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TEST DATA ON THE SHEAR STRENGTH OF MACHINE COUNTERSUNK-RIVETED
JOINTS ASSEMBLED BY AN NACA FLUSH-RIVETING PROCEDURE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESTRICTED BULLETIN

TEST DATA ON THE SHEAR STRENGTH OF MACHINE-COUNTERSUNK RIVETED JOINTS ASSEMBLED BY AN NACA FLUSH-RIVETING PROCEDURE

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SUMMARY

Load-displacement curves for use in establishing allowable-load values for riveted joints assembled by an NACA flush-riveting procedure are presented. Comparative data are also given to show the effect of variations in the procedure on the yield and maximum shear loads for the rivets.

When the manufactured round head of the rivet is driven with a vibrating gun while the shank end is bucked into the countersunk hole with a bar and the portion of the formed head that protrudes above the skin surface after the rivet is driven is removed with a flush-rivet milling tool, it is concluded that:

1. The variations of rivet-head angle investigated (45° to 82°) have no consistent effect on the yield and maximum shear loads

2. The yield load is almost independent of countersunk depth

Interchanging the vibrating gun and the bucking bar in the foregoing method of driving does not change the yield and maximum shear loads for the rivets.

When the hole is countersunk at both ends, a headless rivet inserted, and countersunk heads formed at both ends of the rivet, there is no change in the yield and maximum shear loads from the values obtained by the preceding methods of driving.

INTRODUCTION

The structural quality of a riveted joint must involve a consideration of both the tightness and the strength of

the joint. A joint is tight when the parts joined by the rivets are not permanently displaced with respect to each other until loads approaching the maximum strength of the joint are applied. A suitably defined yield strength, based upon the load-displacement curve, therefore affords a good basis for numerical comparison of the structural quality of riveted joints.

In the previous experimental studies of flush-riveting methods, reported in references 1 to 4, the emphasis was placed on the development of methods for increasing the tightness and flushness of machine-countersunk rivets. This report presents load-displacement curves suitable for use in establishing allowable-load values for riveted joints assembled by one of the flush-riveting procedures described in references 1 and 2. In addition, comparative data are given to show the effect of two variations in this procedure on the yield and maximum shear loads for the rivets.

SPECIMENS, RIVETING METHODS, AND TEST PROCEDURE

The specimens for this study consisted of two sheets of 24S-T aluminum alloy assembled into a lap joint by two Al7S-T aluminum-alloy rivets as shown in figure 1.

The method of riveting used for most of the tests and the two variations of this method are as follows:

Vibrating gun on manufactured head of rivet.- This method, which was designated method E in references 1 and 2, is illustrated in figure 2. The manufactured round head of the rivet is driven with a vibrating gun while the shank end is bucked into the countersunk hole with a bar. After the rivet is driven, the portion of the formed head that protrudes above the skin surface is removed with a flush-rivet milling tool similar to that described in reference 3.

Vibrating gun on shank end of rivet.- This method, illustrated in figure 3, differs from the foregoing method in that the gun and the bar are interchanged in the driving of the rivet.

Rivet countersunk on both ends.- This method is illustrated in figure 4. The hole is countersunk at both ends and a headless rivet is inserted. Countersunk heads are then formed in driving at both ends of the rivet.

L-523

Loads were applied to the specimens through Templin grips with a hydraulic testing machine accurate within one-half of 1 percent. Displacements of one sheet with respect to the other were measured on the edges of the sheets opposite the center of the riveted joint by means of two 18-power microscopes with filar micrometers. Both the displacement under load and the permanent displacement after removal of the load were measured for successively increasing loads until failure occurred.

RESULTS

Vibrating gun on manufactured head of rivet.- Load-displacement curves for different combinations of rivet diameter, sheet thickness, countersunk depth, and rivet-head angle are presented in figures 5 to 16. The yield load and the maximum load are plotted in figures 17, 18, and 19 against the rivet-head angle, and in figures 20, 21, and 22 against the countersunk depth, for varying values of the other dimensions. For purposes of plotting, the yield load is here arbitrarily defined as the shear load per rivet at which the sheets are permanently displaced with respect to each other a distance equal to 4 percent of the rivet diameter. Figures 17, 18, and 19 show, as in figure 16 of reference 1, that within the normal scatter of test data the variations of rivet-head angle investigated had no consistent effect on the yield and the maximum loads. Figures 20, 21, and 22 bear out the conclusion drawn from figure 4 of reference 2 that, for rivets of the type used in this investigation, the yield load is almost independent of countersunk depth.

Vibrating gun on shank end of rivet.- Results of the tests of rivets driven with the vibrating gun on the shank end of the rivet are compared with results of similar tests of rivets driven by the first method in figure 23. From this figure, allowing for normal scatter, it is concluded that interchanging the vibrating gun and the bucking bar in driving the rivets does not change the yield and the maximum loads.

Rivet countersunk on both ends.- Results of tests of rivets countersunk on both ends are compared with results of similar tests of rivets driven by the first method in figure 24. From this figure, allowing for normal scatter, it is concluded that countersinking the rivets on both ends also does not change the yield and the maximum loads.

CONCLUSIONS

When the manufactured round head of the rivet is driven with a vibrating gun while the shank end is bucked into the countersunk hole with a bar and the portion of the formed head that protrudes above the skin surface after the rivet is driven is removed with a flush-rivet milling tool, it is concluded that:

1. The variations of rivet-head angle investigated (45° to 82°) had no consistent effect on the yield and maximum shear loads

2. The yield load is almost independent of countersunk depth

Interchanging the vibrating gun and the bucking bar in the foregoing method of driving does not change the yield and maximum shear loads for the rivets.

When the hole is countersunk at both ends, a headless rivet inserted, and countersunk heads formed at both ends of the rivet, there is no change in the yield and maximum shear loads from the values obtained by the preceding methods of driving.

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REFERENCES

1. Lundquist, Eugene E., and Gottlieb, Robert: A Study of the Tightness and Flushness of Machine-Countersunk Rivets for Aircraft. NACA R. B., June 1942.
2. Gottlieb, Robert: Effect of Countersunk Depth on the Tightness of Two Types of Machine-Countersunk Rivet. NACA R. B., Oct. 1942.
3. Gottlieb, Robert: A Flush-Rivet Milling Tool. NACA R. B., June 1942.
4. Gottlieb, Robert, and Mandel, Mervyn W.: Comparison of Tightness of 78° Machine-Countersunk Rivets Driven in Holes Prepared with 70° and 82° Countersinking Tools. NACA R. B., Sept. 1942.

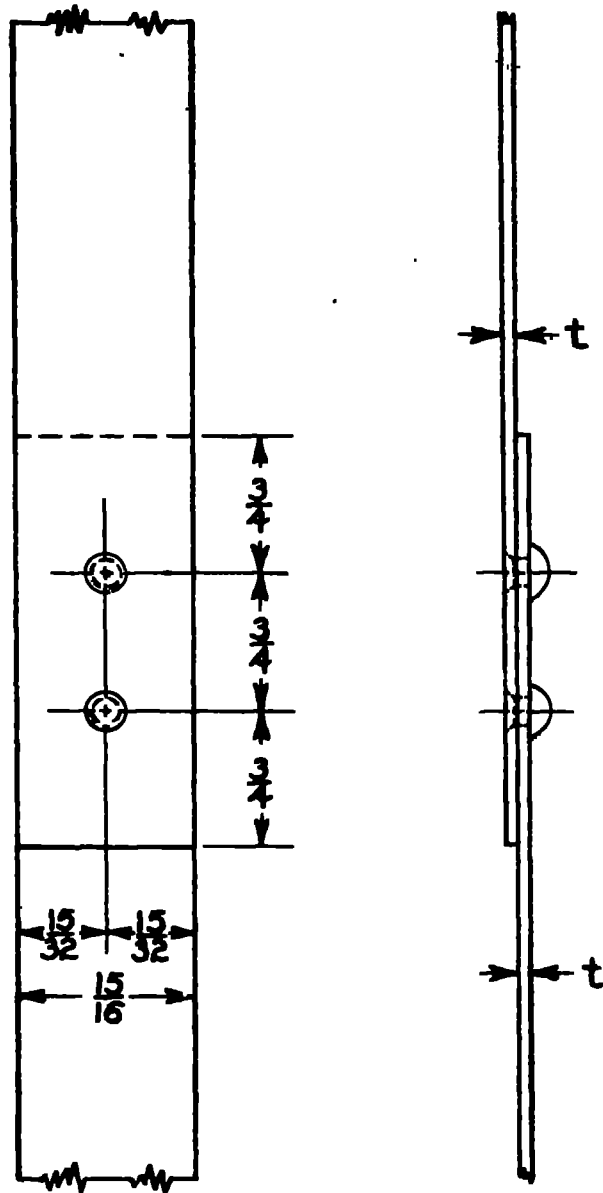


Figure 1.- Test specimen.

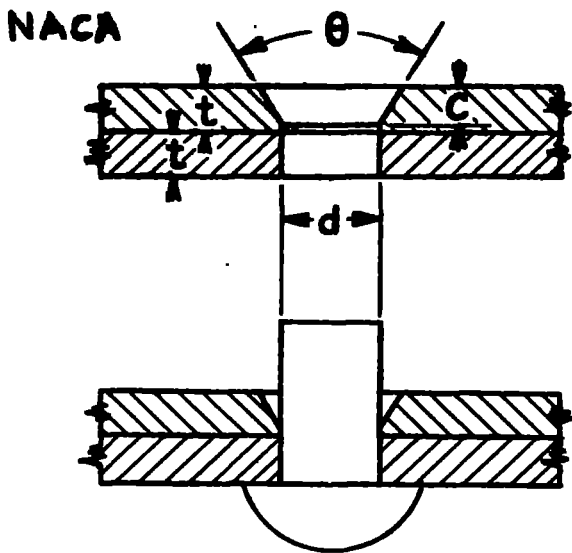
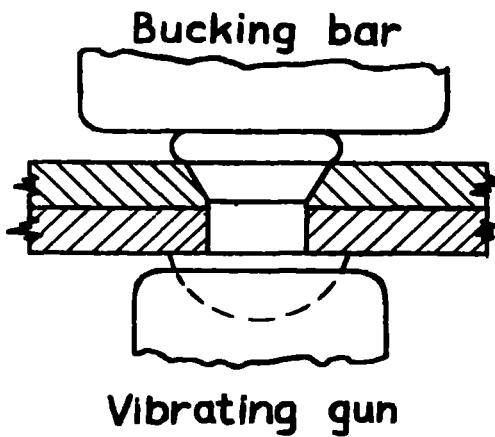


Fig. 2

Countersunk sheet

Rivet before driving



Rivet after driving

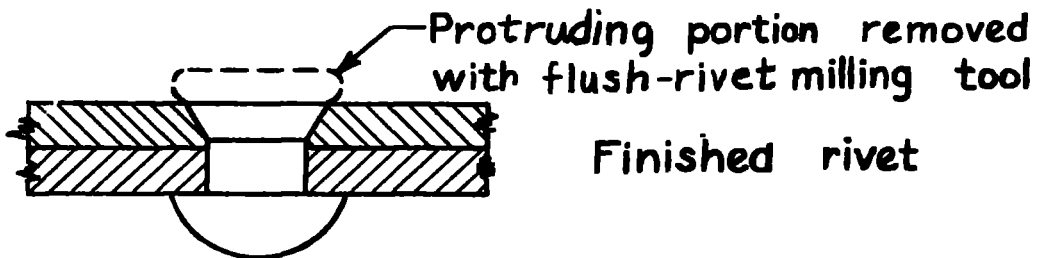
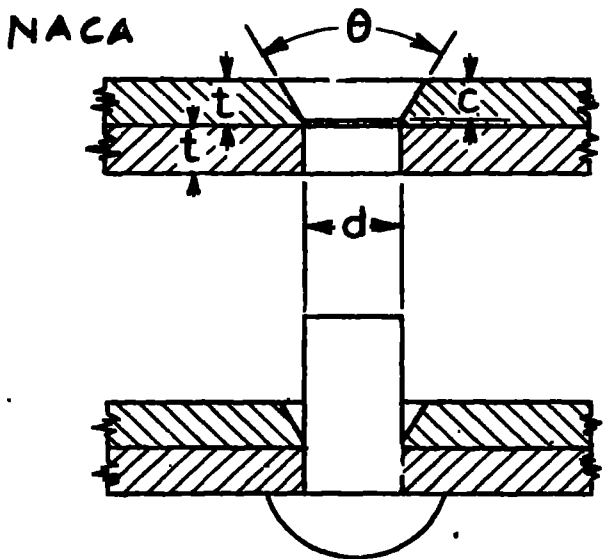


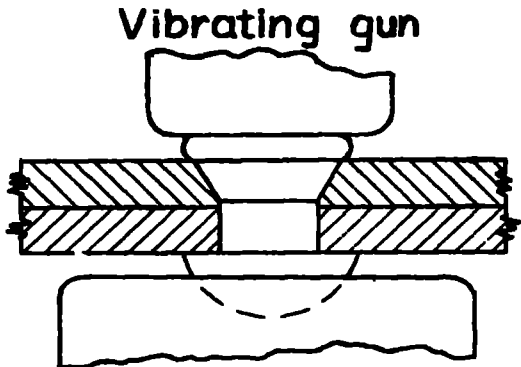
Figure 2. - Successive operations in the flush-riveting procedure.

