AD NUMBER
AD875736
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; AUG 1970. Other requests shall be referred to U.S. Army Aviation Materiel Laboratories Fort Eustis, Virginia 23604. This document contains export-controlled technical data.**
AUTHORITY
USAAMRDL ltr, 23 Jun 1971

USAAVLABS TECHNICAL REPORT 70-23

ON THE STRENGTH OF VARIOUS LAP JOINTS

By

W. H. Horton
C. C. Rogers

August 1970

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-68-C-0035

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS
STANFORD UNIVERSITY
STANFORD, CALIFORNIA

DEPARTMENT OF THE ARMY
HEADQUARTERS US ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS VIRGINIA 23604

This program was carried out under Contract DAAJ02-68-C-0035 with Stanford University under subcontract to Georgia Institute of Technology.

The data contained in this report are the result of research conducted to investigate the strength of various lap joints. The joints were made from aluminum alloy bonded with epoxy resin. The tests cover variations due to change in the geometry of the adherend and change in the thickness of the adhesive.

The report has been reviewed by the U.S. Army Aviation Materiel Laboratories and is considered to be technically sound. It is published for the exchange of information and the stimulation of future research.

DISCLAIMERS

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission, to manufacture, use, or sell any patented invention that may in any way be related thereto.

DISPOSITION INSTRUCTIONS

Destroy this report when no longer needed. Do not return it to the originator.

Task 1F162204A17002
Contract DAAJ02-68-C-0035
USAAVLABS Technical Report 70-23
August 1970

ON THE STRENGTH OF VARIOUS LAP JOINTS

By

W. H. Horton
C. C. Rogers

Prepared by

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia

Under Subcontract to
Department of Aeronautics and Astronautics
Stanford University
Stanford, California

for

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

SUMMARY

This paper presents strength data for single lap joints made from aluminum alloy bonded with epoxy resin. The material covers variations due to change in geometry of the adherend and change in thickness of the adhesive.

FOREWORD

The work in this report was sponsored by the U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, under Contract DAAJ02-68-C-0035. The work was authorized by DA Task 1F162204A17002, "Stress Analysis, Failure, and Design Criteria for Dynamically and Statically Loaded Structures."

Thanks are due to Mr. Dewey Ransom, who made many of the components used in the test program, and also to LCDR M. H. Bank, USN (Ret), and Mr. Prasad Hanagud, who contributed to the program in many ways.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

From the point of view of weight economy, the well-designed monolithic structure would be ideal. Unfortunately, in the majority of engineering applications, structures of this kind are not feasible. Realistic systems consist of a number of individual elements which are joined together. In the past, in aerospace vehicles, such jointing has generally been made with rivets or similar mechanical devices, or by welding. There have been, of course, notable breakaways from this convention, the earliest examples being the De Havilland Hornet (D. H. 103) fighter-bomber of World War II, where redux cement was used extensively in a composite wood-metal wing, and the De Havilland Comet airliner, in which redux cement was used to attach stringers to skin in the fuselage.

This advent of metal-metal or metal-composite bonding brought a new dimension to the design of structures and, in particular, to joints - a new philosophy which has been much enhanced by the development of epoxy resins and fiber materials of outstanding characteristics. It must be admitted that glue joints permit a much smoother transfer of load from one element to another than is normally attainable with discrete element type fastenings. Nevertheless, they are not without their problems. Glues are normally very good in shear, but their characteristics, when there is tension or peeling action, are not so satisfactory. The avoidance of complexities due to these causes, the difficulties due to load diffusion, the problems of notch effects and local stress concentrations, and the uncertainties which come from cracks, voids, and other like disturbances combine to make joint design almost as much an art as a science.

The research reported herein was part of a broad-based systematic experimental and theoretical program designed to provide practical engineering data relevant to joints.

The overall study includes the problems of crack detection and propagation, the influence of geometry and the environment, the significance of material properties of both adhesive and adherend, and the problems of load diffusion. The study ranges from sheet materials to composites. The information presented here, however, is restricted to the behavior of simple lap joints in isotropic materials. Eight variations in the basic joint are considered, as follows:

1. Overlap Length
2. Taper in Adherends
3. Holes in Adherends
4. Thickness of Adhesive
5. Presence of Voids in Adhesives
6. "Bird Mouthing" of Adherends

7. Double Bird Mouth of Adherends

8. "Bird Tongue" of Adherends

In all cases, the adherend was 1 inch by 1/8 inch aluminum alloy strip, specification 70-75-T6, which was prepared according to the following schedule:

1. Trichlorethylene degrease

2. Wash

3. Alkaline cleanse

4. Wash

5. Acid etch

6. Wash

7. Oven dry

The bonding agent was in all cases American Cyanamide sheet glue FM 123, .004 inch thick. Bonding was carried out in vacuum in a thermostatically controlled oven, set at 250°F, for 60 minutes. The tests were made in a 60,000-pound Riehle hydraulically actuated test machine.

1. INFLUENCE OF LAP LENGTH

The specimens for this series of tests were prepared in accordance with the preceding description. Four different lap lengths were used: 1/4 inch, 1/2 inch, 3/4 inch, and $1\frac{1}{2}$ inches. Twenty-nine tests were conducted. The actual load levels achieved in the various joints are listed in Table I, together with the average shear stresses developed. This data is summarized in Table II, where the mean shear stress carried and the root mean square deviation are given for the various groups. The variation in shear stress as a function of overlap length is depicted in Figure 1. It is readily seen from this diagram that as the overlap length increases, the shear stress developed decreases smoothly, the curve of shear stress versus overlap length tending to become asymptotic to a certain minimum value.

