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TECHNICAL NOTE 2012

RESULTS OF SHEAR FATIGUE TESTS OF JOINTS WITH $\frac{3}{16}$-INCH-DIAMETER 24S-T31 RIVETS IN 0.064-INCH-THICK ALCLAD SHEET

By Marshall Holt

Aluminum Company of America

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SUMMARY

Shear fatigue tests were made of joints with $\frac{3}{16}$-inch-diameter 24S-T31 (-T)[1] rivets in 0.064-inch-thick Alclad sheet of the following high-strength aluminum alloys: Alclad 24S-T3 (-T),[1] Alclad 24S-T81, Alclad 24S-T36 (-RT),[1] Alclad 24S-T86, Alclad 75S-T6 (-T),[1] Alclad 14S-T4 (-W),[1] and Alclad 14S-T6 (-T).[1] One series of tests was made on joints with $\frac{3}{16}$-inch-diameter 17S-T31 (-T)[1] rivets in 0.064-inch-thick Alclad 75S-T6 (-T)[1] aluminum alloy.

The results showed that the design of the joint gives a wider range of fatigue strengths than does the choice of material from the group studied. The results also showed that no one sheet alloy showed superiority over the others.

INTRODUCTION

The research program of the Aluminum Research Laboratories has included the fatigue testing of joints of various types using aircraft-size rivets. The results of some of the tests have been presented in references 1 and 2.

It is the purpose of this report to expand the field covered by reference 2 and to summarize the available test data of joints with $\frac{3}{16}$-inch-diameter 24S-T31 rivets in 0.064-inch-thick Alclad sheet of the high-strength aluminum alloys.

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[1]Former temper designation given in parentheses.

MATERIALS AND SPECIMENS

Alclad sheet of the following alloys and tempers was used in these tests: Alclad 24S-T3, Alclad 24S-T81, Alclad 24S-T36, Alclad 24S-T86, Alclad 75S-T6, Alclad 14S-T4, and Alclad 14S-T6. The actual thicknesses of the sheet and of the Alclad coating (each side) are given in table I. The tensile properties are given in table I and all the values satisfy the respective specification requirements. They are also in good agreement with the typical values. The artificially aged materials were obtained from the same lots as the corresponding naturally aged materials.

All the rivets used were 3/16 inch in diameter; 24S-T31 was used for all the rivets except for one set which was of 17S-T31. They were heat-treated, quenched, refrigerated, and driven cold immediately after removal from the refrigerant (-T31 temper). As noted in tables II and III, the manufactured heads of some were of the brazier type and some were countersunk at 100°. The driven heads were all flat. For items 36, 38, 39, and 43, the sheet was machine-countersunk while for items 44, 45, 52, and 53 the sheet was dimpled either by spin-dimpling or coin-dimpling as noted. The rivets were allowed to age at room temperature for at least 4 days before testing.

The individual fatigue specimens were simple lap joints containing a single rivet. They were 1 inch wide and the lap was 3/4 inch long as shown in figure 1. They were cut from panels 20 inches long containing 16 rivets as shown in figure 2. After sawing, the edges of the specimens were finished by machining in the longitudinal direction. The specimens for static test also contained a single rivet and were cut from panels as shown in figure 3.

METHODS OF TESTING

Three different machines were used during the testing of the fatigue specimens and, judging from the overlapping of the plotted data, the fatigue strengths were not influenced by the machine used. The machines are shown in figures 4, 5, and 6. The ARL rotating-beam fatigue machine shown in figure 4 was designed and built at the Aluminum Research Laboratories in 1942 and operates at 1750 rpm. It was used for most of the tests. The adapters for testing a set of four specimens are shown in figure 7. During the test the adapter and specimens formed part of a rotating beam, the central portion of which was subjected to a uniform bending moment. The rivets were thus subjected to a cyclic shearing load which varied from a maximum in one direction to the same value in the opposite direction. The 2-inch

rotating-beam fatigue machine is shown in figure 5. It was designed and built at Aluminum Research Laboratories in 1930 and is described in reference 3. This machine was originally intended for testing rotating solid-beam specimens having a diameter of 2 inches at the test section. By means of the adapters shown in figure 8 it is made suitable for testing these small riveted joints under completely reversed loading. It operates at 1400 rpm. A Krouse direct-stress fatigue machine having a maximum capacity of 5000 pounds is shown in figure 6. This machine is also provided with adapters for testing a set of four specimens. It operates at 1500 rpm. Although this machine is adjustable to give any desired loading cycle, the tests were made with completely reversed stresses. Each of these machines is equipped with a limit switch which automatically stops the machine when a specimen fails. Each also has a counter for determining the number of cycles of stress. In the tests in which the expected life of the specimen was less than about 1000 cycles, the specimen was rotated by hand and the number of cycles counted.

Usually only one of the four joints fails in fatigue and the specimen then collapses. Occasionally it is difficult to determine the location of the initial failure, whether in the rivet or sheet, because the joints are mutilated considerably by the time the machine comes to rest.

RESULTS AND DISCUSSION

The individual test results are given in table II with information on the sheet alloy, type of rivet, preparation of the hole, and location of initial failure. The data are shown as S-N curves in figures 9 to 24. Table III summarizes the indicated fatigue strengths for certain numbers of cycles of stress. The data suggest the following comparisons.

Various Alloys and Tempers

As shown in figures 25 and 26 all the S-N curves for the various alloys and tempers of Alclad sheet used in this investigation are of the same general shape and for each type of joint the curves lie fairly close together so that all of them can be covered by a relatively narrow scatter band. This is particularly true of the joints with brazier-head rivets where the variables of making the specimens can be kept in closer control. No one sheet alloy shows a consistent superiority over all of the others in these tests but it is interesting to note that Alclad 24S-T3 is generally on the high side of the group.

Design of Joint

The data in figures 27 and 28 show that the design of the joint, whether using rivets with protruding heads or with flush heads, gives a wider range of fatigue strengths than does the choice of the material from the group studied in this investigation. For high loads per rivet and small numbers of cycles, the protruding-head rivets in drilled holes are superior to flush-head rivets in machine-countersunk holes. The relative strength of joints with dimpled holes depends on the method used in dimpling the sheet. In the case of Alclad 75S-T6 sheet, the data in figure 29 indicate that coin-dimpling is superior to spin-dimpling. For lives greater than 10^6 cycles, the fatigue strengths of all joints lie within a rather narrow scatter band.

Aluminum Research Laboratories
Aluminum Company of America
New Kensington, Pa., June 1, 1949

REFERENCES

1. Andrews, H. J., and Holt, M.: Fatigue Tests on 1/8-Inch Aluminum Alloy Rivets. NACA TN 971, 1945.

2. Moore, R. L., and Hill, H. N.: Comparative Fatigue Tests of Riveted Joints of Alclad 24S-T, Alclad 24S-T81, Alclad 24S-RT, Alclad 24S-T86, and Alclad 75S-T Sheet. NACA RB 5F11, 1945.

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

TABLE I.- MECHANICAL PROPERTIES OF SHEET USED IN FATIGUE TESTS OF JOINTS WITH $\frac{3}{16}$-INCH-DIAMETER 24S-T31 RIVETS IN 0.064-INCH-THICK ALCLAD SHEET

Item	Alloy and temper	Thickness (in.)		Material	Parallel to direction of rolling				Normal to direction of rolling			
		Sheet	Alclad (coating)		Tensile strength (psi)	Tensile yield strength (psi)	Elongation in 2 in. (percent)	Compressive yield strength (psi)	Tensile strength (psi)	Tensile yield strength (psi)	Elongation in 2 in. (percent)	Compressive yield strength (psi)
23	[a]Alclad 24S-T36	0.066	0.0016	62968-1	71,900	60,900	15.5	------	70,050	54,100	14.0	------
24	[a]Alclad 24S-T86	.068	.0016	62968-2	73,550	69,650	6.5	------	72,650	68,200	6.3	------
25, 43	[a]Alclad 75S-T6	.064	.0018	63317	80,350	71,200	14.0	------	78,800	66,850	14.0	------
26	Alclad XA75S-T6	.064	.0018	66420	70,450	60,850	11.0	------	70,450	58,900	11.0	------
27, 39	[a]Alclad 24S-T3	.064	.0016	67793-1	68,800	51,700	20.3	------	66,850	44,400	19.0	------
28	[a]Alclad 24S-T81	.064	.0016	67793-2	68,900	62,500	6.5	61,750	67,250	60,150	6.3	62,400
35, 36	Alclad 14S-T4	.064	.0018	74466	65,500	47,300	21.5	37,050	64,850	40,350	20.5	43,600
37, 38	Alclad 14S-T6	.064	.0018	74467	68,850	62,050	11.0	61,650	68,200	60,700	9.5	64,300
44	Alclad 75S-T6	.063	.0021	75935	------	------	----	------	79,600	68,350	12.5	------
45	Alclad 75S-T6	.065	.0022	75977	------	------	----	------	78,050	67,000	11.3	------
52, 53	Alclad 75S-T6	.063	.0022	80503	------	------	----	------	78,350	66,500	11.8	------

[a]See also reference 2.

TABLE II.– DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS; JOINTS WITH $\frac{3}{16}$-INCH-DIAMETER 24S-T31 RIVETS IN 0.064-INCH-THICK ALCLAD SHEET

[All tests made with complete reversal of stress]

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
26	Alclad XA75S-T6	Brazier	66420-3	1230	Static	Rivet	A	Figure 12
			-2	350	401,500	Sheet	ARL	
			-1	250	1,327,200	Sheet	ARL	
			-4	200	1,437,500	Sheet	ARL	
			-3	150	12,699,600	Sheet	ARL	
28	Alclad 24S-T81	Brazier	67793-2-1	1000	800	Rivet	K	Figure 14
			-2	800	9,700	Rivet	K	
			-3	650	39,900	Sheet	K	
			-2-4	1150	93	Rivet	K	
35	Alclad 14S-T4	Brazier	74466A-2	1260	Static	Rivet	A	Figure 15
			-4-7	1100	11	Buckled	2-in.	
			-4-8	1000	2,628	Buckled	2-in.	
			-4-6	900	8,829	Sheet	2-in.	
			-3-5	550	99,400	Rivet	ARL	
			-3-11	501	82,800	Sheet	K	
			-2-4	500	125,400	Uncertain	ARL	
			-3-12	413	195,400	Sheet	K	
			-2-3	400	303,600	Uncertain	ARL	
			-4-13	393	185,500	Sheet	K	
			-3-10	307	820,800	Sheet	K	
			-2-2	300	1,265,200	Uncertain	ARL	
			-2-1	200	7,021,600	Sheet	ARL	
			-4-9	200	8,351,100	Sheet	K	
			-4-14	174	3,739,000	Sheet	K	
			-4-15	161	114,870,100	None	K	

[1]Additional data given in reference 2.

[2]A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating-beam fatigue machine; K, Krouse direct-stress fatigue machine; 2-in., rotating-beam fatigue machine for 2-in.-diameter specimens.

TABLE II.- DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS - Continued

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
36	Alclad 14S-T4	Countersunk (machine)	74466B	870	Static	Rivet	A	Figure 16
			-4-9	800	671	Rivet	2-in.	
			-2-8	750	1,550	Rivet	2-in.	
			-2-7	700	10,394	Sheet	2-in.	
			-4-16	500	68,500	Uncertain	ARL	
			-4-15	451	75,700	Sheet	K	
			-2-6	450	4,600	Rivet	ARL	
			-1-4	400	68,800	Rivet	ARL	
			-2-5	350	500,700	Sheet	ARL	
			-4-13	313	470,400	Sheet	K	
			-1-1	300	832,900	Sheet	ARL	
			-4-11	201	3,758,400	Sheet	K	
			-1-2	200	6,089,800	Sheet	ARL	
			-4-12	174	2,965,800	Sheet	K	
			-4-10	147	5,247,200	Sheet	K	
			-4-14	127	454,530,800	None	K	
37	Alclad 14S-T6	Brazier	74467-A-4-8	1250	Static	Rivet	A	Figure 17
			-4-9	1150	108	Uncertain	ARL	
			-3-7	1050	1,326	Rivet	ARL	
			-3-6	950	6,507	Sheet	ARL	
			-2-4	550	83,800	Sheet	ARL	
			-2-3	400	372,400	Uncertain	ARL	
			-3-10	350	498,500	Uncertain	ARL	
			-2-2	300	1,366,100	Uncertain	ARL	
			-2-1	200	4,329,800	Sheet	ARL	
			-4-11	175	4,915,600	Sheet	ARL	
			-3-5	150	100,243,200	None	ARL	
38	Alclad 14S-T6	Countersunk (machine)	74467B	900	Static	Rivet	A	Figure 18
			-2-9	800	13	Rivet	2-in.	
			-2-7	750	50	Rivet	2-in.	
			-2-8	700	7,579	Sheet	2-in.	
			-4	695	4,500		K	
			-2-6	500	45,600	Sheet	ARL	
			-3-11	500	87,500	Uncertain	ARL	
			-4-4	450	78,900	Rivet	ARL	
			-4-2	400	139,100	Rivet	ARL	
			-3-12	375	221,300	Sheet	ARL	
			-4-1	300	447,100	Sheet	ARL	
			-4-3	205	2,581,600	Sheet	ARL	
			-2-5	150	5,840,300	Sheet	ARL	
			-3-10	126	5,432,000	Sheet	K	
			-4-13	115	15,730,600	Sheet	K	
			-4-14	101	213,773,800	None	K	

[1]Additional data given in reference 2.

[2]A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating-beam fatigue machine; K, Krouse direct-stress fatigue machine; 2-in., rotating-beam fatigue machine for 2-in.-diameter specimens.

TABLE II.– DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS – Continued

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
39	Alclad 24S-T3	Countersunk (machine)	67793-1-9	1010	Static	Rivet	A	Figure 19
			-1-8	900	483	Rivet	2-in.	
			-3-7	750	12,422	Sheet	2-in.	
			-2-5	550	96,300	Sheet	ARL	
			-1-3	450	183,600	Rivet	ARL	
			-1-2	350	383,000	Sheet	ARL	
			-1-1	250	2,197,200	Sheet	ARL	
			-2-4	200	5,507,200	Sheet	ARL	
			-3-10	180	14,122,300	Sheet	ARL	
			-3-11	150	342,719,000	None	ARL	
43	Alclad 75S-T6	Countersunk (machine)	63317	800	Static		A	Figure 20
			-3-9	750	28	Rivet	A	
			-3-8	700	657	Rivet	2-in.	
			-2-5	550	60,700	Sheet	ARL	
			-1-3	450	134,800	Sheet	ARL	
			-1-2	350	260,300	Sheet	ARL	
			-1-1	250	876,600	Sheet	ARL	
			-2-4	200	2,135,800	Sheet	ARL	
			-2-6	150	5,741,600	Sheet	ARL	
			-3-7	120	100,552,000	None	ARL	
44	Alclad 75S-T6	Countersunk (spin dimple)	75935	1270	Static	Rivet	A	Figure 21
			-2-3	400	44,800	Sheet	ARL	
			-2-1	300	291,800	Sheet	ARL	
			-2-2	200	3,033,500	Sheet	ARL	
			-3-5	170	3,524,700		ARL	
			-3-6	160	288,290,800	None	ARL	
			-4-7	996	127	Sheet	K	
			-8	808	1,725	Sheet	K	
			-9	604	14,500	Sheet	K	

[1]Additional data given in reference 2.

[2]A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating-beam fatigue machine; K, Krouse direct-stress fatigue machine; 2-in., rotating-beam fatigue machine for 2-in.-diameter specimens.