Fig. 3



Countersunk sheet

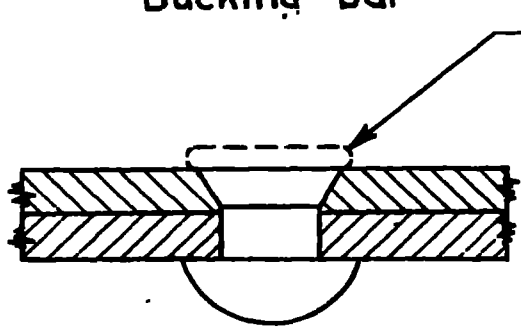
Rivet before driving



Vibrating gun

Rivet after driving

Bucking bar

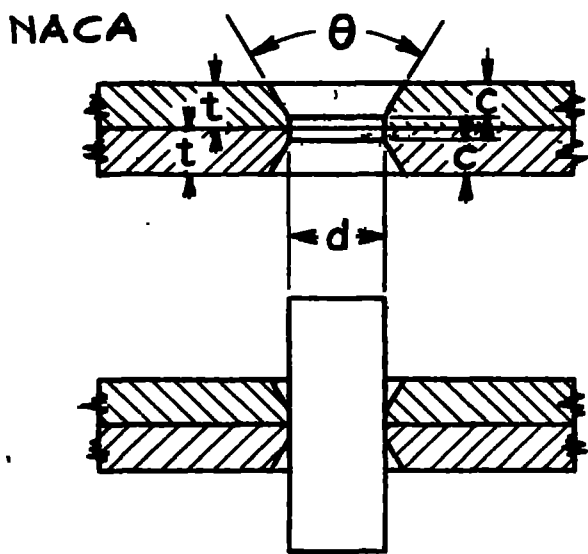


Protruding portion removed with flush-rivet milling tool

Finished rivet

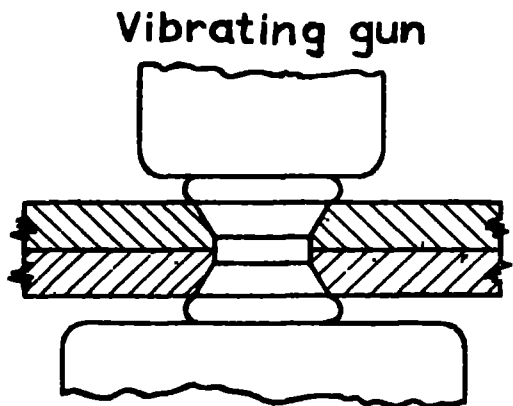
Figure 3. - Successive operations in the flush-riveting procedure with gun and bar interchanged.

Fig. 4



Countersunk sheets

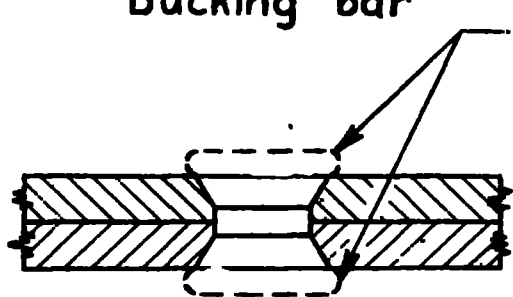
Rivet before driving



Vibrating gun

Rivet after driving

Bucking bar



Protruding portions removed with flush-rivet milling tool

Finished rivet

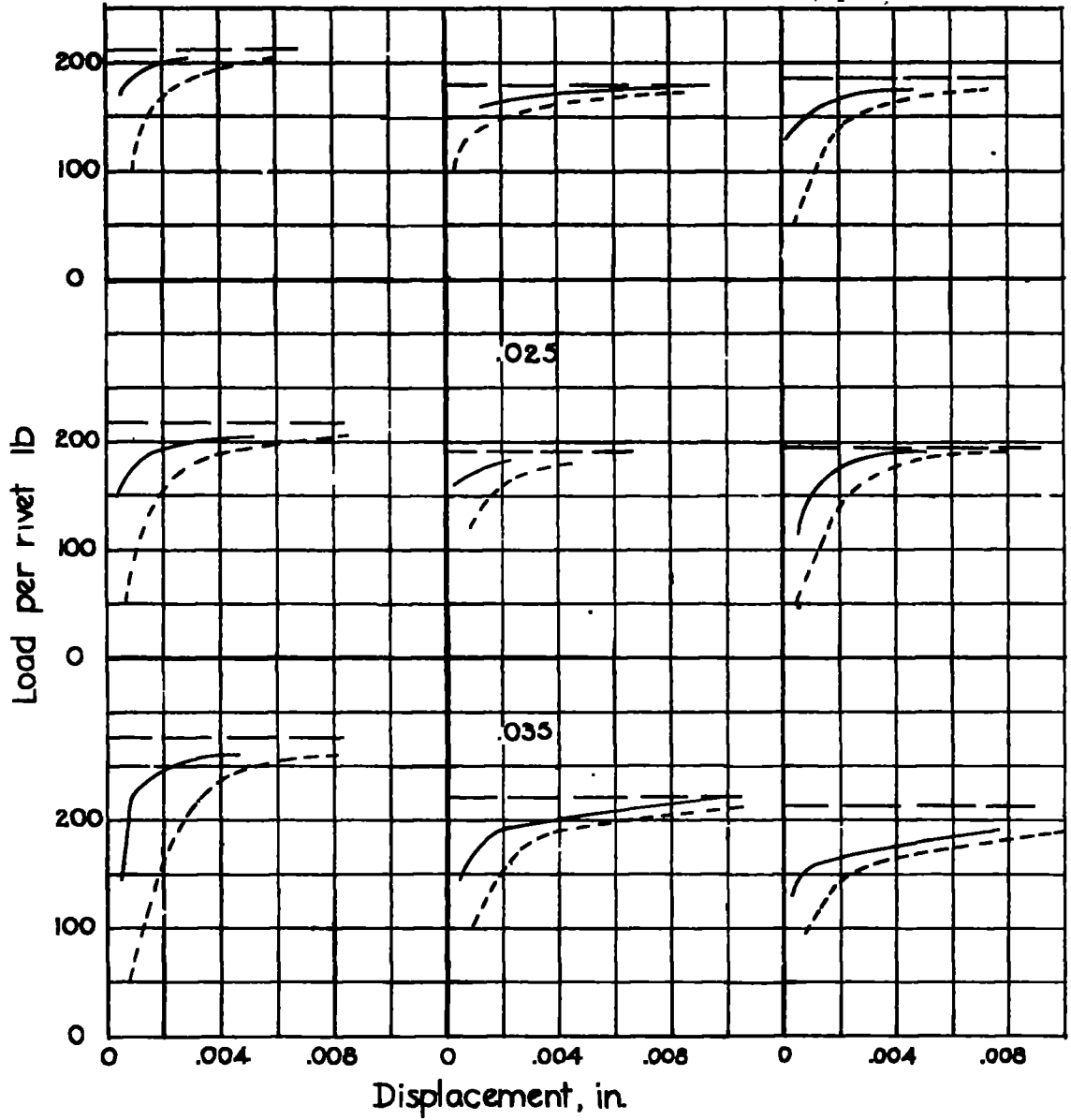
Figure 4. - Successive operations in the flush-riveting procedure with the rivet countersunk on both ends.

$\theta = 45^\circ$

60°

82°

$c = 0.015 \text{ in.}$



- Permanent displacement
- - - - - Displacement under load
- · - · - Maximum load

Figure 5. - Load - displacement curves. $t = 0.025 \text{ in.}$; $d = \frac{3}{32} \text{ in.}$

$C = 0.015$ in.