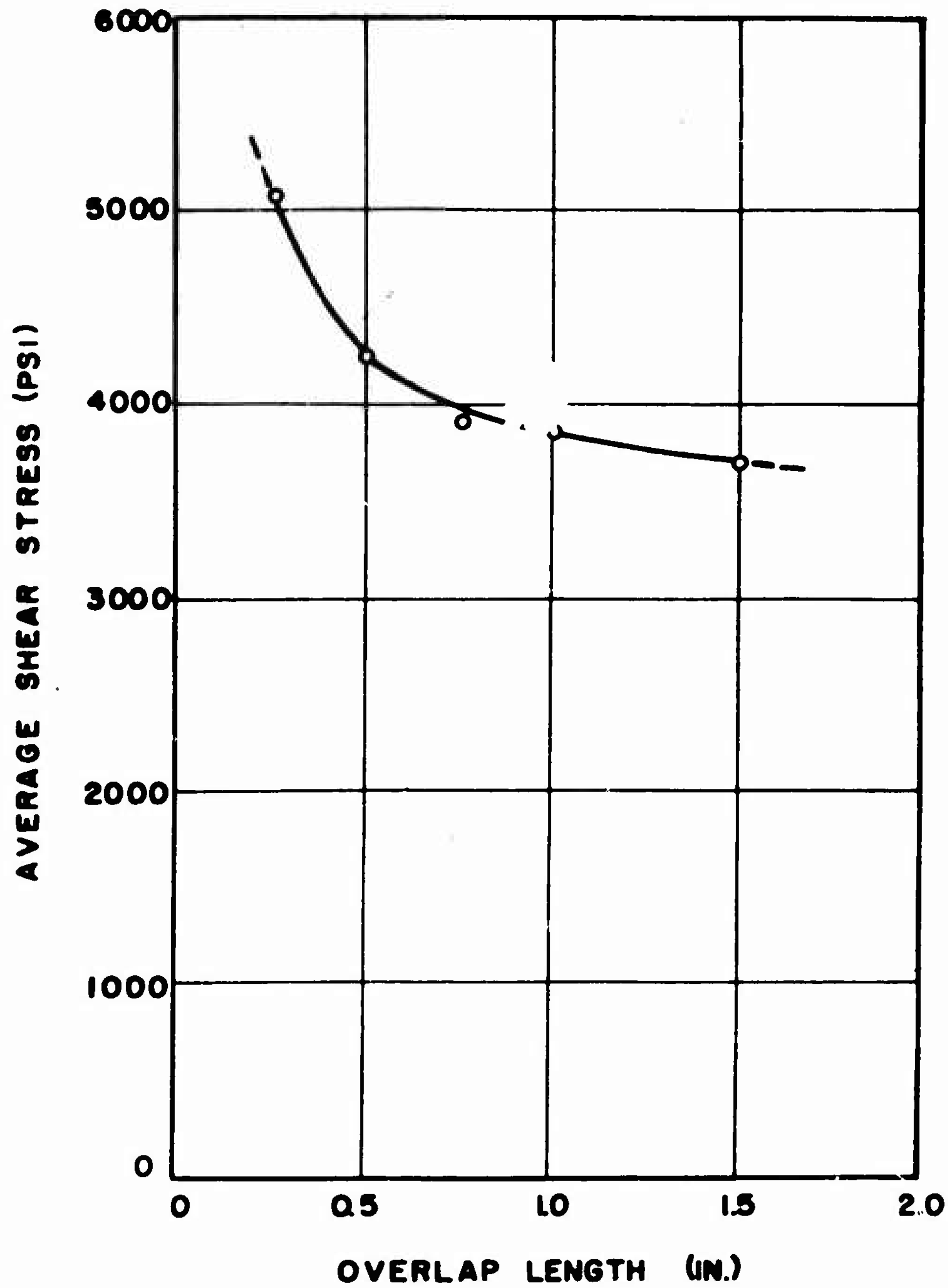


Figure 1. Overlap Length Versus Average Shear Stress.

TABLE I. FAILURE LOADS FOR VARIOUS OVERLAP LENGTHS

Overlap Length (in.)	Failure Load (lb.)	Overlap Length (in.)	Failure Load (lb.)
0.25	1270	0.75	2880
0.25	1240	0.75	2960
0.25	1310	0.75	2860
0.25	1310	0.75	2880
0.25	1240	0.75	2930
0.25	1290	0.75	2940
0.25	1260	1.50	5310
0.50	2260	1.50	5690
0.50	2040	1.50	5730
0.50	2210	1.50	5400
0.50	2090	1.50	5640
0.50	2100	1.50	5500
0.50	2200	1.50	5620
0.75	3000	1.50	5510
0.75	2760		

TABLE II. AVERAGE SHEAR STRESS FOR VARIOUS OVERLAP LENGTHS			
Overlap Length (in.)	Average Shear Stress (lb./in.^{2})	RMS Deviation (lb./in.^{2})	RMS Dev. x 100 Average Shear Stress (pct.)
0.25	5095	256	5.0
0.50	4225	260	6.1
0.75	3900	150	3.9
1.50	3710	144	3.9

2. TAPER IN ADHERENDS

For this series of tests, the specimens were prepared generally as already described, but the ends of the adherends were tapered in accordance with the sketch, Figure 2. In all, 5 different tapers were used and 21 specimens were tested. The load values achieved for the various specimens are listed in Table III. This data is summarized in Table IV, which includes the average shear stress and root mean square for the individual groups. The results are graphically portrayed in Figure 2. They show that for a 1-inch overlap joint, the maximum load-carrying capability exists when the taper length is 3/4 inch. This joint is 25 percent more effective than the standard untapered joint.

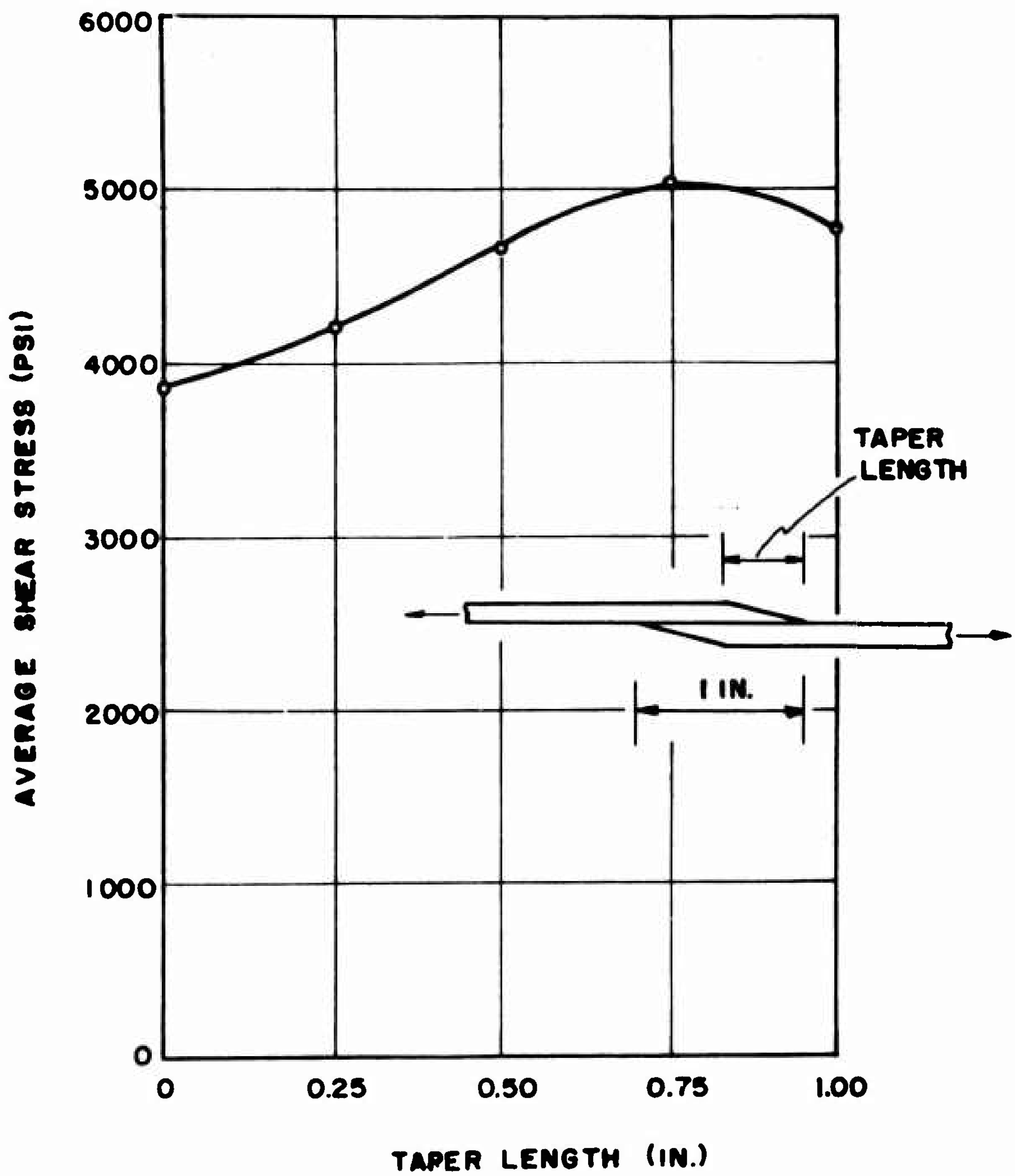


Figure 2. Taper Length Versus Average Shear Stress.

