NAVAL AIR DEVELOPMENT CENTER

WARMINSTER, PA. 18974

REPORT NO. NADC-73023-30 26 January 1973

EFFECT OF BLADE THICKNESS ON SHEAR STRENGTH

PHASE REPORT

AIRTASK NO. A5255203-1/2025/00000000-5303

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DEPARTMENT OF THE NAVY
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA. 18974

AIR VEHICLE TECHNOLOGY DEPARTMENT

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In order to evaluate the various fixtures used in determining the shear strength of fasteners, a round robin test was conducted. It was found that single shear tests yield slightly higher shear strengths.

Reported by: A. E. Simkins
A. E. SIMKINS

Approved by: Leonard Markushewski
L. MARKUSHEWSKI

Released by: T C Herring
T. C. HERRING, Superintendent
Design and Integration Div.

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INTRODUCTION

Historically, many test methods have been utilized to determine fastener shear strength. These tests are of two general types -- single or double shear. In theory the ultimate double shear load, the highest reading obtained when a double test is performed, is twice the single shear load. However, during a single shear test, the specimen tends to rotate. This action together with dependence upon several geometric features of the shear fixtures induces large variations in the ultimate shear strength. A standard double shear test method, MIL-STD-1213 Test 13, has gained wide acceptance and is suitable for a large portion of the shear testing but is not suitable for short length or tapered shank fasteners.

A round robin test was initiated to determine the effect that the blade thickness and type of fixture has upon the ultimate shear strength. Analysis of these results provide the basis for judicious selection and use of shear test methods. The round robin test with Standard Pressed Steel Company, Huck Manufacturing Company, Hi Shear Corporation, Almay Research and Testing Corporation, NASA (National Aeronautics and Space Administration) and NAVAIRDEVCEN (Naval Air Development Center), hereafter denoted arbitrarily as laboratories A through F, participating in the testing and preparation of the specimens was conducted in conjunction with FTDG (Fastener Testing Development Group) under AIRTASK A5255203-1/2025/00000000-5303.

Two single shear fixture configurations, figures 1 and 2, and the half hole double shear fixture were evaluated. Both single shear fixtures attempted to minimize specimen rotation, thus providing a more accurate measurement of the shear strength. The fixture shown in figure 1 is essentially a precision four bar linkage which provides vertical alignment of the shear blades. In the other fixture, figure 2, this alignment is accomplished with thrust bearings. In both cases the radial load component is reacted into the fixture and the vertical (shearing) component into the test machine. Two blade widths were evaluated, ½ D and 1 D. "D" being the nominal diameter of specimen material.

TEST SPECIMENS

Specimens with diameters of .190, .250 and .375 were fabricated from AISI 8740 steel per AMS 6322 or MIL-S-6049. To reduce the scatter due to specimen variation each diameter was obtained from a single source; Huck Manufacturing provided the .190 specimens, Standard Pressed Steel the .250 and Hi Shear Corporation the .375. Specimens of each diameter were prepared from the same chemical heat and heat treated in the same batch to RC 36-40. The material stock diameter was so selected that the final grinding operation, accomplished after heat treatment, removed a sufficient amount of material to insure the absence of any decarburization or carburization. One end of each specimen was sanded and serialized by hand stamping. Magnaflux inspection of each specimen was conducted in accordance with MIL-I-6868 using the acceptance criteria of MIL-B-7838. The unmarked end was sanded to remove the scale; then the hardness, shown on Table I, was determined. The unmarked end was utilized for all tests. To facilitate testing, in some cases the specimens were cut from the test bar. When the bar was cut, care was exercised to prevent excessive frictional heat buildup. All the specimens were vapor degreased prior to testing.

Tensile specimens were machined from the .250 and .375 bar. The ultimate tensile strength of the specimens is shown on Table II.

TEST EQUIPMENT

The double shear fixtures had ½ D or 1 D side blades as applicable with a 1 D center blade of the half hole type essentially in accordance with MIL-STD-1312, Test 13. All critical dimensions such as hole size and blade spacing were in accordance with Test 13.

Both single shear fixtures utilized 1½ inch square blades which were ½ D and 1 D thick and vary only in method of application of the load.

Although the shear fixtures were in good condition, no attempt was made to control the shear surfaces more closely than would be feasible or practical during normal usage. While this does increase the data scatter, it is representative.

All the government and industry test machines which had been calibrated less than six months prior to testing were accurate within 1% when calibrated.

