NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1022

A FIXTURE FOR COMPRESSIVE TESTS OF THIN SHEET METAL BETWEEN LUBRICATED STEEL GUIDES

By James A. Miller
National Bureau of Standards

Washington
April 1946

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 1022

A FIXTURE FOR COMPRESSIVE TESTS OF THIN SHEET METAL BETWEEN LUBRICATED STEEL GUIDES

By James A. Miller

SUMMARY

A fixture for compressive tests of thin sheet metal was designed. It consists of two hardened steel guides between which the specimen is held by two adjustable clamps.

Tests were made with the fixture on specimens about 1/2 inch wide by $2\frac{1}{4}$ inches long. The specimens were coated with a lubricant intended for use in the front wheel bearings of automobiles. Tests were made on aluminum alloy sheets 0.032 and 0.128 inch thick, magnesium alloy J1-h sheet, 1025 carbon steel sheet 0.054 inch thick, and three sheets of stainless steel with thicknesses of 0.020, 0.011, and 0.006 inch and compressive yield strengths in the transverse direction of 240, 170, and 160 ksi, respectively.

The tests indicated that consistent results could be obtained, without undue care, on specimens thicker than 0.010 inch. The results were in good agreement with those obtained by the pack method or the single-thickness method. The tests on thinner sheet were usually successful when the procedure described was carefully followed.

The time required for these compressive tests was about the same as for tensile tests of equal precision.

INTRODUCTION

Tests of flat sheet metal specimens in end compression to determine the compressive yield strength of the material require some means of supporting the specimens against failure by instability before the yield strength is reached. Various methods for obtaining stability have been used in tests of sheet metal (references 1, 2, 3, 4, 5, 6). In the pack test (reference 1) stability is obtained by arranging a number of specimens in a pack and by supplying transverse support to each of the outer specimens through a number of pins. For the thinner and stronger materials additional support was provided by cementing the specimens together and by clamps near the ends (reference 2).

Later tests showed that it was not always necessary to assemble a whole pack of individual specimens but that sufficient stability could be obtained with a single specimen within certain limits of thickness and strength. In the single-thickness test as originated by W. P. Montgomery and improved by R. L. Templin and his associates (reference 3) the transverse support is supplied through rollers in a special fixture. The single-thickness test has an advantage over the pack test not only in requiring less material and less time for machining but also less time for setting up the specimen in the testing machine. However, for the thinner and stronger sheet materials the support provided is not sufficient to prevent buckling, particularly at one end.

To overcome this difficulty, C. S. Aitchison substituted lubricated brass guides for the rollers in the single-thickness fixture. This work was done as part of a research project at the National Bureau of Standards for the Bureau of Aeronautics, Navy Department; it is described in reference 4. The results obtained in tests of 0.032-inch aluminum alloy 24S-RT sheet were in close agreement with those obtained with the use of rollers in the fixture.

The results of later tests with simply clamped solid brass guides, such as are shown in figure 1, indicated that the method was satisfactory for compressive tests of sheet metal as thin as 0.020 inch having a yield strength up to 240 ksi. As a result of these tests a fixture for compressive tests of sheet metal between lubricated steel guides was designed and built. A description of the fixture and test procedure and the results of compressive tests on several sheet metals are given in this paper.

The permission of the Bureau of Aeronautics to publish this material is gratefully acknowledged. The author acknowledges also the assistance and advice received from other members of the engineering mechanics section of the National Bureau of Standards. In particular, he expresses his appreciation to P. L. Peach, who assisted in all the tests.

THE FIXTURE

The fixture (fig. 2) was designed for a specimen 1/2 inch wide with a 1-inch gage length. The spacing between guides may be increased to any value up to 1/2 inch thereby permitting tests of curved (formed) specimens with auxiliary guides as well as flat specimens. The fixture can be taken apart quickly, when cleaning of the guides is necessary, by loosening the set screws (fig. 3) and removing the clamps.

The fixture consists of two hardened tool steel guides and two adjustable clamps. Details are shown in figure 3.

The guides, B and C, are rectangular blocks of hardened tool steel nominally 0.375 by 0.46 by 2.20 inches. One of the 0.46- by 2.20-inch surfaces of each is the guiding surface. A piece, A, for holding the clamps was fastened to guide B after B had been hardened and ground nearly to size. Pieces A and B were finished together to form the "compound guide" in distinction to the "simple guide," C. The compound guide alines the specimen in the testing machine. One face of the simple guide was provided with a conical seat near the bottom and a grooved seat near the top to provide seats for the adjusting screws of the clamps. The simple guide was made 0.002 inch shorter than the compound guide and the conical seat was located so that the lower end would be about 0.002 inch above the lower end of the compound guide. This prevents small changes in the seating of the clamps from causing the lower end of the simple guide to interfere with the alinement of the specimen. The guiding surfaces were ground with special care. The edges were honed and polished with crocus paper to remove burrs which might scratch the specimens.

The details of the clamps are also shown in figure 3. Rigidity of the clamps is obtained by tightening the head of each tension screw against the smaller crossbar and then tightening the lock nuts against the larger crossbar. The adjusting screws have a travel of over 1/8 inch. The position of the larger crossbar can be changed in steps equal to the pitch of the tension screws, 1/32 inch.

While some of the details of design need not be adhered to in constructing a similar fixture, it is recommended that the cross section of the tension members be not increased and that the length under tension be not shortened. If the testing of formed specimens is not contemplated, it is recommended that the thickness of part B of the compound guide be increased from 3/8 inch to 1/2 or 5/8 inch.

SPECIMENS

Specimens were taken from sheets of three aluminum alloys: magnesium alloy J1, 1025 carbon steel, and stainless steel. Compressive stress-strain curves for these sheets had been obtained previously by the pack method described in reference 1 or by the single-thickness method described in reference 3. The specimens were taken from the same region of the sheet in most cases; the exceptions are noted in the tables to follow by giving the average thickness of the specimens.

Specimens were taken also from sheets of full hard stainless steel for which no pack or single-thickness tests were available.

In some cases the specimens were taken only across the direction of rolling (transverse) since, in general, the transverse specimens have the higher compressive yield strengths.

The specimens were 0.5 inch wide by 2.25 inches long for sheet thicknesses not less than 0.02 inch. These dimensions were reduced for thinner specimens to prevent buckling of the unsupported portion. The specimens between 0.01 and 0.02 inch thick were 2.23 inches long and had an unsupported length of approximately 0.03 inch. The specimens less than 0.01 inch thick were 0.48 inch wide by 2.22 inches long, just long enough to provide a clearance of about 0.002 inch between the top of the guides and the bearing block when the yield strain was reached.

The blanks for the specimens 0.128 inch thick were sawed out approximately 0.03 inch oversize in each dimension. The blanks for the other specimens were sheared at least 0.03 inch oversize in each dimension. An identification number was lightly scratched near one end of each blank.

The specimens were finished to size as follows. The shearing or sawing burrs were removed from each blank. The blanks were stacked into a pack up to 5/8 inch thick; covering blanks of 0.032-inch sheet were added to protect specimens less than 0.032 inch thick. The pack was inserted in the machining fixture shown in figure 4. The ends of the specimens were held together with tool-makers' clamps as shown in the figure. The width of the pack was reduced about 1/64 inch by light cuts with a surface grinder and the pack was turned over and was ground to the specified width. The tool-makers' clamps were removed and other clamps were set near the ends of the pack as shown in figure 5. The distance from the outside of one clamp to the outside of the other was about 0.01 inch less than the specified length of specimen. The machining fixture was bolted to a block for grinding one end as shown in figure 5. After about 1/64 inch had been removed from one end, the fixture was removed from the block and was turned over for grinding the other end.

Length measurements were made before the end clamps were removed from the pack. The clamps were removed, releasing the specimens. The burrs were removed from the edges, care being taken not to damage the end surfaces. The specimens were cleaned and weighed. The cross-sectional area of each specimen was computed by dividing the weight by the product of the density of the sheet and the length of the specimen.

