EXPERIMENTAL DETERMINATION OF PRESSURE DISTRIBUTION UNDER A COMBINED FOOTING

Thesis by

Samuel Y. Johnson

Homer J. Scott

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PURPOSE

The object of this experimental research was to determine the general distribution of pressure under a reinforced concrete spread footing of the "combined" type.

INTRODUCTION

The science of foundations at the present time has little available data concerning the way in which pressure distributes itself directly upon the under surface of loaded footings of the rigid slab type. Knowledge of the distribution of pressure in the soil for some distance beneath footings has been experimentally and theoretically investigated, and has resulted in the discovery of the so-called pressure bulb, and the development of the classic Boussinesq theory for its application to determining bearing values of soils. This theory offers a solution for the problem of the stresses which develop within the soil under a loaded footing. The next step in the sequence is a solution of the problem of the stresses which develop in the footing itself. These stresses are due to the direct soil loading on the footing, the point magnitude and distribution of which cannot be determined by the Boussinesq theory, since the Boussinesq theory is based upon an assumed point or distributed load, and it is the assumed distributed load that is desired in this case.

Customary procedure up to date has been designing footings upon the basis of a uniform distribution of soil pressure across the under side of the entire footing area. However according to experiments carried on by M. L. Enger, Frederick J. Converse, and others, the distribution of the soil reactions over the base of a rigid slab is by no means uniform. Dr. Charles Terzaghi in his article "The Science of Foundations"[1] says in regard to this question. "Thus far all attempts to deal theoretically with the problem of stress distribution have failed, and there is little hope for success within the near future. Considering the importance of the possible error involved in assuming uniform stress distribution, the need of a more exhaustive experimental investigation of this phase of the foundation problem becomes obvious."

Previous experiments performed for the purpose of determining pressure distribution under a footing have used round plates[2] with uniform and concentrated loads, or square blocks[3] centrally loaded. In practically all cases the pressure variation found has approximated a parabolic distribution, the maximum pressure often being as great as twice the average pressure over the footing area. That such variation can cause critical stresses within foundations is shown by Dr. Terzaghi in "The Science of Foundations". His analysis shows stresses caused by a parabolic pressure distribution to be double those caused by a uniform distribution of the same total magnitude. In some cases even the direction of stress was reversed. There is reason to believe, with such a variance from uniform distribution with square and round footings, that even greater variations might be expected in the case of a combined footing, with corresponding critical moment and shear stresses in the foundation.

1. Trans. Am. Soc. C.E. Vol. 93 p.277

2. "Der Grundbau" Brennecke & Lohmeyer Vol. 3 pp. 1-13

3. "Distribution of Pressure Under a Square Footing"
F. J. Converse Civil Engineering April 1933

It was to determine the type and magnitude of the pressure variation actually existing beneath a combined footing that this experiment was undertaken. With this pressure distribution known, the degree of error involved in current design practice may be evaluated, and the desirability of modification to fit the experimental data determined.

DESCRIPTION OF APPARATUS

The Pressure Cell

The pressure measuring device used in the investigation is sketched in Fig. 1. Fundamentally, its action depended upon the bending of a thin circular plate simply supported around its entire circumference. The interior, or "working" portion consisted of a disc of 12 gauge mild steel 3-3/16 inches in diameter to which two rods (14 inch sections of 1/8 inch black pipe) were welded normal to the plane of the disc. These rods were placed 1½ inches apart, symmetrically with respect to the center of the plate. As the disc deformed due to the pressure of the soil, the tops of these rods moved apart, magnifying the deformation of the disc to a degree such that it could be measured with a micrometer. To aid in the measurement, insulated contact points were set in the upper ends of the rods and connected to a battery and small light. When measurements were taken, the exact instant that contact was made between the micrometer screw and the points of the vertical rods, was indicated by the flashing of the light.

The outer portion of the device consisted simply of a 13 inch section of 3 inch standard wrought iron pipe. A groove was machined in the lower end of this pipe to form a support for the interior unit. The disc of the interior unit fitted loosely in this groove, with the bottom of the disc flush with the bottom of the pipe so that a level surface was maintained over the entire area of the cell. The contact surfaces of both the groove and the disc were machined to give an even bearing.

The vertical deflection at the center of the thin disc amounted to about 0.004 inches under a pressure of 5000 pounds per square foot. This movement was magnified approximately 20 times by the vertical rods.

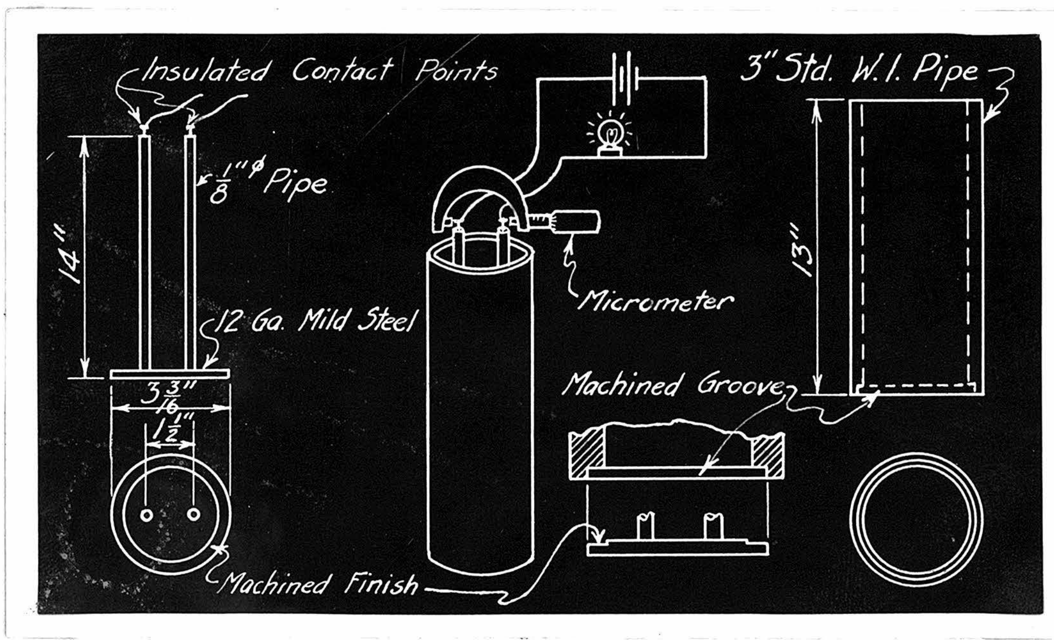


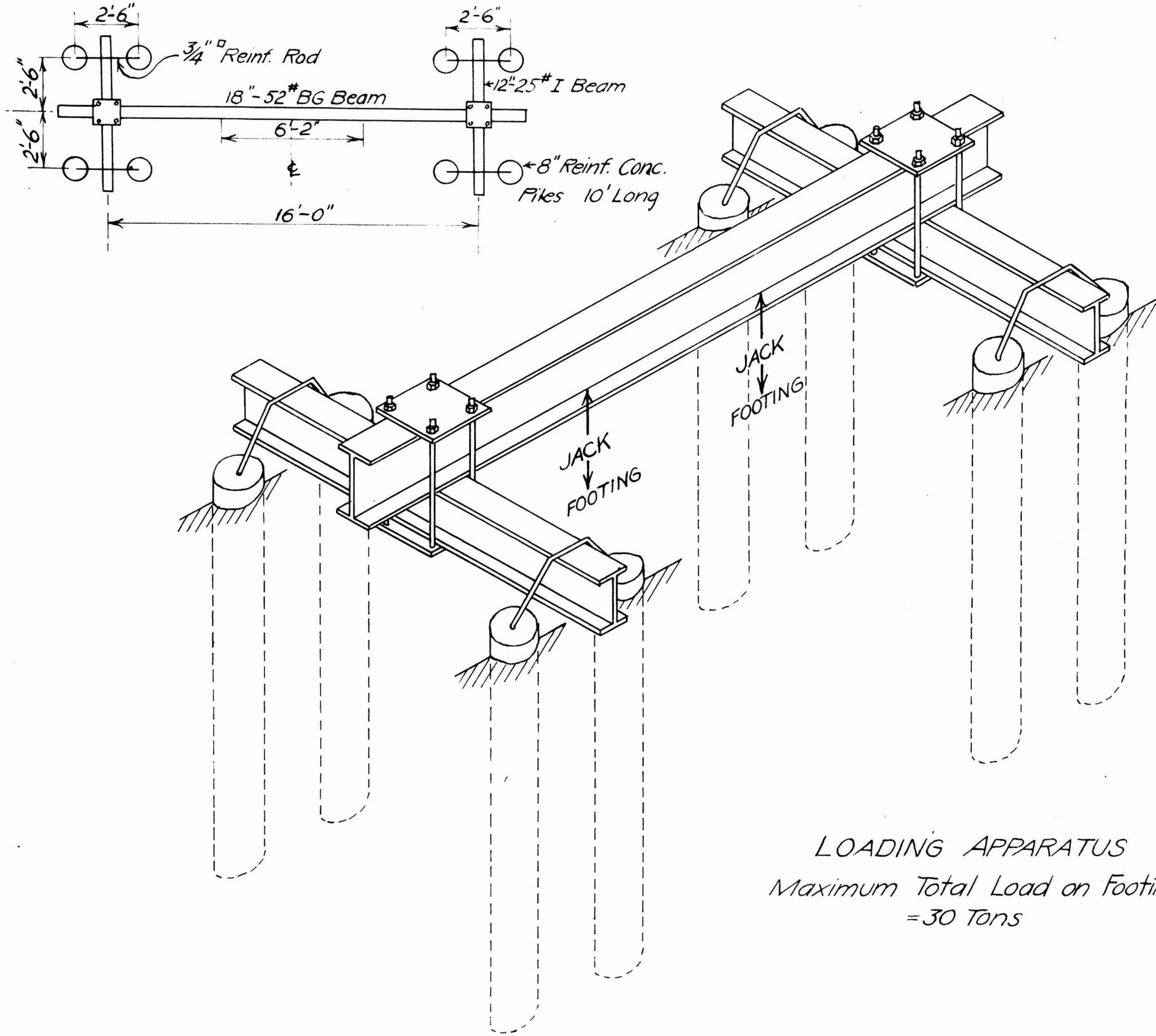
Figure 1

The Loading Apparatus

In order to load the footing with the desired total load of 60,000 lbs. (5000#/ft.^{2} for 12 ft.^{2}), a choice of two methods was available. The footing could be loaded directly with an external load of the desired amount, or it could be loaded by jacking against some fixed object with load-reading jacks. The latter method was selected as the most practicable, and loading was accomplished by jacking against the anchored beam and pile system shown in the full page figure.

As shown in the figure the load was transmitted from the two jacks to a heavy 18"-52# BG beam. At the ends of this beam the load was transmitted to two transverse 12"-25# I beams by means of the bolted plate connections shown. Each transverse beam distributed its load equally to four 8" cast in place concrete piles by means of 3/4" square reinforcing rod straps embedded in the piles. These straps ran the full length of a pile, passed over the end of the transverse beam and ran the full length of a corresponding pile on the other side of the beam as shown in the figure. From the piles the load was transmitted to the soil by means of skin friction.

The heavy beams used were for the purpose of getting the piles far enough away from the loaded footing so that the zone of influence of the distribution of pile loads to the soil would not extend appreciably to the soil under the footing. In the design of the piles, it was decided after proper investigation and consultation, that the soil at the experiment site would safely give 500#/ft.^{2} skin friction on vertical cast in place concrete piles. However, due to the fact that the distri-



LOADING APPARATUS
Maximum Total Load on Footing
=30 Tons

bution of load in the soil would probably be impaired by the proximity of the test hole and the nearness of the piles to each other, the actual design of the piles was on a basis of a maximum 360#/ft.^{2} skin friction with an 8 inch pile 10 feet long.

The holes were dug with an 8" soil auger and the piles were poured with a 2000# concrete. The beam sections were selected on the basis of a limiting bending stress of 18000#/in.^{2} with the maximum 30 ton load applied to the footing. The bolted plate connections were designed on the basis of a limiting shear stress of 10,000#/in.^{2} in the threads, while the 3/4" reinforcing rod straps in the piles develop a tensile stress of 13,400#/in.^{2} at maximum load.

The apparatus performed satisfactorily during the whole course of experiments, and was loaded up to maximum design load.

The Footing

The design of the footing was affected by several practical considerations. Its size was limited by the loading facilities available. The problem was not so much in finding jacks of sufficient capacity, but in providing a reaction for them to work against. The system adopted was capable of resisting a force of 30 tons with a reasonable factor of safety. Since the foundation load desired was $2\frac{1}{2}$ tons per square foot, the area of the footing was fixed at 12 square feet. The desirability of providing symmetry for ease in checking results led to the selection of a rectangular shape and a symmetrical loading arrangement. The dimensions of the footing were therefore taken as 1'-6" by 8'-0", and the pressure cells were arranged so that equal loads could be applied 10 inches from each end. According to an investigation of previous foundation experiments, this size of footing would probably give different settlements than a larger footing with the same unit load, but at the same time the general distribution of pressure under this footing should be the same as that of a footing of proportionally larger size.

In order to avoid excessive depth of footing and to maintain proportions similar to those of full size foundations, it was necessary to reinforce the concrete block for compressive as well as tensile stresses and to provide an unusually large amount of stirrup steel. These measures made possible a total thickness of the block of 12 inches and a distance of 10 inches between compressive and tensile steel. The reinforcement as it appeared just before being placed is shown in Figure 3.

In the design of the footing the following unit stresses were taken as allowable:

Tensile strength of steel	18000 lbs. per sq. in.
Compressive strength of concrete	800 " " " "
Longitudinal shear in concrete	45 " " " "
Vertical shear in concrete	120 " " " "
Bond between steel and concrete	100 " " " "

On account of the use of a water-cement ratio calculated to produce concrete with an ultimate crushing strength of about 3000 lbs. per square inch, the comparatively high allowable stresses were not considered excessive. That this assumption was justified was shown by the fact that no cracks were observed in the concrete under any condition of loading. At points where pressure cells were placed, the heavy pipe was considered to have strength as an arch equal to the strength of the concrete displaced. Since the actual soil pressure was unknown at the time the footing was designed, the customary assumption of uniform pressure over the base was made.

It was thought desirable to obtain further information concerning the proportion of load transmitted from the footing to the earth by friction between the sides of the foundation block and the soil. For this reason the earth was used as forms for the concrete. The sides of the excavation were accurately trimmed to size and care was taken to make them vertical.

