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COMPARATIVE TESTS ON EXTRUDED 14S-T AND EXTRUDED 24S-T HAT-SHAPE STIFFENER SECTIONS

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INTRODUCTION AND OBJECT

The investigation described in this report is a comparison of 14S-T with 24S-T in extruded stiffeners for stiffened flat sheet panels. Since considerable basic information is available for 24S-T, it was selected as the criterion for comparison.

Continued interest has been shown by the aircraft industry in investigations of high-strength aluminum alloy stiffened panels tested in edge compression. Stiffened sheet panels are used very frequently in aircraft as structural members carrying axial loads. The tests and specimens were similar to those previously made at the Aluminum Research Laboratories. (See reference 1.)

These tests were made with stiffened flat sheet panels having three hat-shape stiffeners. Two gages of sheet were used; one was 25 percent thicker than the stiffeners and the other was 25 percent thinner. This provided data which not only compared the strengths of the two alloys but also showed the effect of sheet thickness on relative stiffener strengths. Full-section compressive tests were made on short lengths of the stiffeners of both alloys to determine the relative strength of the sections without any effect from sheet.

SPECIMENS

The sheet used was commercial 24S-T of 0.093- and 0.156-inch thickness. The stiffeners were commercial extruded shapes of hat-shape section and were made by Die No. K-12454. The nominal dimensions and section elements are shown in figure 1. The specimens were constructed so that the sheet was tested in the direction of rolling.

The stiffened sheet specimens were made in triplicate with each combination of sheet thickness and stiffener alloy. The specimens used three hat-shape stiffeners with a spacing between rivet rows of 2-9/16 inch. The rivet spacing for the specimens using 0.156-inch sheet was 1 inch, or about seven times the sheet thickness, and for the specimens using 0.093-inch sheet was 3/4 inch, or about eight times the sheet thickness. The details of these specimens are shown in figure 2. The ratio of unsupported sheet width to thickness (b/t) was 16.4 for the specimens using 0.156-inch gage sheet and 27.6 for the specimens using 0.093-inch gage sheet. The slenderness ratios for both types of specimen were approximately 11.

Before testing, the specimen ends were machined flat and parallel. The panels were clamped flat against the table of the milling machine during the machining operation. After machining, each specimen was checked for parallelism of the ends by measuring the length at a number of points on the cross section with a dial gage mounted on an outside micrometer caliper frame. The variation in length of the various elements was in no case greater than 0.0005 inch.

Mechanical properties of both the sheet and the stiffener material were obtained by the standard tensile test and by the single-thickness compressive test. The compressive properties were also obtained on full-section pieces of the stiffener materials. A specimen length of 4 inches (computed slenderness ratio equal to 3) was used for the full-section specimens. Mechanical properties are given in table I and compared with typical and specified minimum properties. It is apparent that the 24S-T material used in this investigation had unusually high tensile yield strengths.

Typical compressive stress-strain curves obtained on the full-section specimens of the stiffeners are shown in figure 3. The compressive yield strength of the 14S-T stiffeners was 58,650 psi and 49,000 psi for the 24S-T. In this case the 14S-T is 20 percent stronger. The results from the single-thickness compression tests for the stiffener material agree quite well with these results from tests on the full section. The compressive yield strength of the 24S-T sheet is 8 percent less than that of the 24S-T extrusions.

METHOD OF TEST

The specimens were tested in edge compression in a 300,000-pound Amsler hydraulic-type testing machine (Amsler universal testing machine, 300,000-pound capacity, type 150 SZBDA Serial No. 5254) using hardened steel platens. Before the tests, the platens were alined substantially parallel by means of special leveling rings under one head. Dial gage readings showed that the platens were out of parallel by not more than 0.0005 inch in 12 inches. This machine is periodically calibrated, and the errors in the load readings were recently found to be not greater than ±1 percent in the load ranges used.

In some of the specimens there was a slight initial transverse bow in the sheet caused by the riveting of the stiffeners to the sheet. These specimens were flattened elastically by hand and placed in the testing machine, where they were held flat by the end friction. They were then checked for flatness with a straight edge. All the specimens, therefore, were substantially flat when tested. Figure 4 shows the typical testing arrangement for a specimen.

Type A Huggenberger Tensometers operating on a 1-inch gage length and having a multiplication ratio of approximately 1200 were used longitudinally at the edges of the specimens to check the distribution of load.

Electrical resistance wire SR-4 strain gages were used for measuring longitudinal strains near the center of the panels. A Baldwin-Southwark SR-4 portable strain indicator was used in conjunction with the electrical strain gages. One gage was mounted on each face of the sheet on the transverse center line of the specimen. Individual strain readings were taken on the gages, so that the difference in stress on the two faces of the sheet as well as the average stress could be determined. The location of the gages is shown in the sketch in figure 5.

The load was applied in increments, and readings of strain were made at each step. Permanent strain measurements were made at a low load of 2000 pounds after each increment of increasing load, so that a positive load was maintained to prevent shifting of the specimen. This type of loading was continued until the specimen collapsed. The loading was continued with one specimen of each type after the initial failure had occurred to be sure that no secondary maximum greater than the first could be obtained after the buckling of the sheet and stiffeners had taken place.

The cross-sectional areas were calculated from the nominal densities of the materials, the lengths, and the net weights of the specimens. The specimen lengths were measured with a steel scale to the nearest 1/100 inch before testing, and the gross weights were determined to the nearest 0.005 pound. The computed weights of the rivet heads were subtracted from the gross weights to obtain the net weights. The densities of the alloys used are those given in reference 2: namely,

	(lb per cu in.)
24S	0.100
14S	0.101
A17S	0.099

DISCUSSION OF RESULTS

The test specimens were in triplicate, and the ultimate average stress in each set of panels was very consistent. The maximum deviation from average was 1.5 percent. In all the panels the ultimate average stress was greater than the compressive yield strength of the sheet material, as can be seen from table II.

