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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

(April 27, 1933)

THE USE OF FLEXIBLE STEEL GAGES IN GAGING THE MESH OF GILL NETS

State and Canadian authorities controlling fishing on the Great Lakes, and the U. S. Bureau of Fisheries are interested in the conservation of fish in the lakes. Two of the factors bearing on this problem are the adoption of uniform regulations for mesh-size of gill nets and a uniform method of measuring or gaging the mesh-size of gill nets. At the request of the Bureau of Fisheries, the Bureau of Standards has investigated the physical properties of gill nets as now made, and various methods of measuring, or gaging the mesh-size of nets.

At a meeting of representatives of State and Canadian authorities controlling fishing on the Great Lakes, held in Toronto in the fall of 1932, a flexible steel gage was recommended for use in gaging gill nets in the field. Mr. W. T. Conn represented the Bureau of Fisheries at this conference. The flexible type of gage is used in Canada and some of the States. We are informed that gages at present in use are 1/2 inch wide, and have a specified thickness equivalent to No. 29, U. S. Standard Gage for Sheet and Plate Iron and Steel (0.0138 inch) in one State, and No. 30 (0.0123 inch) in Canada.

The gages are made with a length between the parallel ends equal to the minimum specified mesh-size of a legal net and, in using, the gage is flexed or bent by applying pressure to the ends with the fingers until it can be inserted in a mesh. If, upon releasing the pressure, the gage straightens out in the mesh, that mesh is considered of legal mesh-size. If a sufficient proportion of the meshes gaged pass the test, the net is considered legal. If the gage does not straighten out, or if the cord breaks, the mesh is considered below the legal mesh-size. This test is strictly a gaging test and no direct information is obtained as to how much over or under size a mesh may be.

The experience of users of this type of gage has been that cord breakage is quite common and produces an unfavorable or belligerent reaction from the fishermen, especially if the number of meshes in his net passing the gage is sufficient to pass the net, but a small proportion of meshes in which the gage was tried, failed by breaking the cord. Furthermore, the use of a regulatory gaging device that exerts sufficient force to

break the cord presents a difficult problem to the net maker, as he is unable to check his product under the tension exerted by the gage.

It seems desirable to determine, if possible, the tension in the net cord produced by flexible gages now in use. There was available for this purpose a stainless steel gage, 3 1/16" long, 1/2" wide, and 0.0125" thick, graduated on both edges on one side to sixteenths of an inch, and marked on the back 3 1/16 APP.ONT. U. S. 30 P. GA. G & F.

This gage was set up vertically with lower end resting on a steel plate, as shown diagramatically at "A" in Fig. 1. The upper end was loaded with weights and the deflection of the center of the gage from the vertical was measured. The relation of deflection and load is shown by the approximate straight line (A_1), in Fig. 1. At the time the deflection was measured the distance (L) between the ends of the gage was also measured and the relation between deflected length and deflection is shown in Fig. 5.

It is quite apparent that in using the gage in a net mesh that the part of the cord in contact with the convex side of the deflected gage exerts a pressure on the gage tending to straighten it out, and the gage therefore exerts a greater force on the net cords for any particular deflection than the load required to produce that deflection by the set-up "A", Fig. 1.

In order more nearly to approximate gaging conditions, the deflections were measured with the set-up shown diagramatically at (B) and (C), Fig. 1. Here a cord, fixed at its upper end, was wrapped around the gage and weights were attached to the lower end of the cord. In this set-up the weight (T) used determines the tension in the cord across the ends of the gage on the concave side. The tension in that part of the mesh in contact with the convex side is not equal to the tension on the concave side, either in this set-up or when the gage is used to gage the mesh-size of a net, because the cord does not slip or adjust itself perfectly over the ends of the gage.

The tension produced in the mesh cords in gaging a mesh with a flexible gage is undoubtedly greater across the ends on the concave side than in that part of the mesh in contact with the convex side.

In the set-up shown at (B) and (C), the tension in the cord in contact with the convex side will be less than (T) if gage is not disturbed while (T) is gradually increased from a value insufficient to cause deflection to a maximum value. The tension on the convex side may be greater than (T) when (T) is gradually decreased from a maximum value. Deflections read with

(T) increasing are shown by curve marked (C_1), Fig. 1. Deflections determined with (T) decreasing are shown by the curve marked (B_1).

In test "C" the friction of the cords on the ends of the gage acts in a direction to produce a smaller deflection, for any cord tension, than if friction were not present. Similarly in test (B) the friction acts in a direction to prevent the gage from straightening out to the extent it would if friction were not present. If friction between cord and gage, and elastic hysteresis in the gage could be eliminated, curves C_1 and B_1 would coincide.