An attempt was made in arranging the pressure cells in the footing to provide at the same time as much information and as many chances for comparison of results as was possible with the number of cells available.. One longitudinal section down

Figure 3

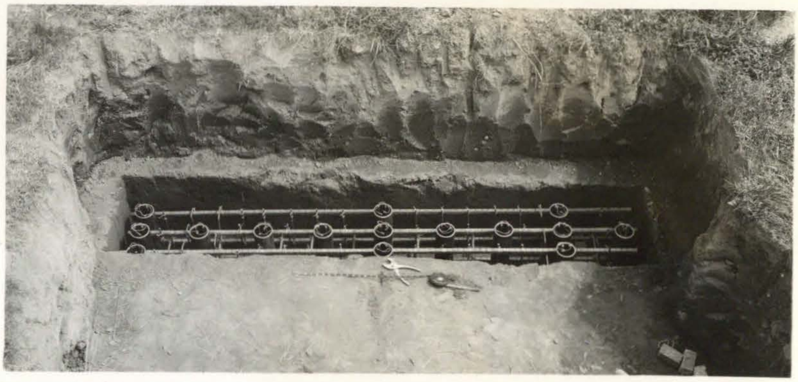


Figure 4

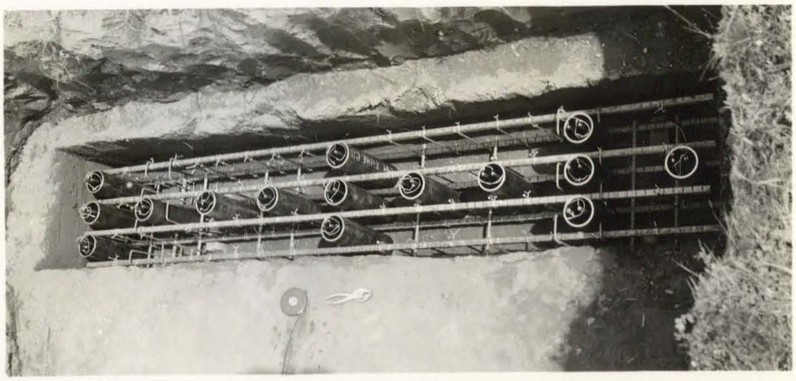


Figure 4a

the center of the footing and three cross-sections in a transverse direction are provided, and except for one case each cell may be checked against another in a similar location elsewhere in the footing. The reinforcing steel and pressure cells are shown in place in the excavation in Figures 4 and 4a. Figure 5 shows the footing dimensions and the location and numbering of the pressure cells.

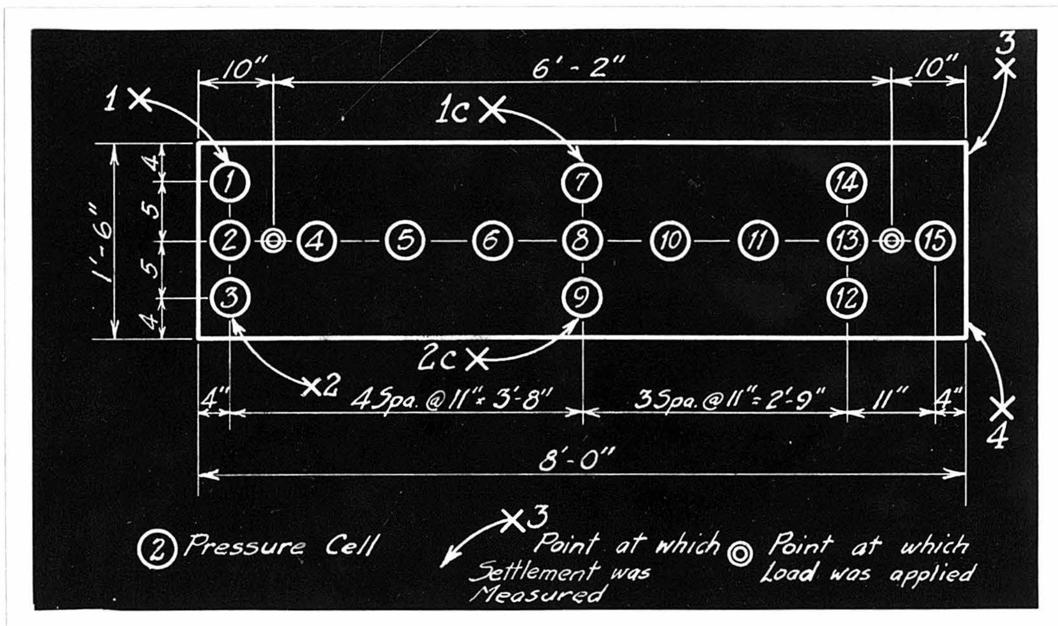


Figure 5

Calibration of the Pressure Cells

In order to determine the earth pressure in the field from the cell deflections measured there, it was first necessary to obtain a load-deflection curve for each individual cell. These curves were determined by calibrating the cells before they were placed in the footing. The calibration was done on a small Fairbanks-Morse platform scales and readings were taken to an accuracy of one pound. Between the cell and the platform, a celotex pad was placed to approximate the effect of the upward pressure of earth. In order to apply and hold small increments of load, the scales were placed on the weighing table of the 150,000# Tinius-Olsen testing machine, and increments of load applied to the top of the pipe by means of the movable head of the testing machine.

Calibration readings of deflection were taken at every 50 lbs. of load. The desired load was hung on the balance arm of the scales, the machine run at low-low speed until the arm came up to the balance point, and the load held at that point until deflections were read by the micrometer method given in the description of the cells. Three calibration runs were run on each cell with 25 lb. intervals from 0-100 lbs., and 50 lb. intervals from 100-400 lbs. The results of these runs were then used to plot the calibration curves of the cells.

MEASUREMENT OF THE PRESSURE DISTRIBUTION

Field Procedure

The test runs in the field were made with two fifty ton pressure-recording gas jacks loaned by Converse & Labarre Co. These jacks were put in place on the footing, centered, and carefully aligned vertically and horizontally. One of the jacks in place is shown in figure 6. The gas attachments were connected up in parallel so that the two jacks always gave the same load, the load being measured from the known area of the jack piston and the guage-recorded gas pressure in the jacks.

In order to check elevations on the footing, a bench mark was established far enough away from the footing to be unaffected by adjacent settlement, and rod readings were taken on the footing by a dumpy level. The elevations taken were points on the tops of the outer end cells on the north end, points on the outer middle cells, and points on the two corners of the south end. In order to read the settlement to the degree of accuracy desired, a steel scale reading to 1/100 of an inch was clamped to the level rod, and level readings taken on this scale after checking it on the bench mark.

A set of zero readings was taken on the pressure cells in the manner described in the description of the cell, and the zero rod readings were made. The footing was then loaded with 6 ton jack loads (2000#/ft.^{2}) and the pressure cell and level rod readings taken. This procedure was repeated for the whole series of test runs. The test runs made with the earth sides intact, in their consecutive order was 0, 2000#/ft.^{2}, 0, 3000#/ft.^{2}, 4000#/ft.^{2}, and 5000#/ft.^{2}

Figure 6

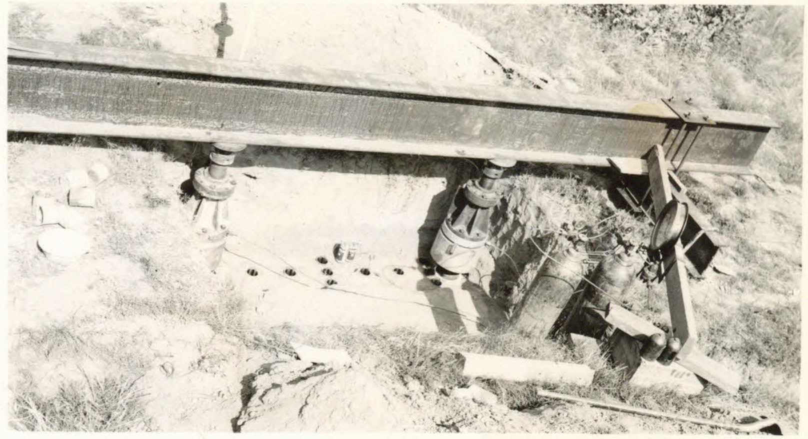


Figure 7

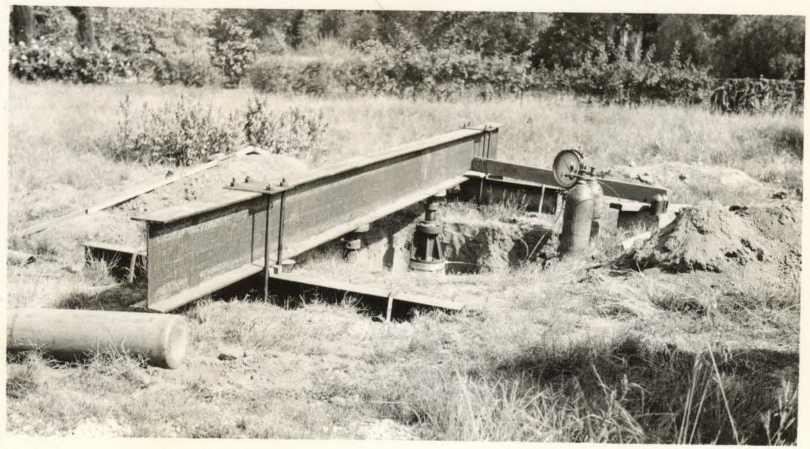


Figure 8

Pictures taken during the course of these runs are shown in figures 7 and 8. The readings taken are recorded in the accompanying data sheets.

Following the completion of the above test runs with the earthen sides intact, the earth was dug away around the four sides of the footing, so that the footing received no support from the side walls. Another series of test runs was then made, recording the same readings of the pressure cells and rod readings. Figure 9 shows the footing with the side walls removed during the course of the second series of runs. The test runs made in their consecutive order with no side wall support were 0, 3000#/ft.^{2}, 4000#/ft.^{2}, and 5000#/ft.^{2} The readings taken are recorded in the accompanying data sheets.

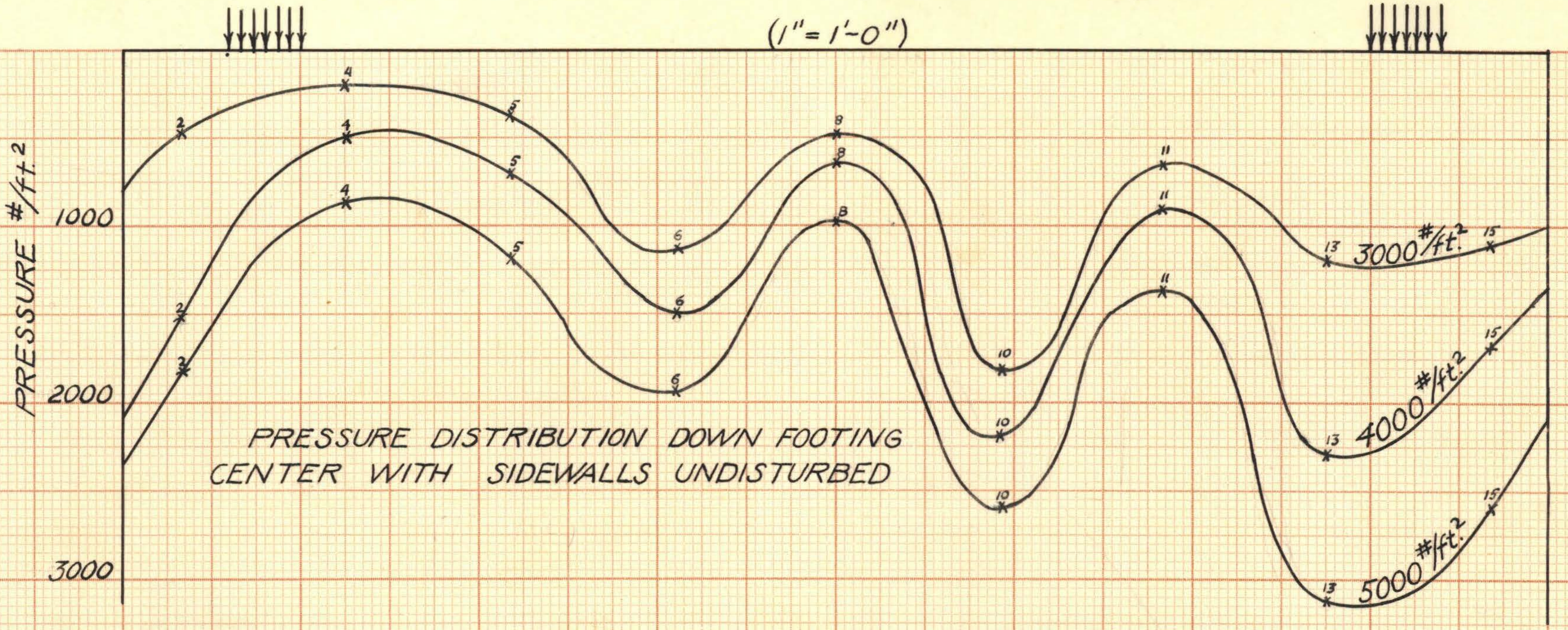
Figure 9

Discussion of Results

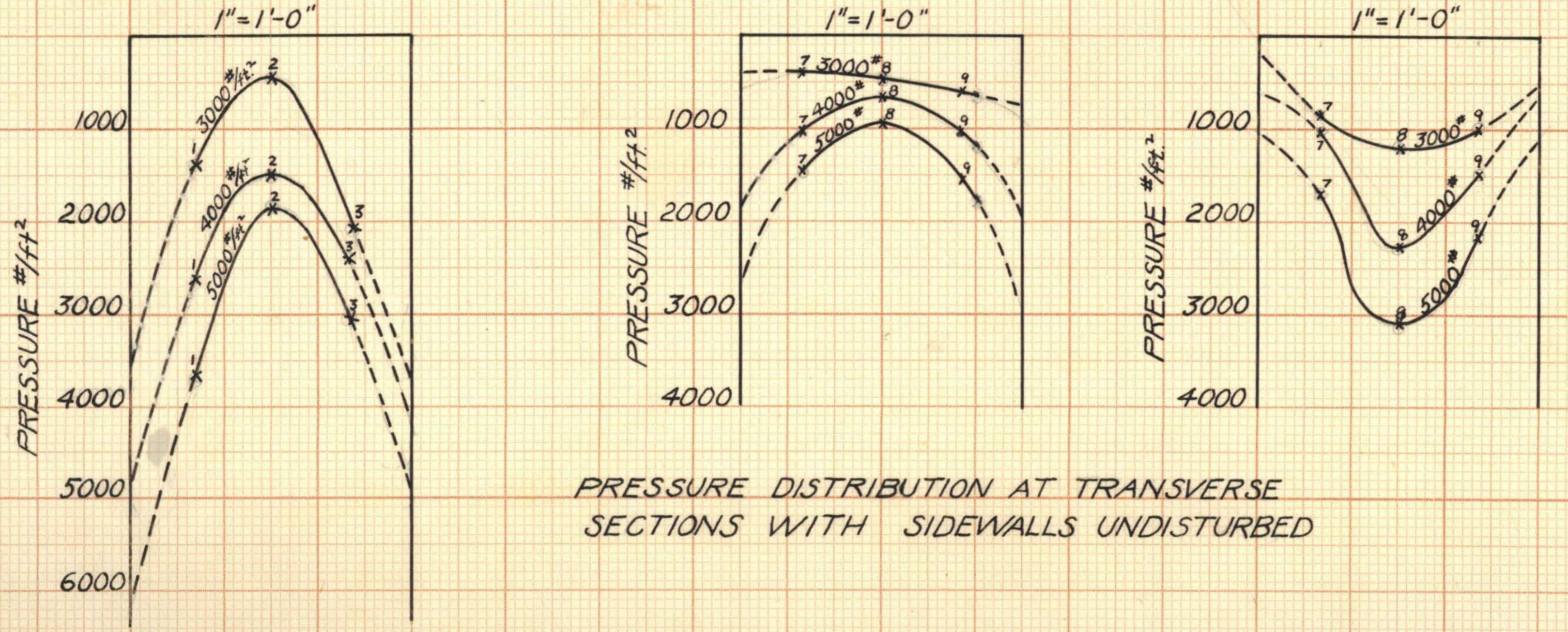
The results obtained for the pressure distribution under the footing are shown in the two pages of pressure distribution curves given, one for the earth walls intact, and the other for the earthen walls dug away.

The pressure distribution obtained from these curves at first seems to be entirely without rhyme or reason. This is particularly true in view of the fact that corresponding cells on opposite ends of the footing fail to check each other as regards to absolute pressures. Also because the transverse rows of cells at the north end of the footing and the center, show maximum pressures near the edges of the footing in a transverse direction, while the transverse row of cells on the south part of the footing shows maximum pressure at the middle of the footing. There is also considerable difference in the distribution of pressure down the center of the footing as regards the north and south half.

