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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

By Norris F. Dow and William A. Hickman

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NACA

WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESTRICTED BULLETIN

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

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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 24S-T aluminum-alloy panels with longitudinal Z-section stiffeners. The panels were selected on the basis of available design charts, and the panel proportions were limited to the region of these charts in which the panels have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners and have such length that failure is by local buckling. The results showed that for these panels the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets. Data are also presented from which the rivet diameter and pitch required to develop a given stress in the panels may be determined.

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 stiffeners 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. Because reference 2 indicates that the local-buckling strength of panels having triangular stiffeners at close spacings could be varied over a wide range by varying the rivet diameter, an investigation is being conducted in the Langley structures research laboratory of the NACA to determine the effect of varying 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 first series of tests for the investigation. The tests of reference 1 were made on approximately 700 panels and, since any number of combinations of rivet diameter and pitch is possible for each panel, the results of the tests on the 140 panels reported herein can cover only a very small region on the design charts of reference 1. The region so far investigated is the local-buckling region of panels having the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners of the panels given in reference 1. Panels of these proportions were chosen to be the first investigated because the connection of stiffeners to sheet is believed to be most critical for such panels. Further testing will be required to determine the effect of rivet size and pitch on longer panels, particularly on panels of maximum structural efficiency in which failure occurs as a combination of local buckling and bending as a column.

SYMBOLS

L length of specimen

ρ radius of gyration

L/ρ slenderness ratio

W width of specimen

b_S spacing of stiffeners on sheet

b_A width of attachment flange of stiffeners

b_W width of web of stiffeners

b_F width of outstanding flange of stiffeners

t_S thickness of sheet

t_W thickness of web of stiffeners

d diameter of rivets

p pitch of rivets

h depth of countersink for rivets

σ_{cy} compressive yield stress for the material

$\bar{\sigma}_f$ average compressive stress at failing load for any specimen

P_1 compressive load per inch of panel width

c coefficient of end-fixity in the Euler column formula

TEST SPECIMENS AND METHOD OF TESTING

The specimens consisted of 24S-T aluminum-alloy panels having Z-type stiffeners, as shown in figure 1. The stiffeners on all panels were identical. The sheet thickness was varied to give five selected ratios of stiffener thickness to sheet thickness: $\frac{t_W}{t_S}$ = 1.25, 1.00, 0.79, 0.63, and 0.51. The proportions $\frac{b_S}{t_S} = 25$, $\frac{b_W}{t_W} = 20$, $\frac{b_A}{t_W} = 9.5$, and $\frac{b_F}{b_W} = 0.4$ were chosen to give the panels of reference 1 that have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners. The lengths of the panels were so chosen $\left(\frac{L}{\rho} = 20\right)$ that no column failures occurred. Accordingly, the term "compressive strength" as applied herein to the panels of the present investigation is used to indicate the strength of the panels for local buckling failures of the general types shown in figure 2.

Tests were made to determine the material properties of the sheet used for the construction of the specimens. The maximum with-grain compressive yield stress σ_{cy} obtained for the material used for the construction of the specimens was 46.0 ksi. The minimum value of σ_{cy} obtained was 41.3 ksi. The average value of σ_{cy} obtained from the results of tests of stress-strain specimens cut from all the sheets of material used in the construction of the panels was 43.7 ksi. The foregoing values of σ_{cy} represent the with-grain properties of the flat-sheet material before forming.

The rivets used throughout the investigation were A17S-T flat-head rivets (AN442AD). Both the size 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 countersink used are given in table 1.

Ultimate compressive loads for the 140 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 flat and parallel before testing to insure an even distribution of load over the panel.