It will be noted that the load-deflection curve (A_1) determined by set-up (A) lies between the (C_1) and (B_1) tension-deflection curves. Bearing in mind that the average of the tensions in the cords on both sides of the gage for any deflection is undoubtedly less than the value of (T) indicated by curve (C_1), and perhaps somewhat greater than indicated by curve (B_1), it is apparent that the load (W) required to produce the deflection by set-up (A) is a close approximation of the tension produced in the cord when the gage is used in a mesh.

The tensile strength of a sample of a single 80/6 cotton cord was found to be 2.4 pounds and of a 70/6 cotton cord, 3.2 pounds. With this gage producing a tension in the cord of from 2 pounds to 2 pounds 10 ounces, it is not surprising that the gage frequently breaks the net cords, considering that under this tension the ends, even if rounded, tend to cut the cord.

Gaging Tension.- It is apparent that flexible steel gages should be made from thinner or narrower strips producing less tension in the cords. Spring, or tempered steel sheets, or strips, are commercially available such that gages can be made that will exert tensions of 8 ozs. or less on the cords of a mesh. To determine a desirable tension for such gages the physical properties of samples of representative gill nets were investigated.

The length of a net cord is affected by

1. Temperature
2. Moisture content of the cord
3. Tension

The magnitude of the variation in the length of cord due to changes in any one of the above factors depends on the material, the weight, and the make-up of the cord. The temperature effect is so small as to be negligible. A loop of 80/6 cotton cord, measured under water at 70° F., and then in ice

water at 32° F., under 1-lb. tension, contracted less than 0.4%, or less than 1/64" on a 3-inch mesh. The shrinkage of a 50/2 linen loop was less than 0.1%. The effect of an increase in moisure content is to decrease the length and increase the stretch per unit tension. So that, for any gill net cord, there is a tension at which the cord will have the same length when thoroughly wet as when normally dry (dried in air of 30% to 40% relative humidity).

The manufacturers of gill netting supplied for test purposes samples of gill netting made of 80/6 and 70/6 sea island cotton cord and 50/2 linen cord with various mesh sizes.

Nets of nominal 2 1/4" and 2 5/8" mesh, 80/6 cotton; 2 1/4" and 2 5/8", 50/2 linen; and 3", 70/6 cotton were measured both wet and dry under various tensions. The procedure was to measure about ten 2-mesh intervals on each net, dry, with the tension on the two cords of a mesh increasing from 2 oz. to 16 oz. Then the nets were left in water over night and measured thoroughly wet at the same points, with tensions increasing from 2 oz. to 16 oz. A dead weight mesh-size measuring device was used for this test. The variations in mesh-size are plotted in Fig. 2. The average mesh-size of the 2 1/4" and 2 5/8" cotton and linen nets was 2 5/16", measured wet under 16 oz. tension. The variations in mesh-size of the 3", 70/6 cotton were adjusted to the same basis, that is, a mesh-size of 2 5/16" at 16 oz. wet. The plot shows that the mesh-size is the same within 1/64" at 16 oz. tension, wet or dry, for 80/6 cotton and 50/6 linen, and the mesh-size for 70/6 cotton is only 1/64" greater when dry than when wet. These results are a strong argument in favor of a measuring tension of 16 oz., provided that the 80/6 and 70/6 cotton and 50/2 linen cords, as now made, are used in gill netting, as the use of this tension practically eliminates any uncertainties in measured mesh-size due to moisture content of the cord.

In addition to the variations that may be obtained in measuring or gaging mesh-size at tensions less than one pound, due to moisture content of the cord, there are several other reasons why the smaller tensions are not desirable. In handling a net for measuring purposes, individual cords may be subjected to tensions of several ounces, either intentionally or unintentionally. These cords are not perfectly elastic and if stretched do not return at once to the original length when tension is removed. If the tension is not excessive, the original length can be closely restored by soaking in water under no load for a period of time. However, if the mesh-size is measured or gaged immediately after the cords have been stretched, a larger value for mesh-size will be obtained than if the cords had not been stretched. A measuring tension

should be used that is greater than the tension that may normally be applied to the cord in handling. This makes tensions less than 1 pound on the two cords of a mesh undesirable.

The use of small measuring tensions for dead weight, or spring tension devices for measuring mesh-size, means that such devices must be designed and made with precision, or the instrument friction may be large in proportion to the measuring tension. Also with flexible steel gages of such thickness as to exert tensions of 2 to 4 ounces on a mesh, a slight finger pressure on the convex side of the gage in a mesh will cause the gage to exert a tension considerably in excess of the intended tension.

There is one objection to the use of higher tensions, that is, with the tension applied to the cords they continue to stretch for some time. This stretch with time is quite noticeable on wet cotton nets measured with tensions of one pound and over. With a flexible steel gage a mesh can be gaged in less than two seconds and the stretch in this time interval is small. All factors considered, one pound seems to be the most desirable measuring tension.