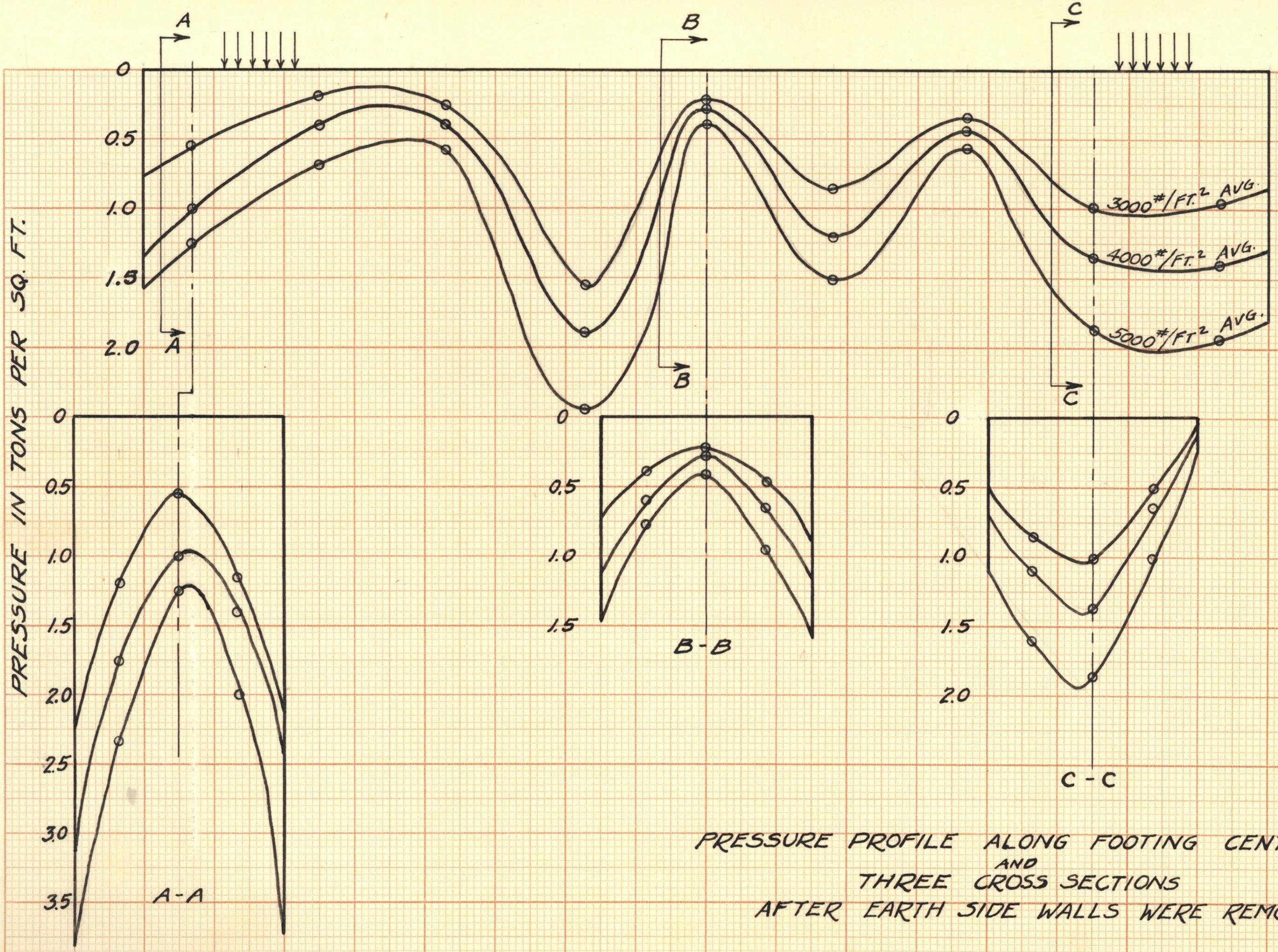
If the cells used were reasonably accurate, the difference between pressure distribution over the two ends of the footing can be explained by only one consideration; namely, a difference in the soil conditions at the two ends. Actually such a difference existed. Shortly after the 3 foot main excavation for the footing was dug, a heavy rainstorm occurred. Although provision had been made for drainage in the excavation, the south end which was the low end, soaked up enough moisture to make it quite soft and mushy as compared with the north end. Due to an impervious clay layer about seven feet below the surface and the extreme shadiness of the southern end of the excavation, the moisture did not drain out of the soil. When the footing



PRESSURE DISTRIBUTION DOWN FOOTING CENTER WITH SIDEWALLS UNDISTURBED



PRESSURE DISTRIBUTION AT TRANSVERSE SECTIONS WITH SIDEWALLS UNDISTURBED



PRESSURE PROFILE ALONG FOOTING CENTER LINE
AND
THREE CROSS SECTIONS
AFTER EARTH SIDE WALLS WERE REMOVED

HORIZONTAL SCALE - 1" = 1 FOOT

was poured several weeks later, the soil at the south end of the earthen footing form was so water-soaked that tamping squeezed water out of it, and pushing a finger into it caused bulging over a diameter of several inches. The soil at the other end was firm and strong. Unfortunately no moisture readings were taken at the time.

A possible significance of the effect of this water is made with the aid of "Der Grundbau", a German book on foundations written by Brennicke and Lohmeyer. In the first chapter of this book a comparison is made between the extremely different actions of a cohesive soil and a cohesionless soil under the same conditions of loading. A cohesive soil acts as a continuous elastic body, and transmits stress by shear. Consequently, considering the case of a rigid body placed upon a perfect continuous elastic body and loaded, the deflection curve is as shown in Figure A.

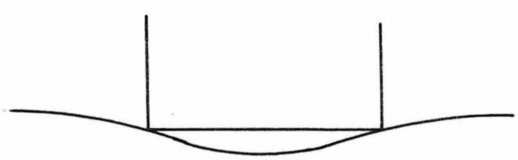


Fig. A

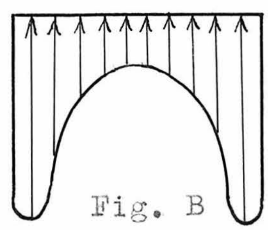


Fig. B

The pressure on the rigid body acts entirely at the edges of it. Actually a cohesive soil has partially continuous elastic qualities, and with the qualities it has, the theoretical pressure on the bottom of a rigid footing as worked out by Brennicke and Lohmeyer is shown in Figure B. The pressure is a maximum at the edge region and decreases rapidly toward the center. With a non cohesive soil pressure is transmitted by grain to grain contact, and there tends to be a "flow" of particles away from the source of load application. Under such action the deflection of the soil is shown in Figure C. The greatest pressure is at the center where the resistance to "flow" is the greatest, or according

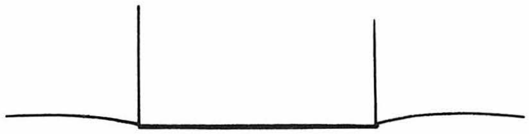


Fig. C

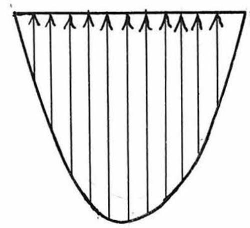


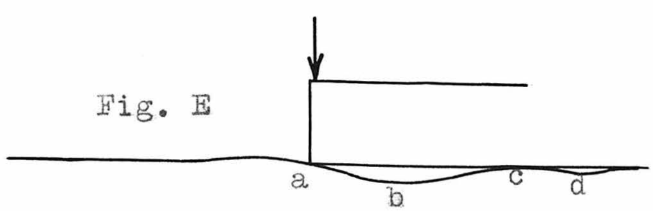
Fig. D

to Boussinesq's theory, where the effect of a series of loads approximating the uniform load, is the greatest. Based upon the actual qualities of a non-cohesive soil, the theoretical pressure distribution over the bottom of a rigid body is shown in Figure D. The pressure is a maximum at the center, and decreases toward the edges in a parabolic distribution. According to experiments covered by Brennicke and Lohmeyer, cohesive loams and clays with active capillary water have shear strengths great enough to cause them to act like a continuous elastic body similar to rock when loaded. However when the capillary water effect is inactive, the cohesion of the soil breaks down, and the clay or loam acts as a cohesionless material. This breakdown in cohesion occurs when the soil becomes water-soaked.

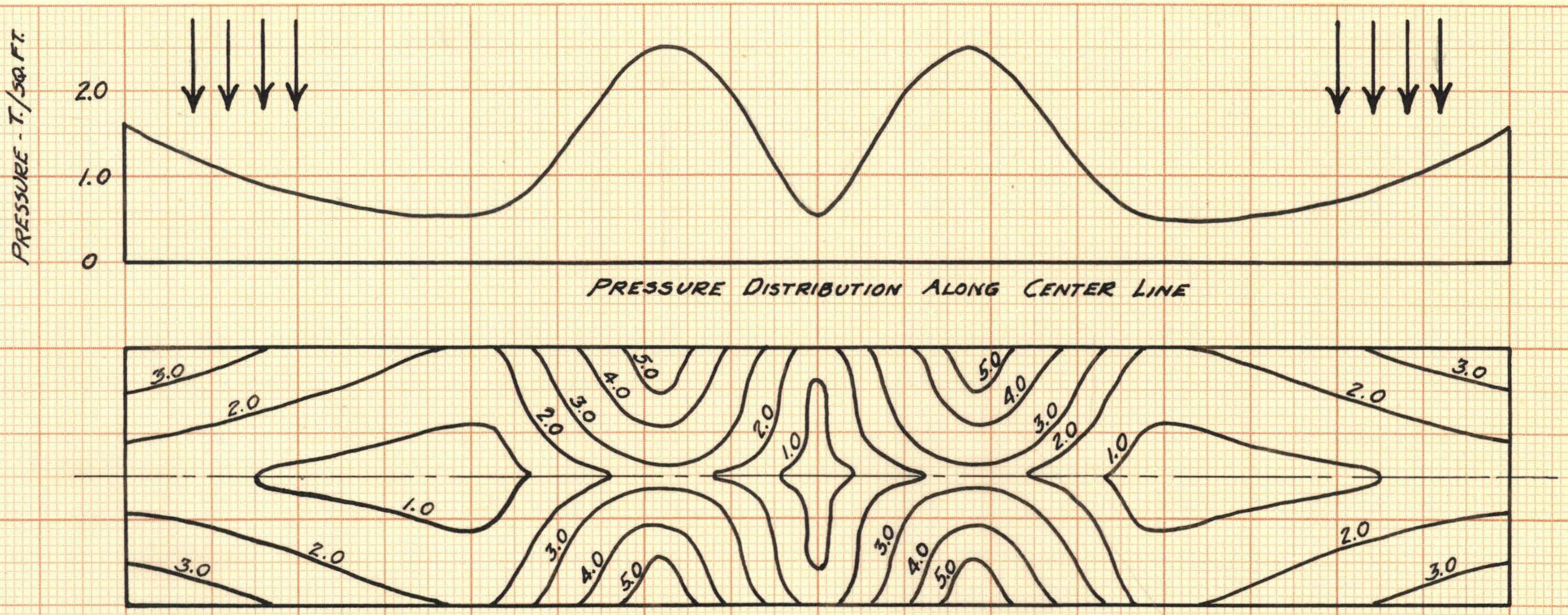
Adapting this explanation to the results obtained, it is found that the transverse pressure distribution at the north end and center of the footing is similar to the theoretical pressure distribution for a rigid body on a cohesive soil, while the transverse pressure distribution at the south end is similar to the theoretical distribution for a rigid body on a cohesionless soil. The actual soil in place is very cohesive, so that an explanation of the differences in pressure distribution between the two ends, seems to be due to the fact that there was a breakdown in the cohesive qualities of the soil under the south end of the footing, because of a high moisture content at that point. A very good verification of this explanation is obtained from the curves of longitudinal pressure distribution with side walls intact. From these curves it is seen that the pressures under the footing near the south end average about double the corresponding pressures at the north end. This additional bottom pressure indicates that the side walls at the north end are taking considerably more pressure than the side walls at the south end. Since the amount of load taken by the side walls is a function of the shear resistance or cohesion of the soil, a considerable decrease in the cohesion of the side walls at the south end is indicated by these curves.

The pressure distribution obtained in a longitudinal direction was the series of waves shown in the curves. The explanation of this distribution of pressure does not seem to be one that can be very easily arrived at. However, hazarding an explanation, if a rigid elastic footing is assumed acting upon a continuous elastic foundation, the deflection of the elastic foundation would be somewhat as shown in Figure E.

Fig. E



This deflection curve with its series of waves is obtained from Timoshenko's "Strength of Materials". The deflection curve derived is for the case of a concentrated load acting on an infinitely long bar, resting on an elastic foundation. The above curve is modified to meet the conditions of the bar ending at a, but is fundamentally the same curve. With this deflection curve high points of pressure would occur at points a and c, and zero



IDEALIZED ISO-PRESSURE LINES
FOR A
COMBINED FOOTING
RESTING ON A COHESIVE LOAM
CAPILLARY PRESSURE ACTIVE

2 15-TON LOADS
PRESSURE INTENSITIES IN TONS PER SQ. FT.

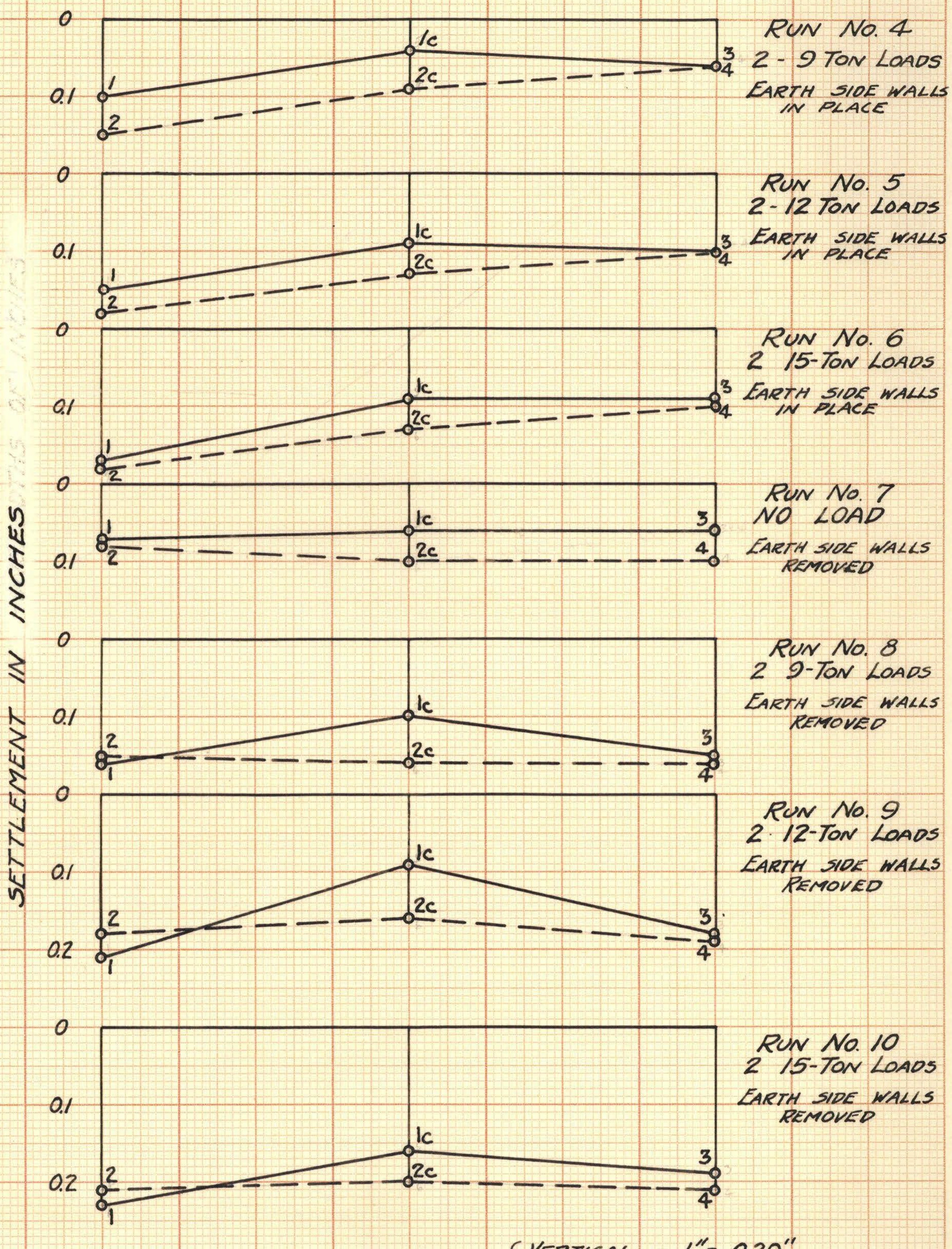
SCALE - 1" = 1'-0"

pressures at points b and d. This analogy carried to a soil of partial continuous elasticity, would give a pressure distribution similar to that obtained in this experiment for the longitudinal distribution. Any explanation of the relative intensities of pressure at the peaks and low points is not attempted at this point, since sonsiderable verification of this pressure distribution is necessary before anything conclusive can be obtained.

