NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2883

BEARING STRENGTHS OF SOME 75S-T6 AND 14S-T6 ALUMINUM-ALLOY HAND FORGINGS

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SUMMARY

Results are given from an investigation of bearing properties of some 75S-T6 and 14S-T6 aluminum-alloy hand forgings in the longitudinal and long transverse directions and in surface and center locations. The tensile properties of the forgings were above those specified for such material and showed the expected directional or locational characteristics. The bearing properties showed less directional or locational variations than did the tensile properties. Ratios of bearing to longitudinal tensile strengths are summarized and nominal values are recommended for use in selecting design bearing strengths.

INTRODUCTION

This report is another of a series dealing with the bearing properties of aluminum alloys of interest to the aircraft industry.

The object of this investigation was to determine the bearing ultimate and yield strengths of 75S-T6 and 14S-T6 aluminum-alloy hand forgings in the longitudinal and long transverse directions and in surface and center locations. Ratios of bearing to tensile properties were also determined.

This work was done by the Aluminum Company of America and has been made available to the National Advisory Committee for Aeronautics for publication because of its general interest.

MATERIAL

The material used in this investigation was supplied by the Cleveland Works of the Aluminum Company of America and consisted of the following 75S-T6 aluminum-alloy hand forgings, heat-treated in full size at the Cleveland Works:

One piece 3 inches by 3 inches by 36 inches

One piece 3 inches by 12 inches by 36 inches

The following 75S aluminum-alloy forgings were received from the Cleveland Works in the "as forged" temper, from which 3-inch-thick slabs for test were removed from the center and heat-treated at the Aluminum Research Laboratories to the -T6 temper:

One piece 5 inches by 12 inches by 36 inches

One piece 8 inches by 8 inches by 24 inches

Also used was one piece of 14S-T6, heat-treated in full size at the Cleveland Works, 5 inches by 12 inches by $25\frac{1}{2}$ inches. Table I shows the tensile properties of the material investigated.

PROCEDURE

Figure 1 shows the locations in the 75S-T6 hand forgings from which the 3/16-inch-thick by 2-inch-wide bearing specimens were taken, and figure 2 shows the locations in the 14S-T6 hand forgings from which the 3/16-inch-thick by 2-inch-wide bearing specimens were removed.

The original length of all the bearing specimens was 12 inches. After tests were made on specimens with an edge distance of 1.5 times the pin diameter, the damaged portion of the specimens was cut off a minimum of 3/4 inch below the center of the pin hole and new pin holes were drilled and reamed for tests of edge distances equal to 2.0 times the pin diameter.

The 3/16-inch-thick specimens were loaded in bearing on a 0.500-inch-diameter steel pin and tested in the arrangement shown in figure 3. The tests were conducted in a 40,000-pound-capacity Amsler hydraulic testing machine (type 20 ZBDA, Serial No. 4318) using the 3-inch-wide Templin grip. Edge distances, measured in the direction of stressing from the center of the pin hole to the edge of the specimen, were 1.5 and 2.0 times the diameter of the pin. All tests were made in duplicate for the

longitudinal and long transverse directions and for the two edge distances specified above.

Hole deformations, from which values of bearing yield strengths were determined, were obtained by measuring the relative movement of the pin and the specimen by means of a filar micrometer microscope, which could be read directly to 0.01 millimeter and by estimation to 0.002 millimeter. These measurements were taken between two references: One, a scribed line on the specimen 1/32 inch under the pin hole, and the other, the point at which the horizontal cross hair of the microscope became tangent to the bottom of the steel pin in the plane of the specimen.

RESULTS AND DISCUSSION

It was noted from table I that the tensile strengths of the 75S-T6 used in these bearing tests were from 5 to 18 percent higher than the specified values for hand forgings in the appropriate size groups. The tensile strengths of the 14S-T6 were 12 to 18 percent higher than the specified values.

It was also noted that the 75S-T6 longitudinal specimens had about 5 percent higher tensile strengths than had the long transverse specimens. Also, specimens cut from locations at or near the surface had about 5-percent-higher tensile strength values than had those cut from center locations. The 14S-T6 forgings exhibited substantially the same characteristics and differences as those of the 75S-T6.

Table II gives the values of bearing ultimate and yield strengths obtained for these tests. The bearing yield strengths were obtained from the curves shown in figures 4 to 8 as the stresses corresponding to an offset from the straight-line portion of the curves equal to 2 percent of the pin diameter. Failures resulted from a combination of tension on the section through the hole and shear above the pin, with the exception of one 75S-T6 specimen which failed by shear above the pin. Figures 9 and 10 show a few typical failures.

While there are some directional and locational differences of bearing properties evident in table II, these are not considered to be consistently large enough to justify any radical departure from previous practice in reference 1 of using only one set of bearing properties for all directions and locations. With this in mind the bearing properties for various directions and locations have been averaged in table II.

Table III shows the ratios of average bearing to average longitudinal tensile strengths of the forgings included in these tests. Ratios for 75S-T6 forgings are slightly lower than those previously reported

for sheet, but not so low as those observed for rolled and extruded bar in 2- to 3-inch thicknesses. The ratios for the 14S-T6 forgings were in fair agreement with those used in table 3.111 (j) of reference 1 for hand forgings in the cross-sectional area group of 36 to 144 square inches and having a forged length of not more than three times the width.

Table IV summarizes the ratios of bearing to longitudinal tensile strengths in alloy and size groups as listed in reference 1, table 3.111(j). These ratios are recommended for use in selecting design bearing strengths.

CONCLUSIONS

The results of this investigation of the bearing properties of some 75S-T6 and 14S-T6 aluminum-alloy hand forgings are believed to warrant the following conclusions:

1. The tensile properties of the forgings tested were above those specified for such material.

2. The tensile properties of the test samples showed the expected directional or locational characteristics.

3. The bearing properties of the forgings showed less directional or locational variations than did the tensile properties.

4. Ratios of bearing to longitudinal tensile strengths for 75S-T6 forgings were slightly lower than those previously reported for sheet, but not quite so low as those observed for rolled and extruded bar in the 2- to 3-inch thickness range. The ratios for the 14S-T6 forgings were in fair agreement with those used in "Strength of Metal Aircraft Elements," ANC-5, June 1951, table 3.111(j), for hand forgings in the cross-sectional area group of 36 to 144 square inches and having a forged length of not more than three times the width.

5. The nominal ratios of bearing to longitudinal tensile strength are recommended for use in selecting design bearing strengths.

Aluminum Research Laboratories
Aluminum Company of America
New Kensington, Pa., August 5, 1952

REFERENCES

1. Anon.: Strength of Metal Aircraft Elements. ANC-5, Munitions Board Aircraft Committee, Revised ed., June 1951.

2. Anon.: Tentative Methods of Tension Testing of Metallic Materials. Designation: E8-51T, A.S.T.M. Standards, 1951 Supp.

TABLE I

TENSILE PROPERTIES[1] OF 75S-T6 AND 14S-T6 ALUMINUM-ALLOY HAND FORGINGS USED IN BEARING TESTS

Specimen	Alloy and temper	Original forging size (in.)	Specimen direction	Approx. location	Ultimate strength (psi)	Yield strength (0.2-percent offset) (psi)	Elongation in 2 in. (percent)
116727-L1	75S-T6	3 by 3 by 36	Longitudinal	Surface	81,300	70,300	11.0
-L2	75S-T6	3 by 3 by 36	Longitudinal	Surface	79,700	68,800	13.0
-L3	75S-T6	3 by 3 by 36	Longitudinal	Center	79,100	68,500	14.0
-L4	75S-T6	3 by 3 by 36	Longitudinal	Center	79,000	68,900	12.0
					Av. 79,800	69,100	12.5
116729-L1	75S-T6	3 by 12 by 36	Longitudinal	Surface	85,300	76,000	5.5
-L2	75S-T6	3 by 12 by 36	Longitudinal	Surface	80,400	70,700	6.5
					Av. 82,900	73,000	6.0
-L3	75S-T6	3 by 12 by 36	Longitudinal	Center	77,300	66,300	13.0
-L4	75S-T6	3 by 12 by 36	Longitudinal	Center	77,700	66,600	13.5
					Av. 77,500	66,500	13.3
116729-T1	75S-T6	3 by 12 by 36	Long transverse	12 in. from end	74,600	63,100	8.5
-T2	75S-T6	3 by 12 by 36	Long transverse	12 in. from end	75,000	63,100	10.0
					Av. 74,800	63,100	9.2
116730-L1	75S-T6	5 by 12 by 36	Longitudinal	Surface	80,900	69,300	11.0
-L2	75S-T6	5 by 12 by 36	Longitudinal	Surface	79,100	68,500	11.0
-L3	75S-T6	5 by 12 by 36	Longitudinal	Surface	79,100	68,300	11.0
					Av. 79,700	68,700	11.0
116730-T1	75S-T6	5 by 12 by 36	Long transverse	12 in. from end	78,400	67,600	8.0
-T2	75S-T6	5 by 12 by 36	Long transverse	12 in. from end	78,900	68,300	7.5
					Av. 78,600	68,000	7.8
116733-L1	75S-T6	8 by 8 by 24	Longitudinal	Surface	81,100	69,000	10.0
-L2	75S-T6	8 by 8 by 24	Longitudinal	Surface	80,500	68,600	10.0
-L3	75S-T6	8 by 8 by 24	Longitudinal	Surface	82,500	70,800	8.0
-L4	75S-T6	8 by 8 by 24	Longitudinal	Surface	85,700	74,500	8.5
					Av. 82,500	70,700	9.1
117269-L1	14S-T6	5 by 12 by $25\frac{1}{2}$	Longitudinal	Surface	67,900	60,700	7.5
-L2	14S-T6	5 by 12 by $25\frac{1}{2}$	Longitudinal	Surface	69,100	62,300	7.5
					Av. 68,500	61,500	7.5
-L3	14S-T6	5 by 12 by $25\frac{1}{2}$	Longitudinal	Center	64,200	56,400	7.0
-L4	14S-T6	5 by 12 by $25\frac{1}{2}$	Longitudinal	Center	64,000	56,600	6.0
					Av. 64,100	56,500	6.5
117269-T1	14S-T6	5 by 12 by $25\frac{1}{2}$	Long transverse	12 in. from end	64,400	56,500	7.0
-T2	14S-T6	5 by 12 by $25\frac{1}{2}$	Long transverse	12 in. from end	64,100	56,200	7.0
					Av. 64,200	56,400	7.0

