NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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BEARING STRENGTHS OF SOME ALUMINUM-ALLOY ROLLED AND EXTRUDED SECTIONS

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SUMMARY

Tests were made to determine bearing yield and ultimate strengths for several sizes of rolled and extruded 14S sections and of rolled 24S-T and 75S-T bar.[1] It was found that ratios of bearing to tensile properties previously proposed for aluminum-alloy sheet and plate appear equally applicable to rolled bar of 24S-T, 14S-W, and 14S-T in thicknesses up to 2 inches and to extruded 14S-W and 14S-T in thicknesses up to 1 inch. For rolled 75S-T bar in thicknesses up to 2 inches and for extruded 14S-W and 14S-T bar in the thickness range of 1 to 2 inches, lower ratios of bearing to tensile properties are proposed.

INTRODUCTION

A survey of the work done in the Aluminum Research Laboratories on the determination of bearing properties for use in the design of riveted, bolted, or pin-connected joints in the high-strength, wrought-aluminum alloys shows that a great many tests have been made on sheet and plate (references 1 to 5) but that little or no work has been done on forgings or rolled bar. The tests that have been made on extrusions, moreover, have been limited for the most part to alloy 75S-T with a few tests on sections of 24S-T (reference 1).

The need for some investigation of the bearing-strength characteristics of different forms of the same alloy was first indicated by the results obtained from tests of sheet and large extrusions of 24S-T. The bearing strengths for a $3\frac{3}{4}$-inch-thick extrusion, for example, were found to be considerably lower, in proportion to the tensile strength, than those for sheet material. The same general tendencies have since been observed for sheet and extrusions of 75S-T. The tests described in this report were undertaken to supplement these findings with observations on the behavior of 14S extrusions. Samples of rolled bar in 14S-T, 24S-T, and 75S-T have also been included.

The object of these tests was to determine bearing yield and ultimate strengths for several sizes of rolled and extruded high-strength, aluminum-alloy sections and to establish, as far as possible, typical

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[1] New temper designations for alloys listed are: 14S-T4 for 14S-W, 14S-T6 for 14S-T, 24S-T4 for 24S-T, 75S-T6 for 75S-T.

ratios of bearing to tensile properties for these types of product. Data of this kind are of interest mainly in the design of riveted, bolted, or pin-connected joints.

MATERIAL

Table I summarizes the mechanical properties obtained for the various test sections. The average tensile properties were in every case above the minimum specified (reference 6) and with a few exceptions (mainly 14S-W extruded bar) were in the range considered typical for these alloys. Although a number of comparisons may be made from the values shown in table I, the following are perhaps of most interest:

1. The extruded sections of both 14S-W and 14S-T angle and bar exhibited higher strengths and lower elongations than those observed for the corresponding rolled sections.

2. The strengths of the 14S-W and 14S-T extruded bar in the 2- by 2-inch size were higher than those obtained for the extruded 1- by 2-inch size, whereas the order of strengths with respect to size was just reversed in the case of the 14S-T rolled sections.

3. There was no significant difference in tensile properties for the two locations investigated in the bar sections, except in the case of the 75S-T. For the 2- by 2-inch size in the latter alloy the strengths obtained for specimen 1, located near the surface as shown in the sketch below table I, were considerably lower than those obtained for specimen 2, located about midway between the surface and the center. The strength values shown in table I for this section are the average of two tests at each location, whereas single tests at each location were made for all other samples.

PROCEDURE

Bearing tests were made in duplicate on $\frac{1}{4}$-inch-thick specimens from each sample, and loadings on a $\frac{1}{2}$-inch-diameter steel pin were used. The specimens machined from the angle sections were $2\frac{1}{4}$ inches wide; all those taken from the bar sections were 2 inches wide. The original length of all specimens was about 18 inches. After the completion of one test, the damaged end was sawed off about 1 inch below the center of the hole and the specimen was redrilled for another test. The sketches below table II indicate the location of the bearing specimens in the bar and angle cross sections.

Edge distances, measured from the center of the pin hole to the edge of the specimen in the direction of stressing, were limited in these tests to 1.5 and 2 times the pin diameter. These are the edge distances for which allowable bearing design values are commonly given (reference 7).

Figure 1 shows the arrangement used in making bearing tests in a 40,000-pound-capacity Amsler hydraulic testing machine. The hole elongations, from which values of bearing yield strength were determined, were measured by means of a filar micrometer microscope which could be read directly to 0.01 millimeter. The under side of the pin projecting from the specimen on the microscope side was flattened slightly to provide a reference mark for the determination of pin movement. A light scratch on the specimen under the pin provided a reference mark for specimen movement.

RESULTS AND DISCUSSION

Table II summarizes the results of the bearing tests. The yield strengths were selected from the bearing stress-hole elongation curves in figures 2 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. Bearing failures occurred by shearing out the portion of the specimen above the pin or by a combination of shear and tensile fracture throughout the pin hole. In general, the behavior was similar to that observed for most of the other high-strength, wrought-aluminum alloys.

A comparison of the strength values given in tables I and II shows that the order of bearing strengths for the different sections and alloys was not always the same as observed for the tensile strengths. The bearing ultimate strengths for the rolled angle sections in both 14S-W and 14S-T, for example, were higher than those obtained for the extruded angles, yet the latter exhibited higher tensile strengths. There was no significant difference between the bearing values obtained for the 14S-T rolled and extruded bar, although there was a considerable difference between the tensile properties of these two types of section, particularly in the 2- by 2-inch size.

Table III gives the ratios of bearing to tensile properties obtained from the average results of these tests. It may be noted that the 14S-W angle and the 24S-T bar sections, having the lowest tensile strengths, developed some of the highest ratios of bearing to tensile properties. The lowest ratios, on the other hand, were observed for the 2- by 2-inch 14S extrusions and the 75S-T rolled bar, having the highest tensile strengths. The most significant observation to be made from the results of these tests, however, is that all the sections tested, with the exception of the 2- by 2-inch extruded bars of 14S-W and 14S-T and the rolled bars of 75S-T, may be placed in the same class as sheet and plate (reference 5) as far as ratios of bearing to tensile properties are concerned. Both the 1- by 2-inch and 2- by 2-inch sections of rolled

75S-T bar and the 2- by 2-inch extruded bars of 14S-W and 14S-T exhibited definitely lower ratios of bearing to tensile properties. The latter were of the same order of magnitude as previously observed for $\frac{1}{4}$-inch-thick extrusions of 75S-T (reference 3).

