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DESIGN ALLOWABLES FOR TITANIUM ALLOYS

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A. W. Sommer
G. R. Martin

North American Rockwell Corporation

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FOREWORD

This report was prepared by North American Rockwell Corporation, Los Angeles Division, under USAF Contract No. AF 33(615)-3979. The contract was initiated under Project No. 7381, "Materials' Application". Task No. 738106, "Engineering and Design Data". The work was administered under the direction of the Air Force Materials Laboratory, Wright-Patterson Air Force, Ohio, by Mr. C. L. Harmsworth, Project Engineer.

Dr. A. W. Sommer of the NR/LAD Research and Engineering Division, Materials and Producibility Laboratory was the Program Manager. Mr. G. R. Martin was the Project Engineer. Others who cooperated in the research and in the preparation of the report were F. Wermuth, M. Harrigan, G. Keller, and R. Lorenz, Statistics.

This report covers work conducted from May 1969. The contractor's report number is NA 69-350.

The report was submitted by the author in May 1969.

This technical report has been reviewed and is approved.

A. OLEVITCH
Chief, Materials Engineering Branch
Materials Support Division
Air Force Materials Laboratory

ABSTRACT

The purpose of this program was to develop design information on four titanium alloys for inclusion into Military Handbook-5. The alloys investigated were Ti-6Al-4V Condition STA, Ti-4Al-3Mo-1V Annealed Condition, Ti-13V-11Cr-3Al Annealed Condition, and Ti-6Al-6V-2Sn Annealed Condition and Condition STA.

The mechanical properties investigated were tensile, compression, shear, bearing, fracture toughness and fatigue. The general results obtained are presented in Section VII of this report and the data generated for Military Handbook-5 are presented in Section VIII.

This abstract has been approved for public release and sale; its distribution is unlimited.

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SECTION I

INTRODUCTION

1.1 PURPOSE OF THE PROGRAM

The program objective was to support the development of MIL-HDBK-5 data on titanium alloys by conducting a mechanical property design data program for four selected titanium alloys. The alloys evaluated are:

1. Ti-4Al-3Mo-1V Cond. A - Sheet
2. Ti-13V-11Cr-3Al Cond. A - Sheet
3. Ti-6Al-4V Cond. STA - Plate
4. Ti-6Al-6V-2Sn Cond. A and STA - Plate

The mechanical property tests performed were tension, compression, bearing, shear, and thermal stability at temperatures from ambient to 800F in conjunction with fracture toughness and fatigue tests at room temperature. The data generated was compared with data obtained by means of a literature search.

1.2 BACKGROUND

MIL-HDBK-5 has long been accepted by the DOD and the FAA as the appropriate source of design allowables on structural materials. In order to establish and maintain an acceptable level of confidence in the handbook the MIL-HDBK-5 Supervisory Committee has imposed certain reliability criteria on the data and their analysis. These include a general requirement for at least ten heats or lots of each material condition from three or more (if possible) producers. A minimum total of 100 tests should go into the establishment of each allowable value. Consequently, the only properties that are genuinely established as "A" and "B" value (statistically reliable allowables) are F_{tu} and F_{ty} at room temperature. The remaining properties such as compression, bearing, and shear, if they are included, are usually derived using ratioing techniques. Elevated temperature properties may also be derived. It is the purpose of this program to obtain these data on several titanium alloys using information from producers, users, data information centers and a test program. The alloys were selected as a result of a review of gaps in MIL Hdbk-5 data and based on requests for data received by the Department of Defense Information Centers.

Section II

TEST MATERIALS

Contained within this section are; (1) material procurement specification requirements, (2) vendor certifications (3) thermal processing history, (4) metallography (5) mechanical properties to be determined, and (6) test conditions for all the materials utilized in this investigation.

2.1 Discussion:

The material data contained herein, identifies the source and provides the chemistry, heat treat condition, and material thickness for all the material used in the subject program. Each material is listed with the applicable vendor heat number, chemical composition, and the results of the supplier's tensile tests as obtained from the vendor certifications. All material utilized under this program sponsorship was procured to MIL-T-9046 requirements with all thermal processing adhering to the requirements of MIL-H-81200.

A brief summary of the materials, source and number of heats is listed below:

Material	Source	Number of Heats
Ti-4Al-3Mo-1V Cond. A	TMCA	5
	RMI	1
Ti-13V-11Cr-3Al Cond. ST	TMCA	5
Ti-6Al-4V Cond. STA	TMCA	5
	RMI	3
Ti-6Al-6V-2Sn Cond. A and STA	TMCA	15

In addition to the data obtained from the test program, data has also been incorporated from North American's Engineering and Quality Control Laboratories and test reports from the following vendors and users:

Titanium Metals Corporation of America
NASA - Langley
DMIC Data Sheets (Battelle Memorial Institute)
The Boeing Company
Reactive Metals, Incorporated

2.2 Material Certification

The following pages present the test material procurement specification requirements along with the vendor certifications sent with the test material. One heat of Ti 4Al-3Mo-1V Condition A was received without an attached certification. Efforts to obtain this certification proved unsuccessful.

2.2.1 Material: Ti 4Al-3Mo-1V Cond A (Specification requirements)

Specification MIL-T-9046 Type III Sheet, Strip and Plate

SPECIFICATION MINIMUM PROPERTIES (KSI)	
Tensile Strength	125
Yield Strength 0.2% Offset	115
Elongation %	10

SPECIFICATION CHEMICAL LIMITS

C (Max.)	Fe (Max)	N	Al	V	Cr	Mo	H	Zr	Sn	Mn	O_2 (Max)	Ti	Total Other Elements (Max.)
0.08	0.30	0.05	5.5 6.75	3.5 4.5	—	—	0.015	—	—	—	0.20	Bal	0.40

2.2.1 (continued)

MATERIAL: Ti 4Al-3Mo-1V Cond. A

VENDOR HEAT NUMBER: G-1595 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.023	VANADIUM	1.1
IRON	0.09	MOLYBDENUM	3.3
NITROGEN	0.008	HYDROGEN	0.012
ALUMINUM	4.6	OXYGEN	0.10

HEAT TREAT CONDITION: Annealed Per MIL-H-81200

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
F-8649	Room	Annealed	0.034	Long.	134.7	123.5	12.5
				Trans.	139.8	128.3	12.0

2.2.1 (continued)

MATERIAL: Ti-4AL-3Mo-1V Cond. A

VENDOR HEAT NUMBER: G-895 (TMCA)

MR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.023	VANADIUM	1.1
IRON	0.09	MOLYBDENUM	3.2
NITROGEN	0.014	HYDROGEN	0.008
ALUMINUM	4.5	OXYGEN	0.11

HEAT TREAT CONDITION: Annealed Per MIL-H-81200

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
J-0679	Room	Annealed	0.055	Long.	133.0	124.1	14.0
				Trans.	137.3	131.8	10.5

2.2.1 (continued)

MATERIAL: Ti-4Al-3Mo-1V Cond. A

VENDOR HEAT NUMBER: G-2446

NR/LAD IDENTIFICATION: Heat 3

CHEMICAL COMPOSITION:

CARBON	0.022	**VANADIUM**	1.1
IRON	0.06	**MOLYBDENUM**	3.2
NITROGEN	0.007	**HYDROGEN**	0.009
ALUMINUM	4.3	**OXYGEN**	0.10

HEAT TREAT CONDITION: Annealed Per MIL-H-81200

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
J-0678	Room	Annealed	0.063	Long.	131.9	123.8	15.5
				Trans.	136.5	130.8	12.0

2.2.1 (continued)

MATERIAL: Ti-4Al-3Mo-1V Cond. A

VENDOR HEAT NUMBER: G-1523 (TMCA)

Heat 4

NR/LAD IDENTIFICATION:

CHEMICAL COMPOSITION:

CARBON	0.025	**VANADIUM**	1.0
IRON	0.09	**MOLYBDENUM**	3.3
NITROGEN	0.010	**HYDROGEN**	0.012
ALUMINUM	4.4	**OXYGEN**	0.12

HEAT TREAT CONDITION: Annealed Per MIL-H-81200

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
F-7737	Room	Annealed	0.051	Long.	134.8	118.0	13.5
				Trans.	136.2	122.6	14.0

2.2.1 (continued)

MATERIAL: Ti-4Al-3Mo-1V Cond. A

VENDOR HEAT NUMBER: G-1401 (TMCA)

MR/LAD IDENTIFICATION: Heat 5

CHEMICAL COMPOSITION:

CARBON	0.025	VANADIUM	1.2
IRON	0.09	MOLYBDENUM	3.3
NITROGEN	0.011	HYDROGEN	0.005
ALUMINUM	4.3	OXYGEN	0.12

HEAT TREAT CONDITION: Annealed Per MIL-H-81200

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
F-7786	Room	Annealed	0.067	L	131.0	121.8	11.5
				T	140.4	136.0	13.5

2.2.1 (continued)

MATERIAL: Ti-4Al-3Mo-1V Cond. A

VENDOR HEAT NUMBER: 321055 (RMI)

NR/LAD IDENTIFICATION: Heat 6

CHEMICAL COMPOSITION:

CARBON	0.015	VANADIUM	0.91
IRON	0.19	MOLYBDENUM	3.27
NITROGEN	0.004	HYDROGEN	62 PPM
ALUMINUM	3.80	OXYGEN	0.091

HEAT TREAT CONDITION: Annealed Per MIL-H-81200

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
-	RT	A	0.110	L	131.5	124.8	13.0
				T	138.8	136.0	14.0

Note: Above tests performed by North American Rockwell, Los Angeles Division

2.2.2 Material: Ti 13V-11Cr-3Al Cond A or ST (Specification Requirements)

Specification MIL-T-9046 Sheet, Strip and Plate
Type IV

SPECIFICATION MINIMUM PROPERTIES (KSI)		
	0.050 Gage	Other 0.050 Gage
Tensile Strength	132	125
Yield Strength 0.2% Offset	126	120 (Min)
Elongation %	8.0	10.

SPECIFICATION CHEMICAL LIMITS													
C (Max)	Fe (Max)	N	Al	V	Cr	Mo	H	Zr	Sn	Mn	O_2 (Max)	Ti	Total Other Elements (Max.)
0.05	0.15 0.30	0.05	2.5 3.5	12.5 14.5	10 12	—	0.025	—	—	—	0.20	Bal.	0.40

2.2.2 (continued)

MATERIAL: Ti-13V-11Cr-3Al

VENDOR HEAT NUMBER: D-7855 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.017	**VANADIUM**	13.7
IRON	0.15	**CHROMIUM**	10.9
NITROGEN	0.030	**HYDROGEN**	0.010
ALUMINUM	3.1	**OXYGEN**	0.13

HEAT TREAT CONDITION: Solution Treated

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
F-2102	Room	ST	0.040	Long.	136.8	128.4	18.0
				Trans	141.7	132.7	9.5
	Room	STA(1)		Long.	194.1	176.3	7.0
				Trans	208.5	192.7	4.5

Lab Aged 24 Hours at 900°F

2.2.2 (continued)

MATERIAL: Ti-13V-11Cr-3Al

VENDOR HEAT NUMBER: D-7770 (TMCA)

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.017	VANADIUM	13.6
IRON	0.16	CHROMIUM	10.8
NITROGEN	0.028	HYDROGEN	0.023
ALUMINUM	3.1	OXYGEN	0.12

HEAT TREAT CONDITION: Solution Treated

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
F-1951	Room	ST	0.038	Long.	134.4	129.0	18.5
				Trans.	140.9	136.8	14.0
	Room	ST(1)		Long.	193.5	175.2	6.0
				Trans.	205.0	188.9	5.0

(1) Lab Aged 24 Hrs. at 900°F

2.2.2 (continued)

MATERIAL: Ti-13V-11Cr-3Al

VENDOR HEAT NUMBER: D-7107 (TMCA)

NR/LAD IDENTIFICATION: Heat 3

CHEMICAL COMPOSITION:

CARBON	0.028	VANADIUM	13.5
IRON	0.16	CHROMIUM	10.8
NITROGEN	.022	HYDROGEN	0.004
ALUMINUM	3.0	OXYGEN	0.14

HEAT TREAT CONDITION: Solution Treated

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
T-0342	Room	ST	0.035	Long.	136.9	133.7	21.0
				Trans.	140.3	135.7	17.0
		STA(1)		Long.	193.2	175.9	9.5
				Trans.	200.1	184.1	7.0

(1) Lab Aged 24 Hrs. at 900°F

2.2.2 (continued)

MATERIAL: Ti-13V-11Cr-3Al

VENDOR HEAT NUMBER: D-7639 (TMCA)

NR/LAD IDENTIFICATION: Heat 4

CHEMICAL COMPOSITION:

CARBON	0.023	**VANADIUM**	13.7
IRON	0.17	**CHROMIUM**	10.6
NITROGEN	0.025	**HYDROGEN**	0.015
ALUMINUM	3.1	**OXYGEN**	0.12

HEAT TREAT CONDITION: Solution Treated

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
C-9887	Room	ST	0.038	Long.	139.7	135.1	16.0
				Trans.	144.6	139.2	13.0
		STA(1)		Long.	197.9	179.1	7.5
				Trans.	208.9	191.4	5.5

(1) Lab Aged 24 Hrs. at 900°F

2.2.2 (continued)

MATERIAL: Ti-13V-11Cr-3Al

VENDOR HEAT NUMBER: D-7110 (TMCA)

NR/LAD IDENTIFICATION: Heat 5

CHEMICAL COMPOSITION:

CARBON	0.027	**VANADIUM**	13.7
IRON	0.16	**CHROMIUM**	10.8
NITROGEN	0.026	**HYDROGEN**	0.003
ALUMINUM	3.0	**OXYGEN**	0.12

HEAT TREAT CONDITION: Solution Treated

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
T-0294	Room	ST	0.037	Long.	133.6	130.7	22.5
				Trans.	138.1	135.9	17.5
		STA(1)		Long.	180.1	164.1	9.0
				Trans.	179.8	165.7	6.5

(1) Lab Aged 24 Hrs. at 900°F

2.2.3 Material: Ti 6Al-4V Cond STA (Specification Requirements)

Specification MIL-T-9046 Sheet, Strip, and Plate
Type III Comp C

SPECIFICATION MINIMUM PROPERTIES (KSI)				
	≥ 1/4" to 1/2"	≥ 1/2" to 3/4"	3/4" to 1"	1" to 1-1/2"
Tensile Strength (Min)	160	160	150	145
Yield Strength (Min) 0.2% Offset	145	145	140	135
Elongation %	8	8	6	6

SPECIFICATION CHEMICAL LIMITS													
C (Max)	Fe (Max)	N	Al	V	Cr	Mo	H	Zr	Sn	Mn	O_2 (Max)	Ti	Total Other Elements (Max)
0.08	0.30	0.05	5.5 6.75	3.5 4.5	—	—	0.015	—	—	—	0.20	Bal.	0.40

2.2.3 (continued)

MATERIAL: Ti-6Al-4V

VENDOR HEAT NUMBER: HT G 4956 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.025	**VANADIUM**	4.1
IRON	0.10	**HYDROGEN**	0.009
NITROGEN	0.010	**OXYGEN**	0.10
ALUMINUM	6.0		

HEAT TREAT CONDITION: Solution Treated and Aged to MIL-T-9046E Type 3 Comp C

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
J-3183	RT	STA	0.250	L	166.6	153.0	8.5
				T	183.2	171.8	8.0

2.2.3 (continued)

MATERIAL: Ti-6Al-4V

VENDOR HEAT NUMBER: HT G-4796 (TMCA)

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.026	VANADIUM	4.2
IRON	0.15	HYDROGEN	0.005
NITROGEN	0.015	OXYGEN	0.14
ALUMINUM	6.4		

HEAT TREAT CONDITION: Solution Treated and Aged to MIL-T-9046E
Type 3 Comp C 1700°F 1/4 Hr - W.Q.
Aged 4 hours - 1000°F A.C.

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
J-4376	RT	STA	0.250	L	176.0	164.0	9.0
				T	180.2	174.3	10.5

2.2.3 (continued)

MATERIAL: Ti-6AL-4V

VENDOR HEAT NUMBER: HT X-53788 (RMI)

NR/LAD IDENTIFICATION: Heat 6

CHEMICAL COMPOSITION:

CARBON	0.03	VANADIUM	4.2
IRON	0.16	HYDROGEN	72 ppm
NITROGEN	0.011	OXYGEN	0.107
ALUMINUM	6.1		

HEAT TREAT CONDITION: Prod. Solution Treated 1725°F for 10 minutes W. Q. Aged 1000°F for 4 Hrs. and Air Cooled

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
	RT	STA	0.250	L	168.0	156.0	8.0
				T	168.0	151.0	8.0

2.2.3 (continued)

MATERIAL: Ti-6Al-4V

VENDOR HEAT NUMBER HT G-6539 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.024	VANADIUM	4.2
IRON	0.16	HYDROGEN	0.005
NITROGEN	0.008	OXYGEN	0.19
ALUMINUM	6.2		

HEAT TREAT CONDITION: Solution Treated and Aged to MIL-T-9046E Type 3 Comp C

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.	% Red. Area
J-3855	RT	STA	0.500	L	171.1	158.1	19.0	41.2
				T	168.1	155.2	16.5	42.6

2.2.3 (continued)

MATERIAL: Ti- 6Al-4V

VENDOR HEAT NUMBER HT G-7278 (TMCA)

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.025	VANADIUM	4.2
IRON	0.17	HYDROGEN	0.005
NITROGEN	0.009	OXYGEN	0.20
ALUMINUM	6.4		

HEAT TREAT CONDITION: Solution Treated and Aged to MIL-T-9046E Type 3 Comp C

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.	% Red. Area
J-5801	RT	STA	0.500	L	175.5	163.3	15.0	39.5
				T	182.2	172.4	14.0	36.8

2.2.3 (continued)

MATERIAL: Ti-6Al-4V

VENDOR HEAT NUMBER HT 302634 (RMI)

NR/LAD IDENTIFICATION: Heat 7

CHEMICAL COMPOSITION:

CARBON	0.02	VANADIUM	4.3
IRON	0.12	HYDROGEN	42 ppm
NITROGEN	0.013	OXYGEN	0.168
ALUMINUM	6.4		

HEAT TREAT CONDITION: Prod. Solution Treated 1725°F for 10 minutes W.Q. Lab Aged 1000°F for 4 Hours Air Cooled.

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
	RT	STA	0.475	L	170.0	153.0	7.0
				T	173.0	162.0	9.0

2.2.3 (continued)

MATERIAL: Ti-6Al-4V

VENDOR HEAT NUMBER HT G-7021 (TMCA)

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.022	**VANADIUM**	4.2
IRON	0.18	**HYDROGEN**	0.004
NITROGEN	0.12	**OXYGEN**	0.17
ALUMINUM	6.3		

HEAT TREAT CONDITION: Solution Treated and Aged to MIL-T-9046E Type 3 Comp C 1675°F, 15 Min. - W.Q. Age 4 Hours 1000°F A.C.

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
J-4821	RT	STA	1.000	L	168.5	155.0	14.5
				T	176.8	165.9	17.0

2.2.3 (continued)

MATERIAL: Ti-6Al-4V

VENDOR HEAT NUMBER HT 293504 (RMI)

MR/LAD IDENTIFICATION: Heat 6

CHEMICAL COMPOSITION:

CARBON	0.03	VANADIUM	4.4
IRON	0.08	HYDROGEN	30 ppm
NITROGEN	0.010	OXYGEN	0.160
ALUMINUM	6.4		

HEAT TREAT CONDITION:

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2% Yield Strength Ksi	% Elong.
	RT	STA	1.025	L	150.0/ 161.0	143.0/ 148.0	12.0/ 14.0
				T	145.0/ 161.0	143.0/ 148.0	11.0/ 15.0

2.2.4 Material: Ti 6Al-6V-2Sn Cond A and STA (Specification Requirements)

Specification MIL-T-9046 Type III Comp E — Sheet, Strip and Plate

SPECIFICATION MINIMUM PROPERTIES (KSI)			
	Annealed	STA To 1-1/2" Thick	STA 1-1/2" to 2" Thick
Tensile Strength (Min)	155	170	160
Yield Strength (Min) 0.2% Offset	145	160	150
Elongation %	(Long) 10 (Trans) 8	8	6

SPECIFICATION CHEMICAL LIMITS

C (Max)	Fe (Max)	N	Al	V	Cr	Mo	H	Zr	Sn	Mn	O_2 (Max)	Ti	Total Other Elements (Max)
0.05	0.35	0.05	5.0	5.0	—	—	0.015	—	1.5	—	0.20	Bal	0.30
	1.00		6.0	6.0					2.5				

2.2.4 (continued)

MATERIAL: Ti- 6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3104 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.011	HYDROGEN	0.006
IRON	0.73	TIN	2.1
NITROGEN	0.016	COPPER	0.61
ALUMINUM	5.6	OXYGEN	0.16
VANADIUM	5.7		

HEAT TREAT CONDITION: Annealed - Anneal Temp.
1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0411	Room	Annealed	0.340	L	155.0	148.4	15.0
				T	166.8	161.5	18.0

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3212 (TMCA)

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.024	HYDROGEN	0.007
IRON	0.70	TIN	2.0
NITROGEN	0.014	COPPER	0.66
ALUMINUM	5.4	OXYGEN	0.13
VANADIUM	5.4		

HEAT TREAT CONDITION: Annealed - Anneal Temp.
1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0414	Room	Annealed	0.320	L	156.1	151.1	15.0
				T	160.3	156.3	16.5

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3211 (TMCA)

NR/LAD IDENTIFICATION: Heat 3

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.006
IRON	0.71	TIN	2.0
NITROGEN	0.010	COPPER	0.67
ALUMINUM	5.6	OXYGEN	0.15
VANADIUM	5.5		

HEAT TREAT CONDITION: Annealed - Anneal Temp. 1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0413	Room	Annealed	0.320	L	157.6	152.7	15.5
				T	155.7	149.9	15.0

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-881 (TMCA)

NR/LAD IDENTIFICATION: Heat 4

CHEMICAL COMPOSITION:

CARBON	0.025	HYDROGEN	0.004
IRON	0.66	TIN	2.0
NITROGEN	0.012	COPPER	0.69
ALUMINUM	5.5	OXYGEN	0.16
VANADIUM	5.5		

HEAT TREAT CONDITION: Annealed - Anneal Temp.

1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0412	Room	Annealed	0.315	L	157.4	151.3	15.0
				T	160.5	155.4	18.0

2.2.4 (continued)

MATERIAL: Ti- 6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G 1537 (TMCA)

NR/LAD IDENTIFICATION: Heat 5

CHEMICAL COMPOSITION:

CARBON	0.025	HYDROGEN	0.004
IRON	0.74	TIN	2.0
NITROGEN	0.013	COPPER	0.76
ALUMINUM	5.5	OXYGEN	0.17
VANADIUM	5.6		

HEAT TREAT CONDITION: Annealed - Anneal Temp. 1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0415	Room	Annealed	0.310	L	159.8	154.7	14.0
				T	163.1	158.1	15.3

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-393 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.022	HYDROGEN	0.004
IRON	0.75	TIN	1.9
NITROGEN	0.009	COPPER	0.64
ALUMINUM	5.5	OXYGEN	0.12
VANADIUM	5.3		

HEAT TREAT CONDITION: Annealed - Anneal Temp.