The 14S-T stiffeners on 24S-T sheet panels developed an ultimate average stress of 55,200 psi with 0.156-inch gage sheet and 52,400 psi with 0.093-inch gage sheet. The 24S-T stiffeners on 24S-T sheet panels developed an ultimate average stress of 52,400 psi with 0.156-inch gage sheet and 46,800 psi with 0.093-inch gage sheet. This indicates an advantage in strength for 14S-T of 5 percent in the panels using 0.156-inch gage sheet and 12 percent in the panels using 0.093-inch gage sheet. These percentages seem to indicate that the advantage of higher strength stiffeners diminishes rapidly as the ratio of sheet area to stiffener area is increased.

Figures 5 and 6 show typical curves of average stress versus strain as measured with the electrical strain gages. These figures also show the difference in stress on the two faces of the sheet. For most of the specimens, the strain measurements indicated a rather definite load at which buckling took place. However, in a few of the specimens there was some initial crookedness in the sheet, and this caused bending to begin as soon as any load was applied; hence there was no sudden buckling phenomenon. Therefore, a permanent strain difference of 0.00005 was arbitrarily selected as a criterion of first buckling.

Measurements for elastic and permanent buckling show that the two occurred simultaneously or nearly so. As indicated in table II, for similar panels the average stress at which buckling of the 24S-T sheet occurred with 14S-T stiffeners was slightly higher than with 24S-T stiffeners. This is as would be expected from a consideration of the fact that the buckling stresses were beyond the elastic range of the 24S-T stiffeners; whereas they were not beyond the elastic range of the 14S-T stiffeners. Therefore, in the panels with the 14S-T stiffeners a redistribution of load between sheet and stiffeners would occur, relieving the sheet of part of its load and postponing the beginning of buckling.

Since buckling of the sheet occurs at stresses above the elastic range, it is meaningless to compare the test values with values calculated by the classical theory based on elastic action. Buckling values can, however, be calculated by the equivalent slenderness ratio method shown in the Alcoa Structural Handbook (reference 5); and these, based on the typical column curve and edge condition halfway between fixed and hinged, are found to be 44,500 psi for the 0.156-inch sheet and 36,200 psi for the 0.093-inch sheet. These are 17 percent higher and 2 percent lower, respectively, than the corresponding test results for the all-24S-T members.

In all the specimens with the 0.156-inch gage sheet the initial failure was by local buckling of the stiffeners, but in the specimens using 0.093-inch gage sheet the sheet buckled first. Typical specimens for each type of panel are shown after testing, in figures 7 and 8.

It is interesting to note that the specimens using 0.156-inch gage sheet with 24S-T stiffeners and those using 0.093-inch gage sheet with 14S-T stiffeners failed at the same average stress and began buckling at the same stress. In the case of both stiffener alloys the load at first buckling of the sheet averaged about 75 percent of the ultimate load.

When additional load was applied to the specimens after the initial failure, secondary failure of the stiffener webs and flanges, as shown in figure 9, and of the rivets was common. Most of these secondary failures in the specimens with 0.156-inch sheet were in the stiffeners; while those in the specimens with 0.093-inch sheet were in the rivets. The fractures in the stiffeners were found in both stiffener alloys, but, of course, only in the region where the initial buckling took place.

CONCLUSIONS

From these data and results of edge-compression tests of panels of 24S-T sheet with extruded 14S-T and 24S-T stiffeners, it seems reasonable to draw these conclusions.

1. The mechanical properties of the materials used in the stiffened sheet panels of this investigation were greater than the specified minimum values. The tensile strengths and tensile and compressive yield strengths are fairly close to published typical properties with the exception of the tensile yield strength of the 24S-T material, which averaged about 20 percent above the typical value.

2. The extruded 14S-T stiffeners used in these tests have compressive yield strengths, based on full-section tests, 20 percent higher than those of the 24S-T stiffeners.

3. The panels using 14S-T stiffeners are stronger than those using 24S-T stiffeners by 5 percent when the 24S-T sheet thickness is

25 percent greater than that of the stiffeners and by 12 percent when the 24S-T sheet thickness is 25 percent less than that in the stiffeners.

4. The percent of extra strength gained by using higher strength stiffeners diminishes rapidly as the ratio of sheet area to stiffener area increases, as may be seen in table II.

5. The average stress at which buckling occurred was higher for the panels using higher strength stiffeners. In the case of both stiffener alloys the load at first buckling of the sheet averaged about 75 percent of the ultimate load.

6. Permanent buckling occurred simultaneously, or nearly so, with elastic buckling.

7. Secondary failure in the form of fractured stiffeners and rivets occurred after the ultimate load was reached in a number of cases. There seemed to be no difference between the two stiffener alloys in this respect.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Penna., March 28, 1946.

REFERENCES

1. Holt, M.: The Effect of Methods of Testing on the Ultimate Loads Supported by Stiffened Flat Sheet Panels under Edge Compression. NACA TN No. 811, 1941.

2. Anon.: Alcoa Aluminum and Its Alloys. Aluminum Co. of Am., 1944a.

3. Anon.: Standard Methods of Tension Testing of Metallic Materials (E8-42). Book of A.S.T.M. Standards, pt. 1, p. 898.

4. Paul, D. A., Howell, F. M., and Grieshaber, H. E.: Comparison of Stress-Strain Curves Obtained by Single-Thickness and Pack Methods. NACA TN No. 819, 1941.

5. Anon.: Alcoa Structural Handbook. Aluminum Co. of Am., 1945.

TABLE I.- MECHANICAL PROPERTIES OF

14S-T AND 24S-T EXTRUDED SECTIONS AND 24S-T SHEET

[Specimens of the extruded sections were taken from the flat sides and top of the hat-shape sections unless otherwise marked.]

(M. T. No. 120143-C)

Alloy	Thickness (in.)	Tension[1] Yield strength (0.2 percent offset) (psi)	Tension[1] Ultimate strength (psi)	Tension[1] Elongation in 2 in. (percent)	Compression Yield strength (0.2 percent offset) (psi)	Remarks
			Sheet			
24S-T	0.093	55,300	72,900	18.3	[2]45,400	With grain
	.156	56,100	71,500	18.5	[2]44,500	With grain
			Extrusion			
24S-T	.125	55,700	72,900	16.0	[2]49,250	Side
	.125	53,500	71,100	16.5	[2]48,500	Top
					49,000	Full section
14S-T	.125	59,150	64,300	11.0	[2]58,900	Side
	.125	58,700	63,800	10.4	[2]59,600	Top
					58,650	Full section
			Typical Properties[3]			
24S-T		46,000	68,000	22.0	46,000	
14S-T		58,000	68,000	13.0	58,000	
			Specified Minimum Properties[3]			
24S-T		42,000	64,000	14.0		Sheet
		42,000	57,000	12.0		Extrusions
14S-T		50,000	60,000	7.0		Extrusions

[1] For standard tension test specimens for sheet metals, see fig. 2 of reference 3.