TEST PROCEDURES

The ultimate shear loads obtained from the double shear fixture were determined in accordance with MIL-STD-1312, Test 11 and those from the single shear fixture in accordance with Appendix A. Each participant performed three tests on each fixture configuration except as noted and forwarded the test results to the NAVAIRDEVCEN for tabulation and analysis.

TEST RESULTS

The ultimate shear loads reported by the various participants were converted to shear strength; Table III lists these values and their associated standard deviation.* The ½ D double shear test provides the lowest average shear strength, smallest standard deviation and least scatter. The departures from the average ultimate shear strength, figure 3, illustrates some laboratory bias, particularly laboratories E and F which were consis-

$$* \quad \sigma = \left[\frac{\Sigma X^2 - \frac{\Sigma (X)^2}{n}}{n-1} \right]^{\frac{1}{2}}$$

where σ = standard deviation
X = shear strength
ΣX^2 = sum of squared results
$\Sigma (X)^2$ = sum of results squared
n = number of tests

tently lower and higher respectively. Also to be noted is the segregation of the single and double shear strength results reported by laboratory D. Examination of the calibration records does not reveal a trend which would attribute this segregation to test machine bias.

The Weibull Plot** of the ultimate shear strength on figures 4 through 6 further focuses attention on the variance among the test results. Since the ½ D double shear is a standard test and the same type of fixture was available to all the participating laboratories, as expected, more uniform results and data were obtained from this fixture. The ultimate strength obtained from the 1 D single shear tests were always the highest values obtained. Lower median rank results from the ½ D single shear and double shear tests on the .250 and .375 inch specimens and to a lesser extent the .190 inch specimen tended to overlap, diverging at the 40 percentile. Another phenomenon to be noted is the extremely steep slope of the initial portion of many of the curves, suggesting a minimum obtainable with a specific fixture. Additional investigation is warranted to better understand the significance of the change in slope.

CONCLUSIONS

1. The ½ D double shear test provides the most conservative test results and should be used whenever practicable.

2. Since the double shear test requires a minimum grip length of 2 D which precludes its use in conjunction with a short grip fastener, a single shear test is necessary.

3. The magnitude of the difference of the ultimate shear strengths obtained from the ½ D single shear and ½ D double shear fixture is insignificant.

4. The ½ D single shear fixture is acceptable for use on fasteners with 1 to 2 D grip lengths.

5. A ½ D single shear test could be substituted for the ½ D double shear test provided the double shear test is used as the referee in case of questionable data.

6. Caution should be used when correlating single and double shear results since the former will be slightly higher.

7. Since there is no apparent difference in the results obtained from the two single shear fixtures, they are considered to be equal.

** The Weibull plot is a graphic method of analyzing statistical data by plotting as the abscissa the logarithm of item and as the ordinate log log 1/(1-F) where F is the median rank of the item under consideration.

RECOMMENDATIONS

Appendix A has been submitted to the FTDG (Fastener Testing Development Group) for inclusion in MIL-STD-1312.

ACKNOWLEDGEMENTS

An evaluation of this nature would not have been possible without the support of the Fastener Testing Development Group. In particular appreciation is extended to Hi Shear Corporation, Huck Manufacturing Company and Standard Pressed Steel Company for specimen preparation and testing and Almay Research and Testing Corporation and NASA, Marshall Space Flight Center for their participation in the round robin testing.