RESULTS

Because the present investigation covers only the local-buckling region of a small part of the design charts of reference 1, no attempt is made herein to present the data by plotting the average stress at failing load $\bar{\sigma}_f$ against the parameter $\frac{P_i}{L/\sqrt{c}}$, as in reference 1. Instead, $\bar{\sigma}_f$ is plotted against the ratio of rivet diameter to the sum of thicknesses of sheet and stiffener $\frac{d}{t_S+t_W}$ in figure 3 in order to present the results in a manner similar to that used in reference 2. Numerical values of $\bar{\sigma}_f$ and $\frac{P_i}{L/\sqrt{c}}$, however, are listed in table 1. Figure 3 shows that, for all values of t_W/t_S investigated, the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

Figure 3 indicates that no substantial increase occurs in panel strength for values of $\frac{d}{t_S+t_W}$ greater than approximately 1.5. Although the value of 1.5 is somewhat higher than the value of 1.25 obtained in reference 2 for triangular stiffeners with the particular rivet pitches investigated therein, the curves of figure 3 show only small increases in panel strength above values of $\frac{d}{t_S+t_W}$ of 1.25.

The rivet pitch required to develop a given stress in panels of the proportions used herein may be determined from figure 3. For example, if it is desired to develop a stress equal to the average yield stress of the material (in this case 43.7 ksi) figure 3 indicates that at a rivet diameter 1.5 times the over-all (sheet plus stiffener) thickness a rivet pitch of less than 7/8 inch is required for each of the five values of t_W/t_S investigated.

CONCLUDING REMARKS

Results are presented of tests to determine the effect of varying rivet diameter and rivet pitch on the compressive strength of 24S-T aluminum-alloy panels with Z-section stiffeners. The panels were selected on the basis of available design charts, and the panel proportions were limited to the region of these charts in which the panels have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners and have such length that failure occurs by local buckling. The results showed that the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets. Data are also presented from which the rivet diameter and pitch required to develop a given stress in the panels may be determined.

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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.: Preliminary Investigation of the Relation of the Compressive Strength of Sheet-Stiffener Panels to the Diameter of Rivet Used for Attaching Stiffeners to Sheet. NACA RB No. L4I13, 1944.

TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER

t_S = 0.051 in.; b_S = 1.28 in.; L = 10.50 in.; W = 7.02 in.; $\frac{t_W}{t_S} = 1.25$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)
1/16	0.035	3/16	44.000	1.304
		3/8	[a]43.750	1.304
		5/8	[a]37.350	1.093
		15/16	34.500	1.014
		$1\frac{5}{16}$	[a]30.350	.902
		$1\frac{3}{4}$	[a]30.175	.895
3/32	.040	9/32	44.600	1.329
		3/8	[a]44.825	1.357
		5/8	[a]41.900	1.217
		15/16	37.650	1.119
		$1\frac{5}{16}$	34.900	1.044
		$1\frac{3}{4}$	[a]32.470	.961
1/8	.050	3/8	44.840	1.331
		5/8	44.100	1.278
		15/16	39.400	1.173
		$1\frac{5}{16}$	36.100	1.078
		$1\frac{3}{4}$	[a]35.575	1.069
5/32	.060	15/32	44.950	1.351
		5/8	45.100	1.308
		15/16	40.750	1.208
		$1\frac{5}{16}$	[a]37.425	1.120
		$1\frac{3}{4}$	36.125	1.086
3/16	.060	9/16	45.900	1.418
		5/8	45.300	1.312
		15/16	42.150	1.255
		$1\frac{5}{16}$	[a]37.850	1.132
		$1\frac{3}{4}$	[a]36.615	1.103
1/4	.060	3/4	43.000	1.290
		15/16	42.750	1.280
		$1\frac{5}{16}$	39.400	1.178
		$1\frac{3}{4}$	36.600	1.080

[a]Average of two tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER - Continued

$t_S = 0.064$ in.; $b_S = 1.60$ in.; $L = 10.40$ in.; $W = 8.64$ in.;