CONCLUSIONS

The following conclusions are based upon the results of bearing tests of several samples of rolled and extruded 14S sections and samples of rolled 24S-T and 75S-T bar:

1. The following ratios of bearing to tensile properties, previously proposed for aluminum-alloy sheet and plate, appear equally applicable to rolled bar of 24S-T, 14S-W, and 14S-T in thicknesses up to 2 inches and to extruded 14S-W and 14S-T in thicknesses up to 1 inch.

Ratios	Edge distances	
	1.5 × pin diameter	2 × pin diameter
$\frac{\text{Bearing ultimate}}{\text{Tensile ultimate}}$	1.5	1.9
$\frac{\text{Bearing yield}}{\text{Tensile yield}}$	1.4	1.6

2. For rolled 75S-T bar in thicknesses up to 2 inches and for extruded 14S-W and 14S-T bar in the thickness range of 1 to 2 inches, the following lower ratios of bearing to tensile properties are proposed:

Ratios	Edge distances	
	1.5 × pin diameter	2 × pin diameter
$\frac{\text{Bearing ultimate}}{\text{Tensile ultimate}}$	1.3	1.6
$\frac{\text{Bearing yield}}{\text{Tensile yield}}$	1.3	1.4

Aluminum Research Laboratories
Aluminum Company of America
New Kensington, Pa., January 20, 1947

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2. Moore, R. L., and Wescoat, C.: Bearing Strengths of Bare and Alclad XA75S-T and 24S-T81 Aluminum Alloy Sheet. NACA TN No. 920, 1943.

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4. Moore, R. L., and Wescoat, C.: Bearing Strengths of 24S-T Aluminum Alloy Plate. NACA TN No. 981, 1945.

5. Moore, R. L.: Bearing Tests of 14S Sheet and Plate. NACA TN No. 1502, 1948.

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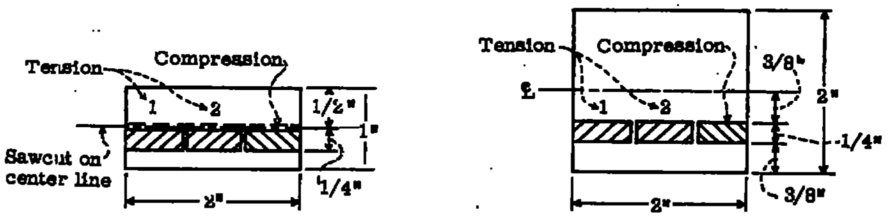
TABLE I

MECHANICAL PROPERTIES OF ALUMINUM-ALLOY ROLLED AND EXTRUDED SECTIONS USED IN BEARING TESTS

[All tensile specimens were standard sheet type for 2-in. gage length. Compression specimens from bar were $\frac{1}{4} \times \frac{5}{8} \times 2\frac{5}{8}$ in. Compression specimens from angle were of full cross section]

Alloy and temper	Section	Size (in.)	Sample	Speci-men	Tensile strength (psi)	Tensile yield strength (offset = 0.2 percent) (psi)	Elongation in 2 in. (percent)	Compressive yield strength (offset = 0.2 percent) (psi)
14S-W	Rolled angle	$3 \times 3 \times \frac{3}{8}$	75945	---	60,500	43,000	24.8	33,800
	Extruded angle	$3 \times 3 \times \frac{3}{8}$	75944	---	65,200	47,400	20.3	40,000
14S-T	Rolled angle	$3 \times 3 \times \frac{3}{8}$	75942	---	67,600	61,500	13.2	59,300
	Extruded angle	$3 \times 3 \times \frac{3}{8}$	75943	---	69,000	62,500	11.7	64,600
14S-W	Extruded bar	1 × 2	75603	1 2 Av.	66,200 67,500 66,800	49,300 49,700 49,500	17.6 15.2 16.4	40,800
14S-W	Extruded bar	2 × 2	75608	1 2 Av.	74,500 76,200 75,400	56,400 58,800 57,600	14.4 14.4 14.4	53,000
14S-T	Extruded bar	1 × 2	75604	1 2 Av.	69,200 71,400 70,300	63,400 65,000 64,200	11.2 12.0 11.6	63,100
14S-T	Rolled bar	1 × 2	74707	1 2 Av.	69,800 68,800 69,300	63,600 62,900 63,200	12.8 11.2 12.0	60,600
14S-T	Extruded bar	2 × 2	75609	1 2 Av.	75,900 76,100 76,000	67,300 66,700 67,000	10.4 9.6 10.0	68,800
14S-T	Rolled bar	2 × 2	74724	1 2 Av.	68,900 68,500 68,700	61,400 60,800 61,100	11.2 12.0 11.6	59,900
24S-T	Rolled bar	1 × 2	74711	1 2 Av.	68,000 67,700 67,800	48,600 48,200 48,400	20.0 19.2 19.6	42,100
24S-T	Rolled bar	2 × 2	74712	1 2 Av.	65,700 65,100 65,400	46,600 46,400 46,500	19.2 18.4 18.8	40,800
75S-T	Rolled bar	1 × 2	74713	1 2 Av.	87,400 88,400 87,900	79,900 79,600 79,800	12.8 9.6 11.2	79,300
75S-T	Rolled bar	2 × 2	73440	1 2 Av.	81,200 91,300 86,300	62,200 75,700 69,000	14.8 8.0 11.4	58,800



Location of tensile and compressive specimens in bar sections.