TABLE III. FAILURE LOADS FOR VARIOUS ADHEREND TAPER LENGTHS

Taper Length (in.)	Failure Load (lb.)	Taper Length (in.)	Failure Load (lb.)
0.25	4180	0.75	5040
0.25	4220	0.75	5180
0.25	4200	0.75	4940
0.50	4360	0.75	5040
0.50	4500	0.75	5020
0.50	5080	1.00	4680
0.50	4500	1.00	4540
0.50	5040	1.00	5080
0.50	4460	1.00	5080
0.50	4640	1.00	4400
		1.00	4900

TABLE IV. AVERAGE SHEAR STRESS FOR VARIOUS ADHEREND TAPER LENGTHS

Taper Length (in.)	Average Shear Stress (lb./in.^{2})	RMS Deviation (lb./in.^{2})	RMS Dev. x 100 / Average Shear Stress (pct.)
0.00	3880	150	3.8
0.25	4200	20	0.5
0.50	4655	289	6.2
0.75	5044	86	1.7
1.00	4780	281	5.9

3. HOLES IN ADHERENDS

This series of tests was intended as a preliminary study of the influence of stress raisers on joint behavior. In general, the joints were prepared in accordance with the standard procedure, but the geometry of the faces was modified in accordance with the sketch, Figure 3; six 1/8-inch-diameter holes, arranged in an equilateral triangle, were drilled in each member. The patterns used and the final assembly arrangements are clearly seen in the figure.

Values of load carried for the various joints are given in Table V. It is interesting to note that the mean shear stress level does not differ appreciably for either hole configuration from the mean stress level for a joint without holes and the same overlap length, 1.125 inches.

It will be shown later in Section 5 that the presence of circular voids in the adhesive can decrease the load-carrying capability of the joint, and it may be that the nonreduction in average shear stress mentioned in the previous paragraph is due not to the fact that there were holes in the adherend but rather as a result of their multiplicity.

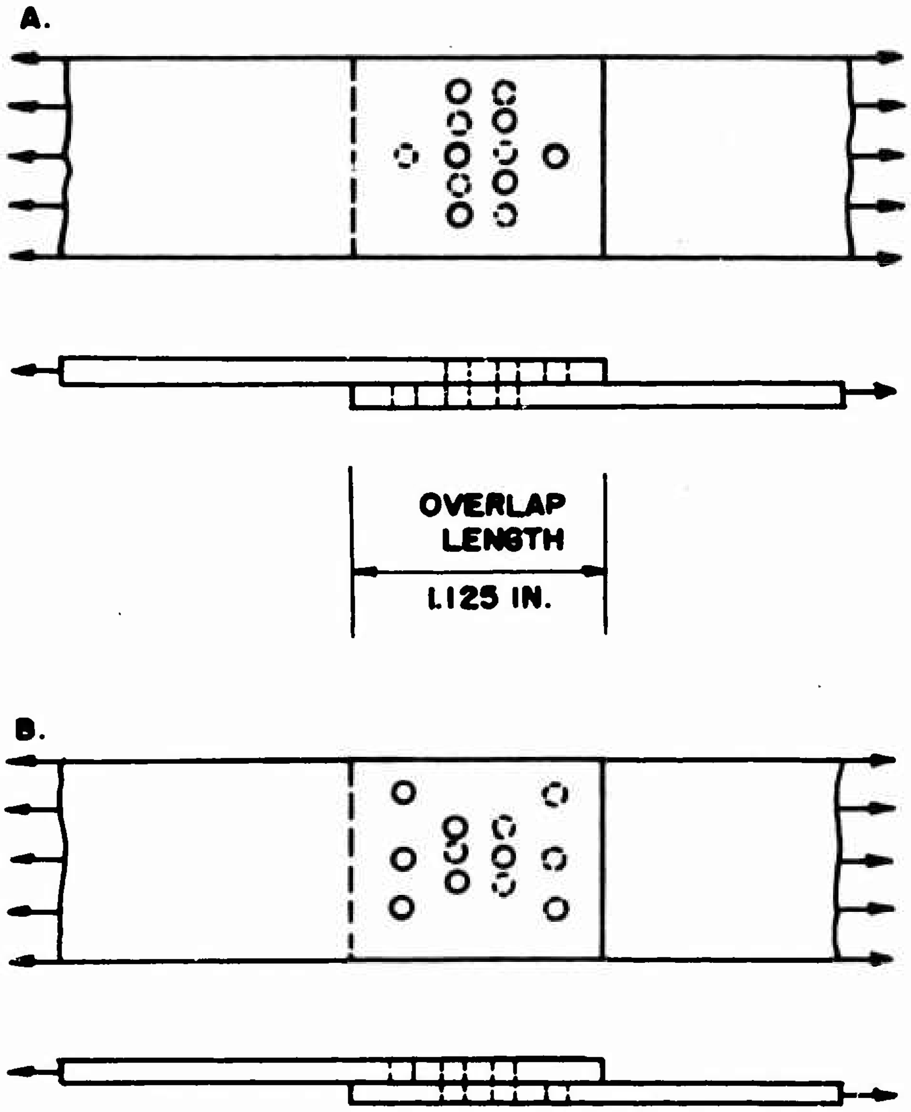


Figure 3. Void Configurations in the Adherends.

TABLE V. FAILURE LOADS IN A JOINT WITH AN ARRAY OF HOLES IN THE ADHEREND

Type (See Fig. 3)	Failure Load (lb.)	Type	Failure Load (lb.)
A	3790	B	4060
A	4400	B	3940
A	3700	B	4040
A	3960	B	4040
A	4200	B	4040
A	4100	B	4140
A	4020	B	4080
A	4200	B	3800

TABLE VI. AVERAGE SHEAR STRESS IN A JOINT WITH AN ARRAY OF HOLES IN THE ADHEREND

Type	Average Shear Stress (lb./in.^{2})	R.M.S. Deviation (lb./in.^{2})	R.M.S.Dev. x 100 / Av. Shear Stress (pct.)
A	4045	235	5.8
B	4020	79	2.0

4. THICKNESS OF ADHESIVE

The joints for this series of tests were made, in general, in accordance with the standard procedure, but the adhesive thickness was varied. Four thicknesses of adhesive layer were used: nominally .004, .006, .009, and .012 inch. Twenty-one tests were conducted. The results of the investigation are given in Table VII, and a summary for the various groups is presented in Table VIII. The variation in load-carrying capability as a function of given adhesive thickness is depicted in Figure 4. The tests show that for the particular configuration used, there is an optimum thickness of adhesive.