TABLE II.– DESCRIPTION OF SPECIMENS AND RESULTS OF FATIGUE TESTS – Concluded

Item	Sheet alloy (1)	Manufactured head style of rivet	Specimen	Load per rivet (lb)	Number of cycles	Type of failure	Machine used (2)	Reference
45	Alclad 75S-T6	Countersunk (spin dimple) (17S-T31 rivets)	75977	1390	Static			Figure 22
			-1-7	350	229,600	Sheet	ARL	
			-1-1	300	159,100	Sheet	ARL	
			-1-3	200	528,300	Sheet	ARL	
			-1-4	150	841,400	Sheet	ARL	
			-2-8	135	46,986,300	Sheet	ARL	
			-1-6	120	207,763,700	None	ARL	
			-2-9	1284	60	Sheet	K	
			-2-13	994	532	Sheet	K	
			-1-10	818	2,600	Sheet	K	
			-3-11	600	3,400	Sheet	K	
			-3-12	600	6,800	Sheet	K	
			-3-14	424	36,000	Sheet	K	
52	Alclad 75S-T6	Countersunk (coin dimple)	805030	1580	Static			Figure 23
			-3-11	930	2,200	Sheet	K	
			-1-3	450	188,500	Sheet	ARL	
			-1-2	350	368,700	Uncertain	ARL	
			-2-5	300	1,248,400	Sheet	ARL	
			-1-4	250	3,264,400	Sheet	ARL	
			-2-6	230	2,775,300	Sheet	ARL	
			-2-7	220	1,479,900	Sheet	ARL	
			-2-8	200	12,296,600	Sheet	ARL	
			-1-1	200	442,735,100	None	ARL	
			-3-12	1266	43	Sheet	K	
53	Alclad 75S-T6	Countersunk (coin dimple)	80503H		Static			Figure 24
			-3-12	1200	137	Sheet	K	
			-3-10	1000	1,100	Sheet	K	
			-3-9	823	4,500	Sheet	K	
			-3-11	750	10,500	Uncertain	K	
			-2-8	555	111,300	Sheet	ARL	
			-1-3	500	119,700	Sheet	ARL	
			-1-2	400	295,300	Sheet	ARL	
			-2-7	300	683,800	Sheet	ARL	
			-1-4	220	2,344,400	Sheet	ARL	
			-2-5	190	3,480,900	Sheet	ARL	
			-2-6	170	114,591,600	None	ARL	

[1]Additional data given in reference 2.

[2]A, Amsler Universal testing machine; ARL, Aluminum Research Laboratories rotating-beam fatigue machine; K, Krouse direct-stress fatigue machine; 2-in., rotating-beam fatigue machine for 2-in.-diameter specimens.

TABLE III.– FATIGUE STRENGTHS AT VARIOUS NUMBERS OF CYCLES; JOINTS WITH $\frac{3}{16}$-INCH-DIAMETER

24S-T31 RIVETS IN 0.064-INCH-THICK ALCLAD SHEET

[All tests made with complete reversal of stress; stress ratio, -1]

Item	Alclad sheet alloy	Manufactured head style of rivet (a)	Static strength (b)	Fatigue strength at various numbers of cycles (lb per rivet) (b)							
				10	10^2	10^3	10^4	10^5	10^6	10^7	10^8
23	[c]24S-T36	Brazier	1250R	1190E	1125E	1010E	825E	590S	330S	170S	120S
24	[c]24S-T86	Brazier	1250R	1185E	1120E	1030E	850E	550R	260S	125S	105S
25	[c]75S-T6	Brazier	1270R	1210R	1140R	1015R	825R	580R	285S	155S	115S
26	XA75S-T	Brazier	1230R	1120E	975E	800E	630E	430E	255S	155S	150E
27	[c]24S-T3	Brazier	1255R	1200S	1140S	1035S	855S	590S	315S	210S	185S
28	[c]24S-T81	Brazier	1250R	1180R	1110R	990R	800R	555U	290S	125S	100S
35	14S-T4	Brazier	1260R	1200R	1145R	1050R	880R	495R	285U	195S	160S
36	14S-T4	Countersunk[d]	870R	865R	845R	780R	610U	430U	265S	160S	130S
37	14S-T6	Brazier	1250F	1205U	1155U	1065R	895R	535S	300S	170S	155S
38	14S-T6	Countersunk[d]	900R	815R	760R	710R	640R	435S	240S	125S	105S
39	24S-T3	Countersunk[d]	1010R	970R	935R	875R	770R	550R	275U	190S	165S
43	75S-T6	Countersunk[d]	800R	765R	730R	695R	640U	490U	240U	155U	125U
44	75S-T6	Countersunk[e]	1270R	1040E	830E	640E	485E	360S	240S	180S	165S
45	75S-T6	Countersunk[e]	1390R	1080E	940E	790E	610E	380U	155S	140S	130S
52	75S-T6	Countersunk[f]	1580U	1390U	1200U	980S	745S	500S	285S	200S	200S
53	75S-T6	Countersunk[g]	-----	1400R	1210R	990R	765U	520S	280S	185S	180S

[a]Driven heads were all flat.
[b]Letters following fatigue strengths have the following meanings: R, rivet failure; S, sheet failure; U, uncertain type of failure; E, estimated from incomplete S-N curve; F, sheet buckled, rivets sheared at 1365 pounds.
[c]Reported in reference 2.
[d]Machine-countersunk.
[e]Spin-dimpled holes.
[f]Coin-dimpled at room temperature.
[g]Coin-dimpled with heated tools.

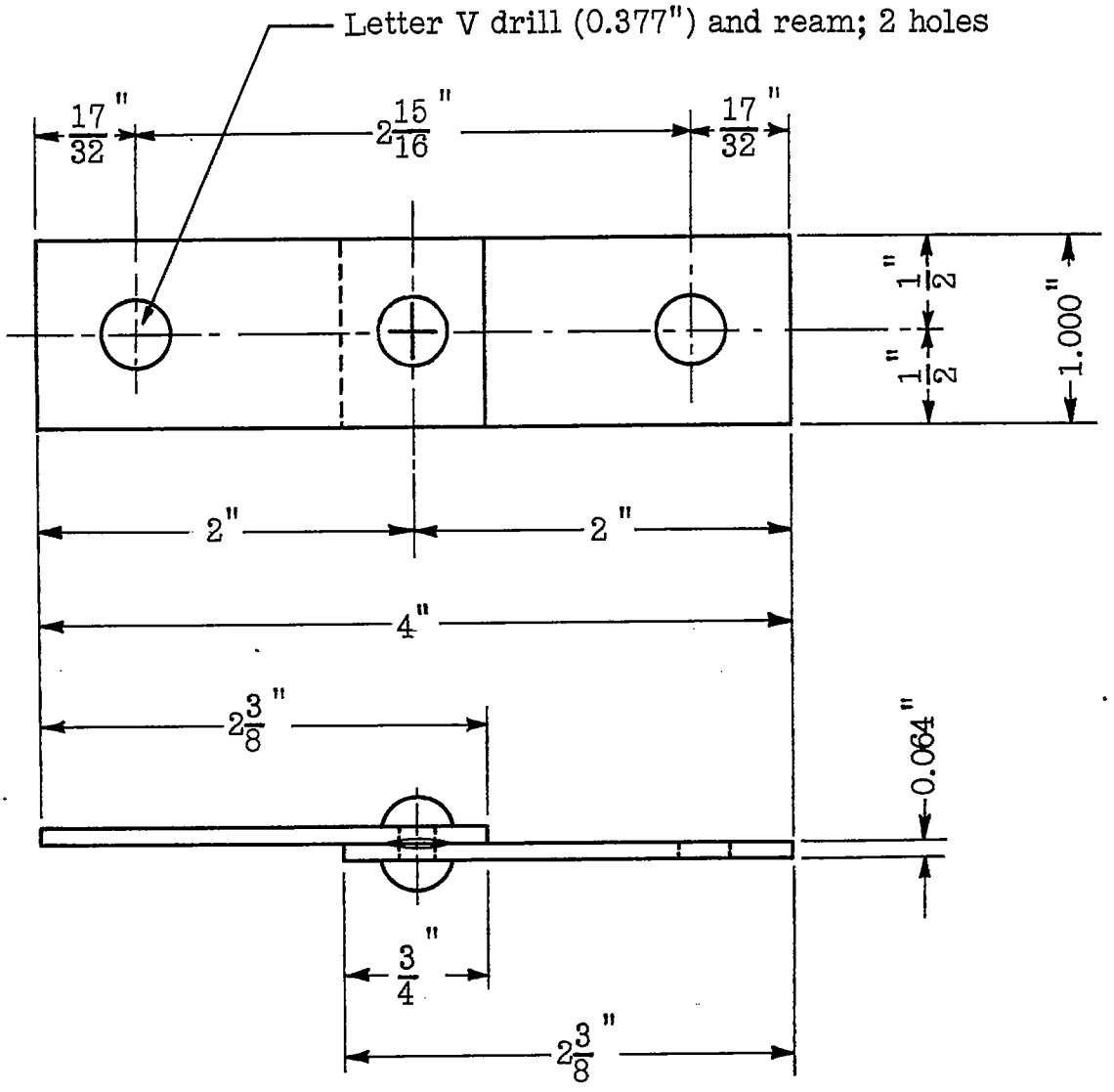

Figure 1.- Riveted specimen, 0.064-inch-thick (14-gage) sheet. Maximum rivet size, $\frac{3}{16}$-inch diameter.

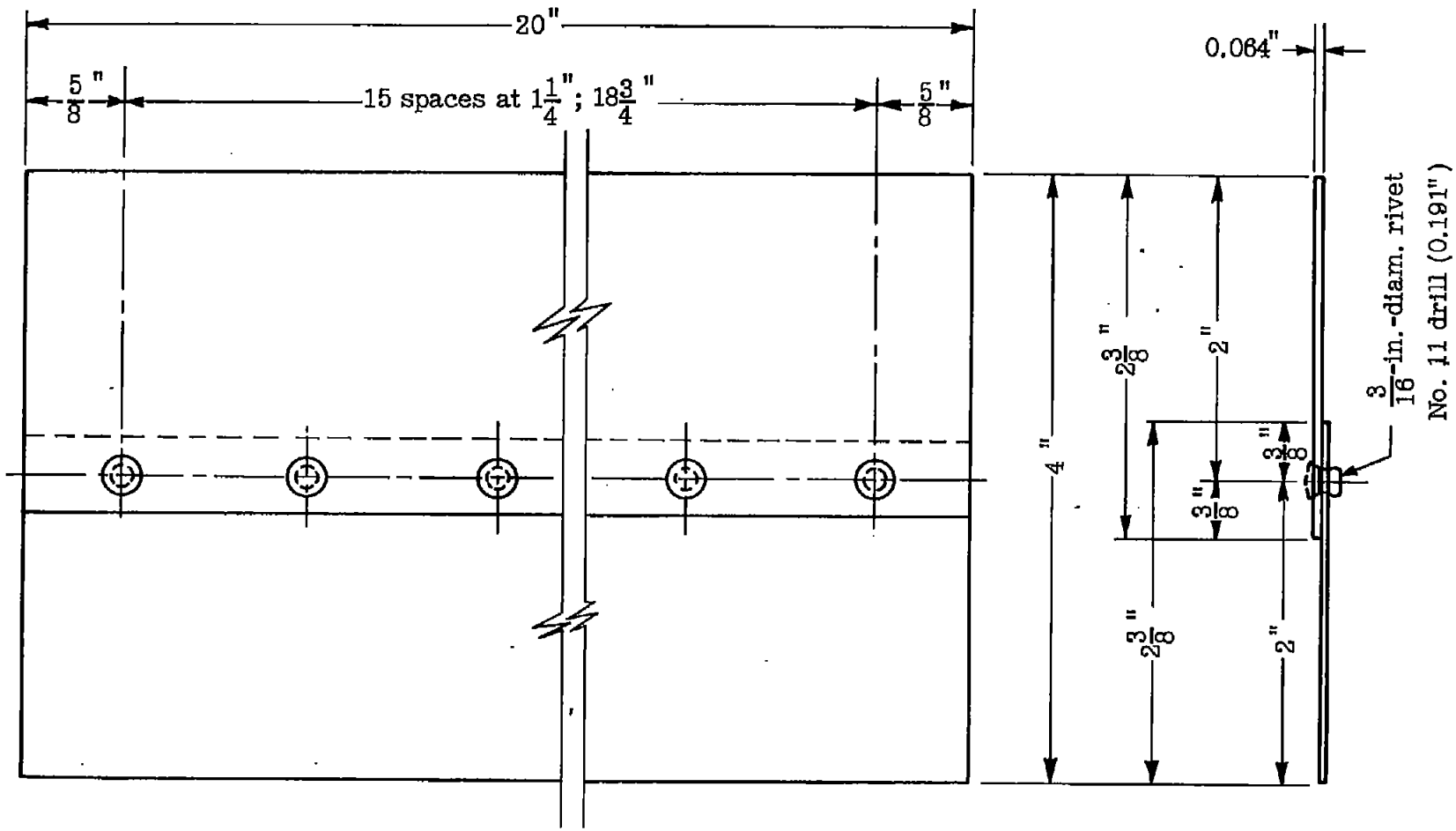

Figure 2.- Panel for fatigue tests of riveted joints.

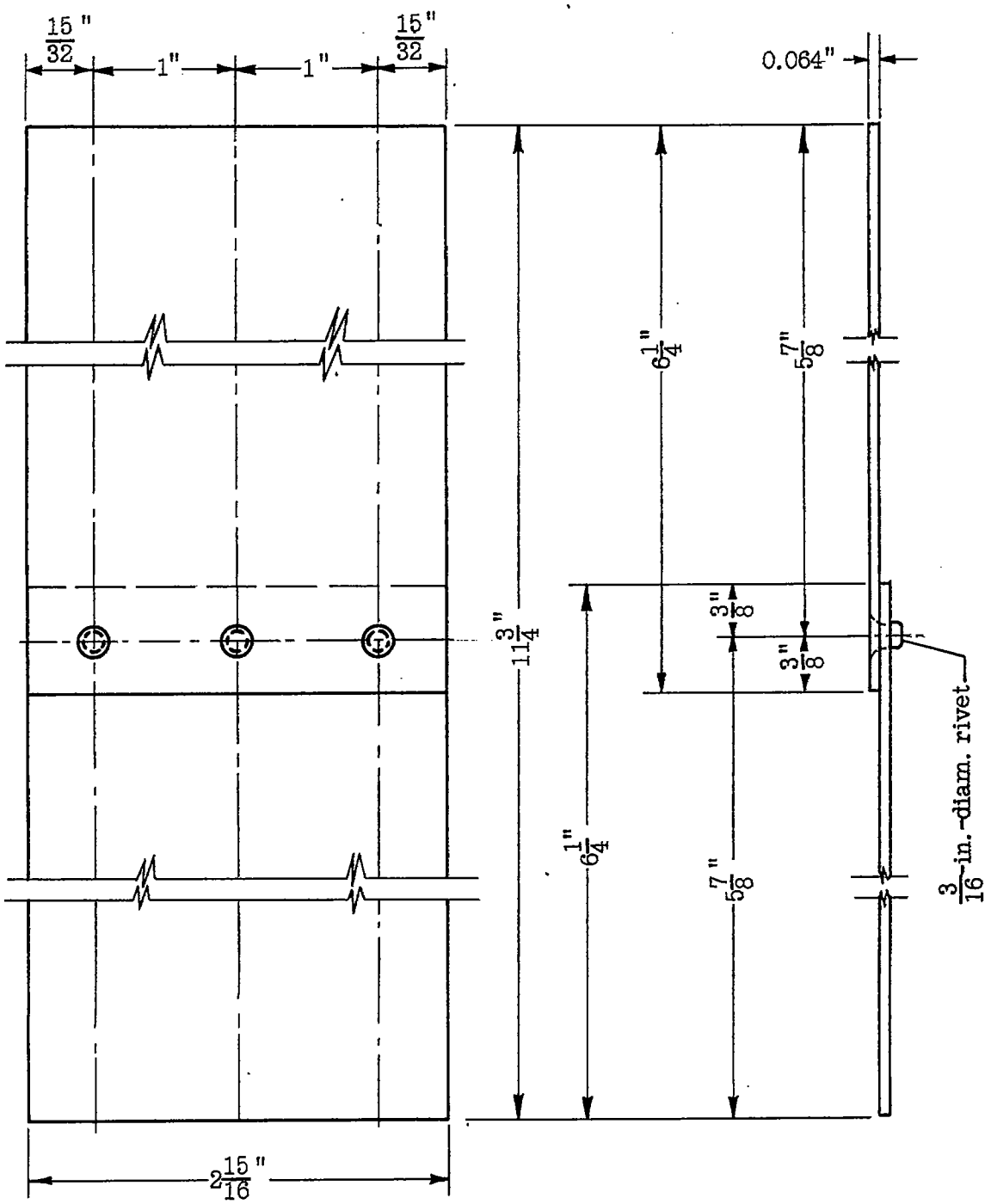

Figure 3.- Panel for static tests of riveted joints.