[2] For single thickness specimens, see reference 4.

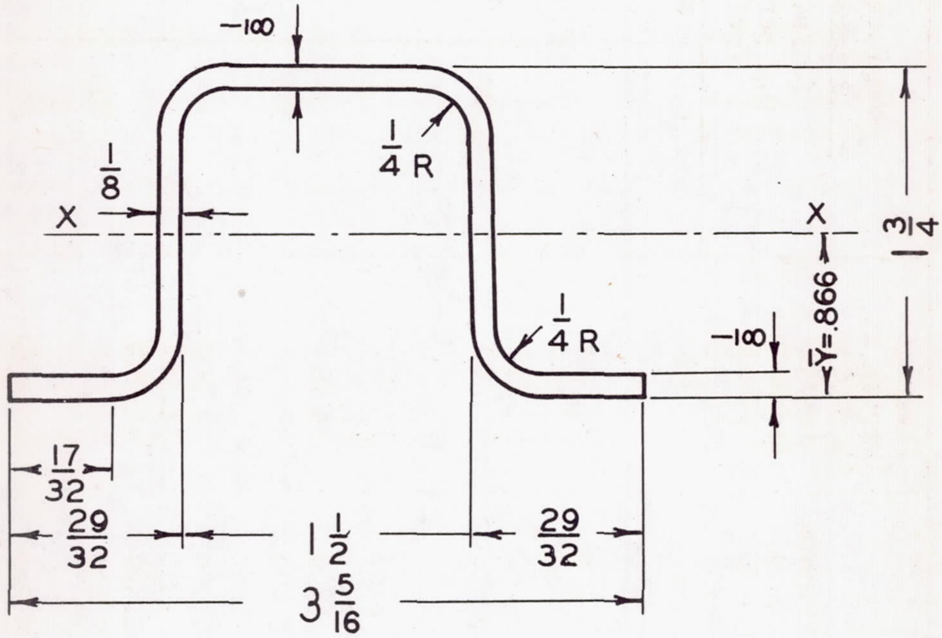
[3] Taken from reference 5.

TABLE II.- SUMMARY OF RESULTS, EDGE-COMPRESSION TESTS ON STIFFENED SHEET PANELS

[Comparative Tests on Extruded 14S-T and 24S-T Hat-Shape Stiffener Sections]

Specimen	24S-T sheet thickness (in.)	Stiffener alloy	Ultimate load, P (lb)	Area A (sq in.)	Ultimate average stress P/A (psi)	Average stress at 0.00005 in./in. permanent strain difference (psi)	Compressive yield strength[1] (offset = 0.2 percent) (psi)	
							Sheet	Stiffener
1A-1	0.156	14S-T	251,800	4.57	55,100	53,900		
1A-2	.156	14S-T	253,000	4.58	55,300	27,500		
1A-3	.156	14S-T	249,400	4.53	55,200	43,300		
	Av.		251,000	4.56	55,200	41,600	44,500	58,650
2A-1	.156	24S-T	239,500	4.55	52,700	37,800		
2A-2	.156	24S-T	243,400	4.58	53,000	41,500		
2A-3	.156	24S-T	237,000	4.59	51,600	34,800		
	Av.		240,000	4.57	52,400	38,030	44,500	49,000
1B-1	.093	14S-T	188,500	3.62	52,100	42,200		
1B-2	.093	14S-T	191,000	3.62	52,800	31,300		
1B-3	.093	14S-T	189,000	3.61	52,300	41,000		
	Av.		189,500	3.62	52,400	38,200	45,400	58,650
2B-1	.093	24S-T	170,000	3.63	46,800	36,900		
2B-2	.093	24S-T	170,300	3.62	47,000	42,000		
2B-3	.093	24S-T	168,600	3.62	46,500	31,800		
	Av.		169,600	3.62	46,800	36,900	45,400	49,000

[1]Taken from table I.