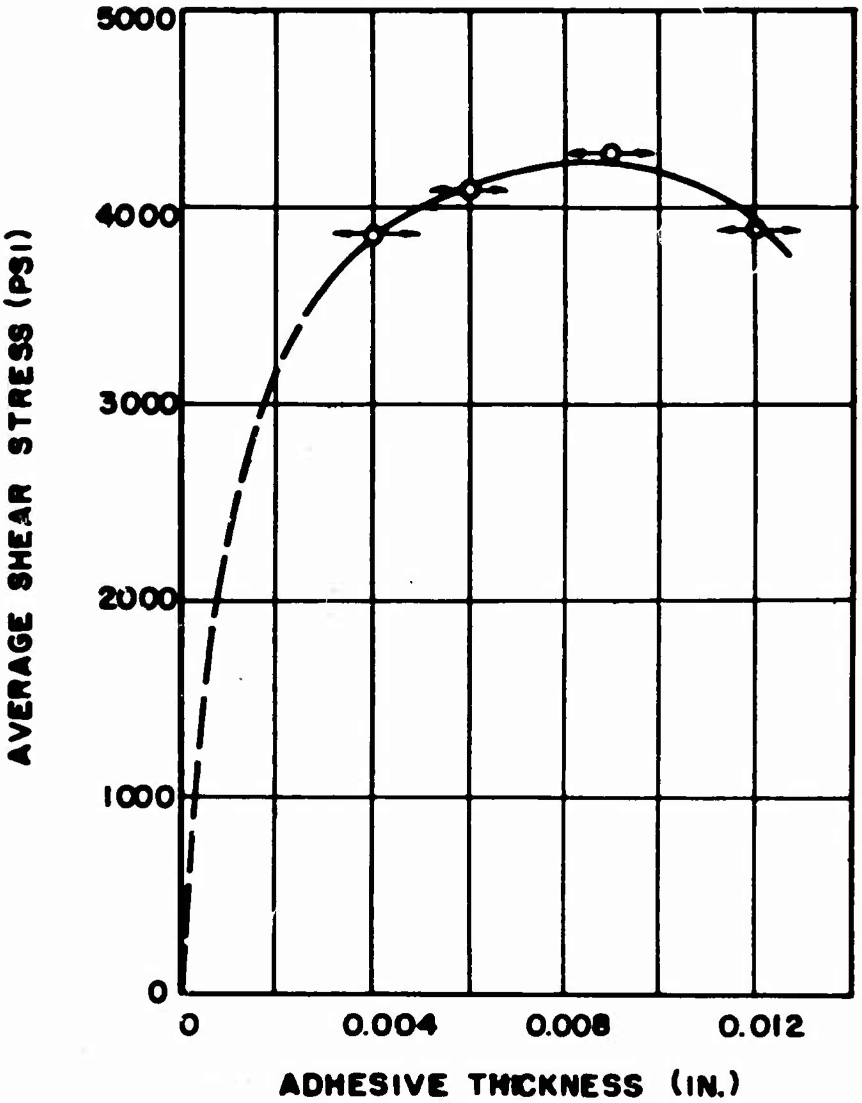


Figure 4. Average Shear Stress Versus Adhesive Thickness.

TABLE VII. FAILURE LOADS FOR VARIOUS ADHESIVE THICKNESSES

Adhesive Thickness (in.)	Failure Load (lb.)	Adhesive Thickness (in.)	Failure Load (lb.)
0.006±.001	4000	0.009±.001	4200
0.006±.001	3900	0.009±.001	4260
0.006±.001	4080	0.009±.001	4300
0.006±.001	3960	0.009±.001	4320
0.006±.001	4160	0.014±.001	3940
0.006±.001	4080	0.014±.001	3940
0.006±.001	4200	0.014±.001	3820
0.006±.001	4100	0.014±.001	4020
0.009±.001	4080	0.014±.001	3880
0.009±.001	4300	0.014±.001	3880
		0.014±.001	3800

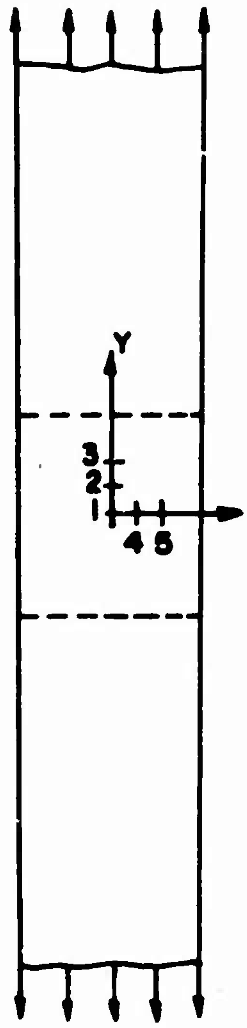
TABLE VIII. AVERAGE SHEAR STRESS FOR VARIOUS ADHESIVE THICKNESSES

Adhesive Thickness (in.)	Average Shear Stress (lb./in.^{2})	R.M.S. Deviation (lb./in.^{2})	$\frac{\text{R.M.S. Dev.} \times 100}{\text{Average Shear Stress}}$ (pct.)
0.004	3880	150	3.8
0.006 $\pm$ .001	4060	108	2.7
0.009 $\pm$ .001	4276	53	1.2
0.012 $\pm$ .001	3877	91	2.3

5. PRESENCE OF VOIDS IN ADHESIVE LAYER

It is well known that voids act as stress raisers. In view of the results of Section 3 (holes in adherends), it is interesting to study the effect of a void which occurs only in the adhesive layers. A start on this problem was made in this series of tests. In a general way, the specimens for this sequence of tests were made in accordance with the standard procedure. However, a 1/4-inch-diameter hole was cut in the sheet adhesive, and the cavity produced was filled with a nonabsorbent, nonsticking material prior to joint assembly. This cavity was located at one or the other of five separate positions (see Figure 5).

The results obtained for the 24 tests conducted are given in Table IX; they are summarized for the grouping in Table X. The results indicate that a hole at the center of the lap does not significantly influence the mean stress developed; but when the hole is moved in the direction of load toward the end of the lap, a significant reduction in load-carrying capability is evident. This result is very different from the preliminary conclusion of Section 3, where it appeared that the hole locations had little or no influence.



POS'N	X	Y
1	0	0
2	0	0.125
3	0	0.25
4	0.125	0
5	0.25	0

Figure 5. Void Positions in the Adhesive.