[1]Standard sheet-type tension test specimen as shown in fig. 6 of reference 2.

TABLE II

BEARING STRENGTHS OF 75S-T6 AND 14S-T6 ALUMINUM-ALLOY HAND FORGINGS

[All failures resulted from a combination of tension on the section through the hole and shear above the pin, except one failure by shear above the pin]

Original forging size (in.)	Specimen direction	Approx. location	Bearing strengths (psi) for edge distances of -			
			1.5 times pin diameter		2.0 times pin diameter	
			Ultimate	Yield (1)	Ultimate	Yield (1)
75S-T6 specimens						
3 by 3 by 36:						
116727-L1	Longitudinal	Surface	109,700	93,700	139,000	107,400
-L2	Longitudinal	Surface	109,800	94,800	143,500	109,000
-L3	Longitudinal	Center	103,200	98,700	139,700	106,500
-L4	Longitudinal	Center	108,400	97,900	147,800	107,900
			Av. 107,800	96,300	142,500	107,700
3 by 12 by 36:						
116729-L1	Longitudinal	Surface	117,600	97,500	150,200	116,000
-L2	Longitudinal	Surface	113,300	94,800	143,900	112,100
-L3	Longitudinal	Center	99,900	92,800	138,900	104,100
-L4	Longitudinal	Center	99,700	92,500	138,800	106,300
-T1	Long transverse	12 in. from end	103,900	90,000	129,600	106,800
-T2	Long transverse	12 in. from end	99,100	91,700	139,000	110,000
			Av. 105,600	93,200	140,100	109,200
5 by 12 by 36:						
116730-L1	Longitudinal	Surface	93,500	89,100	128,000	105,300
-L2	Longitudinal	Surface	97,800	91,700	124,600	105,000
-L3	Longitudinal	Surface	99,500	93,600	129,900	107,600
-T1	Long transverse	12 in. from end	94,500	88,900	119,900	105,100
-T2	Long transverse	12 in. from end	97,900	91,400	129,600	108,000
			Av. 96,600	90,900	126,400	106,200
8 by 8 by 24:						
116733-L1	Longitudinal	Surface	98,500	91,900	133,800	106,800
-L2	Longitudinal	Surface	98,400	91,100	133,300	105,000
-L3	Longitudinal	Surface	99,200	96,500	135,000	110,200
-L4	Longitudinal	Surface	97,400	97,000	139,400	110,500
			Av. 98,400	94,100	135,400	108,100
14S-T6 specimens						
5 by 12 by $25\frac{1}{2}$:						
117269-L1	Longitudinal	Surface	91,800	86,900	119,900	98,000
-L2	Longitudinal	Surface	92,700	87,700	119,100	98,200
-L3	Longitudinal	Center	89,900	85,000	114,500	94,900
-L4	Longitudinal	Center	87,100	84,000	118,400	95,300
-T1	Long transverse	12 in. from end	94,900	89,800	129,200	100,000
-T2	Long transverse	12 in. from end	93,600	87,100	124,500	102,200
			Av. 91,700	86,800	120,900	98,100

(1) Stress corresponding to offset of 2 percent of pin diameter from initial straight-line portion of curves of bearing stress against hole elongation.

TABLE III

RATIOS OF AVERAGE BEARING TO AVERAGE LONGITUDINAL TENSILE STRENGTHS FOR 75S-T6 AND 14S-T6 ALUMINUM-ALLOY HAND FORGINGS

Alloy and temper	Forged size (in.)	Ratios for edge distances of -			
		1.5 times pin diameter		2.0 times pin diameter	
		$\frac{BS}{TS}$ (1)	$\frac{BYS}{TYS}$ (1)	$\frac{BS}{TS}$ (1)	$\frac{BYS}{TYS}$ (1)
75S-T6	3 by 3 by 36	1.35	1.40	1.79	1.56
75S-T6	3 by 12 by 36	1.32	1.34	1.75	1.57
75S-T6	5 by 12 by 36	1.21	1.32	1.59	1.55
75S-T6	8 by 8 by 24	1.19	1.33	1.64	1.53
14S-T6	5 by 12 by $25\frac{1}{2}$	1.38	1.47	1.82	1.66

[1] BS, bearing ultimate strength
TS, tensile ultimate strength
BYS, bearing yield strength
TYS, tensile yield strength

TABLE IV

NOMINAL RATIOS OF BEARING TO LONGITUDINAL TENSILE STRENGTHS FOR 75S-T6 AND 14S-T6 ALUMINUM-ALLOY HAND FORGINGS RECOMMENDED FOR DESIGN

Material (1)	Ratios for edge distances of -			
	1.5 times pin diameter		2.0 times pin diameter	
	$\frac{BS}{TS}$ (2)	$\frac{BYS}{TYS}$ (2)	$\frac{BS}{TS}$ (2)	$\frac{BYS}{TYS}$ (2)
75S-T6, forged length greater than three times the width, and cross-sectional area less than 16 sq in.	1.3	1.4	1.8	1.5
75S-T6, forged length not greater than three times the width, and cross-sectional area from 16 to 36 sq in.	1.3	1.3	1.7	1.5
75S-T6, forged length not greater than three times the width, and cross-sectional area from 36 to 144 sq in.	1.2	1.3	1.6	1.5
14S-T6, forged length not greater than three times the width, and cross-sectional area from 36 to 144 sq in.	1.4	1.4	1.8	1.6

[1] Grouped as in table 3.111(j) of reference 1.

[2] BS, bearing ultimate strength
TS, tensile ultimate strength
BYS, bearing yield strength
TYS, tensile yield strength