Gages Exerting 1-lb. Tension on the Two Cords of a Mesh.- A number of gages, 1/2" wide, 3 1/16" long, were made from available sheets of blue tempered steel of the thicknesses shown in Fig. 3. The force (W) required to deflect these gages 1/4" is plotted in Fig. 3. From this plot it will be noted that the thickness required for an 8 oz. force is about 0.0073". In addition to width and thickness, the modulus of elasticity of the steel used will affect the deflection of the gages. Little variation is probable in the modulus of elasticity of commercial spring, or tempered steel sheets of the thicknesses required. The modulus of elasticity of tempered stainless steel usually shows some variation and may be higher or lower than for the tempered strip steel used. It will be noted that the point marked, "stainless steel", lies above the line for blue tempered steel gages. This may indicate that the modulus of elasticity of the stainless steel is less than the blue tempered steel or probably that the effective thickness of the stainless steel gage is less than the measured thickness, due to the depth of the scale graduations.

A plot of the relation between deflection and load for a 3 1/16" gage, 0.0076" thick, is shown by curve A_2, Fig. 1. B_2 and C_2 curves for this gage are also plotted. Here again it will be noted that the force required to deflect the gage a given amount by set-up (A) is closely equal to the cord tension required to deflect the gage the same amount by set-ups (B) and (C). The same relation was found to hold for a 6-inch gage of such thickness as to deflect 1/10 its length under an 8 oz. load.

Gages were also selected with widths of 1/2" and lengths of 2 1/4" and 5", of such thicknesses as to deflect 1/10 of their lengths under 8 oz. load. The relation of thickness to length for 8 oz. load is shown in Fig. 4.

Measuring mesh-size by gage deflection.- It was found that the mesh-size measurements made with a 3 1/16", 0.0077 in., 9 oz. flexible steel gage, a 3 1/16", 0.0069 in., 7 oz. flexible steel gage and a spring tension device exerting 1-lb. tension on the two cords of a mesh could be compared by the following methods.

First, as previously stated, at the time the relation between load and deflection was determined, (see curves A_1 and A_2, Fig. 1), the distance (L) between the support and weight (see illustration A, Fig. 1) was also carefully measured. This gave us the relation between the deflection and distance L, shown by curve "Distance between ends of gage", Fig. 5.

Now, if the gage be inserted in an undersize mesh so that a measurable deflection is obtained, the mesh-size is the mean of the length of the gage and the distance L between the ends of the gage. The mesh-size-deflection relation is shown by curve, "Mesh-size", Fig. 5. For making the comparison, an 80/6 cotton net of nominal 3 1/16" mesh-size was used. Measurements were made with the net thoroughly wet. This represents the extreme conditions as to stretch of net under tension (see lowest curve, Fig. 2). The 7-oz. gage was first inserted in a mesh and deflection measured. Then the mesh-size of the same mesh was measured with the 1-lb. spring tension device, and finally the deflection of the 9-oz. gage was determined in the same mesh. Ten separate meshes were measured in this way. The average mesh-size is shown in lines 1, 2, and 3, of the following table.

Average Mesh-Size of 80/6 Cotton Net
Measured Wet

Order of measurement	Type of Gage	Average Mesh-Size
1	7 oz. flexible	2 60/64" +
2	1 lb. spring	2 61/64
3	9 oz. flexible	2 63/64
	Gage used in reverse order	
4	9 oz. flexible	2 61/64"
5	1 lb. spring	2 61/64
6	7 oz. flexible	2 62/64 -

It will be noted that the 9-oz. gage shows a mesh-size about 3/64" greater than the 7-oz. gage, and the mesh-size shown by the 1-lb. spring tension device is close to the mean of the mesh-sizes by the 7- and 9-oz. gages. To show the effect of non-elasticity of the net cord and the stretch with time, the test was repeated on ten new meshes, using the gages in reverse order; that is, 9-oz. first, then the 1-lb. spring tension device, and finally the 7-oz. gage. The average mesh-sizes shown in lines 4, 5, and 6, respectively, are the same within 1/64". The 9-oz. gage exerts a tension of approximately 18 ounces on the two cords of a mesh, and the application of this tension to the wet cords of a mesh produced some non-elastic stretch in the eight to fifteen seconds required to make a deflection reading. The cords did not recover their length before the 7-oz. gage was applied, and this gage indicated a mesh-size as large as the 9-oz. gage. Considering the factors of non-elasticity of the cords and stretch with time, we believe that the difference between the 7-oz. and 9-oz. gages on a 2 61/64" mesh, 80/6 cotton net, wet, should be considered as not over 1/32". If the gages differed by but one ounce instead of two, the difference in measured mesh-size should not be over 1/64". With this information we are now ready to recommend specifications for flexible steel gages.