1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.	% Red. Area
J-0416	Room	Annealed	0.630	L	155.6	150.0	18.0	38.2
				T	155.4	151.4	16.5	35.7

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-2443 (TMCA)

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.004
IRON	0.67	TIN	2.1
NITROGEN	0.013	COPPER	0.66
ALUMINUM	5.3	OXYGEN	0.16
VANADIUM	5.7		

HEAT TREAT CONDITION: Annealed - Anneal Temp.

1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0420	Room	Annealed	0.610	L	159.6	156.9	16.0
				T	162.0	158.4	18.0

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-1971 (TMCA)

NR/LAD IDENTIFICATION: Heat 3

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.006
IRON	0.68	TIN	2.1
NITROGEN	0.012	COPPER	0.70
ALUMINUM	5.3	OXYGEN	0.17
VANADIUM	5.4		

HEAT TREAT CONDITION: Annealed - Anneal Temp.
1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-417	Room	Annealed	0.610	L	161.0	158.2	17.0
				T	162.4	157.4	17.0

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-2504

NR/LAD IDENTIFICATION: Heat 4

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.004
IRON	0.66	TIN	2.1
NITROGEN	0.011	COPPER	0.66
ALUMINUM	5.6	OXYGEN	0.16
VANADIUM	5.4		

HEAT TREAT CONDITION: Annealed - Anneal Temp.
1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0418	Room	Annealed	0.610	L	162.1	158.9	16.5
				T	161.1	160.1	19.5

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3106 (TMCA)

NR/LAD IDENTIFICATION: Heat 5

CHEMICAL COMPOSITION:

CARBON	0.016	HYDROGEN	0.005
IRON	0.77	TIN	2.0
NITROGEN	0.019	COPPER	0.59
ALUMINUM	5.6	OXYGEN	0.15
VANADIUM	5.8		

HEAT TREAT CONDITION: Annealed - Anneal Temp. 1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0419	Room	Annealed	0.615	L	159.0	155.6	17.0
				T	158.8	156.3	18.0

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3023 (TMCA)

NR/LAD IDENTIFICATION: Heat 1

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.004
IRON	0.67	TIN	2.0
NITROGEN	0.012	COPPER	0.63
ALUMINUM	5.5	OXYGEN	0.15
VANADIUM	5.6		

HEAT TREAT CONDITION: Annealed - Anneal Temp. 1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0430	Room	Annealed	1.570	L	155.9	145.5	20.0
				T	155.4	145.3	18.5

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3214

NR/LAD IDENTIFICATION: Heat 2

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.004
IRON	0.69	TIN	2.0
NITROGEN	0.011	COPPER	0.65
ALUMINUM	5.4	OXYGEN	0.17
VANADIUM	5.5		

HEAT TREAT CONDITION: Annealed - Anneal Temp. 1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0428	Room	Annealed	1.510	L	155.4	149.4	18.0
				T	156.0	149.8	17.5

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-2070

NR/LAD IDENTIFICATION: Heat 3

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.007
IRON	0.73	TIN	2.0
NITROGEN	0.009	COPPER	0.73
ALUMINUM	5.6	OXYGEN	0.15
VANADIUM	5.6		

HEAT TREAT CONDITION: Annealed - Anneal Temp.

1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0427	Room	Annealed	1.570	L	155.4	149.2	19.0
				T	161.5	151.8	18.5

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-1971 (TMCA)

NR/LAD IDENTIFICATION: Heat 4

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.004
IRON	0.68	TIN	2.1
NITROGEN	0.012	COPPER	0.70
ALUMINUM	5.3	OXYGEN	0.17
VANADIUM	5.4		

HEAT TREAT CONDITION: Annealed - Anneal Temp.
1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0431	Room	Annealed	1.50	L	155.2	149.6	15.5
				T	155.6	147.7	18.5

2.2.4 (continued)

MATERIAL: Ti-6Al-6V-2Sn

VENDOR HEAT NUMBER: HT G-3024 (TMCA)

NR/LAD IDENTIFICATION: Heat 5

CHEMICAL COMPOSITION:

CARBON	0.023	HYDROGEN	0.004
IRON	0.69	TIN	2.0
NITROGEN	0.015	COPPER	0.62
ALUMINUM	5.6	OXYGEN	0.15
VANADIUM	5.6		

HEAT TREAT CONDITION: Annealed - Anneal Temp.
1300F P/M 25F

Vendor Test No.	Test Temp.	Mat'l. Cond.	Nom. Gage	Spec. Direct.	Ult. Tensile Strength Ksi	0.2 % Yield Strength Ksi	% Elong.
J-0429	Room	Annealed	1.60	L	156.4	151.0	17.5
				T	160.1	153.4	18.5

2.3 THERMAL PROCESSING OF MATERIALS

All test materials with the exception of the Ti-6Al-6V-2Sn condition STA, had all the required thermal processing done by the mill prior to receival by NR/LAD. The Ti-6Al-6V-2Sn material which was received in the annealed condition was heat treated to the STA condition by NR/LAD. The thermal processing of all test material both at the mill or at NR/LAD conformed to the requirements of MIL-H-81200.

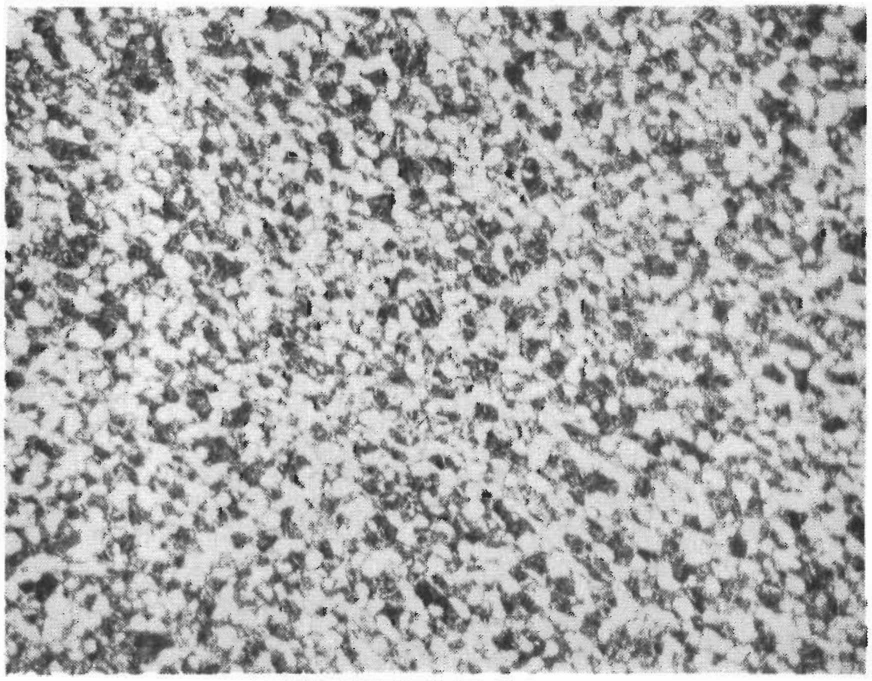
2.4 MICROSTRUCTURAL EXAMINATION OF TEST MATERIALS

A microstructural examination of all test material was performed by NR/LAD. The photomicrographs in conjunction with a brief analysis of the structures observed and their relationship to the resulting mechanical properties are presented in the following section.

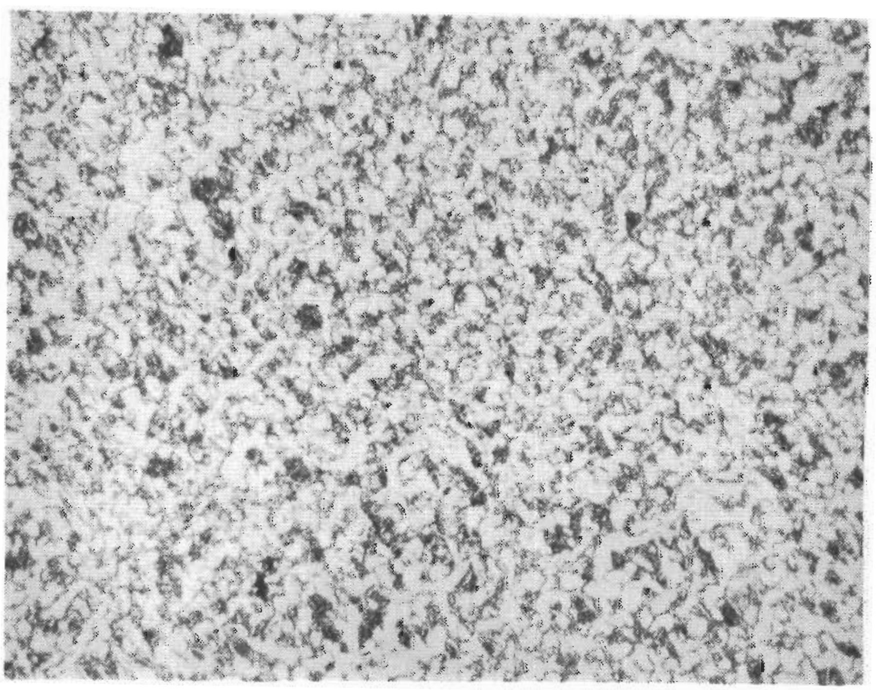
2.4.1 Ti-4Al-3Mo-1V, Cond. A: Photomicrographs typical of microstructures of six heats of Ti-4Al-3Mo-1V, Cond. A, program sheet material ranging in gages from 0.034" to 0.110" are shown in Figures 2-1 through 2-3. NR heat numbers 1 through 5 depict uniform, equi-axed microstructures consisting of islands of primary alpha phase surrounded by a matrix of transformed and retained beta. NR heat #3 shows some slight banding of the alpha phase which is not expected to have any unusual effect in terms of mechanical properties. NR heat #6, Figure 2-3 supplied by a different producer, exhibits a finer, more directional grain structure indicating the probability of a lower final rolling temperature in this instance. This particular photomicrograph displays a very faint trace of a prior beta grain boundary suggesting total rolling reduction may have been less than desired; however, mechanical properties tests indicate comparable mechanical properties with tensile ductility at room temperature perhaps slightly better than the other heats of Ti-4Al-3Mo-1V. In general, the microstructures of all six heats are quite uniform, the above mentioned differences being subtle, and, as would be expected, mechanical properties tests substantiate this microstructural uniformity.

FIG. 2-1

Ti 4Al-3Mo-1V Cond A



Heat G 1596 Nom Gage 0.034" NR Heat #1

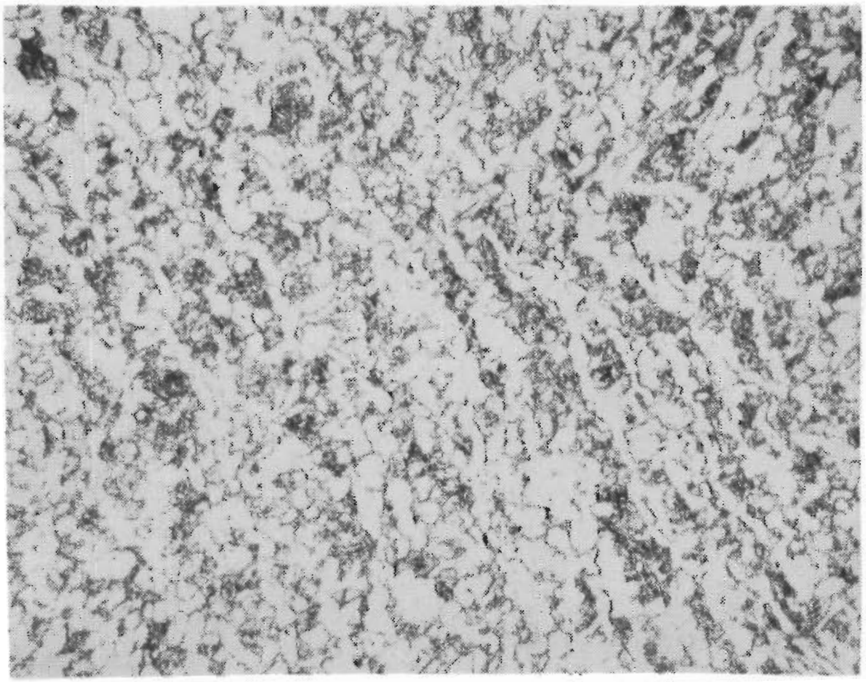


Heat G 895 Nom Gage 0.055" NR Heat #2

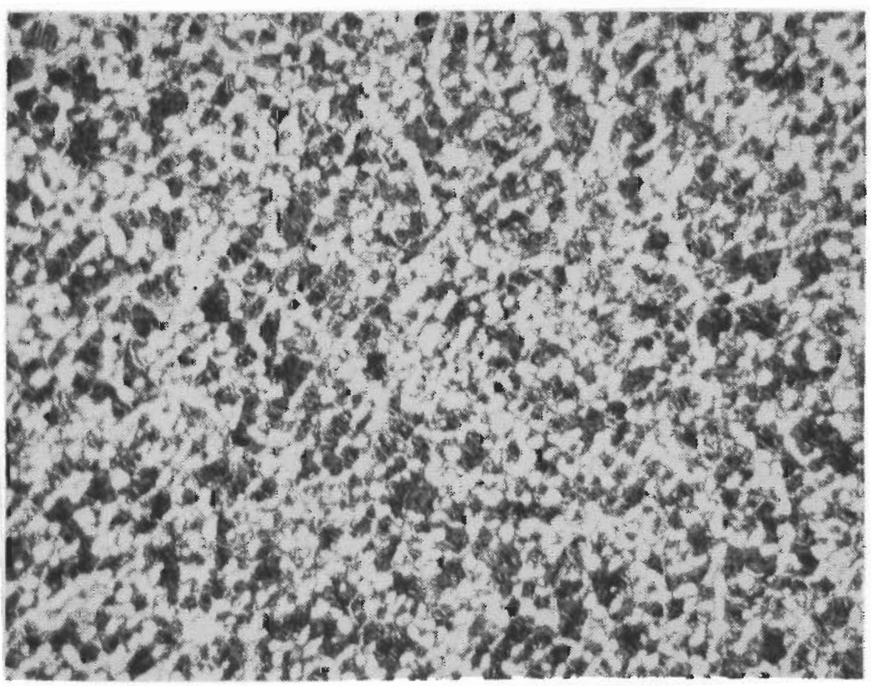
500X

FIG. 2-2

Ti 4Al-3Mo-1V Cond A



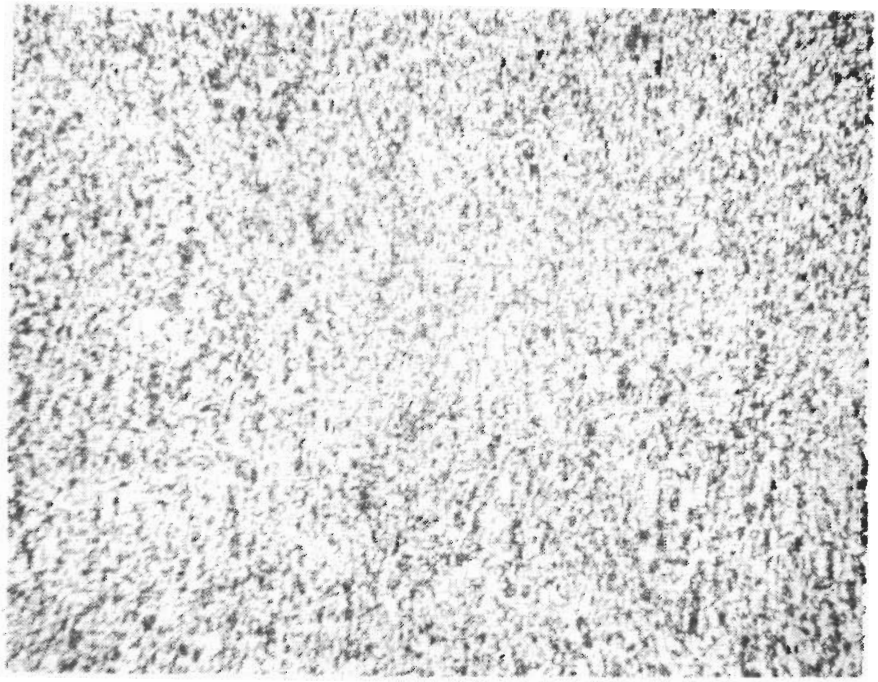
Heat G 2446 Nom Gage 0.063" NR Heat #3



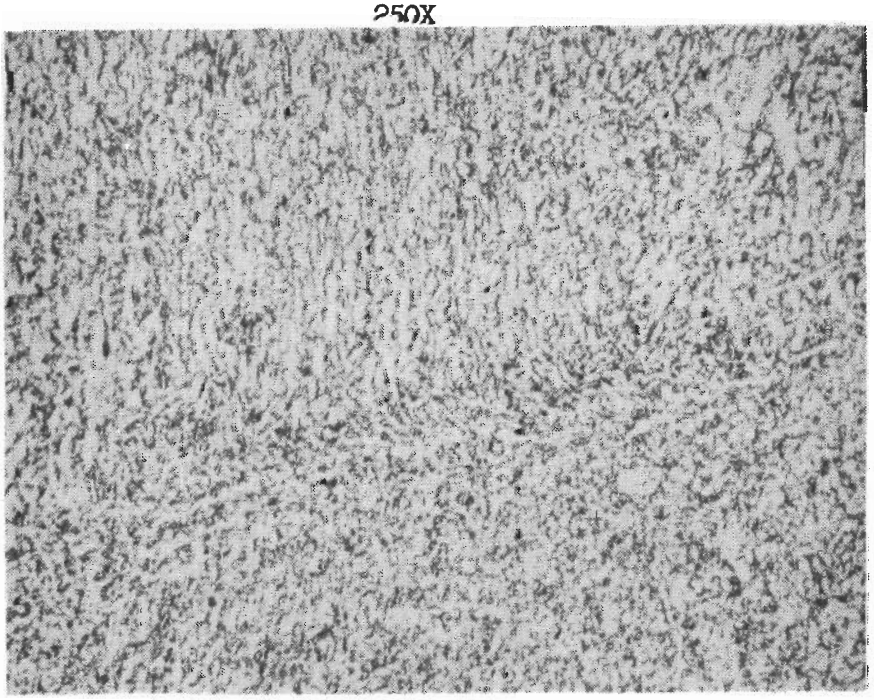
Heat G 1523 Nom Gage 0.051" NR Heat #4
500X

FIG. 2-3

Ti 4Al-3Mo-1V Cond A



Heat G 1401 Nom Gage 0.067 NR Heat #5
250X

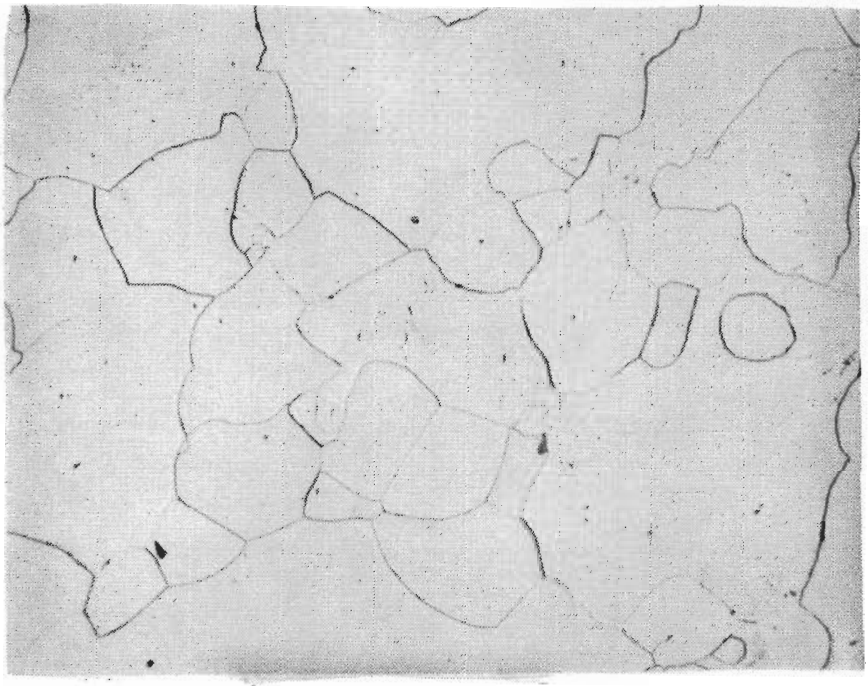


Heat 321055 Nom Gage 0.110" NR Heat #6
500X

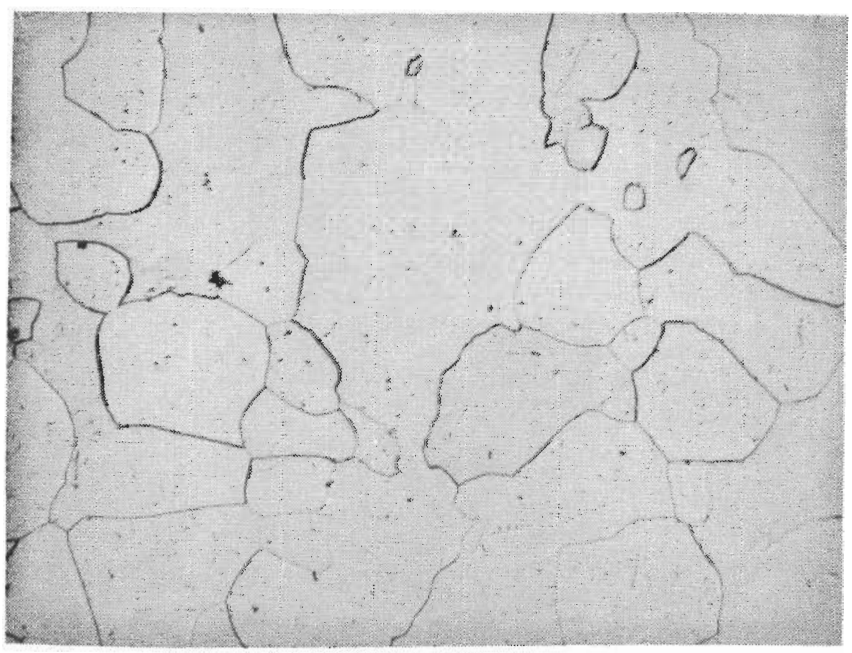
2.4.2 Ti-13V-11Cr-3Al, Cond. A (ST): Typical microstructures from five heats of alloy Ti-13V-11Cr-3Al sheet in the annealed or solution treated condition are shown in Figures 2-4 through 2-6. The photomicrographs depict structures considered normal for the material and illustrate the essentially single-phase, beta microstructure characteristic of the alloy as solution treated. Microstructural variations among the five heats are slight, NR heat numbers 3 and 5 exhibiting somewhat smaller grain size than the others. Mechanical properties of the heats are uniform and similar with NR heat numbers 3 and 5 tending to exhibit properties slightly higher than the average. This is not considered extremely significant since NR heat #4 with comparatively large grain size also exhibits higher than the average properties. Again, microstructural and properties variations are subtle.