Before a specimen was placed in the compressive fixture, the two sheet-faces of the specimen were rubbed lightly with a hardened steel scraper to remove any small particles of the material projecting above the faces. Finally, the ends of each specimen were lapped superficially on a roughly ground hardened steel block to remove any burrs which might have prevented uniform contact with the bearing blocks.

COMPRESSIVE TESTS WITH THE STEEL GUIDE FIXTURE

The specimens were cleaned, covered on both sides with a thin coat of the lubricant (Texaco Marfak No.3) and inserted between the guides in the fixture. The specimen was placed in the fixture with the numbered end or the most marred end down as an added precaution against friction since friction below the gage length would have practically no effect on the measured strain. The adjusting screws were tightened and retightened with intervening sliding of the specimen until the guides did not slide axially under their own weight but did slide smoothly under an additional weight of 1 pound or less. After a little practice it is possible to tell by feel when the desired condition is obtained. When the sliding is not smooth but jerky there may be foreign matter between a guide and the specimen. This may require cleaning of the guides. However, a routine cleaning of the guides each day is usually all that is required when ordinary care is taken in cleaning and greasing the specimens.

The specimen was centered laterally in the fixture by eye. The lower end was set even with the lower end of the compound guide and the excess lubricant was wiped from the ends. The specimen was alined in the fixture by pressing the lower end of the specimen and of the compound guide against a surface plate. The compound guide is heavy enough to keep the fixture from tipping while holding specimens 0.064 inch thick or less. However, in most tests a small weight resting on the smaller crossbar of the lower clamp was used to prevent tipping while the specimen was being centered in the testing machine.

The specimens were tested in a beam and poise, screw type testing machine (designated in the tables as machine A) of 50-kip capacity using the 5-kip range. Most of the specimens were mounted between hardened and ground steel blocks in the subpress (reference 7). When the subpress was not used, the specimens were tested between hardened and ground steel blocks, the upper one of which was sealed to the upper head of the machine by a plaster-of-paris shim. This was cast only once for a series of tests. The casting was made under a load of 0.5 kip while the working surfaces of the steel blocks were held parallel to each other. The rate of loading was, in general, about 1.2 ksi per minute for the magnesium alloy, 2 ksi for the aluminum alloys and 4 ksi for the steels.

Strain was measured by a pair of Tuckerman 1-inch optical strain gages attached to opposite edge-faces of the specimen. For the stainless steel specimens scratches were made for seating the knife-edge of each gage. The gages were attached while the specimens were under a load of about 20 pounds.

At the end of each test, before the load was reduced, the guides were tried to determine whether they could be moved easily. Except as noted in the tables the guides could be moved axially with the index fingers pressed against the guides and without touching the clamps. The force that could be applied in this manner was less than 4 pounds.

The results of the tests are given in tables 1 to 9.

COMPRESSIVE TESTS WITH OTHER MEANS OF LATERAL SUPPORT

Results of previous tests of the sheets by the pack method (references 1 and 2), by the single-thickness method (reference 3), and of preliminary tests with the use of simply clamped brass guides have been included in the tables for comparison.

The brass guides are shown in figure 1. They were rectangular blocks of brass 0.44 by 0.60 by 2.05 inches. One of the 0.44- by 2.05-inch surfaces of each was the guiding surface. For some of the tests the guides were held together by two clamps each consisting of two 1/4-inch square pieces of cold rolled steel and two 8-32 screws. In most of the tests the guides were held by the clamps shown in figure 1. These were similar to the clamps of the steel guide fixture. One guide was cemented to the clamps with Duco cement. The other guide had conical seats for the adjusting screws. The specimens were usually 0.5 by 2.1 inches. The test procedure was similar to that of the tests with steel guides.

Most of the comparison tests were made without the subpress and in other testing machines. Machine B was a beam and poise, screw type testing machine of 20-kip capacity. Machine C was a fluid support, Bourdon tube hydraulic machine having a null-method weighing system. The machine had a capacity of 20 kips. Machine D was a fluid support, Bourdon tube hydraulic machine of 100-kip capacity. Strain was measured by a pair of Tuckerman 1-inch optical strain gages attached to opposite edge-faces of the specimen.

RESULTS

Aluminum Alloy 24S-RT Sheet 0.032 Inch Thick (Table 1).

Previous tests on this sheet by three different methods offered the best opportunity for comparing various kinds of support against premature buckling. All the tests had been made in machine A with the subpress and more material from the same portion of the sheet was available. Two of the longitudinal specimens of the present series were tested without the subpress. The values of Young's modulus were all within 1 percent of each other and the values for yield strength were within 1.4 percent in the longitudinal direction and 1 percent in the transverse direction. Stress-deviation graphs for the longitudinal specimens are shown in figure 6 taking the value of Young's modulus as 10,712 ksi, the average value for the pack and single-thickness tests.

Alclad 24S-T Sheet 0.032 Inch Thick (Table 2)

The pack test for this sheet had been made on a pack of 13 specimens. The specimens for the present series of tests had the same thickness as the average for the pack. The values of Young's modulus and yield strength were within 0.6 percent of those for the pack.

Aluminum Alloy M86-T Sheet 0.128 Inch Thick (Table 3)

This sheet was the thickest sheet tested. Previous tests had been made by the single-thickness method and with brass guides. For any of the tests by all three methods the greatest difference in values of Young's modulus and yield strength was 1.8 percent. Excluding the two tests with brass guides in which the lateral movement of the loading head of the machine exceeded 0.1 inch the greatest difference in Young's modulus was 0.8 percent. For the tests which were made with the subpress in machine A the greatest differences in Young's modulus and yield strength were 0.4 percent and 0.9 percent, respectively.

Magnesium Alloy J1-h (Table 4)

The values of Young's modulus for the specimens tested with the steel guide fixture were within 2.7 percent of that of the corresponding pack. This amounts to a divergence of the stress-strain curves, in the range used for the modulus determination, of less than 0.00003 strain or, in terms of load on one of the single specimens, less than 3 pounds.

In the tests with the steel guide fixture the guides could not be slid with the fingers after the removal of the strain gages. As this material has a yield point and the yielding is localized, the guides probably tightened after the yield point was reached. Figure 7 shows that the friction between the guides and the specimen had little, if any, effect upon the stress-strain relationship up to the 0.2-percent offset yield strength. The yield strengths were from 0 to 1.8 percent less than that of the corresponding pack.

1025 Carbon Steel (Table 5)

The thickness of the portion available from a sheet for which there were pack data was between the average thicknesses of the specimens of the regular and of the shellacked pack. The results of the tests with the steel guide fixture were between the values for the two packs. This material also has a yield point and yields locally. For one of the specimens the guides were tight when the gages were removed. This condition apparently had little effect upon the 0.2-percent yield strength as the values were practically the same for the two specimens.

18-7 Chromium-Nickel Steel (Table 6)

Specimens for test with the steel guide fixture were selected which had the same thickness as those tested with brass guides. The specimens tested with steel guides had about the same values of Young's modulus and a little lower yield strengths than the specimens tested with brass guides, the greatest difference in yield strength amounting to 3.2 percent. Considering only the specimens tested in machine A with the subpress, the greatest differences in Young's modulus and yield strength were 0.7 and 1.5 percent, respectively. The stress-strain graphs for this sheet are shown in figure 8.

0.010-Inch Full Hard 18-8 Chromium-Nickel Steel Sheet,

Longitudinal Specimens (Table 7)

The two packs from this sheet had included some of the thinner material from near the edges of the sheet. Most of the specimens for the present series of tests were taken from the middle of the sheet and a few were taken from near the edges of the sheet. The greatest difference in values of Young's modulus amounted to 3.3 percent. This corresponded to a divergence of the stress-strain curves, in the range used for the modulus determination, of less than 0.00001 strain or a little over a pound load. The yield strengths for the specimens from the middle of the sheet averaged 82.9 ksi and were all within 1.1 percent of that value. The yield strengths for the packs averaged 83.2 ksi or about 0.4 percent higher than the average for the specimens from the middle of the sheet. They were lower than the yield strengths of specimens from near the edges of the sheet.