$\frac{t_W}{t_S} = 1.00$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$

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	43.050	1.233
		3/8	41.450	1.180
		5/8	[a]36.855	1.013
		15/16	[a]38.380	1.093
		$1\frac{5}{16}$	29.300	.840
		$1\frac{3}{4}$	26.700	.768
3/32	.040	9/32	44.800	1.303
		3/8	43.500	1.245
		5/8	[a]38.070	1.069
		15/16	[a]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	[a]43.735	1.227
		15/16	[a]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
		$1\frac{3}{4}$	[a]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
		$1\frac{3}{4}$	[a]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]Average of two tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER- Continued

t_S = 0.081 in.; b_S = 2.03 in.; L = 10.06 in.; W = 10.77 in.;
$\frac{t_W}{t_S} = 0.79$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$

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)
3/32	0.040	9/32	42.500	1.247
		9/16	41.500	1.209
		7/8	[a]37.550	1.074
		$1\frac{7}{32}$	[a]36.935	1.082
		$1\frac{19}{32}$	32.900	.964
		2	27.610	.807
1/8	.060	3/8	43.700	1.286
		9/16	42.800	1.253
		7/8	[a]39.420	1.130
		$1\frac{7}{32}$	37.550	1.090
		$1\frac{19}{32}$	34.820	1.013
		2	29.550	.858
5/32	.065	15/32	[a]43.900	1.273
		9/16	43.600	1.266
		7/8	40.655	1.161
		$1\frac{7}{32}$	38.800	1.131
		$1\frac{19}{32}$	34.750	1.018
		2	30.800	.892
3/16	.075	9/16	45.650	1.328
		7/8	40.845	1.173
		$1\frac{7}{32}$	40.100	1.167
		$1\frac{19}{32}$	35.900	1.056
		2	[a]31.280	.915
1/4	.080	3/4	44.200	1.327
		7/8	[a]42.750	1.228
		$1\frac{7}{32}$	[a]41.450	1.217
		$1\frac{19}{32}$	37.200	1.089
		2	33.000	.964

[a]Average of two tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER - Continued

t_S = 0.102 in.; b_S = 2.55 in.; L = 9.44 in.; W = 13.39 in.;

$\frac{t_W}{t_S} = 0.63$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$

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)
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	[a]43.590	1.431
		9/16	[a]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	[a]45.150	1.451
		7/8	[b]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	[a]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]Average of two tests.
[b]Average of three tests.

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TABLE 1.- NOMINAL DIMENSIONS OF Z-STIFFENED PANELS AND TEST RESULTS SHOWING EFFECTS OF VARYING RIVET PITCH AND RIVET DIAMETER - Concluded

$t_S = 0.125$ in.; $b_S = 3.13$ in.; $L = 8.70$ in.; $W = 16.27$ in.;

$\frac{t_W}{t_S} = 0.51$; $\frac{b_S}{t_S} = 25$; $\frac{b_W}{t_W} = 20$

Diam. of rivets, d (in.)	Depth of countersink, h (in.)	Pitch of rivets, p (in.)	Average stress at failing load, $\bar{\sigma}_f$ (ksi)	$\frac{Pi}{L/\sqrt{c}}$ (ksi)
1/8	0.070	3/8	42.000	1.595
		9/16	41.200	1.563
		7/8	39.190	1.463
		$1\frac{7}{32}$	38.050	1.440
		$1\frac{19}{32}$	[a]37.425	1.409
		2	33.600	1.260
5/32	.080	15/32	41.600	1.593
		9/16	41.350	1.558
		7/8	40.150	1.489
		$1\frac{7}{32}$	[a]38.805	1.475
		$1\frac{19}{32}$	36.200	1.360
		2	34.500	1.296
3/16	.090	9/16	42.700	1.635
		7/8	41.180	1.538
		$1\frac{7}{32}$	39.450	1.488
		$1\frac{19}{32}$	37.500	1.410
		2	34.900	1.313
1/4	.100	3/4	[a]42.600	1.609
		7/8	42.200	1.584
		$1\frac{7}{32}$	41.400	1.566
		$1\frac{19}{32}$	38.560	1.452
		2	[a]37.150	1.396

[a]Average of two tests.