TABLE IX. FAILURE LOADS FOR JOINTS WITH CIRCULAR VOIDS IN THE ADHESIVE

Void Location x, y (in.)	Failure Load (lb.)	Void Location x, y (in.)	Failure Load (lb.)
0.0	3800	0.25,0	3920
0.0	3900	0.25,0	3920
0.0	3850	0.25,0	3740
0.0	3940	0.25,0	3780
0.0	3780	0,0.125	3680
0.125,0	3820	0,0.125	4100
0.125,0	3570	0,0.125	3820
0.125,0	3680	0,0.125	3570
0.125,0	4100	0,0.25	3080
0.25,0	3920	0,0.25	2800
0.25,0	3960	0,0.25	2840
0.25,0	3660	0,0.25	2820

TABLE X. AVERAGE SHEAR STRESS FOR JOINTS WITH CIRCULAR VOIDS IN THE ADHESIVE

Void Location x, y (in.)	Average Shear Stress ($lb./in.^2$)	R.M.S.Deviation ($lb./in.^2$)	R.M.S. Dev. x 100 (pct.)
0,0	3855	75	1.9
0.125,0	3790	228	6.0
0.25,0	3840	118	3.1
0,0.125	3700	158	4.3
0,0.25	2880	127	4.4

6. BIRD MOUTH OF ADHERENDS

In Section 2, it was demonstrated that load-carrying capability for a given overlap length could be improved by "diffusing" the load from one plate to the other. To do this, adherend plates were tapered. The series of tests now discussed was conducted on an alternate variation of geometry, the bird mouth, depicted in Figure 6. In this figure, the several dimensions used are clearly shown. In all, 57 tests were conducted. The results for these studies are given in Table XI; they are grouped and summarized in Table XII. The graphical representation of Figure 7 shows the behavior pattern for the joints. It is seen from this figure that a 60° bird mouth with a 1/8 inch "root" radius gives approximately a 10 percent increase in average shear stress compared to the average shear stress carried by the standard 1-inch overlap joint with square ends, while a 30° bird mouth carries 10 percent less shear stress.

In an effort to gain extra load-carrying capabilities, it might be worthwhile machining the adherends with the 60° bird mouth configuration. However, for wide joints it would be more practical to machine a series of bird mouths side by side; tests on multiple bird mouths are discussed later.

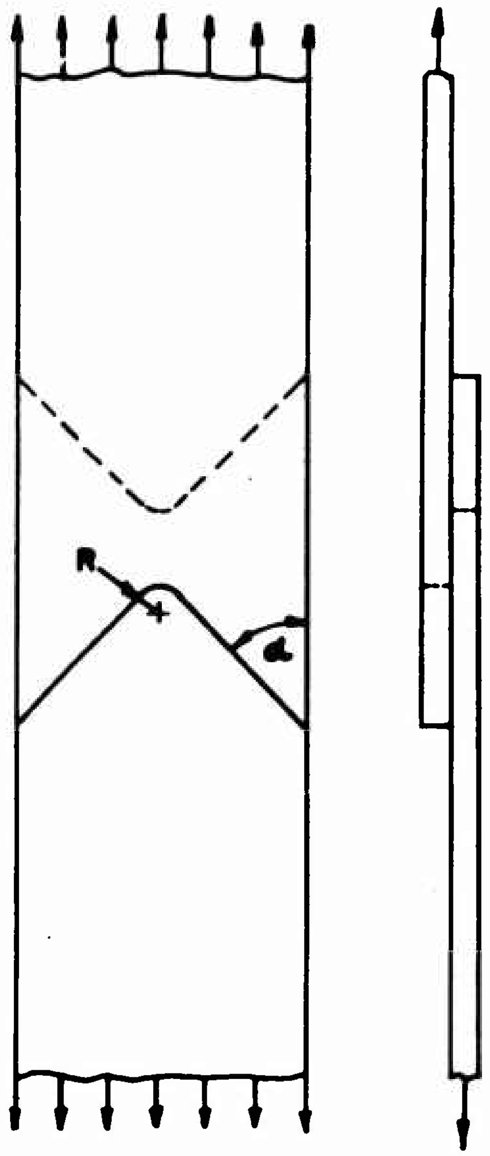


Figure 6. **Single Bird Mouth Lap Shear Specimen.**

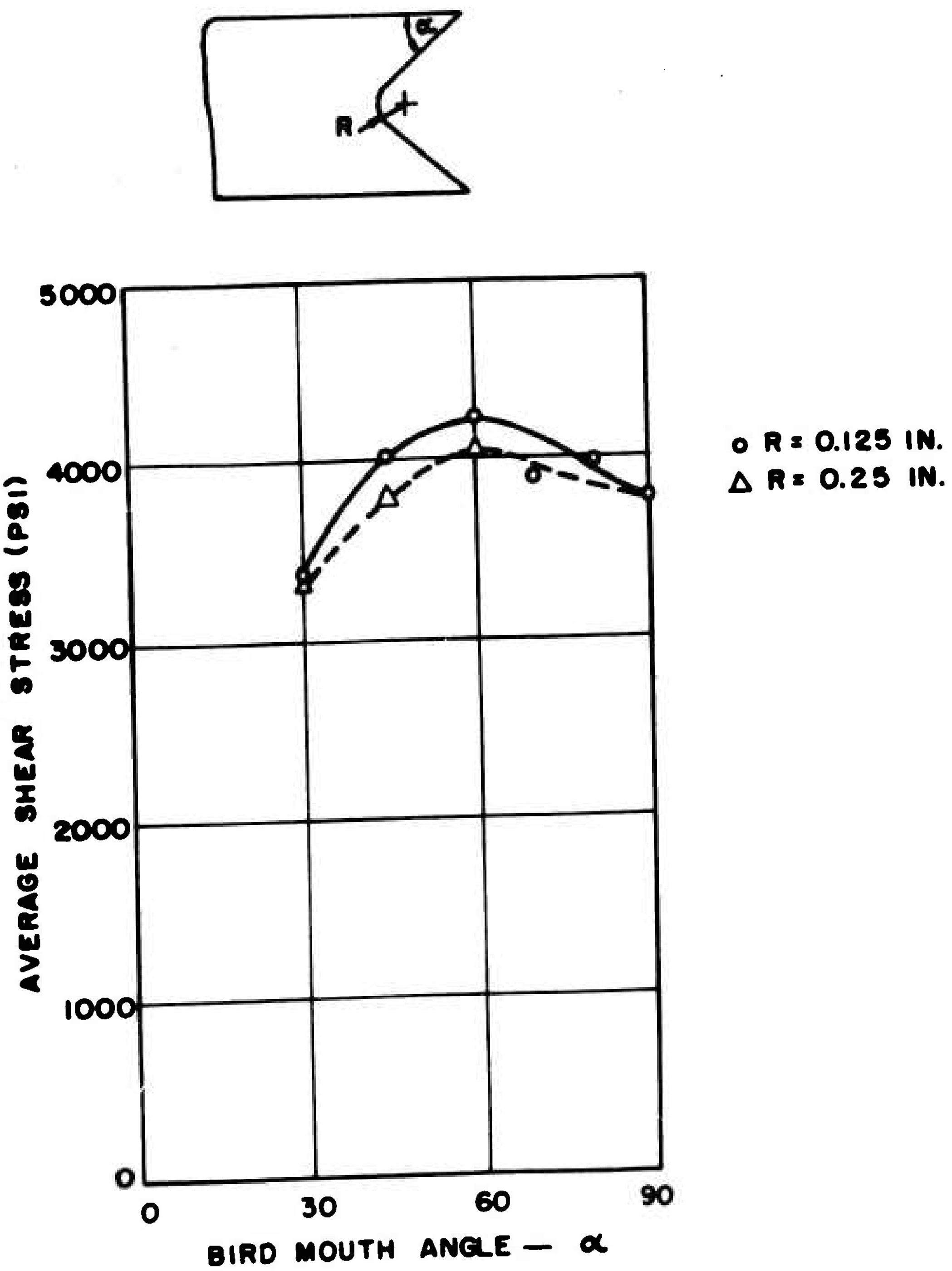


Figure 7. Average Shear Stress Versus Bird Mouth Angle.