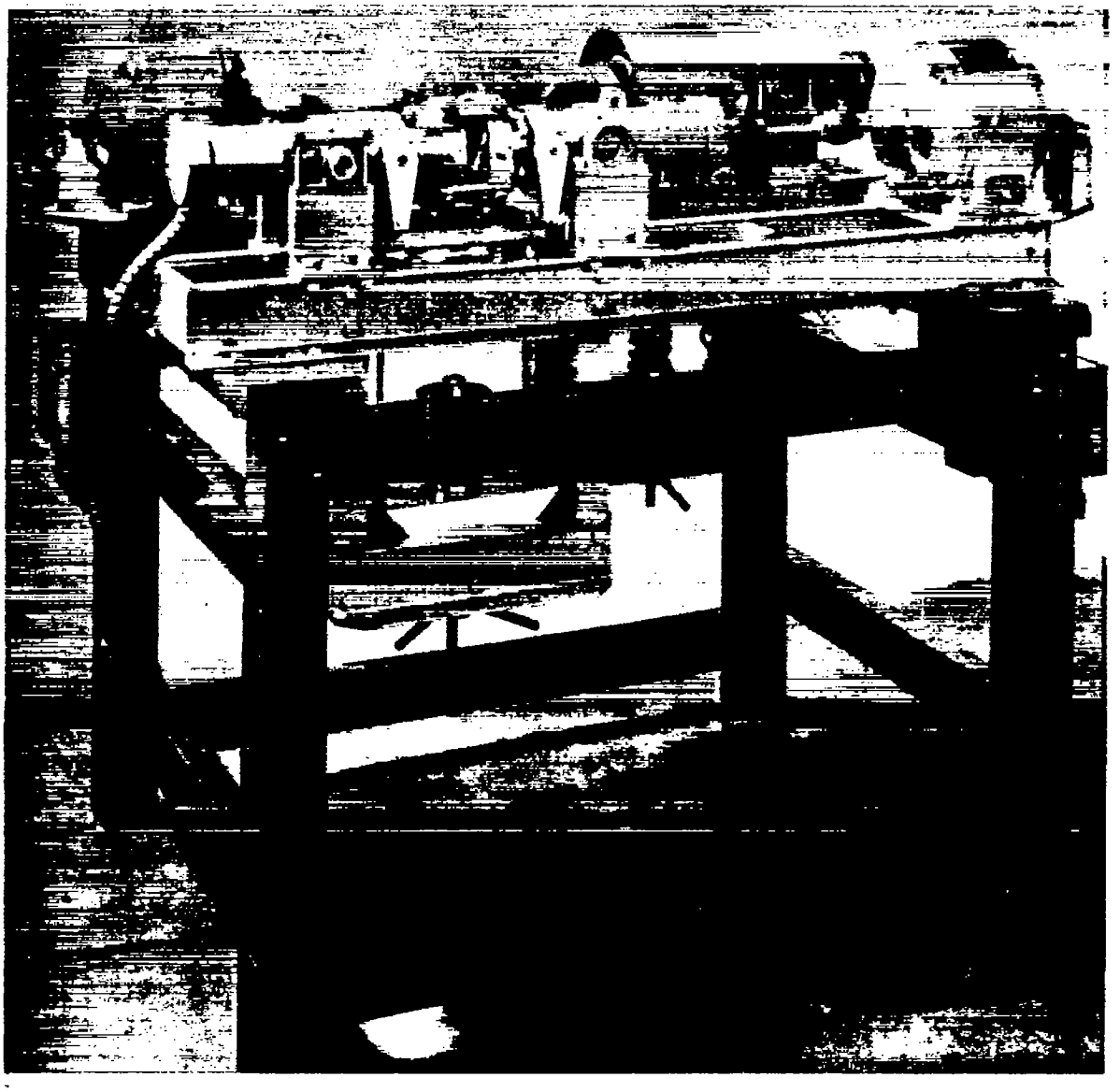

Figure 4.- ARL rotating-beam fatigue testing machine designed and built at Aluminum Research Laboratories in 1942.

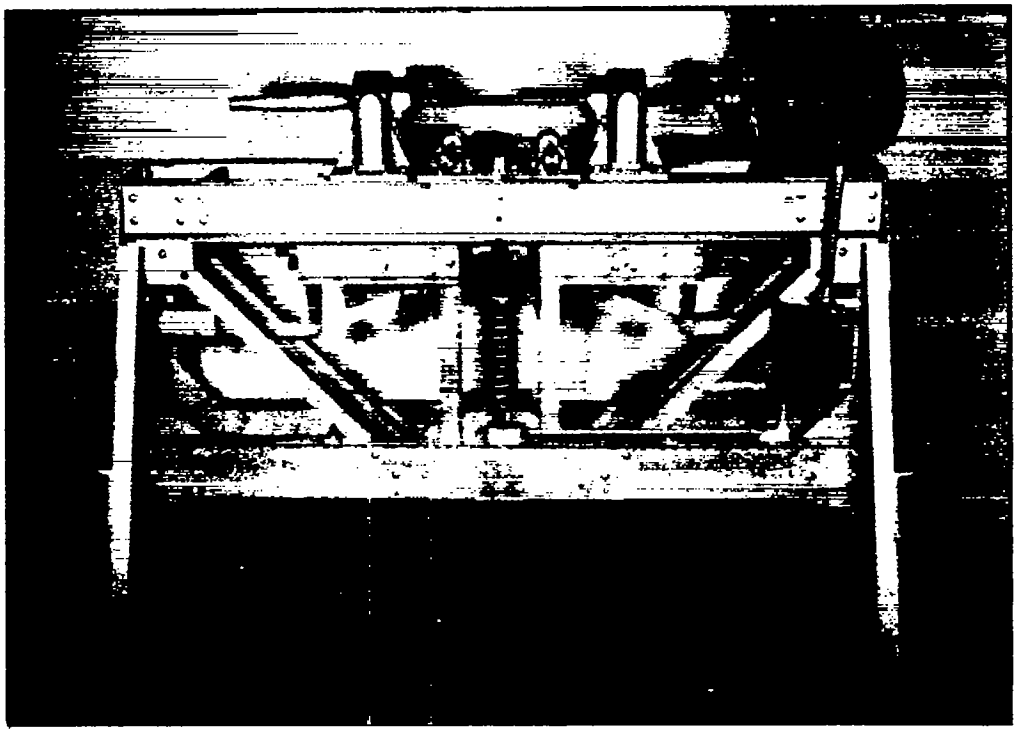

Figure 5.- The 2-inch rotating-beam fatigue testing machine designed and built at Aluminum Research Laboratories in 1930.

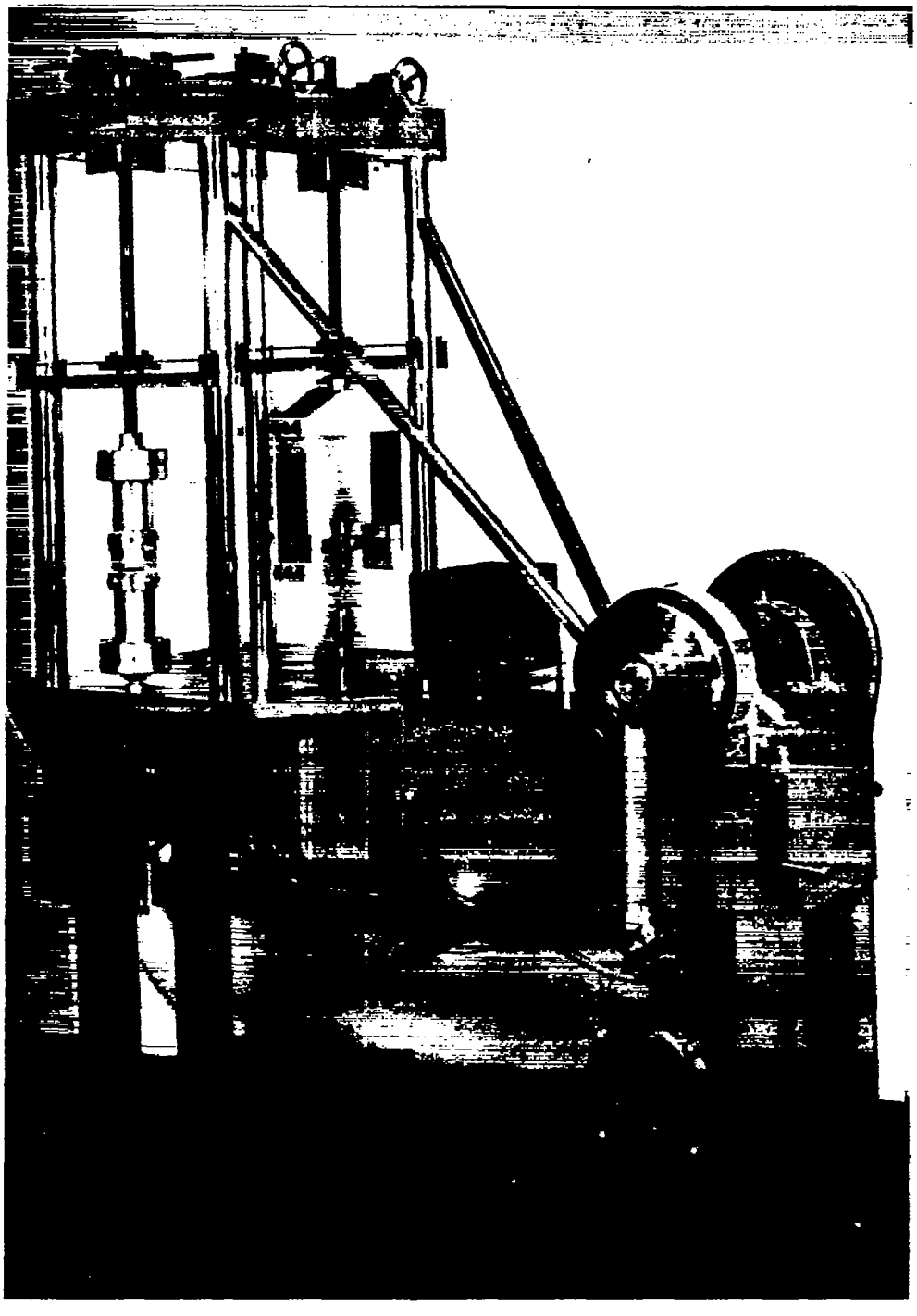

Figure 6.- Krouse direct-stress fatigue testing machine.

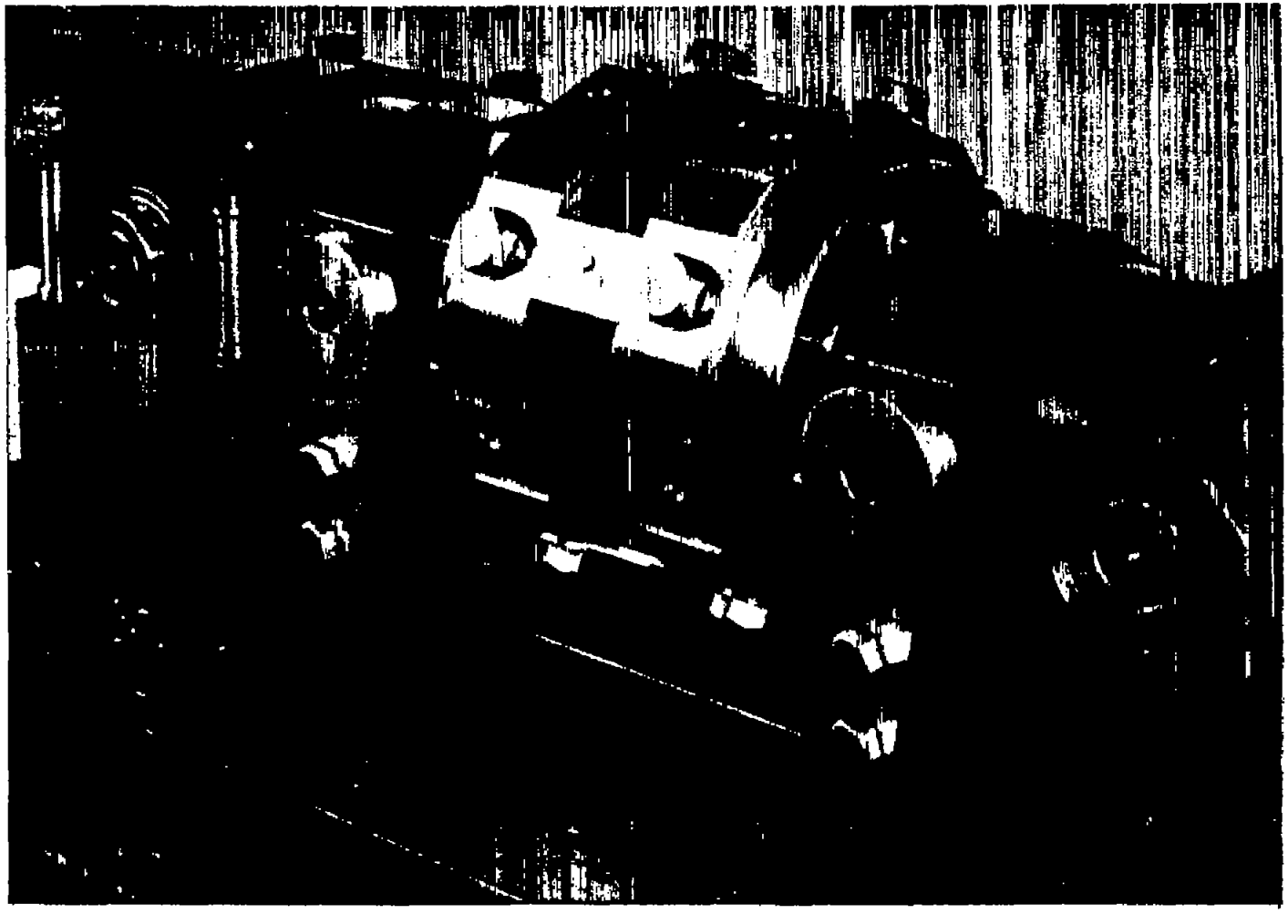

Figure 7.- Fixtures for loading riveted joints in ARL rotating-beam fatigue machine.

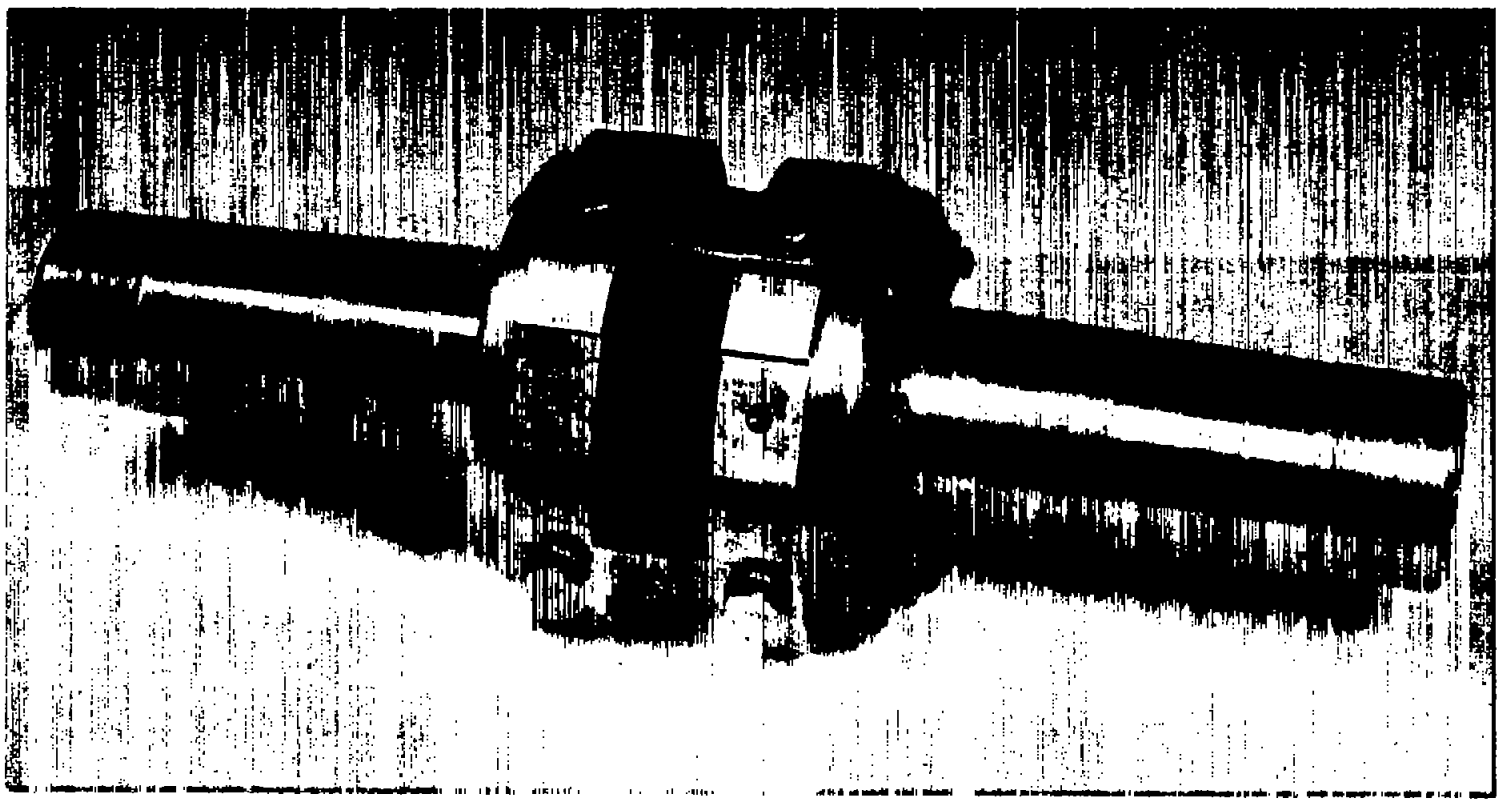

Figure 8.- Fixtures for loading riveted joints in 2-inch rotating-beam fatigue machine.

