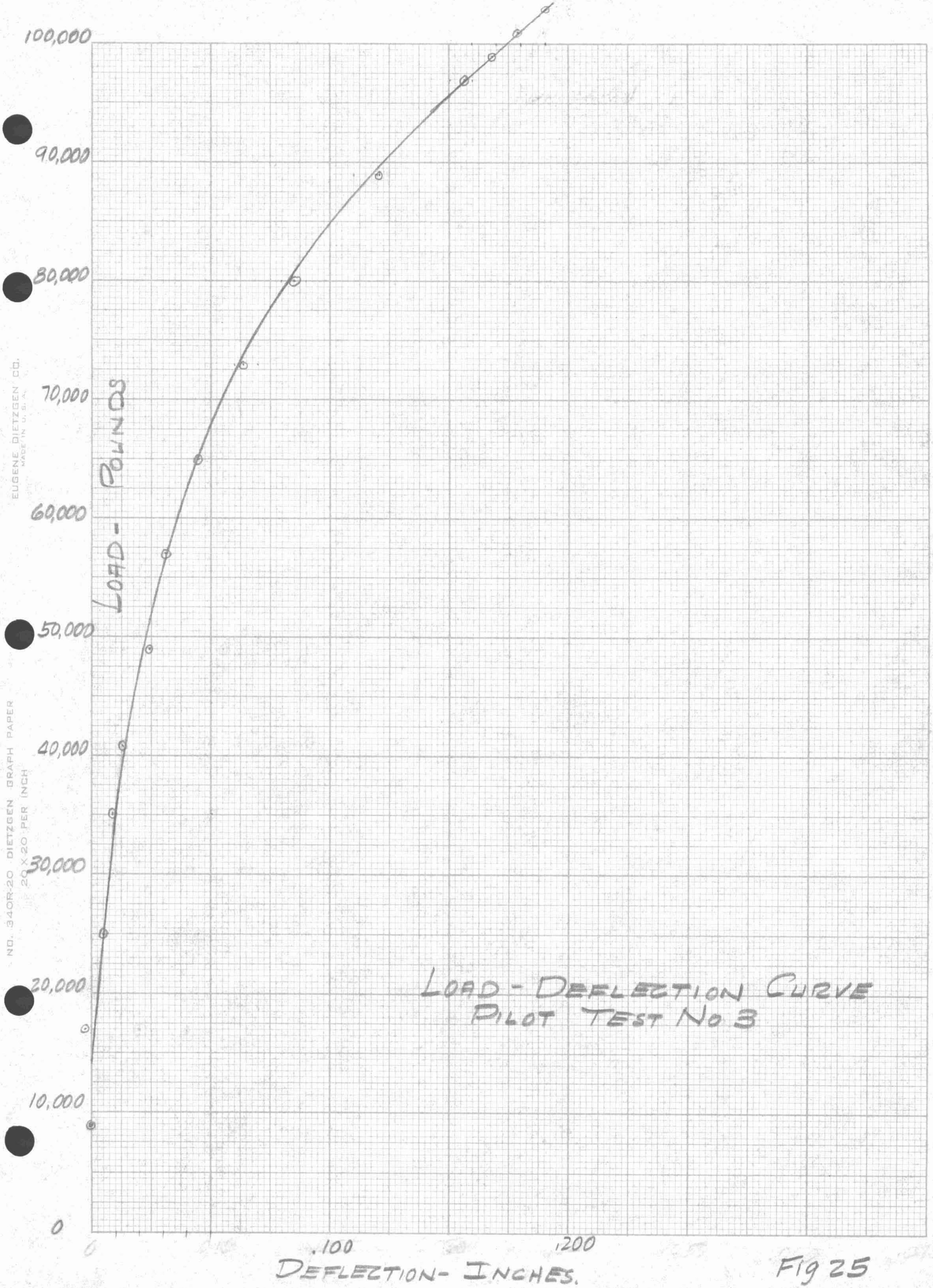
Fig 23



LOAD- DEFLECTION CURVE
PILOT TEST NO2.

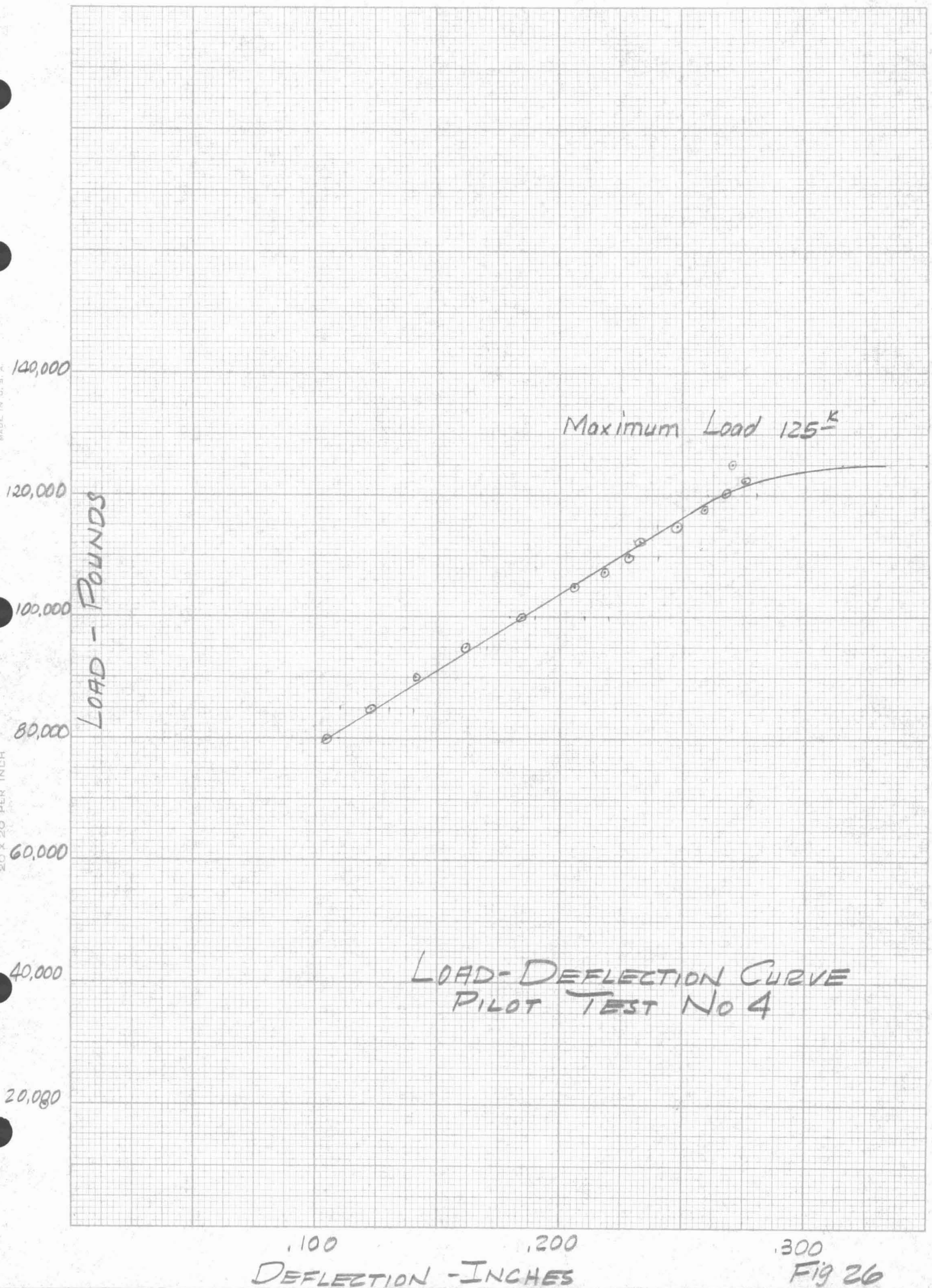
Note Plate loaded to 25,000 lb. load reduced to 1,000 lb, and test continued. Initial negative deflection obtained in this manner.