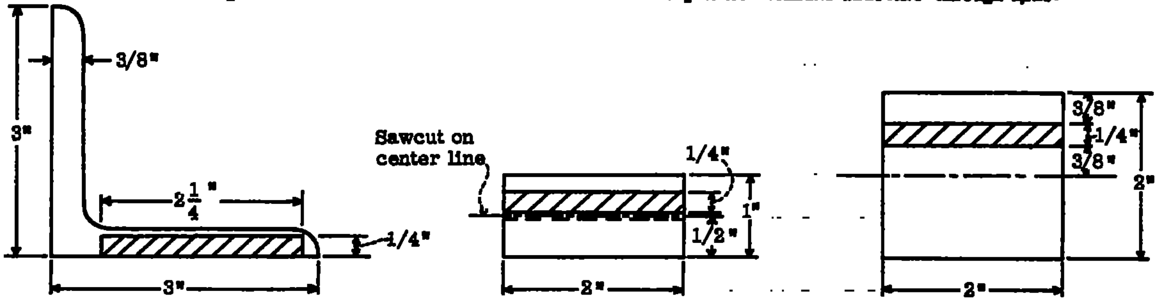
TABLE II

BEARING STRENGTHS OF ALUMINUM-ALLOY ROLLED AND EXTRUDED SECTIONS

Alloy and temper	Section	Size (in.)	Test	Bearing strengths (psi)					
				Edge distance = 1.5 × pin diameter			Edge distance = 2 × pin diameter		
				Ultimate	Yield (1)	Type of failure (2)	Ultimate	Yield	Type of failure
14S-W (75945)	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1 2 Av.	98,400 99,600 99,000	63,800 66,200 65,000	S TS	124,100 123,800 124,000	72,500 71,400 71,900	S S
14S-W (75944)	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1 2 Av.	99,400 93,300 96,400	67,300 65,000 66,200	S S	118,200 118,900 118,600	75,800 75,900 75,900	TS S
14S-T (75942)	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1 2 Av.	104,900 104,400 104,700	87,100 86,500 86,800	TS TS	132,100 130,700 131,400	94,000 94,100 94,100	TS TS
14S-T (75943)	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1 2 Av.	104,300 100,300 102,300	87,100 83,800 85,500	S TS	128,900 125,500 127,200	93,500 96,000 94,800	TS TS
14S-W (75603)	Extruded bar	1 × 2	1 2 Av.	99,000 95,400 97,200	66,000 65,000 65,500	S S	120,100 124,500 122,300	76,300 78,800 77,500	TS TS
14S-W (75608)	Extruded bar	2 × 2	1 2 Av.	100,500 99,300 99,900	71,000 68,000 69,500	TS TS	124,000 124,400 124,200	81,000 82,500 81,800	TS S
14S-T (75604)	Extruded bar	1 × 2	1 2 Av.	102,000 102,000 102,000	87,900 84,200 86,100	TS TS	131,700 129,400 130,600	99,200 94,400 96,800	TS TS
14S-T (74707)	Rolled bar	1 × 2	1 2 Av.	101,300 104,300 102,800	87,700 87,500 87,600	TS TS	130,200 128,700 129,500	97,900 97,200 97,600	TS TS
14S-T (75609)	Extruded bar	2 × 2	1 2 Av.	100,400 102,000 101,200	84,800 84,800 84,800	TS TS	126,300 125,500 125,900	96,900 97,000 97,000	TS TS
14S-T (74724)	Rolled bar	2 × 2	1 2 Av.	99,400 99,400 99,400	86,500 85,200 85,900	TS TS	123,300 125,000 124,200	97,000 96,000 96,500	TS TS
24S-T (74711)	Rolled bar	1 × 2	1 2 Av.	98,600 98,300 98,500	68,500 69,000 68,800	TS TS	122,800 123,200 123,000	82,700 84,200 83,500	S TS
24S-T (74712)	Rolled bar	2 × 2	1 2 Av.	98,600 98,200 98,400	70,200 70,000 70,100	TS TS	122,600 124,200 123,400	79,500 79,000 79,300	TS TS
75S-T (74713)	Rolled bar	1 × 2	1 2 Av.	113,200 117,900 115,500	105,400 106,500 105,900	TS TS	155,700 148,200 151,900	115,000 117,100 116,100	TS TS
75S-T (73440)	Rolled bar	2 × 2	1 2 Av.	108,200 110,900 109,500	89,000 88,500 88,800	TS TS	137,600 143,200 140,400	101,500 105,300 103,400	TS S

[1] Yield strength corresponds to offset of 2 percent of pin diameter on bearing stress-hole elongation curves.

[2] S indicates shear above pin. TS indicates combination of shear above pin and tensile fracture through hole.



Location of bearing specimens. All tests made on $\frac{1}{2}$-inch-diameter steel pin.

TABLE III

RATIOS OF AVERAGE BEARING TO TENSILE STRENGTHS

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

Alloy and temper	Section	Size (in.)	Ratios for edge distances of -			
			1.5 × pin diameter		2 × pin diameter	
			BS/TS	BYS/TYS	BS/TS	BYS/TYS
14S-W	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1.64	1.51	2.05	1.67
14S-W	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1.48	1.40	1.82	1.60
14S-T	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1.54	1.41	1.94	1.53
14S-T	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1.48	1.37	1.85	1.52
14S-W	Extruded bar	1 × 2	1.46	1.32	1.83	1.56
14S-W	Extruded bar	2 × 2	1.33	1.21	1.65	1.42
14S-T	Extruded bar	1 × 2	1.45	1.34	1.86	1.51
14S-T	Rolled bar	1 × 2	1.48	1.39	1.87	1.55
14S-T	Extruded bar	2 × 2	1.33	1.27	1.66	1.45
14S-T	Rolled bar	2 × 2	1.45	1.41	1.81	1.58
24S-T	Rolled bar	1 × 2	1.45	1.42	1.81	1.73
24S-T	Rolled bar	2 × 2	1.51	1.51	1.89	1.71
75S-T	Rolled bar	1 × 2	1.32	1.33	1.73	1.46
75S-T	Rolled bar	2 × 2	1.27	1.29	1.63	1.50

