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INVESTIGATION OF METHODS OF SUPPORTING SINGLE-THICKNESS SPECIMENS IN A FIXTURE FOR DETERMINATION OF COMPRESSIVE STRESS-STRAIN CURVES

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INVESTIGATION OF METHODS OF SUPPORTING SINGLE-THICKNESS SPECIMENS IN A FIXTURE FOR DETERMINATION OF COMPRESSIVE STRESS-STRAIN CURVES

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SUMMARY

An investigation was made of the methods of supporting single-thickness specimens of aluminum-alloy sheet material in a fixture for determination of compressive stress-strain curves. The specimens were supported in the fixture by rollers, offset-grooved plates, opposite-grooved plates, flat brass plates, or flat wooden plates.

It was found that the measured values of compressive yield stress and modulus of elasticity obtained with the roller supports were independent of the supporting force applied to the specimen provided that a sufficient minimum force is used to overcome initial deviations from flatness. The stress-strain curves obtained by the use of the plate types of support were affected by an increase in the supporting force. Satisfactory stress-strain curves were obtained with all types of support, however, when the supporting force was approximately 45 pounds.

The investigation also showed that the compression fixture, the specimen support, and the single-thickness specimens must be accurately made in order to obtain accurate stress-strain curves consistently.

INTRODUCTION

Compressive stress-strain curves for aluminum-alloy sheet material are being obtained in many laboratories throughout the aircraft industry to provide information on the properties of the materials used in aircraft. It is important that the method for determination of the curves be reliable, accurate, and relatively simple. Among the various methods proposed, the single-thickness method introduced by W. P. Montgomery of Vought-Sikorsky Aircraft appeared to be the most promising. In the method proposed by Montgomery and further developed at the Aluminum Research Laboratories of the Aluminum Company of America, a fixture was used for supporting a single thickness of sheet material so as to prevent buckling. (See reference 1.) In this fixture, closely spaced rollers on each side of the specimen provided lateral support and permitted shortening of the specimen under load. In order to simplify the Montgomery type of compression fixture, the National Bureau of Standards substituted solid brass plates for the rollers. (See reference 2.)

In experimental work at the Langley structures research laboratory, in which the single-thickness method and a compression fixture similar to those of references 1 and 2 were used, great difficulty was encountered in consistently obtaining accurate stress-strain curves. It was therefore decided to make a thorough investigation of the single-thickness method of determining compressive stress-strain curves for thin sheet material. Various types of support were used in the compression fixture and stress-strain curves were obtained for specimens that were supported with different values of supporting force.

SPECIMEN SUPPORTS AND COMPRESSION FIXTURE

In the single-thickness method, the function of the compression fixture is to support a specimen of thin sheet material so that the stress-strain curve obtained is the same as would be obtained for an unsupported specimen of the same material having such proportions that buckling could not occur. The degree to which the compression fixture fulfills its function depends largely on the performance of the supports, such as the rollers or flat brass plates, that come into contact with the specimen. For ideal performance, the supports should hold the specimen straight but should not resist changes in length, thickness, or width of the specimen.

Rollers, grooved brass plates, flat brass plates, and flat wooden plates were used in the present investigation for supporting the specimens. These supports are shown in figure 1 and are described as follows:

(1) Steel rollers - In the roller type of support, 25 hardened steel rollers 0.0925 inch in diameter and spaced 0.10 inch supported the specimen on each side. The rollers were supported at their conical ends by spring-brass plates that permitted the rollers to roll downward as the specimen shortened during loading.

(2) Grooved brass plates - Two types of grooved brass plate were included in the investigation. In the first type, the grooves of one plate were opposite the grooves of the other plate and, in the second type, the grooves of one plate were offset so as to be opposite the crests of the other plate (fig. 2). With the offset-grooved plates, there is less resistance to increase of specimen thickness during loading than there is with the opposite-grooved plates. Both types of grooved plate were lubricated with a heavy grease (Marfax No. 2).

(3) Flat brass plates - The brass plates were machined to a smooth flat finish. The plates were lubricated with grease in one series of tests and with a mixture of graphite and oil in another series.

(4) Flat wooden plates - The plates were made of hardwood (maple) finished to a smooth flat surface and were lubricated with a heavy grease (Marfax No. 2).

The various types of support were used in the compression fixture that is shown in figure 3. The fixture is composed of a steel holder that is mounted on a hardened steel base and into which are fitted two steel blocks. One of the steel blocks is cylindrically seated to make it self-alining, and the other is a sliding block that permits adjustment of the compression fixture for specimens of various thicknesses. The test specimen and the supports that come into contact with the specimen are inserted between the self-alining and the sliding steel blocks. A loading screw acting upon a loading plate provides a means of applying the supporting load to the supports for the specimen.

TESTS

Specimens 0.53 inch wide, 2.53 inches long, and 0.064 inch thick were cut from one sheet of 24S-T aluminum alloy with the grain of the sheet parallel to the direction of loading. These specimens were tested in the compression fixture with the four types of support and the four values of supporting force shown in table I.

During routine testing for investigations other than the present investigation it was sometimes observed that for specimens of high-strength material, 0.53 inch wide, there was evidence of bending in the plane of the specimen. It was therefore decided to increase the width of the specimens to 0.80 inch. The substantial increase in width from 0.53 to 0.80 inch was selected in order that the specimens might be of suitable dimensions for testing not only the aluminum alloys with compressive yield stresses of approximately 60 to 80 ksi in current use but also for testing alloys that may be developed with even higher yield stresses.

Specimens of 24S-T and R301-T aluminum alloy 0.80 inch wide, 2.51 inches long, and 0.064 inch thick were tested with rollers and offset-grooved plates as supports and with the same values of supporting force that were used for the 0.53-inch-wide specimens. (See table II.)