FIG. 2-4

Ti 13V-11Cr-3Al   Cond A or ST



Heat D-7855   Nom Gage 0.040"   NR Heat #1

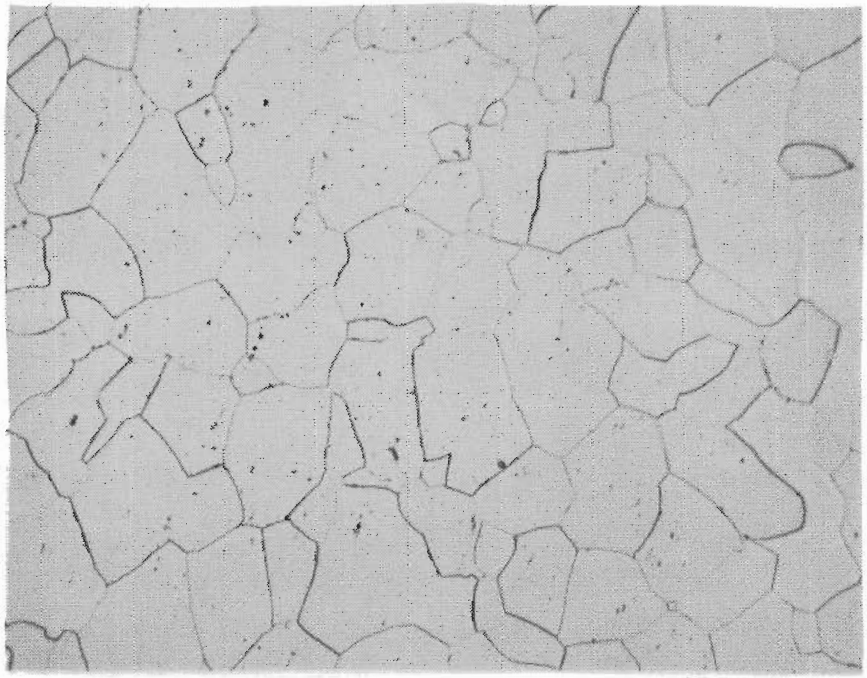


Heat D-7770   Nom Gage 0.038"   NR Heat #2

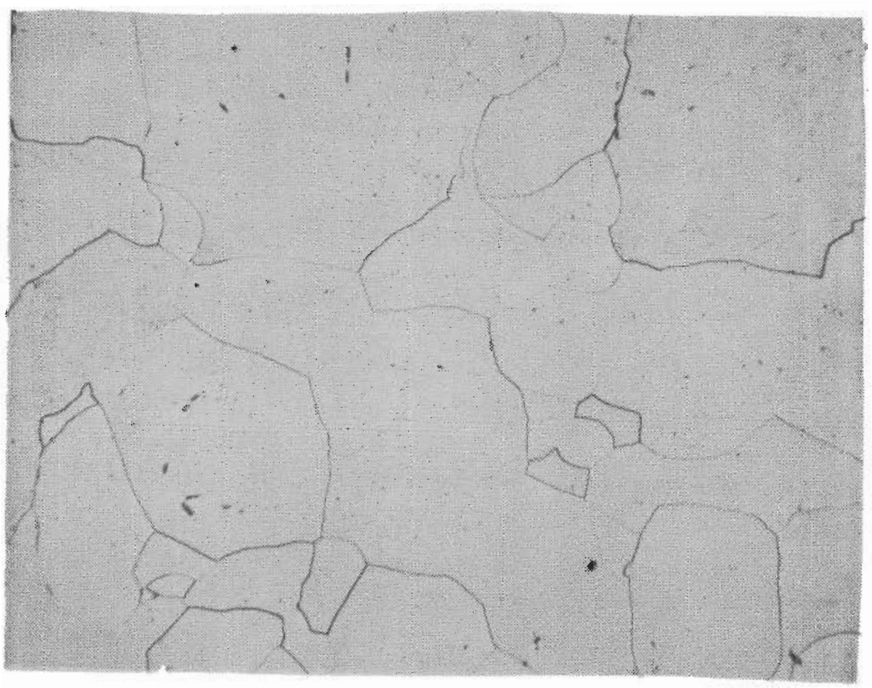
275X

FIG. 2-5

Ti 13V-11Cr-3Al   Cond A or ST



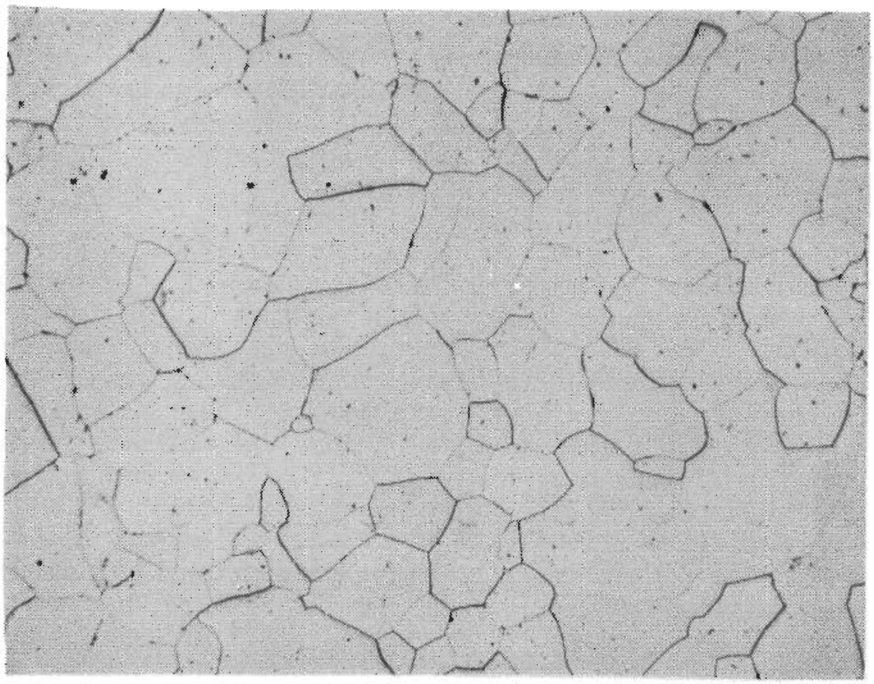
Heat D 7107   Nom Gage 0.035   NR Heat #3



Heat D 7639   Nom Gage 0.038"   NR Heat #4
275X

FIG. 2-6

Ti 13V-11Cr-3Al   Cond A or ST



Heat D 7110   Nom Gage 0.037   NR Heat #5

275 X

2.4.3 Ti-6Al-4V, Cond. STA: Microstructures representing eight heats of Ti-6Al-4V, Cond. STA plate are shown in Figures 2-7 through 2-10. In contrast to the other program materials, a wide variation in microstructures from heat to heat was obtained and considerable variation in mechanical properties as a function of gage, supplier, heat, and testing direction also noted.

With respect to the nominal 0.250-inch gage material, three different microstructures were obtained from the three heats of material represented. The first, G4956, Figure 2-7, shows a transus-type structure, i.e., free from primary alpha with acicular alpha, and possible alpha prime, resulting from quenching from high in the alpha-beta field. Some banding is also noted and mechanical properties are considered satisfactory for heat-treated material. The second, heat G4796, represents material though stated to be heat treated is, to the contrary, believed to be annealed. It is suggested the material was thoroughly worked during rolling at relatively low final rolling temperatures resulting in a mixture of equiaxed alpha and intergranular beta. It might be argued that the photomicrograph represents material quenched from low in the alpha-beta phase, approximately 1500°F or lower; however, properties obtained show a spread between ultimate and yield strength much more indicative of annealed material than that associated with quenched and aged retained beta. In addition, the level of mechanical properties obtained would be quite low for material at 0.15% oxygen, solution treated at 1700°F and aged at 1000°F. The third, heat X53788, represents material finished from above the beta transus temperature and quenched from high in the alpha beta field. The microstructure is uniform, fine-grained and exhibits good strength, lower tensile ductility, and relatively good fracture toughness associated with such structures.

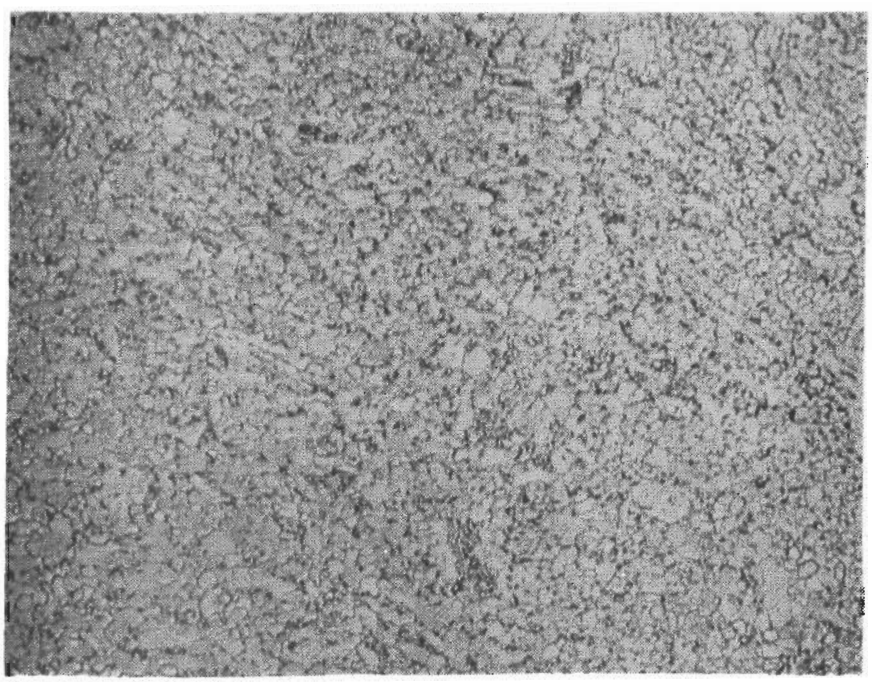
Material in the nominal 0.500-inch gage again displays a variation in microstructure. Heats G6539 and G7278, are similar and more nearly typify structures normally associated with heat treated and aged thin-sectioned Ti-6Al-4V products. Both show a mixture of primary alpha plus aged alpha prime with the latter heat showing some gross rolling deformation. Properies too reflect typical strength levels and tensile ductilities for such material in both cases, the latter indicating greater anisotropy, as might be expected. Material from heat 302634, Figure 2-9 again illustrates material finish rolled from above the beta transus, quenched from high in the alpha-beta field and aged. Microstructure is similar to that of 0.250-inch gage heat X53788 with somewhat higher strength, probably due to higher oxygen content.

In the nominal 1.00-inch plate gage somewhat different microstructures were obtained for the two heats of material displayed, Figure 2-10, representing somewhat different working histories. Both display material rolled and heat treated in the alpha-beta field; however, with properties expected of material so processed.

FIG. 2-7

Ti 6Al-4V Cond STA

Heat G 4956 Nom Gage 0.250" NR Heat #1

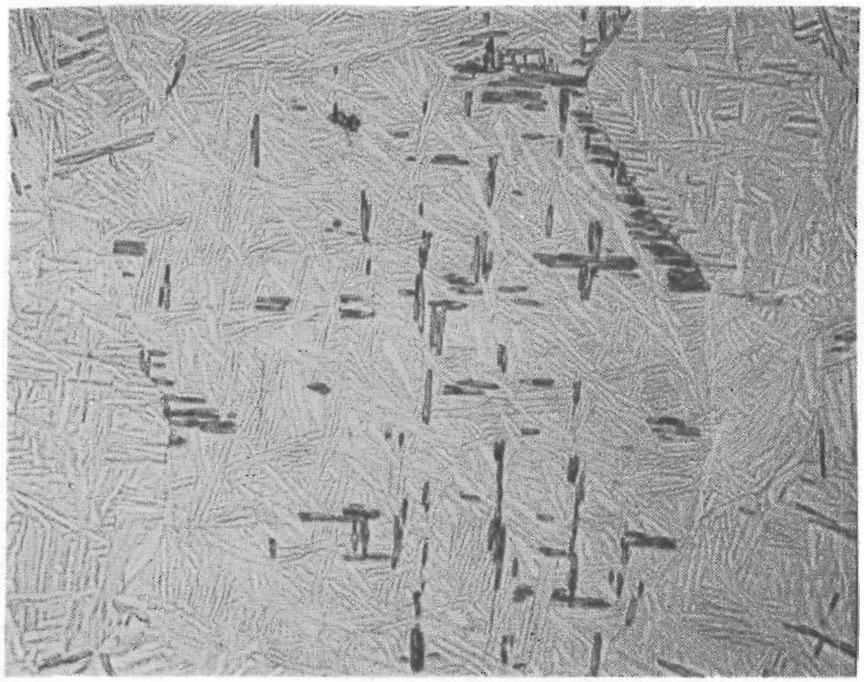


Heat G 4796 Nom Gage 0.250" NR Heat #2

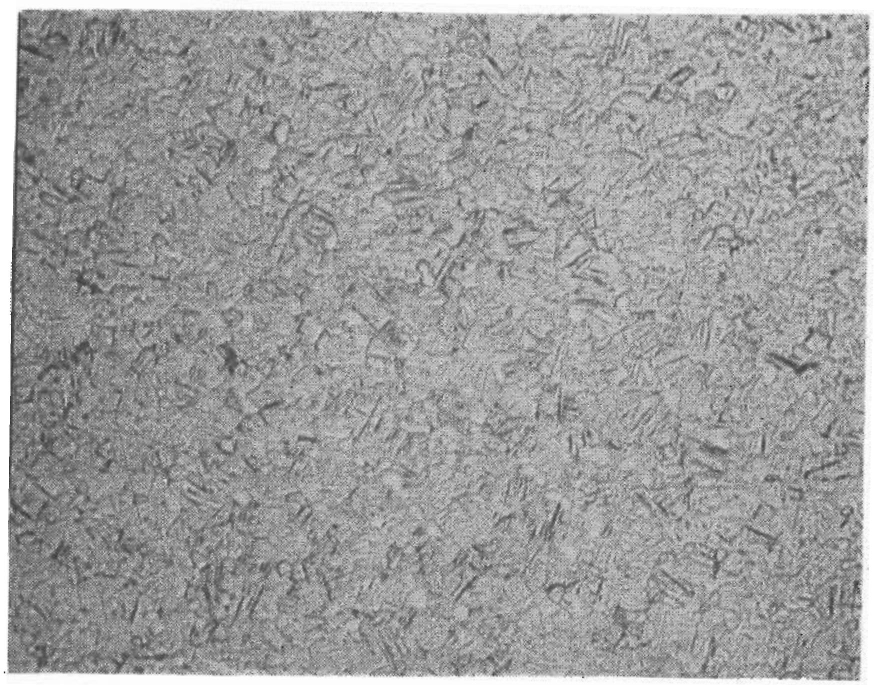
250 X

FIG. 2-8

Ti 6Al-4V   Cond STA



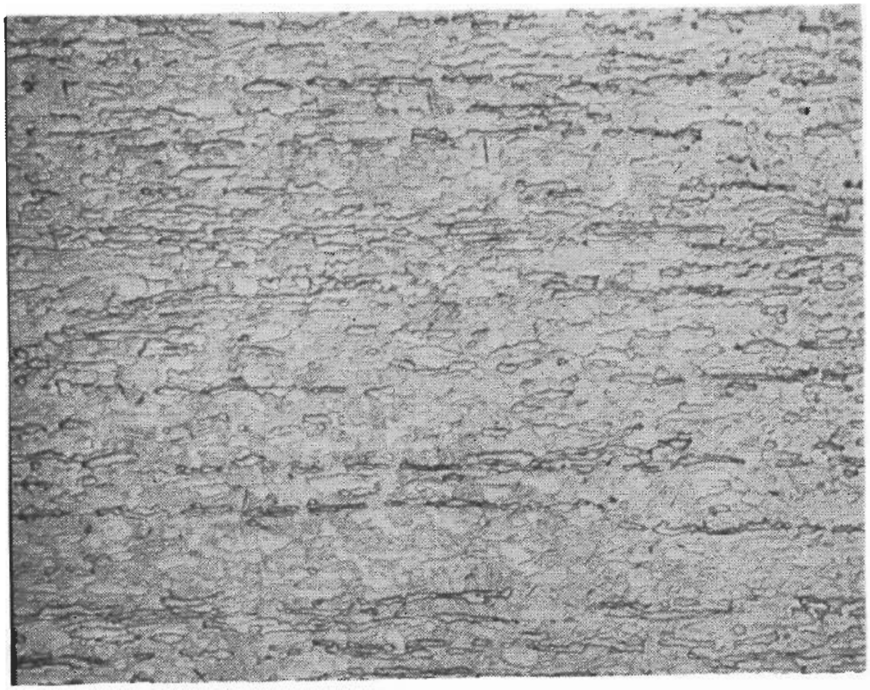
Heat X 53788   Nom Gage 0.250"   NR Heat #6



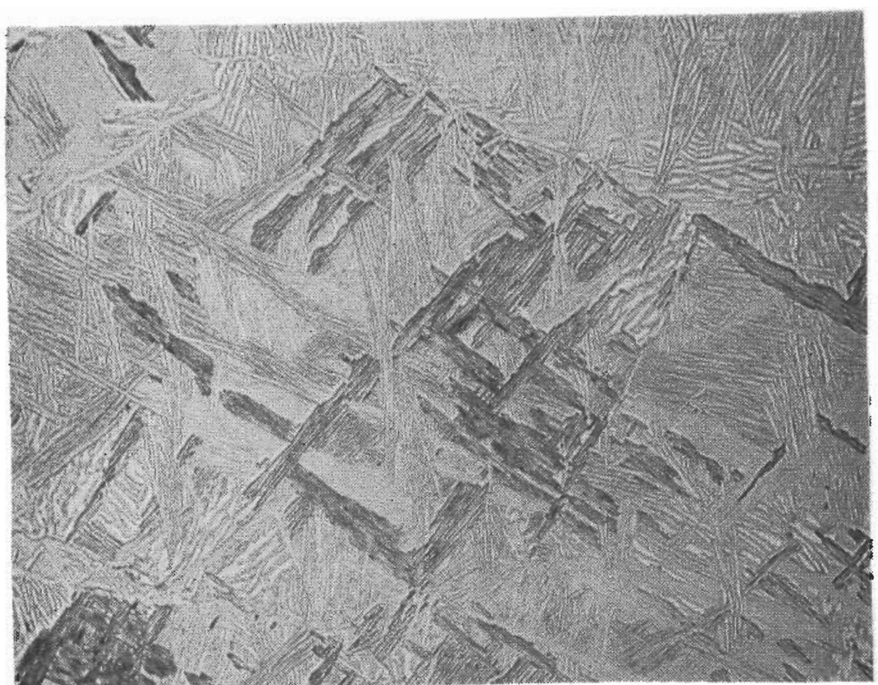
Heat G 6539   Nom Gage 0.500"   NR Heat #1

FIG. 2·9

Ti 6Al-4V   Cond STA



Heat G 7278   Nom Gage 0.500"   NR Heat #2

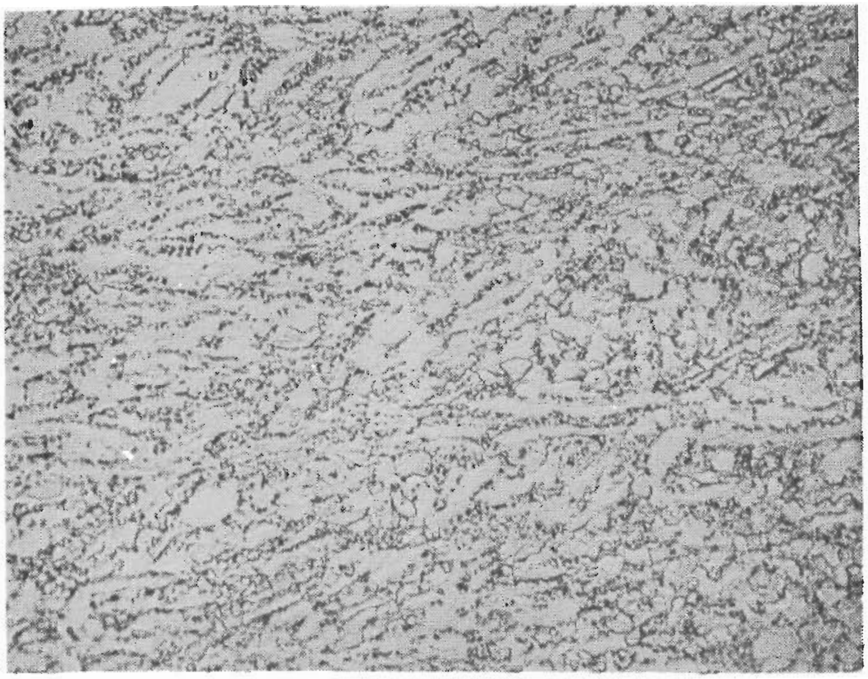


Heat 302634   Nom Gage 0.475"   NR Heat #7

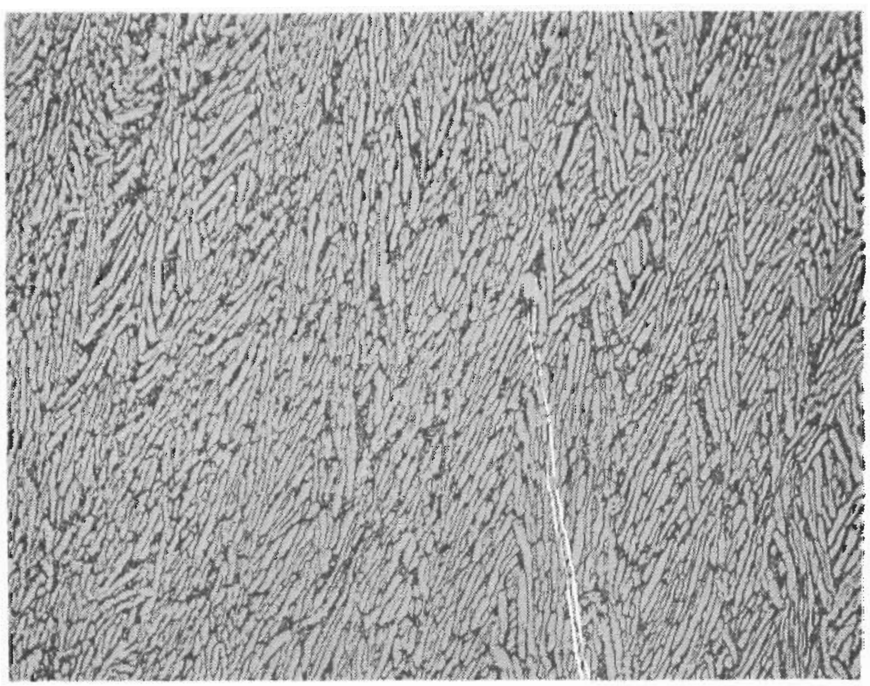
250 X

FIG. 2-10

Ti 6Al-4V Cond STA



Heat G 7021 Nom Gage 1.025" NR Heat #2



Heat 293504 Nom Gage 1.025" NR Heat #6

250 X

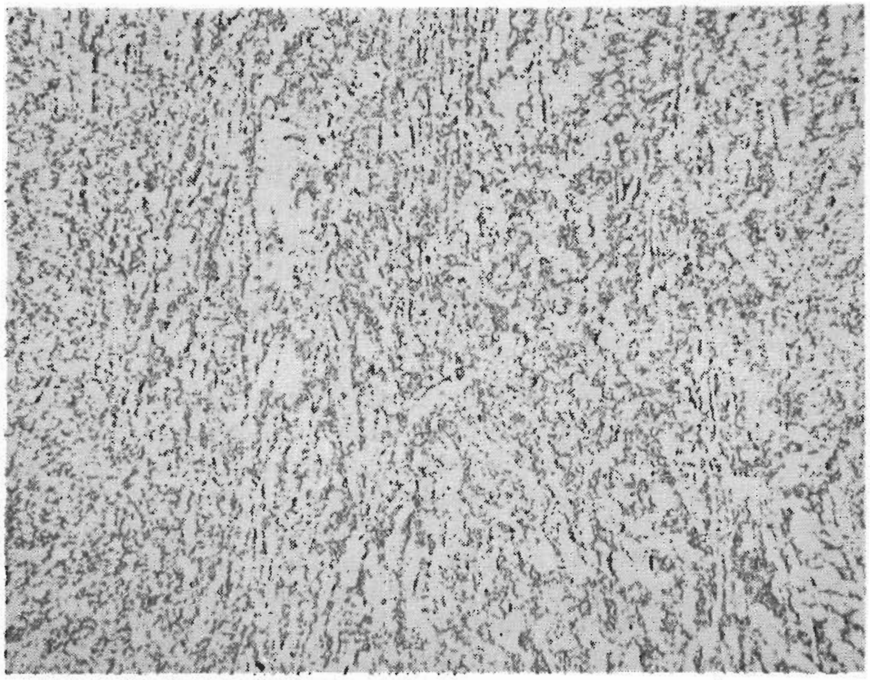
2.4.4 Ti-6Al-6V-2Sn, Cond. A and STA: Typical microstructures of 14 heats of alloy Ti-6Al-6V-2Sn plate both annealed and fully heat treated are shown in Figures 2-11 through 2-25. Photomicrographs for annealed plate of the nominal 0.250 inch gage (0.310 to 0.340-inch), Figures 2-11 through 2-13 depict thoroughly worked microstructures of primary alpha phase in a retained beta phase matrix. Phase delineation is not distinct in any of the five, the microstructures all showing evidence of considerable grain deformation from working at low, final rolling temperatures, and of course fine grain size. Variations among the five heats are extremely small metallographically and, as expected, properties are also uniformly high.

