

WAIC TECHNICAL REPORT 58-326
ASTIA DOCUMENT NO. AD 155865



TENSION-TENSION FATIGUE INVESTIGATION OF HIGH STRENGTH AIRCRAFT BOLTS EFFECT OF NUT ENGAGEMENT AND THREAD ROOT RADIUS

THOMAS C. BAUMGARTNER
EDWARD F. GOWEN, JR.
COREY CRISPELL

STANDARD PRESSED STEEL COMPANY
JENKINTOWN, PENNSYLVANIA

FEBRUARY 1958

CONTRACT NO. AF 33(616) 3646

FILE COPY
RECEIVED
ASTIA
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA
ATTN: TISS

AD No. **155 865**
ASTIA FILE COPY

AIRCRAFT LABORATORY
WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

ASTIA
RECEIVED
JAN 19 1958
TIPDR E

WADC TECHNICAL REPORT 58-326
ASTIA DOCUMENT NO. AD 155865

**TENSION-TENSION FATIGUE INVESTIGATION OF HIGH
STRENGTH AIRCRAFT BOLTS EFFECT OF NUT
ENGAGEMENT AND THREAD ROOT RADIUS**

THOMAS C. BAUMGARTNER
EDWARD F. GOWEN, JR.
COREY CRISPELL

STANDARD PRESSED STEEL COMPANY
JENKINTOWN, PENNSYLVANIA

FEBRUARY 1958

PROJECT 1318
TASK 13444

AIRCRAFT LABORATORY
WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This report was prepared by Standard Pressed Steel Co., Jenkintown, Pennsylvania, under United States Air Force Contract No. AF 33(616)-3646. This contract was initiated under Project No. 1318, Task No. 1544. The work was administered under the direction of the Special Project Branch, WCLSJ-3, Aircraft Laboratory, Wright Air Development Center with Mr. A. B. Nutt, Branch Chief; Mr. J. W. Evans, Section Chief; Mr. F. A. Hannon, Project Engineer.

This report covers the period of work from April 2, 1956 to February 15, 1958.

ABSTRACT

The object of this project was to establish the tension-tension fatigue properties of external threads without the influence of stress concentrations resulting from engagement; and further, to compare the fatigue characteristics of bolts to those of unengaged threads. These comparisons were to be made on parts heat treated to two strength levels, 160,000 psi and 220,000 psi. Also, fatigue properties of the higher strength parts with thread roots to MIL-B-7838 and high radius thread roots were to be compared.

A stud with a reduced diameter threaded section in the center was developed to evaluate the fatigue characteristics of unengaged threads. The bolts used to determine the fatigue properties of engaged threads conformed to MS 20004 series and SPS EWB 22 dimensions. The nuts used were SPS 42 FW and SPS EWN 22 type without slots or locking action. Fatigue tests were also run using standard self locking all metal nuts and those with a non-metallic locking element.

S-N tension-tension fatigue curves were developed on studs and bolts heat treated to 160,000 psi and 220,000 psi. These were made from the following materials: AISI 8740, AISI 6150, AISI 4340, Hy Tuf and Vascojet 1000. The test thread diameters ranged from 1/4 inch to one inch.

Threads were formed by each of these methods, cutting, grinding and rolling after heat treatment. Tests were run on both studs and bolts with the thread root radii conforming to MIL-B-7838 and with high radius thread roots.

All bolts were cadmium plated. The studs were tested with and without plating. The tension-tension fatigue tests showed:

1. The fatigue strength of unengaged threads is 1 1/4 to 2 1/2 times greater than the engaged threads.
2. By increasing the material strength from 160,000 psi to 220,000 psi (1.4 times) the fatigue strength increases 1.2 to 2.8 times.
3. The fatigue strength of the high radius thread is 1.4 times greater than the MIL-B-7838 thread.
4. All metal locknuts yield higher bolt fatigue strength than those with non-metallic locking elements.
5. Plating reduces the fatigue strength of threads about 15%.
6. The fatigue strength of unengaged threads rolled after heat treatment is 1 1/4 to 2 times greater than cut or ground threads under similar conditions.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:


RANDALL D. KEATOR
Colonel, USAF
Chief, Aircraft Laboratory
Directorate of Laboratories

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. TEST PROGRAM	3
III. TEST PIECES	5
A. Bolts	5
B. Studs	6
C. Nuts	8
IV. TEST EQUIPMENT	10
A. Tensile	10
1. Machines	10
2. Accessories	10
3. Fixtures	11
B. Fatigue	11
1. Machines	11
2. Fixtures	12
3. Load Measuring	13
C. Nuts	14
D. Washers	14
V. TEST PROCEDURES	15
A. Tensile	15
B. Shear	16
C. Fatigue	18
1. Plotting of Data	19
VI. SUMMARY OF RESULTS	20

TABLE OF CONTENTS - Continued

	Page
VII. DISCUSSION OF RESULTS	21
A. Stud Design	21
B. Effect of Engaging Threads on Fatigue Life	21
C. Effect of Material on Fatigue Strength	23
D. Effect of Material Strength on Fatigue Strength of Threads	23
E. Effect of Thread Root Radius on Fatigue Strength	23
F. Effect of Nut Design on Fatigue Strength of Bolts	24
G. Effect of Plating on the Fatigue Strength of Unengaged Threads	24
H. Effect of Cut Threads on Fatigue	26
I. Effect of Ground Threads on Fatigue	26
VIII. CONCLUSION	28
APPENDIX I Raw Data for 160,000 psi Parts	111
II Raw Data for 220,000 psi Parts	148

LIST OF ILLUSTRATIONS

	Page
1 Military Standard - Bolt - Internal Wrenching, 160,000 psi	45
2 Bolt, External Wrenching, 220,000 psi Minimum	46
3 Bolt, External Wrenching, EWB TM 9 for 900°F Applications	47
4 Initial Tension-Tension Fatigue Test Specimen for Determining Characteristics of Unengaged Threads	48
5 Tension-Tension Fatigue Fracture Located in the 1/2-20 Thread of the Above 3/8-24 Stud	48
6 Second Tension-Tension Fatigue Test Specimen for Determining the Characteristics of Unengaged Threads	49
7 Tension-Tension Fatigue Fracture Located at the Thread Termination of the Above 1/4-28 Stud	49
8 Special Thread Dies for Rolling Stud with Six Inch Radius Tangent to Thread Major Diameter.	50
9 Third Tension-Tension Fatigue Test Specimen for Determining the Characteristics of Unengaged Threads	51
10 Tension-Tension Fatigue Fracture Located at the Thread Termination of the Above 1/4-28 Stud.	51
11 Fourth Design of Tension-Tension Fatigue Test Specimen for Determining the Characteristics of Unengaged Threads	52
12 Tension-Tension Fatigue Fracture Located at the Termination of the Above 1/4-28 Stud	52
13 Fifth Design of Tension-Tension Fatigue Test Specimen for Determining Characteristics of Unengaged Threads	53
14 Tension-Tension Fatigue Fracture Located in Last Full Thread of the Above Stud	53
15 Sixth Design of Tension-Tension Fatigue Test Specimen for Determining the Characteristics of Unengaged Threads	54
16 Tension-Tension Fatigue Fracture of the Above Stud Located at the Junction of the Taper and the Full Thread.	54

LIST OF ILLUSTRATIONS - Continued

	Page
17 Cross Section of Special Thread Roll Dies used to Produce Studs with Tapered Runout	55
18 Seventh Design of Tension-Tension Fatigue Test Specimen to Determine the Characteristics of Unengaged Threads	56
19 Tension-Tension Fatigue Fracture of the Above Stud Located at the Junction of the Taper from the Threads	56
20 Eighth Design of Tension-Tension Fatigue Specimen to Determine the Characteristics of Unengaged Threads	57
21 Appearance of the Above Stud after Rolling. Note Shivers of Metal and Incomplete Thread Form on Part of Stud	57
22 Special Thread Roll Dies used to try to Produce 1/4-28 Thread on the Curved Surface	58
23 Final Design of Studs to Determine the Tension-Tension Fatigue Characteristic of Unengaged Threads	59
24 Profile of Threads Rolled to MIL-B-7838 on 3/4 Studs	60
25 Profile of Threads Cut to MIL-S-7742 on 3/4 Studs. Note Flat Root with Small Radius Blending to Flanks	60
26 Profile of Threads Rolled to High Radius Form on 3/4 Stud. Note Large Radius in Root of Thread	60
27 30,000 Pound Timius Olsen Electomatic Universal Testing Machine	61
28 60,000 Pound Timius Olsen Super "L" Hydraulic Universal Testing Machine	62
29 120,000 Pound Timius Olsen Electomatic Universal Testing Machine	63
30 400,000 Pound Timius Olsen Super "L" Hydraulic Universal Testing Machine	64
31 Proving Rings for Calibration of Tensile Machines	65

LIST OF ILLUSTRATIONS - Continued

Page

32	Extensometers used in Tensile Testing	66
33	Specimen Extensometer Assembled in Tensile Machine	67
34	Bolt Extensometer Being used on 60,000 Pound Tensile Machine	68
35	3,000 Pound Capacity Testing Link	69
36	15,000 Pound Capacity Testing Link	70
37	60,000 Pound Capacity Testing Link	71
38	120,000 Pound Capacity Testing Link	72
39	Adapter for Top Crosshead 400,000 Pound Tensile Machine	73
40	Counterbored Adapter for 3,000 Pound Testing Link	74
41	Adapter for 15,000 and 60,000 Pound Tensile Link	75
42	Adapter for 120,000 Pound Tensile Link	76
43	Tapped Bars for Tensile Testing Machine	77
44	Tapped Bars for Tensile Testing Machine	78
45	Bottom Shearing Die Shearing #10 to 1" Diameter	79
46	Top Shearing Die Shearing #10 to 1" Diameter	80
47	Setup for Shear Test on Bolts	81
48	5,000 Pound Krouse Direct Stress Fatigue Machine with Hydraulic Load Maintainer.	82
49	15,000 Pound Krouse Direct Stress Fatigue Machine with Hydraulic Load Maintainer.	83
50	60,000 Pound Ivy Inertia Compensated Fatigue Machine.	84
51	60,000 Pound Krouse Fatigue Machine	85
52	220,000 Pound Amaler Fatigue Machine.	86
53	Fixture and Adapter Assembly used in Fatigue Testing Bolts.	87

LIST OF ILLUSTRATIONS - Continued

	Page
54 220,000 Pound Tensile Fatigue Adapter	88
55 Threaded Adapter, 3,000 Pound Fatigue Links	89
56 Threaded Adapter, 15,000 and 60,000 Pound Fatigue Links .	90
57 5,000 to 15,000 Pound Tension Fatigue Adapter	91
58 25,000 to 60,000 Pound Tensile Fatigue Adapter	92
59 60,000 to 200,000 Pound Tension Fatigue Adapter	93
60 15,000 Pound Adapter Krouse Machine	94
61 60,000 Pound Adapter Krouse Machine	95
62 Close up of Fatigue Failure of NAI 160 Fatigue Link - 200,000 Pound Capacity	96
63 Full View of NAI 160 Fatigue Link. Failure is Noticeable in Upper Part.	97
64 Fatigue Failure of NAI 160, 15,000 Pound Link	98
65 Location of Strain Gages on Flexure Plates	99
66 Instrumentation used on each Fatigue Machine to Measure Dynamic Loads	100
67 Oscillograph Pattern of Dynamic Load and Measuring Circuit	101
68 Fatigue Test Nuts for Tension Bolts under 200,000 psi Ultimate	102
69 Fatigue Test Nuts for Tension Bolts under 240,000 psi Ultimate	103
70 Special Nuts for Studs.	104
71 "FLEXLOC" Self-Locking External Wrenching Nut for use with 180,000 psi Minimum Bolts.	105
72 ESNA EB Nut	106
73 SPS WC 22 Washer	107
74 Fatigue Fracture Resulting from Bending	108

LIST OF ILLUSTRATIONS - Continued

	Page
75 Fatigue Fracture Resulting from Uniaxial Loading	108
76 Bolt Body Showing Rubbing Marks Resulting from Non-Axial Loading	108
77 Fatigue Fracture in Shank of 3/4 Inch Test Specimen	109
78 Fatigue Fracture in Thread Section of 3/4 Inch Test Specimen Resulting from Peening of Radius	109
79 Fatigue Fracture in 2-12 Cut Thread Rather than 1-14 Rolled Thread	109
80 Typical Fatigue Fracture of Cut or Ground Unengaged Thread	110

LIST OF CHARTS

	Page
1 Tension-Tension Fatigue Test - Average Results of All Sizes of Studs and Bolts	29
2 Tension-Tension Fatigue Test, 1/2-20 Studs, High Radius Thread Form, Heat Treatment 220,000-240,000 psi	30
3 Tension-Tension Fatigue Test, 1/2-20 External Wrenching Bolts High Radius Thread Form, Heat Treatment 220,000-240,000 psi	31
4 Tension-Tension Fatigue Test, External Wrenching Bolts, Thread Form per MIL-B-7838, Heat Treatment 220,000-240,000 psi	32
5 Tension-Tension Fatigue Test, 1/2-20 Stud, MIL-S-7108 Material Heat Treatment 220,000-240,000 psi	33
6 Tension-Tension Fatigue Test, 3/4-16 Stud, MIL-S-7108 Material Heat Treatment 220,000-240,000 psi	34
7 Tension-Tension Fatigue Test, 1/2-20 EWB 22 External Wrenching Bolt, MIL-S-7108 Material, Heat Treatment 220,000- 240,000 psi	35
8 Tension-Tension Fatigue Test, 3/4-16 EWB 22 External Wrenching Bolt, MIL-S-7108 Material, Heat Treatment 220,000- 240,000 psi	36
9 Tension-Tension Fatigue Test, 5/16-24 External Wrenching Nut	37
10 Tension-Tension Fatigue Test, 5/8-18 External Wrenching Nut	38
11 Tension-Tension Fatigue Test, 3/4-16 Unengaged Threads (Cut and Rolled)	39
12 Tension-Tension Fatigue Test, 3/4-16 Unengaged Threads (Ground and Rolled)	40
13 Tension-Tension Fatigue Test, MIL-S-6049 Studs, Heat Treat- ment 160,000-180,000 psi, Thread Form per MIL-B-7838 .	41
14 Tension-Tension Fatigue Test, MS 20004 Internal Wrenching Bolt, MIL-S-6049 Material	42
15 Tension-Tension Fatigue Test, MIL-S-7108 Studs, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	43

LIST OF CHARTS - Continued

Page

16	Tension-Tension Fatigue Test, EWB 22 External Wrenching Bolts, MIL-S-7108 Material, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	44
17	Tension-Tension Fatigue Test, 1/4-28 MS 20004 Internal Wrenching Bolt	112
18	Tension-Tension Fatigue Test, 3/8-24 MS 20006 Internal Wrenching Bolt	115
19	Tension-Tension Fatigue Test, 1/2-20 MS 20008 Internal Wrenching Bolt	118
20	Tension-Tension Fatigue Test, 3/4-16 MS 20012 Internal Wrenching Bolt	121
21	Tension-Tension Fatigue Test, 1-14 MS 20016 Internal Wrenching Bolt	124
22	Tension-Tension Fatigue Test, 1/4-28 Stud, Heat Treatment 160,000-180,000 psi	127
23	Tension-Tension Fatigue Test, 1/4-28 Stud, Heat Treatment 160,000-180,000 psi (Plated).	128
24	Tension-Tension Fatigue Test, 3/8-24 Stud, Heat Treatment 160,000-180,000 psi	131
25	Tension-Tension Fatigue Test, 3/8-24 Stud, Heat Treatment 160,000-180,000 psi (Plated).	132
26	Tension-Tension Fatigue Test, 1/2-20 Stud, Heat Treatment 160,000-180,000 psi	135
27	Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 160,000-180,000 psi	138
28	Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 160,000-180,000 psi (Plated).	139
29	Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 160,000-180,000 psi (Cut and Ground Thread)	142
30	Tension-Tension Fatigue Test, 1-14 Stud, Heat Treatment 160,000-180,000 psi	145

LIST OF CHARTS - Continued

	Page
31 Tension-Tension Fatigue Test, 1/4-28 MS 20004 Form Internal Wrenching Bolt, MIL-S-8503 Material, Heat Treatment 220,000-240,000 psi	149
32 Tension-Tension Fatigue Test, 1/4-28 EWB 22 External Wrenching Bolt, Thread Form per MIL-B-7838	152
33 Tension-Tension Fatigue Test, 3/8-24 EWB 22 External Wrenching Bolt, Thread Form per MIL-B-7838	155
34 Tension-Tension Fatigue Test, 1/2-20 MS 20008 Form Internal Wrenching Bolt, MIL-S-8503 Material, Heat Treatment 220,000-240,000 psi	158
35 Tension-Tension Fatigue Test, 1/2-20 EWB 22 External Wrenching Bolt, Thread Form per MIL-B-7838	161
36 Tension-Tension Fatigue Test, 1/2-20 EWB 22 External Wrenching Bolt, High Radius Thread Form	164
37 Tension-Tension Fatigue Test, 1/2-20 EWB TM 9-8 External Wrenching Bolt, VascoJet 1000 Material, High Radius Thread Form	167
38 Tension-Tension Fatigue Test, 3/4-16 EWB 22 External Wrenching Bolt, Thread Form per MIL-B-7838	170
39 Tension-Tension Fatigue Test, 3/4-16 EWB 22 External Wrenching Bolt, High Radius Thread Form	173
40 Tension-Tension Fatigue Test, 1-14 EWB 22 External Wrenching Bolt, Thread Form per MIL-B-7838	176
41 Tension-Tension Fatigue Test, 1/4-28 Stud, Heat Treatment 220,000-240,000 psi, MIL-S-8503 Material, Thread Form per MIL-B-7838	179
42 Tension-Tension Fatigue Test, 1/4-28 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	182
43 Tension-Tension Fatigue Test, 1/4-28 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838 (Plated)	183
44 Tension-Tension Fatigue Test, 3/8-24 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	186

LIST OF CHARTS - Continued

	Page
45 Tension-Tension Fatigue Test 3/8-24 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838 (Plated)	187
46 Tension-Tension Fatigue Test, 1/2-20 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	190
47 Tension-Tension Fatigue Test, 1/2-20 Stud, Heat Treatment 220,000-240,000 psi, High Radius Thread Form	193
48 Tension-Tension Fatigue Test, 1/2-20 Stud, Heat Treatment 220,000-240,000 psi, High Radius Thread Form, VascoJet 1000 Material	196
49 Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	199
50 Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838 (Plated)	200
51 Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 220,000-240,000 psi, High Radius Thread Form.	203
52 Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 220,000-240,000 psi, High Radius Thread Form (Plated) . . .	204
53 Tension-Tension Fatigue Test, 3/4-16 Stud, Heat Treatment 220,000-240,000 psi, Threads Cut and Ground to MIL-B-7838	207
54 Tension-Tension Fatigue Test, 1-14 Stud, Heat Treatment 220,000-240,000 psi, Thread Form per MIL-B-7838	

LIST OF TABLES

	Page
I Thread Root Radii Specified in MIL-B-7838	9
II Thread Root Radii Specified for High Radius Thread.	9
III Gage Sizes for Parts Tested in Tensile.	15
IV Bolts Tested for Mechanical Properties	16
V Studs For Testing Mechanical Properties of Unengaged Threads .	17
VI Fatigue Strengths at 8,000,000 Cycles	22
VII Effect of Plating on the Fatigue Strength of Unengaged Threads .	25
VIII Rolled Thread after Heat Treatment vs Cut Thread, Fatigue Strength to Produce Fracture at 100,000 Cycles	26
IX Rolled Thread after Heat Treatment vs Ground Thread, Fatigue Strength to Produce Fracture at 100,000 Cycles	27

SECTION I

INTRODUCTION

Rapidly increasing speeds of aircraft and missiles demand increased static and dynamic properties per pound of material. This objective may be gained by three different methods.

- a. The development of alloys with higher strength-to-weight ratios.
- b. The development of processing methods to attain increased properties from existing alloys heat treated to higher strengths.
- c. The design of parts to utilize an increased percentage of the inherent properties of the alloy.

At the present time progress is being made to develop alloys with greater strength-to-weight ratios. The titanium alloys presently being used are a step in this direction. New alloys of both titanium and other elements are being developed, but these will require time to evaluate and further develop for commercial applications.

While this alloy development progresses, techniques of processing to increase the strength-to-weight ratio must be continued. In this manner, even greater improvement may be achieved with the use of the new alloys. Two of the improvements realized in recent years through fabrication procedures are increased strength and fatigue life. These have resulted from the selection of existing materials which have higher strength with good ductility and the development of production methods to produce threads on hardened alloys.

Additional gains in the strength-to-weight ratio can be achieved by utilizing designs which provide an increased percentage of the inherent properties of the alloy. Studies of the stress distribution in structural elements have disclosed points of high stress concentration located in areas where the stress had been estimated to be at a minimum. In other instances, it has been known that stress concentrations existed but their effect has never been determined. Design criteria developed from these studies will be applicable when new alloys and fabrication techniques are developed. Thus, an additional gain in the strength-to-weight ratio may be realized.

Since threaded fasteners are used in many applications on aircraft, a test program was established by the Aircraft Laboratory, Wright Air Development Center, to determine some of the dynamic properties of threaded fasteners. Basically, the object of the project was to determine the tension-tension fatigue characteristics of:

- a. present high strength aircraft bolts

Manuscript released by authors January 1958 for publication as a WADC Technical Report.

- b. unengaged threads
- c. the high radius thread form
- d. plated threads
- e. cut threads
- f. ground threads

The bolts tested were heat treated to 160,000/180,000 and 220,000/240,000 psi. The studs with unengaged threads were fabricated to the same strength levels. The thread forms tested were fabricated in accordance with MIL-R-7838 and with high radius threads. These threads were tested on bolts in conjunction with nuts and on studs so designed that the threads were not engaged.

SECTION II

TEST PROGRAM

This test program was set up to evaluate the static and dynamic characteristics of threads. Comparisons were made between the tension-tension fatigue strengths of threaded assemblies and unengaged male threads. Threaded parts 1/4 to one inch diameter were tested. The threads were produced by a single rolling operation on studs and bolts heat treated to 160,000/180,000 psi and 220,000/240,000 psi. In addition, an evaluation was made of the fatigue strength of unengaged male threads produced by cutting and grinding. A comparison of two modifications in the MIL-S-7742 thread form, which consisted of different size radii in the thread root, were conducted on the high strength parts. Since alloy steel bolts are usually cadmium plated for corrosion resistance, the effect of this coating on the fatigue life was determined.

Bolts were fabricated to standard configurations. All metal nuts were used in determining the static and fatigue properties of the bolts. Additional tests were conducted using all-metal and non-metallic insert locknuts to determine if there was any difference in the fatigue life of a threaded assembly due to the design of the locking element of the nut.

The fatigue properties of unengaged male threads were determined on studs which had the test thread located in the center. The goal of the stud design was to develop a part which would fail in fatigue near the center of the male test thread. Thus the influence of stress concentrations resulting from nut engagement and thread termination could be eliminated. However, it was not found possible to completely eliminate the effect of thread runout.

The bolts and studs heat treated to 160,000/180,000 psi were fabricated from MIL-S-6049 (AISI 8740) alloy in all sizes except the one inch which was made from MIL-S-5000 (AISI 4340) alloy. The 220,000/240,000 psi parts were fabricated from MIL-S-8503 (AISI 6150), MIL-S-7108 (Hy Tuf) and Vasco-Jet 1000.

Each lot of parts was subjected to static and dynamic tests to determine their properties. The following static tests were conducted on each lot of bolts.

- a. Tensile strength of the threaded fastener.
- b. Yield strength of the threaded fastener.
- c. Shear strength of the bolt body.
- d. Tensile strength of the base material.
- e. Yield strength of the base material.
- f. Percent elongation of the base material.
- g. Percent reduction of area of the base material.

The static mechanical properties of the base material of each lot of studs were determined. Tensile tests were conducted on some lots of studs, but these tests were discontinued because fracture did not occur in the test section.

Tension-tension fatigue tests were conducted at five stress levels on all lots of bolts and studs. Four stress levels were selected to produce failures between 10,000 and 1,000,000 cycles. Five pieces were tested at each of these stress levels. The fifth stress level was selected to produce 8,000,000 cycles with no failure. Two pieces were tested at this stress level.

SECTION III

TEST PIECES

A. BOLT:

The 160,000/180,000 psi bolts were made in 1/4, 5/16, 3/8, 1/2, 5/8, 3/4 and one inch diameters to MS 20004 series dimensions, Figure 1. The threads were produced on the hardened and ground parts by a single rolling process to the dimensions, form and contour shown in Specification MIL-B-7838. All diameters except the one inch were fabricated from MIL-S-6049 (AISI 8740) alloy. The one inch diameter was made from MIL-S-5000 (AISI 4340) alloy. The bolts were cadmium plated to Specification QQ-P-416, Type 1, Class C and baked at $375^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for a minimum of three hours.

One group of 220,000/240,000 psi bolts was made in 1/4, 3/8, 1/2, 3/4 and one inch diameters to SPS EWB 22-4 series dimensions, Figure 2. The threads were produced on the hardened and ground parts by a single rolling process to the dimensions, form and contour shown in Specification MIL-B-7838. All these bolts were fabricated from MIL-S-7108 (Hy Tuf) alloy. They were cadmium plated from a fluoborate bath in accordance with Specification NAS 672 and baked at $375^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for a minimum of 23 hours. This type plating was used to reduce the possibility of embrittlement due to hydrogen.

One lot of 1/4-28 bolts heat treated to 220,000/240,000 psi were made to MS 20004 dimensions, Figure 1. The threads were produced on the hardened and ground parts by a single rolling process to the dimensions, form and contour shown in Specification MIL-B-7838. These bolts were fabricated from MIL-S-8503 (AISI 6150) alloy. These bolts were cadmium plated to Specification QQ-P-416, Type 1, Class C and baked at $375^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for a minimum of three hours.

The 220,000/240,000 psi bolts were also made in 1/2 and 3/4 inch diameters to SPS EWB 22-4 series dimensions, Figure 2. The threads were produced on the hardened and ground parts by a single rolling process to the dimensions, form and contour of the high radius thread form. These bolts were fabricated from MIL-S-7108 (Hy Tuf) alloy. They were cadmium plated from a fluoborate bath in accordance with Specification NAS 672 and baked at $375^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for a minimum of 23 hours.

One lot of 1/2-20 bolts heat treated to 220,000/240,000 psi were made to SPS EWB TM 9-4 series dimensions, Figure 3. The threads were produced on the hardened and ground parts by a single rolling process to the dimensions, form and contour of the high radius thread form. These bolts were fabricated from a 5% Cr die steel (VascoJet 1000). The bolts were

nickel-cadmium diffused plated in accordance with Specification AMS 2416. This plating was used to provide corrosion resistance up to 1000°F.

B. STUDS:

To determine the tension-tension fatigue properties of unengaged threads, it was necessary to develop a test specimen. The goal of this design was to produce fatigue failures in the center portion of the test threads. To achieve this, the effect of stress concentrations at the thread termination and those due to the nut engagement had to be eliminated. Therefore, the test thread could not be loaded through a nut and the effect of thread termination had to be minimized. Various designs of specimens described below were fabricated and tested. It was found impossible to eliminate entirely the effect of the thread termination. However, in the design adapted, the effect of the thread runout was minimized. Failures occurred predominantly in the last full thread except in the case of the cut and ground threads where fractures occurred near the center of the threaded portion.

The basic shape of all specimens was a stud with a reduced threaded section in the center. All development work on stud design was carried out on parts fabricated from AISI 8740 material heat treated to 160,000/180,000 psi. The thread form used conformed to MIL-B-7838 and was rolled subsequent to heat treatment.

The initial design, Figure 4, had a 1/2-20 thread on each end with a 3/8-24 thread in the center. The radius joining the two threads, the 1/2 inch to the 3/8 inch, was made tangent to the root of the smaller thread. A .065 inch radius fillet blended this to the thread. In fatigue, failure of the 1/2-20 thread occurred prior to the 3/8-24, Figure 5. In all subsequent designs, the threads on the ends of the studs were made twice the diameter of the test thread.

Since fatigue occurred first in the 1/2-20 thread, it was decided to conduct all future tests for design development on studs with 1/2-20 threads on the end and 1/4-28 MIL-B-7838 threads in the center. All such parts were made from AISI 8740 material heat treated to 160,000 psi minimum tensile strength.

The first stud of this design was made with a six inch radius blending the two threads and tangent to the 1/4-28 thread at its major diameter. The dimensions are shown in Figure 6. Special thread roll dies were made, as shown in Figure 8, to produce the thread between two runout angles. As shown in Figure 7, failure occurred at the thread runout.

Next, studs were made with the six inch radius blending the two threads tangent to the pitch diameter of the smaller thread. Figure 9 shows the

dimensions of the parts. Fatigue failure occurred at the thread termination as shown in Figure 10.

These parts were modified as shown in Figure 11 by machining a 3/16 radius at the termination of the test thread. This fillet was tangent to the thread root and was cold worked by forcing a roller against the radius. Figure 12 shows the fatigue failure located in the 3/16 radius.

The next stud design had the six inch radius tangent to the thread root. The 1/4-28 thread was rolled before grinding the six inch radius. Two full threads at each end of the smaller thread were ground off when finishing the six inch radius. This was made tangent to the thread root as shown in Figure 13. Fatigue fracture occurred in the first full thread from the termination as shown in Figure 14.

To try and reduce the stress in the thread termination area further so that fatigue failure would occur nearer the center, a new design was tried. This is shown in Figure 15. The thread runout was tapered from the full thread form to the six inch radius which was tangent to the major diameter of the test thread. The shape of the dies used is shown in Figure 16. As shown in Figure 17, fatigue failure occurred at the junction of the taper and the full thread form.

Figure 18 shows the design of the next stud tested. A uniform taper blended the major diameter to the root diameter. Standard thread roll dies 1.952 inches wide were used to thread these parts. The fatigue failure occurred at the junction of the tapers from the 1/2 inch thread and the 1/4 inch thread, as shown in Figure 19.

The final design tested is shown in Figure 20. A 1/4-28 thread form was planned on a five inch radius. The axis of each thread was perpendicular to the axis of the stud. A satisfactory thread form could not be produced due to the difference in surface speeds between the die and the part along the contour. The special thread roll dies made to produce these parts are shown in Figure 21. As shown in Figure 22, the thread was not fully formed over the entire length and had a protruding sliver of metal. Etched specimens showed laps and very rough surfaces. A satisfactory thread could not be produced.

At a meeting held at Wright Air Development Center, it was decided to discontinue further stud development and use the design shown in Figures 13 and 14. This was the only design which produced fatigue failures in the fully formed threads. The fractures were located in the last full thread before the run out thread. Studs of all sizes were fabricated to the dimensions shown in Figure 23.

The steel specimens were produced to two strength levels, 160,000/180,000 psi and 220,000/240,000 psi. The lower strength parts were fabri-

cated from MIL-S-6069 (AISI 8740) with test thread diameters of 1/4, 3/8, 1/2 and 3/4 inch. The one inch size was fabricated from MIL-S-5000 (AISI 4340) material. The threads on these sizes were produced by a single rolling process on the hardened and ground studs. The thread form conformed to MIL-S-7742 as modified by MIL-B-7838, Table 1 and Figure 24. The 3/4 inch size was also produced with both cut and ground threads. The threads were cut before heat treating and conformed to MIL-S-7742. The root of the thread was flat with small radii blending to the flanks, Figure 25. The ground threads were produced after heat treatment with root radii rounded to MIL-B-7838.

Some of the 1/4, 3/8 and 3/4 inch test threads at 160,000 psi with rolled threads were cadmium plated to Specification QQ-P-416, Type 1, Class C. These were baked at 375°F for 3 hours to remove hydrogen.

Higher strength level, 220,000/240,000 psi, specimens were fabricated from MIL-S-7109 (Hy-Tuf) material with test thread diameters of 1/4, 3/8, 1/2, 3/4 and one inch. Also, a lot was produced in the 1/4 inch size from MIL-S-8503 (AISI 6150) material. Threads were produced by a single rolling operation on the hardened and ground studs. The thread form conformed to MIL-S-7742 as modified by MIL-B-7838, Table 1. The 1/2 and 3/4 inch sizes were also fabricated with the high radius thread, Figure 26 and Table 2. Test specimens with rolled threads in the 1/4, 3/8 and 3/4 inch size at 220,000 psi were cadmium plated from a fluoborate bath to Specification NAS 672. These were baked at 375°F for 23 hours to remove hydrogen. Studs with the 3/4 inch size threads were also made by cutting and grinding. The threads were cut to MIL-S-7742 before heat treating. The root was flat with small radii blending to the flanks, Figure 23. The MIL-B-7838 thread form was ground after heat treatment.

A lot of 1/2-20 studs were produced from a 5% chromium hot work die steel, VascoJet 1000 and were heat treated to 220,000/240,000 psi. The high radius thread form was rolled after heat treatment.

C. NUTS:

The locknuts tested in fatigue to evaluate the effect of design were standard external wrenching nuts for 160,000 psi bolts. The all metal designs were the SPS 42FW 524 and 42FW 1018. The nuts with a non-metallic locking element were the ESNA EB0524 and EB 1018.

TABLE I

Thread Root Radii Specified in MIL-B-7838

Size	Radius (inch)	
	Minimum	Maximum
1/4	.0040	.0051
5/16	.0050	.0060
3/8	.0050	.0060
1/2	.0060	.0072
5/8	.0060	.0080
3/4	.0070	.0090
1	.0080	.0103

TABLE II

Thread Root Radii Specified for High Radius Thread

Size	Radius (inch)	
	Minimum	Maximum
1/2	.0078	.0090
3/4	.0092	.0112

SECTION IV

TEST EQUIPMENT

A. TENSILE:

1. Machines

Timius Olsen Universal Testing Machines which were used in this project had the following capacities:

<u>Max. Capacity-*</u>	<u>Additional Tensile Ranges</u>	<u>Type Operation</u>	<u>Figure</u>
30,000	6,000; 1,200; 300	Electomatic	27
60,000	12,000; 1,200	Hydraulic	28
120,000	24,000; 6,000; 1,200	Electomatic	29
400,000	80,000; 20,000	Hydraulic	30

The electomatic machines operate by a variable speed motor driving the loading screws. The load is measured through a lever system and load cells consisting of differential transformers on a beam. The guaranteed accuracy of these machines is $\pm 1\%$.

The hydraulic machines are loaded by fluid pressure. The load is measured through differential transformers on sensitive Bourdon tubes. The guaranteed accuracy of these machines is also $\pm 1\%$.

All tensile machines were calibrated using proving rings certified by the U. S. Bureau of Standards. The rings shown in Figure 31 have the following capacities:

3,000 pounds
30,000 pounds
300,000 pounds

2. Accessories

Each machine is equipped with the following accessories:

- a. Pacer - to control loading at a fixed rate in pounds per minute.
- b. Recorder - to plot load in pounds vs extension.
- c. Strain rate indicator - to control loading at a fixed strain rate.

All tests were run with one of the extensometers shown in Figure 32. The extensometer in the lower left corner was used to measure the elong-

ation of bolts in inches. The "S" series of extensometers was used to measure smooth specimen elongation in inch per inch. The particular gage lengths used for the specimen were 0.50, 1.0, 1.4 and 2.0 inches. An application of the extensometer on a specimen may be seen in Figure 33. Figure 34 shows how the bolt extensometer is used on bolts up to fifteen inches long.

The lever arm of the extensometers actuates the differential transformer, which in turn transmits the signal to the recorder. In this way the elongation is plotted on the recorder according to the magnification selected on the recorder panel. Each extensometer has three magnification ranges. These ranges vary from 50 to 1000 depending on the extensometer used.

To accurately locate the bolt extensometer, a center drill hole is made at the point and in the head recess or socket. This gives point contact. The specimen extensometers are put directly on the smooth gage section of the piece. The gage length used for specimens was four times the gage diameter. The guaranteed accuracy of the recorder is $\pm 1\%$.

3. Fixtures

To attain the required alignment for accurate values, fixtures fabricated to close tolerances were used for tensile testing.

The links used are shown in Figures 35 thru 39. These were also used in fatigue testing. With the use of adapters, Figures 40 thru 42, these links provided a means to test from 1/4 to 1 1/2 inch diameters. Both the links and the adapters were fabricated within very close tolerance to insure axial loading.

Bolt and nut combinations were pulled in tensile with links and adapters at both ends. The stud specimens were pulled with the link set up on one end and a tapped bar on the other. The tapped bar was held in the tensile machine by jaws. The tapped bars are pictured in Figures 43 and 44.

The drawings, Figure 45 and 46 show the top and bottom of the room temperature shear die. The set up is shown in Figure 47. The shear tests were run in the Universal Testing Machines.

B. FATIGUE:

1. Machines

Fatigue machines of the following models and capacities were used to test the bolts and studs of this program:

- a. 5,000 pound Krouse operating at 1650 CPM, Figure 48.
- b. 15,000 pound Krouse operating at 1050 CPM, Figure 49.
- c. 60,000 pound Ivy operating at 1200 CPM, Figure 50.
- d. 60,000 pound Krouse operating at 850 CPM, Figure 51.
- e. 220,000 pound Amaler operating at 500 CPM, Figure 52.

Load multiplying fixtures were used on a 15,000 pound Krouse and the Ivy machine to produce 60,000 pounds.

The 5,000 and 15,000 pound Krouse machines operate on the principle of an adjustable throw crank applying the alternating load to the specimen thru a lever and a parallelogram of flexure plates. The minimum load is applied by a hydraulic cylinder attached to a stationary holder. During the test, constant load limits are maintained on the specimen by electrical contacts on the lever. These contacts operate solenoids which permit oil to flow to the hydraulic cylinders. In this manner, the loads can be maintained within $\pm 2\%$ at all times.

The 60,000 pound Krouse is basically the same machine as the 15,000 pound Krouse. The load is applied to the specimen through 4:1 multiplying levers, Figure 51.

The 12,000 pound Ivy machine is an inertia-compensated machine that develops the alternating force by rotating an adjustable mass. The static load is applied through a torsion bar. The loads are applied by means of an oscillating beam. The load multiplier increases the capacity five times. Since the dynamic load alternates about the mean static load, the static load is controlled to maintain the load limits within $\pm 2\%$. This is done by a reluctance gage and an electronic circuit.

The 220,000 pound Amaler machine applied all loads by hydraulic pressure. The loads are maintained within $\pm 2\%$ at all times by electric contacts on pressure gages.

2. Fixtures

The adapters and links provided a method for testing both studs and bolts of different diameters in the same machine. Figure 53 shows the basic tension-tension fatigue set up using a bolt, adapters, links and washer.

Links were made in various sizes ranging from 3,000 to 220,000 pound maximum capacity as shown in Figures 35 thru 37 and 54. The tolerances of squareness and concentricity were held to very close limits to insure uni-axial loading. In this way alignment is built into the set up and not left up to the operator. The design of the links meets the requirements of NAS 1069.

The adapters used in the links are shown in Figures 40 thru 42. Note that the tolerances of squareness, concentricity and size were held to a practicable minimum to insure uniaxial loading. Figures 55 and 56 show the adapters used to test the threaded studs when nuts were not used.

Originally all links were fabricated in accordance with Specification NAI 160 "Tension-Tension Fatigue Test Standardization", October 1956. These are shown in Figures 57, 58 and 59. Threaded adapters to mount these links on the 60,000 pound Krouse are shown in Figure 60 and 61. However, failure of the links at low cycles and low loads forced the use of the links as shown in Figure 52. Figures 62 and 63 show where the failure occurred in the large (200,000 pound) NAI link at 173,200 cycles under a 90,500 pound load. Figure 64 shows failure of the 15,000 pound NAI link. The design of these NAI links have since been changed to increase the fatigue life. The NAI 160 specification has been superseded by NAS 1069.

3. Load Measuring

The loads were measured by resistance strain gages bonded to the loading column, Figure 65. To insure accuracy, the gages were calibrated under dynamic loading to develop a machine constant. A calibrated load cell was used.

Figure 66 shows the electronic equipment used to measure the output from the strain gages. These units are from left to right.

- a. Baldwin or Ellis Associates, six channel switching and balancing unit. This provides a convenient method of balancing the individual circuits and switching from one set of gages to another.
- b. Ellis Associates, BA-12 Bridge and Amplifier. This unit supplies DC power to the circuit, amplifies the output from the gages and provides a means of measuring the strain at the gage location. Basically, it completes the Wheatstone bridge of the circuit with various precision resistors to provide different ranges of operation. The chopper circuit, in which the output is controlled by a variable precision resistor adjusted by an indicating micrometer screw, provides the means of measuring the gage output accurately.
- c. DuMont Type 304 A or 350 Oscillograph with a P-7 screen. Through this instrument a means of visual adjustment of the measuring circuit, as well as a picture of the loading cycle, is possible.

Measurements of loads are taken by adjusting the variable precision resistor on the amplifier unit by a micrometer screw until the horizontal line on the oscillograph is tangent to the peak or trough of the load line wave.

Figure 67 shows a typical pattern on the oscilloscope. The horizontal measuring line is shown at zero stress. The readings on the micrometer are multiplied by the constant derived by calibration for that machine.

All cables were shielded with a metal covering. The shielding and all instruments were grounded to eliminate fuzziness and distortion from the oscilloscope pattern.

C. NUTS:

The 160,000 psi bolts were tested with the fatigue nuts shown in Figure 68. Another fatigue nut, Figure 69, was used to test the 220,000 psi bolts. The studs were tested with nuts and with threaded bushings.

Special 1 3/4" and 2" nuts, Figure 70, were used to test the one inch unengaged threads.

All nuts varied from standard because they had neither locking device nor plating. The squareness of the bearing face with respect to the axis of the pitch diameter was .003 inch TIR maximum.

To test the effect of nut locking devices on fatigue life, tests were run with SPS 42 FW 524 and SPS 42 FW 1018 nuts, Figure 71 and ESNA EB 524 and EB 1018, Figure 72. The SPS nut had a metallic locking device, while the ESNA nut had a non-metallic insert.

D. WASHERS:

To prevent the head-to-shank fillets from bearing directly on the adapters, countersunk washers per SPS WC 22, Figure 73, were used under the bolt heads for all tests. No washers were used under the nuts.

SECTION V

TEST PROCEDURES

A. TENSILE:

After fabrication all parts were dimensionally inspected to the applicable print. The thread form, contour, and dimensions were particularly noted as to their conformance to specification requirements.

The bolts made for this test program are listed in Table IV. The studs tested are listed in Table V.

Two smooth specimens of each lot of bolts and studs were pulled in tensile to determine the static mechanical properties of the base material of the finished part. The specimens were fabricated to sizes listed in "Federal Test Standards", No. 151, published July 17, 1956. The gage sizes used for each thread diameter tested are given in Table III.

TABLE III
Gage Sizes for Parts Tested in Tensile

<u>Nominal Thread Diameter</u>	<u>Gage Diameter</u>	<u>Gage Length</u>
1/4	.113	0.45
3/8	.252	1.0
1/2	.357	1.4
3/4	.505	2.0
1	.505	2.0

The ultimate strength of all parts was obtained directly from the dial on the tensile machine. The yield strength of the specimens was determined by the 0.2% offset method. Elongation and reduction of area were calculated from direct measurement. Results of all tests are reported in Appendices I and II.

Extensometers of the appropriate gage length were used on all specimens tested as shown in Figure 33.

Two bolts of each lot were pulled in tensile to obtain the ultimate and yield strengths. The overall bolt extensometer was used to plot the load extension curves as shown in Figure 34. The yield strength was determined as that point where the slope of the plastic region of the load extension curve is equal to 2/3 the slope of the elastic range of the same curve. Tensile tests were not run on the studs since failure occurred in the shank rather than the threaded portion.

TABLE IV

**Bolts Tested for Mechanical Properties
160,000 psi Heat Treatment**

<u>Diameter</u>	<u>Configuration</u>	<u>Material</u>	<u>Thread Form</u>
1/4-28	MS 20004	MIL-S-6049	MIL-B-7838
3/8-24	MS 20006	MIL-S-6049	MIL-B-7838
1/2-20	MS 20008	MIL-S-6049	MIL-B-7838
3/4-16	MS 20012	MIL-S-6049	MIL-B-7838
1-14	MS 20016	MIL-S-5000	MIL-B-7838

220,000 psi Heat Treatment

1/4-28	EWB 22-4	MIL-S-7108	MIL-B-7838
1/4-28	MS 20004	MIL-S-8503	MIL-B-7838
3/8-24	EWB 22-6	MIL-S-7108	MIL-B-7838
1/2-20	EWB 22-8	MIL-S-7108	MIL-B-7838
1/2-20	EWB 22-8	MIL-S-7108	High Radius
1/2-20	EWB TM 9	VascoJet 1000	High Radius
3/4-16	EWB 22-12	MIL-S-7108	MIL-B-7838
3/4-16	EWB 22-12	MIL-S-7108	High Radius
1-14	EWB 22-16	MIL-S-7108	MIL-B-7838

TABLE V

Studs For Testing Mechanical Properties of Unengaged Threads

160,000 psi Heat Treat

<u>Diameter</u>	<u>Material</u>	<u>Thread Form</u>	<u>Thread Formed By</u>	<u>Plate</u>
1/4-28	MIL-S-6049	MIL-B-7838	rolling	None
1/4-28	MIL-S-6049	MIL-B-7838	rolling	Cadmium (Cyanide)
3/8-24	MIL-S-6049	MIL-B-7838	rolling	None
3/8-24	MIL-S-6049	MIL-B-7838	rolling	Cadmium (Cyanide)
1/2-20	MIL-S-6049	MIL-B-7838	rolling	None
3/4-16	MIL-S-6049	MIL-B-7838	rolling	None
3/4-16	MIL-S-6049	MIL-B-7838	rolling	Cadmium (Cyanide)
3/4-16	MIL-S-6049	MIL-B-7838	grinding	None
1/4-16	MIL-S-6049	MIL-B-7838	cutting*	None
1-14	MIL-S-5000	MIL-B-7838	rolling	None

220,000 psi Heat Treat

1/4-28	MIL-S-7108	MIL-B-7838	rolling	None
1/4-28	MIL-S-7108	MIL-B-7838	rolling	Cadmium (Fluoborate)
1/4-28	MIL-S-8503	MIL-B-7838	rolling	None
3/8-24	MIL-S-7108	MIL-B-7838	rolling	None
3/8-24	MIL-S-7108	MIL-B-7838	rolling	Cadmium (Fluoborate)
1/2-20	MIL-S-7108	MIL-B-7838	rolling	None
1/2-20	MIL-S-7108	High Radius	rolling	None
1/2-20	VascoJet 1000	High Radius	rolling	None
3/4-16	MIL-S-7108	MIL-B-7838	rolling	None
3/4-16	MIL-S-7108	MIL-B-7838	rolling	Cadmium (Fluoborate)
3/4-16	MIL-S-7108	High Radius	rolling	None
3/4-16	MIL-S-7108	High Radius	rolling	Cadmium (Fluoborate)
3/4-16	MIL-S-7108	MIL-B-7838	grinding	None
3/4-16	MIL-S-7108	MIL-B-7838	cutting*	None
1-14	MIL-S-7108	MIL-B-7838	rolling	None

* Threads cut before heat treatment; all other threads formed after heat treatment.

All tensile tests were run at a rate of 65,000 psi per minute. The tensile machines were calibrated with proving rings certified by the Bureau of Standards.

B. SHEAR:

Double shear tests were conducted on the shanks of two bolts of each lot. The shear die set up is shown in Figure 47. The rate of loading was 100,000 psi per minute.

C. FATIGUE:

Each lot of studs and bolts was run in tension-tension fatigue to develop a full S-N curve with four stress levels between 10,000 cycles and the endurance limit. Five pieces were tested at each stress level. Pieces were run to determine the 8,000,000 cycle endurance limit, and two pieces were tested at that stress level.

Cadmium plated studs were fatigue tested at a minimum of two stress levels. These levels were selected to determine the relative location of the S-N curves.

In all fatigue tests the low load was ten percent of the maximum load. Loads were maintained within $\pm 2\%$ by the various methods described in the section on Test Equipment. Fatigue stress calculations were based on the tensile stress area(1), and plotted values were maximum stresses.

In setting up a fatigue specimen, it is extremely important that the alignment and squareness of the adapters be as accurate as possible to insure uniaxial loading. Therefore, it was standard procedure to check the following:

- a. That the adapters sat squarely in the links without rocking.
- b. That the part slid freely through the adapters at both extremes of the stroke.

(1)* The tensile stress area is calculated by the equation -

$$A = 3.1416 (E/2 - 3H/16)^2$$

where A = Tensile stress area
E = Basic Pitch Diameter
H = Height of sharp V thread

The term $3H/16$ is equal to $1/2$ the addendum of the external thread. The tensile stress areas are listed in Table 1.3, page 129 of "Screw-Standards for Federal Services" 1957 Handbook H-28.

The first piece of any lot run at a particular stress was assembled into the machine and adjustments of the loading mechanism were made until the required loads were attained. This piece was run to failure and examined for indications of bending, as follows:

- a. Bending is indicated by the fatigue fracture progressing from one side of the part to the final tensile fracture, which is located on the opposite side of the origin, Figure 74.
- b. Uniaxial loading results in a fracture that shows fatigue crack propagation from all sides of the part toward the center, Figure 75. Note the difference in appearance between Figures 74 and 75.
- c. Severe bending is indicated by rubbing marks on the body of the bolt where it engaged opposite sides of one of the adapters, Figure 76.
- d. If, in other samples tested, the location of the start of the fatigue crack is always located at the same relative position to the link and adapter, then the loading is not uniaxial.

1. Plotting of Data

The fatigue data were plotted on semi-logarithmic paper. The maximum stress based on the tensile stress area was plotted as the ordinate and the cycle life was plotted as the abscissa on a logarithmic scale.

The load in pounds was shown on the left hand side of the chart. The results of each test were plotted and the curve of best fit was drawn through the logarithmic mean lives. These were computed by the equation

$$\frac{\log X_1 + \log X_2 + \log X_3 + \log X_4}{n} = \log \bar{X}$$

where X = Test result at a given stress level

n = Number of Specimens tested at that stress level

$\bar{X}$ = Logarithmic Mean Life

SECTION VI

SUMMARY OF RESULTS

The raw data for all tests are presented in the Appendices. The tensile properties of the parts and base material are tabulated on data sheets for each lot of pieces. The tension-tension fatigue cycles are tabulated by lot and also plotted to show an S-N curve. Appendix I includes the results of the tests on all parts heat treated to 160,000 psi and Appendix II includes those for the 220,000 psi parts.

