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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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By H. J. Andrews and M. Holt
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Washington
February 1945

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INTRODUCTION

For a number of years the Aluminum Company of America has been investigating in the Aluminum Research Laboratories the fatigue characteristics of riveted joints in aluminum alloy sheet. Because of the general interest of aircraft manufacturers in these tests, the NACA published some of the results. Reference 1 presents fatigue data from tests of 17S-T and 53S-T specimens with rivets having diameters of 1/4 inch or more.

The purpose of the present report is to summarize all the results of fatigue tests that have been made to date in the Aluminum Research Laboratories of lap joints having 1/8-inch aluminum alloy rivets. The rivet materials used were 17S-T, A17S-T, and 24S-T aluminum alloys, while the plate materials were 24S-T and alclad 24S-T.

APPARATUS AND TESTS

All the joints tested were lap joints in 24S-T or alclad 24S-T aluminum alloy sheet, 1 inch wide and containing one 17S-T, A17S-T, or 24S-T rivet per joint. The total lap in each case was 1/2 inch, giving an edge distance in the direction of stressing equal to 1/4 inch or two times the nominal rivet diameter. Table I gives a descriptive list of the test specimens. All tests were made in a rotating-beam-type machine giving a complete reversal of load tending to shear the rivets.

Figures 1 and 2 show photographs of the fatigue testing machines used. The machine shown in figure 1 was designed and built at the Aluminum Research Laboratories in 1930 and is described in reference 2. This machine was intended originally for testing rotating beam specimens having a maximum diameter of 2 inches, but it has been provided with special fixtures (shown in fig. 3) for testing joints. The machines shown in figure 2 were designed and built at the Aluminum Research Laboratories in 1942 and are specifically intended for use in tests of joints using the fixtures shown in figure 4.

The procedure for testing joints is the same in each of the two machines. In each test, four joints are bolted to the fixtures and the assembly subjected to a uniform bending moment and rotated about the axis of the fixtures. This procedure subjects each individual joint to a complete reversal of load during each cycle. The machine shown in figure 1 operates at 1400 rpm and the machine shown in figure 2 at 1750 rpm. Each is equipped with a switch which automatically turns off the current to the machine when a specimen fails.

Usually only one of the four joints fails in fatigue and this then precipitates the failure of the other three joints. It is sometimes difficult to determine the location of initial failure, whether in the rivet or the sheet, because the joints are mutilated considerably by the time the rotating beam finally stops. Such cases are reported as a combination failure. Usually, however, the location of initial failure is definite.

SUMMARY OF RESULTS

Table I summarizes the test results of 1/8-inch diameter rivets, with information on alloy and type of rivet, sheet alloy and thickness, preparation of the rivet holes, and type of failure. The data have been plotted in figures 5 to 14.

Table II gives the fatigue strengths as indicated by the curves of figures 5 to 14, for certain numbers of cycles of stress. The joints are listed in the order of decreasing strengths under static loading.

The data presented in this report suggest the following comparisons, although in some cases the evidence is rather meager:

1. For 17S-T and A17S-T rivets, the joints can be

divided into three groups according to strength, the strongest being those in dimpled sheet, the next strongest those with plain drilled holes, and finally those with machine countersunk holes. The only exception is item 9 with 0.040-inch-thick sheet machine countersunk 0.050 inch deep with rivets driven by NACA Method E of reference 3. Since the depth of countersink was greater than the thickness of the sheet, the shear area of the rivets in these joints was greater than that of the other joints, which accounts partially, at least, for their higher strength.

2. The effect of the depth of the countersink on the strength of the joint could not be definitely determined. When the manufactured head is countersunk, the joints with full-thickness machine countersink are not as strong as those in which the countersink is only three-fourths the thickness of the sheet. This probably results from the high stresses developed by the feather edge obtained with a full-depth countersink. When the driven head is countersunk (NACA method of driving), the joints with more-than-full-thickness machine countersink are stronger than those in which the countersink is only three-fourths of the thickness of the sheet. The additional shear area produced by the more-than-full-thickness countersink apparently offsets any detrimental effects of a feather edge at the rim of the hole.

3. The joints with 17S-T or A17S-T rivets in dimpled 0.040-inch sheet failed by tensile fatigue fracture of the sheet. The 24S-T rivets of item 2 were driven in 0.064-inch sheet; consequently, the joints failed by shearing the rivets. As a rule, the joints with plain drilled holes failed by shearing the rivets; while in the case of those with machine-countersunk holes the type of failure could not be definitely determined.

4. A comparison of items 1 and 3 indicates that the fatigue strength of joints in 24S-T sheet is a little greater than that of similar joints in alclad 24S-T.

5. A comparison of item 3 with 4, and 5 with 7 indicates that in static tests and in fatigue tests of small numbers of cycles (high stresses) 17S-T rivets are stronger than A17S-T rivets; whereas for large numbers of cycles (low stresses) the strengths are practically the same.

6. A comparison of items 8 and 10 indicates that, when the fatigue failures occur in the rivet, the thickness of the sheet, whether 0.051 inch or 0.064 inch, is relatively unimportant except in the fatigue tests at high stresses (low number of cycles). In this case the use of thicker sheet results in a stronger joint.

7. A comparison of items 2, 5, and 8 indicates that 24S-T rivets are stronger in fatigue than 17S-T and A17S-T rivets.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., July 25, 1944.

REFERENCES

1. Templin, R. L.: Fatigue Properties of Light Metals and Alloys. Proc., A.S.T.M., vol. 33, pt. II, 1933.

2. Hartmann, E. C., Lyst, J. O., and Andrews, H. J.: Fatigue Tests of Riveted Joints - Progress Report of Tests of 17S-T and 53S-T Joints. NACA ARR 4I15, 1944.

3. Lundquist, Eugene E., and Gottlieb, Robert: A Study of Tightness and Flushness of Machine-Countersunk Rivets for Aircraft. NACA RB, June 1942.

TABLE I

FATIGUE TEST RESULTS ON 1/8-IN. DIAMETER ALUMINUM ALLOY RIVETS. (All fatigue tests made on 1-in. wide lap joints in aluminum alloy sheet with one rivet per joint. Tests made under complete reversal of load. All static tests made on 1-in. wide lap joints in aluminum alloy sheet with two rivets per joint. Edge distance parallel to load 1/4 in.)

Item No.	Rivet Alloy	Types of Heads: Manufactured	Types of Heads: Driven	Sheet Alloy	Nominal Sheet Thickness	Preparation of Holes	Maximum Load per Rivet, lb	No. of Cycles	Location of Initial Failure
1*	17S-T	Ctsk, 100°	Flat	24S-T	0.040	Dimpled, 100° ctsk	581[illegible]	Static test	rivet
							284[illegible]	88 300	sheet
							281[illegible]	140 600	sheet
							247[illegible]	212 900	sheet
							196[illegible]	223 100	sheet
							176[illegible]	490 500	sheet
							154[illegible]	30 359 100	sheet
							131[illegible]	105 097 000	No failure
2*	24S-T	Button	Flat	24S-T	0.064	Drilled	580[illegible]	Static test	rivet
							189[illegible]	1 500 100	rivet
							172[illegible]	732 300	rivet
							156[illegible]	7 390 900	rivet
							135[illegible]	8 135 200	rivet
							127[illegible]	3 229 800	rivet
							112[illegible]	97 579 500	No failure
3*	17S-T	Ctsk, 100°	Flat	Alc.24S-T	0.040	Dimpled, 100° ctsk	572[illegible]	Static test	rivet
							240[illegible]	90 600	sheet
							159[illegible]	407 200	sheet
							124[illegible]	1 575 900	sheet
							117[illegible]	1 624 000	sheet
							102[illegible]	7 704 800	sheet
							97[illegible]	30 044 400	sheet
							92[illegible]	23 956 500	sheet
4*	A17S-T	Ctsk, 100°	Flat	Alc.24S-T	0.040	Dimpled, 100° ctsk	516[illegible]	Static test	rivet
							250[illegible]	152 600	sheet
							200[illegible]	403 600	sheet
							150[illegible]	1 767 600	sheet
							120[illegible]	6 634 500	sheet
							110[illegible]	49 216 800	Sheet
							100[illegible]	111 872 600	No failure

* Tests made in fatigue testing machine shown in figure 2. Other tests made in fatigue testing machine shown in figure 1.

