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TESTS OF HYDRAULICALLY EXPANDED RIVETS

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SUMMARY

An investigation was made to determine the tightness, shear strength, tensile strength, and life under pulsating loads of hollow, hydraulically expanded rivets. Two types of 17S-T aluminum-alloy rivets of 1/8-inch diameter - countersunk-head rivets with a 24S-T aluminum-alloy insert in the hollow shank and modified-roundhead rivets with no insert - were investigated. The test results indicate that the countersunk-head rivets, with inserts, had an average maximum load in shear more than 150 percent greater than the average maximum load for the modified-roundhead rivets, which had no inserts. The average yield load for the countersunk-head rivets, however, was only slightly more than that for the modified-roundhead rivets. For modified-roundhead rivets having bores of 0.085-inch or of 0.100-inch diameter, there was no appreciable difference due to bore diameter in either the yield load or the maximum load in shear, or in the maximum tensile load. In tension tests, both types of rivet tended to fail by pulling the shank end of the rivet through the sheet, if the hollow length of the rivet protruded 0.116 inch or less beyond the sheets. In the pulsating-load tests, the looseness of the rivets apparently induced relatively severe loading conditions. As a result, the life of the joints was very short, 70 cycles or less.

INTRODUCTION

A number of different types of blind rivet have been developed for use in aircraft. One type for which data have been lacking is the hydraulically expanded rivet. An investigation was therefore conducted at the NACA structures research laboratory to determine the tightness, shear strength, tensile strength, and life under pulsating loads of joints assembled with this type of rivet. The results of this investigation are presented herein.

RIVETS AND METHOD OF RIVETING

The rivets were furnished in two types, modified-roundhead and 100° countersunk-head, as illustrated in figure 1. They were manufactured by drilling out solid rivets to the desired depth and then rolling in the edges of the drilled hole at the head to reduce the size of the opening. The depth a of the hole was 0.280 inch for all rivets; the diameter b of the hole was 0.100 inch for the flush rivets and for some of the modified-roundhead rivets and 0.085 inch for the other modified-roundhead rivets. A 24S-T aluminum-alloy insert had been pressed into the hole in each countersunk-head rivet before the edge of the hole in the head was rolled in.

After preparation by heat treatment, the rivets were expanded in the rivet holes by use of the equipment shown in figure 2. Oil was injected into the cavity in the rivet from a chamber in the rivet-expanding gun (fig. 2(a)), which had a hollow cone-pointed tip that was held firmly against the opening in the rivet head. Compressed air at relatively low pressure in a separate oil container forced the oil through a valve into the chamber. The valve, normally closed against the pressure necessary to expand the rivet, was operated by a button to allow the oil to enter the chamber and rivet. The pressure that expanded the rivet was then created by a piston forced into the chamber when the lever on the side of the gun was pressed (fig. 2(b)). The pressure expanded the rivet to form a bulb on the shank end and to fill the hole in the sheets.

TEST SPECIMENS

Each test specimen consisted of two sheets of 24S-T aluminum alloy riveted together by 1/8-inch-diameter, hydraulically expanded rivets of 17S-T aluminum alloy. Two rivets were used for each shear specimen and each pulsating-load specimen and one rivet for each tension specimen. The three types of specimen are shown in

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figure 3 and the dimensions are given in tables I to III. The height of the rivet heads above the surface of the sheet before expansion was varied by varying the depth of countersink for the countersunk-head-rivet specimens. This height h_b (fig. 1) was measured with a dial gage graduated in ten-thousandths of an inch, as described in reference 1.

Some of the rivets in the test specimens were fractured during expansion, the fracture taking the form of a single crack in the bulb parallel to the axis of the rivet.

TEST PROCEDURE

Loads were applied to both shear and tension specimens by means of a hydraulic testing machine accurate to within one-half of 1 percent.

The shear specimens were loaded through Templin grips. Two 18-power microscopes with filar micrometers were used to measure the relative displacement, in the direction of loading, of the edges of the sheets opposite the center of the riveted joint. Both the displacement under load and the permanent displacement remaining after removal of load were measured for successively increasing loads until failure occurred.

The tension specimens were loaded in the special fixtures shown in figure 4. The small rods on each of the fixtures pass through the holes in one of the sheets of the test specimen and bear against the other sheet, pushing the sheets of the specimen apart. Only the maximum load and the type of failure were recorded for each tension test.

The pulsating-load specimens were tested in the machine shown in figure 5. This machine produces on the specimen a pulsating load composed of a mean load equal to the weights hung from the lower end of the specimen and an alternating load that results from the vibration of the weights forced by a vibrator. The alternating load is assumed to vary harmonically in the case of tight joints and is determined from the weights hung from the specimen and the amplitude and frequency of vibration. In case the rivets do not grip the joined sheets tightly, the alternating load does not vary harmonically and cannot be determined with the available equipment.

All specimens were tested at approximately the same frequency of vibration, 2700 cycles per minute. The mean load for the modified-roundhead rivet specimens was about 15 pounds per rivet and for the countersunk-head-rivet specimens about 38 pounds per rivet.