To simplify the data, combined S-N curves plotted as tensile stress area, which is mean area, versus logarithmic mean life are given as follows:

<u>TITLE</u>	<u>CHART NO.</u>
S-N curve of Engaged and Unengaged Threads	1
S-N curves of 1/2 inch diameter Unengaged Threads rolled on MIL-S-7108 and VascoJet 1000 heat treated to 220,000 psi	2
S-N curves of 1/2 inch diameter Bolts made from MIL-S-7108 and VascoJet 1000	3
S-N curves of 1/2 and 1/4 inch diameter Bolts made from MIL-S-7108 and MIL-S-8504	4
S-N curve of 1/2 inch diameter Unengaged Threads with high radius and MIL-B-7838 thread forms	5
S-N curve of 3/4 inch diameter Unengaged Thread with high radius and MIL-B-7838 thread forms	6
S-N curve of 1/2 inch diameter Engaged Threads with high radius and MIL-B-7838 thread forms	7
S-N curve of 3/4 inch diameter Engaged Threads with high radius and MIL-B-7838 thread forms	8
S-N curve of 5/16 inch MS 20005 Bolts with All-Metal and Non-Metallic Locking Element Nuts	9
S-N curve of 5/8 inch MS 20010 Bolts with All-Metal and Non-Metallic Locking Element Nuts	10
S-N curves of 3/4 inch Unengaged Threads formed by cutting and rolling	11
S-N curves of 3/4 inch Unengaged Threads formed by grinding and rolling	12
S-N curves of 1/4 thru one inch diameter Unengaged Threads rolled on MIL-S-6049 material at 160,000 psi	13
S-N curves of 1/4 thru one inch diameter Bolts heat treated to 160,000 psi	14
S-N curves of 1/4 thru one inch diameter Unengaged Threads rolled on MIL-S-7108 at 220,000 psi	15
S-N curves of 1/4 thru one inch diameter Bolts made from MIL-S-7108 at 220,000 psi	16

SECTION VII

DISCUSSION OF RESULTS

A. STUD DESIGN:

To evaluate the properties of unengaged threads, it was necessary to develop a specimen with threads which were not loaded through female threads. As outlined in the section on Test Pieces, various designs were tried, to determine if fracture could be induced near the center of the test thread. This could not be achieved on the specimens roll threaded after heat treatment; therefore, a design was selected which induced fatigue fracture in the last full thread before the termination. Thus the effect of the thread runout was reduced to the lowest possible degree. However, in the larger sizes, 3/4 and 1 inch diameters, it was necessary to cold work by shot-peening the radius blending the test section to the loading threads. A P-33 shot was used at an intensity of .014 C2. Without this, fatigue fracture occurred outside the test area. Figures 77 and 78.

The initial one-inch test specimens were produced with two inch cut threads on the ends. Fatigue failure occurred at the junction of this thread and the radius as shown in Figure 79. Fatigue failures were produced in the 1-14 thread by using a 1 3/4-12 rolled thread on the ends.

The test specimens with cut and ground threads were made to the same configuration as the roll threaded parts. In this case, fatigue failure occurred near the center of the test cut and ground threads, Figure 80.

B. EFFECT OF ENGAGING THREADS ON FATIGUE LIFE:

The fatigue strength of unengaged threads is 1 1/4 to 2 1/2 times greater than that of the engaged threads. This comparison is based on the maximum stress which would produce a fatigue life greater than 8,000,000 cycles. The difference between the average fatigue life of all studs and bolts with MIL-B-7838 threads is shown in Chart I. Table VI lists the fatigue strength at 8,000,000 cycles for each lot of bolts and studs with MIL-B-7838 threads.

TABLE VI

**Fatigue Strength at 8,000,000 Cycles
Stress Calculated on Tensile Stress Area**

**MIL-S-6049 Material - 160,000 psi minimum
MIL-B-7838 Thread Form**

Test Thread Diameter	Stress to Produce Fatigue Life of More Than 8,000,000 Cycles	
	Stud	Bolt
1/4	95,000	40,000
3/8	80,000	40,000
1/2	100,000	40,000
3/4	100,000	40,000
1	100,000	50,000

**MIL-S-7108 Material - 220,000 psi minimum
MIL-B-7838 Thread Form**

1/4	120,000	80,000
3/8	100,000	60,000
1/2	120,000	65,000
3/4	120,000	55,000
1	135,000	80,000

In the case of 160,000 psi heat treatment, the stud fatigue strength was 2 to 2 1/2 times greater than the bolt. For the 220,000 psi strength level with the MIL-B-7838 thread roots the stud strength was 1 1/2 to 2 times greater. The studs with the high radius thread root made from Hy Tuf at 220,000 psi had a fatigue strength only 1 1/4 to 1 1/2 times greater than the bolt with the same thread form. Since the difference between the fatigue strength of the stud and bolt is less with the high radius thread than the MIL-B-7838 threads, the stress concentration in the threads must be less with the high radius thread than the MIL-B-7838 thread. This indicates that bolts with larger thread root radii are affected less by the stress concentration due to the nut. This is demonstrated by the bolt fatigue strength being nearer the unengaged fatigue strength.

C. EFFECT OF MATERIAL ON FATIGUE STRENGTH:

The fatigue strength of the studs fabricated from VascoJet 1000 is 10% greater than similar parts made from MIL-S-7108 material, Chart 2. The fatigue strength of the VascoJet 1000 bolts is 18% greater than those made from MIL-S-7108, Chart 3.

The fatigue strength of the MIL-S-8503 material is slightly lower than the Hy Tuf in both stud and bolt tests, Chart 4.

D. EFFECT OF MATERIAL STRENGTH ON FATIGUE STRENGTH OF THREADS:

By increasing the strength of the material from 160,000 psi to 220,000 psi (1.4 times) an increase of 1.2 to 1.45 was obtained in the fatigue strength of the studs. MIL-S-8503 had a 1.2 increase in fatigue life, MIL-S-7108 a 1.3 increase, while VascoJet 1000 showed a 1.45 increase.

The increase in the fatigue strength of the bolts due to the increase of 1.4 in tensile strength was between 1.4 and 2.8. The bolts made from MIL-S-7108 and MIL-S-8503 were about the same at 1.4 to 2. The one lot of VascoJet studs with the high radius threads increased 2.8 times. This is an increase of twice the increase in tensile strength.

The increase in the bolt fatigue life is equal to or greater than the increase in tensile strength. However, the stud fatigue life increased slightly less than the tensile strength. This may be due to the stress concentration in the thread termination which was not completely eliminated by the design of the stud.

E. EFFECT OF THREAD ROOT RADIUS ON FATIGUE STRENGTH:

The comparison of the effect of MIL-B-7838 and high radius root radii on the fatigue life is based on parts heat treated to 220,000 psi. These were the only parts made with both thread forms.

At the high stress levels the fatigue strength of the unengaged high radius thread is superior to the MIL-B-7838 thread. This is shown in Charts 5 and 6. At a life of more than 8,000,000 cycles, there was little or no difference between the thread forms.

The fatigue strength of the bolts with the high radius thread form was at least 1.5 times greater than the parts with the MIL-B-7838 thread. This comparison is shown in Chart 7 for the 1/2 inch diameter bolts and Chart 8 for the 3/4 inch diameter bolts.

Since the bolt tests showed a definite superiority of the high radius over the MIL-B-7838 thread, it is probable that the same difference was not found in the studs because the effect of the thread termination was greater than that of the thread form. The stress concentration due to the thread engagement with the bolt was sufficiently large enough to cause fatigue failures to occur in the area of the nut bearing face rather than at the thread termination.

F. EFFECT OF NUT DESIGN ON FATIGUE STRENGTH OF BOLTS:

Charts 9 and 10 show comparative S-N curves developed with locknuts having metallic threads and those having a non-metallic element in the locking section. In both tests the nuts with all-metal threads produced superior fatigue life in the mating part. It appears that as the size increases the difference between the two designs becomes greater. The superiority of the all-metal nut can be attributed to less stress concentration in the bolt resulting from better load distribution in the nut. With more metallic threads the load per thread is less; thus the stress concentration is reduced.

G. EFFECT OF PLATING ON THE FATIGUE STRENGTH OF UNENGAGED THREADS:

Plating decreases the fatigue strength of threaded parts. A reduction of 6% to 11% was found on the studs heat treated to 160,000 psi. The cadmium plating of the 220,000 psi studs reduced the fatigue strength 9% to 16%. A reduction of 10% was found in the one lot of 220,000 psi studs with the high radius thread.

As shown in Table VII, size had no effect on the fatigue life reduction due to plating.

TABLE VII

Effect of Plating on the Fatigue Strength of Unengaged Threads
Fatigue Stress to Produce a Life of 100,000 Cycles

<u>Size</u>	<u>Strength</u>	<u>Thread Form</u>	<u>Stress Non-Plated</u>	<u>Plated</u>	<u>% Reduction</u>
1/4	160,000	MIL-B	127,000	120,000	5.51
3/8	160,000	MIL-B	117,000	104,000	11.1
3/4	160,000	MIL-B	128,000	120,000	6.25
1/4	220,000	MIL-B	150,000	122,000	18.7
3/8	220,000	MIL-B	134,000	122,000	8.96
3/4	220,000	MIL-B	157,000	135,000	14.0
3/4	220,000	High Radius	158,000	142,000	10.13

H. EFFECT OF CUT THREADS ON FATIGUE:

The fatigue strength of the unengaged cut threads is 34% to 60% of the rolled MIL-B-7838 thread. The fatigue strength at a life of 100,000 cycles of the cut threads on parts heat treated to 160,000 psi was 60% of that obtained with rolled threads. Under similar conditions the fatigue strength of the cut threads on studs heat treated to 220,000 psi was 34% of the rolled threads, Chart 11.

Table VIII shows the comparative fatigue strength of unengaged cut and rolled threads at a life of 100,000 cycles.

TABLE VIII

Rolled Thread after Heat Treatment vs Cut Thread
Fatigue Strength to Produce Fracture at 100,000 Cycles
All parts were 3/4-16 unengaged threads

Tensile Strength - psi minimum	Fatigue Strength - psi	
	Rolled	Cut
160,000	126,000	75,000
220,000	160,000	55,000

I. EFFECT OF GROUND THREADS ON FATIGUE:

The fatigue strength of ground threads is less than rolled threads but greater than cut threads.

The fatigue strength at 100,000 cycles of the ground threads on parts heat treated to 160,000 psi is 68% of that obtained by rolled threads. On studs heat treated to 220,000 psi the fatigue strength of the unengaged ground thread was 56% of the rolled thread, Chart 12.

Part of the difference between the ground and cut threads can be due to the thread forms. The cut thread had a flat root where as the ground thread had a radius conforming to MIL-B-7838.

Table IX shows the comparative fatigue strength of unengaged ground and rolled threads at a life of 100,000 cycles.

TABLE IX

**Rolled Thread after Heat Treatment vs Ground Thread
Fatigue Strength to Produce Fracture at 100,000 Cycles
All parts were 3/4-16 unengaged threads**

Tensile Strength - psi minimum	Fatigue Strength - psi	
	Rolled	Ground
160,000	126,000	85,000
220,000	160,000	90,000

SECTION VIII

CONCLUSIONS

The fatigue strength of unengaged threads is about 1 1/2 times that of engaged threads.

With the proper selection of the material the fatigue strength of rolled threads increases in direct proportion to the tensile strength.

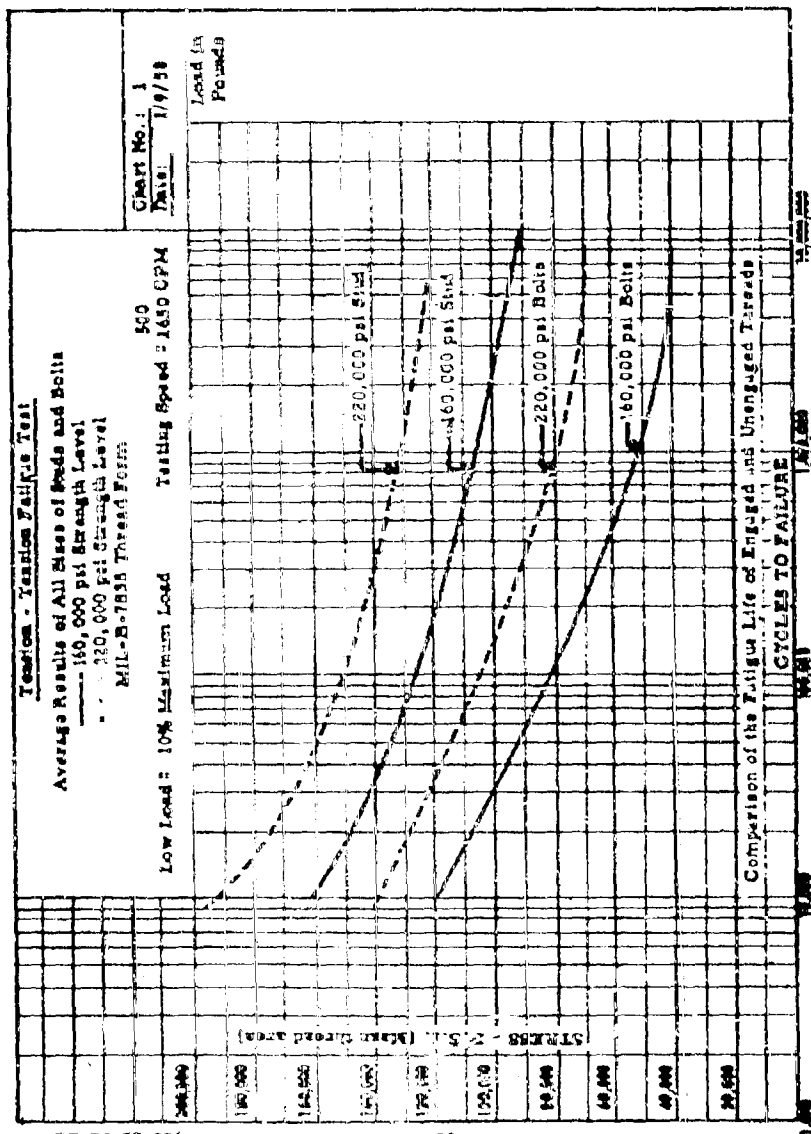
By increasing the thread root radius, the fatigue strength of threads can be increased.

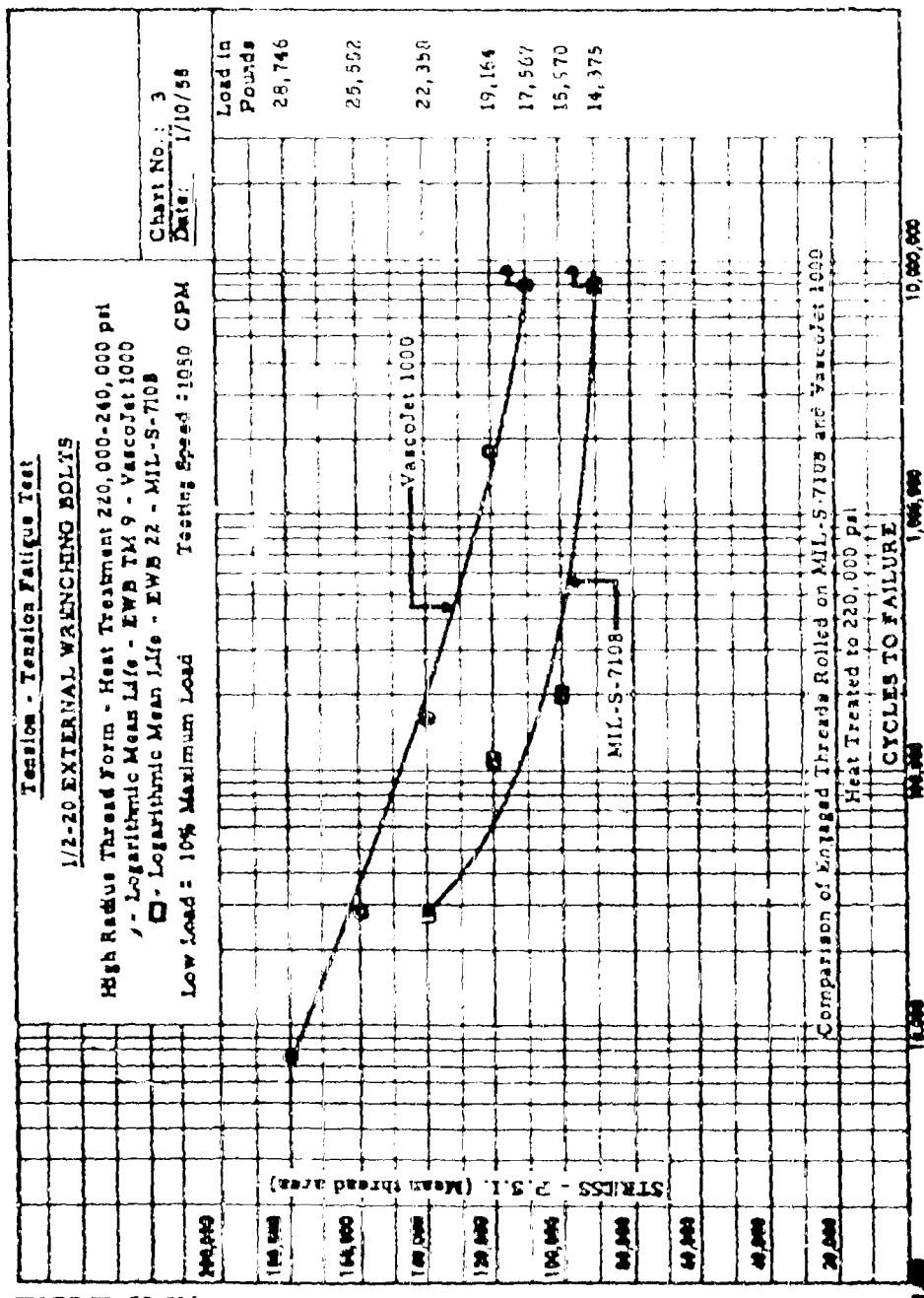
Nut design affects the fatigue strength of fasteners. Generally as the thread engagement decreases the strength decreases.

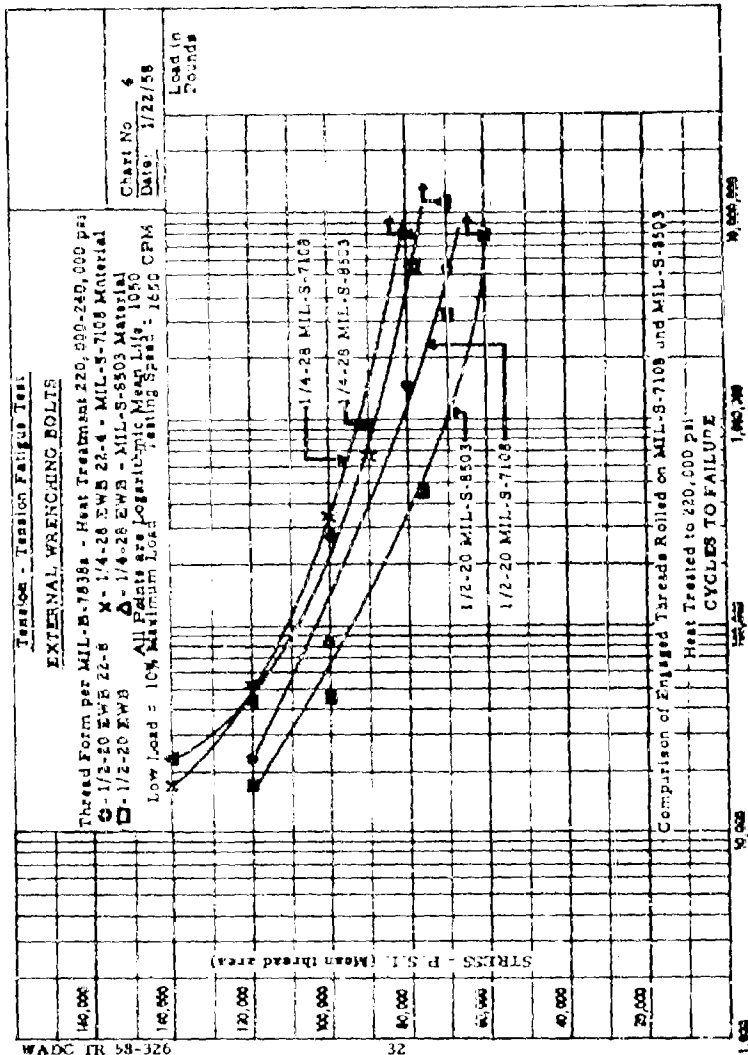
Cadmium plating reduces the fatigue strength of threads an average of 15%.

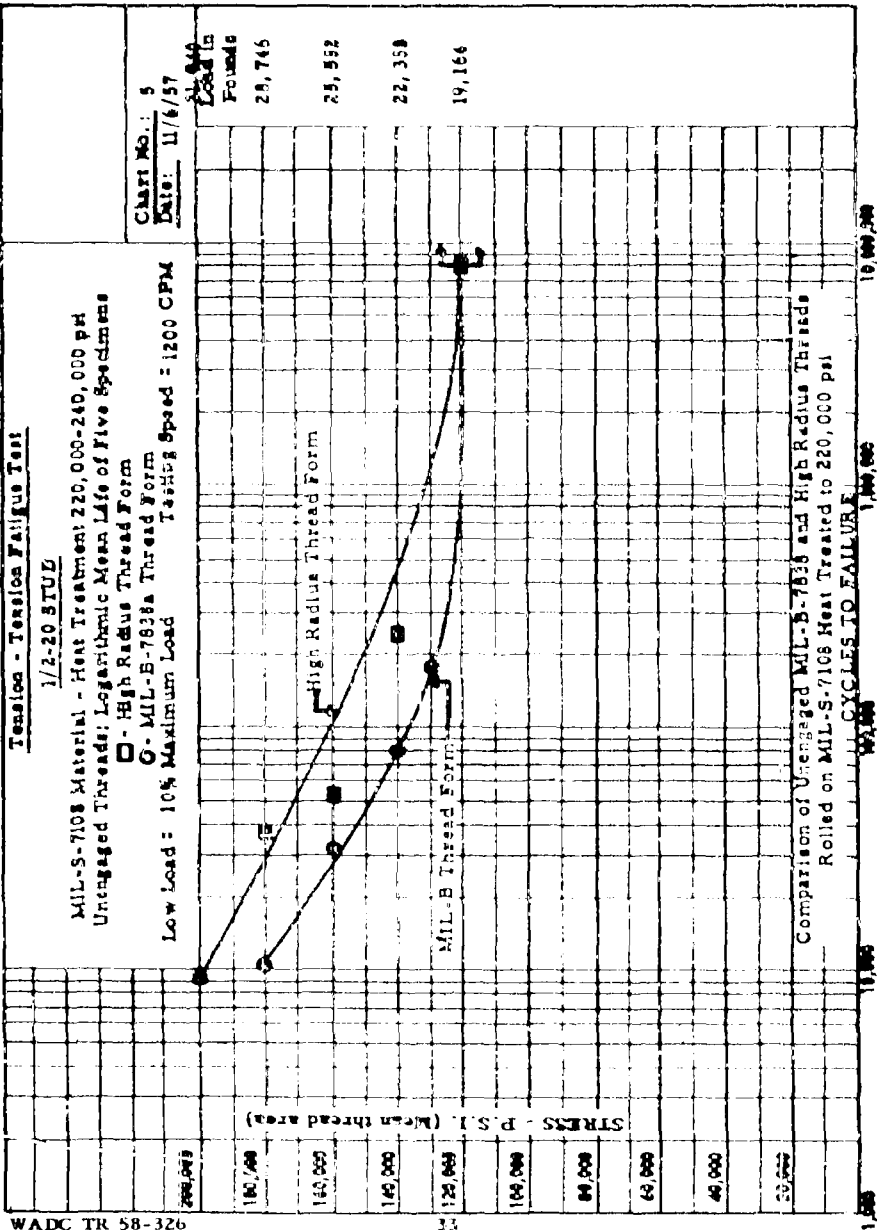
The fatigue strength of unengaged cut threads is 34% of the rolled threads on parts heat treated to 160,000 psi and 60% of rolled threads on 220,000 psi parts.

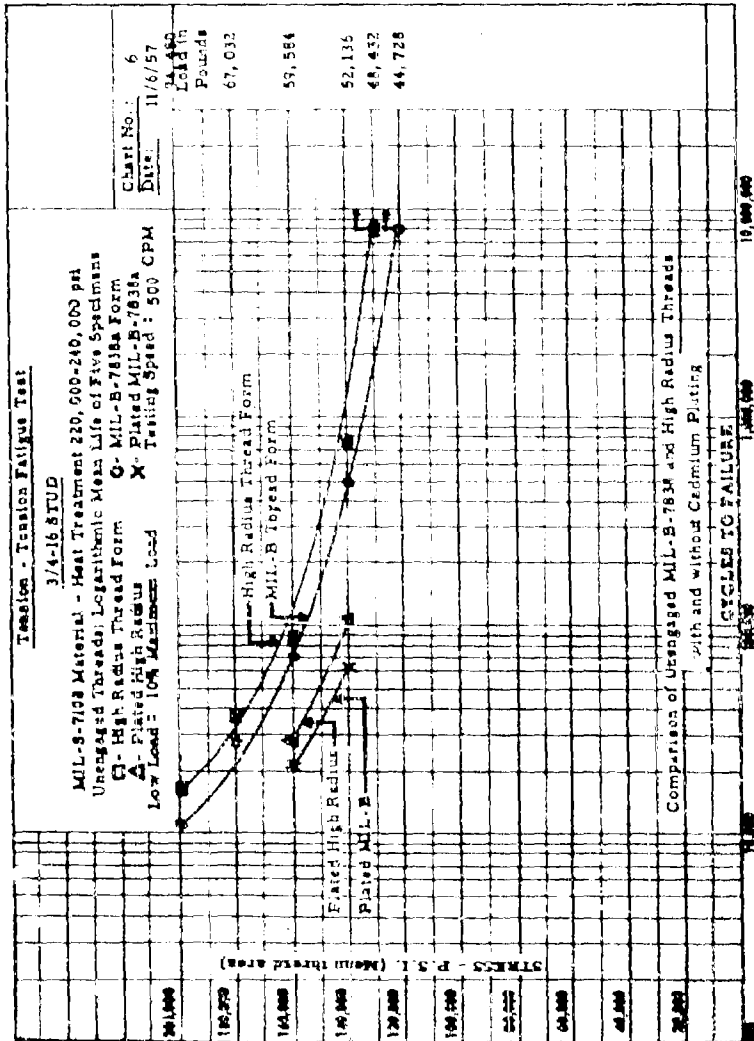
The fatigue strength of unengaged ground threads is greater than that of cut threads but less than rolled threads. The fatigue strength of the ground thread is 66% of the thread rolled on 160,000 psi material and 56% on 220,000 psi material.

