NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1467

EFFECT OF VARIATION IN DIAMETER AND PITCH OF RIVETS ON COMPRESSIVE STRENGTH OF PANELS WITH Z-SECTION STIFFENERS

PANELS OF VARIOUS STIFFENER SPACINGS THAT FAIL BY LOCAL BUCKLING

By Norris F. Dow and William A. Hickman

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

An experimental investigation is being conducted to determine the effect of varying the rivet diameter and pitch on the compressive strength of flat 24S-T aluminum-alloy Z-stiffened panels of the type for which design charts are available. The present part of the investigation is concerned with panels which have the smallest values of width-to-thickness ratio of the webs of the stiffeners given by the design charts and have such length that failure is by local buckling. The results showed that for these panels, regardless of their stiffener spacing, the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

INTRODUCTION

The design and analysis of sheet-stiffener panels for aircraft structures have been the subject of extensive experimental and theoretical investigations, but the determination of the size and pitch of rivets for attaching sheet to stiffener is a problem that has not been adequately solved. In reference 1 charts and procedures are presented for the design of Z-stiffened panels to carry a given intensity of loading at a given panel length. The test data on which these design charts were based, however, were obtained for an arbitrary diameter and pitch of the rivets. An investigation is therefore being conducted in the Langley structures research laboratory of the NACA to determine the effect of a variation in the rivet diameter and pitch on the strength of 24S-T aluminum-alloy panels with longitudinal Z-section stiffeners of the type for which the design charts of reference 1 were prepared.

Results are presented of the third series of tests for the investigation. Some results of the first series of tests, reported in reference 2, are combined herein with the results of the third series. Since any number of combinations of rivet diameter and pitch are possible for any panel, the results of the tests made in these first three series can cover only a small region on the design charts of reference 1. The first series of tests (reference 2) covered the region in which the panels have the closest stiffener spacings, the smallest value of width-to-thickness ratio for the webs of the stiffeners, and such lengths that failure is by local buckling. The second series of tests (reference 3) covered the same region as the tests of reference 2 except for the limitation on the panel lengths. The third series of tests, with which the present paper is concerned, covers the region in which the panels have the smallest value of width-to-thickness ratio for the webs of the stiffeners, such lengths that failure is by local buckling, and no limitation on the stiffener spacing. Further testing will be required to determine the effect of rivet diameter and pitch on panels having higher values of width-to-thickness ratio for the webs of the stiffeners.

SYMBOLS

L	length of specimen, inches
ρ	radius of gyration, inches
L/ρ	slenderness ratio
W	width of specimen, inches
b_S	spacing of stiffeners on sheet, inches
b_A	width of attachment flange of stiffeners, inches
b_W	width of web of stiffeners, inches
b_F	width of outstanding flange of stiffeners, inches
t_S	thickness of sheet, inches
t_W	thickness of web of stiffeners, inches

d	diameter of rivets, inches
p	pitch of rivets, inches
h	depth of countersink for rivets, inches
σ_{cy}	compressive yield stress for material, ksi
$\bar{\sigma}_f$	average compressive stress at failing load for any specimen, ksi
c	coefficient of end fixity in Euler column formula
P_i	compressive load per inch of panel width, kips per inch
R	radius of bend

TEST SPECIMENS AND METHOD OF TESTING

The specimens consisted of 24S-T aluminum-alloy panels having longitudinal Z-section stiffeners as shown in figures 1 and 2. Seven stiffener spacings $\left(\frac{b_S}{t_S} = 25, 30, 35, 40, 50, 60, \text{ and } 75\right)$ were investigated. The stiffeners on all panels were identical. Two thicknesses of sheet were used to give two ratios of stiffener thickness to sheet thickness: $\frac{t_W}{t_S} = 1.00$ and 0.63. The lengths of the panels were so chosen $\left(\frac{L}{\rho} = 20\right)$ that no column failures occurred. The proportions $\frac{b_W}{t_W} = 20$, $\frac{b_A}{t_W} = 9.5$, and $\frac{b_F}{b_W} = 0.4$ were chosen to give the panels from the design charts of reference 1 that have the smallest values of width-to-thickness ratio for the webs of the stiffeners. In order to allow for the larger rivets used in the present investigation, the value of $\frac{b_A}{t_W}$ for the panels was slightly larger than that used for the panels of reference 1 which had $\frac{t_W}{t_S} = 1.00$.

The rivets used throughout the investigation were A17S-T flat-head rivets (AN442AD). Both the diameter and pitch of the rivets were varied for each ratio of sheet thickness to stiffener thickness, as is shown in table 1. The minimum rivet pitch used in all cases was equal to three times the rivet diameter. On all panels the rivets were driven by the NACA flush-riveting process in which the rivet is inserted with the head opposite the countersunk end of the hole, the shank of the rivet is driven into the cavity formed by the countersink, and the excess material is removed with a milling tool. A countersink angle of 60° was used throughout. The depths of the countersink used are given in table 1.

Ultimate compressive loads for the 348 specimens were determined in a hydraulic testing machine having an accuracy of one-half of 1 percent of the load. The ends of the specimens were ground accurately flat and parallel in a special grinder, and the method of alinement in the testing machine was such as to insure a uniform bearing over the ends of the specimens.

The with-grain compressive yield strength σ_{cy} of the material before forming was found to be as follows: 48.0 ksi (max.), 44.2 ksi (av.), and 40.4 ksi (min.).