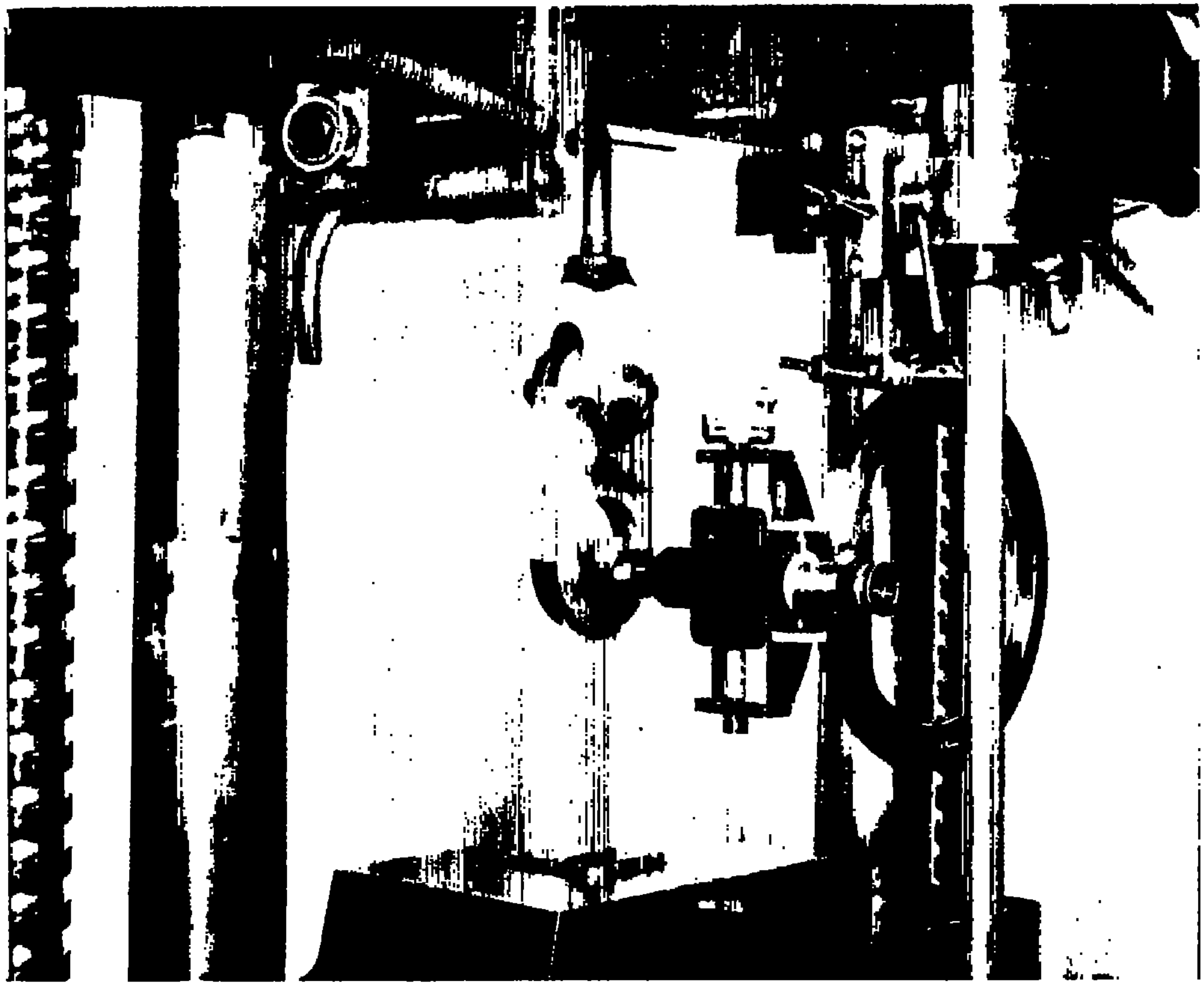


Figure 1.- Arrangement for bearing tests. Microscope used for measurement of hole elongations.

