# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## TECHNICAL NOTE

No. 942

## THE SHEAR STRENGTH OF ALUMINUM ALLOY DRIVEN RIVETS AS AFFECTED BY INCREASING D/t RATIOS

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Aluminum Company of America

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## INTRODUCTION AND OBJECT

A decrease in shear strengths for increasing D/t ratios was shown in a previous investigation of protruding-head aluminum alloy rivets in double shear conducted at Aluminum Research Laboratories in 1942. Since single shear joints are more common than double shear joints, it was desirable to extend the investigation to single shear joints. This report describes the results of this investigation of single shear joints and also includes the results of the previous investigation on double shear joints.

## MATERIAL AND SPECIMENS

For all specimens button-head aluminum alloy rivets 1/2 inch in diameter were used. To obtain a wide range of shear strengths rivet alloys 53S-O, 53S-T61, 53S-T, and 17S-T were used. The 17S-T rivets were driven immediately after quenching, and all others were driven in the tempers indicated. 24S-T alloy plate and sheet were employed in thicknesses of 1/2, 3/8, 1/4, 3/16, 1/8, 0.081, and 0.064 inch.

The test panels were made up as shown in the sketch in figure 1. These panels then were cut to provide three single butt-strap specimens each $2\frac{3}{8}$ inches wide containing one rivet on each side of the joint. Thicknesses of main and strap plates were the same except in one group where the thicknesses of the strap plates were varied; while the thickness of the main plates was held constant at 3/8 inch.

The rivets were driven in 33/64-inch drilled and reamed holes with cone-point heads except in one case where flat-driven heads were used.

## PROCEDURE

One of the three specimens from each set of three for each rivet alloy except 53S-T was tested in tension in a 20,000-pound capacity Amsler testing machine (Serial No. 4725, Type 10SZBDA). Movement of the main plates relative to the strap plate in this specimen was measured as indicated in figure 2 by means of fine lines scribed across the edges of the plates opposite the center lines of the rivets. The movements were measured as the displacement of this line at the faying surfaces, the readings being taken at four locations with a hand Brinell microscope reading direct to 0.1 millimeter and by estimation to 0.02 millimeter. The remaining two specimens of each group of three were tested in tension in the 40,000-pound capacity Amsler testing machine (Serial No. 4318, Type 20ZBDA) without any readings for movements of the plate.

## RESULTS AND DISCUSSION

The results of the tests are shown in detail in table I and are summarized in table II. Figure 3 shows the results of the tests plotted to show the decrease in shear strength resulting from an increase in the bearing stress on the rivets. Ratios of shear strength to basic shear strength are used as ordinates and ratios of bearing stress to basic shear strength as abscissas, thus providing a nondimensional plot of the test results. Basic shear strength as used here is the shear strength obtained when the ratio of rivet diameter D to plate thickness t is unity (D/t = 1).

A study of table II and figure 3 indicates that the ratio of shear strength to basic shear strength reduces at nearly the same rate regardless of rivet alloys. The single shear strength starts to drop off noticeably when the bearing strength exceeds about $2\frac{1}{2}$ times the basic shear strength. A dotted curve has been drawn in figure 3 to show the trend of the double shear tests data in table III taken from the previous report. It is evident that the decrease of double shear strength starts at about the same value of bearing strength as the decrease in single shear strength but that the reduction is more rapid in the double shear than in the single shear tests.

The data in figure 3 have been replotted in figure 4 using diameter-to-thickness ratios as abscissas. In this figure a simple straight line has been drawn to indicate the trend of the data. Such a straight line appears to be a close enough approximation of the test results to be useful for establishing allowable design values in actual practice. Using such a straight-line formula, a simple rule could be written for allowable single shear strength of protruding-head aluminum alloy rivets driven in aluminum alloy plates as follows:

For values of D/t up to 3,

Single shear strength = basic allowable single shear strength

For values of D/t greater than 3,

Single shear strength = basic allowable single shear strength $\times$ $[1 - 0.04\ (D/t - 3)]$,

where

D nominal diameter of rivet, inch

t thickness of plate, inch

The fact that a straight-line formula seems to be acceptable in the case of single shear tests suggests that a similar straight-line formula might well be used in connection with double shear tests. Having this in mind, the double shear data in table III taken from the previous report have been replotted in figure 5; and, based on this replot, the following rule can be stated for determining the double shear strength of protruding head aluminum alloy rivets in aluminum alloy plates:

For values of D/t up to 1.5,

Double shear strength = basic allowable double shear strength

For values of D/t greater than 1.5,

$$\text{Double shear strength} = \text{basic allowable double shear strength} \times [1 - 0.13\,(D/t - 1.5)].$$

In aircraft design the present method of taking account of the reduced shear strength of rivets resulting from increasing D/t ratios is to limit the allowable bearing stress on the rivets to $3\frac{1}{3}$ times the basic shear strength. (See reference 1.) Figure 6 shows a comparison of this present rule with the proposed new rules in double shear and single shear. The small area marked "A" in each figure indicates the range in which the proposed new rule is slightly more conservative (up to 8 percent) than the present rule, and the large area marked "B" in each figure indicates the range in which the proposed new rule gives higher allowable values than the present rule.

These differences are further brought out in table IV which shows allowable rivet values based on current allowable stresses given in ANC-5 and those which would result from the application of the proposed new rules. It should be emphasized that throughout this discussion only protruding-head rivets are under consideration and that the proposed rules are not intended to apply to countersunk rivets.

Figures 7, 8, 9, and 10 show the plotted data from the measurements of plate movement in the various tests. In order to establish some measure of first yielding in the specimens the same criterion previously used in bearing tests of aluminum alloys has been adopted; namely, the yield load is considered to be the load at which the permanent set per plate is equal to 2 percent of the hole diameter. Since in these specimens there were two plates of identical thickness involved in each measurement of movement, the total movement defining the yield load is twice 2 percent or 4 percent of the hole diameter, and this is the point marked on each of the curves. The resulting yield loads are listed in table I together with the corresponding shear and bearing stresses.

A study of the bearing stresses at the yield load in table I indicates that in no case was this bearing stress equal to the typical bearing yield strength of the 24S-T plates.* Since none of the bearing stresses at the yield load equals the bearing yield strength of the plates, it

*The typical bearing yield strength of the 24S-T plates is calculated to be 46,000 × 1.6 = 73,600 psi.

may be safely assumed that the yielding is primarily in the rivets; and, therefore, the shear stress corresponding to the yield load is probably more significant than the bearing stress. These shear stresses have been summarized in table II as shear yield strengths of the rivets. In the last column of the table the ratio of these shear yield strengths to the corresponding shear strengths is listed, and it will be noted that the minimum value of this ratio is 0.83. Since this ratio is considerably above 2/3, it would appear that shear yield strength of rivets would never be a controlling feature in the design, and for this reason no further consideration will be given to shear yield strength in this report.

In one group of specimens involving 53S-T61 rivets a study was made of the effect of varying the thickness of the strap plate while holding the thickness of the main plate constant. The results of this study may be found listed with the rest of the values for the 53S-T61 rivets in table II. Referring to the column of ratios of shear strength to basic shear strength for 53S-T61 rivets in table II and comparing the third value with the sixth, the fourth with the seventh, and the fifth with the eighth, it becomes evident that there is practically no difference in the results whether the main plate is the same thickness as the strap plate or whether it is thicker than the strap plate. This indicates that the results of this investigation may be applied generally to single shear rivets without regard to the exact proportions of the riveted joints.

## CONCLUSIONS

The following conclusions are based on tests of 1/2-inch-diameter protruding-head aluminum alloy rivets driven in aluminum alloy plates of various thicknesses:

1. The single and double shear strength of protruding head aluminum alloy rivets driven in aluminum alloy plates decreases below the "basic" value if the bearing stress exceeds about $2\frac{1}{2}$ times the shear stress on the rivet. The rate of decrease of shear strength is greater with double shear than with single shear rivets as shown in figure 3.