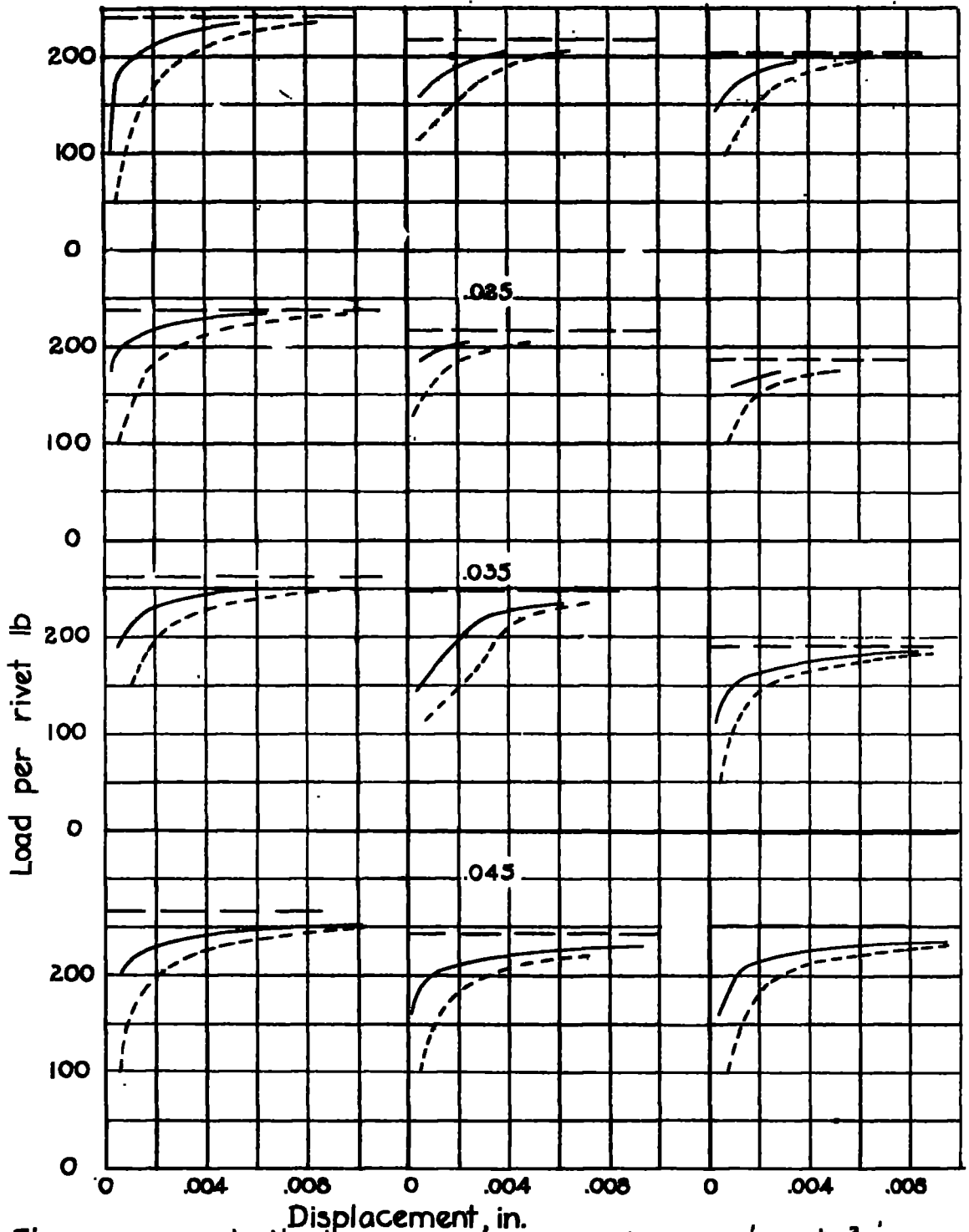
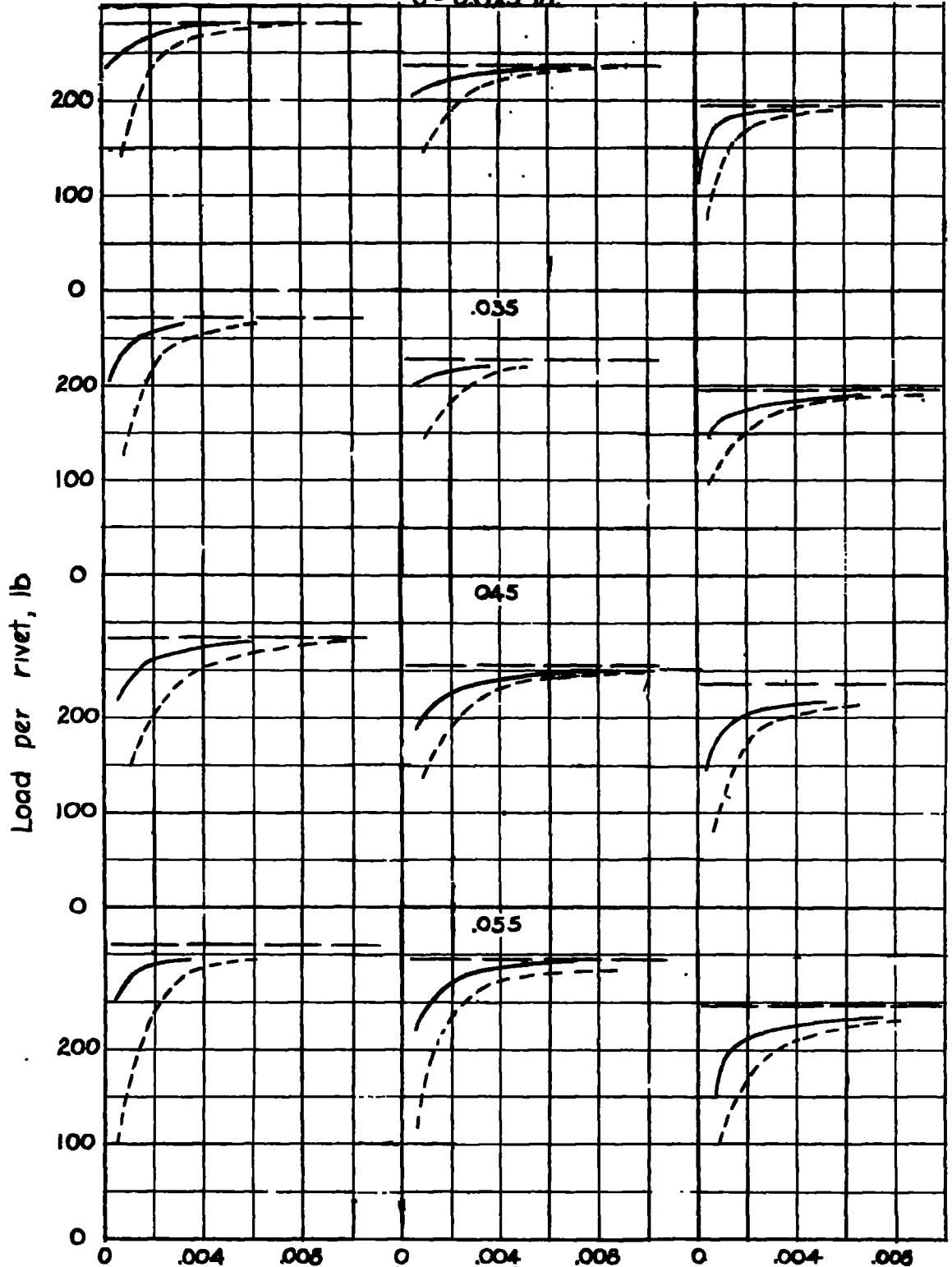


Figure 6. - Load-displacement curves. $t = 0.032$ in.; $d = \frac{3}{32}$ in.

- Permanent displacement
- Displacement under load
- · - · - Maximum load

$c = 0.025 \text{ in.}$

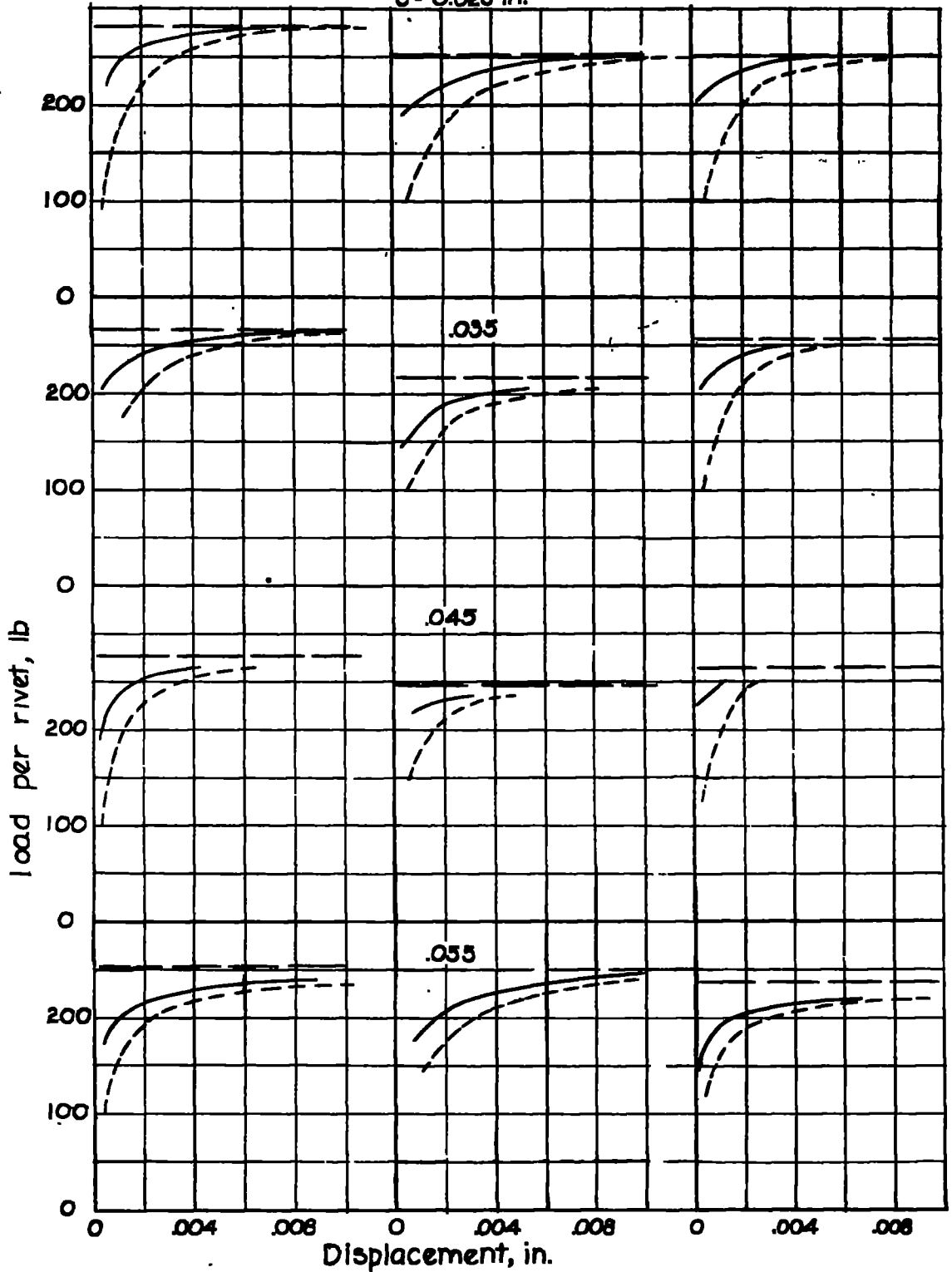


(Figure 7.-Load-displacement curves
 $t = 0.040 \text{ in.}$;
 $d = \frac{1}{32} \text{ in.}$)

Displacement, in.

————— Permanent displacement
 - - - - - Displacement under load
 - · - · - Maximum load

$c = 0.025$ in.



- Permanent displacement
- Displacement under load
- · - · - Maximum load

Figure 8.- Load-displacement curves, $t = 0.051$ in., $d = \frac{3}{8}$ in.

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$\theta = 45^\circ$

60°

82° Fig. 9

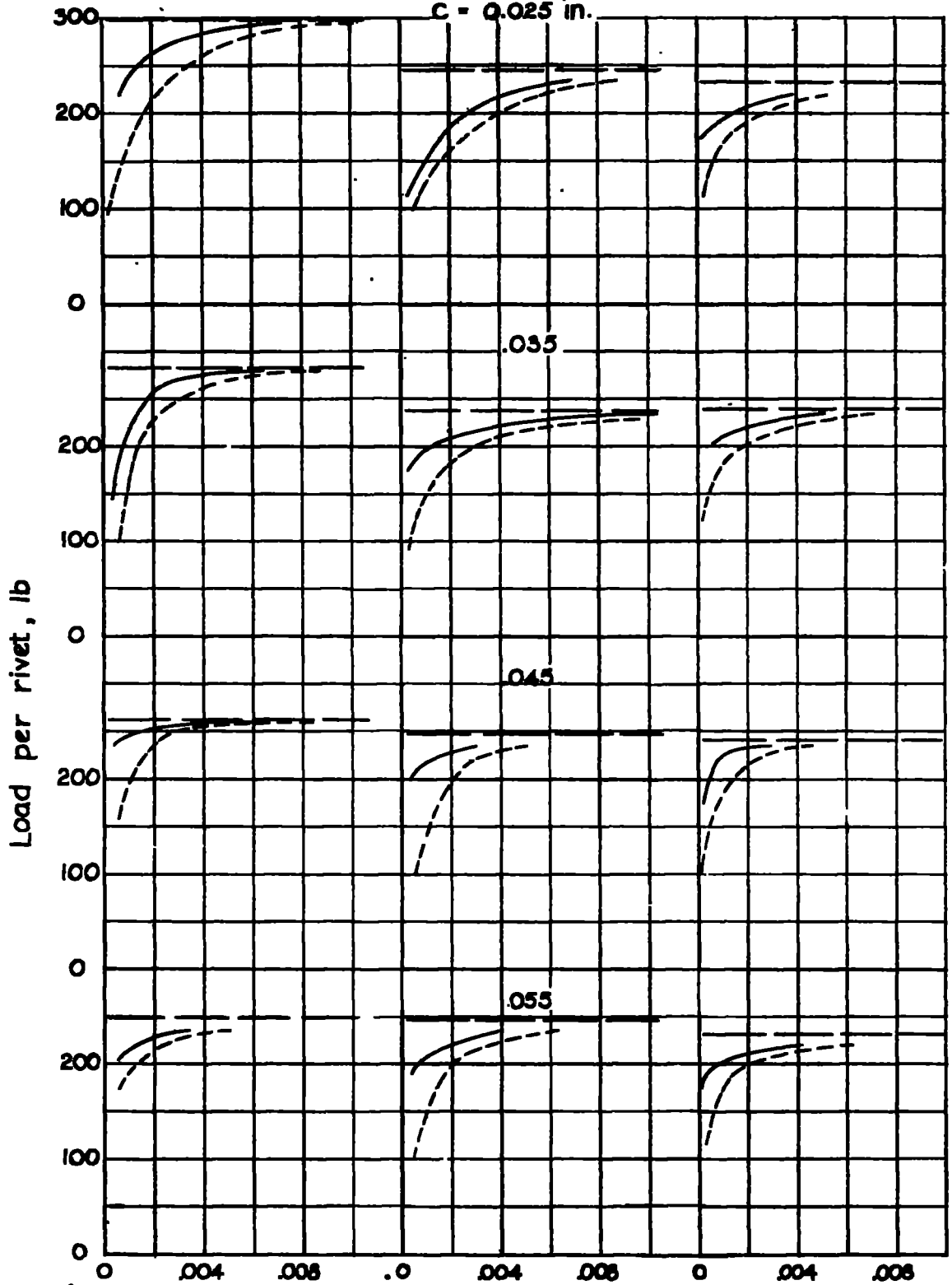


Figure 9. - Load-displacement curves.