TABLE I (Cont'd.)

Item No.	Rivet Alloy	Types of Heads		Sheet Alloy	Nominal Sheet Thickness	Preparation of Holes	Maximum Load per Rivet, lb	No. of Cycles	Location of Initial Failure
		Manufactured	Driven						
5*	17S-T	Button	Flat	Alc.24S-T	0.040	Drilled	496	Static test	rivet
							246	153 100	sheet
							189	358 500	rivet
							141	2 362 600	combination
							118	11 724 300	combination
							110	6 270 700	sheet
							108	1 546 200	sheet
							105	4 319 000	combination
							103	3 970 300	combination
							100	13 404 700	combination
							93	100 507 600	No failure
7*	A17S-T	Brazier	Flat	Alc.24S-T	0.040	Drilled	445	Static test	rivet
							265	33 900	rivet
							189	466 400	rivet
							175	318 500	rivet
							141	1 450 000	rivet
							126	4 759 700	rivet
							112	4 116 900	rivet
							102	2 854 800	rivet
							92	29 869 300	rivet
							83	36 405 400	rivet
							77	2 088 900	rivet
8	A17S-T	Button	Flat	24S-T	0.064	Drilled	451	Static test	rivet
							200	63 500	rivet
							150	226 000	rivet
							125	653 000	rivet
							100	2 848 800	rivet
							90	28 425 200	No failure
9*	A17S-T	Button	Ctsk 60° N.A.C.A. Method of Driving	24S-T	0.040	Machine ctsk 0.050 in. deep	421	Static test	rivet
							246	21 000	rivet
							196	205 800	rivet
							141	454 500	rivet
							131	1 131 800	rivet
							117	2 635 300	rivet
							102	1 670 300	rivet
							102	78 599 400	rivet
							92	101 007 500	No failure

* Tests made in fatigue testing machine shown in figure 2. Other tests made in fatigue testing machine shown in figure 1.

TABLE I (Concluded)

Item No.	Rivet Alloy	Types of Heads		Sheet Alloy	Nominal Sheet Thickness	Preparation of Holes	Maximum Load per Rivet, lb	No. of Cycles	Location of Initial Failure
		Manufactured	Driven						
10	A17S-T	Button	Flat	24S-T	0.051	Drilled	416	Static test	rivet
							200	100	rivet
							150	173 100	rivet
							125	109 000	rivet
							125	788 900	rivet
							100	21 555 700	rivet
11	17S-T	Ctsk,100°,	Flat	Alc.24S-T	0.040	Machine ctsk 100°	198	100	rivet
						(3/4 depth)	175	171 100	sheet
							149	459 900	combination
							140*	908 900	combination
							125	620 400	combination
							111*	4 587 100	combination
							109	5 118 500	combination
							105*	1 544 500	combination
							100*	1 257 800	combination
							89	8 988 800	combination
12*	A17S-T	Button	Ctsk 60°	24S-T	0.040	Machine ctsk 0.030 in.	386	Static test	rivet
			N.A.C.A.			deep	239	2 000	rivet
			Method of				214	59 000	rivet
			Driving				196	105 700	rivet
							179	88 500	rivet
							141	57 800	rivet
							152	665 900	rivet
							116	875 700	rivet
							97	12 932 300	rivet
							92	6 959 000	rivet
							87	97 742 400	rivet
							84	1 196 600	rivet
13	17S-T	Ctsk,100°,	Flat	Alc.24S-T	0.040	Machine ctsk 100°	185*	600	sheet
						(full depth)	151*	215 400	combination
							148	500	rivet
							125	150	rivet
							125	910 200	sheet
							99	1 289 800	sheet
							92*	1 147 000	combination
							85*	5 759 700	combination
							75	3 141 800	-
							65*	62 570 200	No failure
							55	32 841 600	No failure

* Tests made in fatigue testing machine shown in figure 2. Other tests made in fatigue testing machine shown in figure 1.

TABLE II

SUMMARY OF STATIC AND FATIGUE TEST RESULTS ON 1/8-IN. DIAMETER ALUMINUM ALLOY RIVETS. ALL FATIGUE TESTS MADE UNDER COMPLETE REVERSAL OF LOAD. EDGE DISTANCE PARALLEL TO LOAD 1/4 IN.

Item No.	Rivet Alloy	Type of Heads		Sheet Alloy	Nominal Sheet Thickness, in.	Preparation of Holes	Static Strength, lb/rivet	Fatigue Strength, lb/rivet		
		Manufactured	Driven					10^5 cycles	10^6 cycles	10^7 cycles
1	17S-T	ctsk, 100°	flat	24S-T	0.040	dimpled, 100° ctsk	581	250 S*	155 S	137 S
2	24S-T	button	flat	24S-T	0.064	drilled	580	255 R	185 R	135 R
3	17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	dimpled, 100° ctsk	572	232 S	132 S	100 S
4	A17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	dimpled, 100° ctsk	516	265 S	170 S	113 S
5	17S-T	button	flat	Alc.24S-T	0.040	drilled	498	260 C	150 C	104 C
7	A17S-T	brazier	flat	Alc.24S-T	0.040	drilled	445	250 R	153 R	98 R
8	A17S-T	button	flat	24S-T	0.064	drilled	451	178 R	118 R	92 R
9	A17S-T	button	ctsk, 60°	24S-T	0.040	machine ctsk, 0.050" deep	421	202 R	129 R	106 R
10	A17S-T	button	flat	24S-T	0.051	drilled	416	142 R	125 R	107 R
11	17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	machine ctsk, 3/4 depth	402	169 C	123 C	100 C
12	A17S-T	button	ctsk, 60°	24S-T	0.040	machine ctsk, 0.030" deep	386	193 R	119 R	93 R
13	17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	machine ctsk, full depth	379	158 R	102 S	80 C

* S indicates initial failure in the sheet, R in the rivet, and C a combination failure.