2. Through the use of simple straight-line formulas the shear strength of protruding-head aluminum alloy rivets driven in aluminum alloy plate can be readily predicted for various plate or sheet thicknesses as follows:

Single Shear

For values of D/t up to 3,

Single shear strength = basic allowable single shear strength

For values of D/t greater than 3,

Single shear strength = basic allowable single shear strength $\times$ [1 – 0.04 (D/t – 3)],

where

D nominal diameter of rivet, inch

t thickness of plate, inch

Double Shear

For values of D/t up to 1.5,

Double shear strength = basic allowable double shear strength

For values of D/t greater than 1.5,

Double shear strength = basic allowable double shear strength $\times$ [1 – 0.13 (D/t – 1.5)].

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., March 31, 1944.

REFERENCE

1. Anon.: Strength of Aircraft Elements. ANC-5, Amendment 1, Oct. 22, 1943, tables 5-14.

TABLE I.- SINGLE SHEAR TESTS OF DRIVEN ALUMINUM ALLOY RIVETS IN 24S-T ALLOY PLATE

[All rivets 1/2 in. in diameter driven with cone-point heads in 33/64-in.-diameter holes; shear area = 0.2088 sq in.]

| Specimen | Plate thickness (in.) | | Nominal D/t | Bearing area (sq in.) | Load (lb) | | Shear stress (psi) | | Bearing stress (psi) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strap | Main | | | Yield* | Ultimate | Yield | Ultimate | Yield | Ultimate |
| | | | | | 53S-0 Rivets | | | | | |
| 1 | 1/2 | 1/2 | 1.00 | 0.2578 | 1950 | 2320 | | | | |
| 2 | | | | | | 2265 | | | | |
| 3 | | | | | | 2240 | | | | |
| Av. | | | | | 1950 | 2275 | 9,340 | 10,900 | 7,560 | 8,830 |
| 1 | 3/8 | 3/8 | 1.33 | .1934 | 2020 | 2285 | | | | |
| 2 | | | | | | 2280 | | | | |
| 3 | | | | | | 2270 | | | | |
| Av. | | | | | 2020 | 2280 | 9,670 | 10,910 | 10,430 | 11,780 |
| 1 | 1/4 | 1/4 | 2.00 | .1289 | 1990 | 2295 | | | | |
| 2 | | | | | | 2265 | | | | |
| 3 | | | | | | 2270 | | | | |
| Av. | | | | | 1990 | 2280 | 9,530 | 10,900 | 15,430 | 17,660 |
| 1 | 3/16 | 3/16 | 2.67 | .0967 | 1990 | 2260 | | | | |
| 2 | | | | | | 2225 | | | | |
| 3 | | | | | | 2235 | | | | |
| Av. | | | | | 1990 | 2240 | 9,530 | 10,730 | 20,600 | 23,160 |
| 1 | 1/8 | 1/8 | 4.00 | .0645 | 1890 | 2160 | | | | |
| 2 | | | | | | 2135 | | | | |
| 3 | | | | | | 2120 | | | | |
| Av. | | | | | 1890 | 2140 | 9,050 | 10,240 | 29,300 | 33,150 |
| 1 | 0.081 | 0.081 | 6.17 | .0417 | 1910 | 2070 | | | | |
| 2 | | | | | | 2020 | | | | |
| 3 | | | | | | 2100 | | | | |
| Av. | | | | | 1910 | 2065 | 9,150 | 9,880 | 45,800 | 49,480 |
| 1 | .064 | .064 | 7.81 | .0330 | None | 1805 | | | | |
| 2 | | | | | | 1760 | | | | |
| 3 | | | | | | 1805 | | | | |
| Av. | | | | | None | 1790 | ——— | 8,570 | ——— | 54,240 |

*See footnote on p. 10.

TABLE I.- (Continued)

| Specimen | Plate thickness (in.) Strap | Main | Nominal D/t | Bearing area (sq in.) | Load (lb) Yield* | Ultimate | Shear stress (psi) Yield | Ultimate | Bearing stress (psi) Yield | Ultimate |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 53S-T61 Rivets | | | | | |
| 1 | 1/2 | 1/2 | 1.00 | 0.2578 | None | 4770 | | | | |
| 2 | | | | | | 4910 | | | | |
| 3 | | | | | | 4800 | | | | |
| Av. | | | | | None | 4825 | ------- | 23,120 | ------- | 18,720 |
| 1 | 3/8 | 3/8 | 1.33 | .1934 | 4750 | 4870 | | | | |
| 2 | | | | | | 4920 | | | | |
| 3 | | | | | | 4900 | | | | |
| Av. | | | | | 4750 | 4895 | 22,750 | 23,450 | 24,550 | 25,320 |
| 1 | 1/4 | 1/4 | 2.00 | .1289 | 4650 | 4850 | | | | |
| 2 | | | | | | 4880 | | | | |
| 3 | | | | | | 4895 | | | | |
| Av. | | | | | 4650 | 4875 | 22,270 | 23,350 | 36,100 | 37,820 |
| 1 | 3/16 | 3/16 | 2.67 | .0967 | None | 4795 | | | | |
| 2 | | | | | | 4880 | | | | |
| 3 | | | | | | 4830 | | | | |
| Av. | | | | | None | 4835 | ------- | 23,160 | ------- | 50,000 |
| 1 | 1/8 | 1/8 | 4.00 | .0645 | None | 4600 | | | | |
| 2 | | | | | | 4640 | | | | |
| 3 | | | | | | 4610 | | | | |
| Av. | | | | | None | 4615 | ------- | 22,110 | ------- | 71,580 |
| 1 | 1/4 | 3/8 | 2.00 | .1289 | None | 4870 | | | | |
| 2 | | | | | | 4910 | | | | |
| 3 | | | | | | 4910 | | | | |
| Av. | | | | | None | 4895 | ------- | 23,450 | ------- | 37,990 |
| 1 | 3/16 | 3/8 | 2.67 | .0967 | None | 4790 | | | | |
| 2 | | | | | | 4865 | | | | |
| 3 | | | | | | 4865 | | | | |
| Av. | | | | | None | 4840 | ------- | 23,180 | ------- | 50,050 |

*See footnote on p. 10.

TABLE I.- (Continued)

| Specimen | Plate thickness (in.) Strap | Plate thickness (in.) Main | Nominal D/t | Bearing area (sq in.) | Load (lb) Yield* | Load (lb) Ultimate | Shear stress (psi) Yield | Shear stress (psi) Ultimate | Bearing stress (psi) Yield | Bearing stress (psi) Ultimate |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 53S-T61 Rivets | | | | | | |
| 1 | 1/8 | 3/8 | 4.00 | 0.0645 | 4450 | 4620 | | | | |
| 2 | | | | | | 4765 | | | | |
| 3 | | | | | | 4620 | | | | |
| Av. | | | | | 4450 | 4670 | 21,310 | 22,360 | 69,000 | 72,380 |
| | | | | 53S-T Rivets | | | | | | |
| 1 | 1/2 | 1/2 | 1.00 | .2578 | None | 5620 | | | | |
| 2 | | | | | | 5520 | | | | |
| 3 | | | | | | 5500 | | | | |
| Av. | | | | | None | 5545 | ------- | 26,570 | ------- | 21,500 |
| 1 | 3/8 | 3/8 | 1.33 | .1934 | None | 5530 | | | | |
| 2 | | | | | | 5460 | | | | |
| 3 | | | | | | 5510 | | | | |
| Av. | | | | | None | 5500 | ------- | 26,340 | ------- | 28,420 |
| 1 | 1/4 | 1/4 | 2.00 | .1289 | None | 5470 | | | | |
| 2 | | | | | | 5620 | | | | |
| 3 | | | | | | 5500 | | | | |
| Av. | | | | | None | 5530 | ------- | 26,490 | ------- | 42,900 |
| 1 | 3/16 | 3/16 | 2.67 | .0967 | None | 5500 | | | | |
| 2 | | | | | | 5510 | | | | |
| 3 | | | | | | 5475 | | | | |
| Av. | | | | | None | 5495 | ------- | 26,320 | ------- | 56,800 |
| 1 | 1/8 | 1/8 | 4.00 | .0645 | None | 5180 | | | | |
| 2 | | | | | | 5270 | | | | |
| 3 | | | | | | 5220 | | | | |
| Av. | | | | | None | 5225 | ------- | 25,020 | ------- | 81,000 |

*See footnote on p.10.