In preliminary tests on specimens of this thickness 2.25 inches long, some became bent at one end. This was prevented by making the specimens 2.23 inches long (0.03 inch longer than the guides). Also, for such thin sheet more than the usual care must be taken in preparing the blanks for machining to avoid bending near the ends.

0.010-Inch Full Hard 18-8 Chromium-Nickel Steel Sheet,

Transverse Specimens (Table 8)

The specimens were taken from the middle of the sheet. The measured thickness was 0.0114 inch. As there were no tests by any other method on transverse specimens from this sheet, three of the specimens were set up for test with special care by an experienced operator to obtain the best possible results which would serve as a standard for comparison. Conditions for the other tests were varied. Two specimens were the fourth and fifth tested by an inexperienced operator. Some of the specimens were set up in a routine manner - the guides were not cleaned between tests and the clamps were adjusted until the specimen seemed to slide properly in the guides. For others, the clamps were set tighter than usual, then were loosened and adjusted until the guides would slide as usual. The average value of Young's modulus and of yield strength were 29,840 ksi, and 171.5 ksi, respectively, for the specimens tested with special care and 29,800 ksi and 171.8 ksi for the remaining specimens. The greatest difference in values of Young's modulus for any of the tests amounted to 1.3 percent; the greatest difference in yield strength amounted to 1 percent. These tests included one test in which the specimen was wavy at the end of the test and in which the average thickness of each lubricant film was more than 0.0003 inch, and another in which the guides were so tight that it was necessary to push on the clamps to move the guides with the fingers at the end of the test. While these were not considered particularly good tests, the results were near the average for the series. The tests indicated that material of this thickness and strength can be tested in compression without unusual care.

0.005-Inch Full Hard 18-8 Chromium-Nickel Steel Sheet, Transverse Specimens (Table 9)

The specimens were taken from the middle of the sheet. The actual thickness of the specimens was about 0.0058 inch. In addition to single specimens, packs of 2, 4, and 6 specimens were made up for test in the fixture. In these the specimens were cemented together with shellac before they were machined.

Difficulty was experienced in obtaining satisfactory packs. In several there was apparently a breakdown of the bond at the ends during machining as the packs were flared at the ends. This usually resulted in premature failure either by further separation and buckling of the specimens at an end or by buckling near the middle because of excessive separation between the guides. The 2-specimen pack listed in table 9 was taken as a standard of comparison because the guides could be moved easily when the gages were removed after the yield strength had been reached. The 4-specimen pack buckled at about 5 ksi above the yield strength; the buckling occurred before the gages were removed and the guides were checked. The stress-strain curve showed no irregularities up to the yield strength. The values of Young's modulus and yield strength for the two packs agreed within 0.6 percent.

Preliminary tests on single specimens were made with brass guides. Most of the specimens that were about 0.04 inch wider than the guides were wavy after test. In some, the waviness was much more noticeable near the edges. On the other hand, most of the specimens that were only 0.02 inch wider than the guides showed very little evidence of waviness when the average thicknesses of the films of lubricant were less than 0.0002 inch. Best results were obtained when the specimens were just long enough so that there was a clearance of about 0.002 inch between the end of the longer guide and the upper bearing block at the maximum strain. In some cases the guides tilted due to bending of the specimen at the upper end so that a guide touched the upper bearing block before the test was completed. This bending may have been caused by the initial curvature of the specimens which corresponded to a height of arc from 0.03 to 0.04 inch in about 2 inches. The curvature at the ends may have been increased inadvertently during preparation of the specimens; such additional curvature would be difficult to detect because of the initial curvature. The results of the final tests with brass guides are included in table 9.

The greatest difference in values of Young's modulus for all the tests was 3.1 percent. This corresponds to a divergence of the stress-strain curves, in the stress range used for the modulus determination, of 0.00002 strain or 1.7 pounds for a single specimen. The yield strengths for the single specimens were equal to or higher than the yield strength of the 2-specimen pack. The average and highest values for the specimens supported by brass guides were respectively 1.4 and 1.7 percent above the yield strength for the 2-specimen pack. The corresponding values of yield strength for the specimens supported by steel guides were 1.9 and 3.1 percent higher than that of the 2-specimen pack. For further comparison, stress-deviation graphs using the value of Young's modulus for the 2-specimen pack, 29,240 ksi, are given in figure 9 for the 2- and 4-specimen packs and for the specimens with each kind of lateral support which showed the greatest differences in strain in the region of the yield strength.

DISCUSSION

Steel versus Brass Guides

Comparison of the results of tests made with the subpress on specimens supported by steel guides and by brass guides shows that the yield strengths for the tests with steel guides were on the average about 0.4 percent lower than for the tests with brass guides, although in some cases they were higher.

Maintenance of the guiding surfaces is easier with the steel guides. They are not so easily scratched. Also materials such as magnesium alloy J1-h burnish the brass guides where the specimens yield locally.

The Lubricant Film

The lubricant used for the tests of reference 4 consisted of flake graphite in cup grease. Although this lubricant gave good results, the guiding surfaces soon became scratched by impurities in the graphite. As it was desirable to keep the guiding surfaces smooth, other lubricants were tried. The oils and light greases tried were not considered satisfactory, although the results of a test with petrolatum were in good agreement with the results of pack and single-thickness tests on the same sheet. It was found that with these lubricants the guides seized at comparatively low average pressures, probably because of concentrations of pressure due to curvature of the specimen and the absence of polished surfaces.

A lubricating grease intended for lubrication of automobile wheel bearings operating in heavy duty service (Texaco Marfak No. 3) was found to provide suitable lubrication. This is a soda-soap-base grease which was supplied to the U.S. Government under the General Schedule of Supply for the period January 20 to December 31, 1943, as complying with the specifications for item 14-G-1425-5 of that schedule. These specifications require:

Mineral oil constituent:

Viscosity, S.U. at 210° F., seconds (min.)	75
Flash point, °F. (min.)	350

Grease:

Work consistency, grade No. (N.L.G.I.)	3
Penetration, worked (min.)	220
Penetration, worked (max.)	250
Mineral-oil content, percent (min.)	70
Water content, percent (max.)	Trace
Free alkalinity (calculated as NaOH) percent (max.)	0.5
Free acidity (as oleic acid) percent (max.)	0.3
Insoluble matter, percent (max.)	0.10
Dropping point, °F. (min.)	300

No other lubricants of this type were tried. Preliminary tests indicated that the film thickness of this lubricant was not a critical factor for specimens 0.0275 and 0.128 inch thick. Data for the latter, the thickest sheet tested, are given in table 3 (specimens CB2T, CB3T, and C5T).

Measurements of the combined thickness of guides, specimens, and lubricant films were made to determine the average thickness of the lubricant film for most of the tests. For the specimens thinner than 0.010 inch the average thickness of a lubricant film was less than 0.0002 inch. It appears advisable to limit the thickness of each lubricant film to 0.0002 inch in testing specimens thinner than 0.01 inch. The average film thickness for the specimens between 0.01 and 0.03 inch thick was usually less than 0.0003 inch. One of the specimens having thicker lubricant films was appreciably wavy. For most of the specimens thicker than

0.03 inch the average film thickness was less than 0.0004 inch. The thickness of film is affected to some extent by the stiffness of the specimens and the amount of initial curvature. Usually an operator adjusting the clamps for the first time did not obtain as thin films as an experienced operator. The results, however, were in good agreement with those obtained by an experienced operator.

Tests without the Subpress

Tests on single specimens made in machine A without the subpress are reported in tables 1, 3, and 6. See also figures 6 and 8. For tests in which no appreciable lateral movement of the loading head of the machine took place, the results were in good agreement with the results obtained with the subpress. When appreciable lateral movement of the loading head was noted, the values of Young's modulus or yield strength were a little higher. In the tests made in machine C without the subpress the readings of the two gages agreed as well as in the tests with the subpress in machine A.

Comparison of Tensile Tests with Compressive Tests Using Steel Guides

Since the compressive specimens have the same cross-sectional area as standard tensile specimens of the same thickness, the accuracy of the stresses exclusive of friction is the same for both tests. For most cases - when the guides can be moved up with two fingers without pushing on the clamps while the specimen is stressed above the yield strength - this friction is less than 3 or 4 pounds.