EXTRUDED STIFFENER

HAT-SECTION

DIE No. K-12454

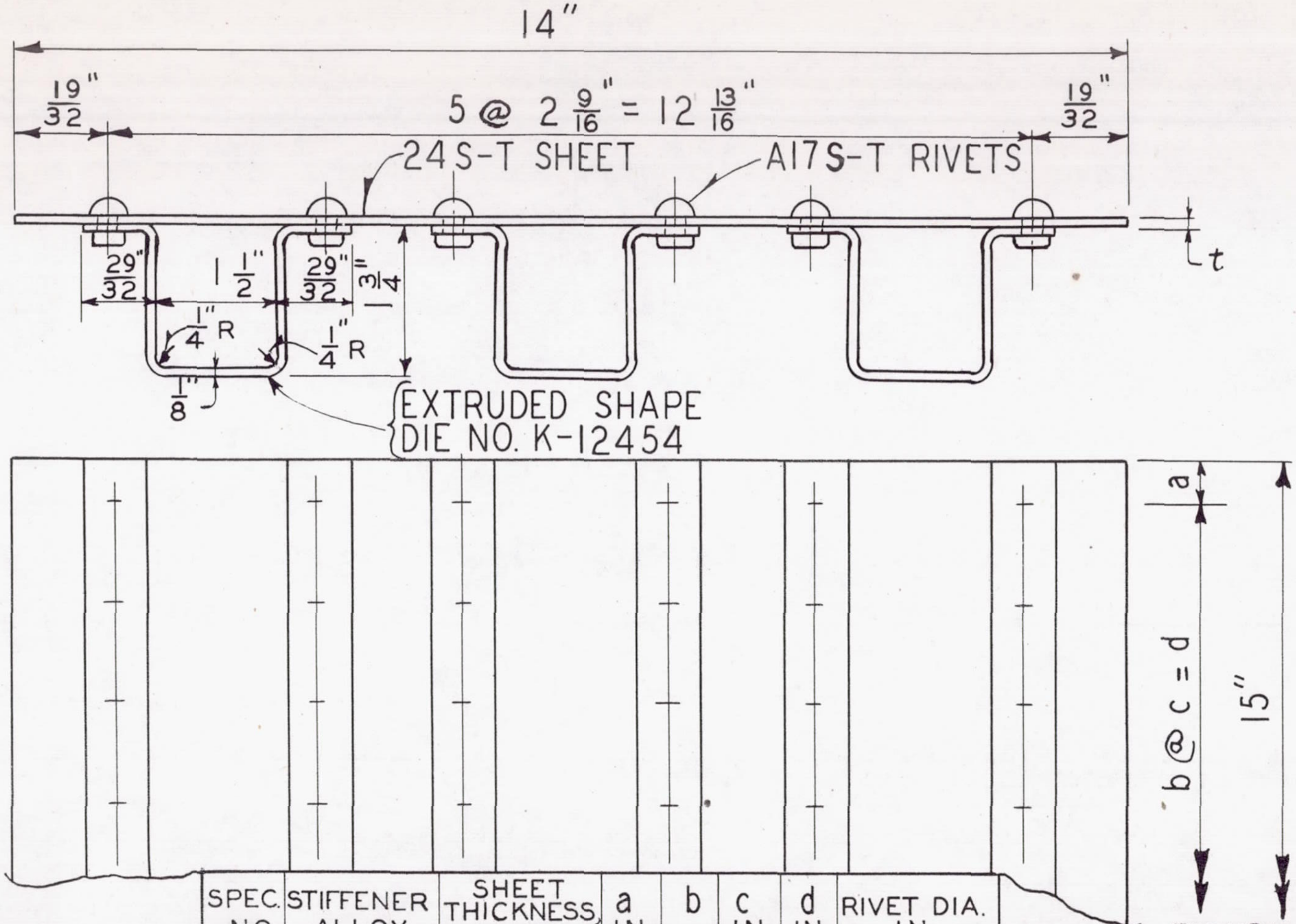
AREA 0.752 IN.^{2}

Ixx 0.365 IN.^{4}

Rx 0.697 IN.

$\bar{Y}$ 0.866 IN.

FIGURE 1.



SPEC. NO.	STIFFENER ALLOY	SHEET THICKNESS, t, IN.	a IN.	b	c IN.	d IN.	RIVET DIA. IN.
1A	14S-T	0.156	1/2"	14	1	14	1/4"
1B	14S-T	0.093	3/8"	19	3/4"	14 1/4"	3/16"
2A	24S-T	0.156	1/2"	14	1	14	1/4"
2B	24S-T	0.093	3/8"	19	3/4"	14 1/4"	3/16"

FIGURE 2.- STIFFENED FLAT SHEET SPECIMENS FOR EDGE COMPRESSION TESTS.

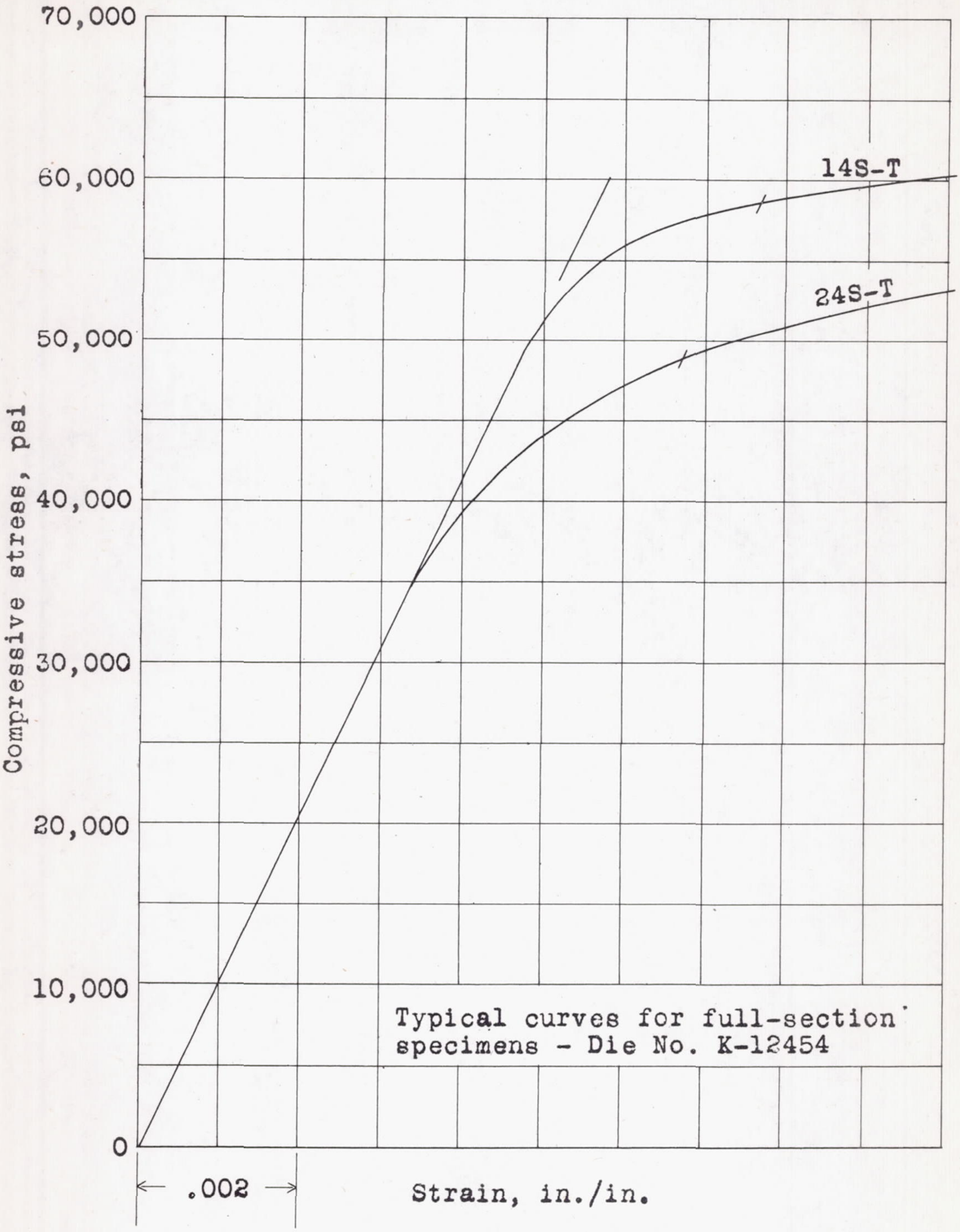


Figure 3.- Compressive stress-strain curves, Aluminum alloy extrusions as noted, (typical).