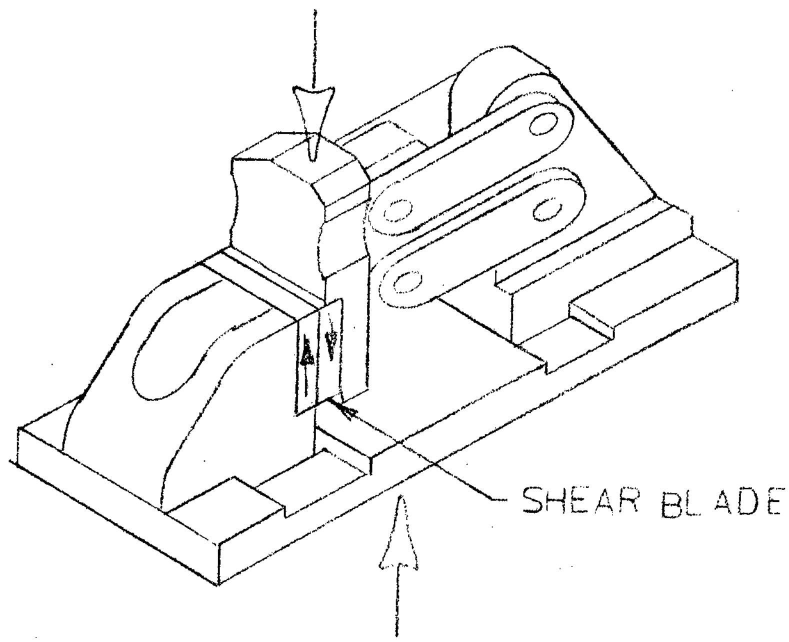

Figure 1. Stapler Type Shear Fixture

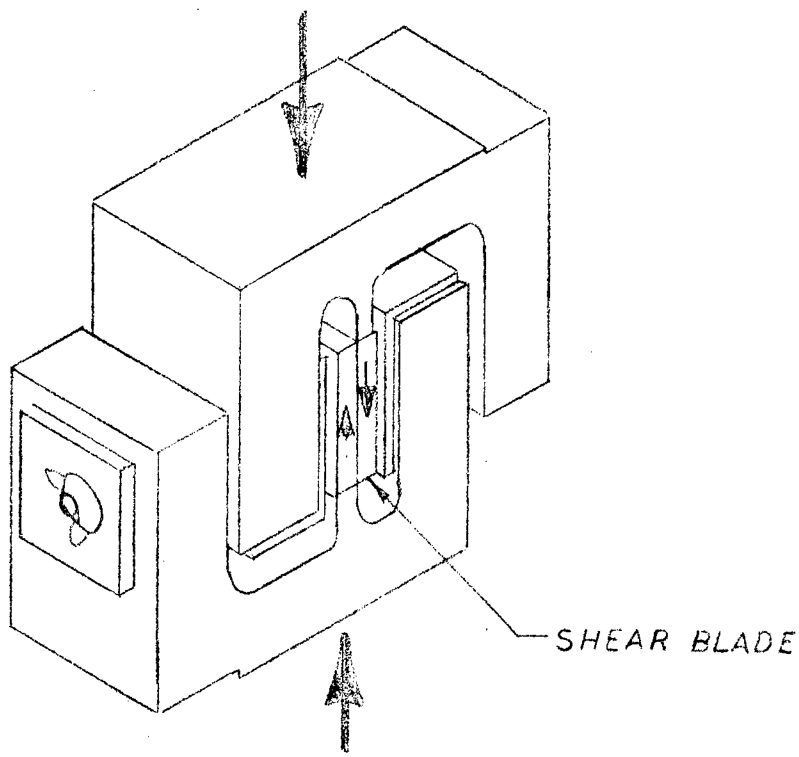

Figure 2. Guillotine Type Shear Fixture

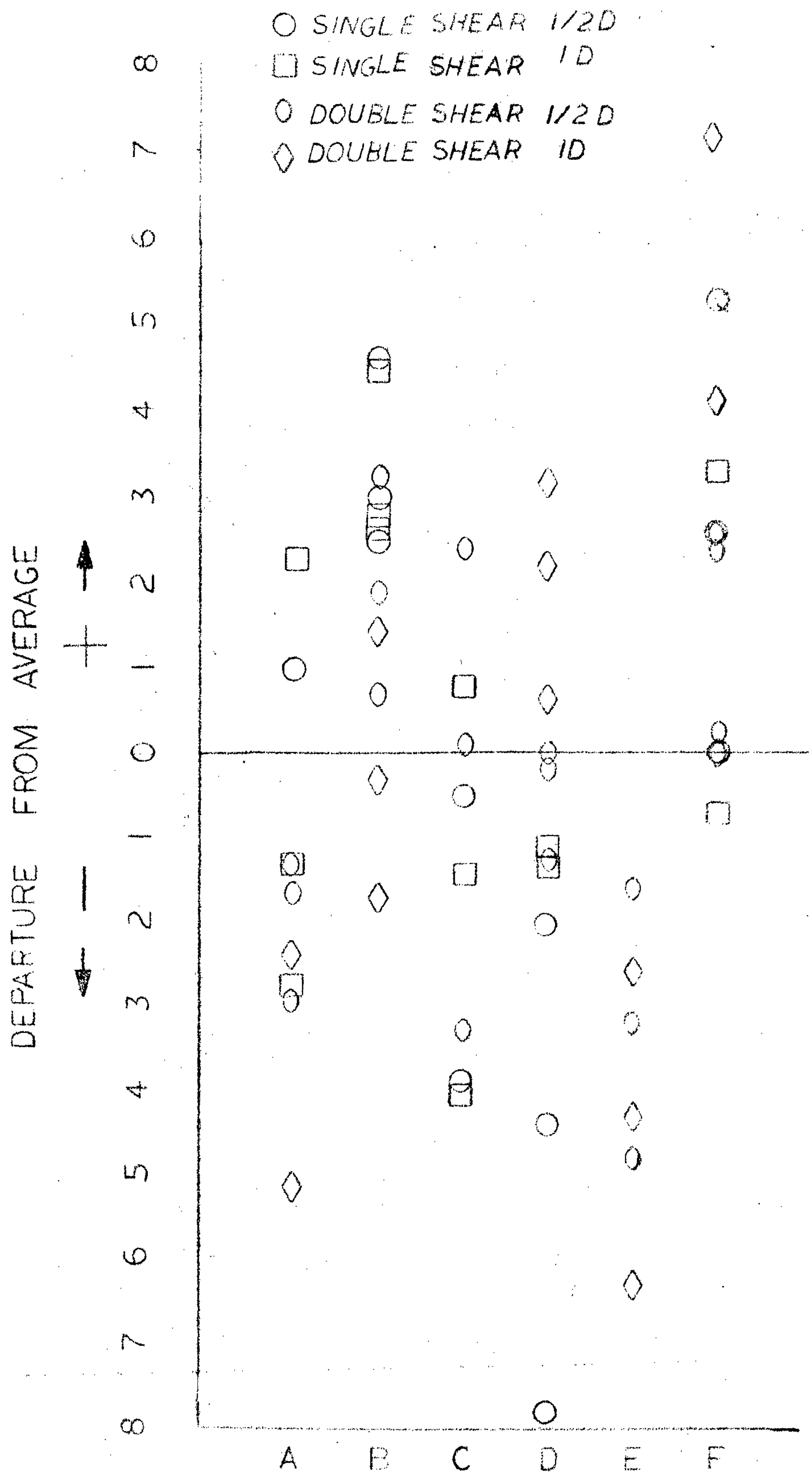