RESULTS AND DISCUSSION

The results are presented in figure 3 and table 1. In figure 3, $\bar{\sigma}_f$, calculated simply as the failing load divided by the cross-sectional area of the panel, is plotted against the sum of the thicknesses of sheet and stiffener $\frac{d}{t_S + t_W}$ in order to present the results in a manner similar to that used in references 2 and 3. Figure 3 shows that for all values of $\frac{t_W}{t_S}$ and $\frac{b_S}{t_S}$ investigated the compressive strengths increased with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

The type of failure also changed with increasing rivet diameter and decreasing rivet pitch, as is shown in figure 4. For the weakest riveting (see lower left corner of fig. 4), there was a fairly long wave-length bulging of the sheet away from the stiffeners accompanied by numerous rivet failures. As the strength of riveting increased (upward and toward the right on fig. 4) the wave length of the bulge decreased and fewer rivet failures occurred. In order to avoid this bulging altogether and to achieve a plate buckling pattern which varied sinusoidally along and across the sheet at failure, a very strong riveting was required. (See top part of fig. 4.)

These results suggest that the conception of a limited critical range of the ratio of rivet pitch to sheet thickness (the "danger zone" tentatively established in reference 4) for which rivet failures may be expected to reduce the panel strength may be misleading. At least for rivet pitches smaller than those corresponding to the lower limit of the critical range of reference 4, and for the type of stiffeners tested, perhaps a somewhat truer conception is that the strength for local buckling failure always depends upon both the rivet pitch and diameter as well as upon such other variables as panel proportions.

CONCLUDING REMARKS

Results are presented of tests to determine the effect of varying the rivet diameter and pitch on the compressive strength of flat 24S-T aluminum-alloy Z-stiffened panels of the type for which design charts are available. The present part of the investigation is concerned with panels which have the smallest values of width-to-thickness ratio of the webs of the stiffeners given by the design charts and have such length that failure is by local buckling. The results showed that for these panels, regardless of their stiffener spacing, the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., August 1, 1947

REFERENCES

1. Schuette, Evan H.: Charts for the Minimum-Weight Design of 24S-T Aluminum-Alloy Flat Compression Panels with Longitudinal Z-Section Stiffeners. NACA ARR No. L5F15, 1945.

2. Dow, Norris F., and Hickman, William A.: Effect of Variation in Diameter and Pitch of Rivets on Compressive Strength of Panels with Z-Section Stiffeners. I - Panels with Close Stiffener Spacing That Fail by Local Buckling. NACA RB No. L5G03, 1945.

3. Dow, Norris F., and Hickman, William A.: Effect of Variation in Diameter and Pitch of Rivets on Compressive Strength of Panels with Z-Section Stiffeners. Panels of Various Lengths with Close Stiffener Spacing. NACA TN No. 1421 , 1947.

4. Levy, Samuel, McPherson, Albert E., and Ramberg, Walter: Effect of Rivet and Spot-Weld Spacing on the Strength of Axially Loaded Sheet-Stringer Panels of 24S-T Aluminum Alloy. NACA TN No. 856, 1942.

TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS

SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
t_S = 0.064 in.; b_S = 1.60 in.; L = 10.40 in.; W = 8.64 in.; $\frac{t_W}{t_S}$ = 1.00; $\frac{b_S}{t_S}$ = 25[a]; $\frac{b_W}{t_W}$ = 20				
1/16	0.035	3/16	43.050	1.233
		3/8	41.450	1.180
		5/8	[b]36.855	1.013
		15/16	[b]38.380	1.093
		$1\frac{5}{16}$	29.300	.840
		$1\frac{3}{4}$	26.700	.768
3/32	.040	9/32	44.300	1.303
		3/8	43.500	1.245
		5/8	[b]38.070	1.069
		15/16	[b]40.035	1.140
		$1\frac{5}{16}$	33.400	.950
		$1\frac{3}{4}$	30.700	.891
1/8	.050	3/8	44.600	1.317
		5/8	[b]43.735	1.227
		15/16	[b]41.710	1.186
		$1\frac{5}{16}$	34.750	.990
		$1\frac{3}{4}$	32.200	.856
5/32	.060	15/32	45.000	1.318
		5/8	43.870	1.197
		15/16	40.500	1.142
		$1\frac{5}{16}$	36.100	1.032
		$1\frac{3}{4}$	[b]33.800	.973
3/16	.065	9/16	45.340	1.329
		5/8	44.700	1.232
		15/16	40.850	1.160
		$1\frac{5}{16}$	37.600	1.077
		$1\frac{3}{4}$	[b]33.800	.968
1/4	.065	3/4	44.485	1.272
		15/16	44.485	1.290
		$1\frac{5}{16}$	38.900	1.104
		$1\frac{3}{4}$	35.350	1.022

[a]Data for $\frac{b_S}{t_S}$ = 25 is from reference 2.

[b]Average of two tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.064$ in.; $b_S = 1.92$ in.; $L = 10.02$ in.; $W = 10.24$ in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 30$; $\frac{b_W}{t_W} = 20$				
1/16	0.035	3/16	41.640	1.086
		3/8	39.900	1.042
		5/8	36.550	.952
		15/16	35.200	.927
		$1\frac{5}{16}$	33.140	.865
		$1\frac{3}{4}$	32.310	.845
3/32	.040	9/32	41.860	1.103
		3/8	42.640	1.106
		5/8	39.400	1.019
		15/16	36.550	.938
		$1\frac{5}{16}$	31.830	.818
		$1\frac{3}{4}$	28.160	.727
1/8	.050	3/8	39.150	1.019
		5/8	38.900	.992
		15/16	36.100	.895
		$1\frac{5}{16}$	34.050	.876
		$1\frac{3}{4}$	30.370	.791
5/32	.060	15/32	44.070	1.146
		5/8	42.190	1.096
		15/16	40.620	1.049
		$1\frac{5}{16}$	35.150	.908
		$1\frac{3}{4}$	31.910	.828
3/16	.065	9/16	42.750	1.116
		5/8	43.440	1.126
		15/16	40.000	1.026
		$1\frac{5}{16}$	36.570	.933
		$1\frac{3}{4}$	33.100	.858
1/4	.065	3/4	43.220	1.133
		15/16	43.810	1.140
		$1\frac{5}{16}$	38.370	.984
		$1\frac{3}{4}$	33.550	.860