Fig 24



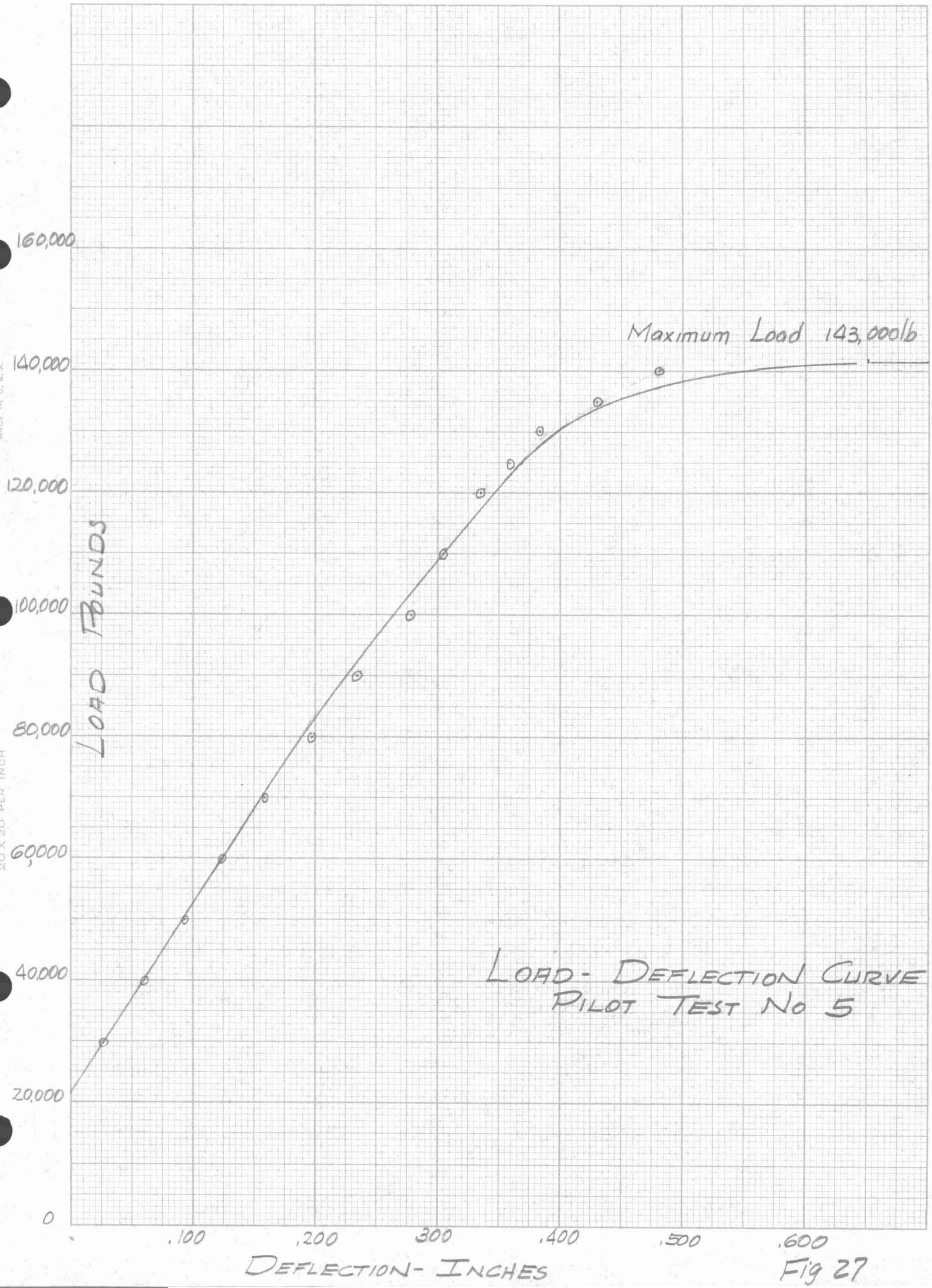
LOAD - DEFLECTION CURVE
PILOT TEST NO 3

Fig 25



LOAD-DEFLECTION CURVE
PILOT TEST NO 4

Fig 26



LOAD- DEFLECTION CURVE
PILOT TEST NO 5

Fig 27

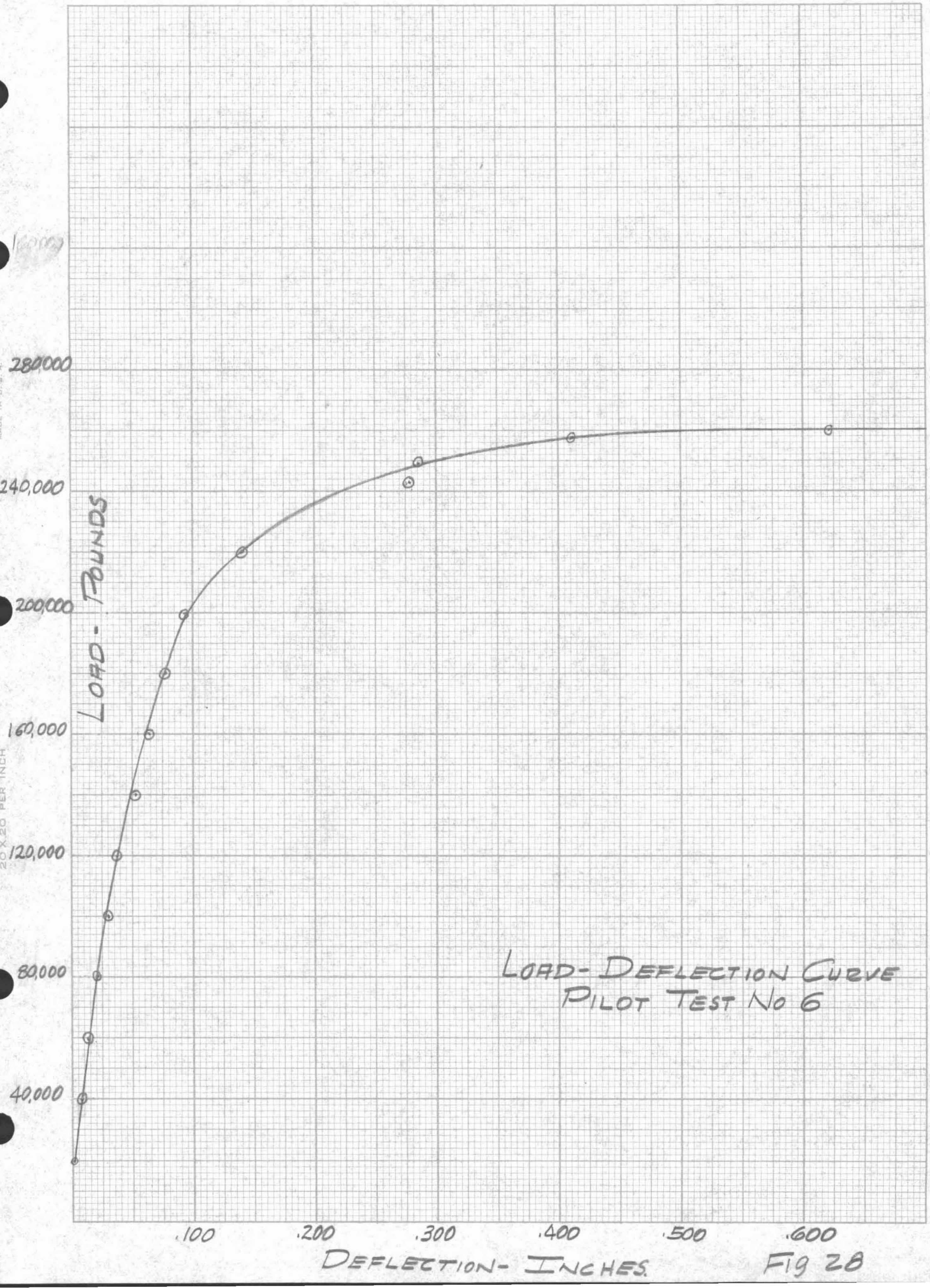
