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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1125

EFFECT OF RATIO OF RIVET PITCH TO RIVET DIAMETER ON THE FATIGUE STRENGTH OF RIVETED JOINTS OF 24S-T ALUMINUM-ALLOY SHEET

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EFFECT OF RATIO OF RIVET PITCH TO RIVET DIAMETER ON THE FATIGUE STRENGTH OF RIVETED JOINTS OF 24S-T ALUMINUM-ALLOY SHEET

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SUMMARY

An extensive series of tests were conducted on riveted joints to determine the effect of rivet size and rivet pitch on the fatigue life of joints subjected to "prying" (combined tensile and bending) loads. For each sheet thickness tested, there appeared to be a value of the ratio of rivet pitch to rivet diameter that would ensure a near maximum of the ratio of fatigue strength to static ultimate strength for the joint.

INTRODUCTION

Although rivets are normally designed to resist only shear loads, there are a number of applications in which rivets act under "prying" (combined tensile and bending) loads. In aircraft structures, such loads are frequently of an alternating nature and the rivets and other elements of the riveted joint are therefore subjected to fatigue failure. Common examples of riveted joints in which repeated applications of combined loads occur can be found in brackets, clip angles, and sheet-to-stiffener connections in which buckling of the sheet occurs.

In order to obtain information by which riveted joints can be proportioned to give best resistance to alternating prying loads and concurrently to meet static strength requirements, an extensive series of fatigue tests were run. The purpose of the present paper is to give the results of this investigation.

SYMBOLS

a depth of flange, inches

b rivet offset, inches

d rivet diameter, inches

p rivet pitch (measured between rivet center lines), inches

t sheet thickness, inches

P tensile load on specimen, pounds

P_f fatigue load per rivet of the riveted joint for a given number of cycles to failure, pounds

P_u static ultimate strength per rivet of the riveted joint, pounds

TEST SPECIMENS AND TESTING PROCEDURE

The specimens consisted of two 24S-T aluminum-alloy strips of equal thickness riveted together through a bent-up flange with two round-head A17S-T aluminum-alloy rivets (fig. 1). Table 1 gives the nominal dimensions of each of the 20 groups of specimens tested. Dimensions varied were the sheet thickness t, the rivet diameter d, and the rivet pitch p. The effect of varying the rivet offset b was not investigated; however, b was kept as small as practicable in the construction of the specimens.

All specimens were tested with a complete reversal of load, from a given tensile load P (as shown in fig. 1) to an equal compressive load, in the fatigue machine shown in figure 2. The load on the specimen was determined by measuring the strains in the calibrated loading beam (marked A in fig. 2) by means of electrical resistance-type strain gages. Loads could be set within an estimated accuracy of 4 percent for low loads and 1 percent for high loads. A sensitive electronic limit switch stopped the test if the load

on the specimen dropped approximately 10 pounds. If such a drop in load occurred, the load on the specimen was then reset and the test continued until failure occurred. The failure was either a separation of the rivet shank between the sheets or the formation of visible cracks in the sheet along the rivet line.

For each group of specimens, static ultimate-strength tests were run. These tests were made in a hydraulic testing machine, which indicated loads with an accuracy of one-half of 1 percent. Flat "vee" grips were used in these static tests in order to reproduce the fixity applied by the grips used in the fatigue tests.

TEST RESULTS AND DISCUSSION

The average of four static ultimate-strength tests for each group of specimens is given in table 1.

In figure 3 the results of the fatigue tests for each group of specimens are presented in the form of conventional S-N curves, that is, curves of the number of cycles to failure against load per rivet. These S-N curves represent the basic fatigue data obtained for each group of specimens. It may be noted that the continuity of the S-N curves was not disrupted by a change from sheet to rivet failure.

In figure 4 the data presented in figure 3 (tabulated in table 1) are replotted to show the variation of the ratio P_f/P_u with the ratio p/d; where P_f is the fatigue load per rivet for a given number of cycles to failure, P_u is the static ultimate tensile strength per rivet, p is the rivet pitch, and d is the rivet diameter. The data are admittedly rather meager for the purpose of drawing general conclusions and therefore the uniqueness of the plot used for figure 4 cannot be confirmed. The parameters used in that figure, however, seem to offer a useful and consistent plot of the data at hand. The parameter P_f/P_u, which might be termed the "fatigue efficiency," provides a convenient means of comparing the fatigue strengths of joints designed to carry the same static load. The parameter p/d was chosen because the tests indicated that, for a given fatigue life and sheet thickness, P_f/P_u

would be reasonably well-defined by the ratio p/d, independently of the absolute values of p and d used.

Inspection of the curves in figure 4 shows for each sheet thickness that there is an apparent optimum value of p/d for which P_f/P_u is a maximum. These optimum values of p/d for different sheet thickness are tabulated in table 2. Inspection shows very little variation of these optimum values of p/d with variation in the number of cycles to failure; therefore average values of p/d are also given in the table for each sheet thickness.

In figure 5 the average optimum values of p/d are plotted against sheet thickness. The points fall approximately on the straight line shown in the figure. Although insufficient tests were made to establish definitely the validity of this line, it seems reasonable to assume that this curve represents a near-optimum value of p/d for any sheet size within the range of tests.

Since, in a riveted joint, sheet thickness and rivet area per inch will usually be dictated by static-strength requirements, it is possible by use of figure 5 to choose a value of p/d that will ensure that the joint is well proportioned to resist alternating "prying" loads and will consistently meet the static strength requirements.