Specifications for Flexible Steel Gages.- The 3 1/16", 7-oz. and 9-Oz. gages were 1/2" wide and thickness was 0.0069" and 0.0077" respectively. For a gage deflecting 1/10 its length under a load of 8 ± 1/2 ounces, the thickness of a gage 1/2" wide would be approximately 0.0073 ± 0.0002". Now it is not considered commercially possible to control the thickness of tempered steel strips within the limits of ± 0.0002". However, the gages need not be exactly 1/2" wide. A tolerance of ± 1/16" on width, giving gages between width limits of 7/16" and 9/16", can conveniently be allowed.

A gage 7/16" wide and 0.0086" thick will require a load of 8 1/2 oz. to deflect 1/10 of its length, and a gage 9/16" wide and 0.0063" thick will deflect 1/10 its length under a load of 7 1/2 oz., provided that the modulus of elasticity is the same as for the steel used in these tests.

A tolerance on width of ± 1/16", therefore, gives ample leeway in selecting steel strips of the proper thicknesses.

Scale graduations on the gages are objectionable, especially with thin gages. They reduce the effective thickness by an uncertain amount and in time will cause fatigue failure of the gage. It is recommended that gages be not graduated and that necessary markings, such as length, "std. 8 oz.", maker's mark,

or state marks, be as brief and as shallow as possible and be placed near the ends of the gage.

While the variation in modulus of elasticity for tempered steel may not be a serious factor, stainless steel of various makes may show a pronounced variation in the modulus. For this reason we recommend that all gages be tested for deflection under load by means of a simple set-up, such as is shown diagramatically at (A), Fig 1.

The recommended specifications are:-

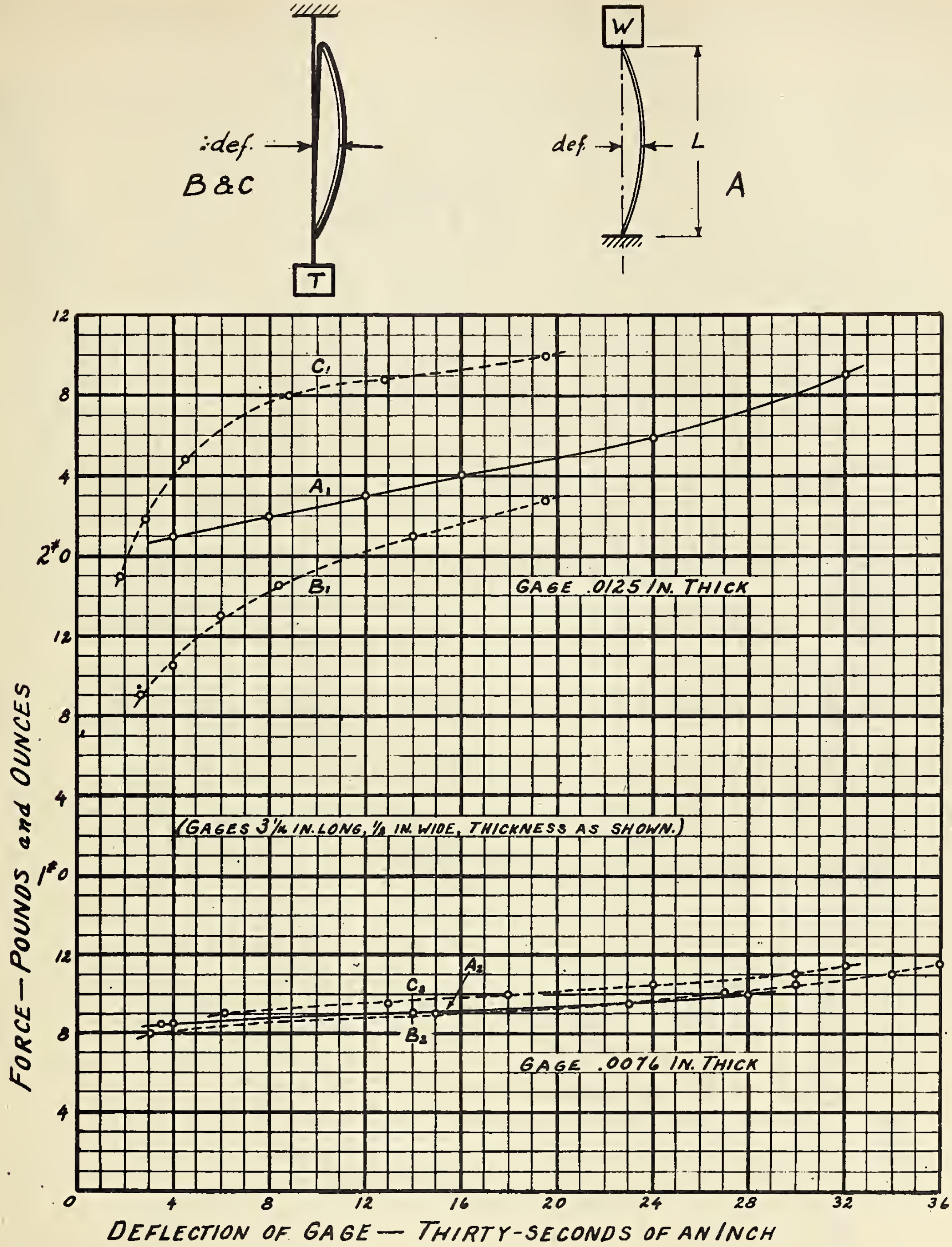
1. Gage shall be made of tempered carbon steel, or tempered stainless steel as specified.
2. Width of gage shall be 1/2" ± 1/16".
3. Mean length shall be as specified within ± 0.002".
4. Sharp edges, or burrs, at ends shall be removed, and the ends rounded, but ends shall not be sharpened to make a knife edge.
5. Gage shall be straight and ends shall be parallel within 0.002".
6. Thickness of gage shall be such that when set vertically on a solid anvil, and with the upper end of the gage loaded with a dead weight between 7 1/2 and 8 1/2 ounces, the gage shall deflect at its middle 1/10 of its length.
7. Gage shall not be graduated and any necessary markings such as length shall be placed near end of gage.