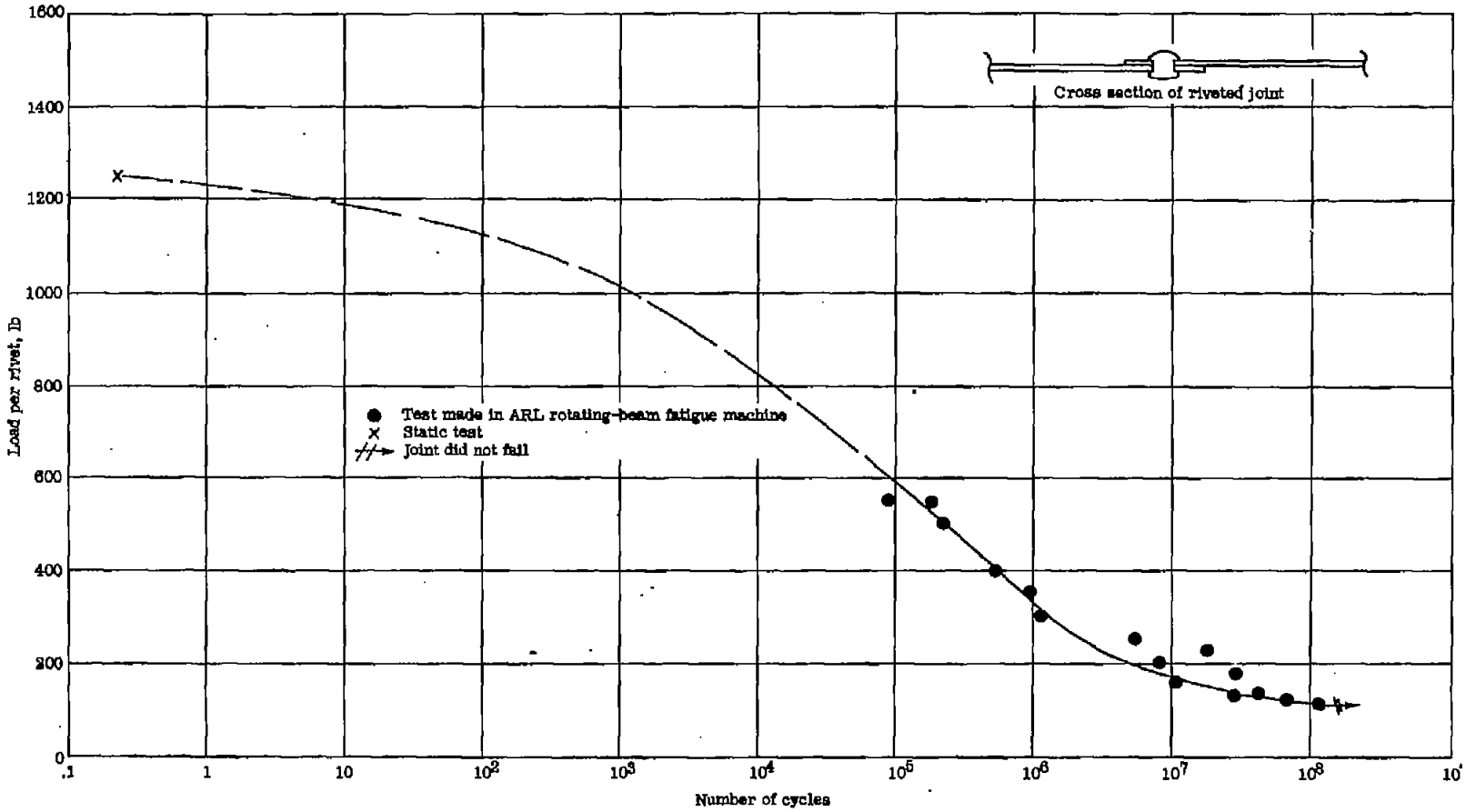

Figure 9.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T36 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II, reference 2. All tests made with complete reversal of stress.

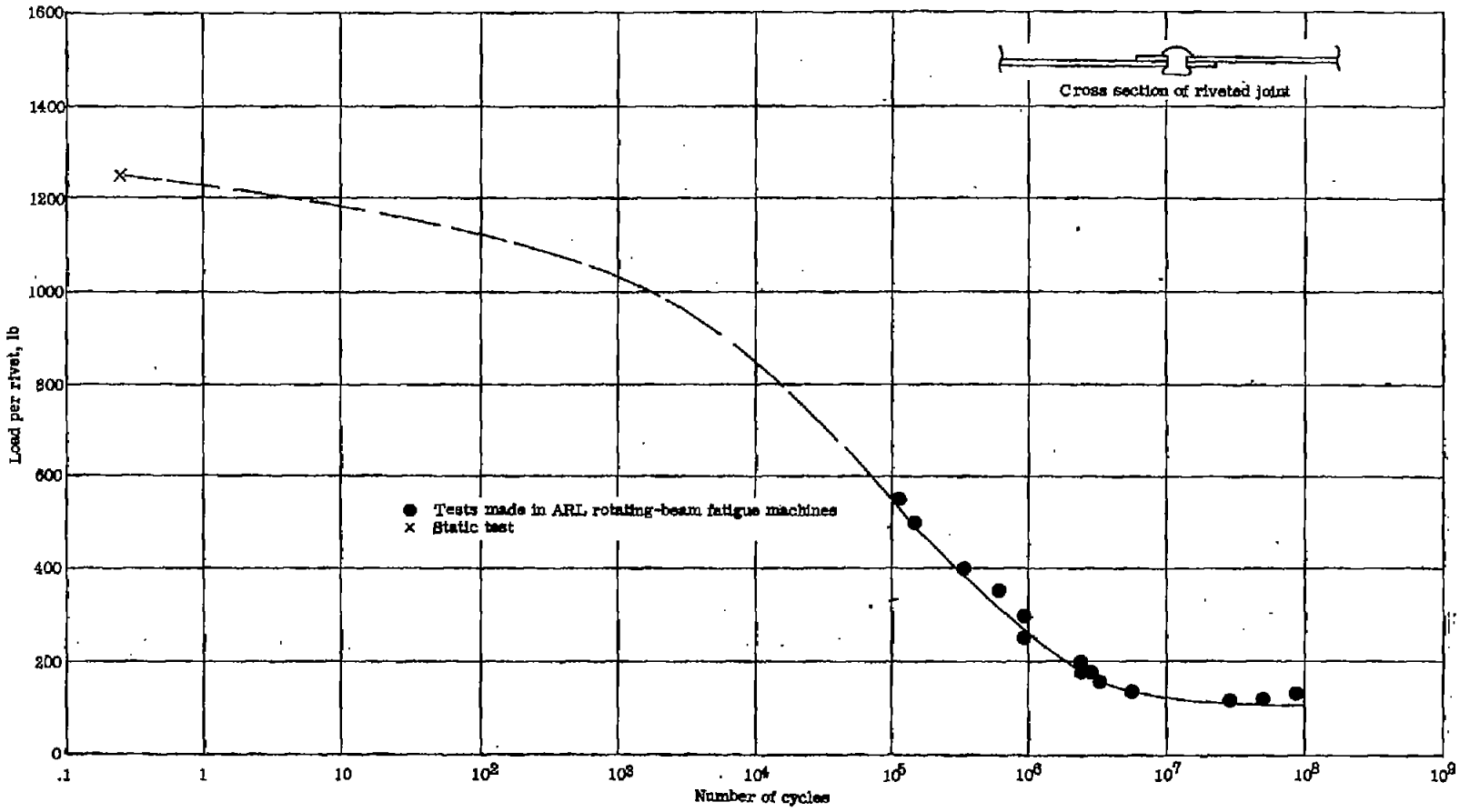

Figure 10.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T86 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II, reference 2. All tests made with complete reversal of stress.

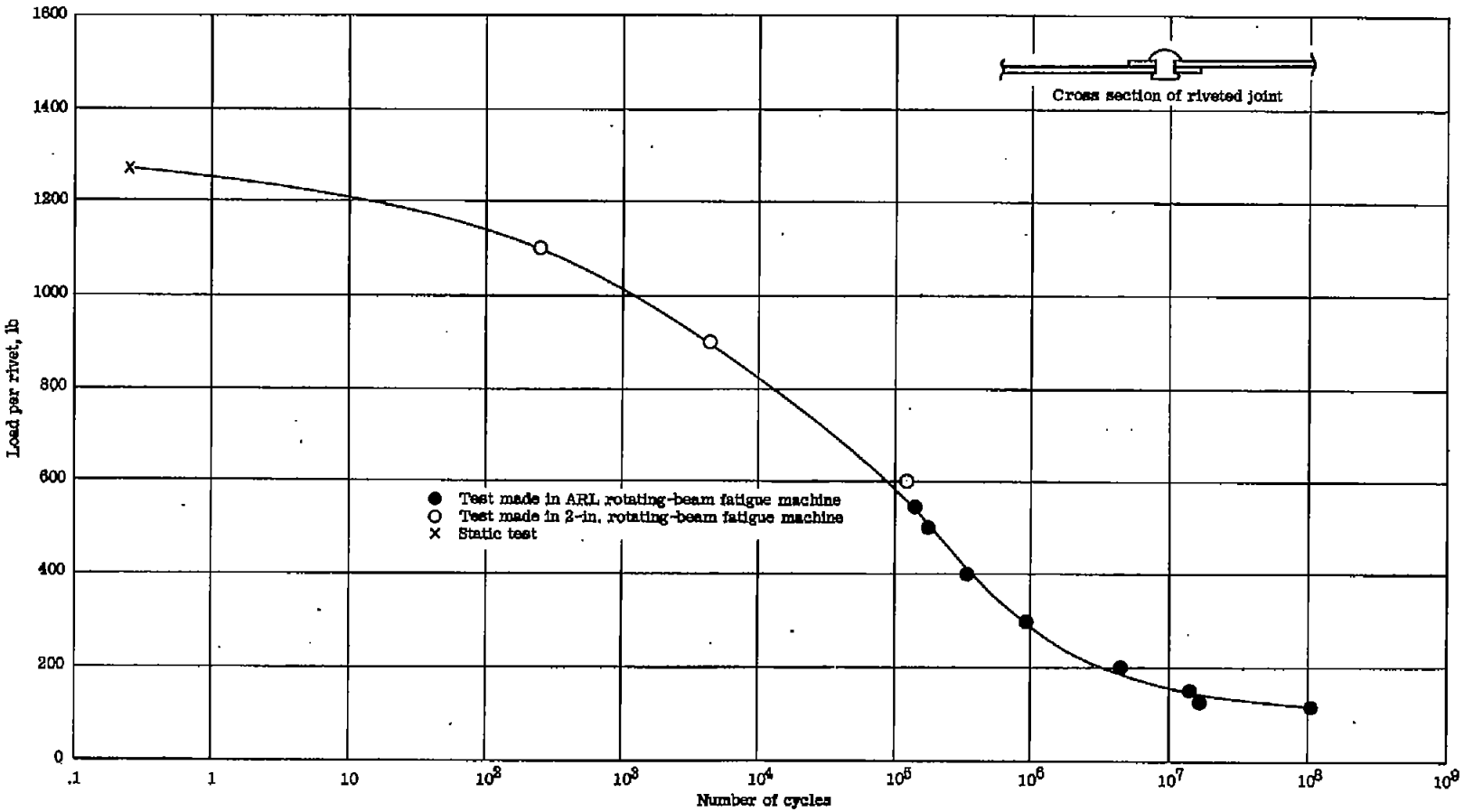

Figure 11.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II, reference 2. All tests made with complete reversal of stress.

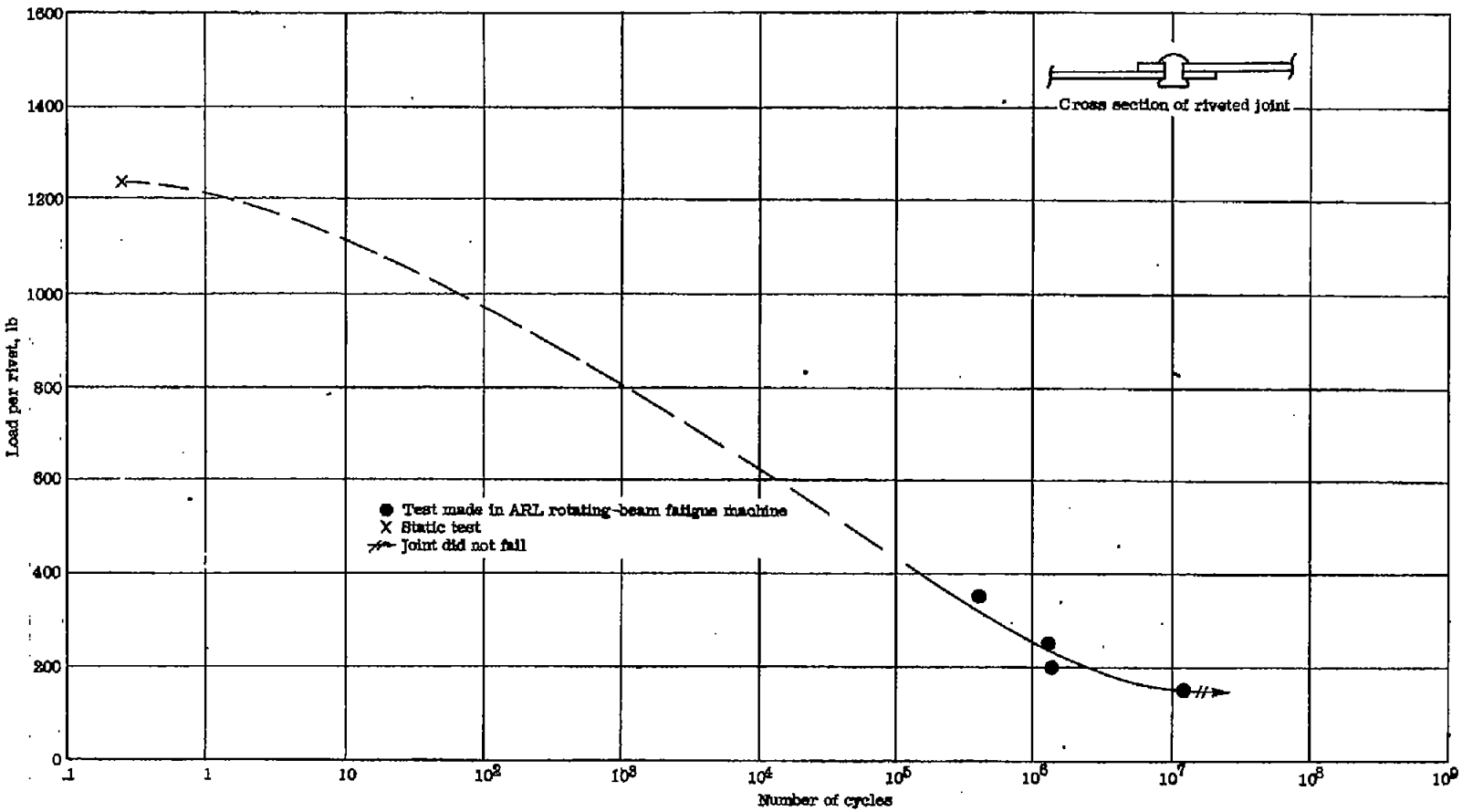

Figure 12.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad XA75S-T sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 26, table II of present paper. All tests made with complete reversal of stress.