CONCLUSIONS

The following tentative conclusions may be drawn from the tests to determine the effect of rivet pitch and rivet diameter on the fatigue life of joints of 24S-T aluminum-alloy sheet and A17S-T round-head rivets subjected to "prying" (combined tensile and bending) loads:

1. For each sheet thickness tested, there appeared to be a value of the ratio of rivet pitch to rivet diameter that would ensure a near maximum of the ratio of fatigue strength to static ultimate strength for the joint.

2. These optimum ratios of rivet pitch to rivet diameter were, for all practical purposes, independent of the number of cycles to failure.

Langley Memorial Aeronautical Laboratory
National Advisory Committee For Aeronautics
Langley Field, Va. March 25, 1946

TABLE 1.- TEST-SPECIMEN DATA

Specimen group	Nominal dimensions						
	Sheet thickness t (in.)	Rivet diameter d (in.)	Rivet pitch p (in.)	Rivet offset b (in.)	Depth of flange a (in.)	p/d	Static ultimate strength per rivet P_u (lb) (a)
1	0.091	1/8	5/8	1/2	3/4	5.00	398
2	.091	5/32	5/8	5/8	7/8	4.00	552
3	.091	3/16	5/8	5/8	7/8	3.33	680
4	.091	1/4	5/8	3/4	$1\frac{1}{16}$	2.50	1160
5	.064	1/8	1/2	7/16	3/4	4.00	344
6	.064	1/8	5/8	7/16	3/4	5.00	346
7	.064	1/8	3/4	7/16	3/4	6.00	401
8	.064	1/8	1	7/16	3/4	8.00	388
9	.064	5/32	5/8	1/2	7/8	4.00	537
10	.064	5/32	7/8	1/2	7/8	5.60	505
11	.064	5/32	1	1/2	7/8	6.40	521
12	.064	3/16	5/8	1/2	7/8	3.33	604
13	.040	1/8	5/8	5/16	9/16	5.00	240
14	.040	1/8	3/4	5/16	9/16	6.00	261
15	.040	1/8	7/8	5/16	9/16	7.00	275
16	.040	1/8	1	5/16	9/16	8.00	306
17	.032	1/8	5/8	5/16	9/16	5.00	241
18	.032	3/32	5/8	5/16	9/16	6.67	158
19	.032	3/32	13/16	5/16	9/16	8.67	194
20	.032	3/32	15/16	5/16	9/16	10.00	196

[a] Average of four tests.

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TABLE 2.- FATIGUE-TEST RESULTS

Number of cycles to failure	Optimum values of p/d for maximum values of P_f/P_u			
	t=0.091	t=0.064	t=0.040	t=0.032
2×10^3	3.1	5.5	6.0	7.6
5×10^3	3.1	5.4	6.2	7.6
1×10^4	3.0	5.3	6.3	7.7
5×10^4	2.9	5.4	6.4	7.7
1×10^5	2.8	5.3	6.5	7.7
1×10^6	2.7	5.5	6.0	7.2
Average	2.9	5.4	6.2	7.6

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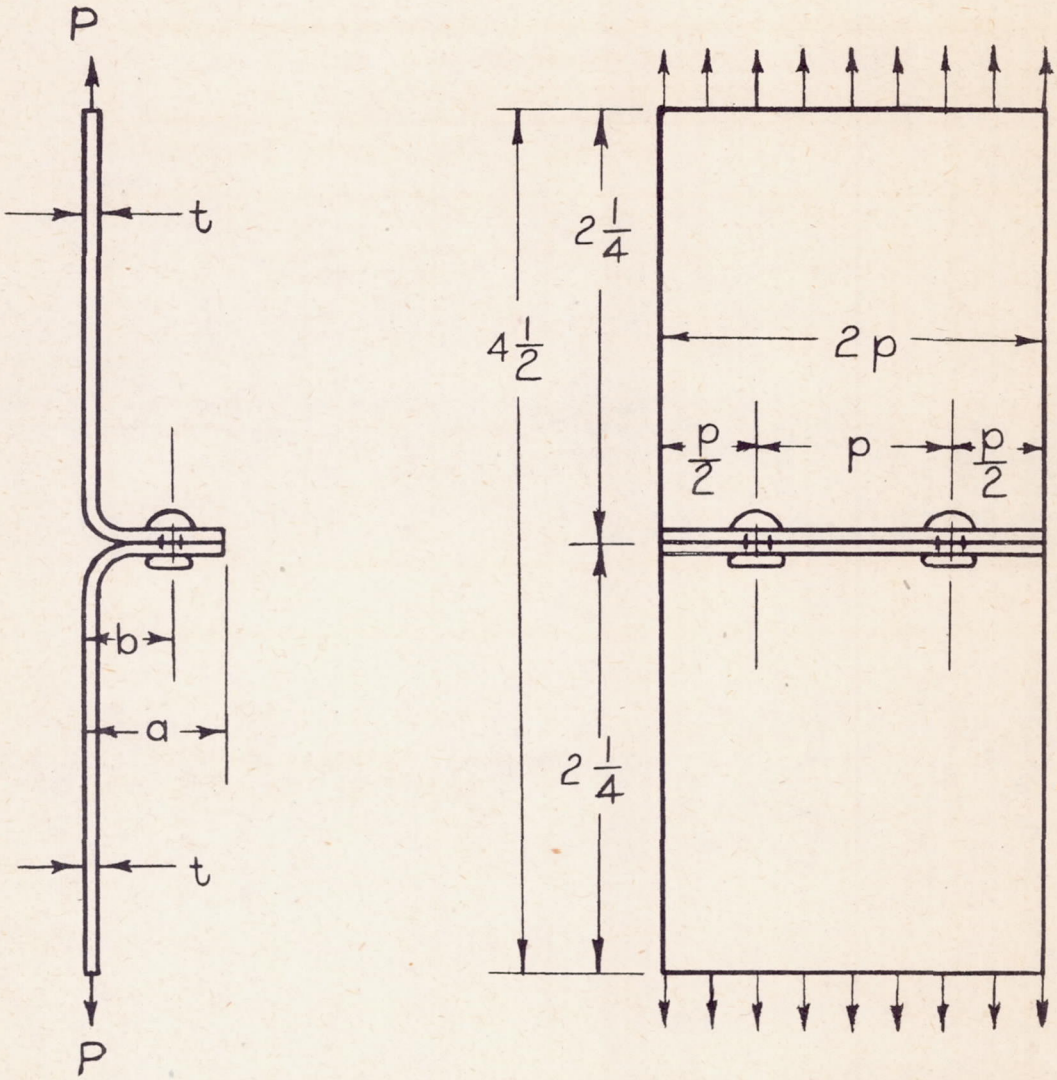