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
t_S = 0.064 in.; b_S = 2.24 in.; L = 9.84 in.; W = 11.84 in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 35$; $\frac{b_W}{t_W} = 20$				
1/16	0.035	3/16	38.420	0.928
		3/8	34.540	.822
		5/8	33.790	.792
		15/16	32.340	.794
		$1\frac{5}{16}$	28.310	.687
		$1\frac{3}{4}$	25.940	.631
3/32	.040	9/32	38.370	.936
		3/8	38.600	.936
		5/8	37.090	.900
		15/16	34.980	.851
		$1\frac{5}{16}$	32.350	.786
		$1\frac{3}{4}$	26.990	.653
1/8	.050	3/8	39.130	.947
		5/8	37.940	.924
		15/16	39.370	.950
		$1\frac{5}{16}$	33.230	.810
		$1\frac{3}{4}$	28.950	.702
5/32	.060	15/32	40.080	.978
		5/8	38.990	.944
		15/16	37.980	.921
		$1\frac{5}{16}$	33.230	.810
		$1\frac{3}{4}$	30.200	.732
3/16	.065	9/16	38.400	.898
		5/8	39.210	.953
		15/16	38.360	.930
		$1\frac{5}{16}$	34.240	.832
		$1\frac{3}{4}$	31.740	.769
1/4	.065	3/4	40.380	.994
		15/16	40.480	.979
		$1\frac{5}{16}$	36.280	.883
		$1\frac{3}{4}$	32.590	.794

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
$t_S = 0.064$ in.; $b_S = 2.56$ in.; $L = 9.64$ in.; $W = 13.44$ in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 40$; $\frac{b_W}{t_W} = 20$				
1/16	0.035	3/16	37.940	0.868
		3/8	36.370	.839
		5/8	31.040	.719
		15/16	29.160	.669
		$1\frac{5}{16}$	26.180	.601
		$1\frac{3}{4}$	23.940	.554
3/32	.040	9/32	38.600	.892
		3/8	38.440	.886
		5/8	34.190	.787
		15/16	34.130	.784
		$1\frac{5}{16}$	28.290	.646
		$1\frac{3}{4}$	24.320	.560
1/8	.050	3/8	38.660	.886
		5/8	37.280	.847
		15/16	34.920	.807
		$1\frac{5}{16}$	30.400	.695
		$1\frac{3}{4}$	27.700	.634
5/32	.060	15/32	38.360	.884
		5/8	37.700	.869
		15/16	37.580	.860
		$1\frac{5}{16}$	31.620	.732
		$1\frac{3}{4}$	28.590	.656
3/16	.065	9/16	37.960	.872
		5/8	39.070	.897
		15/16	37.440	.867
		$1\frac{5}{16}$	32.930	.756
		$1\frac{3}{4}$	30.180	.692
1/4	.065	3/4	38.510	.894
		15/16	38.460	.896
		$1\frac{5}{16}$	34.820	.777
		$1\frac{3}{4}$	31.030	.709

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
t_S = 0.064 in.; b_S = 3.20 in.; L = 9.28 in.; W = 16.64 in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 50$; $\frac{b_W}{t_W} = 20$				
1/16	0.035	3/16	34.840	0.713
		3/8	33.260	.688
		5/8	32.270	.694
		15/16	30.260	.621
		$1\frac{5}{16}$	25.080	.511
		$1\frac{3}{4}$	21.800	.447
3/32	.040	9/32	35.510	.768
		3/8	33.820	.697
		5/8	34.320	.731
		15/16	31.080	.634
		$1\frac{5}{16}$	28.620	.590
		$1\frac{3}{4}$	26.240	.569
1/8	.050	3/8	35.520	.722
		5/8	34.490	.714
		15/16	33.980	.698
		$1\frac{5}{16}$	28.990	.595
		$1\frac{3}{4}$	26.960	.554
5/32	.060	15/32	34.930	.720
		5/8	35.010	.724
		15/16	33.750	.696
		$1\frac{5}{16}$	32.330	.666
		$1\frac{3}{4}$	26.790	.576
3/16	.065	9/16	35.590	.742
		5/8	35.420	.729
		15/16	34.340	.703
		$1\frac{5}{16}$	31.680	.651
		$1\frac{3}{4}$	28.290	.581
1/4	.065	3/4	34.700	.718
		15/16	34.590	.716
		$1\frac{5}{16}$	33.760	.720
		$1\frac{3}{4}$	29.220	.601

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

t_S = 0.064 in.; b_S = 3.840 in.; L = 8.92 in.; W = 19.84 in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 60$; $\frac{b_W}{t_W} = 20$

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
1/16	0.035	3/16	31.870	0.629
		3/8	31.720	.629
		5/8	29.610	.585
		15/16	25.340	.503
		$1\frac{5}{16}$	23.230	.462
		$1\frac{3}{4}$	20.760	.416
3/32	.040	9/32	31.690	.625
		3/8	32.080	.640
		5/8	31.230	.616
		15/16	28.100	.557
		$1\frac{5}{16}$	28.210	.563
		$1\frac{3}{4}$	22.930	.455
1/8	.050	3/8	32.260	.642
		5/8	31.650	.626
		15/16	31.450	.623
		$1\frac{5}{16}$	27.080	.539
		$1\frac{3}{4}$	24.740	.488
5/32	.060	15/32	32.470	.636
		5/8	32.570	.644
		15/16	31.770	.632
		$1\frac{5}{16}$	29.940	.590
		$1\frac{3}{4}$	25.840	.516
3/16	.065	9/16	32.680	.650
		5/8	32.240	.633
		15/16	31.930	.635
		$1\frac{5}{16}$	29.930	.603
		$1\frac{3}{4}$	25.400	.507
1/4	.065	3/4	32.480	.646
		15/16	32.420	.650
		$1\frac{5}{16}$	31.260	.625
		$1\frac{3}{4}$	26.580	.526