TABLE I.- (Continued)

| Specimen | Plate thickness (in.) | | Nominal D/t | Bearing area (sq in.) | Load (lb) | | Shear stress (psi) | | Bearing stress (psi) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strap | Main | | | Yield* | Ultimate | Yield | Ultimate | Yield | Ultimate |
| | | | | | 17S-T Rivets | | | | | |
| 1 | 1/2 | 1/2 | 1.00 | 0.2578 | 6700 | 7340 | | | | |
| 2 | | | | | | 7395 | | | | |
| 3 | | | | | | 7390 | | | | |
| Av. | | | | | 6700 | 7375 | 32,090 | 35,320 | 25,900 | 28,610 |
| 1 | 3/8 | 3/8 | 1.33 | .1934 | None | 7210 | | | | |
| 2 | | | | | | 7290 | | | | |
| 3 | | | | | | 7230 | | | | |
| Av. | | | | | None | 7245 | -------- | 34,690 | -------- | 37,450 |
| 1 | 1/4 | 1/4 | 2.00 | .1289 | 6200 | 7290 | | | | |
| 2 | | | | | | 7260 | | | | |
| 3 | | | | | | 7280 | | | | |
| Av. | | | | | 6200 | 7275 | 29,690 | 34,850 | 48,100 | 56,450 |

*Where word "none" appears, no yield was obtained because specimen failed before required permanent set (2 percent of hole diameter) was reached.

TABLE II.- SUMMARY OF DATA FROM SINGLE SHEAR TESTS

| Rivet alloy | Thickness (in.) | | Nominal | Stress at failure (psi) | | Shear yield strength | SS | BS | SYS |
|---|---|---|---|---|---|---|---|---|---|
| | Main | Strap | D/t | Shear | Bearing | (psi) | BSS | BSS | BSS |
| 53S-0 | 1/2 | 1/2 | 1.00 | 10,900 | 8,830 | 9,340 | 1.00 | 0.81 | 0.86 |
| | 3/8 | 3/8 | 1.33 | 10,910 | 11,780 | 9,670 | 1.00 | 1.08 | .89 |
| | 1/4 | 1/4 | 2.00 | 10,900 | 17,660 | 9,530 | 1.00 | 1.62 | .87 |
| | 3/16 | 3/16 | 2.67 | 10,730 | 23,160 | 9,530 | .99 | 2.12 | .87 |
| | 1/8 | 1/8 | 4.00 | 10,240 | 33,150 | 9,050 | .94 | 3.04 | .83 |
| | 0.081 | 0.081 | 6.17 | 9,880 | 49,480 | 9,150 | .91 | 4.54 | .84 |
| | .064 | .064 | 7.81 | 8,570 | 54,240 | ------- | .79 | 4.97 | ----- |
| 53S-T61 | 1/2 | 1/2 | 1.00 | 23,120 | 18,720 | ------- | 1.00 | .81 | ----- |
| | 3/8 | 3/8 | 1.33 | 23,450 | 25,320 | 22,750 | 1.01 | 1.10 | .98 |
| | 1/4 | 1/4 | 2.00 | 23,350 | 37,820 | 22,270 | 1.01 | 1.64 | .96 |
| | 3/16 | 3/16 | 2.67 | 23,160 | 50,000 | ------- | 1.00 | 2.16 | ----- |
| | 1/8 | 1/8 | 4.00 | 22,110 | 71,580 | ------- | .96 | 3.10 | ----- |
| | 3/8 | 1/4 | 2.00 | 23,450 | 37,990 | ------- | 1.01 | 1.64 | ----- |
| | 3/8 | 3/16 | 2.67 | 23,180 | 50,050 | ------- | 1.00 | 2.16 | ----- |
| | 3/8 | 1/8 | 4.00 | 22,360 | 72,380 | 21,310 | .97 | 3.13 | .92 |
| 53S-T | 1/2 | 1/2 | 1.00 | 26,570 | 21,500 | ------- | 1.00 | .81 | ----- |
| | 3/8 | 3/8 | 1.33 | 26,340 | 28,420 | ------- | .99 | 1.07 | ----- |
| | 1/4 | 1/4 | 2.00 | 26,490 | 42,900 | ------- | 1.00 | 1.62 | ----- |
| | 3/16 | 3/16 | 2.67 | 26,320 | 56,800 | ------- | .99 | 2.14 | ----- |
| | 1/8 | 1/8 | 4.00 | 25,020 | 81,000 | ------- | .94 | 3.05 | ----- |
| 17S-T | 1/2 | 1/2 | 1.00 | 35,320 | 28,610 | 32,090 | 1.00 | 0.81 | .91 |
| | 3/8 | 3/8 | 1.33 | 34,690 | 37,450 | ------- | .98 | 1.06 | ----- |
| | 1/4 | 1/4 | 2.00 | 34,850 | 56,450 | 29,690 | .99 | 1.60 | .84 |

D Nominal diameter of rivet, in.
t Thickness of plate, in.
SS Shear strength of rivet, psi
BSS Basic shear strength (shear strength when D/t = 1), psi.
BS Bearing stress on rivet, psi.
All failures by shearing of rivets.

TABLE III.- SUMMARY DATA FROM DOUBLE SHEAR TESTS

FROM PREVIOUS REPORT (42-48)

[1/2-in. rivets in 33/64-in. holes]

| Rivet alloy | Plate alloy | Nominal D/t | Stress at failure (psi) Shear | Bearing | SS/BSS | BS/BSS |
|---|---|---|---|---|---|---|
| 3S | 17S-T | 1.00 | 13,780 | 22,410 | 1.00 | 1.63 |
| 3S | 17S-T | 1.33 | 13,700 | 29,730 | 1.00 | 2.16 |
| 3S | 17S-T | 2.00 | 13,090 | 42,220 | .95 | 3.06 |
| 3S | 17S-T | 2.67 | 11,560 | 49,470 | .84 | 3.59 |
| 3S | 17S-T | 4.00 | 9,580 | 61,070 | .70 | 4.44 |
| 53S-W | 17S-T | 1.00 | 21,660 | 35,100 | 1.00 | 1.62 |
| 53S-W | 17S-T | 1.33 | 21,150 | 45,820 | .98 | 2.11 |
| 53S-W | 17S-T | 2.00 | 19,700 | 63,640 | .91 | 2.94 |
| 53S-W | 17S-T | 2.67 | 17,880 | 76,370 | .83 | 3.52 |
| 53S-W | 17S-T | 4.00 | 15,070 | 96,030 | .70 | 4.43 |
| 53S-W | 53S-T | 1.00 | 23,470 | 38,560 | 1.00 | 1.64 |
| 53S-W | 53S-T | 1.33 | 23,830 | 51,880 | 1.01 | 2.21 |
| 53S-W | 53S-T | 2.00 | 22,500 | 72,750 | .96 | 3.10 |

D Nominal diameter of rivet, in.
t Thickness of plate, in.
SS Shear strength of rivet, psi
BSS Basic shear strength (shear strength when D/t = 1), psi
BS Bearing stress on rivet, psi

All failures by shearing of rivets.

TABLE IV.– COMPARISON OF ALLOWABLE RIVET VALUES

BY PRESENT AND PROPOSED NEW RULES

[All values are for 3/16–in. diameter A17S–T rivets in 0.191–in. diameter holes in 24S–T sheet using an edge distance of 3/8 inch (e = 2D)]

Allowable bearing stress on sheet = 120,000* psi.
Allowable bearing stress on rivet = 100,000* psi.
Basic allowable shear stress on rivet = 30,000* psi.
Shear area = 0.0286 sq in.
D Nominal diameter of rivet, in.

| Sheet thickness, t (in.) | D/t | Allowable value for one rivet (lb) | | | |
|---|---|---|---|---|---|
| | | Single shear | | Double shear | |
| | | Present rule | Proposed new rule | Present rule | Proposed new rule |
| 3/16 | 1.00 | 860 | 860 | 1720 | 1720 |
| 5/32 | 1.20 | 860 | 860 | 1720 | 1720 |
| 1/8 | 1.50 | 860 | 860 | 1720 | 1720 |
| 0.102 | 1.84 | 860 | 860 | 1720 | 1645 |
| .081 | 2.31 | 860 | 860 | 1548 | 1540 |
| .064 | 2.93 | 860 | 860 | 1222 | 1400 |
| .051 | 3.68 | 860 | 836 | 975 | 1170** |
| .040 | 4.69 | 765 | 802 | 765 | 915** |
| .032 | 5.85 | 611 | 733** | 611 | 733** |

*See reference 1 (Army–Navy values).
**Controlled by bearing on sheet.