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Figure 1.- Test specimen.

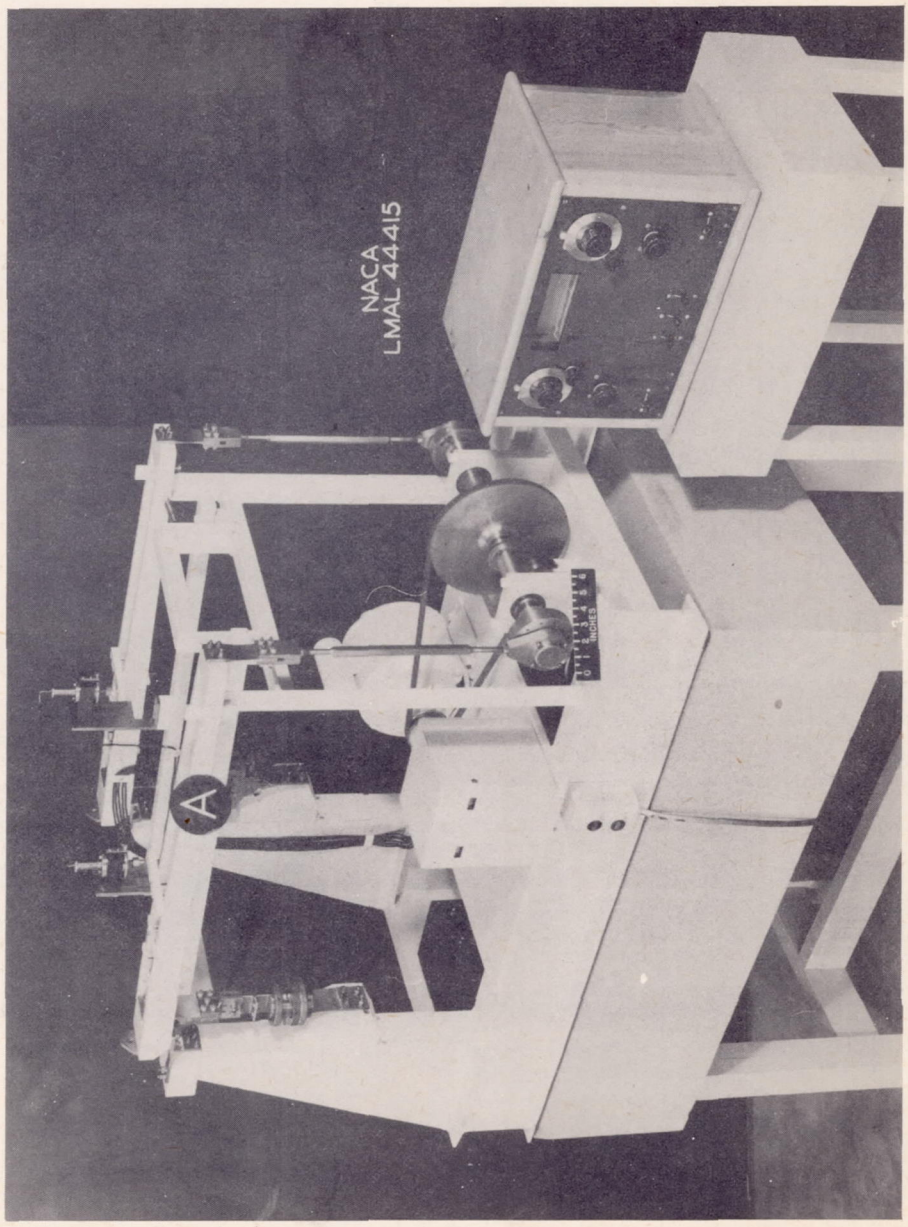