As gages are increased, variation in rolling practice becomes evident. The five heats of the nominal 0.500-inch gage (0.610 to 0.630-inch) plate shown in Figures 2-14 through 2-16, both annealed and heat treated, continue to illustrate a fine-grained, thoroughly-worked microstructure. Phase demarkation is somewhat greater; however, even in the annealed material suggesting higher finish rolling temperatures. This is a matter of small degree, nevertheless, since annealed properties remain quite high for the annealed 0.500-inch material in comparison to the 0.250-inch. The effects of heat treatment to Cond. STA are quite clearly illustrated showing an increase in the beta phase at the expense of alpha due to quenching from high in the alpha-beta field.

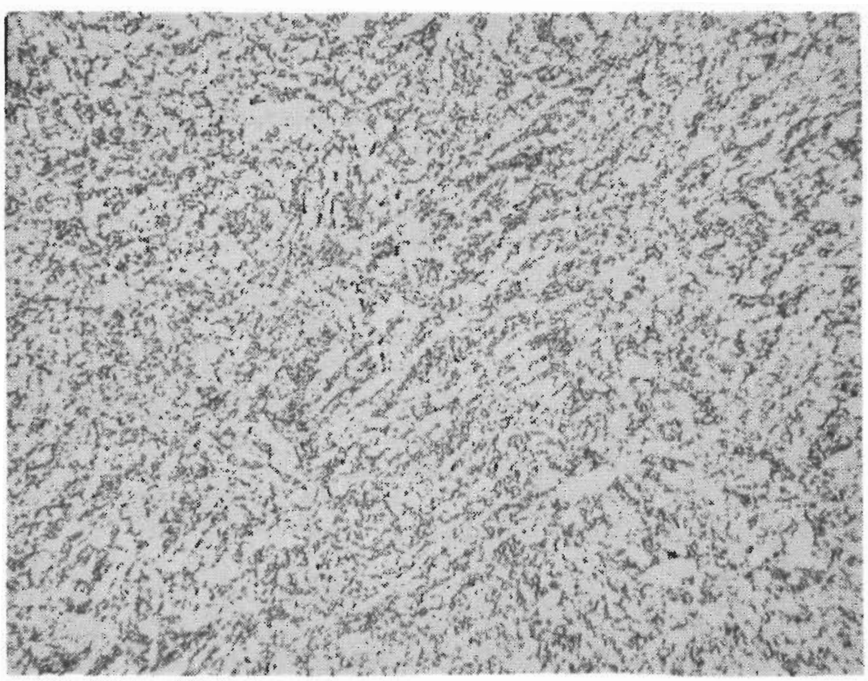
With increase in gage of plate to 1.50-inch nominal gage (1.50 to 1.60-inch), the higher finish rolling temperature required becomes evident, particularly in the microstructures of annealed material, Figures 2-17 through 2-19. The alpha phase is seen to be present, in all five heats, in the form of moderately coarse platelet form, fairly well distributed throughout the microstructure with little evidence of prior beta grain boundaries. Properties are correspondingly lower than the annealed thinner gage material, as would be expected. Again uniformity of properties among the five heats is evident both annealed and heat treated, in spite of the localized aberations noted in two of the microstructures of Cond. STA material. Some rather pronounced coarseness of the primary alpha plates with the suggestion of prior beta grain boundary alpha formation is seen in NR heat #8, Figure 2-24, and in contrast, a localized enrichment of beta phase material is evident in the microstructure of NR heat #10, Figure 2-25, due probably to chemical segregation of beta-stabilizer element(s) in the ingot. Neither of these conditions appears to be general throughout the material to the extent that mechanical properties test results show no effect.

FIG. 2-11

Ti 6Al-6V-2Sn Cond A



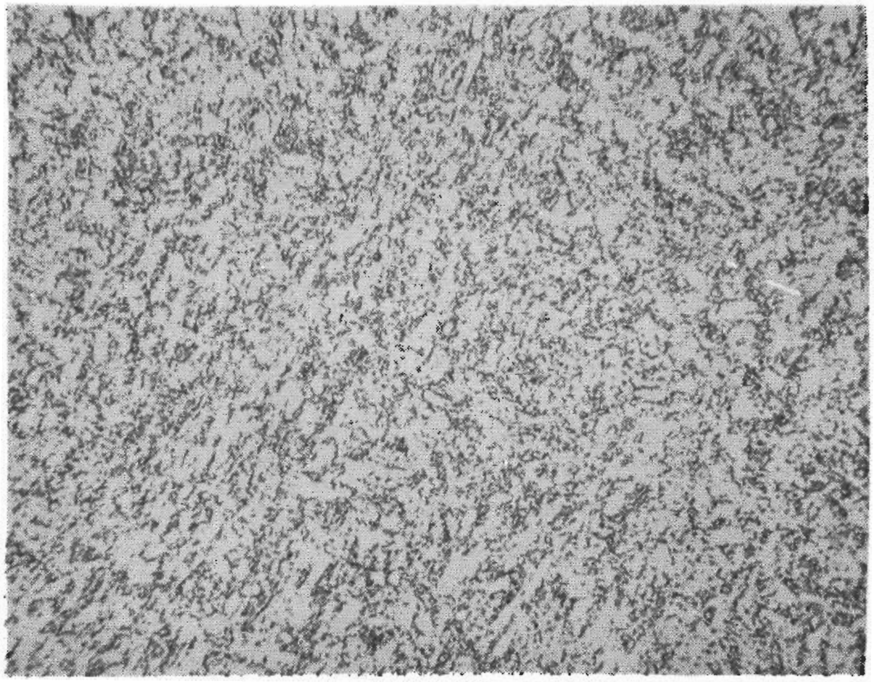
Heat G 31C5 Nom Gage 0.340" NR Heat #1



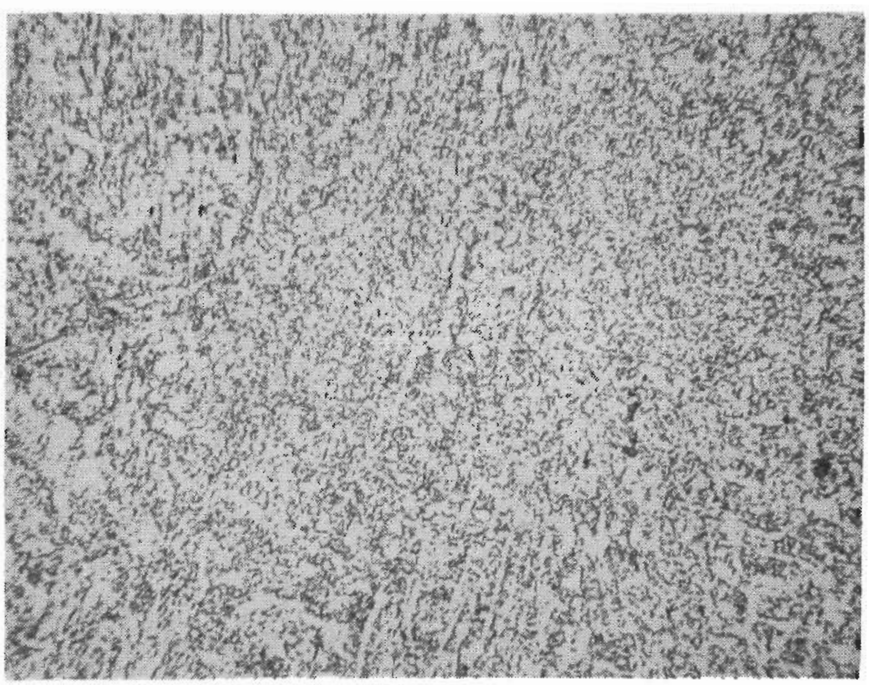
Heat G 3212 Nom Gage 0.320 NR Heat #2
275X

FIG. 2-12

Ti 6Al-6V-2Sn Cond A



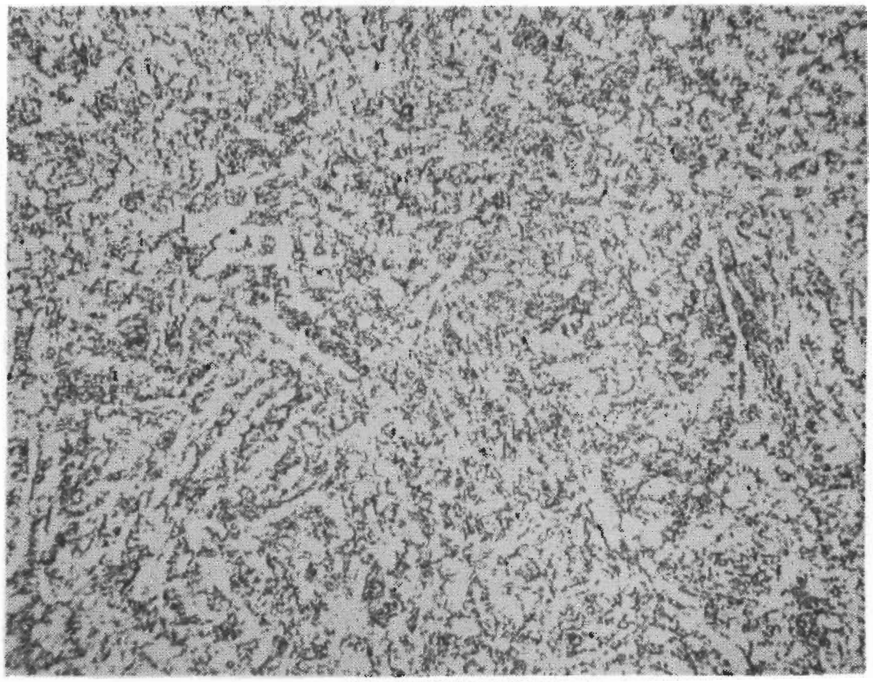
Heat G 3211 Nom Gage 0.320 NR Heat #3



Heat G 881 Nom Gage 0.315 NR Heat #4
275X

FIG. 2-13

Ti 6Al-6V-2Sn Cond A

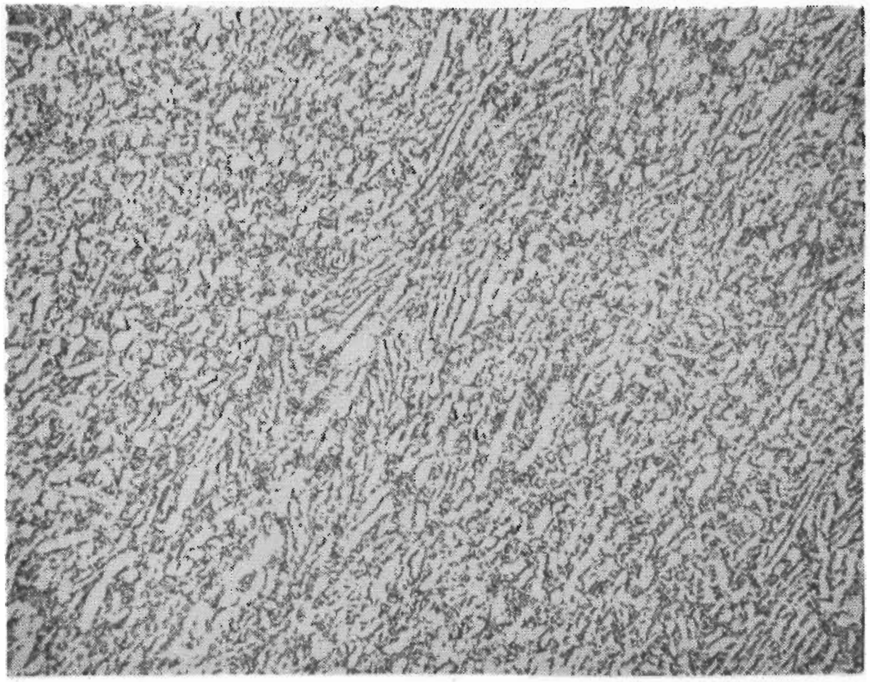


Heat G 1537 Nom Gage 0.310 NR Heat #5

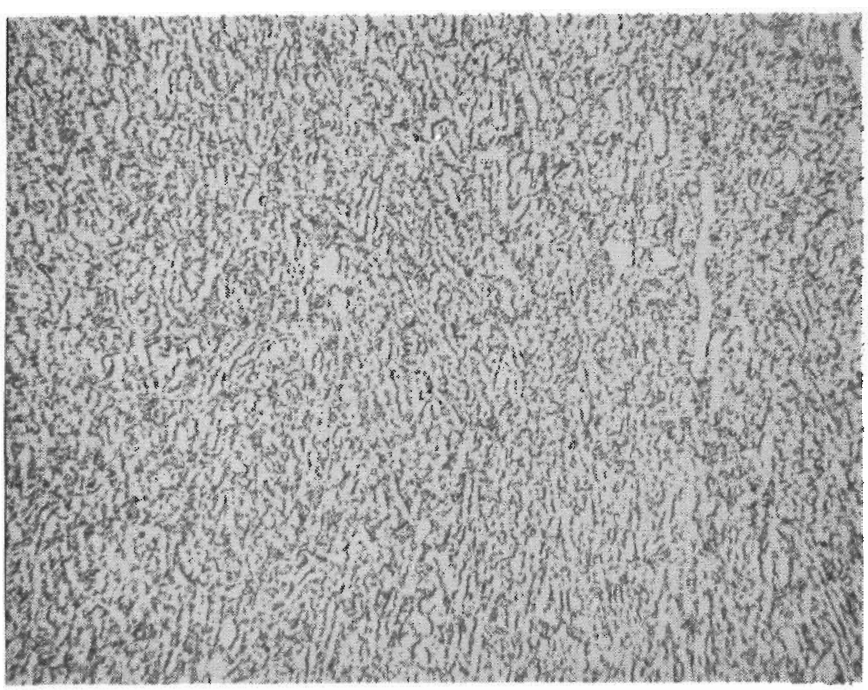
275X

FIG. 2-14

Ti 6Al-6V-2Sn



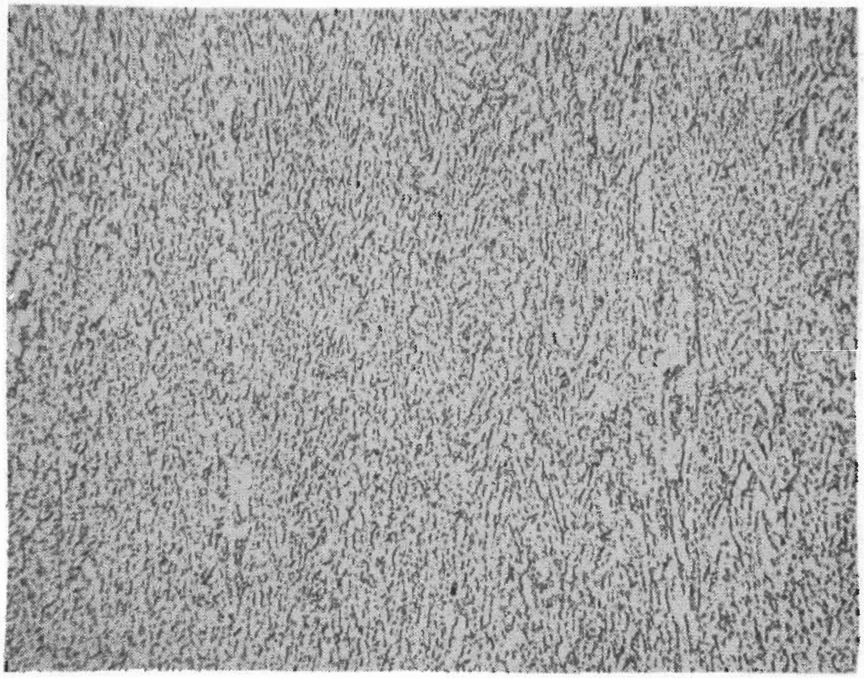
Heat G 393 Nom Gage 0.630" NR Heat #1



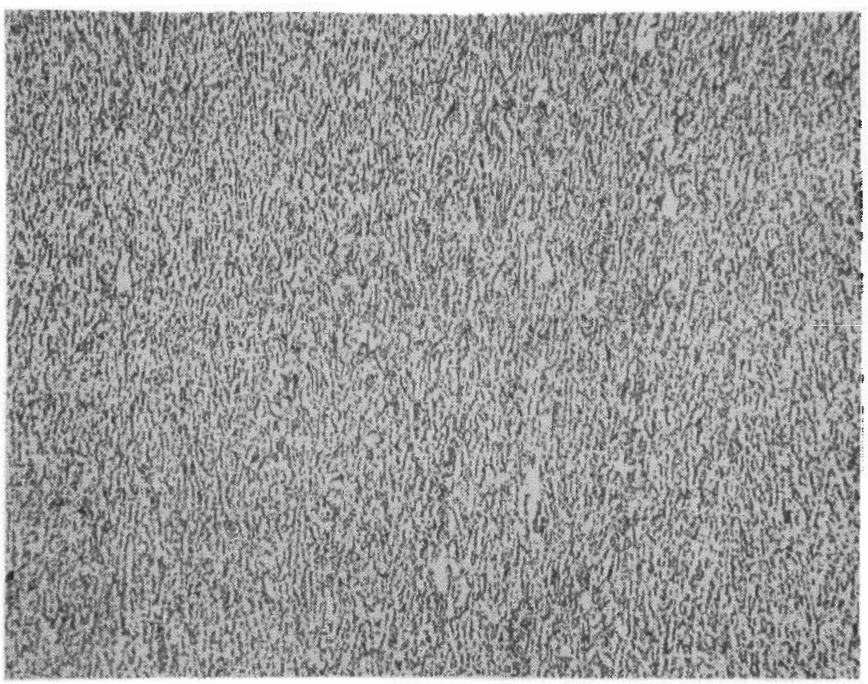
Heat G 2443 Nom Gage 0.610" NR Heat #2
275X