To compare the total load on the concrete block as measured by the pressure cells, with that applied by the jacks, the cell pressures in Run No. 10 (5000#/ft.^{2}) were plotted on a plan of the block, and pressure contours drawn by interpolation between the plotted values. By measuring the contour areas obtained, the total upward pressure recorded on the block was found to be 87% of the jack load. The north or left half of the footing gave a recorded upward pressure of 98% of the jack load. Since this was the half that was unaffected by apparent exdess moisture, it was taken as typical of pressures obtained under ordinary conditions with this type of soil. On this basis the idealized iso-pressure lines for a combined footing resting on a cohesive loam with active capillary water, were drawn, and are presented in the results. With this idealized pressure distribution for an average load of 2.5 tons/ft.^{2}, 96% of the jack loads are accounted for. Further experimentation of course is needed to verify this distribution.

By comparison of center line distribution with different magnitudes of loading, the total recorded pressures for the walls intact was calculated to by 67% of the total recorded pressures with the side walls removed. The remaining 33% of the total load was undoubtedly carried by friction on the sides of

SETTLEMENT DIAGRAMS



SCALE { VERTICAL - 1" = 0.20"
HORIZONTAL - 1" = 2'-0"

SEE FIG. 5 FOR LOCATION OF NUMBERED POINTS the footing block.

The settlements obtained during the course of these runs is shown in the settlement diagrams. These settlements show that the footing deflected slightly, but appear to have no bearing upon the pressure distribution obtained.

A mechanical analysis of the soil on which the footing was placed was made according to the A.S.T.M. Standards (Serial D137-22T). Clay was taken as that part of the soil which did not settle out through 8 centimeters of water in 8 minutes. Of the soil which did settle out, that passing a 200 mesh Tyler Standard sieve was taken as silt, and that retained on the sieve was taken as sand. The percentage of each size was based on the dry weight of the soil sample. Moisture content was 14% of the dry weight at the time of the tests. The analysis showed the soil to be composed of 49% sand, 34% silt, and 17% clay. According to the U.S. Bureau of Public Roads, this soil would be classified as loam. The extreme cohesion noted in the excavation is thought to be due to the large proportion of the sand particles ranging just above the 200 mesh size.

The most conclusive thing achieved from this research is the necessity for further verification of these results. Unfortunately, due to difficulties in financing the project, work was not started until the middle of the second term. Consequently with the necessary delays for concrete to harden etc., actual testing of the footing did not occur until the middle of May, and was limited to a very short period. In order to verify some of the theories and assumptions advanced here, test runs should be made on the footing with the soil dried out, and then with the region soaked with water. Also the footing should be lifted off the ground, and sand put in place, so that tests could be made on purely cohesionless material. Before starting any such tests, it would be advisable to lift the footing up and calibrate the cells in place in the footing. There was always a question as to whether the rough treatment and water infiltration during concrete pouring might not have affected the calibration curves of the cells considerably. The period of testing on this project should only be beginning at this point. The discussion in this thesis is based upon one set of ten runs, and because of the need of verification, is made extremely general in nature. On this basis, no recommendation as yet can be made toward any change in the customary procedure of combined footing design.

CONCLUSIONS

1. When a concrete combined footing is poured into an earthen form of cohesive soil, the side walls will take as much as one-third of the total load on the footing.

2. The pressure distribution under a rigid combined footing is not uniform.

3. The pressure distribution under a rigid combined footing seems to occur in waves, similar to what would theoretically be expected for a rigid body on a continuous elastic foundation.

4. The pressure distribution under a rigid loaded footing is apparently quite sensitive to the relationship between moisture-content and cohesive qualities of the soil.

5. The necessity for further verification and experimentation, precludes any recommendation at the present time, for any change in the present procedure of designing this type of footing.

APPENDIX

1. Field Data Sheets
2. Pressure Cell Calibration Curves

FIELD SHEET

RUN #1 - NO LOAD - SIDES INTACT

Cell #	Jack Loads	Micrometer Readings #1	#2	#3	Aver.	Corr. Read.	LOAD
1	0	.6530	.6530	.6530	.6530	-	0
2	0	.5995	.6015	.6015	.6010		0
3	0	.7060	.7060	.7055	.7060		0
4	0	.6090	.6090	.6090	.6090		0
5	0	.4260	.4270	.4270	.4270		0
6	0	.5665	.5670	.5675	.5670		0
7	0	.4380	.4380	.4380	.4380		0
8	0	.2220	.2220	.2220	.2220		0
9	0	.3470	.3475	.3480	.3475		0
10	0	.6425	.6425	.6425	.6425		0
11	0	.3995	.3995	.3995	.3995		0
12	0	.4555	.4550	.4560	.4555		0
13	0	.5065	.5065	.5060	.5065		0
14	0	.5060	.5060	.5060	.5060		0
15	0	.4660	.4665	.4665	.4665		0

End Rod Reading #1 = 4.23"
#2 = 4.26
#3 = 4.945
#4 = 4.90

Center Reading #1 = 4.31"
#2 = 4.13

FIELD SHEET

RUN #2 - 2000#/ft.² - SIDES INTACT

Cell #	Jack Loads	Micrometer Readings #1	#2	#3	Aver.
1	12000	.6560	.6570	.6565	.6565
2	"	.5990	.5990	.5990	.5990
3	"	.7125	.7115	.7115	.7115
4	"	.6090	.6095	.6085	.6095
5	"	.4385	.4380	.4385	.4385
6	"	.5710	.5710	.5712	.5710
7	"	.4515	.4520	.4525	.4520
8	"	.2350	.2350	.2350	.2350
9	"	.3655	.3650	.3650	.3650
10	"	.6480	.6475	.6475	.6475
11	"	.4180	.4180	.4180	.4180
12	"	.4765	.4765	.4770	.4765
13	"	.5215	.5225	.5220	.5220
14	"	.5135	.5135	.5140	.5135
15	"	.4865	.4875	.4870	.4870

End Rod Reading #1 = 4.26"
#2 = 4.31
#3 = 4.93
#4 = 4.91

Center Reading #1 = 4.31"
#2 = 4.17

FIELD SHEET

RUN #3 - NO LOAD - SIDES INTACT

Cell#	JACK LOADS	Micrometer Readings #1	#2	#3	Aver.	Corr. Factor	LOAD (Chart)
1	0	.6530	.6530	.6530	.6530	+.0090	0
2	0	.6020	.6010	.6010	.6010	+.0040	0
3	0	.7030	.7030	.7030	.7030	+.0025	0
4	0	.6090	.6095	.6090	.6090	+.0055	0
5	0	.4345	.4340	.4340	.4340	-.0010	0
6	0	.5600	.5600	.5600	.5600	+.0105	0
7	0	.4375	.4390	.4385	.4380	+.0090	0
8	0	.2215	.2205	.2205	.2210	+.0040	0
9	0	.3545	.3540	.3530	.3540	-.0070	0
10	0	.6290	.6285	.6285	.6285	+.0080	0
11	0	.4070	.4075	.4075	.4075	-.0095	0
12	0	.4635	.4635	.4635	.4635	-.0015	0
13	0	.5090	.5095	.5095	.5095	+.0005	0
14	0	.5095	.5095	.5095	.5095	+.0080	0
15	0	.4725	.4725	.4730	.4725	0	0

End Rod Reading #1 = 4.25"
#2 = 4.29
#3 = 4.94
#4 = 4.91

Center Reading #1 = 4.29"
#2 = 4.17

FIELD SHEET

RUN #4 - 3000 #/ft.² - SIDES INTACT

Cell #	Jack Loads	Micrometer Readings #1	#2	#3	Aver.	Correc. Read.	Load (Chart)	Pressure Tons/ft.²
1	18000	.6705	.6700	.6695	.6700	.6790	69	.69
2	"	.6030	.6030	.6030	.6030	.6070	23	.23
3	"	.7140	.7140	.7135	.7140	.7165	105	1.05
4	"	.6105	.6105	.6110	.6105	.6160	10	.10
5	"	.4500	.4495	.4495	.4495	.4485	18	.18
6	"	.5660	.5665	.5655	.5660	.5765	57	.57
7	"	.4660	.4650	.4650	.4655	.4645	20	.20
8	"	.2450	.2450	.2450	.2450	.2490	24	.24
9	"	.3770	.3760	.3765	.3765	.3695	33	.33
10	"	.6405	.6405	.6405	.6405	.6485	92	.92
11	"	.4350	.4350	.4345	.4350	.4255	32	.32
12	"	.4960	.4965	.4960	.4960	.4945	42	.42
13	"	.5285	.5290	.5285	.5285	.5290	60	.60
14	"	.5230	.5235	.5235	.5235	.5315	50	.50
15	"	.5045	.5045	.5040	.5045	.5045	55	.55

End Rod Reading #1 = 4.33"
#2 = 4.41
#3 = 5.00
#4 = 4.96

Center Reading #1 = 4.35"
#2 = 4.22

FIELD SHEET

RUN #5 - 4000 #/ft.² - SIDES INTACT

Cell #	Jack Loads	Micrometer Readings #1	#2	#3	Aver	Correc. Read.	Load (Chart)	Pressure Tons/Ft.²
1	24000	.6840	.6865	.6865	.6860	.6950	132	1.32
2	"	.6105	.6100	.6095	.6100	.6140	76	.76
3	"	.7155	.7165	.7160	.7160	.7185	120	1.20
4	"	.6140	.6150	.6150	.6150	.6205	25	.25
5	"	.4620	.4625	.4620	.4620	.4610	35	.35
6	"	.5690	.5695	.5695	.5695	.5800	76	.76
7	"	.4785	.4790	.4790	.4790	.4880	52	.52
8	"	.2530	.2525	.2525	.2525	.2565	31	.31
9	"	.3905	.3905	.3900	.3905	.3835	59	.59
10	"	.6220	.6220	.6220	.6220	×	×	×
11	"	.4470	.4470	.4470	.4470	.4375	45	.45
12	"	.5005	.5000	.5010	.5005	.4990	51	.51
13	"	.5440	.5440	.5440	.5440	.5445	115	1.15
14	"	.5300	.5290	.5300	.5295	.5375	74	.74
15	"	.5185	.5180	.5170	.5180	.5180	84	.84

End Rod Reading #1 = 4.38"
#2 = 4.44
#3 = 5.04
#4 = 5.00

Center Reading #1 = 4.40"
#2 = 4.26

FIELD SHEET

RUN #6 – 5000#/FT.² – SIDES INTACT

CELL #	JACK LOADS	MICROMETER READINGS 1	2	3	Aver.	CORR. READ.	LOAD #/CELL	PRESSURE T./SQ.FT.
1	30 KIPS	.6995	.6995	.7000	.6995	.7085	187	1.87
2	"	.6125	.6120	.6130	.6125	.6165	91	0.91
3	"	.7220	.7215	.7215	.7215	.7240	152	1.52
4	"	.6195	.6195	.6195	.6195	.6250	43	0.43
5	"	.4770	.4770	.4765	.4770	.4760	60	0.60
6	"	.5685	.5675	.5675	.5675	.5780	×	
7	"	.4925	.4930	.4925	.4925	.5015	74	0.74
8	"	.2675	.2675	.2675	.2675	.2715	48	0.48
9	"	.4055	.4055	.4055	.4055	.3985	90	0.90
10	"	.5610	.5610	.5615	.5610	.6565	130	1.30
11	"	.4635	.4630	.4635	.4635	.4540	68	0.68
12	"	.5145	.5145	.5140	.5145	.5130	86	0.86
13	"	.5555	.5545	.5545	.5550	.5555	157	1.57
14	"	.5375	.5380	.5380	.5380	.5460	107	1.07
15	"	.5340	.5340	.5340	.5340	.5340	129	1.29

Rod Readings – Point #1 4.40"

Point	Reading
1	4.40"
2	4.44
3	5.03
4	5.00
1c	4.40
2c	4.26

FIELD SHEET

RUN # 7 - NO LOAD - SIDES LOOSE

CELL No.	JACK LOAD	MICROMETER READINGS 1	2	3	AVG	CORR. FACTOR
1	0	.6565	.6570	.6570	.6570	+.0050
2	"	.6010	.6005	.6010	.6010	+.0040
3	"	.7025	.7025	.7025	.7025	+.0030
4	"	.6080	.6075	.6080	.6080	+.0065
5	"	.4480	.4480	.4475	.4480	-.0150
6	"	.5435	.5430	.5435	.5435	+.0370
7	"	.4545	.4545	.4545	.4545	-.0076
8	"	.2390	.2390	.2390	.2390	-.0140
9	"	.3670	.3675	.3665	.3670	-.0200
10	"	.5410	.5405	.5410	.5410	+.0955
11	"	.4250	.4250	.4250	.4250	-.0270
12	"	.4720	.4715	.4725	.4720	-.0100
13	"	.5115	.5115	.5115	.5115	-.0015
14	"	.5065	.5070	.5070	.5070	+.0105
15	"	.4655	.4655	.4655	.4655	+.0070

ROD READINGS Point #1 4.30"
2 4.34
3 5.00
4 5.05 (NEW POINT)
1c 4.37
2c 4.23

FIELD SHEET

RUN #8 - 3000#/FT.² - SIDES LOOSE

CELL No.	JACK LOAD	MICROMETER READINGS 1	2	3	AVG.	CORR. READ.	PRESSURE #/CELL	T/SQ.FT.
1	9T	6870	6860	6865	6865	6915	119	1.19
2	"	6060	6070	6080	6070	6110	55	0.55
3	"	7150	7150	7150	7150	7180	116	1.16
4	"	6125	6125	6120	6125	6190	18	0.18
5	"	4700	4700	4700	4700	4550	26	0.26
6	"	5605	5600	5600	5600	5970	156	1.56
7	"	4860	4850	4850	4850	4775	38	0.38
8	"	2605	2610	2605	2605	2465	22	0.22
9	"	3975	3980	3980	3980	3780	47	0.47
10	"	5525	5525	5525	5525	6470	85	0.85
11	"	4560	4565	4560	4560	4290	36	0.36
12	"	5070	5065	5070	5070	4970	48	0.48
13	"	5410	5420	5415	5415	5400	99	0.99
14	"	5305	5300	5305	5305	5410	86	0.86
15	"	5140	5145	5145	5145	5215	94	0.94