$t = 0.064$ in.

$d = 7/32$ in.

Displacement, in.

Permanent displacement

Displacement under load

Maximum load

$c = 0.015$ in.

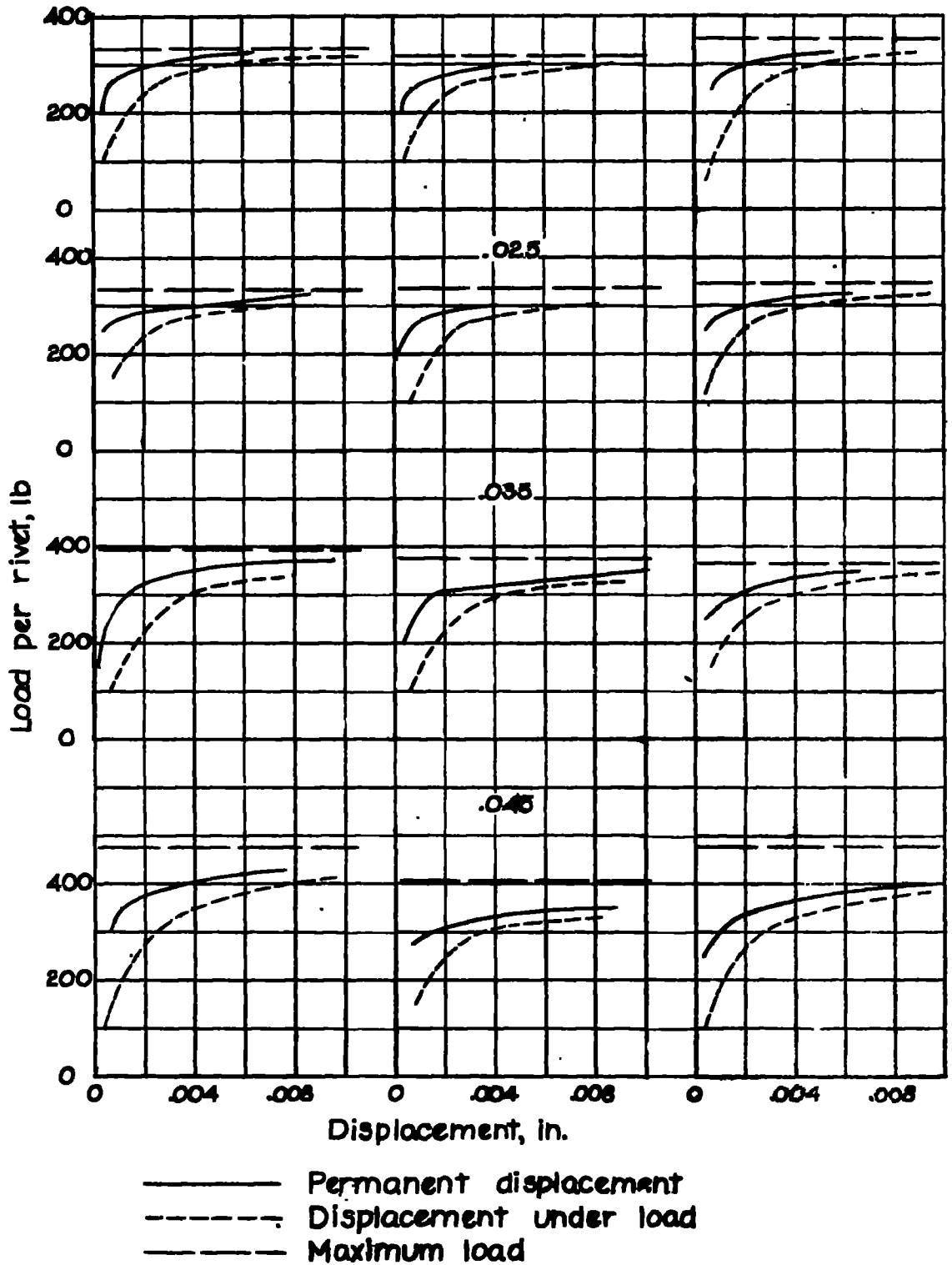


Figure 10.-Load - displacement curves. $t = 0.032$ in., $d = \frac{1}{8}$ in.

$c = 0.025$ in.

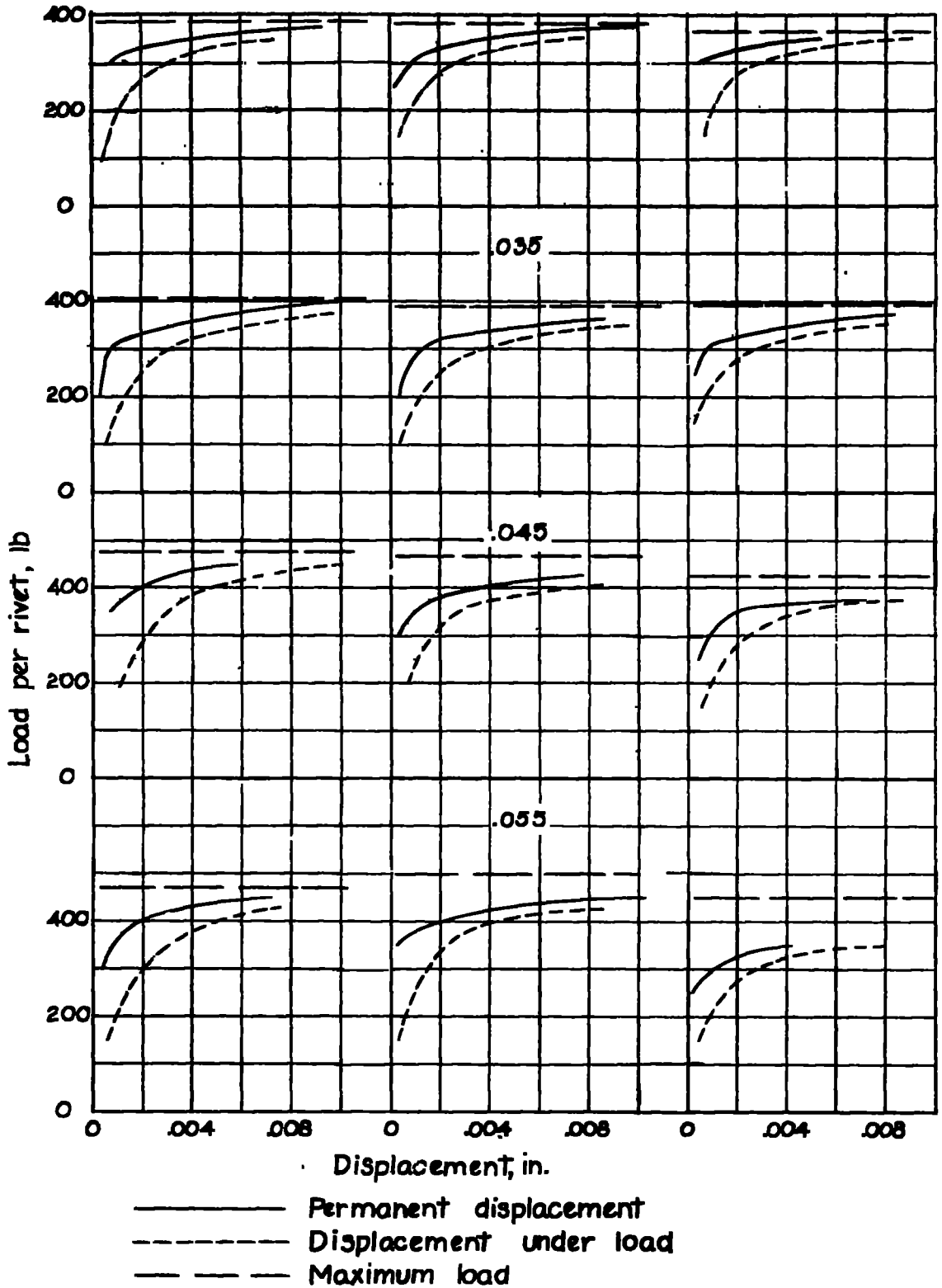


Figure 11.-Load- displacement curves. $t = 0.040$ in., $d = \frac{1}{8}$ in.

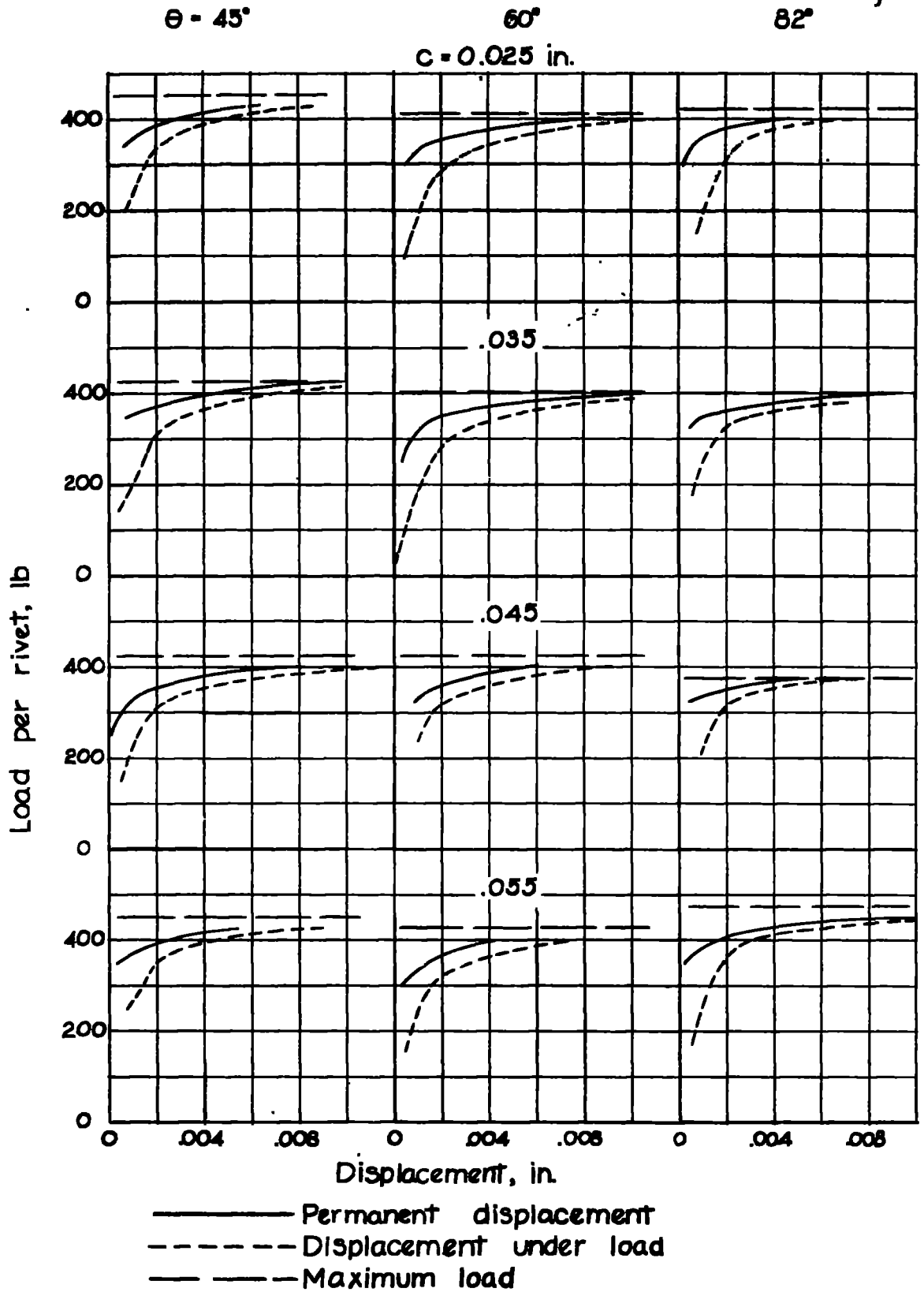


Figure 12.-Load-displacement curves. $t = 0.05$ in., $d = \frac{1}{8}$ in.