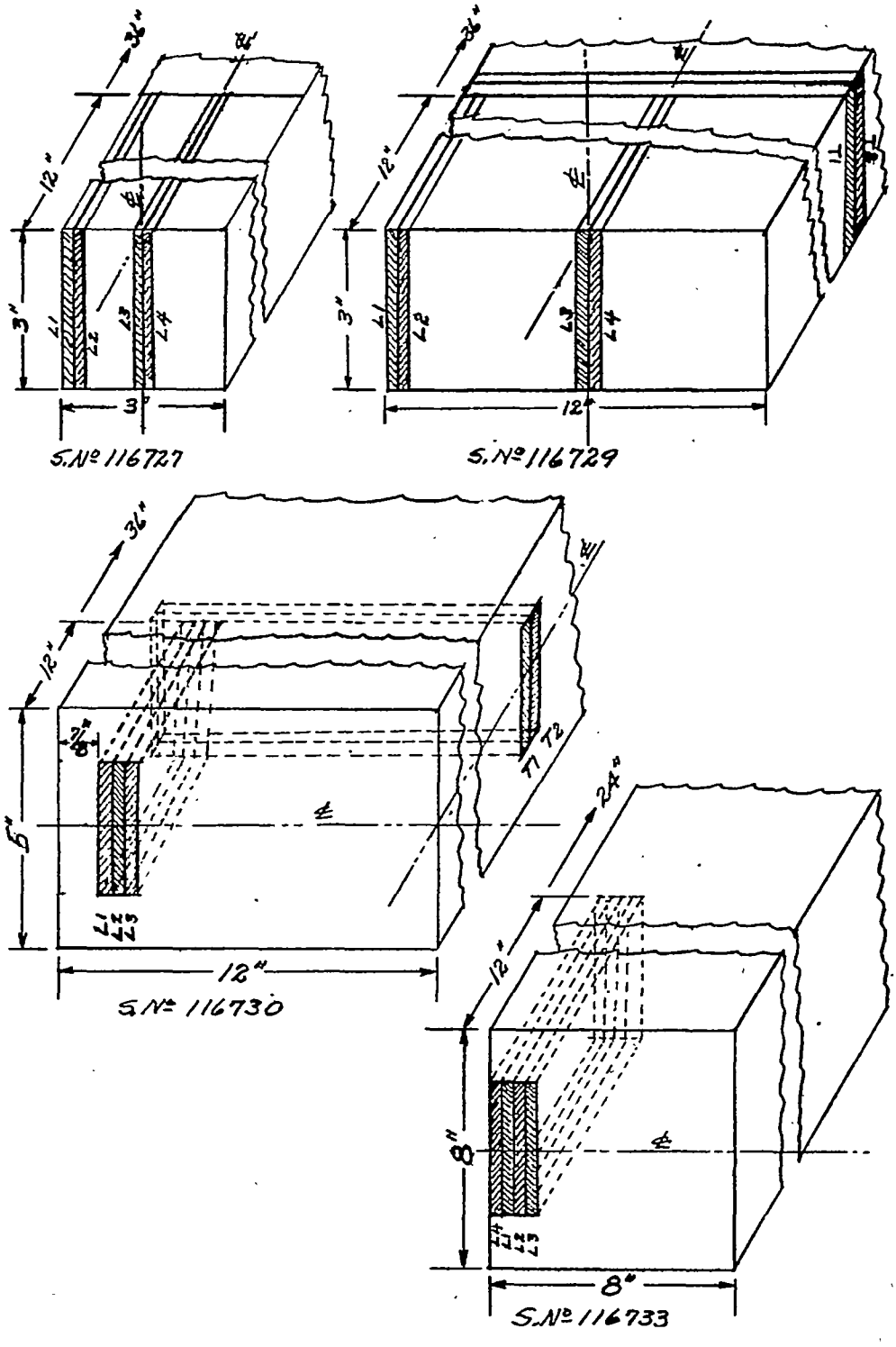

Figure 1.- Locations in 75S-T6 aluminum-alloy hand forgings from which bearing specimens were obtained. Specimen size, 3/16 inch by 2 inches by 12 inches.

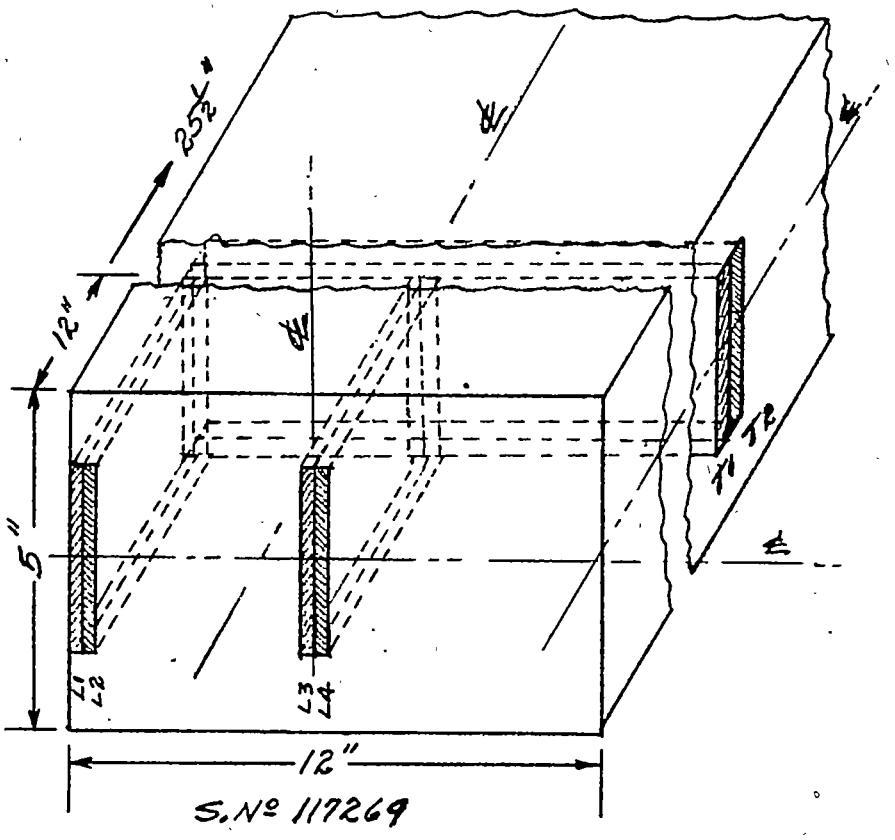

Figure 2.- Locations in 14S-T6 aluminum-alloy hand forgings from which bearing specimens were obtained. Specimen size, 3/16 inch by 2 inches by 12 inches.

Figure 3.- Arrangement for making bearing tests.

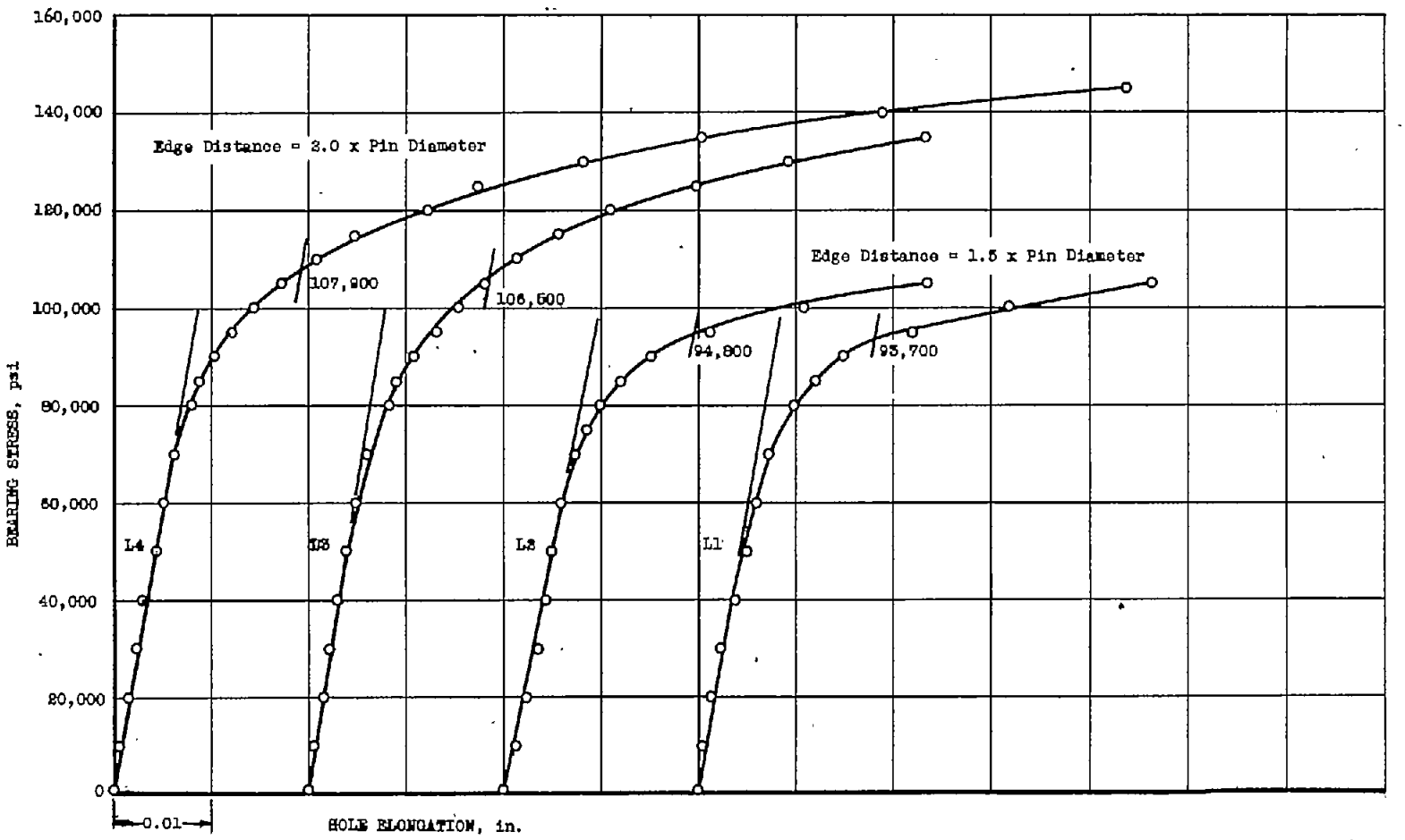

Figure 4.- Curves of bearing stress against hole elongation for 75S-T6 aluminum-alloy hand forgings. Specimens 116727-L1, -L2, -L3, and -L4. Bearing yield offset, 0.02 times pin diameter; pin diameter, 0.500 inch; specimen thickness, 0.188 inch (machined from sections of hand forgings); specimen width, 2.00 inches.