The straightness of the gages should now be discussed. Thin blue tempered strip steel comes in rolls, but when a gage is made from this stock it appears to be straight. However, the maximum load that a gage will support without deflection can be found approximately by extending the A_1 and A_2 lines of Fig. 1 to the line of zero deflection. Actually it was found that gages would not support this load without a perceptible deflection in one direction due to the fact that the stock had been rolled for a long time and the outside fiber strain on the two sides of the strip was not equal. We found that this effect could be practically eliminated by bending the strip in a direction opposite to the natural inclination of the strip several times.

To test the straightness of a gage and to correct the unequal strain, the following procedure is recommended. Hold the strip by the ends between the thumb and forefinger with a flat side in a horizontal plane, bend the strip by applied finger pressure; if the strip bends downward, turn the strip over so that the side that was previously up is now underneath, then again apply finger pressure. If gage again bends downward the gage is sufficiently straight. If in either position the gage bends upward, forcibly bend gage in opposite direction until it is found that it will bend downward with either side up.

In gaging a mesh with a flexible gage it should be held only by the ends between thumb and forefinger, line up the net cord parallel with edge of gage and release finger pressure. If the gage does not straighten out in the mesh immediately, the mesh should be considered undersized. Attempting to gage the same mesh repeatedly will stretch the cords and increase the mesh-size.

U. S. Bureau of Standards,
Washington, D. C.



COMPARISON OF GAGE DEFLECTIONS PRODUCED BY COMPRESSIVE FORCE "W" AND CORD TENSION "T"