Figure 3. Variation of Ultimate Shear Strength Results

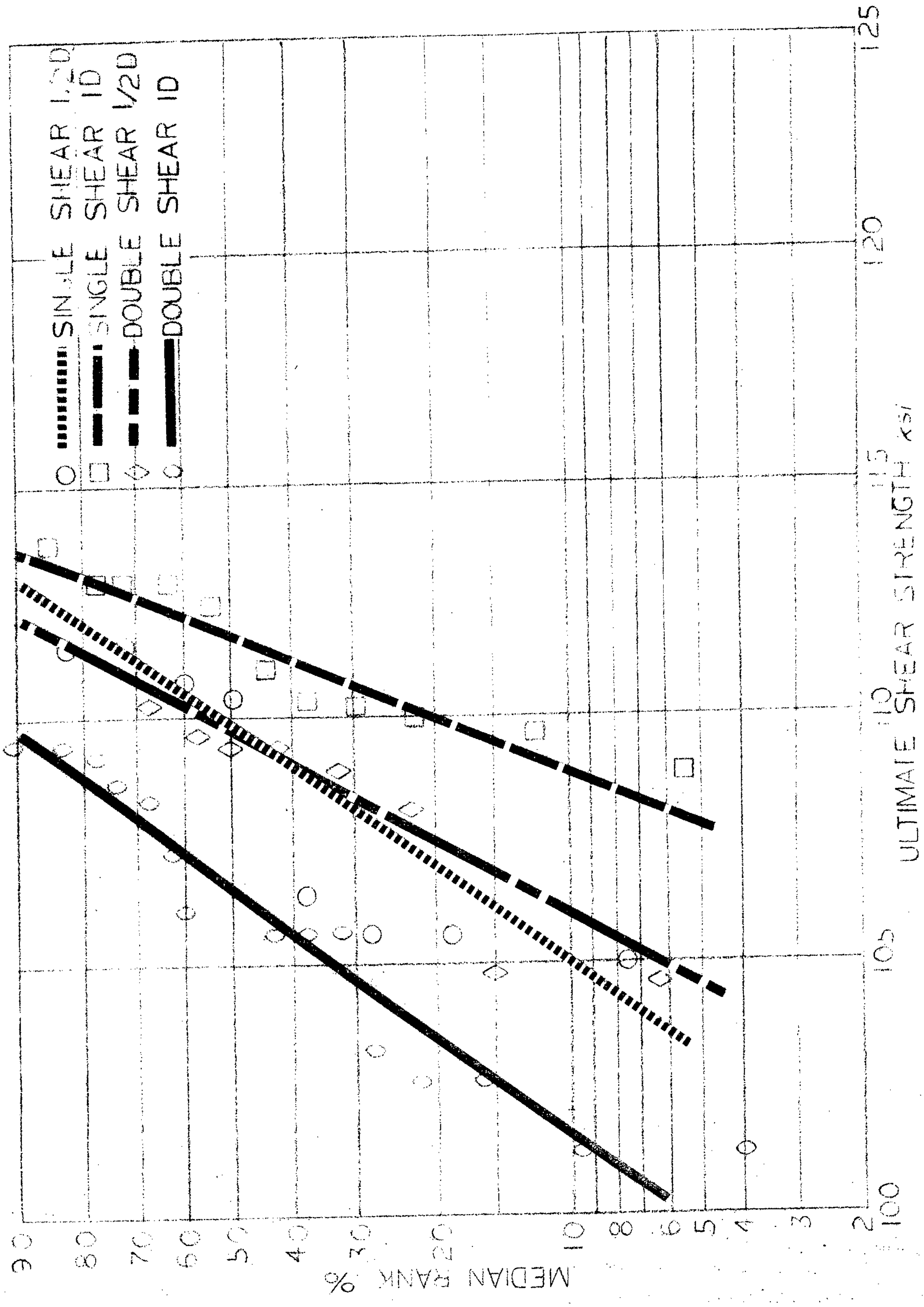

Figure 4. Distribution of .190 Inch Specimen Results

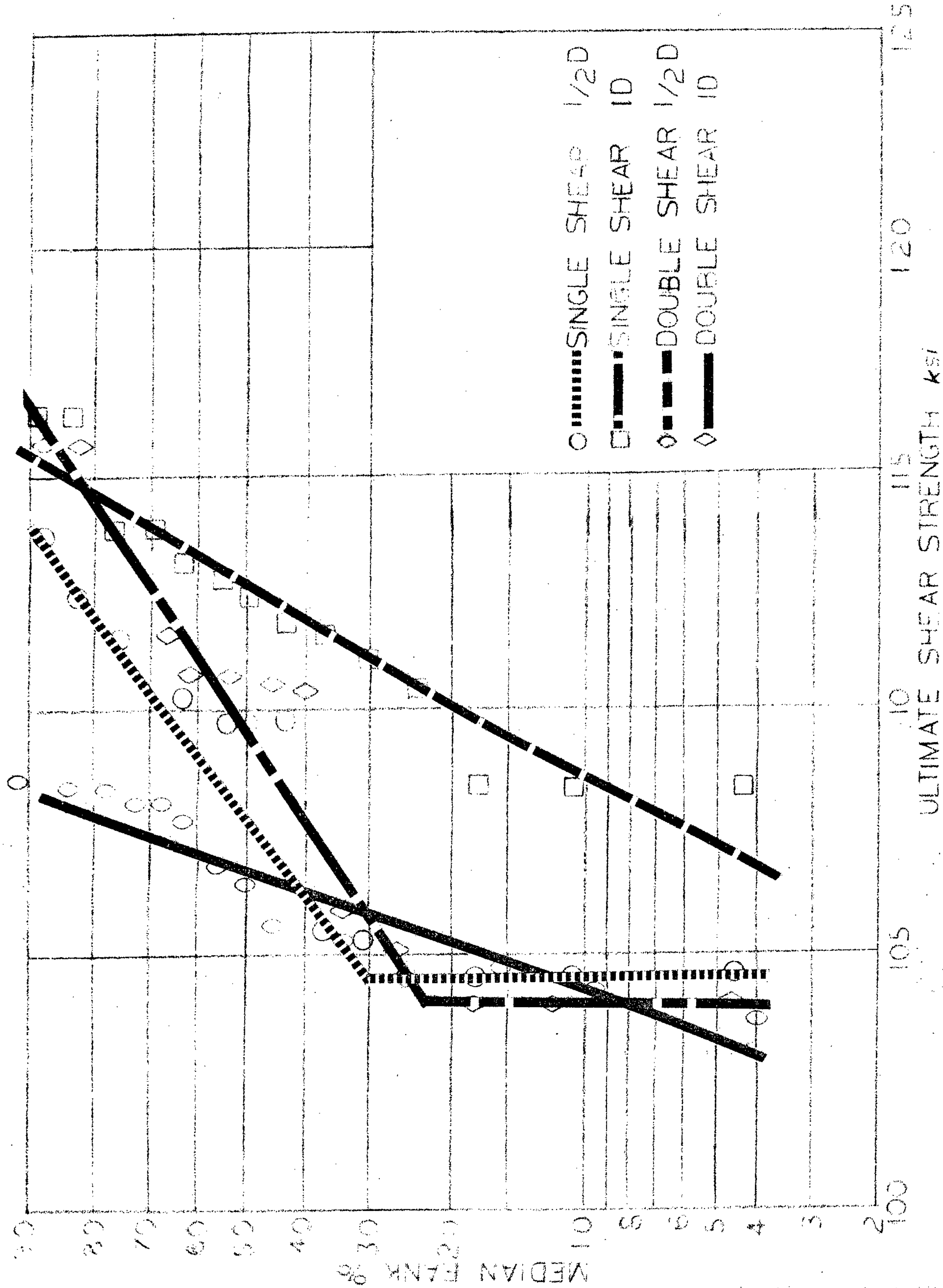

Figure 5. Distribution of .250 Inch Specimen Results