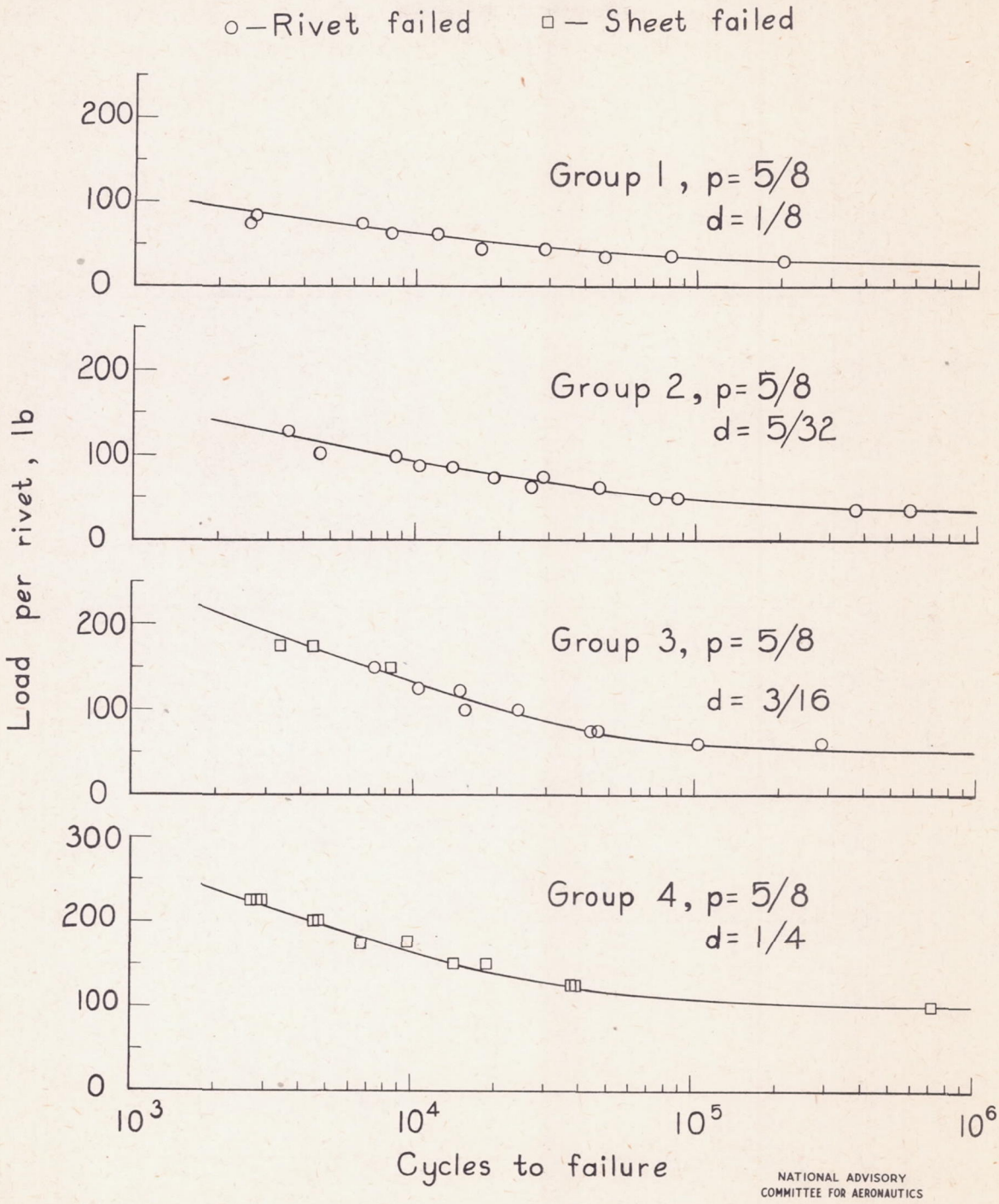
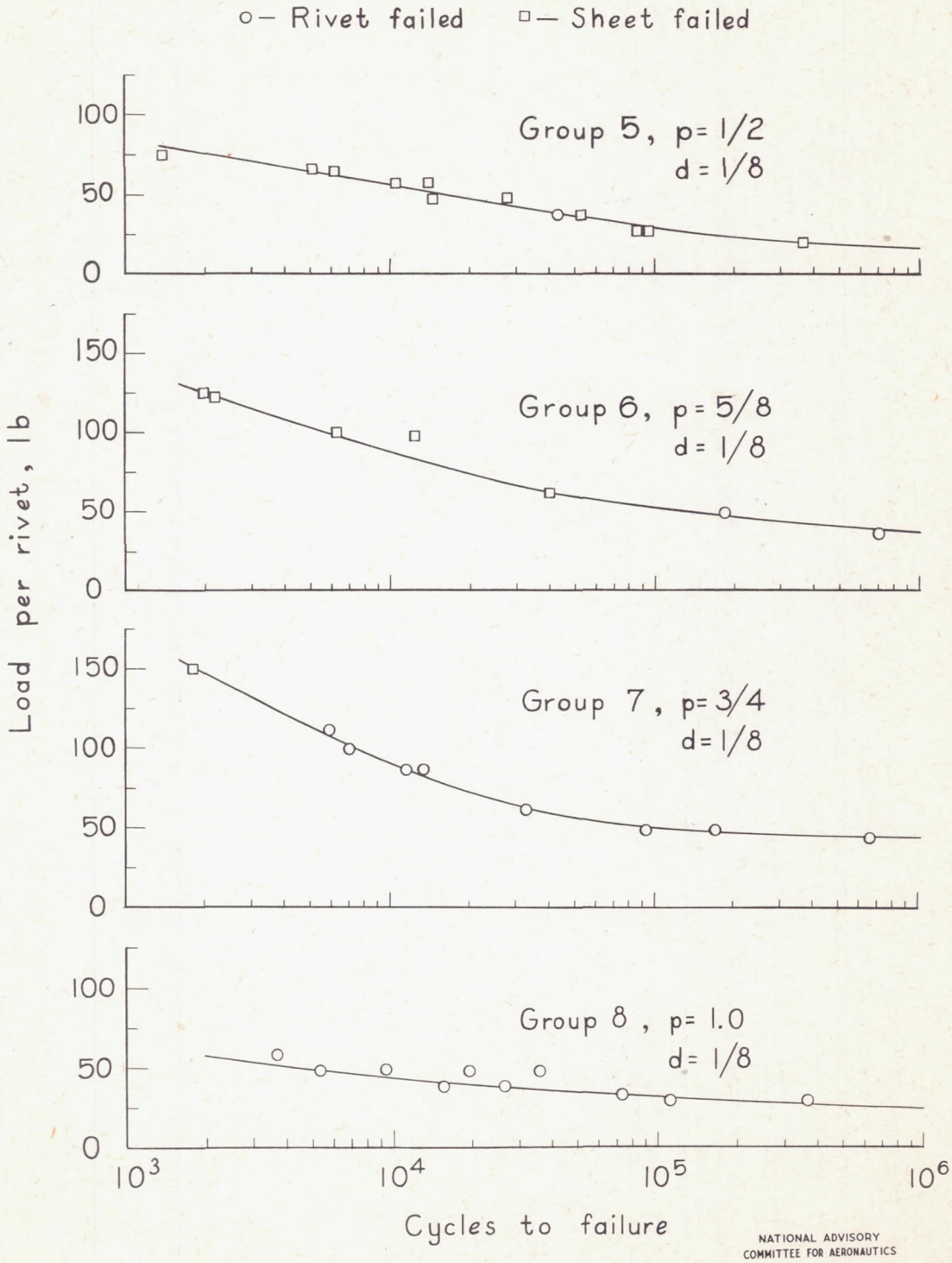