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.064$ in.; $b_S = 4.80$ in.; $L = 8.48$ in.; $W = 24.64$ in.; $\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 75$; $\frac{b_W}{t_W} = 20$				
1/16	0.035	3/16	29.610	0.572
		3/8	28.150	.536
		5/8	27.810	.523
		15/16	26.250	.499
		$1\frac{5}{16}$	24.000	.458
		$1\frac{3}{4}$	21.320	.404
3/32	.040	9/32	29.320	.560
		3/8	28.580	.549
		5/8	28.510	.545
		15/16	27.160	.520
		$1\frac{5}{16}$	26.100	.501
		$1\frac{3}{4}$	22.240	.425
1/8	.050	3/8	29.850	.569
		5/8	28.830	.549
		15/16	28.970	.553
		$1\frac{5}{16}$	25.800	.494
		$1\frac{3}{4}$	23.670	.452
5/32	.060	15/32	30.010	.565
		5/8	29.340	.555
		15/16	29.320	.561
		$1\frac{5}{16}$	27.680	.529
		$1\frac{3}{4}$	23.550	.452
3/16	.065	9/16	29.430	.556
		5/8	29.340	.563
		15/16	28.780	.547
		$1\frac{5}{16}$	28.150	.541
		$1\frac{3}{4}$	24.160	.464
1/4	.065	3/4	30.100	.573
		15/16	29.650	.568
		$1\frac{5}{16}$	27.660	.530
		$1\frac{3}{4}$	24.970	.478

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
t_S = 0.102 in.; b_S = 2.55 in.; L = 9.44 in.; W = 13.39 in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 25^a$; $\frac{b_W}{t_W} = 20$				
3/32	0.050	9/32	42.300	1.412
		9/16	39.300	1.288
		7/8	38.170	1.218
		$1\frac{7}{32}$	35.400	1.158
		$1\frac{19}{32}$	34.500	1.129
		2	30.000	.984
1/8	.060	3/8	43.800	1.445
		9/16	40.400	1.321
		7/8	39.700	1.263
		$1\frac{7}{32}$	37.800	1.237
		$1\frac{19}{32}$	35.500	1.167
		2	30.240	.984
5/32	.070	15/32	[b]43.590	1.431
		9/16	[b]42.335	1.388
		7/8	41.050	1.310
		$1\frac{7}{32}$	37.850	1.236
		$1\frac{19}{32}$	35.750	1.168
		2	31.800	1.049
3/16	.080	9/16	[b]45.150	1.451
		7/8	[c]41.150	1.327
		$1\frac{7}{32}$	38.800	1.263
		$1\frac{19}{32}$	38.150	1.253
		2	31.900	1.042
1/4	.090	3/4	44.050	1.471
		7/8	[b]43.000	1.378
		$1\frac{7}{32}$	40.700	1.329
		$1\frac{19}{32}$	39.800	1.307
		2	34.100	1.120

[a]Data for $\frac{b_S}{t_S} = 25$ is from reference 2.
[b]Average of two tests.
[c]Average of three tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
t_S = 0.102 in.; b_S = 3.06 in.; L = 8.58 in.; W = 15.94 in.; $\frac{t_W}{t_S}$ = 0.63; $\frac{b_S}{t_S}$ = 30; $\frac{b_W}{t_W}$ = 20				
3/32	0.050	9/32	37.780	1.153
		9/16	35.850	1.089
		7/8	35.350	1.067
		$1\frac{7}{32}$	34.450	1.033
		$1\frac{19}{32}$	31.690	.957
		2	30.990	.935
1/8	.060	3/8	38.020	1.143
		9/16	37.970	1.158
		7/8	37.210	1.141
		$1\frac{7}{32}$	34.610	1.055
		$1\frac{19}{32}$	32.400	.976
		2	26.010	.781
5/32	.070	15/32	37.480	1.138
		9/16	38.140	1.168
		7/8	36.370	1.100
		$1\frac{7}{32}$	35.260	1.070
		$1\frac{19}{32}$	33.790	1.018
		2	30.880	.926
3/16	.080	9/16	38.970	1.194
		7/8	38.950	1.187
		$1\frac{7}{32}$	37.070	1.124
		$1\frac{19}{32}$	34.840	1.057
		2	32.130	.973
1/4	.090	3/4	39.630	1.200
		7/8	38.790	1.178
		$1\frac{7}{32}$	38.540	1.165
		$1\frac{19}{32}$	36.960	1.124
		2	33.630	.973

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
t_S = 0.102 in.; b_S = 3.57 in.; L = 8.24 in.; W = 18.49 in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 35$; $\frac{b_W}{t_W} = 20$				
3/32	0.050	9/32	37.340	1.157
		9/16	33.790	1.001
		7/8	33.320	1.009
		$1\frac{7}{32}$	31.480	.953
		$1\frac{19}{32}$	28.630	.848
		2	30.650	.926
1/8	.060	3/8	36.040	1.074
		9/16	36.030	1.094
		7/8	35.000	1.037
		$1\frac{7}{32}$	33.880	.999
		$1\frac{19}{32}$	31.220	.942
		2	29.230	.894
5/32	.070	15/32	36.120	1.078
		9/16	34.890	1.037
		7/8	35.930	1.096
		$1\frac{7}{32}$	32.440	.951
		$1\frac{19}{32}$	30.850	.944
		2	30.430	.919
3/16	.080	9/16	38.050	1.179
		7/8	36.270	1.105
		$1\frac{7}{32}$	35.570	1.085
		$1\frac{19}{32}$	32.850	.962
		2	30.040	.905
1/4	.090	3/4	[b]36.310	1.073
		7/8	36.940	1.097
		$1\frac{7}{32}$	35.080	1.037
		$1\frac{19}{32}$	34.720	1.033
		2	31.730	.952