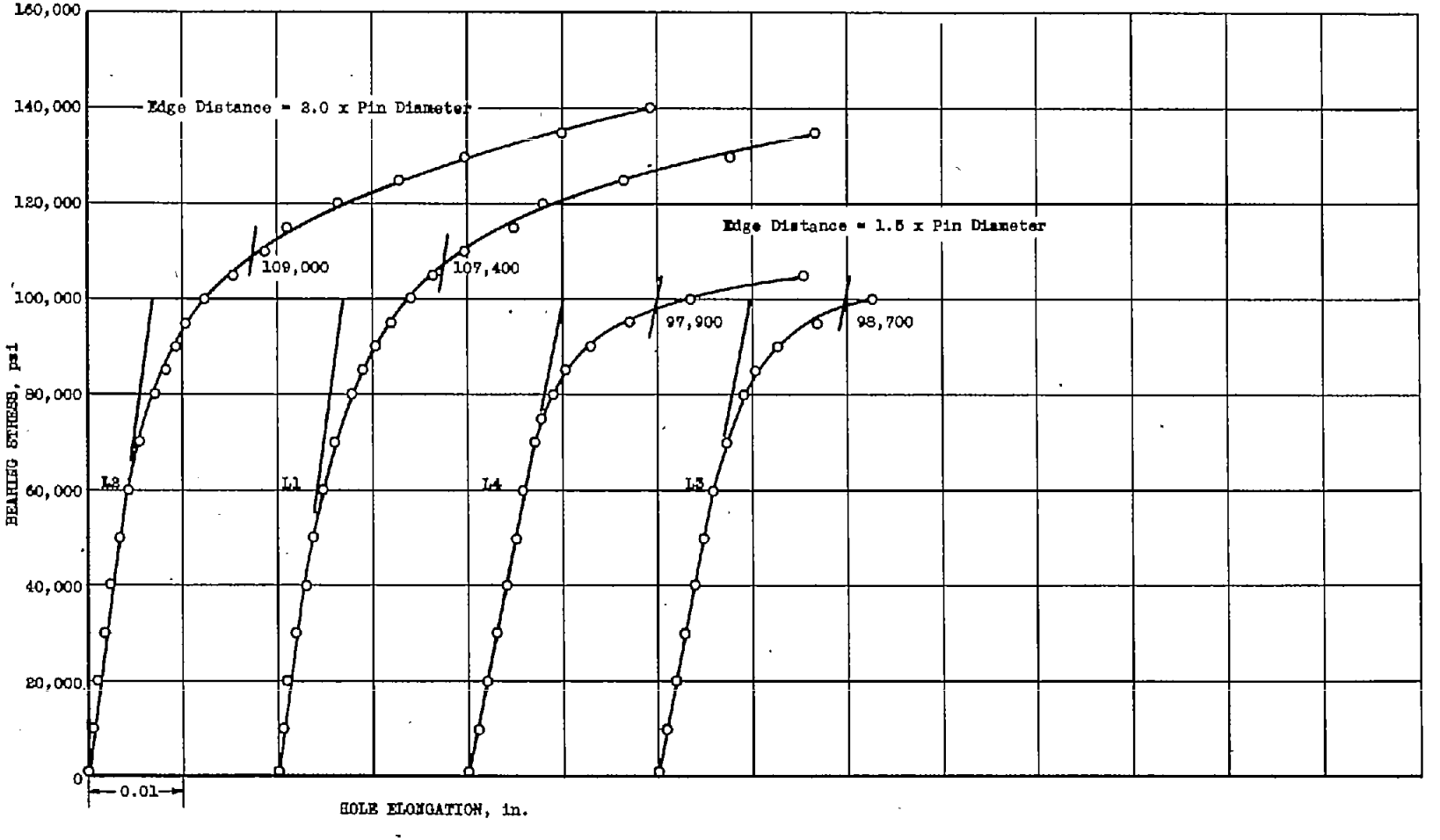

Figure 4.- Concluded.

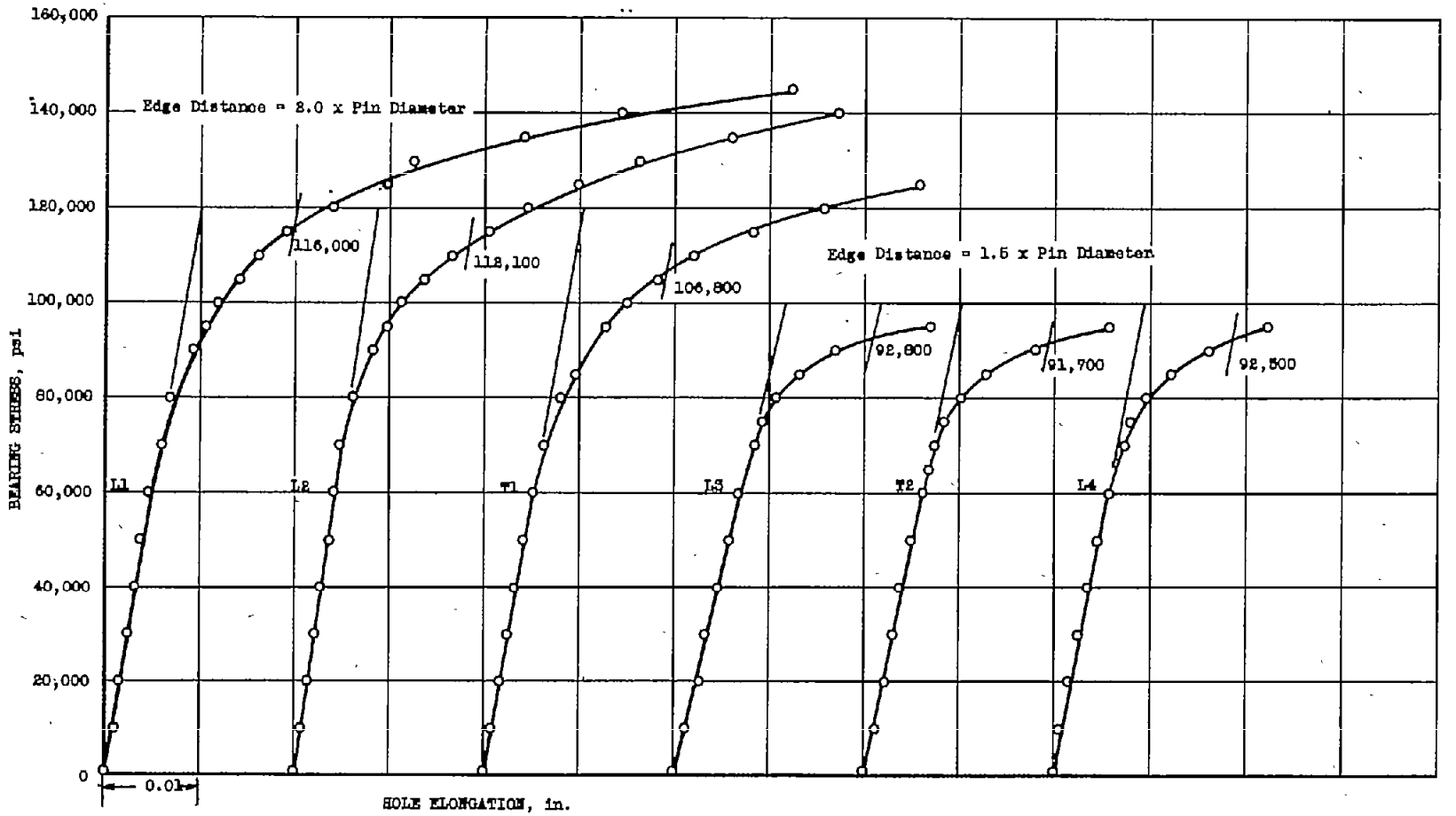

Figure 5.- Curves of bearing stress against hole elongation for 75S-T6 aluminum-alloy hand forgings. Specimens 116729-L1, -L2, -L3, -L4, -T1, and -T2. Bearing yield offset, 0.02 times pin diameter; pin diameter, 0.500 inch; specimen thickness, 0.188 inch (machined from sections of hand forgings); specimen width, 2.00 inches.