Numerous compressive tests using the steel guide fixture and tensile tests have been made to obtain the stress-strain graphs. The same testing machine and the same strain gages were used. The stress-deviation graphs for the compressive tests have been as smooth as or smoother than for the tensile tests.

The time required for the two kinds of tests is practically the same.

No tests were made using an autographic stress-strain recorder although the method can be readily adapted for use with such a recorder. As the edges of the specimen are free, an averaging gage can be used. An averaging gage adjustable for specimens up to 1 inch in diameter would be suitable. Such gages usually have a gage length of 2 inches. For use with such a gage a specimen about 0.75 by 3.5 inches and guiding surfaces about 0.71 by 3.45 inches are suggested.

National Bureau of Standards,
Washington, D. C., June 15, 1945.

REFERENCES

1. Aitchison, C. S. and Tuckerman, L. B.: The "Pack" Method for Compressive Tests of Thin Specimens of Materials Used in Thin-Wall Structures. NACA Rep. No. 649, 1939.

2. Aitchison, C. S.: Extension of Pack Method for Compressive Tests. NACA TN No. 789, 1940.

3. 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.

4. Anon.: Compressive Tests of Sheet Metal with Solid Guides for Lateral Support. Structures Memorandum No. 10, Bur. of Aeronautics, Navy Department, Nov. 10, 1942.

5. Jackman, K. R.: Improved Methods for Determining the Compression Properties of Sheet Metal. Automotive and Aviation Industries, vol. 90, No. 11, June 1, 1944, pp. 36-38, 82.

6. Welter, Georges: Micro-deformation under Tension and Compression Loads of Thin Aluminum Alloy Sheets for Aircraft Construction, Proc. A.S.T.M., vol. 44, 1944, pp. 665-681.

7. Aitchison, C. S. and Miller, James A.: A Subpress for Compressive Tests. NACA TN No. 912, Dec. 1943.

TABLE 1

RESULTS OF COMPRESSIVE TESTS OF 0.032-INCH ALUMINUM ALLOY 24S-RT SHEET

Specimen or pack number	Kind of test or lateral support	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Remarks
Longitudinal				
C1L	Pack (13-spec.)	10,720	57.0	
C2L	-----do---------	10,720	57.2	
M1L	Single-thickness	10,710	57.4	
M8L	-----do---------	10,700	57.3	
FB1L	Brass guides	10,690	57.1	Fixed-end specimen.
FB5L	-----do---------	10,750	57.1	Do.
C21L	Steel guides	10,720	56.8	
C22L	-----do---------	10,740	56.6	Inexperienced operator (first test).
C23L	-----do---------	10,730	57.3	Without subpress, head of machine guided.
C24L	-----do---------	10,700	56.9	Do.
Transverse				
C1T	Pack (13-spec.)	10,650	61.3	
C2T	-----do---------	10,650	61.4	
M1T	Single-thickness	10,750	61.4	
M4T	-----do---------	10,650	61.4	
FB4T	Brass guides	10,700	61.0	Fixed-end specimen.
FB6T	-----do---------	10,690	61.1	Do.
C21T	Steel guides	10,670	60.8	
C22T	-----do---------	10,700	61.0	Inexperienced operator (first test).

Note: All tests made in machine A and, unless otherwise stated, with the subpress.

TABLE 2

RESULTS OF COMPRESSIVE TESTS OF 0.032-INCH ALCLAD ALUMINUM ALLOY 24S-T SHEET,

TRANSVERSE SPECIMENS

Specimen number	Kind of test or lateral support	Average thickness of specimens (in.)	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Machine	Remarks
C1T	Pack(13-specimen)	0.0321	10,520	46.5	D	
C21T	Steel guides	.0321	10,550	46.8	A[1]	Inexperienced operator (first test).
C22T	--do-----	.0321	10,580	46.6	A[1]	

[1] With subpress.

TABLE 3

RESULTS OF COMPRESSIVE TESTS OF 0.128-INCH ALUMINUM ALLOY M86-T SHEET,

TRANSVERSE SPECIMENS

Specimen number	Kind of tests or lateral support	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Machine	Remarks
M1T	Single-thickness	10,690	68.4	A[1]	
M2T	------do--------	10,690	68.8	A[1]	
CB12T	Brass guides	10,650	68.4	A[1]	
CB1T	------do--------	10,790	68.1	A	Lateral displacement of loading head of machine greater than 0.1 in.
CB14T	------do--------	10,790	68.1	A	Do.
CB2T	------do--------	10,630	67.7	C	Note 1.
CB3T	------do--------	10,620	67.6	C	Note 2.
CB4T	------do--------	10,640	67.6	C	
CB13T	------do--------	10,610	67.6	C	
C21T	Steel guides	10,660	68.5	A[1]	
C22T	------do--------	10,660	68.2	A[1]	Inexperienced operator (second test).
C30T	------do--------	10,620	67.8	A	Head of machine guided.
C5T	No lateral support	10,600	-	C	Note 3.

[1] With subpress.

Note 1. Clamps set tight, average film thickness 0.0001 in. Specimen slid noticeably in guides under a weight of 7.5 lb. Stress corresponding to 0.0065 strain 63.1 ksi.

Note 2. Clamps set in usual manner, average film thickness 0.0004 in. Specimen slid noticeably in guides under a weight of 1 lb. Stress corresponding to 0.0065 strain 63.0 ksi.

Note 3. Buckled at 64 ksi. Last strain read 0.0065. Stress corresponding to 0.0065 strain 62.9 ksi.

TABLE 4

RESULTS OF COMPRESSIVE TESTS OF 0.032-INCH MAGNESIUM ALLOY J1-h SHEET

Specimen number	Kind of test or lateral support	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Remarks
Longitudinal				
CF4L	Pack	6,500	24.5	5-specimen pack cemented with "Bostick." Tested with fixed ends.
C21L	Steel guides	6,330	24.2	Guides tight at end of test.
C22L	---do--------	6,410	24.1	Do. Inexperienced operator (first test).
Transverse				
CF3T	Pack	6,550	28.5	5-specimen pack cemented with "Bostick." Tested with fixed ends.
C21T	Steel guides	6,420	28.0	Guides tight at end of test.
C22T	---do--------	6,370	28.5	Do. Inexperienced operator (third test).

Note: All tests made in machine A with the subpress.

TABLE 5

RESULTS OF COMPRESSIVE TESTS OF 0.054-INCH 1025 CARBON STEEL SHEET,

TRANSVERSE SPECIMENS

Specimen number	Kind of test or lateral support	Average thickness of specimens (in.)	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Machine	Remarks
C1T	Pack	0.0528	32,660	63.6	D	5-specimen pack.
CF6T	-do--	.0551	31,510	66.3	A[1]	3-specimen pack cemented with shellac. Tested with fixed ends.
C21T	Steel guides	.0541	31,800	65.2	A[1]	Guides tight at end of test.
C22T	-do--	.0541	31,740	65.1	A[1]	Inexperienced operator (first test).

[1] With subpress.

TABLE 6

RESULTS OF COMPRESSIVE TESTS OF 0.020-INCH 18-7 CHROMIUM-NICKEL STEEL SHEET,

TRANSVERSE SPECIMENS

Specimen number	Kind of lateral support	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Machine	Remarks
CB12T	Brass guides	30,550	244.3	A[1]	
CB15T	--do---------	30,390	248.5	A	Lateral displacement of loading head of machine greater than 0.1 in.
CB14T	--do---------	30,380	246.2	B	
CB13T	--do---------	30,130	244.3	C	
C21T	Steel guides	30,340	241.1	A[1]	
C24T	--do---------	30,450	240.8	A[1]	
C25T	--do---------	30,380	241.3	A[1]	

[1]With subpress.