FIG. 1

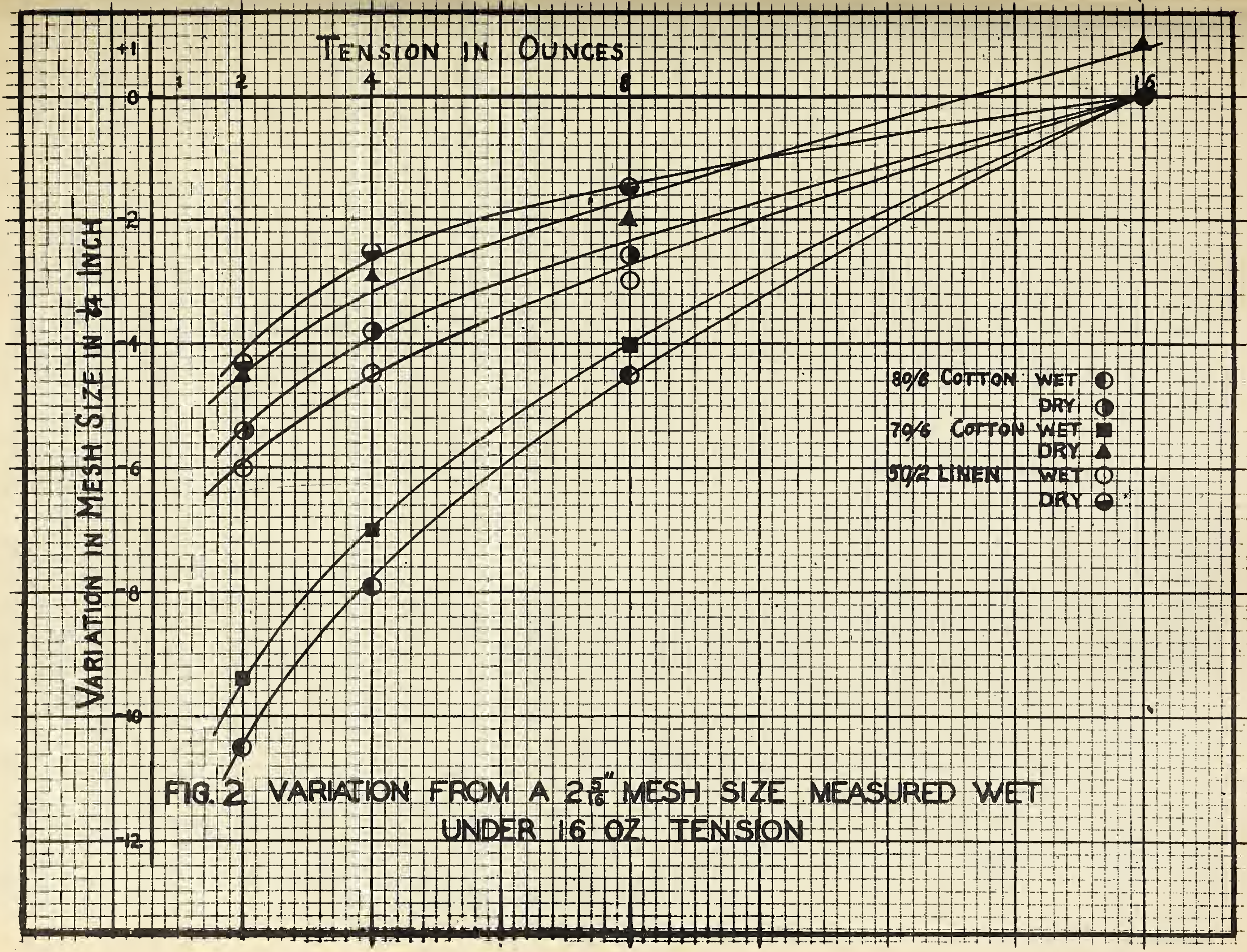


FIG. 2 VARIATION FROM A 2 5/16" MESH SIZE MEASURED WET UNDER 16 OZ. TENSION

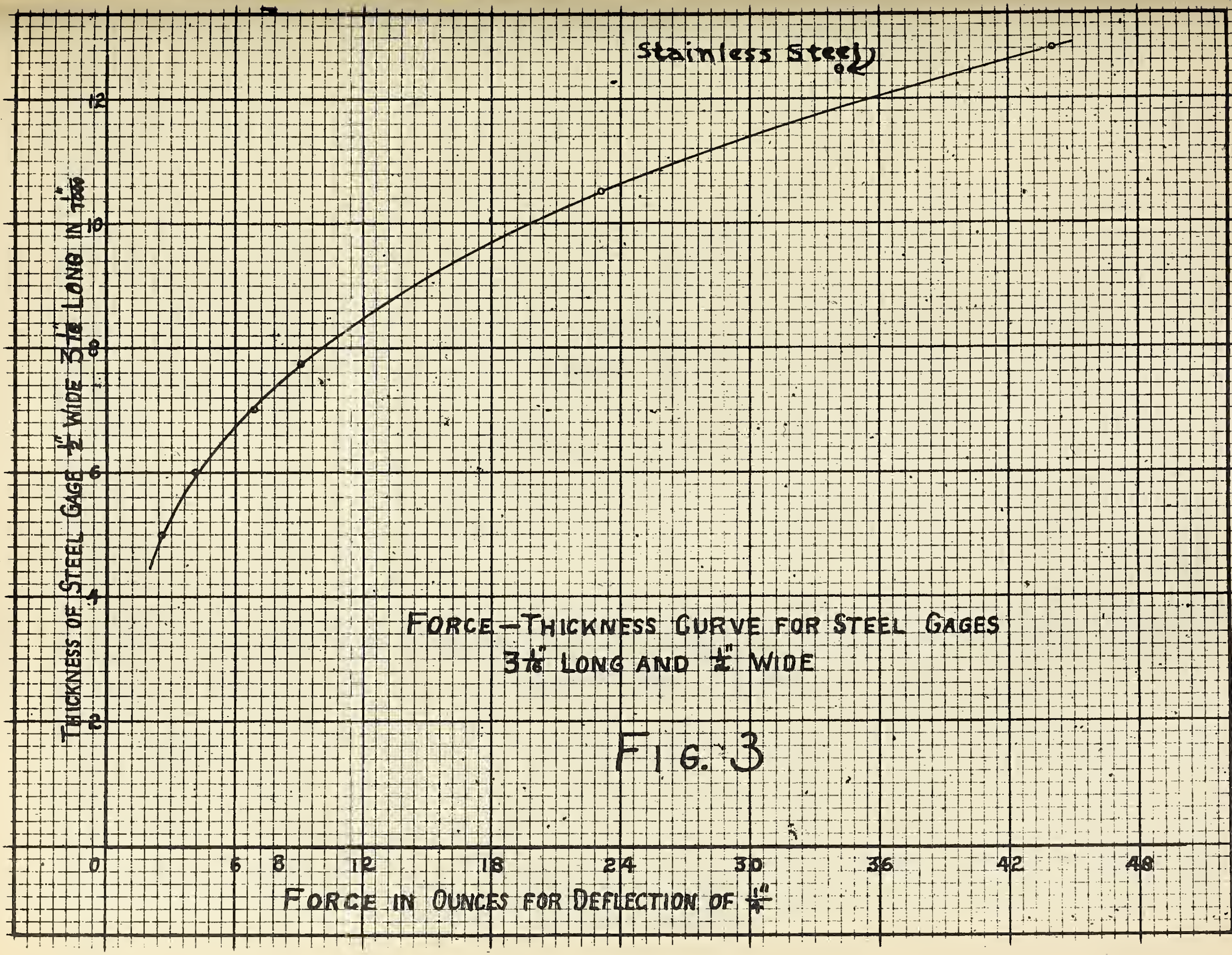

Stainless Steel
Force—Thickness Curve for Steel Gages
$3\frac{1}{16}$" Long and $\frac{1}{2}$" Wide
Thickness of Steel Gage $\frac{1}{2}$" Wide $3\frac{1}{16}$" Long in $\frac{1}{1000}$"
0
2
4
6
8
10
12
6
8
12
18
24
30
36
42
48
Force in Ounces for Deflection of $\frac{1}{4}$"