RESULTS AND DISCUSSION

Shear tests.- The results of the shear tests are presented in table I. All countersunk-head-rivet specimens had load-displacement curves similar to the one shown in figure 6(a). These curves seem to indicate that the expanding operation swelled the hollow shank of the rivet away from the insert, causing the hollow shank to bear the load until it had deflected sufficiently to make contact with the insert. In each case, failure was by shear of the rivets on a plane just below the top of the insert. The yield load was arbitrarily selected as the load at which the permanent displacement is 4 percent of the rivet diameter, and no variation of the yield load or of the maximum load was evident with variation of h_b. (See fig. 6(c).)

In the case of the modified-roundhead rivets, for which a typical load-displacement curve is shown in figure 6(b), failure was by shear of the rivets. Failure was preceded by a partial collapse of the portion of the hollow shank inside the sheets, observed to begin at a load of 75 to 90 pounds per rivet. No significant difference due to bore diameter was noted in either the yield load or the maximum load for the modified-roundhead rivets having bores of 0.085-inch or of 0.100-inch diameter.

The average maximum load for the countersunk-head rivets with the 24S-T aluminum-alloy inserts was more than 150 percent greater than the average maximum load for the modified-roundhead rivets. The average yield load for the countersunk-head rivets, however, was only slightly raised over that for the modified-roundhead rivets without inserts.

Tension tests.- The results of the tension tests are presented in table II. Ten of the tension specimens failed by constriction of the bulb formed on the end of the shank during expansion, which allowed the rivet to pull through the hole in the sheet. Four specimens failed by tension of the hollow portion of the shank and two specimens failed by a combination of both types of failure.

The variation of maximum tensile load with h_b for the countersunk-head-rivet specimens is shown in figure 7. The decrease of maximum load with increasing h_b is probably due to the decrease in the protruding hollow length of the rivet. The data indicate that, for protruding hollow lengths of 0.116 inch or less, the bulb on the shank end of the rivet tended to pull through the sheet before the full tensile strength of the hollow portion of the rivet shank was developed.

No significant difference due to the bore diameter was noted in the maximum tensile load for the modified-roundhead rivets with bores of 0.085-inch or of 0.100-inch diameter.

Pulsating-load tests.- The results of the pulsating-load tests are presented in table III. All specimens failed by shear of the rivets before the machine had reached full speed. Apparently the joints were sufficiently loose, as indicated by the large displacements of similar joints under shear load, to induce impact or other relatively severe loading conditions. As a result, the life of the joints was 70 cycles or less.

CONCLUSIONS

The following conclusions concerning the 1/8-inch-diameter hydraulically expanded rivets may be drawn from the results of the tests:

Shear tests:

(1) For two 0.081-inch-thick sheets of 24S-T aluminum alloy assembled with two countersunk-head hydraulically expanded rivets, no variation of yield load or maximum load was evident with h_b.

(2) The average maximum load for the countersunk-head rivets with the 24S-T aluminum-alloy inserts was more than 150 percent greater than the average maximum load for the modified-roundhead rivets, which had no inserts. The average yield load for the countersunk-head rivets was, however, only slightly greater than that for the modified-roundhead rivets.

(3) No significant difference due to the bore diameter was noted in either the yield load or the maximum load of modified-roundhead rivets having bores of 0.085- or of 0.100-inch diameter.

Tensile tests:

(1) The data indicate that for protruding hollow lengths of 0.116 inch or less, the bulb on the shank of the rivet tended to pull through the sheet before the full tensile strength of the hollow portion of the shank was developed.

(2) No significant difference due to the bore diameter was noted in the maximum tensile load for modified-roundhead rivets having bores of 0.085-inch or of 0.100-inch diameter.

Pulsating-load tests:

(1) In the pulsating-load tests, the looseness of the rivets apparently induced relatively severe loading conditions. As a result, the life of the joints was very short, 70 cycles or less.

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REFERENCE

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

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TABLE I.- DIMENSIONS AND STRENGTH OF SHEAR SPECIMENS

$\left[d = \frac{1}{8} \text{ inch; } a = 0.28 \text{ inch}\right]$

Speci-men	t, in.	h_b, in.	Load per rivet, lb				
			At permanent displacement of				Maxi-mum
			0.01d	0.02d	0.03d	0.04d (Yield load)	
100° countersunk-head rivet; b = 0.100 inch							
S-1	0.081	-0.011	26	48	67	82	[a]339
S-2		-.010	51	67	80	87	315
S-3		-.004	0	50	64	70	307
S-4		.000	47	68	77	87	320
S-5		.006	0	47	62	68	311
S-6		.011	40	56	62	71	312
S-7		.022	56	77	89	97	327
S-8		.032	35	62	78	88	328
Aver-age		------	-----	-----	-----	81.3	319.9
Modified-roundhead rivets; b = 0.085 inch							
S-9	0.032	------	34	48	55	61	[a]109
S-10	.040	------	26	44	50	54	[a]106
Aver-age	-----	------	-----	-----	-----	57.5	107.5
Modified-roundhead rivet; b = 0.100 inch							
S-11	0.032	------	20	42	58	68	[a]129
S-12	.032	------	35	59	67	73	124
S-13	.032	------	12	37	52	60	[a]104
S-14	.040	------	52	71	81	87	[a]135
S-15	.040	------	35	53	62	67	103
Aver-age	-----	------	-----	-----	-----	71.0	119.0

[a]One rivet fractured in expansion.