FIG. 2-15

Ti 6Al-6V-2Sn Cond A



Heat G 1971 Nom Gage 0.610" NR Heat #3

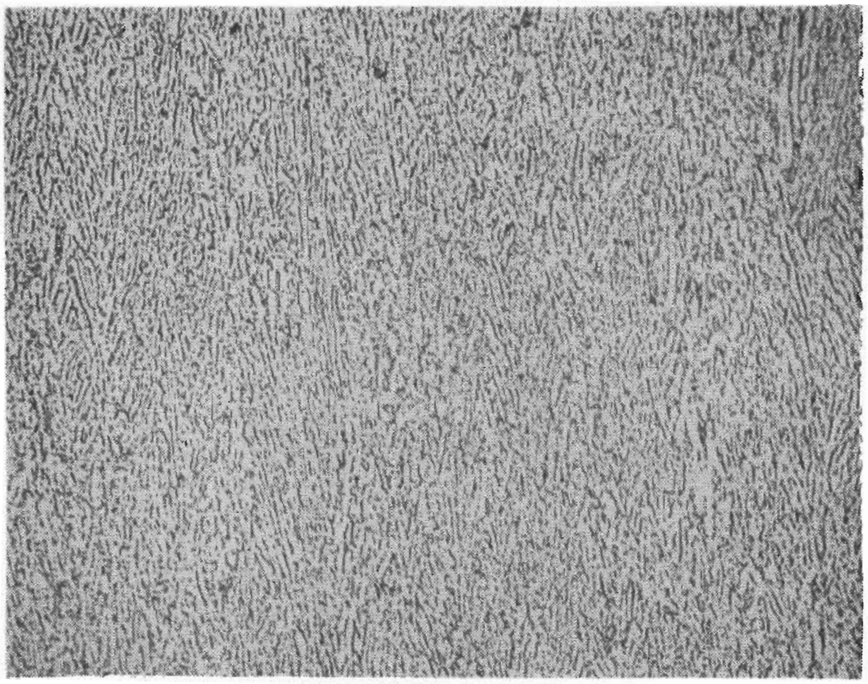


Heat G 2504 Nom Gage 0.610" NR Heat #4

275 X

FIG. 2-16

Ti 6Al-6V-2Sn Cond A

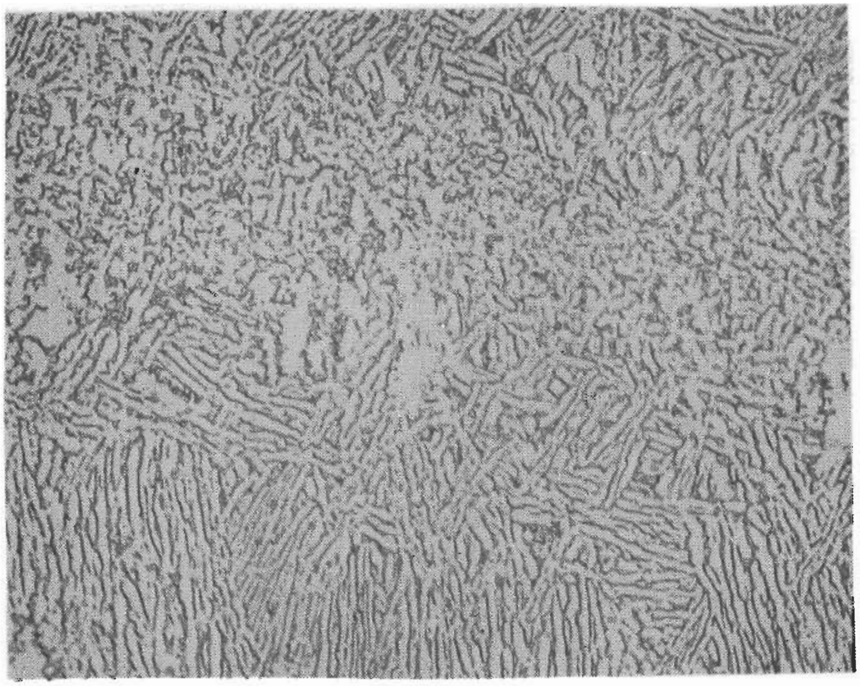


Heat G 3106 Nom Gage 0.615 NR Heat #5

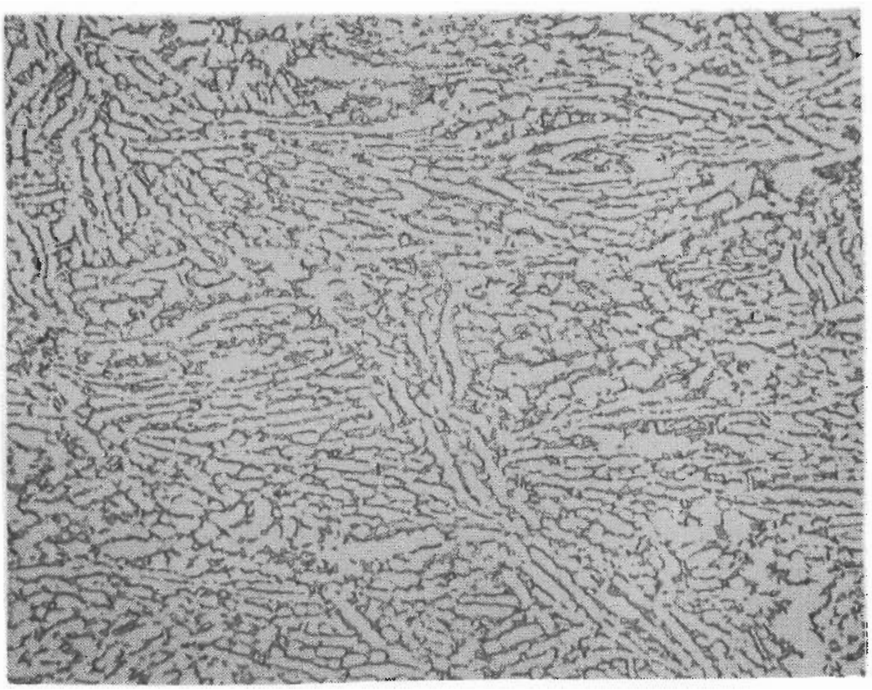
275X

FIG. 2-17

Ti 6Al-6V-2Sn Cond A



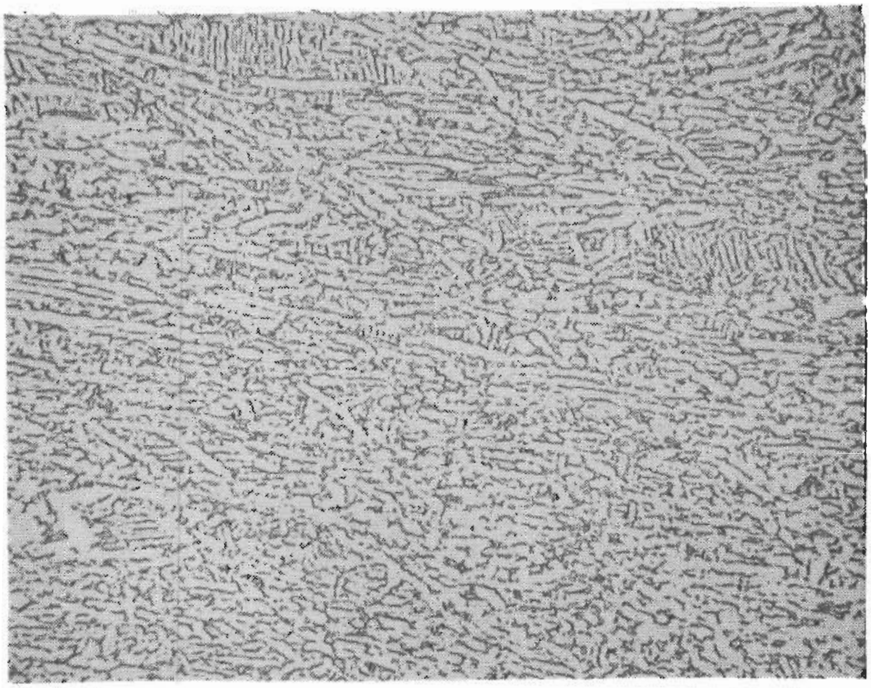
Heat G 3023 Nom Gage 1.570" NR Heat #1



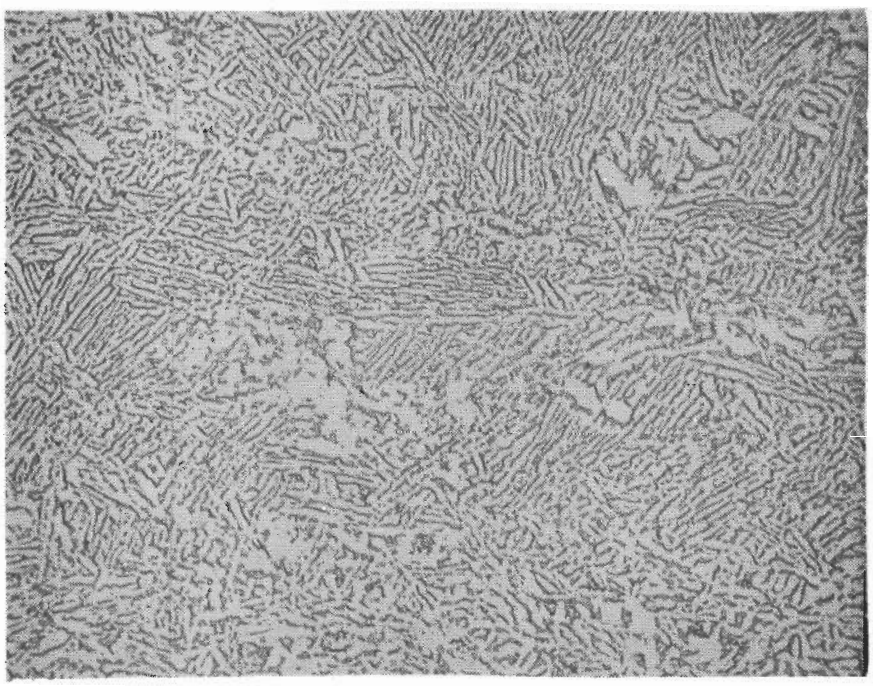
Heat G 3214 Nom Gage 1.570 NR Heat #2
275X