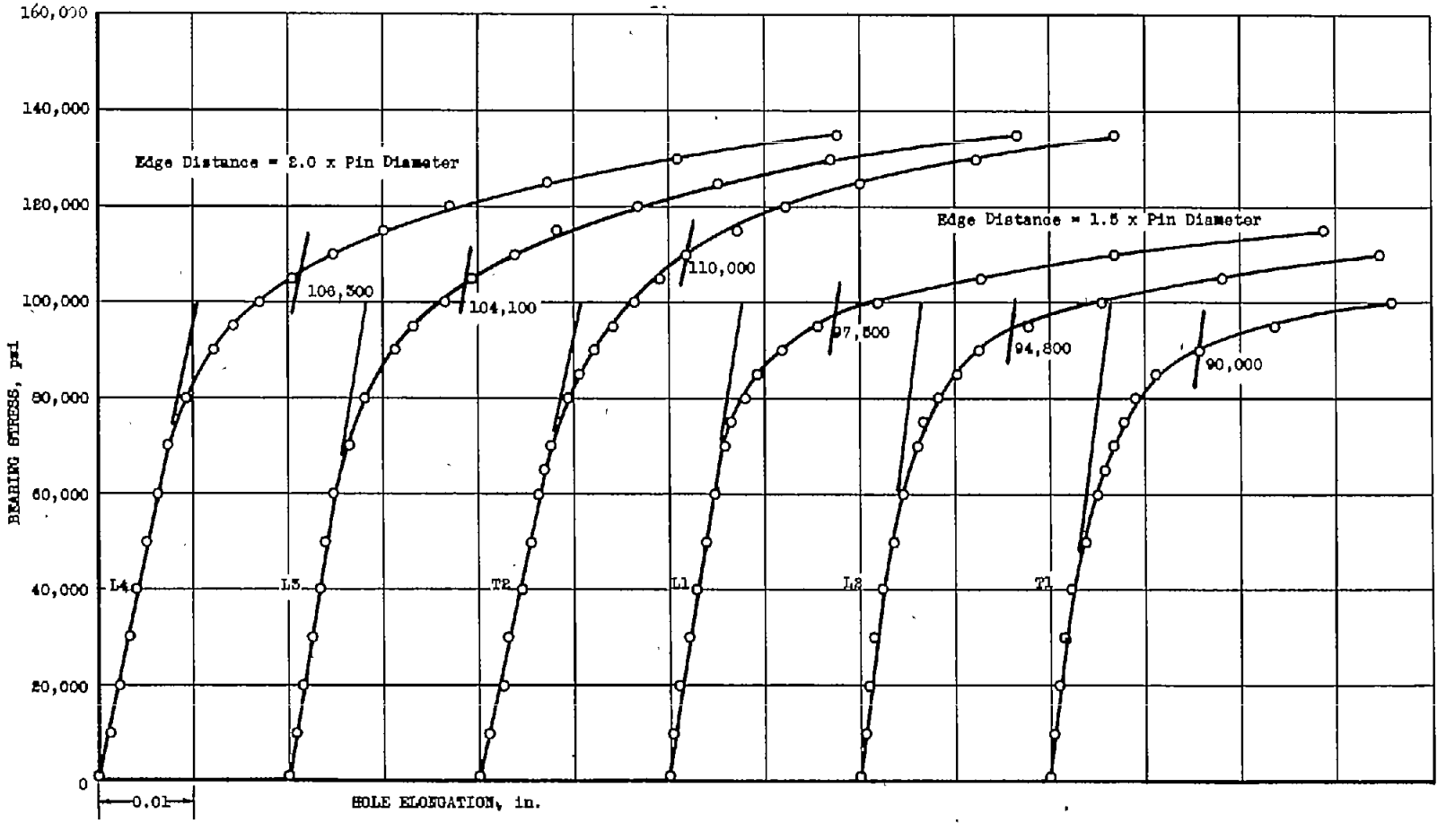

Figure 5.- Concluded.

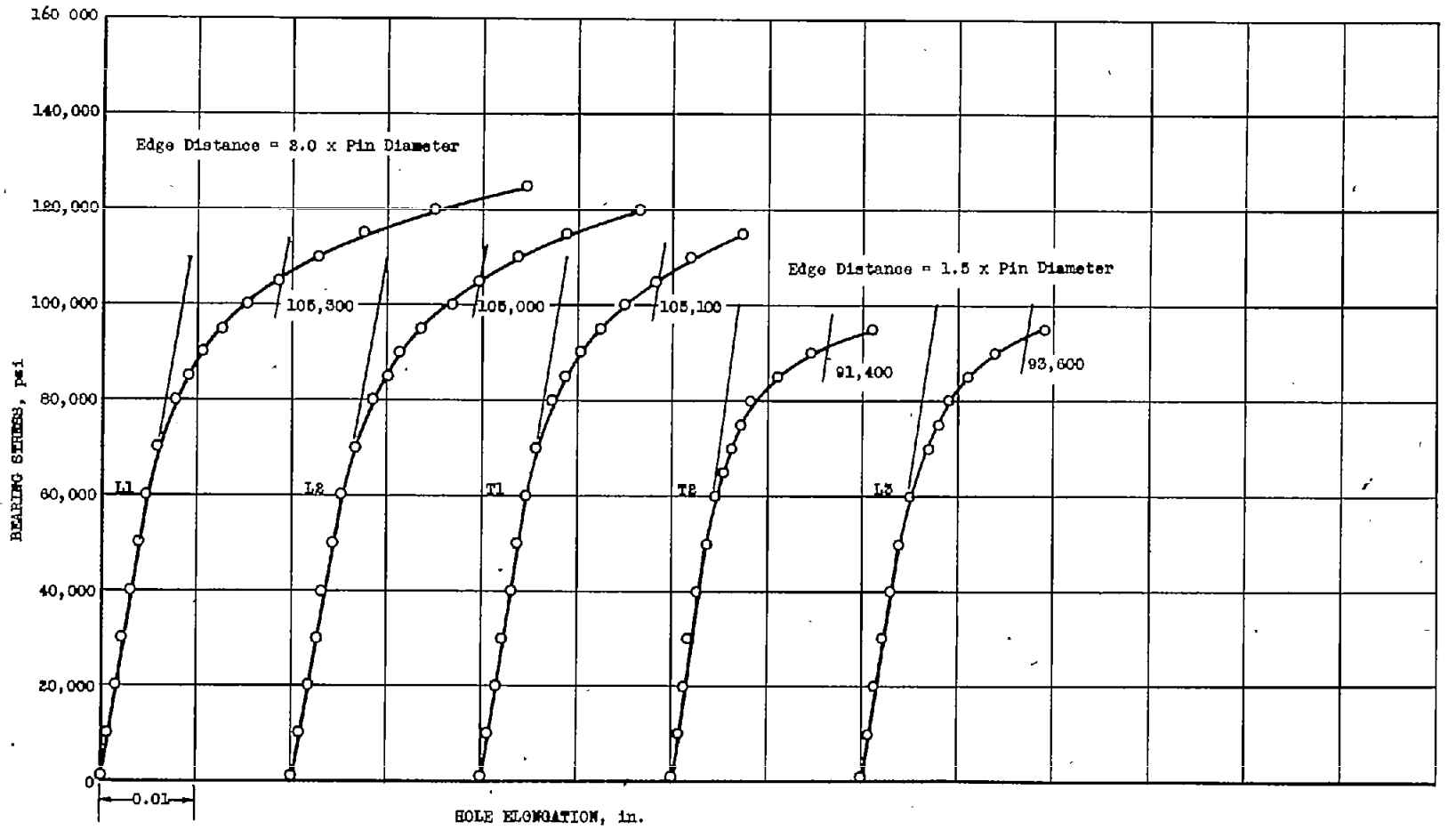

Figure 6.- Curves of bearing stress against hole elongation for 75S-T6 aluminum-alloy hand forgings. Specimens 116730-L1, -L2, -L3, -T1, and -T2. Bearing yield offset, 0.02 times pin diameter; pin diameter, 0.500 inch; specimen thickness, 0.188 inch (machined from sections of hand forgings); specimen width, 2.00 inches.