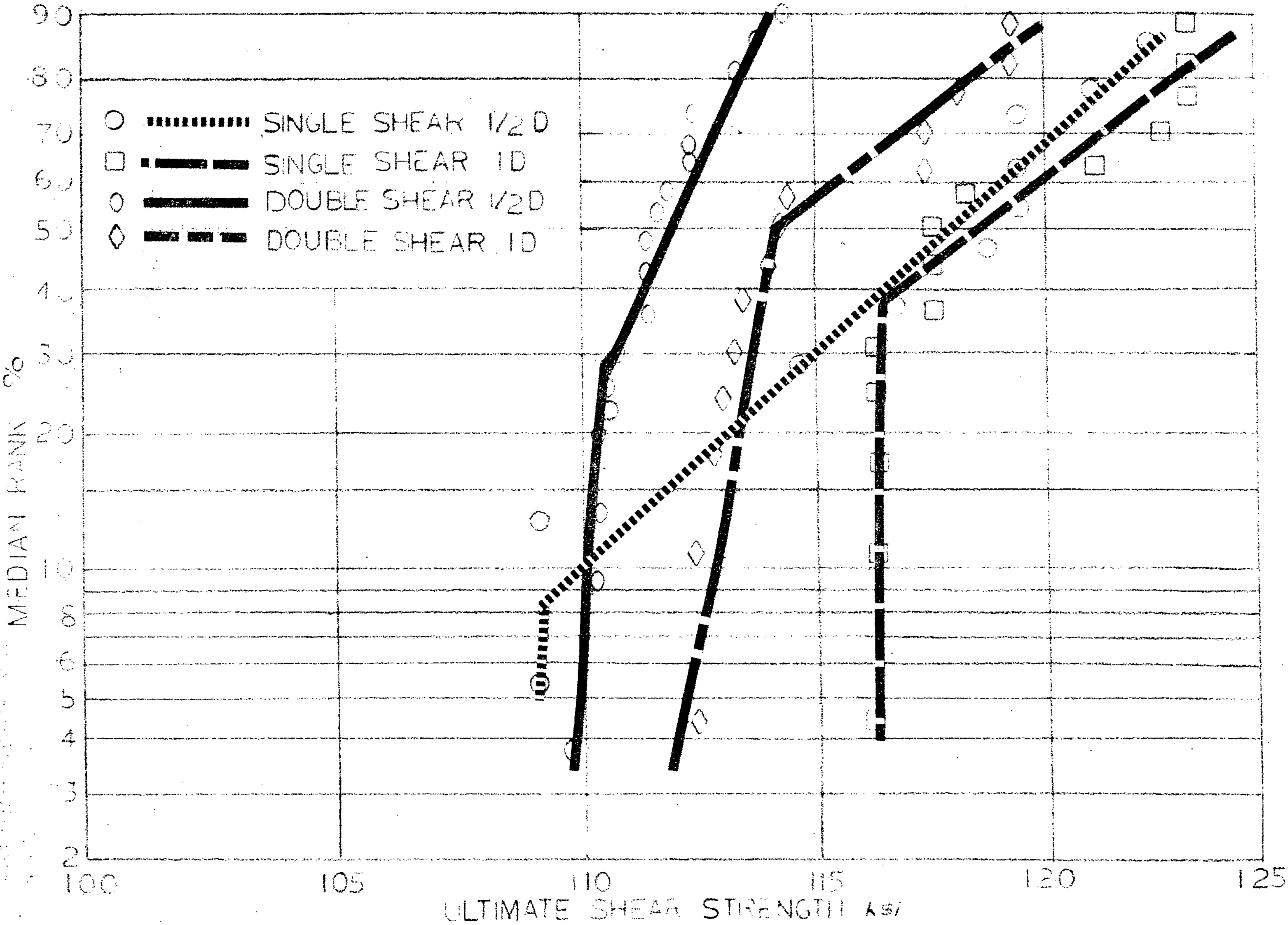

Figure 6. Distribution of .375 Inch Specimen Results

TABLE I

HARDNESS OF SHEAR SPECIMENS

	.190 DIA		.250 DIA		.375 DIA	
PARTICIPANT	SPECIMEN NO.	R_c	SPECIMEN NO.	R_c	SPECIMEN NO.	R_c
A	K	38	13	40	44 63 26 27	39 38 39 39
B	J	38½	8	40	50 12 59 68	39 39 39 39
C	M	38½	14	40	6 41 1	39 39 39
D	C	38	15	40	3 6 33 51	39 39 39 39
E	L	38	12	40	12 46 61 69	39 39 39 39
F	I	38	9	40	20 52 54 19	39 39 39 39