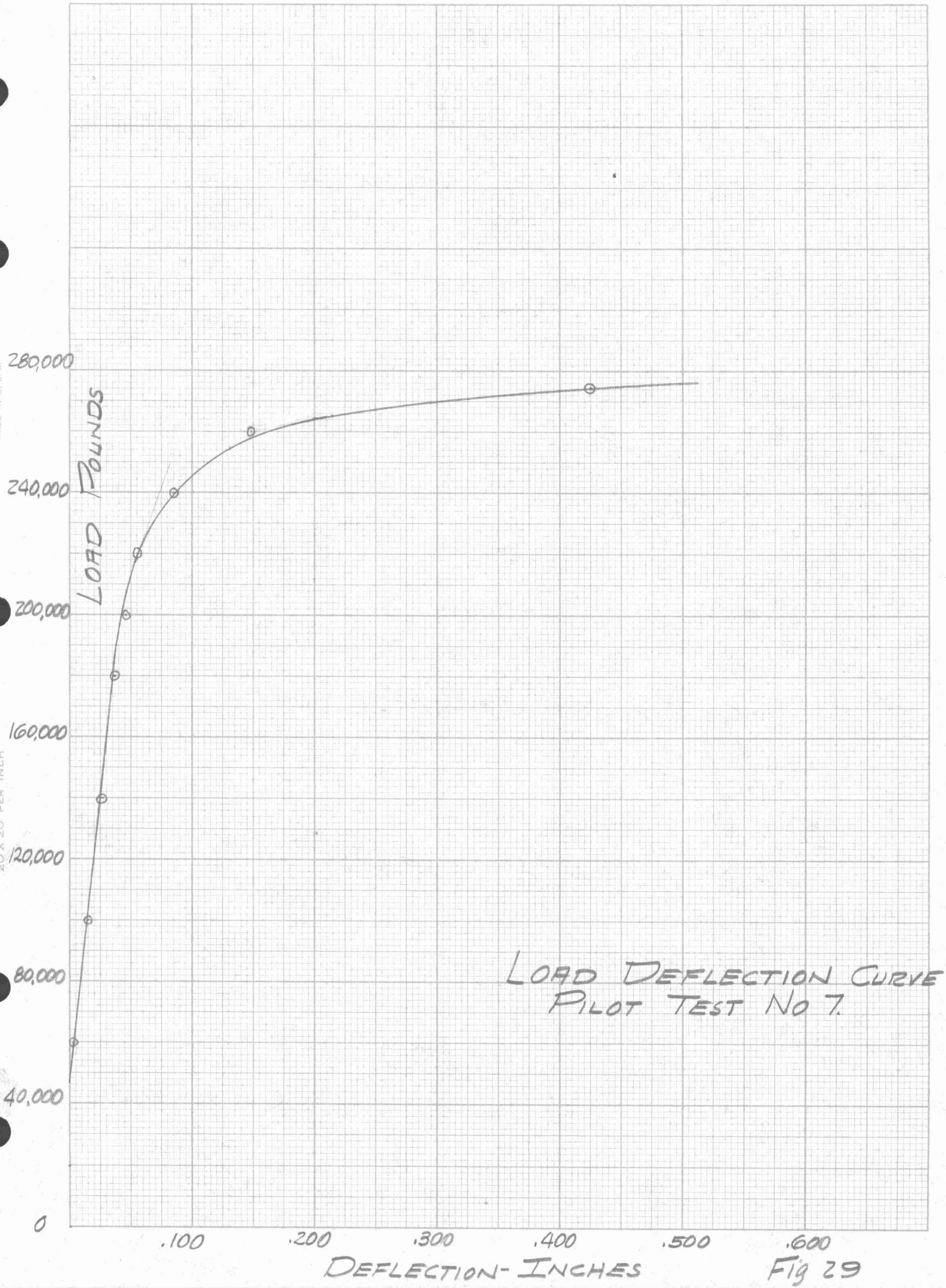

LOAD- DEFLECTION CURVE
PILOT TEST No 6
LOAD - POUNDS
280,000
240,000
200,000
160,000
120,000
80,000
40,000
.100
.200
.300
.400
.500
.600
DEFLECTION- INCHES

Fig 28



LOAD DEFLECTION CURVE
PILOT TEST NO 7.