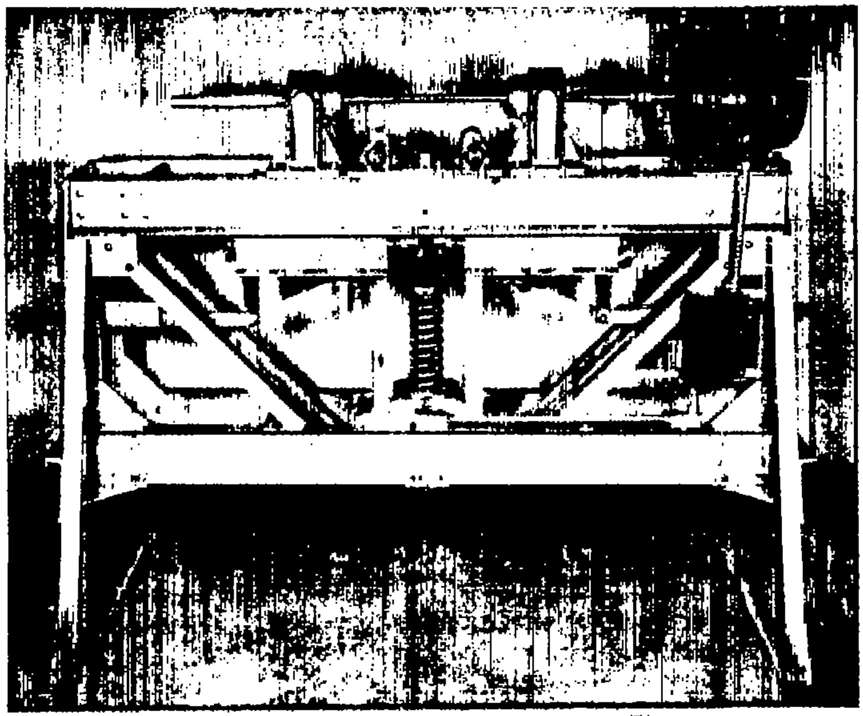
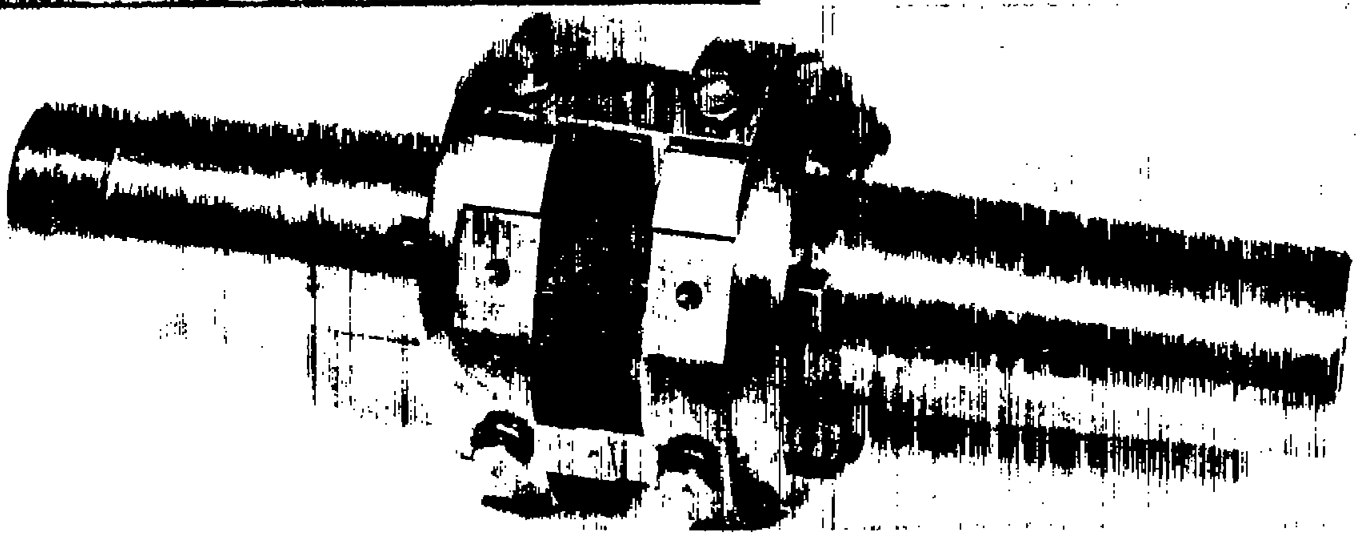


Figure 1.- Fatigue testing machine of rotating beam type designed and built at Aluminum Research Laboratories in 1930.

Figure 3.- Fixtures for loading riveted joints in fatigue testing machine shown in figure 1.



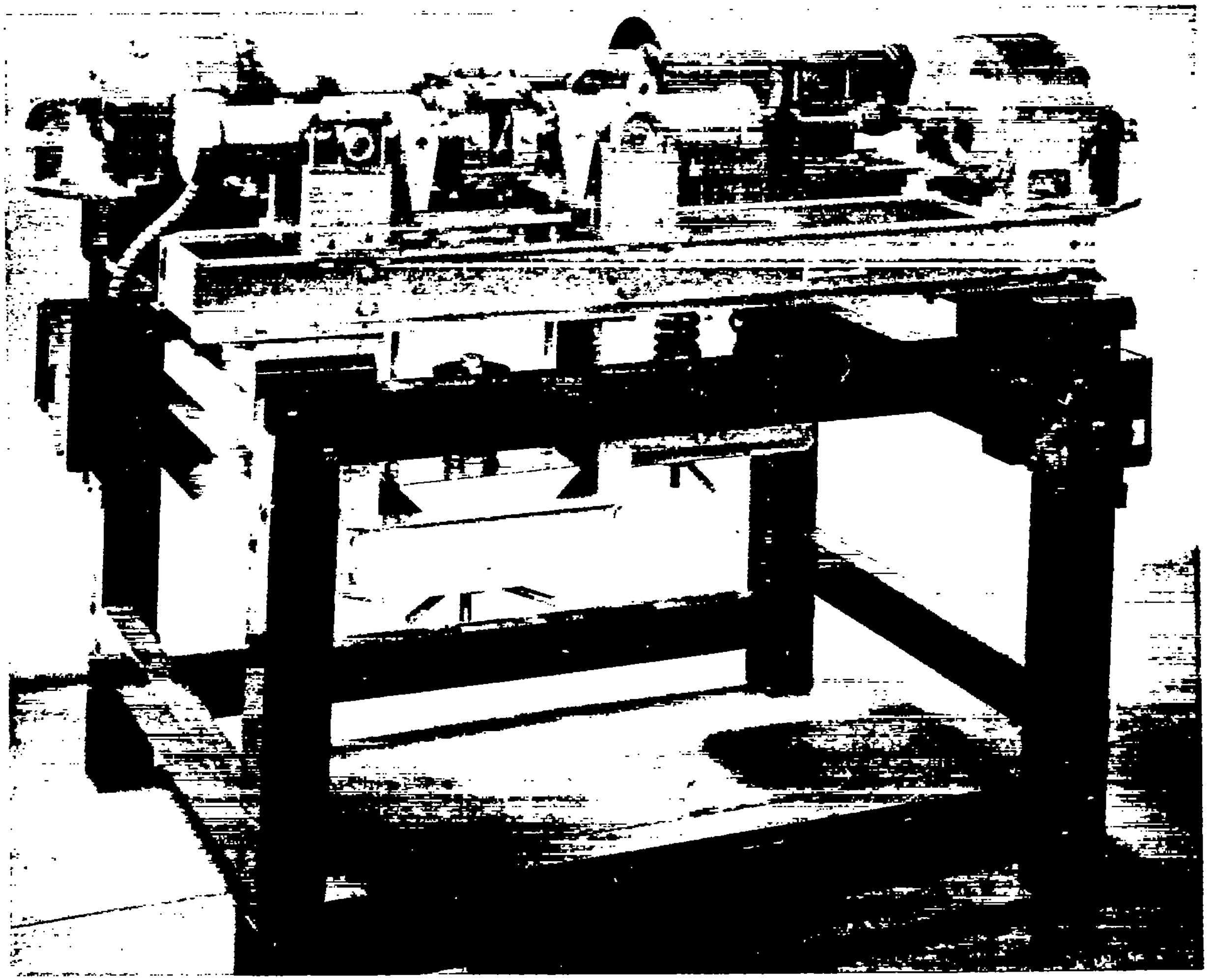


Figure 2.- Fatigue testing machines of rotating beam type designed and built at Aluminum Research Laboratories in 1942.