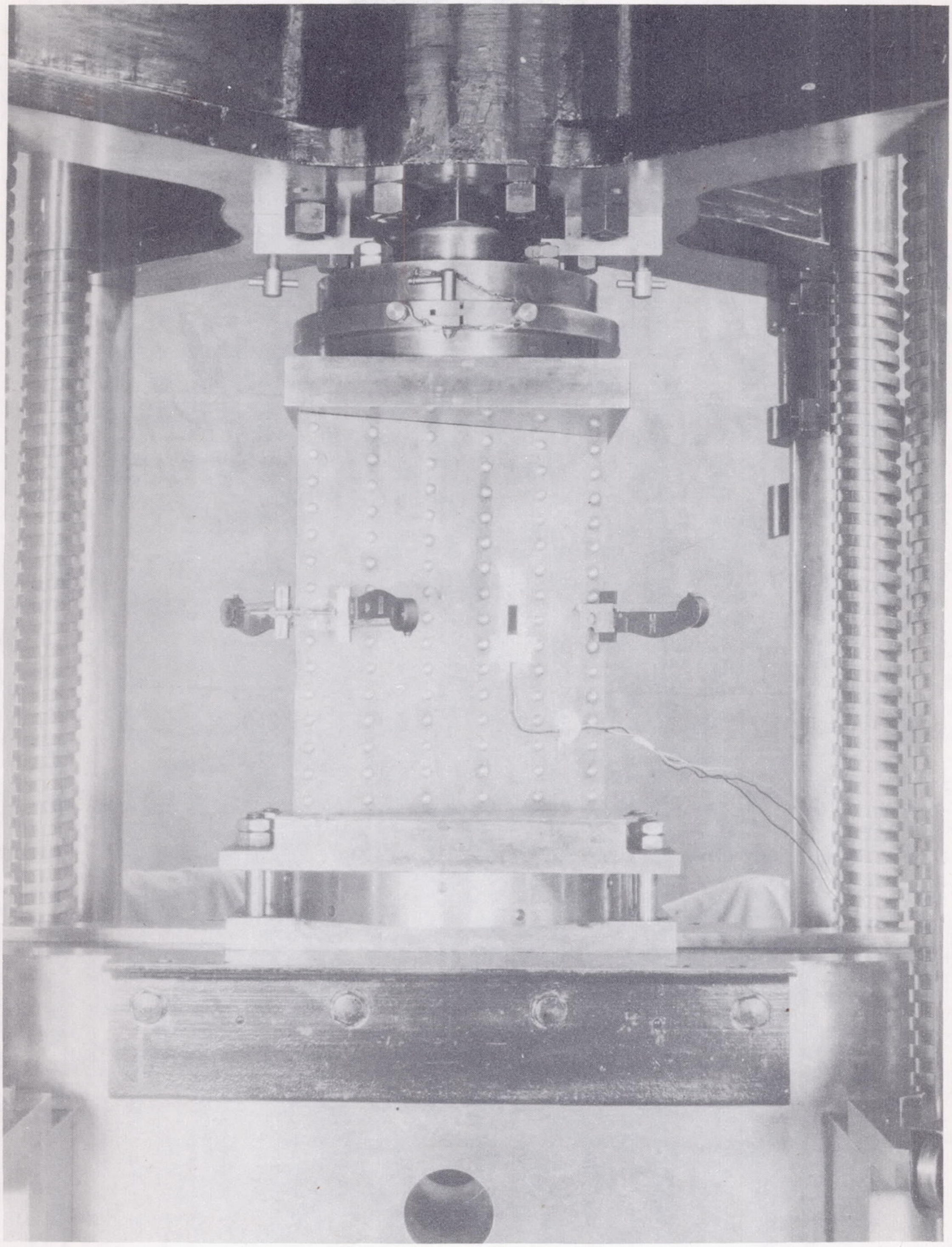


Figure 4.- Setup for edge-compression test on stiffened sheet panel.