Fig 29

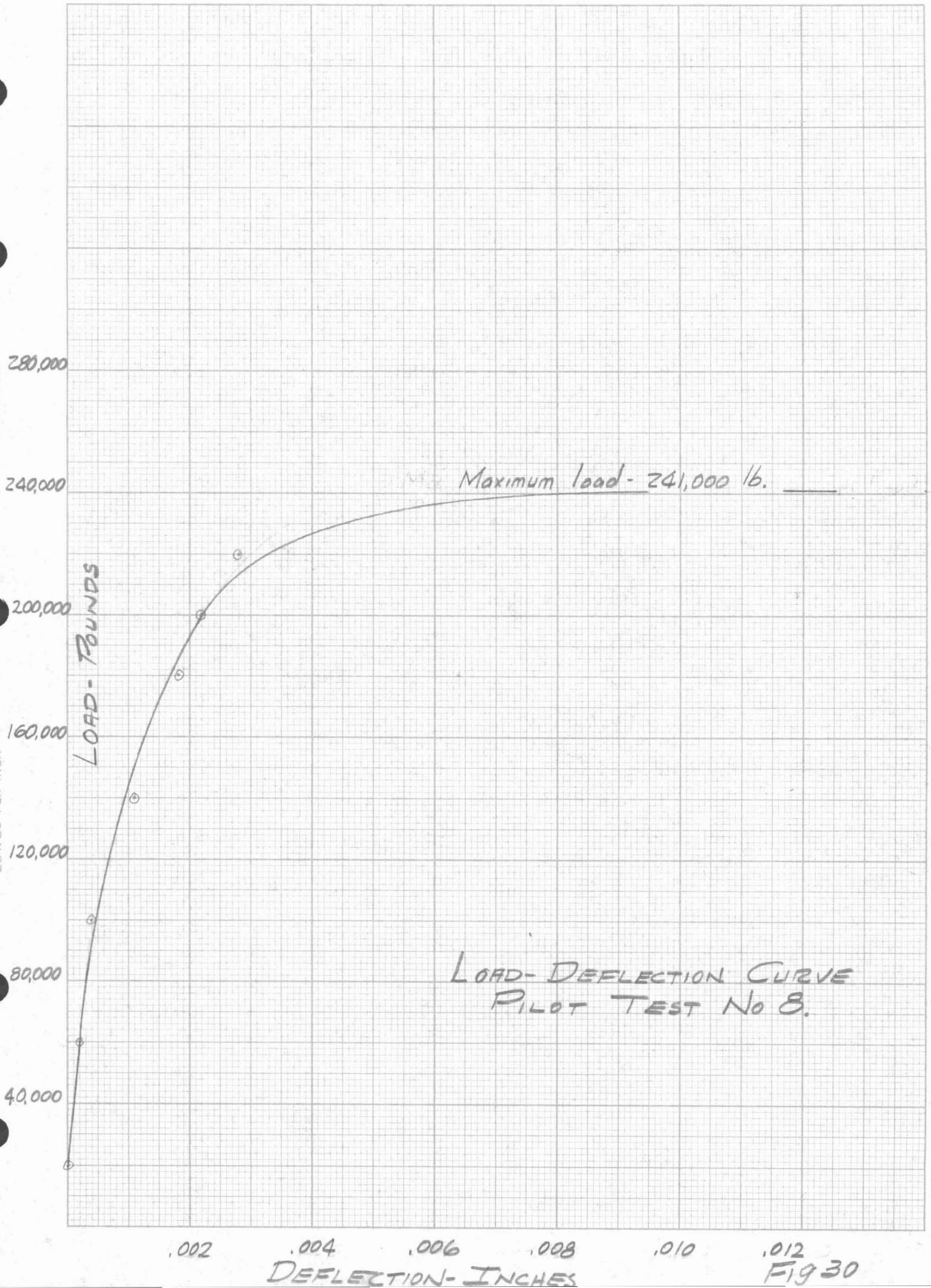

280,000
240,000
200,000
160,000
120,000
80,000
40,000
LOAD - POUNDS
Maximum load - 241,000 lb.
LOAD - DEFLECTION CURVE
PILOT TEST No 8.
.002
.004
.006
.008
.010
.012
DEFLECTION - INCHES