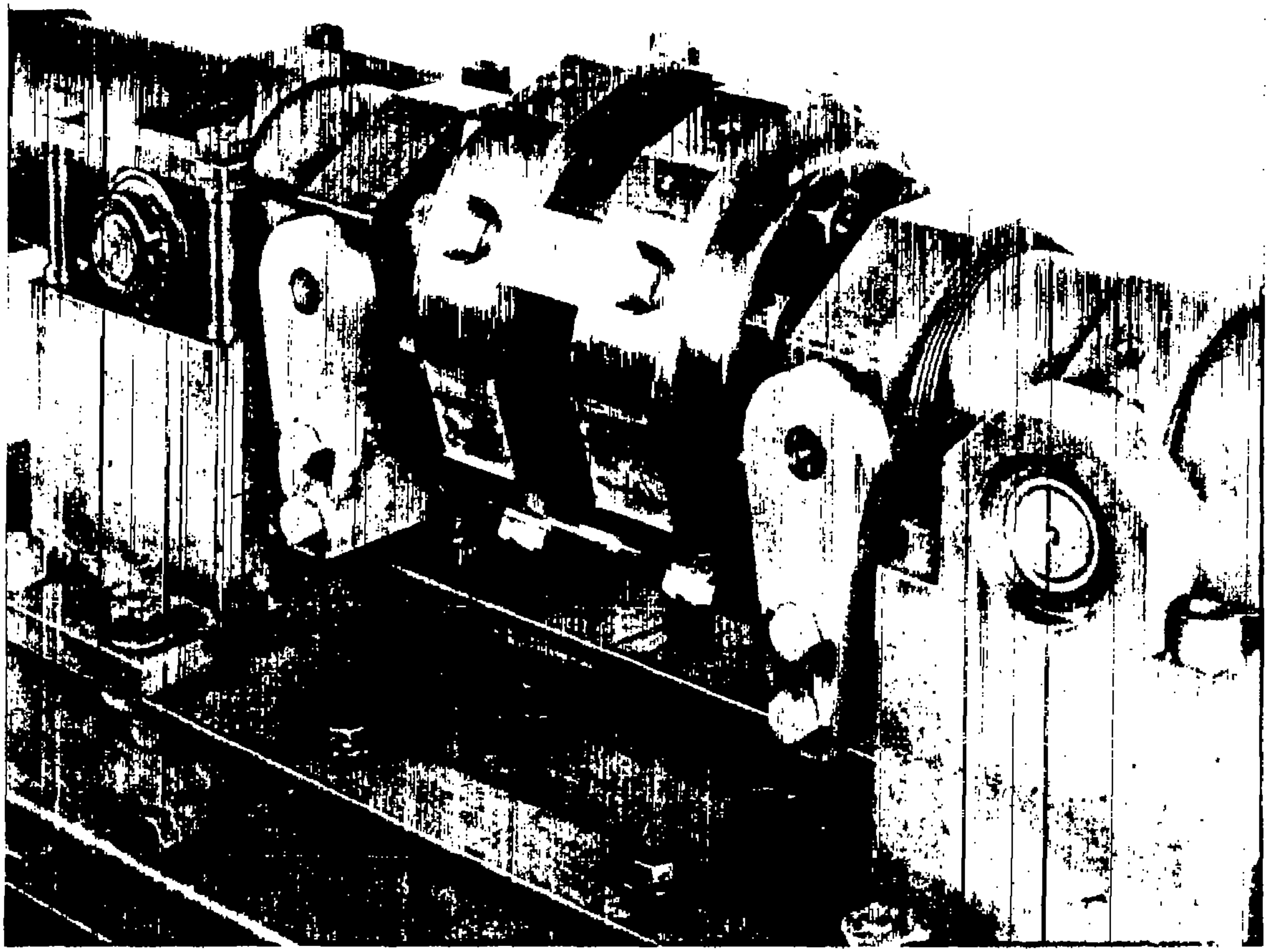


Figure 4.- Fixtures for loading riveted joints in fatigue testing machine shown in figure 2.