TABLE II.- DIMENSIONS AND STRENGTH OF TENSILE SPECIMENS

[$d = \frac{1}{8}$ inch; a = 0.28 inch]

Specimen	t, in.	h_b, in.	Protruding hollow length, in.	Maximum load, lb	Type of failure
100° countersunk-head rivet; b = 0.100 inch					
T-1	0.081	-0.012	0.130	157	(c)
T-2		-.010	.128	152	(d)
T-3		-.003	.121	180	(d)
T-4		.002	.116	121	(c)
T-5		.003	.115	153	(c)
T-6		.011	.107	155	(c)
T-7		.015	.103	116	(c)
T-8		.035	.083	96	(c)
Modified-roundhead rivet; b = 0.085 inch					
T-9	0.032	------	0.126	143	(c)
T-10	.040	------	.110	148	(e)
T-11	.040	------	.110	[a]128	(e)
Modified-roundhead rivet; b = 0.100 inch					
T-12	0.032	------	0.126	[a]147	(d)
T-13	.032	------	.126	[a]131	(d)
T-14	.032	------	.126	[b]18	(c)
T-15	.040	------	.110	138	(c)
T-16	.040	------	.110	130	(c)

[a]Rivet fractured in expansion.

[b]Rivet incompletely expanded.

[c]Shank pulled through.

[d]Tension failure of hollow shank.

[e]Combination in which shank pulled through and hollow portion of shank failed in tension.

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TABLE III.- DIMENSIONS AND NUMBER OF CYCLES REQUIRED FOR FAILURE OF PULSATING-LOAD SPECIMENS

$\left[d = \frac{1}{8} \text{ inch; } a = 0.28 \text{ inch}\right]$

Specimen	t_u, in.	t_L, in.	h_b, in.	Cycles to failure
100° countersunk-head rivet; b = 0.100 inch				
P-1	0.064	0.081	-0.008	40
P-2			-.006	20
P-3			.003	30
P-4			.004	30
P-5			.013	70
P-6			.014	30
Modified-roundhead rivet; b = 0.085 inch				
P-7	0.040	0.051	------	10
P-8	.040	.051	------	30
Modified-roundhead rivet; b = 0.100 inch				
P-9	0.040	0.051	------	20
P-10			------	20
P-11			------	30
P-12			------	20
P-13			------	30
P-14			------	20

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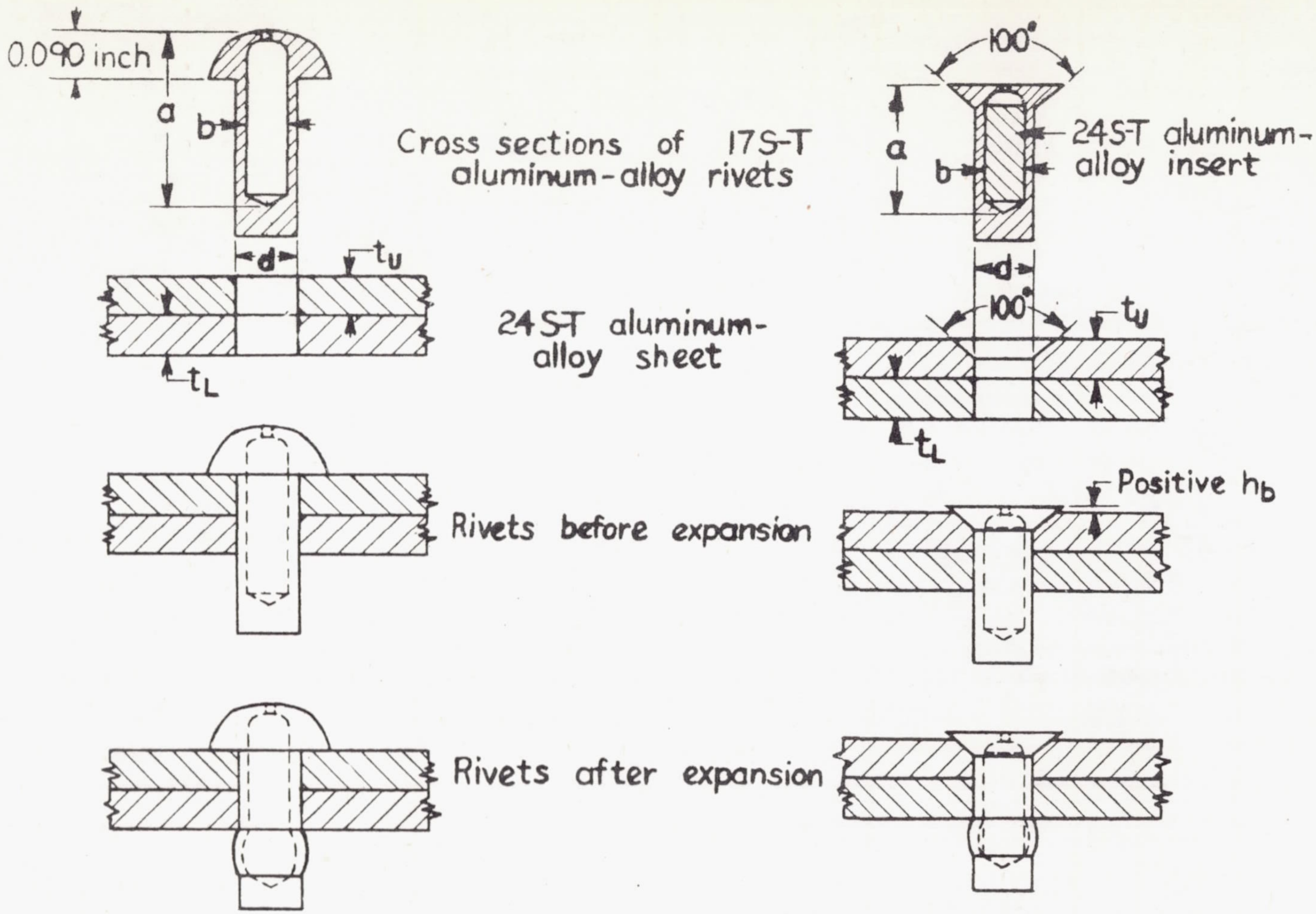