[b]Average of two tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\overline{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 4.08$ in.; $L = 7.92$ in.; $W = 21.04$ in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 40$; $\frac{b_W}{t_W} = 20$				
3/32	0.050	9/32	33.610	1.012
		9/16	33.180	1.013
		7/8	32.200	.937
		$1\frac{7}{32}$	28.960	.887
		$1\frac{19}{32}$	26.970	.833
		2	25.810	.756
1/8	.060	3/8	34.580	.997
		9/16	34.220	.997
		7/8	33.530	.977
		$1\frac{7}{32}$	32.490	.952
		$1\frac{19}{32}$	30.790	.939
		2	29.420	.901
5/32	.070	15/32	33.480	.963
		9/16	34.370	1.001
		7/8	34.410	1.062
		$1\frac{7}{32}$	33.390	1.027
		$1\frac{19}{32}$	29.700	.908
		2	27.810	.813
3/16	.080	9/16	34.870	1.019
		7/8	34.300	1.049
		$1\frac{7}{32}$	33.830	.995
		$1\frac{19}{32}$	32.550	.997
		2	30.540	.945
1/4	.090	3/4	34.310	1.033
		7/8	34.720	1.067
		$1\frac{7}{32}$	33.520	.981
		$1\frac{19}{32}$	33.250	1.019
		2	29.480	.861

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
t_S = 0.102 in.; b_S = 5.10 in.; L = 7.40 in.; W = 26.14 in.; $\frac{t_W}{t_S}$ = 0.63; $\frac{b_W}{t_S}$ = 50; $\frac{b_W}{t_W}$ = 20				
3/32	0.050	9/32	29.500	0.866
		9/16	29.660	.876
		7/8	29.440	.876
		$1\frac{7}{32}$	28.730	.883
		$1\frac{19}{32}$	28.060	.867
		2	26.820	.806
1/8	.060	3/8	29.460	.869
		9/16	29.340	.876
		7/8	30.710	.945
		$1\frac{7}{32}$	29.790	.920
		$1\frac{19}{32}$	[b] 26.810	.798
		2	27.430	.838
5/32	.070	15/32	29.620	.873
		9/16	[b] 29.860	.881
		7/8	31.110	.941
		$1\frac{7}{32}$	30.380	.944
		$1\frac{19}{32}$	27.960	.841
		2	28.960	.890
3/16	.080	9/16	32.830	1.033
		7/8	31.120	.944
		$1\frac{7}{32}$	30.510	.943
		$1\frac{19}{32}$	29.890	.922
		2	27.340	.826
1/4	.090	3/4	30.860	.922
		7/8	29.840	.883
		$1\frac{7}{32}$	30.600	.947
		$1\frac{19}{32}$	30.220	.934
		2	28.990	.871

[b] Average of two tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS - Continued

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 6.12$ in.; $L = 6.96$ in.; $W = 31.24$ in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 60$; $\frac{b_W}{t_W} = 20$				
3/32	0.050	9/32	28.800	0.876
		9/16	[b]29.080	.888
		7/8	[b]28.810	.876
		$1\frac{7}{32}$	[b]27.760	.848
		$1\frac{19}{32}$	27.060	.837
		2	[b]27.760	.846
1/8	.060	3/8	29.460	.895
		9/16	29.200	.893
		7/8	28.670	.887
		$1\frac{7}{32}$	26.570	.828
		$1\frac{19}{32}$	[b]27.320	.836
		2	26.930	.823
5/32	.070	15/32	29.470	.891
		9/16	29.090	.890
		7/8	29.680	.919
		$1\frac{7}{32}$	29.320	.909
		$1\frac{19}{32}$	29.320	.908
		2	27.390	.847
3/16	.080	9/16	29.830	.918
		7/8	28.760	.868
		$1\frac{7}{32}$	29.420	.908
		$1\frac{19}{32}$	28.540	.874
		2	30.260	.962
1/4	.090	3/4	29.660	.893
		7/8	29.510	.899
		$1\frac{7}{32}$	29.190	.900
		$1\frac{19}{32}$	28.560	.882
		2	27.830	.855

[b]Average of two tests.

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TABLE 1.– NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS – Concluded

Diam. of rivets d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (ksi)
$t_S = 0.102$ in.; $b_S = 7.65$ in.; L = 6.42 in.; W = 38.89 in.; $\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 75$; $\frac{b_W}{t_W} = 20$				
3/32	0.050	9/32	25.830	0.829
		9/16	24.880	.801
		7/8	23.280	.751
		$1\frac{7}{32}$	23.260	.748
		$1\frac{19}{32}$	21.000	.661
		2	18.820	.604
1/8	.060	3/8	26.520	.851
		9/16	26.610	.860
		7/8	24.430	.784
		$1\frac{7}{32}$	23.720	.763
		$1\frac{19}{32}$	22.005	.710
		2	19.880	.643
5/32	.070	15/32	25.780	.831
		9/16	26.710	.841
		7/8	25.490	.820
		$1\frac{7}{32}$	24.300	.781
		$1\frac{19}{32}$	24.480	.793
		2	23.980	.756
3/16	.080	9/16	27.550	.924
		7/8	26.000	.819
		$1\frac{7}{32}$	25.070	.806
		$1\frac{19}{32}$	25.140	.813
		2	21.380	.681
1/4	.090	3/4	26.380	.847
		7/8	27.220	.854
		$1\frac{7}{32}$	24.920	.787
		$1\frac{19}{32}$	24.150	.778
		2	26.000	.835