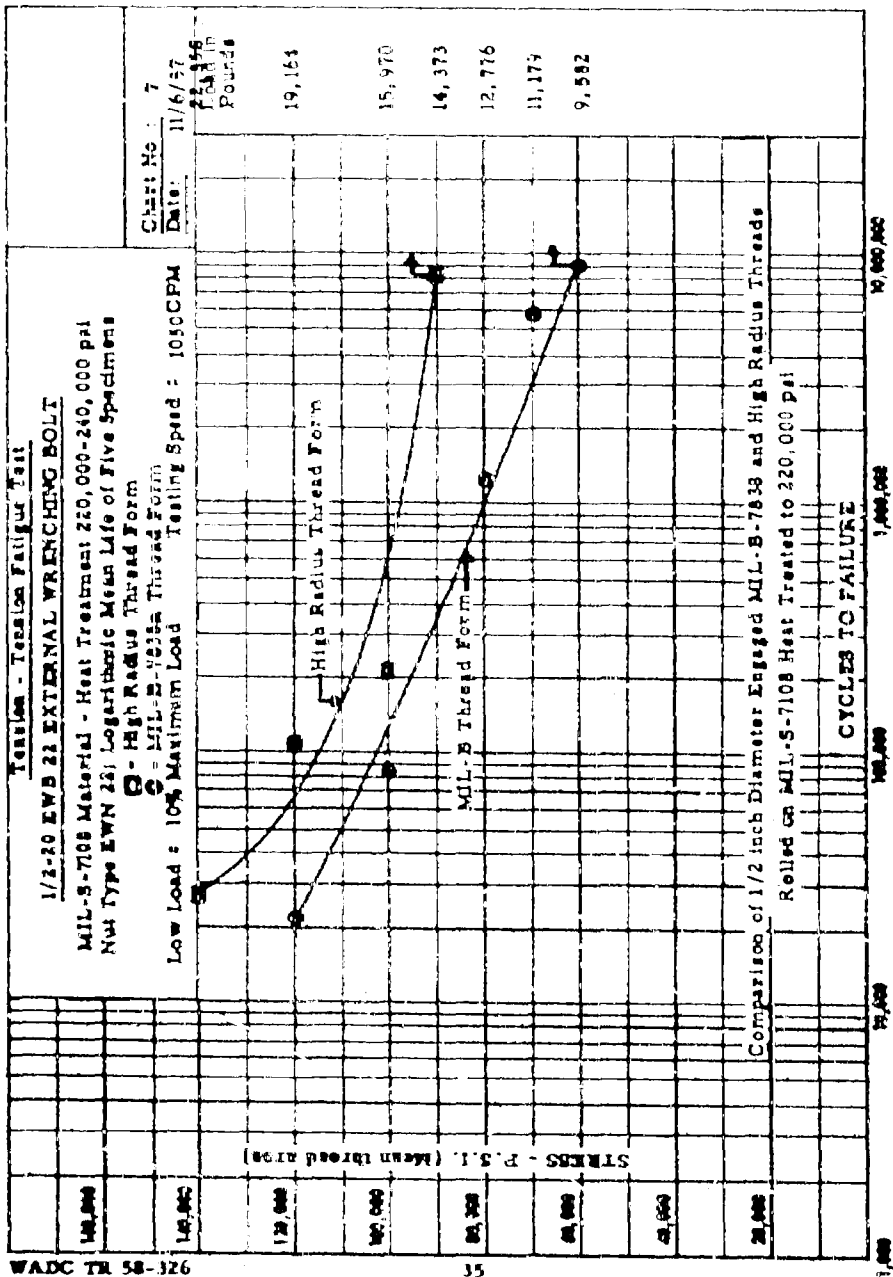


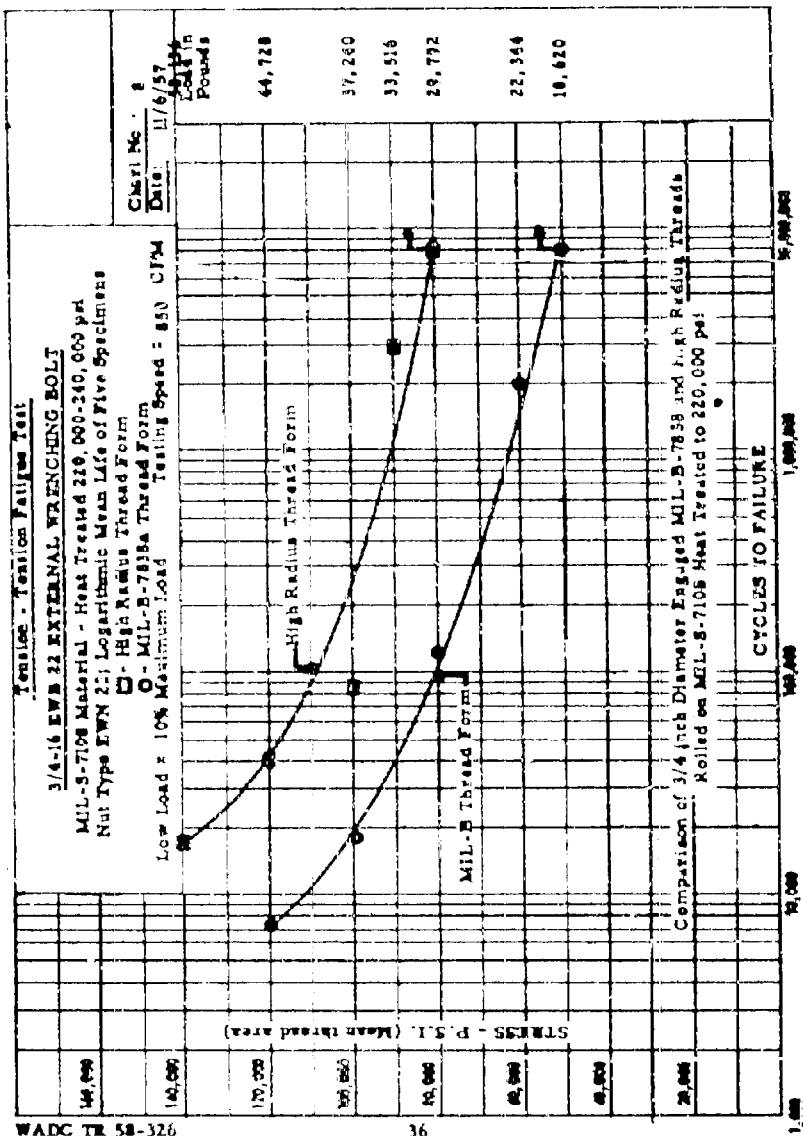


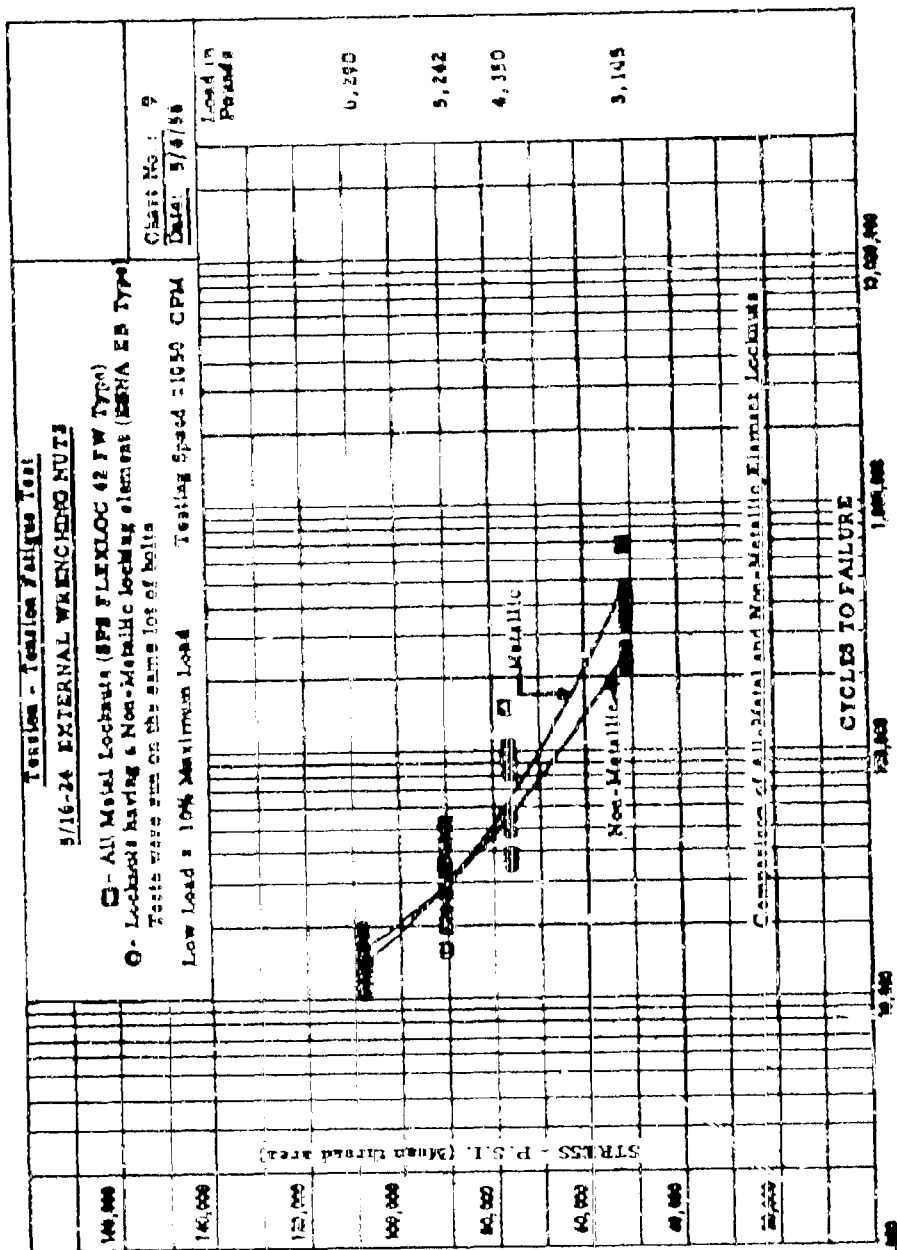


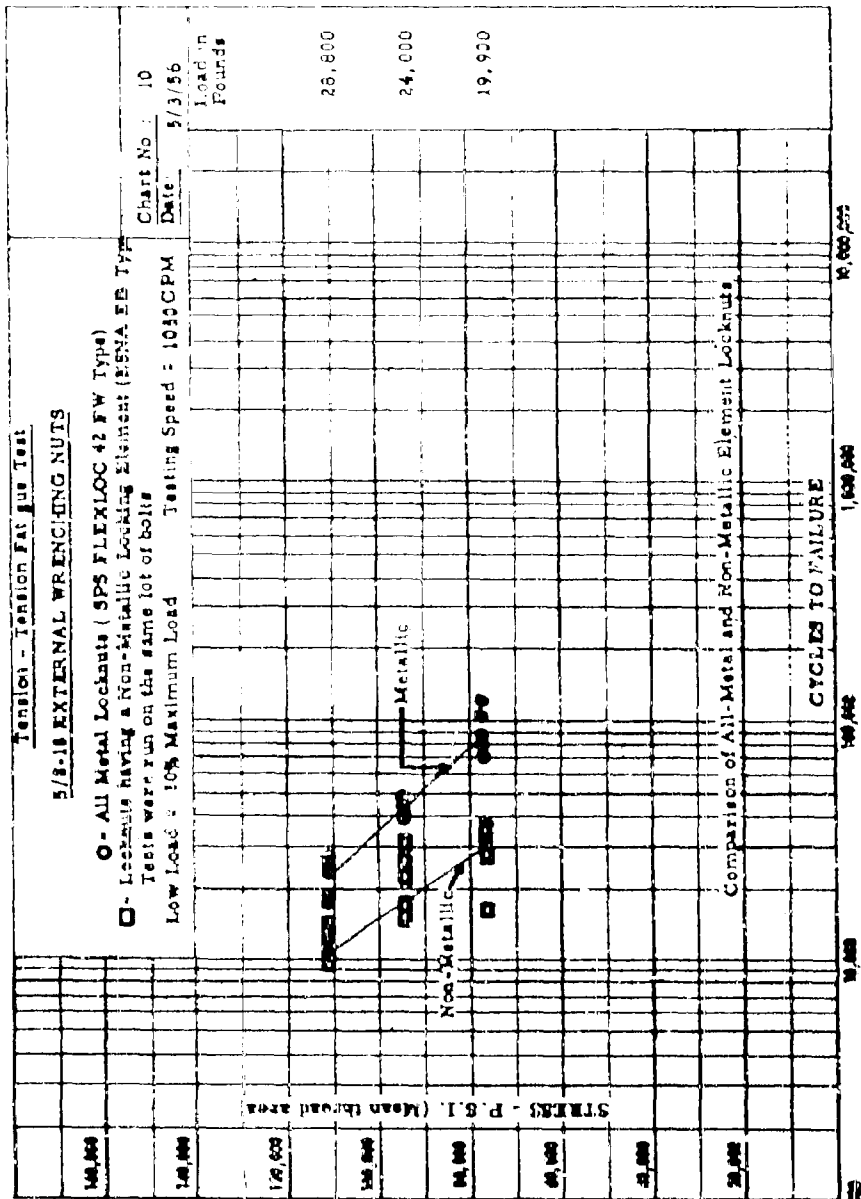


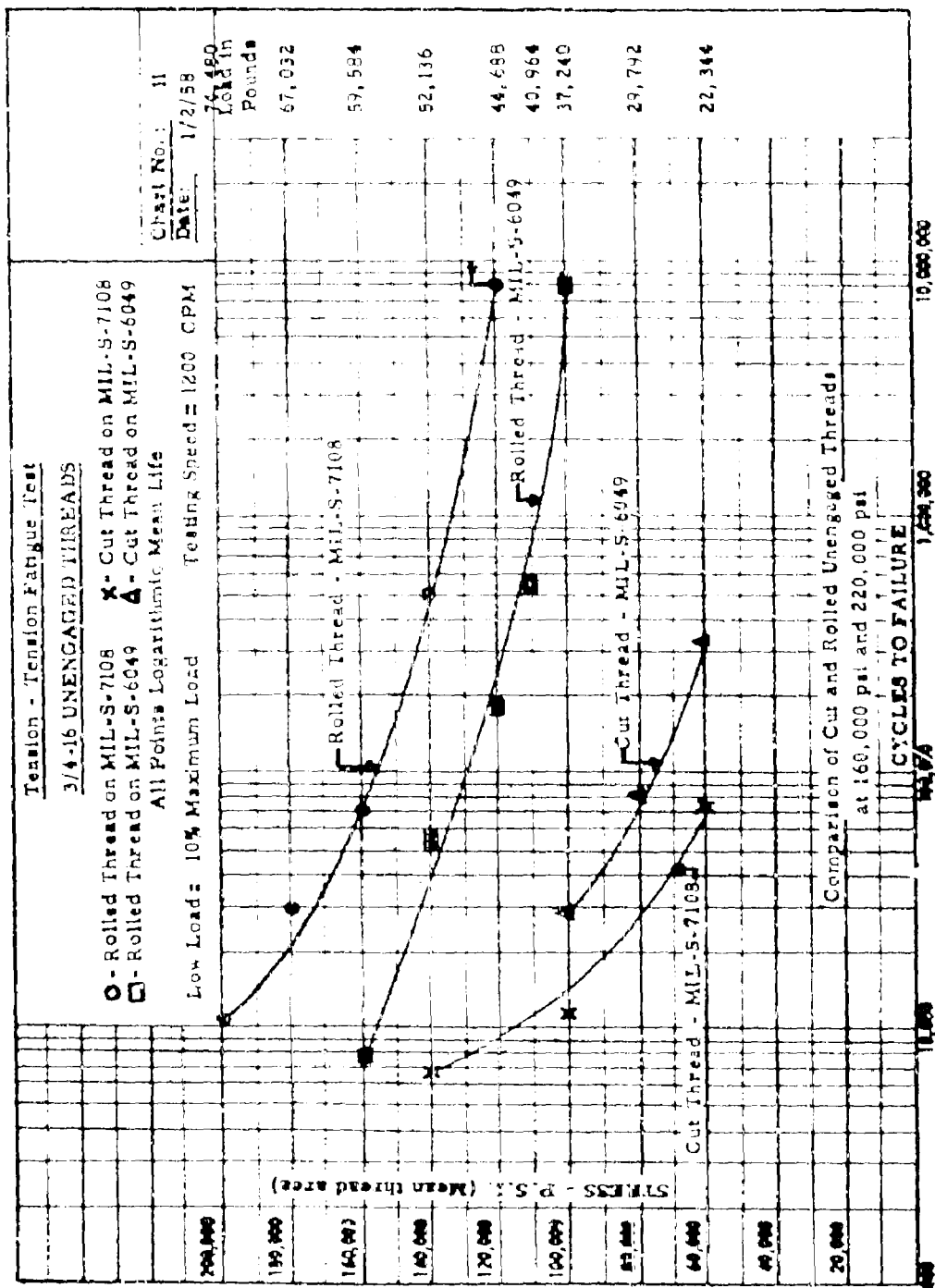


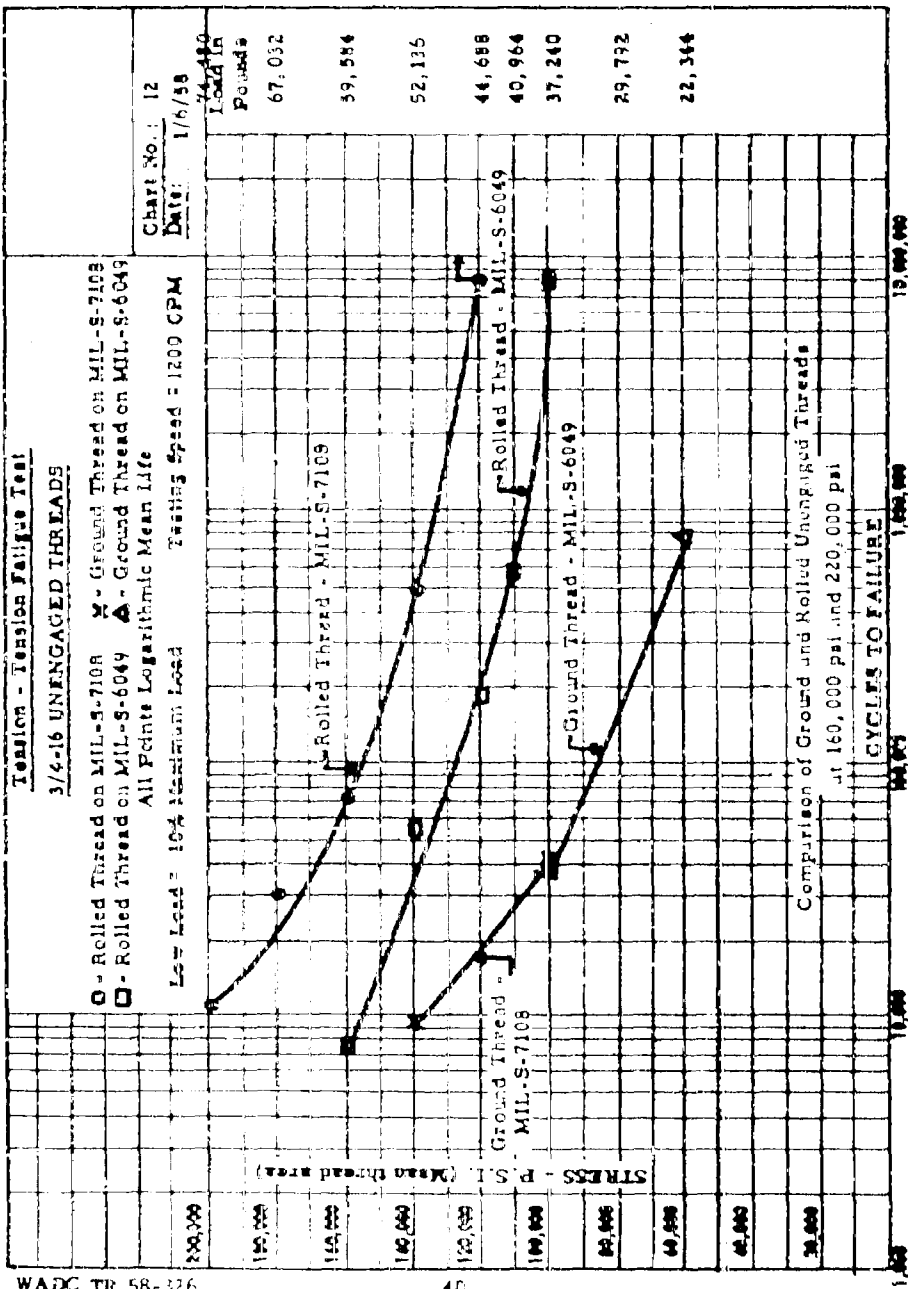


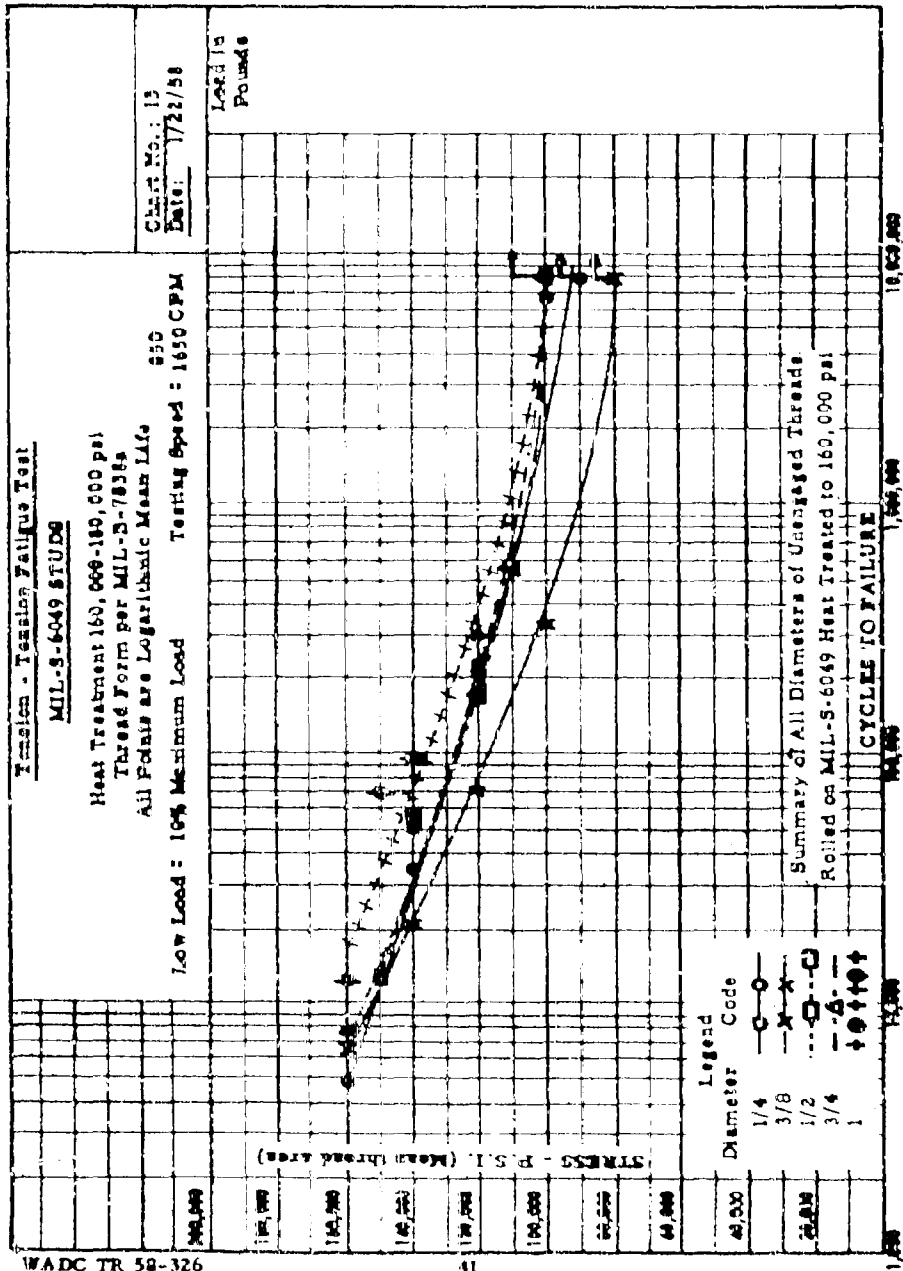


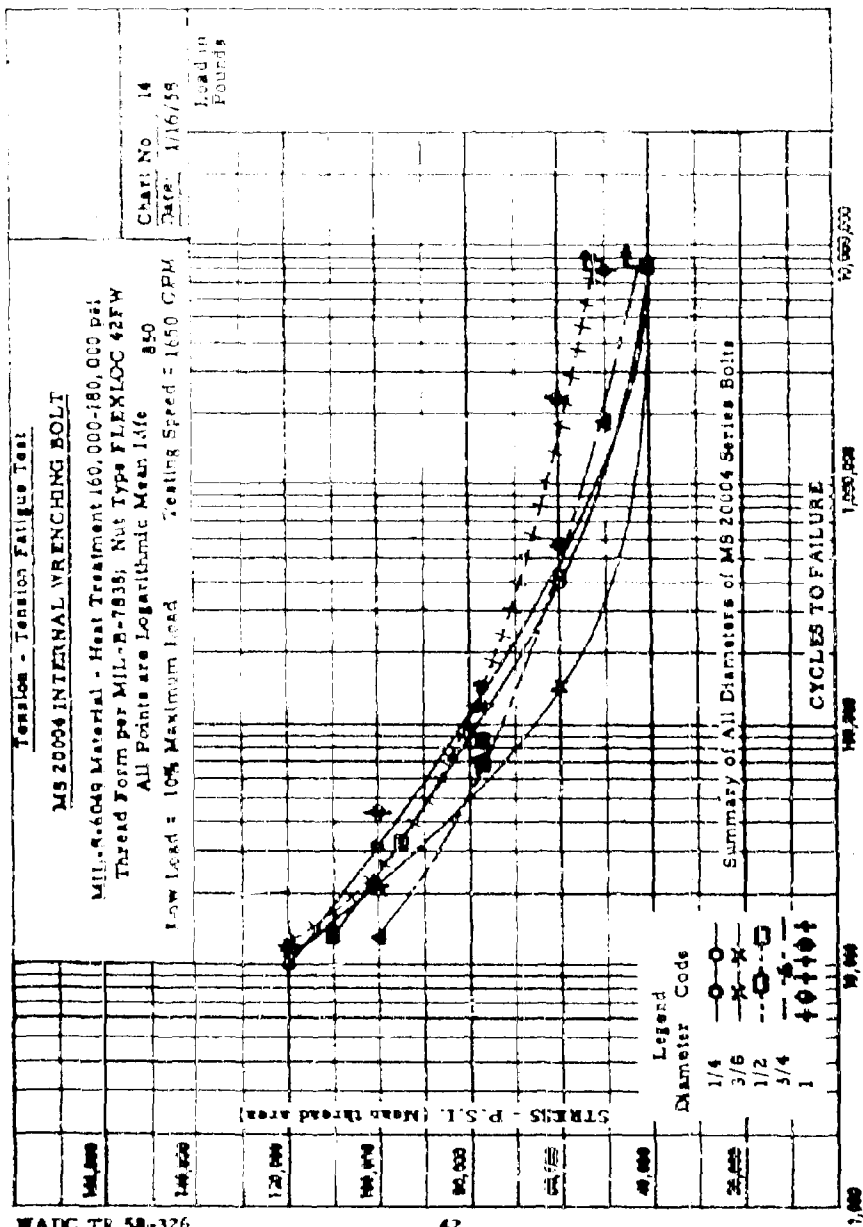


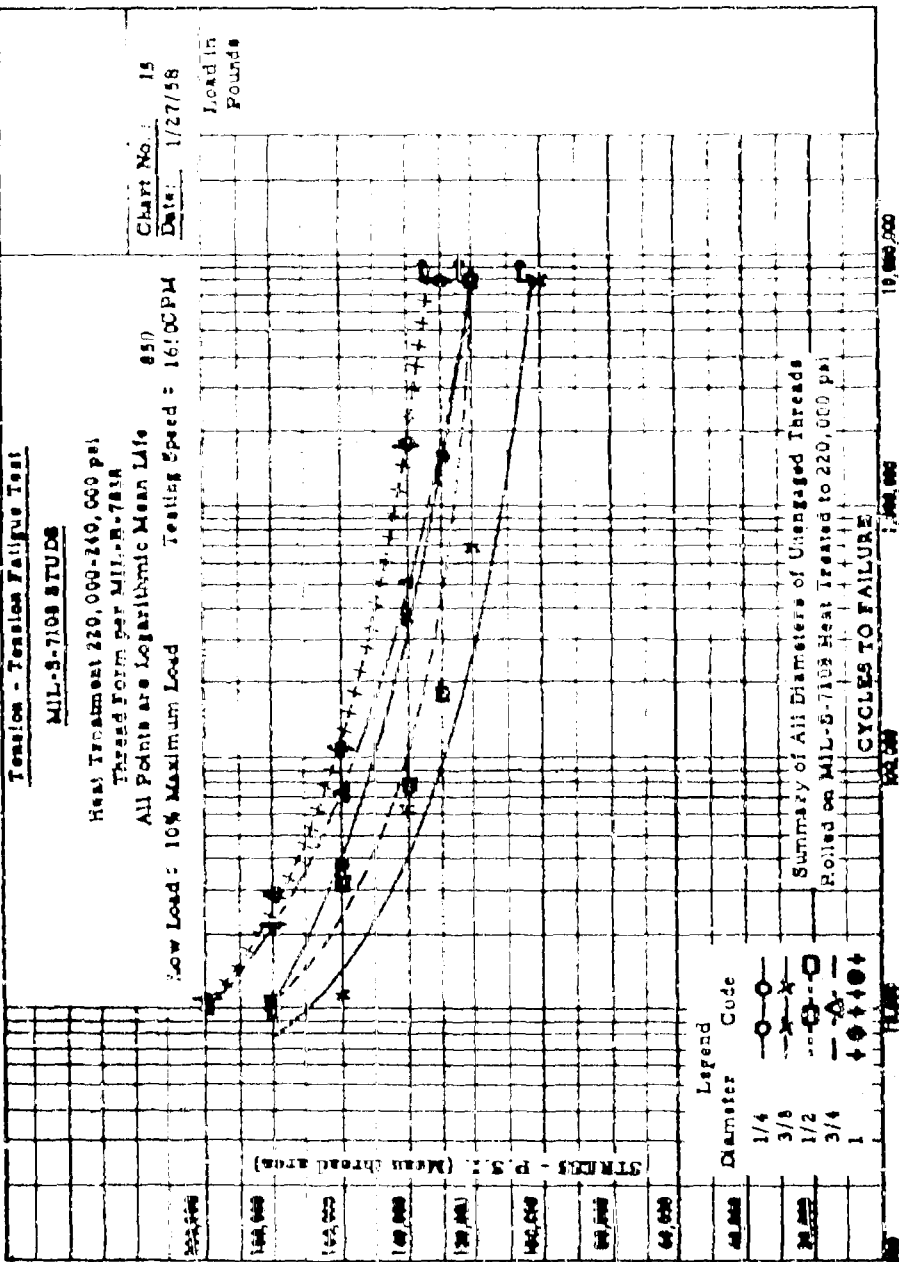


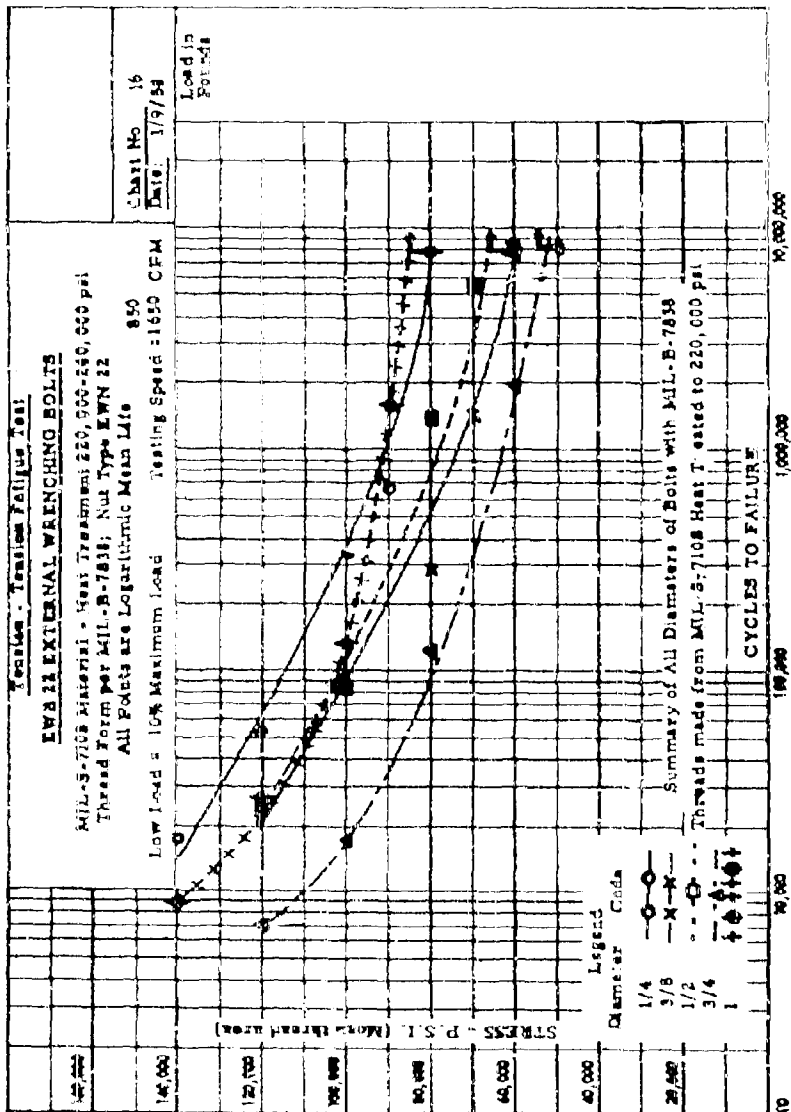


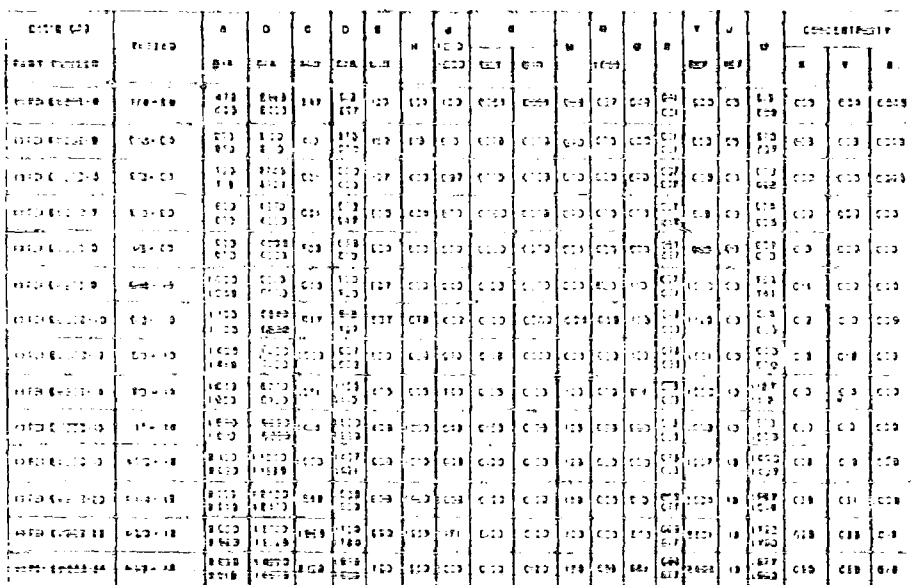












- [illegible]

620 H TO FRODO BAGGINS TO REUNITE ORRLED NEAR

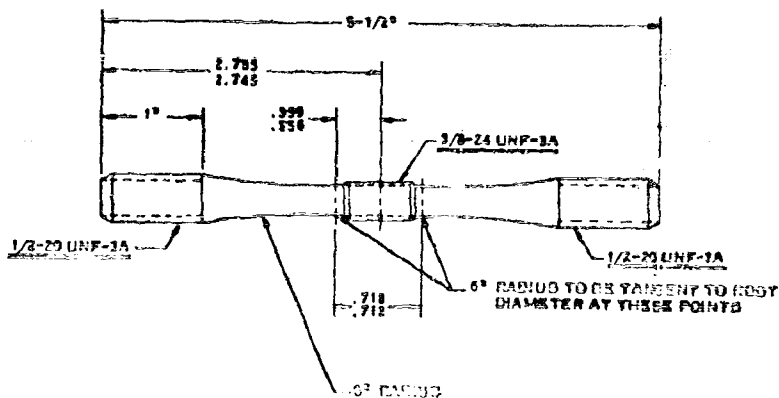
DESIGN BASH NUMBER INDICATES SHEET LENGTH IN FEET/INCHES. BASH NUMBER SHOWN IN TABLE ON SHEET 2 INDICATES MAXIMUM SHEET LENGTH. IN 12" HIGH INCREMENTS, CASH LENGTH IS AN ADDITION TO THE 2" INCREMENTS ARE AVAILABLE IN 12" HIGH INCREMENTS BY THE USE OF DISCREPANT CASH NUMBERS. SHEETS HAVE CASH LENGTH IN 6" HIGH INCREMENTS MAY BE OBTAINED BY SPECIFYING INTERMEDIATE CASH NUMBERS. LENGTH AND GUSSET OF A BOLT WITH AN END GUSSET FOR THE CASH NUMBER 8 WILL BE .041" HIGH GREATER THAN BUSH FOR THE CASH NUMBER 8. SHEET LENGTHS ARE GIVEN IN FEET AND INCHES.

EXAMPLES OF PART NUMBERS -		1/4" EXT. DIA.	1/4" EXT. DIA.	1/4" EXT. DIA.	1/4" EXT. DIA.
10 000 000 000 000	1/4" EXT. DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.
10 000 000 000 000	1/4" EXT. DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.
10 000 000 000 000	1/4" EXT. DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.
10 000 000 000 000	1/4" EXT. DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.	1.00 INCH DIA.

Bolt, External Wrenchlag, 220,000 PSI Minimum

THIS
PAGE
IS
MISSING
IN
ORIGINAL
DOCUMENT

47



REVISIONS AND OTHER REVISIONS TO, CORRECTIONS TO, AND FOLLOW-UP WORK FOR AFTER REVISIONS.

FIGURE 4

Initial Tension-Tension Fatigue Test Specimen for Determining the Characteristics of Unengaged Threads

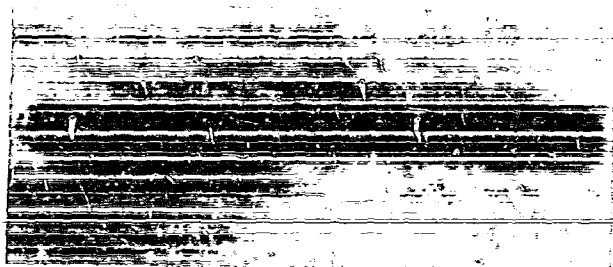
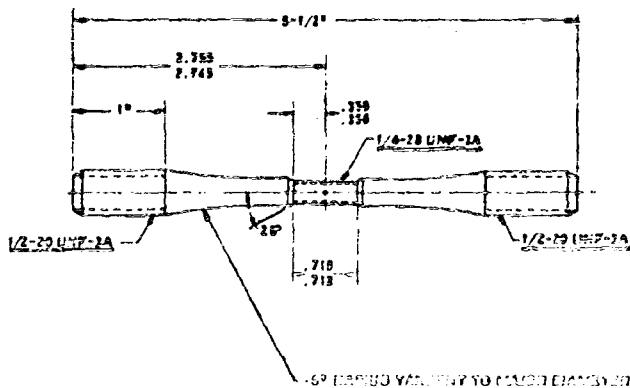


FIGURE 5

Tension-Tension Fatigue Fracture Located in the 1/2-20 Thread of the Above 3/8-24 Stud



MATERIAL: 7050-T6 ALUMINUM
 DIMENSIONS: 1/4-28 UNF-1A, 1/2-28 UNF-2A, 1/2-28 UNF-2A

FIGURE 6

Second Tension-Tension Fatigue Test Specimen for Determining
 the Characteristics of Unengaged Threads

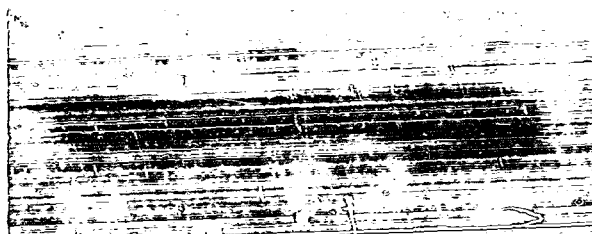
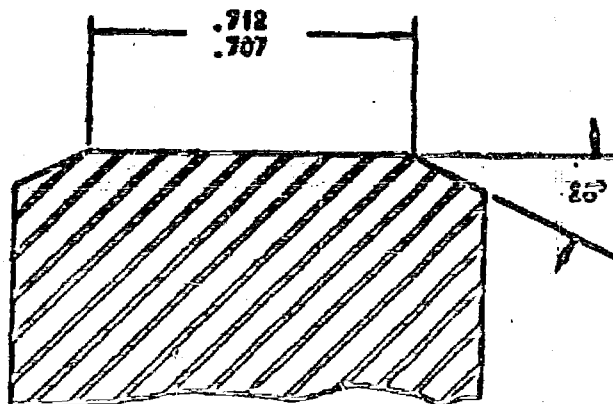


FIGURE 7

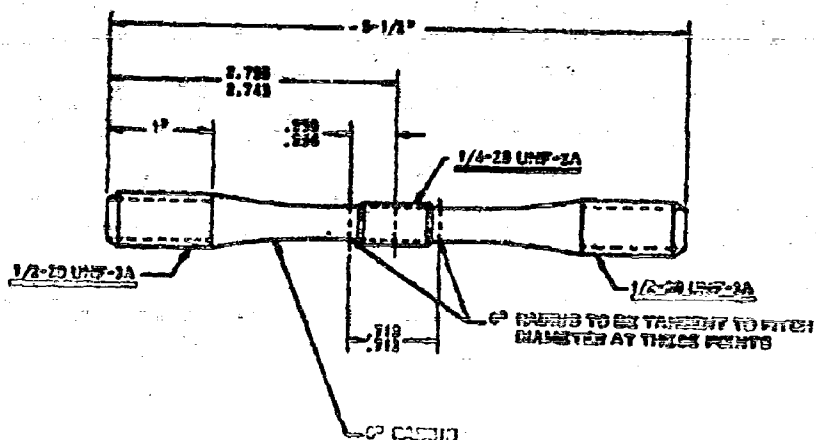
Tension-Tension Fatigue Fracture Located at the Thread Termination
 of the Above 1/4-28 Stud



STANDARD 1/4-20 M30 A
 60° WATERBURY
 STANDARD ROLL DIE
 TYPE A

FIGURE 0

Special Thread Dies for Rolling Stud with Six Inch Radius Tangent
 to Thread Major Diameter



MATERIAL: ALUMINUM 7075-T6; GAGE SECTION: 1/4-28 UNF-2A; GAGE SECTION: 1/4-28 UNF-2A; GAGE SECTION: 1/4-28 UNF-2A.

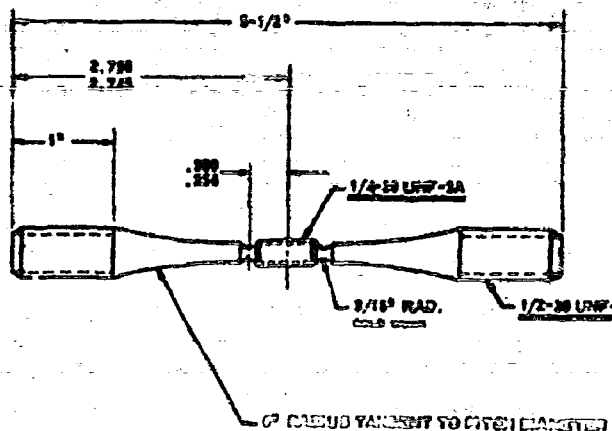
FIGURE 9

Third Tension-Tension Fatigue Test Specimen for Determining
the Characteristics of Unengaged Threads



FIGURE 10

Tension-Tension Fatigue Fracture Located at the Thread Termination
of the Above 1/4-28 Stud



MATERIAL: AND CEE (RAY TREAT: 10, CO/10, CO CO
 COLL. 10L-0-7000. TIGAS FIRM AFTER RAY TREAT.

FIGURE 11

**Fourth Design of Tension-Tension Fatigue Test Specimen for Determining
 the Characteristics of Unengaged Threads**

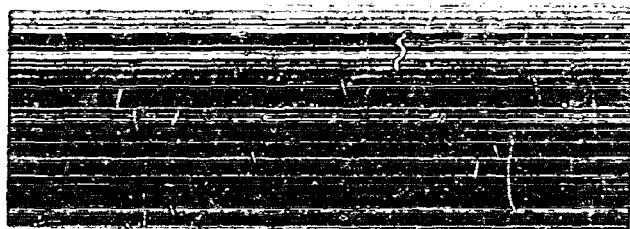
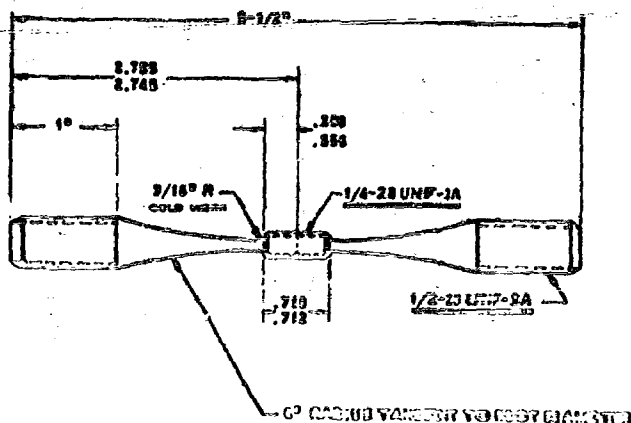


FIGURE 12

**Tension-Tension Fatigue Fracture Located at the Termination of
 the Above 1/4-28 Stud**



POWELL AND CO. MAY 1941, 10, 01/10, 01/10
GIP DIAMETER 1/2-20 UNF-2A

FIGURE 13

**Fifth Design of Tension-Tension Fatigue Test Specimen for Determining
the Characteristics of Unengaged Threads**

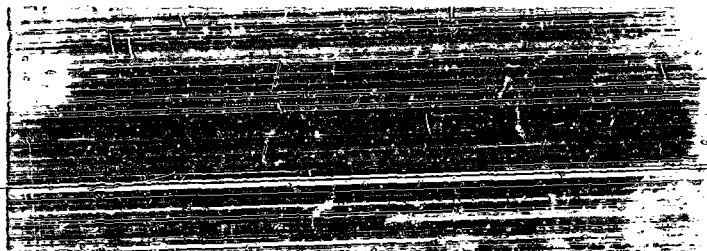
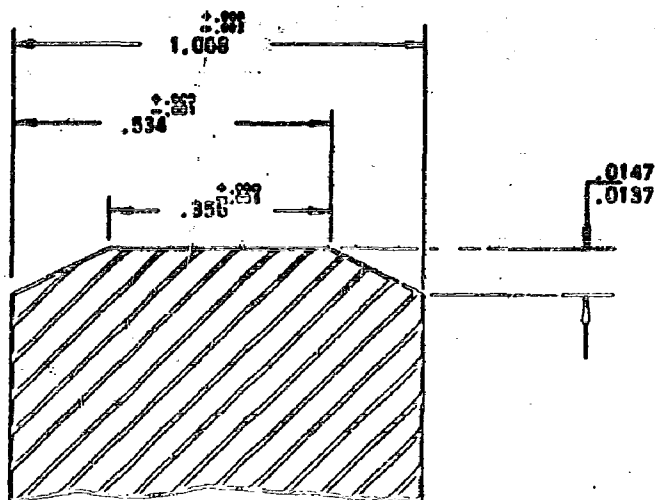


FIGURE 14

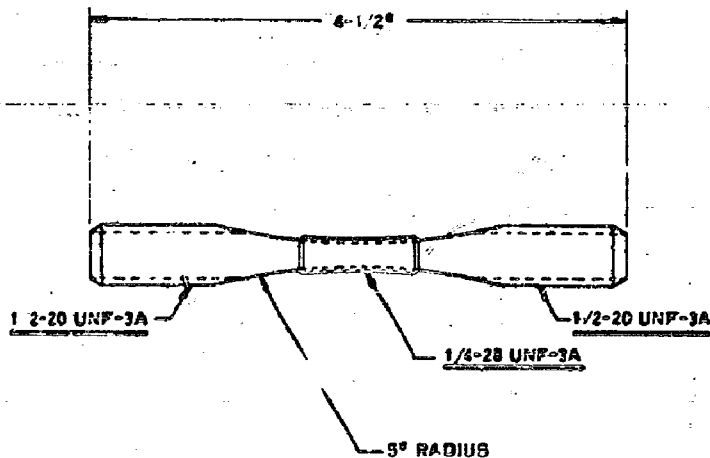
**Tension-Tension Fatigue Fracture Located in Last Full Thread
of the Above Stud**



STANDARD 1/4-20 MSG-A
 030 WATERBURY
 THREAD ROLL DIE
 TYPE B

FIGURE 17

**Cross Section of Special Thread Roll Die used to Produce
 Studs with Tapered Runout**



MATERIAL: AMS 6332 HEAT TREAT: 100,000/100,000 PSI
 GILL MIL-C-7692A THREAD FORM AFTER HEAT TREAT.

FIGURE 20

**Eighth Design of Tension-Tension Fatigue Specimen to Determine
 the Characteristics of Unengaged Threads**

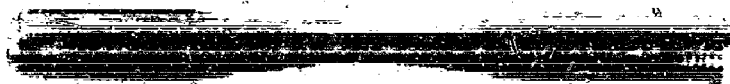
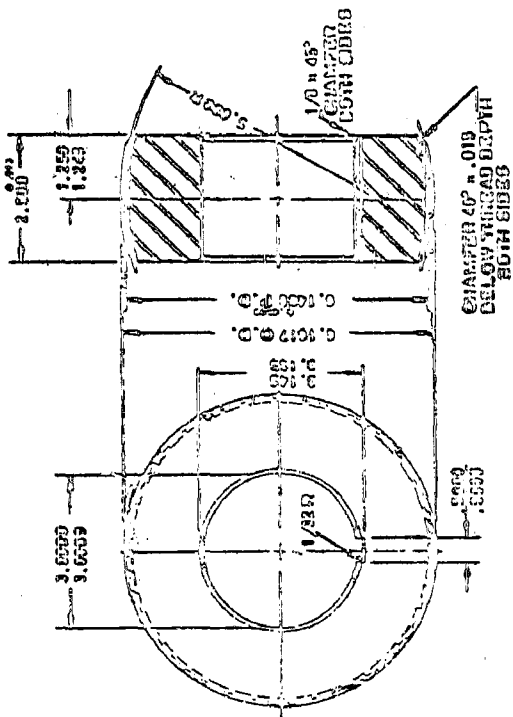


FIGURE 21

**Appearance of the Above Stud after Rolling
 Note Slivers of Metal and Incomplete Thread Form on Part of Stud**



- NOTES:
1. I.D. & O.D. TO BE CONCENTRIC WITHIN .003 TIR.
 2. END SURFACES TO BE PARALLEL & SQUARE WITH BORE WITHIN .003 TIR.
 3. GRIND THREADS AFTER HEAT TREAT.
 4. GRIND THREADS LEFT HAND

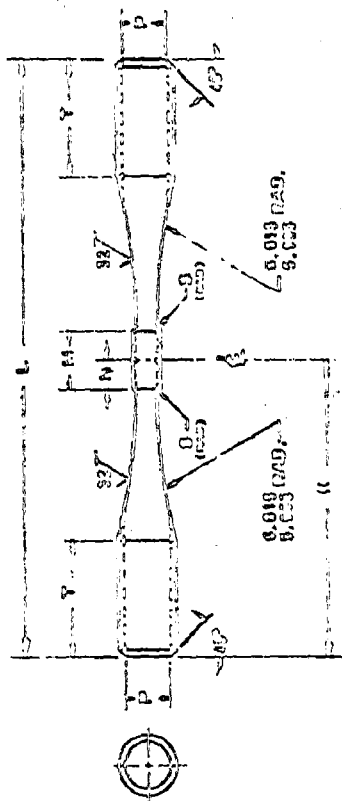
SIZE	THREAD	DICTION	LEES	CHILL	RSP.	R ₂	NO. OF
1/4-28	.0323	.03571	1.0559	2.321	.6543	.6540	28
	.0419					.6530	

FIGURE 22

Special Thread Roll Dies used to try to Produce
1/4-28 Thread on the Curved Surface

NOTED:

1. LARGE RADIUS TO BE TANGENT TO ROST DIA. AT JUNCTION OF LARGE AND SMALL RADIUS.



ROST SIZE	CROSS THICK.	LARGE THICK.	L	H		P		R		r		Y	
				MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1/4	1/2-13	1/2-10	8.149	8.678	8.653	.653	.657	.6313	.6259	.638	.635	1.018	.963
3/8	3/4-14	3/4-11	8.625	9.153	9.128	.703	.707	.675	.673	.69	.687	1.018	1.483
1/2	1-16	1-13	9.101	9.629	9.604	1.009	1.013	.978	.976	.997	.995	1.018	1.963
3/4	1 1/2-18	1 1/2-15	9.576	10.104	10.079	1.503	1.507	1.468	1.466	1.489	1.487	1.512	2.918
1	2-20	2-17	10.051	10.579	10.554	2.003	2.007	1.964	1.962	1.987	1.985	2.012	3.918

FIGURE 23

Final Design of Slude used to Determine the
Tension-Tension Fatigue Characteristics of Unengaged Threads



FIGURE 24

Profile of Threads to MIL-B-7838 on 3/4 Stud

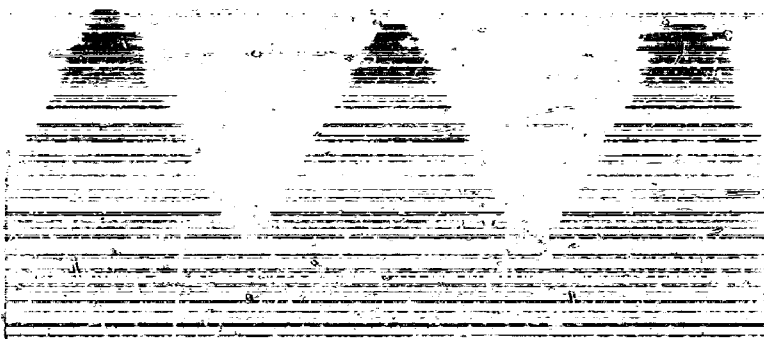


FIGURE 25

**Profile of Threads Cut to MIL-S-7742 on 3/4 Studs
Note Flat Root with Small Radii Blending to Flanks**



FIGURE 26

**Profile of Threads to High Radius Form on 3/4 Studs
Note Large Radius in Root of Thread**

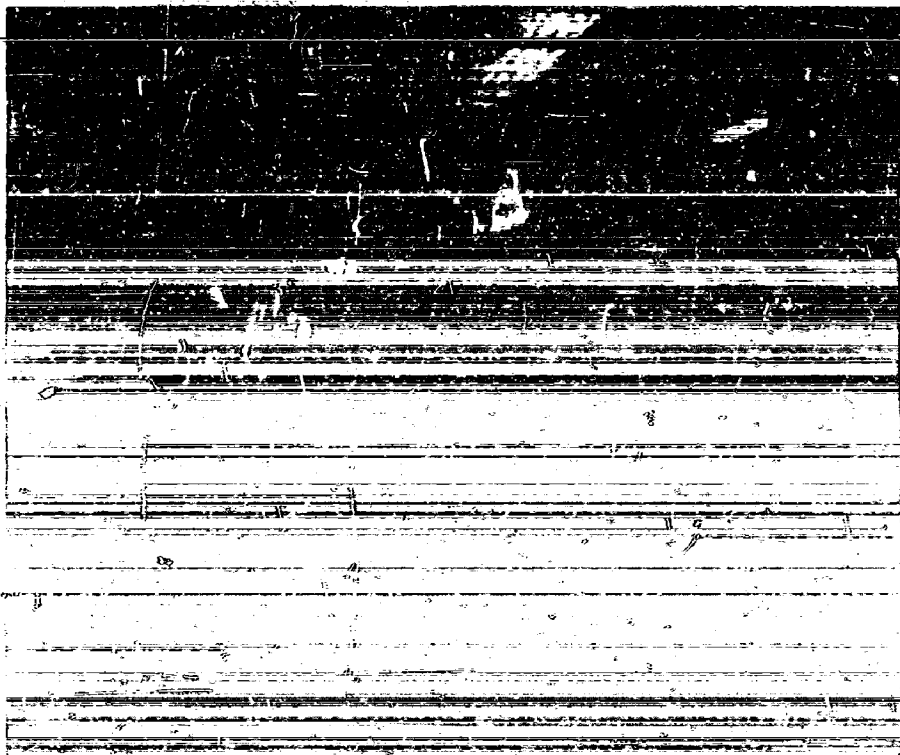


FIGURE 27

30,000# Tinius Olsen Electromatic Universal Testing Machine

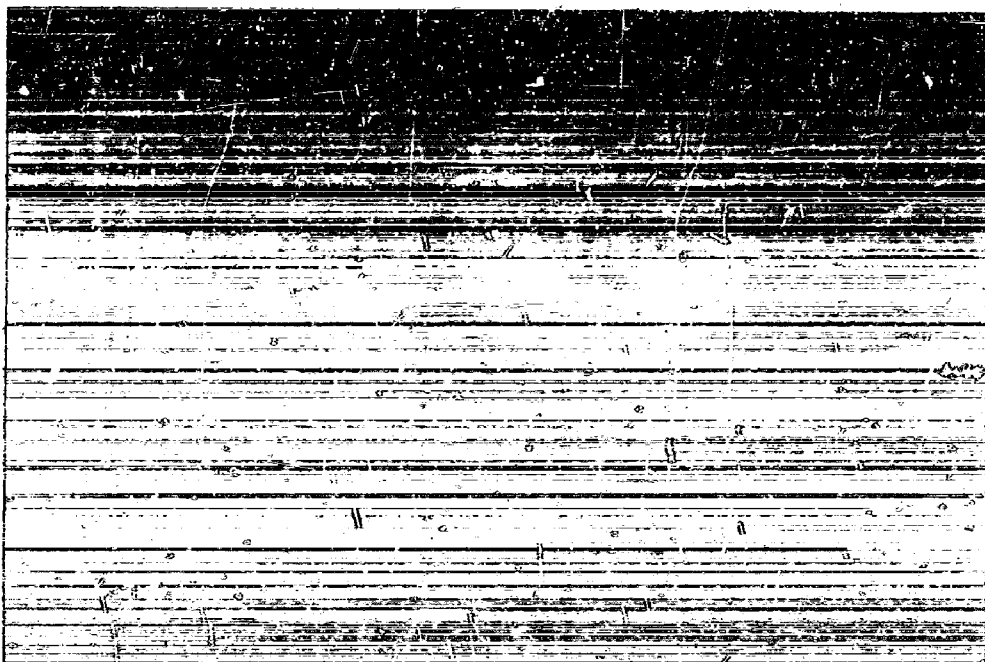


FIGURE 28

60,000# Tinius Olson Super "L" Hydraulic Universal Testing Machine



FIGURE 29

120,000# Timus Olson Electromatic Universal Testing Machine

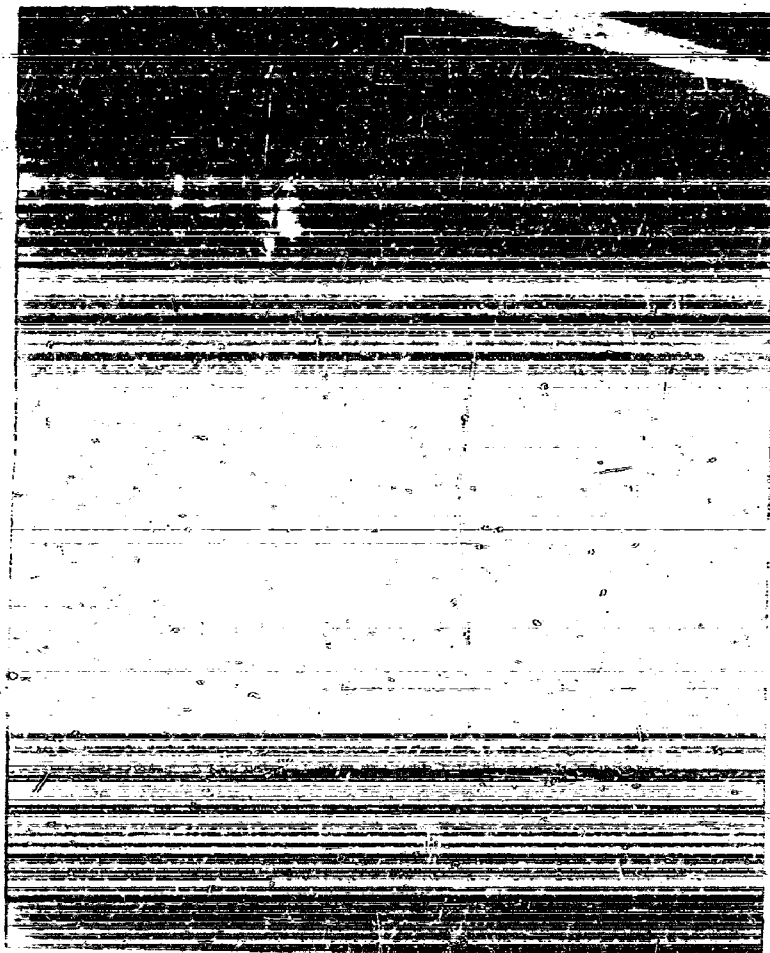


FIGURE 30

400,000# Tinius Olsen Super "L" Hydraulic Universal Testing Machine



FIGURE 31

Provis: Rings for Calibration of Tensile Machines

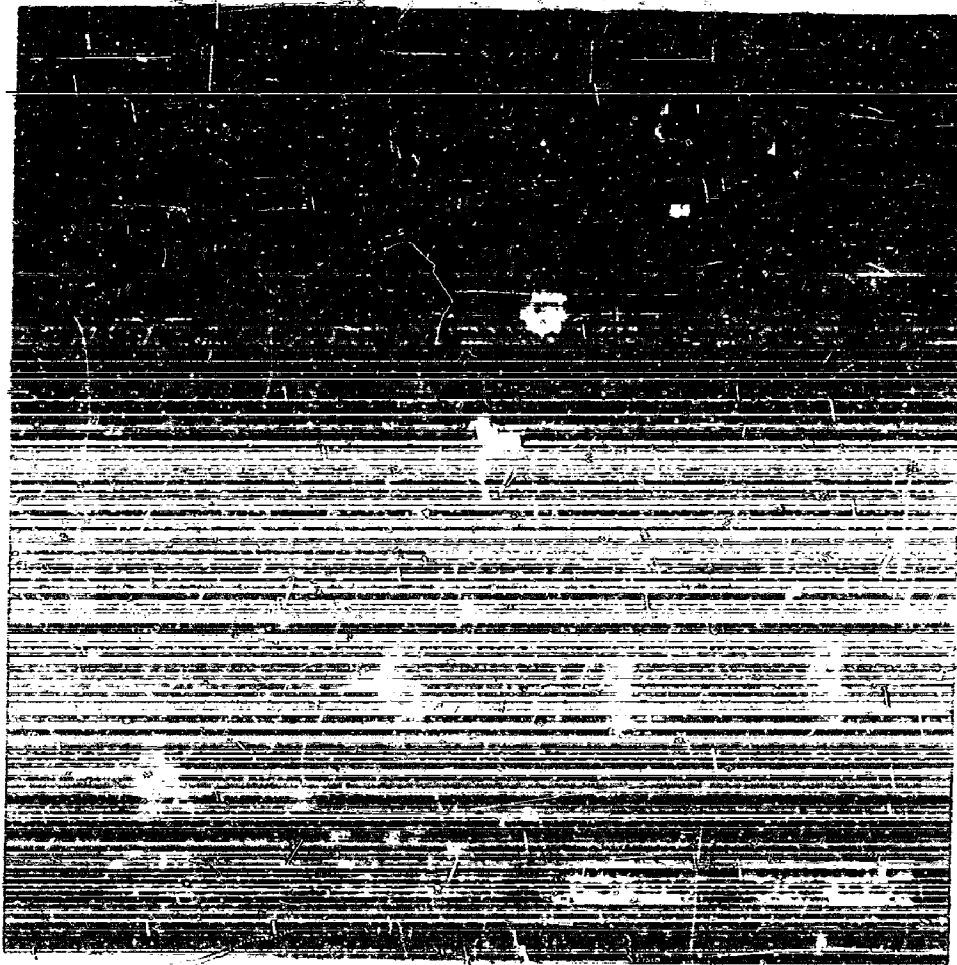


FIGURE 32

Extensometers used in Tensile Testing



FIGURE 33

Specimen Extensometer Assembled in Tensile Machine

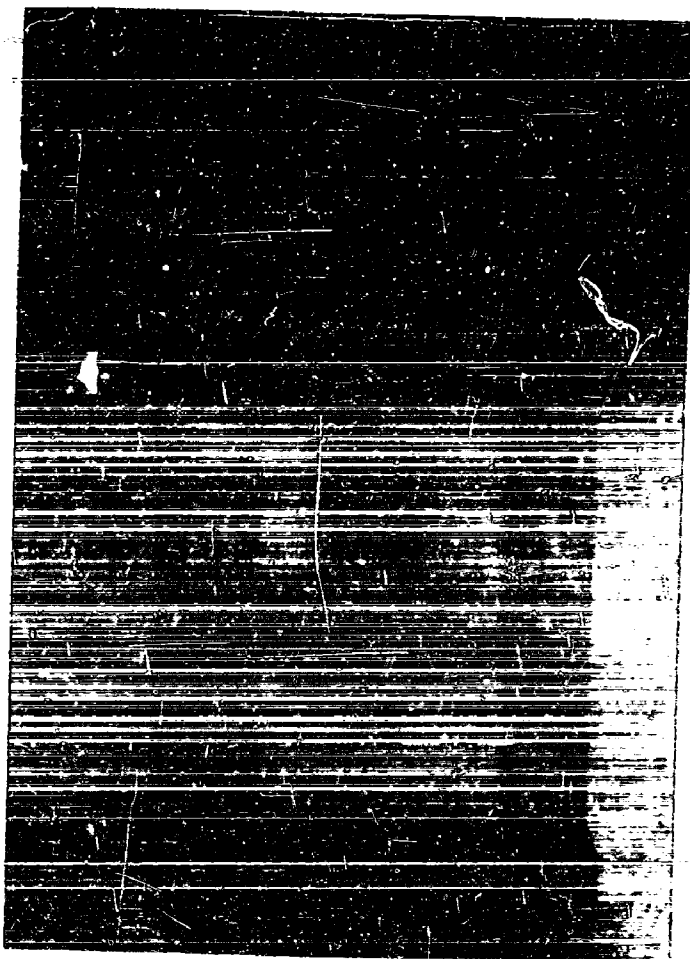
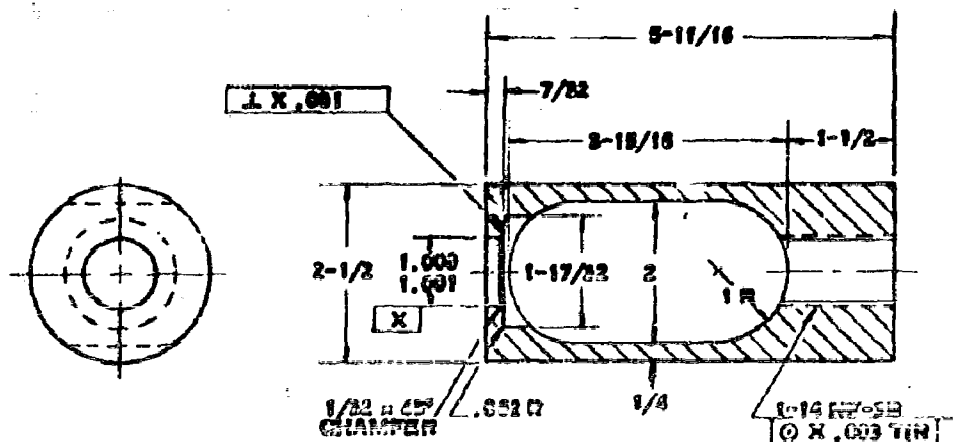


FIGURE 34

Bolt Extensometer Being used on 60,000# Tensile Machine

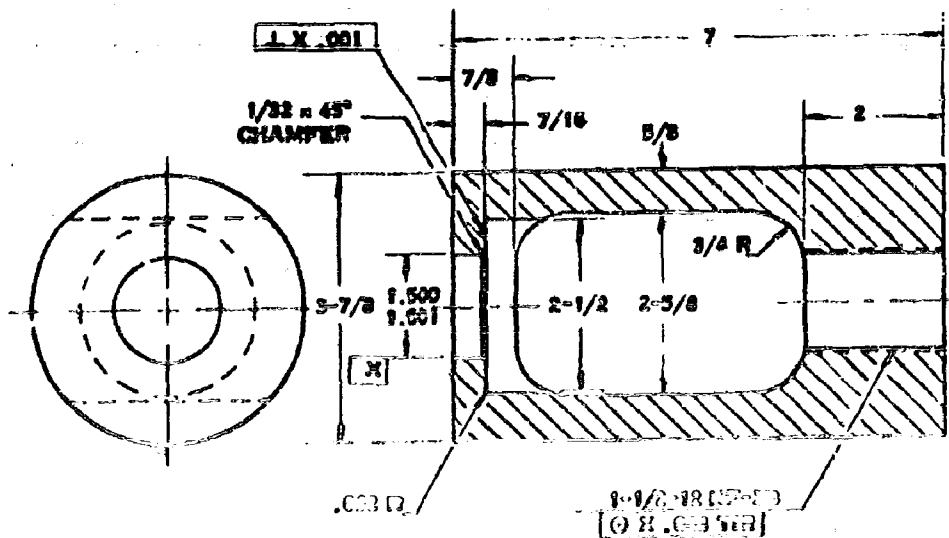


NOTES:

1. TOLERANCES UNLESS SPECIFIED: FRACTIONS $\pm 1/32$, DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$
2. SURFACE FINISH: 60 RMS.
3. MATERIAL: 40 CARBON STEEL.
4. HEAT TREAT: 35-33 H.

FIGURE 35

Testing Link, 3,000 Pound Capacity

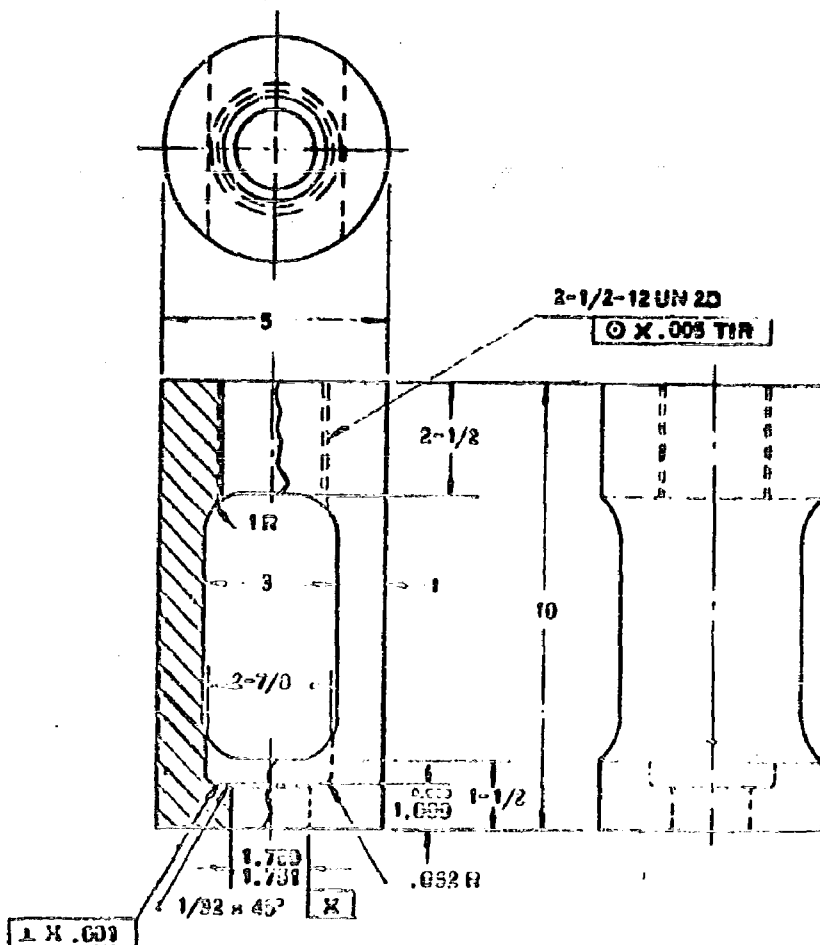


NOTES:

1. TOLERANCES UNLESS SPECIFIED: FRACTIONS $\pm 1/32$ DECIMALS $\pm .010$ ANGLES $\pm 1^\circ$
2. SURFACE FINISH: 32 RMS
3. MATERIAL: 40 CARBON ALLOY STEEL
4. HEAT TREAT: 30-35 R_c

FIGURE 36

Testing Link, 15,000 Pound Capacity

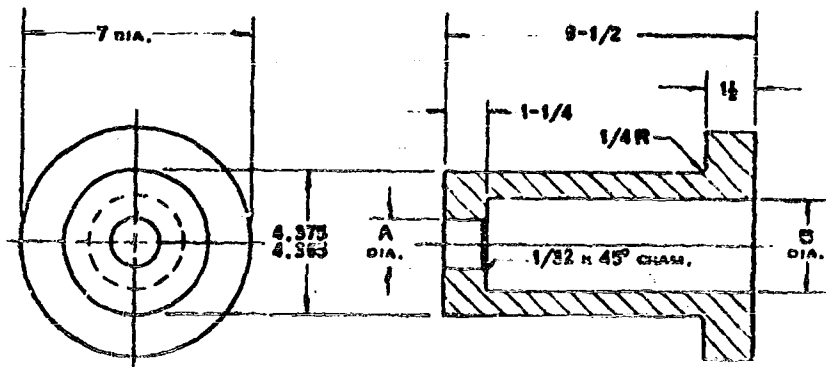


NOTES:

1. ALL RADII SHALL BE A SMOOTH BLEND.
2. BREAK ALL SHARP EDGES.
3. MATERIAL: 40 CARBON ALLOY STEEL.
4. HEAT TREAT: 32-35 R_C.
5. TOLERANCES UNLESS SPECIFIED: FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$

FIGURE 38

Testing Link, 120,000 Pound Testing Machine



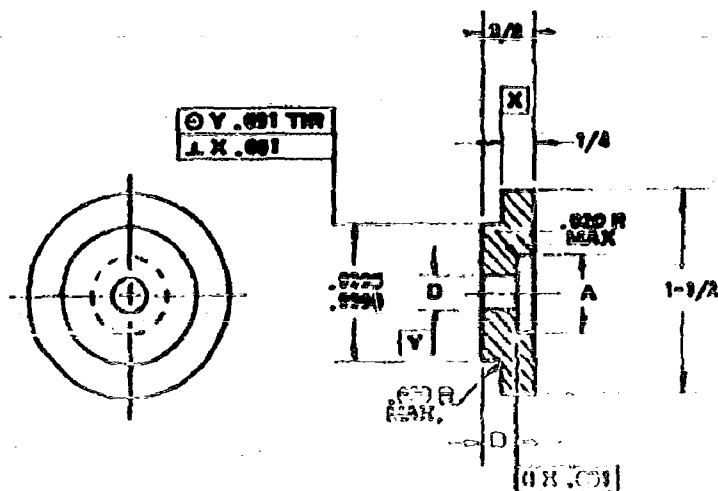
COIL	0.003	0.013
COIL	0.003	0.013
5/8	1.453	1.453
7/8	1.653	1.653
1	1.853	1.853
1-1/8	2.153	2.153
1-1/4	2.353	2.353
1-3/4	2.653	2.653
2	2.853	2.853

NOTE:

1. MATERIAL: 4240 STEEL.
2. HEAT TREAT 15-40 R_c
3. TOLERANCE UNLESS SPECIFIED, FRACTIONS $\pm 1/64$, DECIMALS $\pm .003$, ANGLES $\pm 2^\circ$.