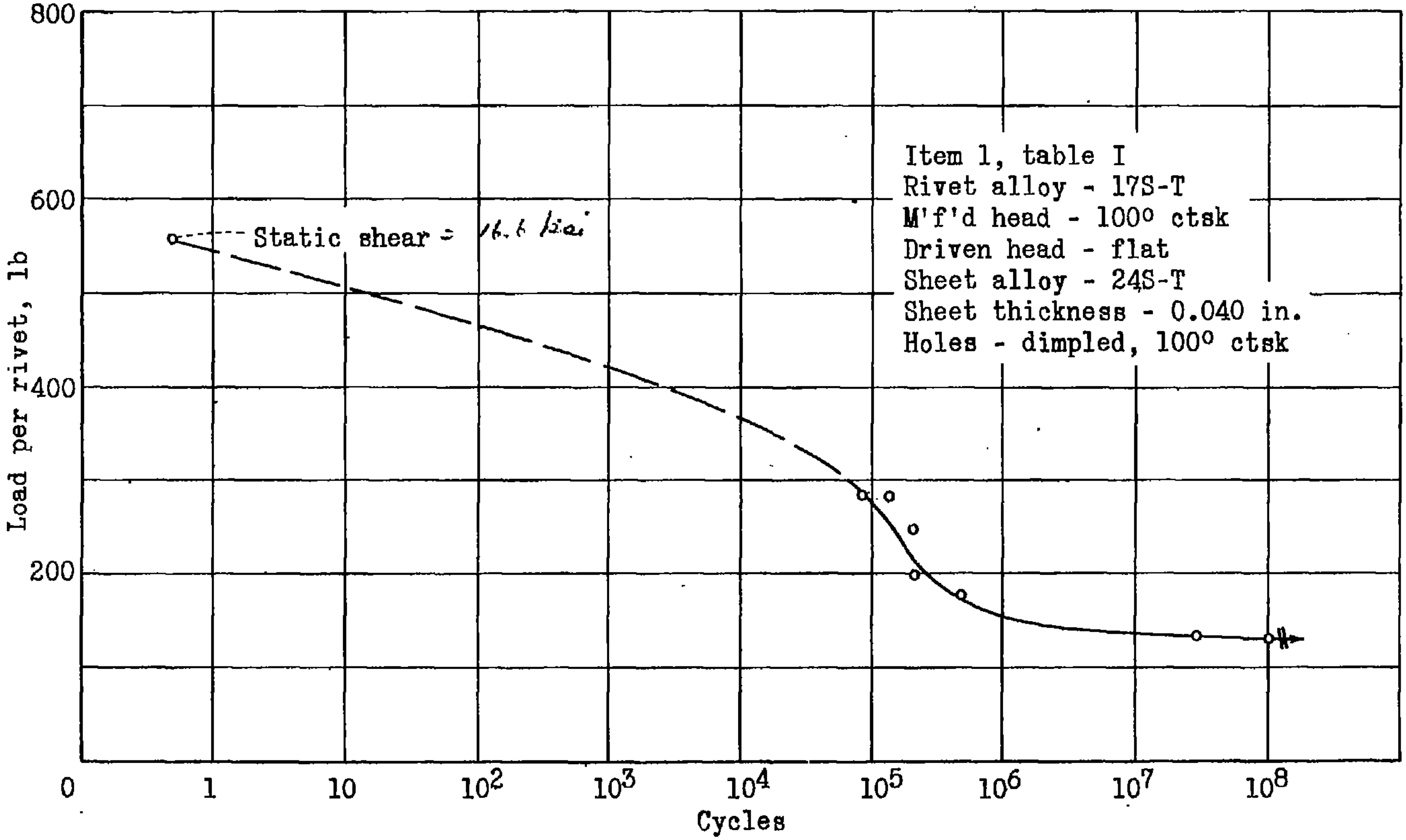


Figure 5.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

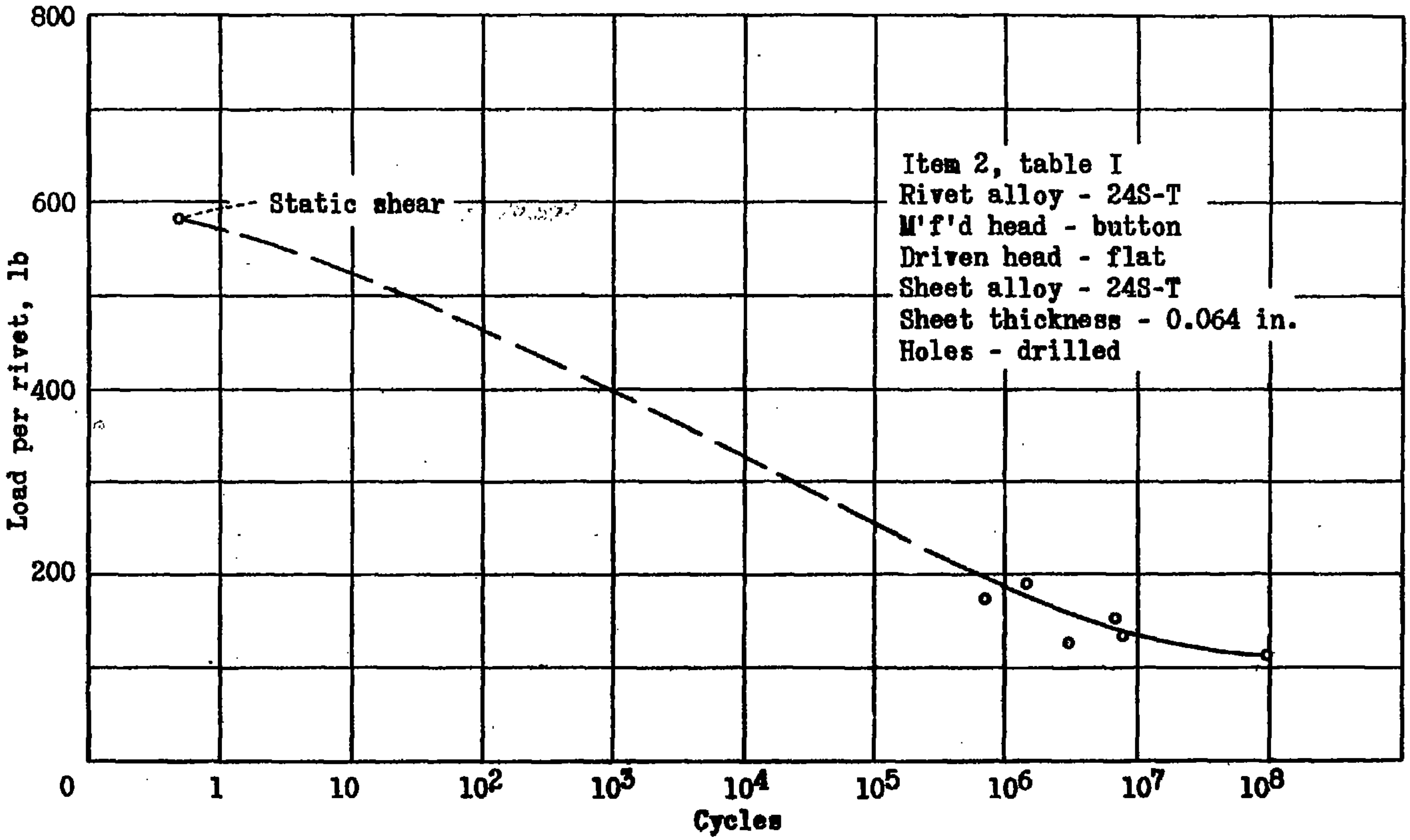


Figure 6.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

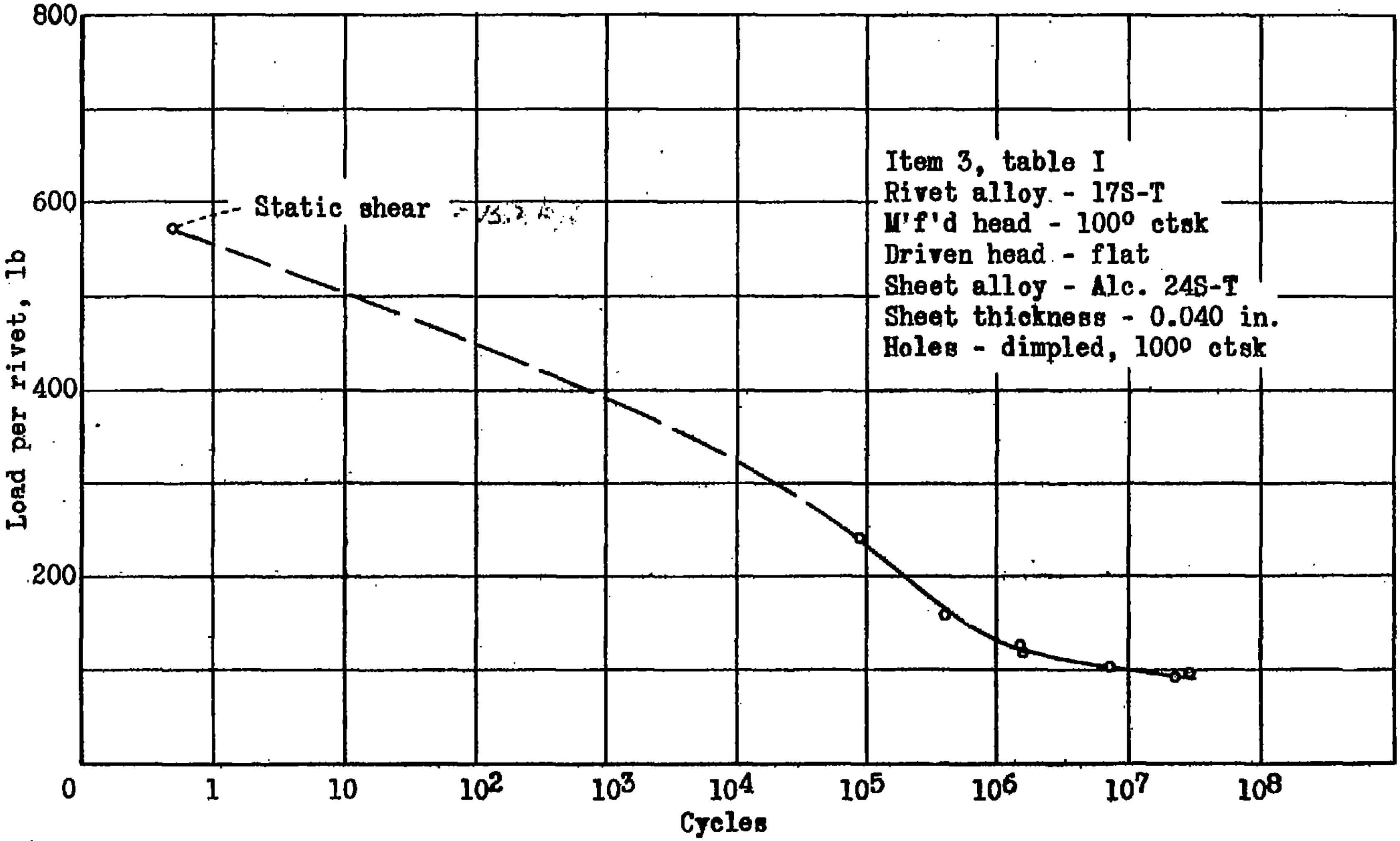


Figure 7.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