(a) Modified-roundhead rivets.

(b) Countersunk-head rivets.

Figure 1.- Riveting procedure.

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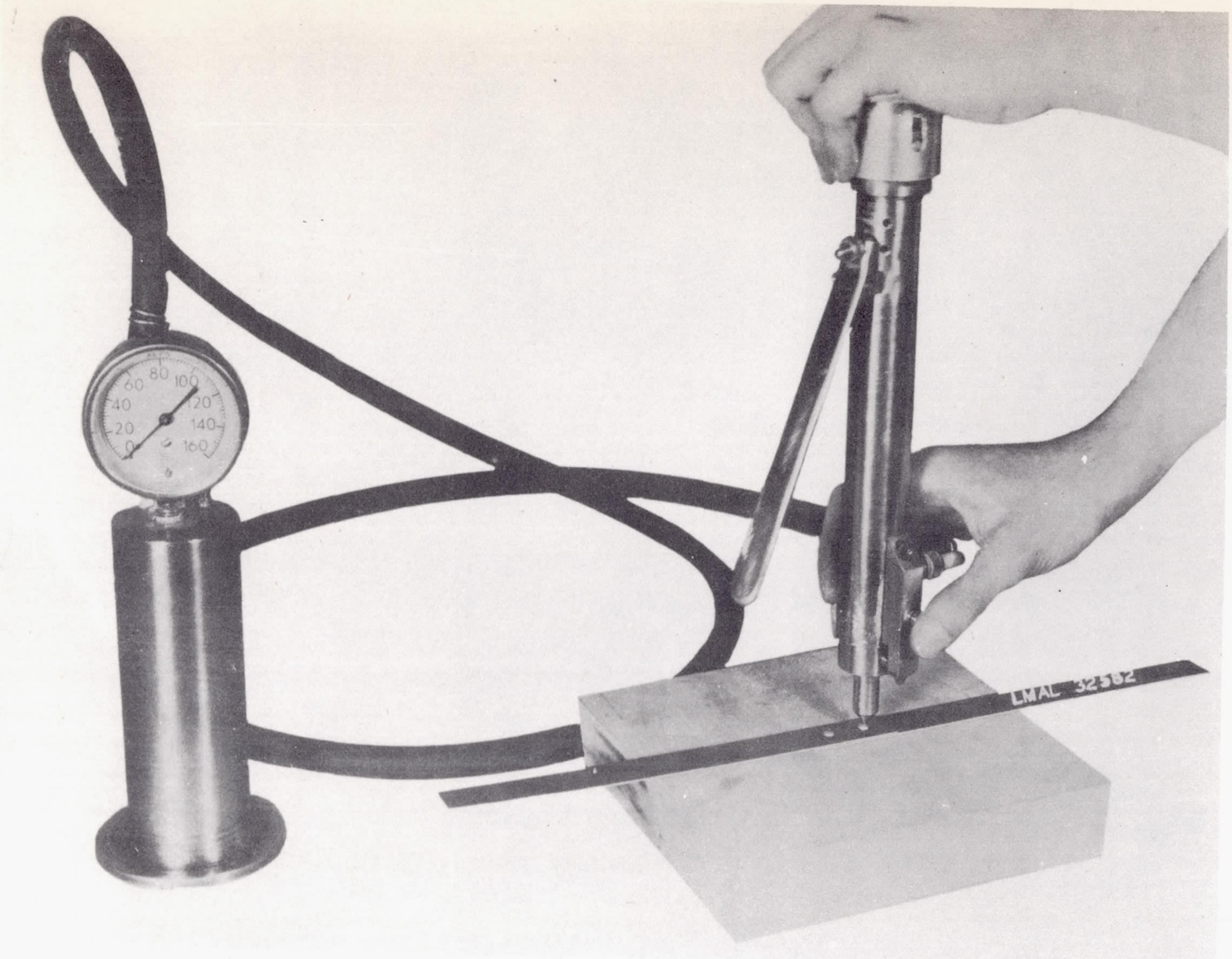

(a) Injection of oil into cavity of rivet.

Figure 2.- Hydraulically expanded rivet equipment in use.