Examination of column curves for 24S-T and R301-T aluminum alloys indicated that buckling between rollers might occur for specimens of thin sheet material. Tests accordingly were made of 0.80-inch-wide specimens of 0.025-inch-thick 24S-T and 0.020-inch-thick R301-T aluminum alloy supported in the compression fixture with roller supports. Similar specimens supported by offset-grooved plates were tested for comparison.

In all the tests, strains were measured on the two free edges of each specimen by Tuckerman optical strain gages of 1-inch gage length. Figure 4 shows the compression fixture with specimen and strain gages in position before the test.

RESULTS AND DISCUSSION

The tests showed that the stress-strain curves obtained from single-thickness specimens were dependent on the type of support used in the compression fixture, on the magnitude of the supporting force applied to the specimen, and on the quality of the test apparatus and the test specimen. The amount by which the measured values of compressive yield stress and modulus of elasticity varied with the type of support and the magnitude of the supporting force is illustrated in table I and in figure 5 for the 0.53-inch-wide specimens and in table II and in figure 6 for the 0.80-inch-wide specimens. These tables and figures show that:

(1) The values of compressive yield stress obtained from tests with the roller type of support were independent of the magnitude of the supporting force. For supports other than rollers, the measured yield stress increased as the supporting force initially applied to the specimen was increased. The greatest increase was obtained with the flat wooden plates.

(2) The values of compressive modulus of elasticity obtained from tests with the rollers and with the offset-grooved plates were independent of the supporting force. For supports other than rollers and offset-grooved plates, the values of the modulus of elasticity increased as the supporting force was increased. The greatest increase was obtained with the flat brass plates lubricated with Marfax No. 2.

(3) The stress-strain curves for specimens supported by other than rollers were distorted by increasing amounts as the supporting force was increased. The distortion was greatest for specimens supported by flat brass plates or by flat wooden plates. As an example of the distortion which occurred, figure 7 shows that the compressive yield stress, the proportional limit, the compressive modulus of elasticity, and the initial part of the stress-strain curve were changed when the specimen was supported between flat brass plates and the supporting force was increased from 22 to 380 pounds.

The stress-strain curves that were obtained for the roller type of support were more accurate than the curves obtained for the other types of support. The roller type of support, however, is more difficult to construct than the other types and must be constructed with precision to ensure accurate results. This fact was emphasized in the present investigation when one inaccurately constructed roller support had to be discarded because of the unreliable test results that were obtained. The flat-plate and grooved-plate types of support are easier to construct than the roller type but more care must be exercised in their use to obtain an accurate stress-strain curve for the material. When the supporting force was in the range of 22 to 45 pounds, the results obtained with the flat-plate or grooved-plate supports agreed very closely with the results obtained with the rollers. These results are illustrated for the offset-grooved plates by the typical stress-strain curves given in figures 8 and 9.

The results of the tests of 0.80-inch-wide specimens with roller support indicated that a supporting force of 22 pounds was inadequate. Although there was no evidence that the 0.020-inch-thick specimens buckled between rollers as the column curves had indicated they might, examination of these specimens after test revealed buckles of wave length greater than the spacing of the rollers. It is believed that this buckling occurred because the supporting force of 22 pounds was insufficient to remove the slight deviations from flatness that usually exist in the specimens. With a supporting force of 45 pounds, satisfactory stress-strain curves were obtained consistently with all types of support. The buckling of the roller-supported specimens as described indicates that, without sufficient supporting force, the roller-supported specimens may give unsatisfactory stress-strain curves.

The present investigation and subsequent routine laboratory tests showed that accurate stress-strain curves could not be obtained consistently unless the fixture and specimens were accurately made. Variations in the test results were caused by specimen defects or inaccuracies such as ends not parallel, not flat, or not perpendicular to the longitudinal axis of the specimen; free edges of the specimen not straight and parallel; and faces of the specimen scratched or marred so that interference occurred with shortening of the specimen. The accuracy of the single-thickness specimen is so important that production of the specimens by a punch and die or by a shearing process is not recommended even if it can be shown that the material properties are not appreciably affected by the cold work in these processes.

CONCLUSIONS

An investigation was made of the methods of supporting single-thickness specimens of aluminum-alloy sheet material in a fixture for determination of compressive stress-strain curves. As a general conclusion, the results showed that for the roller type of support the accuracy of the stress-strain curves obtained was independent of the supporting force used. Plate types of support, however, also gave satisfactory results provided that the supporting force applied to the specimen was approximately 45 pounds.

For the types of support and values of supporting force used, the following detailed conclusions were drawn:

1. The values of compressive yield stress obtained from tests with roller supports were independent of the supporting force. For supports other than rollers, the yield stress increased with the supporting force and was largest in tests with flat wooden plates.

2. The values of compressive modulus of elasticity obtained from tests with rollers and offset-grooved plates were independent of the supporting force. For supports other than rollers and offset-grooved plates, the compressive modulus of elasticity increased with the supporting force.

3. As the supporting force was increased, stress-strain curves obtained with plate types of supports were distorted and the compressive yield stress and modulus of elasticity were raised by increasing amounts.

4. A supporting force sufficient to overcome the slight deviations from flatness that usually exist in the specimens must be used.

5. The compression fixture, the specimen supports, and the single-thickness specimens must be accurately made.

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1. Paul, D. A., Howell, F. M., and Grieshaber, H. E.: Comparison of Stress-Strain Curves Obtained by Single-Thickness and Pack Methods. NACA TN No. 819, 1941.

2. Anon.: Compressive Tests of Sheet Metal with Solid Guides for Lateral Support. Struc. Memo. No. 10, Bur. Aero., Navy Dept., Nov. 10, 1942.