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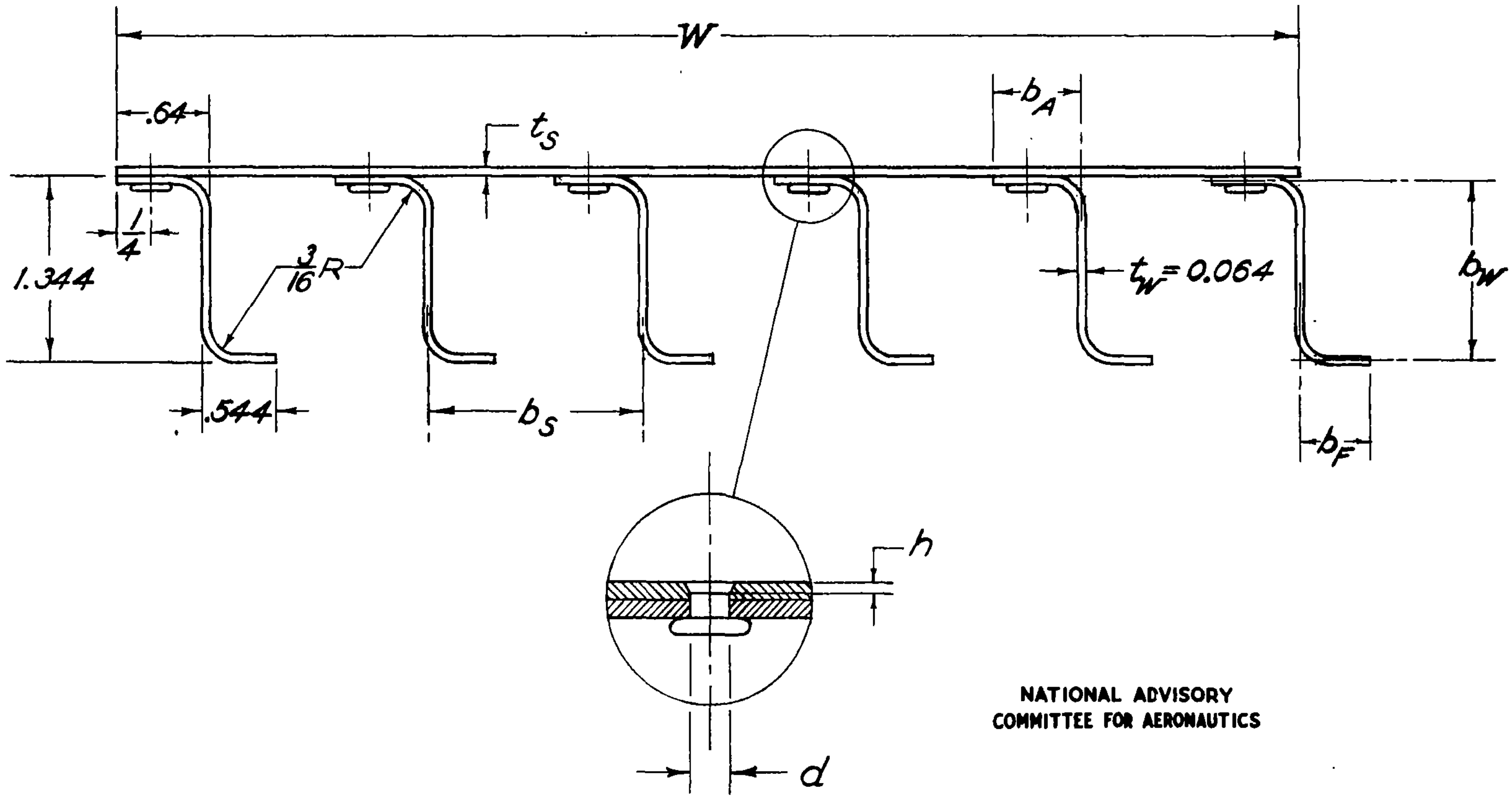

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Figure 1.– Cross section of test specimens.