TABLE XI. FAILURE LOADS FOR JOINTS WITH SINGLE BIRD MOUTH ADHERENDS

r,α (in.,deg.)	Failure Load (lb.)	r,α (in.,deg.)	Failure Load (lb.)
0.125,30	3320	0.125,80	4000
0.125,30	3320	0.125,80	3940
0.125,30	3400	0.125,80	4000
0.125,30	3380	0.125,80	3940
0.125,30	3480	0.125,80	4000
0.125,30	3340	0.125,80	4060
0.125,30	3420	0.125,80	3940
0.125,45	4140	0.25,45	3720
0.125,45	4140	0.25,45	3920
0.125,45	3980	0.25,45	3960
0.125,45	3880	0.25,45	3960
0.125,45	3920	0.25,45	3760
0.125,45	4240	0.25,45	3620
0.125,60	4200	0.25,45	3940
0.125,60	4340	0.25,45	3680
0.125,60	4260	0.25,30	3390
0.125,60	4280	0.25,30	3275
0.125,60	4220	0.25,30	3430
0.125,60	4140	0.25,30	3235
0.125,60	4360	0.25,30	3460
0.125,70	3800	0.25,30	3220
0.125,70	4120	0.25,30	3335
0.125,70	3780	0.25,60	4145
0.125,70	3880	0.25,60	3955
0.125,70	3840	0.25,60	4185
0.125,70	3700	0.25,60	3920
0.125,70	4080	0.25,60	4230
0.125,70	4120	0.25,60	3870
		0.25,60	4050

TABLE XII. AVERAGE SHEAR STRESS FOR VARIOUS BIRD MOUTH ANGLES			
r, α (in., deg.)	Average Shear Stress (lb./in.^{2})	R.M.S. Deviation (lb./in.^{2})	$\frac{\text{R.M.S.Dev.} \times 100}{\text{Av. Shear Stress}}$ (pct.)
0.125,30	3380	59	1.8
0.125,45	4050	140	3.5
0.125,60	4260	76	1.8
0.125,70	3915	168	4.3
0.125,80	3985	45	1.1
0.25,30	3335	88	3.8
0.25,45	3820	130	3.4
0.25,60	4050	130	3.1

7. DOUBLE BIRD MOUTH OF ADHERENDS

The program of Section 6 was extended to cover the case of the double bird mouth shown in Figure 8. No departure in manufacture technique from standard other than in the geometry of the ends of the face members was used; 56 tests were conducted with the several configurations. The results of these tests are given in Table XIII; they are grouped and summarized in Table XIV. Comparing the values of average shear stress to that of the standard 1-inch overlap joint, the indication is that no significant increase in load-carrying capability can be achieved with any geometry, but it is worth noting that the maximum reduction in shear stress, which occurs for the 60° case, is only 10 percent below the standard value. The variation in load-carrying capacity as a function of geometry is graphically displayed in Figure 9.

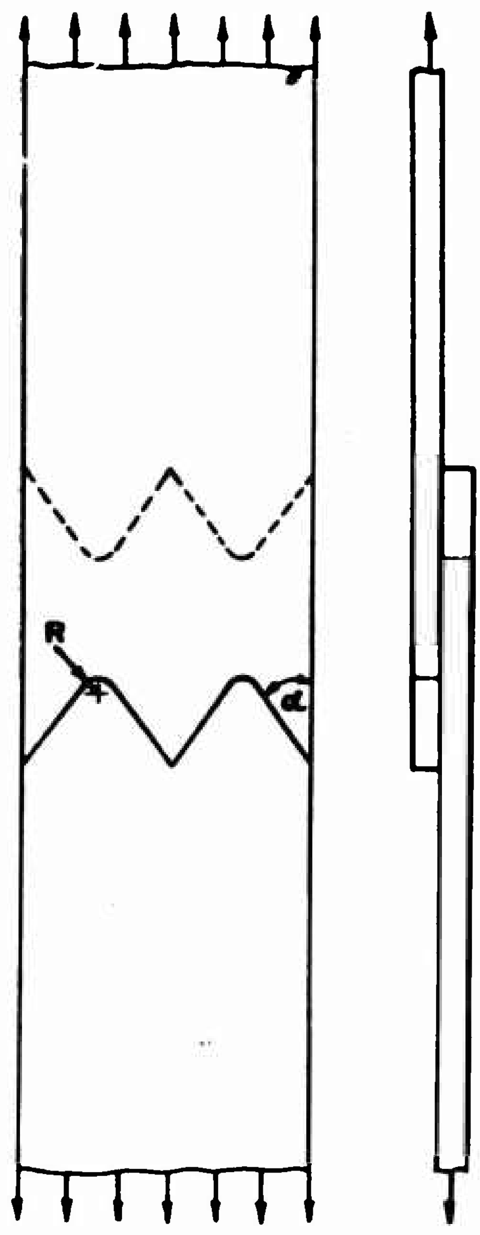


Figure 8. Double Bird Mouth Lap Shear Specimen.

TABLE XIII. FAILURE LOADS FOR JOINTS WITH DOUBLE BIRD MOUTH ADHERENDS

r, α (in., deg.)	Failure Load (lb.)	r, α (in., deg.)	Failure Load (lb.)
0.0625, 20	3850	0.0625, 55	3380
0.0625, 20	3890	0.0625, 55	4000
0.0625, 20	3940	0.0625, 55	3970
0.0625, 20	4040	0.0625, 55	3830
0.0625, 20	4000	0.0625, 55	3850
0.0625, 20	3920	0.0625, 55	3860
0.0625, 20	3940	0.0625, 55	4050
0.0625, 20	4030	0.0625, 55	4020
0.0625, 30	3640	0.0625, 60	3300
0.0625, 30	3770	0.0625, 60	3770
0.0625, 30	3570	0.0625, 60	3480
0.0625, 30	3590	0.0625, 60	3650
0.0625, 30	3500	0.0625, 60	3520
0.0625, 30	3770	0.0625, 60	3470
0.0625, 30	3710	0.0625, 60	3200
0.0625, 30	3700	0.0625, 60	3580
0.0625, 45	3900	0.0625, 65	3760
0.0625, 45	3960	0.0625, 65	3760
0.0625, 45	3840	0.0625, 65	3460
0.0625, 45	4050	0.0625, 65	3100
0.0625, 45	3880	0.0625, 65	3570
0.0625, 45	3810	0.0625, 65	3380
0.0625, 45	3870	0.0625, 70	3980
0.0625, 45	3940	0.0625, 70	4040
0.0625, 45	3810	0.0625, 70	4140
0.0625, 45	3920	0.0625, 70	4140
		0.0625, 70	3930
		0.0625, 70	3870
		0.0625, 70	3900
		0.0625, 70	4080

TABLE XIV. SHEAR STRESS FOR JOINTS WITH DOUBLE BIRD MOUTH ADHERENDS			
r,α (in.,deg.)	Average Shear Stress (lb./in.^{2})	R.M.S. Deviation (lb./in.^{2})	R.M.S.Dev. x 100 / Av. Shear Stress (pct.)
0.0625,20	3950	63	1.5
0.0625,30	3655	92	2.5
0.0625,45	3900	70	1.7
0.0625,55	3870	201	5.2
0.0625,60	3495	171	4.8
0.0625,65	3505	231	6.6
0.0625,70	4010	99	2.5