Fig 30

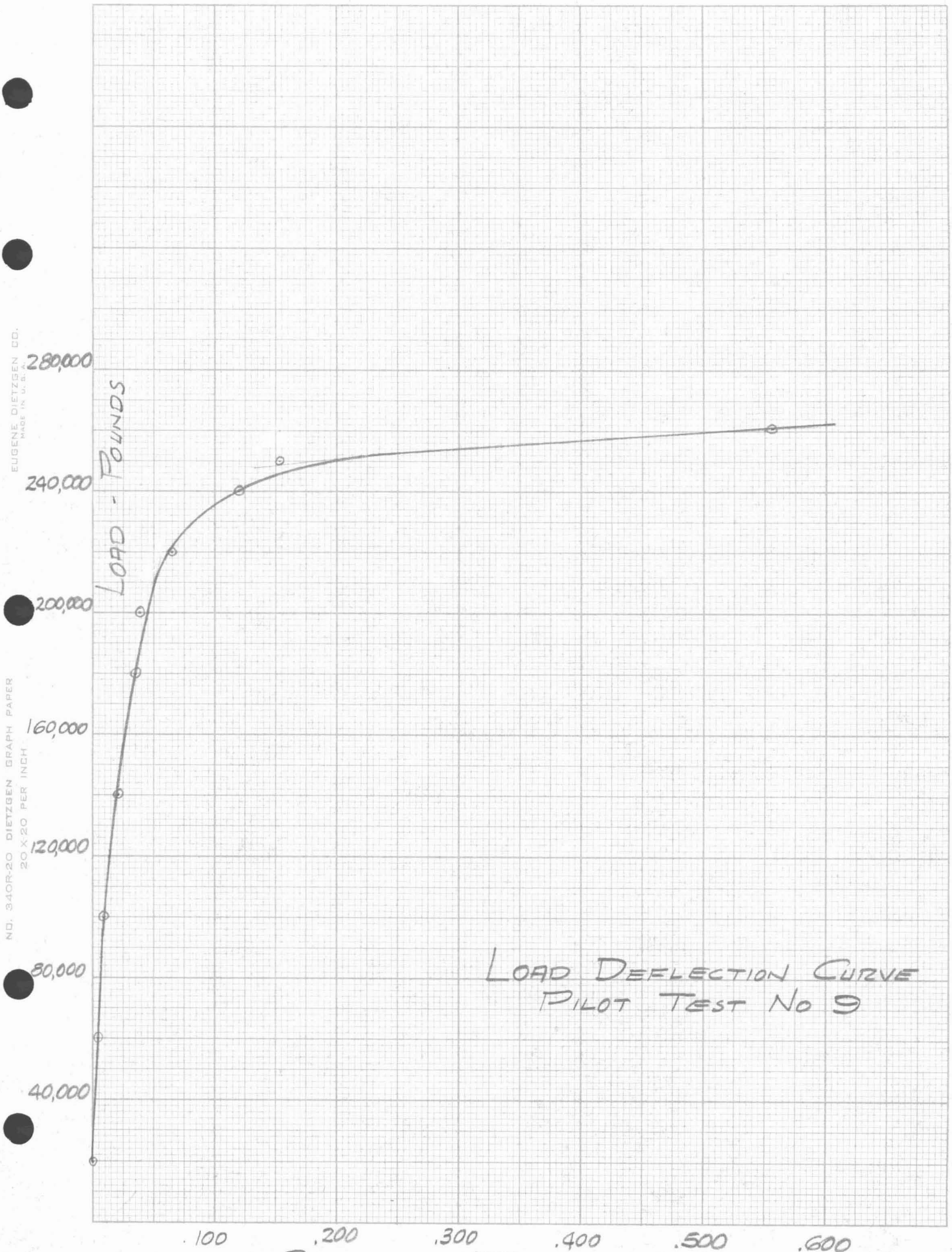