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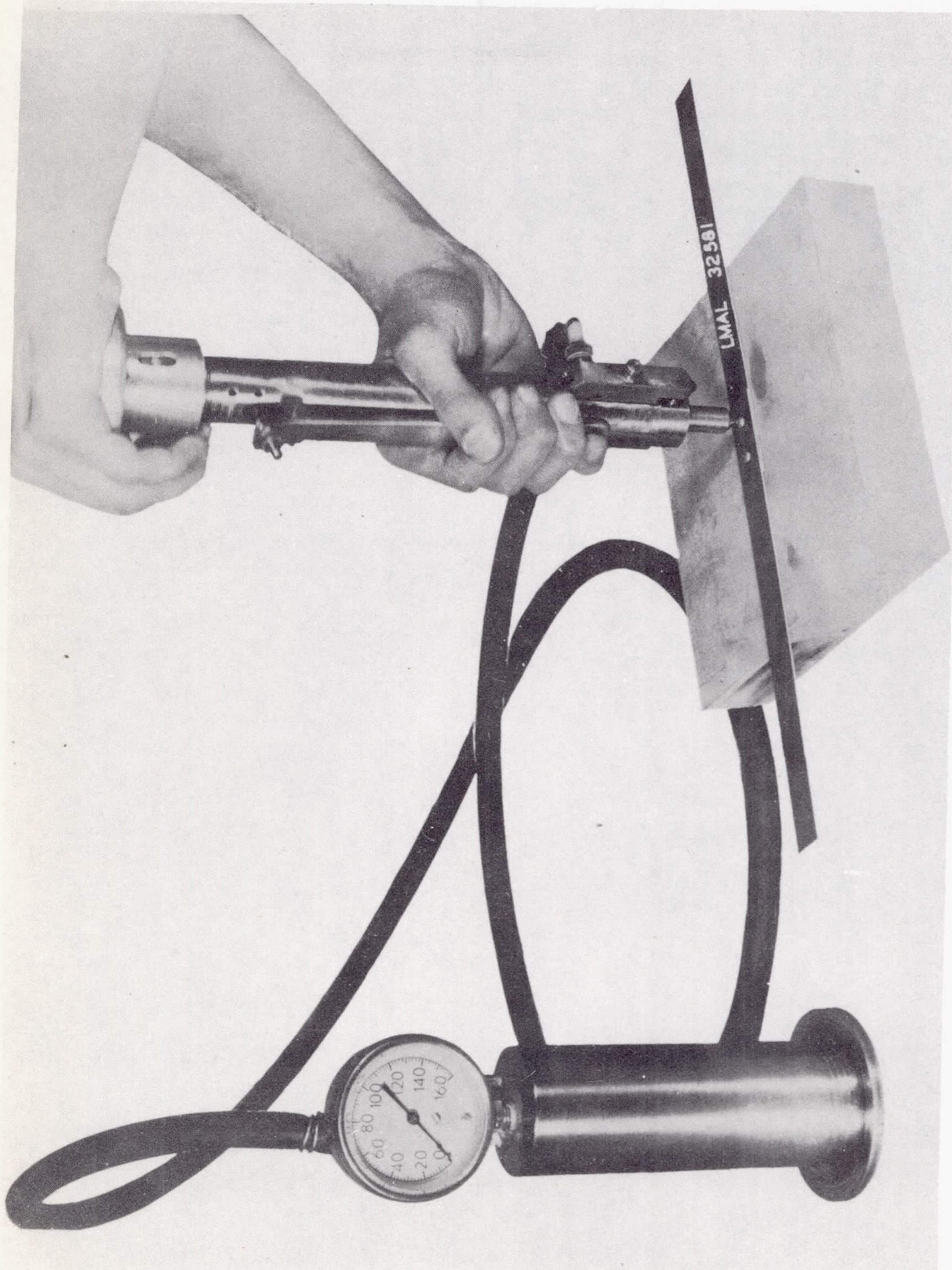
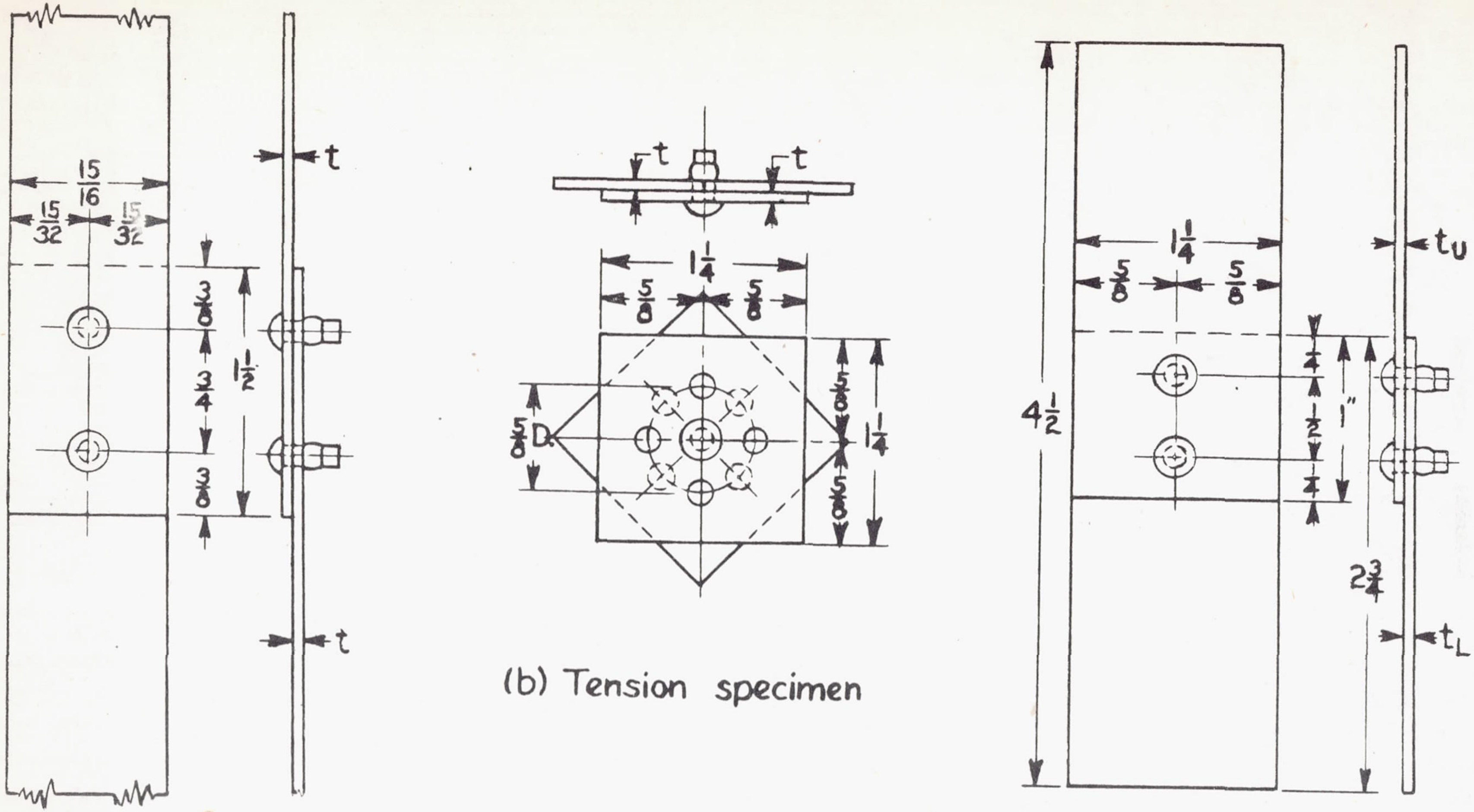