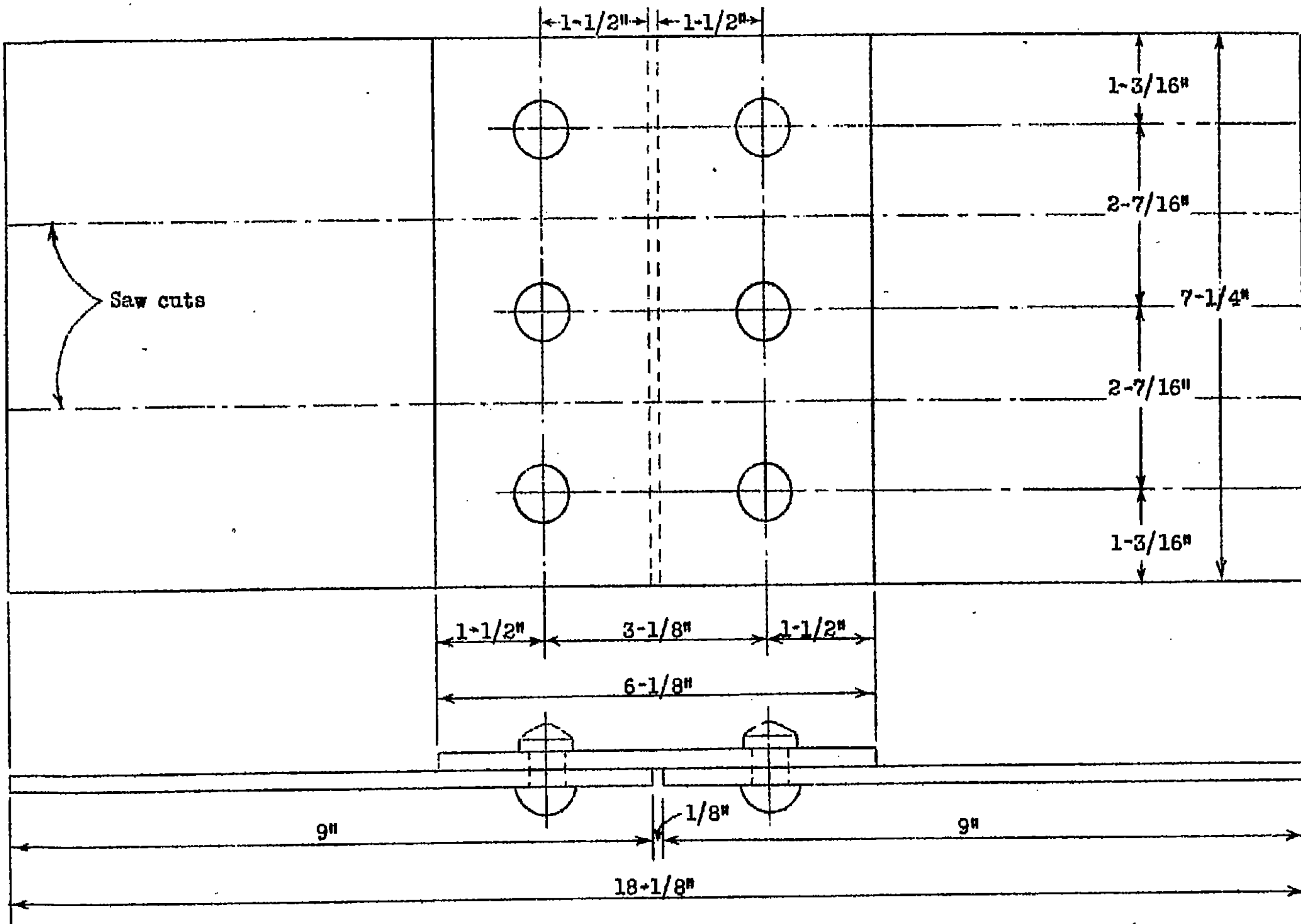



Figure 1.- Specimen for single shear tests on driven rivets (1/2" dia.) all holes 33/64" dia.