TABLE I

COMPRESSIVE YIELD STRESS AND MODULUS OF ELASTICITY OF 24S-T ALUMINUM ALLOY TESTED WITH FOUR TYPES OF SUPPORT AND FOUR VALUES OF SUPPORTING FORCE

[Specimens 0.53 in. wide, 2.53 in. long, 0.064 in. thick; all values for specimens cut from same sheet; corresponding values of compressive yield stress and modulus of elasticity for same specimen]

	Compressive yield stress (ksi) (1)				Compressive modulus of elasticity (ksi)			
Support \ Supporting force (lb)	22	45	190	380	22	45	190	380
Rollers	44.1 44.4	44.4 44.3	44.1 44.3	44.4 44.5	10,700 10,740	10,680 10,730	10,740 10,710	10,720 10,730
Opposite-grooved brass plates with Marfax No. 2	44.7 44.4	44.6 44.6	45.7 45.5	47.2 47.1	10,720 10,720	10,710 10,720	11,020 11,000	10,870 11,080
Flat brass plates with graphite and oil	44.5 44.4	44.9 44.1	44.7 44.7	46.3 46.3	10,740 10,730	10,860 10,880	10,920 10,930	11,110 11,140
Flat brass plates with Marfax No. 2	44.2 44.1	44.4 44.1	45.5 45.9	46.5 46.5	10,690 10,800	10,870 10,860	11,140 11,140	11,220 11,310
Flat wooden plates with Marfax No. 2	44.1 44.1	44.5 44.2	46.1 46.2	47.5 47.3	10,710 10,710	10,730 10,690	10,910 11,080	11,130 11,090

[1]Compressive yield stress determined by 0.2-percent-offset method.

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TABLE II

COMPRESSIVE YIELD STRESS AND MODULUS OF ELASTICITY OF 24S-T AND R301-T ALUMINUM ALLOYS TESTED WITH TWO TYPES OF SUPPORT AND FOUR VALUES OF SUPPORTING FORCE

[Specimens 0.80 in. wide, 2.51 in. long; all values for specimens of same alloy and thickness cut from same sheet; corresponding values of compressive yield stress and modulus of elasticity for same specimen; 24S-T specimens 0.064 in. thick not cut from same sheet as specimens reported in table I]

	Compressive yield stress (ksi) (1)				Compressive modulus of elasticity (ksi)			
Support \ Supporting force (lb)	22	45	190	380	22	45	190	380
	24S-T aluminum alloy; t = 0.025 in.							
Rollers	45.3 45.3	45.5 45.7	46.1 45.6	45.9 45.8	10,600 10,640	10,670 10,620	10,640 10,690	10,710 10,730
Offset-grooved plates with Marfax No. 2	45.8 45.5	45.8 45.5	47.3 47.1	48.7 48.1	10,670 10,670	10,710 10,710	10,670 10,710	10,800 10,740
	24S-T aluminum alloy; t = 0.064 in.							
Rollers	43.6 43.5	43.1 43.4	43.3 43.5	43.3 43.5	10,710 10,730	10,800 10,670	10,730 10,730	10,740 10,670
Offset-grooved plates with Marfax No. 2	42.7 43.3	43.7 43.5	44.0 44.1	44.9 44.7	10,800 10,740	10,820 10,800	10,740 10,840	10,800 10,780
	R301-T aluminum alloy; t = 0.020 in.							
Rollers	58.7 58.4	59.1 58.8	59.4 59.2	59.3 59.5	10,670 10,690	10,730 10,690	10,690 10,710	10,710 10,730
Offset-grooved plates with Marfax No. 2	59.5 59.4	59.0 59.3	60.3 60.9	62.5 62.3	10,720 10,610	10,610 10,620	10,670 10,710	10,620 10,620
	R301-T aluminum alloy; t = 0.064 in.							
Rollers	59.7 59.7	59.8 59.9	60.7 60.3	59.8 60.3	10,640 10,610	10,580 10,610	10,670 10,670	10,710 10,710
Offset-grooved plates with Marfax No. 2	60.2 60.0	59.8 60.3	60.7 60.7	61.5 61.5	10,710 10,640	10,690 10,610	10,620 10,670	10,620 10,670

[1] Compressive yield stress determined by 0.2-percent-offset method.

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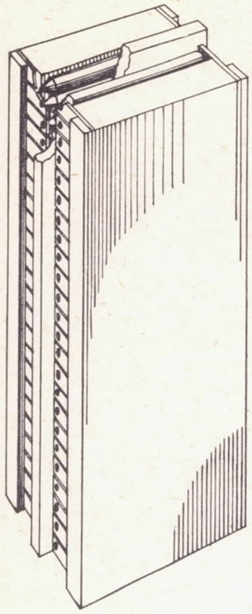
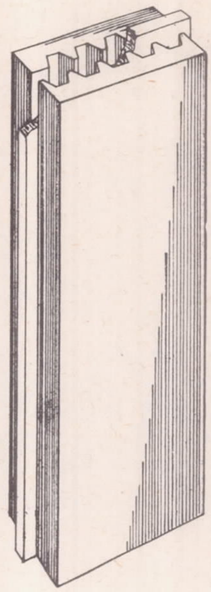
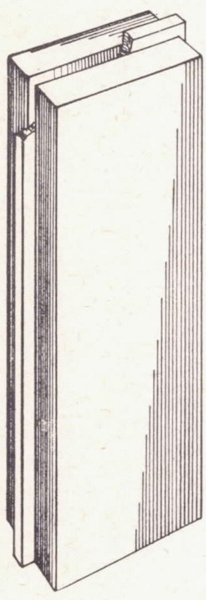


(a) Steel rollers.



(b) Grooved brass plates.



(c) Flat brass plates.

(d) Flat wooden plates.