TABLE 7

RESULTS OF COMPRESSIVE TESTS OF 0.010-INCH 18-8 CHROMIUM-NICKEL STEEL SHEET,

FULL HARD, LONGITUDINAL SPECIMENS

Specimen number	Kind of test or lateral support	Average thickness of specimens (in.)	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Remarks
C1L	Pack(10-specimen)	0.0114	26,290	82.6	Cemented with shellac, tested with fixed ends.
C2L	Pack(8-specimen)	.0112	26,320	83.8	Do.
C36L	Steel guides	.0108	26,520	85.0	Specimen near one edge of sheet.
C32L	---do--------	.0111	26,240	84.2	Do.
C35L	---do--------	.0112	26,720	83.9	Do.
C24L	---do--------	.0115	26,400	83.4	
C22L	---do--------	.0115	26,110	82.0	
C26L	---do--------	.0115	26,190	82.3	
C21L	---do--------	.0115	26,340	82.0	
C23L	---do--------	.0115	26,000	83.4	
C27L	---do--------	.0115	25,870	83.5	
C28L	---do--------	.0115	26,200	83.6	
C29L	---do--------	.0115	26,390	83.0	

Note: All tests made in machine A with the subpress.

TABLE 8

RESULTS OF COMPRESSIVE TESTS OF 0.010-INCH 18-8 CHROMIUM-NICKEL STEEL SHEET,

FULL HARD, TRANSVERSE SPECIMENS

Specimen number	Kind of lateral support	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Remarks
C21T	Steel guides	29,870	171.0	Test made with special care.
C43T	---do---------	29,680	171.9	Do.
C51T	---do---------	29,960	171.5	Do.
C41T	---do---------	29,800	171.6	Inexperienced operator (4th test). Average lubricant film thickness more than 0.0003 in. Specimen slightly wavy after test.
C49T	---do---------	29,960	171.0	Inexperienced operator (5th test)
C22T	---do---------	29,750	172.7	Twice usual speed after Young's modulus determination.
C44T	---do---------	29,790	171.4	Do.
C42T	---do---------	29,900	171.9	Twice usual speed after Young's modulus determination. "Routine." Guides could be moved at max. load by pushing on clamps.
C46T	---do---------	29,870	171.6	Twice usual speed after Young's modulus determination. "Routine."
C50T	---do---------	29,690	172.2	Do.
C45T	---do---------	29,690	172.5	"Routine"
C52T	---do---------	29,890	171.3	Clamps tightened till specimen did not move easily, then loosened and readjusted.
C48T	---do---------	29,620	172.0	Do.

Note: All tests made in machine A with the subpress.

TABLE 9

RESULTS OF COMPRESSIVE TESTS OF 0.005-INCH 18-8 CHROMIUM-NICKEL STEEL SHEET, FULL-HARD, TRANSVERSE SPECIMENS

Specimen number	Kind of test or lateral support	Young's modulus (ksi)	Yield strength (offset =0.2%) (ksi)	Remarks
4-C1T	4-specimen shellacked pack, steel guides	29,150	161.1	
2-C2T	2-specimen shellacked pack, steel guides	29,240	160.2	
C53T	Brass guides	28,990	162.9	
C55T	---do---------	29,020	162.6	
C56T	---do---------	29,240	162.1	
C111T	Steel guides	29,000	165.2	Needed to push on clamps to move guides at max. load.
C114T	---do---------	28,890	164.9	Do.
C118T	---do---------	29,290	162.9	
C121T	---do---------	29,530	163.0	Needed to push on clamps to move guides at max. load.
C135T	---do---------	29,270	162.7	Do.
C136T	---do---------	29,010	162.9	Do.
C144T	---do---------	28,620	163.5	
C145T	---do---------	29,310	160.2	

Note: All tests were made in machine A with the subpress.

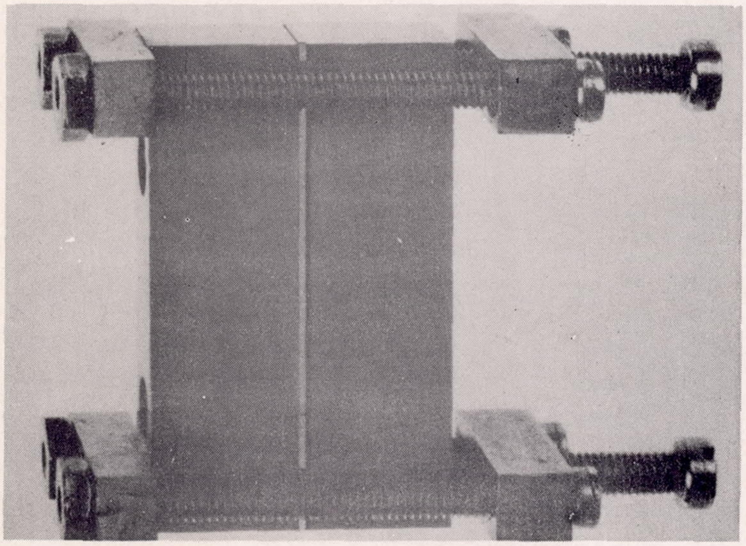


Figure 1.- Improvised solid brass guide fixture for compressive tests of thin sheet metal.

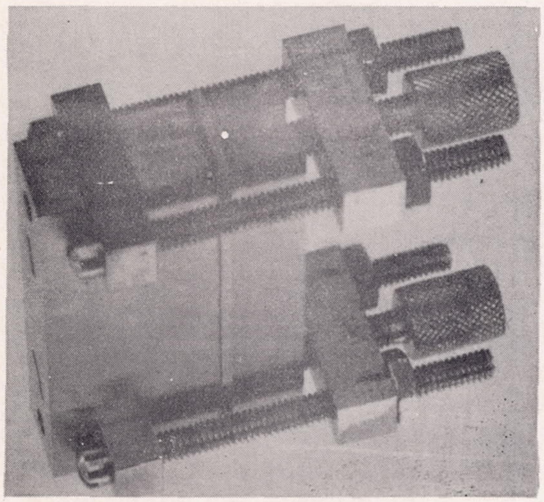
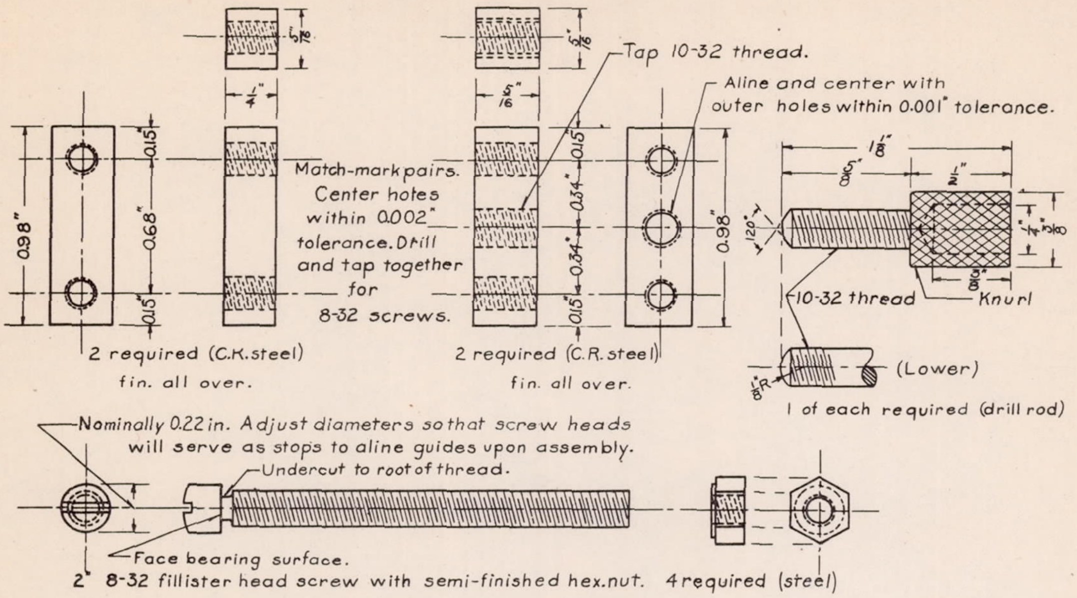
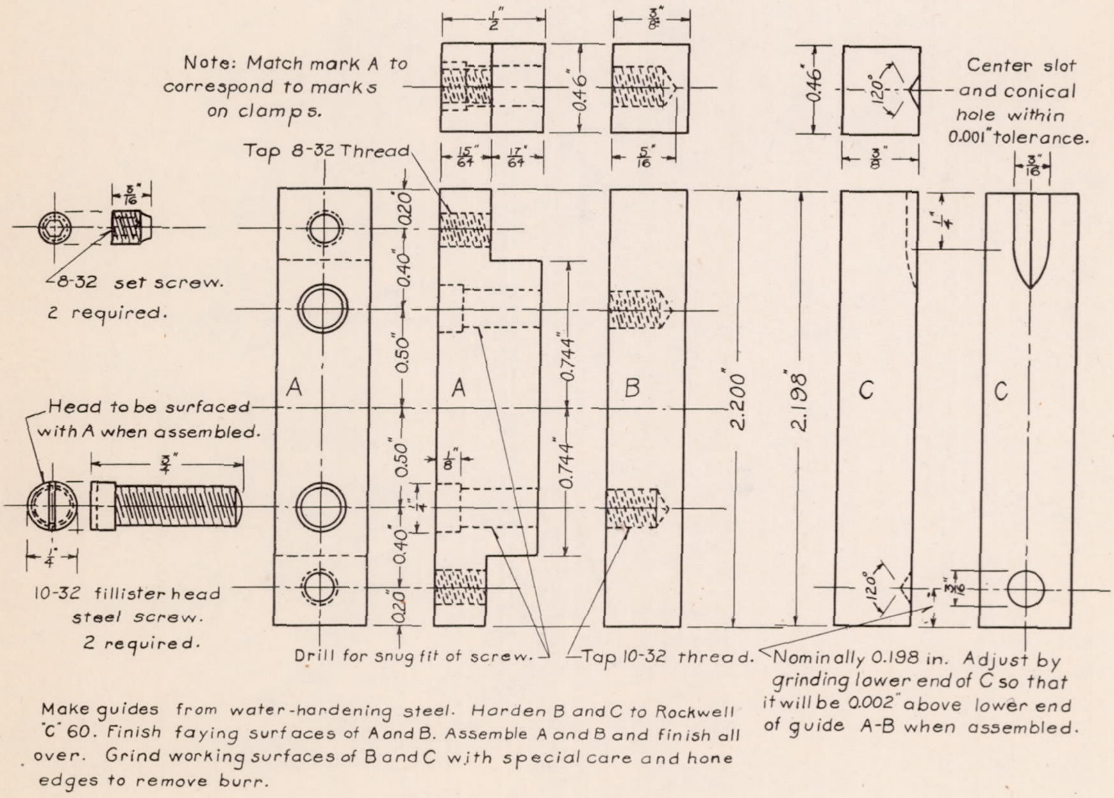