TABLE II

RESULTS OF TENSILE TESTS

Sample No.	Ultimate Tensile Strength psi
.190 Diameter	
1	171,052
2	171,052
3	170,877
Ave.	170,994
.250 Diameter	
1	175,159
2	175,369
3	173,762
Ave.	174,763
.375 Diameter	
1	190,524
2	188,866
3	189,314
Ave.	189,314

TABLE III

RESULTS OF SHEAR TESTS
Ultimate Shear Strength ksi (Standard Deviation)

	A	B	C	D	E	F	
.190 Dia			Single Shear ½D Blades				
		112.7		105.8		105.4	
		111.2		105.1		110.1	
		111.3		106.2		110.5	
Ave.		111.7 (.8)		105.7 (.6)		108.7 (2.8)	108.7 (2.9)
			Single Shear 1D Blades				
	109.2	112.3	112.3	110.1			
	110.8	114.1	112.3	110.1			
	110.0	113.0	111.6	109.8			
Ave.	110.0 (.8)	113.1 (.9)	112.1 (.4)	110.0 (.2)			111.3 (1.5)
			Double Shear ½D Side Blades				
	102.8	108.7	107.1	105.6	101.0	108.3	
	103.2	109.1	105.8	105.6	101.0	109.0	
	102.8	109.1	106.2	105.6	-----	108.0	
Ave.	102.9 (.2)	109.0 (.2)	106.4 (.6)	105.6 (-)	101.0 (-)	108.4 (.5)	105.8 (2.8)
			Double Shear 1D Side Blades				
		108.3		112.9	105.4	109.1	
		109.4		112.7	104.9	109.4	
		109.8		112.5	-----	110.1	
Ave.		109.2 (.7)		112.7 (.2)	105.2 (.4)	109.5 (.5)	109.5 (2.7)
.250 Dia.			Single Shear ½D Blades				
	110.0	114.1	104.5	104.5		110.0	
	110.0	112.0	105.5	104.7		113.0	
	110.3	115.0	105.7	104.9		112.0	
Ave.	110.1 (.5)	113.7 (1.5)	105.2 (.6)	104.7 (.2)		111.7 (.5)	109.1 (3.7)

TABLE III (cont.)

.250 Dia.			Single Shear 1D Blades				
	114.0	116.7	108.2	111.0		112.4	
	112.9	116.9	108.0	111.4		110.4	
	114.0	116.8	108.3	111.2		112.2	
Ave.	113.6 (.6)	116.8 (.1)	108.2 (.4)	111.2 (.2)		111.6 (1.1)	112.3 (2.9)
			Double Shear ½D Side Blades				
	104.8	108.5	109.0	105.4	104.1	108.0	
	105.5	109.5	109.0	105.9	103.3	106.7	
	105.5	108.5	110.0	105.9	-----	107.0	
Ave.	105.3 (.4)	108.8 (.6)	109.3 (.3)	105.7 (.3)	103.7 (.6)	107.2 (.7)	106.9 (2.0)
			Double Shear 1D Side Blades				
	103.9	110.5		110.7	103.8	119.4	
	105.2	112.0		111.0	103.8	116.1	
	105.8	112.0		111.0	-----	116.1	
Ave.	105.0 (1.0)	111.5 (.9)		110.8 (.3)	103.8 (-)	117.2 (1.9)	110.1 (5.0)
.375 Dia.			Single Shear ½D Blades				
		119.5	118.6	110.0		121.0	
		119.5	114.9	109.0		122.5	
		119.5	115.8	109.0		123.1	
Ave.		119.5 (-)	116.4 (1.9)	109.3 (.6)		122.2 (1.1)	116.9 (5.1)
			Single Shear 1D Blades				
	116.1	122.6*	117.6*	117.3*		121.2*	
	116.1	123.1*	117.6*	116.3*		123.0*	
	115.9	123.1*	118.1*	116.3*		123.4*	
Ave.	116.9 (.1)	122.9 (.3)	117.8 (.3)	116.6 (.6)		122.5 (1.2)	119.2 (3.1)
			Double Shear ½D Side Blades				
	110.8	111.3	112.7	112.7	109.8	114.0	
	110.3	112.4	111.3	111.5	110.3	114.5	
	110.3	113.8	111.7	111.3	110.4	114.0	
Ave.	110.5 (.3)	112.5 (1.3)	111.9 (.7)	111.8 (.8)	110.2 (.3)	114.2 (.3)	111.8 (1.5)

* .245 Inch Blades Used

TABLE III (cont.)