Figure 2.- Fatigue testing machine.



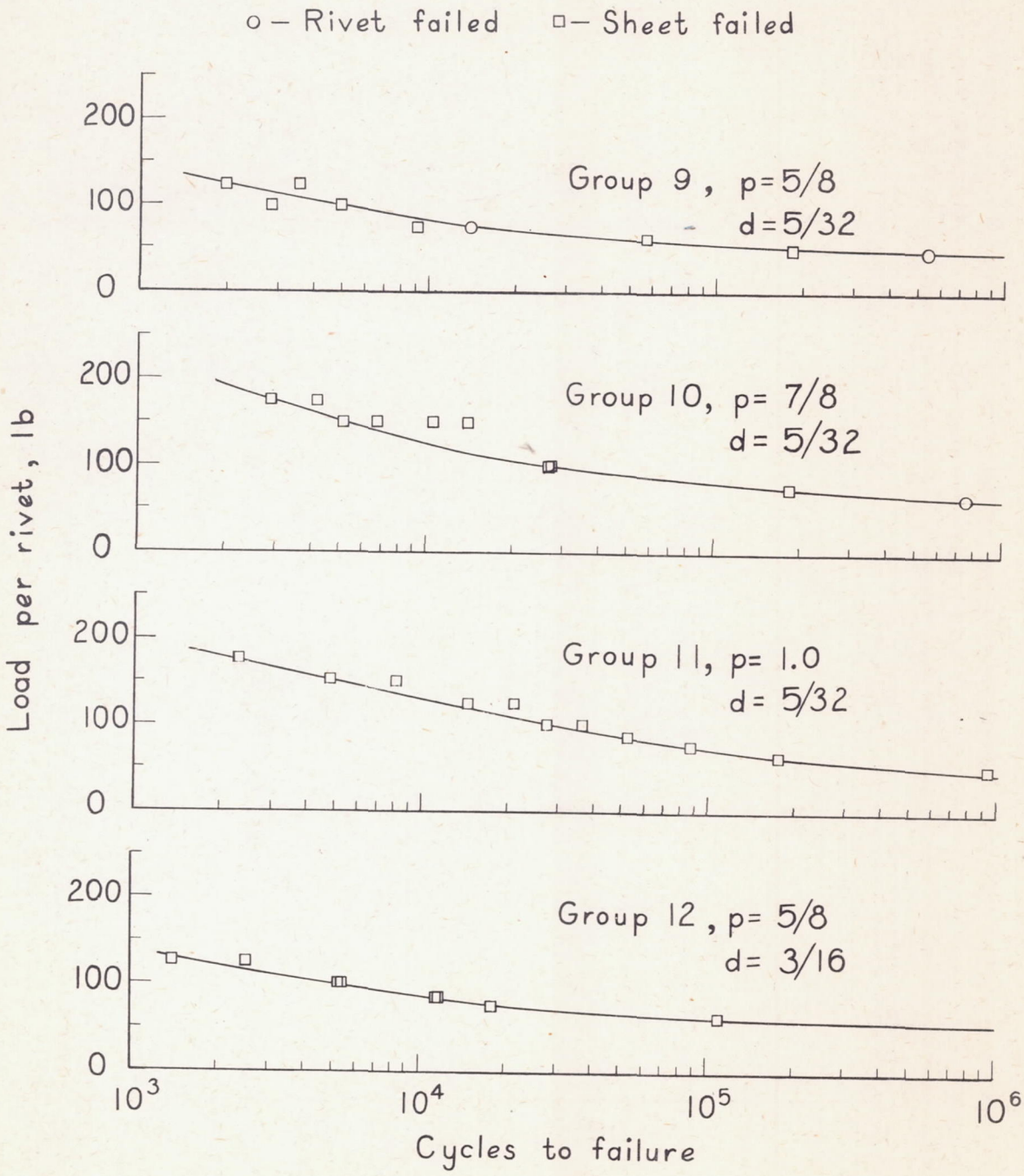
(a) Specimens of 0.091-inch 24S-T aluminum-alloy sheet with round-head A17S-T rivets.

