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EFFECT OF STRAIN RATE ON THE STRENGTH PROPERTIES OF SINGLE AND MULTIPLE RIVETED LAP AND BUTT JOINTS

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FOREWORD

This report was prepared by the Metals Branch and was conducted under Project No. 7360, "Materials Evaluation and Evaluation Techniques", Task No. 73605, "Design Data for Metals", formerly RDO No. 614-13, "Design and Evaluation Data for Structural Metals", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. R. F. Klinger acting as project engineer. The original data are recorded in United States Air Force "Engineering Project Record Book No. 1776".

Since the completion of this report a new aluminum alloy designation system has been established by the Aluminum Association. The new designations have not been used in this report but are listed below for convenient reference:

Old Designation	New Designation
24S-T31	2024-T31
A17S-T3	2117-T3
75S-T6	7075-T6

ABSTRACT

Slow and rapid loading tensile shear tests were conducted at room temperature on single and multiple rivet lap joints and also on butt joints with multiple riveted cover plates. The rivets were made of 24S-T31 and A17S-T3 aluminum alloys in 1/8 inch and 3/16 inch diameters. The sheet material used was 0.064 inch and 0.072 inch clad 75S-T6 aluminum alloy. The joints were fabricated by standard machine riveting and shop practice. The ultimate strengths of the joints were determined with times to the ultimate load of 0.03 seconds and one minute. All failures were by rivet shear. No pronounced effect of rapid loading on the ultimate strength of any of the riveted joints tested was found although a slight trend toward decreasing strength was observed.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

INTRODUCTION

This work was conducted to determine the effect of rapid loading on the ultimate strength of single and multiple riveted lap and butt joints. Rapid loading conditions are developed in aircraft and missile structures where times to reach peak loads are in the vicinity of 0.01 second. These rapid loading rates may be reduced for large sections by inertia effects but can be of a very rapid nature at concentrated locations such as attachment points. Since design is based on rivet joint properties obtained during slow loading and some applications involve rapid loading, a better understanding of the relationship between static and rapid loading properties of riveted joints should be established. To partially establish this relationship, slow and rapid loading tests were conducted on single rivet lap joints, multiple rivet lap joints and multiple rivet butt joints of typical aluminum alloy rivet and sheet materials.

MATERIAL AND PROCEDURE

The riveted joints used in this investigation were manufactured by standard machine and shop practice. The joints were designed to provide failure by rivet shear. Three types of joints were tested. One was a single rivet lap joint shown in Figure 1, the second, single row lap joint of 4 rivets and the third, a single row butt joint of 6 rivets. The last two specimen types are shown in Figure 2. Each of the three joint types were manufactured with 0.064 inch and 0.072 inch clad 75S-T6 aluminum alloy using 1/8 inch and 3/16 inch diameter rivets. Also, 24S-T31 and A17S-T3 aluminum alloy rivets were investigated. The edge distances of 1.5D and 2D and rivet spacings of 3/4 inch and 1/2 inch were used. A complete tabulation of the types of specimens studied is given in Table I.

Two specimens of each type were tested at a slow loading rate in a universal testing machine. The loading rate was maintained constant and was at a rate to produce failure in the joint in about one minute. Two specimens of each type were tested at a high loading rate in a General Motors Rapid Loading Machine. The time to failure at the high loading rate was about 0.03 seconds.

The strength for the rapid loading rate was measured by means of a series dynamometer and Consolidated Engineering Corporation Type 5-114P4 oscillograph and Type 7-218 galvanometer. The dynamometer consisted of a modified flat tensile specimen with ends arranged for bolt and pin loading to the specimen and machine. The dynamometer gage section was of sufficient size to prevent exceeding the proportional limit when maximum joint load was applied. Two A17-2 SR-4 strain gages were applied to each side of the dynamometer. The two gages on the same side of the dynamometer were series wired and incorporated into a wheatstone bridge. The output was fed to the oscillograph galvanometer. The dynamometer was calibrated by applying known loads and measuring the galvanometer deflection. The dynamometer was found to have a linear relation to load applied. Each record was calibrated for load by inserting a parallel resistance into the bridge circuit providing a galvanometer deflection representing a given load. The oscillograph provided a time calibrated paper speed of 115 in/sec which combined with the dynamometer load indication gave a trace of time versus load. The time was measured to the failure point of the joint and the maximum load carried by the joint calculated from measurements made to 0.01 inch from the calibration deflection and the load-time trace. A more complete description of the application of rapid loading instrumentation is given in AF Technical Report No. 5899, "Tensile Properties of Some Aircraft Structural Materials at Various Rates of Loading."