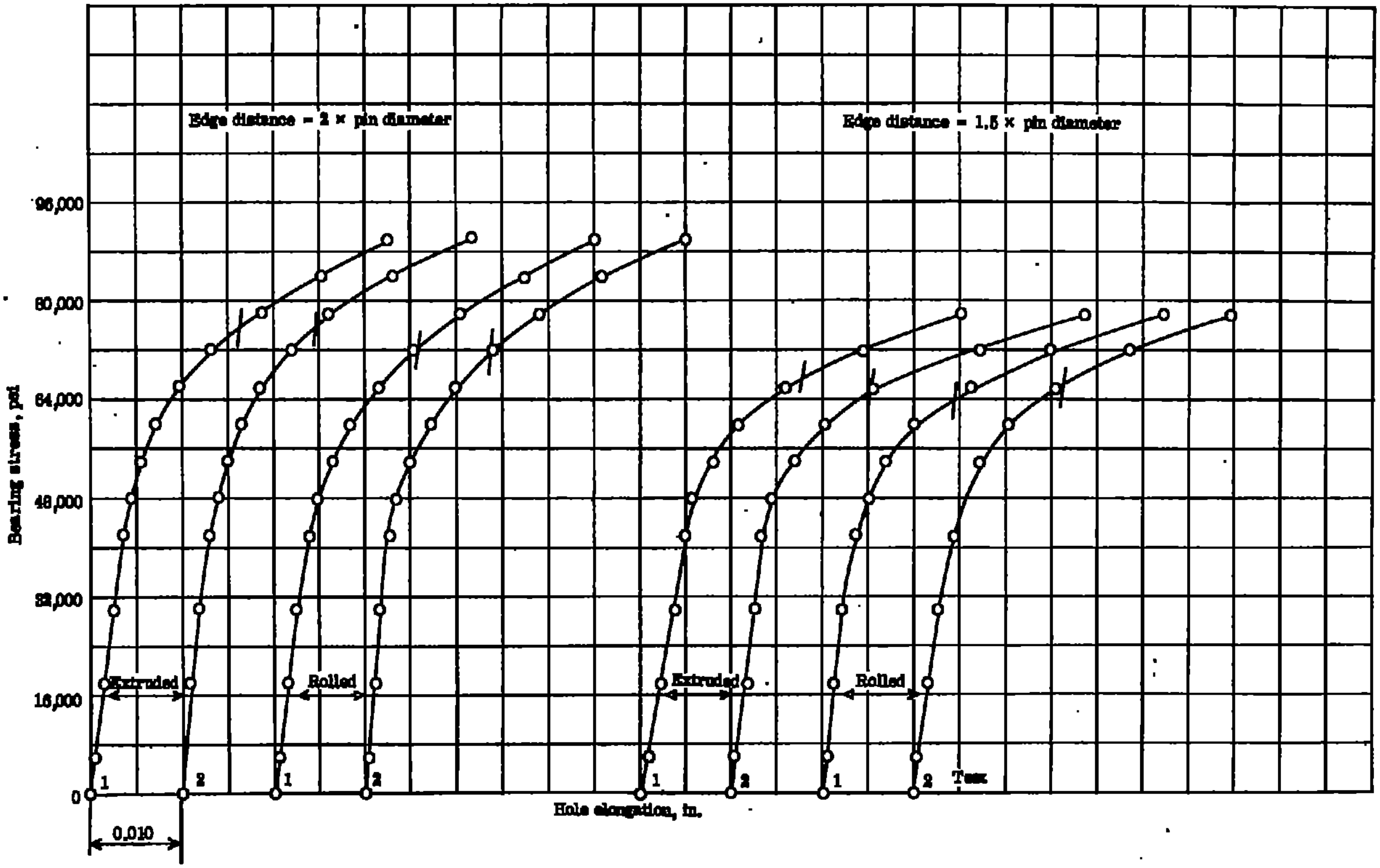


Figure 2.- Bearing stress-hole elongation curves for 3- by 3- by $\frac{3}{8}$-inch 14S-W angle (samples 75944 and 75945). Specimen thickness, 0.250 inch; specimen width, $2\frac{1}{4}$ inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

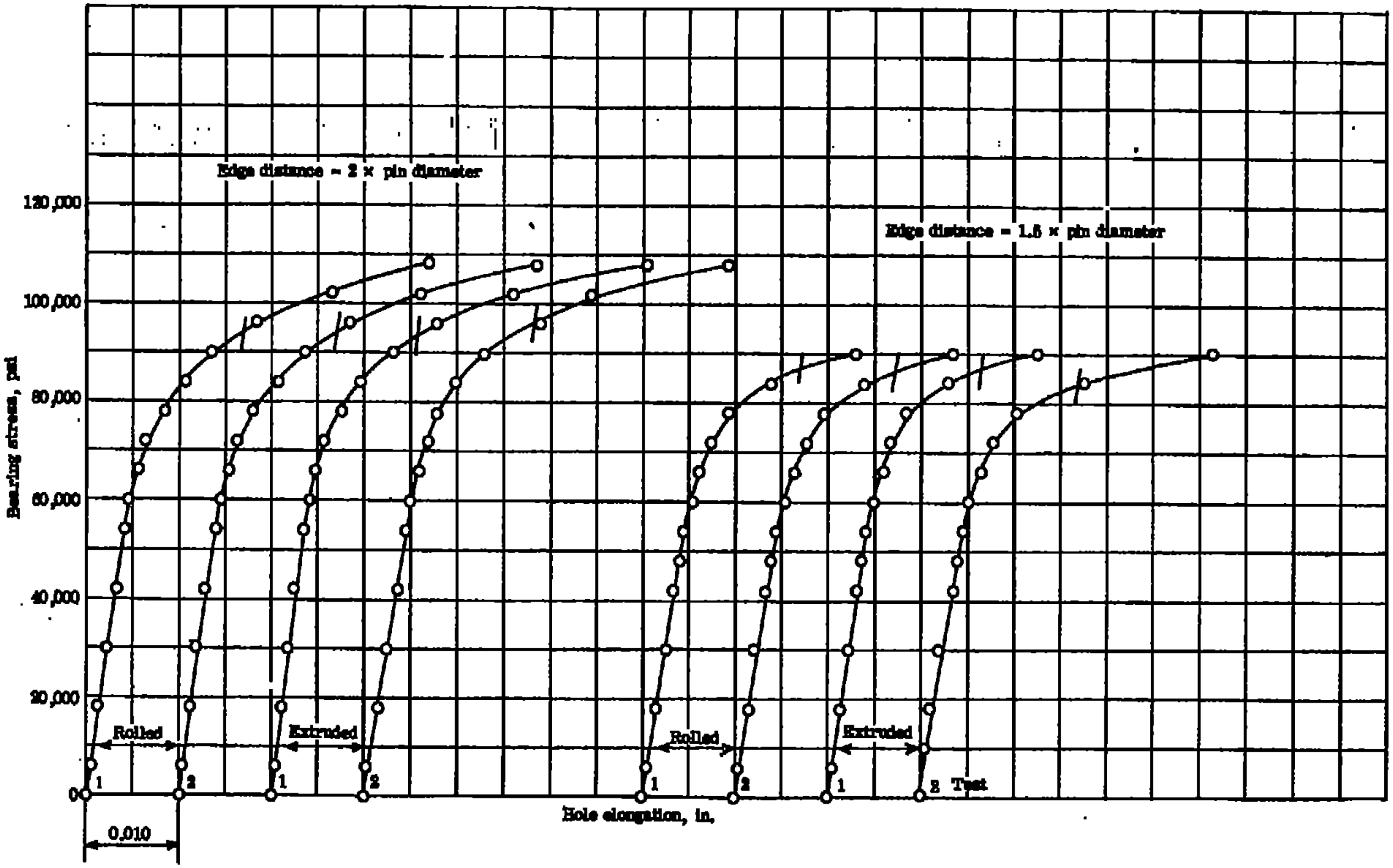


Figure 3.- Bearing stress-hole elongation curves for 3- by 3- by $\frac{3}{8}$-inch 14S-T angle (samples 75942 and 75943). Specimen thickness, 0.250 inch; specimen width, $2\frac{1}{4}$ inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