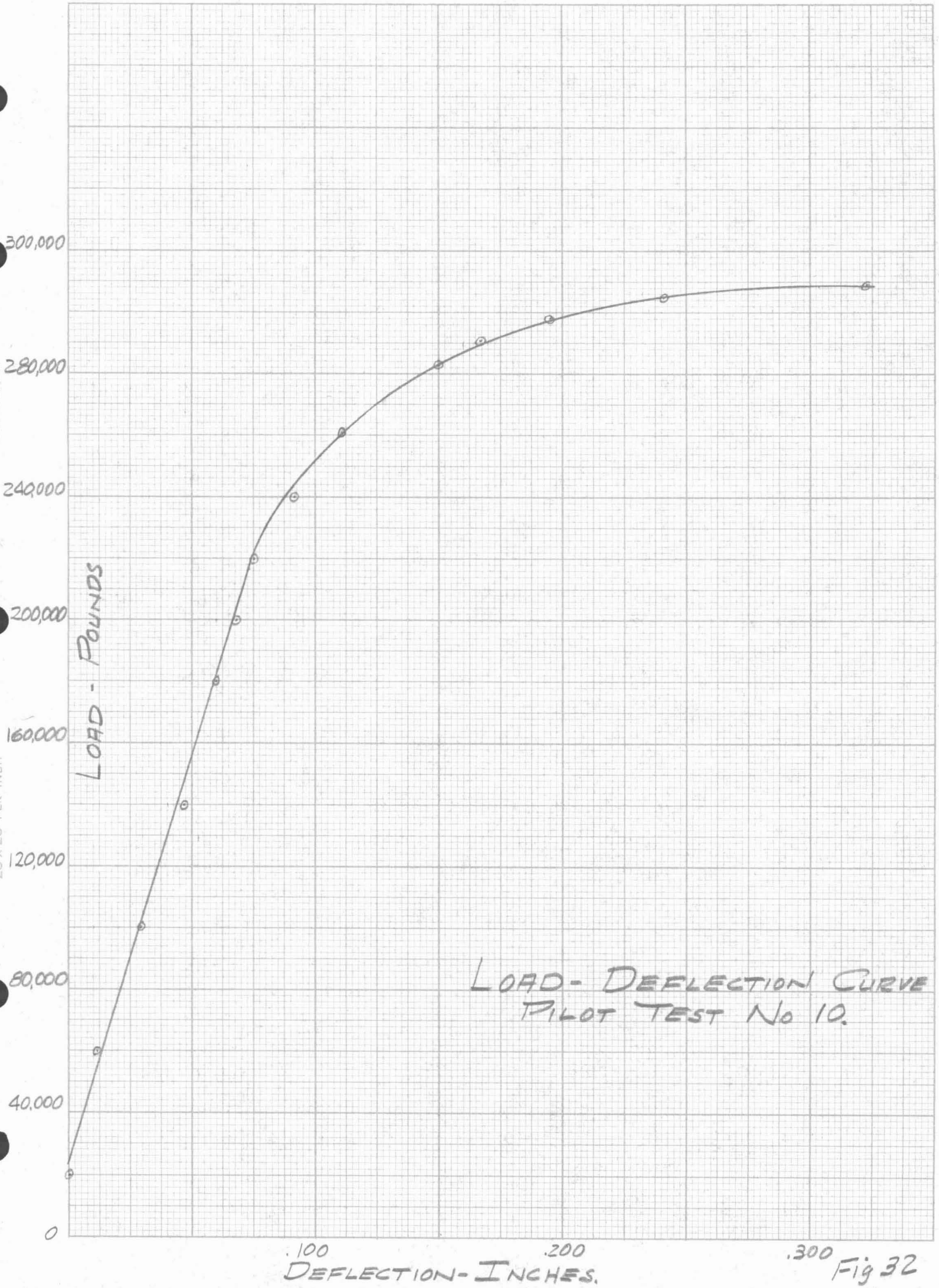
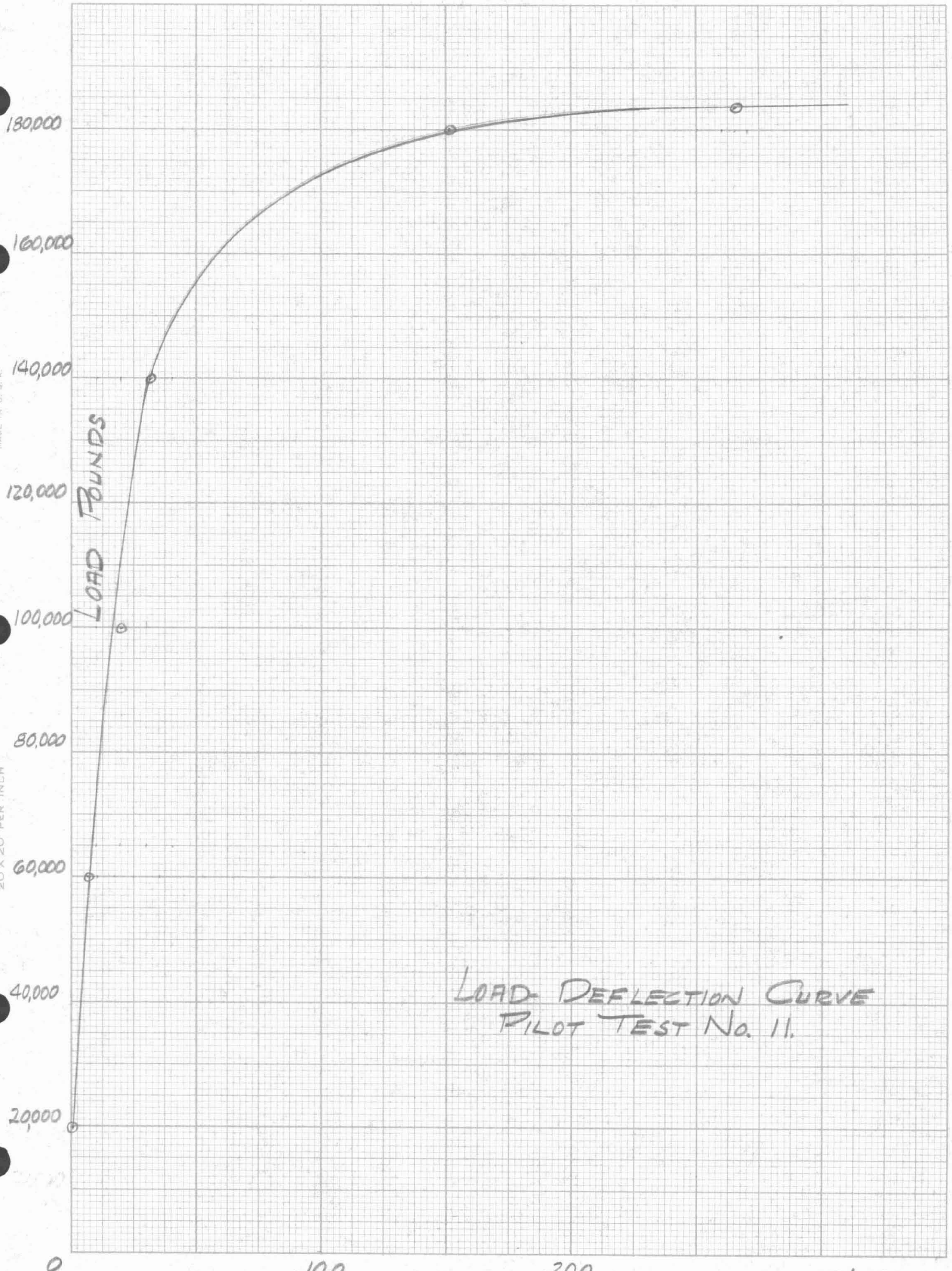