DISCUSSION OF RESULTS

The results very generally indicate trend toward lower ultimate load with increased loading rate. This trend appears to be independent of the joint type, rivet diameter, rivet spacing and sheet material as investigated. The above trend can be said to exist very generally because only two specimens were tested for each condition and this does not allow for a reasonably accurate evaluation of each test condition. Additional tests would establish more definite relationships.

Of the eight conditions tested using single riveted specimens, five showed practically no change in ultimate load under rapid loading and three showed slight decreases. In the three conditions showing decreases in ultimate load there was one case of overlapping results. That is, the ultimate load for one of the specimens tested in rapid loading was greater than the ultimate load of at least one of the specimens tested with slow loading.

In the multiple rivet lap joint specimens seven of the eight conditions showed a decrease or no change in ultimate load under rapid loading and only one of those showing a decrease is a case of overlapping results.

The multiple rivet butt joint specimens showed a decrease in ultimate load at rapid loading in five of the eight conditions with two remaining specimens showing practically no change. There was no case of overlapping results in the conditions showing decreases.

The consistency of results is better for the multiple rivet specimens where the drop in ultimate load with higher loading rate is better defined than in the case of the single rivet specimens.

Though there is a trend toward lower ultimate load with greater loading rate for the rivet joints investigated, no effect comparable to that obtained at the California Institute of Technology in 1947 was found. The above work was reported in a thesis "A Study of the Effects of Rapidly Applied Loads and Repeated Loads on Countersunk Riveted Joints" by Lt Comdr O. A. Seli and Lt. W. E. Ditch, USN, but is unpublished. In that work very significant drops in ultimate strength of about 30% were reported for countersunk butt joints at a rapid loading rate comparable to that used in this work. The specimens reported herein did not duplicate the countersunk condition studied by the California Institute of Technology. However, the specimen difference does not appear to supply the reason for the large difference in the effect of rapid loading found in these two investigations.

The conflicting results found in the effect of loading rate indicate that a more complete program should be established to produce more definite indications of riveted joint strength under rapid loading.

CONCLUSIONS

The ultimate loads of the riveted joints tested were not appreciably affected by rapid loading (0.03 second to failure) although there is a slight trend toward lower ultimate joint loads at the higher rate of loading.

The rapid loading effects appeared to be independent of the joint variables investigated.

A larger number of joint specimens and variables should be tested to establish a more definite static-rapid loading relationship.

Table I

Types of Rivet Specimens Tested

Rivet Type (1)	Edge Distance E, in	Sheet Thickness T, in	Sheet Width W, in	Rivet Spacing S, in
Single Rivet Lap Joint				
AN430AD4-6	3/16	.064	1	—
"	1/4	"	"	—
AN430AD6-8	9/32	.072	1-1/2	—
"	3/8	"	"	—
AN430DD4-6	3/16	.064	1	—
"	1/4	"	"	—
AN430DD6-8	9/32	.072	1-1/2	—
"	3/8	"	"	—
Multiple Rivet Lap Joint				
AN430AD4-6	3/16	.064	2	1/2
"	1/4	"	"	"
AN430AD6-8	9/32	.072	3	3/4
"	3/8	"	"	"
AN430DD4-6	3/16	.064	2	1/2
"	1/4	"	"	"
AN430DD6-8	9/32	.072	3	3/4
"	3/8	"	"	"
Multiple Rivet Butt Joint				
AN430AD4-6	3/16	.064	1-3/4	1/2
"	1/4	"	"	"
AN430AD6-8	9/32	.072	2-5/8	3/4
"	3/8	"	"	"
AN430DD4-6	3/16	.064	1-3/4	1/2
"	1/4	"	"	"
AN430DD6-8	9/32	.072	2-5/8	3/4
"	3/8	"	"	"

Notes (1)
AN430=Air Force - Navy Aeronautical Standard
AD=A17S-T3 aluminum alloy; DD=24S-T31 aluminum alloy
First number following AD or DD=Rivet diameter in 1/32"
Second number following AD or DD= Rivet length in 1/32"