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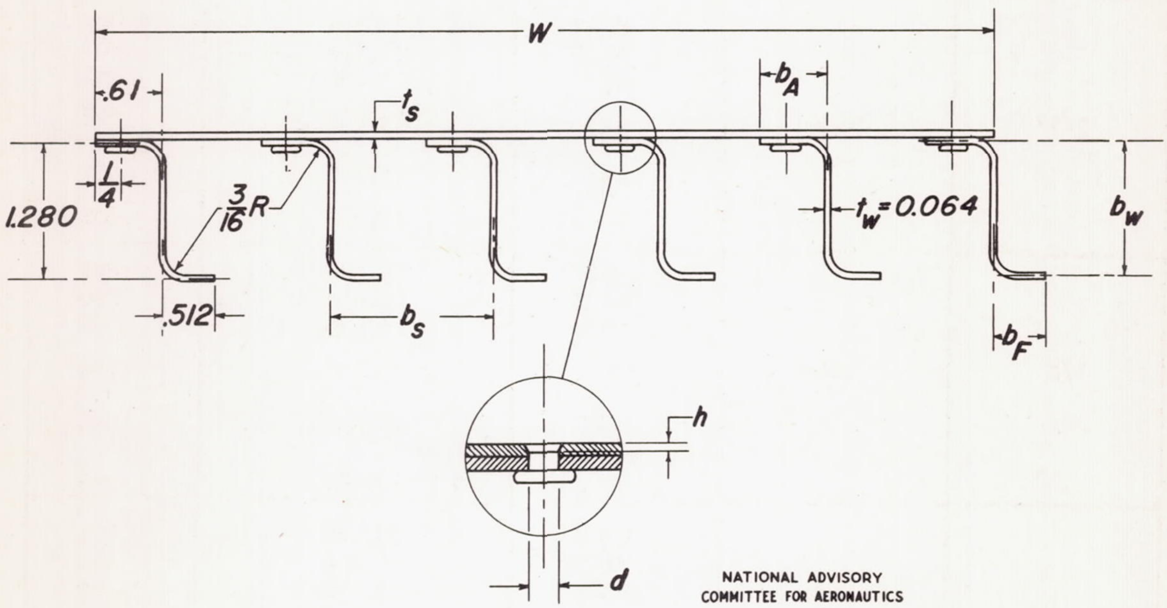


Figure 1.- Cross section of test specimens.