FIG. 2-18

Ti 6Al-6V-2Sn   Cond A



Heat G 2070   Nom Gage 1.570   NR Heat #3

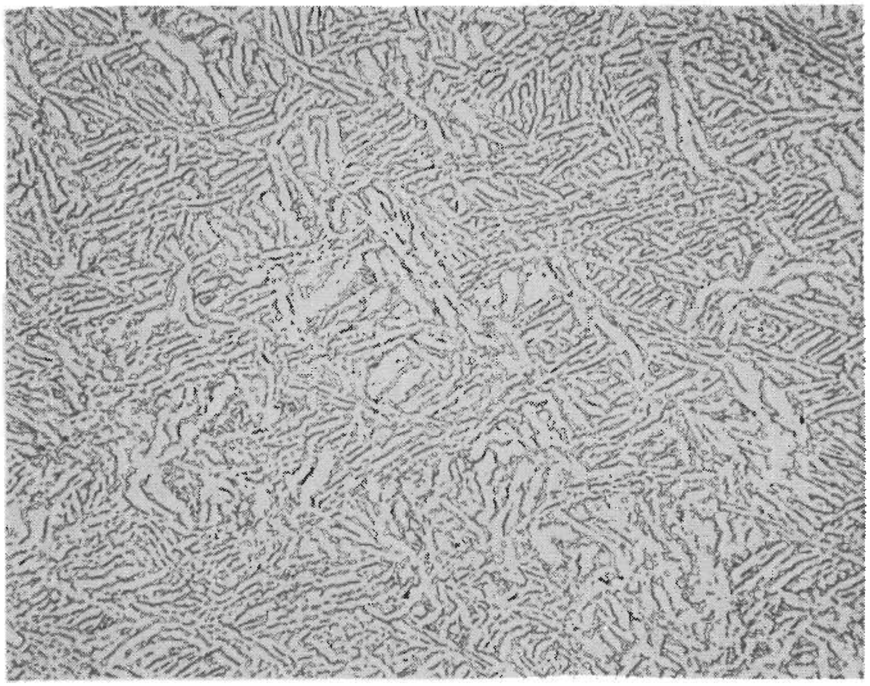


Heat G 1971   Nom Gage 1.50   NR Heat #4

275X

FIG. 2-19

Ti 6Al-6V-2Sn Cond A



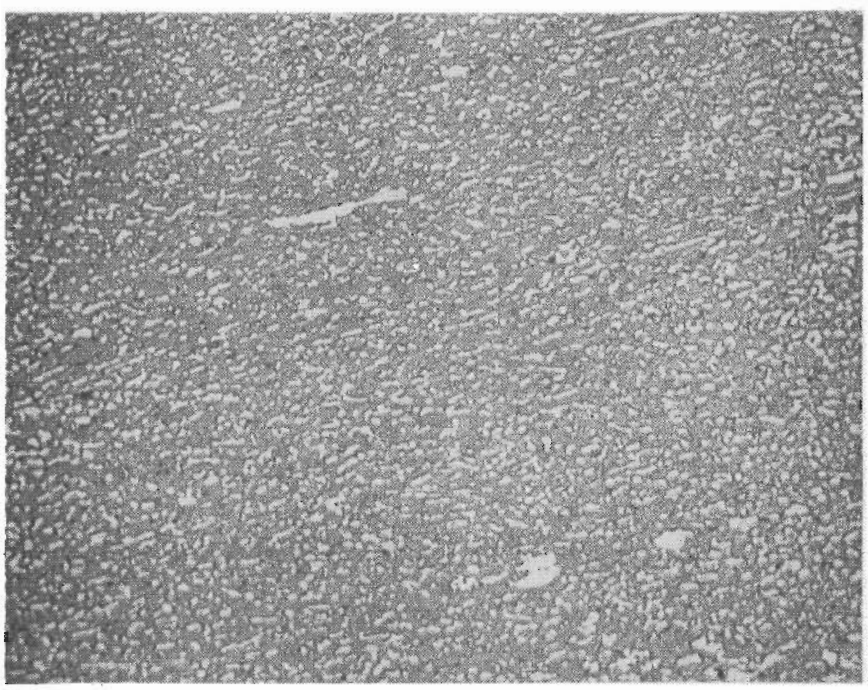
Heat G 3024 Nom Gage 1.60" NR Heat 5

275X

FIG. 2-20

Ti 6Al-6V-2Sn Cond STA

Heat G 393 Nom Gage 0.630" NR Heat #6

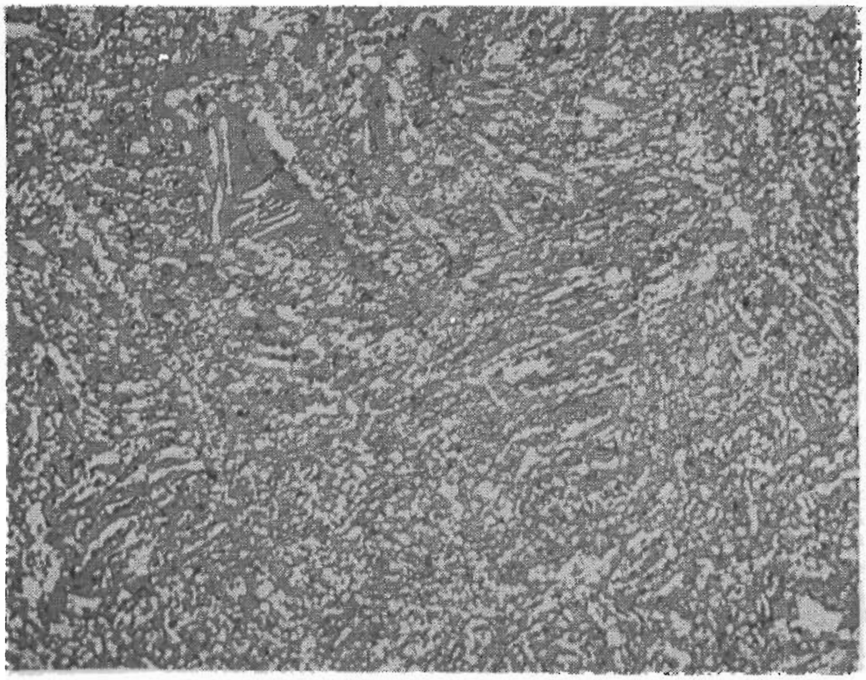


Heat G 2443 Nom Gage 0.610" NR Heat #7

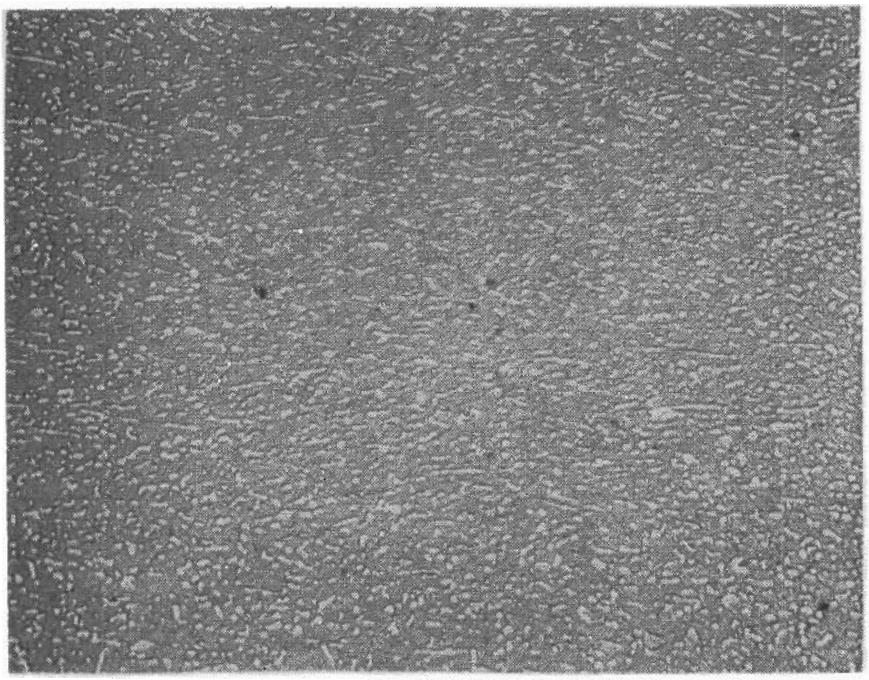
250X

FIG. 2-21

Ti 6Al-6V-2Sn Cond STA



Heat G 1971 Nom Gage 0.610" NR Heat #8

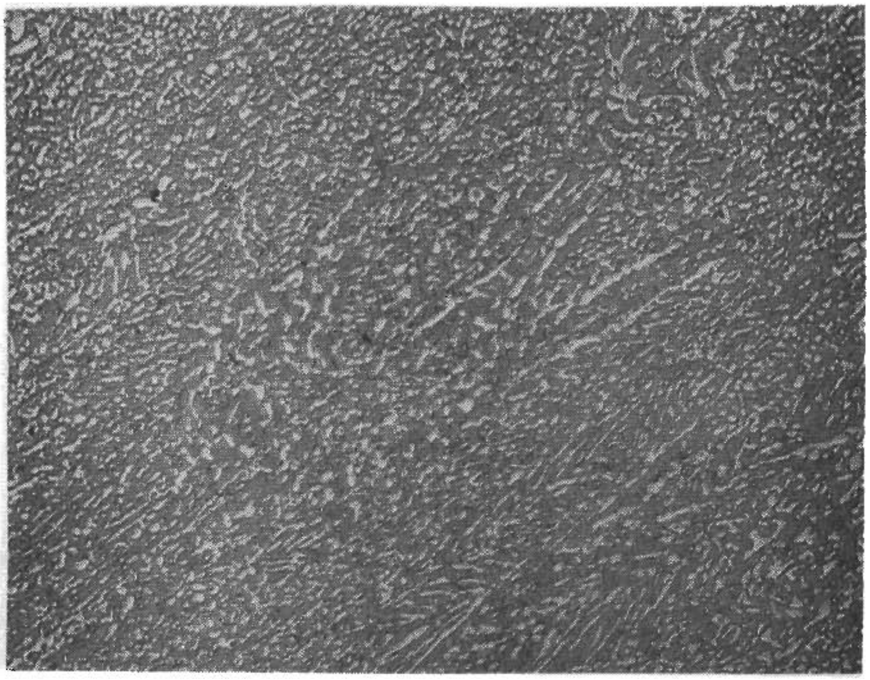


Heat G 2504 Nom Gage 0.610" NR Heat #9

250X

FIG. 2-22

Ti 6Al-6V-2Sn   Cond STA

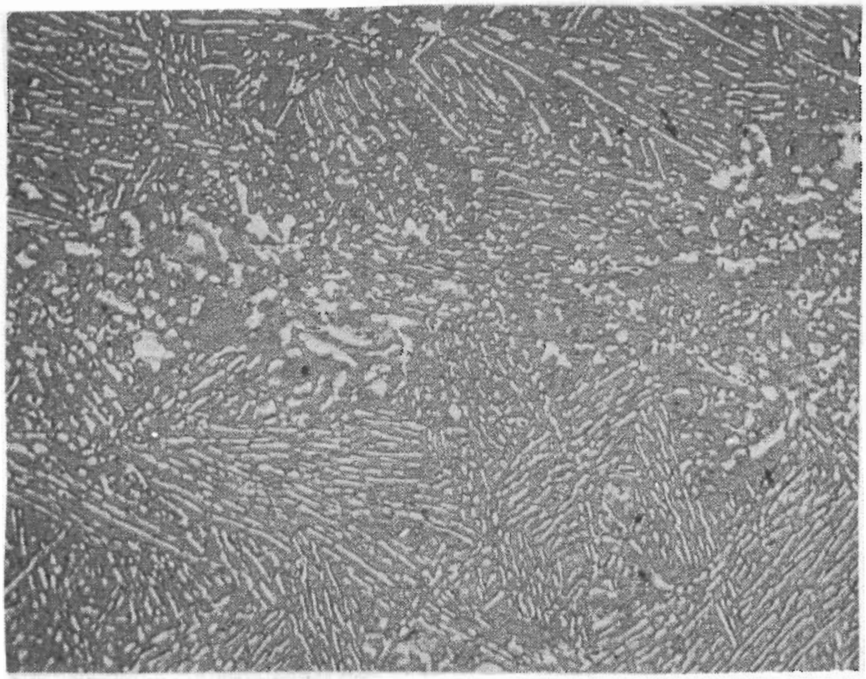


Heat G 3106   Nom Gage 0.615   NR Heat #10

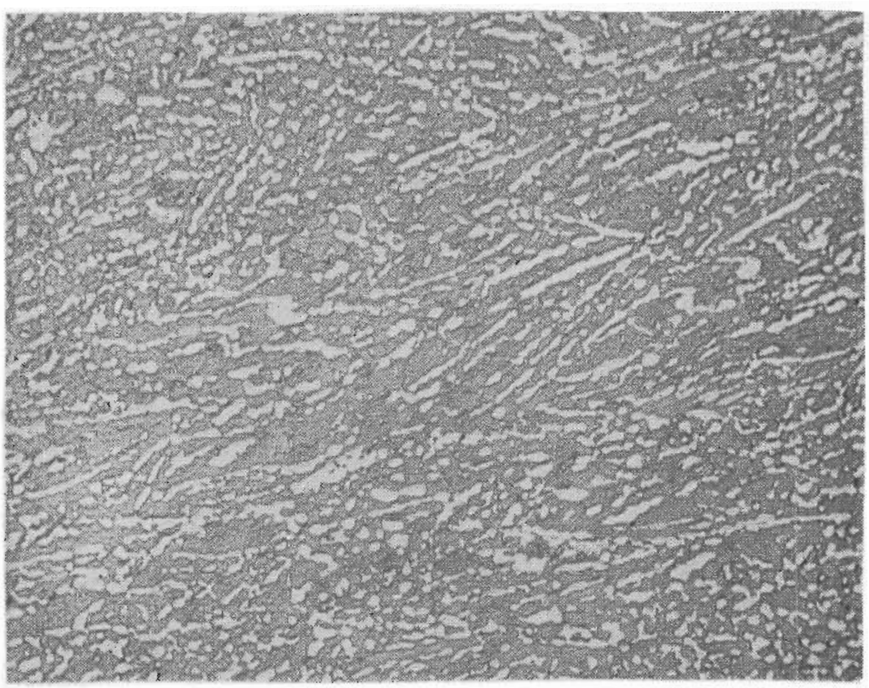
250 X

FIG. 2-23

Ti 6Al-6V-2Sn   Cond STA



Heat G 3023   Nom Gage 1.570"   NR Heat #6

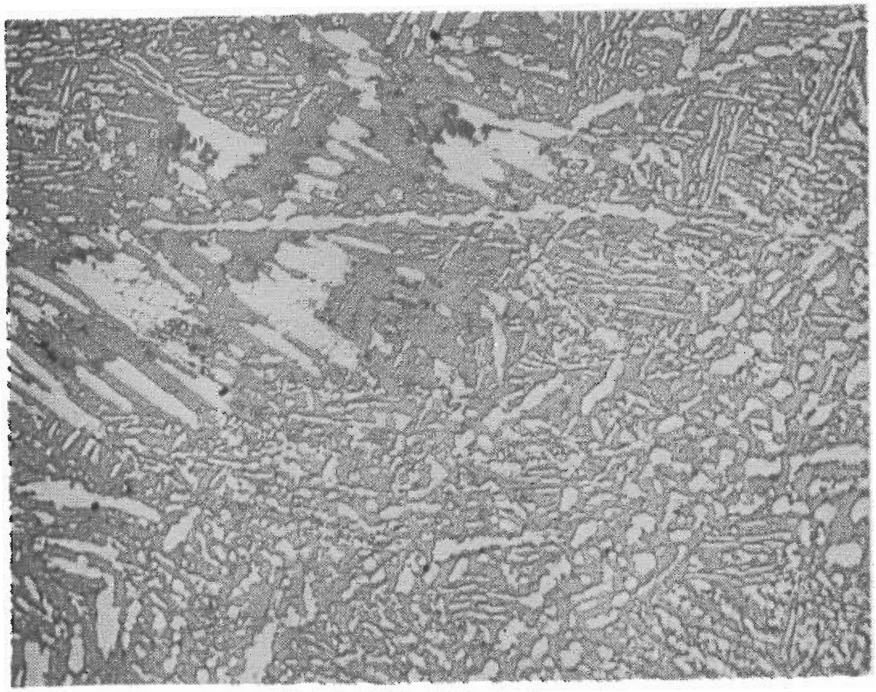


Heat G 3214   Nom Gage 1.570"   NR Heat #7

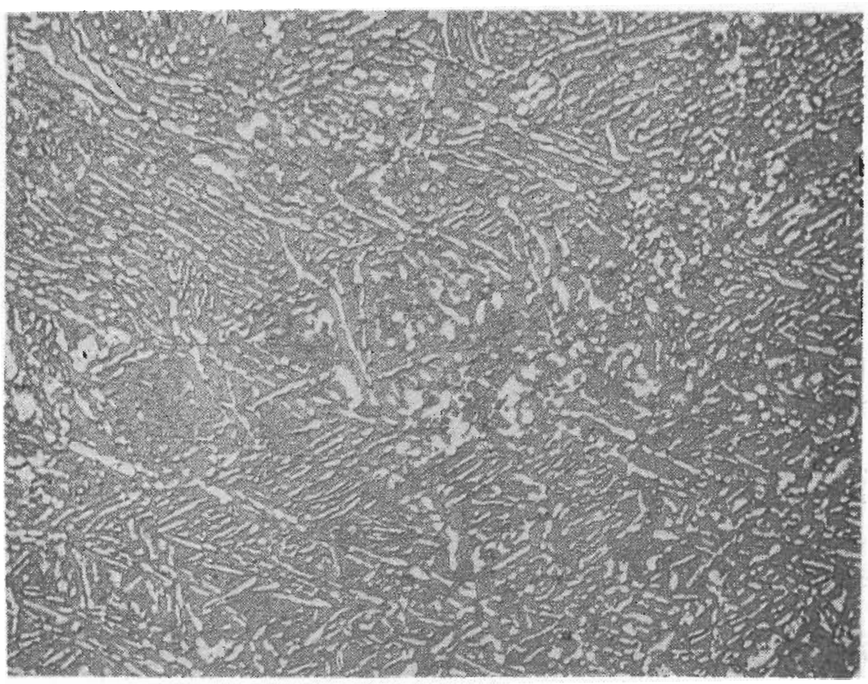
250X

FIG. 2-24

Ti 6Al-6V-2Sn Cond STA



Heat G 2070 Nom Gage 1.570 NR Heat #8

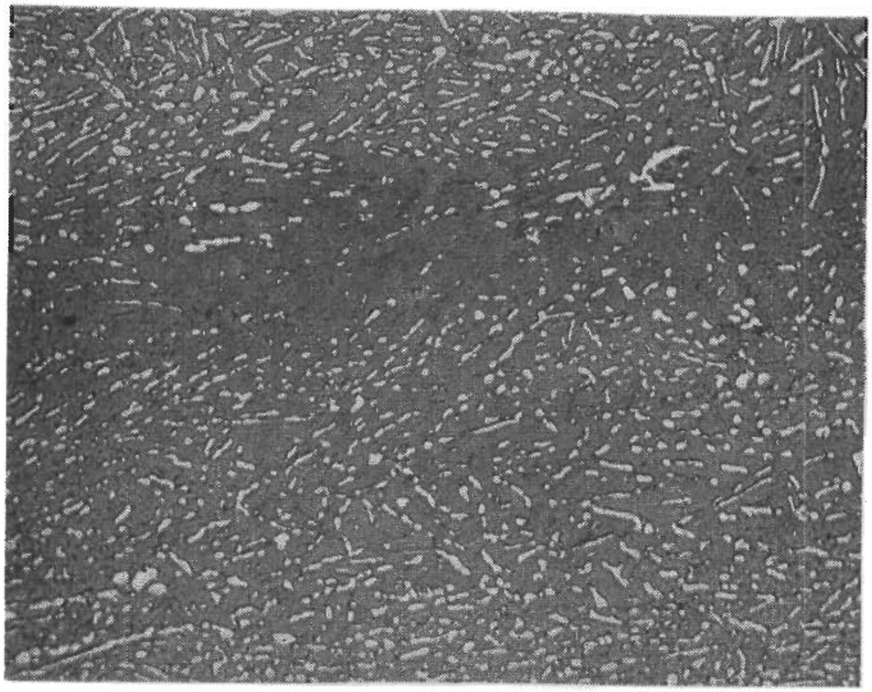


Heat G 1971 Nom Gage 1.50 NR Heat #9

250 X

FIG. 2-25

Ti 6Al-6V-2Sn Cond STA



Heat G 3024 Nom Gage 1.60 NR Heat #10

250 X

Mechanical Properties Determined

2.5 The various mechanical properties determined from each type of test performed are as follows:

1. Tensile Tests - Sheet and Plate

   (a) Ultimate Tensile Strength
   (b) 0.2% Offset Tensile Yield Strength
   (c) Percent Elongation
   (d) Percent Reduction of Area
   (e) Precision Elastic Tension Modulus (Selected Sample)

2. Compression Tests - Sheet and Plate

   (a) 0.2% Offset Compression Yield Strength

3. Bearing Tests - Sheet and Plate
   e/D = 1.5 and e/D = 2.0

   (a) Ultimate Bearing Strength
   (b) 2% Offset Bearing Yield Strength

4. Shear Tests - Sheet and Plate

   (a) Ultimate Shear Strength

5. Fracture Toughness Tests - Plate

   (a) Plane Strain Fracture Toughness Value (Kic)

6. Thermal Stability Tests - Sheet and Plate

   (a) Ultimate Tensile Strength, 0.2% Offset Yield Strength, % Elongation, % Reduction in Area for test specimens at room temperature and elevated temperature after exposure to elevated temperature for prolonged periods of time.

7. Fatigue Tests - Sheet and Plate

   (a) Stress versus number of cycles to failure, as a function of specimen geometry (smooth and notched) as well as stress-ratio.

2.6 Test Conditions

Room and elevated temperature, tension, compression, bearing, and shear mechanical property tests for the longitudinal and transverse direction as well as limited test in the short transverse direction for the four materials were performed in an air atmosphere. The range of elevated test temperatures included 400F, 600F, and 800F. The thermal stability tests which determined the effects of exposure in air temperatures of 400F, 600F, and 800F for times of 10, 100, and 1000 hours, were complied from tests at exposure temperature and at room temperature after exposure.

Fracture toughness test data were obtained at room temperature in air. In addition, fracture toughness tests were made on specimens at room temperature which had been exposed at 400F, 600F, and 800F for periods of 10, 100, and 1000 hours.

Axial fatigue tests were performed on three of the materials in the longitudinal direction using smooth test specimen configurations ($K_t = 1.0$) and notched test specimen configurations ($K_t = 3.0$). The tests were run at room temperature at stress ration of R = 1.0, -0.3, 0 and +0.3 where:

$$R = \frac{\text{Minimum Stress}}{\text{Maximum Stress}}$$

Test conditions for the complete program are shown in Tables II-1 through 11-6.

Table II-1

TENSION TESTS

NUMBER OF TESTS PER TEMPERATURE

Material	Thickness (inches)	RT	400°F	600°F	800°F	Thermal Stability					
						Tested at Rm. Temp.			Tested at Elevated Temp.		
						400°F	600°F	800°F	400°F	600°F	800°F
Ti 4AL-3Mo-1V (Cond. A)	≤ 0.110	12	8	8	8	3	3	3	3	3	3
Ti 13V-11CR-3AL (Cond. A)	≤ 0.110	10	6	6	6	3	3	3	3	3	3
Ti 6AL-4V (STA)	0.250-0.300	6	5	5	5	3	3	3	3	3	3
Ti 6AL-4V (STA)	0.500-0.650	6	2	2	2	3	3	3	-	-	-
Ti 6AL-4V (STA)	≥ 1.000	6	3	3	3	-	-	-	-	-	-
Ti 6AL-6V-2Sn (Cond. A)	0.250-0.300	10	5	5	5	3	3	3	3	3	3
Ti 6AL-6V-2Sn (Cond. A)	0.500-0.650	10	2	2	2	3	3	3	-	-	-
Ti 6AL-6V-2Sn (Cond. A)	≥ 1.000	15	3	3	3	3	3	3	-	-	-
Ti 6AL-6V-2Sn (STA)	0.250-0.300	2	1	1	1	1	-	-	-	-	-
Ti 6AL-6V-2Sn (STA)	0.500-0.650	14	2	2	2	3	3	3	-	-	-
Ti 6AL-6V-2Sn (STA)	≥ 1.000	20	3	3	3	3	3	3			

Table II-2

COMPRESSION TESTS

NUMBER OF TESTS PER TEMPERATURE

Material	Thickness (inches)	RT	400°F	600°F	800°F
Ti 4AL-3Mo-1V (Cond. A)	≤0.110	12	4	4	4
Ti 13V-11CR-3AL (Cond. A)	≤0.110	10	2	2	2
Ti 6AL-4V (STA)	0.250-0.300	6	4	4	4
Ti 6AL-4V (STA)	0.500-0.650	6	2	2	2
Ti 6AL-4V (STA)	≥1.000	6	3	3	3
Ti 6AL-6V-2Sn (Cond. A)	0.250-0.300	10	2	2	2
Ti 6AL-6V-2Sn (Cond. A)	0.500-0.650	10	2	2	2
Ti 6AL-6V-25n (Cond. A)	≥1.000	15	3	3	3
Ti 6AL-6V-2Sn (STA)	0.250-0.300	2	-	-	-
Ti 6AL-6V-2Sn (STA)	0.500-0.650	10	2	2	2
Ti 6AL-6V-2Sn (STA)	≥1.000	15	3	3	3

Table II-3

BEARING TESTS

NUMBER OF TESTS PER TEMPERATURE

Material	Thickness (inches)	e/D = 1.5 RT	e/D = 1.5 400°F	e/D = 1.5 600°F	e/D = 1.5 800°F	e/D = 2.0 RT	e/D = 2.0 400°F	e/D = 2.0 600°F	e/D = 2.0 800°F
Ti 4AL-3Mo-1V (Cond. A)	≤0.110	8	4	4	4	8	4	4	4
Ti 13V-11CR-3AL (Cond. A)	≤0.110	6	2	2	2	6	2	2	2
Ti 6AL-4V (STA)	0.250-0.300	5	4	4	4	5	4	4	4
Ti 6AL-4V (STA)	0.500-0.650	4	1	1	1	4	1	1	1
Ti 6AL-4V (STA)	≥1.000	5	1	1	1	5	1	1	1
Ti 6AL-6V-2Sn (Cond. A)	0.250-0.300	6	2	2	2	6	2	2	2
Ti 6AL-6V-2Sn (Cond. A)	0.500-0.650	6	1	1	1	6	1	1	1
Ti 6AL-6V-2Sn (Cond. A)	≥1.000	8	1	1	1	8	1	1	1
Ti 6AL-6V-2Sn (STA)	0.250-0.300	1	-	-	-	1	-	-	-
Ti 6AL-6V-2Sn (STA)	0.500-0.650	6	1	1	1	6	1	1	1
Ti 6AL-6V-2Sn (STA)	≥1.000	8	1	1	1	8	1	1	1

Table II-4

SHEAR TESTS

NUMBER OF TESTS PER TEMPERATURE

Material	Thickness (inches)	RT	400°F	600°F	800°F
Ti 4AL-3Mo-1V (Cond. A)	≤0.110	8	4	4	4
Ti 13V-11CR-3AL (Cond. A)	≤0.110	6	2	2	2
Ti 6AL-4V (STA)	0.250-0.310	5	4	4	4
Ti 6AL-4V (STA	0.500-0.630	4	1	1	1
Ti 6AL-4V (STA)	≥-1.00	3	1	1	1
Ti 6AL-6V-2Sn (Cond. A)	0.250-0.310	6	2	2	2
Ti 6AL-6V-2Sn (Cond. A)	0.500-0.630	6	1	1	1
Ti 6AL-6V-2Sn (Cond. A)	≥ 1.00	6	1	1	1
Ti 6AL-6V-2Sn (STA)	0.250-0.310	1	-	-	-
Ti 6AL-6V-2Sn (STA)	0.500-0.630	6	1	1	1
Ti 6AL-6V-2Sn (STA)	≥-1.00	6	1	1	1

Table II-5

FRACTURE TOUGHNESS TESTS

NUMBER OF TESTS

Material	Material Thickness	RT	Thermal Stability - Tested at R.T. 400°F	600°F	800°F
Ti 6AL-4 (STA)	0.250 to 0.300	5	3	3	3
Ti 6AL-6V-25n (Cond. A)	0.250 to 0.300	6	3	3	3
Ti 6AL-6V-25n	0.250 to 0.300	1	-	-	-

Table II-6

TENSION-TENSION FATIGUE TESTS

NUMBER OF TESTS

Material	Material Thickness	RT	
		Smooth $K_t = 1.0$	Notched $K_t = 3.0$
Ti 4AL-3Mo-1V (Cond. A)	≤ 0.110"	32	32
Ti 6AL-4V (STA)	- 1.000"	24	24
Ti 6AL-6V-2Sn (Cond. A)	≥ 1.000"	32	32
Ti 6AL-6V-2Sn (STA)	≥ 1.000"	32	32

Section III

TEST SPECIMENS

Contained within this section are the; (1) test specimen identification codes, (2) test specimen sampling, (3) test specimen configurations and (4) test specimen preparation procedures.

SECTION III

TEST SPECIMENS

3.1 SPECIMEN IDENTIFICATION CODES

A typical test specimen identification would be as follows: TV1ZLTR1. In general, test specimen code numbers will have the above form with each letter or number having a specific meaning as indicated below:

The letter "T" or "R" indicates the producer which are Titanium Metals Corp. and Reactive Metals, Inc.

The next letter in the coding system indicates the alloy:

A - Ti-6Al-4V (Cond. STA)
V - Ti-6Al-6V-2Sn (Cond. A and STA)
C - Ti-13V-11Cr-3Sn (Cond. A or ST)
M - Ti-4Al-3Mo-1V (Cond. A)

The following number in the coding sequence identifies the heat number for the particular alloy. There can be as many as 10 heats.

The next letter in the coding sequence relates to the gage of material being tested. In this regard these letters have been utilized in the following manner:

X - Gages of Material $<$ 0.250 In.
Y - Gages of Material $\leq$ 0.630 In.
Z - Gages of Material $\geq$ 1.000 In.

The above applies to both sheet and plate stock gages with all sheet specimens using the X designation.

The next letter indicates test specimen orientation in relation to the rolling direction marked on the raw stock. The directions test specimens were taken are as follows:

L - Longitudinal (parallel to the rolling direction)
T - Transverse (perpendicular to the rolling direction)
S - Short transverse (through the thickness of the heavy gage plate)
LE - Refers to bearing specimens only, with the test specimen being taken on edge parallel to the direction of rolling
TE - Refers to bearing specimens only, with the test specimens being taken on edge perpendicular to the direction of rolling

The next letter refers to the type of test which is to be performed. The following indicates the types of tests:

T - Tension
C - Compression
S - Shear
B1 - Bearing e/D = 1.5
B2 - Bearing e/D = 2.0
F - Fracture Toughness
V - Fatigue
W - Room Temperature Stability
X - Elevated Temperature Stability

Where a stability test is indicated, the type of stability test is identified, i.e., (X) with the type of test specimen following, i.e., (T) tensile.

The next to last letter or number in the coding sequence refers to the test temperature or the exposure temperature:

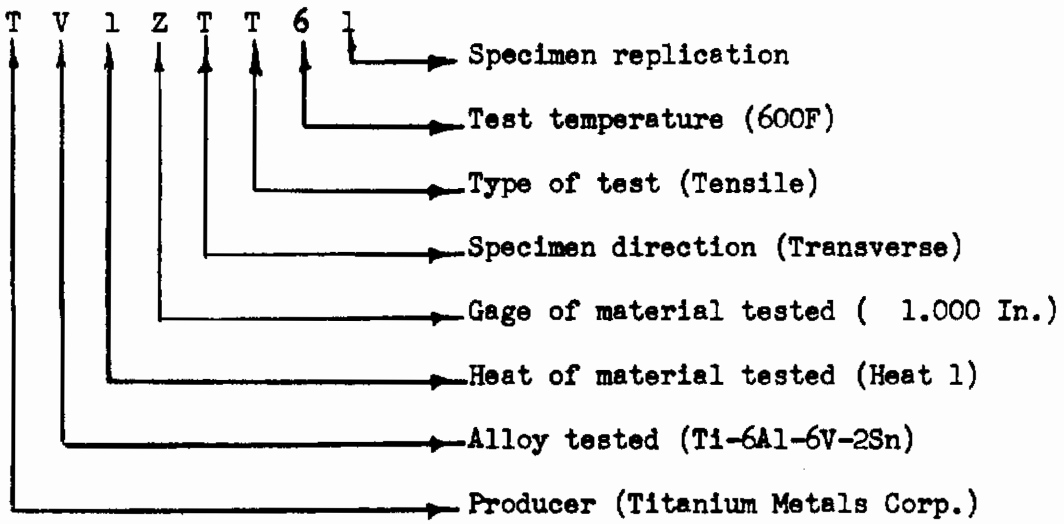
R - Room Temperature
4 - 400F
6 - 600F
8 - 800F

The last number in the sequence reflects individual specimen replication (i.e., 1, 2 and 3).

Miscellaneous notations and exceptions to the coding system: The last number in the coding sequence of the thermal stability test specimen refers to the exposure time rather than specimen replication. In this regard:

1 - 10 hours exposure
2 - 100 hours exposure
3 - 1000 hours exposure

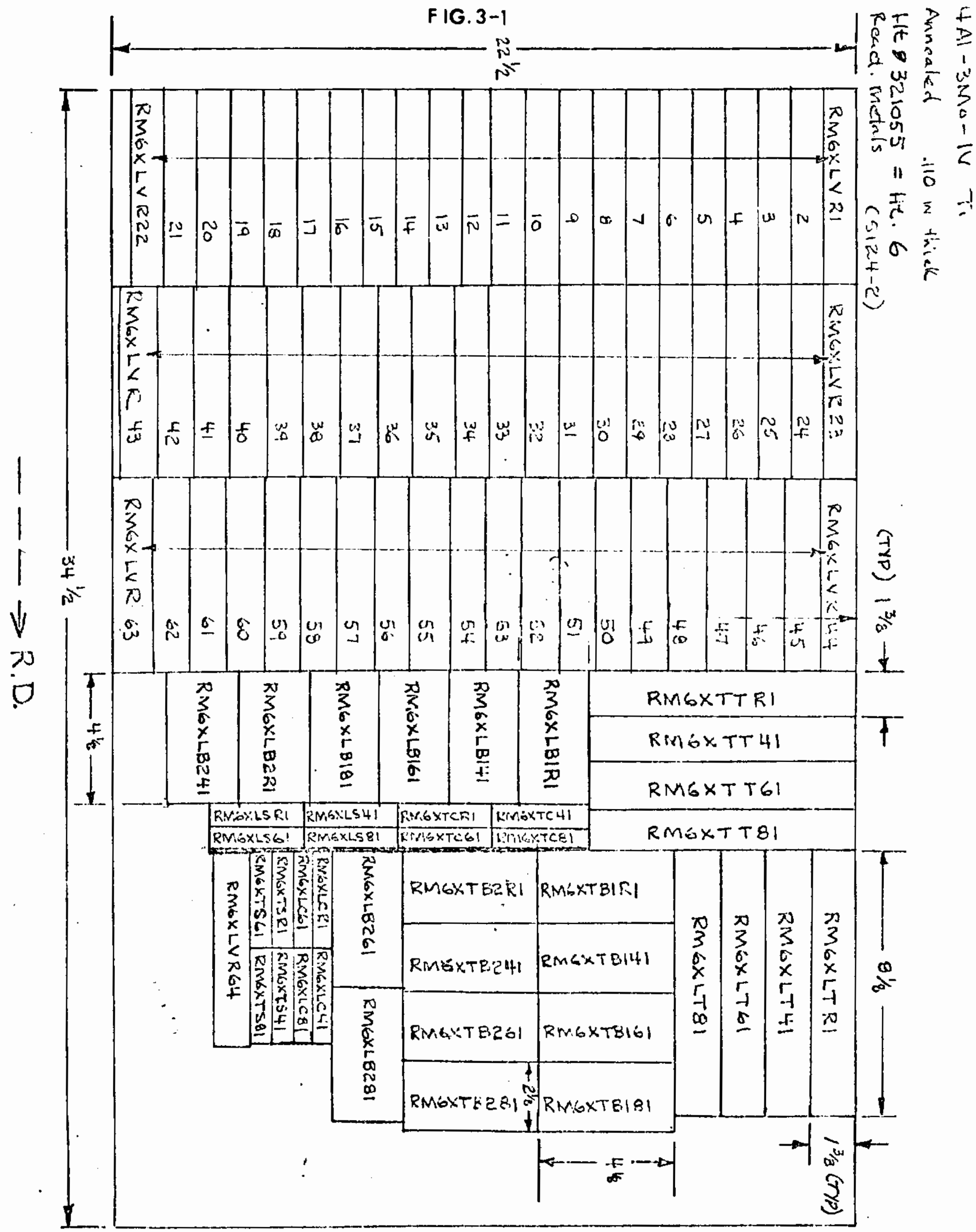
An example of the coding system is shown in the diagram below:



3.2 SPECIMEN SAMPLING

Due to the fact that most of the test material was received from the two suppliers as bits and pieces, the layout of test coupons was necessarily dictated by the size of the piece of material. A typical test specimen layout for one of the sheet gage heats is shown in Figure 3-1. As can be seen, removal of committed test coupons resulted in a minimum of surplus material.