ROD READINGS - Point #	
1	4.39
2	4.41
3	5.09
4	5.11
1c	4.41
2c	4.29

Field Sheet

Run #9 - 4000#/Ft.² - Sides Loose

Cell No.	Jack Load	Micrometer Readings 1	2	3	Avg.	Corr. Read.	Pressure Lbs/Cell	T/Sq. Ft.
1	12T	.7000	.7005	.7010	.7005	.7055	175	1.75
2	"	.6135	.6145	.6140	.6140	.6180	100	1.00
3	"	.7195	.7185	.7185	.7190	.7220	140	1.40
4	"	.6175	.6185	.6180	.6180	.6245	40	0.40
5	"	.4785	.4785	.4785	.4785	.4635	39	0.39
6	"	.5670	.5670	.5665	.5670	.6040	188	1.88
7	"	.4970	.4965	.4970	.4970	.4895	60	0.60
8	"	.2685	.2675	.2680	.2680	.2540	28	0.28
9	"	.4065	.4055	.4060	.4060	.3860	65	0.65
10	"	.5595	.5590	.5590	.5590	.6545	120	1.20
11	"	.4615	.4615	.4615	.4615	.4345	42	0.42
12	"	.5140	.5140	.5145	.5140	.5040	62	0.62
13	"	.5515	.5515	.5520	.5515	.5500	136	1.36
14	"	.5365	.5360	.5365	.5365	.5470	110	1.10
15	"	.5305	.5295	.5305	.5305	.5375	140	1.40

Rod Readings

	Point #	
	1	4.44
	2	4.44
	3	5.12
	4	5.14
	1c	4.40
	2c	4.29

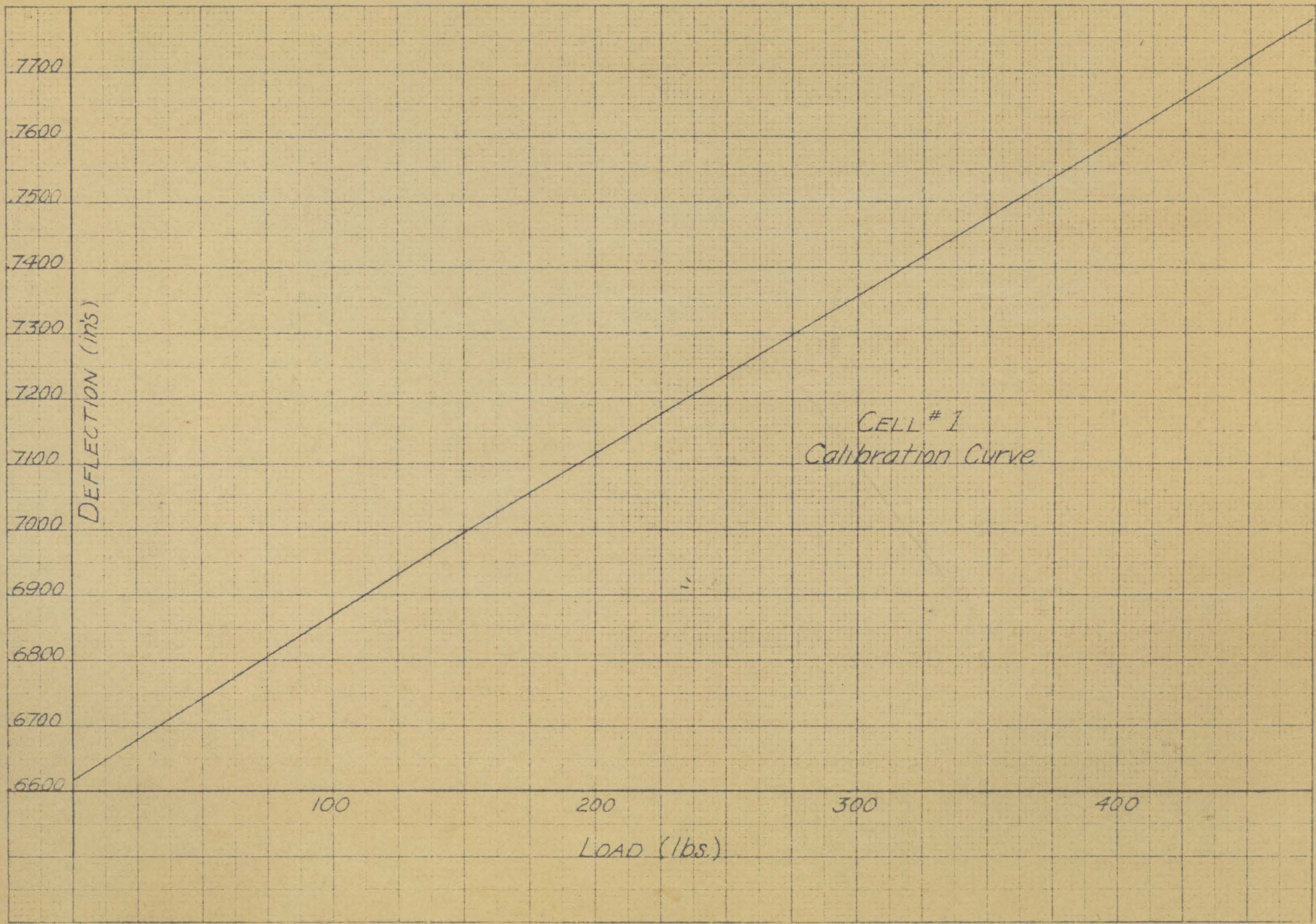
FIELD SHEET

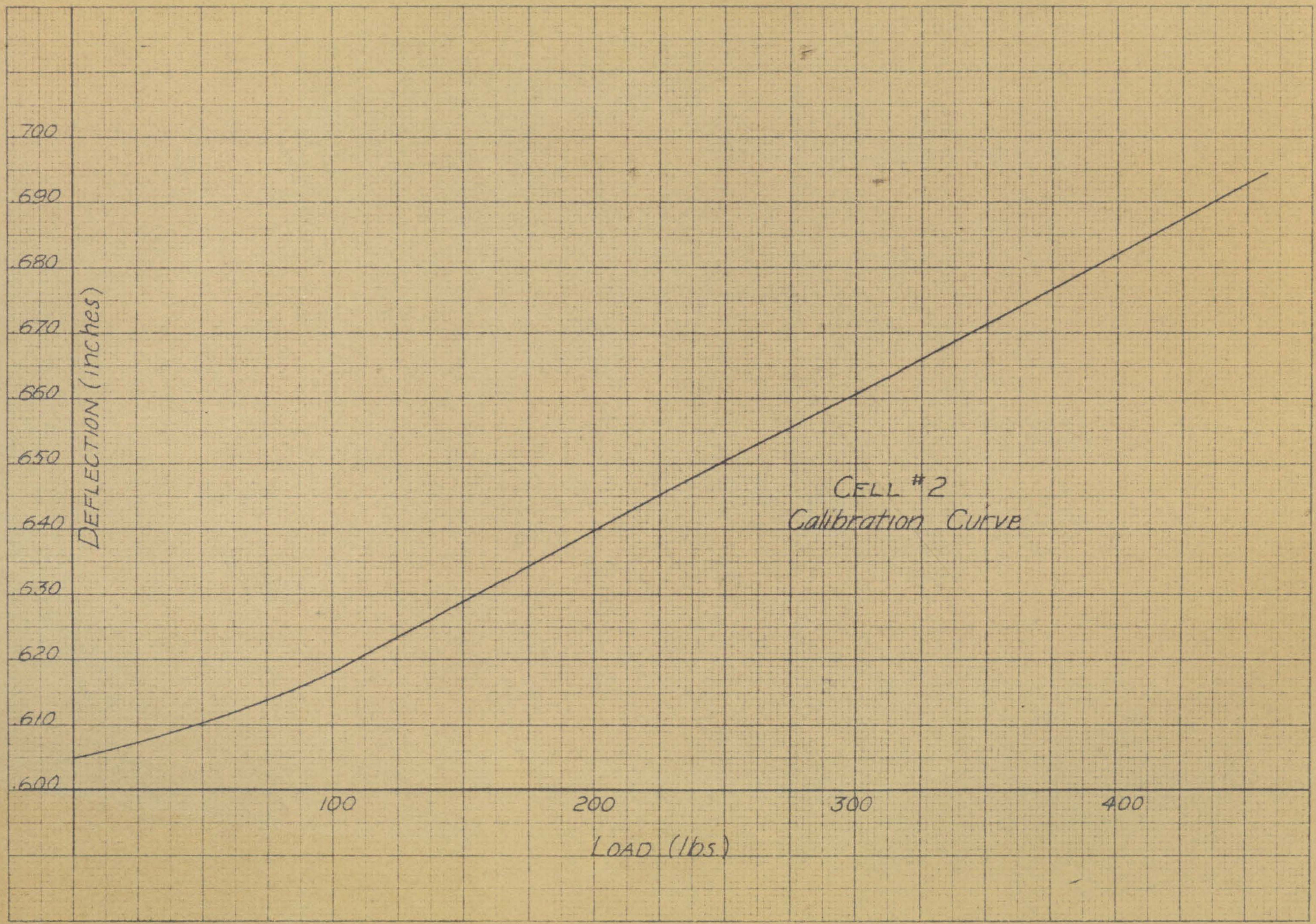
RUN #10 - 5000 #/FT.² - SIDES LOOSE

CELL No	JACK LOAD	MICROMETER READINGS 1	2	3	AVG.	CORR. READ.	PRESSURE LBS/CELL	T/SQ. FT.
1	15T	.7145	.7145	.7145	.7145	.7195	233	2.33
2	"	.6190	.6190	.6190	.6190	.6230	124	1.24
3	"	.7290	.7295	.7295	.7295	.7325	200	2.00
4	"	.6245	.6245	.6250	.6245	.6310	68	0.68
5	"	.4900	.4900	.4900	.4900	.4750	58	0.58
6	"	.5790	.5795	.5795	.5795	.6165	243	2.43
7	"	.5100	.5100	.5100	.5100	.5025	76	0.76
8	"	.2775	.2775	.2775	.2775	.2635	39	0.39
9	"	.4190	.4185	.4185	.4185	.3985	95	0.95
10	"	.5655	.5660	.5655	.5655	.6610	151	1.51
11	"	.4740	.4740	.4740	.4740	.4470	58	0.58
12	"	.5275	.5265	.5270	.5270	.5170	99	0.99
13	"	.5635	.5645	.5640	.5640	.5625	185	1.85
14	"	.5480	.5480	.5480	.5480	.5585	159	1.59
15	"	.5450	.5440	.5455	.5450	.5520	193	1.93