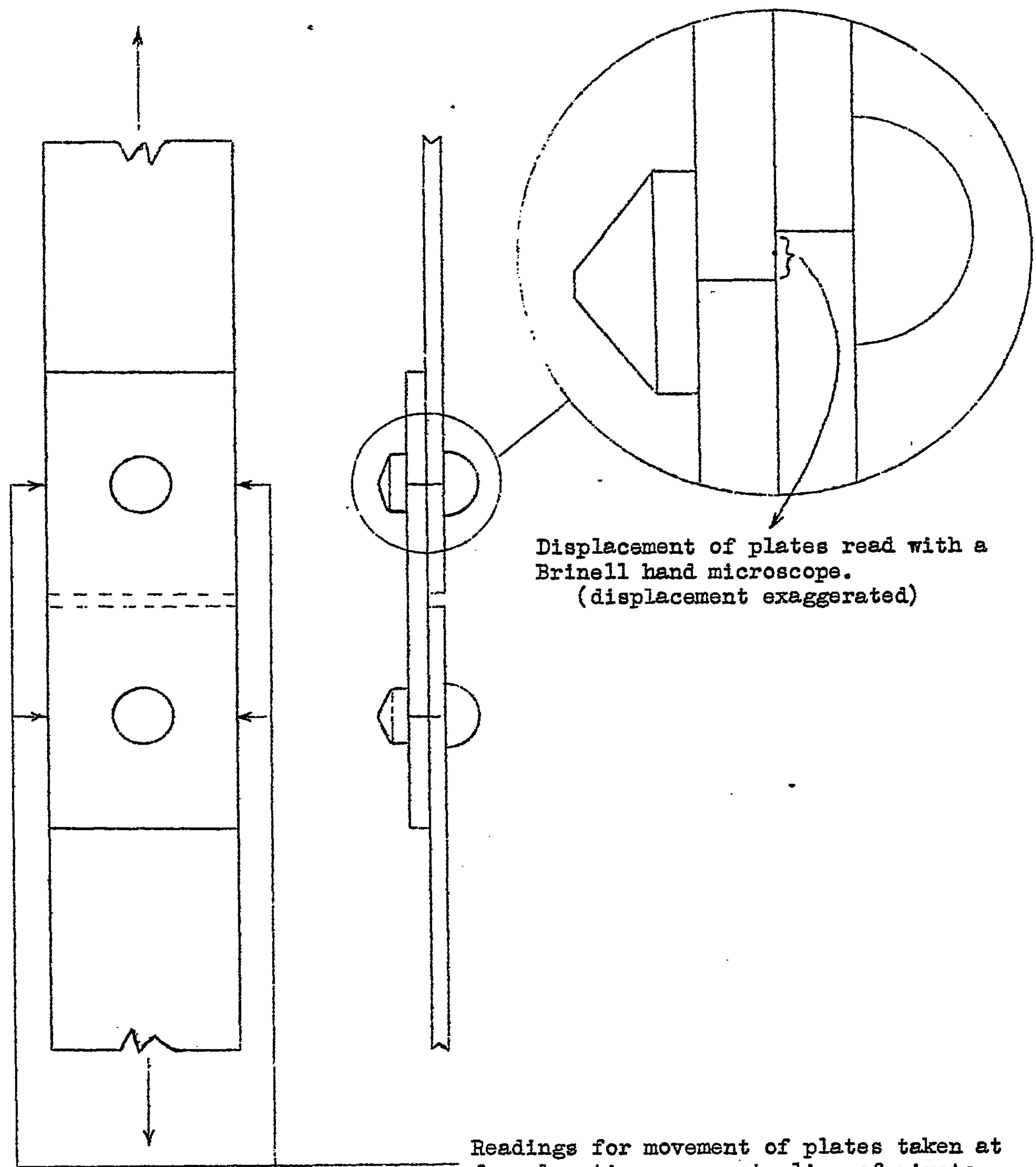
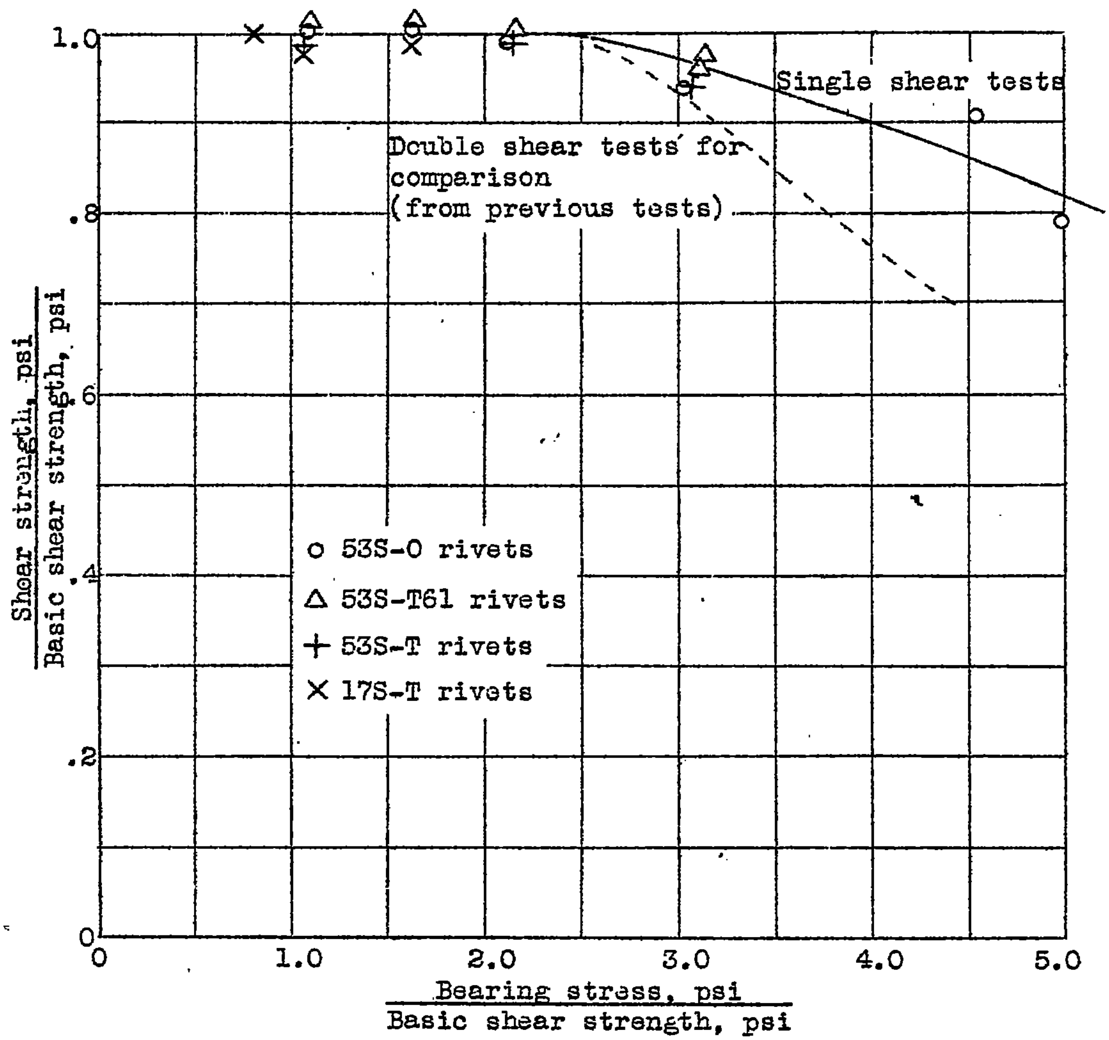
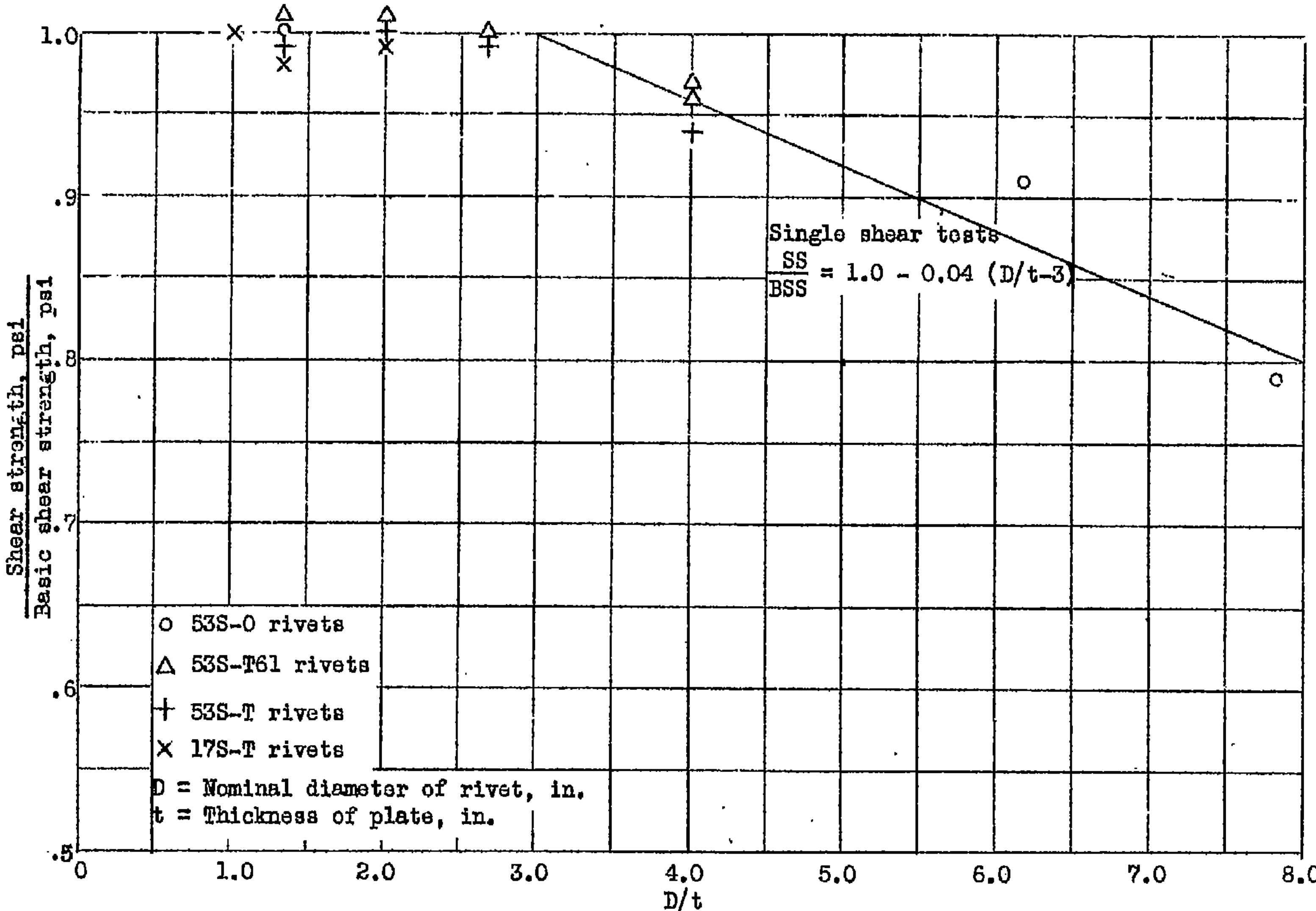

Displacement of plates read with a Brinell hand microscope. (displacement exaggerated)
Readings for movement of plates taken at four locations on centerline of rivets.

Figure 2.