$c = 0.035$ in.

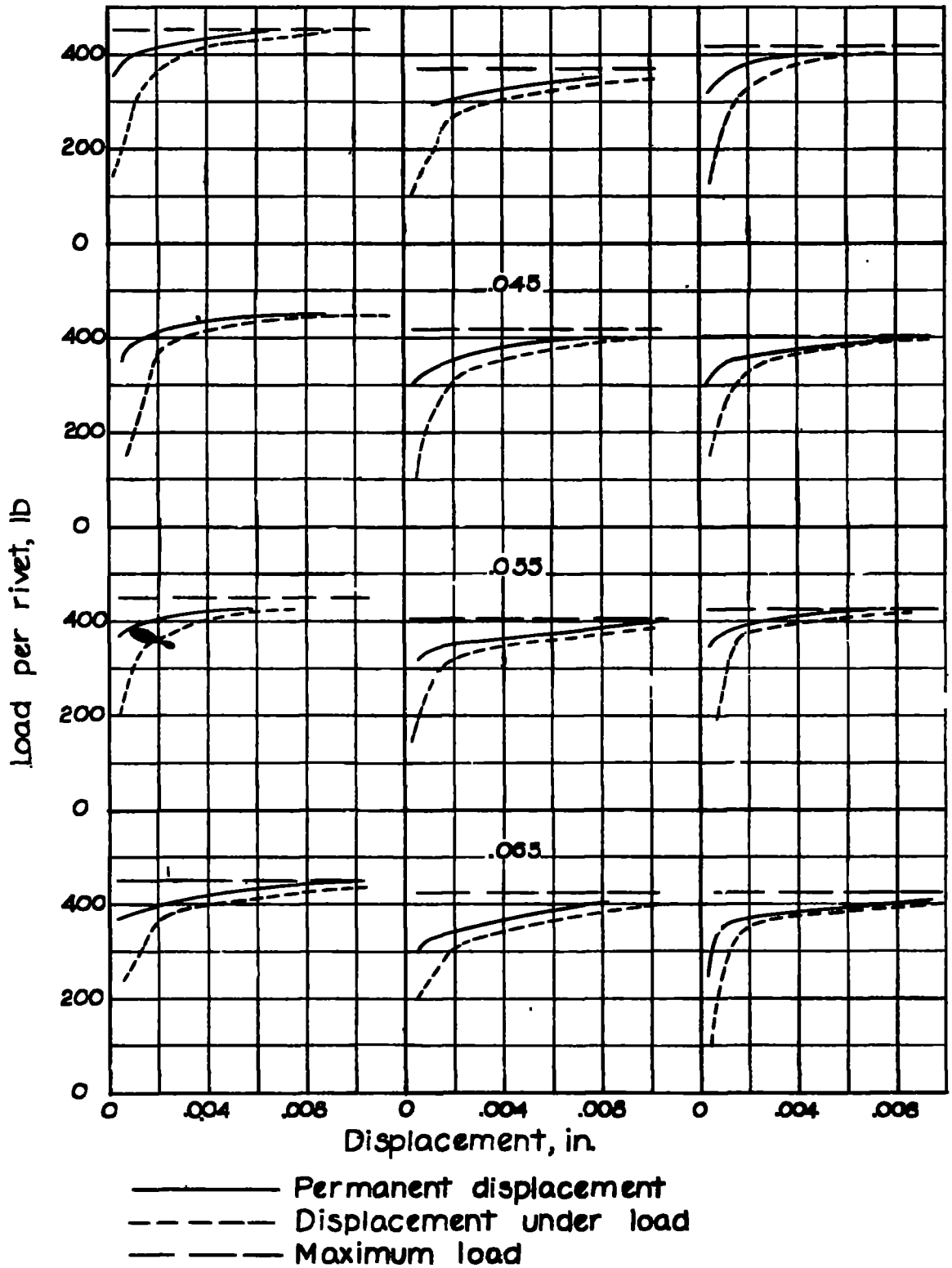
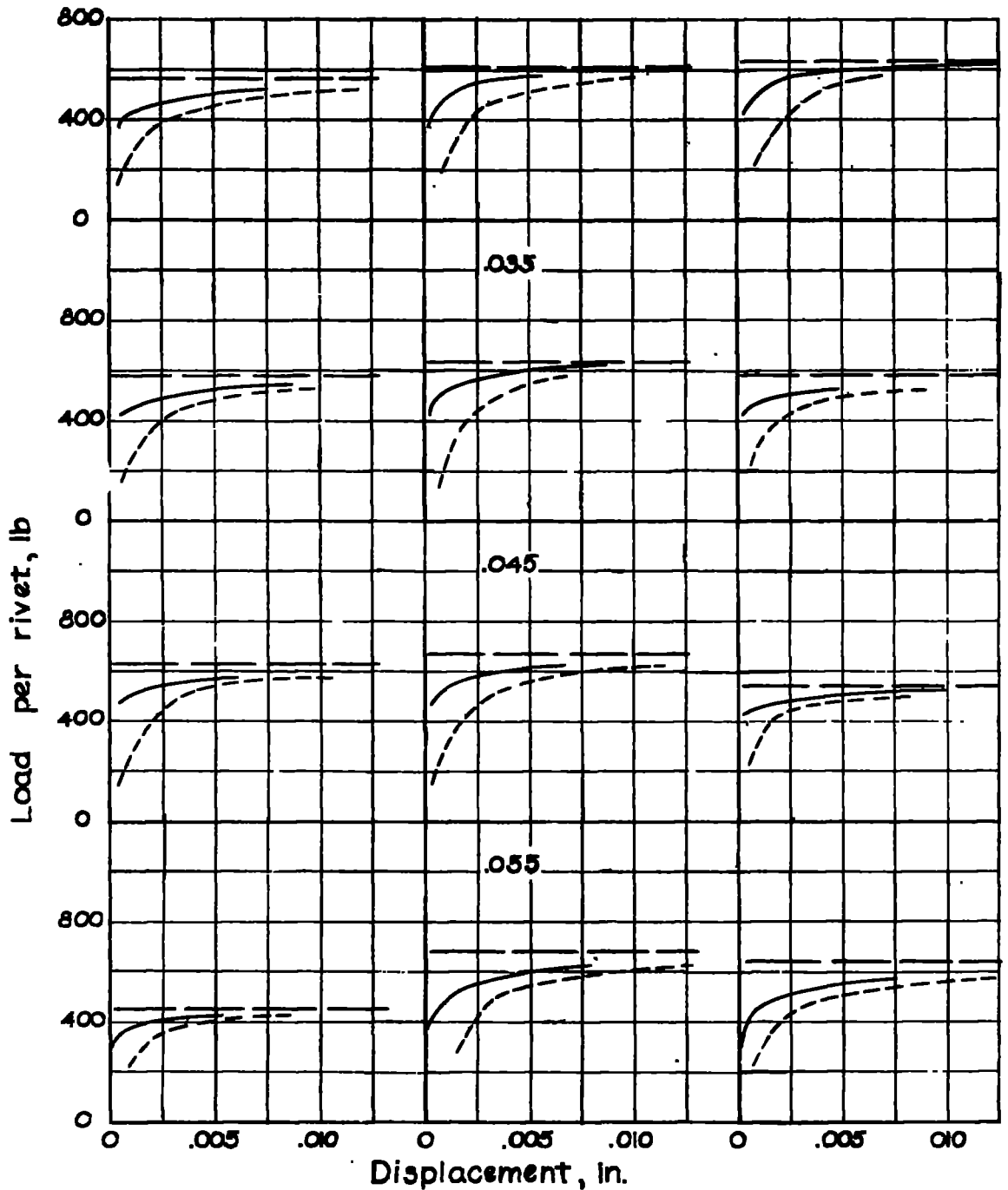


Figure 13.-Load-displacement curves. $t = 0.064$ in.,

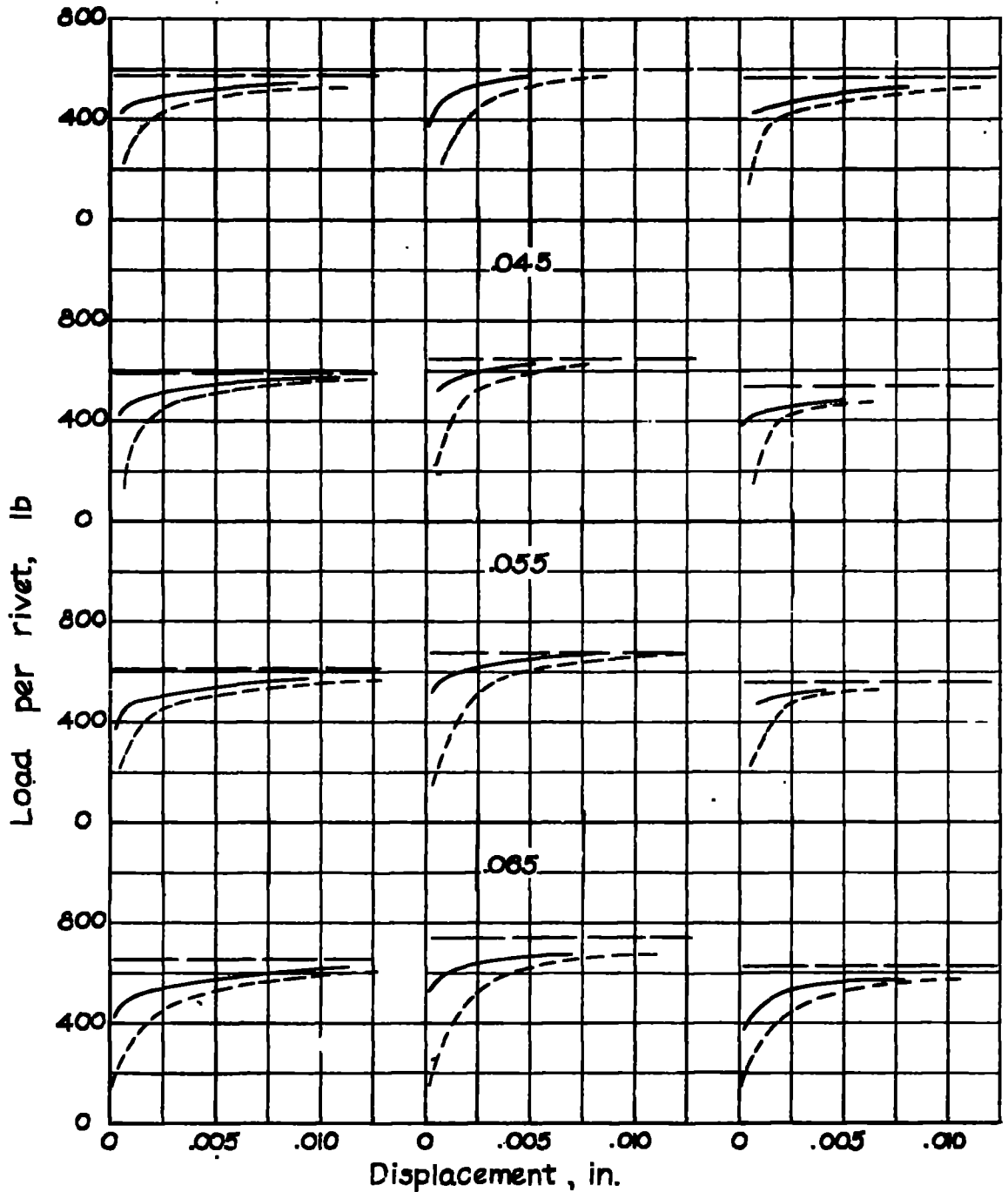
$C = 0.025$ in.