280,000
240,000
200,000
160,000
120,000
80,000
40,000
LOAD - POUNDS
.100
.200
.300
.400
.500
.600
DEFLECTION- INCHES
LOAD DEFLECTION CURVE
PILOT TEST NO 9

Fig 31



LOAD - DEFLECTION CURVE
PILOT TEST No 10.

Fig 32



LOAD DEFLECTION CURVE
PILOT TEST No. 11.

Fig 33

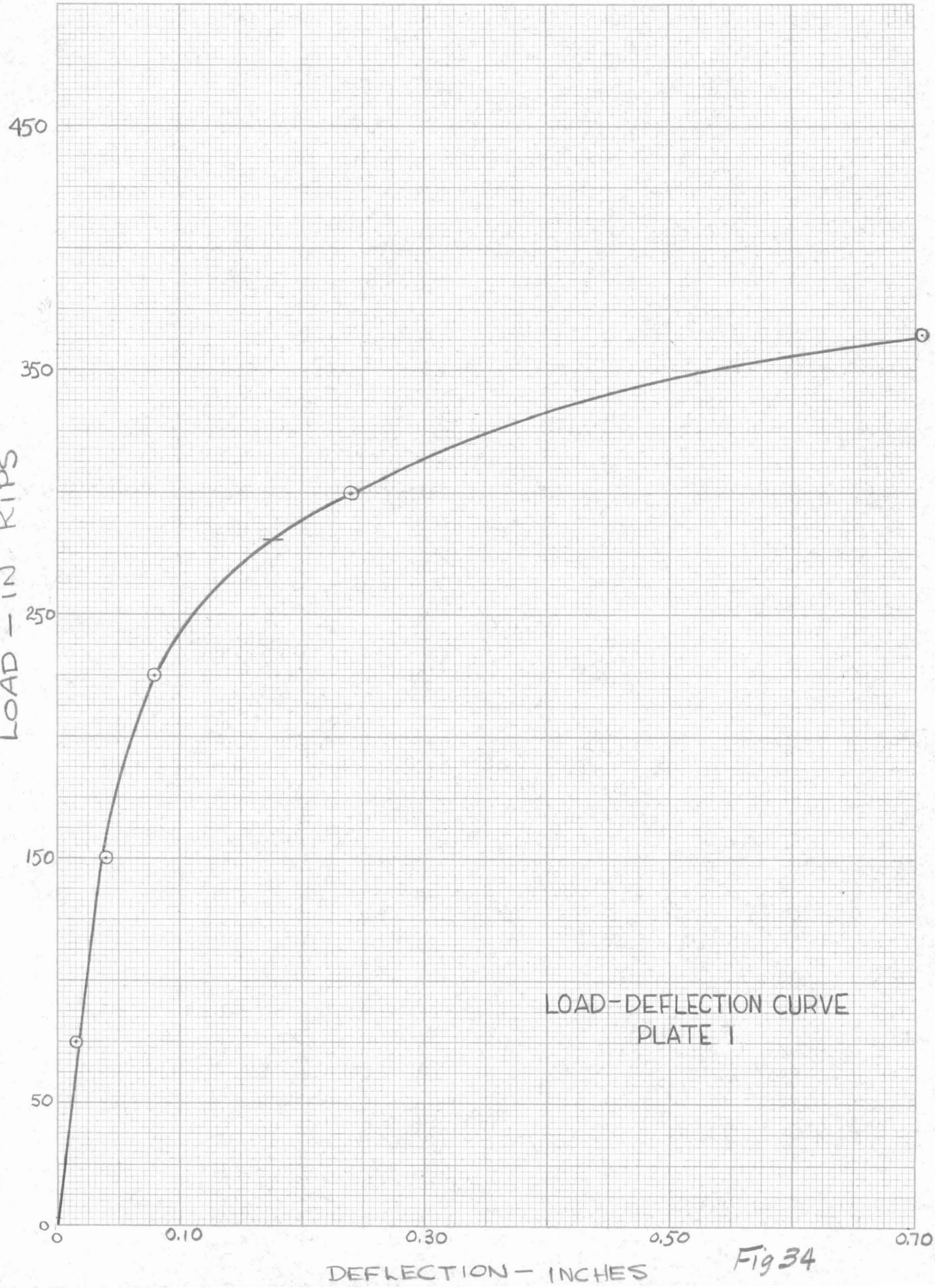
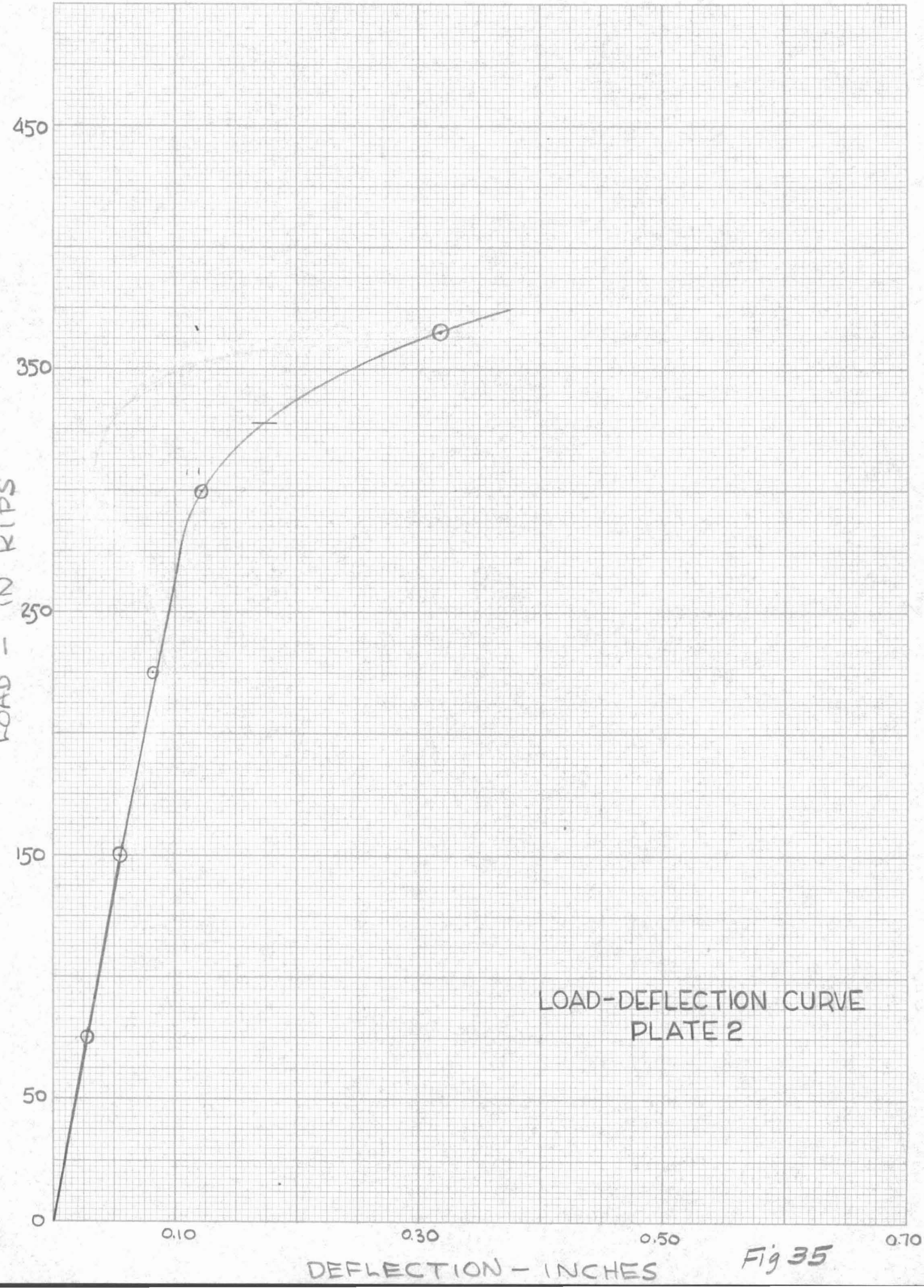