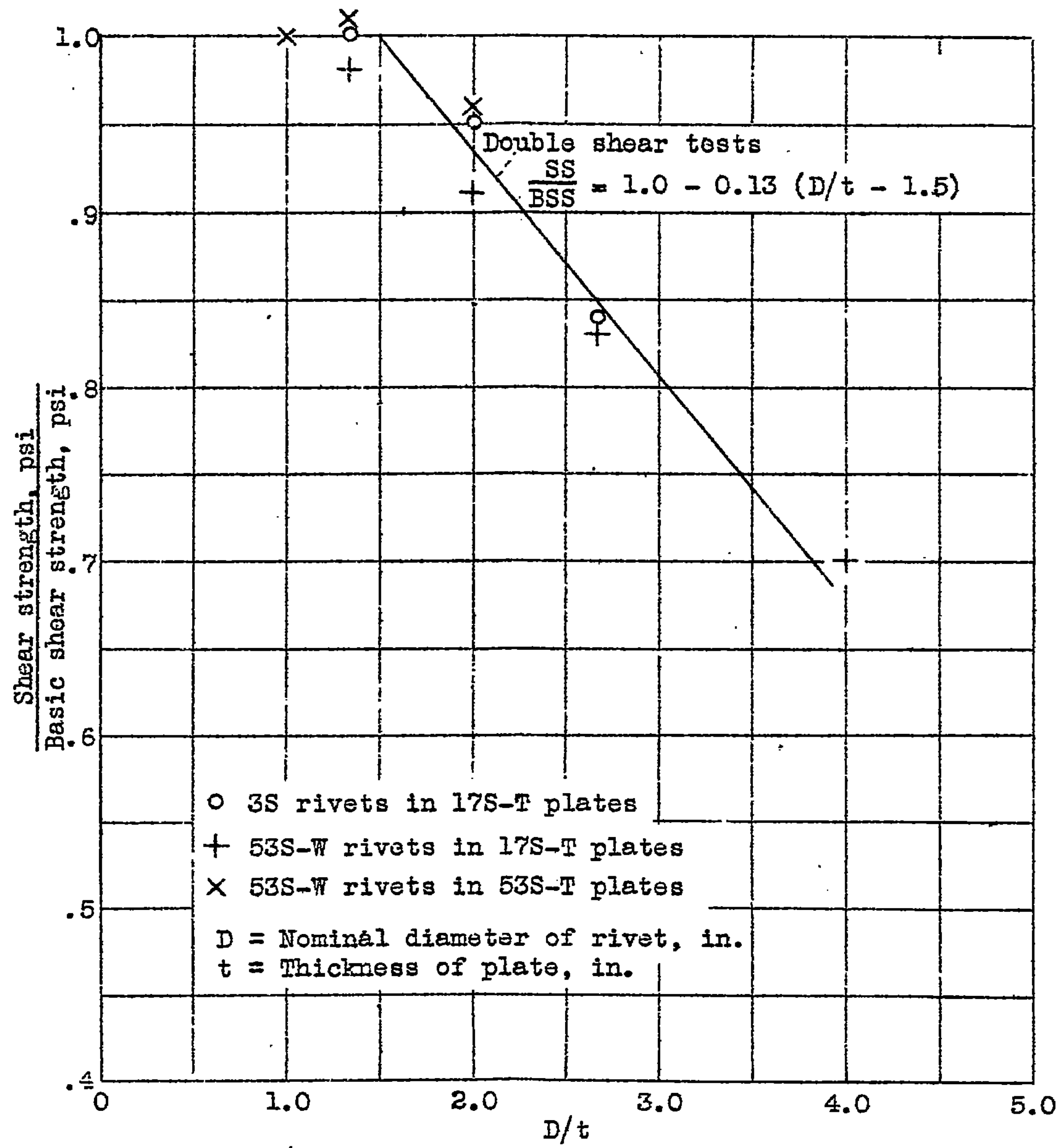

All rivets 1/2 inch in diameter driven with cone-point heads tested in single shear in 24S-T plates. Each plotted point represents average of at least three tests.

Figure 3.- Decrease in shear strength caused by increasing bearing stresses.




All rivets 1/2 inch in diameter, driven with cone-point heads, tested in single shear in 24S-T plates. Each plotted point represents average of at least three tests.

Figure 4.- Decrease in shear strength caused by increasing D/t ratio, single shear.




All rivets 1/2 inch in diameter driven with cone-point heads and tested in double shear. Each plotted point represents the average of at least two tests.

Figure 5.- Decrease in shear strength caused by increasing D/t ratio, double shear.