(b) Expansion of rivet.

Figure 2.- Concluded.



(a) Shear specimen

(b) Tension specimen

(c) Pulsating-load specimen

Figure 3.- Test specimens.

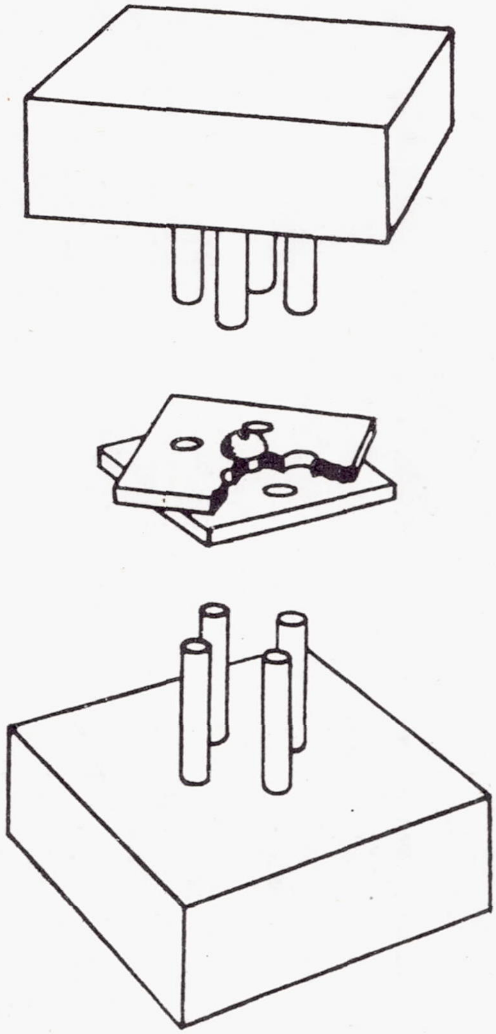


Figure 4. ~ Fixtures and specimen for rivet tension tests.