FIG. 3-1


4Al-3Mo-1V Ti
Annealed .110 in thick
Ht # 321055 = Ht. 6
Reac. Metals (5124-2)
22 1/2
34 1/2
R.D.
(TYP) 1 3/8
4 1/8
8 1/8
2 1/8
1 3/8 (TYP)
RM6XLVR1
RM6XLVR22
RM6XLVR23
RM6XLVR43
RM6XLVR44
RM6XLVR63
RM6XLVR64
RM6XTTR1
RM6XTT41
RM6XTT61
RM6XTT81
RM6XLB241
RM6XLB2R1
RM6XLB181
RM6XLB161
RM6XLB141
RM6XLB1R1
RM6XLSR1
RM6XLS41
RM6XLS61
RM6XLS81
RM6XTCR1
RM6XTC41
RM6XTC61
RM6XTC81
RM6XTS61
RM6XTSR1
RM6XTS81
RM6XTS41
RM6XLC61
RM6XLCR1
RM6XLC81
RM6XLC41
RM6XLB261
RM6XLB281
RM6XTB2R1
RM6XTB1R1
RM6XTB241
RM6XTB141
RM6XTB261
RM6XTB161
RM6XTB281
RM6XTB181
RM6XLT81
RM6XLT61
RM6XLT41
RM6XLTR1

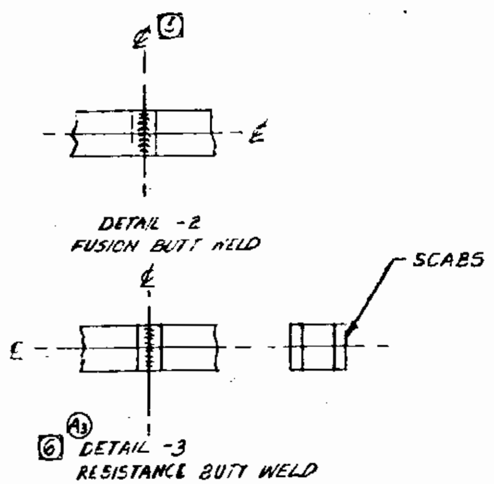
3.3 SPECIMEN CONFIGURATION

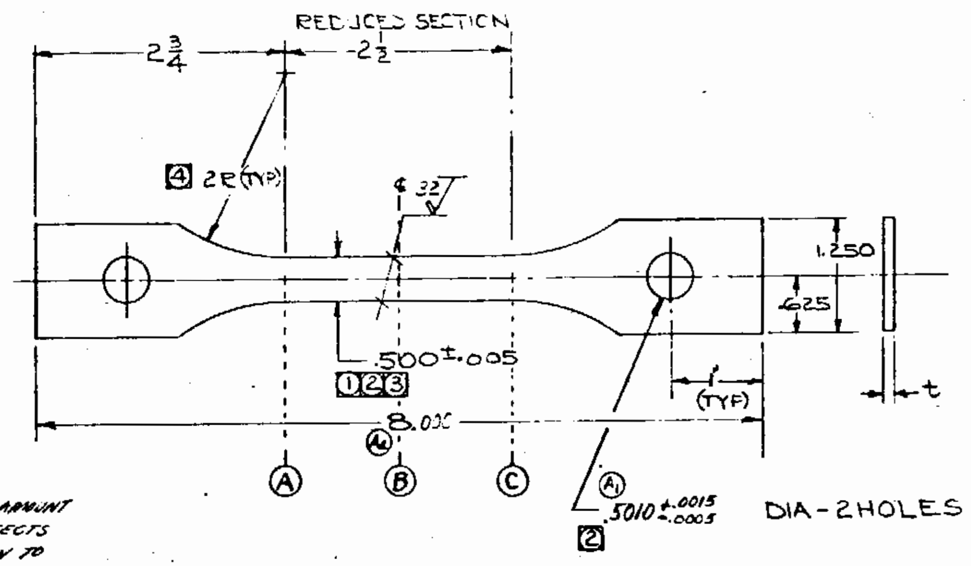
Typical test specimen configurations used on this program are shown in Figures 3-2 through 3-12. The configurations selected were tailored to material sizes available. The use of sub size specimens were avoided with the exception of those test specimens taken in the short transverse direction (through the thickness) of the heavy gage plate stock and the round bar fatigue tests. All test specimens conform, where applicable, to ASTM Standards.

FIG. 3-2

A TT-15139

SYM	DESCRIPTION	DISPOS	DATE	SIGNATURE
	1 MAY BE REWORKED 2 CANNOT BE REWORKED 3 RECORD CHANGE 4 NOW SHOP PRACTICE 5 PARTS MADE OK			
A	1. [illegible] 2. ADDED [illegible] 3. ADDED [illegible] 4. 8.000 WAS 5			





11. MAX THICKNESS OF SPECIMEN .125

10. WHEN NOTED ON ATTACHED INSTRUCTION SHEET TO HAVE WELD BEAD MACHINED FLUSH, MACHINE MINIMUM AMOUNT TO REMOVE WELD BUILD-UP DROP-THRU, UNDERCUT, AND DEFECTS FROM FACE & ROOT SURFACES. SURFACE OF ENTIRE SPECIMEN TO BE MACHINED TO UNIFORM THICKNESS ±.005. FINISH MACHINED THICKNESS TO BE NO LESS THAN 75% OF ORIGINAL PARENT METAL THICKNESS. 15% OF PARENT METAL THICKNESS IS MAXIMUM AMOUNT TO BE MACHINED FROM ONE SURFACE

5 9. CENTER OF REDUCED SECTION MUST BE ON CENTERLINE OF WELD BEAD ROOT (DETAIL -2 ONLY)

8. RETURN TO TEST ENGINEER FOR LIGHT ETCH IF WELD LOCATION IS NOT VISIBLE (DETAIL -2 ONLY)

7. BLANK WIDTH $\frac{1}{32}$ GREATER FOR .062 & UNDER STOCK, $\frac{1}{16}$ GREATER FOR .062 & OVER STOCK

6. IDENTIFY PER NAA SPEC LA0104-003

4 5. RADIUS MUST NOT UNDERCUT THE REDUCED SECTION.

3 4. SIDES OF REDUCED SECTION MUST BE PARALLEL TO EACH OTHER & TO THE CENTERLINE WITHIN .001 T.I.R.

2 3. HOLES TO BE ON CENTERLINE OF REDUCED SECTION WITHIN ±.003

1 2. EDGES OF REDUCED SECTION TO BE LEFT SHARP

1. MACHINE PER NAA SPEC LA0103-02A

NOTES: UNLESS OTHERWISE NOTED.

14. WIDTH AT Ⓐ AND/OR Ⓒ TO EXCEED WIDTH AT Ⓑ BY +0.0005 TO −0.003 INCHES

A2 6 13. SPECIMENS SHOULD BE CUT FROM THE AREAS MARKED ON THE PANELS

A2 6 12. SCABS SHOULD BE REMOVED FROM _ SIDES

REQD RH	REQD LH	PART NO.	DESC	MATERIAL	SIZE	ZONE	MATL SPEC	LINE 001	QTY PER END ITEM	USED ON	NEXT ASSY
				LIST OF MATERIAL						APPLICATION	

DRILLED HOLE TOLERANCES: .040 TO .1285 +.002, −.001; .136 TO .228 +.003, −.001; .234 TO 1/2 +.004, −.001; 33/64 TO 3/4 +.005, −.001; 49/64 TO 1 +.007, −.001; 1-1/64 TO 2 +.010, −.001

TOLERANCES EXCEPT AS NOTED: ANGLES ±1/2° FRACTIONS ±1/32 DECIMALS ±.010

SURFACE ROUGHNESS PER MIL-STD-10 (FA6-2191)

HEAT TREAT

FINISH

DATE MAY 2 1960 · DR BY HAYS[illegible] · CHK BY · APPD BY [illegible] · APPD BY

INSPECT PER MIL-I-6870 (LO0501-0071) CLASS

SPECIMEN-TENSILE TEST, FLAT

NORTH AMERICAN AVIATION, INC.
ENGINEERING
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIF.

DWG SIZE C · CODE IDENT 4099 · TT-15139 · SCALE FULL · WT · SHEET OF

DASH NO	D	A	L	C	(4) T	[illegible]	B	P
-3	.125 ±.002	1 1/2	2 3/8	.2500 +.0000 −.0087	1/4-28	.007	1/2	1/8
-5	.187 ±.003	1 1/8	2 1/2	.3750 +.0000 −.0084	3/8-16	.009	1/2	3/16
-7	.250 ±.004	1 1/8	2 5/8	.4375 +.0000 −.0103	7/16-14	.010	1/2	1/4
-9	.250 ±.004	1 1/8	2 5/8	.500 +.0000 −.0094	1/2-20	.007	1/2	1/4
-11	.250 ±.004	2 1/4	4	.5000 +.0000 −.0081	1/2-20	.007	5/8	1/4
-13	.312 ±.006	1 5/8	3 1/2	.5000 +.0000 −.0109	1/2-13	.011	5/8	5/16
-15	.375 ±.007	2 1/4	4 1/4	.5625 +.0000 −.0114	9/16-12	.012	5/8	3/8
-17	.437 ±.006	2 1/4	4 5/8	.6250 +.0000 −.0121	5/8-11	.013	3/4	7/16
-19	.500 ±.010	2 1/4	5	.7482 +.0000 −.0129	3/4-10	.014	7/8	1/2
-21	.500 ±.010	2 1/4	5	.7500 +.0000 −.0094	3/4-16	.009	7/8	1/2
-23	.125 ±.002	5/8	1 3/4	.2500 +.0000 −.0091	1/4-20	.007	1/2	1/8
-25	.100 ±.002	1/4	1	.1675 +.0000 −.0072	10-32	.007	7/32	1/4

REVISIONS

SYM	DESCRIPTION	DISPOS	DATE	SIGNATURE
	[1] MAY BE REWORKED [2] CANNOT BE REWORKED [3] RECORD CHANGE [4] NOW SHOP PRACTICE [5] PARTS MADE OK			
A	1. REDRAWN & REL. DIMENSIONED 2. C' SIZE WAS B SIZE			
B	INACTIVATED			

TT-11017

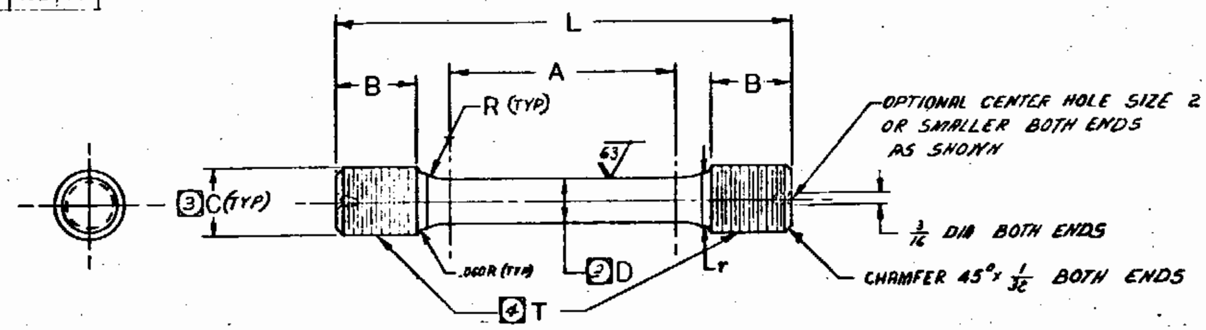


FIG. 3-3

A TT-11017

INACTIVE FOR DESIGN - USE TT-11007

REQD RH	REQD LH	PART NO.	DESC	MATERIAL	SIZE	ZONE	MATL SPEC
		-23	SPECIMEN	(1)	5/16 DIA x 2 3/8		(1)
		-21			13/16 DIA x 5"		
		-19			13/16 DIA x 5"		
		-17			11/16 DIA x 4 7/8		
		-15			5/8 DIA x 4 1/4		
		-13			9/16 DIA x 3 1/2		
		-11			9/16 DIA x 4		
		-9			9/16 DIA x 2 7/8		
		-7			1/2 DIA x 2 7/8		
		-5			7/16 DIA x 2 1/2		
		-3	SPECIMEN	(1)	5/16 DIA x 2 3/8		(1)

LIST OF MATERIAL

QTY PER END ITEM | USED ON | NEXT ASSY — APPLICATION

(5) 10. CREEP SPECIMEN FOR NOTCH SENSITIVE MATERIALS
(4) 9. THREADS TO BE A CLASS 2A FIT
(3) 8. CONCENTRIC WITHIN .003 T.I.R.
(2) 7. HEAT TREATMENT TO BE PERFORMED PRIOR TO FINISH MACHINING & THREADING
(1) 6. SEE ATTACHED INSTRUCTION SHEET FOR THIS INFORMATION
5. DIA "D" MAY BE INCREASED TOWARD FILLETS NOT TO EXCEED .003
4. DO NOT COLD ROLL THREADS ON TITANIUM SPECIMEN
3. NO UNDERCUTTING OF RADIUS "R"
2. IDENTIFY PER NAA SPEC FA6-54 ON ENDS
1. MACHINE PER NAA SPEC FA6-125
NOTES: UNLESS OTHERWISE NOTED

DRILLED HOLE TOLERANCES
.040 TO .1285: +.002 −.001
.136 TO .228: +.003 −.001
.234 TO 1/2: +.004 −.001
33/64 TO 3/4: +.005 −.001
49/64 TO 1: +.007 −.001
1-1/64 TO 2: +.010 −.001

TOLERANCES EXCEPT AS NOTED
ANGLES ± 1/2° FRACTIONS ± 1/32 DECIMALS ± .010
SURFACE ROUGHNESS PER MIL-STD-10 (FA6-2191)
HEAT TREAT (1)(2)
FINISH (1)

DATE 7-8-55
DR BY [illegible]
CHK BY
APPD BY [illegible]
APPD BY

SPECIMEN-ROUND TENSION TEST

SCALE FULL SIZE | WT

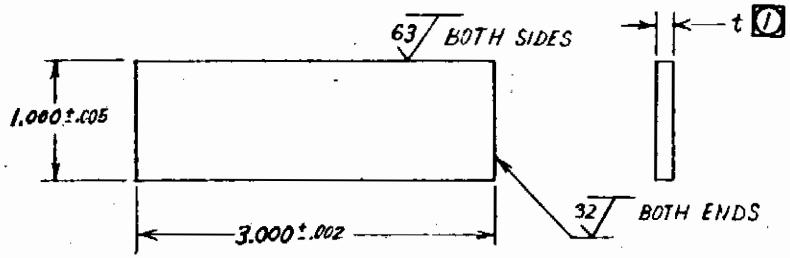
NORTH AMERICAN AVIATION, INC.
ENGINEERING
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIF.

DWG SIZE C | TT-11017

FIG. 3-4

TT-14299

SYM	REVISIONS DESCRIPTION	DISPOS	DATE	SIGNATURE
	1 MAY BE REWORKED 3 RECORD CHANGE 2 CANNOT BE REWORKED 4 NOW SHOP PRACTICE 5 PARTS MADE OK			



NOTES: UNLESS OTHERWISE NOTED

1. ENDS PARALLEL WITHIN .0005.
2. ENDS & SIDES TO BE SQUARE WITHIN 1/4 OF ONE DEGREE.
3. (1) SEE ATTACHED INSTRUCTION SHEET FOR THIS INFORMATION.
4. DO NOT BREAK EDGES OR SCRATCH SURFACE OF SPECIMEN.
5. DO NOT METAL IMPRESSION STAMP. GUMMED LABEL TAPE OR CRAYON MAY BE USED FOR IDENTIFICATION.
6. BLANK WIDTH & LENGTH 1/8 GREATER FOR .062 & UNDER, BLANK WIDTH & LENGTH 3/16 GREATER FOR .062 TO .125, OVER .125 CONSULT RESEARCH CONSTRUCTION.
7. (2) HEAT TREATMENT TO BE PERFORMED PRIOR TO FINISH MACHINING.

REQD	REQD	PART NO	DESC	MATERIAL	SIZE	ZONE	MATL SPEC
		TT-14299	SPECIMEN	1	1		1
RH	LH	LIST OF MATERIAL					

QTY PER END ITEM	USED ON	NEXT ASSY
	APPLICATION	

DRILLED HOLE TOLERANCES	
.040 TO .1285	+.002, −.001
.136 TO .228	+.003, −.001
.234 TO 1/2	+.004, −.001
33/64 TO 3/4	+.005, −.001
49/64 TO 1	+.007, −.001
1-1/64 TO 2	+.010, −.001

TOLERANCES EXCEPT AS NOTED: ANGLES ±1/2°, FRACTIONS ±1/32, DECIMALS ±.010

√ SURFACE ROUGHNESS PER MIL-STD-10 (FA6-219)

HEAT TREAT: 1 2

FINISH: 1

DATE	5-7-57
DR BY	S. ALLISON
CHK BY	[illegible]
APPD BY	[illegible]
APPD BY	

SPECIMEN - COMPRESSION TEST, GENERAL USE, TO 1850F

SCALE FULL　WT

NORTH AMERICAN AVIATION, INC.
ENGINEERING
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIF.

DWG SIZE B　TT-14299

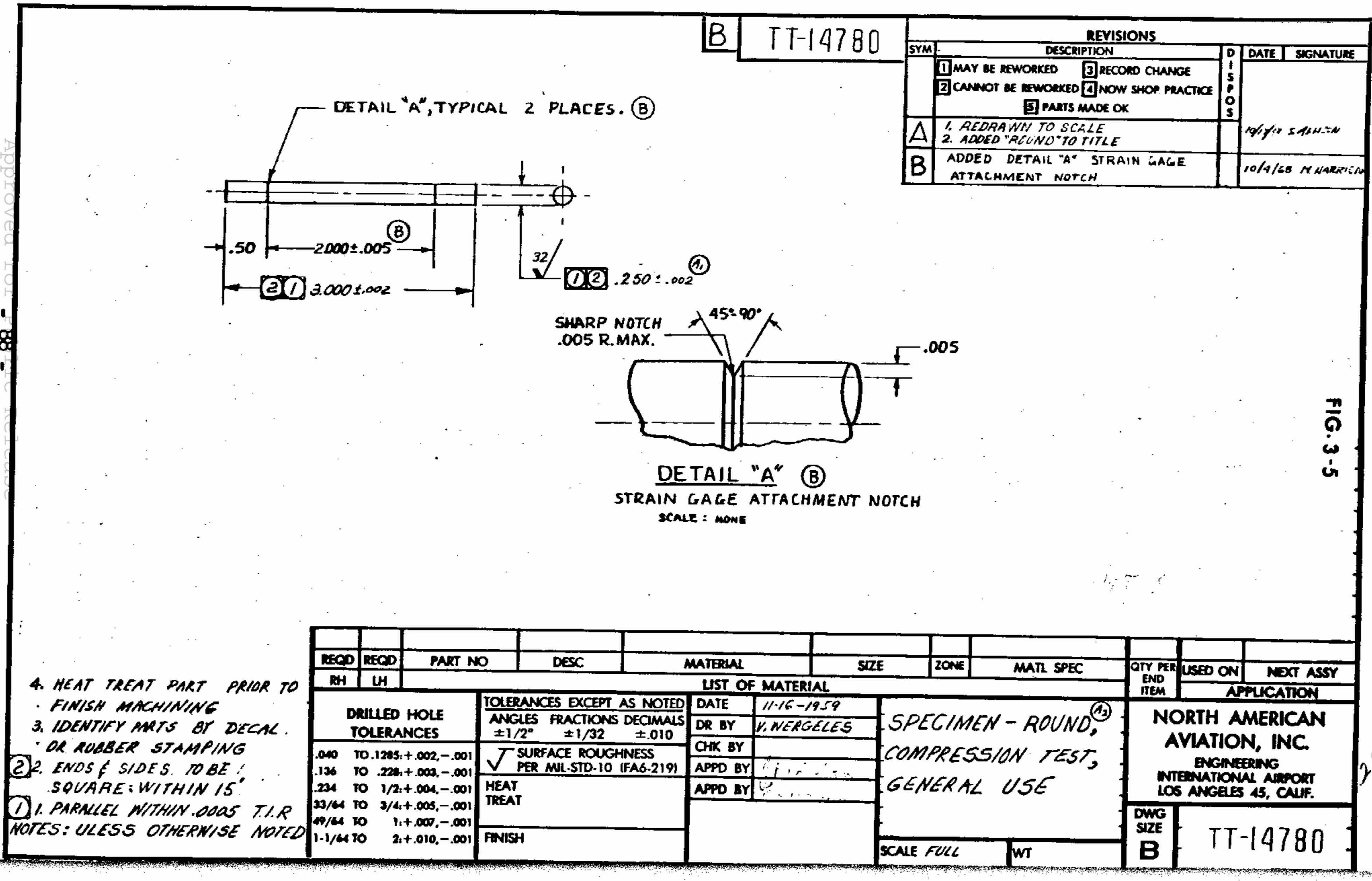
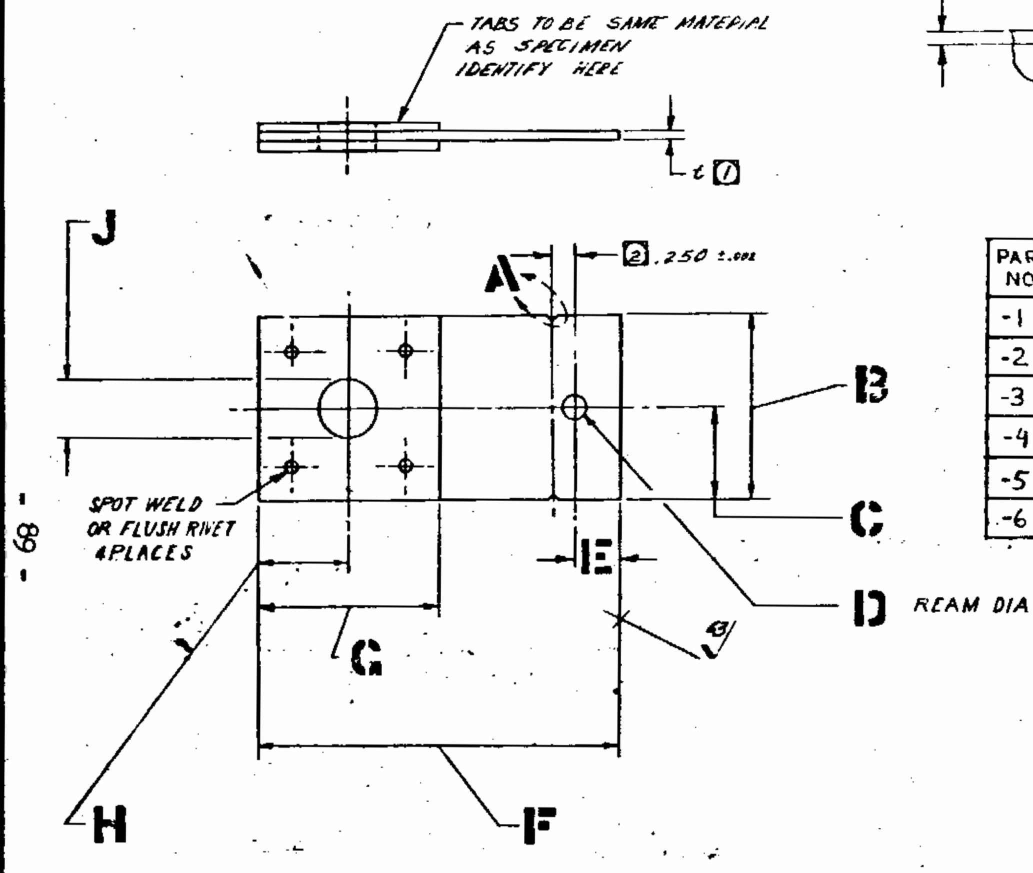

B TT-14780
REVISIONS
SYM
DESCRIPTION
DISPOS
DATE
SIGNATURE
1 MAY BE REWORKED
2 CANNOT BE REWORKED
3 RECORD CHANGE
4 NOW SHOP PRACTICE
5 PARTS MADE OK
A 1. REDRAWN TO SCALE 2. ADDED "ROUND" TO TITLE
B ADDED DETAIL "A" STRAIN GAGE ATTACHMENT NOTCH
10/4/68
DETAIL "A", TYPICAL 2 PLACES. (B)
.50
2.000±.005 (B)
2 1 3.000±.002
32
1 2 .250±.002 (A1)
SHARP NOTCH .005 R. MAX.
45°-90°
.005
DETAIL "A" (B)
STRAIN GAGE ATTACHMENT NOTCH
SCALE : NONE
4. HEAT TREAT PART PRIOR TO FINISH MACHINING
3. IDENTIFY PARTS BY DECAL OR RUBBER STAMPING
2 2. ENDS & SIDES TO BE SQUARE: WITHIN 15'
1 1. PARALLEL WITHIN .0005 T.I.R
NOTES: ULESS OTHERWISE NOTED
REQD RH
REQD LH
PART NO
DESC
MATERIAL
SIZE
ZONE
MATL SPEC
LIST OF MATERIAL
QTY PER END ITEM
USED ON
NEXT ASSY
APPLICATION
DRILLED HOLE TOLERANCES
.040 TO .1285: +.002, -.001
.136 TO .228: +.003, -.001
.234 TO 1/2: +.004, -.001
33/64 TO 3/4: +.005, -.001
49/64 TO 1: +.007, -.001
1-1/64 TO 2: +.010, -.001
TOLERANCES EXCEPT AS NOTED
ANGLES ±1/2°
FRACTIONS ±1/32
DECIMALS ±.010
SURFACE ROUGHNESS PER MIL-STD-10 (FA6-219)
HEAT TREAT
FINISH
DATE 11-16-1959
DR BY V. NERGELES
CHK BY
APPD BY
APPD BY
SPECIMEN - ROUND, (A1)
COMPRESSION TEST,
GENERAL USE
NORTH AMERICAN AVIATION, INC.
ENGINEERING
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIF.
SCALE FULL
WT
DWG SIZE B
TT-14780