FIGURE 39

Adapter for Top Crosshead 400,000 Pound Tensile Machine

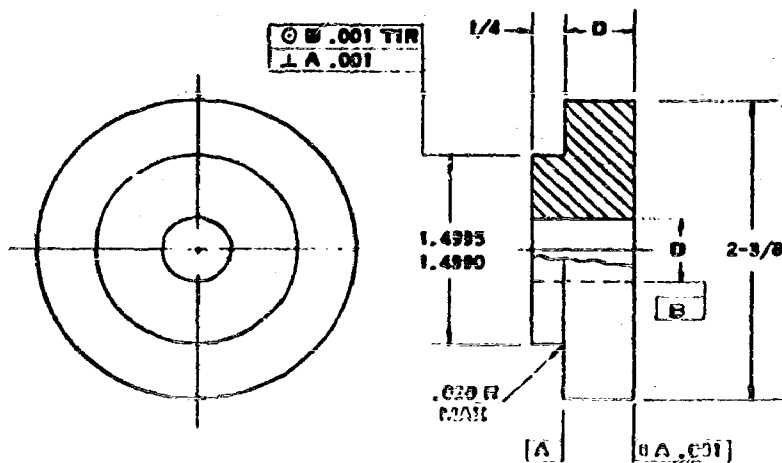


NOTES:

1. TOLERANCES UNLESS SPECIFIED: FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$
2. SURFACE FINISH: 63 RMS
3. MATERIAL: 40 CARBON STEEL
4. HEAT TREAT: 33-38 R_c

FIGURE 40

Counterbored Adapter 3,000 Pound Testing Link



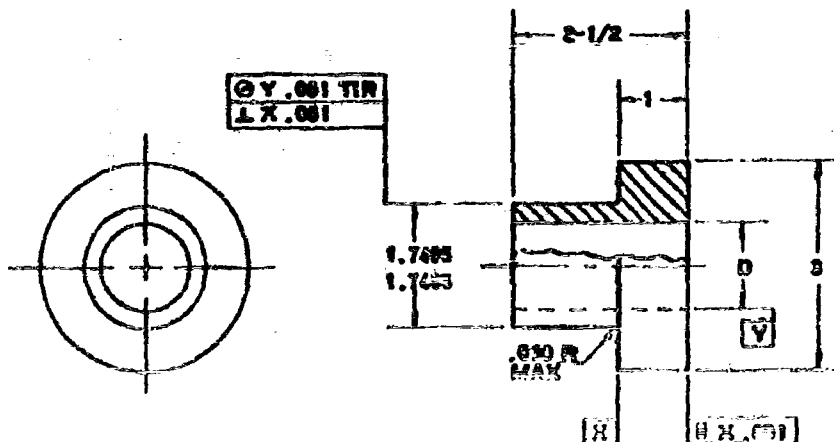
ONLY	D	
SIZE	MIN	MAX
#10	.101	.102
1/4	.231	.232
5/16	.313	.314
3/8	.373	.377
7/16	.453	.459
1/2	.531	.532
9/16	.613	.620
5/8	.693	.697
3/4	.781	.782
7/8	.876	.877
1	1.001	1.002

NOTES:

1. TOLERANCE UNLESS SPECIFIED; FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$
2. SURFACE FINISH: 63 RMS
3. MATERIAL: 40 CARBON STEEL
4. HEAT TREAT: 15-18 H.

FIGURE 41

Adapter for 15,000 and 60,000 Pound Fatigue Link



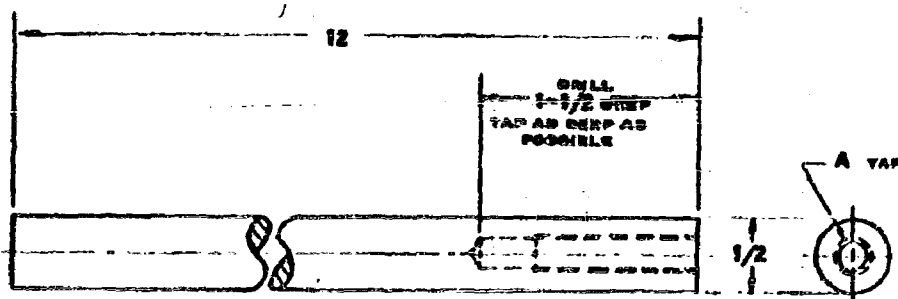
DIA. V SIZE	D	
	MIN	MAX
1	1.031	1.053
1-1/8	1.125	1.127
1-1/4	1.231	1.259
1-3/4	1.573	1.577
1-1/2	1.501	1.522

NOTES:

1. TOLERANCES UNLESS SPECIFIED: FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$, ANGLES $\pm 5^\circ$
2. SURFACE FINISH: 60 RMS
3. MATERIAL: 40 CARBON STEEL
4. HEAT TREAT: 13-13 R₂

FIGURE 42

Adapter 120,000 Pound Fatigue Link



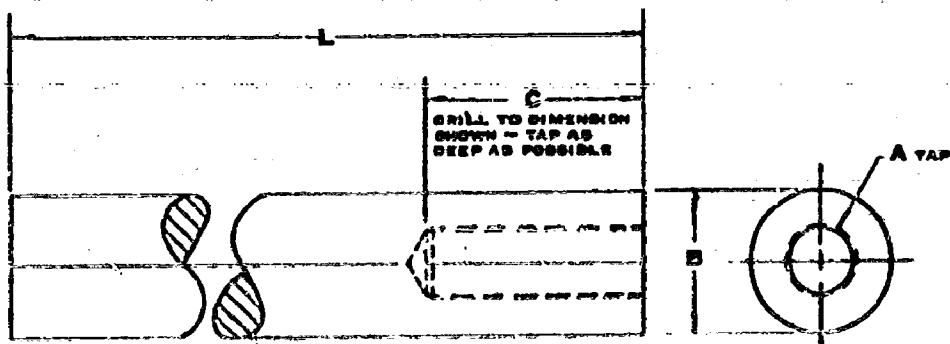
A
TAP SIZE
03-23 NF-2A
60-23 NF-2A
60-24 NF-2A
60-24 NF-2A
60-24 NF-2A
1/4-20 UNF-2A
1/4-20 UNC-2A

NOTES:

1. MATERIAL: 1018 CARBON STEEL.
2. HEAT TREAT 20-33 R_c.
3. TOLERANCE UNLESS SPECIFIED: FRACTIONS $\pm 1/64$, DECIMALS $\pm .003$, ANGLES $\pm 2^\circ$.

FIGURE 43

Tapped Bars for Tensile Testing Machine



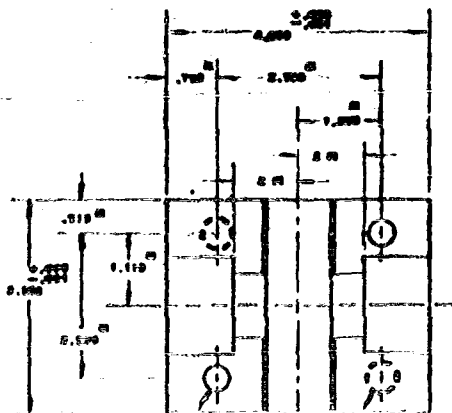
A TAPER DIA	B	C	L	A TAPER DIA	B	C	L	A TAPER DIA	B	C	L
3/16-24	5/8	1-1/2	12	3/16-10	1-1/2	2	12	1-1/2-12	3	3-1/2	12
1/8-13	5/8	1-1/2	12	3/16-10	1-1/2	2	12	1-1/2-9	3	3-1/2	12
3/8-20	3/4	1-1/2	12	7/16-14	1-3/4	2-1/2	12	1-3/4-12	2-1/2	2-1/2	12
3/8-16	3/4	1-1/2	12	7/16-14	1-3/4	2-1/2	12	1-3/4-9	2-1/2	2-1/2	12
1/4-19	7/8	1-1/2	12	1-16	2	2-1/2	12	1-3/4-12	2-1/2	2-1/2	12
1/4-13	7/8	1-1/2	12	1-8	2	2-1/2	12	1-3/4-9	2-1/2	2-1/2	12
1/2-10	1	1-1/2	12	1-16	2	2-1/2	12	1-3/4-12	2-1/2	2-1/2	12
1/2-13	1	1-1/2	12	1-8	2	2-1/2	12	1-3/4-9	2-1/2	2-1/2	12
5/16-18	1-1/4	1-3/4	12	1-16	2	2-1/2	12	2-12	4	4-1/2	25
5/16-12	1-1/4	1-3/4	12	1-8	2	2-1/2	12	2-9	4	4-1/2	25
5/8-10	1-1/4	1-3/4	12	1-3/8-12	2-3/4	3	12				
5/8-11	1-1/4	1-3/4	12	1-3/8-8	2-3/4	3	12				

NOTES:

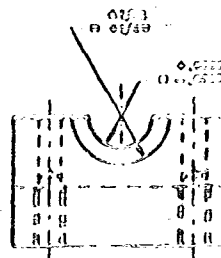
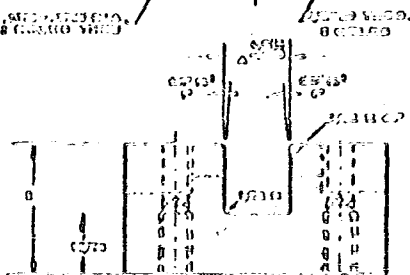
1. MATERIAL: 40 CARBON STEEL.
2. HEAT TREAT 30-36 R_c.
3. TOLERANCE UNLESS SPECIFIED: FRACTIONS ±1/64, DECIMALS ±0.005, ANGLES ±2°.

FIGURE 41

Tapped Bars for Tensile Testing Machine



HOLE SIZE	$\frac{.001}{.002}$ A	R
#10	.180	.095
1/4	.251	.125
5/16	.313	.157
3/8	.375	.188
7/16	.438	.219
1/2	.501	.251
9/16	.563	.282
5/8	.625	.313
3/4	.751	.375
7/8	.875	.438
1"	1.001	.501

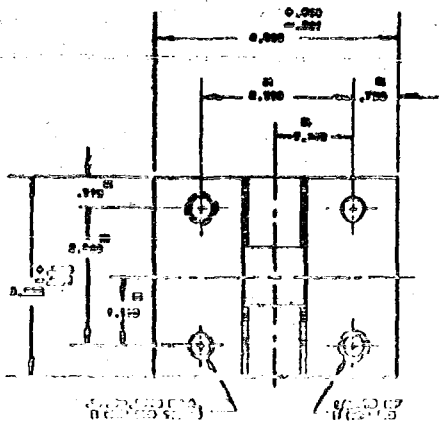


NOTES:

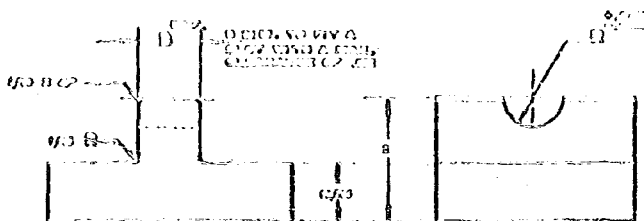
1. DIES TO BE LOCATED IN A DIAGONAL POSITION (45°-45°) ON DIE SET TO ALLOW EASY REMOVAL OF LONG PIECES.
2. THE LOCATION OF HOLES DIMENSIONED WITH "A" ARE TO BE JIG DRILLED.
3. MATERIAL: D-2 STEEL.
4. HEAT TREAT: 60-62 Rc.
5. TOLERANCE UNLESS SPECIFIED, FRACTIONS .1/64, DECIMALS .002 ANGLE .1°

FIGURE 45

Bottom Shearing Die Shearing #10 to 1" Diameter



BOLT SIZE	PREP ID	PREP R
#10	.191	.000
1/4	.250	.125
5/16	.312	.157
3/8	.375	.188
7/16	.437	.219
1/2	.500	.250
9/16	.562	.282
5/8	.625	.313
3/4	.750	.375
7/8	.875	.438
1	1.000	.500



NOTES:

1. HOLE TO BE LOCATED IN A DIAGONAL POSITION (35°-45°) ON DIE SET TO ALLOW SHEARING OF LONG PIECES.
2. IF THE LOCATION OF HOLE DIMENSIONED WITH 2 ANGLES TO BE DRILLED, USE DRG TR 400 J.

FIGURE 46

Top Shearing Die Shearing #10 to 1" Diameter

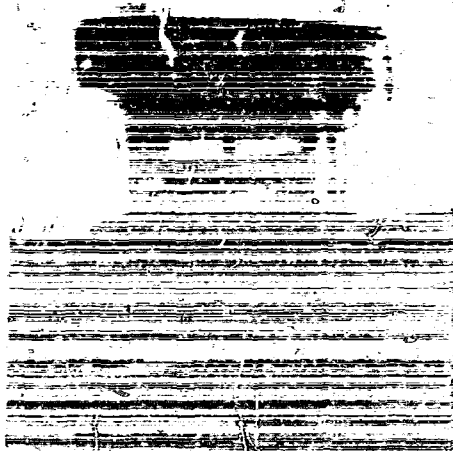


FIGURE 47

Setup for Shear Test on Bolts



FIGURE 48

**5,000# Krouse Direct Stress Fatigue Machine
with Hydraulic Load Maintainer**

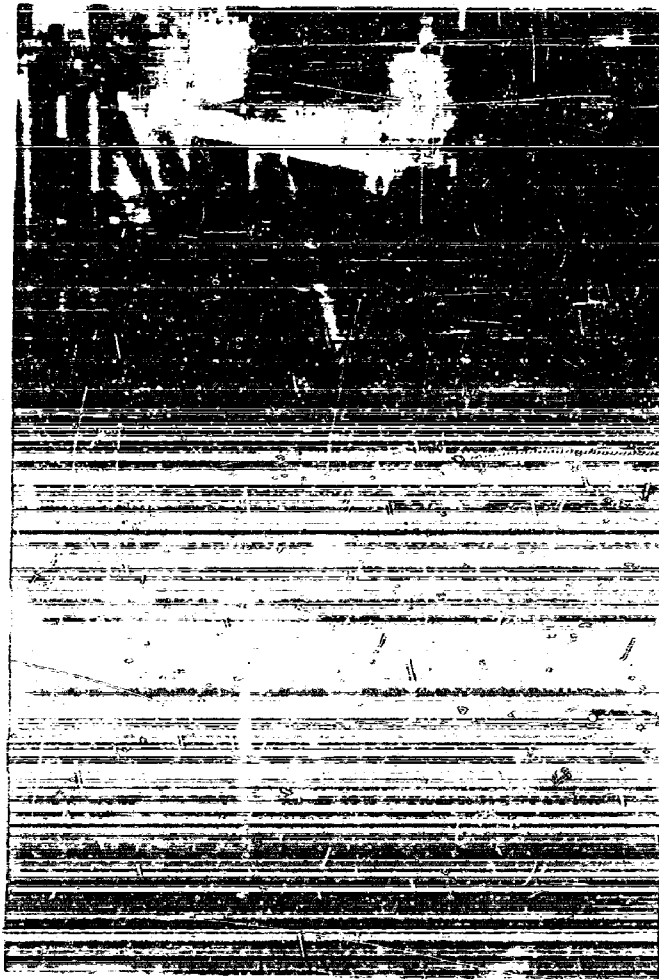


FIGURE 49

15,000# Krouse Direct Stress Fatigue Machine
with Hydraulic Load Maintainer



FIGURE 50

60,000# Ivy Inertia Compensated Fatigue Machine

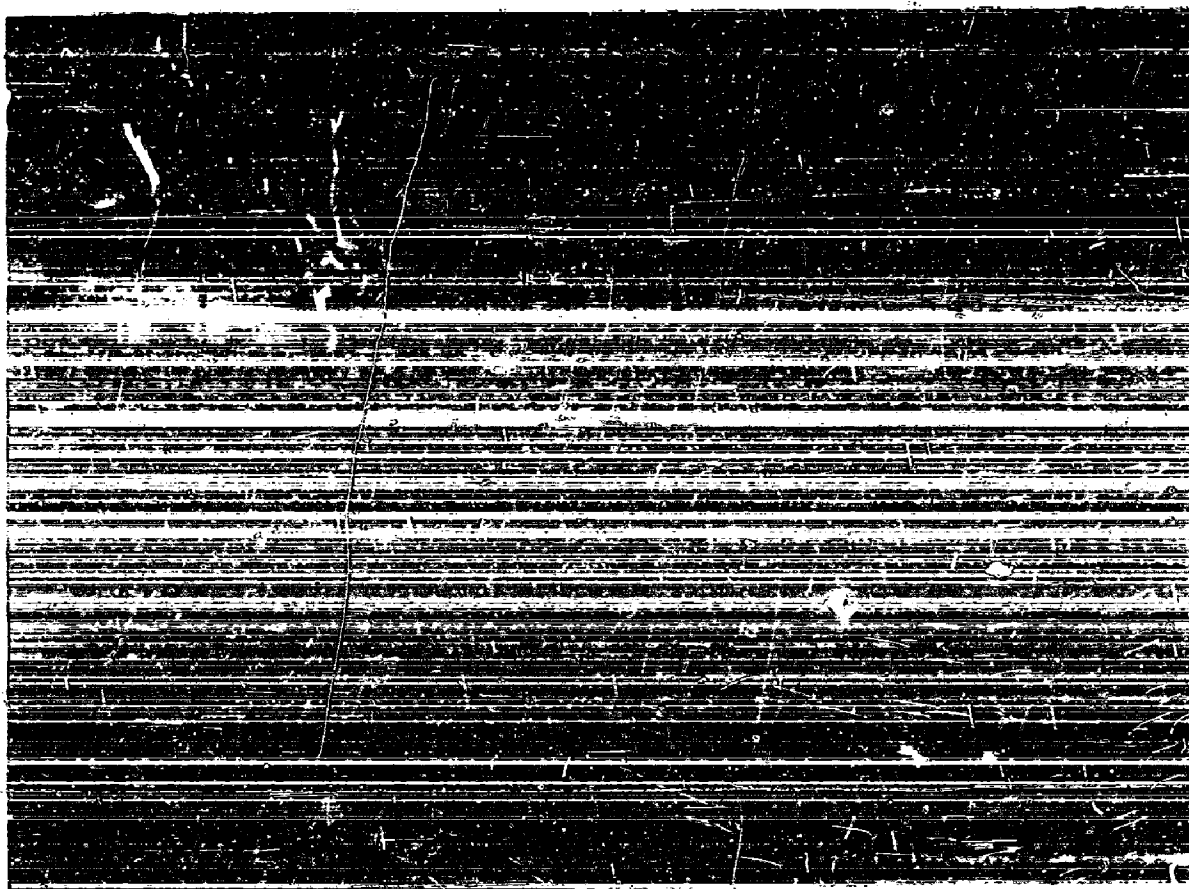


FIGURE 51

60,000# Krouse Fatigue Machine

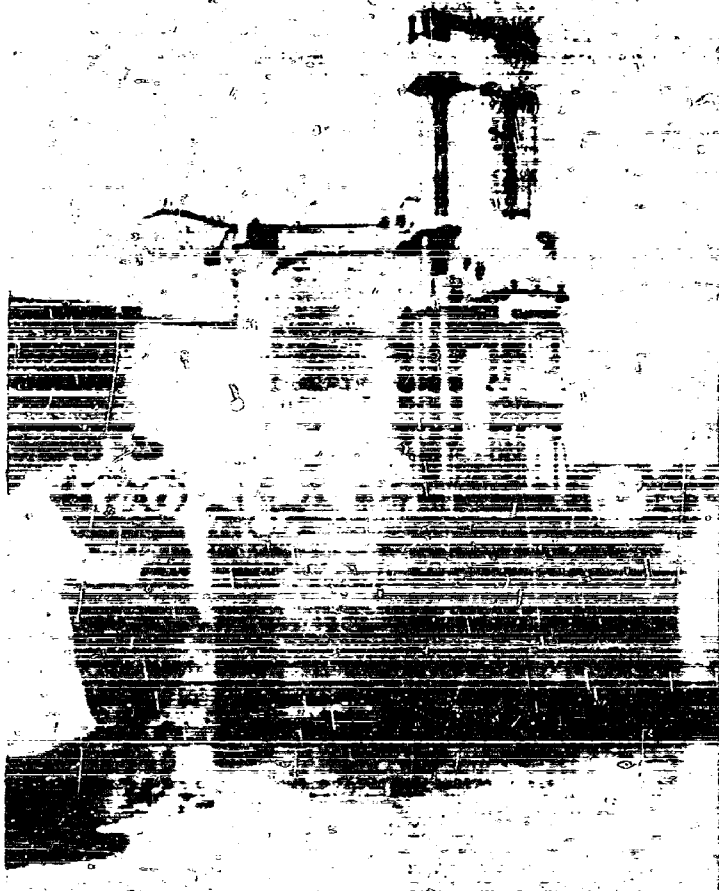


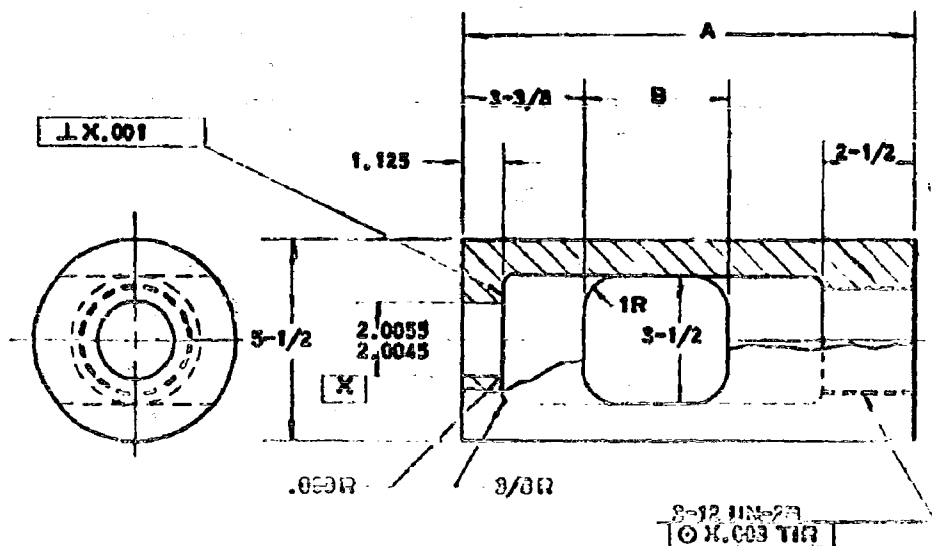
FIGURE 52

220,000# Amster Fatigue Machine



FIGURE 53

Fixture and Adapter Assembly used in Fatigue Testing Bolts



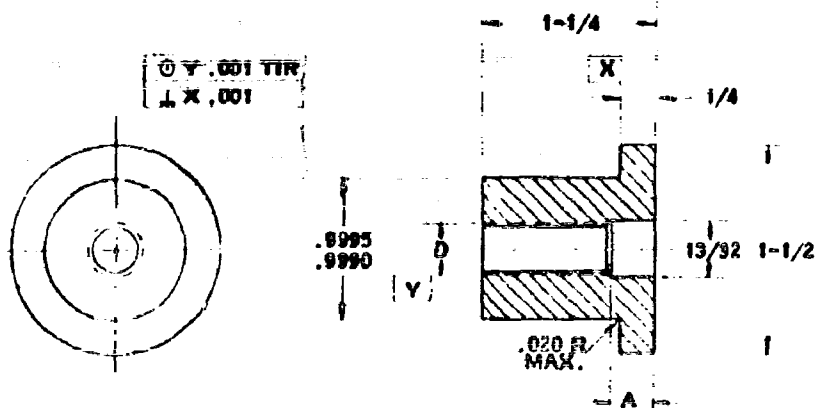
	A	B
TOP LINK	10-1/2	10
BOTTOM LINK	12-1/2	4

NOTES:

1. ALL RADII MUST BE A SMOOTH BLEND.
2. TOLERANCES UNLESS SPECIFIED:
FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$.
3. MATERIAL: 40 CARBON ALLOY STEEL.
4. HEAT TREAT: 32-38 R_c.

FIGURE 54

220,000 Pound Tension Fatigue Adapter



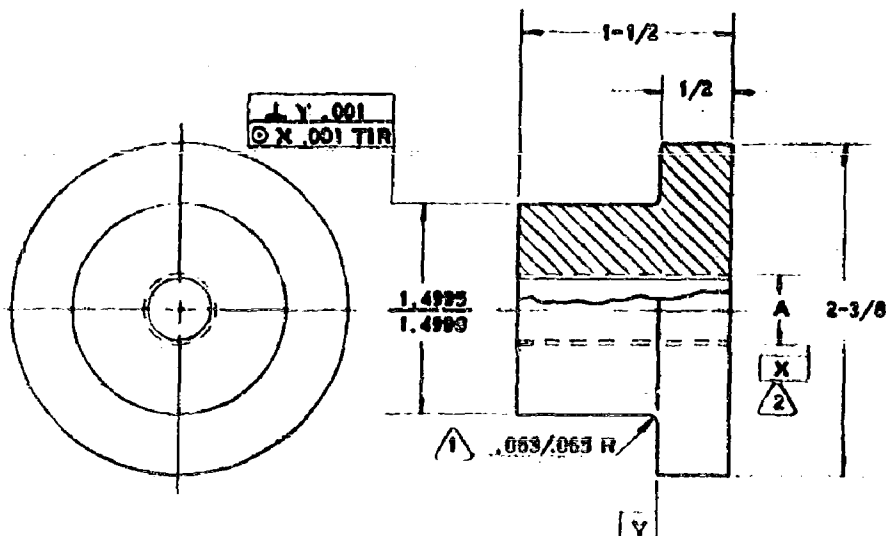
D	A
1/8-32 NF	23/32
1/4-28 NF	5/8
1/4-28 NF	5/8
5/16-18 NF	13/32
5/16-24 NF	10/32
3/8-16 NF	5/16
3/8-24 NF	5/10

NOTES:

1. THREADS TO BE CLASS 2.
2. TOLERANCE UNLESS SPECIFIED: FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$.
3. SURFACE FINISH: 60 RMS.
4. MATERIAL: 40 CARBON STEEL.
5. HEAT TREAT: 93-99 Rc

FIGURE 55

Threaded Adapter 3,000 Pound Fatigue Link



A
9/16-32 NF
1/4-20 NG
1/8-20 NF
5/16-18 NG
5/16-24 NF
3/8-16 NG
3/8-24 NF

A
7/16-14 NG
7/16-20 NF
1/2-13 NG
1/2-20 NF
9/16-12 NG
9/16-18 NF
5/8-11 NG

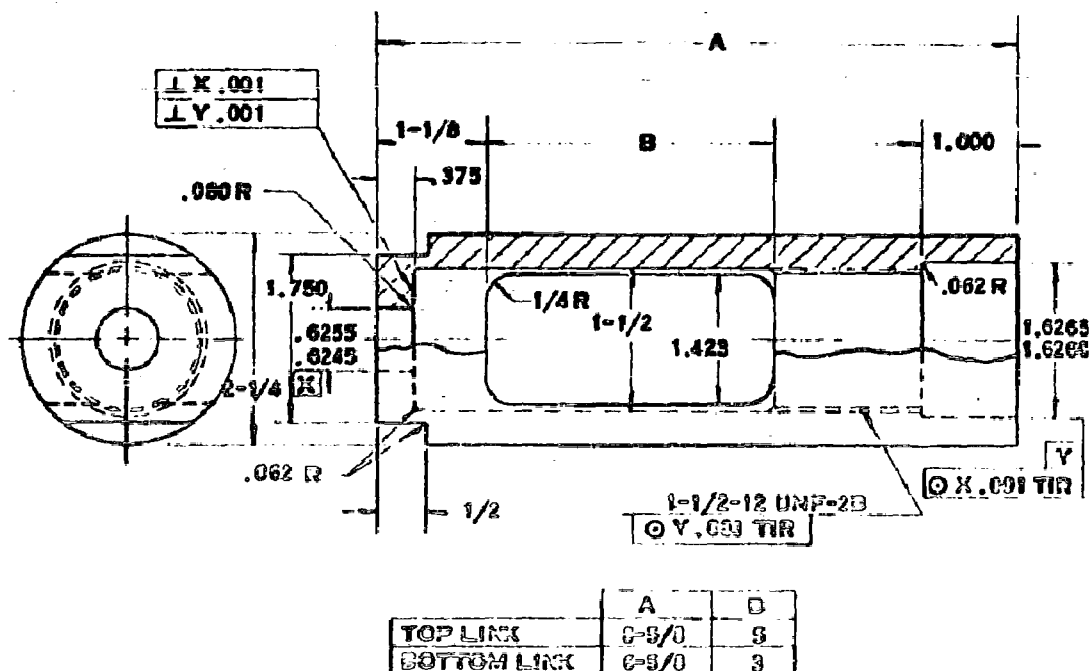
A
5/8-18 NF
3/4-19 NG
5/8-10 NF
7/8-8 NG
7/8-14 NF
1 - 8 NG
1 - 14 NF

NOTES:

1. RADIUS TO BE COLD WORKED AFTER HEAT TREAT
2. THREADS TO BE CLASS 3B
3. TOLERANCES UNLESS SPECIFIED: FRACTIONS $\pm 1/64$, DECIMALS $\pm .010$ ANGLES $\pm 2^\circ$
4. SURFACE FINISH: 60 RMS
5. MATERIAL: 40 CARBON STEEL
6. HEAT TREAT: 33-38 R_c

FIGURE 56

Threaded Adapter 15,000 and 60,000 Pound Fatigue Link

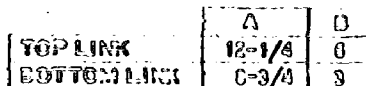


NOTES:

1. ALL RADIUS SHALL BE A SMOOTH BLEND.
2. TOLERANCE UNLESS SPECIFIED;
FRACTIONS $\pm 1/64$, DECIMALS $\pm .003$, ANGLES $\pm 2^\circ$.
3. MATERIAL: 40 CARBON ALLOY STEEL.
4. HEAT TREAT: 32-35 R_c.

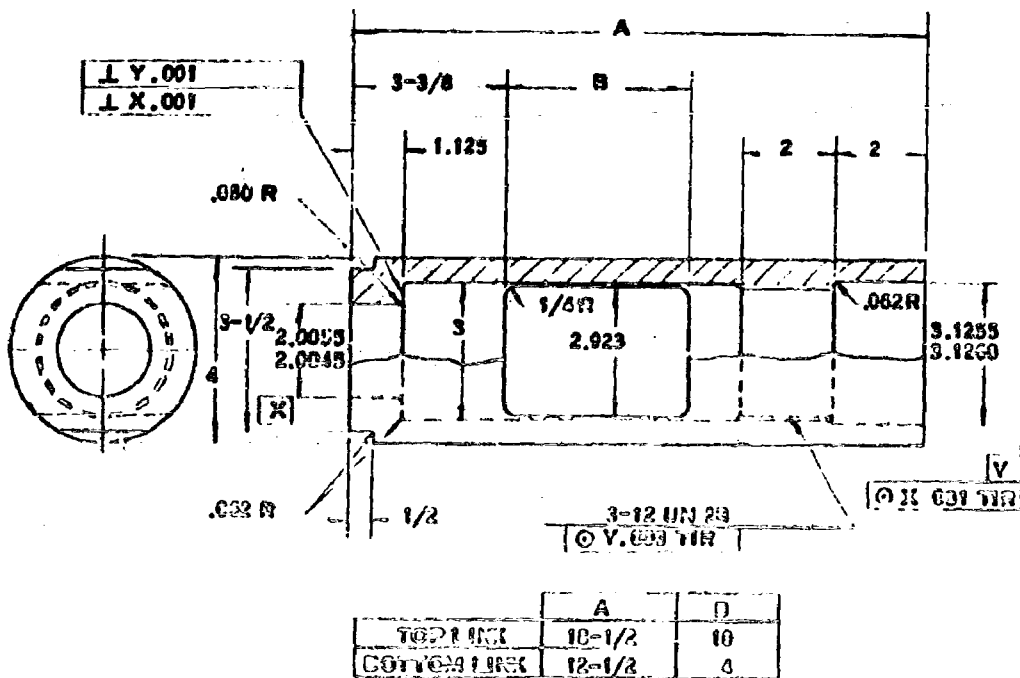
FIGURE 57

5,000 to 15,000 Pound Tension Fatigue Adapter



1. ALL RADII MUST BE A SMOOTH BLEND.
2. TOLERANCE UNLESS SPECIFIED:
FRACTIONS $\pm 1/64$, DECIMALS $\pm .005$
3. MATERIAL; 40 CRON ALLOY STEEL
4. HEAT TREAT; 32-35 H_C.

25,000 to 60,000 Pound Tension Fatigue Adapter



NOTES:

1. ALL RADII SHALL BE A SMOOTH BLEND.
2. TOLERANCE UNLESS SPECIFIED:
FRACTIONS $\pm 1/64$, DECIMALS $\pm .003$, ANGLES $\pm 2^\circ$.
3. MATERIAL, 40 CARBON ALLOY STEEL.
4. HEAT TREAT: 32-35 R_c.

FIGURE 59

60,000 to 200,000 Pound Tension Fatigue Adapter

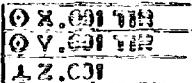




FIGURE 62

**Close up of Fatigue Failure of NAI-160 Fatigue Link
200,000# Capacity**

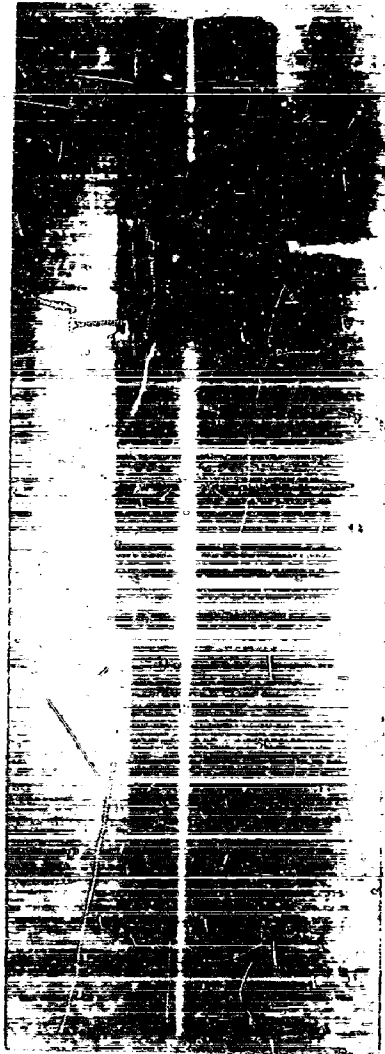


FIGURE 63

**Full View of NAI-160 Fatigue Link
Failure is Noticeable in Upper Part**

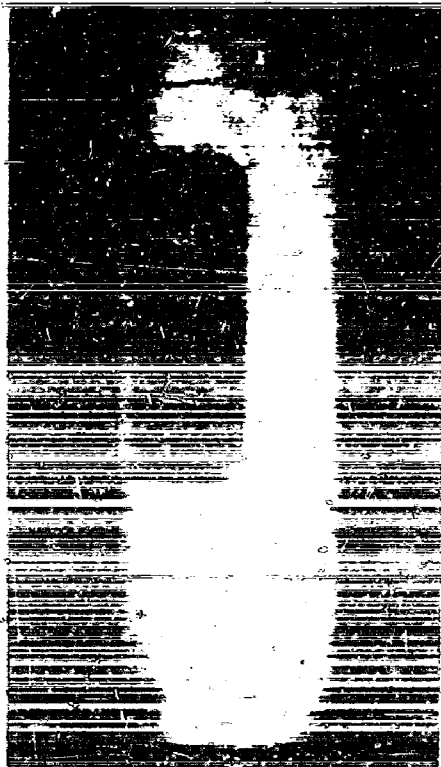
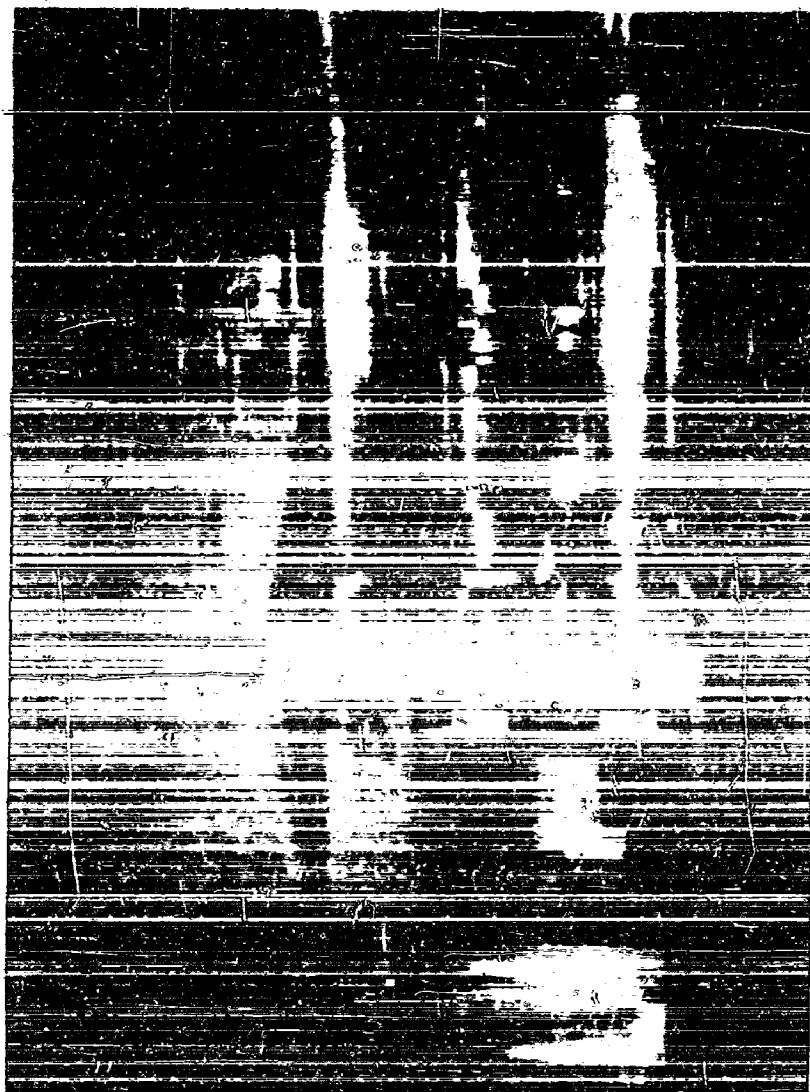


FIGURE 64

Fatigue Failure of NAI 160, 15,000 Pound Link



Location of Strain Gages on Flexure Plates

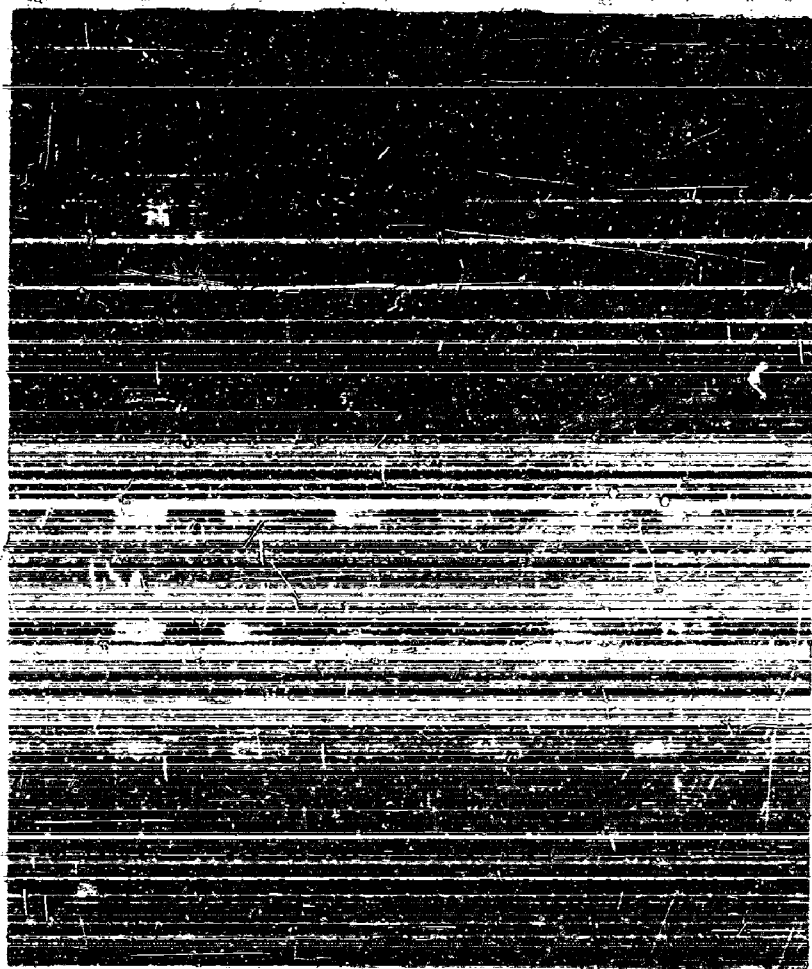


FIGURE 66

**Instrumentation used on each Fatigue Machine
To Measure Dynamic Loads**

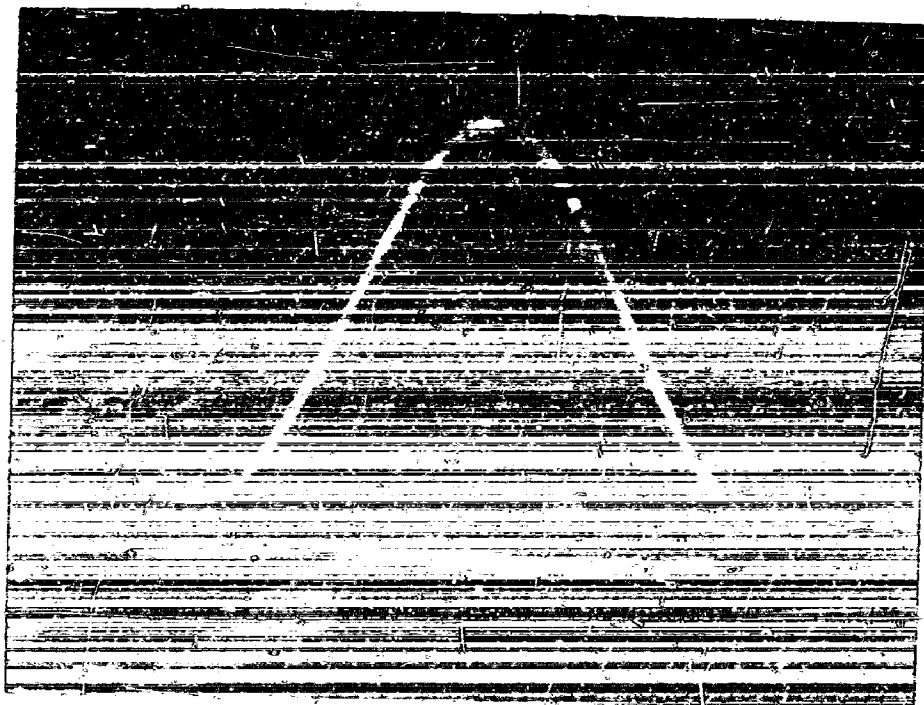
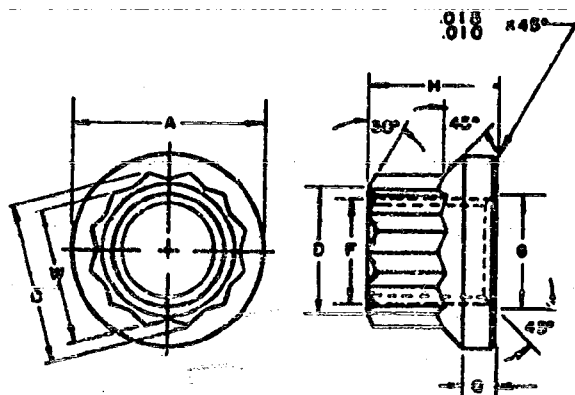


FIGURE 67

Oscillograph Pattern of Dynamic Load and Measuring Circuit



CONE	A ±.010	G MIN	D ±.010	F ±.010	G ±.010	H ±.010	G ±.010	MAX	MIN
1/8-20	1.891	.480	.970	.803	1.891	.823	.670	.670	.807
9/16-24	1.491	.491	.843	.699	1.491	.699	.659	.659	.699
3/4-24	1.449	.591	.800	.650	1.449	.650	.624	.624	.650
7/16-27	.781	.631	.832	.638	.449	.818	.112	.584	.553
1/2-28	.875	.785	.825	.515	.551	.850	.125	.657	.616
9/16-18	.850	.743	.807	.670	.503	.693	.107	.650	.610
9/8-10	1.632	.652	.781	.650	.619	.672	.159	.783	.771
3/8-16	1.270	1.059	.858	.780	.781	.781	.183	.840	.828
7/8-14	1.439	1.259	1.053	.850	.908	.653	.219	1.024	1.022
1"-14	1.633	1.344	1.123	1.018	1.631	1.123	.269	1.180	1.178
1-1/8-12	1.973	1.597	1.378	1.163	1.158	1.299	.303	1.577	1.564
1-1/4-12	2.129	1.659	1.500	1.263	1.291	1.370	.360	1.592	1.460
1-3/8-12	2.313	1.842	1.623	1.350	1.468	1.550	.350	1.637	1.616
1-1/2-12	2.500	2.056	1.813	1.515	1.631	1.625	.378	1.814	1.800

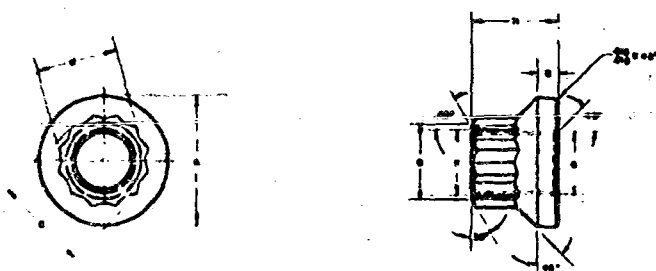
NOTES:

1. BEARING SURFACES MUST BE SQUARE WITH PITCH DIAMETER WITHIN .003 TIR.
2. ALL THREADS TO BE CLASS 3B.
3. TAP THREADS AFTER HEAT TREAT.
4. APPLY RUST PREVENTING OIL.
5. MATERIAL: 8630AQ - 8740AQ

**DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED,
TOLERANCES, DECIMALS ±.010, ANGLES ±2°**

FIGURE 68

Fatigue Test Nuts for Tension Bolts under 200,000 PSI Ultimate



THREAD	A Dia	B OD	C ID	D Pitch	E Pitch	F Pitch	G Pitch	H Pitch	I Pitch	J Pitch	K Pitch	L Pitch	M Pitch	N Pitch	O Pitch	P Pitch	Q Pitch	R Pitch	S Pitch	T Pitch	U Pitch	V Pitch	W Pitch	X Pitch	Y Pitch	Z Pitch	AA Pitch	AB Pitch	AC Pitch	AD Pitch	AE Pitch	AF Pitch	AG Pitch	AH Pitch	AI Pitch	AJ Pitch	AK Pitch	AL Pitch	AM Pitch	AN Pitch	AO Pitch	AP Pitch	AQ Pitch	AR Pitch	AS Pitch	AT Pitch	AU Pitch	AV Pitch	AW Pitch	AX Pitch	AY Pitch	AZ Pitch	BA Pitch	BB Pitch	BC Pitch	BD Pitch	BE Pitch	BF Pitch	BG Pitch	BH Pitch	BI Pitch	BJ Pitch	BK Pitch	BL Pitch	BM Pitch	BN Pitch	BO Pitch	BP Pitch	BQ Pitch	BR Pitch	BS Pitch	BT Pitch	BU Pitch	BV Pitch	BW Pitch	BX Pitch	BY Pitch	BZ Pitch	CA Pitch	CB Pitch	CC Pitch	CD Pitch	CE Pitch	CF Pitch	CG Pitch	CH Pitch	CI Pitch	CJ Pitch	CK Pitch	CL Pitch	CM Pitch	CN Pitch	CO Pitch	CP Pitch	CQ Pitch	CR Pitch	CS Pitch	CT Pitch	CU Pitch	CV Pitch	CW Pitch	CX Pitch	CY Pitch	CZ Pitch	DA Pitch	DB Pitch	DC Pitch	DD Pitch	DE Pitch	DF Pitch	DG Pitch	DH Pitch	DI Pitch	DJ Pitch	DK Pitch	DL Pitch	DM Pitch	DN Pitch	DO Pitch	DP Pitch	DQ Pitch	DR Pitch	DS Pitch	DT Pitch	DU Pitch	DV Pitch	DW Pitch	DX Pitch	DY Pitch	DZ Pitch	EA Pitch	EB Pitch	EC Pitch	ED Pitch	EE Pitch	EF Pitch	EG Pitch	EH Pitch	EI Pitch	EJ Pitch	EK Pitch	EL Pitch	EM Pitch	EN Pitch	EO Pitch	EP Pitch	EQ Pitch	ER Pitch	ES Pitch	ET Pitch	EU Pitch	EV Pitch	EW Pitch	EX Pitch	EY Pitch	EZ Pitch	FA Pitch	FB Pitch	FC Pitch	FD Pitch	FE Pitch	FF Pitch	FG Pitch	FH Pitch	FI Pitch	FJ Pitch	FK Pitch	FL Pitch	FM Pitch	FN Pitch	FO Pitch	FP Pitch	FQ Pitch	FR Pitch	FS Pitch	FT Pitch	FU Pitch	FV Pitch	FW Pitch	FX Pitch	FY Pitch	FZ Pitch	GA Pitch	GB Pitch	GC Pitch	GD Pitch	GE Pitch	GF Pitch	GG Pitch	GH Pitch	GI Pitch	GJ Pitch	GK Pitch	GL Pitch	GM Pitch	GN Pitch	GO Pitch	GP Pitch	GQ Pitch	GR Pitch	GS Pitch	GT Pitch	GU Pitch	GV Pitch	GW Pitch	GX Pitch	GY Pitch	GZ Pitch	HA Pitch	HB Pitch	HC Pitch	HD Pitch	HE Pitch	HF Pitch	HG Pitch	HH Pitch	HI Pitch	HJ Pitch	HK Pitch	HL Pitch	HM Pitch	HN Pitch	HO Pitch	HP Pitch	HQ Pitch	HR Pitch	HS Pitch	HT Pitch	HU Pitch	HV Pitch	HW Pitch	HX Pitch	HY Pitch	HZ Pitch	IA Pitch	IB Pitch	IC Pitch	ID Pitch	IE Pitch	IF Pitch	IG Pitch	IH Pitch	II Pitch	IJ Pitch	IK Pitch	IL Pitch	IM Pitch	IN Pitch	IO Pitch	IP Pitch	IQ Pitch	IR Pitch	IS Pitch	IT Pitch	IU Pitch	IV Pitch	IW Pitch	IX Pitch	IY Pitch	IZ Pitch	JA Pitch	JB Pitch	JC Pitch	JD Pitch	JE Pitch	JF Pitch	JG Pitch	JH Pitch	JI Pitch	IJ Pitch	JK Pitch	KL Pitch	JM Pitch	JN Pitch	JO Pitch	JP Pitch	JQ Pitch	JR Pitch	JS Pitch	JT Pitch	JU Pitch	JV Pitch	JW Pitch	JX Pitch	JY Pitch	JZ Pitch	KA Pitch	KB Pitch	KC Pitch	KD Pitch	KE Pitch	KF Pitch	KG Pitch	KH Pitch	KI Pitch	KJ Pitch	KK Pitch	KL Pitch	KM Pitch	KN Pitch	KO Pitch	KP Pitch	KQ Pitch	KR Pitch	KS Pitch	KT Pitch	KU Pitch	KV Pitch	KW Pitch	KX Pitch	KY Pitch	KZ Pitch	LA Pitch	LB Pitch	LC Pitch	LD Pitch	LE Pitch	LF Pitch	LG Pitch	LH Pitch	LI Pitch	LJ Pitch	LK Pitch	LL Pitch	LM Pitch	LN Pitch	LO Pitch	LP Pitch	LQ Pitch	LR Pitch	LS Pitch	LT Pitch	LU Pitch	LV Pitch	LW Pitch	LX Pitch	LY Pitch	LZ Pitch	MA Pitch	MB Pitch	MC Pitch	MD Pitch	ME Pitch	MF Pitch	MG Pitch	MH Pitch	MI Pitch	MJ Pitch	MK Pitch	ML Pitch	MM Pitch	MN Pitch	MO Pitch	MP Pitch	MQ Pitch	MR Pitch	MS Pitch	MT Pitch	MU Pitch	MV Pitch	MW Pitch	MX Pitch	MY Pitch	MZ Pitch	NA Pitch	NB Pitch	NC Pitch	ND Pitch	NE Pitch	NF Pitch	NG Pitch	NH Pitch	NI Pitch	NJ Pitch	NK Pitch	NL Pitch	NM Pitch	NO Pitch	NP Pitch	NQ Pitch	NR Pitch	NS Pitch	NT Pitch	NU Pitch	NV Pitch	NW Pitch	NX Pitch	NY Pitch	NZ Pitch	OA Pitch	OB Pitch	OC Pitch	OD Pitch	OE Pitch	OF Pitch	OG Pitch	OH Pitch	OI Pitch	OJ Pitch	OK Pitch	OL Pitch	OM Pitch	ON Pitch	OO Pitch	OP Pitch	OQ Pitch	OR Pitch	OS Pitch	OT Pitch	OU Pitch	OV Pitch	OW Pitch	OX Pitch	OY Pitch	OZ Pitch	PA Pitch	PB Pitch	PC Pitch	PD Pitch	PE Pitch	PF Pitch	PG Pitch	PH Pitch	PI Pitch	PJ Pitch	PK Pitch	PL Pitch	PM Pitch	PN Pitch	PO Pitch	PP Pitch	PQ Pitch	PR Pitch	PS Pitch	PT Pitch	PU Pitch	PV Pitch	PW Pitch	PX Pitch	PY Pitch	PZ Pitch	QA Pitch	QB Pitch	QC Pitch	QD Pitch	QE Pitch	QF Pitch	QG Pitch	QH Pitch	QI Pitch	QJ Pitch	QK Pitch	QL Pitch	QM Pitch	QN Pitch	QO Pitch	QP Pitch	QQ Pitch	QR Pitch	QS Pitch	QT Pitch	QU Pitch	QV Pitch	QW Pitch	QX Pitch	QY Pitch	QZ Pitch	RA Pitch	RB Pitch	RC Pitch	RD Pitch	RE Pitch	RF Pitch	RG Pitch	RH Pitch	RI Pitch	RJ Pitch	RK Pitch	RL Pitch	RM Pitch	RN Pitch	RO Pitch	RP Pitch	RQ Pitch	RR Pitch	RS Pitch	RT Pitch	RU Pitch	RV Pitch	RW Pitch	RX Pitch	RY Pitch	RZ Pitch	SA Pitch	SB Pitch	SC Pitch	SD Pitch	SE Pitch	SF Pitch	SG Pitch	SH Pitch	SI Pitch	SJ Pitch	SK Pitch	SL Pitch	SM Pitch	SN Pitch	SO Pitch	SP Pitch	SQ Pitch	SR Pitch	SS Pitch	ST Pitch	SU Pitch	SV Pitch	SW Pitch	SX Pitch	SY Pitch	SZ Pitch	TA Pitch	TB Pitch	TC Pitch	TD Pitch	TE Pitch	TF Pitch	TG Pitch	TH Pitch	TI Pitch	TJ Pitch	TK Pitch	TL Pitch	TM Pitch	TN Pitch	TO Pitch	TP Pitch	TQ Pitch	TR Pitch	TS Pitch	TT Pitch	TU Pitch	TV Pitch	TW Pitch	TX Pitch	TY Pitch	TZ Pitch	UA Pitch	UB Pitch	UC Pitch	UD Pitch	UE Pitch	UF Pitch	UG Pitch	UH Pitch	UI Pitch	UJ Pitch	UK Pitch	UL Pitch	UM Pitch	UN Pitch	UO Pitch	UP Pitch	UQ Pitch	UR Pitch	US Pitch	UT Pitch	UU Pitch	UV Pitch	UW Pitch	UX Pitch	UY Pitch	UZ Pitch	VA Pitch	VB Pitch	VC Pitch	VD Pitch	VE Pitch	VF Pitch	VG Pitch	VH Pitch	VI Pitch	VJ Pitch	VK Pitch	VL Pitch	VM Pitch	VN Pitch	VO Pitch	VP Pitch	VQ Pitch	VR Pitch	VS Pitch	VT Pitch	VU Pitch	VV Pitch	VW Pitch	VX Pitch	VY Pitch	VZ Pitch	WA Pitch	WB Pitch	WC Pitch	WD Pitch	WE Pitch	WF Pitch	WG Pitch	WH Pitch	WI Pitch	WJ Pitch	WK Pitch	WL Pitch	WM Pitch	WN Pitch	WO Pitch	WP Pitch	WQ Pitch	WR Pitch	WS Pitch	WT Pitch	WU Pitch	WV Pitch	WW Pitch	WX Pitch	WY Pitch	WZ Pitch	XA Pitch	XB Pitch	XC Pitch	XD Pitch	XE Pitch	XF Pitch	XG Pitch	XH Pitch	XI Pitch	XJ Pitch	XK Pitch	XL Pitch	XM Pitch	XN Pitch	XO Pitch	XP Pitch	XQ Pitch	XR Pitch	XS Pitch	XT Pitch	XU Pitch	XV Pitch	XW Pitch	XX Pitch	XY Pitch	XZ Pitch	YA Pitch	YB Pitch	YC Pitch	YD Pitch	YE Pitch	YF Pitch	YG Pitch	YH Pitch	YI Pitch	YJ Pitch	YK Pitch	YL Pitch	YM Pitch	YN Pitch	YO Pitch	YP Pitch	YQ Pitch	YR Pitch	YS Pitch	YT Pitch	YU Pitch	YV Pitch	YW Pitch	YX Pitch	YY Pitch	YZ Pitch	ZA Pitch	ZB Pitch	ZC Pitch	ZD Pitch	ZE Pitch	ZF Pitch	ZG Pitch	ZH Pitch	ZI Pitch	ZJ Pitch	ZK Pitch	ZL Pitch	ZM Pitch	ZN Pitch	ZO Pitch	ZP Pitch	ZQ Pitch	ZR Pitch	ZS Pitch	ZT Pitch	ZU Pitch	ZV Pitch	ZW Pitch	ZX Pitch	ZY Pitch	ZZ Pitch
--------	----------	---------	---------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------

NOTES:

1. BEARING SURFACE MUST BE SQUARE WITH PITCH DIAMETER WITHIN .002 T.Y.R.
2. ALL THREADS TO BE CLASS 2B.
3. TAP THREADS AFTER HEAT TREAT.
4. APPLY RUST PREVENTING OIL.
5. MATERIAL: ALLOY STEEL, AND 4130, AND 4340.

FIGURE 69

Fatigue Test Nuts for Tension Bolts under 240,000 PSI Ultimate

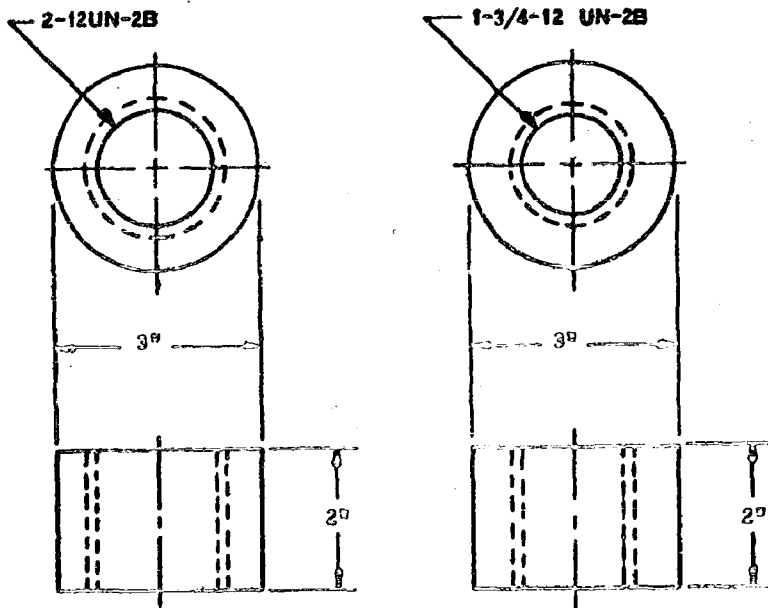
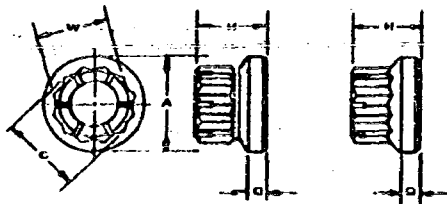


FIGURE 61.
SPECIAL NUTS FOR STUDS

FIGURE 70
Special Nuts for Studs



STYLE A

STYLE B

STYLE	PART NO.	THREAD	A DIA.	C MIN.	H	O	W	TENSILE STRENGTH	APPROX. WT. PER 1,000 PIECES IN LBS.
A	42PW003	1/2"-20	.631 .631	.010	.100	.100	.178	9,000	10.1
	42PW010	3/16"-24	.629 .629	.011	.118	.100	.159	10,000	10.0
	42PW013	1/3"-28	.620 .620	.011	.113	.100	.152	17,000	10.0
	42PW016	1/16"-13	.621 .621	.011	.118	.117	.153	23,000	10.1
	42PW020	1/8"-32	.620 .620	.013	.100	.119	.149	13,000	10.0
	42PW030	9/16"-13	.610 .610	.010	.100	.113	.150	12,000	17.7
	42PW040	1/2"-13	0.618 0.622	.009	.077	.101	.143	10,000	10.0
	42PW080	3/2"-12	0.610 0.620	0.009	.070	.100	.150	10,000	111.0
B	42PW010	1/2"-18	0.610 0.620	0.009	.070	.100	.150	97,000	100.0
	42PW013	1/2"-18	0.610 0.618	0.009	.070	.100	0.150	120,000	100.0
	42PW016	1"-1/8"-18	0.610 0.620	0.009	.070	.100	0.150	120,000	111.0
	42PW020	1"-1/4"-12	0.610 0.618	0.009	.070	.100	0.150	120,000	111.0
	42PW030	1"-1/2"-12	0.610 0.618	0.009	.070	.100	0.150	120,000	111.0
	42PW040	1"-3/4"-12	0.610 0.618	0.009	.070	.100	0.150	120,000	111.0
	42PW080	1"-3/4"-12	0.610 0.618	0.009	.070	.100	0.150	120,000	111.0
	42PW160	1"-3/4"-12	0.610 0.618	0.009	.070	.100	0.150	120,000	111.0

CADMIUM PLATE PER SP8-P-2A
THREADS TO BE CLASS NF-3 PER MIL-S-7742
MATERIAL: AMS 6263 MIN.

FIGURE 71
FLEXLOC Self-locking External Wrenching Nut
for use with 180,000 psi Minimum Bolts



(1992) 6-2249-2252, 1993 NRC, Inc. (2/93)

1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 26

FOIA b(7) - DUE TO OVERLAP WITH OTHER INFORMATION, IT IS DELETED. P. 13

የጋራ ጥያቄ

10439 • *Cell Growth* 15(12):2011-2021, 2005. doi:10.1007/s12071-005-0029-5

This document contains neither recommendations nor conclusions of the FBI. It is the property of the FBI and is loaned to your agency; it and its contents are not to be distributed outside your agency.

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED
DATE 08-19-2010 BY 60322 UCBAW/BJS

התאחדות העובדים הכללית לא תאשר את ההצעה הזו. ההצעה הזו היא פגיעה בכושר התארגנות של העובדים, והיא פגיעה בכושר התארגנות של העובדים, והיא פגיעה בכושר התארגנות של העובדים.

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED
DATE 06-01-2013 BY 60322

01234567891011121314151617181920212223242526272829303132333435363738394041424344454647484950515253545556575859606162636465666768697071727374757677787980818283848586878889909192939495969798991001011021031041051061071081091101111121131141151161171181191201211221231241251261271281291301311321331341351361371381391401411421431441451461471481491501511521531541551561571581591601611621631641651661671681691701711721731741751761771781791801811821831841851861871881891901911921931941951961971981992002012022032042052062072082092102112122132142152162172182192202212222232242252262272282292302312322332342352362372382392402412422432442452462472482492502512522532542552562572582592602612622632642652662672682692702712722732742752762772782792802812822832842852862872882892902912922932942952962972982993003013023033043053063073083093103113123133143153163173183193203213223233243253263273283293303313323333343353363373383393403413423433443453463473483493503513523533543553563573583593603613623633643653663673683693703713723733743753763773783793803813823833843853863873883893903913923933943953963973983994004014024034044054064074084094104114124134144154164174184194204214224234244254264274284294304314324334344354364374384394404414424434444454464474484494504514524534544554564574584594604614624634644654664674684694704714724734744754764774784794804814824834844854864874884894904914924934944954964974984995005015025035045055065075085095105115125135145155165175185195205215225235245255265275285295305315325335345355365375385395405415425435445455465475485495505515525535545555565575585595605615625635645655665675685695705715725735745755765775785795805815825835845855865875885895905915925935945955965975985996006016026036046056066076086096106116126136146156166176186196206216226236246256266276286296306316326336346356366376386396406416426436446456466476486496506516526536546556566576586596606616626636646656666676686696706716726736746756766776786796806816826836846856866876886896906916926936946956966976986997007017027037047057067077087097107117127137147157167177187197207217227237247257267277287297307317327337347357367377387397407417427437447457467477487497507517527537547557567577587597607617627637647657667677687697707717727737747757767777787797807817827837847857867877887897907917927937947957967977987998008018028038048058068078088098108118128138148158168178188198208218228238248258268278288298308318328338348358368378388398408418428438448458468478488498508518528538548558568578588598608618628638648658668678688698708718728738748758768778788798808818828838848858868878888898908918928938948958968978988999009019029039049059069079089099109119129139149159169179189199209219229239249259269279289299309319329339349359369379389399409419429439449459469479489499509519529539549559569579589599609619629639649659669679689699709719729739749759769779789799809819829839849859869879889899909919929939949959969979989991000100110021003100410051006100710081009101010111012101310141015101610171018101910201021102210231024102510261027102810291030103110321033103410351036103710381039104010411042104310441045104610471048104910501051105210531054105510561057105810591060106110621063106410651066106710681069107010711072107310741075107610771078107910801081108210831084108510861087108810891090109110921093109410951096109710981099110011011102110311041105110611071108110911101111111211131114111511161117111811191120112111221123112411251126112711281129113011311132113311341135113611371138113911401141114211431144114511461147114811491150115111521153115411551156115711581159116011611162116311641165116611671168116911701171117211731174117511761177117811791180118111821183118411851186118711881189119011911192119311941195119611971198119912001201120212031204120512061207120812091210121112121213121412151216121712181219122012211222122312241225122612271228122912301231123212331234123512361237123812391240124112421243124412451246124712481249125012511252125312541255125612571258125912601261126212631264126512661267126812691270127112721273127412751276127712781279128012811282128312841285128612871288128912901291129212931294129512961297129812991300

- [illegible]

[illegible][illegible]

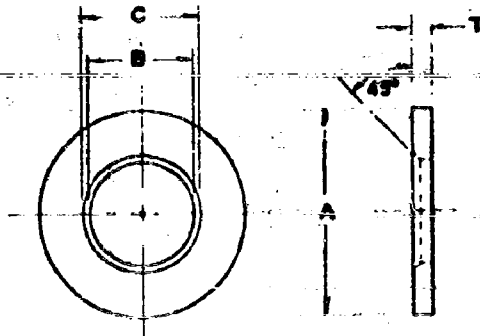
62-153400

CLASIS
1992

NUT-DOUBLE HEX. HIGH TENSILE

EB

TABLE 1. *Continued*



COUNTERSUNK WASHER

PART NO	SIZE	A MIN	B MAX	B MIN	C MIN	C MAX	T MIN
WC22-4	1/8	.031	.255	.231	.939	.039	.039
WC22-5	3/16	.010	.310	.290	.031	.033	.039
WC22-6	3/8	.020	.350	.330	.030	.033	.039
WC22-7	7/16	.028	.400	.380	.030	.039	.039
WC22-8	1/2	.033	.450	.431	.032	.039	.039
WC22-9	9/16	.120	.500	.480	.077	.039	.039
WC22-10	5/8	.173	.631	.617	.178	.039	.039
WC22-12	3/4	.180	.700	.682	.039	.039	.039
WC22-14	7/8	.170	.851	.837	.133	.119	.039
WC22-15	1"	.030	1.000	1.002	1.000	.119	.039
WC22-18	1-1/8	2.295	1.191	1.127	1.275	.119	.039
WC22-20	1-1/4	2.015	1.215	1.222	1.437	.119	.039
WC22-22	1-3/4	2.000	1.301	1.307	1.632	.119	.039
WC22-24	1-1/2	3.100	1.500	1.502	1.657	.119	.039

NOTES:

1. CODE;
2. MATERIAL: ALLOY STEEL MIL-2-8763 OR MIL-5-10719
3. APPLY RUST PREVENTING OIL.
4. MAXIMUM 100 G. EXERCISE-1-2222
5. WASHER FACES MUST BE PARALLEL WITHIN .002 INCH
6. DIMENSIONS IN INCHES, UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS $\pm .010$, ANGLES $\pm 2^\circ$.

FIGURE 73

SPS WC 22 Washers

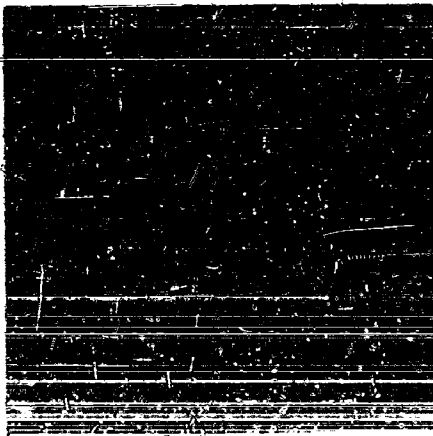


FIGURE 74

**Fatigue Fracture Resulting
From Bending**

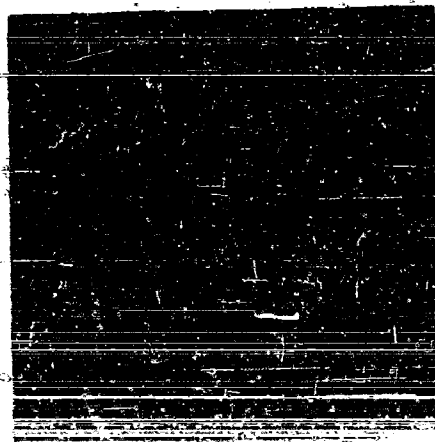


FIGURE 75

**Fatigue Fracture Resulting
From Uniaxial Loading**

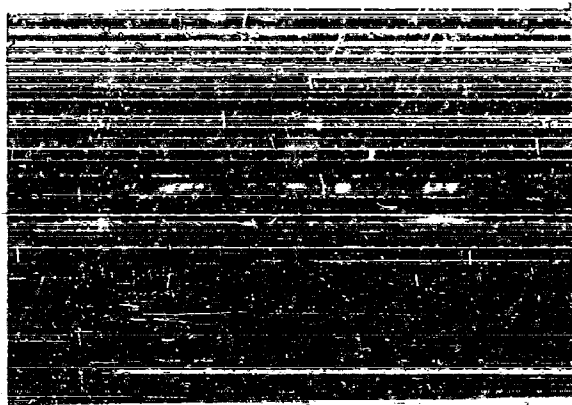


FIGURE 76

**Bolt Body Showing Rubbing Marks Resulting
From Non-Axial Loading**

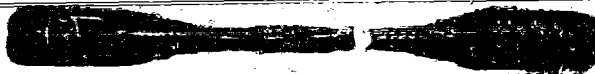


FIGURE 77

Fatigue Fracture in Shank of 3/4 inch Test Specimen



FIGURE 78

**Fatigue Fracture in Thread Section of 3/4 inch Test Specimen
Resulting from Shot Peening of Radius**



FIGURE 79

Fatigue Fracture in 2-12 Cut Thread Rather than 1-14 Rolled Thread

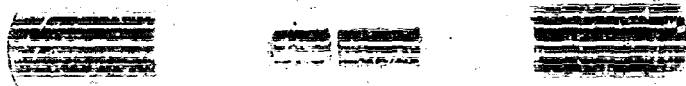
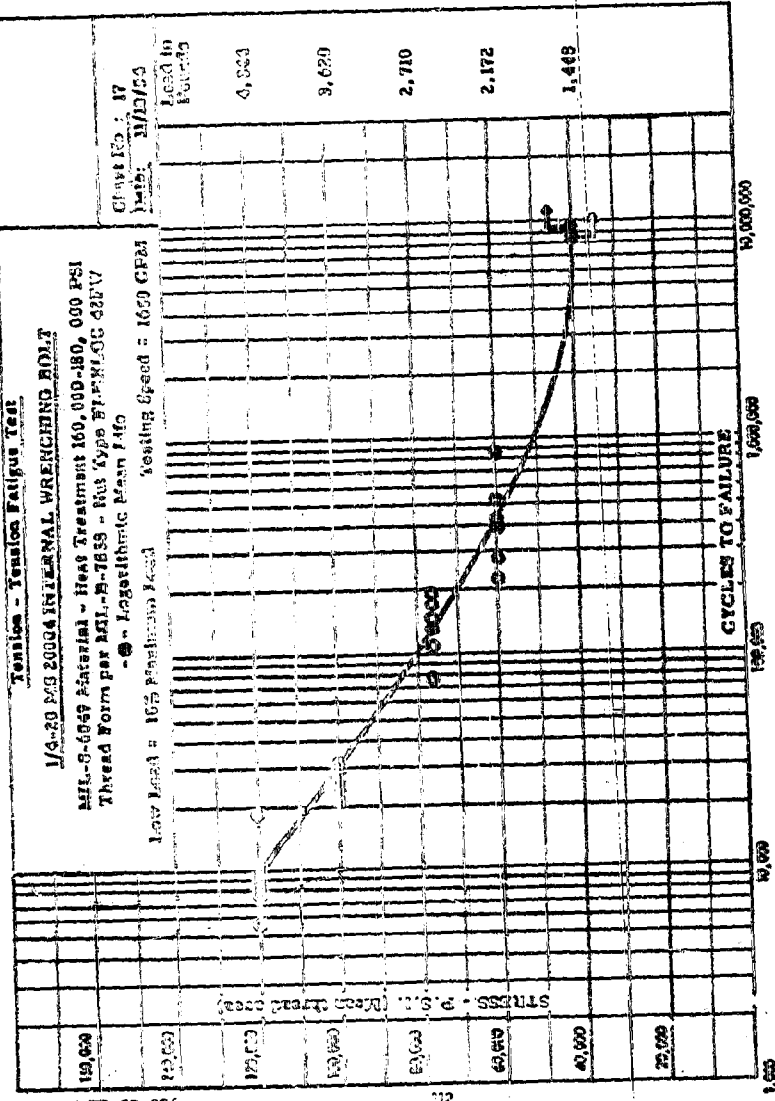


FIGURE 80

Typical Fatigue Fracture of Cut and Ground Unengaged Threads

APPENDIX I

RAW DATA FOR 160,000 PSI PARTS



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 11-18-54

Bolt Design	MS 20004
Size	1/4-28
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium plate per QQ-P-416 Type I, Class C

Stress Area	.0362 Square inches
-------------	---------------------

Nut Type	
Style	42FV
Material	AISI 0630
Heat Treatment	Re 27-32

Testing Machine	
Make	Kvenco
Capacity	5,000 pound
Speed	1650 rpm

Maximum Load	4,3440	3,6200	2,8960
Stress	120,000 psi	100,000 psi	80,000 psi

19,500	29,100	80,400
9,100	28,000	87,000
8,600	25,600	76,400
7,900	23,400	73,100
6,700	22,300	

Average	10,360	25,680	
---------	--------	--------	--

Logarithmic Mean Life	9,582	25,550	
-----------------------	-------	--------	--

Maximum Load	2,710#	2,172#	1,448#
Stress	77,000(MIL-D)	66,000 psi	40,000 psi

199,200	833,200	8,477,000 NF
163,000	525,200	8,951,000 NF
104,200	427,300	
77,800	277,900	
	222,100	

Average	136,000	455,120	8,714,000
---------	---------	---------	-----------

Logarithmic Mean Life	128,500	409,700	
-----------------------	---------	---------	--

MECHANICAL PROPERTIES

Date November 18, 1954

For Chart No. 17

Bolt Description

Type	MS 20004
Size	1/4-28
Material	MIL-S-6049

<u>Bolt Strength Pounds</u>	<u>Specimen 1</u>	<u>Specimen 2</u>
Ultimate Tensile	6,660	6,780
Yield Strength	5,500	5,600

Material Strength PSI

Gage Specimen		
Tensile Strength	159,000	165,000
Yield Strength	149,500	150,500

Elongation - % in 4 Diameter

Gage Specimen	12.5	12.5
---------------	------	------

Reduction of Area - %

Gage Specimen	51.3	53.7
---------------	------	------

Shear Strength - Bolt Body

Pounds - Double Shear	10,460	10,060
PSI	105,900	110,000

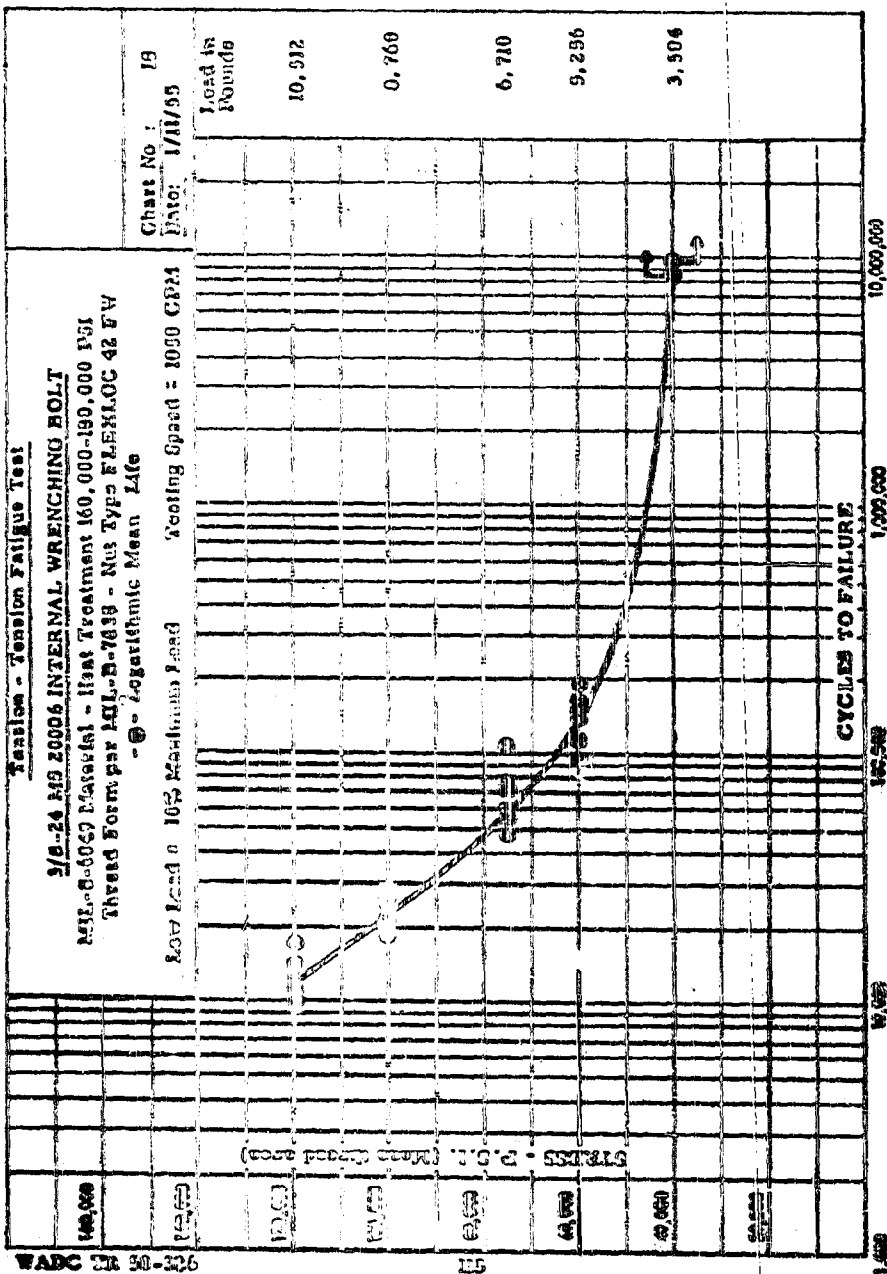
Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	1,448
PSI (Mean Area)	40,000

Lot No.

6S4144E



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 1-6-58

Bolt Design	MS 20006
Size	3/8-24
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Plate per QQ-P-416 Type I, Class C

Stress Area	.0876 Square inches
-------------	---------------------

Nut Type	62FW
Style	ALC 0630
Material	Rc 27-32
Heat Treatment	

Testing Machine	Evereco
Make	15,000 pounds
Capacity	1050 cpm
Speed	

Maximum Load	10,5129	0,7607	6,7109
Stress	120,000 psi	100,000 psi	MIL-B
	11,000	21,400	72,000
	11,500	20,500	107,000
	10,000	20,500	69,000
	11,400	21,400	71,800
	17,000	20,800	69,600
Average	12,180	20,920	77,680

Logarithmic Mean Life	11,960	20,925	76,710
-----------------------	--------	--------	--------

Maximum Load	5,2568	3,5048
Stress	60,000 psi	40,000 psi
	163,000	10,373,500
	93,400	9,442,200
	126,000	
	190,900	
	129,700	
Average	140,740	9,907,850

Logarithmic Mean Life	136,050	8,000,000
-----------------------	---------	-----------

WADC TR 58-326	116
----------------	-----

MECHANICAL PROPERTIES

Date January 11, 1955

For Chart No. 18

Bolt Description

Type	MS 20006
Size	3/8-24
Material	MIL-S-6049

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	15,000	15,400
Yield Strength	12,600	12,600

Material Strength PSI

.252 Gage Specimen		
Tensile Strength	171,300	160,700
Yield Strength	149,200	147,000

Elongation - % in 4 Diameter

.252 Gage Specimen	13.4	13.6
--------------------	------	------

Reduction of Area - %

.252 Gage Specimen	52.4	52.4
--------------------	------	------

Shear Strength - Bolt Body

Pounds - Double Shear	22,000	22,500
PSI	99,600	101,900

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	3,504
PSI (Mean Area)	40,000

Lot No.

12264K47K

Tension - Tension Fatigue Test

1/2-20 MS 20093 INTERNAL WRENCHING BOLT

MIL-S-6049 Material - Heat Treatment 160,000-180,000 PSI

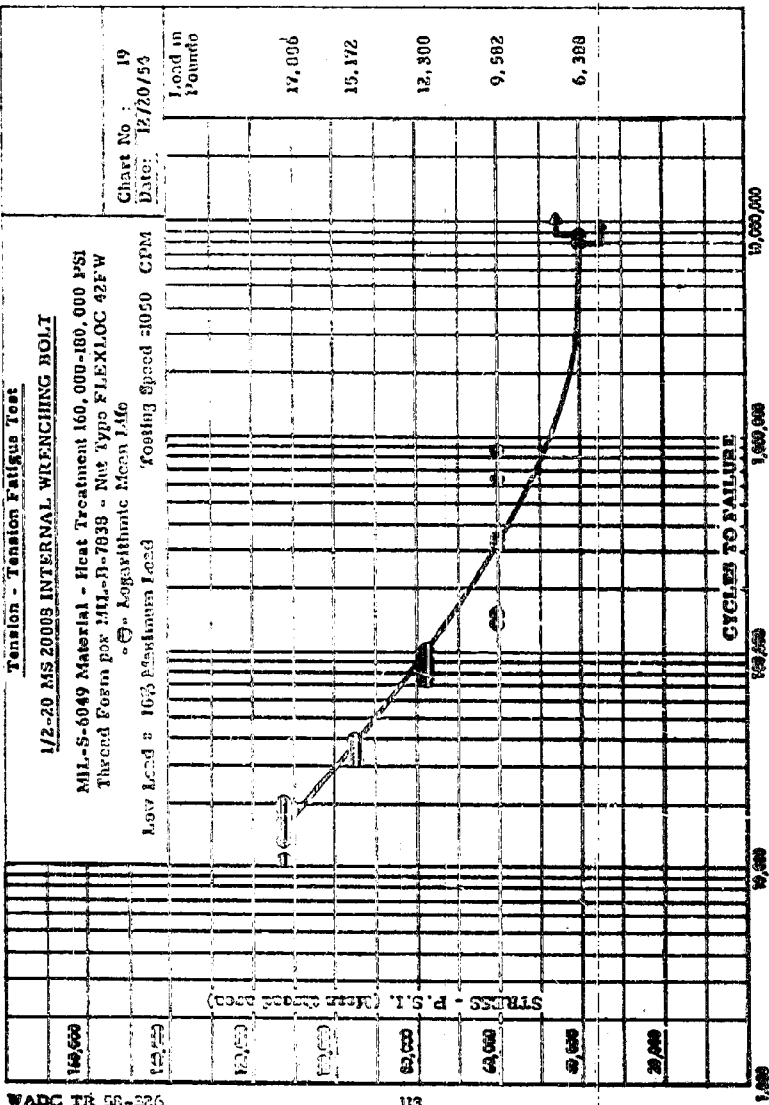
Thread Form per MIL-B-7839 - Nut Type FLEXLOC 42FW

• σ - Logarithmic Mean Life

Low Load = 1675 Pounds Minimum Load Testing Speed = 1050 CPM

Chart No. : 19

Date: 12/20/53



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 12-20-54

Bolt Design	MS 20008
Size	1/2-20
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Plate per QQ-P-416 Type 1, Class C

Stress Area	.1597 Square inches
-------------	---------------------

Nut Type	42 FW
Style	MSI 6200
Material	Re 27-32
Heat Treatment	

Testing Machine	Krouce
Make	15,000 pound
Capacity	1050 cpm
Speed	

Maximum Load	17,000#	15,172#	17,300#
Stress	111,700 psi	93,050 psi	MIL-B
	19,700	39,500	103,000
	18,800	37,600	90,000
	15,000	37,000	86,500
	12,900	36,500	84,600
	10,440	35,000	72,000
	15,440	37,120	87,220

Average			
Logarithmic Mean Life	15,057	37,090	86,642

Maximum Load	9,582#	6,388#
Stress	60,000 psi	40,000 psi

	813,600	8,000,000 NF
	645,200	8,982,600 NF
	331,800	
	131,900	
	130,000	
	390,500	8,491,300

Average		
Logarithmic Mean Life	113,720	

WADC TR 58-326

MECHANICAL PROPERTIES

Date December 20, 1954 For Chart No. 19

Bolt Description

Type	MS 20008
Size	1/2-20
Material	MIL-S-6049

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	29,300	31,000
Yield Strength	25,000	26,000

Material Strength PSI

.357 Gage Specimen		
Tensile Strength	172,700	176,100
Yield Strength	157,800	159,600

Elongation - % in 4 Diameter

.357 Gage Specimen	13.8	16.4
--------------------	------	------

Reduction of Area - %

.357 Gage Specimen	56.2	60.0
--------------------	------	------

Shear Strength - Bolt Body

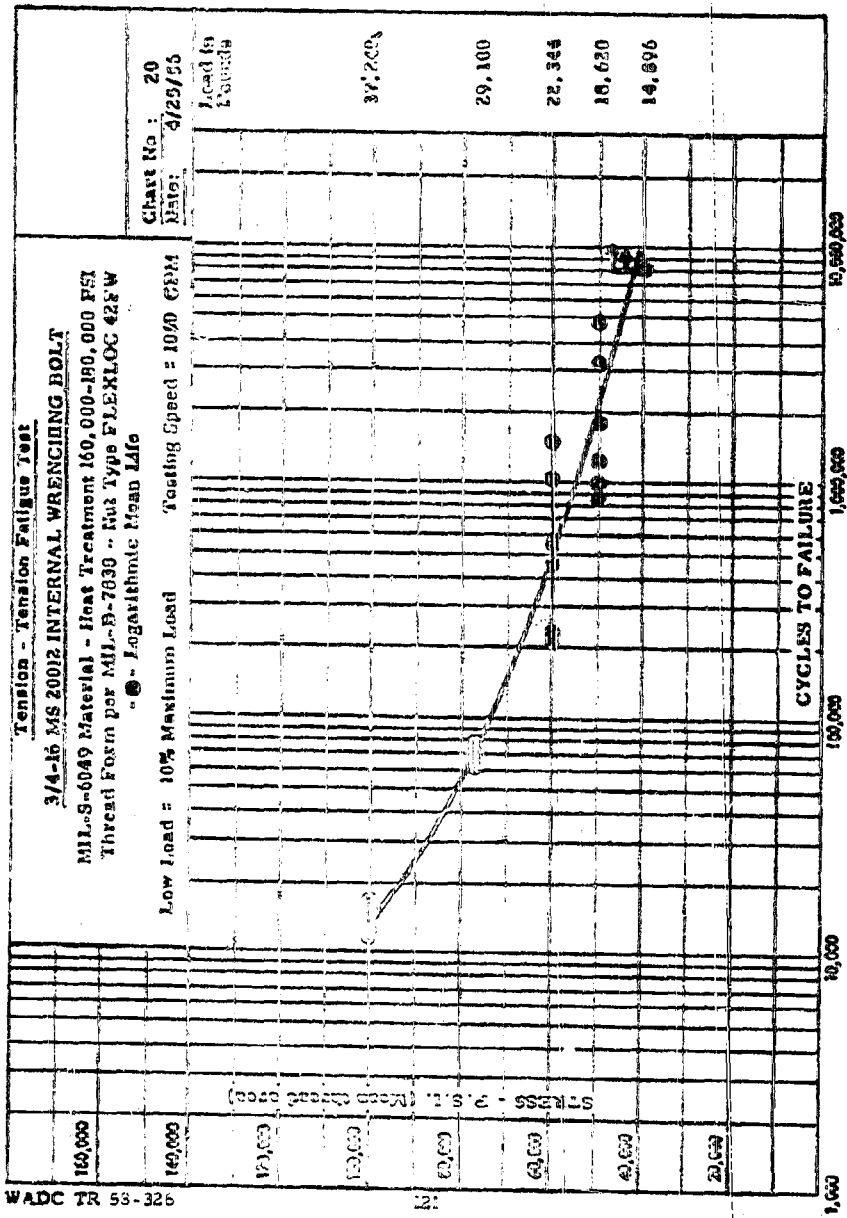
Pounds - Double Shear	41,690	41,750
PSI	105,900	106,000

Fatigue Strength @ 0,000,000

Cycles 10% Low Load

Pounds	6,388
PSI (Mean Area)	40,000

Lot No. 1154M48A



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 4-25-57

Bolt Design	MS 20012
Size	3/4-16
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium plate per QQ-P-416 Type I, Class C

Stress Area	0.3724 Square inches
-------------	----------------------

Nut Type	
Style	42FW
Material	AISI 0740
Heat Treatment	Rc 30-44

Testing Machine	
Make	Krougee
Capacity	60,000 pound
Speed	850 cpm

Maximum Load	37,240#	29,100#	22,344#
Stress	<u>100,000 psi</u>	<u>MIL-B</u>	<u>60,000 psi</u>
	15,200	76,100	1,532,000
	15,100	75,400	1,067,700
	14,200	75,400	467,700
	13,700	62,600	213,000
	<u>12,600</u>	<u>61,800</u>	<u>206,300</u>
Average	14,160	70,260	697,300
Logarithmic Mean Life	14,130	69,900	507,200

Maximum Load	18,620#	14,896#
Stress	<u>50,000 psi</u>	<u>40,000 psi</u>
	1,214,600	8,746,800 NF
	3,106,300	8,681,500 NF
	4,872,100	
	983,000	
	<u>849,700</u>	
Average	2,205,140	8,713,700
Logarithmic Mean Life	1,728,000	

MECHANICAL PROPERTIES

Date March 28, 1955 For Chart No. 20

Bolt Description

Type	MS 20012
Size	3/4-16
Material	MIL-S-6049

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	70,600	72,600
Yield Strength	60,000	62,000

Material Strength PSI

.505 Gage Specimen		
Tensile Strength	177,700	177,700
Yield Strength	162,800	162,800

Elongation % in 4 Diameter

.505 Gage Specimen	14.7	13.9
--------------------	------	------

Reduction of Area - %

Gage Specimen	43.0	44.2
---------------	------	------

Shear Strength - Bolt Body

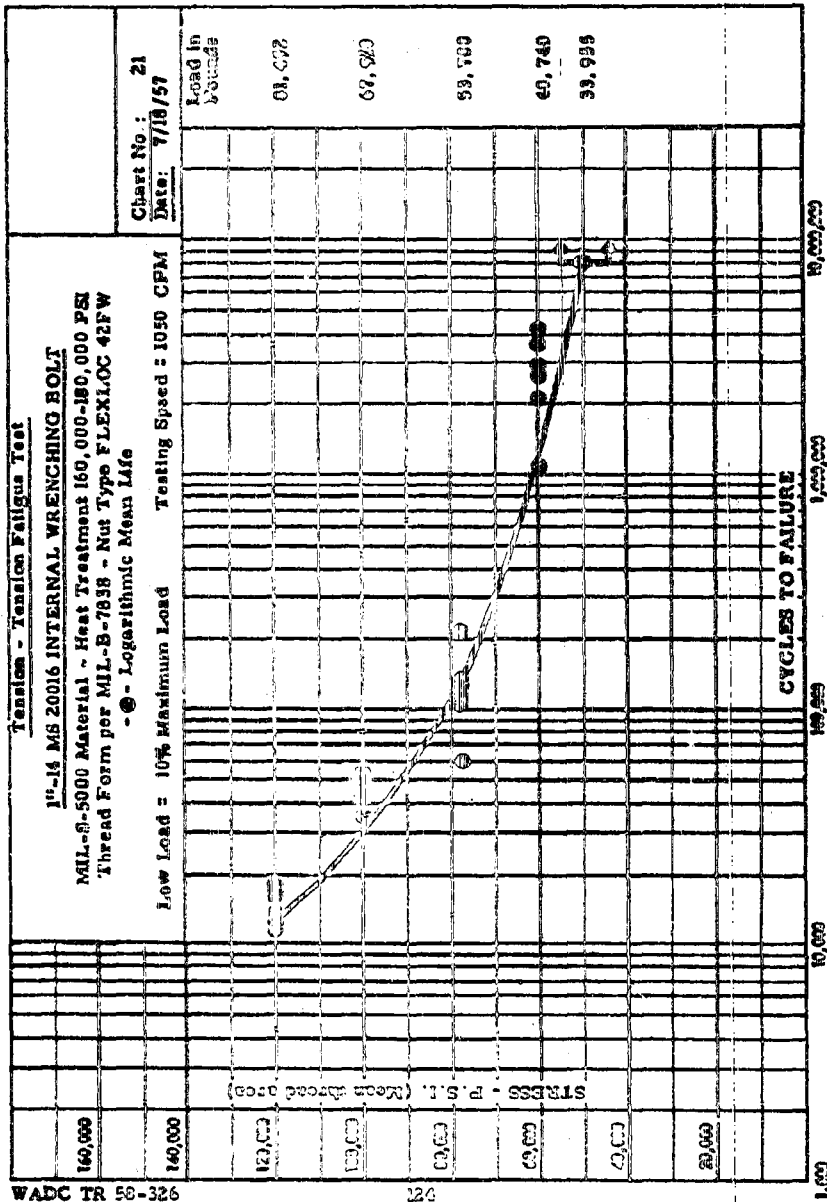
Pounds - Double Shear	92,000	95,300
PSI	103,100	107,900

Fatigue Strength @ 9,000,000

Cycles 10% Low Load

Pounds	14,895
PSI (Mean Area)	40,000

Lot No.	216S94P72
---------	-----------



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 7-18-57

Bolt Design	MS 20016
Size	1-14
Material	MIL-S-5000
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plato	Cadmium Plate per QQ-P-416
	Type I, Class C

Stress Area	0.6791 Square inches
--------------------	-----------------------------

Nut Type	42 FW
Style	AISI 0740
Material	Rc 30-34
Heat Treatment	

Testing Machine	Amelcor
Make	220,000 pound
Capacity	500 cpm
Speed	

Maximum Load	01,4920	67,9100	53,7000
Stress	120,000 psi	100,000 psi	MIL-B
	12,400	35,000	60,000
	13,000	42,300	105,500
	16,200	43,900	131,300
	16,900	44,800	132,300
	10,100	51,300	212,000
Average	15,300	43,400	128,200
Logarithmic Mean Life	15,160	42,740	118,400

Maximum Load	40,7400	31,9550
Stress	60,000 psi	50,000 psi
	1,076,800	0,000,000
	2,276,000	0,000,000
	2,831,000	
	3,665,000	
	4,190,000	
Average	2,607,700	0,000,000
Logarithmic Mean Life	2,544,000	0,000,000

MECHANICAL PROPERTIES

Date July 24, 1957

For Chart No. 21

Bolt Description

Type
Size
Material

MS 20016
1"-14
MIL-S-5000

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1

126,000
115,000

Specimen 2

127,000
117,000

Material Strength PSI

.505 Gage Specimen
Tensile Strength
Yield Strength

32,500
31,250

34,000
32,750

Elongation % in 4 Diameter

.505 Gage Specimen

10.0

10.0

Reduction of Area - %

.505 Gage Specimen

54.9

52.0

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

156,000
99,300

156,000
99,300

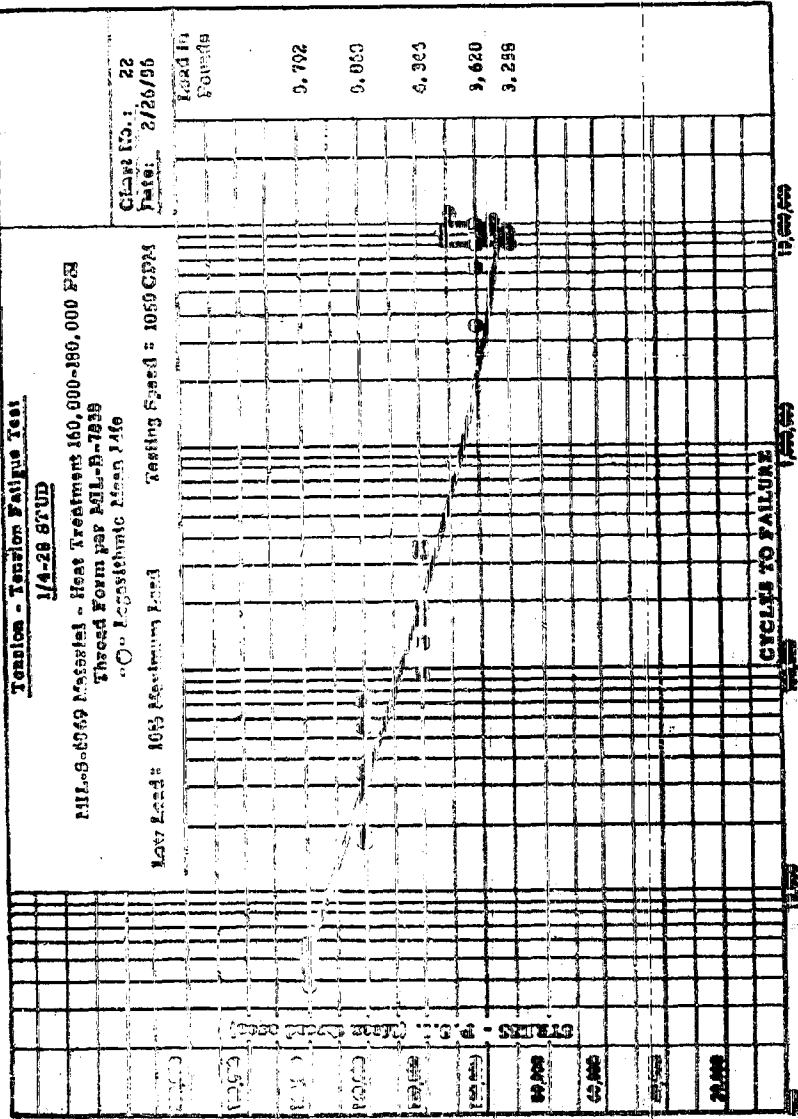
Fatigue Strength @ 8,000,000 Cycles 10% Low Load

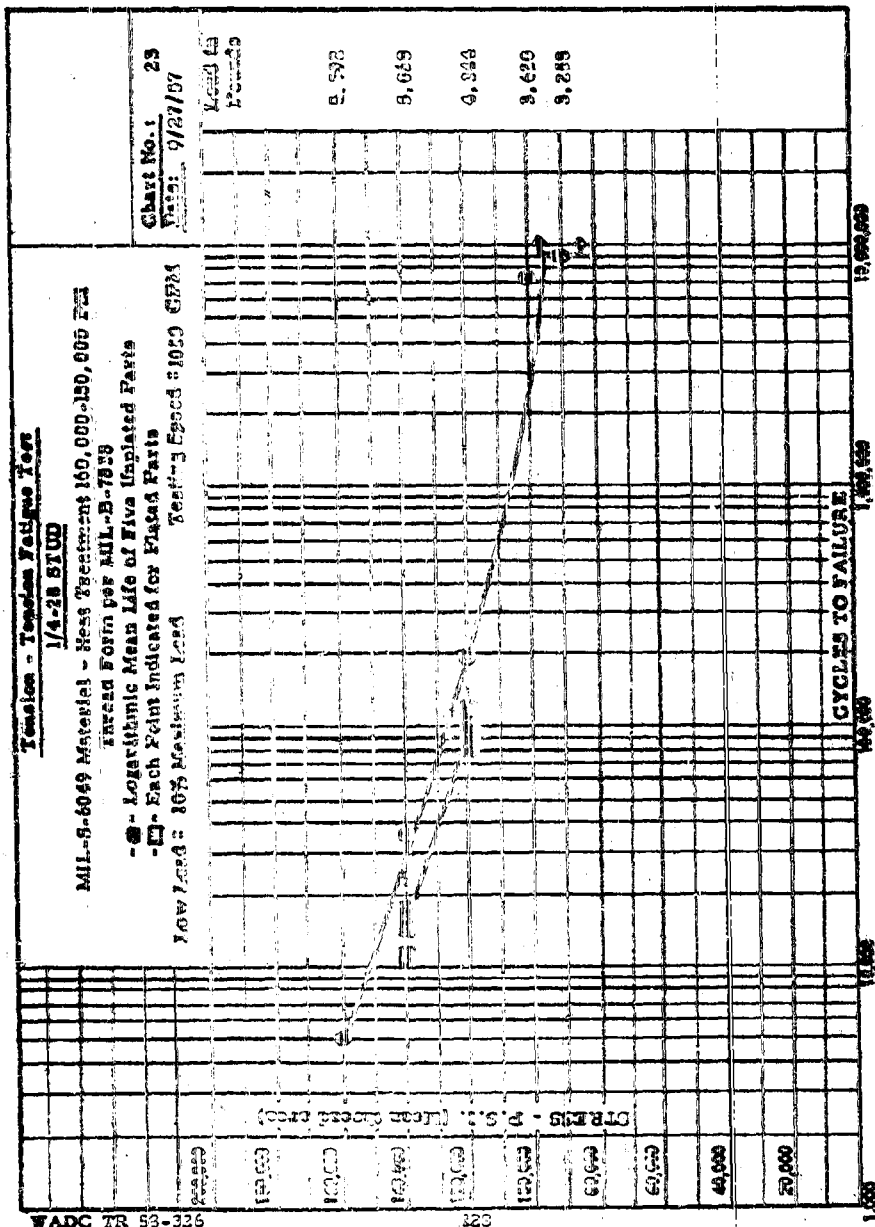
Pounds
PSI (Mean Area)

33,955
50,000

Lot No.