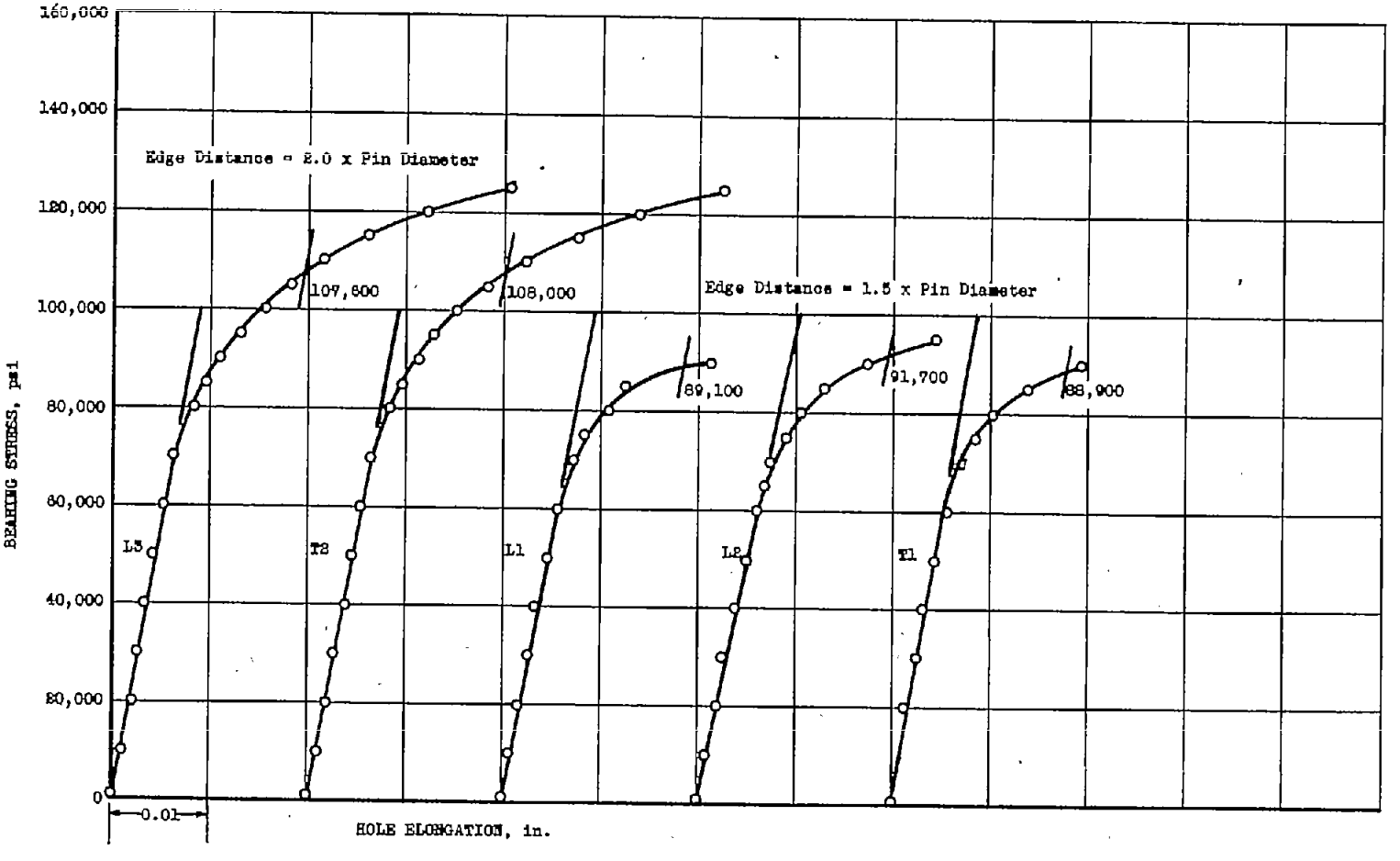

Figure 6.- Concluded.

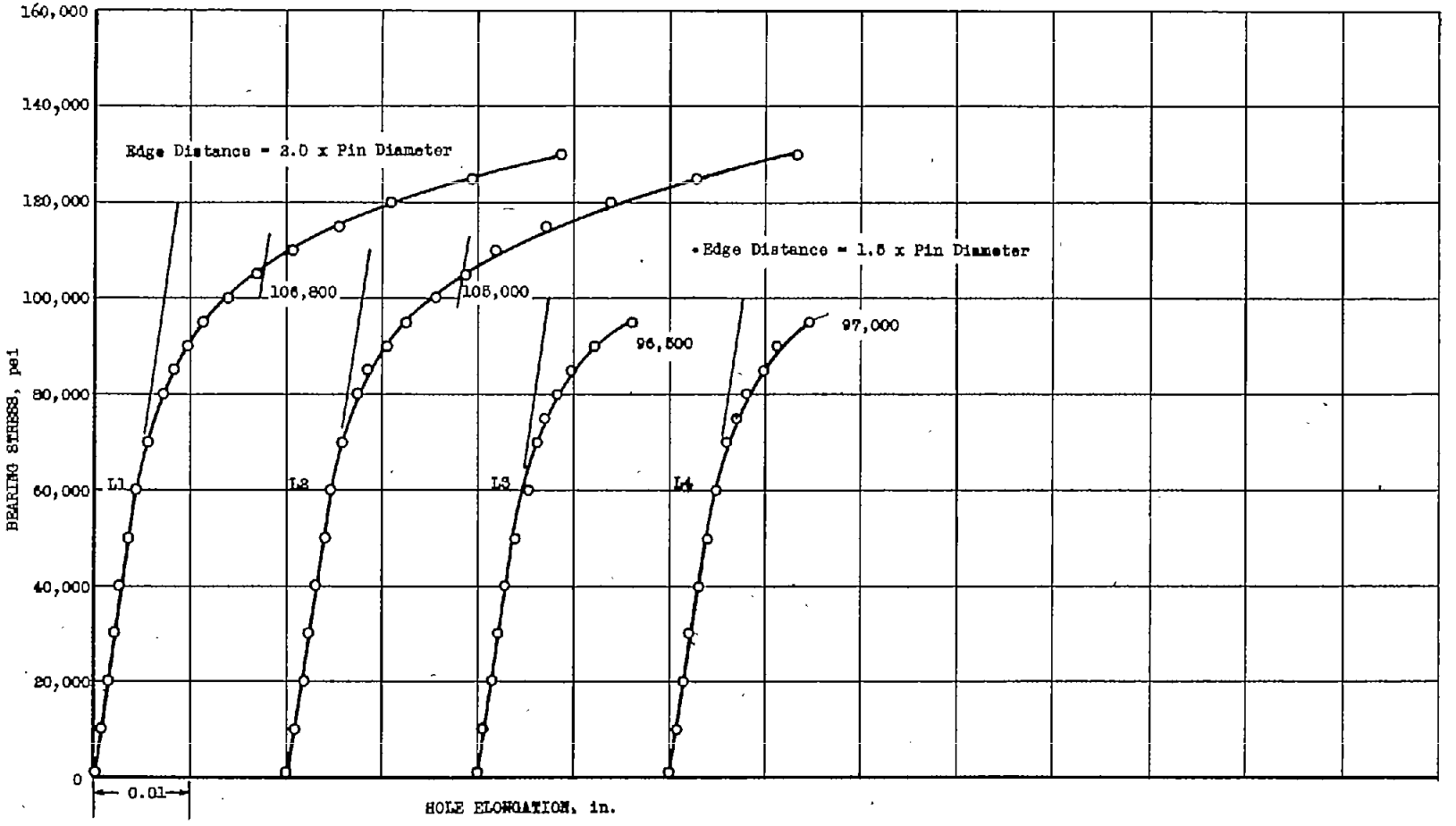

Figure 7.- Curves of bearing stress against hole elongation for 75S-T6 aluminum-alloy hand forgings. Specimens 116733-L1, -L2, -L3, and -L4. Bearing yield offset, 0.02 times pin diameter; pin diameter, 0.500 inch; specimen thickness, 0.188 inch (machined from sections of hand forgings); specimen width, 2.00 inches.