Fig. 3

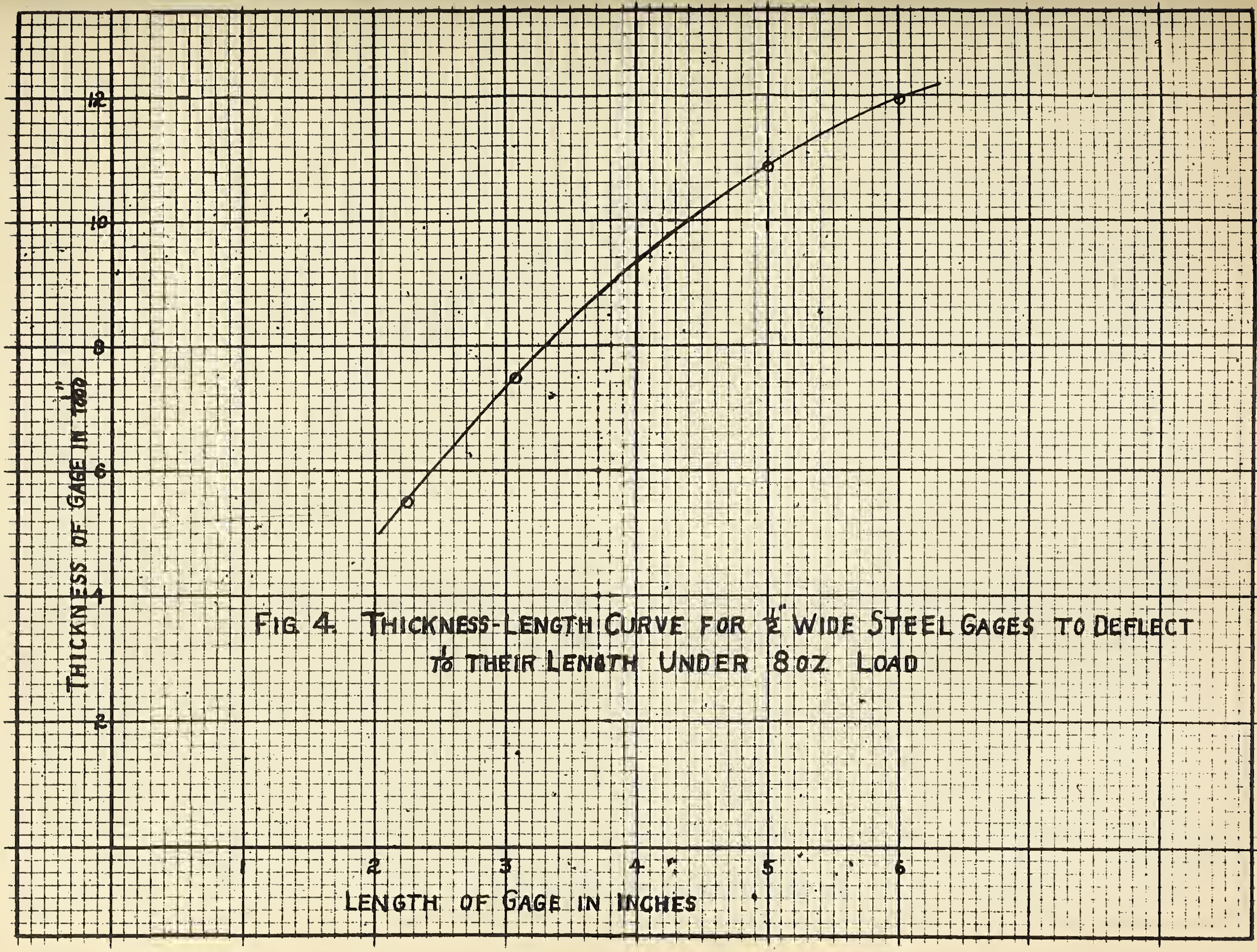


FIG 4. THICKNESS-LENGTH CURVE FOR $\frac{1}{2}''$ WIDE STEEL GAGES TO DEFLECT $\frac{1}{10}$ THEIR LENGTH UNDER 8 OZ. LOAD

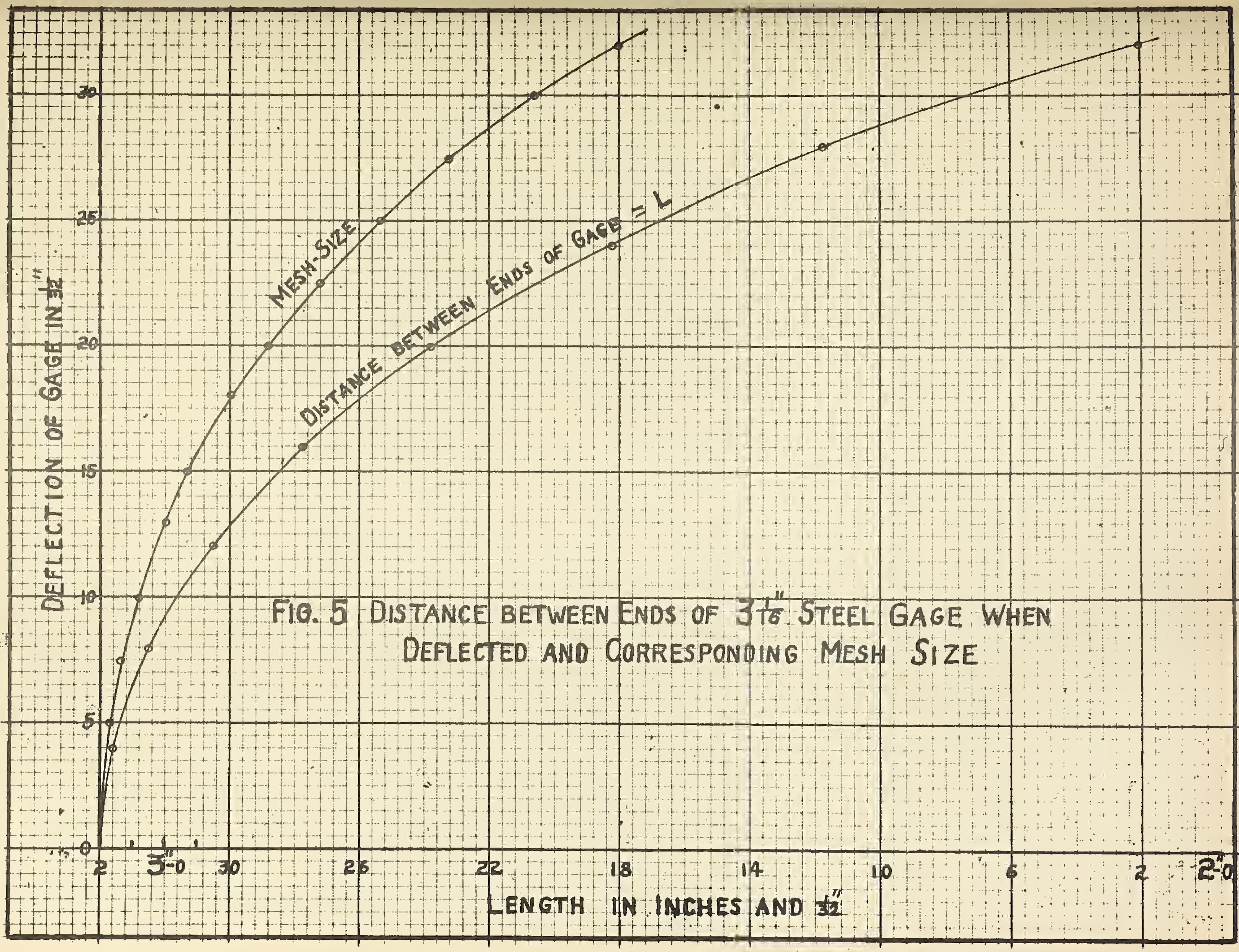


Fig. 5 Distance between Ends of $3\frac{1}{16}''$ Steel Gage when Deflected and Corresponding Mesh Size