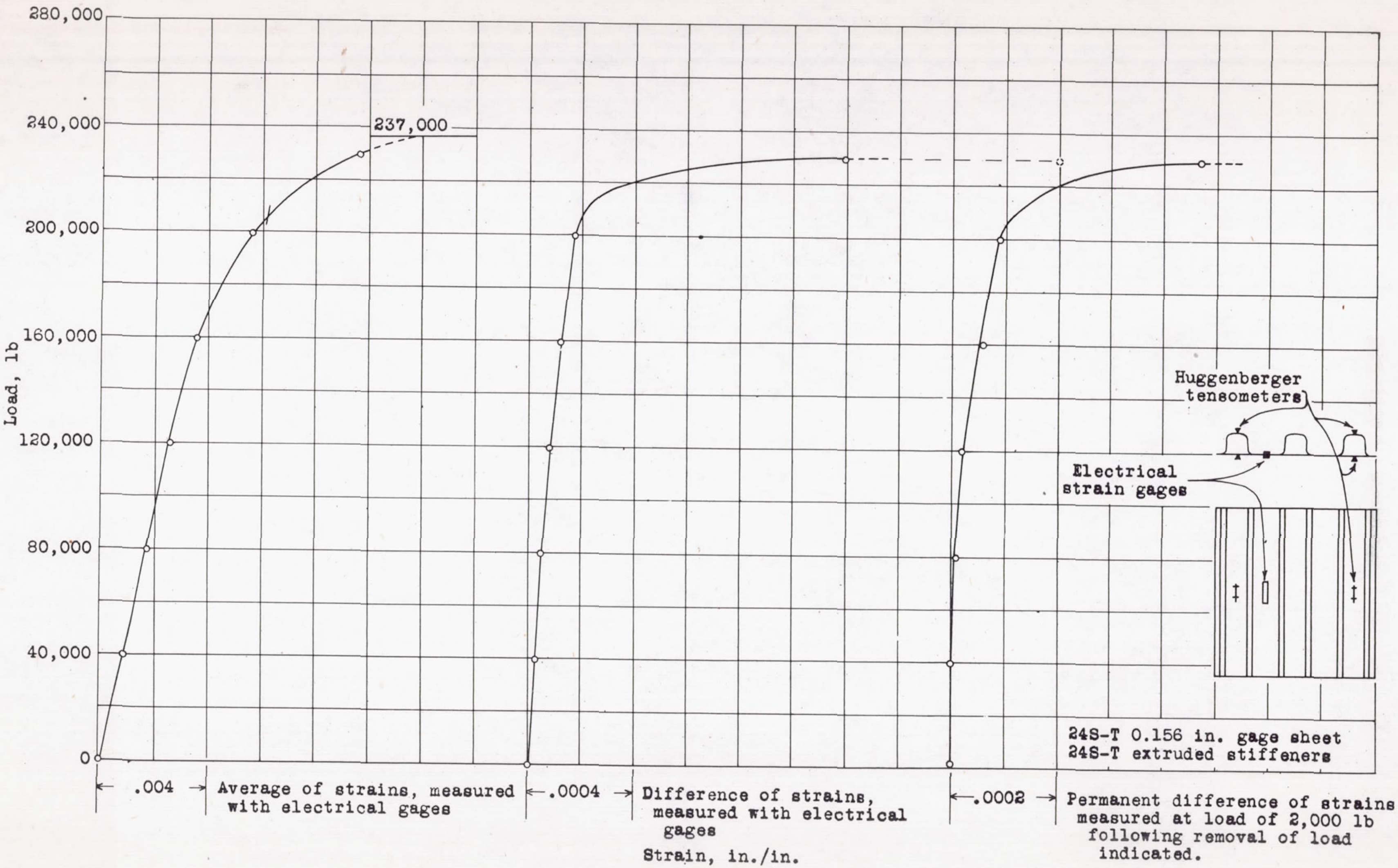


Figure 5.- Compressive load-strain data, stiffened sheet panels, 24S-T (2A-B).

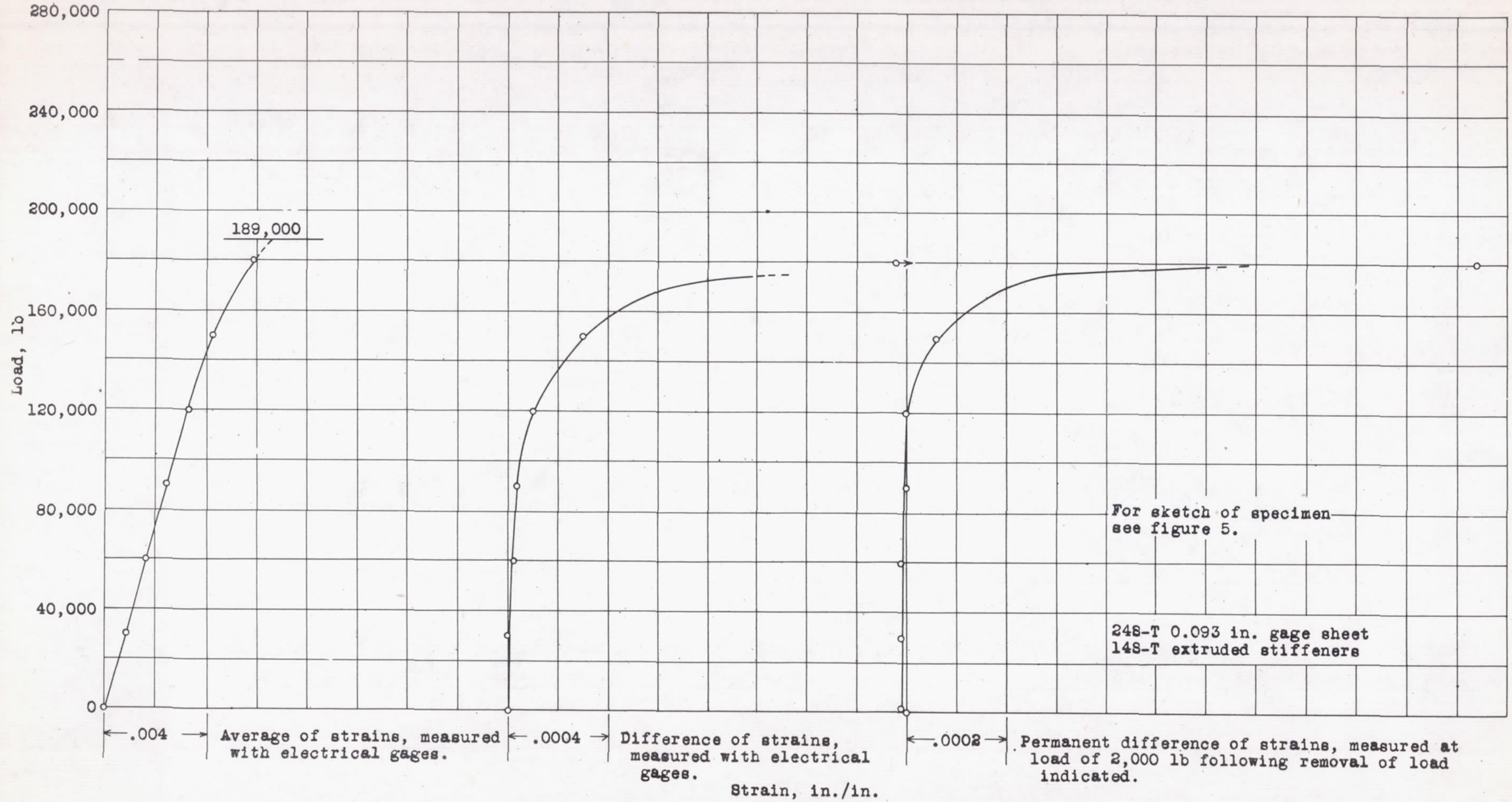


Figure 6.- Compressive load-strain data, stiffened sheet panels, 14S-T (1B-3) and 24S-T.