89





TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 2-26-57

Bolt Design	Stud
Size	1/4-28
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	None

Stress Area	Unengaged
-------------	-----------

Nut Type	
Style	
Material	
Heat Treatment	

Testing Machine	
Make	Krouso
Capacity	5,000 pound
Speed	1650 cpm

Maximum Load	5,792#	5,068#	4,344#		
Stress	160,000 psi	140,000 psi	120,000 psi		
		unplated	plated	unplated	plated
	5,600	70,000	12,300	362,000	81,300
	5,600	56,500	16,400	350,800	90,200
	4,800	32,400	17,100	159,000	101,300
	4,700	18,500	17,260	133,500	124,600
	4,000	17,000		94,200	
Average	4,940	39,160	15,750	220,060	99,350
Logarithmic Mean Life	4,912	33,540	15,610	191,100	98,060

Maximum Load	3,620#	3,258#
Stress	100,000 psi	90,000 psi
	11,501,200 NF	9,188,300 NF
	8,150,300 NF	6,183,800 NF
	6,145,300	
	3,650,900	
Average	7,361,900	8,686,000
Logarithmic Mean Life	6,772,000	

MECHANICAL PROPERTIES

Date March 14, 1957 For Chart No. 22 and 23

Bolt Description

Type	Stud
Size	1/4-28
Material	MIL-S-6049

Bolt Strength Pounds

	Specimen 1	Specimen 2
--	------------	------------

Ultimate Tensile		
Yield Strength		

Material Strength PSI

.113 Gage Specimen		
Tensile Strength	101,000	104,000
Yield Strength	172,500	171,500

Elongation - % in 4 Diameter

.113 Gage Specimen	20.0	11.0
--------------------	------	------

Reduction of Area - %

.113 Gage Specimen	51.0	51.0
--------------------	------	------

Shear Strength - Bolt Body

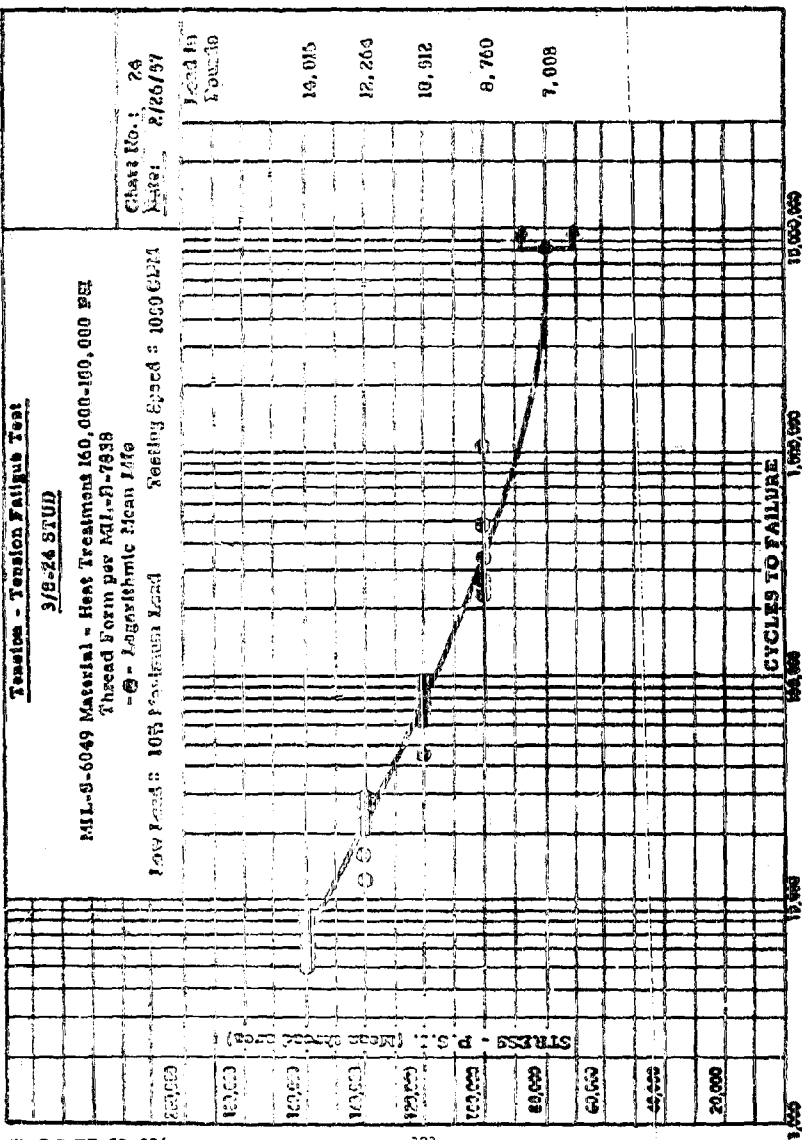
Pounds - Double Shear	
PSI	

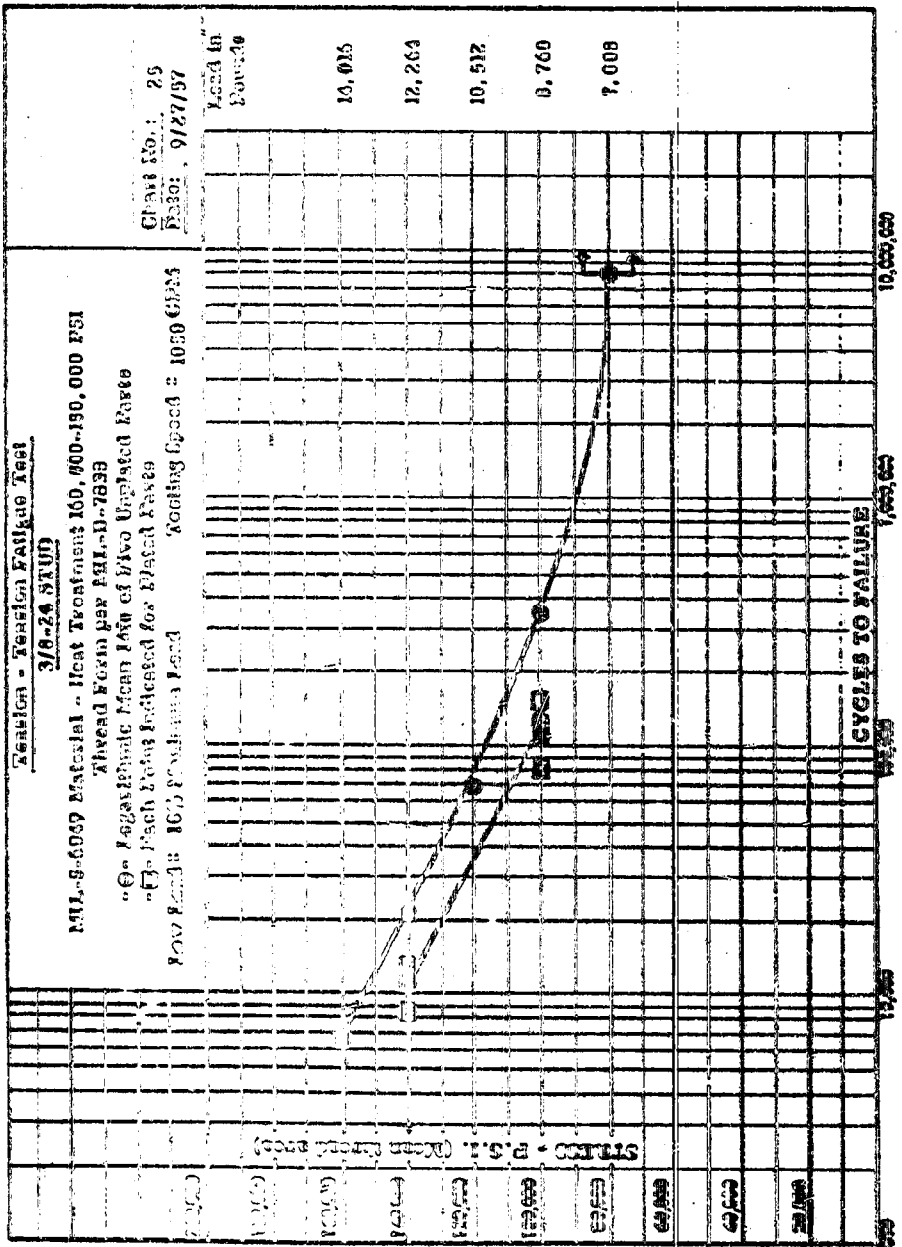
Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	3,475
PSI (Mean Area)	98,600

Lot No.	74
---------	----





TENSION- TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 2-26-57

Bolt Design	Stud
Size	3/8-24
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	None

Stress Area	.0876 Square inches
-------------	---------------------

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	Krouco
Make	
Capacity	15,000 pound
Speed	1050 rpm

Maximum Load	14,0160	12,2640	10,5120
Stress	160,000 psi	140,000 psi	120,000 psi
	Unplated	Plated	
	0,100	29,500	8,600
	7,700	26,300	11,300
	6,400	22,600	11,400
	5,700	16,000	13,200
	5,300	13,300	
Average	6,640	21,540	11,130
			46,800
Logarithmic Mean Life	6,550	20,600	11,000
			70,400

Maximum Load	8,760#	7,008#
Stress	100,000 psi	90,000 psi
	Unplated	Plated
	1,056,300	80,700
	478,400	113,000
	258,300	124,800
	242,400	162,300
	219,700	
Average	450,960	1,00,200
		8,000,000
Logarithmic Mean Life	370,200	116,600

MECHANICAL PROPERTIES

Date February 26, 1957

For Chart No. 24 and 25

Bolt Description

Type	Stud
Size	3/8-24
Material	MIL-S-6049

Bolt Strength Pounds

	Specimen 1	Specimen 2
--	------------	------------

Ultimate Tensile		
Yield Strength		

Material Strength PSI

.252 Gage Specimen		
Tensile Strength		
Yield Strength		

174,000	173,000
169,000	161,300

Elongation - % in 4 Diameter

.252 Gage Specimen		
--------------------	--	--

15.0	16.0
------	------

Reduction of Area - %

.252 Gage Specimen		
--------------------	--	--

54.5	54.5
------	------

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

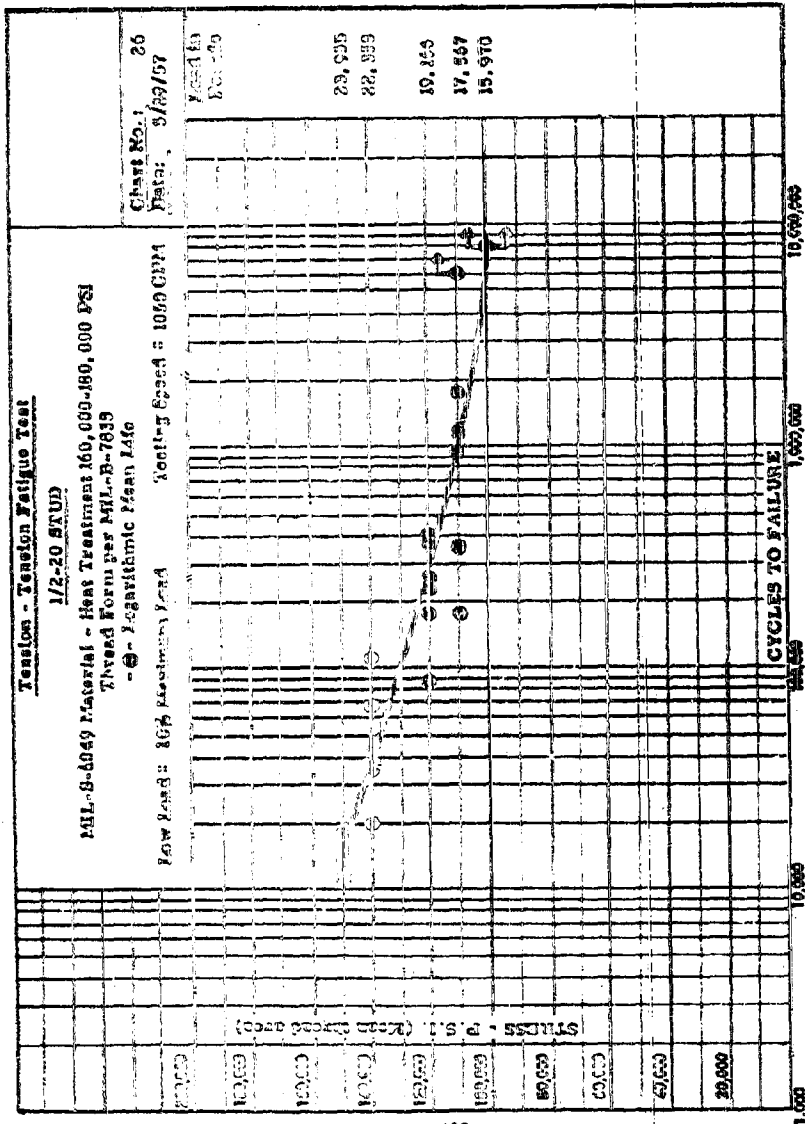
Fatigue Strength - Bolt Body Cycles 10% Low Load

Pounds
PSI (Mean Area)

7,008
80,000

Lot No.

52



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 5-29-57

Bolt Design	Stud
Size	1/2-20
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	None

Stress Area	.1597 Square inches
-------------	---------------------

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	Krouse
Make	
Capacity	60,000 pound
Speed	350 rpm

Maximum Load	23,955#	22,350#	19,162#
Stress	150,000 psi	140,000 psi	120,000 psi
	10,900	20,700	65,800
	11,000	34,200	161,900
	15,200	37,200	229,000
	15,700	66,900	358,000
	18,300	108,400	372,600
Average	14,220	53,480	241,660
Logarithmic Mean Life	13,925	45,310	212,100

Maximum Load	17,567#	15,970#
Stress	110,000 psi	100,000 psi
	368,200	8,200,000 NF
	1,836,100	8,250,000 NF
	6,500,000 NF	
	166,900	
	1,107,200	
Average	1,995,700	8,200,000
Logarithmic Mean Life	959,200	8,200,000

MECHANICAL PROPERTIES

Date May 2, 1957

For Chart No. 26

Bolt Description

Type

Stud

Size

1/2-20

Material

MIL-S-6049

Bolt Strength, Pounds

Specimen 1

Specimen 2

Ultimate Tensile

Yield Strength

Material Strength, PSI

.357 Gage Specimen

Tensile Strength

182,000

172,500

Yield Strength

164,000

165,000

Elongation - % in 4 Diameter

.357 Gage Specimen

16.4

12.1

Reduction of Area - %

.357 Gage Specimen

51.0

50.2

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

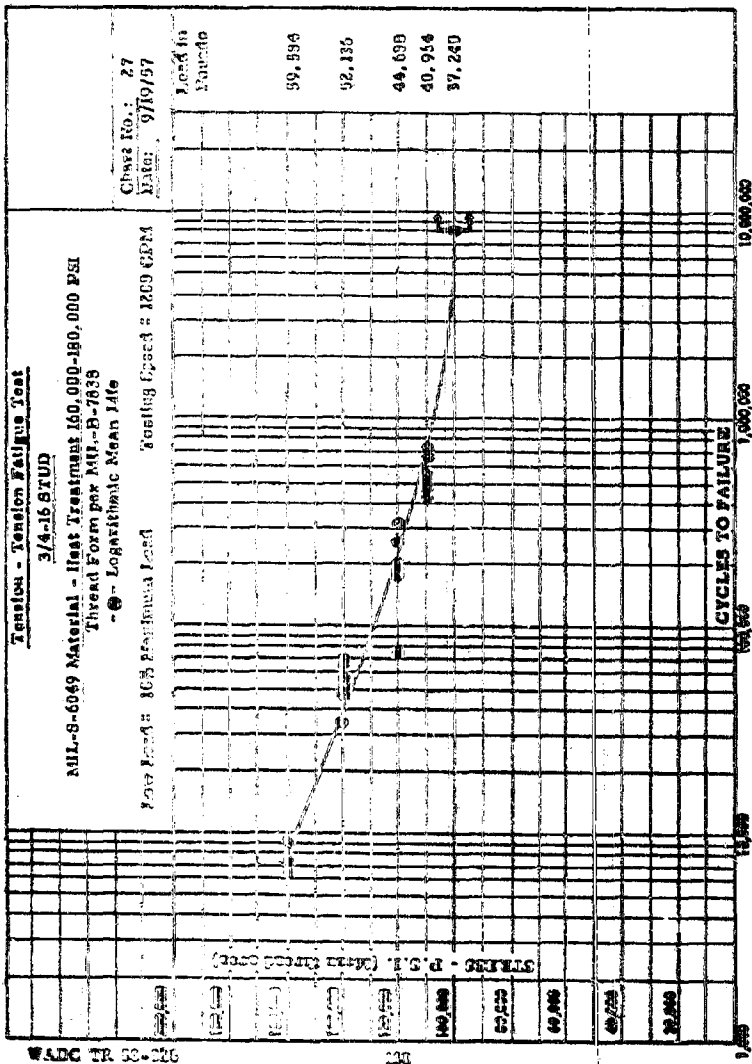
15,970

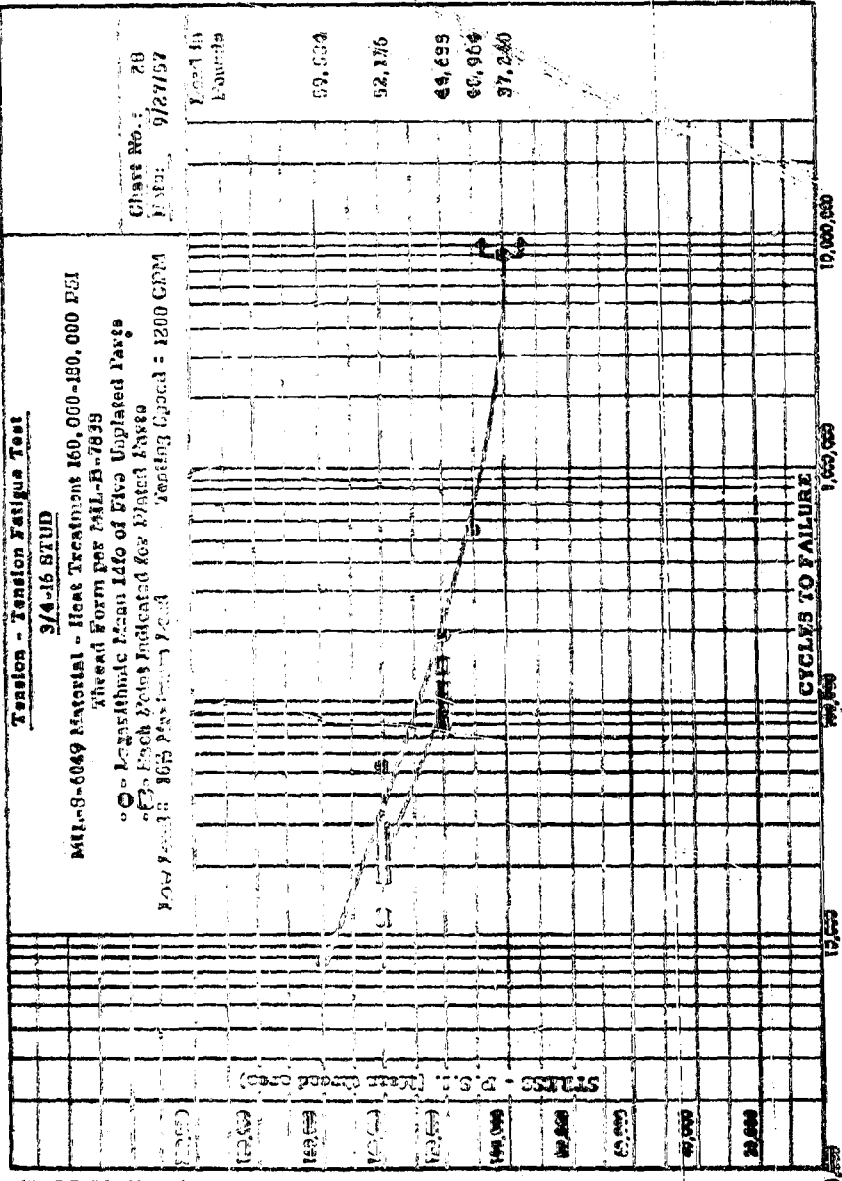
PSI (Mean Area)

100,000

Lot No.

00





TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 9-19-57

Bolt Design	Stud
Size	3/4-16
Material	MIL-S-6049
Heat Treatment	160,000-180,000 psi
Thread Form	MIL-B-7838
Plate	None

Stress Area	0.3724 Square inches
-------------	----------------------

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	Key
Make	
Capacity	60,000 pounds
Speed	1200 rpm

Maximum Load	59,934#	52,136#	
Stress	160,000 psi	140,000 psi	
	Unplated	Plated	
	6,500	35,500	13,600
	7,100	45,000	10,700
	7,160	54,100	24,100
	7,500	64,600	28,200
	9,300	68,700	
Average	7,420	53,740	21,150
Logarithmic Mean Life	7,302	52,280	20,390

Maximum Load	44,698#	40,964#	37,240#
Stress	120,000 psi	110,000 psi	100,000 psi
	Unplated	Plated	
	75,000	82,300	426,000
	194,000	96,800	498,000
	207,000	112,300	525,000
	262,000	151,100	658,000
	326,000		700,000
Average	213,600	110,600	561,400
Logarithmic Mean Life	191,500	107,800	552,100

MECHANICAL PROPERTIES

Date May 17, 1957

For Chart No. 27 and 28

Bolt Description

Type

Stud

Size

3/4-16

Material

M11-S-6049

Bolt Strength Report

Specimen 1 Specimen 2

Ultimate Tensile
Yield Strength

Material Strength Test

.505 Gage Specimen
Tensile Strength
Yield Strength

165,800

163,500

155,100

150,200

elongation - 4 in G Specimen

.505 Gage Specimen

16.0

16.0

Reduction of Area - 4 in G

.505 Gage Specimen

91.0

50.4

Shear Strength - Bolt Body

Ends - Shear Load

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

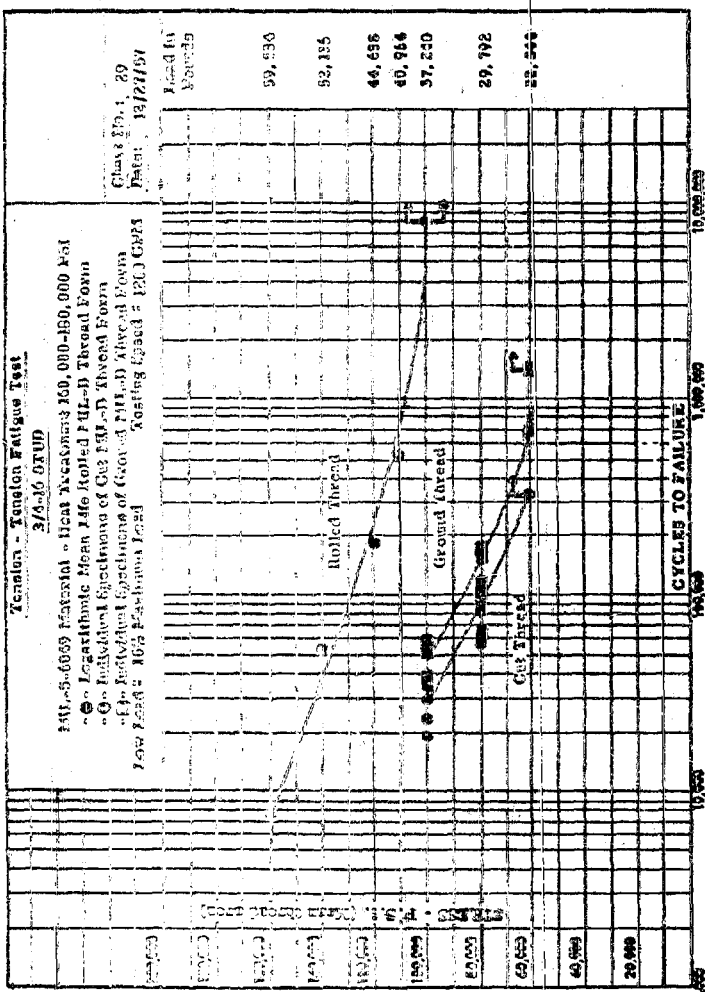
37,240

PSI (Mean Area)

100,000

Lot No.

77



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 12/27/57

Bolt Design	Stud	Stud
Size	3/4-16	3/4-16
Material	AMS 6322	AMS 6322
Heat Treatment	160,000-180,000 psi	160,000-180,000 psi
Thread Form	Cut UNF 3A	Ground MIL-B-7838
Plate	None	None

Stress Area .3724 Square Inches

Nut Type	Unengaged	Unengaged
Style		
Material		
Heat Treatment		

Testing Machine

Make	Ivy	Ivy
Capacity	60,000 pound	60,000 pound
Speed	1200 rpm	1200 rpm

Cut Thread

Ground Thread

Load	37,240#	37,240#
Stress	100,000 psi	100,000 psi
	25,000	33,000
	19,000	34,000
	29,000	52,000
	41,000	50,000

Load	29,792#	29,792#
Stress	80,000 psi	80,000 psi
	58,000	63,000
	82,000	98,000
	97,000	165,000
	124,000	175,000

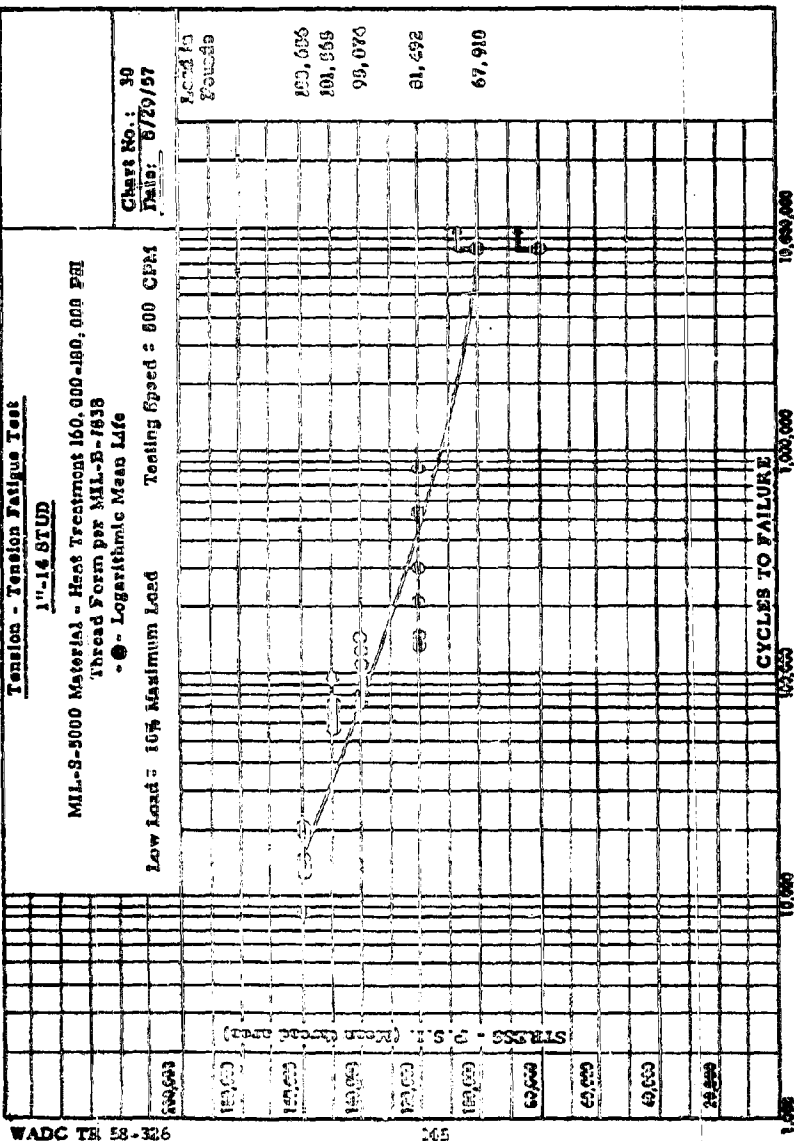
Load	22,344#	22,344#
Stress	60,000 psi	60,000 psi
	331,000	1,300,000 NF
		706,000

MECHANICAL PROPERTIES

Date December 28, 1957

For Chart No. 29

<u>Bolt Description</u>	<u>Cut Thread</u>		<u>Ground Thread</u>	
Type	Stud		Stud	
Size	3/4-16		3/4-16	
Material	MIL-S-6049		MIL-S-6049	
<u>Bolt Strength Pounds</u>	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Ultimate Tensile				
Yield Strength				
<u>Material Strength PSI</u>				
.505 Gage Specimen				
Tensile Strength	175,000	172,000	166,000	160,500
Yield Strength	155,000	161,600	152,500	155,000
<u>Elongation - % in 3 Diameter</u>				
.505 Gage Specimen	13.5	11.5	13.5	14.0
<u>Reduction of Area - %</u>				
.505 Gage Specimen	55.7	54.1	50.9	61.1
<u>Shear Strength - Bolt Body</u>				
Pounds - Double Shear				
PSI				
<u>Fatigue Strength @ 8,000,000</u>				
<u>Cycles 10% Low Load</u>				
Pounds				
PSI (Mean Area)				
<u>Lot No.</u>	<u>526</u>		<u>560</u>	



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 8-29-57

Bolt Design	Stud
Size	1"-14
Material	MIL-S-5000
Heat Treatment	160,000-180,000 psi
Thread Form	
Plate	

Stress Area . 6791 Square inches

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	
Make	Amelcor
Capacity	220,000 pound
Speed	500 cpm

Maximum Load	108,656#	101,865#	95,074#
Stress	160,000 psi	150,000 psi	140,000 psi
	0,600	60,000	124,000
	13,100	60,000	73,100
	14,200	66,000	76,800
	19,200	69,000	135,000
	22,300	96,000	151,000
Average	13,480	70,200	111,980
Logarithmic Mean Life	13,900	69,090	93,600

Maximum Load	91,492#	67,910#
Stress	120,000 psi	100,000 psi

	166,000	8,000,000 NF
	174,000	8,000,000 NF
	207,000	
	816,000	
	540,000	
Average	380,600	8,000,000
Logarithmic Mean Life	306,300	8,000,000

WADC TR 58-326

146

MECHANICAL PROPERTIES

Date August 29, 1957

For Chart No. 30

Bolt Description

Type

Stud

Size

1"-14

Material

MIL-S-5000

Bolt Strength Pounds

Specimen 1

Specimen 2

Ultimate Tensile

Yield Strength

Material Strength PSI

.505 Gage Specimen

Tensile Strength

179,000

180,000

Yield Strength

172,500

172,500

Elongation - 1/2 in 4 Diameter

.505 Gage Specimen

13.5

12.5

Reduction of Area - 1/2

.505 Gage Specimen

52.0

46.3

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

67,916

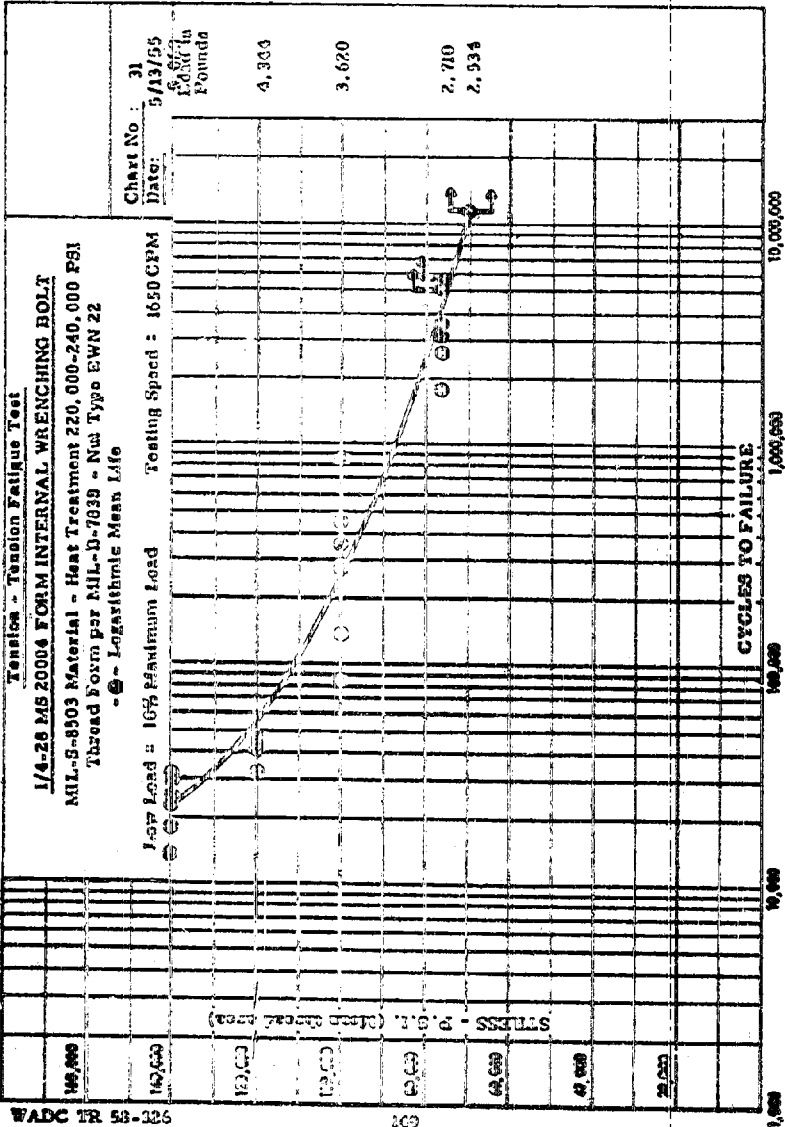
PSI (Mean Area)

100,000

Lot No.

199

APPENDIX II
RAW DATA FOR 220,000 FSI PARTS



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 5-13-58

Bolt Design	MS 20004
Size	1/4-28
Material	MIL-S-8503
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Plate per QQ-P-416 Type I, Class C

Stress Area .0362 Square inches

Nut Type	
Style	EWN 22
Material	AISI 0630
Heat Treatment	Rc 27-32

Testing Machine	
Make	Krouso
Capacity	5,000 pound
Speed	1650 cpm

Maximum Load	5,060#	4,344#	3,620#
Stress	140,000 psi	120,000 psi	100,000 psi
	31,100	52,100	842,900
	29,000	50,600	433,900
	22,300	49,300	354,500
	18,500	31,400	135,900
	14,300		83,800
Average	23,040	45,850	370,000
Logarithmic Mean Life	22,140	44,830	271,600

Maximum Load	2,710#	2,534#
Stress	77,000 (MIL-B)	70,000 psi
	5,612,100 NF	10,283,300 NF
	5,421,000 NF	10,283,300 NF
	3,463,200	
	2,451,700	
	1,862,500	
Average	3,762,100	10,283,300
Logarithmic Mean Life	3,409,000	10,283,300

MECHANICAL PROPERTIES

Date May 13, 1955

For Chart No. 31

Bolt Description

Type	MS 20004
Size	1/4-28
Material	MIL-S-8503

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	9,300	9,350
Yield Strength	7,900	8,000

Material Strength PSI

.113 Gage Specimen		
Tensile Strength	234,000	236,000
Yield Strength	190,000	190,000

Elongation - 3/4 in 4 Diameter

.113 Gage Specimen	16.5	16.5
--------------------	------	------

Reduction of Area - 3/4

.113 Gage Specimen	60.4	47.2
--------------------	------	------

Shear Strength - Bolt Body

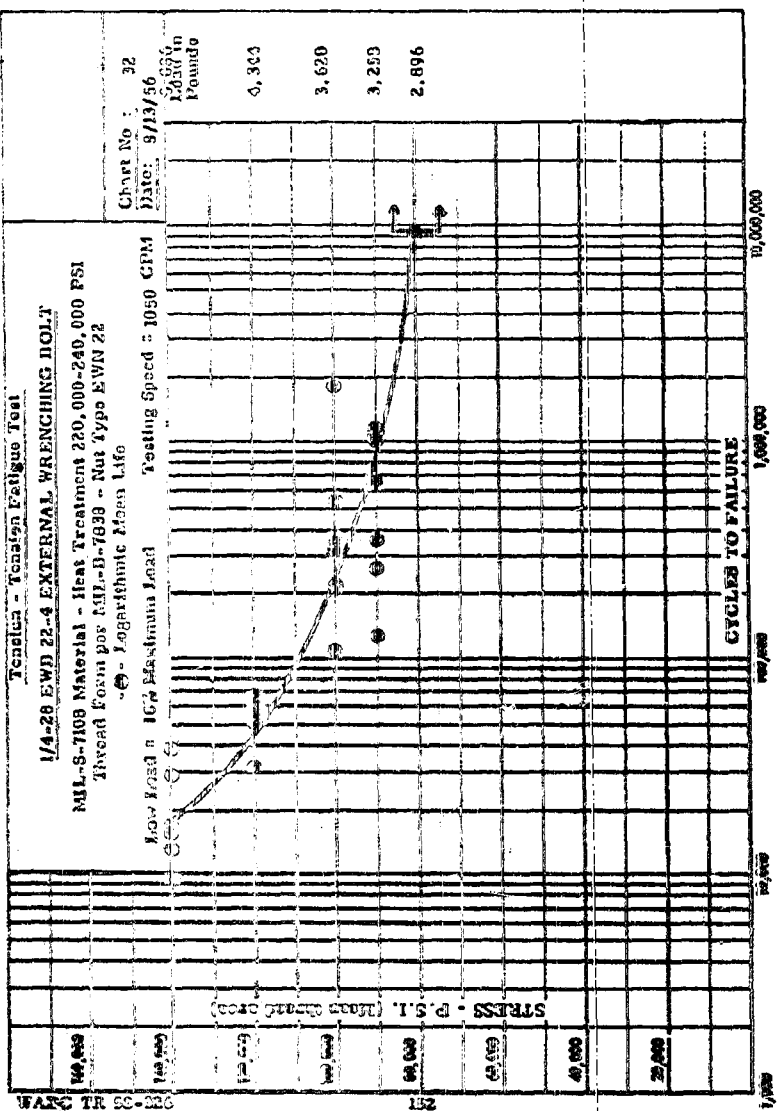
Pounds - Double shear	13,200	14,270
PSI	134,400	145,000

Fatigue Strength 0.000,000

Cycles 10% Low Load

Pounds	2,534
PSI (Mean Area)	70,000

Lot No. 279S4148A



WANG TR 80-280

132

1,000

TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 8-13-56

Bolt Design	EWB 22-4
Size	1/4-28
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Fluoborate per NAS 672

Stress Area	.0362 Square inches
-------------	---------------------

Nut Type	EWN 22
Style	AMS 6280
Material	Qc 27-32
Heat Treatment	

Testing Machine	Krouse
Model	15,000 pound
Capacity	1050 rpm
Speed	

Maximum Load Stress	5,069# 140,000 psi	4,344# 120,000 psi	3,620# 100,000 psi
	39,600	59,600	1,837,100
	29,200	56,200	551,300
	16,400	49,700	355,300
	13,100	41,300	217,500
	9,100	22,300	106,500
Average	21,480	95,860	613,540
Logarithmic Mean Life	18,660	43,400	383,900

Maximum Load Stress	3,258# 90,000 psi	2,896# 80,000 psi
	1,222,600	9,744,800 NF
	1,160,900	9,744,800 NF
	1,085,000	
	387,700	
	225,000	
Average	816,200	9,744,800
Logarithmic Mean Life	669,400	9,744,800

MECHANICAL PROPERTIES

Date August 13, 1956 For Chart No. 32

Bolt Description

Type
Size
Material

EWB 22-4
1/4-28
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1	Specimen 2
9,620	9,940
8,000	8,300

Material Strength PSI

.113 Gage Specimen
Tensile Strength
Yield Strength

237,800	249,000
227,500	247,500

Elongation - % in 4 Diameter

.113 Gage Specimen

12.5	12.5
------	------

Reduction of Area - %

.113 Gage Specimen

32.0	34.0
------	------

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

13,820	13,680
140,700	139,300

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds
PSI (Mean Area)

2,896
80,000

Lot No.

628S9172

MECHANICAL PROPERTIES

Date August 13, 1956

For Chart No. 32

Bolt Description

Type

EWB 22-4

Size

1/4-28

Material

MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile

Specimen 1

Specimen 2

9,620

9,940

Yield Strength

8,000

8,300

Material Strength PSI

.113 Gage Specimen

Tensile Strength

237,900

249,000

Yield Strength

227,500

247,300

Elongation - % in 4 Diameter

.113 Gage Specimen

12.5

12.5

Reduction of Area - %

.113 Gage Specimen

32.0

34.0

Shear Strength - Bolt Body

Pounds - Double Shear

13,820

13,680

PSI

140,700

139,300

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

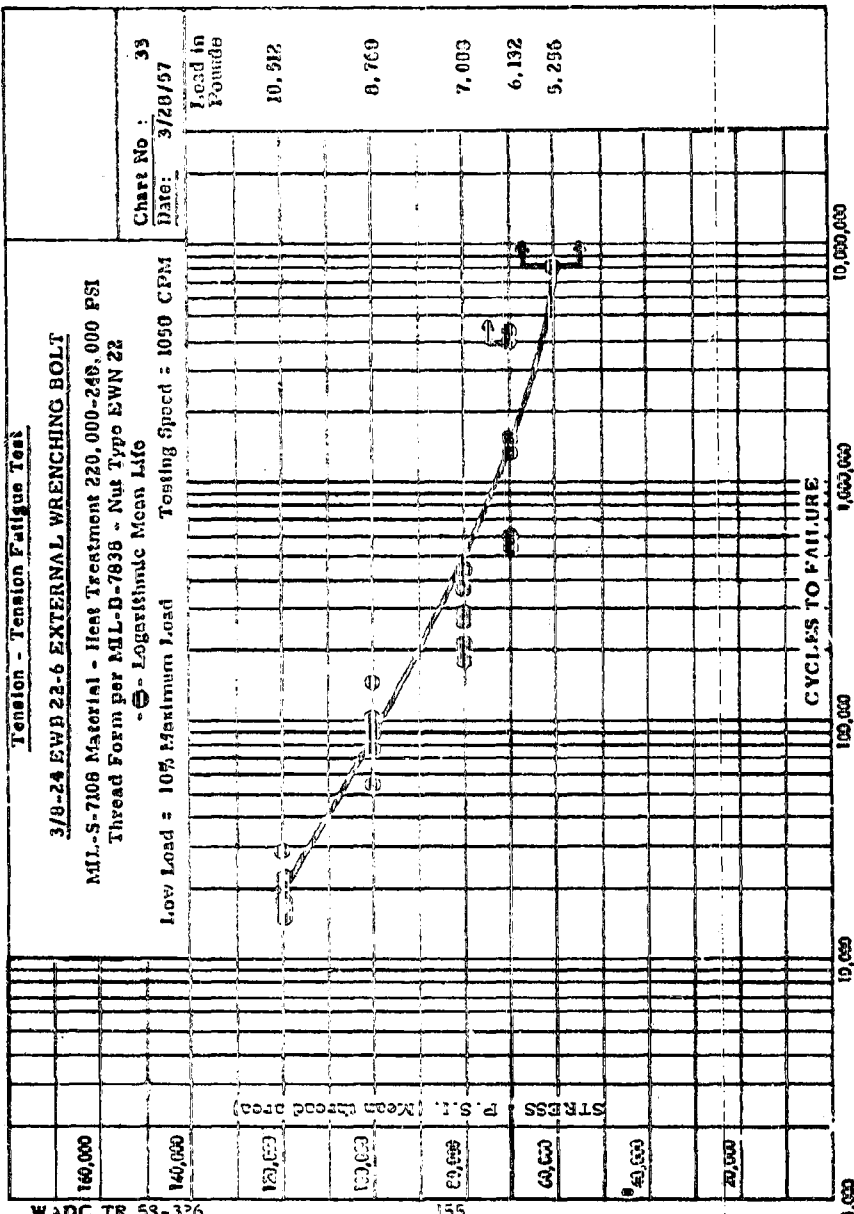
2,896

PSI (Mean Area)

80,000

Lot No.