Figure 3.- S-N curves.



(b) Specimens of 0.064-inch 24S-T aluminum-alloy sheet with round-head A17S-T rivets.

Figure 3.- Continued.



(b) Concluded.

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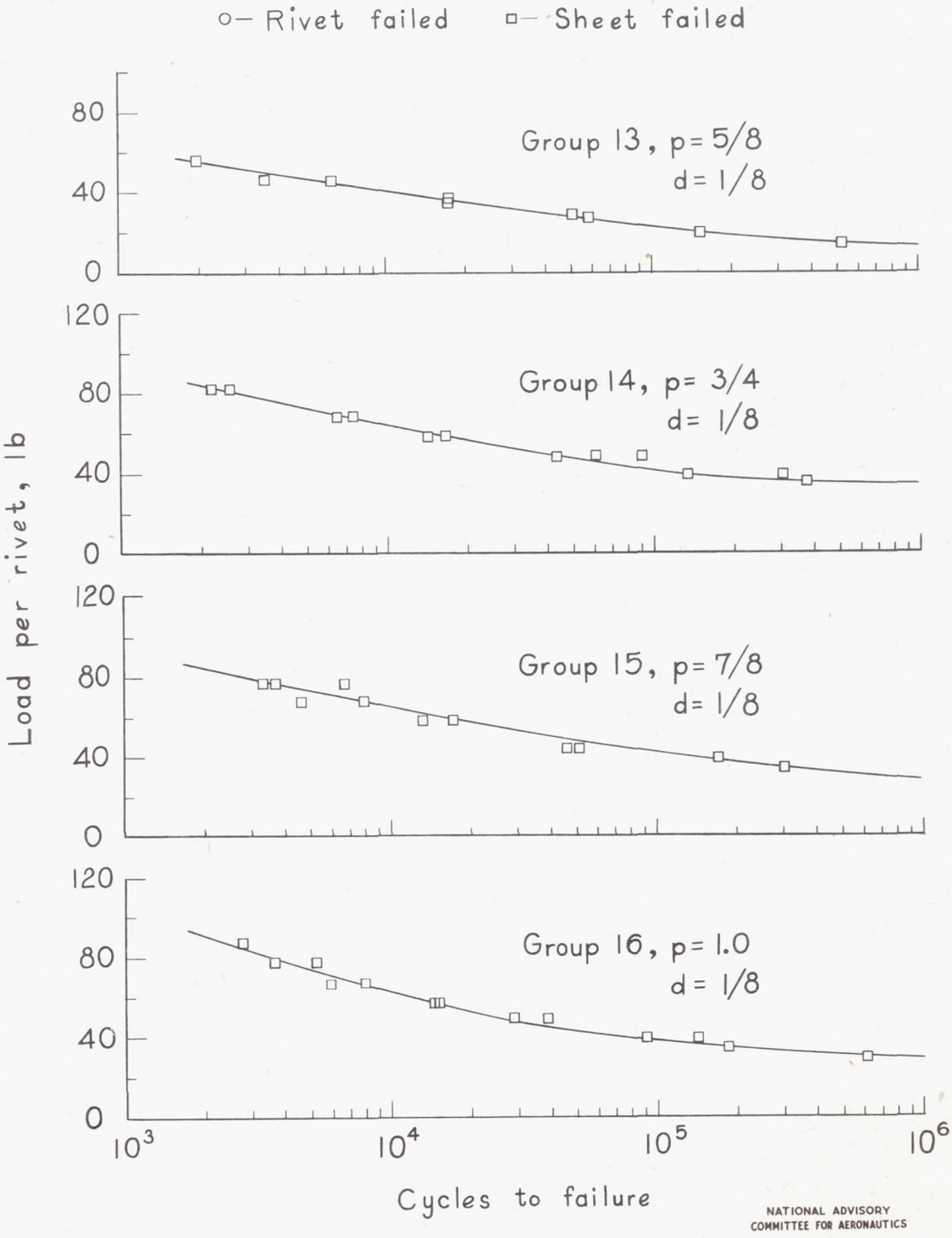
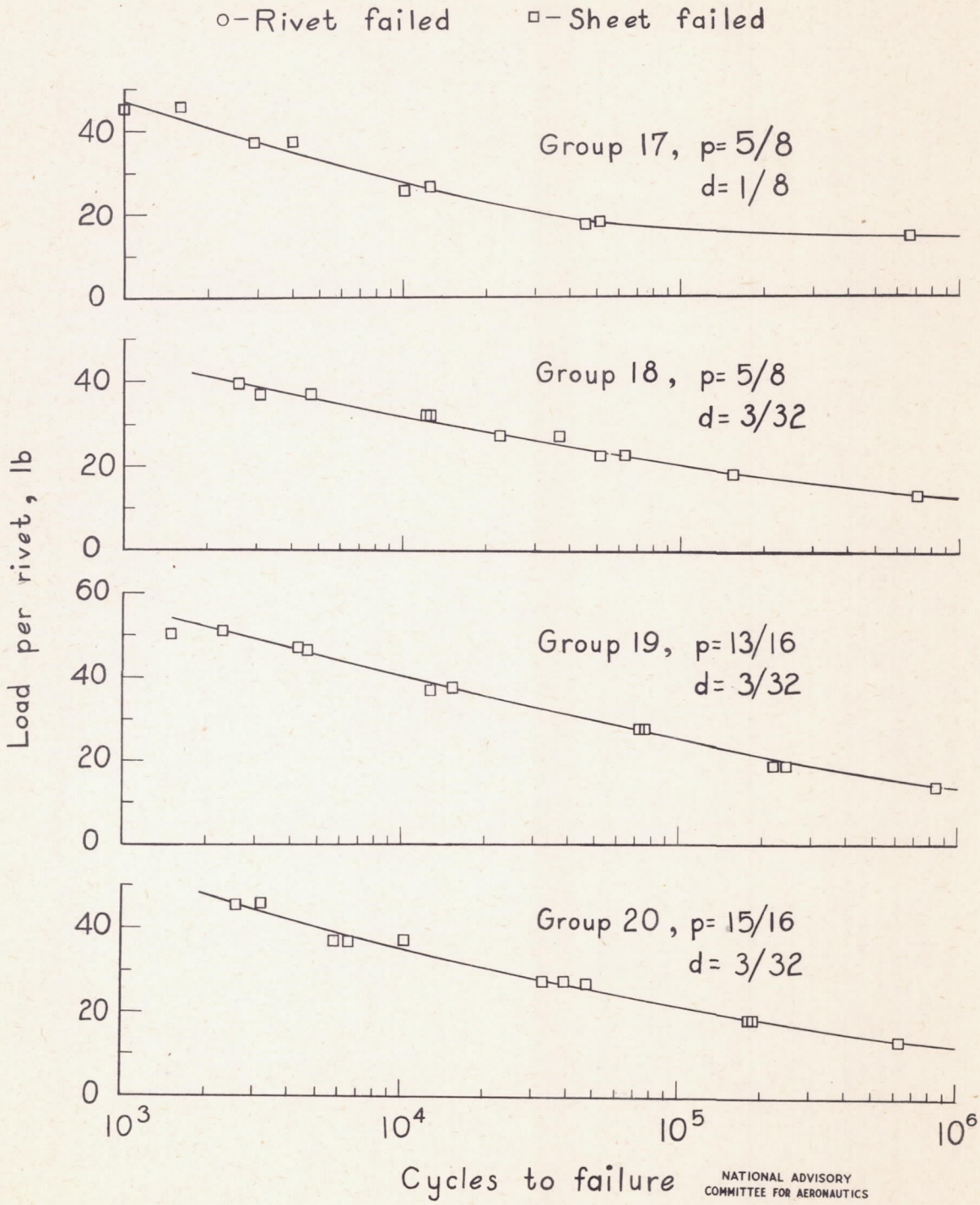
Figure 3.- Continued.