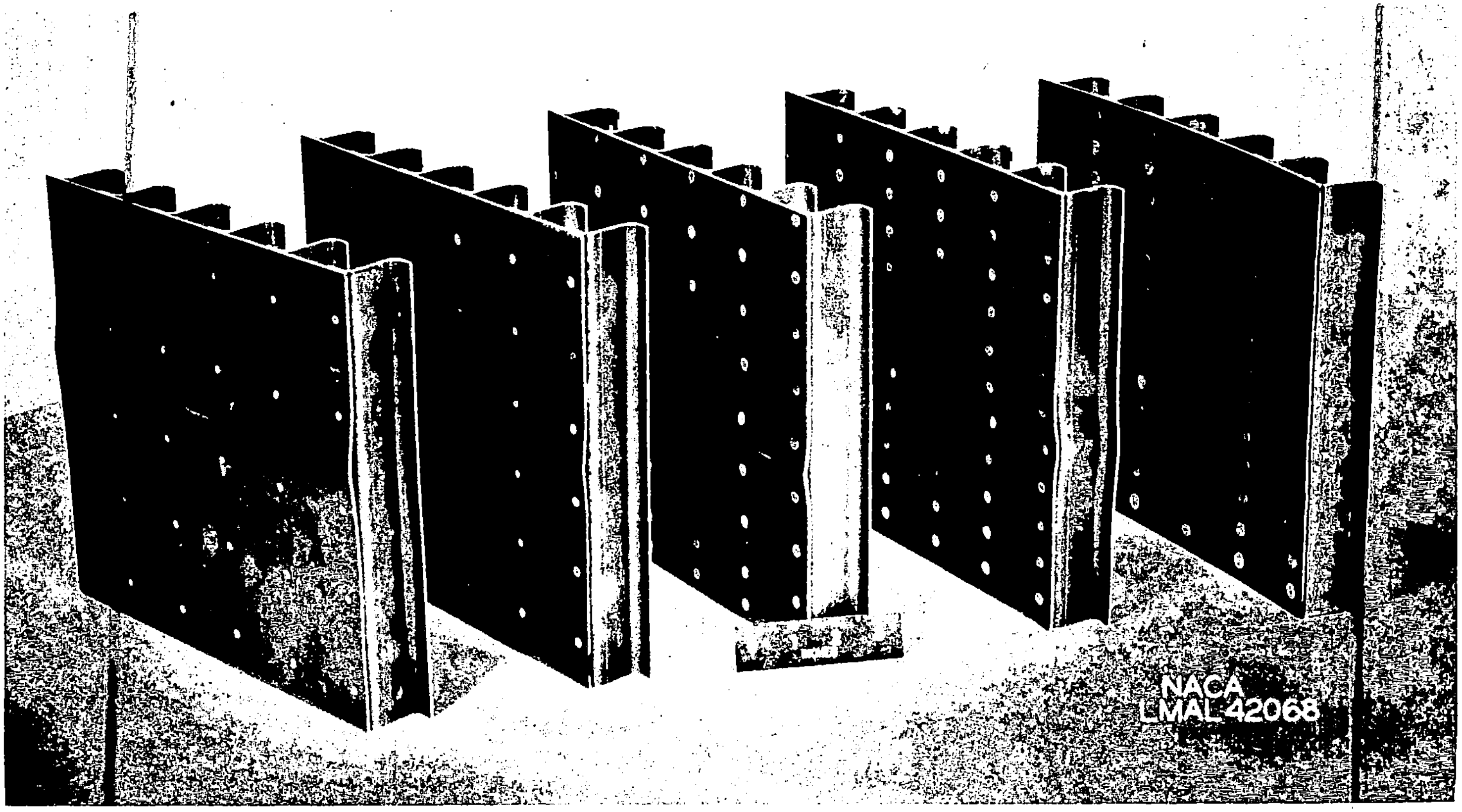

Figure 2.- Test specimens after failure.