.375 Dia.			Double Shear 1D Side Blades			
	114.5	112.7	117.6	113.3	119.5	
	112.8	114.0	117.6	113.2	119.5	
	111.9	114.3	117.9	112.3	119.5	
Ave.	113.1 (1.3)	113.7 (.9)	117.7 (.2)	112.8 (.5)	119.5 (-)	115.4 (2.9)

APPENDIX A

Proposed MIL-STD-1312
Single Shear Test

Proposed MIL-STD-1312

SINGLE SHEAR TEST

1. SCOPE.

1.1 This method covers the procedure and apparatus for testing fasteners in single shear.

2. APPLICABLE DOCUMENTS.

MIL-C-45662 - Calibration of Standards; ASTM E4 - Standard Methods of Verification of Testing Machines.

3. APPARATUS.

3.1 Testing Machine. The testing machine shall be capable of applying a compressive load at a controllable rate. The machine shall conform to the requirements of MIL-C-45662. Its accuracy shall be verified every six months by a method complying with ASTM E4, using a calibration device which shall have been calibrated by the National Bureau of Standards not more than two years prior to its use. The loads of the fasteners tested shall be within the loading range of the testing machine as defined in ASTM E4.

3.2 Test Fixtures.

3.2.1 Test Plate. Plates must maintain the following essential properties:

a. The hole diameter for installation formed fasteners shall be as specified in the product specification and (D + .001) + .002 - .000, where D is the maximum fastener shank diameter for cylindrical body fasteners.

b. The hole shall be perpendicular to the test plate within fifteen minutes of arc.

c. The hole shall be radiused at one end to provide clearance between fastener head and shank fillet.

d. The hole shall be chamfered or broken .005/.010 in the shear plane.

3.2.2 Holding Fixture. Jigs shall be capable of providing shear loading while preventing rotation of the fastener. Shear loading shall remain perpendicular to the longitudinal axis of the fastener throughout the complete test.

4. PROCEDURE

4.1 The ultimate single shear strength shall be obtained as follows:

a. Fasteners shall be installed in the test plates in accordance with the recommendations of the manufacturer, using approved installation equipment. Unless specified otherwise, no preload shall be used, except where such preload is a normal consequence of fastener installation.

b. The specimen shall be installed in the jig and placed between the compression heads of the testing machine. When hydraulic testing machines are used, care shall be exercised to locate the jig at the center of the piston.

c. The test load is then applied at a uniform load rate as specified in Table I. The ultimate strength is determined by increased deformation of the specimen without increased load. Load rates for oversized fasteners (including blind bolts) shall be the same as for normal size fasteners of the corresponding nominal size. Load rates for larger or smaller size fasteners shall be calculated as 50,000 pounds per minute per square inch of nominal shear area. A tolerance of ±10% shall apply on the load rate. Nominal shear area is equal to the nominal shank area for load rate calculation only.

5. TEST REPORTS.

The test report shall contain the following:

a. Fastener Description
b. Part Number
c. Material
d. Manufacturer
e. Measured diameter of each specimen
f. Individual ultimate load

TABLE I

SINGLE SHEAR LOAD RATES

NOMINAL DIAMETER	LOAD RATE LB./MIN.	NOMINAL DIAMETER	LOAD RATE LB./MIN.
1/8	2,480	9/16	49,600
5/32	3.840	5/8	61,200
#8	4,200	3/4	88,000
3/16 or #10	5,600	7/8	120,000
1/4	10,000	1	156,000
5/16	15,400	1-1/8	200,000
3/8	22,000	1-1/4	244,000
7/16	30,000	1-3/8	296,000
1/2	39,200	1-1/2	352,000

The testing agency, at their option, may use a constant strain rate which will produce the specified load rate ($\pm$10%) in the elastic range. That is, the strain rate shall equal the load rate divided by the elastic modulus in shear.

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13. ABSTRACT

In order to evaluate the various fixtures used in determining the shear strength of fasteners, a round robin test was conducted. It was found that single shear tests yield slightly higher shear strengths.

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