Figure 2.- Steel guide fixture for compressive tests of thin sheet metal.



DETAILS of CLAMPS



DETAILS of GUIDES

Figure 3.- Details of fixture for compressive tests of thin sheet metal.

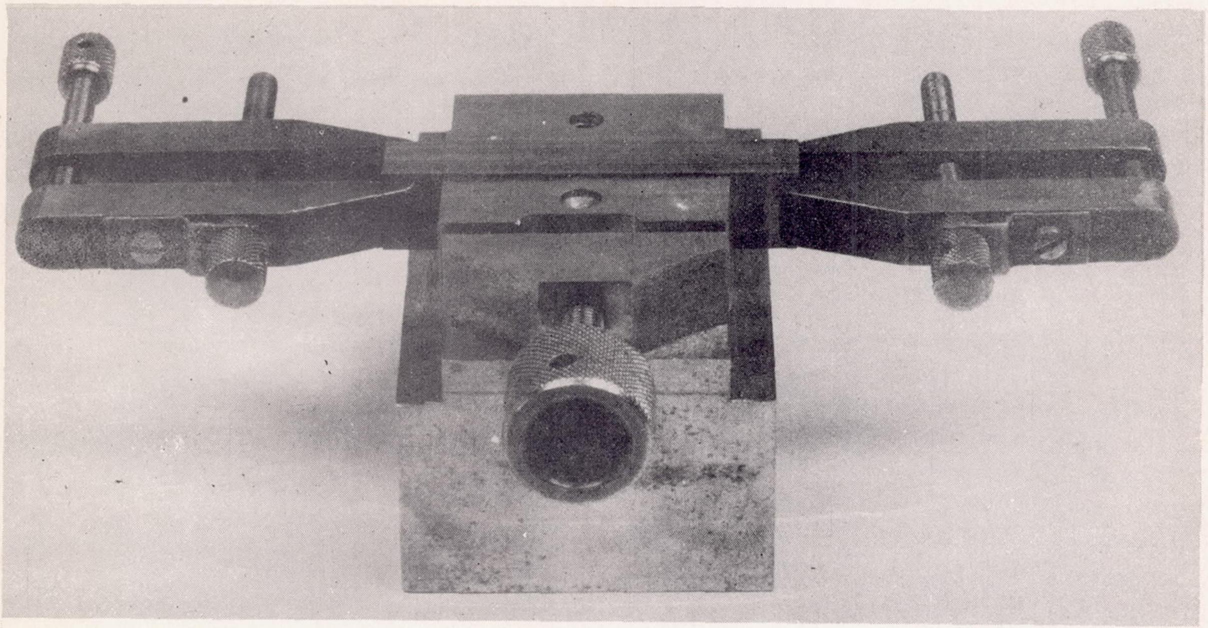


Figure 4.- Pack of specimens in machining fixture ready for grinding one side.

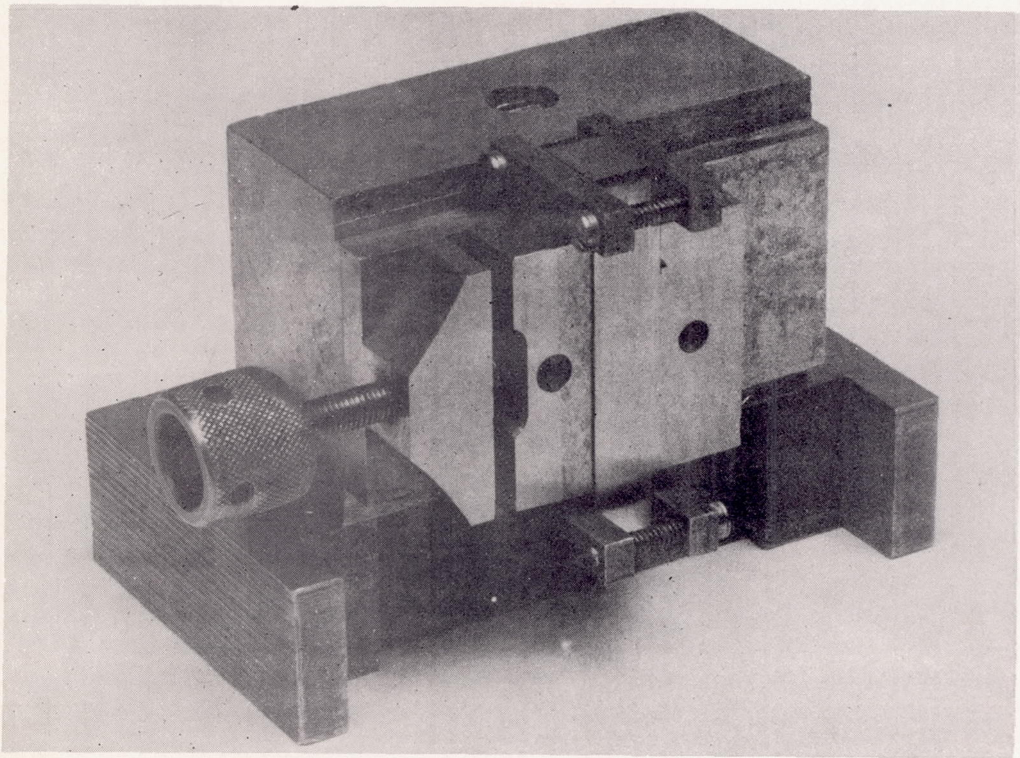


Figure 5.- Pack of specimens in machining fixture ready for grinding one end.