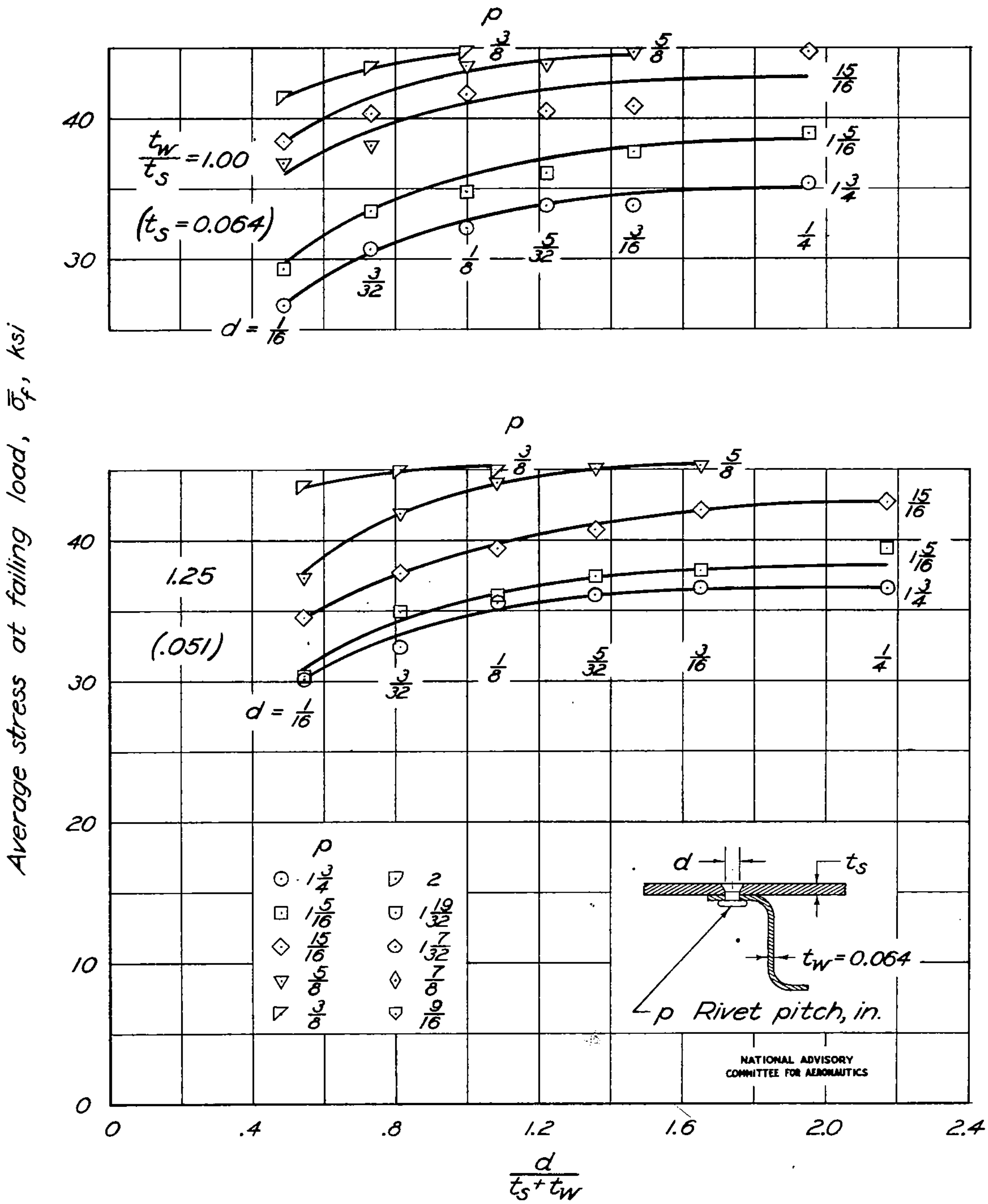

Figure 3.- Variation in local buckling strength of panels with rivet diameter.