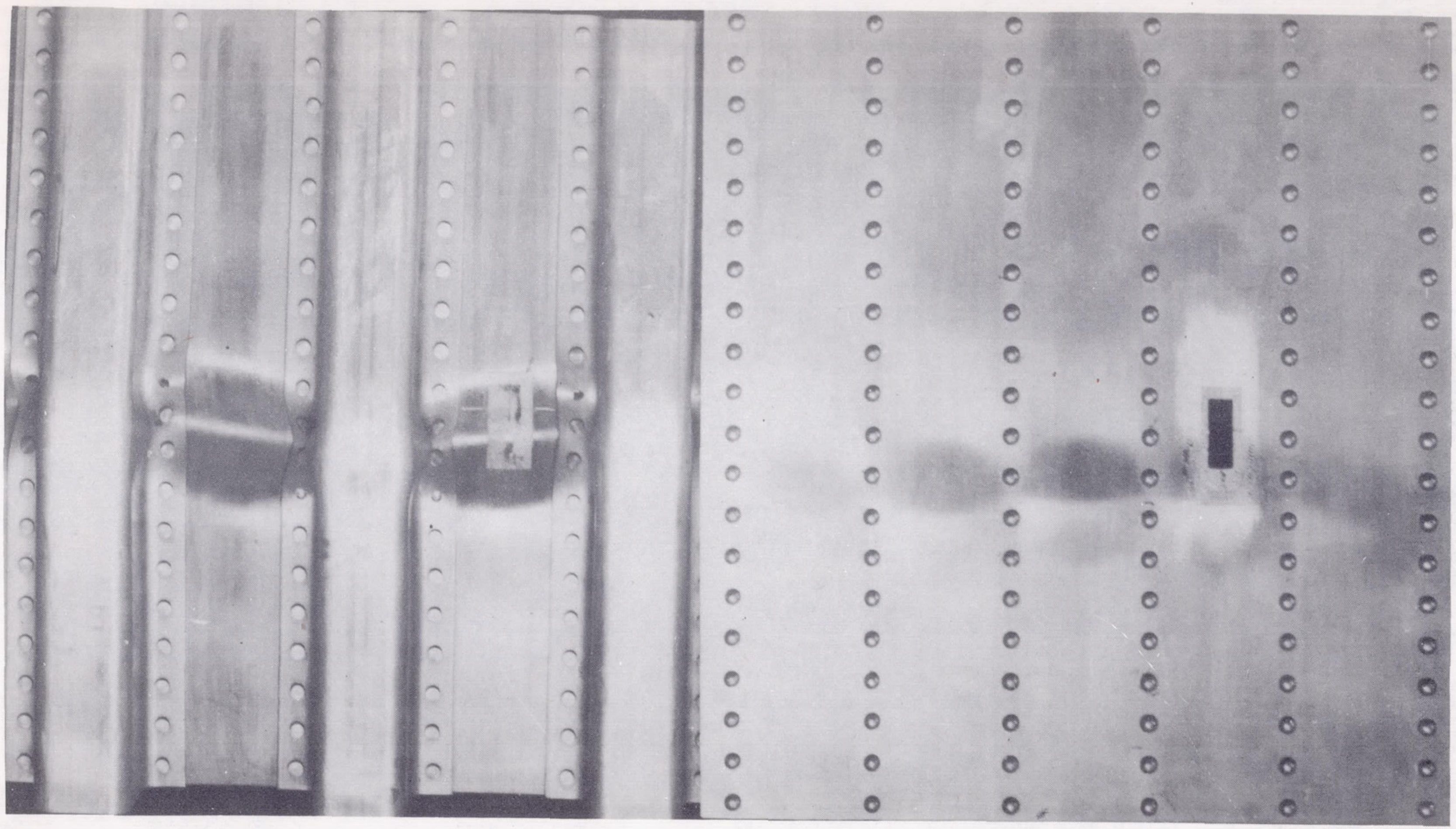


Figure 7.- Typical specimens with 0.093-in. gage sheet after testing. The specimen on the left was loaded until rivet and stiffener failures occurred.