620S9172



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 3-28-57

Bolt Design	EWB 22-6
Size	3/8-24
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plat	Cadmium Fluoborate per NAS 672

Stress Area .0876 Square inches

Nut Type	
Style	EWN 22
Material	AMS 6280
Heat Treatment	Rc 27-32

Testing Machine	
Make	Kronco
Capacity	15,000 pound
Speed	1050 rpm

Maximum Load	10,512#	0,760#	7,000#
Stress	<u>120,000 psi</u>	<u>100,000 psi</u>	<u>80,000 psi</u>
	28,800	168,500	438,400
	21,400	107,300	376,000
	19,700	98,400	269,800
	18,500	77,000	214,400
	<u>15,800</u>	<u>54,100</u>	<u>173,000</u>
Average	20,840	101,060	294,320
Logarithmic Mean Life	20,520	94,180	277,500

Maximum Load	6,132#	5,256#
Stress	<u>70,000 psi</u>	<u>60,000 psi</u>
	4,218,000	8,379,000 NF
	4,000,000 NF	8,379,000 NF
	1,560,000 NF	
	547,600	
	<u>547,200</u>	
Average	2,174,660	8,379,000
Logarithmic Mean Life	1,511,000	8,379,000

WADC TR 58-326

156

MECHANICAL PROPERTIES

Date March 28, 1957 For Chart No. 33

Bolt Description

Type	EWB 22-6
Size	3/8-24 x 4 11/16
Material	MIL-S-7108

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	23,300	22,800
Yield Strength	21,275	18,000

Material Strength PSI

.252 Gage Specimen		
Tensile Strength	242,300	242,900
Yield Strength	206,100	204,100

Elongation - $\frac{3}{8}$ in 4 Diameter

.252 Gage Specimen	10.50	19.0
--------------------	-------	------

Reduction of Area - $\frac{3}{8}$

.252 Gage Specimen	46.0	47.6
--------------------	------	------

Shear Strength - Bolt Body

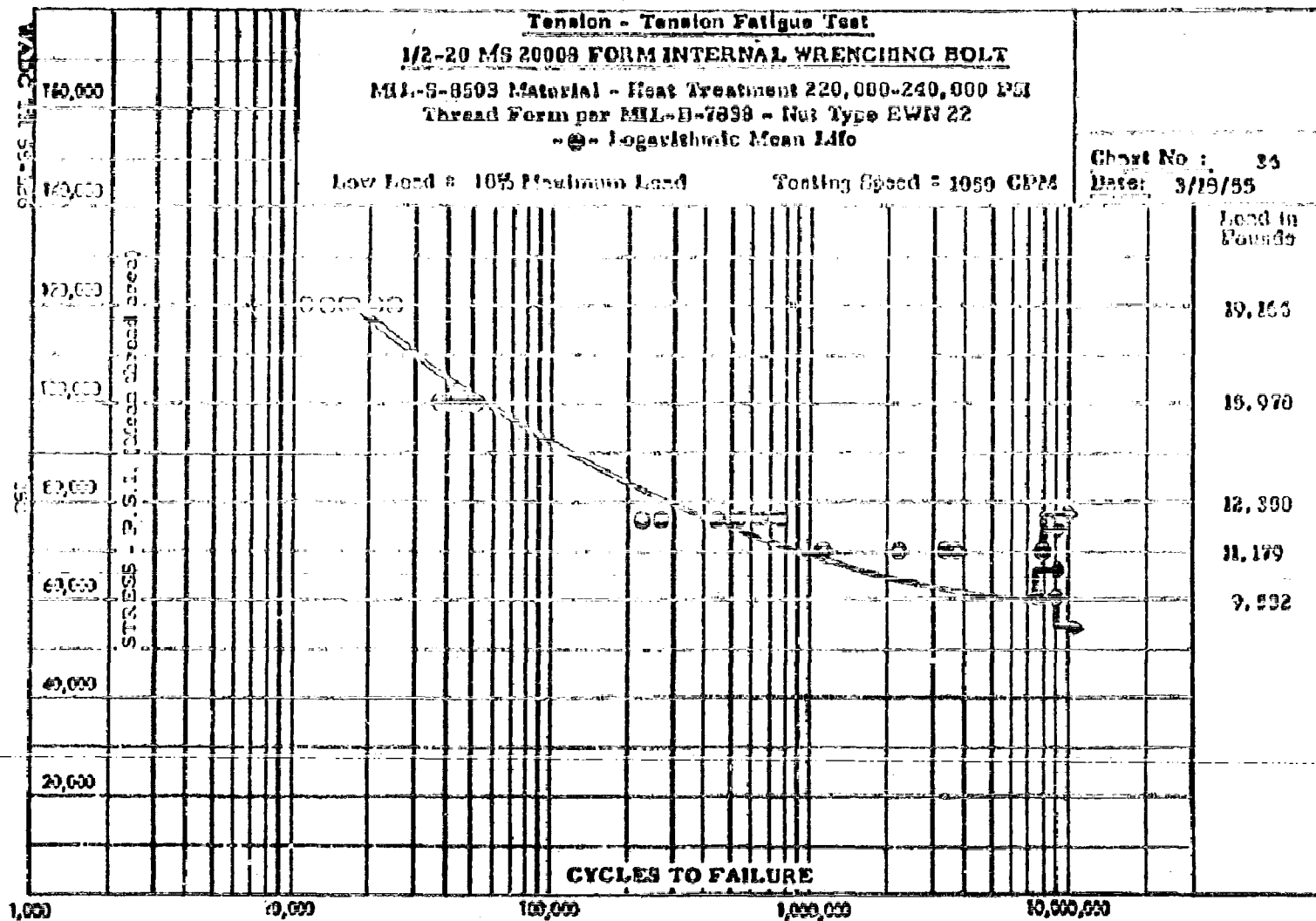
Pounds - Double Shear	30,750	30,900
PSI	139,300	139,900

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	5,256
PSI (Mean Area)	60,000

Lot No. 629S9K75



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 3-18-57

Bolt Design	MS 20008
Size	1/2-20
Material	MIL-S-8503
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Plate per QQ-P-416 Type I, Class C

Stress Area	0.1597 Square Inches
-------------	----------------------

Nut Type	UNF 22
Style	ANSI 8630
Material	RC 27-32
Heat Treatment	

Testing Machine	Kyocera
Make	15,000 pound
Capacity	1050 cpm
Speed	

Maximum Load	19,162#	15,970#	12,300#
Stress	120,000 psi	100,000 psi	741,000

	24,000	54,800	747,000
	21,700	49,500	613,000
	18,300	45,400	564,500
	16,500	43,200	295,800
	13,000	37,900	250,000
Average	18,700	46,160	499,240

Logarithmic Mean Life	18,290	45,810	451,300
-----------------------	--------	--------	---------

Maximum Load	11,179#	9,582#
Stress	70,000 psi	60,000 psi

	8,000,000 NF	8,020,500 NF
	8,000,000 NF	8,020,500 NF
	3,780,000	
	2,393,000	
	1,114,400	
Average	4,663,500	8,020,500

Logarithmic Mean Life	3,564,000	8,020,500
-----------------------	-----------	-----------

STATE OF CALIFORNIA - DEPARTMENT OF REVENUE

Date: March 10, 1955

San Francisco

40

Full Description

Type

Full Description

Class

Full Description

Structure

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

Full Description

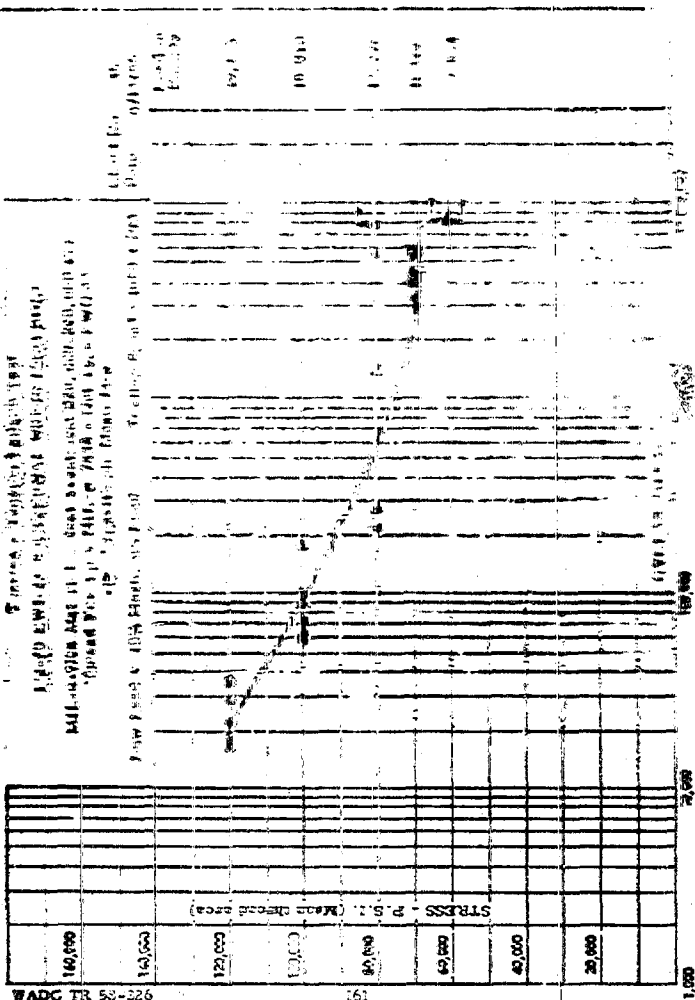
Full Description

Full Description

Full Description

Full Description

Full Description



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 8-13-56

Part Design	EWB 22-8
Size	1/2-20
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Fluoroborate per NAS 672

Nominal Area .1597 Square Inches

Part Type	FWN 22
Style	AMS 6280
Material	Rc 27-32
Heat Treatment	

Testing Machine	Krouse
Make	
Capacity	15,000 pound
Speed	1650 cpm

Maximum Load	19,164#	15,970#	12,776#
Stress	120,000 psi	100,000 psi	80,000 psi
	34,600	184,200	8,794,800
	28,800	100,700	5,405,900
	19,100	72,500	2,885,900
	18,100	63,000	282,000
	16,000	60,000	221,000
Average	23,720	96,080	3,517,700

Logarithmic Mean Life	22,160	87,340	1,536,000
-----------------------	--------	--------	-----------

Maximum Load	11,179#	9,582#
Stress	70,000 psi	60,000 psi
	5,820,600	8,290,200
	5,346,800	8,290,200
	4,038,100	
	3,223,300	
Average	4,607,200	8,290,200

Logarithmic Mean Life	4,485,000
-----------------------	-----------

MECHANICAL PROPERTIES

Date August 13, 1956

For Chart No. 35

Bolt Description

Type

Size

Material

EWB 22-8 - MIL-B Thread

1/2-20

MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile

Yield Strength

Specimen 1

41,700

30,500

Specimen 2

41,700

31,500

Material Strength PSI

. 357 Gage Specimen

Tensile Strength

Yield Strength

239,000

202,000

239,000

196,000

Elongation - % in 4 Diameter

. 357 Gage Specimen

11.6

11.6

Reduction of Area - %

. 357 Gage Specimen

50.2

48.6

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

56,900

239,700

56,200

286,200

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

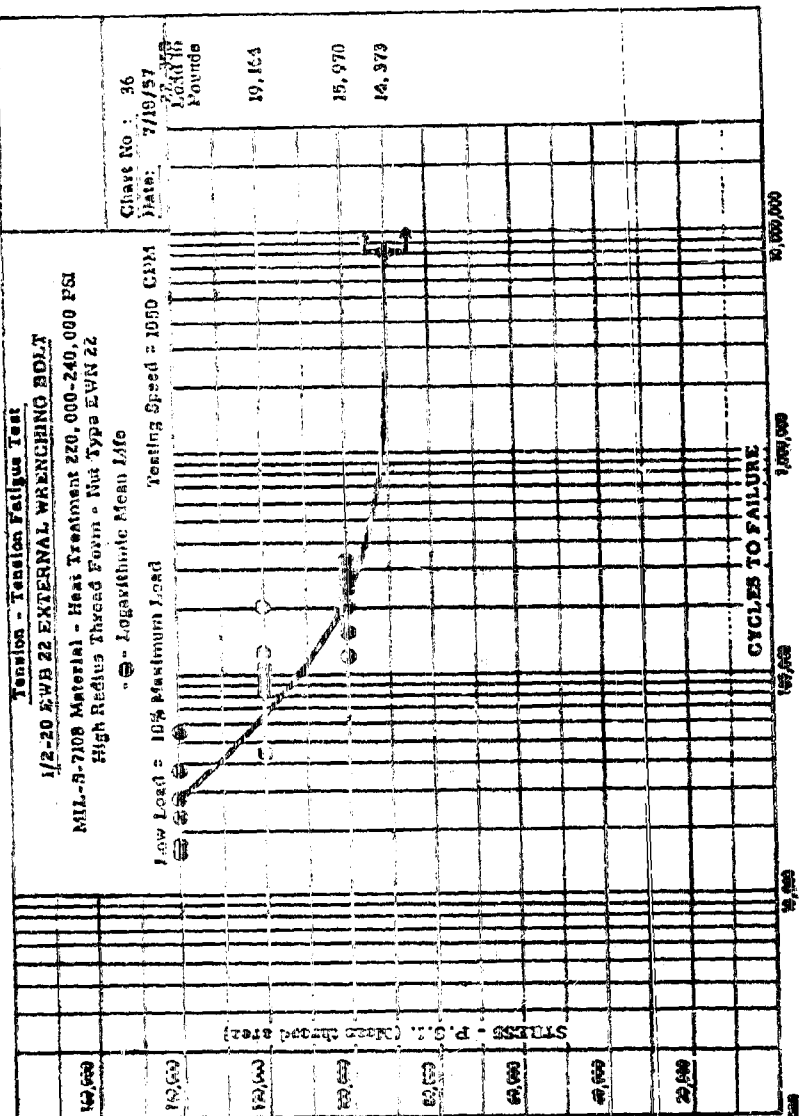
PSI (Mean Area)

10,700

67,000

Lot No.

63059M94



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 7-18-57

Bolt Design	EWB 22-8
Size	1/2-20
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	High Radius
Plate	Cadmium Fluoborate per NAS 672

Stress Area	0.1597
-------------	--------

Not Type	
Style	EWN 22
Material	AMS 6280
Heat Treatment	Re 27-32

Testing Machine	
Make	Krouse
Capacity	60,000 pound
Speed	850 cpm

Maximum Load	22,358#	19,164#	15,970#
Stress	140,000 psi	120,000 psi	100,000 psi
	10,000	82,900	305,400
	10,500	93,200	230,500
	23,100	43,800	286,500
	54,100	202,000	125,900
	37,800	121,300	142,600
Average	30,300	107,640	218,180
Logarithmic Mean Life	27,500	108,600	203,000

Maximum Load	14,383#
Stress	90,000 psi

	8,000,000
Average	8,000,000
	8,000,000

Logarithmic Mean Life	8,000,000
-----------------------	-----------

MECHANICAL PROPERTIES

Date May 16, 1957

For Chart No. 36

Bolt Description

Type	EWN 22-8 High Radius Thread
Size	1/2-20
Material	ML-S-7108

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	43,000	43,000
Yield Strength	30,600	30,000

Material Strength PSI

. 357 Gage Specimen		
Tensile Strength	237,500	240,500
Yield Strength	198,000	200,000

Elongation - % in 4 Diameter

. 357 Gage Specimen	11.6	11.6
---------------------	------	------

Reduction of Area - %

. 357 Gage Specimen	49.4	49.4
---------------------	------	------

Shear Strength - Bolt Body

Pounds - Double Shear	56,900	56,200
PSI	289,700	286,200

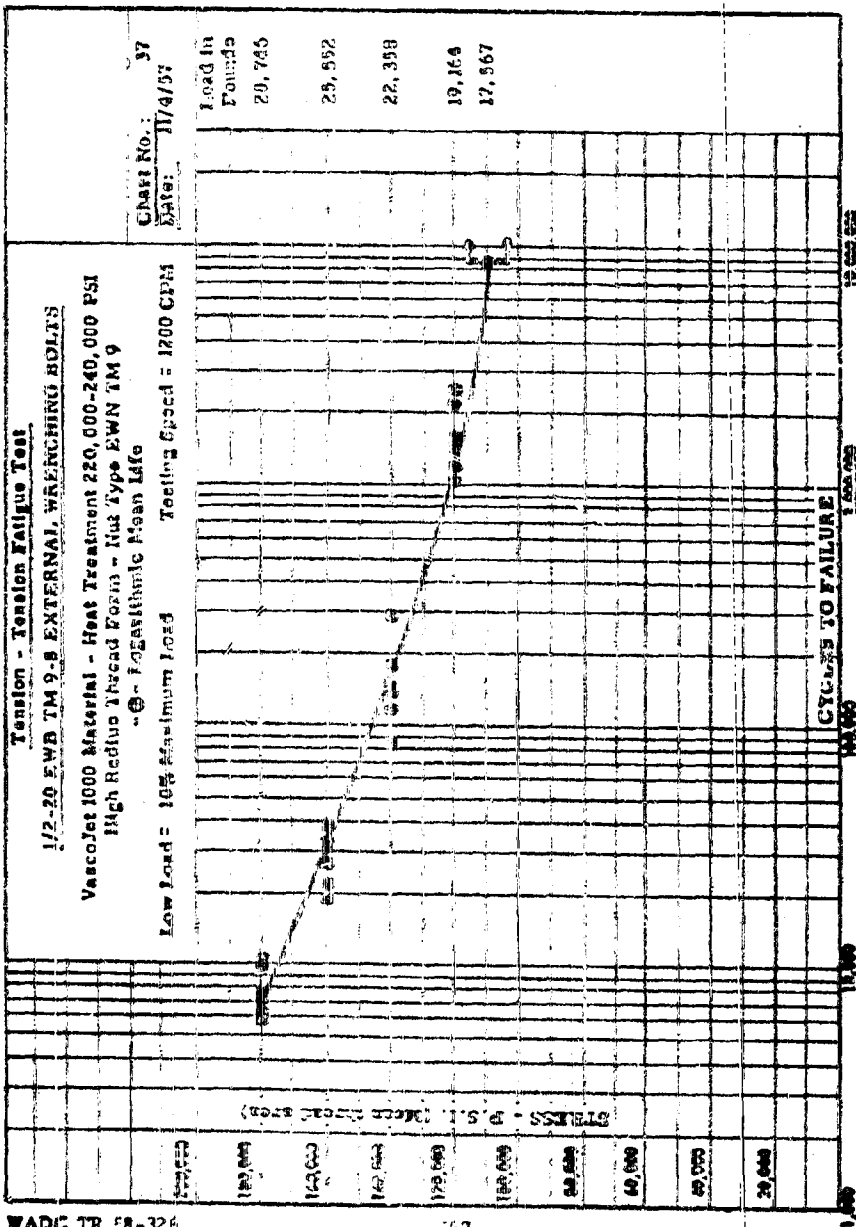
Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	14,373
PSI (Mean Area)	90,000

Lot No.

87



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 11-4-57

Bolt Design	EWB TM 9-8
Size	1/2-20
Material	VascoJet 1800
Heat Treatment	220,000-240,000 psi
Thread Form	High Radius
Plate	AMS 2416

Stress Area	.1597 Square inches
-------------	---------------------

Nut Type	EWB TM 9
Style	AMS 6304
Material	Rc 27-32
Heat Treatment	

Testing Machine	Ivy
Make	60,000 pound
Capacity	1200 rpm
Speed	

Maximum Load	28,746#	25,552#	22,358#
Stress	180,000 psi	160,000 psi	140,000 psi
	6,000	19,000	85,000
	6,000	23,000	135,000
	7,000	32,000	154,000
	10,000	32,000	177,000
	10,000	36,000	292,000
Average	7,800	28,400	168,600
Logarithmic Mean Life	7,591	27,630	155,600

Maximum Load	19,164#	17,567#
Stress	120,000 psi	110,000 psi
	1,141,000	9,136,000
	1,333,000	8,746,000
	1,545,000	
	2,195,000	
	2,240,000	
Average	1,690,000	8,000,000
Logarithmic Mean Life	1,631,060	8,000,000

WADC TR 58-326

168

MECHANICAL PROPERTIES

Date July 26, 1957

For Chart No. 37

Bolt Description

Type	EWB TM 9
Size	1/2-20 x 5
Material	VascoJet 1000

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	41,800	40,000
Yield Strength	31,500	30,000

Material Strength PSI

Gage Specimen		
Tensile Strength	235,000	235,000
Yield Strength	205,000	200,000

Elongation - % in 4 Diameter

Gage Specimen	12.1	11.4
---------------	------	------

Reduction of Area - %

Gage Specimen	31.3	32.3
---------------	------	------

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

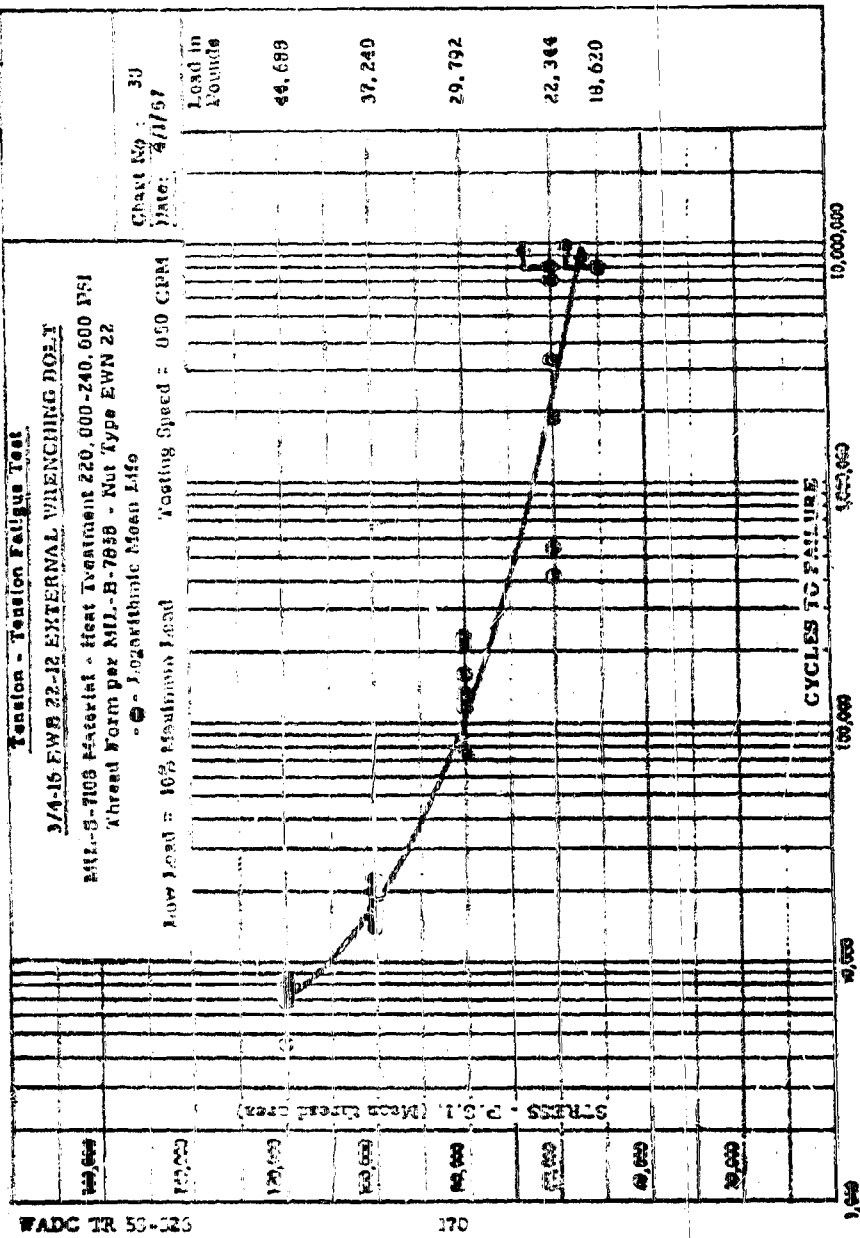
Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	17,567
PSI (Mean Area)	110,655

Lot No.

207



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 4-1-57

Bolt Design	EWN 22-12
Size	3/4-16
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838a
Plate	Cadmium Fluoborate per NAS 672

Stress Area	.3724 Square inches
-------------	---------------------

Nut Type	
Style	EWN 22
Material	AMS 6200
Heat Treatment	Rc 27-32

Testing Machine	
Make	Krouse
Capacity	60,000 pound
Speed	850 cpm

Maximum Load Stress	44,688# 120,000 psi	37,240# 100,000 psi	29,792# 80,000 psi
	4,400	15,100	74,600
	6,000	16,100	128,000
	7,100	19,700	163,400
	7,700	20,000	205,200
	8,900	21,300	213,400
Average	6,980	18,440	157,108

Logarithmic Mean Life	6,800	18,280	127,100
-----------------------	-------	--------	---------

Maximum Load Stress	22,344# 60,000 psi	18,620# 50,000 psi
---------------------	-----------------------	-----------------------

	401,300	8,143,200 NF
	547,500	8,143,200 NF
	2,321,800	
	7,398,900	
	8,194,300	
Average	3,772,800	8,143,200

Logarithmic Mean Life	1,987,000	8,143,200
-----------------------	-----------	-----------

MECHANICAL PROPERTIES

Date April 1, 1957

For Chart No. 38

Bolt Description

Type
Size
Material

FWB 22-12 MIL.-B Thread
3/4-16
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1

96,000
70,100

Specimen 2

95,100
70,100

Material Strength PSI

.505 Gage Specimen
Tensile Strength
Yield Strength

240,000
107,500

231,000
191,250

Elongation - % in 4 Diameter

.505 Gage Specimen

12.5

12.5

Reduction of Area - %

.505 Gage Specimen

49.6

49.8

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

126,000
142,900

127,000
144,100

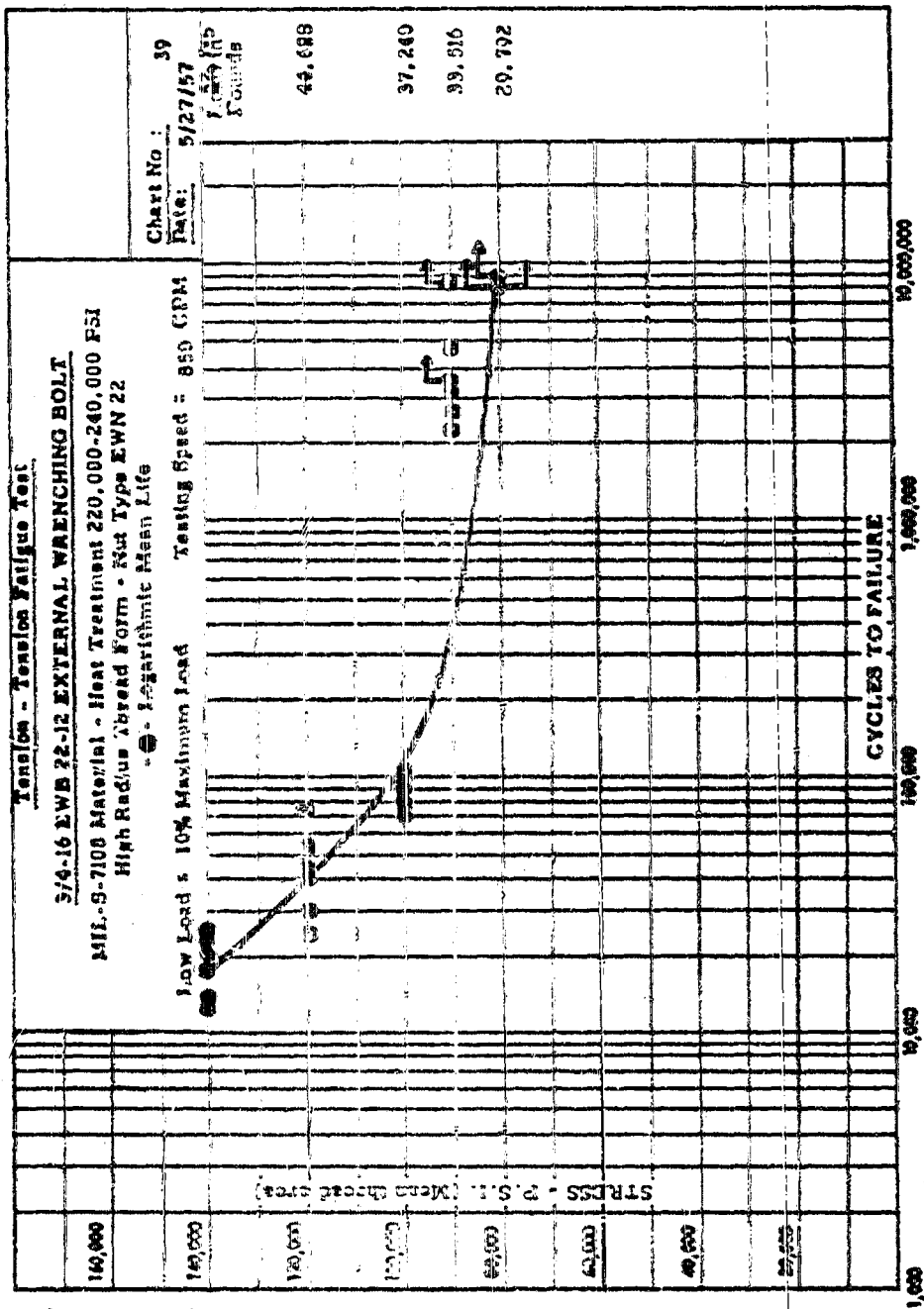
Fatigue Strength @ 8,000,000 Cycles 10% Low Load

Pounds
PSI (Mean Area)

20,492
55,000

Lot No.

85



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 4-25-57

Bolt Design	EWB 22-12
Size	3/4-16
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	High Radius
Plate	Cadmium Fluoride per NAS 672

Stress Area	.3724 Square inches
-------------	---------------------

Nut Type	
Style	ENW 22
Material	AMS 6280
Heat Treatment	Re 27-32

Testing Machine	
Make	Krouse
Capacity	60,000 pound
Speed	650 cpm

Maximum Load	52,136#	44,698#	37,240#
Stress	140,000 psi	120,000 psi	100,000 psi
	14,000	25,100	70,400
	14,600	30,100	76,600
	19,900	43,200	82,700
	21,100	54,300	91,700
	22,300	76,300	103,400
Average	18,380	45,600	104,950
Logarithmic Mean Life	18,050	42,260	81,800

Maximum Load	33,516#	29,792#
Stress	90,000 psi	80,000 psi
	2,332,300	8,872,400 NF
	2,637,000	8,451,200 NF
	3,500,000 NF	8,194,300 NF
	4,837,500	
	8,000,000 NF	
Average	4,261,560	8,506,000
Logarithmic Mean Life	3,838,000	8,506,000

MECHANICAL PROPERTIES

Date April 25, 1957

For Chart No. 39

Bolt Description

Type
Size
Material

EWD 22-12 High Radius
3/4-16
MIL-S-7108

Bolt Strength Pounds

	Specimen 1	Specimen 2
Ultimate Tensile	97,200	91,200
Yield Strength	67,000	70,000

Material Strength PSI

.505 Gage Specimen		
Tensile Strength	234,000	232,500
Yield Strength	193,000	190,000

Elongation - % in 4 Diameter

.505 Gage Specimen	13.2	14.0
--------------------	------	------

Reduction of Area - %

.505 Gage Specimen	51.0	50.4
--------------------	------	------

Shear Strength - Bolt Body

Pounds - Double Shear	123,000	125,000
PSI	139,500	141,800

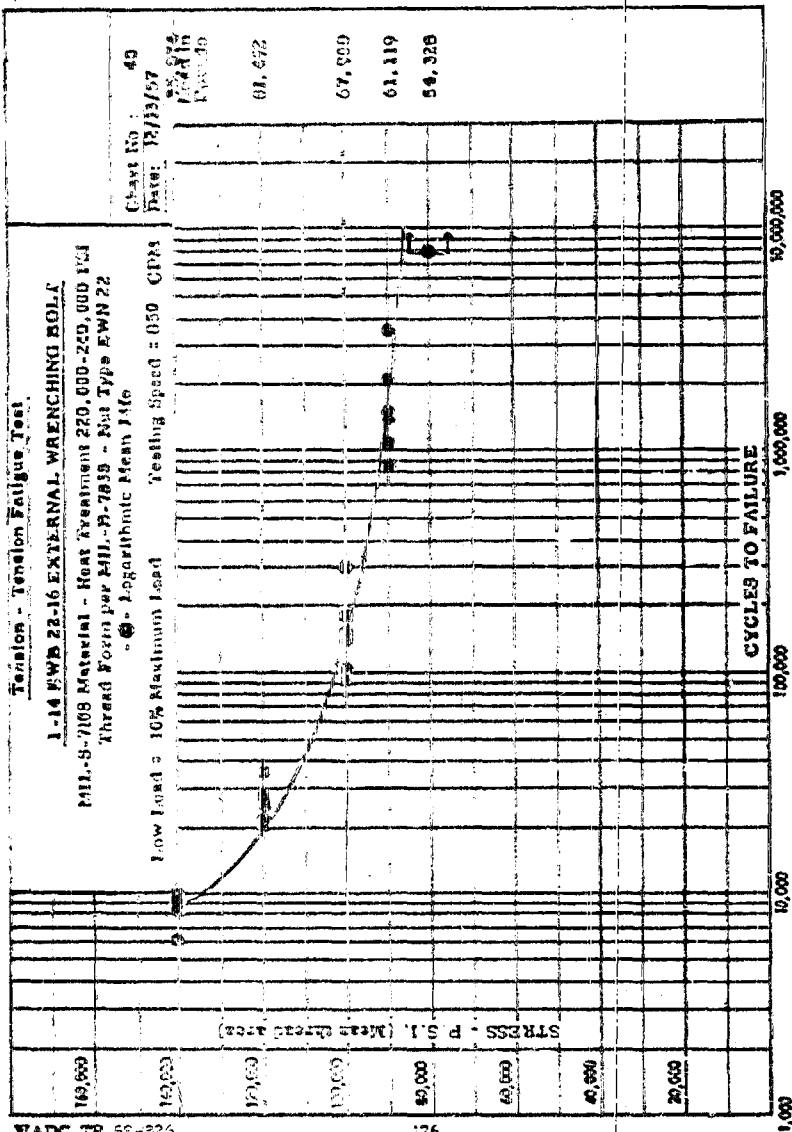
Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds	29,792
PSI (Mean Area)	80,000

Lot No.

86



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 12-13-57

Bolt Design	ENB 22-16
Size	1-14
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	Cadmium Fluoride per NAS 672

Stress Area	0.67910 Square inches
-------------	-----------------------

Nut Type	ENB 22
Style	ENB 22
Material	MS 6280
Heat Treatment	220,000 psi

Testing Machine	Amster
Make	Amster
Capacity	220,000 pound
Speed	500 rpm

Maximum Load	95,074#	81,492#	67,900#
Stress	140,000 psi	120,000 psi	100,000 psi
	6,200	22,300	115,300
	8,800	22,500	156,700
	9,300	27,000	95,200
	9,800	27,700	170,000
	10,200	37,300	300,000
Average	8,860	27,360	167,440
Logarithmic Mean Life	0.731	26,870	154,400

Maximum Load	61,119#	54,328#
Stress	90,000 psi	80,000 psi
	879,300	8,134,000
	1,121,000	8,032,000
	1,523,200	
	2,215,500	
	3,706,800	
Average	1,889,000	8,000,000
Logarithmic Mean Life	1,653,000	8,000,000

MECHANICAL PROPERTIES

Date November 8, 1957

For Chart No. 40

Bolt Description

Type
Size
Material

EWB 22 16
1-14
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1	Specimen 2
165,000	165,000
126,000	126,000

Material Strength PSI

.505 Gage Specimen
Tensile Strength
Yield Strength

243,000	230,000
200,000	201,000

Elongation - 5 in 4 Diameter

.505 Gage Specimen

15.6	15.65

Reduction of Area - $\frac{5}{8}$

.505 Gage Specimen

49.0	47.2

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

207,500	202,500
131,800	133,400

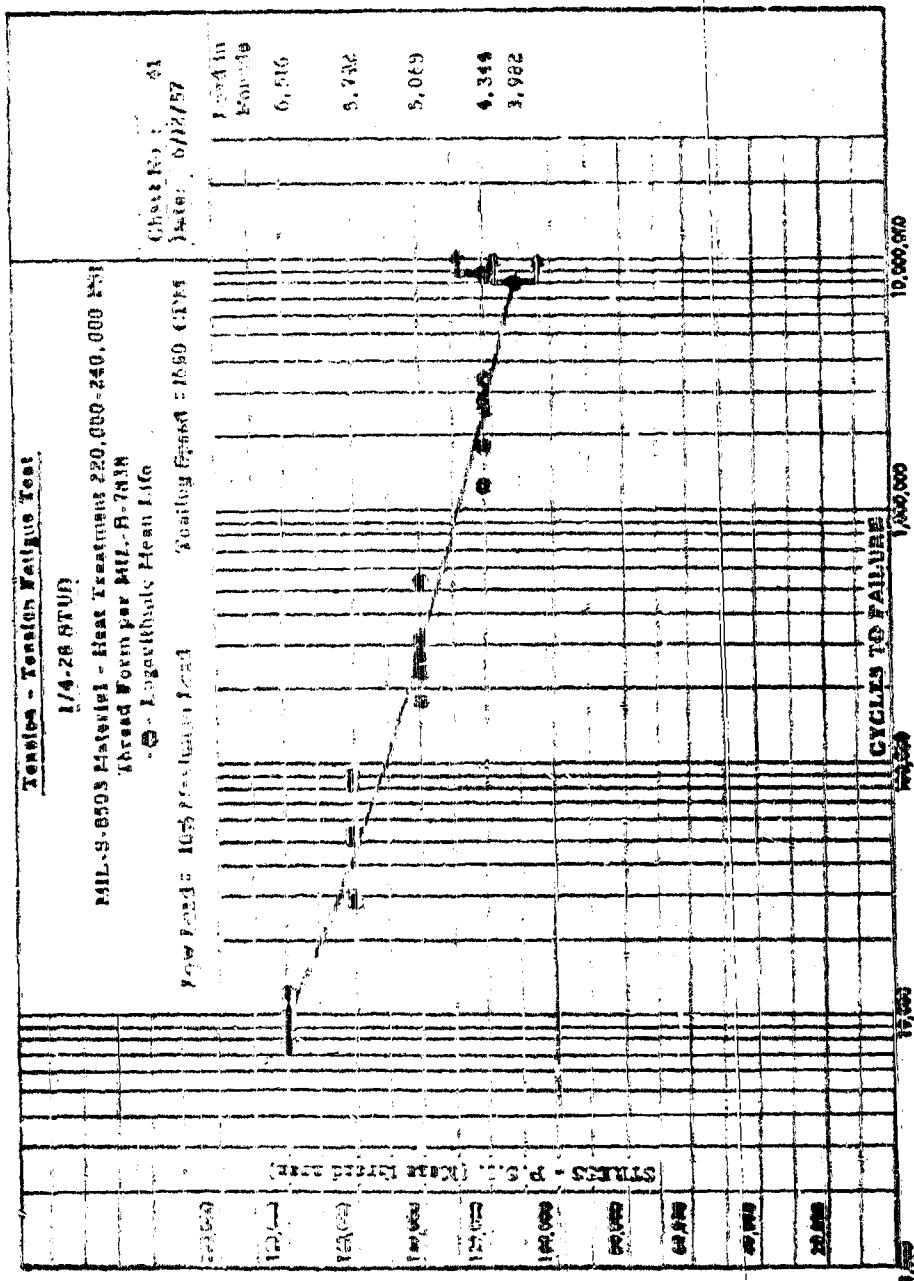
Fatigue Strength 40,000,000 Cycles 10% Low Load

Pounds
PSI (Mean Area)

54,320
80,000

Lot No.

77859S131



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 6-12-57

Bolt Design	Stud
Size	1/4-28
Material	MIL-S-8503
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-D-7838
Plate	None

Stress Area	.0362 Square inches
-------------	---------------------

Not Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	Kroose
Make	
Capacity	15,000 pound
Speed	1650 rpm

Maximum Load	6,516#	5,722#	5,068#
Stress	180,000 psi	160,000 psi	140,000 psi
	9,000	29,500	301,300
	10,000	91,300	103,500
	7,600	20,700	244,200
	7,800	53,200	253,500
	12,000	84,400	535,600
Average	9,201	57,420	303,600

Logarithmic Mean Life	9,201	51,060	284,900
-----------------------	-------	--------	---------

Maximum Load	4,344#	3,982#
Stress	120,000 psi	110,000 psi

	1,301,900	8,123,000 NF
	1,701,600	8,123,000 NF
	2,618,800	
	3,173,000	
	8,900,000	
Average	3,538,400	8,123,000

Logarithmic Mean Life	2,772,000	8,123,000
-----------------------	-----------	-----------

WADC TR 58-326	180
----------------	-----

MECHANICAL PROPERTIES

Date June 10, 1957

For Chart No. 41

Bolt Description

Type

Stud

Size

1/4-28

Material

ML-8-8503

Bolt Strength Pounds

Ultimate Tensile

Specimen 1

Specimen 2

Yield Strength

Material Strength PSI

H3 Gage Specimen

Tensile Strength

236,500

237,500

Yield Strength

222,500

215,000

Elongation - 5 in 4 Diameter

H3 Gage Specimen

11.5

11.5

Reduction of Area - 5

H3 Gage Specimen

44.7

44.7

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

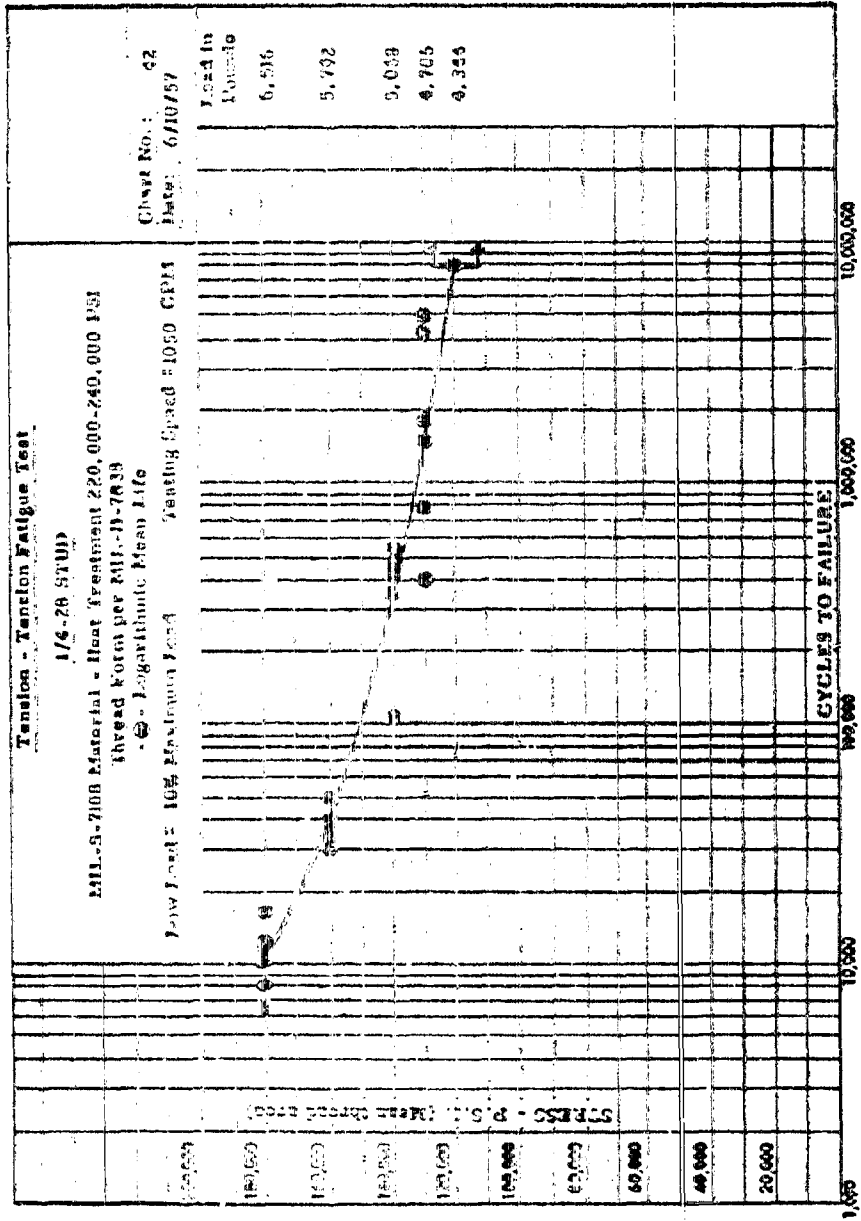
3,982

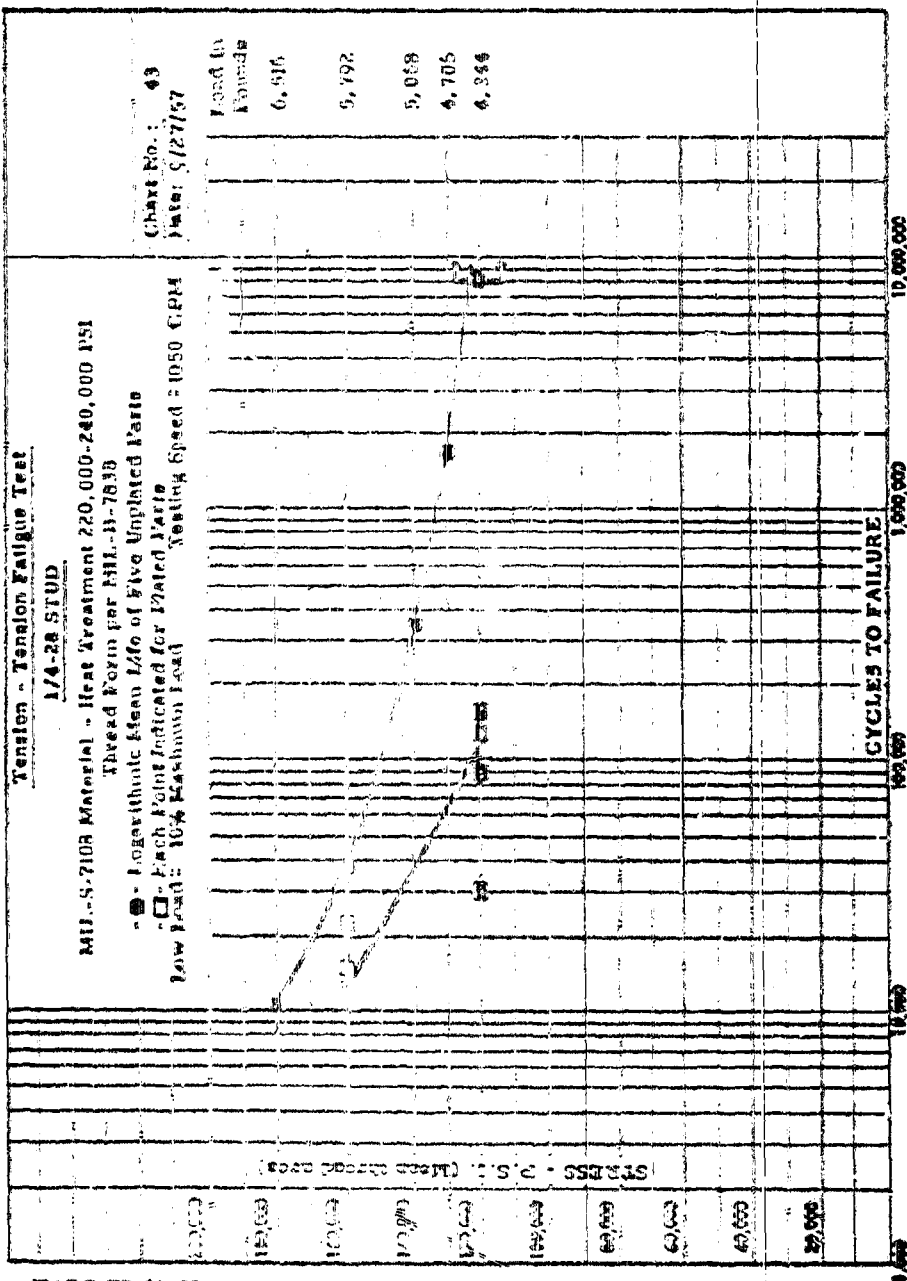
PSI (Mean Area)

110,000

Lot No.

173





TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 6-10-57

Bolt Design	Stud
Size	1/4-28
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	None

Stress Area .0362 Square inches

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	
Make	Krohn
Capacity	15,000 pound
Speed	1050 rpm

Maximum Load Stress	6,516# 100,000 psi	5,792# 160,000 psi	5,069# 140,000 psi
		Unplated	Plated
	16,400	50,500	12,100
	12,100	38,100	13,800
	11,600	33,700	16,300
	8,100	32,100	22,700
	6,400	31,900	
Average	10,920	37,260	16,230
Logarithmic Mean Life	10,360	36,680	15,770
			350,900

Maximum Load Stress	4,706# 130,000 psi	4,344# 120,000 psi	
		Unplated	Plated
	399,600	9,115,900 NF	30,300
	4,470,000	9,115,900 NF	89,900
	787,500		138,700
	4,981,000		160,200
	1,823,000		
Average	2,492,200	9,115,900	104,780
Logarithmic Mean Life	1,642,000	9,115,900	88,200

MECHANICAL PROPERTIES

Date March 14, 1957

For Chart No. 42

Bolt Description

Type
Size
Material

Stud
1/4-28
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1

Specimen 2

Material Strength PSI

.113 Gage Specimen
Tensile Strength
Yield Strength

227,300
207,300

231,700
297,700

Elongation - % in 4 Diameter

.113 Gage Specimen

11.5

12.1

Reduction of Area - %

.113 Gage Specimen

52.1

53.9

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength @ 8,000,000 Cycles 10% Low Load

Pounds
PSI (Mean Area)

4,344
120,000

Lot No.