Table II

Test Results on Single Rivet Specimens-Lap Joint

Spec. No.	Ultimate Load, Lb Slow Loading	Ultimate Load, Lb Rapid Loading
1/8" D A17S-T Al Alloy Rivets 0.064" Sheet, 1.5 x D Edge Distance		
1	464	470
2	484	460
Avg	474	465
% Change		-2
2 x D Edge Distance		
1	459	480
2	472	459
Avg	466	470
% Change		+1
1/8" D 24S-T Al Alloy Rivets 0.064" Sheet, 1.5 x D Edge Distance		
1	598	586
2	596	566
Avg	597	576
% Change		-4
2 x D Edge Distance		
1	584	561
2	572	582
Avg	578	572
% Change		-1

Spec. No.	Ultimate Load, Lb Slow Loading	Ultimate Load, Lb Rapid Loading
3/16" D A17S-T Al Alloy Rivets 0.072 Sheet, 1.5 x D Edge Distance		
1	1106	1042
2	1068	1109
Avg	1087	1076
% Change		-1
2 x D Edge Distance		
1	1106	1052
2	1168	1071
Avg	1137	1062
% Change		-7
3/16" D 24S-T Al Alloy Rivets 0.072" Sheet, 1.5 x D Edge Distance		
1	1244	1215
2	1238	1291
Avg	1241	1253
% Change		+1
2 x D Edge Distance		
1	1366	1188
2	1230	1251
Avg	1298	1220
% Change		-6

All Failures - Rivet Shear
All Sheet Material 75S-T Aluminum Alloy

Table III

Test Results on Multiple Rivet Specimens-Lap Joint

Spec. No.	Ultimate Load, Lb Slow Loading	Ultimate Load, Lb Rapid Loading
1/8" D A17s-T Al Alloy Rivets 0.064" Sheet		
1.5 x D Edge Distance		
1	1865	1730
2	1860	1715
Avg	1863	1723
% Change		-8
2 x D Edge Distance		
1	1870	1860
2	1950	1850
Avg	1910	1855
% Change		-3
1/8" D 24S-T Al Alloy Rivets 0.064" Sheet		
1.5 x D Edge Distance		
1	2265	2230
2	2450	2320
Avg	2358	2275
% Change		-4
2 x D Edge Distance		
1	2260	2340
2	2240	2240
Avg	2250	2290
% Change		+2

Spec. No.	Ultimate Load, Lb Slow Loading	Ultimate Load, Lb Rapid Loading
3/16" D A17S-T Alloy Rivets 0.072" Sheet		
1.5 x D Edge Distance		
1	4425	4400
2	4440	4500
Avg	4433	4450
% Change		0
2 x D Edge Distance		
1	4240	4420
2	4320	4470
Avg	4280	4445
% Change		+4
3/16" D 24S-T Al Alloy Rivets 0.072" Sheet		
1.5 x D Edge Distance		
1	5410	5420
2	5490	5520
Avg	5450	5470
% Change		0
2 x D Edge Distance		
1	5480	5370
2	5680	5230
Avg	5580	5300
% Change		-5

All Failures-Rivet Shear
All Sheet Material 75S-t Aluminum Alloy

Table IV

Test Results on Multiple Rivet Specimens-Butt Joint

Spec. No.	Ultimate Load, Lb Slow Loading	Ultimate Load, Lb Rapid Loading
1/8" D A17S-T Al Alloy Rivets 0.064" 75S-T Al Alloy Sheet 1.5 x D Edge Distance		
1	1465	1355
2	1440	1405
Avg	1453	1380
% Change		-5
2 x D Edge Distance		
1	1410	1380
2	1438	1405
Avg	1424	1393
% Change		-2
1/8" D 24S-T Al Alloy Rivets 0.064" 75S-T Al Alloy Sheet 1.5 x D Edge Distance		
1	1840	1820
2	1860	1784
Avg	1850	1802
% Change		-3
2 x D Edge Distance		
1	1742	1662
2	1725	1690
Avg	1734	1676
% Change		-3