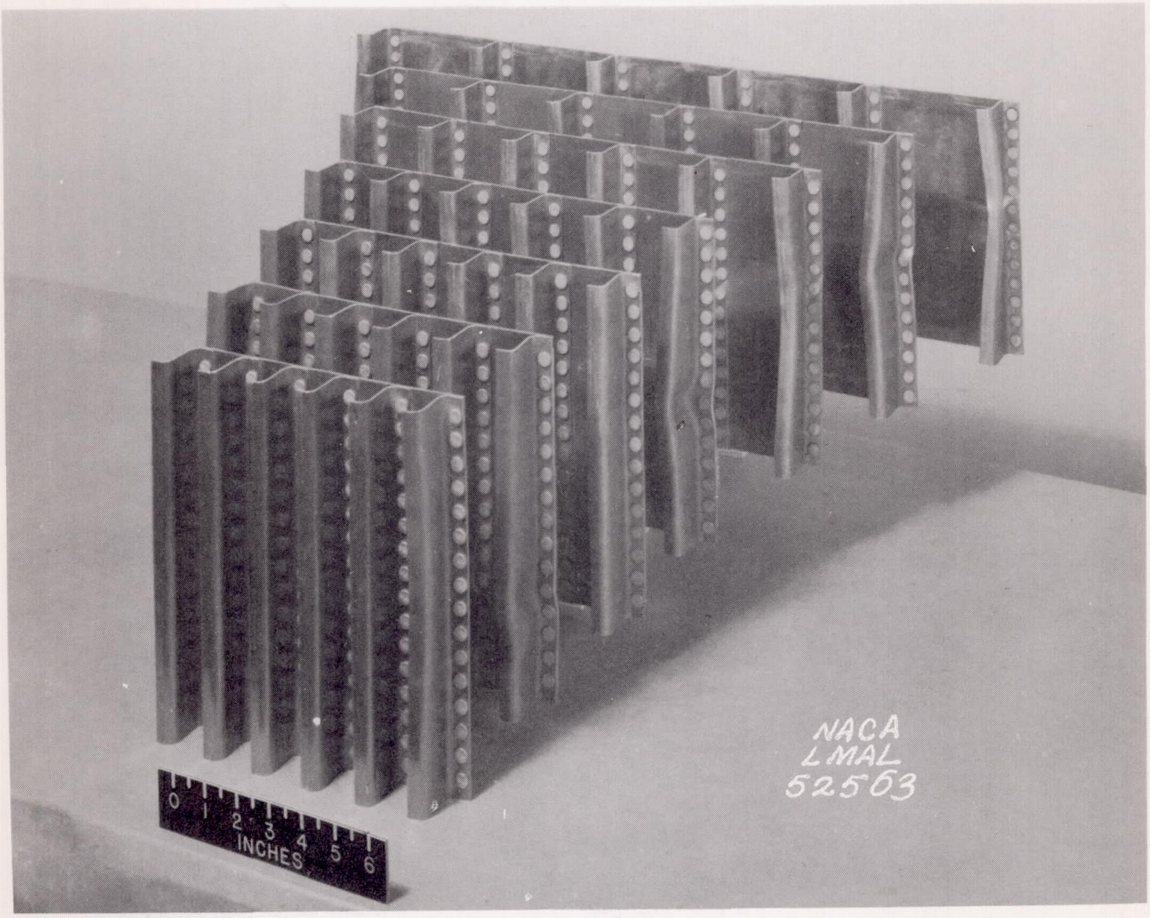
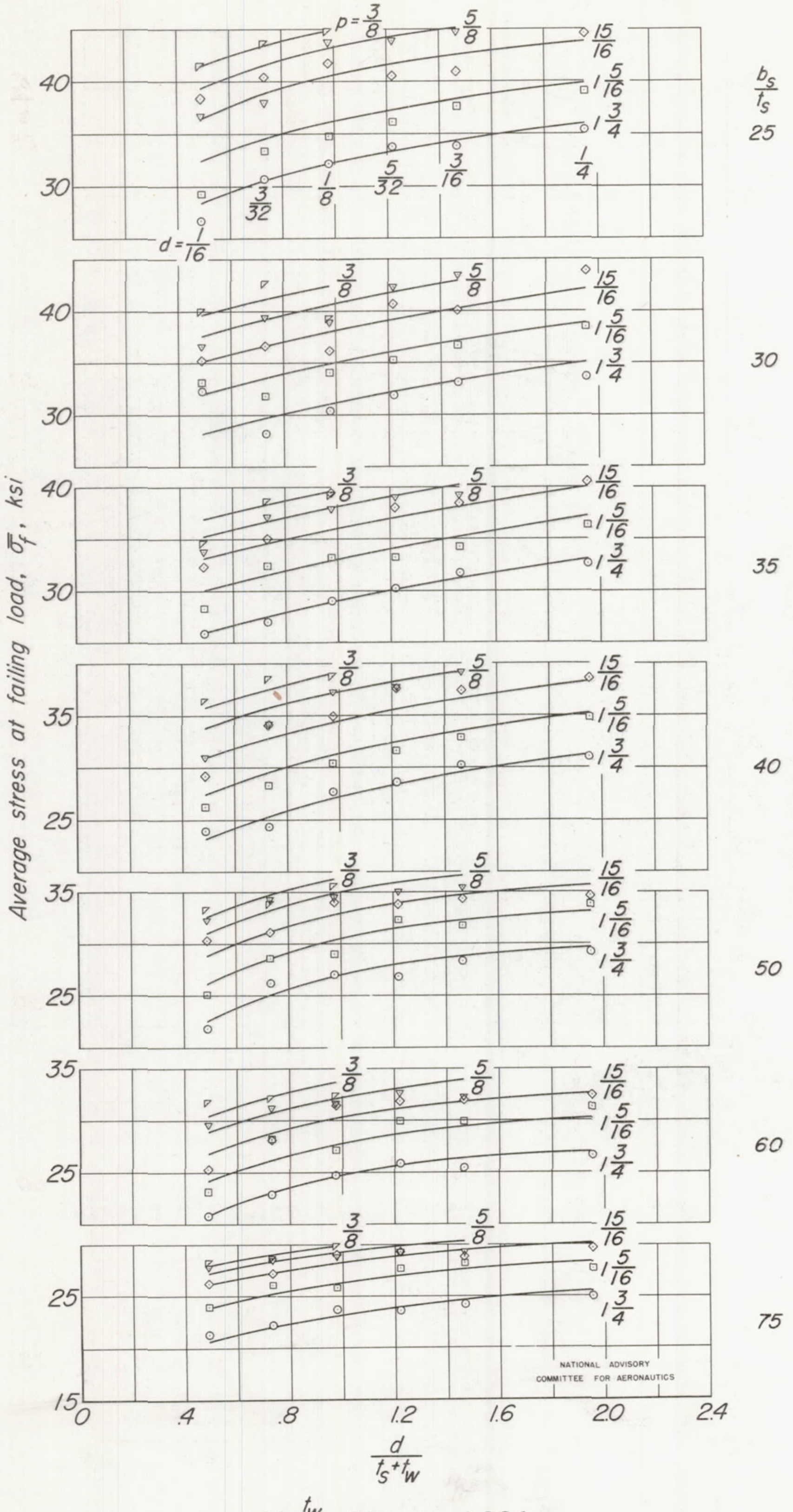
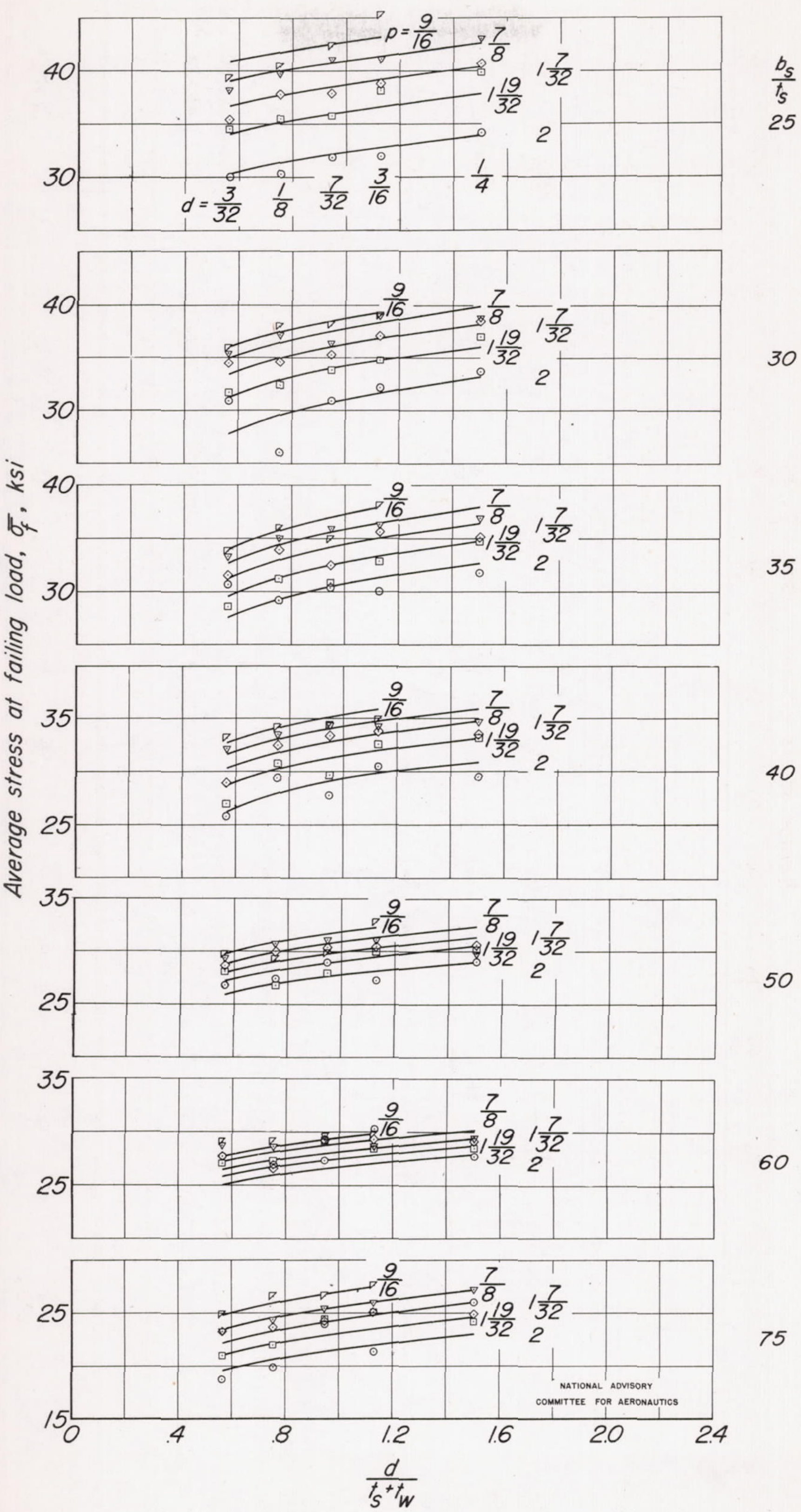