— Permanent displacement
- - - Displacement under load
- · - Maximum load

Figure 14. - Load-displacement curves. $t = 0.051$ in.; $d = \frac{5}{32}$ in.

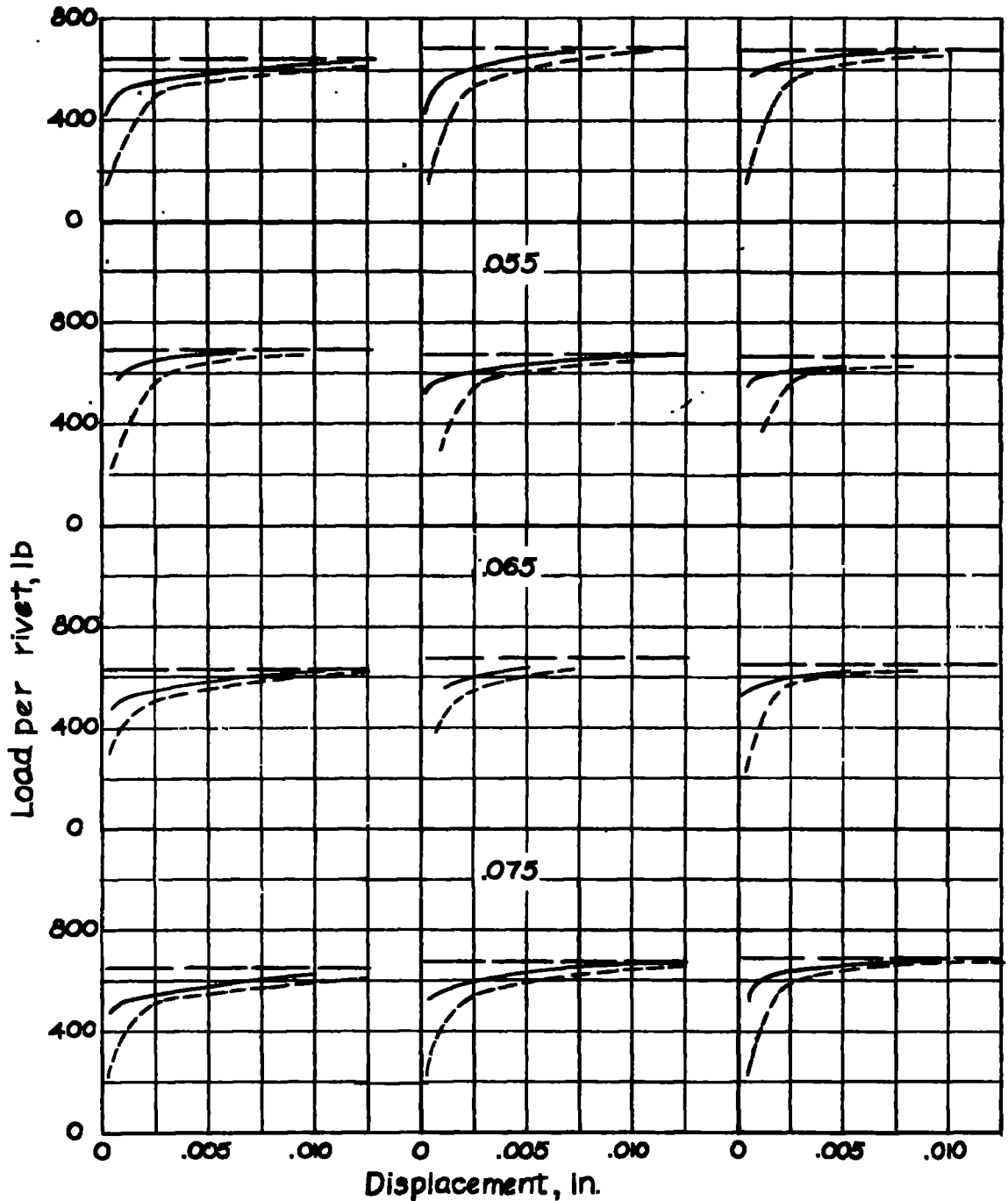
$C = 0.035$ in.



- Permanent displacement
- - - Displacement under load
- · - Maximum load

Figure 15. - Load-displacement curves $t = 0.064$ in.; $d = \frac{5}{32}$ in.

$C = 0.045$ in.



- Permanent displacement
- - - Displacement under load
- · - Maximum load

Figure 16. - Load-displacement curves $t = 0.081$ in., $d = \frac{5}{32}$ in.

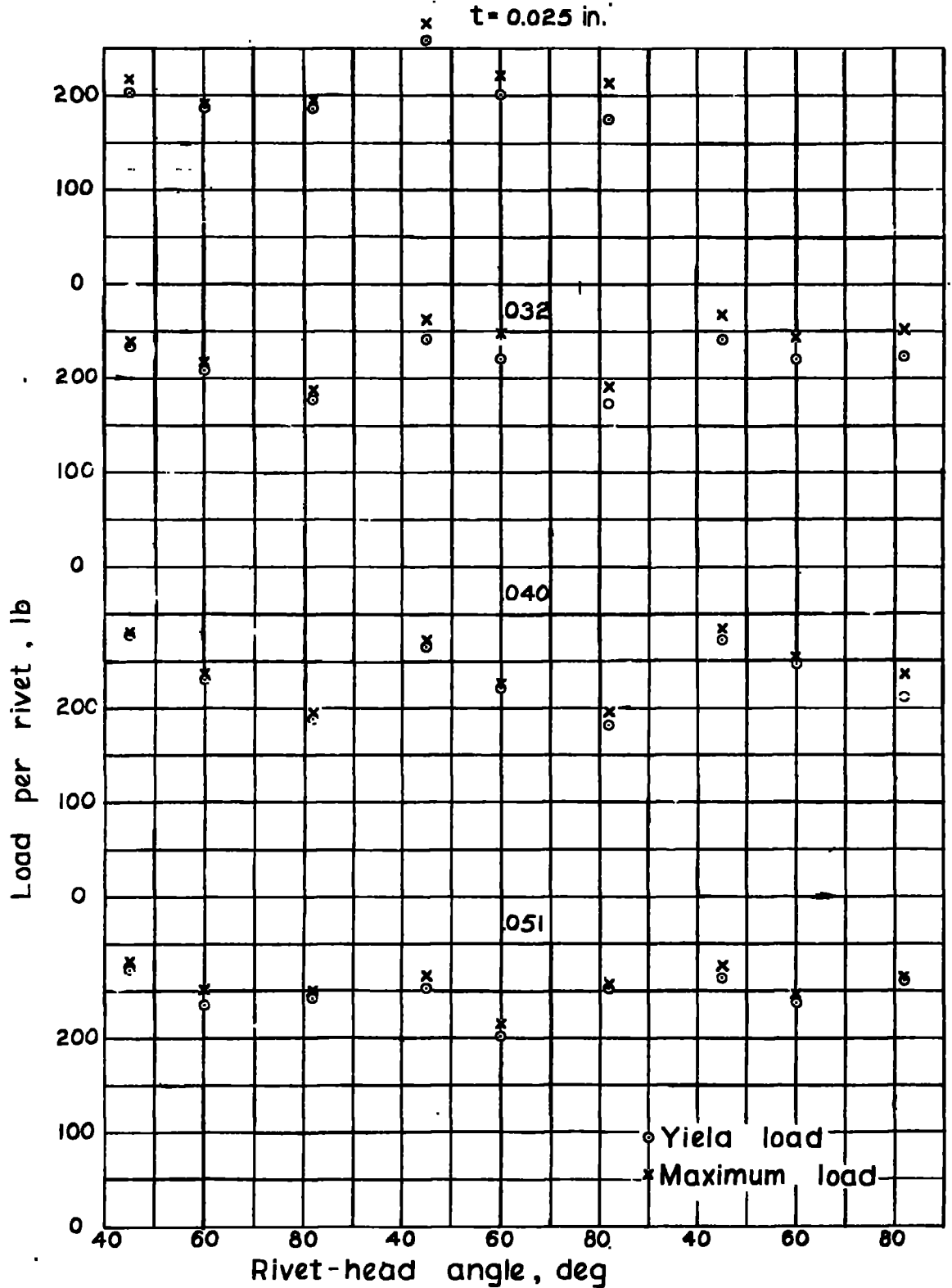


Figure 17.- Variation of yield load and maximum load with rivet-head angle for $\frac{3}{32}$ -inch-diameter rivets.

t = 0.032 in.

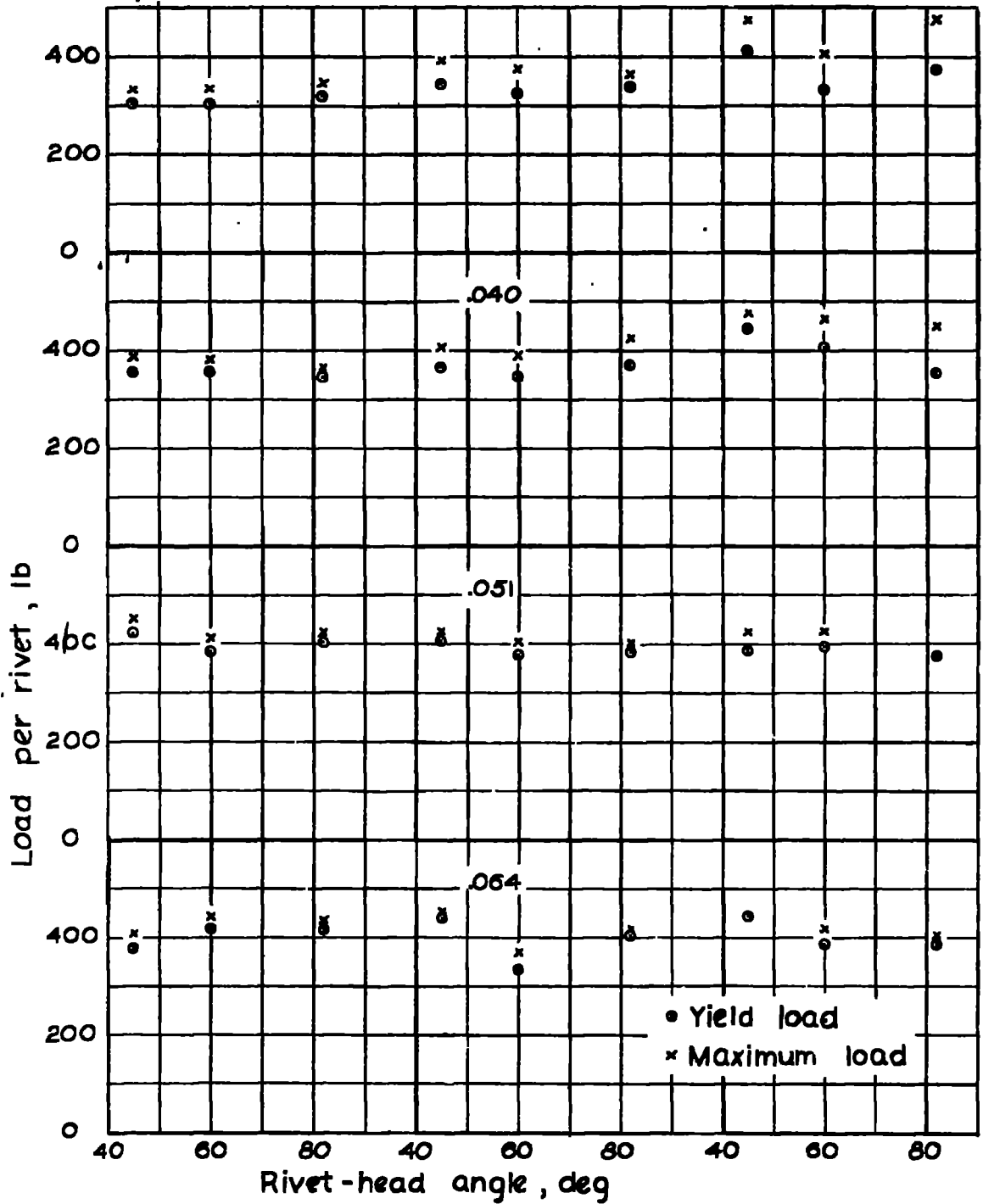


Figure 18.- Variation of yield load and maximum load with rivet-head angle for 1/8-inch-diameter rivets.

t = 0.040 in.