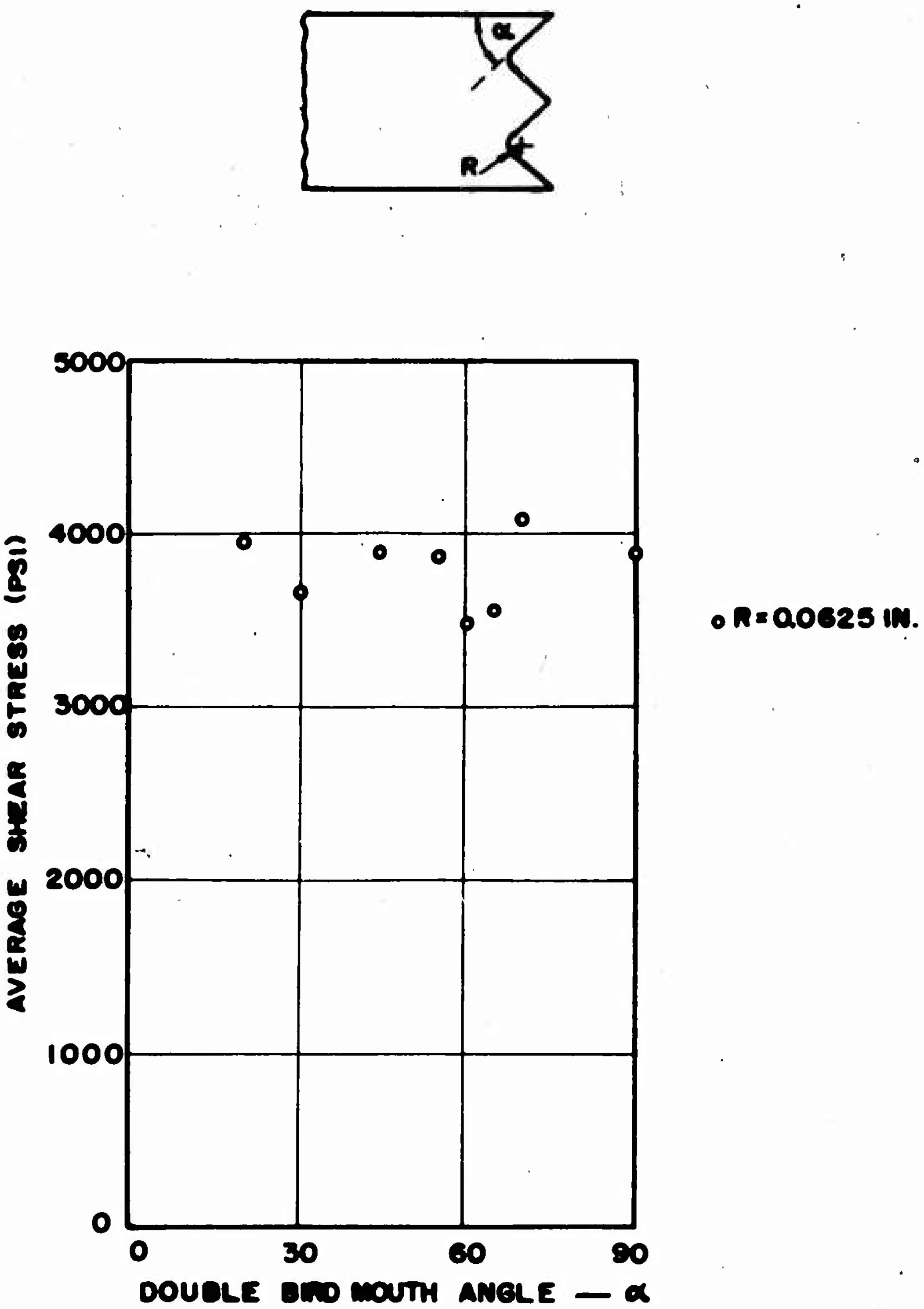


Figure 9. Average Shear Stress Versus Double Bird Mouth Angle.

8. BIRD TONGUE OF ADHERENDS

In this series of tests, the only deviation from standard procedure was in the end shape of the lap faces. These were cut according to the geometrical pattern shown in Figure 10; 48 tests were conducted with the various shapes. The results for these tests are given in Table XV; they are grouped and summarized in Table XVI and are graphically portrayed in Figure 11. It is clear from these presentations that until the included angle at the tip of the tongue gets below 30 degrees (i.e., the tongue gets very long), this geometric shaping has little or no influence on the joint strength.

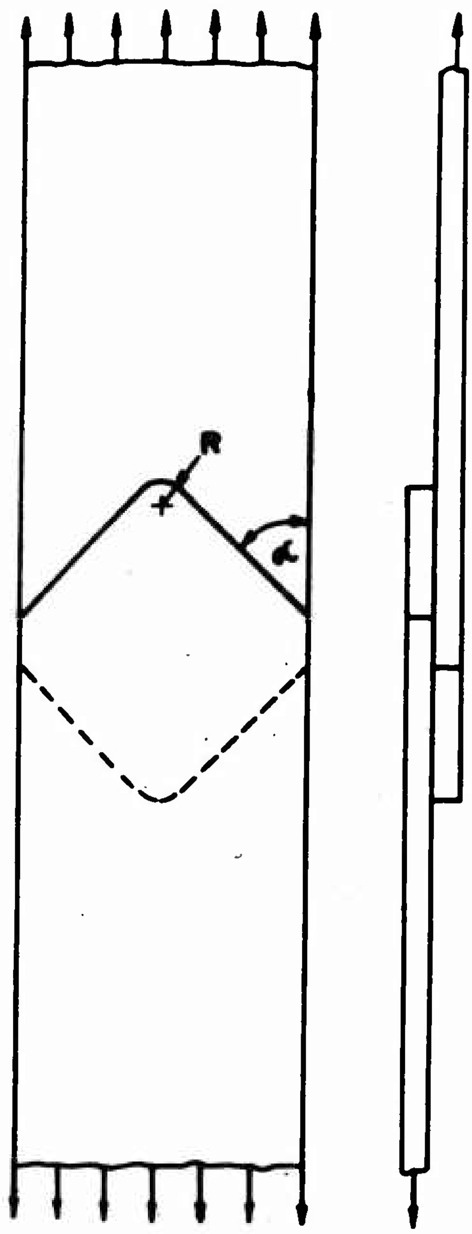


Figure 10. Bird Tongue Lap Shear Specimen.