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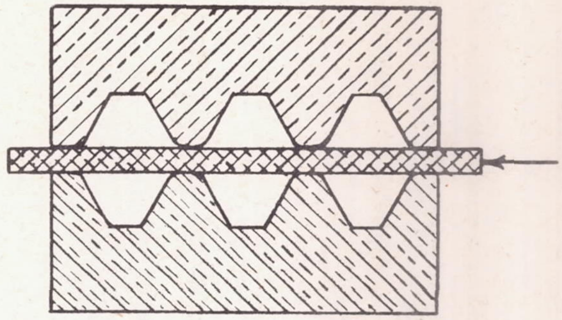
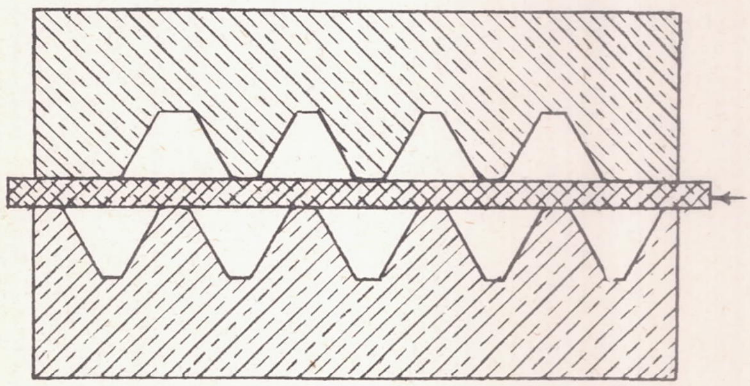
Figure 1.- Types of support used in the fixture for determination of compressive stress-strain curves.



(a) Opposite-grooved brass plates.



(b) Offset-grooved brass plates.

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Figure 2.- Opposite- and offset-grooved supporting plates. Sections are perpendicular to direction of load application.

1. Steel holder
2. Hardened steel base
3. Self-alining steel block
4. Sliding steel block
5. Roller support
6. Loading screw
7. Loading plate

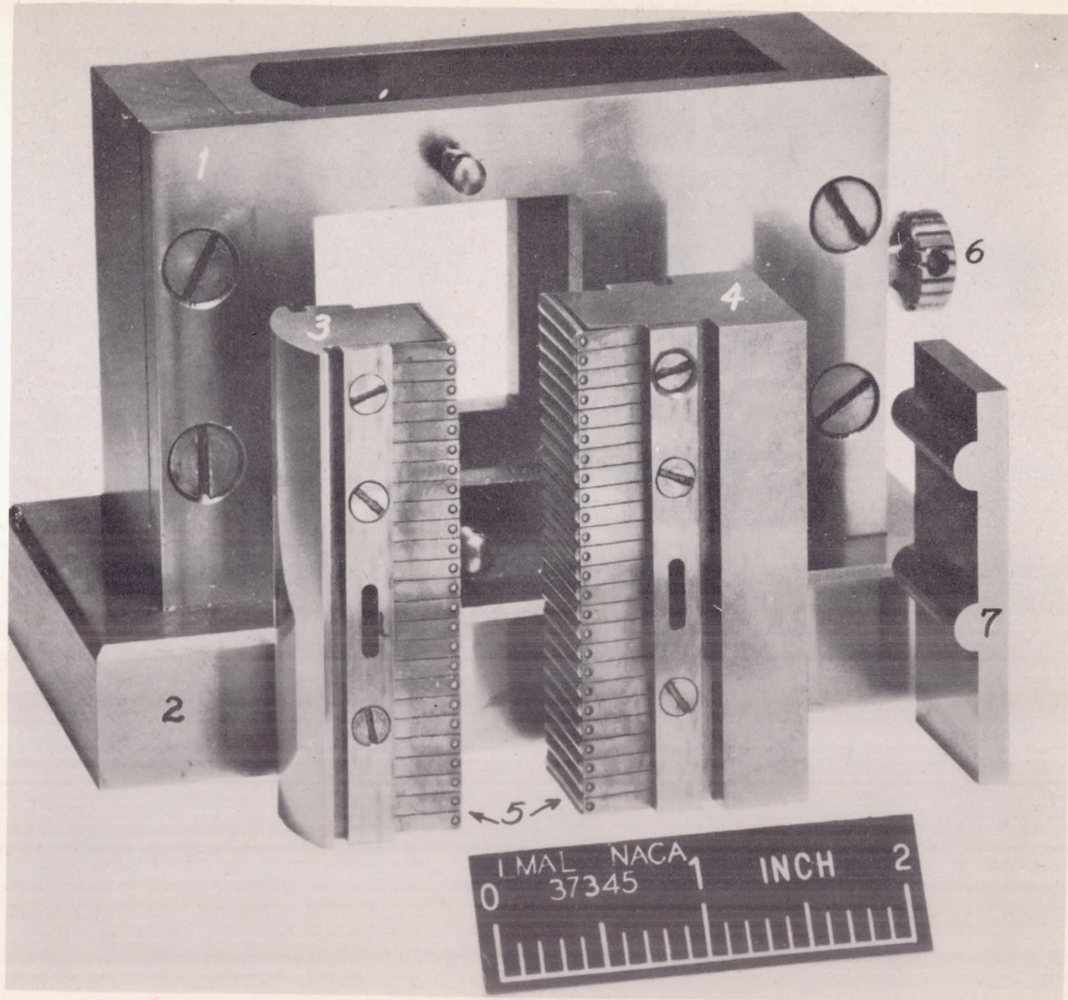

Figure 3.- Compression fixture with roller supports.