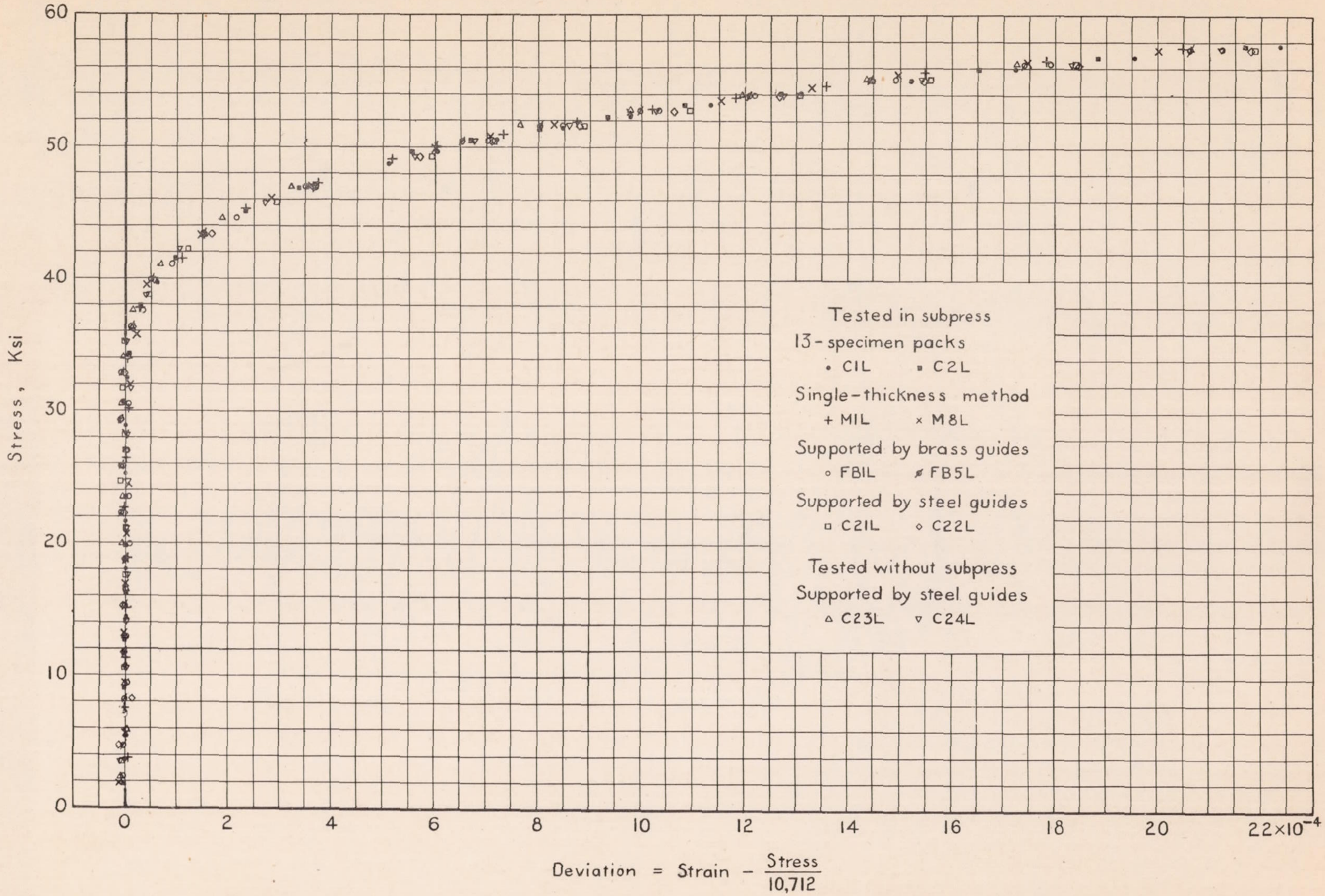


Figure 6.- Compressive stress-deviation graphs, .032-inch aluminum alloy 24S-RT sheet, longitudinal specimens.

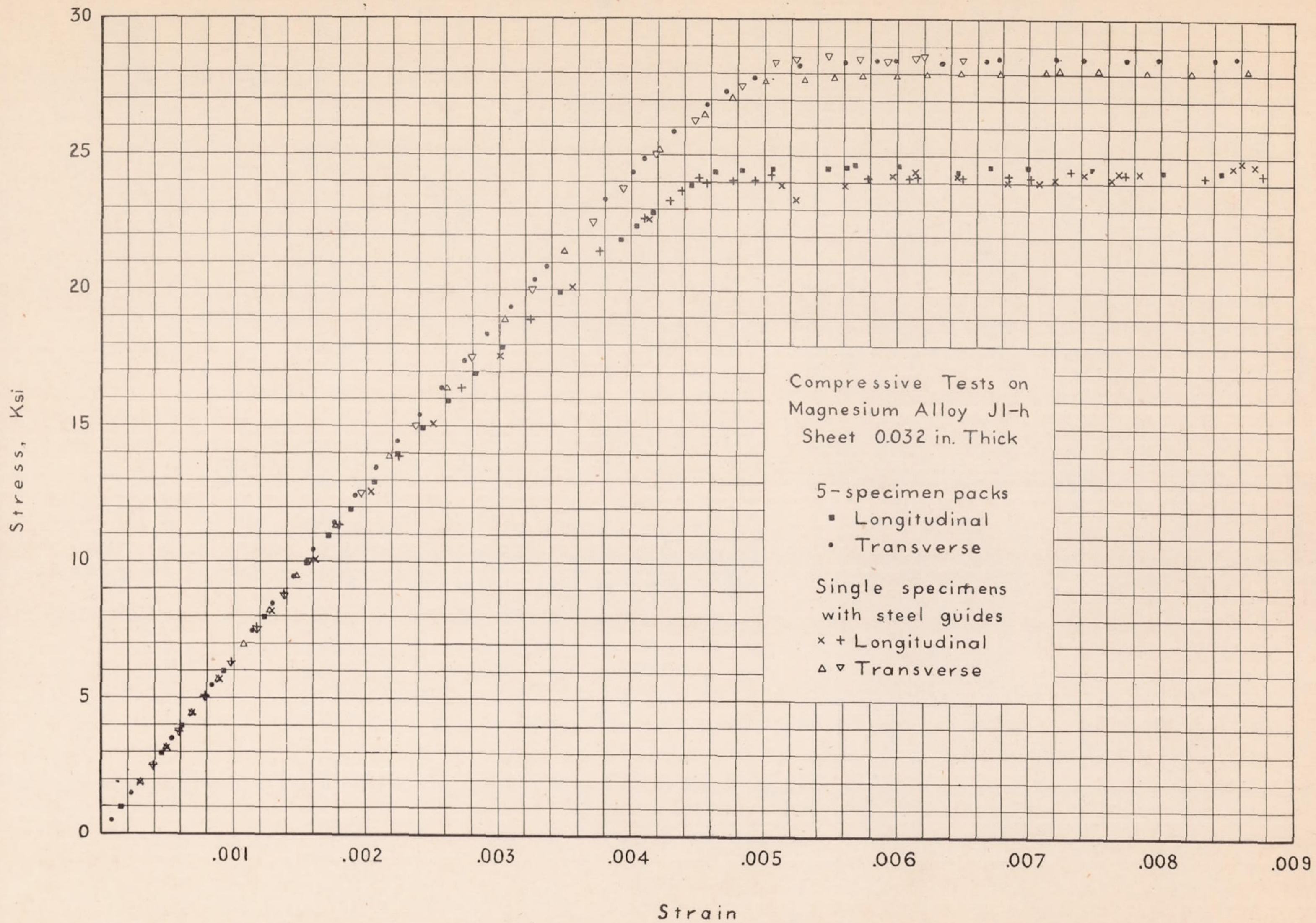


Figure 7.- Compressive stress-strain graphs, .032-inch magnesium alloy J1-h sheet.