Figure 2.- Typical specimens after failure.



(a) $\frac{t_w}{t_s} = 1.00$; $t_s = 0.064$.

Figure 3.- Variation in compressive strength of panels with rivet diameter.



(b) $\frac{t_w}{t_s} = 0.63$; $t_s = 0.102$.

Figure 3.–Concluded.

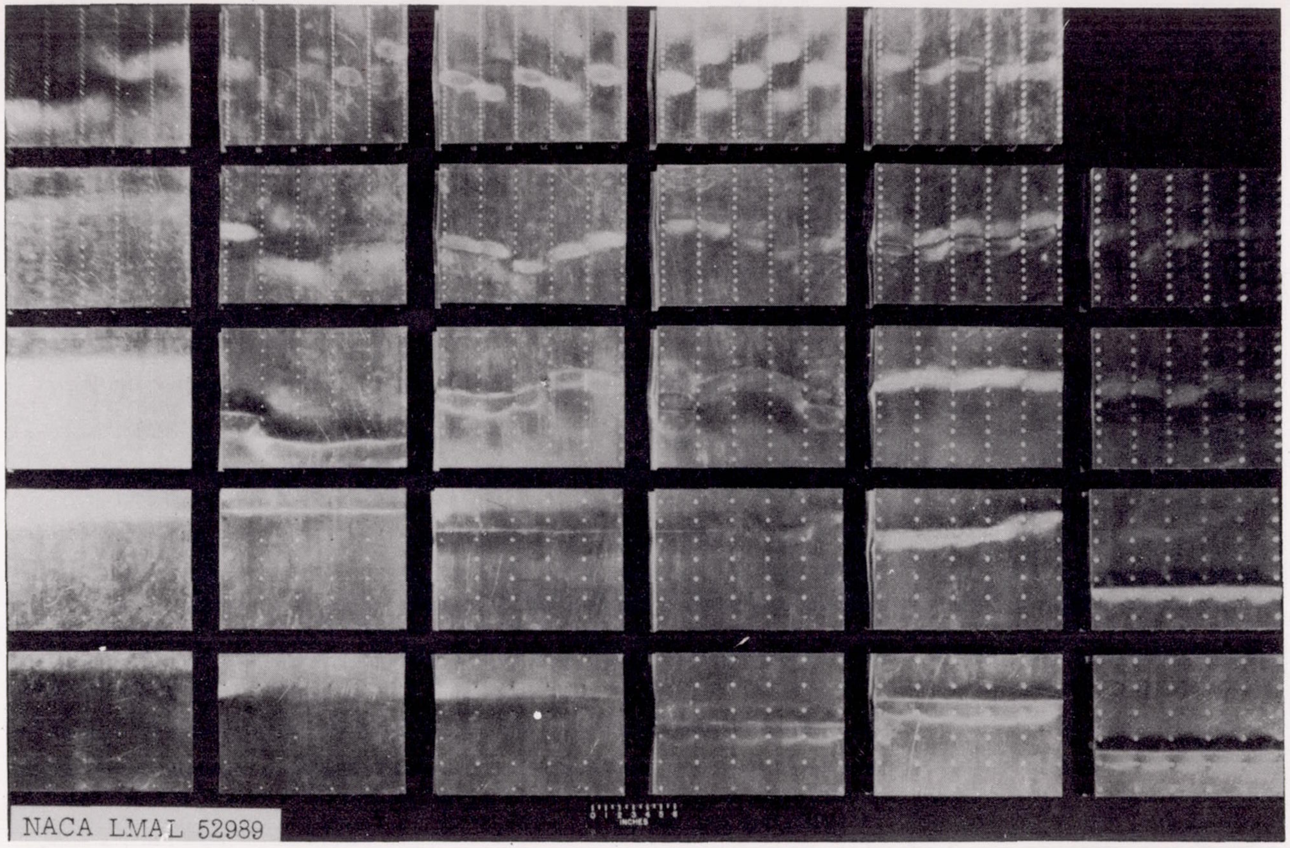


Figure 4.- Failure of panels having $\frac{b_S}{t_S} = 30$ and $\frac{t_W}{t_S} = 1.00$.