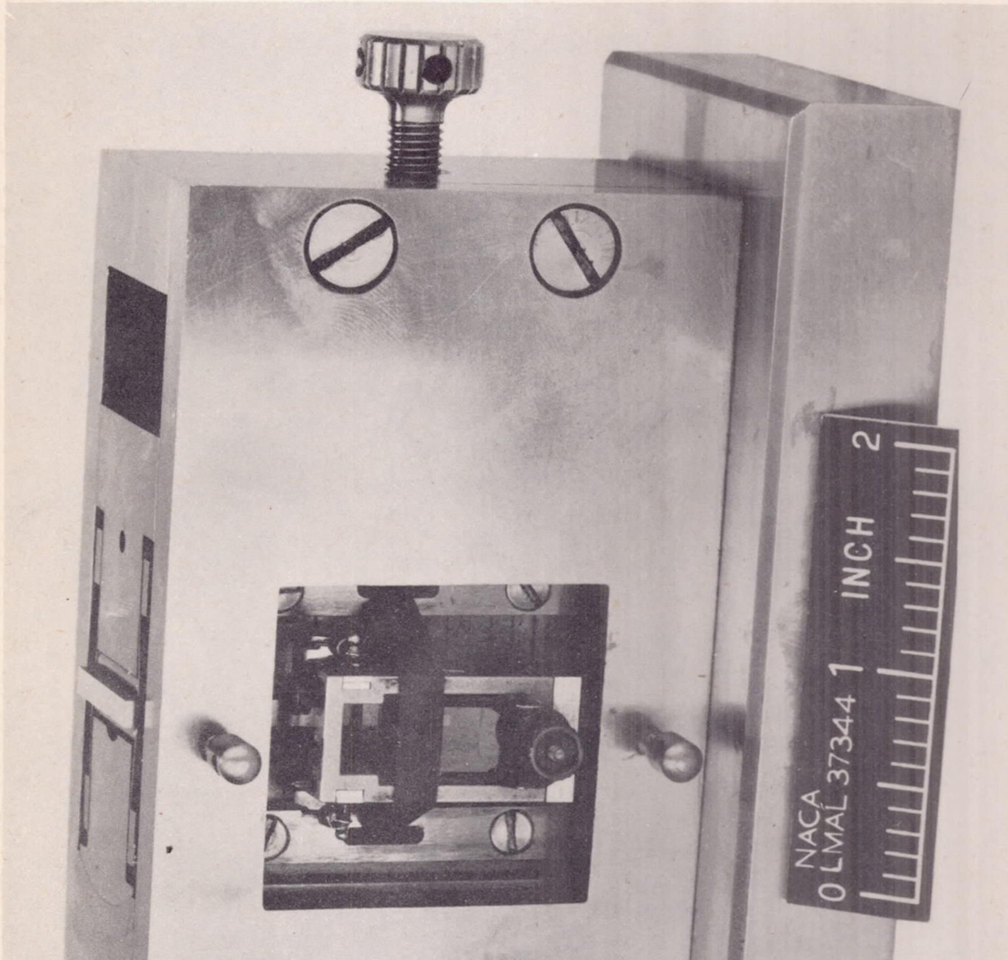

Figure 4.- Specimen in compression fixture before test.