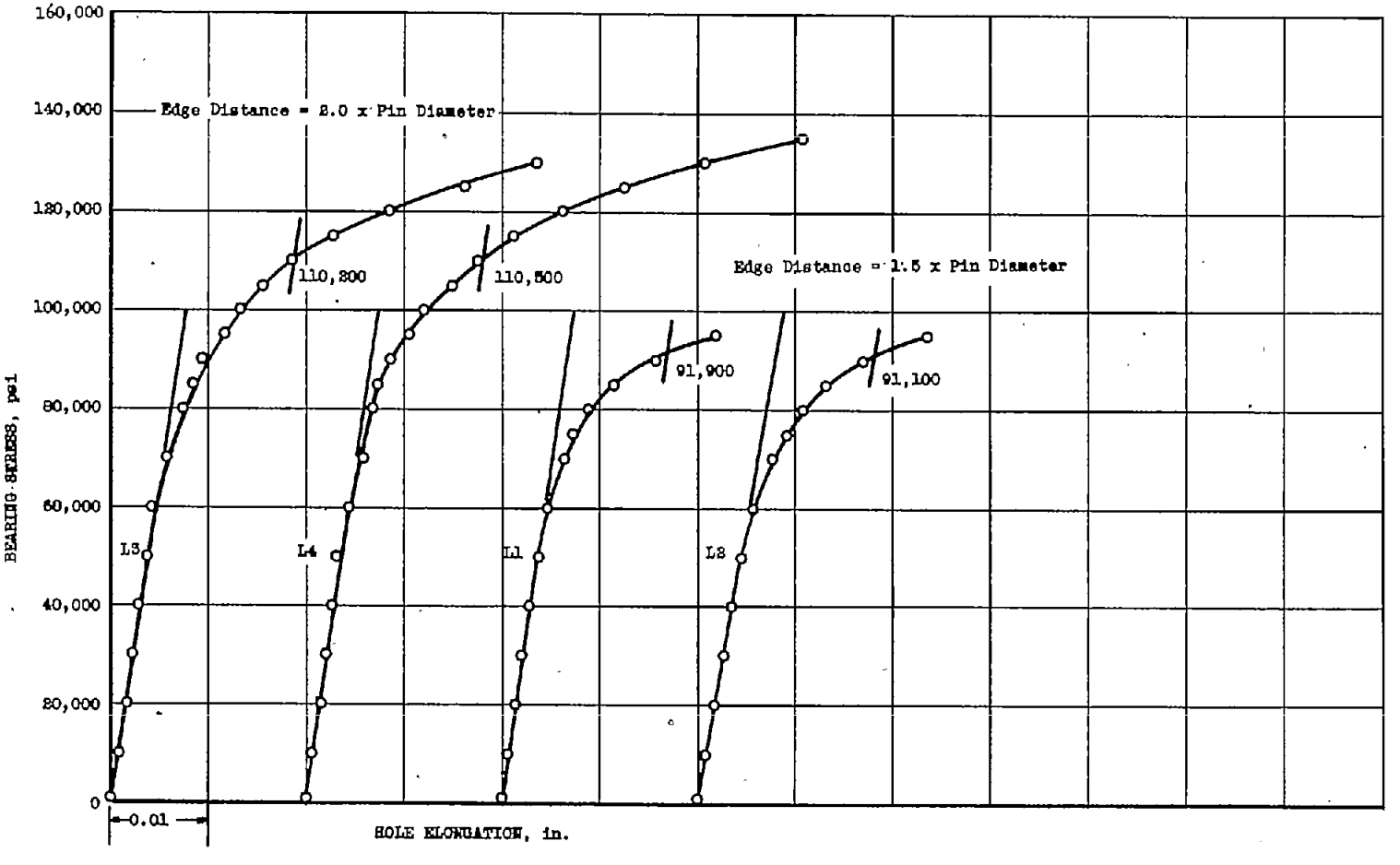

Figure 7.- Concluded.

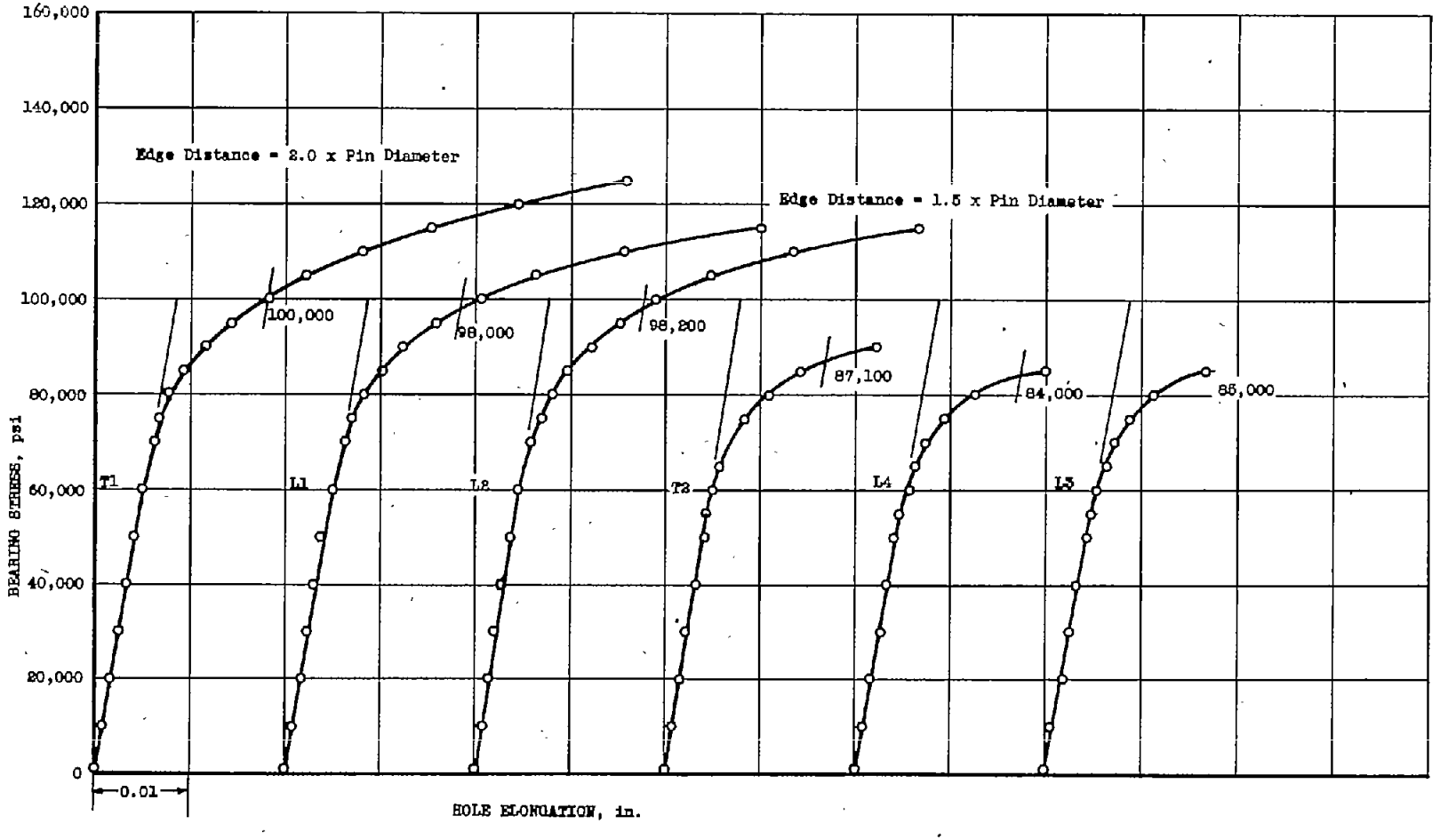

Figure 8.- Curves of bearing stress against hole elongation for 148-T6 aluminum-alloy hand forgings. Specimens 117269-L1, -L2, -L3, -L4, -T1, and -T2. Bearing yield offset, 0.02 times pin diameter; pin diameter, 0.500 inch; specimen thickness, 0.188 inch (machined from sections of hand forgings); specimen width, 2.00 inches.

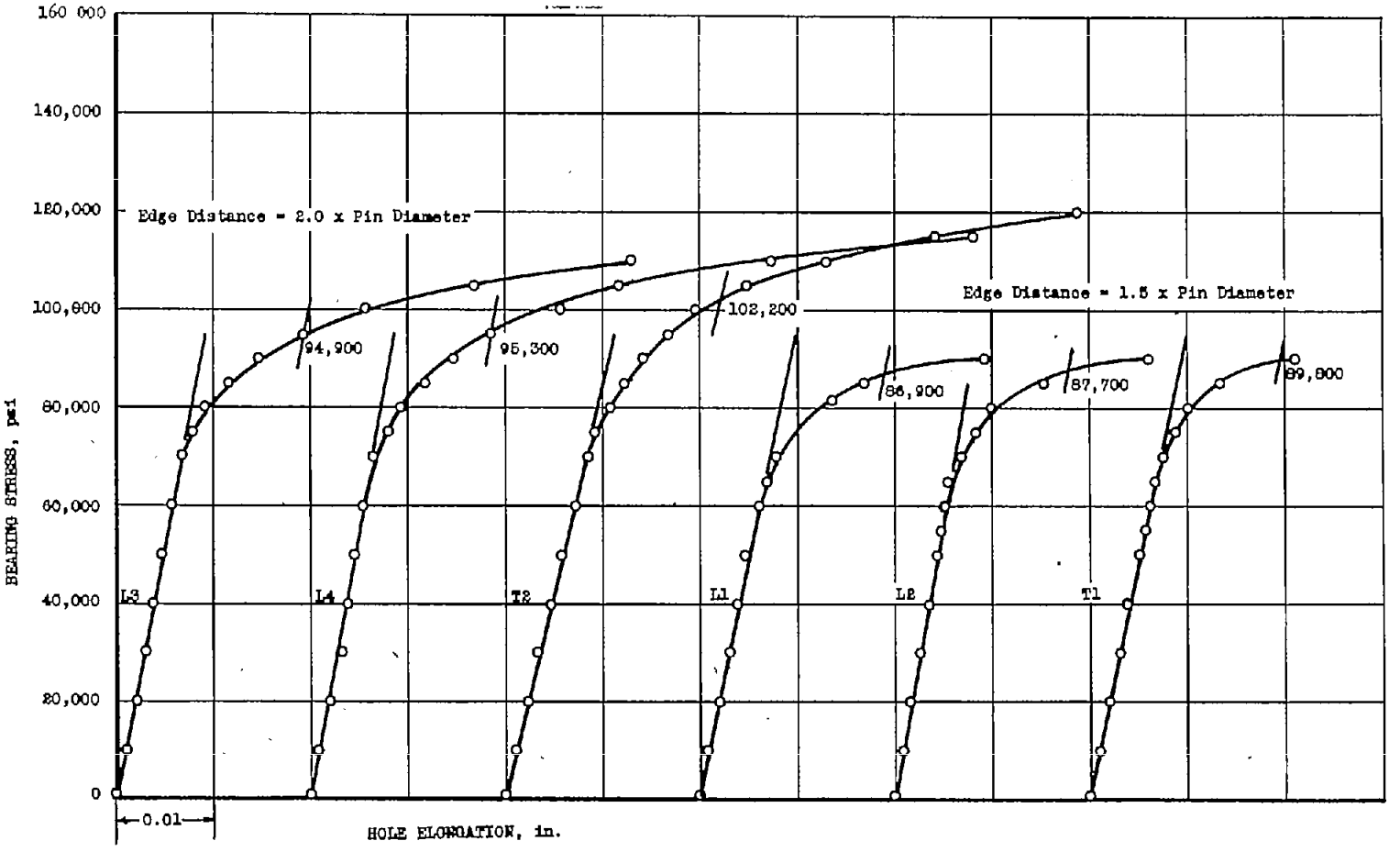

Figure 8.- Concluded.