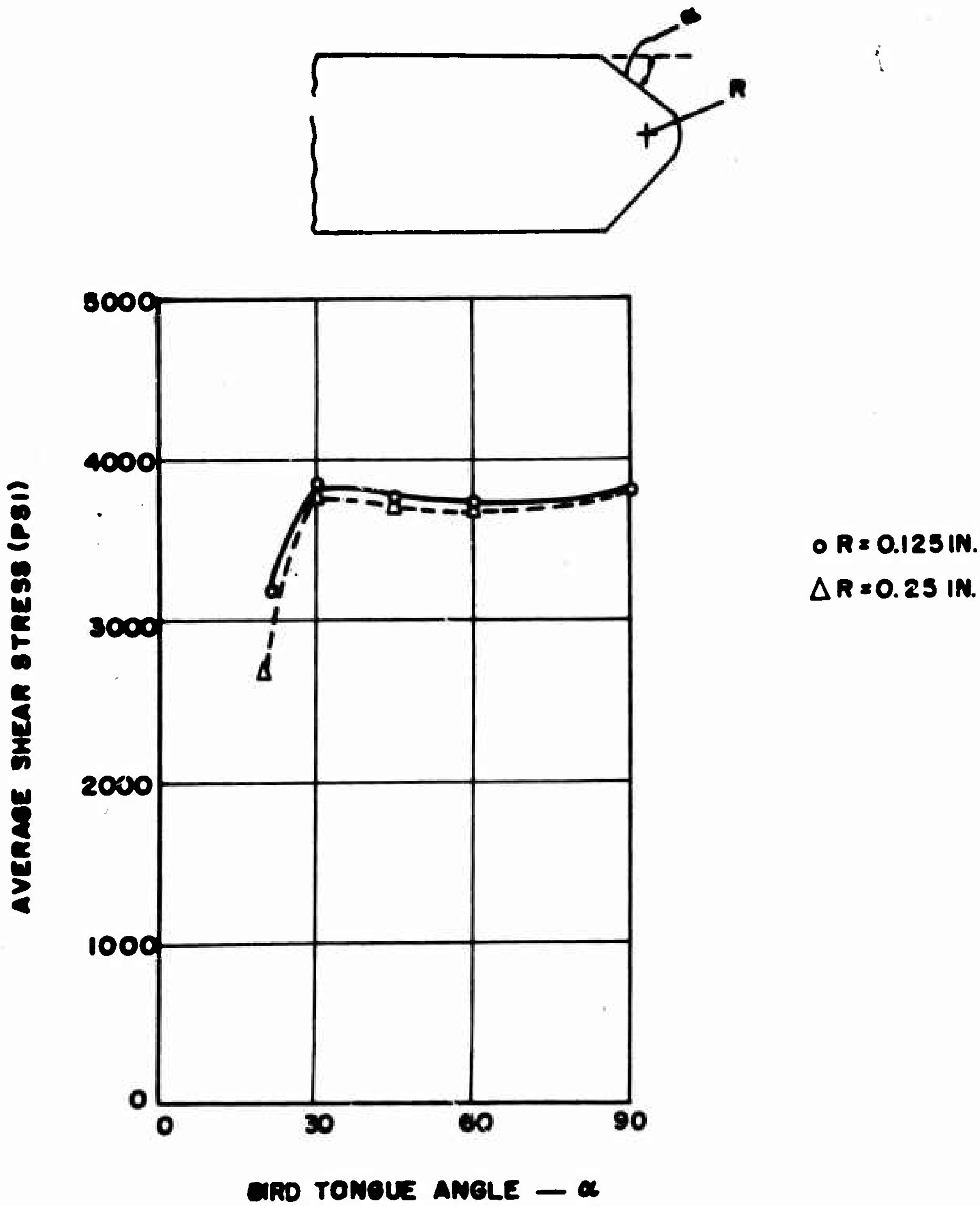


Figure 11. Average Shear Stress Versus Bird Tongue Angle.

TABLE XV. FAILURE LOADS FOR JOINTS WITH SINGLE BIRD TONGUE ADHERENDS			
r,α (in.,deg.)	Failure Load (lb.)	r,α (in.,deg.)	Failure Load (lb.)
0.125,60	3880	0.125,20	6340
0.125,60	4100	0.125,20	6325
0.125,60	3940	0.125,20	6350
0.125,60	4000	0.125,20	6550
0.125,60	4100	0.25,60	3800
0.125,60	3600	0.25,60	3680
0.125,45	4580	0.25,60	3650
0.125,45	4050	0.25,60	3840
0.125,45	4080	0.25,45	3900
0.125,45	3860	0.25,45	3820
0.125,45	4080	0.25,45	3580
0.125,45	4280	0.25,45	3780
0.125,45	4040	0.25,30	3820
0.125,30	4700	0.25,30	3820
0.125,30	4660	0.25,30	3800
0.125,30	4340	0.25,30	3720
0.125,30	4480	0.25,20	5080
0.125,30	4260	0.25,20	5300
0.125,30	4500	0.25,20	5280
0.125,30	4500	0.25,20	5790
0.125,20	6720	0.25,20	5100
0.125,20	6470	0.25,20	5500
0.125,20	6320	0.25,20	5620
0.125,20	6050	0.25,20	5780

TABLE XVI. AVERAGE SHEAR STRESS FOR JOINTS WITH SINGLE BIRD TONGUE ADHERENDS

r, α (in., deg.)	Average Shear Stress (lb./in.^{2})	R.M.S. Deviation (lb./in.^{2})	R.M.S.Dev. x 100 / Av. Shear Stress (pct.)
0.125,60	3830	165	4.3
0.125,45	3850	200	5.2
0.125,30	3910	126	3.2
0.125,20	3195	92	2.9
0.25,60	3750	82	2.2
0.25,45	3770	136	3.6
0.25,30	3790	48	1.3
0.25,20	2700	125	4.6

CONCLUSIONS

The test results given in this report show that the shear strength of a simple lap joint is significantly influenced by adhesive thickness and by the geometry of the face members. Taper in thickness of plate has a good effect on strength achieved. The presence of holes in the adherend does not give rise to serious stress concentrations within the limits studied, but voids in the adhesive layer only are in general detrimental. Bird mouthing or scalloping of a joint edge may give some slight improvement in joint capability, but it is more likely to be deleterious. On the other hand, in cases where a single tongue is used, no change in performance over the square-cut end is to be anticipated unless the aspect ratio of the tongue is high, in which case the shaping will be detrimental.

APPENDIX

METAL BOND ETCHING PROCESS

PROCESS	SOLUTION COMPOSITION (by weight)	TEMP. (^oF)
1. Degrease	100% Trichlorethylene	Vapor Temp.
2. Wash	Tap Water	Room Temp.
3. Alkaline Cleanse	5% Wyandotte Altrex 95% Distilled Water	170 $\pm$ 10
4. Wash	Tap Water	Room Temp.
5. Acid Etch	24% Conc. Sulphuric Acid 73% Distilled Water 3% Sodium Dichromate	145 $\pm$ 160
6. Wash	Tap Water	Room Temp.
7. Oven Dry		150

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Georgia Institute of Technology, Atlanta, Georgia (under subcontract to Stanford University, Stanford, California)	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. REPORT TITLE ON THE STRENGTH OF VARIOUS LAP JOINTS	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report	
5. AUTHOR(S) (First name, middle initial, last name) Wilfred H. Horton Colin C. Rogers	
6. REPORT DATE August 1970	7a. TOTAL NO. OF PAGES 47 / 7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. DAAJ02-68-C-0035 b. PROJECT NO. Task 1F162204A17002 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) USAAVLABS Technical Report 70-23 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
10. DISTRIBUTION STATEMENT This document is subject to special export controls, and each transmittal to foreign governments or foreign nationals may be made only with prior approval of U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia 23604.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Aviation Materiel Laboratories Fort Eustis, Virginia

13. ABSTRACT

This report presents strength data for single lap joints made from aluminum alloy bonded with epoxy resin. The material covers the variations due to change in geometry of the adherend and change in thickness of the adhesive.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Lap Joints						
Adhesive Bonded Joints						

Unclassified

Security Classification