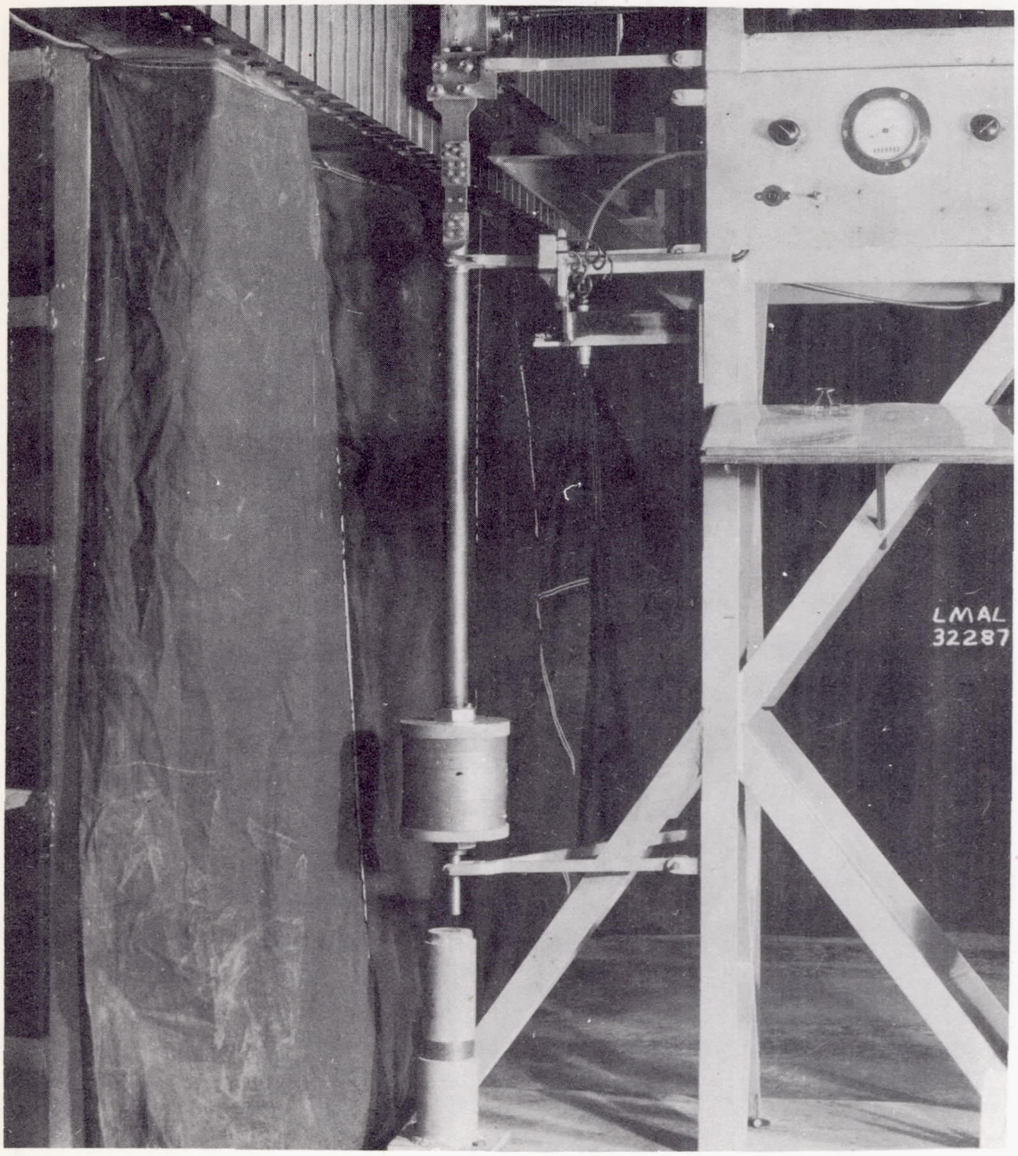


Figure 5.- Pulsating-load machine.

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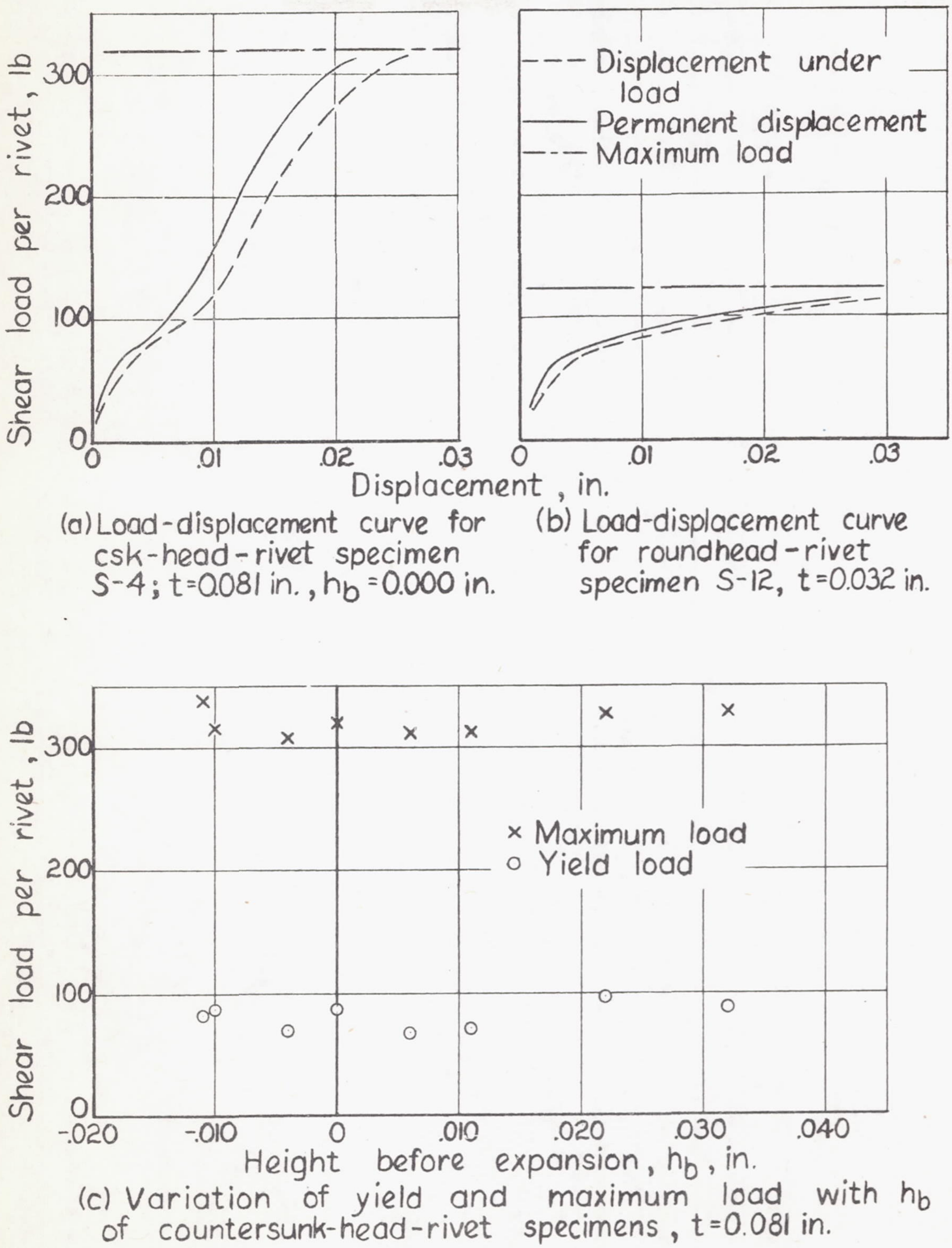