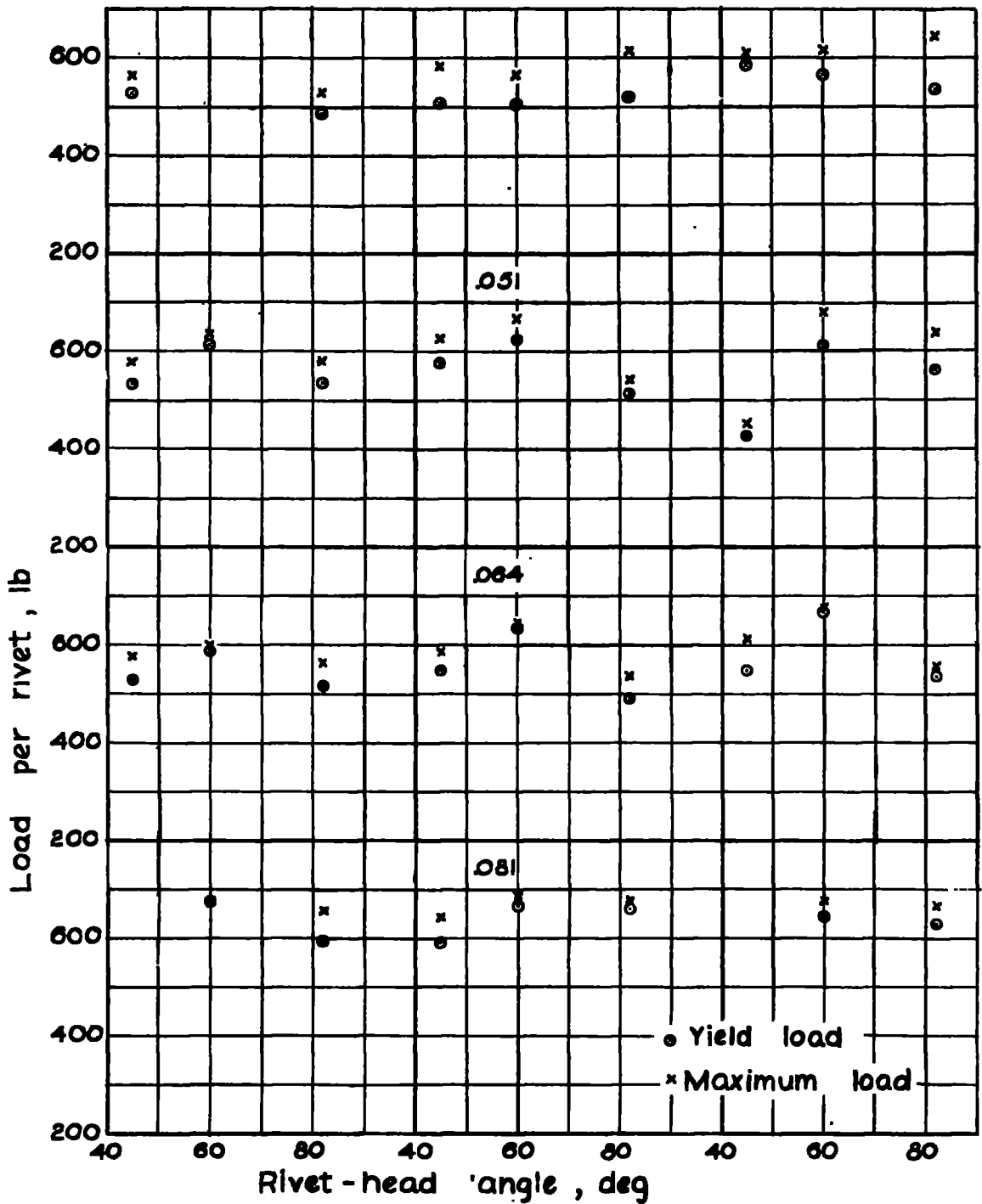


Figure 19 - Variation of yield load and maximum load with rivet-head angle for $\frac{5}{32}$ -inch-diameter rivets.

$t = .0025$ in.

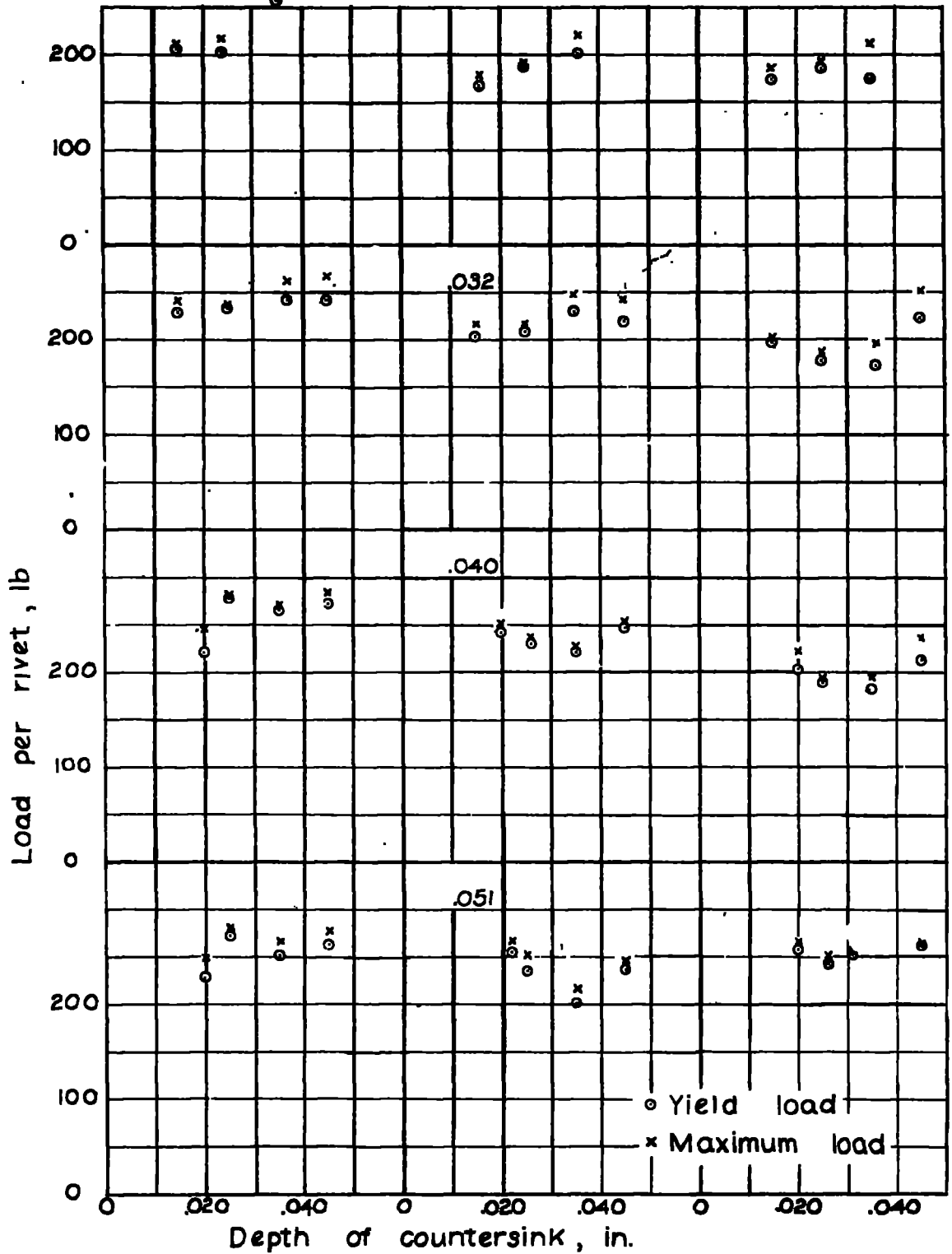


Figure 20.-Variation of yield load and maximum load with depth of countersink for $\frac{1}{32}$ -inch-diameter rivets.

$t = 0.092$ in.

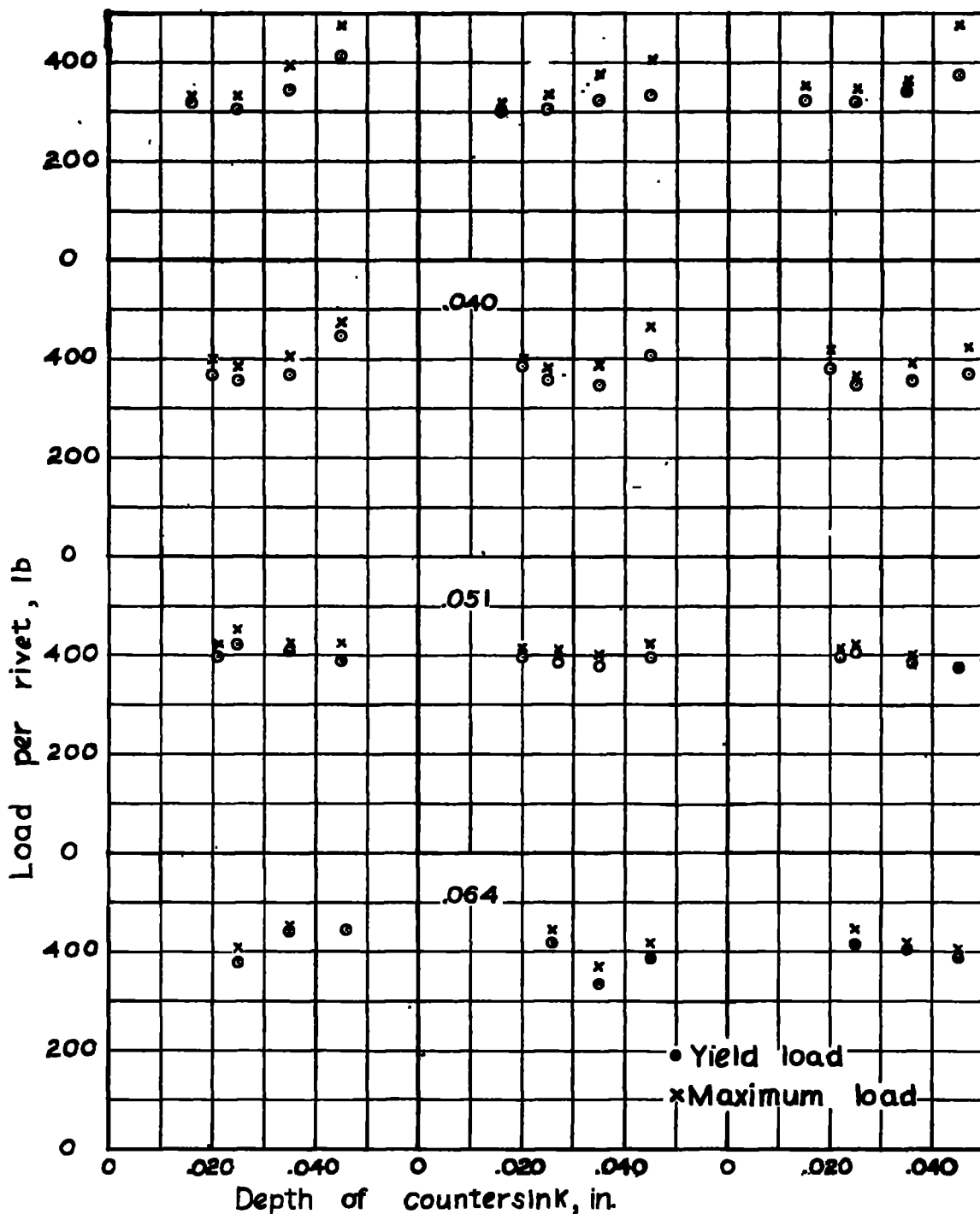


Figure 21. - Variation of yield load and maximum load with depth of countersink for $\frac{1}{8}$ -inch-diameter rivets

$t = 0.040$ in.