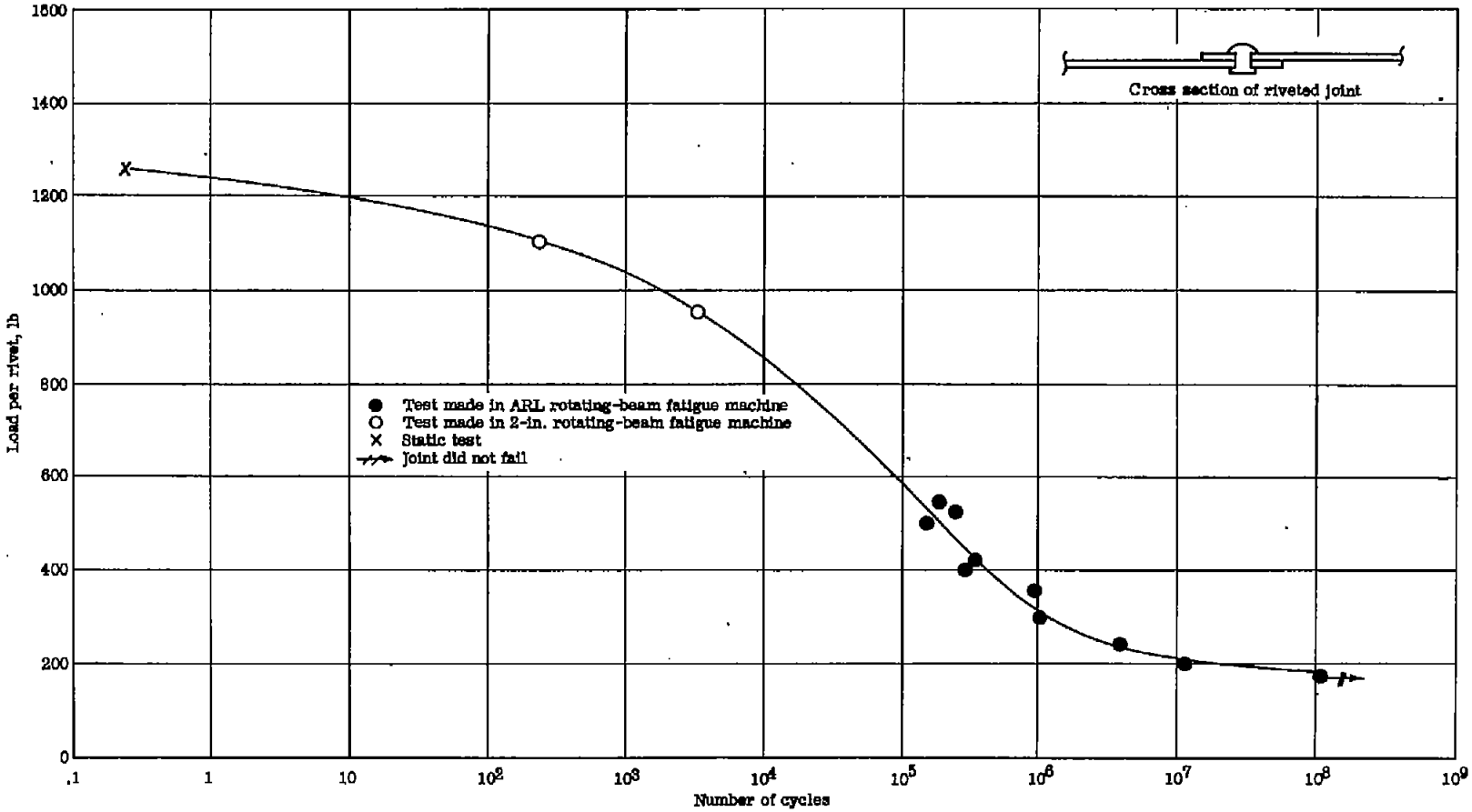

Figure 13.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T3 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II of reference 2. All tests made with complete reversal of stress.

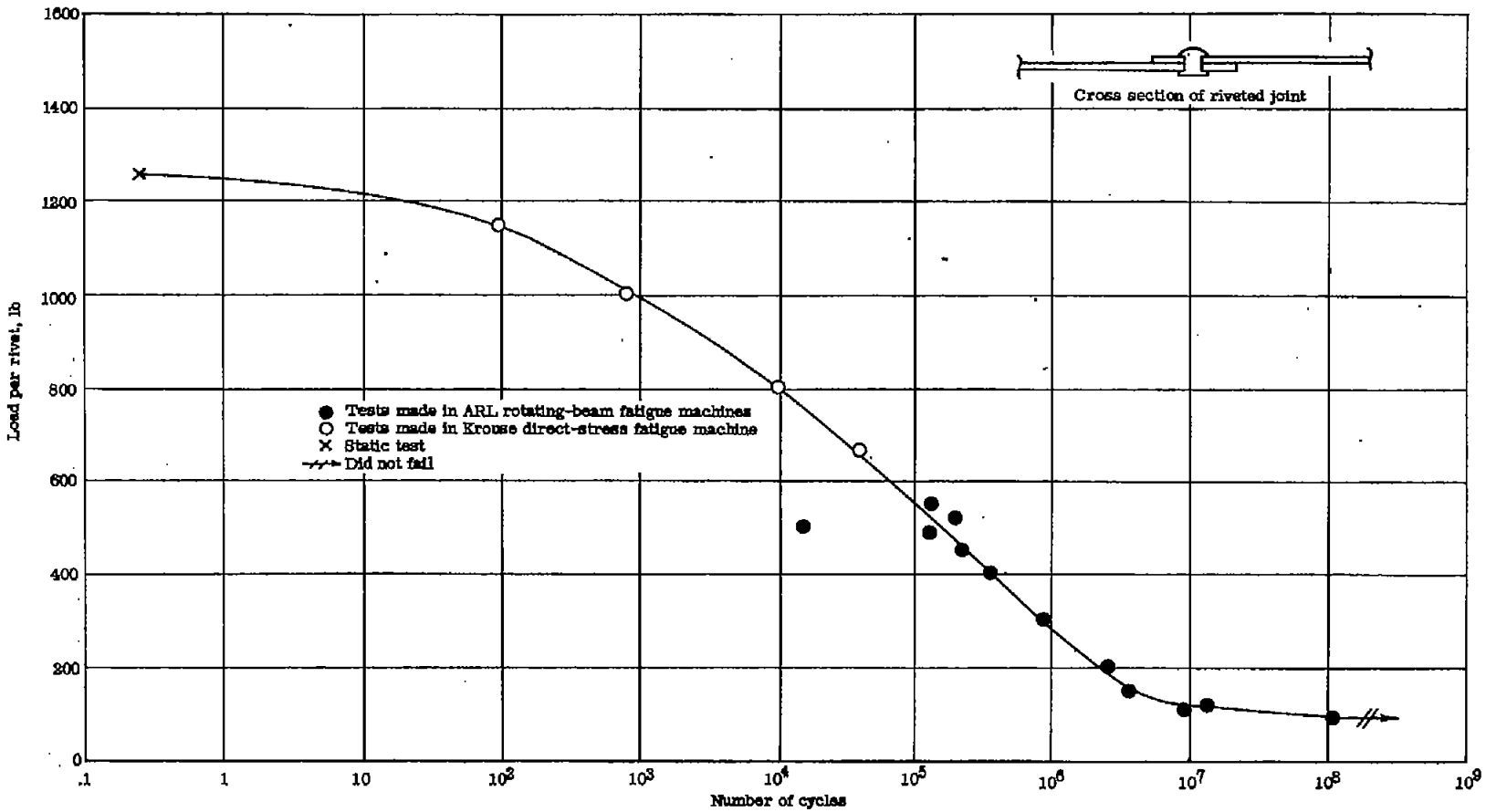

Figure 14.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 24S-T81 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see table II of reference 2 and item 28, table II of present paper. All tests made with complete reversal of stress.

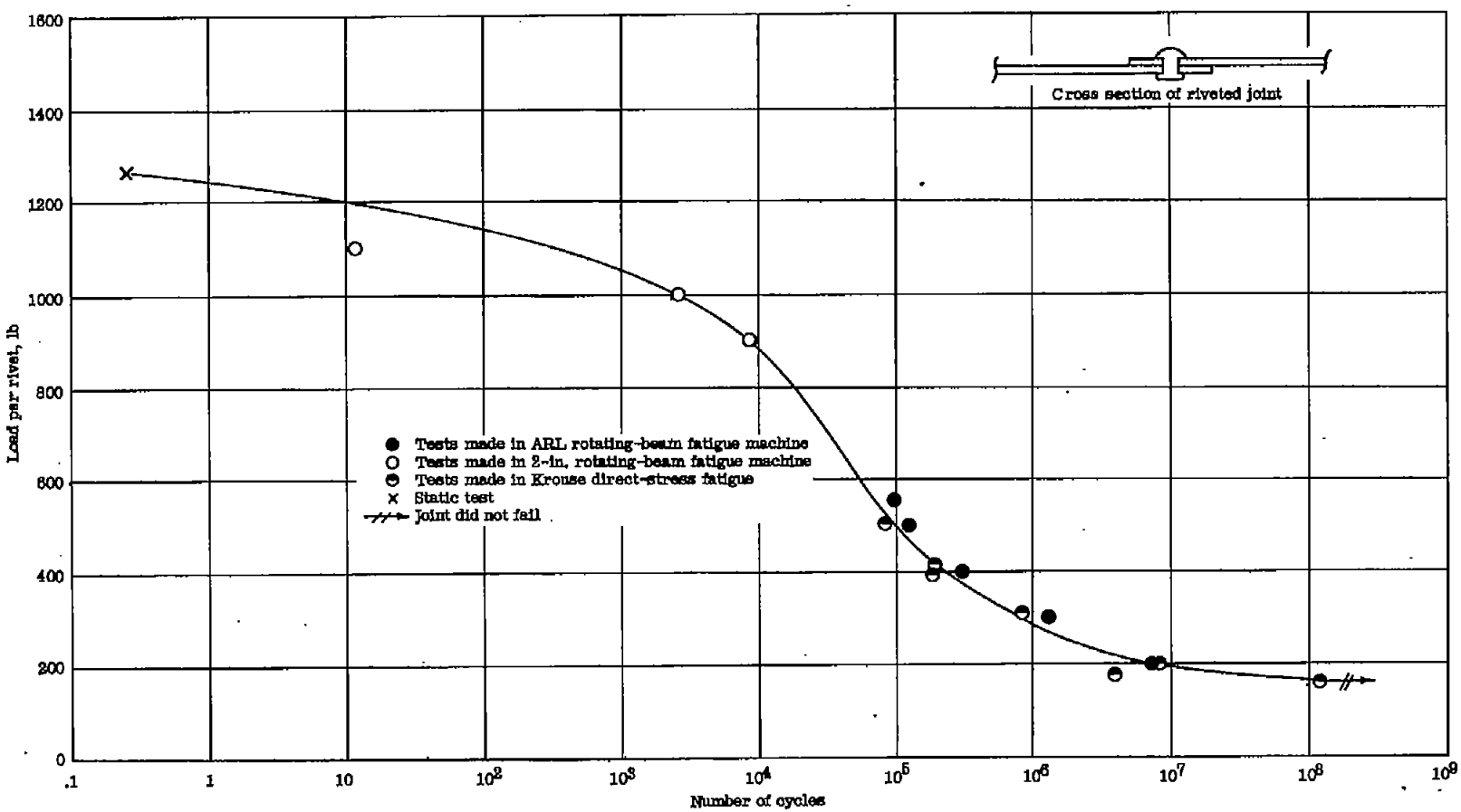

Figure 15.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 14S-T4 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 35, table II of present paper. All tests made with complete reversal of stress.

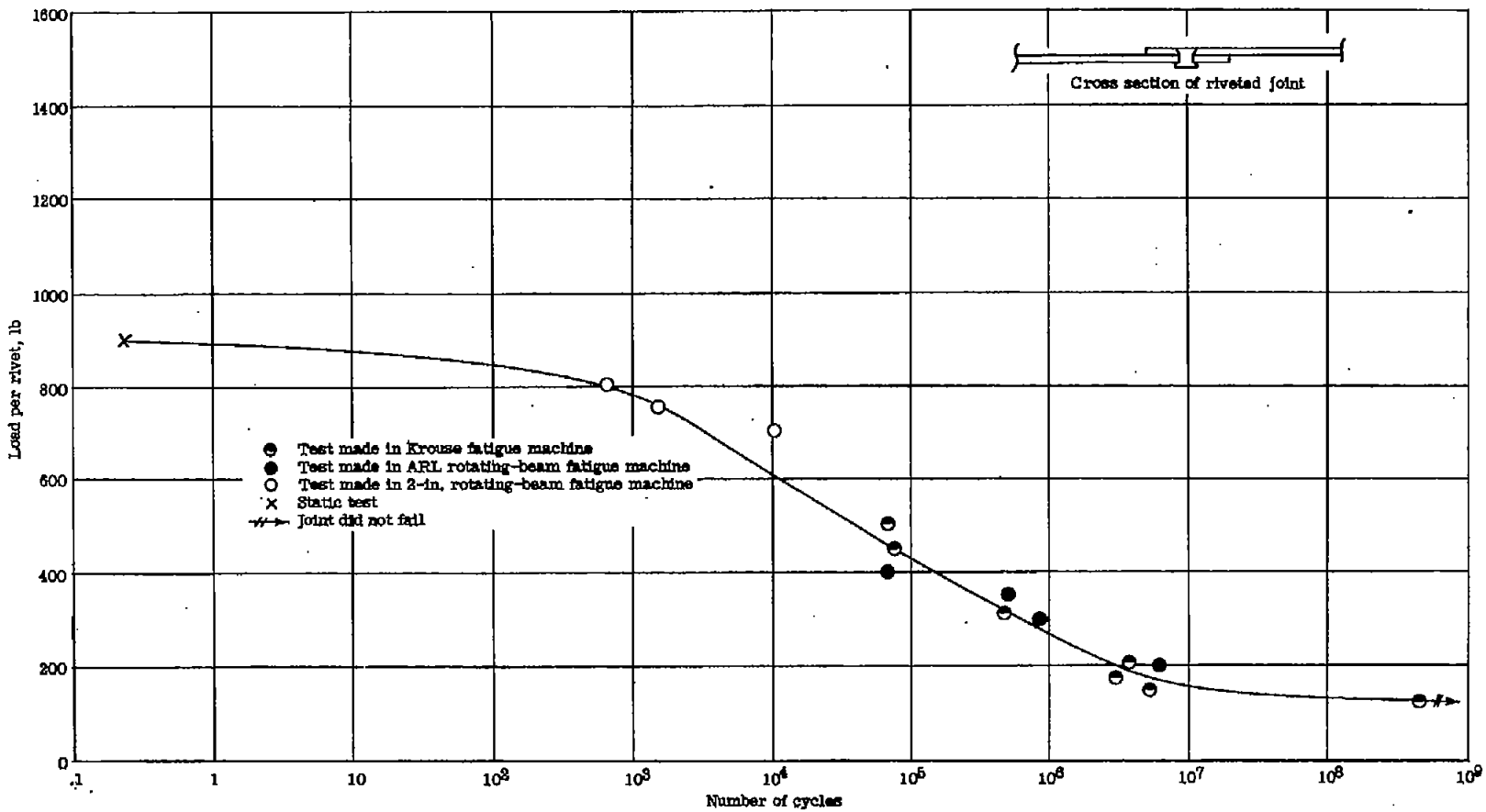

Figure 16.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 14S-T4 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 36, table II of present paper. All tests made with complete reversal of stress.