(c) Specimens of 0.040-inch 24S-T aluminum-alloy sheet with round-head A17S-T rivets.

Figure 3.-Continued.



(d) Specimens of 0.032-inch 24S-T aluminum-alloy sheet with round-head A17S-T rivets.

Figure 3.-Concluded.

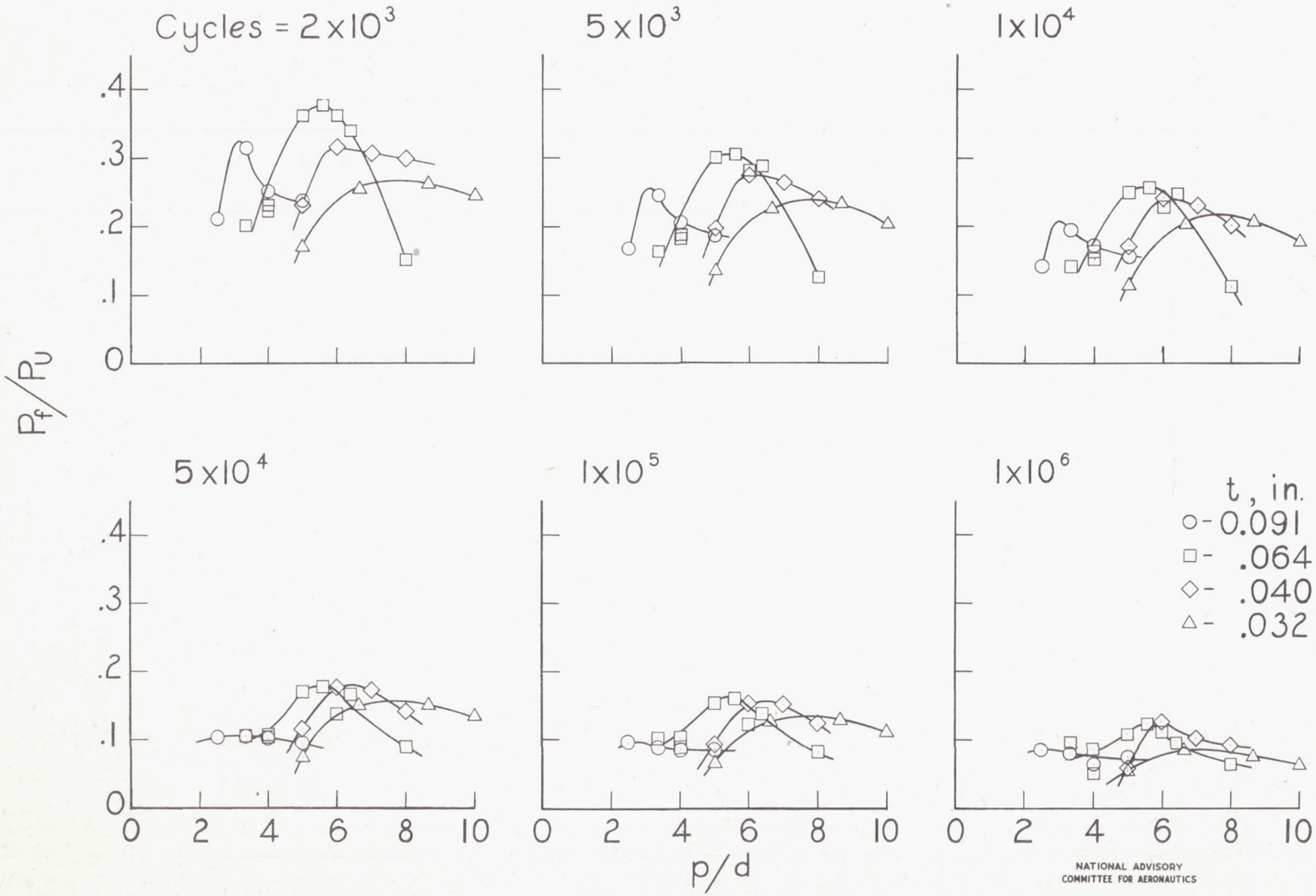