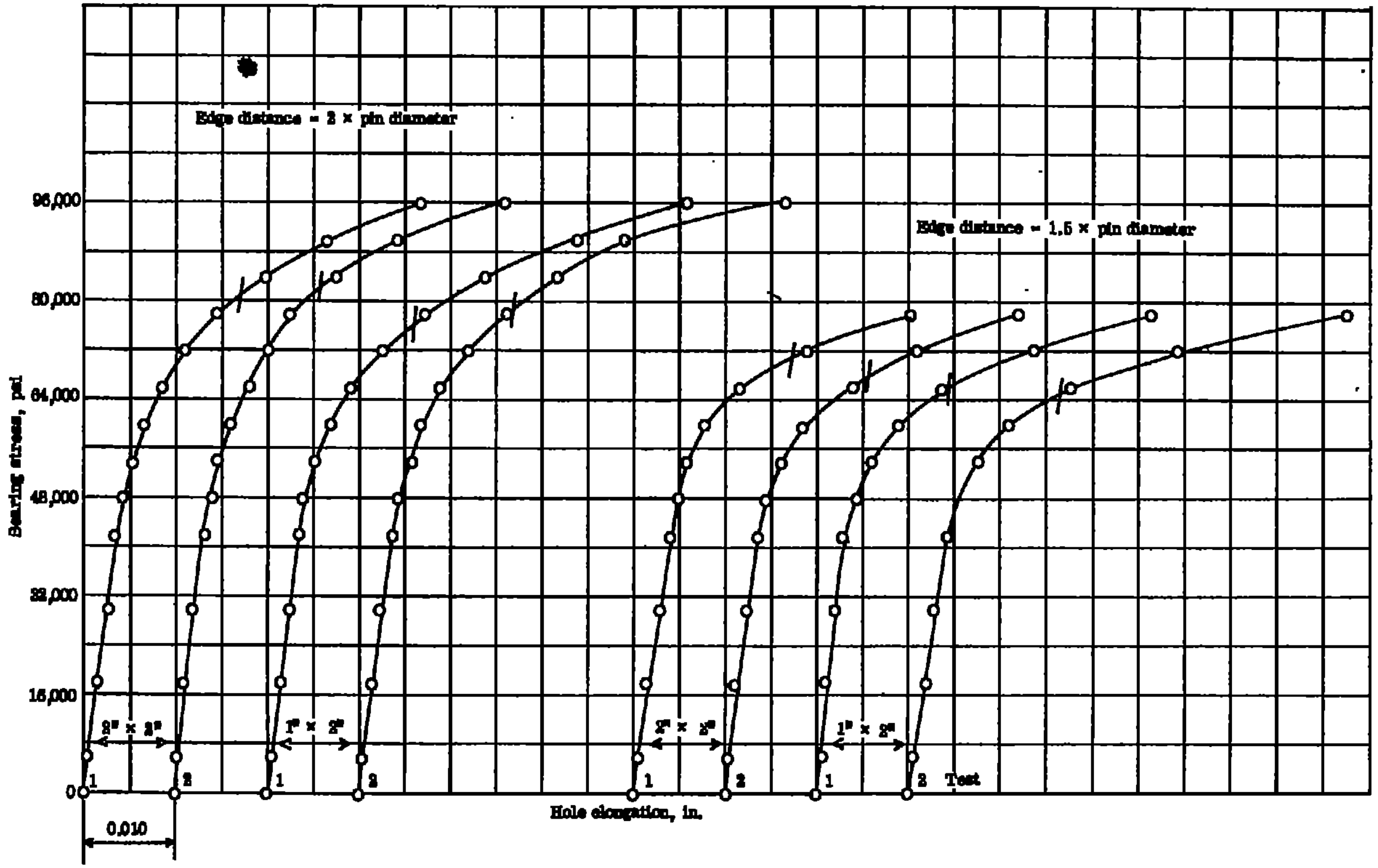


Figure 4.- Bearing stress-hole elongation curves for 14S-W extruded bar (samples 75603 and 75608). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

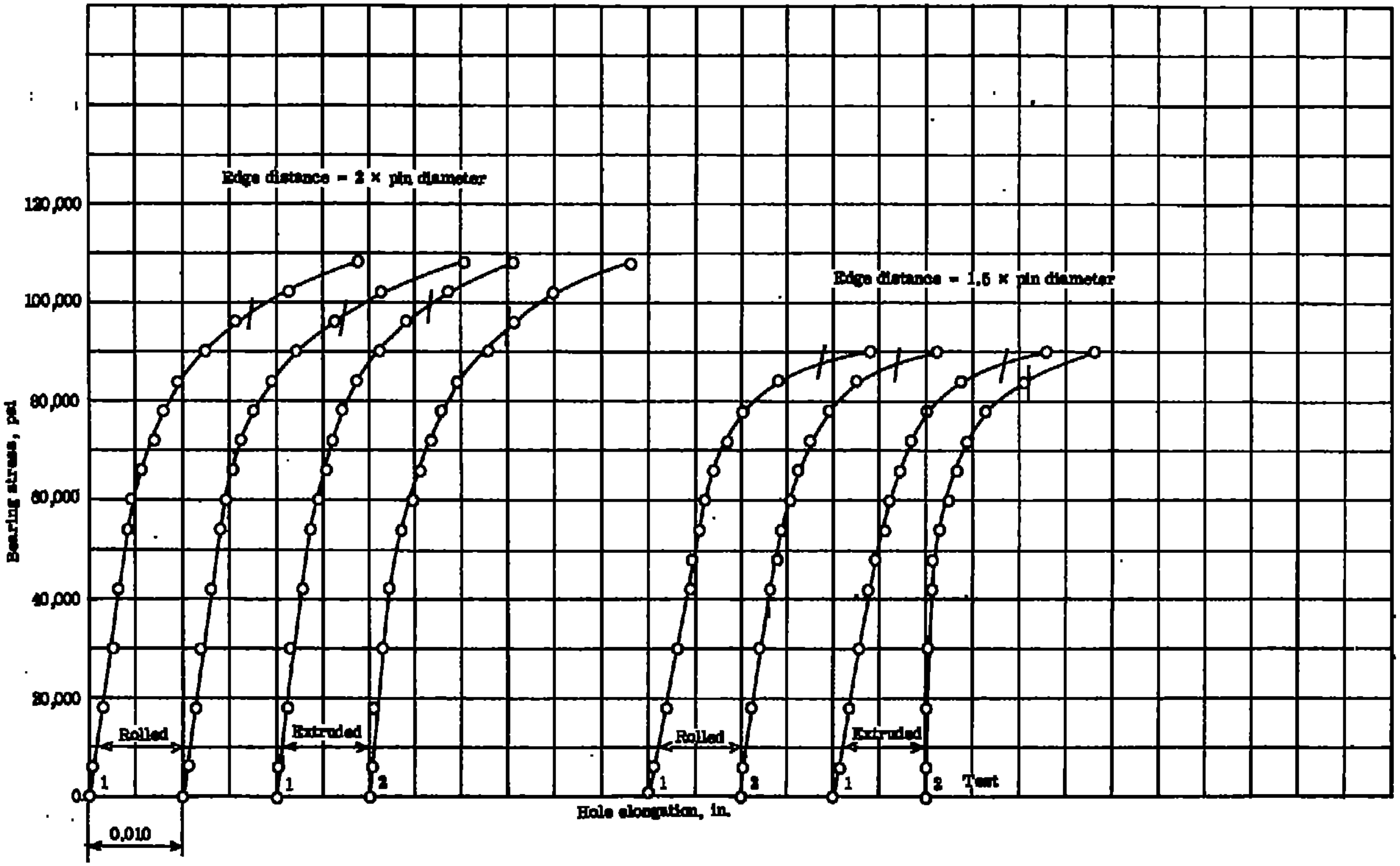


Figure 5.- Bearing stress-hole elongation curves for 1- by 2-inch 14S-T bar (samples 74707 and 75604). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