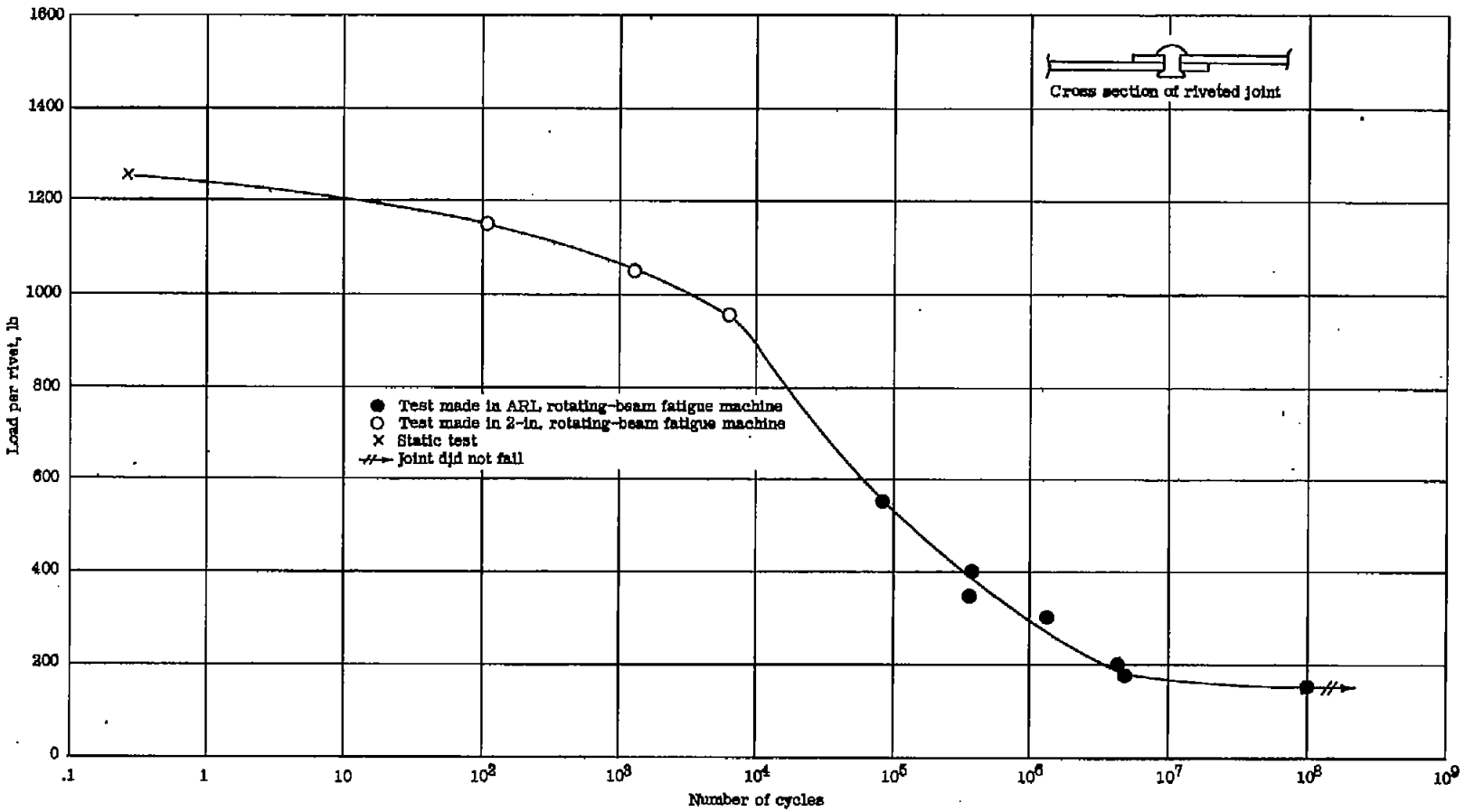

Figure 17.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven flat in drilled holes. Specimen, Alclad 14S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 37, table II of present paper. All tests made with complete reversal of stress.

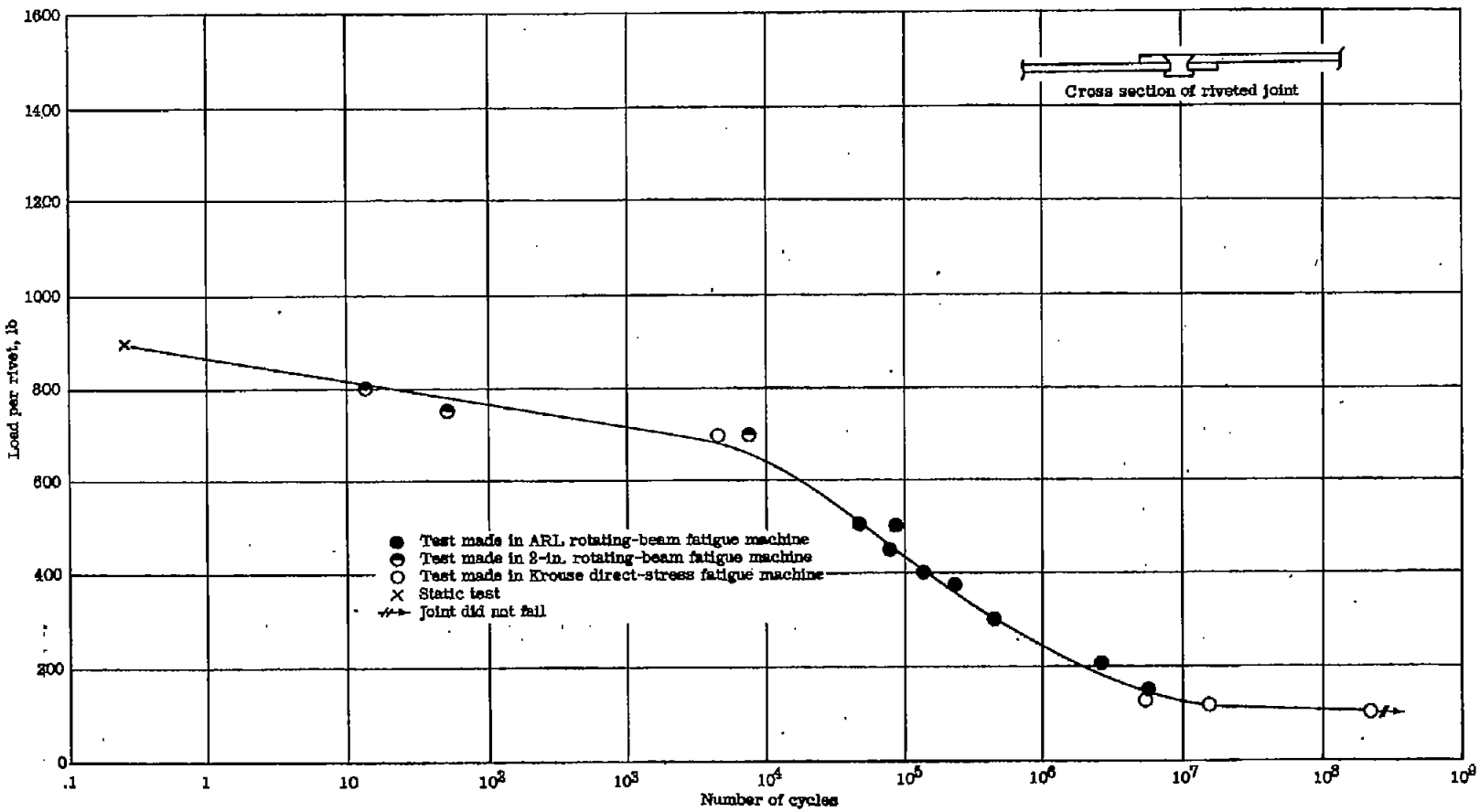

Figure 18.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 14S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 38, table II of present paper. All tests made with complete reversal of stress.

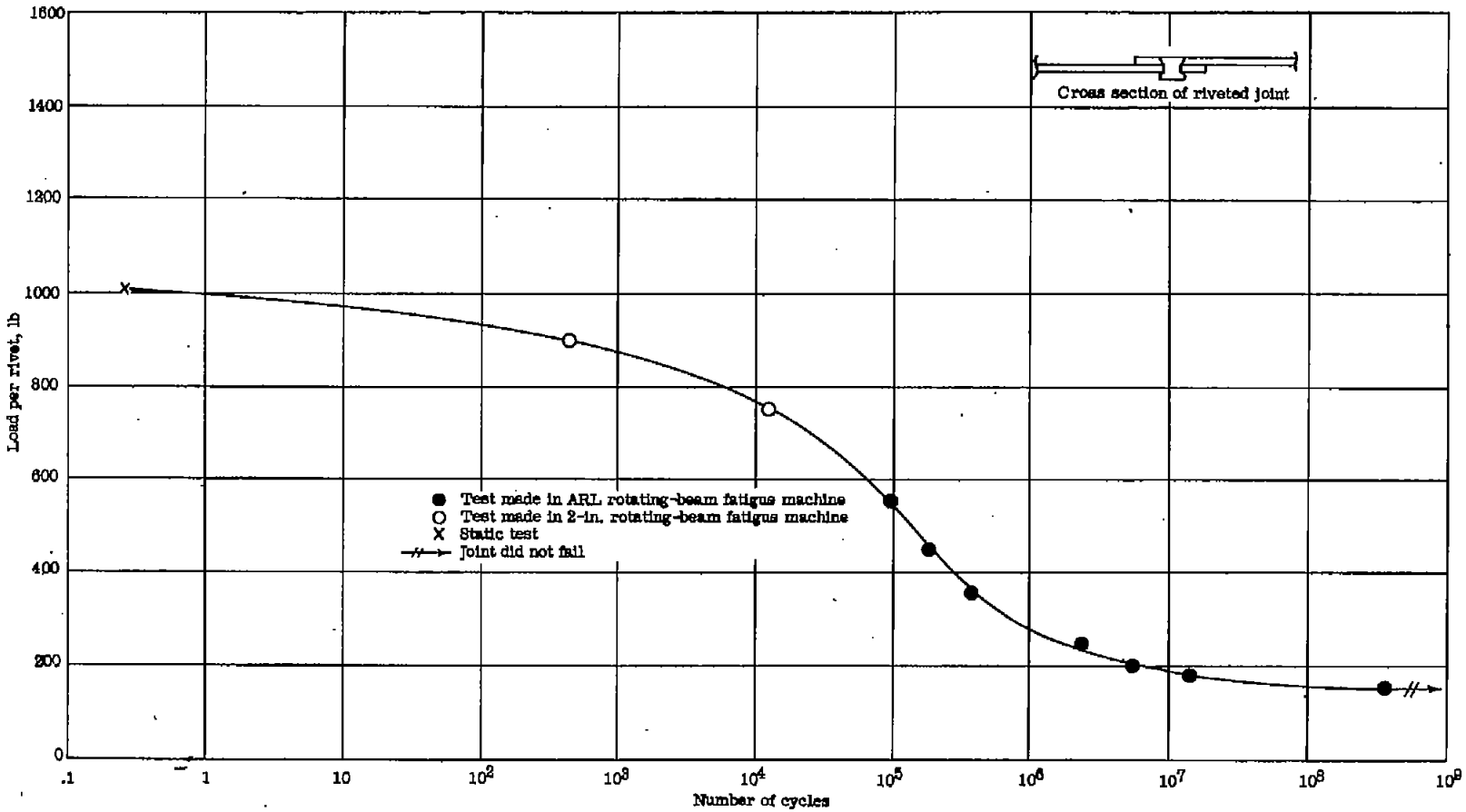

Figure 19.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 24S-T3 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 39, table II of present paper. All tests made with complete reversal of stress.

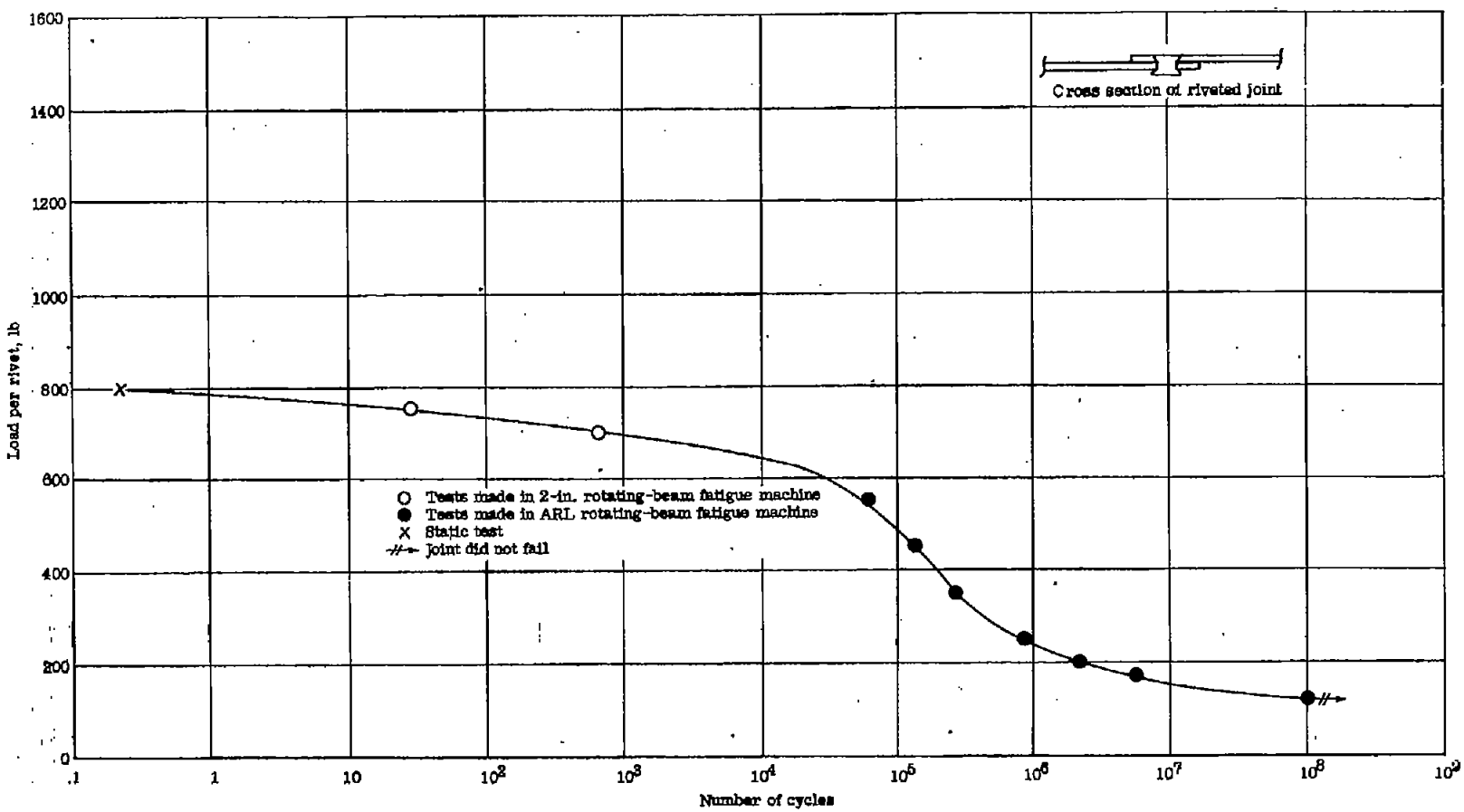

Figure 20.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in machine-countersunk holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 43, table II of present paper. All tests made with complete reversal of stress.

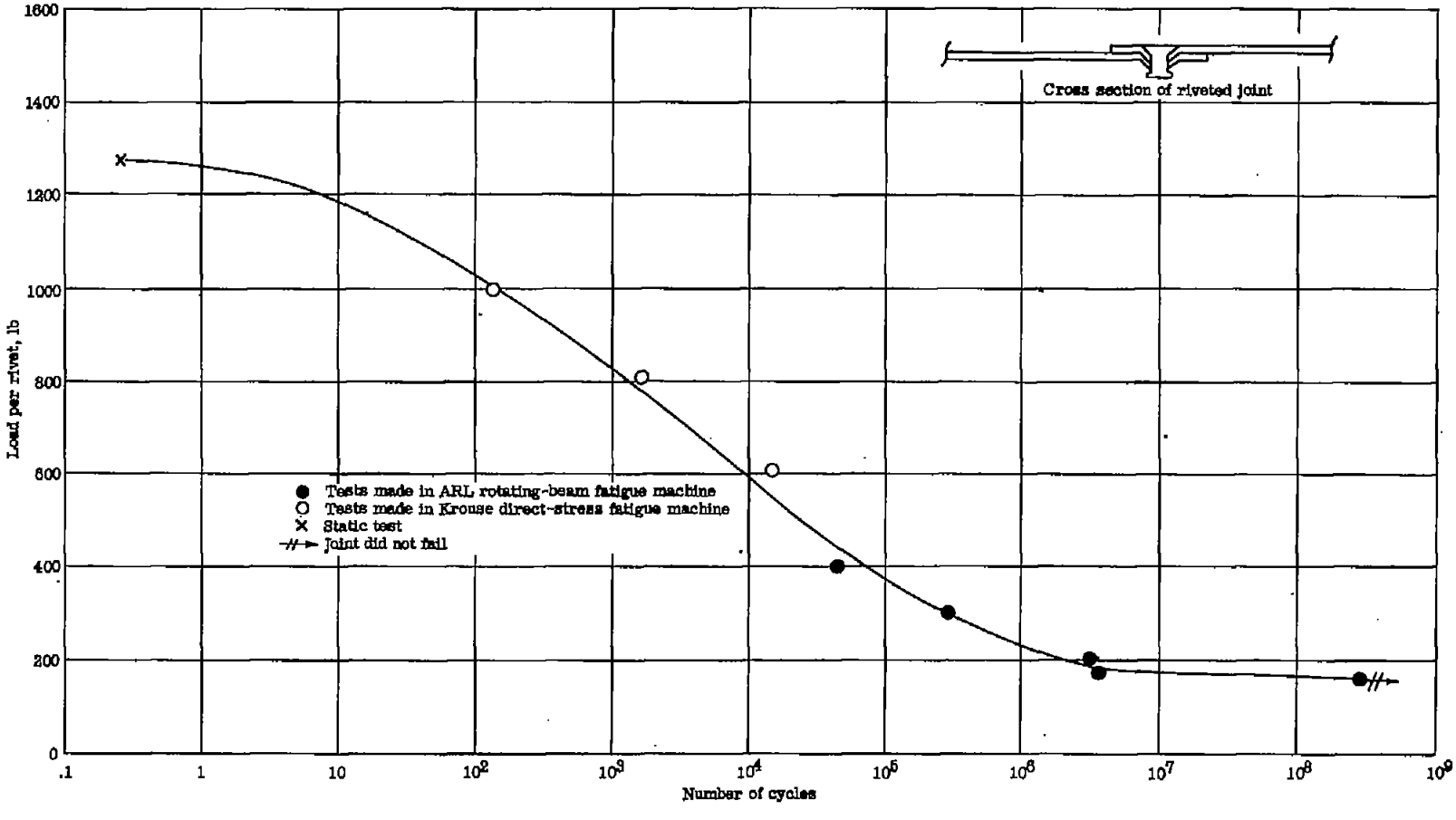

Figure 21.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in spin-dimpled holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 44, table II of present paper. All tests made with complete reversal of stress.