Figure 4.- Variation of ratio of fatigue strength to ultimate tensile strength of joint with ratio of rivet pitch to rivet diameter.

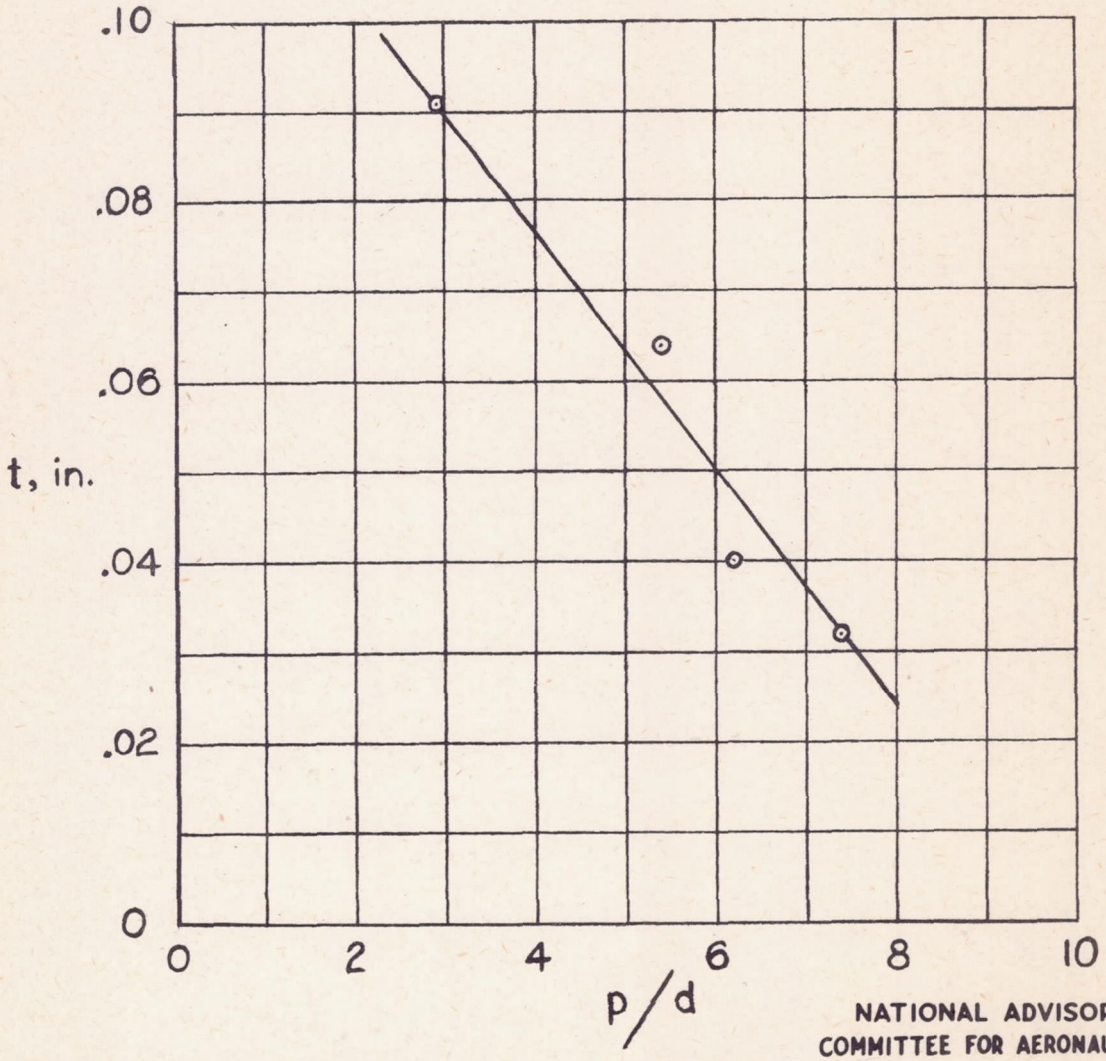


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Figure 5.- Variation of optimum ratio of rivet pitch to rivet diameter with sheet thickness.