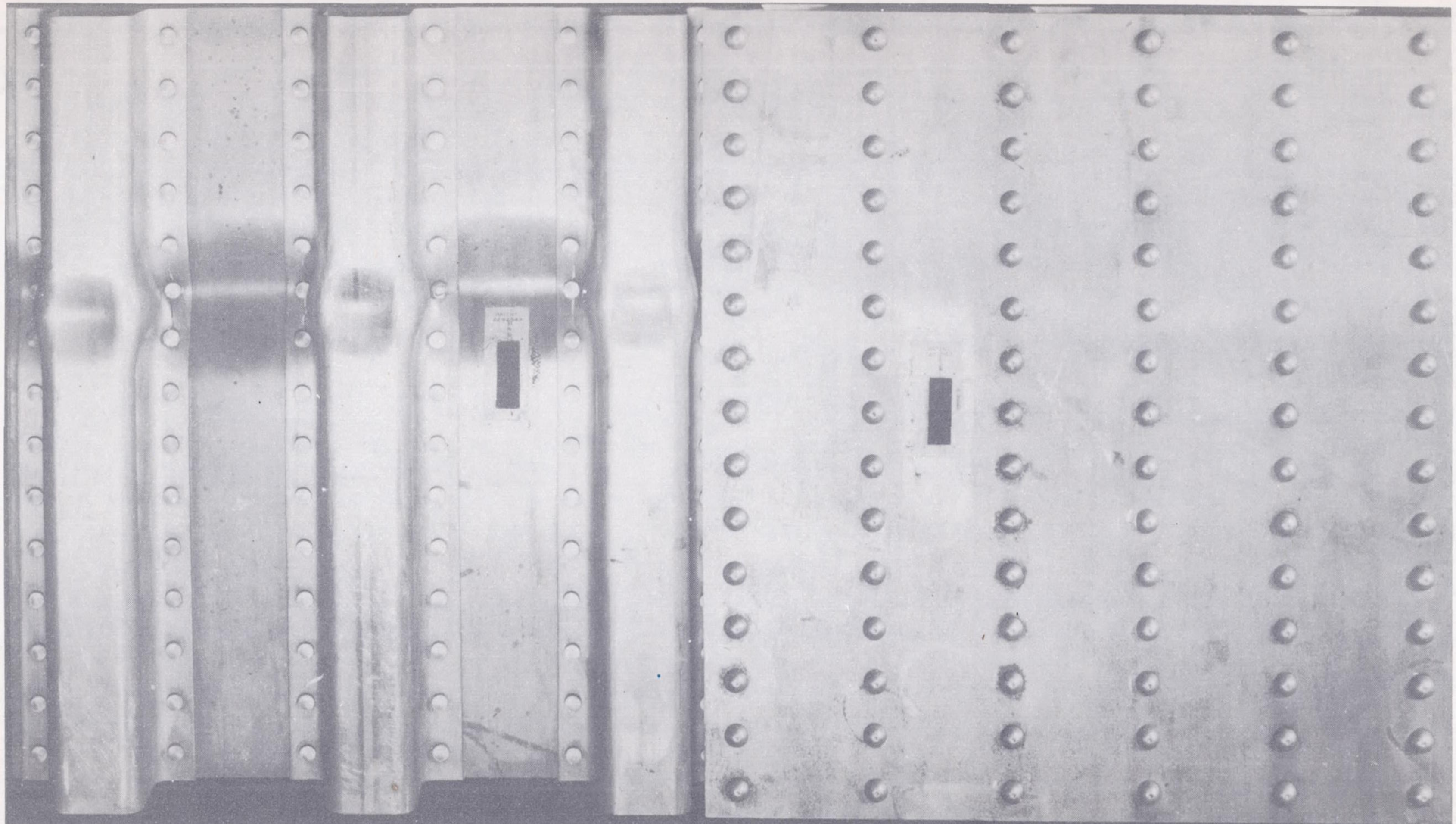


Figure 8.- Typical specimens with 0.156-in. gage sheet after testing. The specimen on the left was loaded until failure of the rivets and stiffeners occurred.

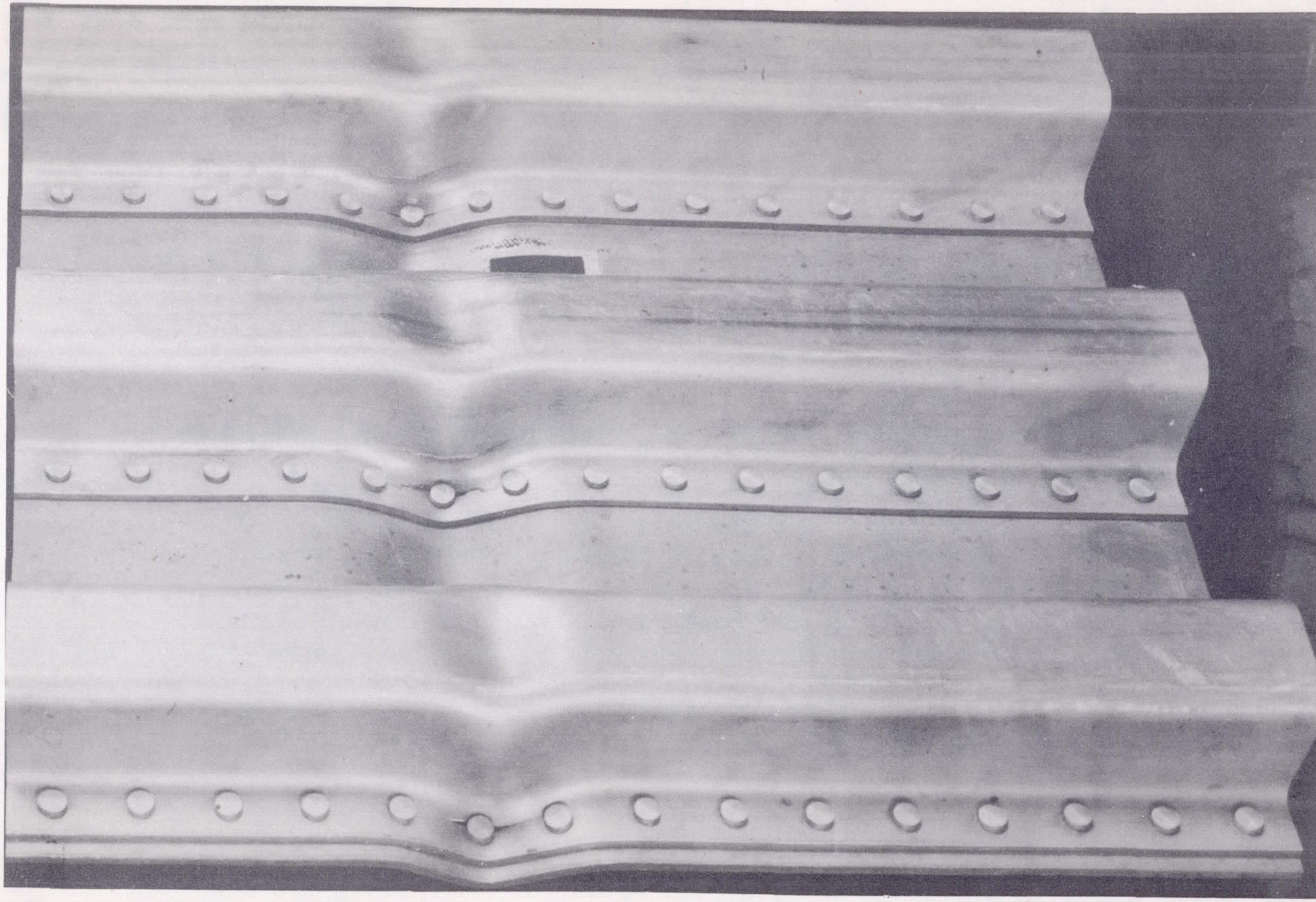


Figure 9.- Specimen with 0.156-in. gage sheet after testing showing tension failure of the stiffener webs. These fractures occurred after the buckling failure.