75

Tension - Tension Fatigue Test

3/8-24 5F10P

MIL-S-2100 Material - Heat Treatment 220,000-240,000 PSI

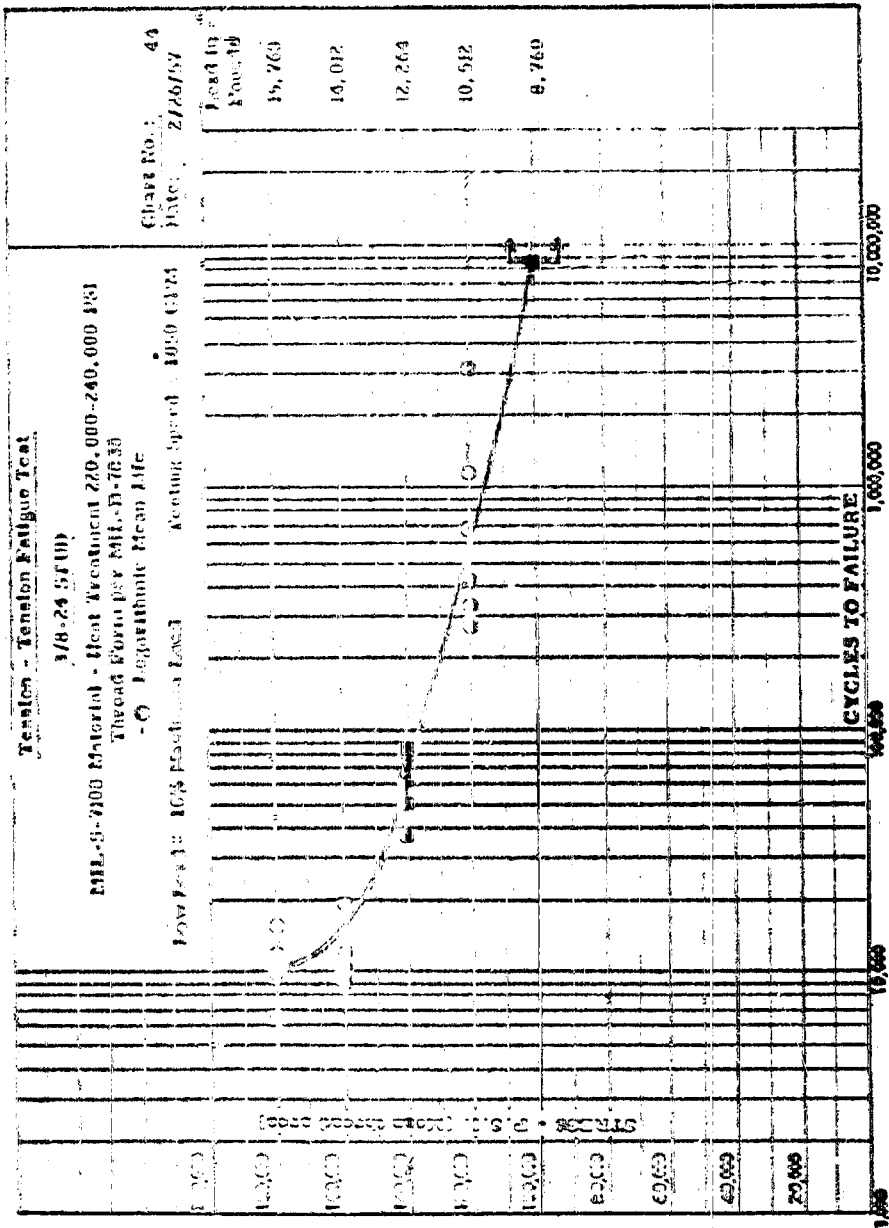
Thread Form per MIL-D-7638

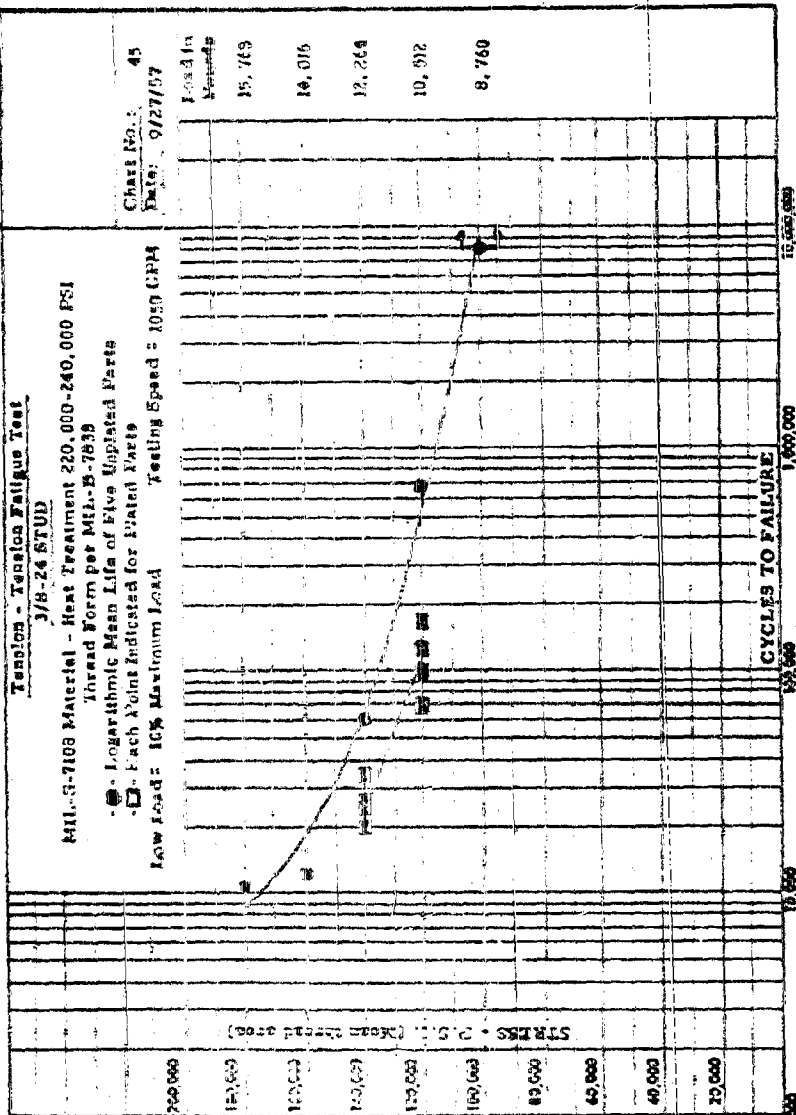
- O Representative Mean Life

Low Stress 12 103 Machine Load

Test Speed - 1000 CPM

Chart No. 43
Date: 2/26/57





TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 2-26-57

Bolt Design	Stud
Size	3/8-24
Material	Mill.-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	Mill.-H-7838
Plate	None

Stress Area	.0876 Square inches
-------------	---------------------

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	
Make	Reynolds
Capacity	15,000 pounds
Speed	1050 rpm

Maximum Load Stress	15,768# 180,000 psi	14,016# 160,000 psi	12,264# 140,000 psi	
			Unplated	Plated
	15,000	23,000	81,000	20,300
	11,100	11,400	60,700	24,200
	10,200	11,400	74,700	26,300
	9,800	10,000	51,100	27,100
	6,500	9,600	18,400	33,800
Average	10,520	12,480	65,490	26,340

Logarithmic Mean Life	10,160	12,010	62,560	25,860
-----------------------	--------	--------	--------	--------

Maximum Load Stress	10,512# 120,000 psi	8,760# 100,000 psi	
	Unplated	Plate	
	3,136,400	69,800	8,067,300
	1,375,000	97,400	8,067,300
	492,300	128,300	
	307,400	172,100	
	286,400		
Average	1,101,600	116,900	8,067,300

Logarithmic Mean Life	686,800	110,700	8,067,300
-----------------------	---------	---------	-----------

MECHANICAL PROPERTIES

Date February 26, 1957

For Chart No. 44

Bolt Description

Type
Size
Material

Stud
3/0-24
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1

Specimen 2

Material Strength PSI

.252 Gage Specimen
Tensile Strength
Yield Strength

227,600

224,000

191,800

197,500

Elongation - % in 4 Diameter

.252 Gage Specimen

13.0

13.0

Reduction of Area - %

.252 Gage Specimen

53.5

55.6

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength (20,000,000 Cycles 10% Low Load)

Pounds

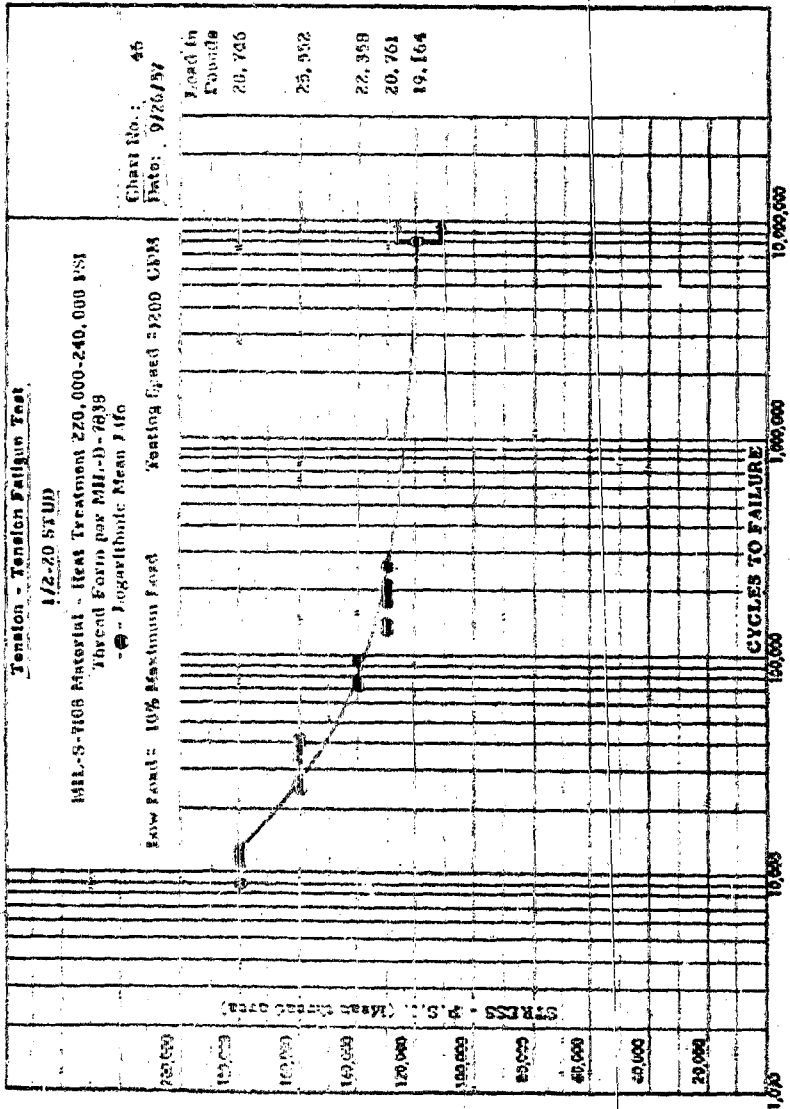
8,760

PSI (Mean Area)

100,000

Lot No.

53



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 9-26-57

Bolt Design	Stud
Size	1/2-20
Material	MIL-S-7168
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-B-7838
Plate	None

Stress Area .1577 Square inches

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	Ivy
Make	
Capacity	60,000 pound
Speed	1200 rpm

Maximum Load	28,746#	25,552#	22,358#
Stress	180,000 psi	160,000 psi	140,000 psi
	9,200	25,200	75,000
	10,800	27,600	76,000
	10,900	34,800	79,100
	11,000	41,000	80,500
	13,000	41,000	95,300
Average	10,980	33,920	80,980
Logarithmic Mean Life	10,910	33,240	80,550

Maximum Load	20,761#	19,164#
Stress	130,000 psi	120,000 psi
	122,000	8,431,000
	126,000	8,306,000
	196,000	8,640,000
	208,000	
	270,000	
Average	184,400	8,000,000
Logarithmic Mean Life	176,100	8,000,000

MECHANICAL PROPERTIES

Date May 8, 1957

For Chart No. 45

Bolt Description

Type

Size

Material

Stud

1/2-20 MIL-D Thread

MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile

Yield Strength

Specimen 1

Specimen 2

Material Strength PSI

357 Gage Specimen

Tensile Strength

Yield Strength

232,000

230,000

200,000

203,000

Elongation - % in 4 Diameter

357 Gage Specimen

11.6

10.5

Reduction of Area - %

357 Gage Specimen

47.0

46.1

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

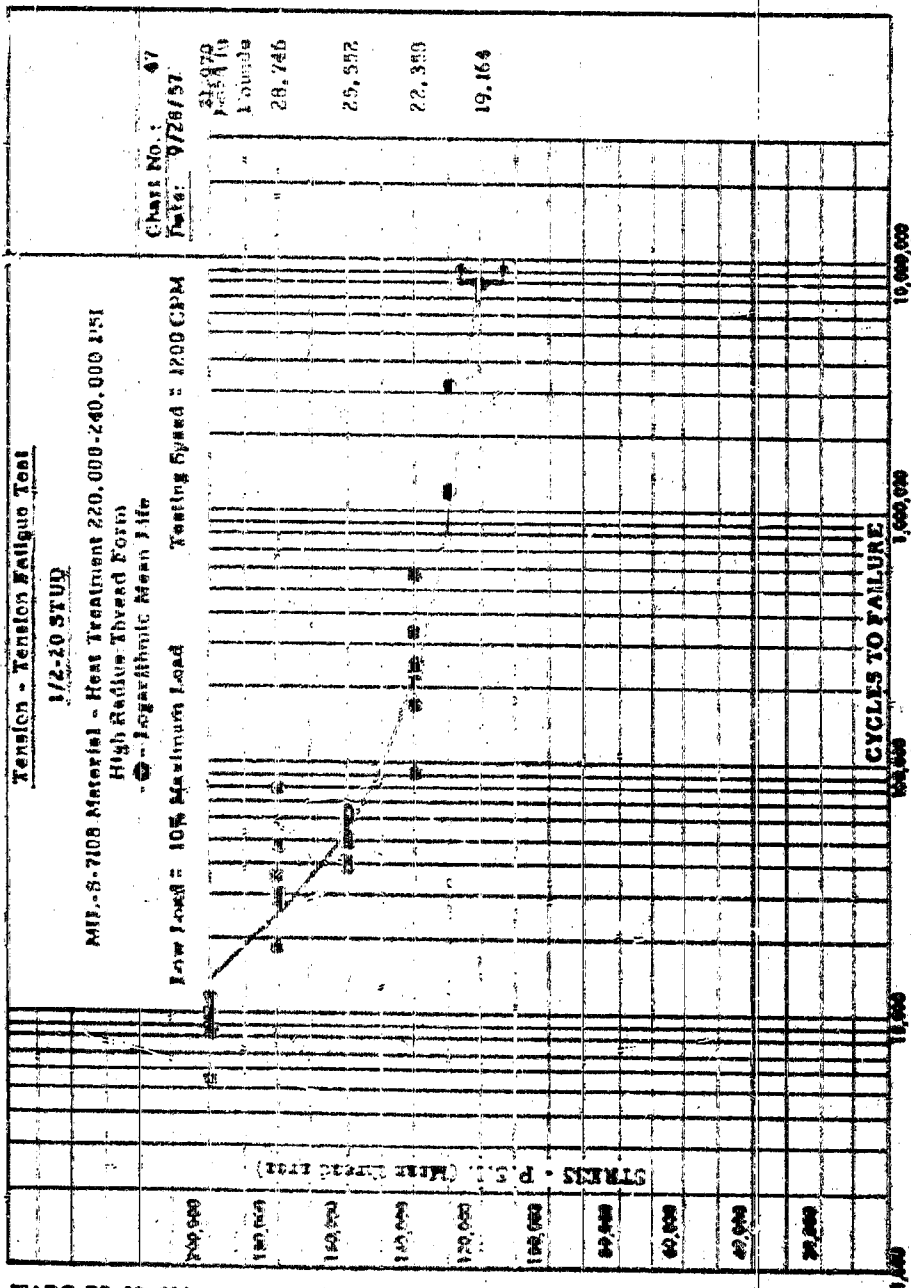
19,164

PSI (Mean Area)

120,000

Lot No.

81



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 9-28-56

Bolt Design
Size
Material
Heat Treatment
Thread Form
Plate

Stud
1/2-20
MIL-S-7108
220,000-240,000 psi
High Radius
None

Stress Area

0.1597 Square Inches

Not Type
Style
Material
Heat Treatment

Testing Machine
Make
Capacity
Speed

Ivy
60,000 pound
1200 CPM

Maximum Load
Stress

31,970# 200,000 psi	28,740# 180,000 psi	25,552# 160,000 psi
------------------------	------------------------	------------------------

5,500	19,800	40,700
0,700	20,000	41,000
9,600	31,600	54,500
10,100	47,300	60,500
11,200	81,500	63,200
9,020	41,640	52,180

Average

Logarithmic Mean Life

6,777	36,000	51,220
-------	--------	--------

Maximum Load
Stress

22,358# 140,000 psi	20,761# 130,000 psi	19,164# 120,000 psi
------------------------	------------------------	------------------------

93,400	1,386,000	8,500,000 NF
165,300	3,315,700	8,240,000 NF
251,600		
348,000		
576,000		
286,900	2,351,000	8,350,000

Average

Logarithmic Mean Life

238,900

MECHANICAL PROPERTIES

Date May 8, 1957

For Chart No. 47

Bolt Description

Type
Size
Material

Stud
1/2-20 High Radius
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1 Specimen 2

Material Strength PSI

.357 Gage Specimen

Tensile Strength

232,000

230,000

Yield Strength

200,000

205,000

Elongation - % in 4 Diameter

.357 Gage Specimen

11.6

10.5

Reduction of Area - %

.357 Gage Specimen

47.0

46.1

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength @ 8,000,000

Cycles at Low Load

Pounds

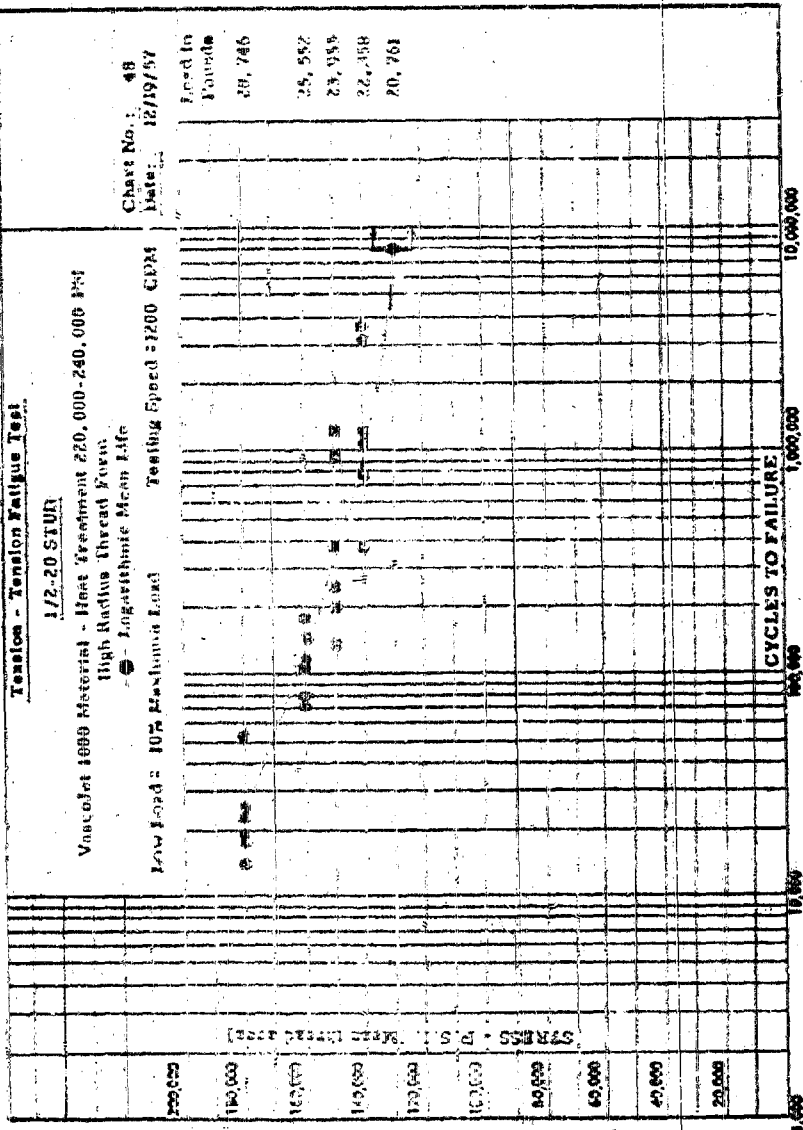
19,164

PSI (Mean Area)

129,000

Lot No.

82



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 12-19-57

Bolt Design
Size
Material
Heat Treatment
Thread Form
Plate

Std.
1/2-20
VacoJet 1000
220,000-240,000 psi
High Radius
None

Stress Area

.1927 Square inches

Nut Type

None

Style

Material

Heat Treatment

Testing Machine

Model

Capacity

Speed

Hy

60,000 pound

1200 rpm

Maximum Load
Stress

20,740

100,000 psi

26,582

130,000 psi

24,950

120,000 psi

15,000

72,000

983,000

17,000

80,000

114,000

19,000

108,000

192,000

23,000

142,000

227,000

24,000

183,000

1,319,000

26,000

117,000

571,000

Average

Logarithmic Mean Life

24,150

110,000

376,600

Maximum Load
Stress

22,350

140,000 psi

20,761

130,000 psi

387,000

38,523,000 NF

761,700

16,044,000 NF

1,104,300

6,119,000 NF

3,221,000

3,361,000

1,767,000

8,000,000

Average

Logarithmic Mean Life

1,287,000

8,000,000

MECHANICAL PROPERTIES

Date December 28, 1957

For Chart No. 48

Bolt Description

Type
Size
Material

Stud
1/2-20
VascoJet 1000

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1 Specimen 2 Specimen 3

Material Strength PSI

.357 Gage Specimen

Tensile Strength
Yield Strength

238,360	234,900	239,300
196,300	194,600	202,100

Elongation - % in 4 Diameter

.357 Gage Specimen

12.0	12.0	12.0
------	------	------

Reduction of Area - %

.357 Gage Specimen

48.9	46.8	40.8
------	------	------

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength (18,000,000
Cycles 10% Low Load)

Pounds
PSI (Mean Area)

20,671
130,000

Lot No.

529

Tension - Tension Fatigue Test

3/4-16 STUD

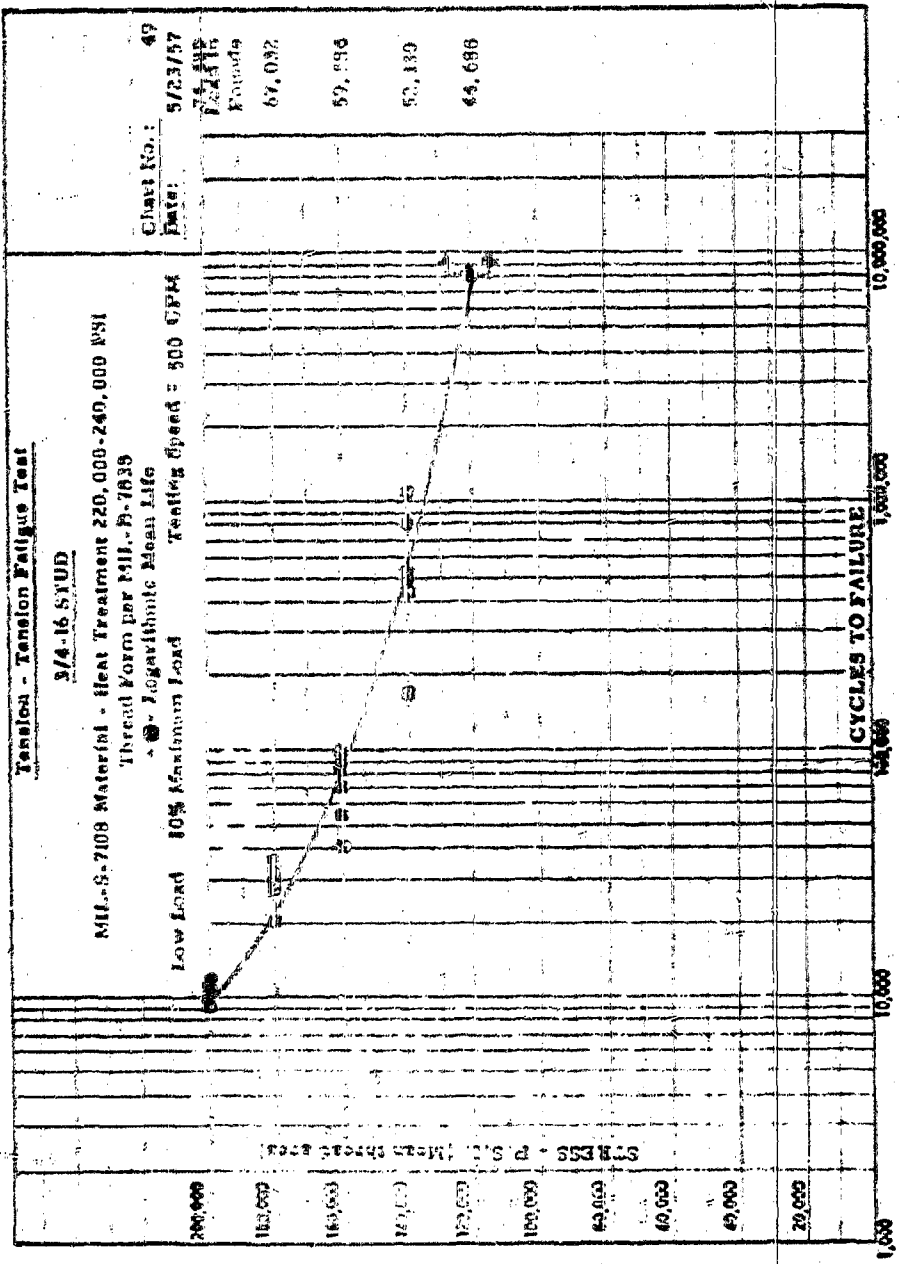
MIL-S-708 Material - Heat Treatment 220,000-240,000 PSI

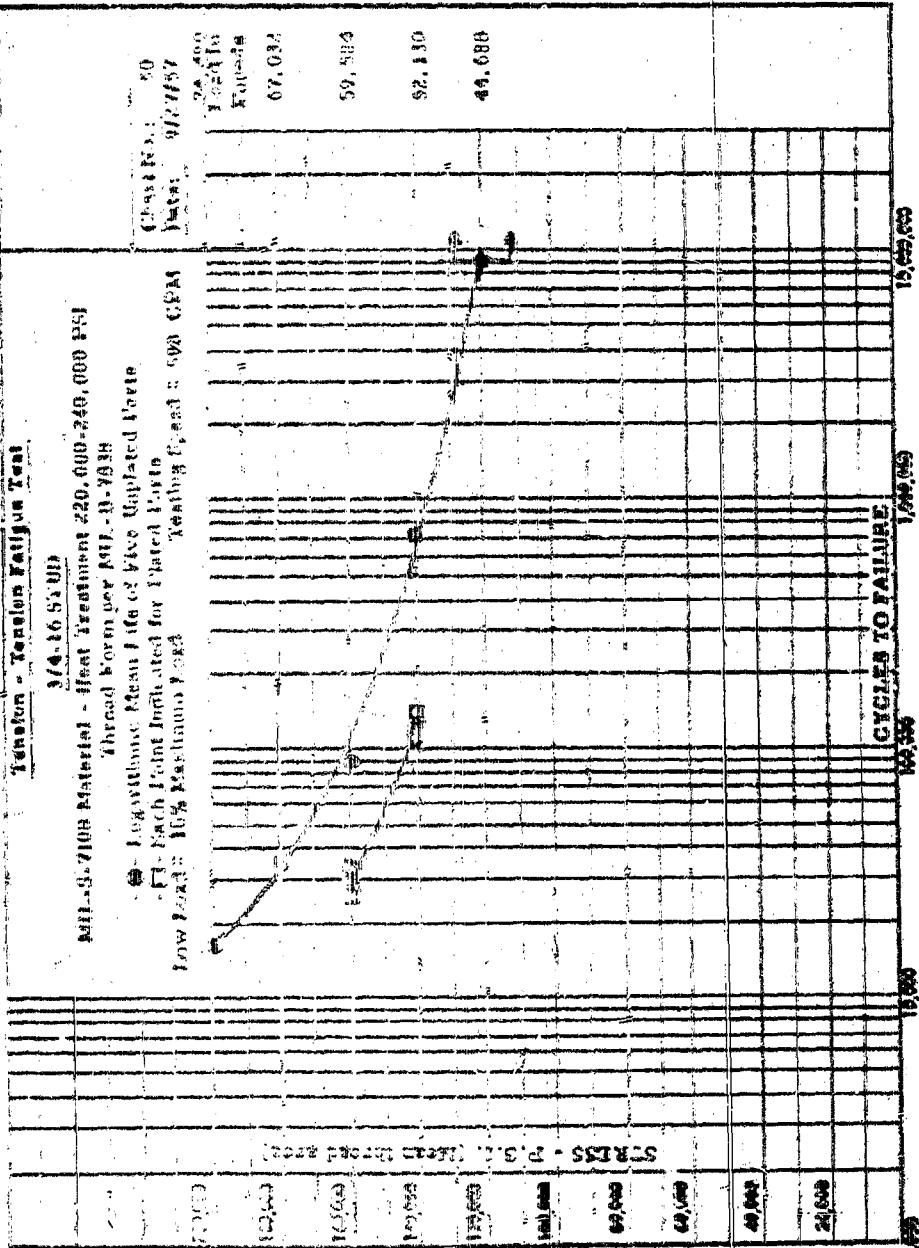
Thread Form per MIL-B-7039

• 9 - Logarithmic Mean Life

Low Load 10% Minimum Load Testing Speed = 500 CPM

Chart No.: 49
Date: 5/23/57





TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 5-28-67

Bolt Design	Stud
Size	3/4-16
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	MIL-D-7838
Plate	None

Stress Area .3724 Square inches

Nut Type	Unengaged
Style	
Material	
Heat Treatment	

Testing Machine	
Make	Amesley
Capacity	220,000 pound
Speed	500 cpm

Maximum Load	74,480#	67,042#	59,694#	
Stress	200,000 psi	180,000 psi	160,000 psi	
	9,600	20,500	54,900	20,200
	10,400	31,500	80,800	23,100
	9,500	36,400	40,500	23,600
	10,300	32,000	96,200	25,000
	10,100	28,400	82,600	28,700
Average	10,020	29,740	72,600	24,200
Logarithmic Mean Life	9,970	29,200	69,040	24,140

Maximum Load	52,136#	44,688#	
Stress	140,000 psi	120,000 psi	
	Unplated	Plated	
	1,175,900	40,900	8,046,000 NF
	521,200	57,200	8,046,000 NF
	172,000	63,100	
	444,000	90,400	
	823,100		
Average	627,220	62,900	8,046,000
Logarithmic Mean Life	521,400	60,440	8,046,000

3
Area
7

	42,500	
	160,000 psi	
Repl. test	Plated	
53,900	20,200	
82,000	24,100	
43,500	24,400	
91,200	25,000	
82,600	28,700	
71,600	24,200	
64,040	24,430	
46,688*		
± 20,000 psi		
0,046,000 Nf		
0,046,000 Nf		
0,046,000		
0,046,000		

MECHANICAL PROPERTIES

Date May 28, 1957 For Chart No. 49

Bolt Description

Type
Size
Material

Stud
3/4-16 MIL-B Thread
MIL-S-7108

Bolt Strength Pounds

Specimen 1 Specimen 2

Ultimate Tensile
Yield Strength

Material Strength PSI

50% Gage Specimen

Tensile Strength

250,000

247,500

Yield Strength

220,000

215,000

Elongation - 5 in 4 Diameter

50% Gage Specimen

13.0

15.0

Reduction of Area - 5

50% Gage Specimen

47.2

45.1

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength 1/2 B; 000,000
Cycles 10% Low Load

Pounds
PSI (Mean Area)

44,688
120,000

Lot No.

78

MECHANICAL PROPERTIES

Date May 28, 1957

For Chart No. 49

Bolt Description

Type
Size
Material

Stud
3/4-16 MIL-B Thread
MIL-S-7108

Bolt Strength Pounds

Ultimate Tensile
Yield Strength

Specimen 1

Specimen 2

Material Strength PSI

.505 Gage Specimen

Tensile Strength

250,000

237,500

Yield Strength

220,000

212,000

elongation - 4 in. Diameter

.505 Gage Specimen

15.0

15.0

Reduction of Area - 5

.505 Gage Specimen

47.2

46.1

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength 616,000,000

Cycles 10% Low Load

Pounds

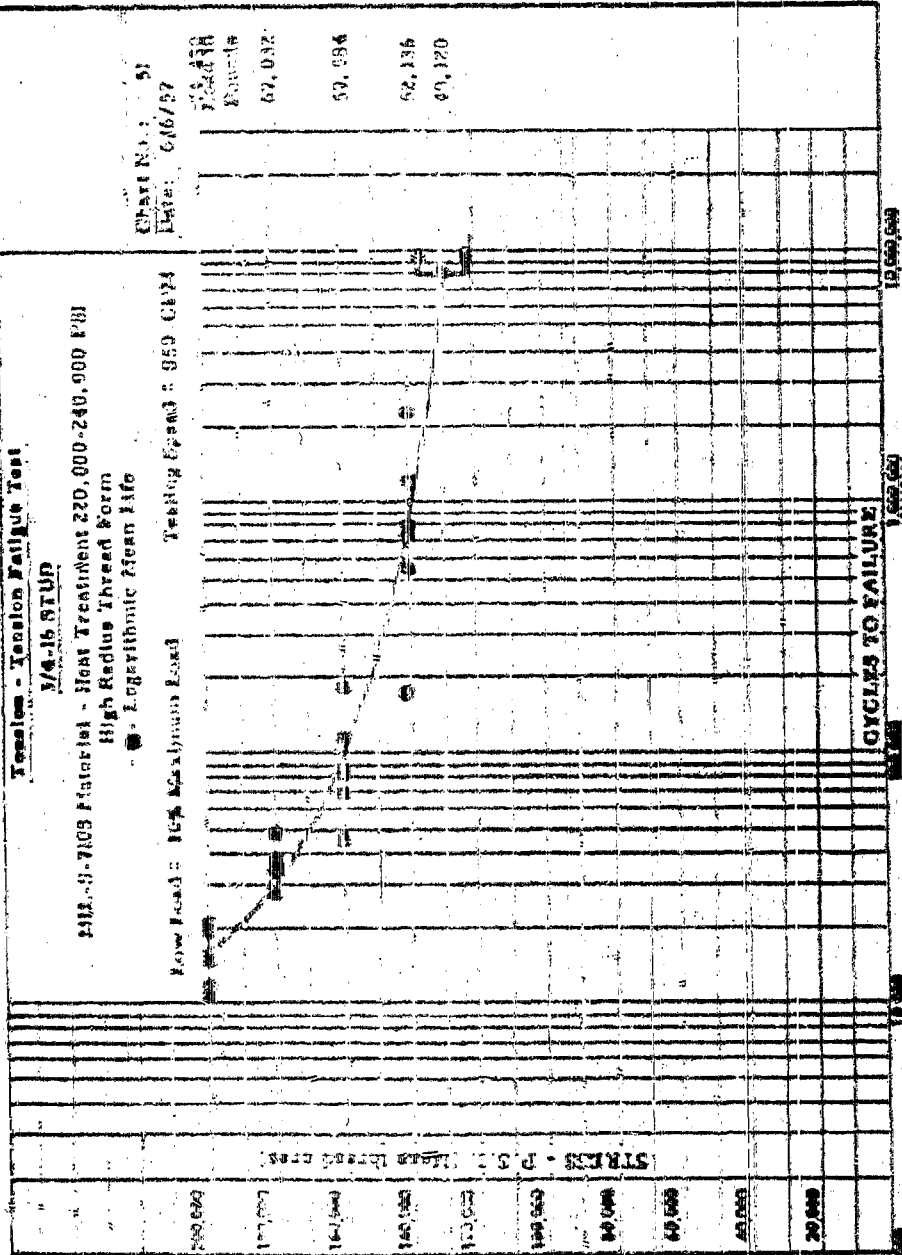
46,698

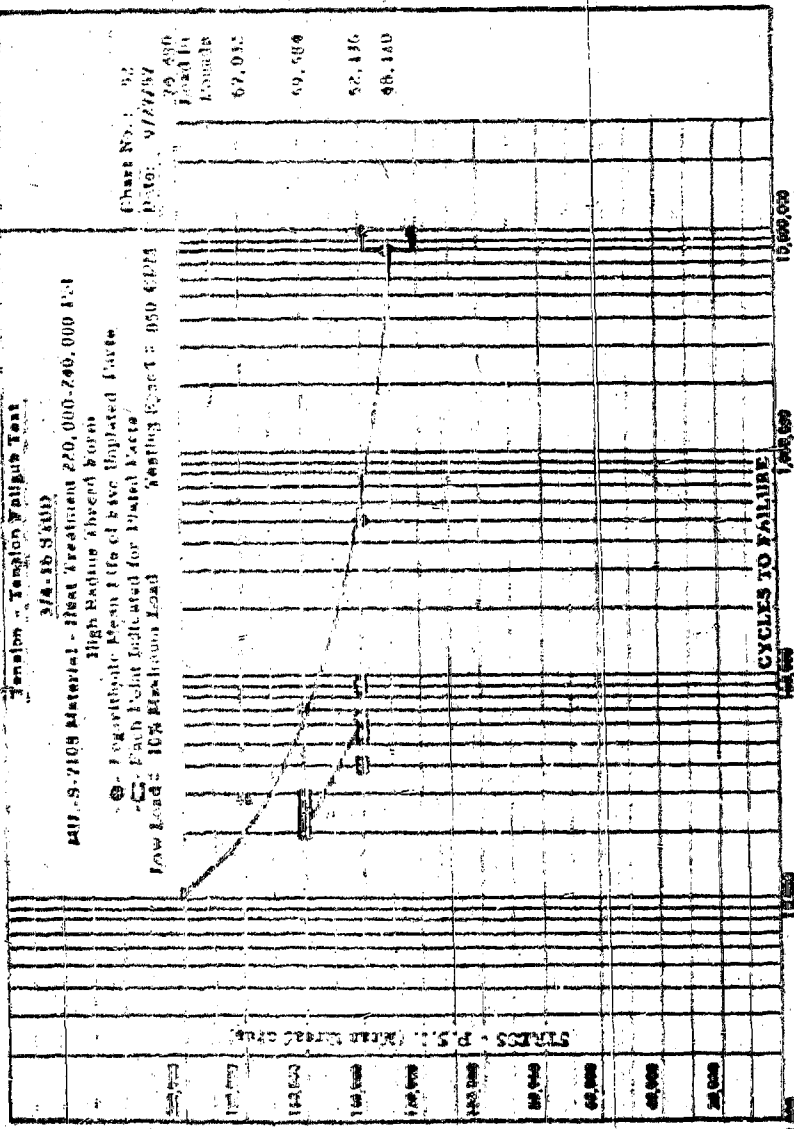
PSI (Mean Area)

120,000

Lot No.

78





TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 6-6-57

Bolt Design	Stud
Size	3/4-16
Material	MIL-S-7108
Heat Treatment	220,000-240,000 psi
Thread Form	High Radius
Plate	None

Stress Area	0.3724 square inches
-------------	----------------------

Not Type	Unpackaged
Style	
Material	
Heat Treatment	

Testing Machine	Krupp
Make	
Capacity	60,000 pounds
Speed	850 rpm

Maximum Load	73,400#	67,072#	57,564#	
Stress	200,000 psi	180,000 psi	150,000 psi	
	11,200	49,900	Unplated	Plated
	11,300	39,500	180,600	20,200
	29,600	27,100	85,600	23,100
	21,000	36,300	46,800	23,600
	15,200	30,200	69,700	25,800
	15,860	36,400	111,300	28,700
Average			98,800	24,280
Logarithmic Mean Life	15,280	35,590	89,890	24,140

Maximum Load	52,136#	48,120#	
Stress	140,000 psi	130,000 psi	
	Unplated	Plated	
	2,313,000	40,900	8,043,000 NF
	168,000	57,280	8,943,000 NF
	1,340,000(Body)	63,100	
	785,000	90,400	
	562,700		
Average	1,033,600	62,900	8,043,000
Logarithmic Mean Life	745,300	60,440	8,043,000

MECHANICAL PROPERTIES

Date May 28, 1957

For Chart No. 51 and 52

Bolt Description

Type
Size
Material

Stud
3/4-16 High Radius
MIL-S-7108

Bolt Strength Pounds

Specimen 1 Specimen 2

Ultimate Tensile
Yield Strength

Material Strength PSI

.505 Gage Specimen
Tensile Strength
Yield Strength

250,000 237,500
220,000 212,000

Elongation - 5 in 4 Diameter

.505 Gage Specimen

14.0 15.0

Reduction of Area - %

.505 Gage Specimen

49.2 45.1

Shear Strength - Bolt Body

Pounds - Double Shear
PSI

Fatigue Strength @ 8,000,000
Cycles 10% Low Load

Pounds
PSI (Mean Area)

48,420
130,000

Lot No.

49

Tension - Tension Fatigue Test

3/9-16 STUN

MIL-S-7108 Material - Heat Treatment 220,000-240,000 PSI

• - Logarithmic Mean Life of Rolled MIL-B Thread Form

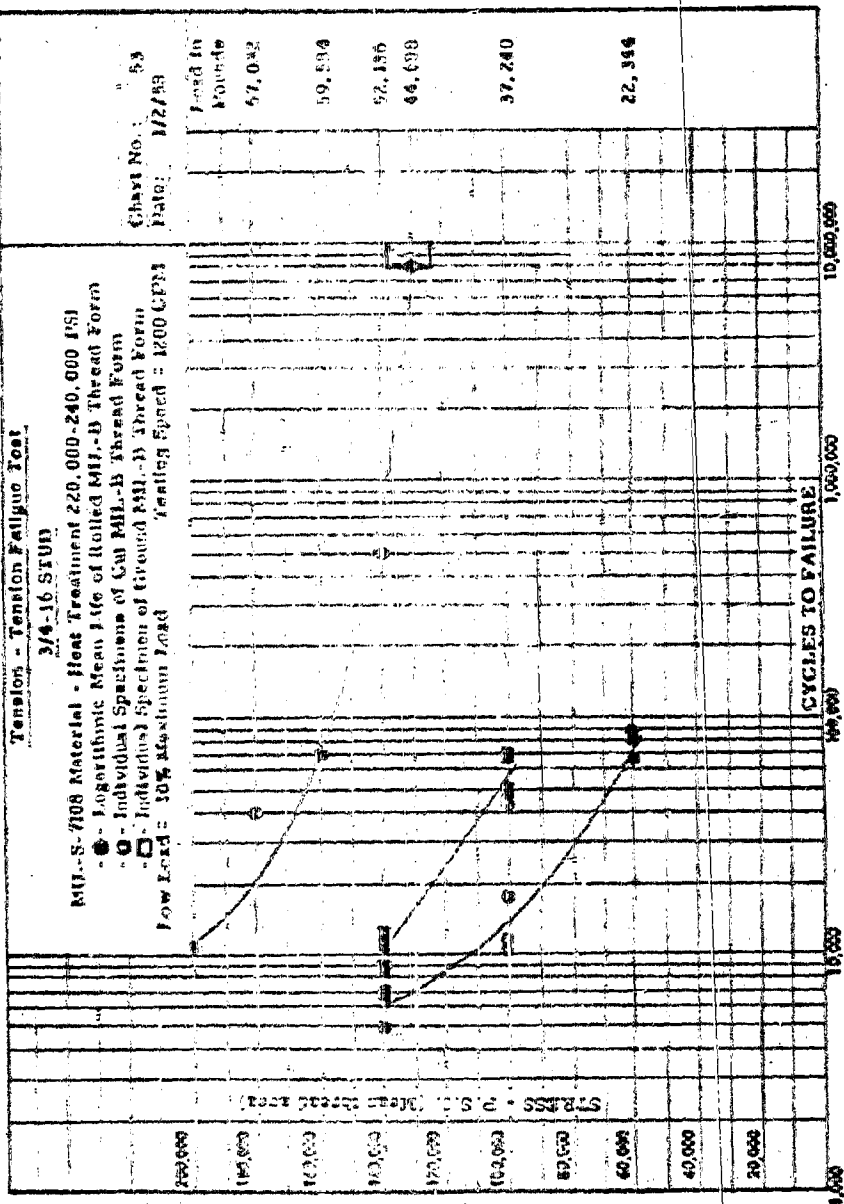
• - Individual Specimens of Cut MIL-B Thread Form

• - Individual Specimens of Ground MIL-B Thread Form

Low Load = 10% Maximum Load

Testing Speed = 1200 CPN

Chart No. 53
Date: 1/2/53



TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 1-2-58

Bolt Design	Stud	Stud
Size	3/4-16	3/4-16
Material	MIL-S-7108	MIL-S-7108
Heat Treatment	220,000-240,000 psi	220,000-240,000 psi
Thread Form	Cut UNF 3A	Ground MIL-B
Plate	None	None

Stress Area .3724 Square Inches

Nut Type	Unengaged	Unengaged
Style		
Material		
Heat Treatment		

Testing Machine		
Make	Ivy	Ivy
Capacity	60,000 pound	60,000 pound
Speed	1200 rpm	1200 rpm
	Cut Thread	Ground Thread

Load	53,136#	52,136#
Stress	140,000 psi	140,000 psi
	5,000	9,000
	7,000	11,000
	7,000	11,000
	7,000	12,000

Load	37,240#	37,240#
Stress	100,000 psi	100,000 psi
	11,000	44,000
	11,000	47,000
	17,000	49,000
		71,000

Load	22,344#
Stress	60,000 psi
	70,000
	84,000
	88,000

MECHANICAL PROPERTIES

Date December 28, 1957

For Char. No. 53

Bolt Description

Cut Thread

Ground Thread

Type

Stud

Stud

Size

3/4-16

3/4-16

Material

MIL-S-710H

MIL-S-710H

Bolt Strength Pounds

Specimen 1

Specimen 2

Specimen 1

Specimen 2

Ultimate Tensile

Yield Strength

Material Strength Psi

50% Gage Specimen

Tensile Strength

251,500

237,500

233,000

232,800

Yield Strength

200,000

200,000

191,000

191,000

Elongation - 5 in 2 Diameter

50% Gage Specimen

10.0

12.0

12.0

11.0

Reduction of Area - %

50% Gage Specimen

46.3

47.5

49.5

48.3

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

PSI (Mean Area)

Lot No.

527

571

Tension - Tensile Fatigue Test

12-18 STUD

2417-S-7109 Material - Heat Treatment 220,000-240,000 PSI

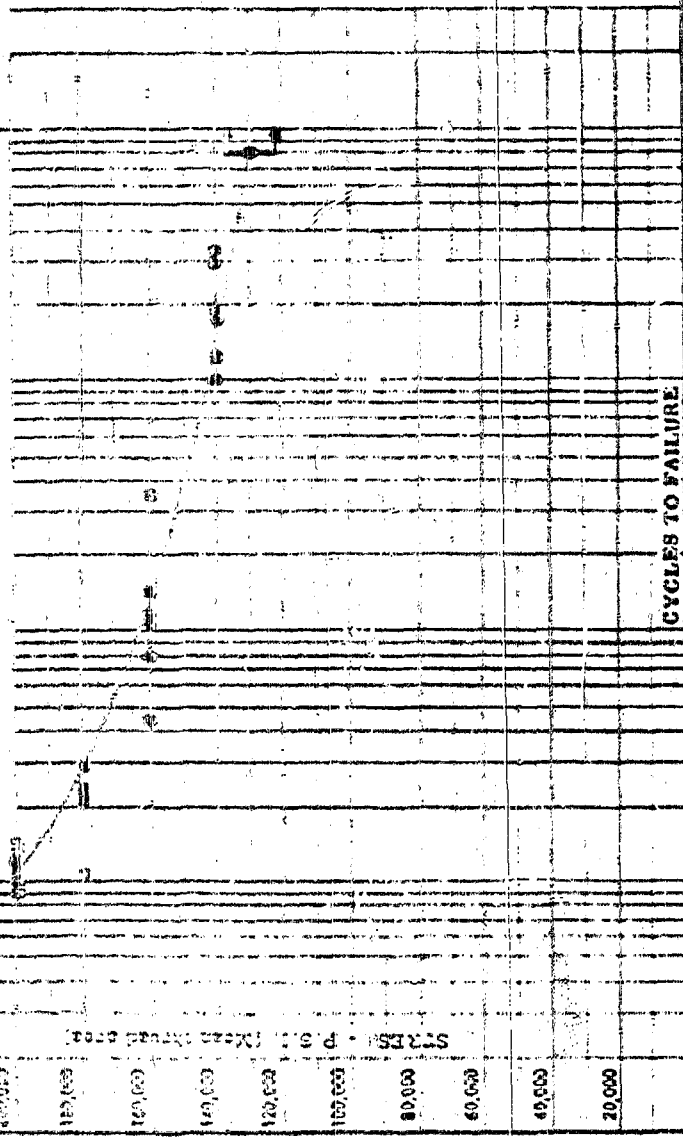
Thread Turns per Rev - 3-7/8

• 2 - Logarithmic Mean Life

Low Load - 10% Machine Load Testing Speed - 500 RPM

Chart No. 54
Date: 12/10/57

382,830
100%
100%
127,236
108,656
95,074
99,283



CYCLES TO FAILURE

10,000 100,000 1,000,000

TENSION - TENSION FATIGUE TEST RESULTS

10% Preload - Stress Calculated on Tensile Stress Area

Date: 12-16-57

Bolt Design
Size
Material
Heat Treatment
Thread Form
Plate

Stud
1"-14
A514-S-7108
220,000-240,000 psi
MIL-B-7838
none

Stress Area

.6791 Square inches

Nut Type
Style
Material
Heat Treatment

None

Testing Machine

Make
Capacity
Speed

Amstor
220,000 pound
500 rpm

Maximum Load
Stress

135,0200	122,2300	103,6560
200,000 psi	180,000 psi	160,000 psi

9,000	11,000	44,800
10,000	21,000	80,900
11,400	24,000	105,000
13,000	30,000	136,000
15,000	32,000	365,000
11,720	23,600	146,340

Average

Logarithmic Mean Life

11,520	22,140	313,600
--------	--------	---------

Maximum Load
Stress

95,0749	88,2830
140,000 psi	130,000 psi

973,000	8,000,000 MP
1,413,300	8,000,000 MP

1,833,000
3,149,700
3,561,000

Average

2,186,000	8,000,000
-----------	-----------

Logarithmic Mean Life

1,951,000	8,000,000
-----------	-----------

MECHANICAL PROPERTIES

Date December 9, 1957

For Chart No. 54

Bolt Description

Type

Stud

Size

1"-14

Material

Hy. Tol.

Bolt Strength Pounds

Ultimate Tensile

Specimen 1

Specimen 2

Yield Strength

Material Strength PSI

.505 Gage Specimen

Tensile Strength

227,500

222,500

Yield Strength

194,300

195,700

Elongation - % in 4 diameter

.505 Gage Specimen

11.3

11.3

Reduction of Area - %

.505 Gage Specimen

47.7

47.7

Shear Strength - Bolt Body

Pounds - Double Shear

PSI

Fatigue Strength @ 8,000,000

Cycles 10% Low Load

Pounds

PSI (Mean Area)

88,283

Lot No.

244