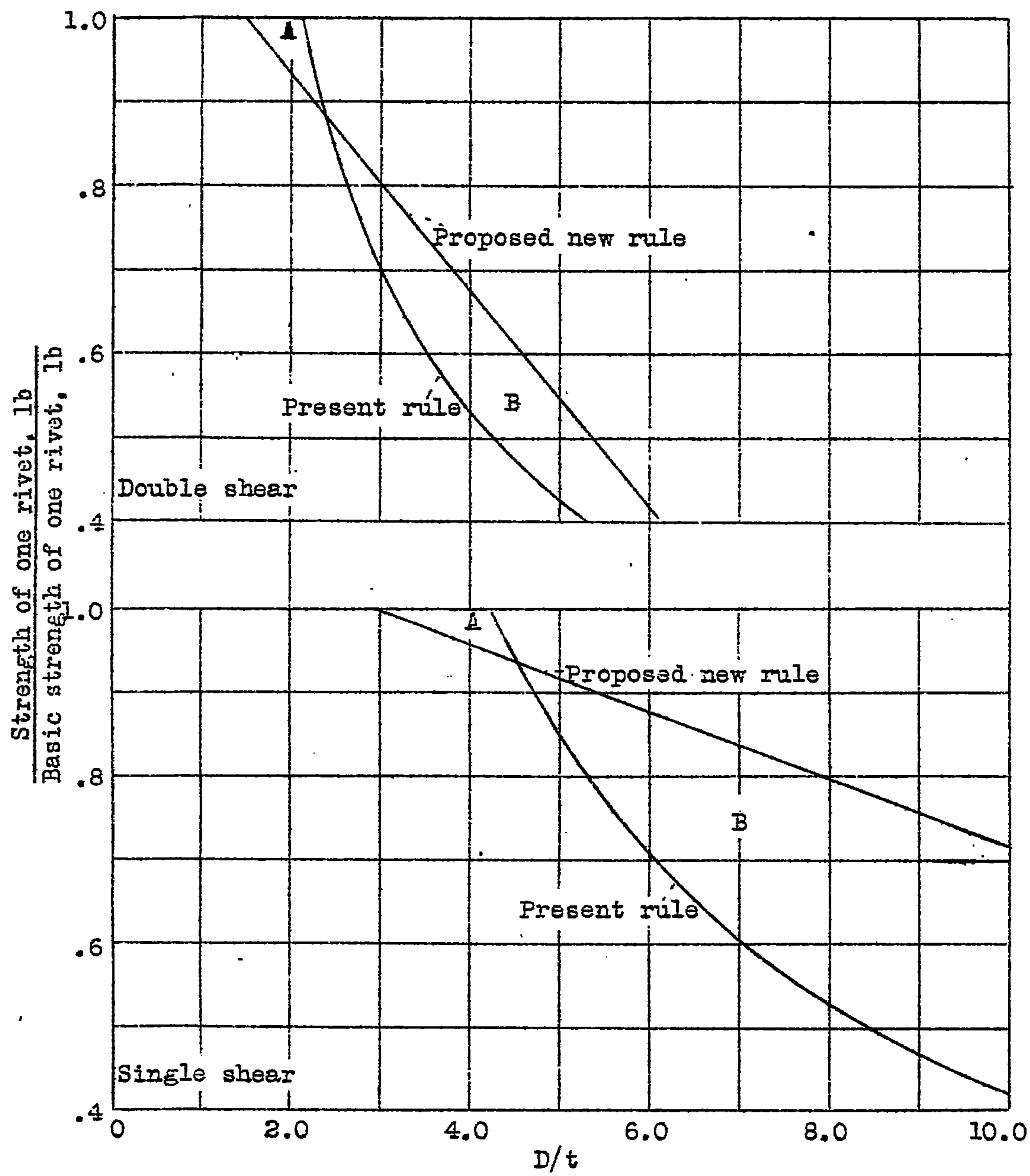
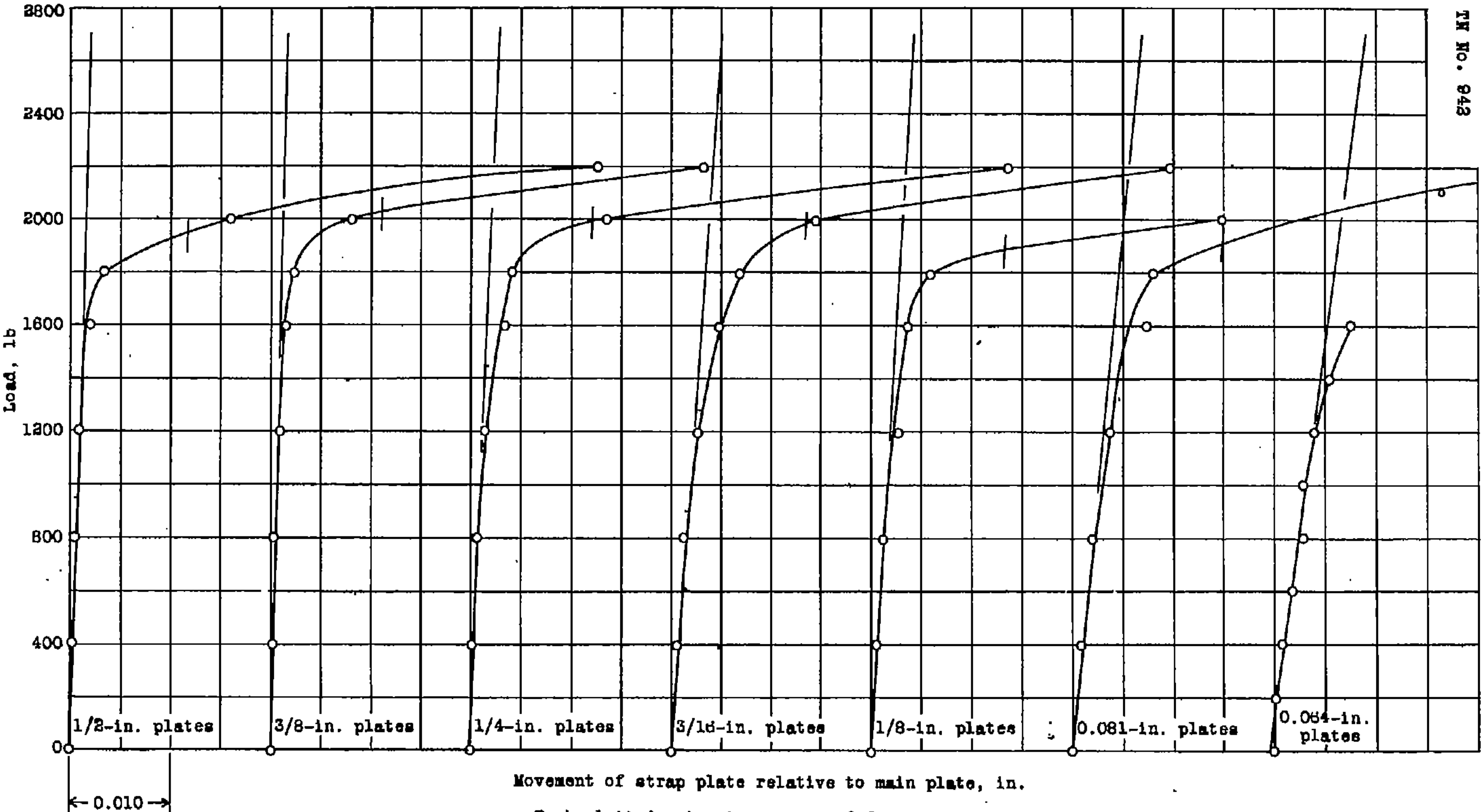
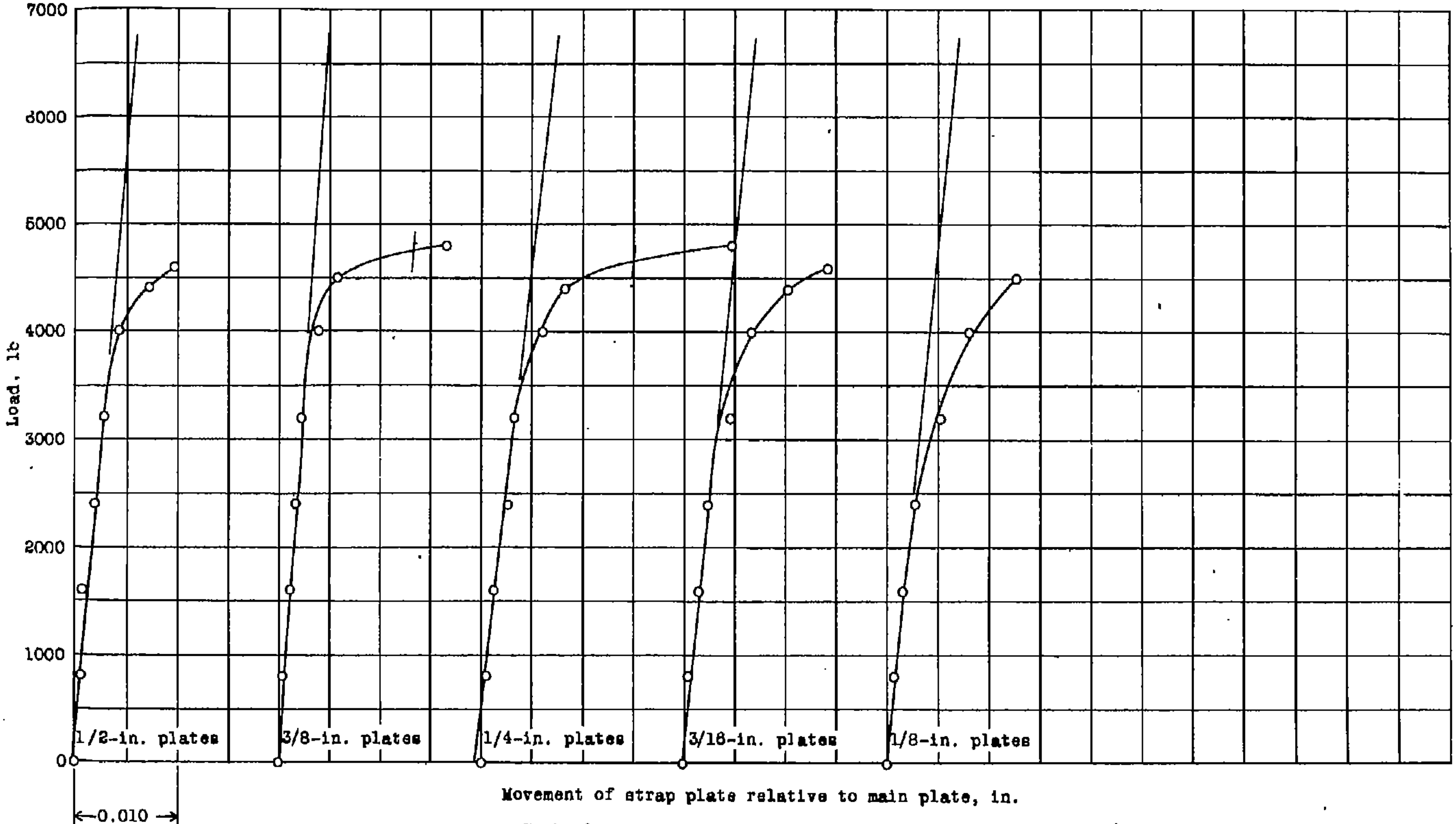



Figure 6.- Comparison of present rule and proposed new rules for effect of D/t on shear values, aluminum alloy.