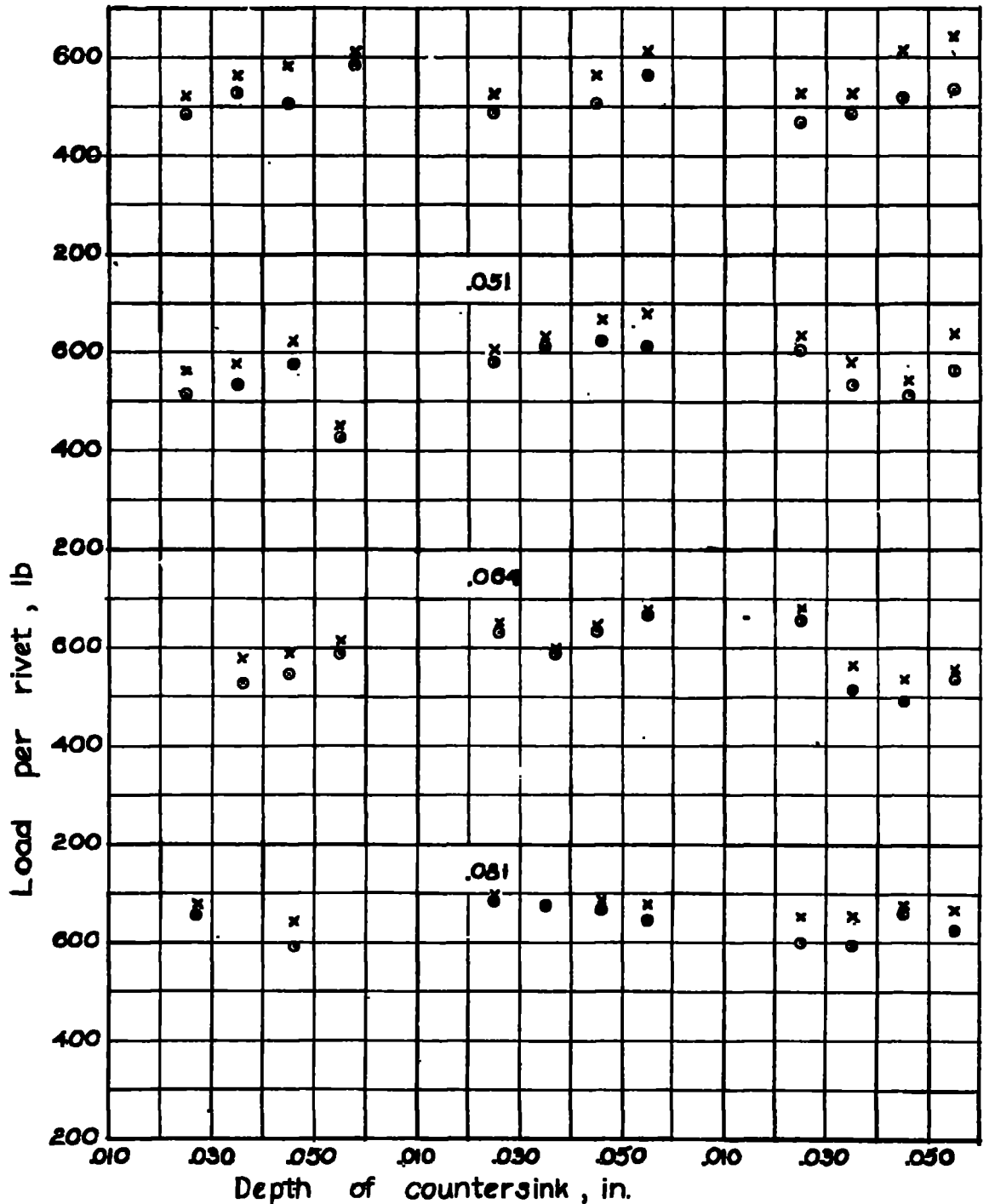


Figure 22.- Variation in yield load and maximum load with depth of countersink for $\frac{5}{16}$ -inch diameter rivets.

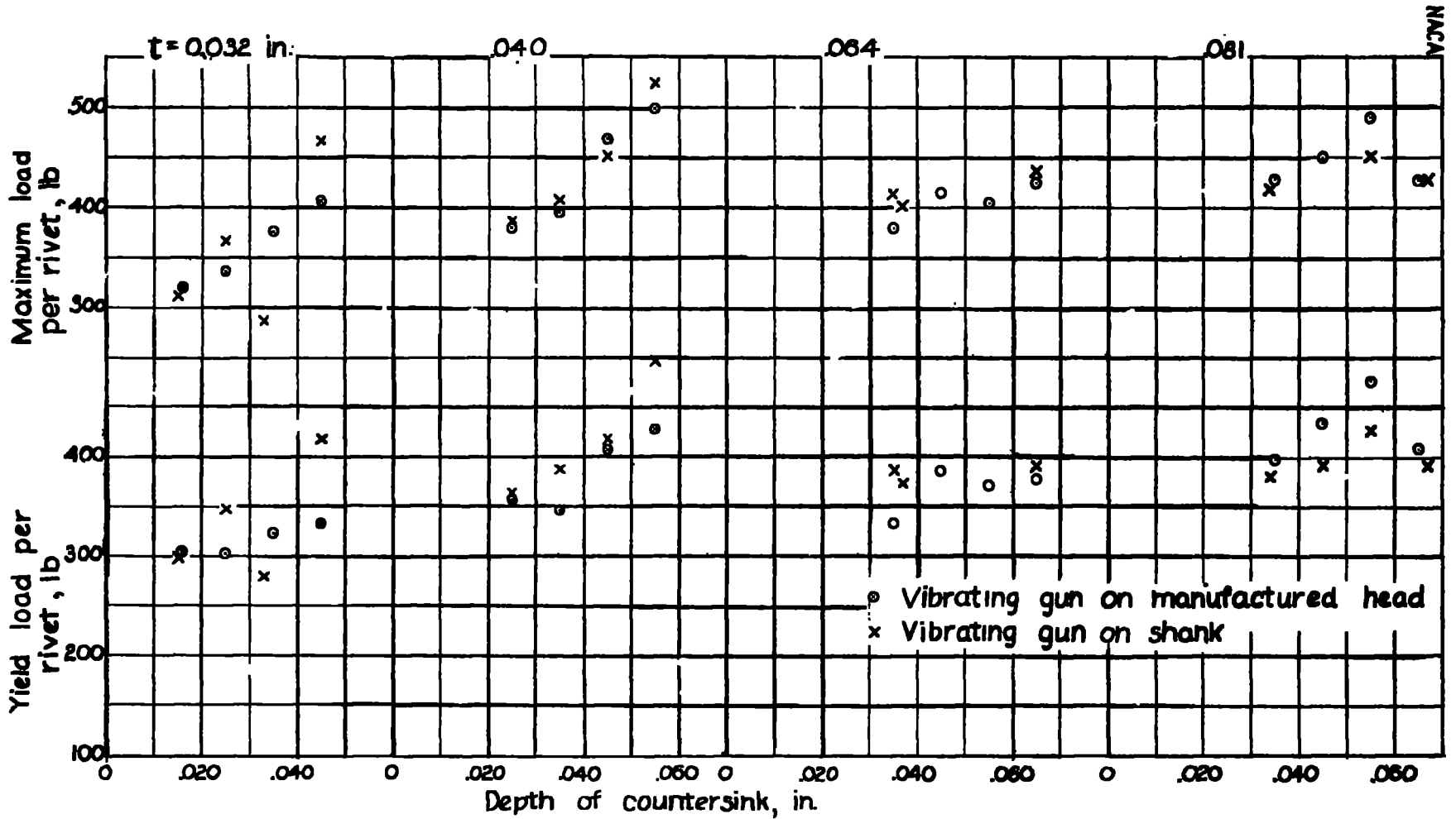


Figure 23 - Effect of interchanging gun and bar on yield and maximum loads $d = \frac{1}{8}$ in. ; $\theta = 60^\circ$.

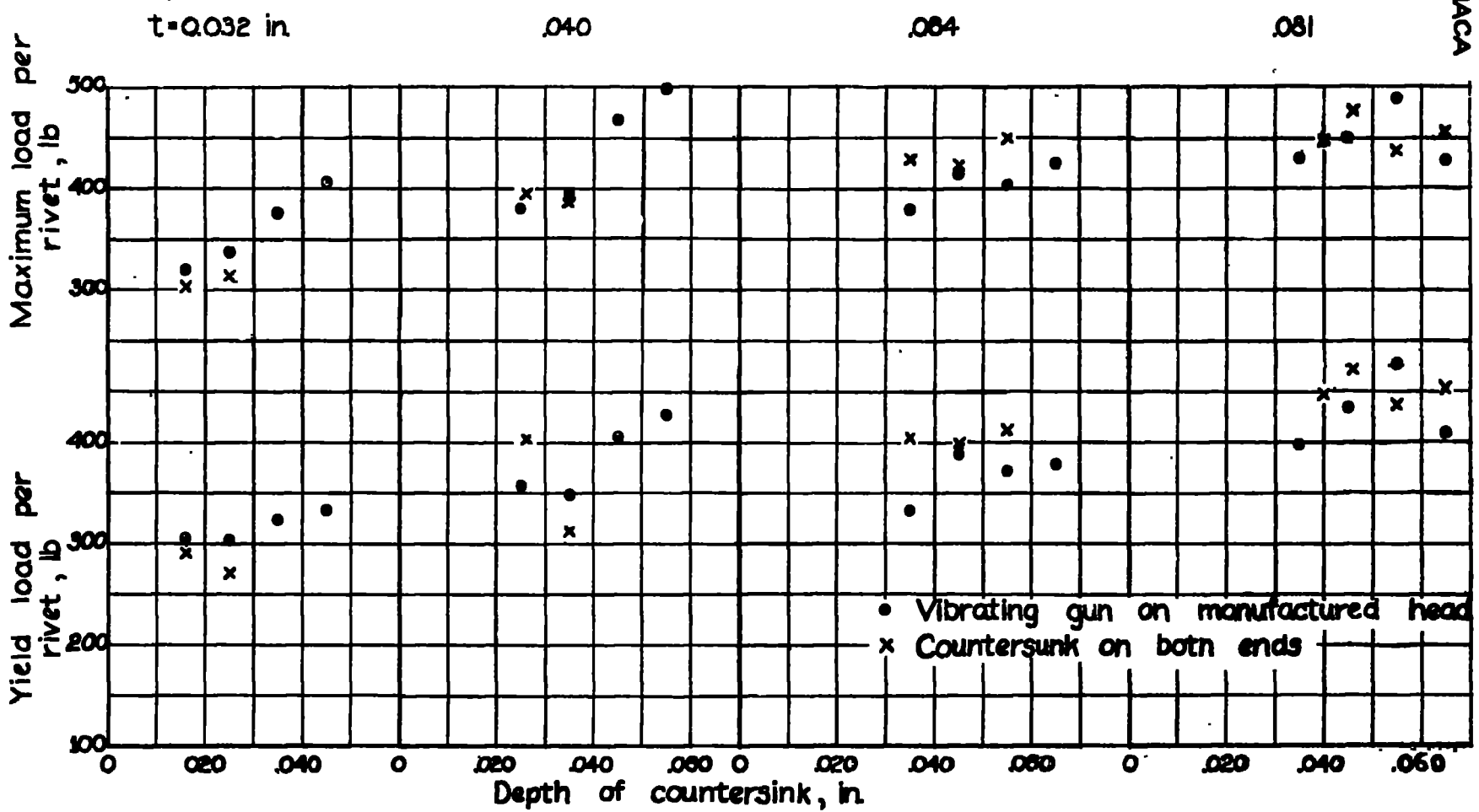


Figure 24. - Effect of countersinking rivet at both ends on yield and maximum loads . d = 1/8 in. ; $\theta = 60^\circ$.



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