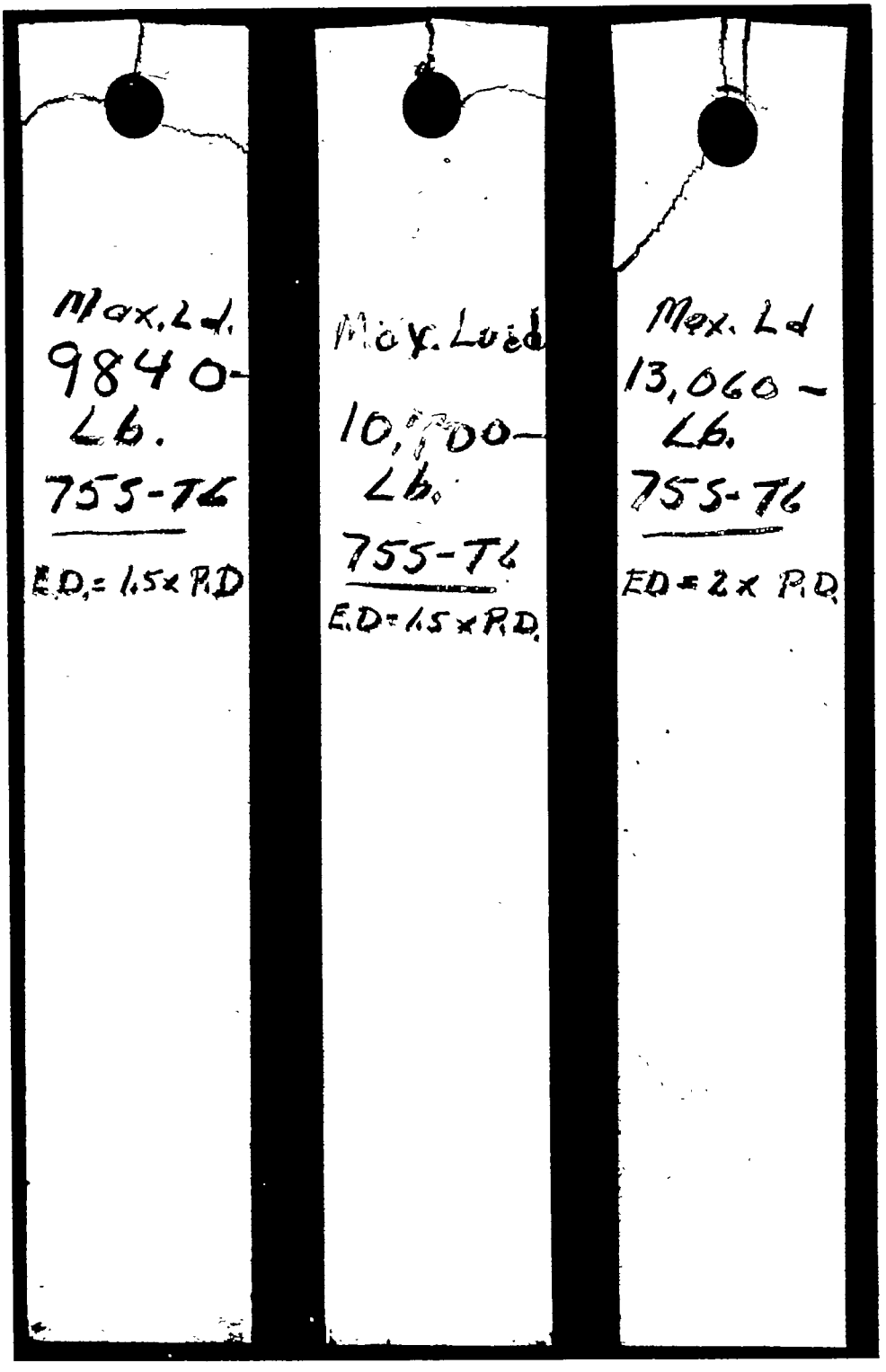

Figure 9.- Samples of bearing test failures in 75S-T6 aluminum-alloy hand forgings.

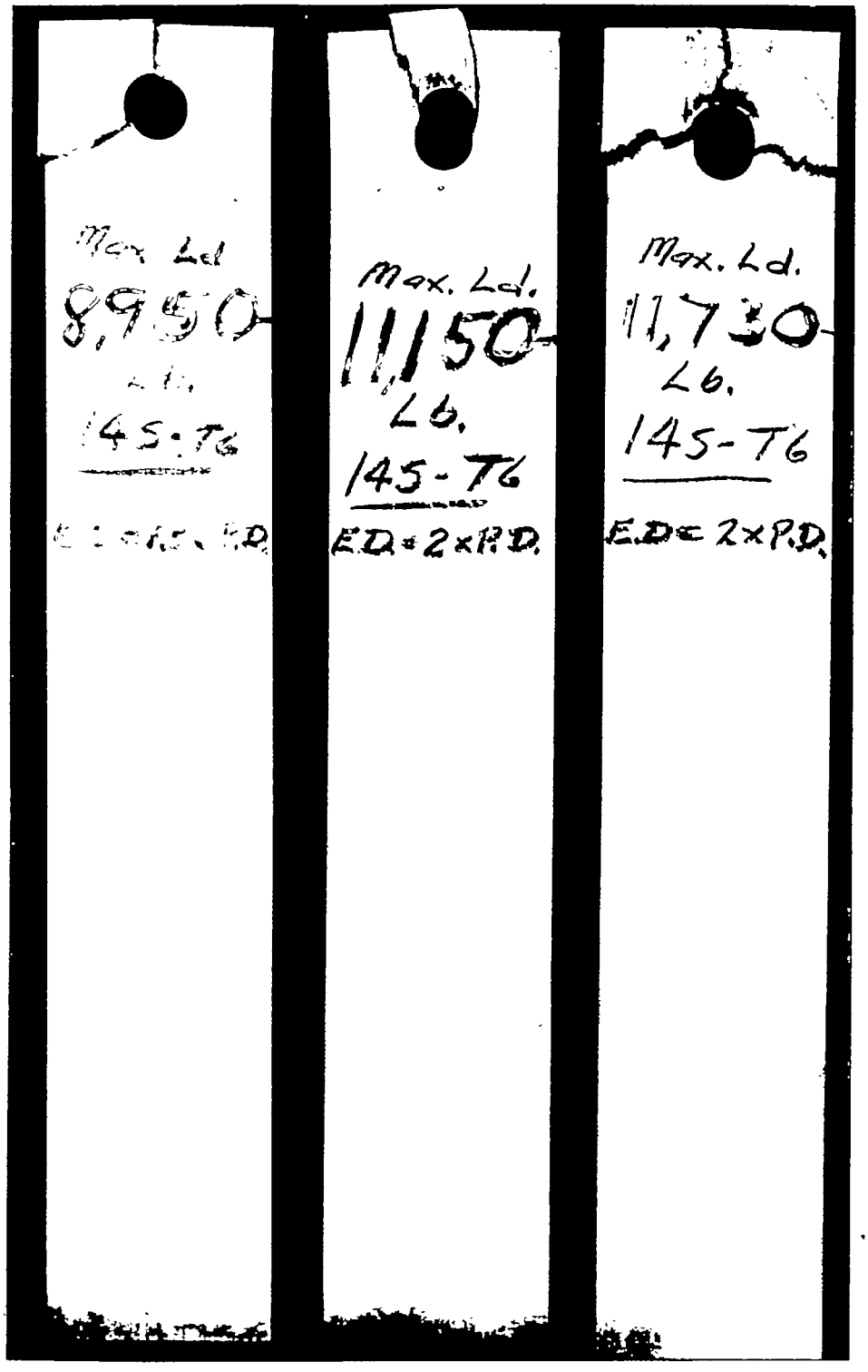

Figure 10.- Samples of bearing test failures in 14S-T6 aluminum-alloy hand forgings.

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