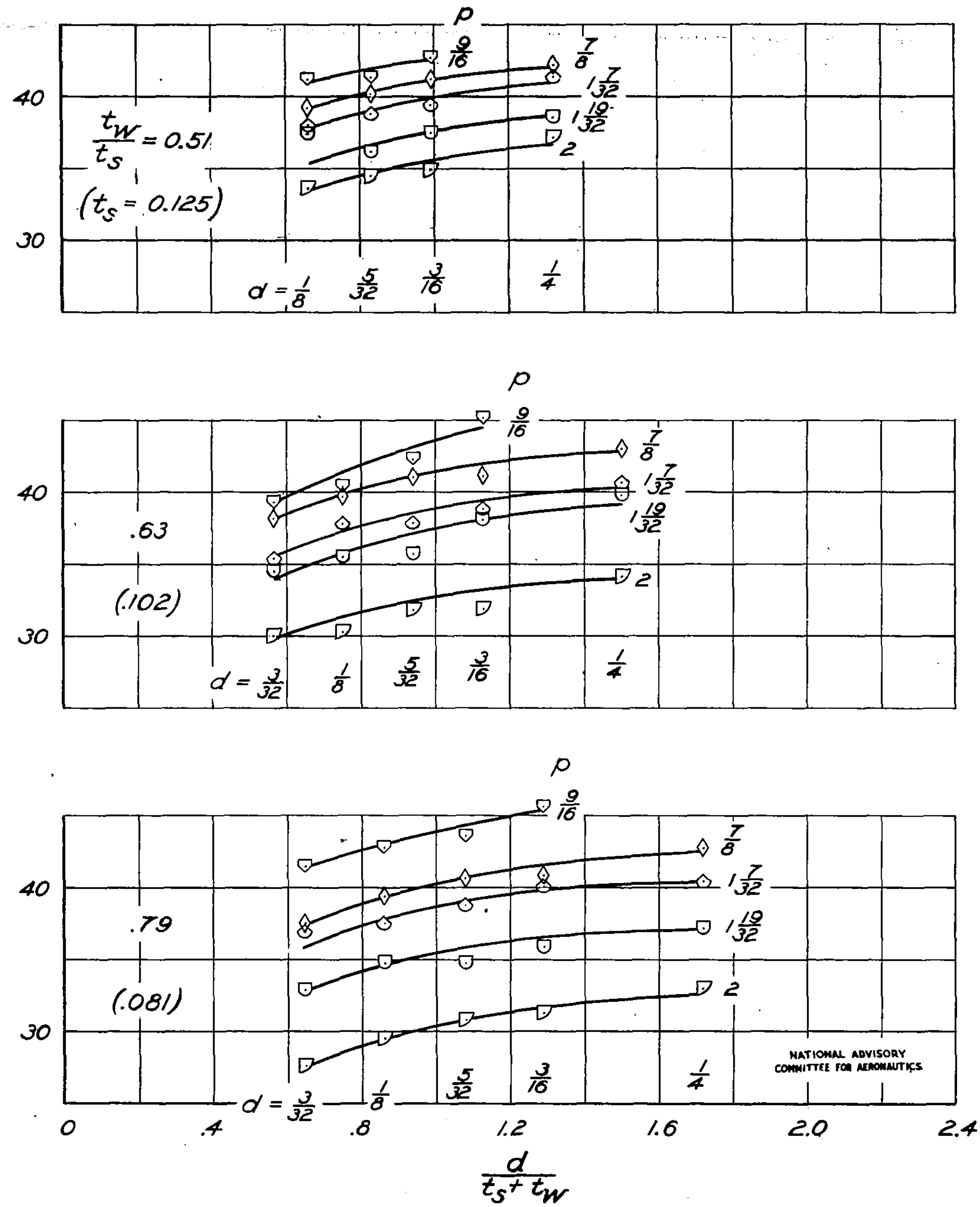

Figure 3.—Concluded.