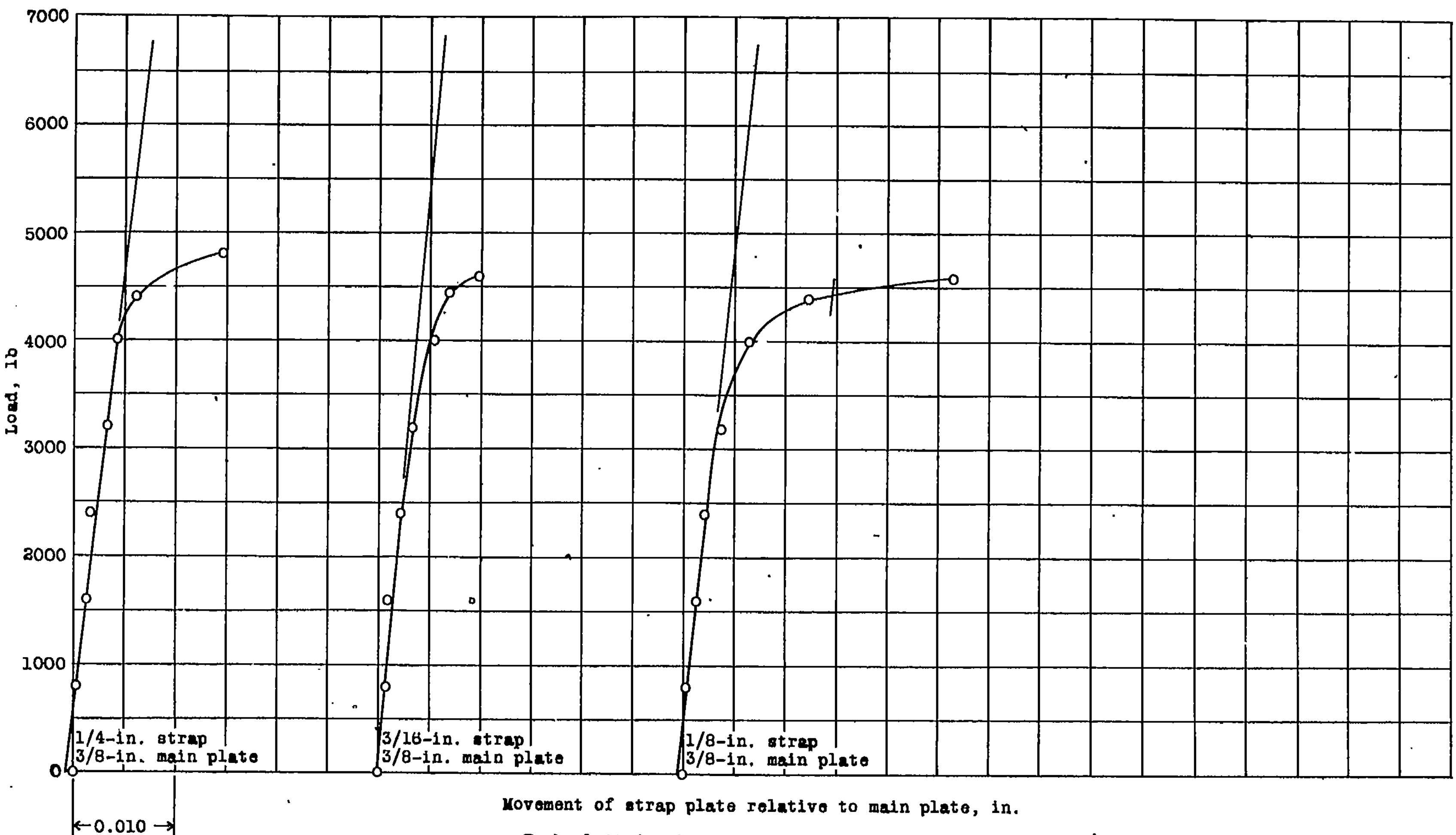

Each plotted point is average of four readings.

Figure 7.- Load-deformation curves for single shear riveted joints, 53S-O rivets, 24S-T plate.




Each plotted point is average of four readings.

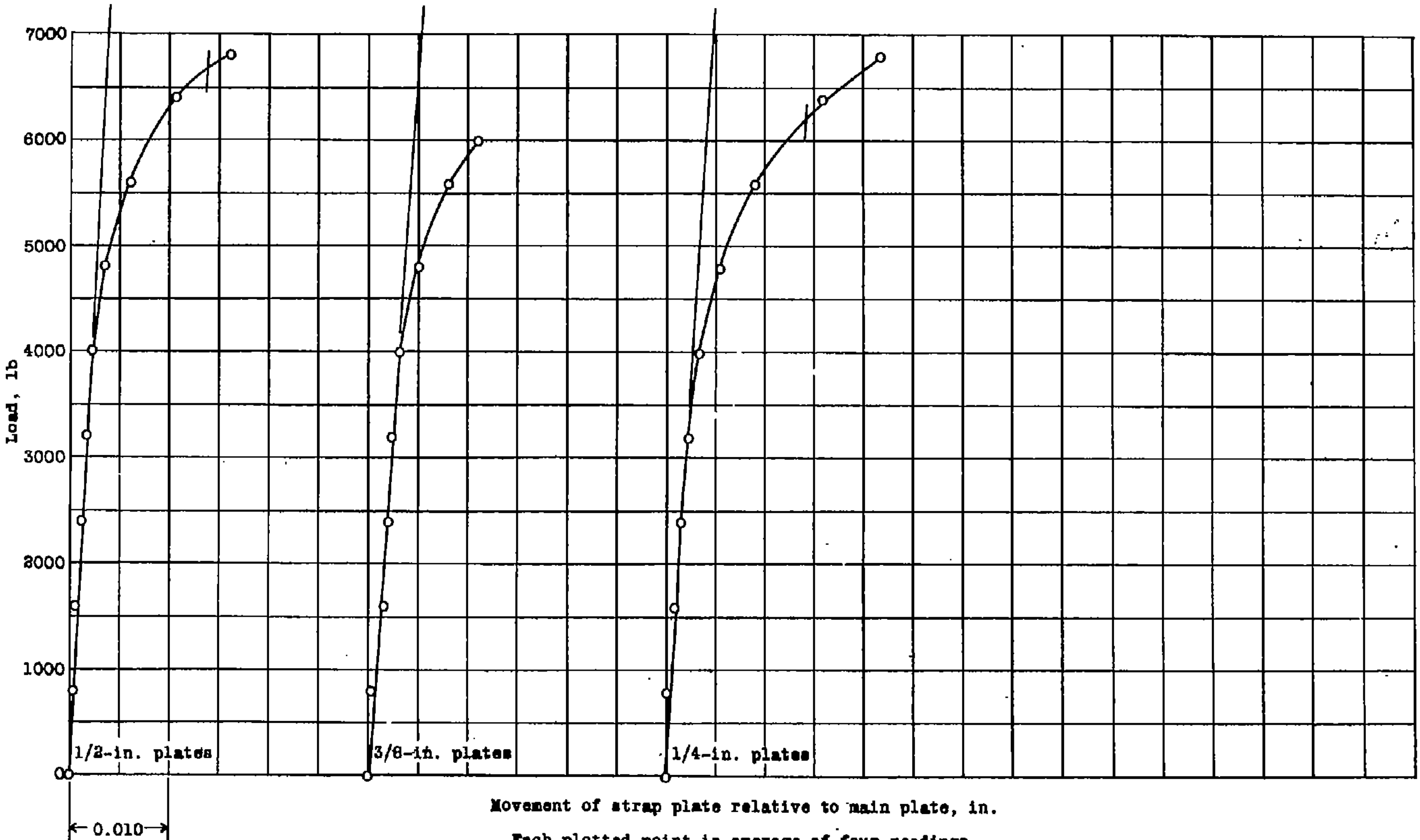
Figure 8.- Load-deformation curves for single shear riveted joints, 53S-T61 rivets, 24S-T plate.




Movement of strap plate relative to main plate, in.

Each plotted point is average of four readings.

Figure 9.- Load-deformation curves for single shear riveted joints, 53S-T61 rivets, 24S-T plate.




Movement of strap plate relative to main plate, in.

Each plotted point is average of four readings.

Figure 10.- Load-deformation curves for single shear riveted joints, 17S-T rivets, 24S-T plate.