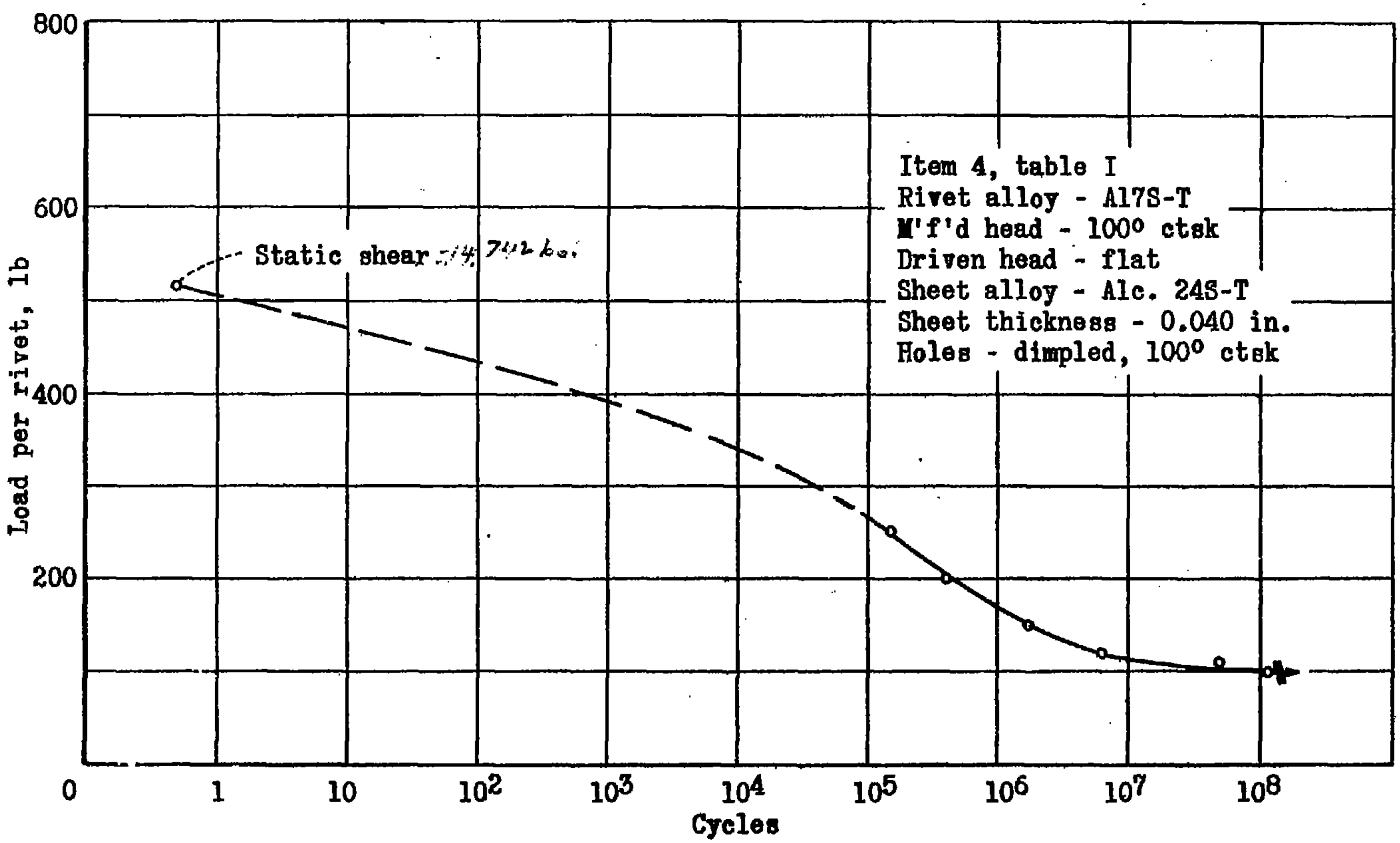


Figure 8.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

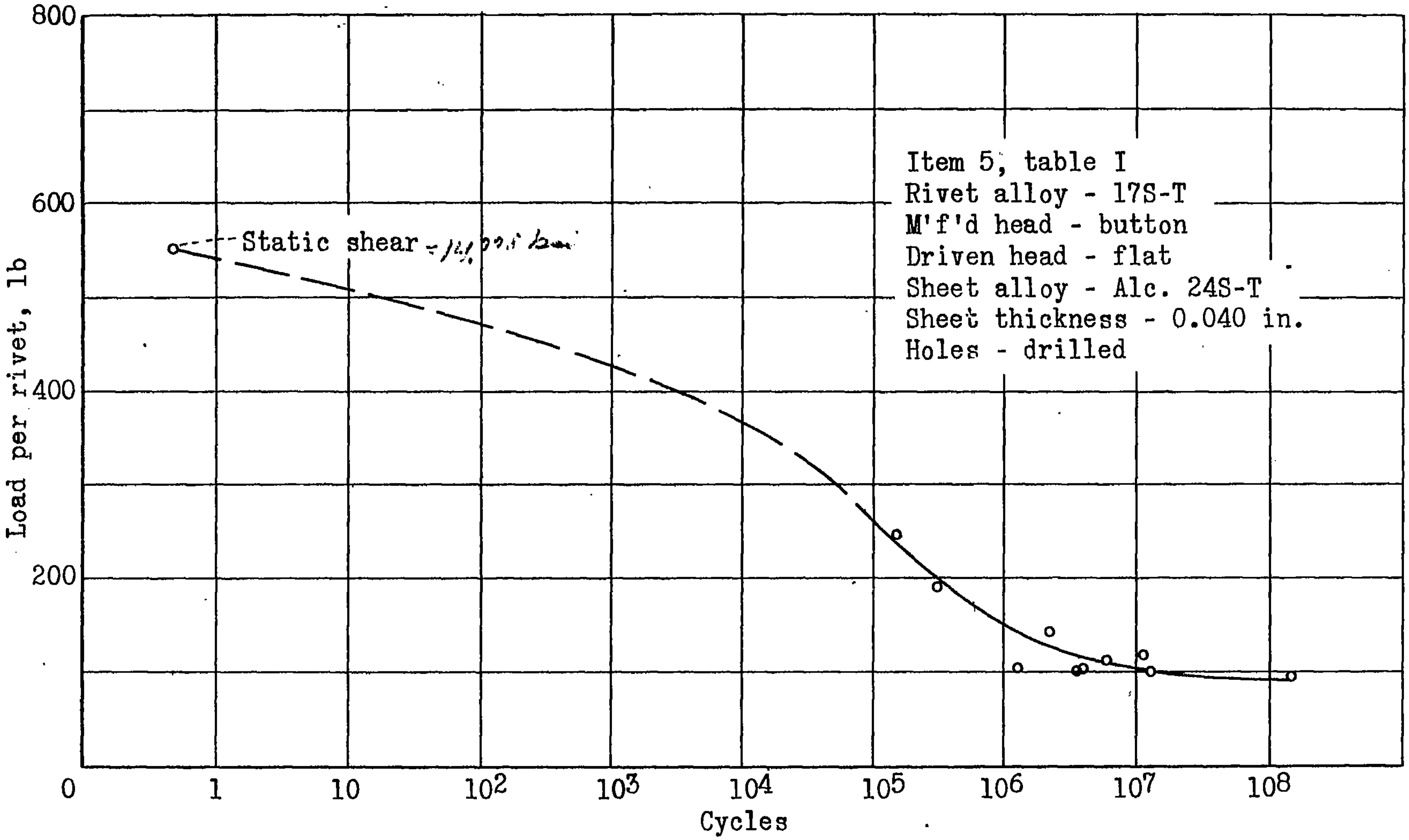


Figure 9.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

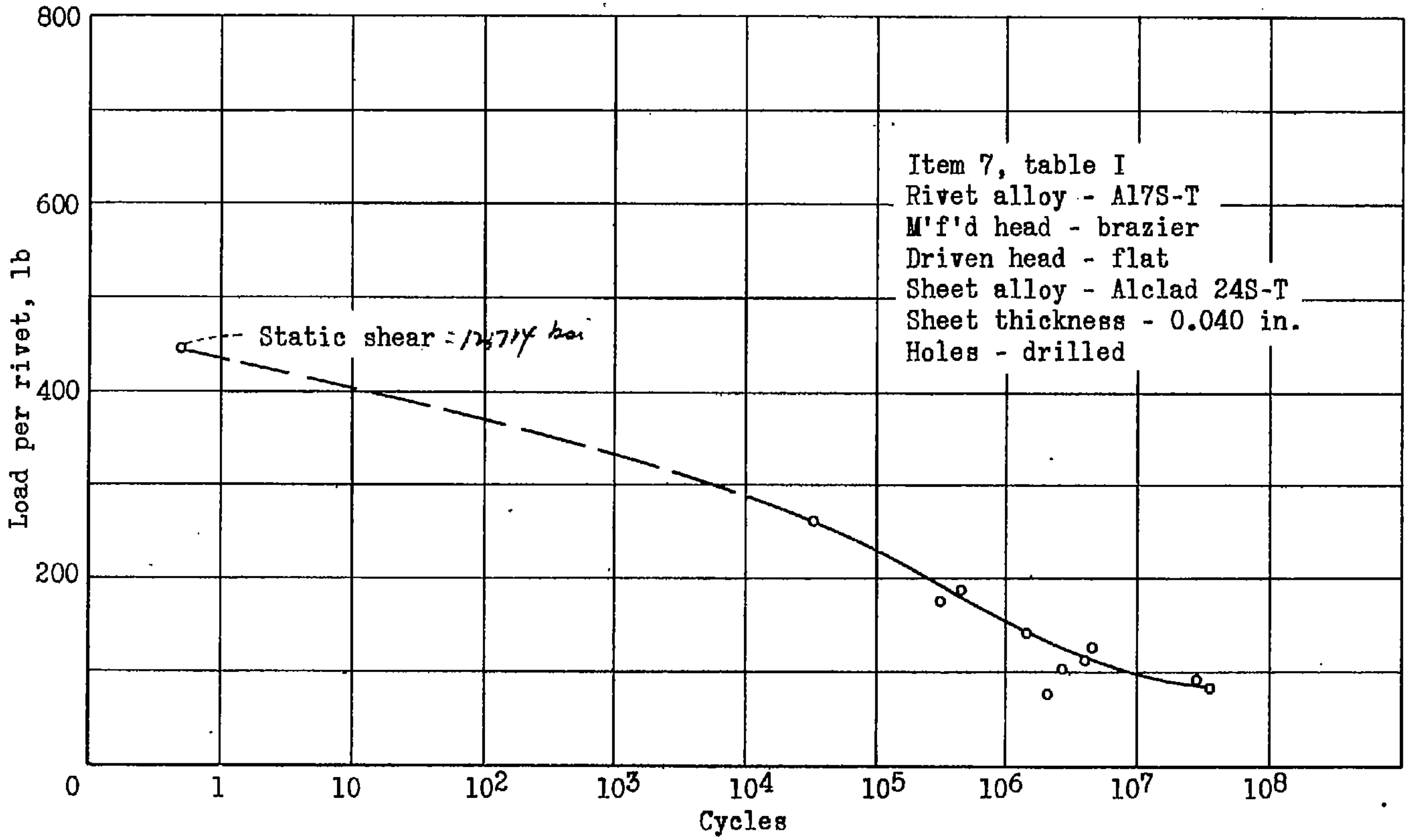


Figure 10.- Shear fatigue tests for 1/8-in. diameter aluminum alloy rivets.