Figure 6.– Typical load-displacement curves, yield loads, and maximum loads of shear specimens; $d = \frac{1}{8}$ in.

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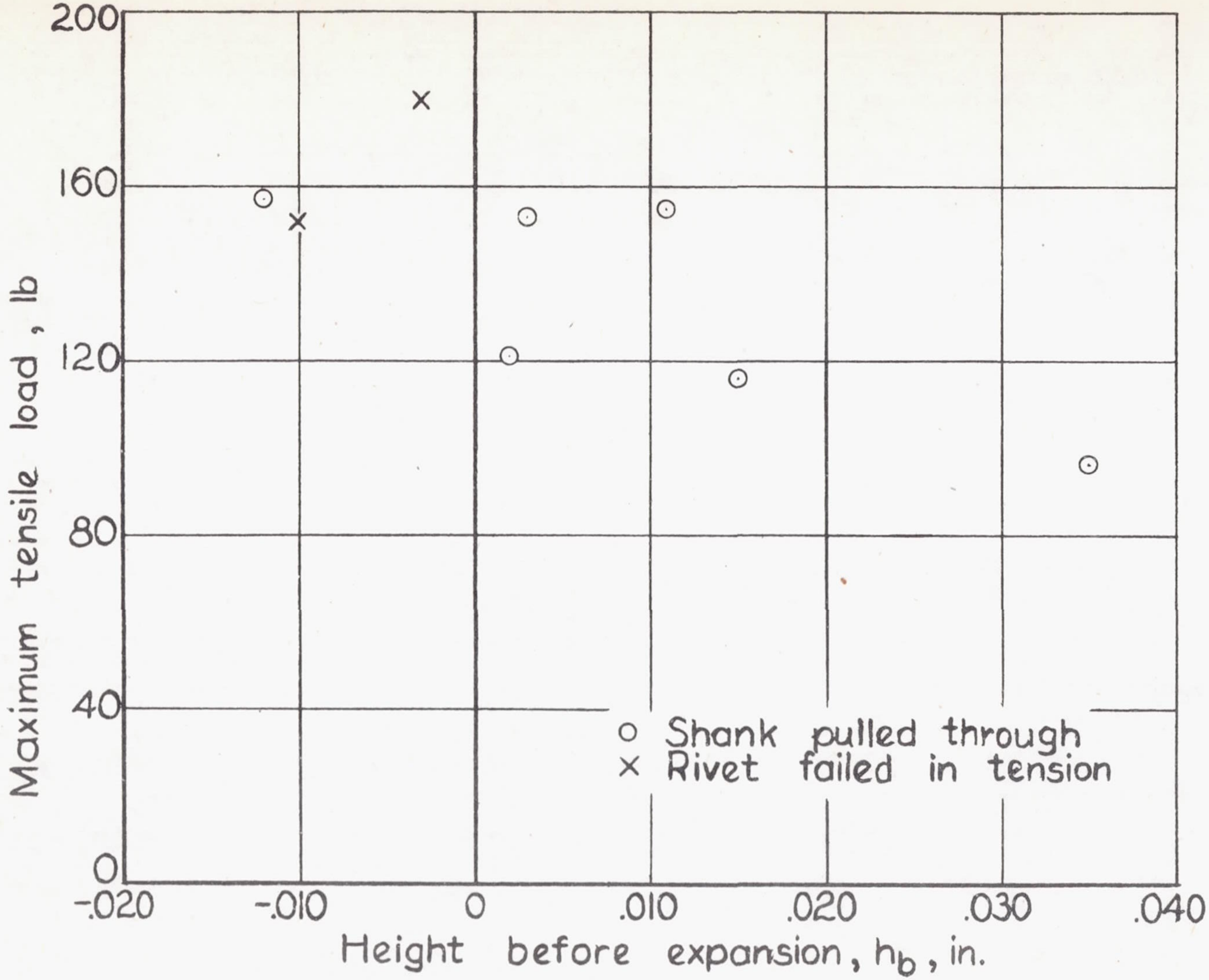

Figure 7.- Variation of maximum tensile load with h_b; t = 0.081 in.