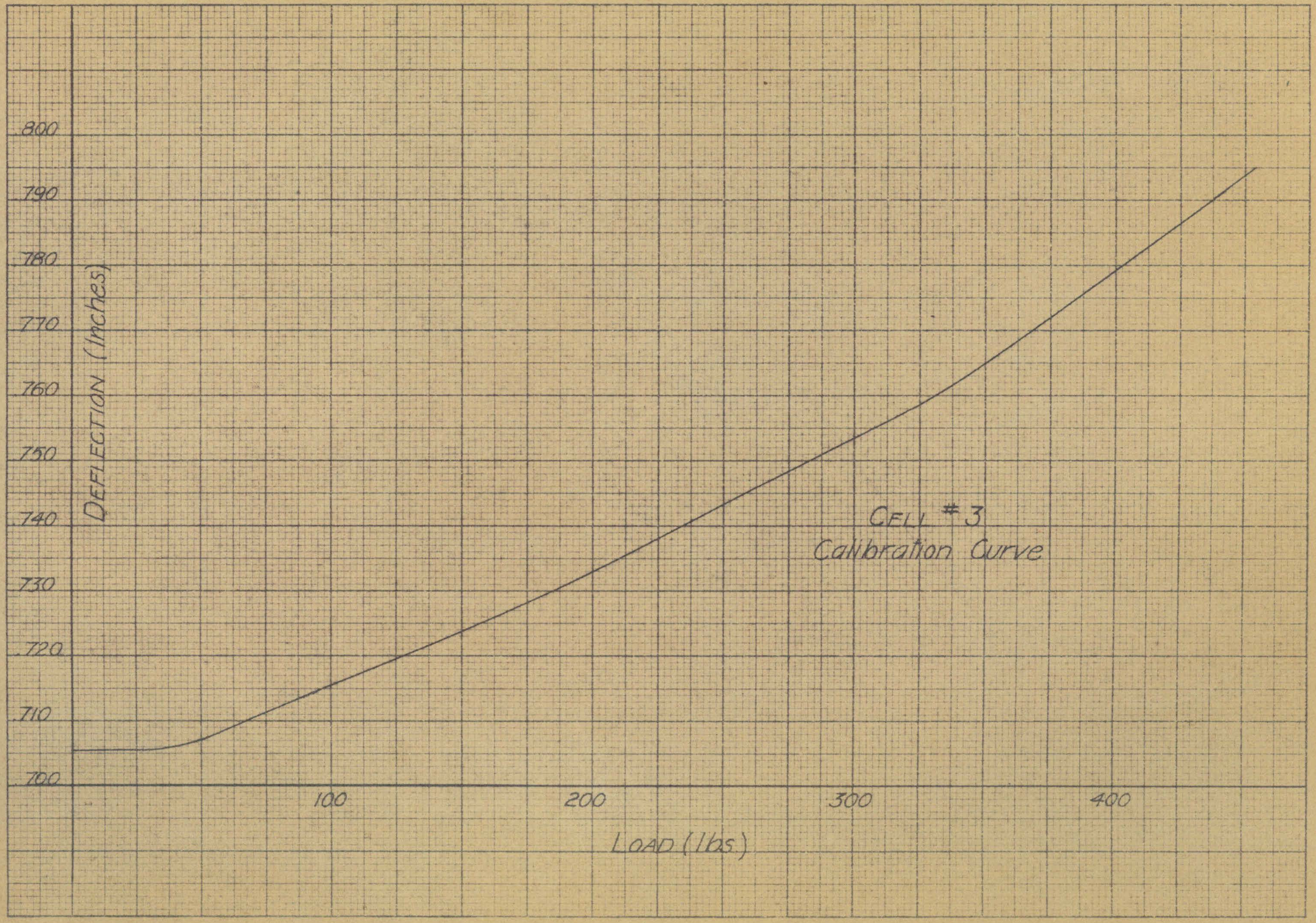
ROD READINGS

Point #	
1	4.45
2	4.47
3	5.13
4	5.16
1C	4.47
2C	4.33

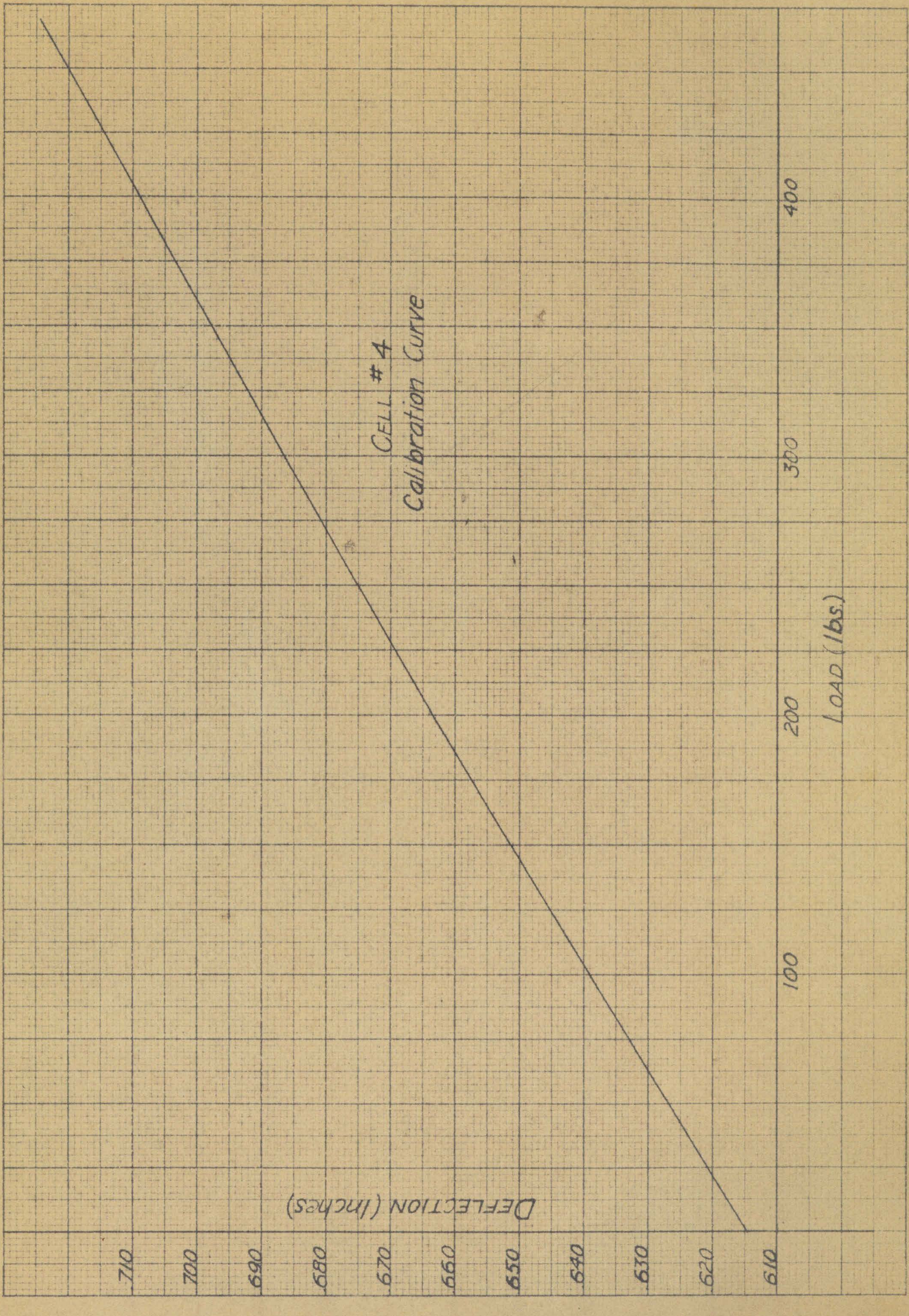

CELL # I
Calibration Curve
DEFLECTION (in's)
.7700
.7600
.7500
.7400
.7300
.7200
.7100
.7000
.6900
.6800
.6700
.6600
100
200
300
400
LOAD (lbs.)

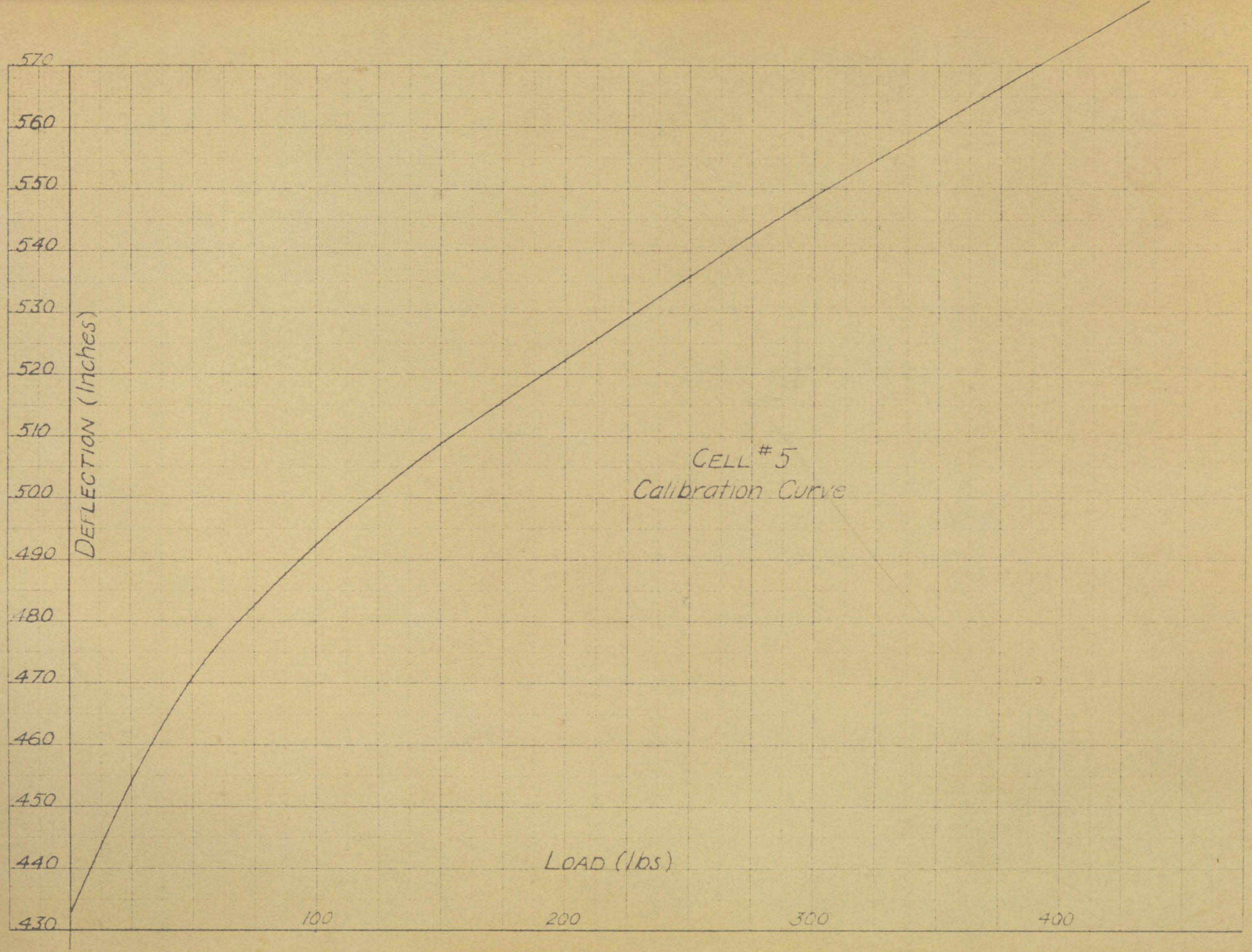


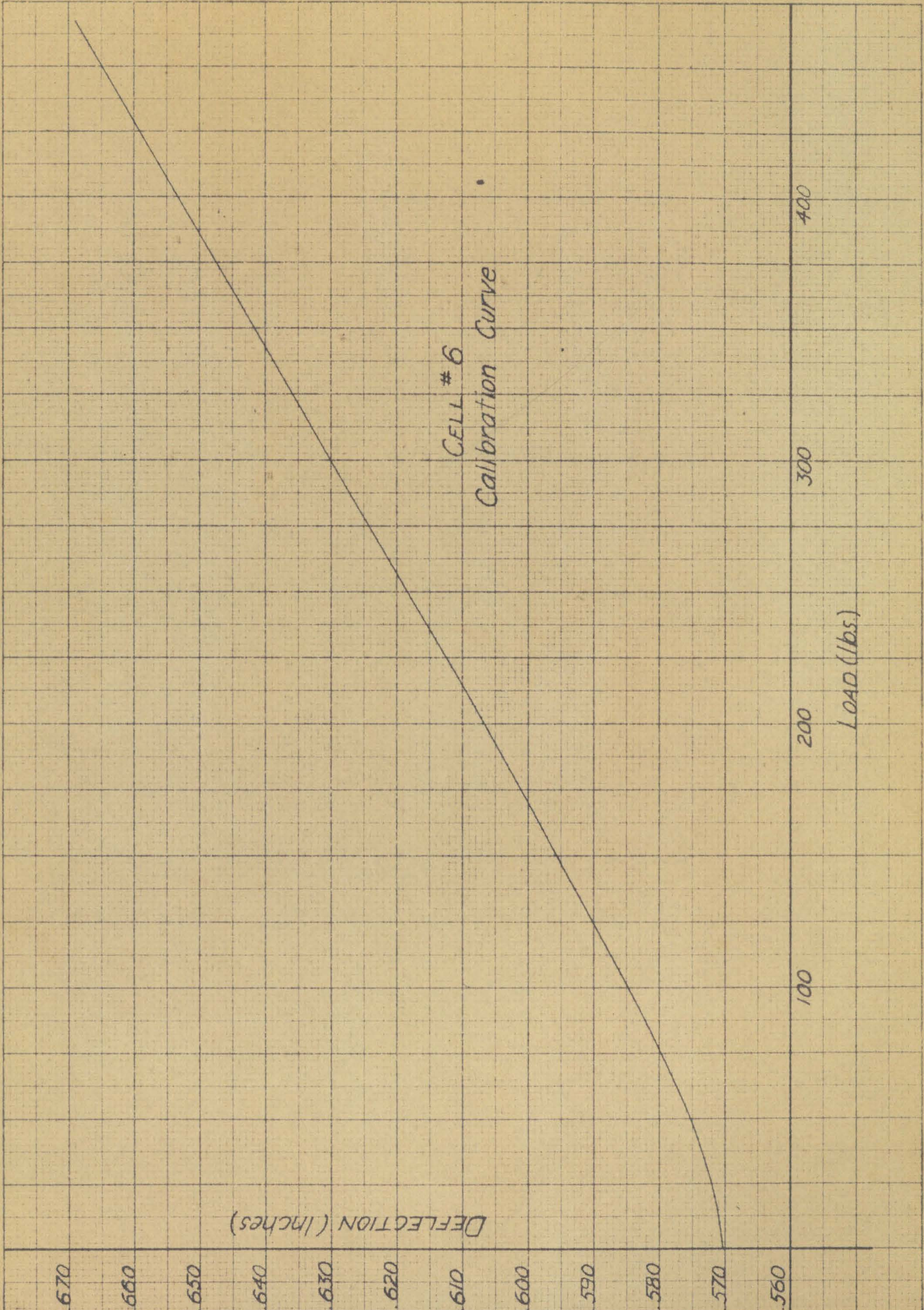
CELL #2
Calibration Curve
DEFLECTION (inches)
.700
.690
.680
.670
.660
.650
.640
.630
.620
.610
.600
100
200
300
400
LOAD (lbs.)