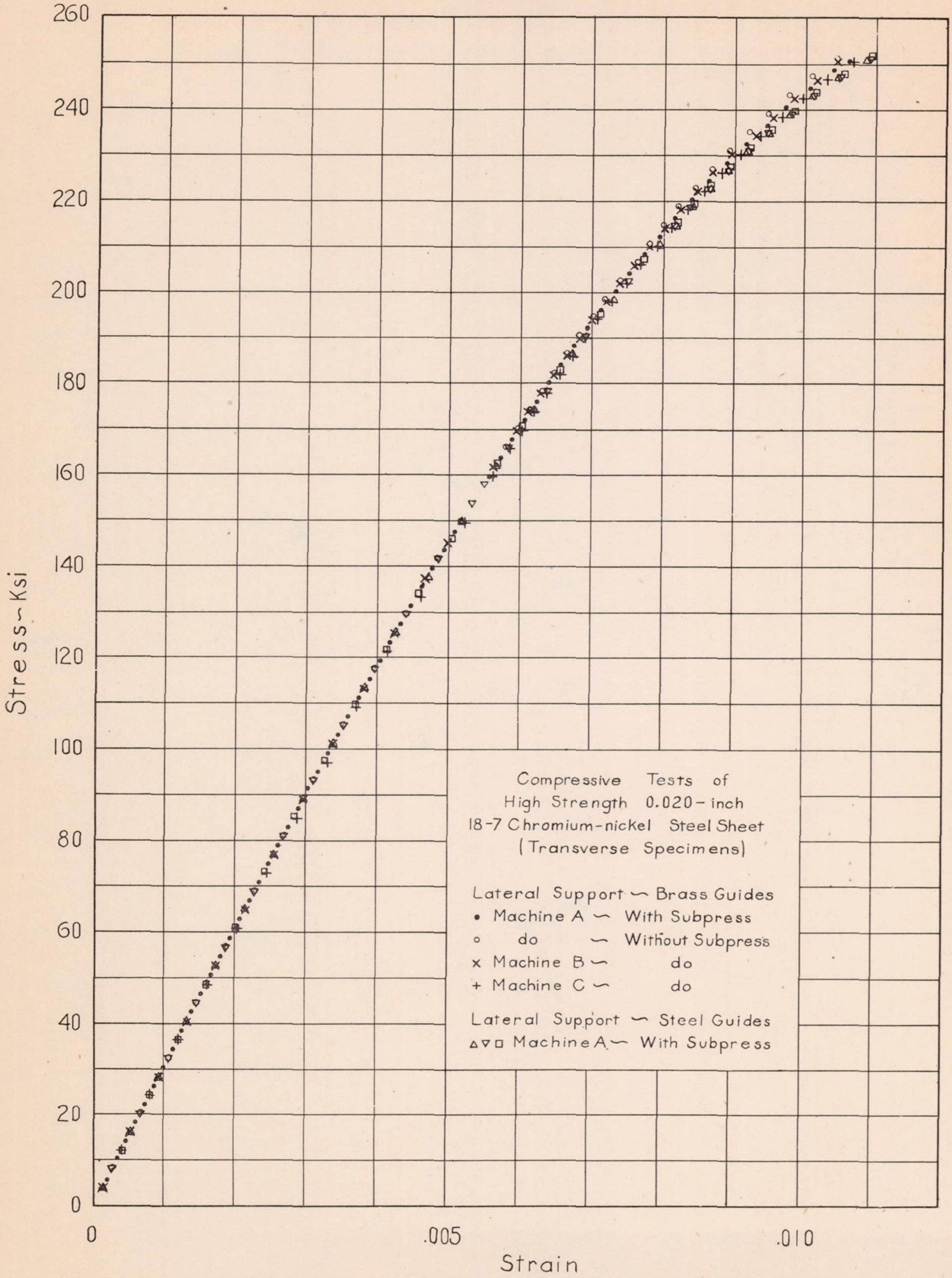


Figure 8.- Compressive stress-strain graphs, .020-inch 18-7 chromium-nickel steel sheet, transverse specimens.

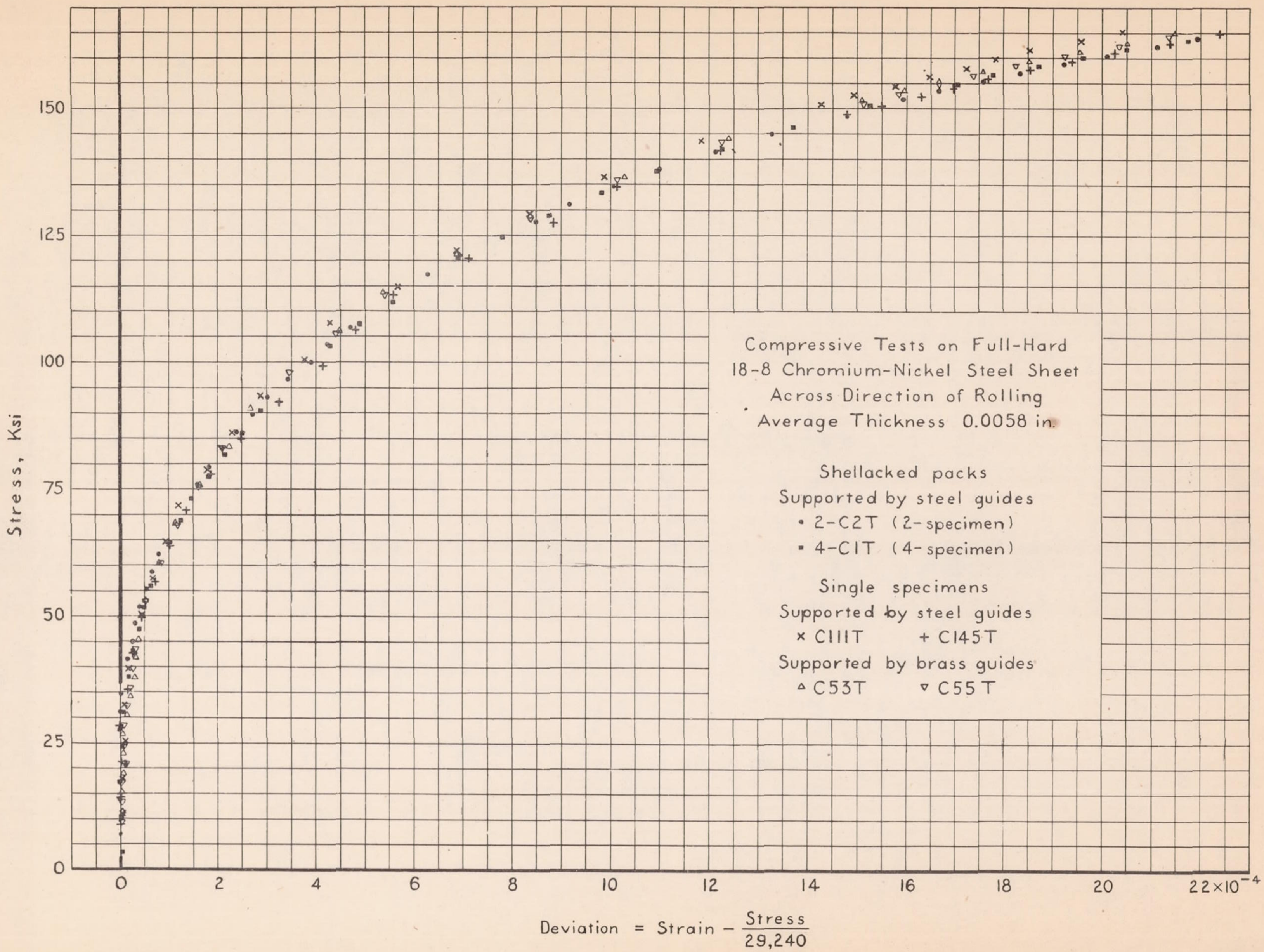


Figure 9.- Compressive stress-deviation graphs, .005-inch full-hard 18-8 chromium-nickel steel sheet, transverse specimens.