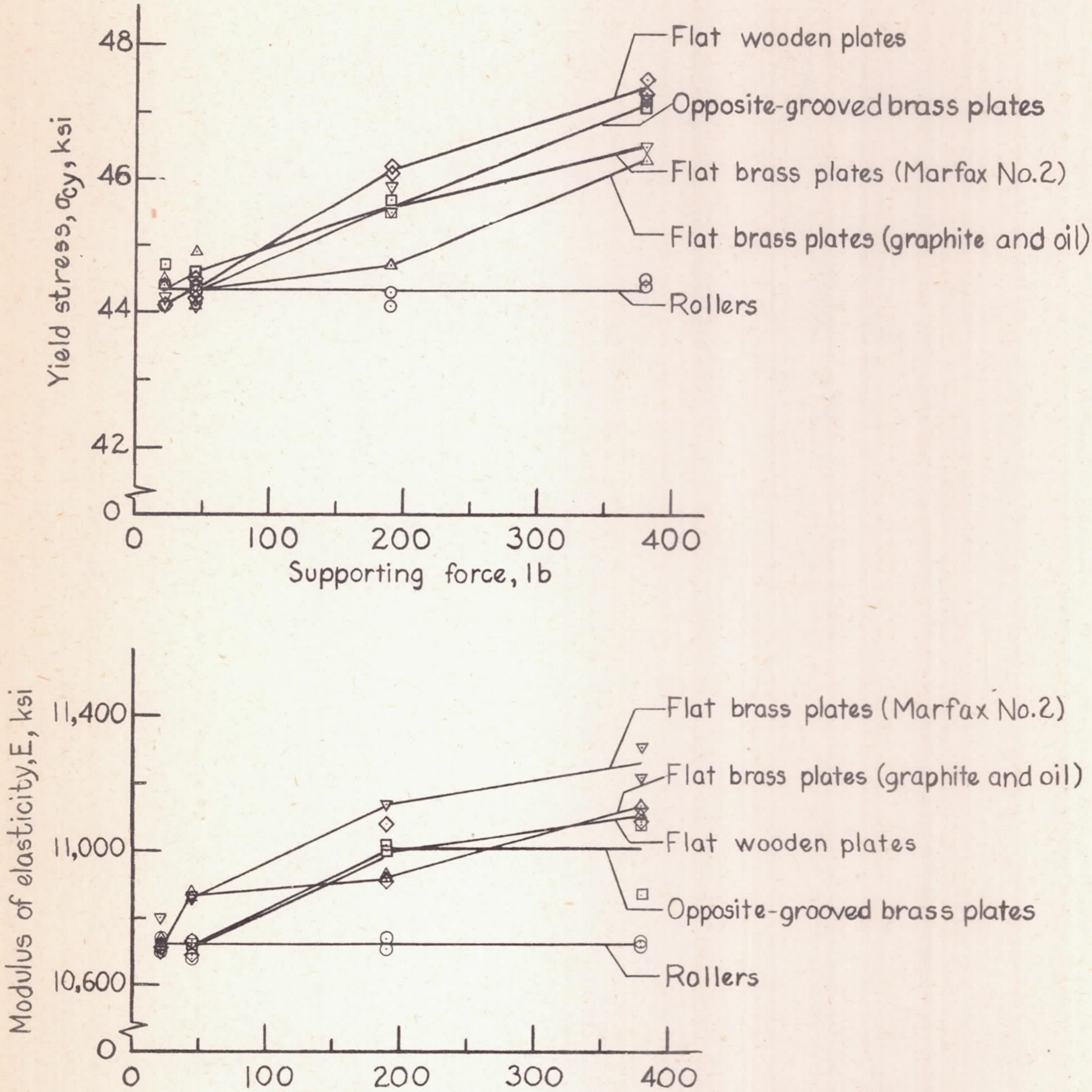

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Figure 5.- Influence of type of support and supporting force on compressive yield stress and modulus of elasticity. 24S-T aluminum alloy 0.064 inch thick and 0.53 inch wide.

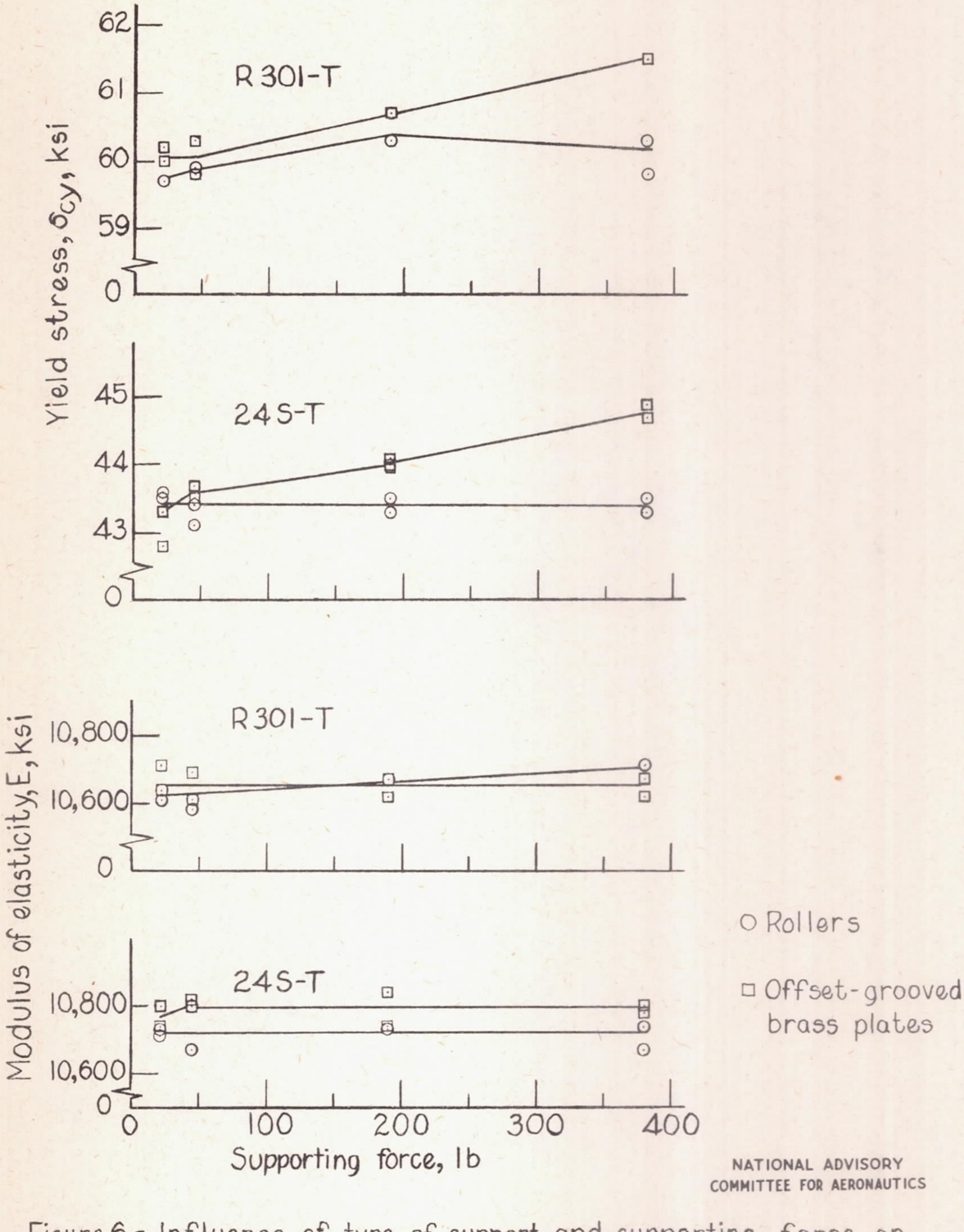

Figure 6.- Influence of type of support and supporting force on compressive yield stress and modulus of elasticity. Specimens 0.064 inch thick and 0.80 inch wide.