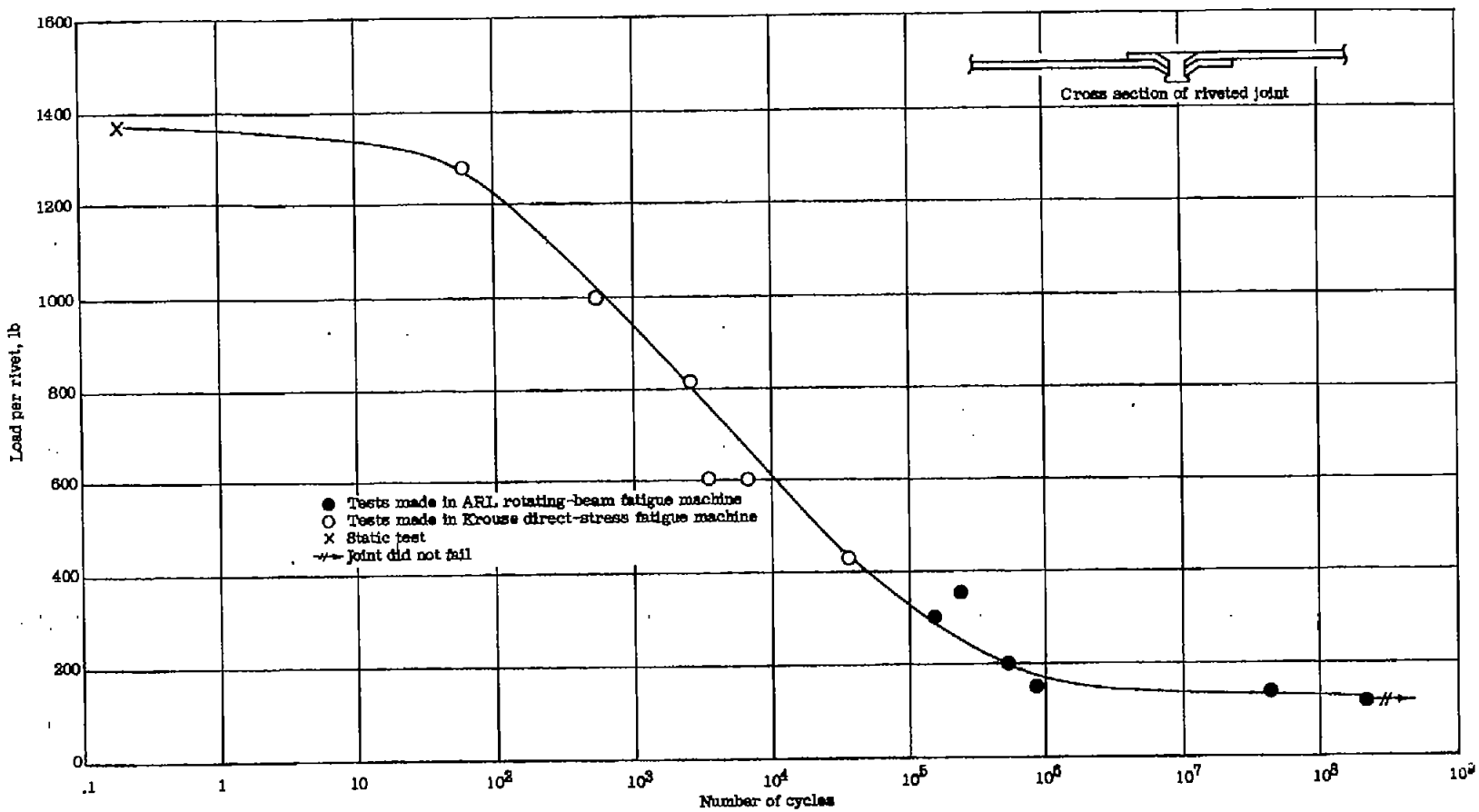

Figure 22.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 17S-T31 countersunk rivets driven in spin-dimpled holes. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 45, table II of present paper. All tests made with complete reversal of stress.

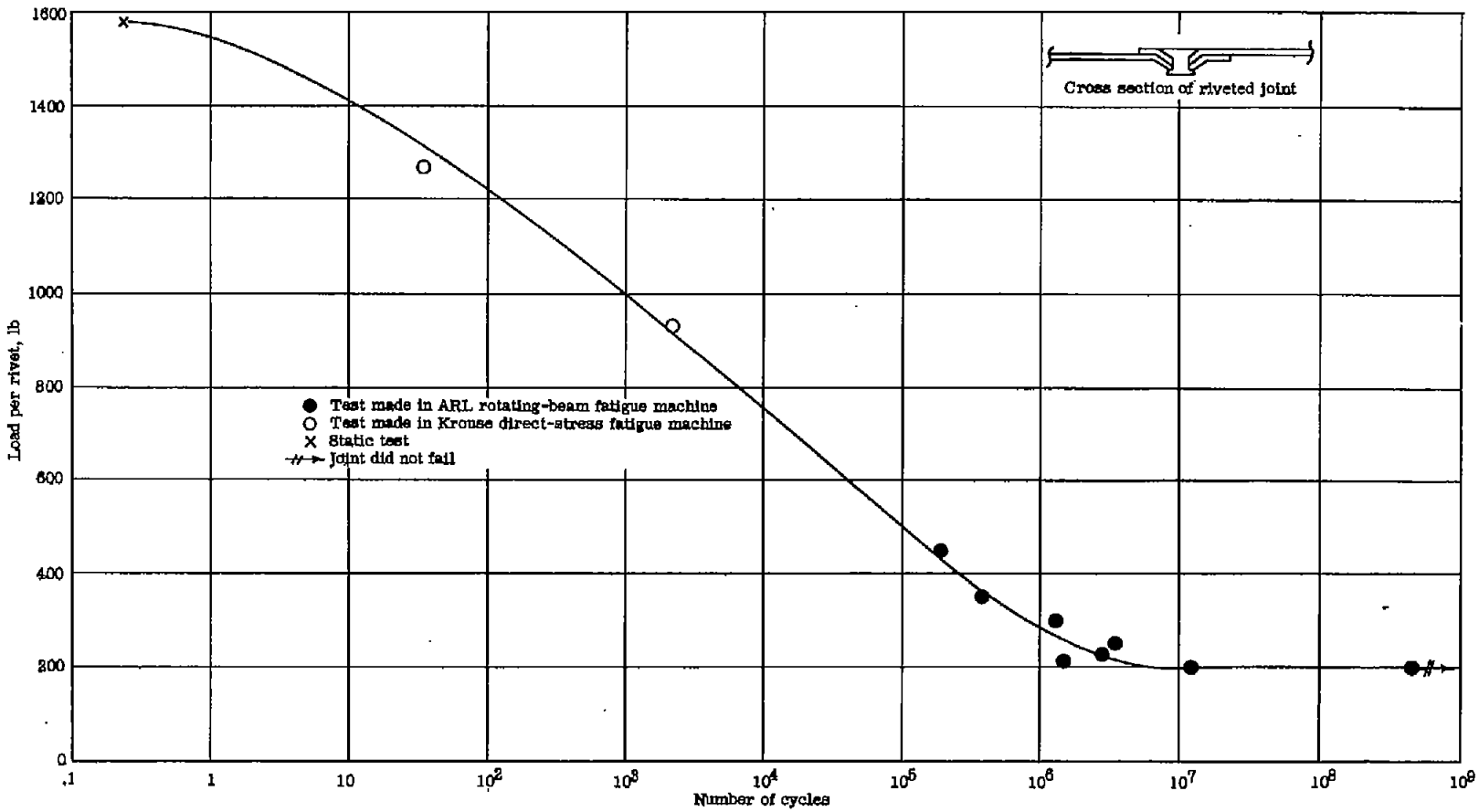

Figure 23.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in coin-dimpled holes (dimpled "cold" at room temperature). Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 52, table II of present paper. All tests made with complete reversal of stress.

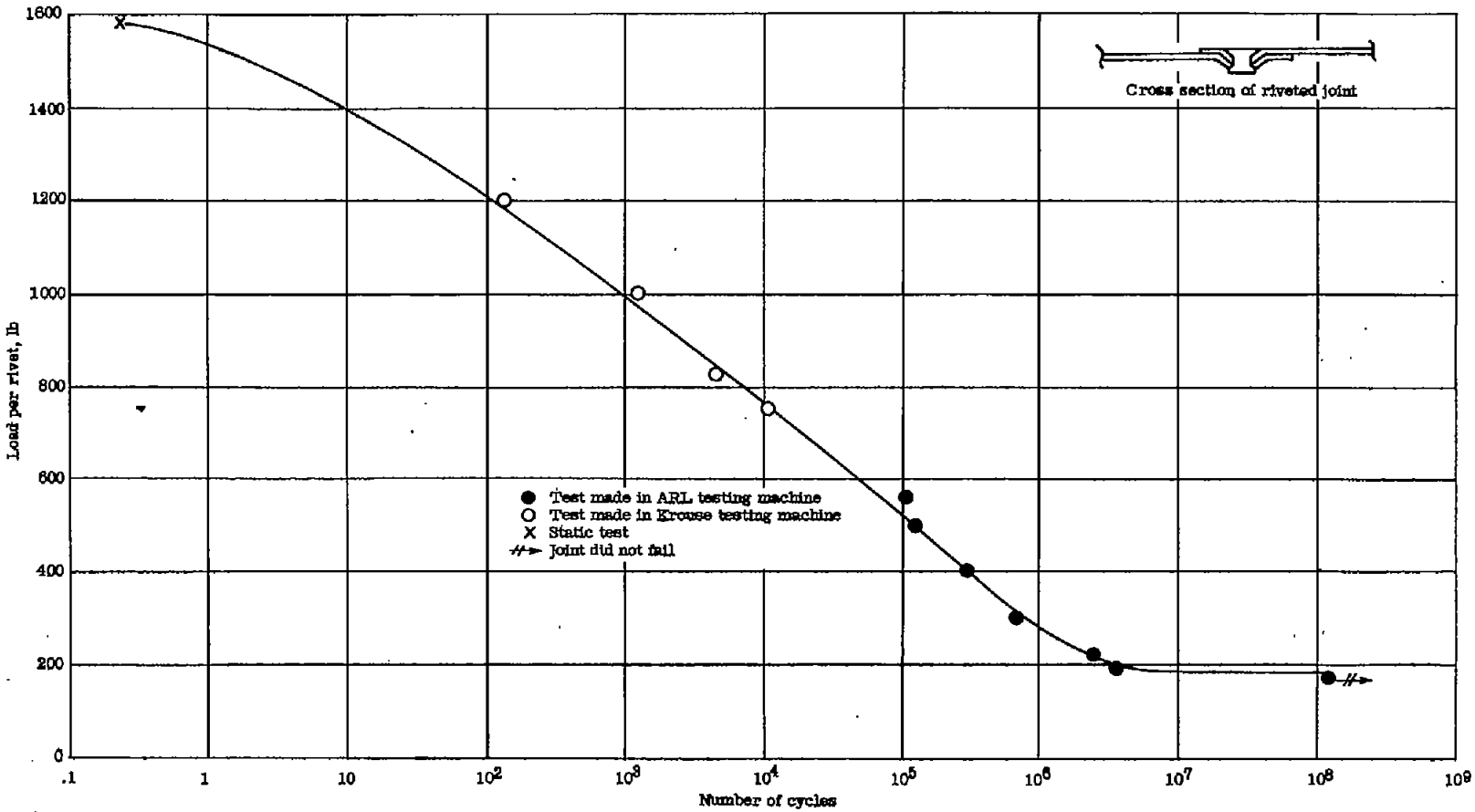

Figure 24.- Shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 countersunk rivets driven in coin-dimpled holes (dimpled "hot," with heated tools). Specimen, Alclad 75S-T sheet 0.064 inch thick by 1 inch wide. For data from which curve is plotted, see item 53, table II of present paper. All tests made with complete reversal of stress.

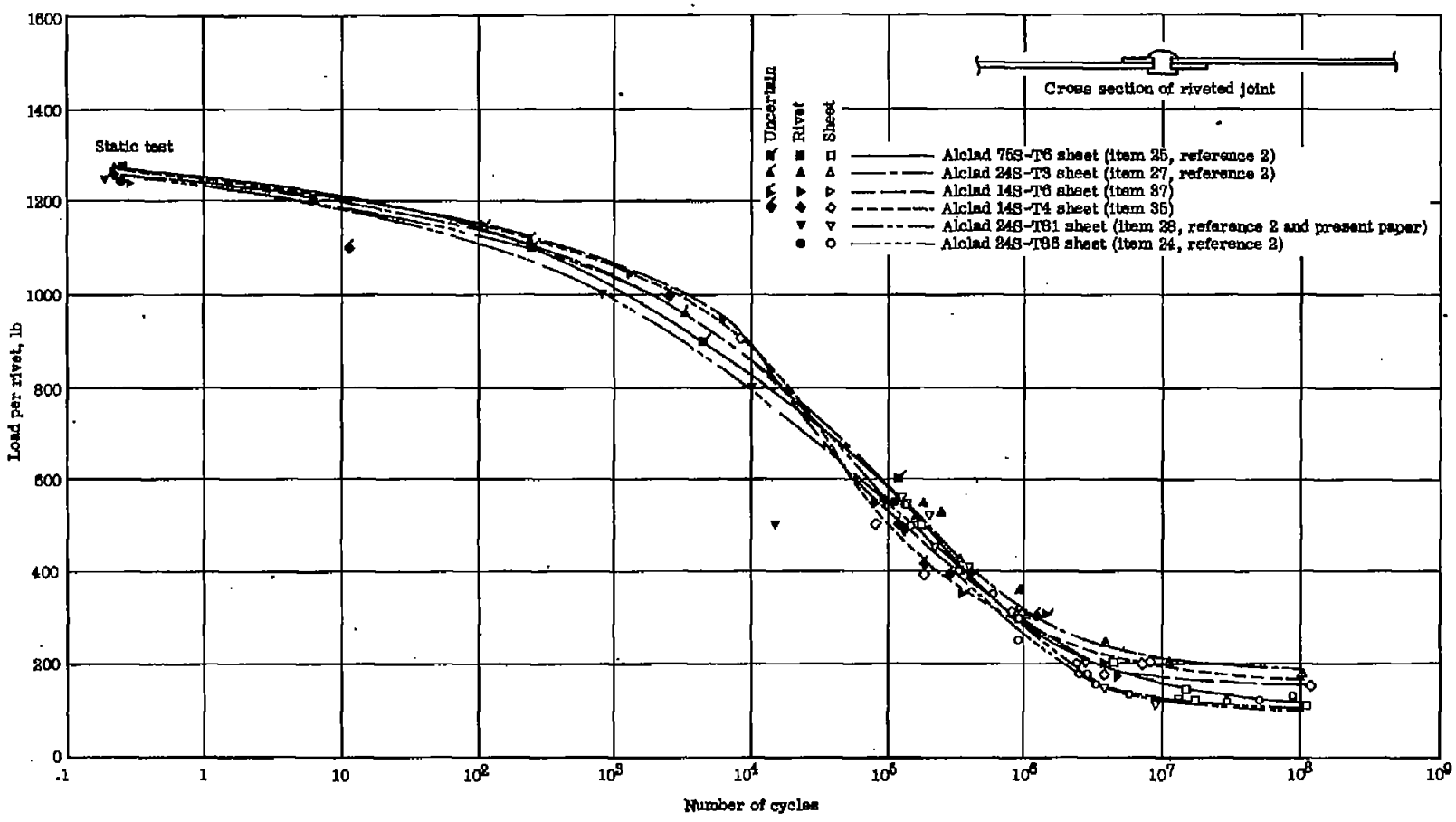

Figure 25.- Results of shear fatigue tests of joints with $\frac{3}{16}$-inch-diameter 24S-T31 brazier-head rivets driven in drilled holes. Specimens, Alclad sheet 0.064 inch thick by 1 inch wide, various alloys and tempers. All tests made with complete reversal of stress.