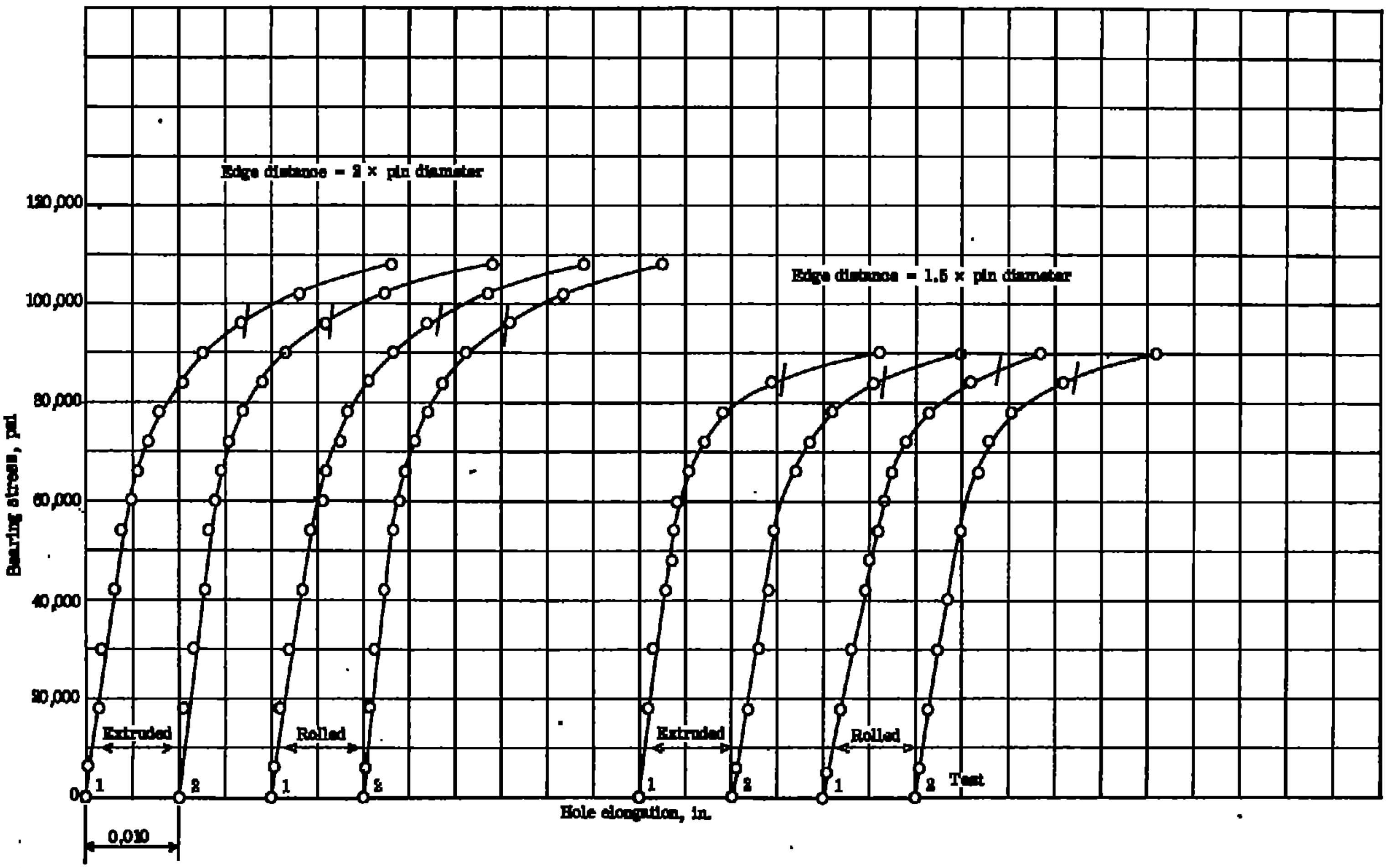


Figure 6.- Bearing stress-hole elongation curves for 2- by 2-inch 14S-T bar (samples 74724 and 75609). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