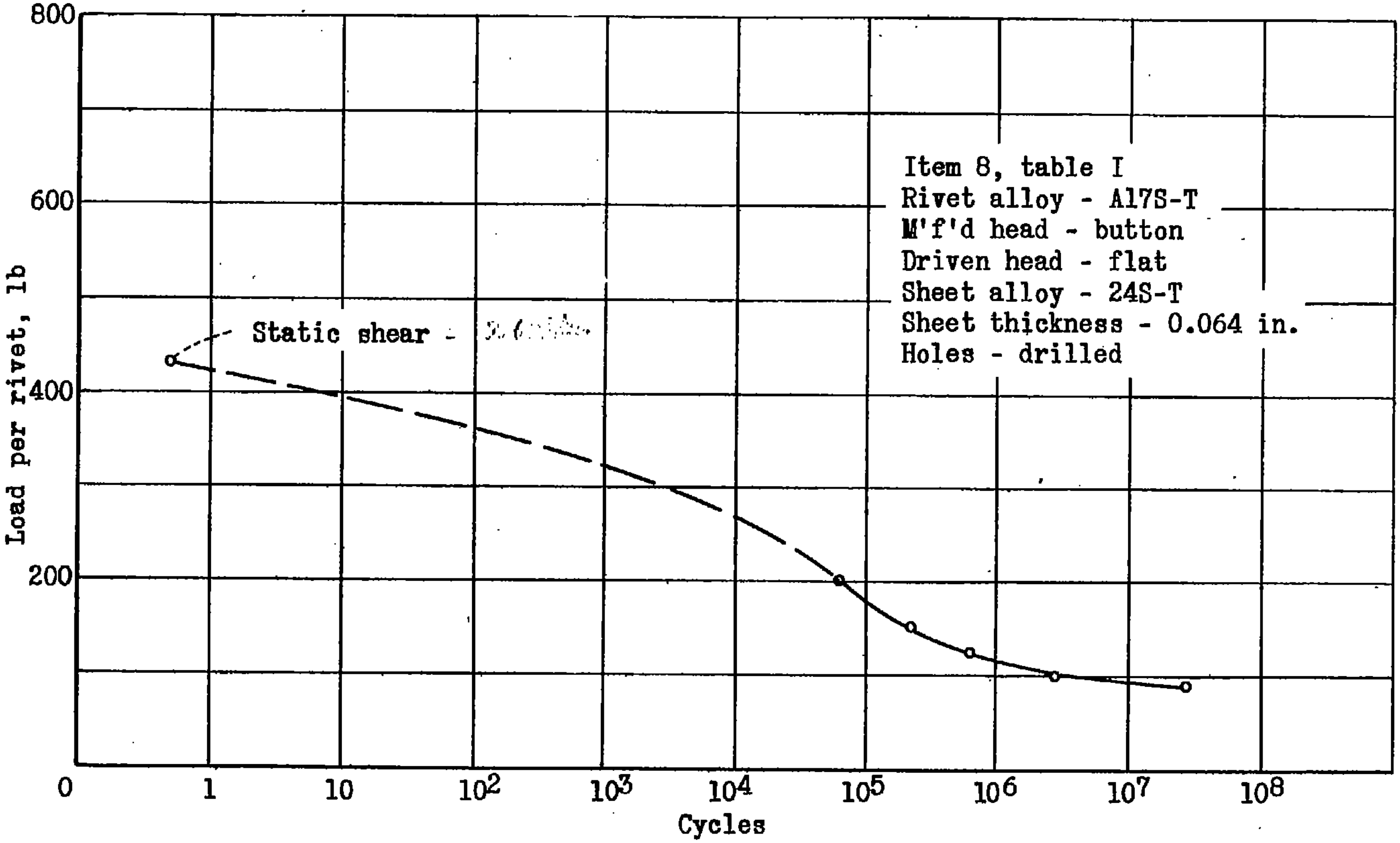


Figure 11.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

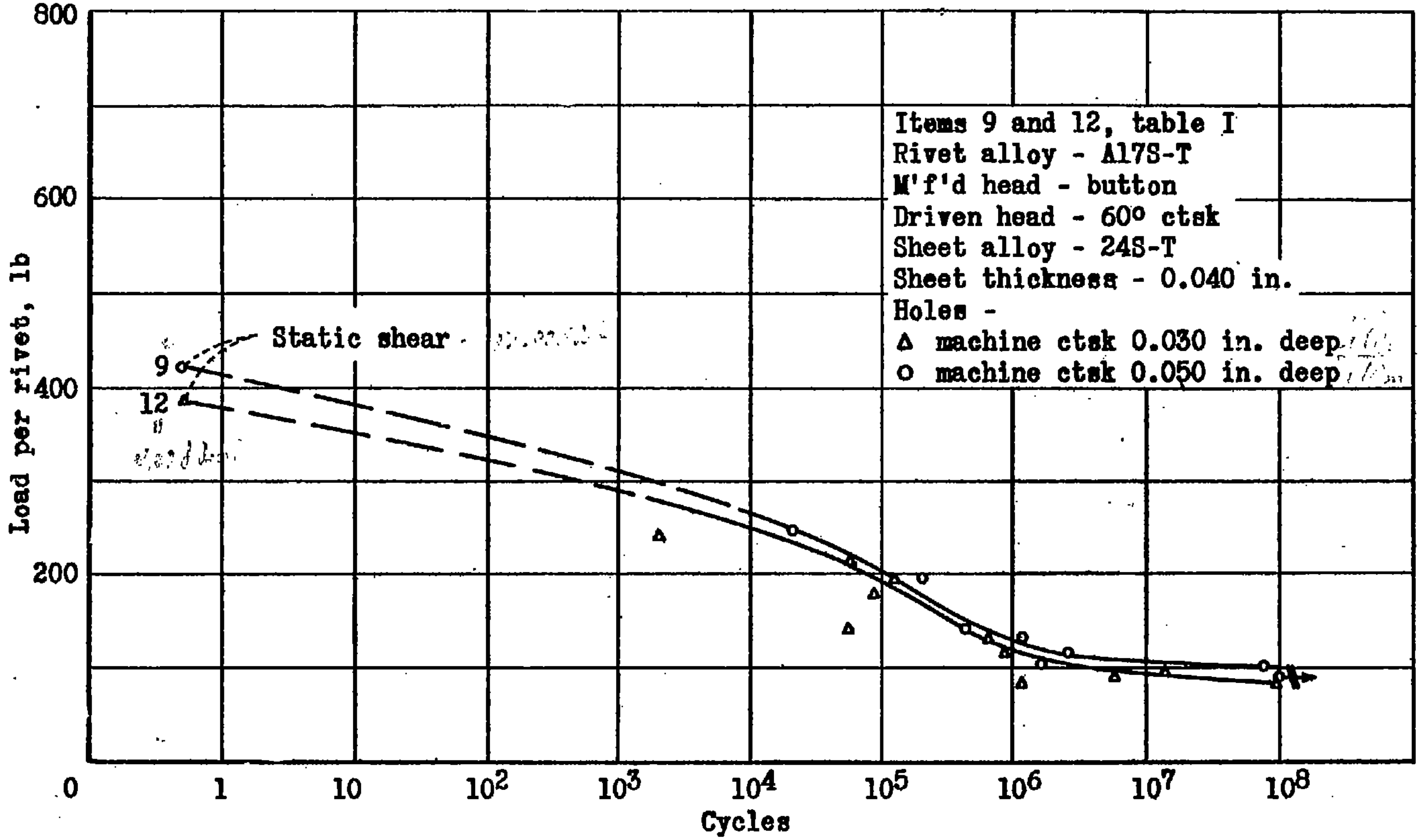


Figure 12.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