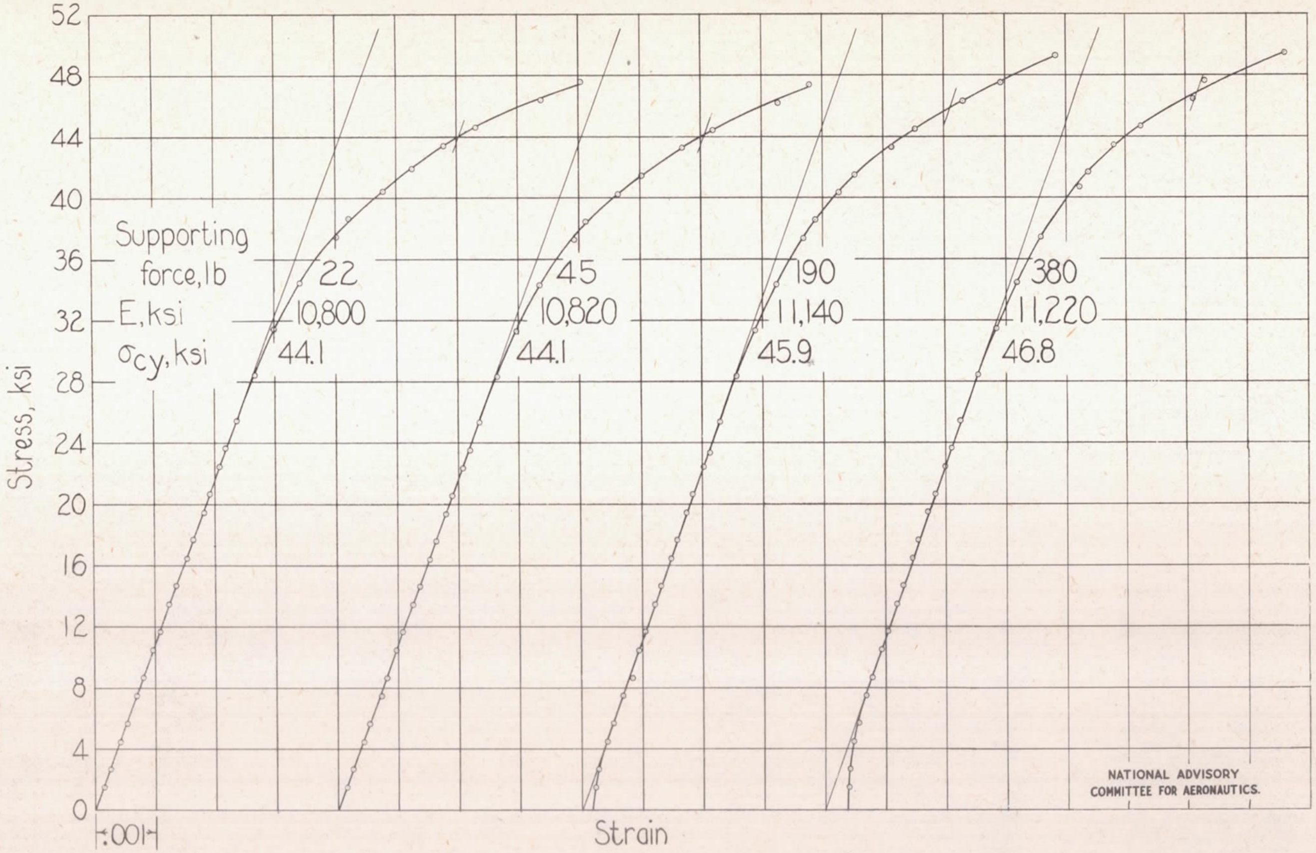

Figure 7.-Effect of supporting force on shape of stress-strain curves. 24S-T aluminum alloy 0.53 inch wide, 0.064 inch thick; supports, flat brass plates lubricated with Marfax No. 2.