Spec. No.	Ultimate Load, Lb Slow Loading	Ultimate Load, Lb Rapid Loading
3/16" D A17S-T Al Alloy Rivets 0.072" 75S-T Al Alloy Sheet 1.5 x D Edge Distance		
1	3270	3260
2	3285	3230
Avg	3278	3245
% Change		-1
2 x D Edge Distance		
1	3155	3210
2	3190	3170
Avg	3173	3190
% Change		+1
3/16" D 24S-T Al Alloy Rivets 0.072" 75S-T Al Alloy Sheet 1.5 x D Edge Distance		
1	4115	3960
2	4100	3910
Avg	4108	3935
% Change		-4
2 x D Edge Distance		
1	4130	4160
2	3950	4120
Avg	4040	4140
% Change		+2

All Failures - Rivet Shear
All Sheet Material 75S-T Aluminum Alloy

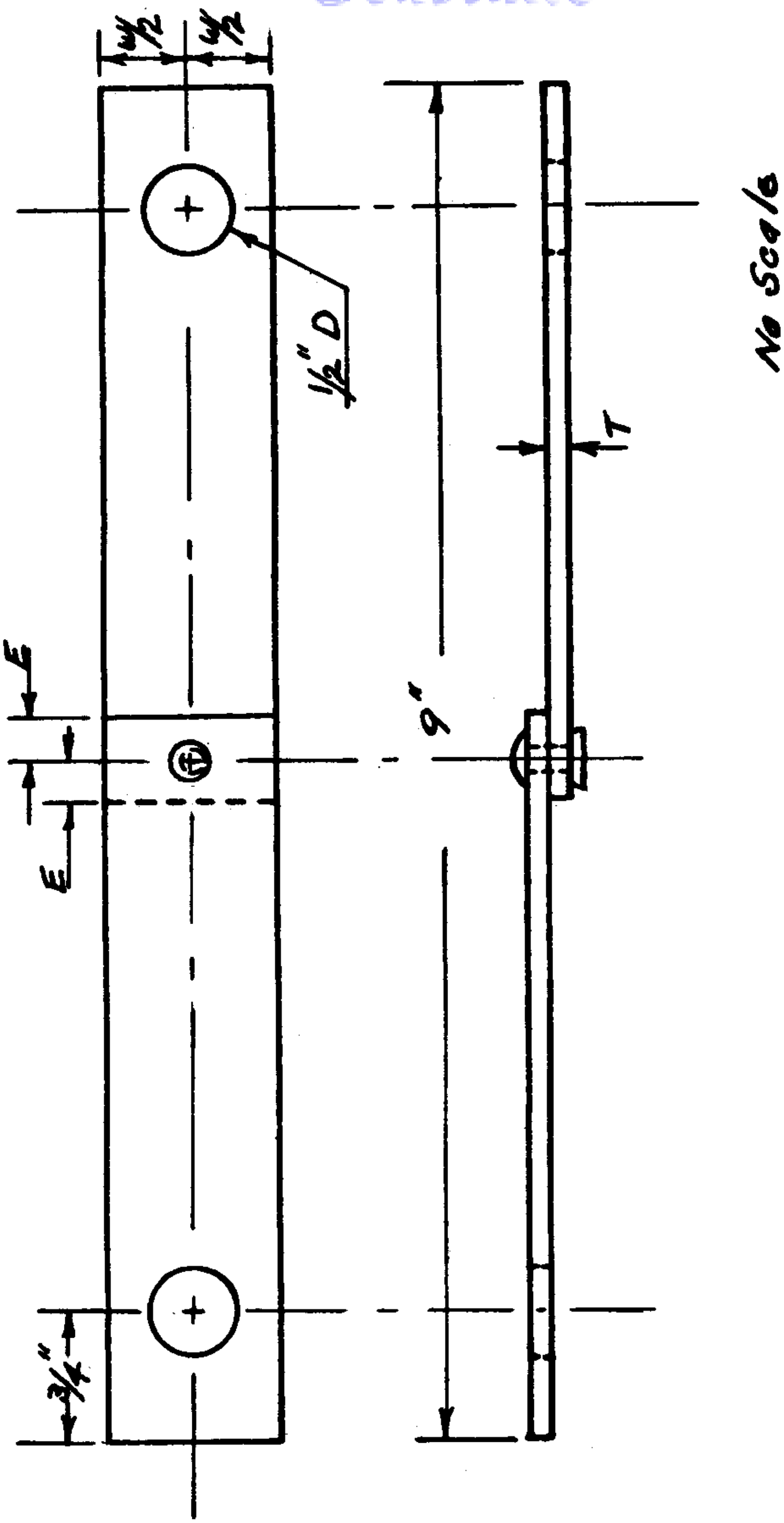

Figure 1 Single Rivet Specimen

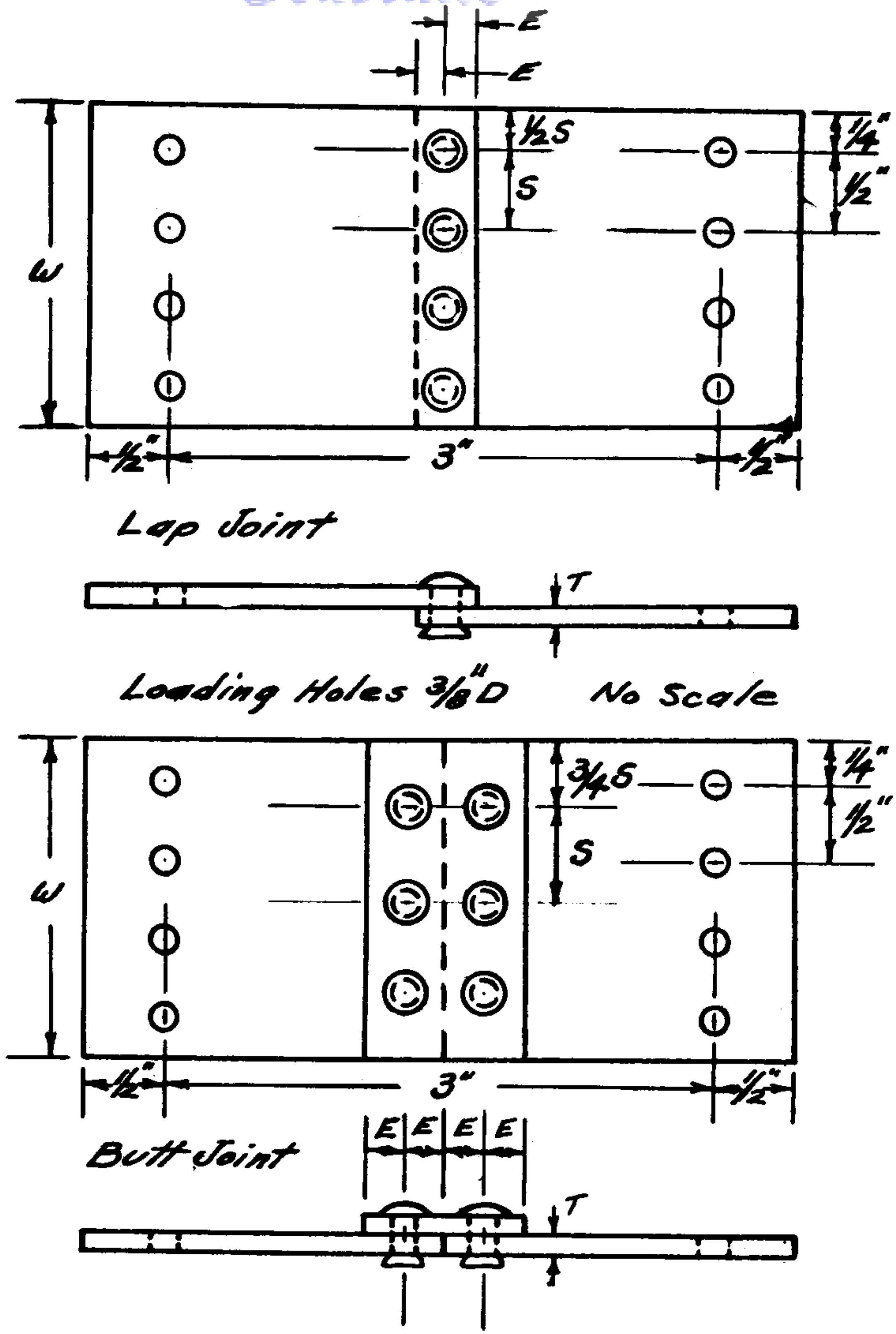

Figure 2 Multiple Rivet Specimens