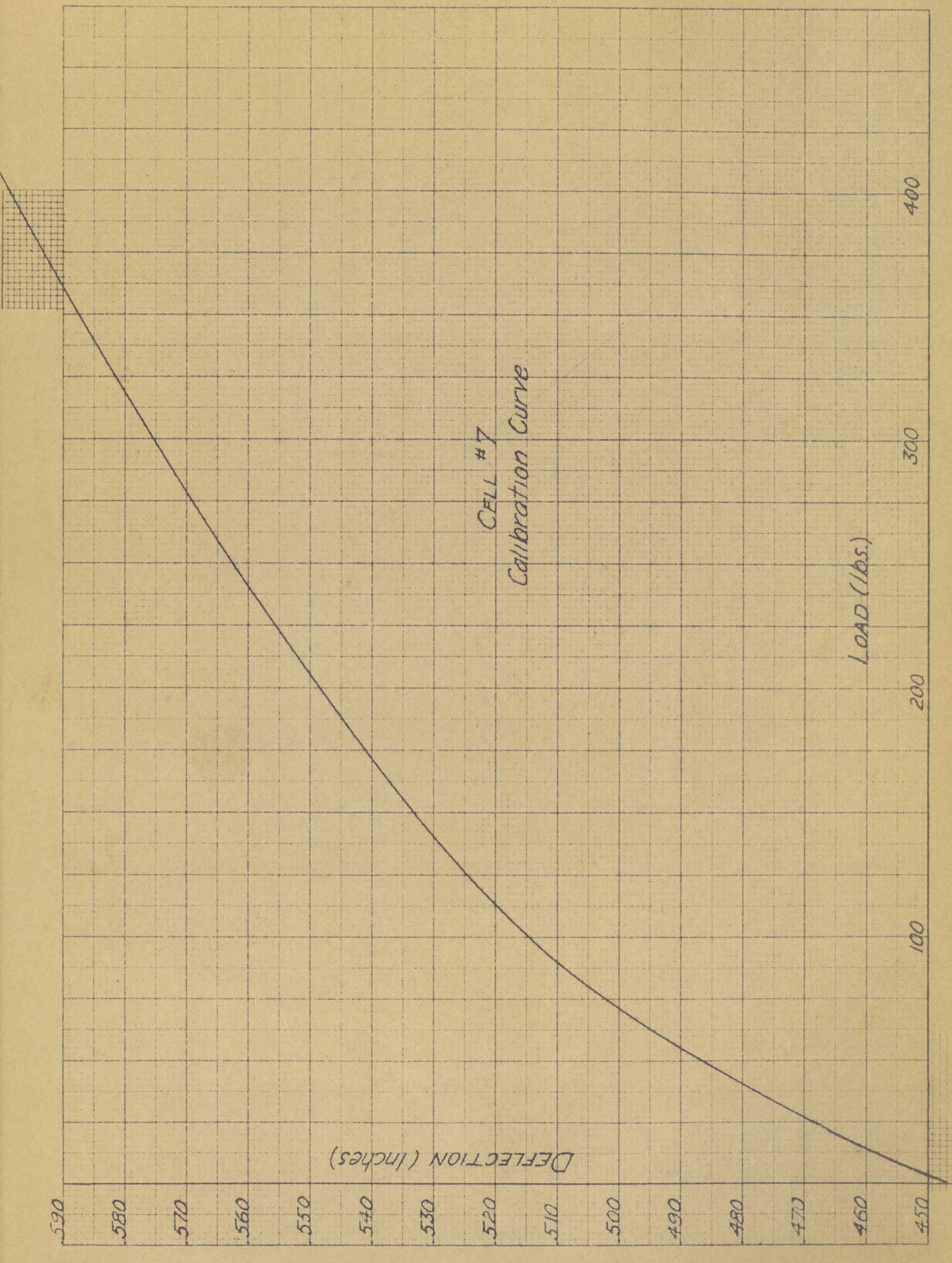


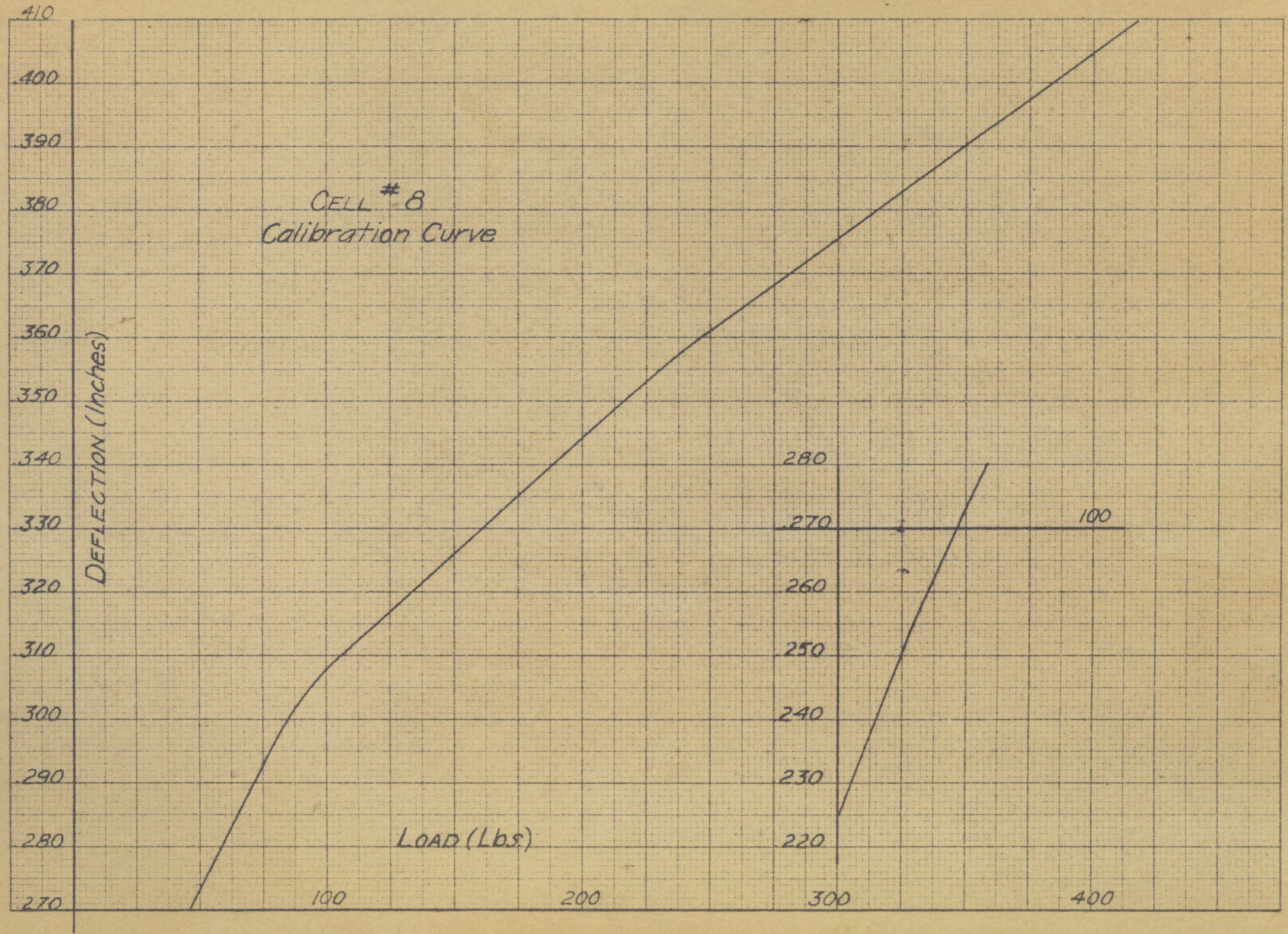
CELL # 3
Calibration Curve
DEFLECTION (Inches)
LOAD (lbs)
800
790
780
770
760
750
740
730
720
710
700
100
200
300
400


CELL # 4
Calibration Curve
LOAD (lbs.)
100
200
300
400
DEFLECTION (inches)
610
620
630
640
650
660
670
680
690
700
710

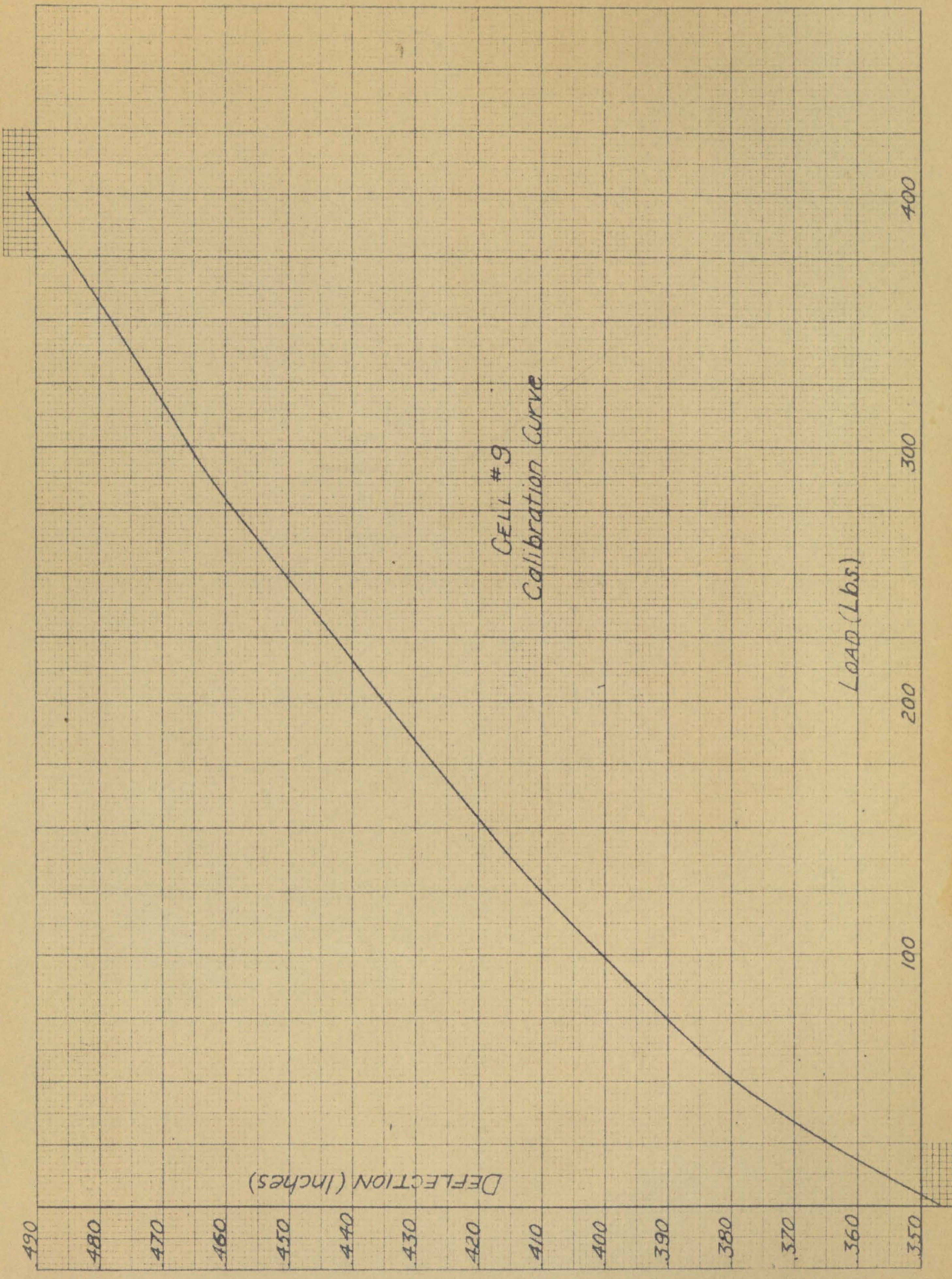

CELL # 5
Calibration Curve
DEFLECTION (Inches)
LOAD (lbs)
570
560
550
540
530
520
510
500
490
480
470
460
450
440
430
100
200
300
400

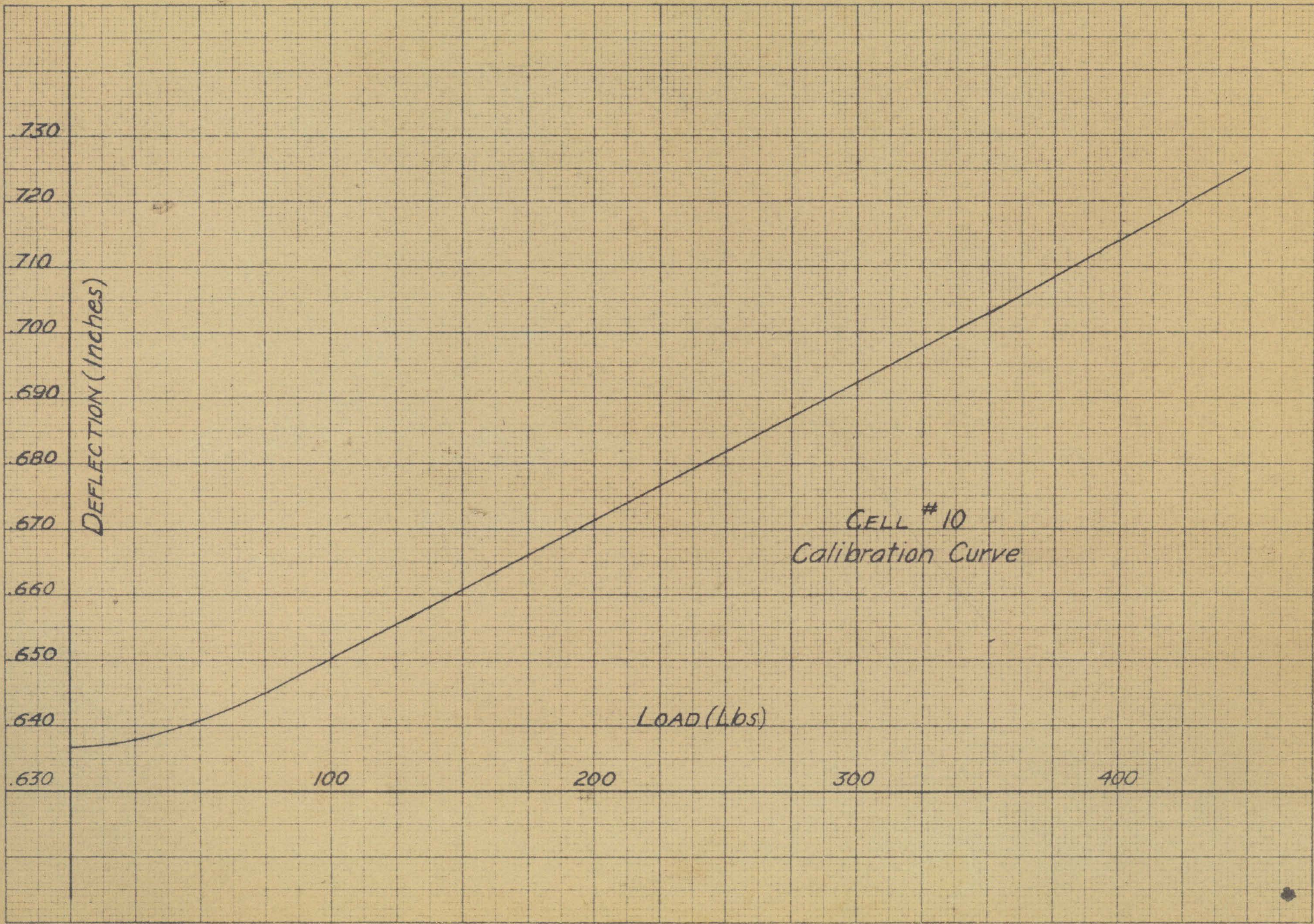

CELL #6
Calibration Curve
LOAD (lbs.)
DEFLECTION (inches)
100
200
300
400
670
660
650
640
630
620
610
600
590
580
570
560


CELL #7
Calibration Curve
LOAD (lbs.)
100
200
300
400
DEFLECTION (Inches)
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450