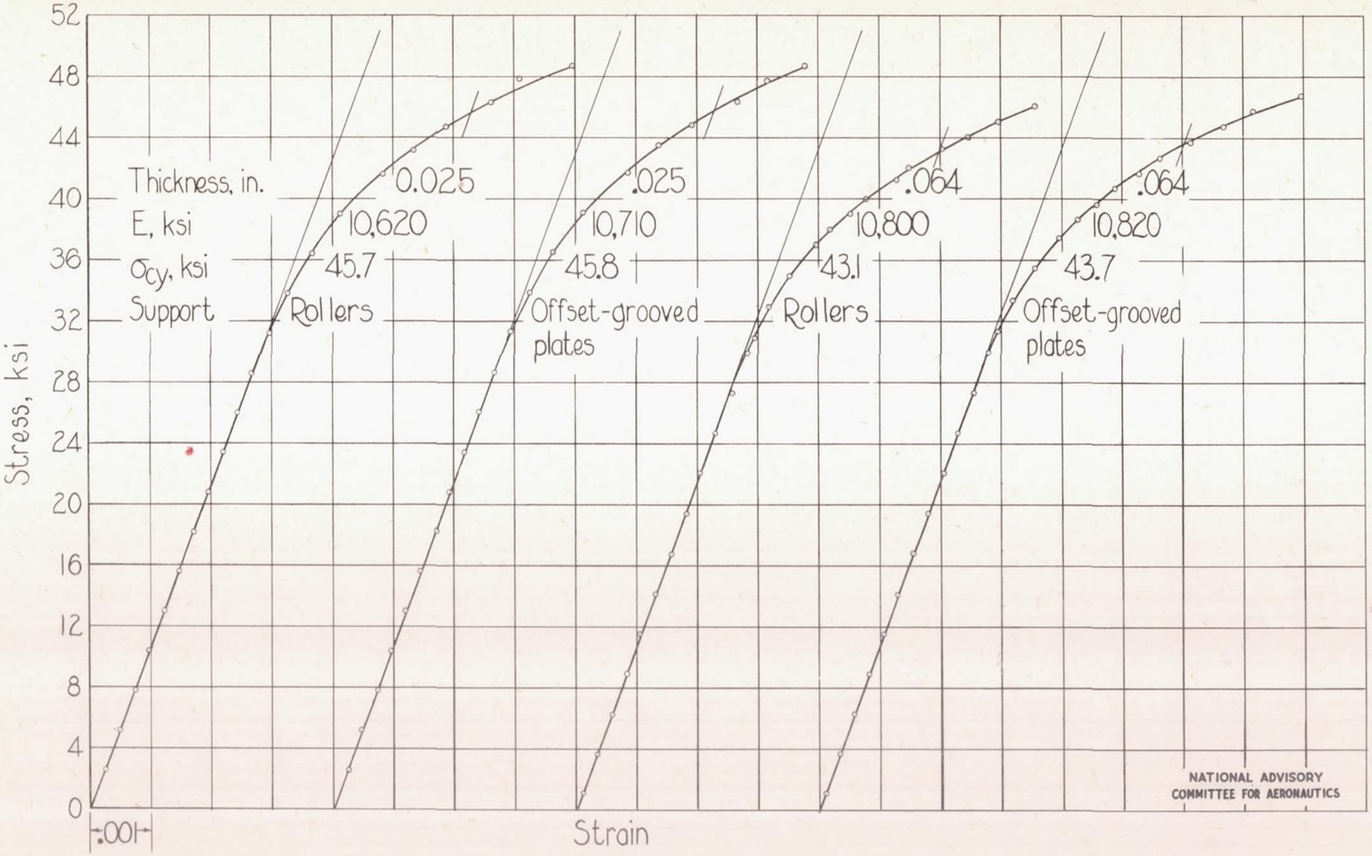

Figure 8.- Typical stress-strain curves for 0.025- and 0.064-inch 24S-T aluminum-alloy sheet. Supporting force, 45 pounds; specimen length, 2.51 inches; specimen width, 0.80 inch.

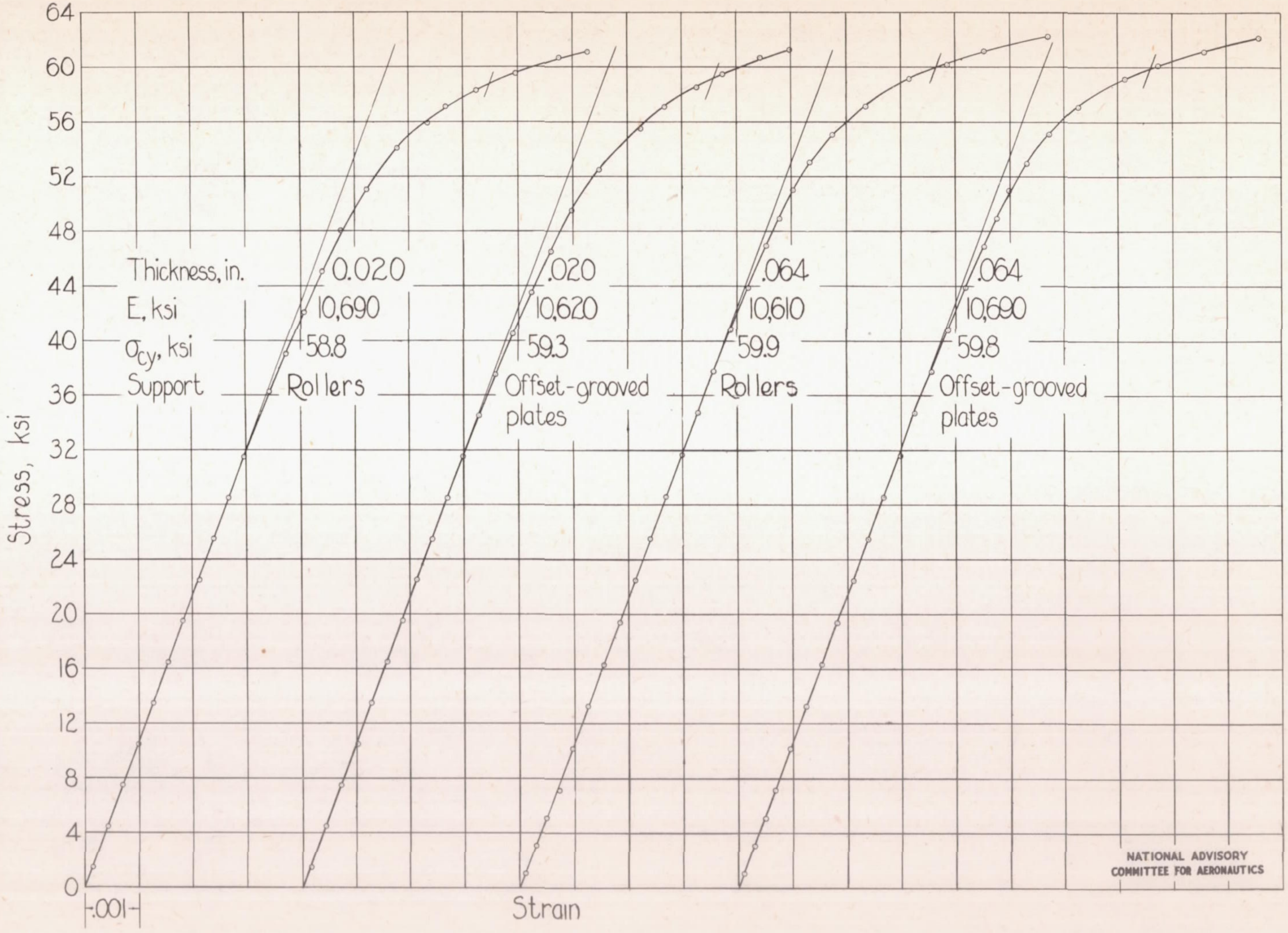

Figure 9.-Typical stress-strain curves for 0.020-and 0.064-inch R301-T aluminum-alloy sheet. Supporting force, 45 pounds; specimen length, 2.51 inches; specimen width, 0.80 inch.