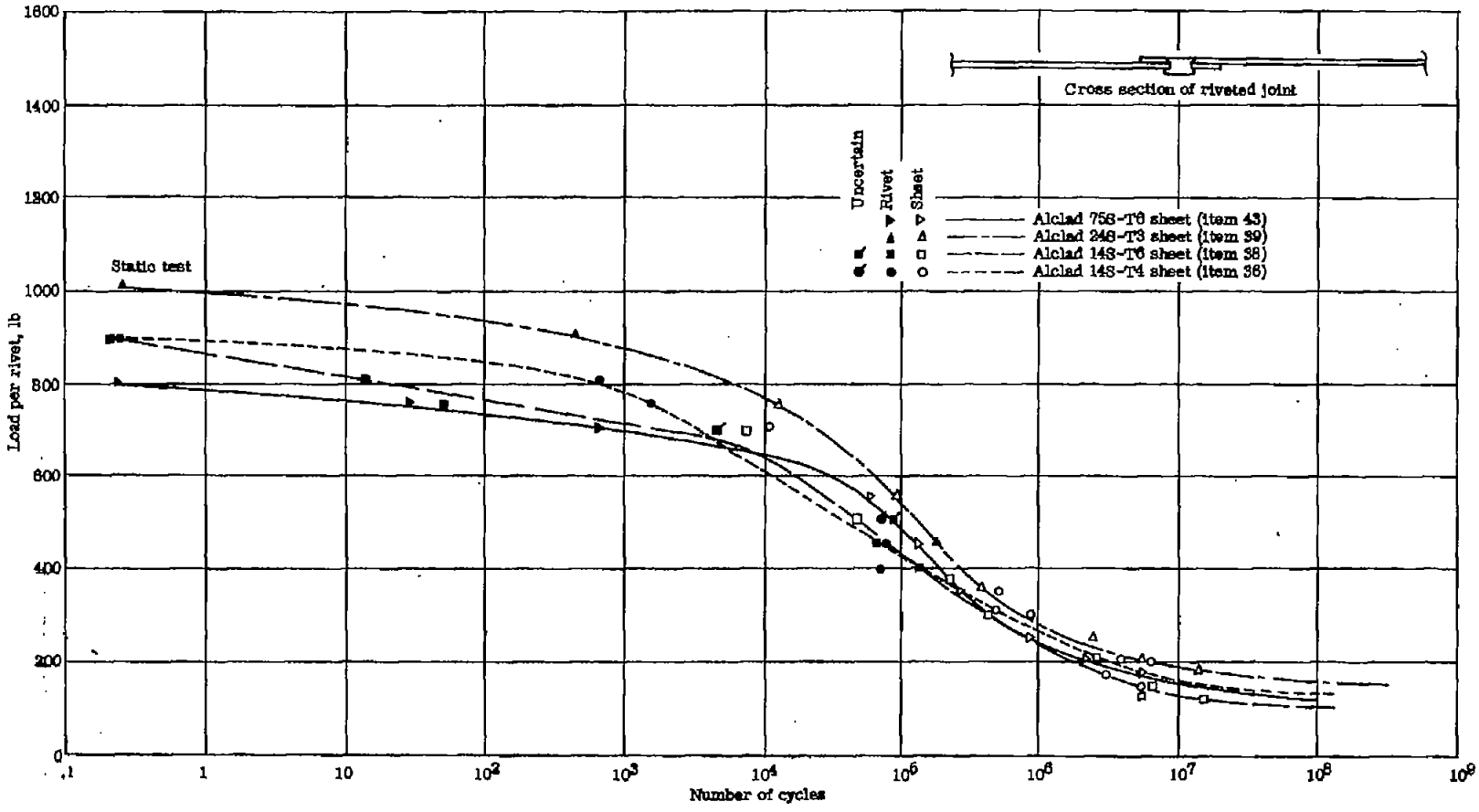

Figure 26.- Results of shear fatigue tests of $\frac{3}{16}$-inch-diameter 24S-T31 countersunk-head rivets driven in machine-countersunk holes. Specimens, Alclad sheet 0.064 inch thick by 1 inch wide, various alloys and tempers. All tests made with complete reversal of stress.

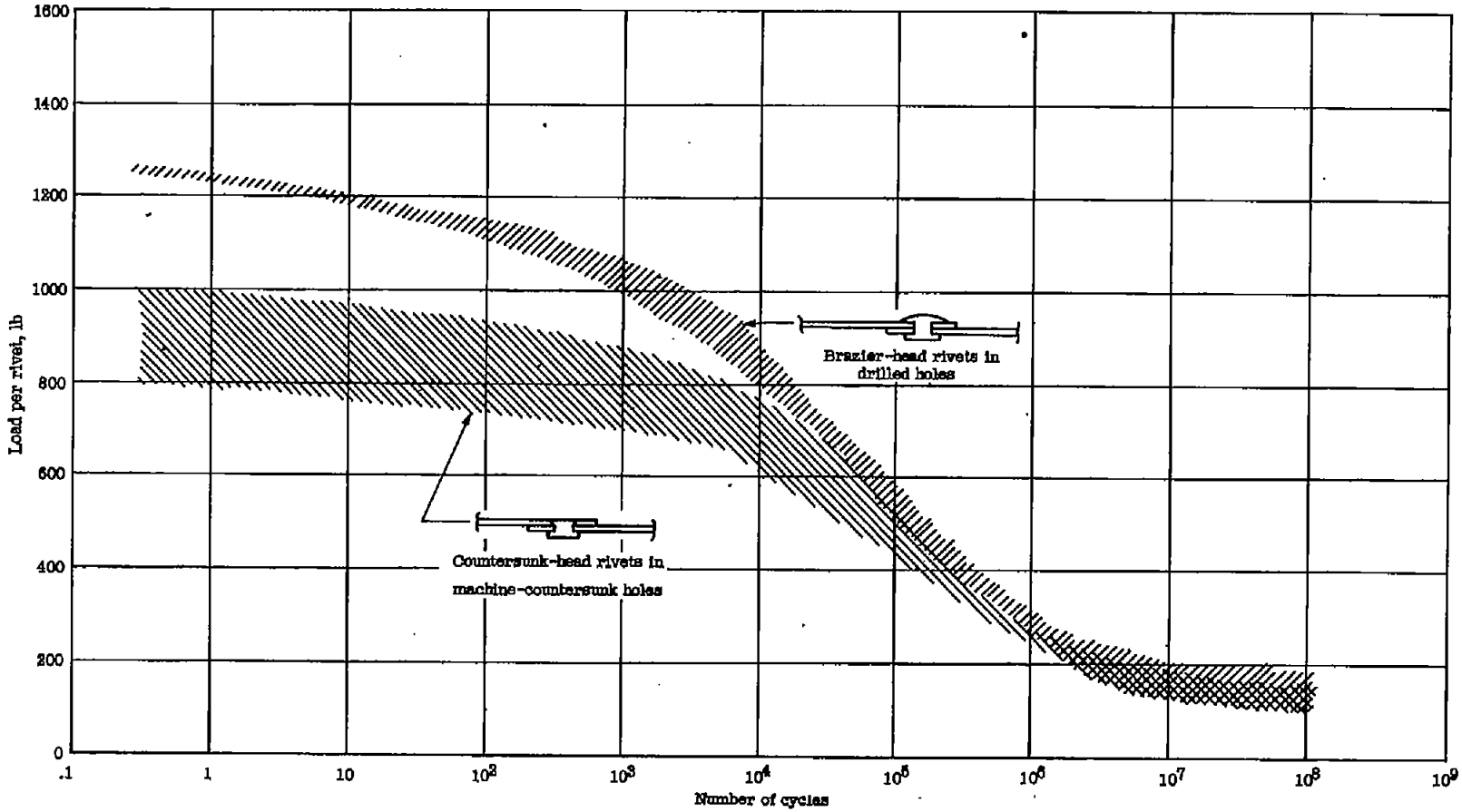

Figure 27.- Results of shear fatigue tests of riveted joints. Specimens, Alclad sheet, 0.064 inch thick by 1 inch wide, various alloys and tempers. Rivets, $\frac{3}{16}$-inch-diameter 24S-T31, brazier-head in drilled holes and countersunk-head in machine-countersunk holes. Each scatter band includes Alclad 75S-T6, 24S-T3, 14S-T6, and 14S-T4. Band for brazier-head rivets also includes 24S-T81 and 24S-T86. All tests made with complete reversal of stress.

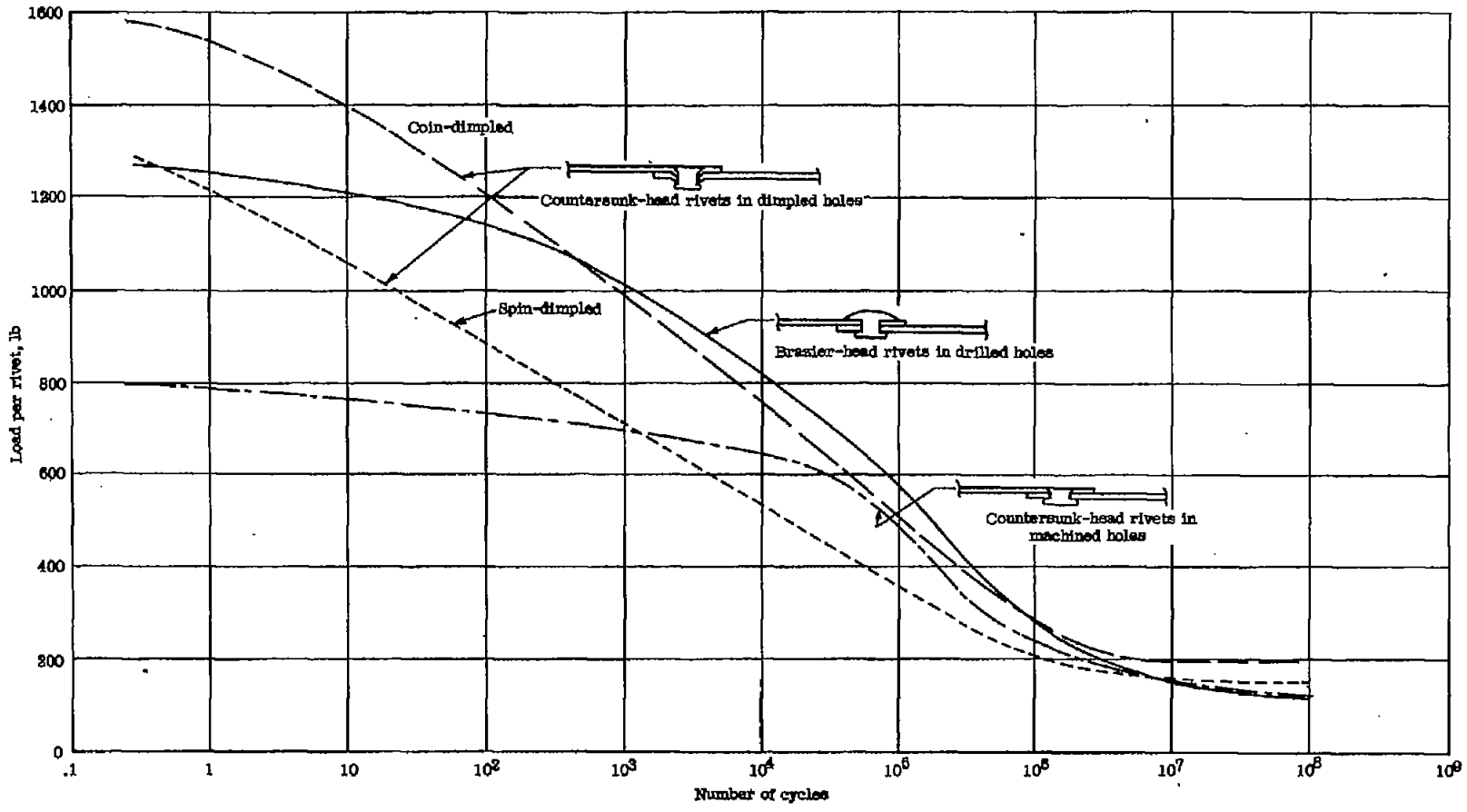

Figure 28.- Results of shear fatigue tests of riveted joints. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. Rivets, $\frac{3}{16}$-inch-diameter 24S-T31, brazier-head and countersunk-head in different types of holes. All tests made with complete reversal of stress.

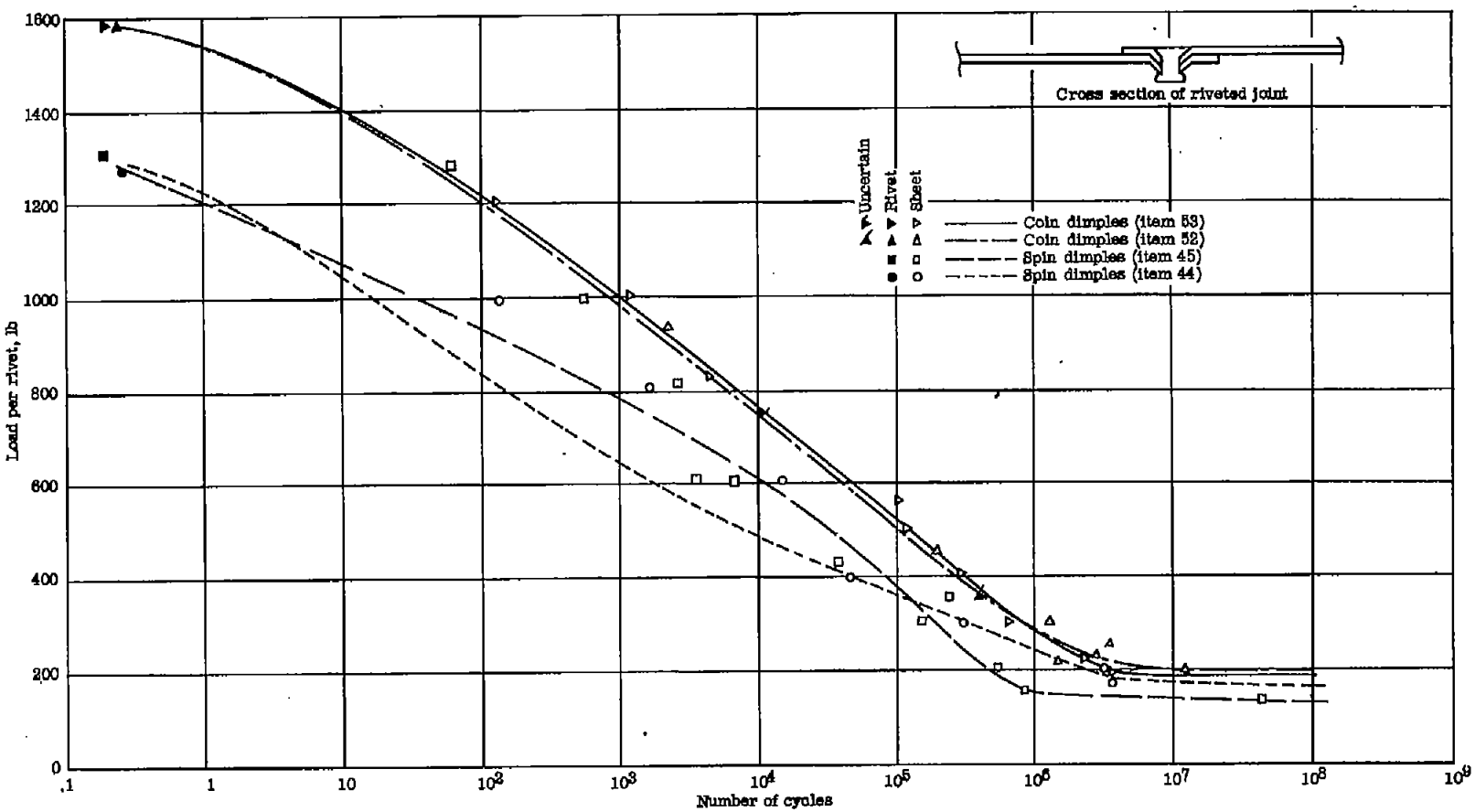

Figure 29.- Results of shear fatigue tests of riveted joints. Specimen, Alclad 75S-T6 sheet 0.064 inch thick by 1 inch wide. Rivets, $\frac{3}{16}$-inch-diameter 24S-T31 countersunk-head driven in holes coin-dimpled or spin-dimpled. All tests made with complete reversal of stress.

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