LOAD-DEFLECTION CURVE
PLATE 1
LOAD — IN KIPS
450
350
250
150
50
0
DEFLECTION — INCHES
0
0.10
0.30
0.50
0.70

Fig 34



LOAD-DEFLECTION CURVE
PLATE 2

Fig 35

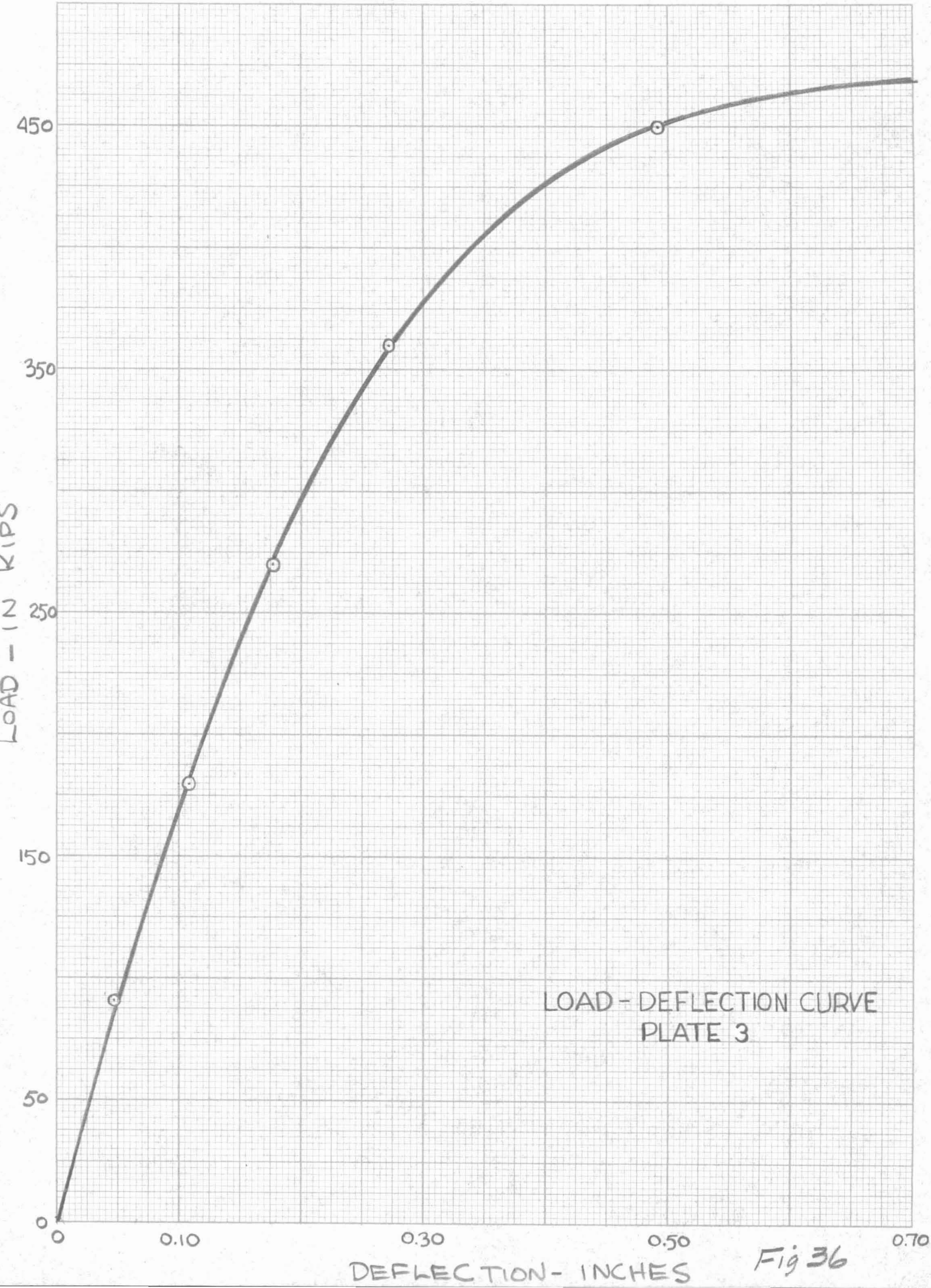
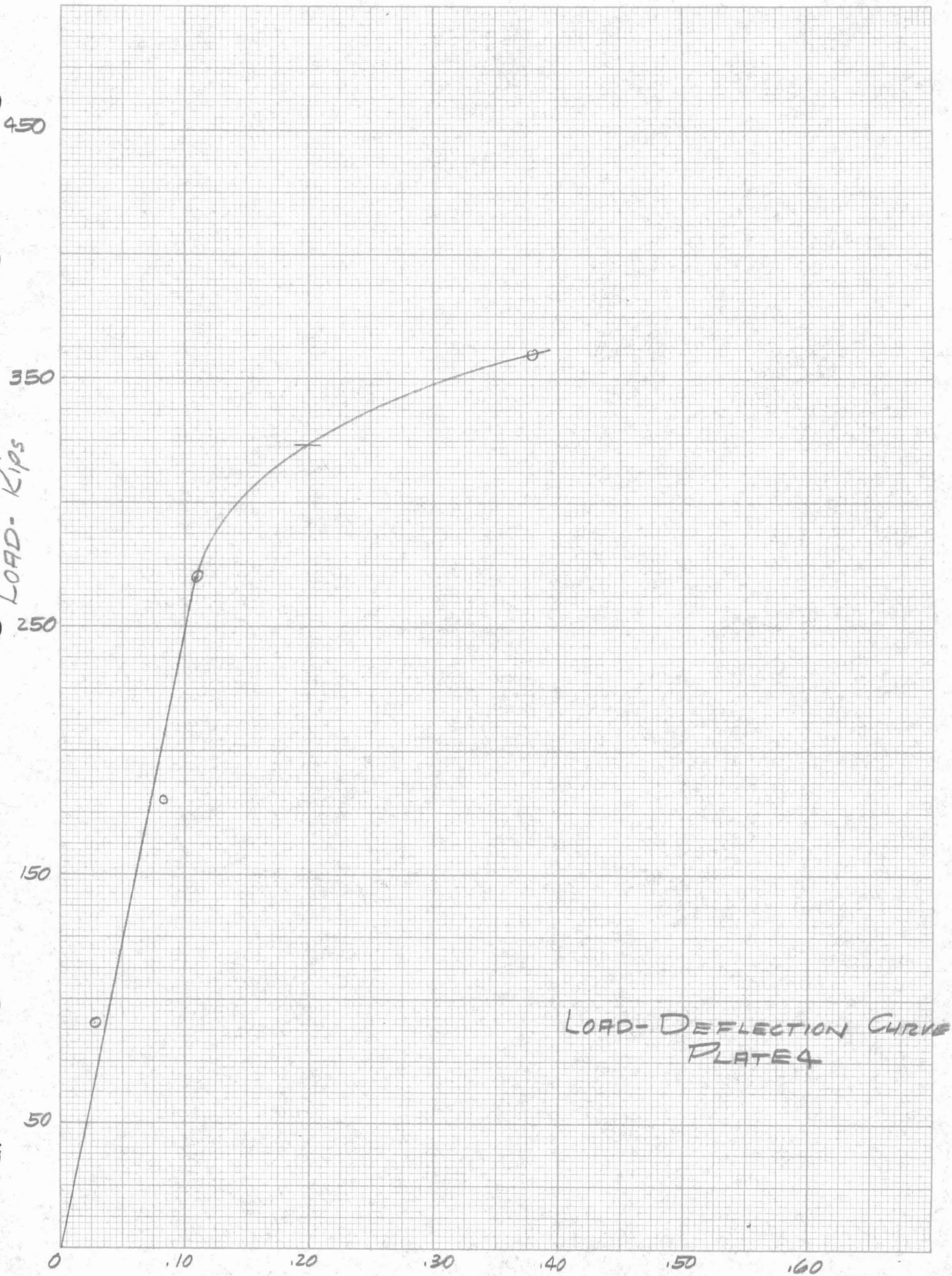

LOAD - DEFLECTION CURVE
PLATE 3
LOAD - IN KIPS
DEFLECTION- INCHES
0
50
150
250
350
450
0
0.10
0.30
0.50
0.70

Fig 36



450
350
250
150
50
LOAD- Kips
0
.10
.20
.30
.40
.50
.60
Deflection - Inches
LOAD- DEFLECTION CURVE
PLATE 4
NO. 340R-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.

Fig 37