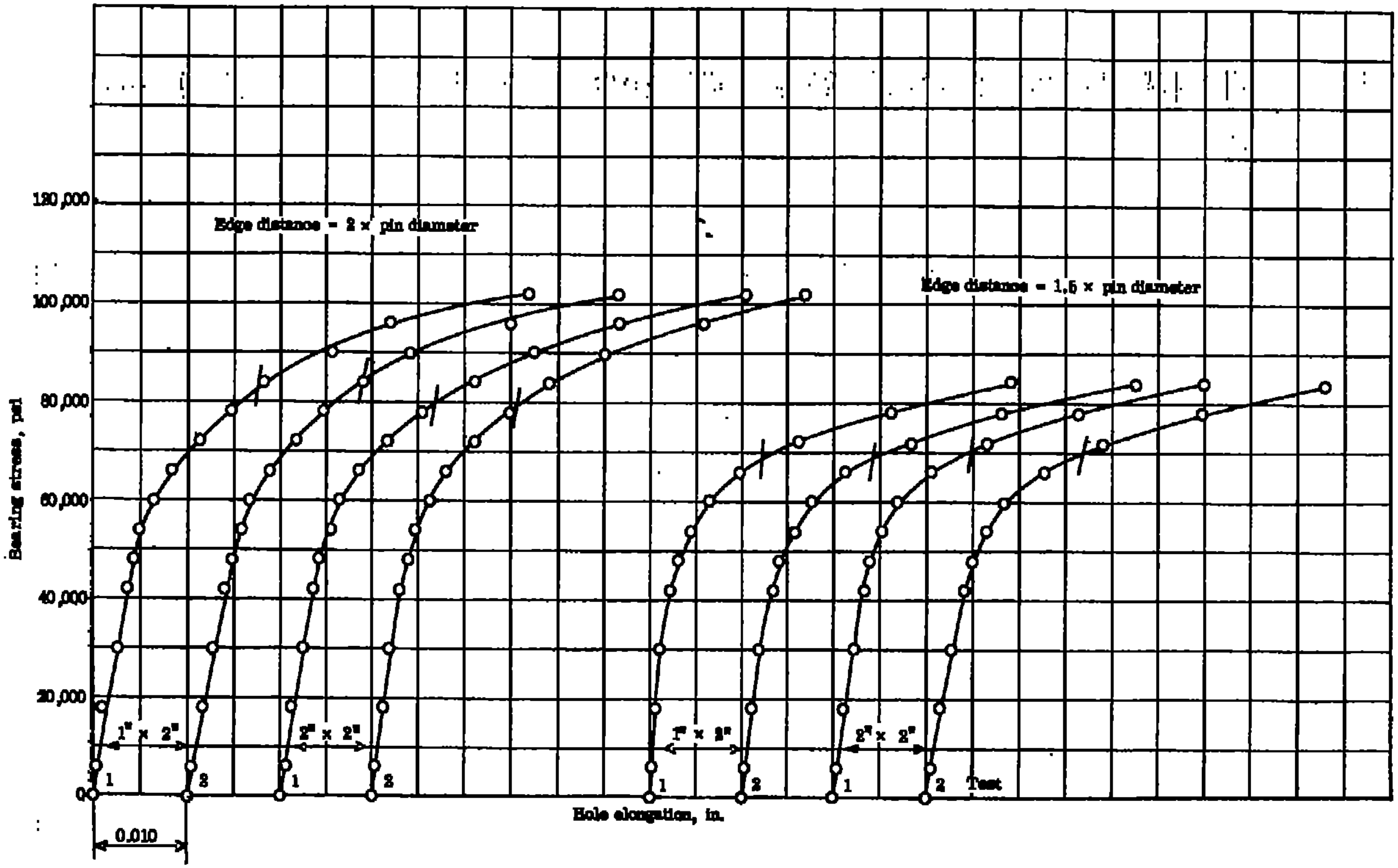


Figure 7.- Bearing stress-hole elongation curves for 24S-T rolled bar (samples 74711 and 74712). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

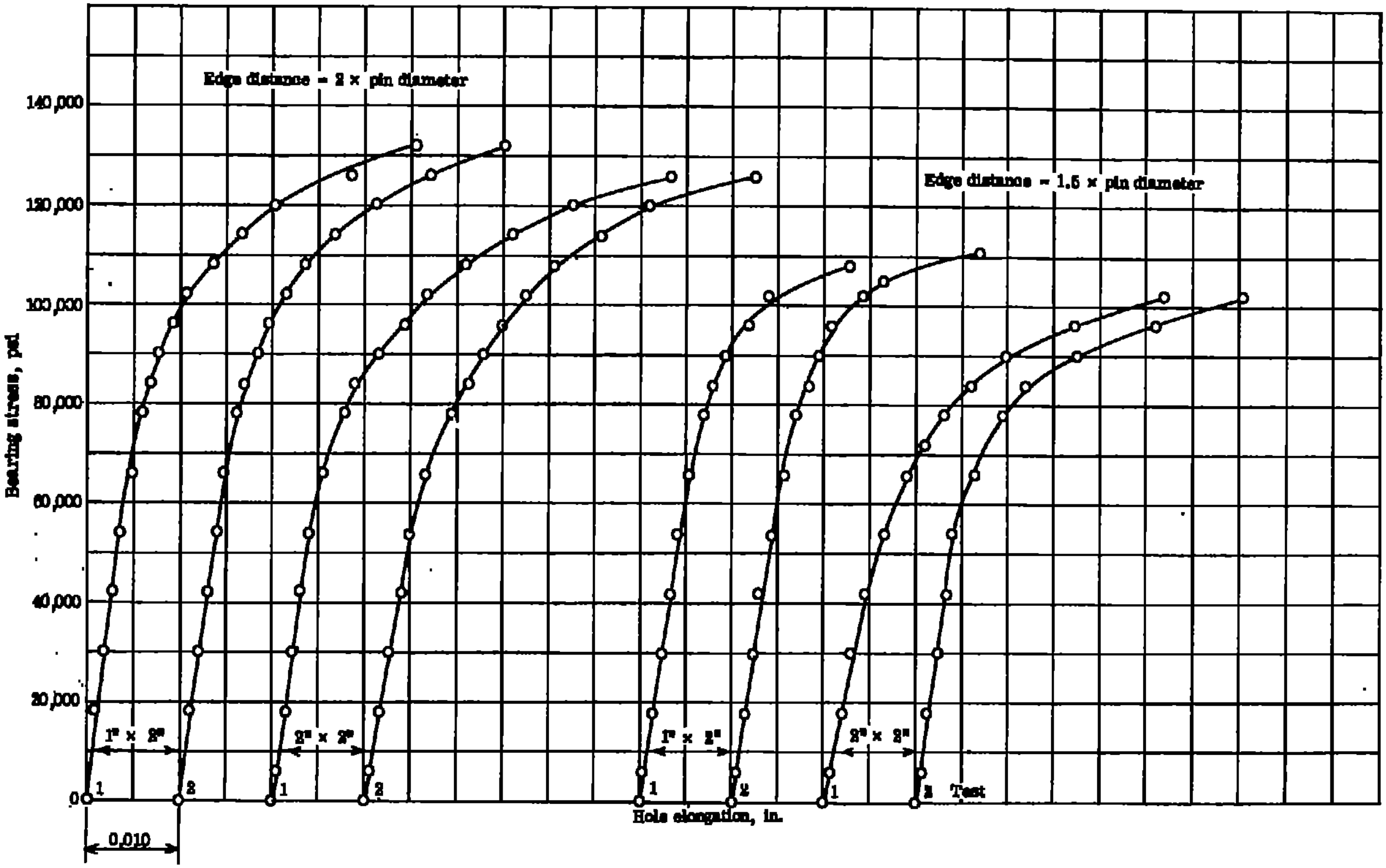


Figure 8.- Bearing stress-hole elongation curves for 75S-T rolled bar (samples 73440 and 74713). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.