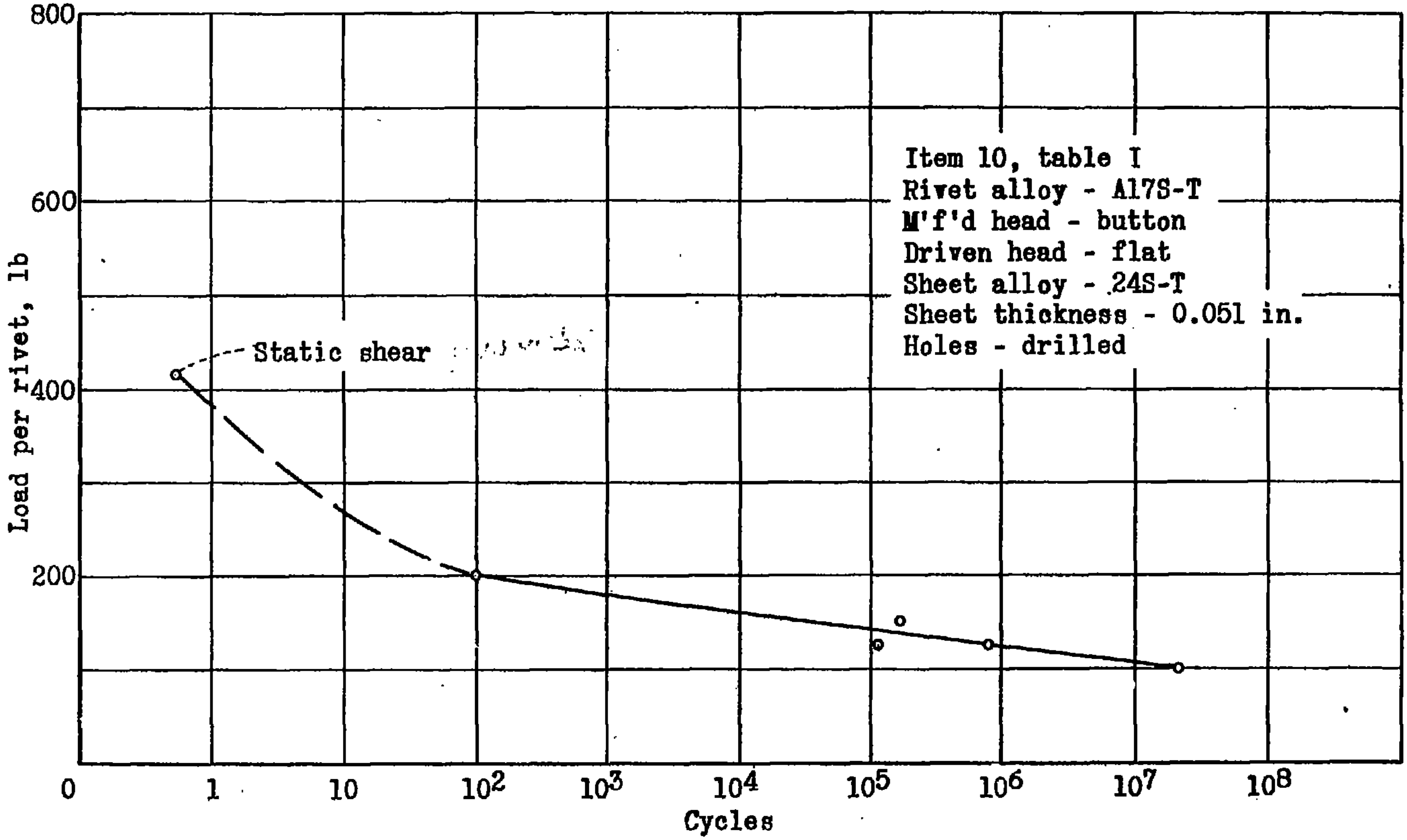


Figure 13.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

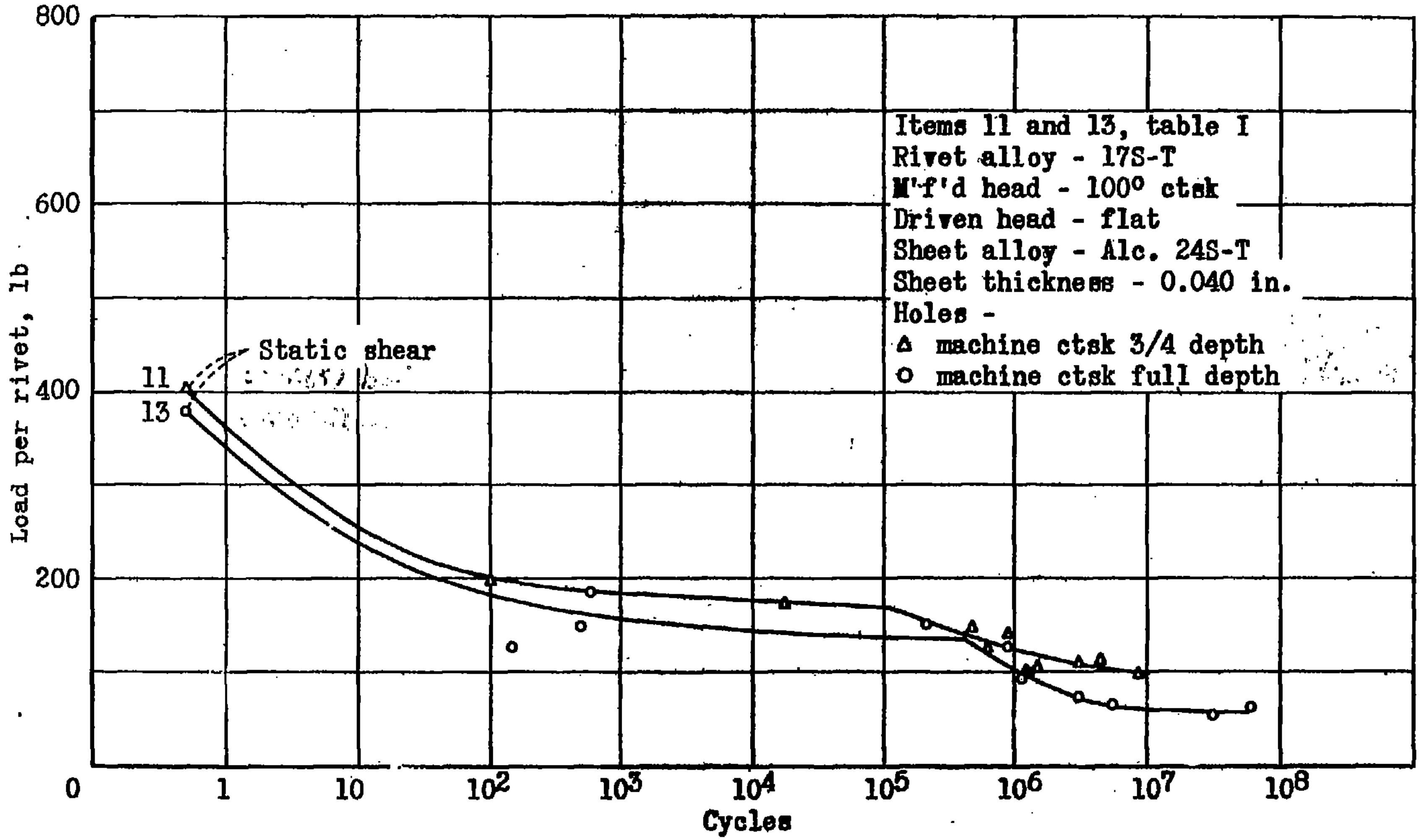


Figure 14.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.