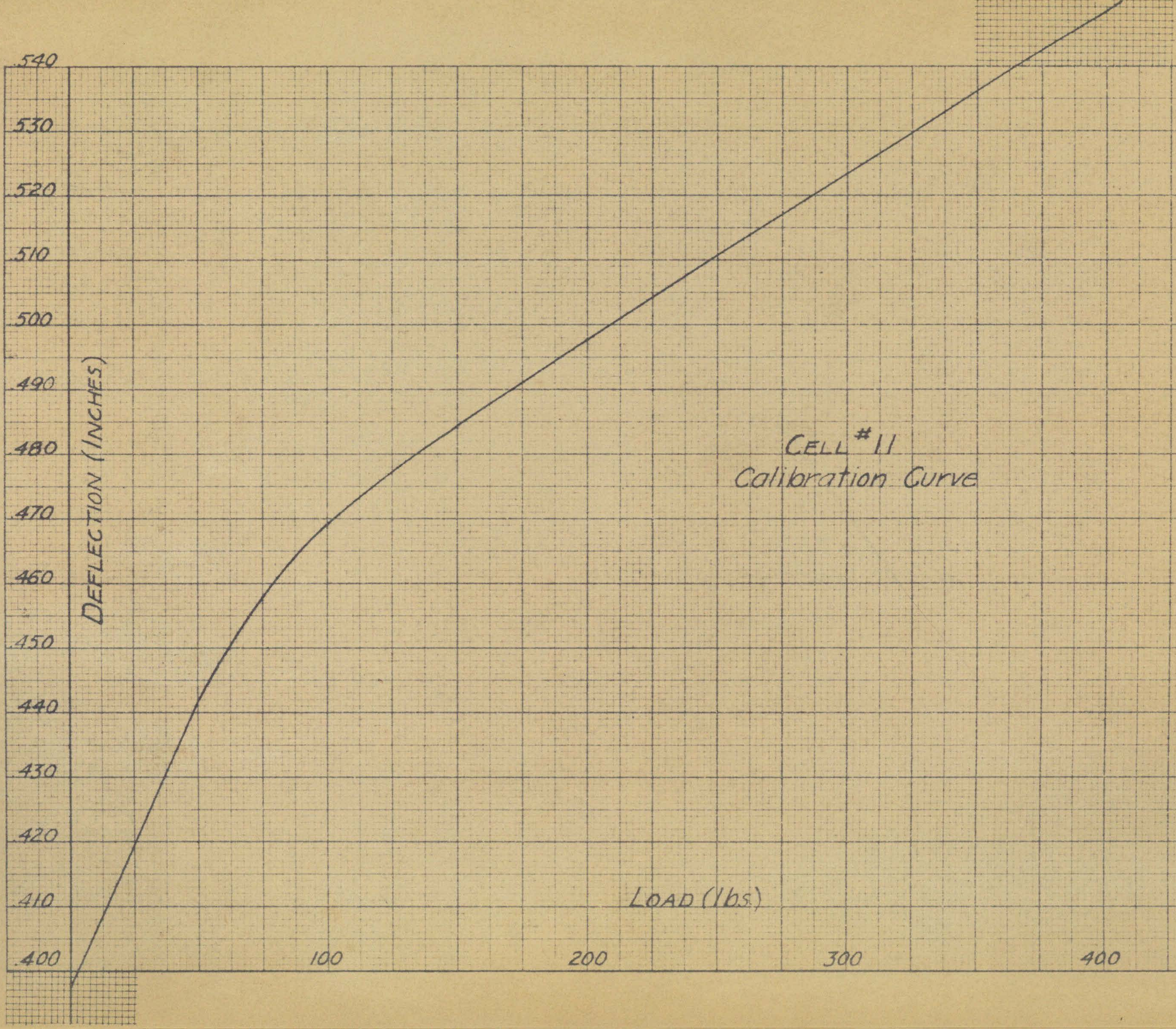


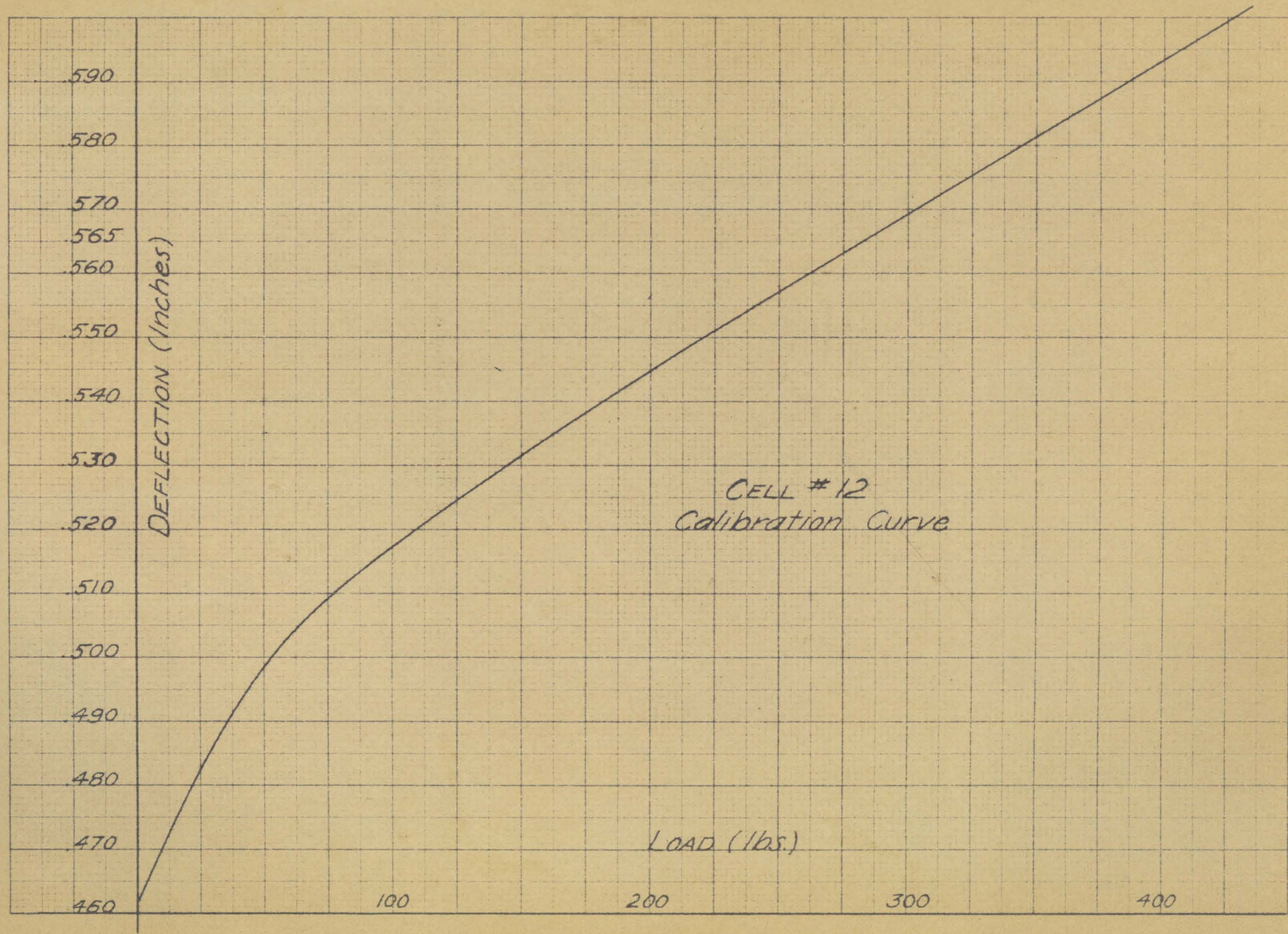
CELL # 8
Calibration Curve
DEFLECTION (Inches)
LOAD (Lbs)
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
100
200
300
400
280
270
260
250
240
230
220
100

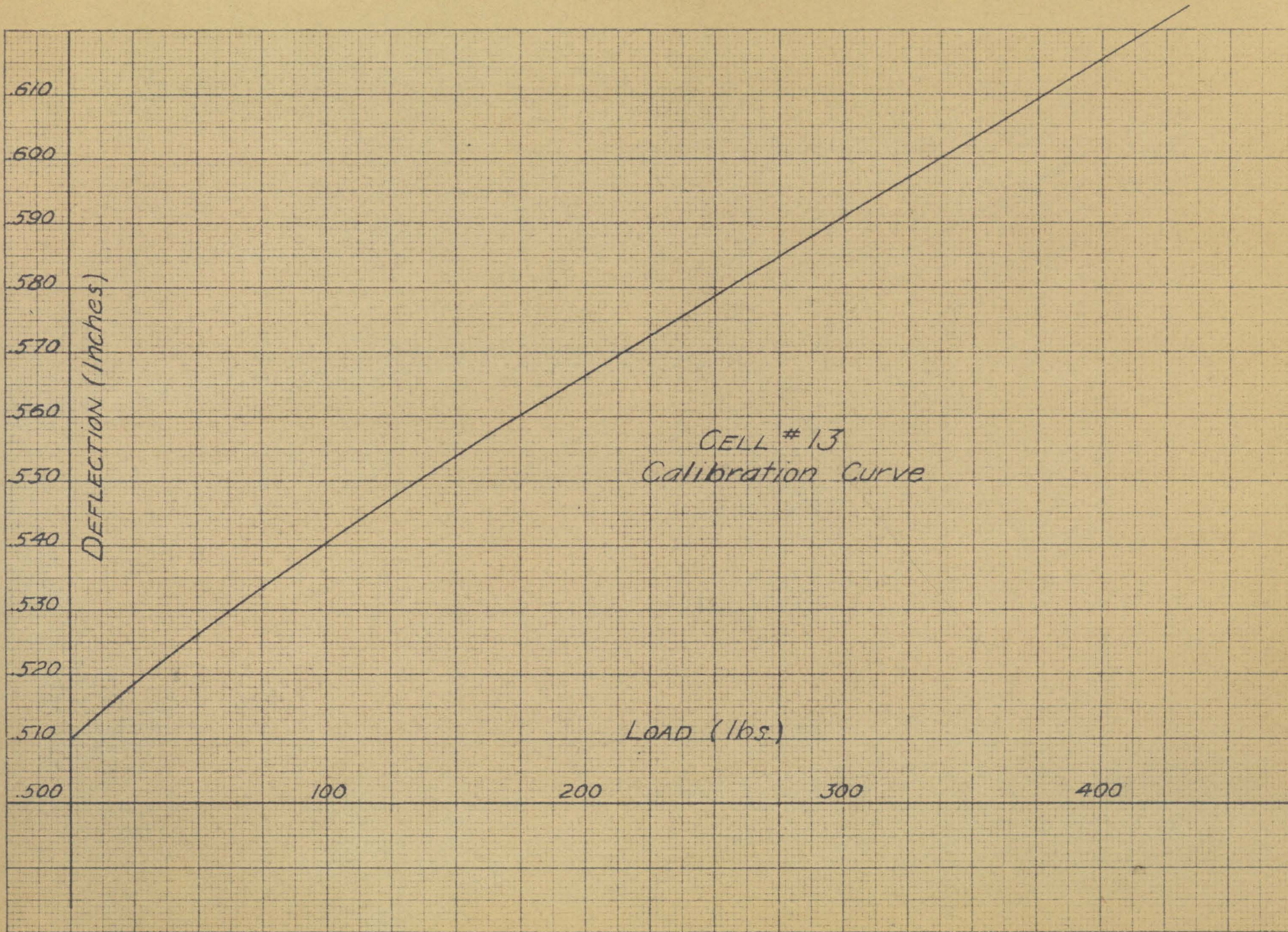

CELL #9
Calibration Curve
LOAD (Lbs.)
DEFLECTION (Inches)
100
200
300
400
490
480
470
460
450
440
430
420
410
400
390
380
370
360
350

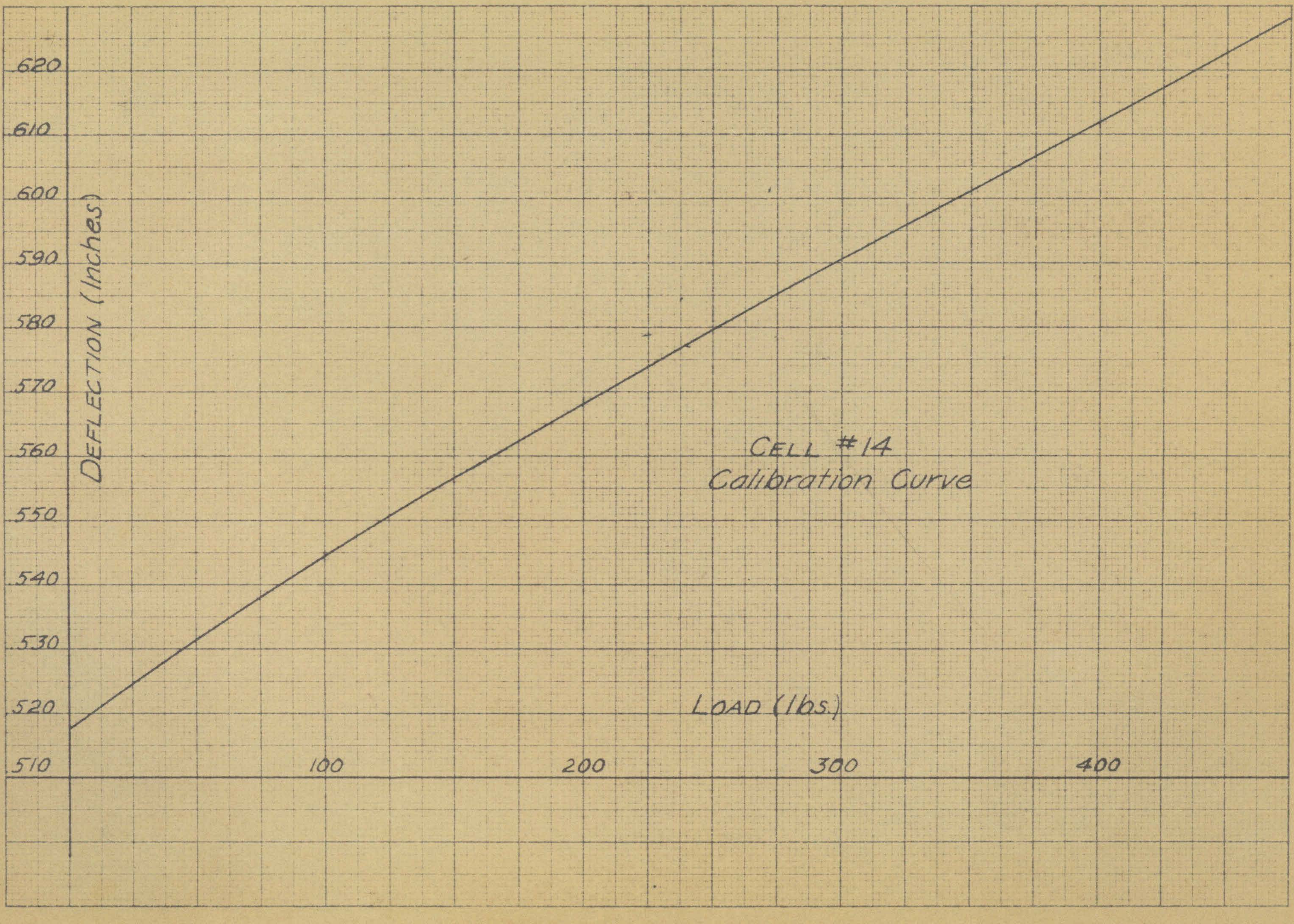


CELL # 10
Calibration Curve
DEFLECTION (Inches)
LOAD (Lbs)
.730
.720
.710
.700
.690
.680
.670
.660
.650
.640
.630
100
200
300
400

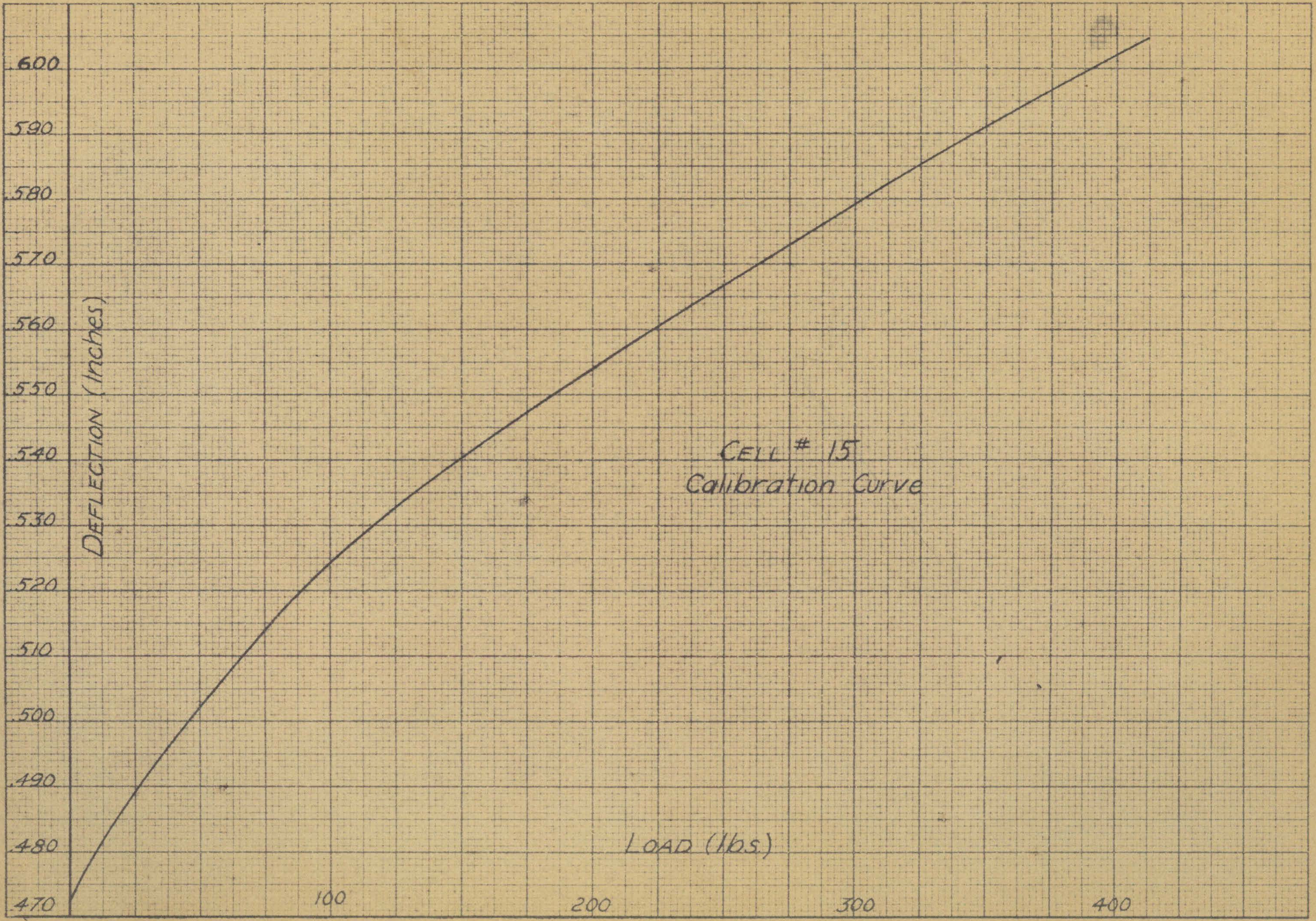

CELL #11
Calibration Curve
DEFLECTION (INCHES)
LOAD (lbs)
.540
.530
.520
.510
.500
.490
.480
.470
.460
.450
.440
.430
.420
.410
.400
100
200
300
400


CELL # 12
Calibration Curve
DEFLECTION (Inches)
LOAD (lbs.)
.590
.580
.570
.565
.560
.550
.540
.530
.520
.510
.500
.490
.480
.470
.460
100
200
300
400


CELL # 13
Calibration Curve
DEFLECTION (Inches)
LOAD (lbs.)
.610
.600
.590
.580
.570
.560
.550
.540
.530
.520
.510
.500
100
200
300
400



Cell #14
Calibration Curve
Deflection (Inches)
Load (lbs.)
620
610
600
590
580
570
560
550
540
530
520
510
100
200
300
400


CELL # 15
Calibration Curve
DEFLECTION (Inches)
LOAD (lbs.)
.600
.590
.580
.570
.560
.550
.540
.530
.520
.510
.500
.490
.480
.470
100
200
300
400