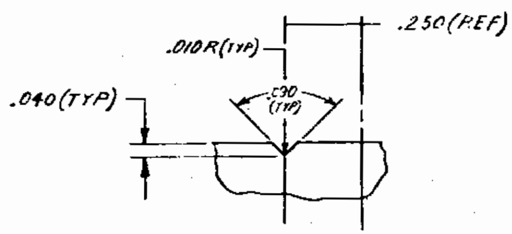
FIG. 3-5

FIG. 3-6

REVISIONS				
SYM	DESCRIPTION		DATE	SIGNATURE
	[1] MAY BE REWORKED [2] CANNOT BE REWORKED [3] RECORD CHANGE [4] NOW SHOP PRACTICE [5] PARTS MADE OK			
A	1. ADDED [illegible] (TYP), .030(TYP)		[illegible]	[illegible]
B	[illegible] ADDED 2. DIMENSIONS ADDED B,C,D,E,F, G,H,J 3. NOTE B ADDED 4. -6 ADDED TO NOTE 7		[illegible]	[illegible]

B TT-15117





DETAIL **A**
NO SCALE

PART NO.	B	C	D	E	F	G	H	J	E/D RATIO
-1	1	1/2	0.1255 ±[illegible]	0.1875 ±.0005	2	1	1/2	0.250 ±[illegible]	1 1/2
-2	1	1/2	0.1255 ±[illegible]	.250 ±.001	2	1	1/2	.250 ±[illegible]	2
-3	2	1	.250 ±[illegible]	.375 ±.002	4	2	1	.627 ±[illegible]	1 1/2
-4	2	1	.250 ±[illegible]	.500 ±.002	4	2	1	.627 ±[illegible]	2
-5	2	1	.375 ±[illegible]	.562 ±.002	4	2	1	.627 ±[illegible]	1 1/2
-6	2	1	.375 ±[illegible]	.750 ±.002	4	2	1	.627 ±[illegible]	2

B TT-15117

8. ALL DIMENSIONS IN BOX ARE IN INCHES
[3] 7. USE -5 OR -6, FOR LOADS OVER 6000 lb
[2] 6. NOTCHES MUST BE INLINE WITHIN ±.005
[1] 5. SEE ATTACHED INSTRUCTION SHEET FOR THIS INFORMATION
4. BLANK WIDTH 1/32 GREATER FOR .062 & UNDER, 1/16 GREATER FOR OVER .062
3. HOLES TO BE ON ℄ WITHIN ±.005
2. 125√ ALL MACHINED SURFACES
1. IDENTIFY PER LA0104-003

NOTES: UNLESS OTHERWISE NOTED

REQD RH	REQD LH	PART NO.	DESC	MATERIAL	SIZE	ZONE	MATL SPEC	LINE	QTY PER IND ITEM	USED ON	NEXT ASSY
	[3]	-5	SPECIMEN	[1]	[1]		[1]				
		-3	SPECIMEN	[1]	[1]		[1]	001			

LIST OF MATERIAL — APPLICATION

DRILLED HOLE TOLERANCES	
.040 TO .1285	+.002, -.001
.136 TO .228	+.003, -.001
.234 TO 1/2	+.004, -.001
33/64 TO 3/4	+.005, -.001
49/64 TO 1	+.007, -.001
1-1/64 TO 2	+.010, -.001

TOLERANCES EXCEPT AS NOTED: ANGLES ±1/2°, FRACTIONS ±1/32, DECIMALS ±.010

√ SURFACE ROUGHNESS PER MIL-STD-10 (FA6-2191)

HEAT TREAT [1]

FINISH [1]

INSPECT PER MIL-I-6870 (LOOSRY-COT) CLASS

DATE 5-2-1960
DR BY [illegible]
CHK BY
APPD BY [illegible]
APPD BY

SPECIMEN-BEARING TEST, STANDARD AND MINIATURE-ROOM AND ELEVATED TEMPERATURE

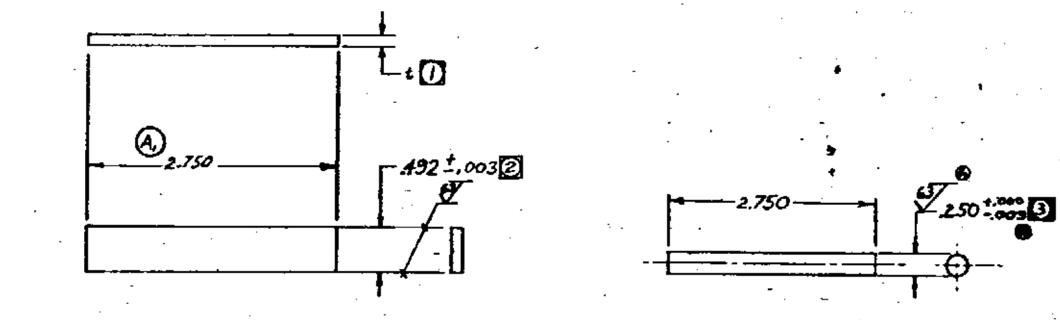
SCALE FULL WT

NORTH AMERICAN AVIATION, INC.
ENGINEERING
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIF.

DWG SIZE C TT-15117 SHEET OF

REVISIONS

SYM	DESCRIPTION	DISPOS	DATE	SIGNATURE
	1 MAY BE REWORKED 3 RECORD CHANGE 2 CANNOT BE REWORKED 4 NOW SHOP PRACTICE 5 PARTS MADE OK			
A	1. 2.750 WAS 6 2. ADDED -3 SPECIMEN 3. REVISED NOTES 1 & 4 4. ADDED NOTE 5	1 3 3 1		S. Allison
B	1. .250 WAS .250 2. ADDED √, NOTE 6.	5 5		S. Allison
C	1. .492 WAS .495	1		S. Allison
D	1. DOUBLE WAS SINGLE	1	9-3-59	S. Allison



-1 SPECIMEN
2 SHEET MAT'L ONLY

A1 -3 SPECIMEN
ROUND BAR MAT'L ONLY

FIG. 3-7

D TT-12584

4 6 HEAT TREATMENT TO BE PERFORMED PRIOR TO FINISH MACHINING. 6

A 3 5 LONG MACHINED SURFACES TO BE PARALLEL WITHIN .002

A 2 4- BLANK WIDTH TO BE 9/16 FOR GAGES UP TO .063 AND 5/8 FOR THICKER MAT'L

2 3- EDGES TO BE LEFT SHARP ON ALL FLAT SURFACES

2- IDENTIFY PER SPEC. FA6-54

A1 1 1- SEE ATTACHED INSTRUCTION SHEET FOR THIS INFORMATION

NOTES: UNLESS OTHERWISE NOTED

REQD RH	REQD LH	PART NO	DESC	MATERIAL	SIZE	ZONE	MATL SPEC
				0	0		0

LIST OF MATERIAL

QTY PER END ITEM	USED ON	NEXT ASSY
	APPLICATION	

DRILLED HOLE TOLERANCES

.040	TO .1285	+.002, -.001
.136	TO .228	+.003, -.001
.234	TO 1/2	+.004, -.001
33/64	TO 3/4	+.005, -.001
49/64	TO 1	+.007, -.001
1-1/64	TO 2	+.010, -.001

TOLERANCES EXCEPT AS NOTED: ANGLES ±1/2°, FRACTIONS ±1/32, DECIMALS ±.010

√ SURFACE ROUGHNESS PER MIL-STD-10 (FA6-219)

HEAT TREAT: 1 4 6

FINISH: 1

DATE: [illegible]
DR BY: T. Gomez
CHK BY:
APPD BY:
APPD BY:

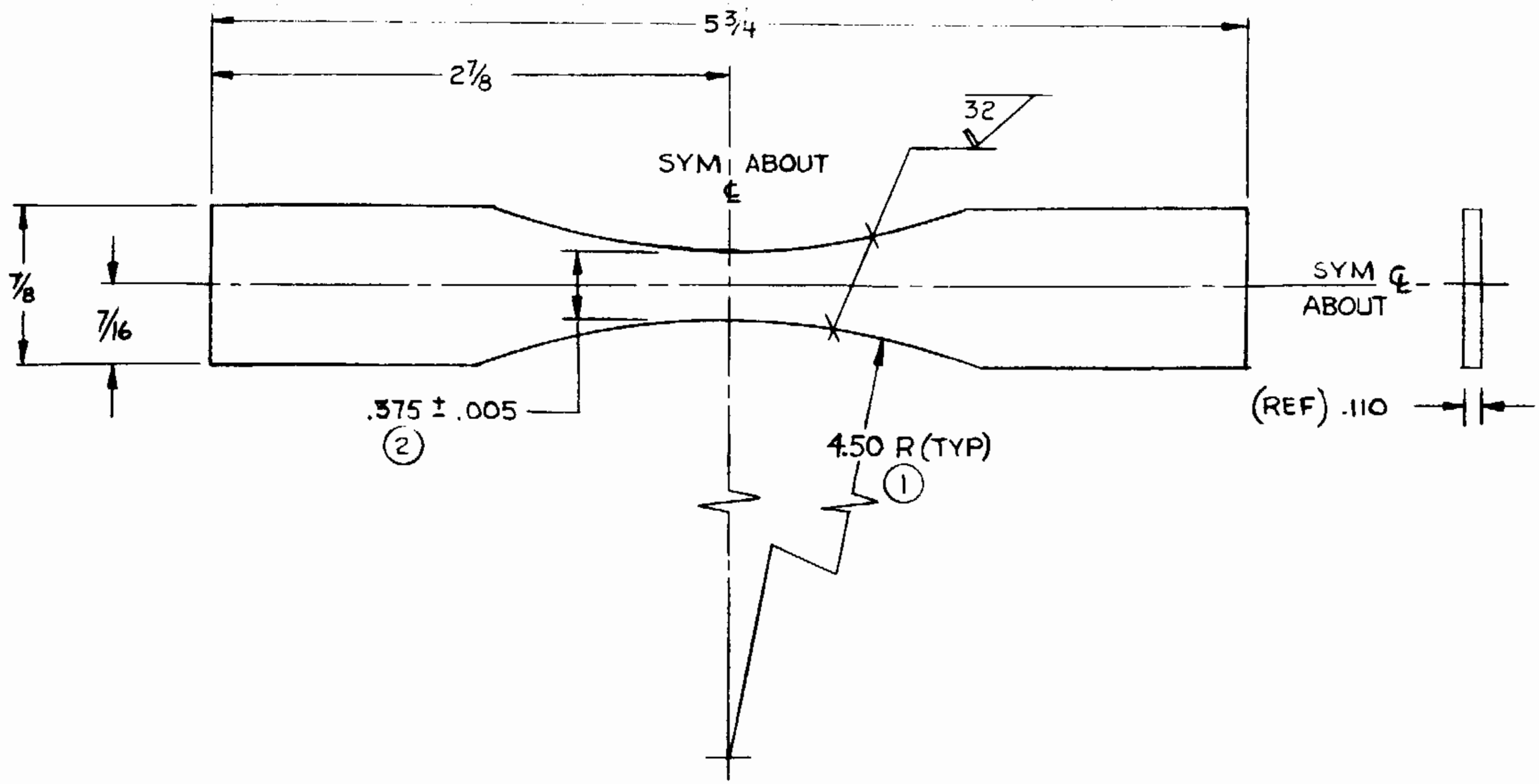
SPECIMEN - DOUBLE D SHEAR TEST

SCALE FULL   WT

NORTH AMERICAN AVIATION, INC.
ENGINEERING
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIF.

DWG SIZE C   TT-12584

FIG. 3-8

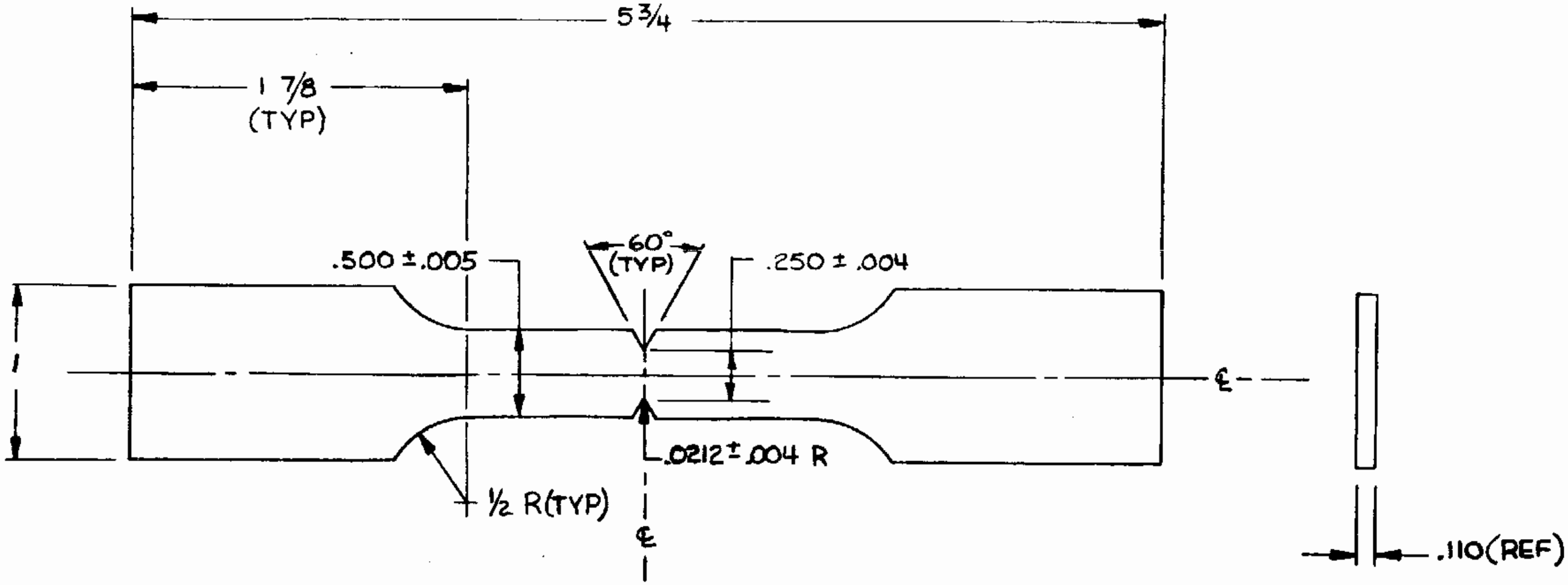


4. √ SURFACE ROUGHNESS PER MIL-STD-10 (FA6-219)
(2) 3. RADIUS MUST NOT UNERCUT THE REDUCED SECTION
(1) 2. EDGES OF REDUCED SECTION TO BE LEFT SHARP
1. TOLERANCES: FRACTIONS ± 1/32 , DECIMALS ± .010

NOTES: UNLESS OTHERWISE NOTED

SPECIMEN —
FATIGUE TEST,
SMOOTH

SCALE : FULL



8. NOTCH AND REDUCED SECTION TO BE SYMMETRICAL ABOUT ℄ ±.002.
7. CENTERLINE OF NOTCHES TO BE LESS THAN .005 APART.
6. MACHINE NOTCH SURFACE 32√
5. TOOL CHATTER, METAL TEARING, OR OTHER TOOL MARKS IN NOTCH WILL BE CAUSE FOR REJECTION. DO NOT BUFF.
4. NOTCHES TO BE MADE WITH LIGHT FINISHING CUTS OR LIGHT GRINDING & MUST HAVE CONTOUR SHOWN.
3. MACHINE SURFACES 125√
2. √ SURFACE ROUGHNESS PER MIL-STD-10 (FA6-219).
1. TOLERANCES: ANGLES ± ½°, FRACTIONS ± 1/32.

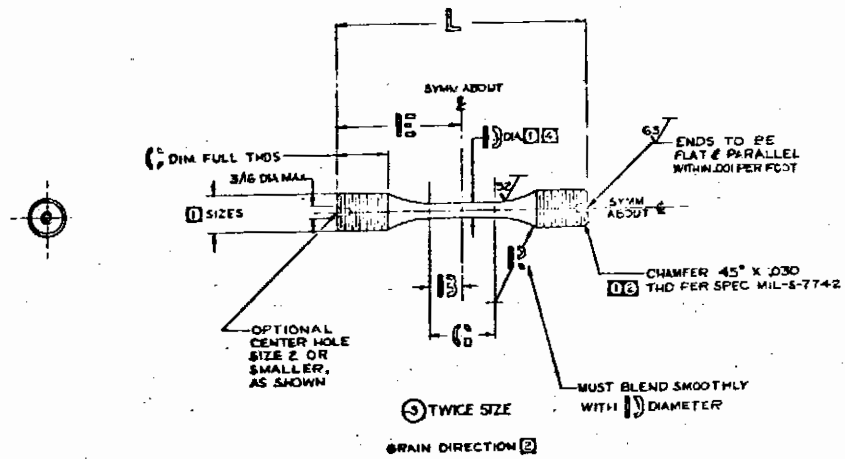
NOTES: UNLESS OTHERWISE NOTED

SPECIMEN — FATIGUE TEST, NOTCHED

SCALE: FULL

FIG. 3-9

FIG. 3-10



PART NO.	D	SIZES	L	C	E	G	R	PITCH DIA	B	ROLL THD
	IN.	INCHES	IN.	IN.	IN.	IN.	IN.	INCHES	IN.	
-3	0138 ±.005	5/16 - 24 CLASS [illegible]	2 1/8	7/16	1 1/16	9/16	23/32	[illegible]	9/32	UNF-3A
-5	0195 ±.005	7/16 - 20 CLASS 3A .4375 [illegible]	2 5/8	7/16	1 5/16	13/16	31/32	[illegible]	13/32	UNF-3A

7. AFTER LIGHT FINISH MACHINING POLISH THE TEST PORTION OF THE SPECIMEN WITH FINE EMERY PAPER. USE NO. 0 & 00, FOLLOWED BY A FINAL LONGITUDINAL POLISH WITH NO 000 EMERY PAPER. DO NOT BUFF OR GRIND.
6. NO UNDERCUTTING OF R DIM. RADIUS.
5. HEAT TREATMENT TO BE PERFORMED PRIOR TO FINISH MACHINING & THREADING.
4. SEE ATTACHED INSTRUCTION SHEET FOR THIS INFORMATION.
3. REDUCED SECTION MUST BE PARALLEL WITHIN .005 T.I.R.
2. MACHINE PER NAA SPEC LA0103-004
1. CONCENTRIC WITHIN .003 T.I.R.

NOTES: UNLESS OTHERWISE NOTED.

SPECIMEN - FATIGUE SUB-SIZE FOR AMSLER FATIGUE MACHINE (TEST)

NORTH AMERICAN AVIATION, INC.
LOS ANGELES 45, CALIF.

A TT-15568

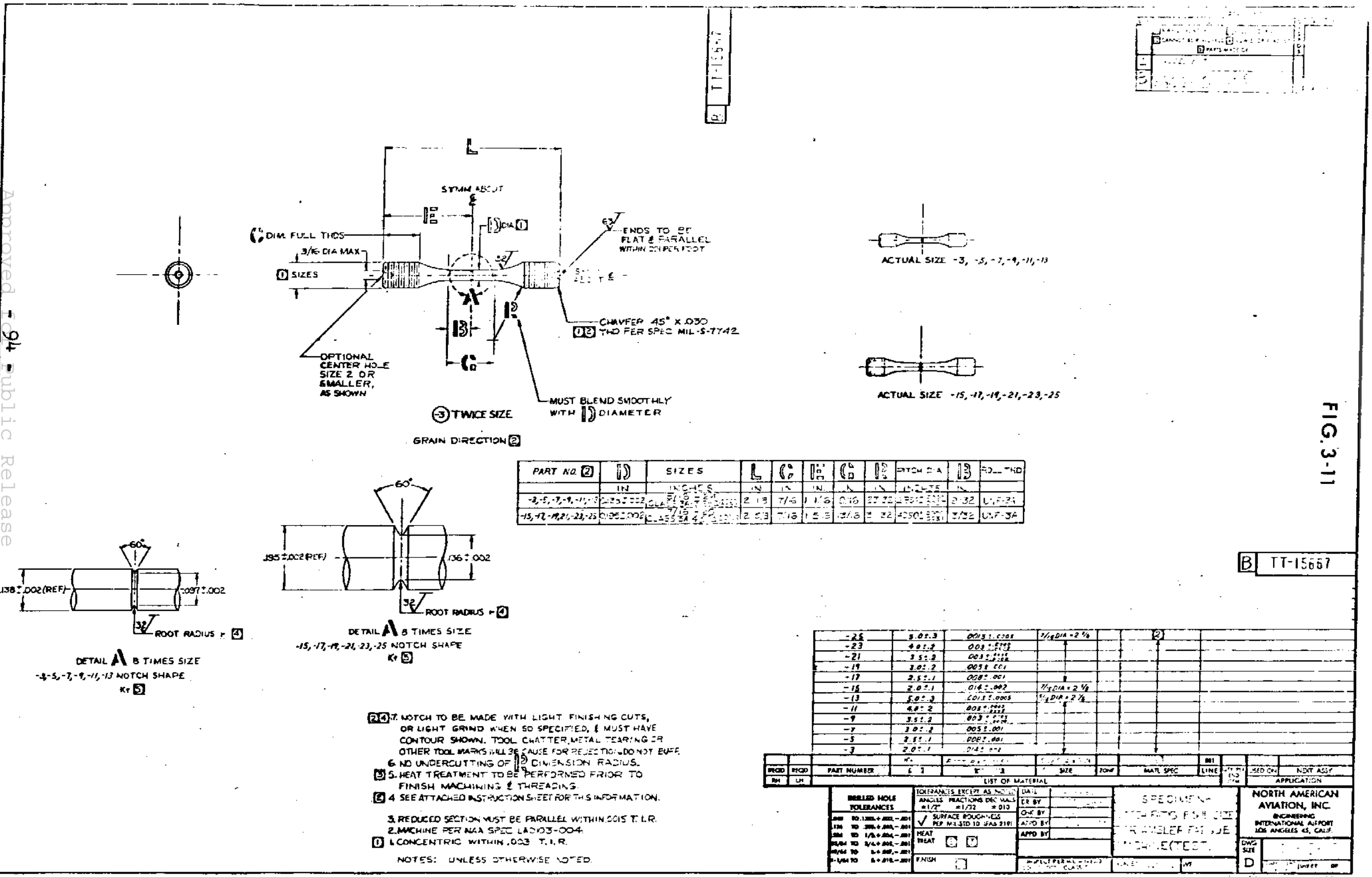
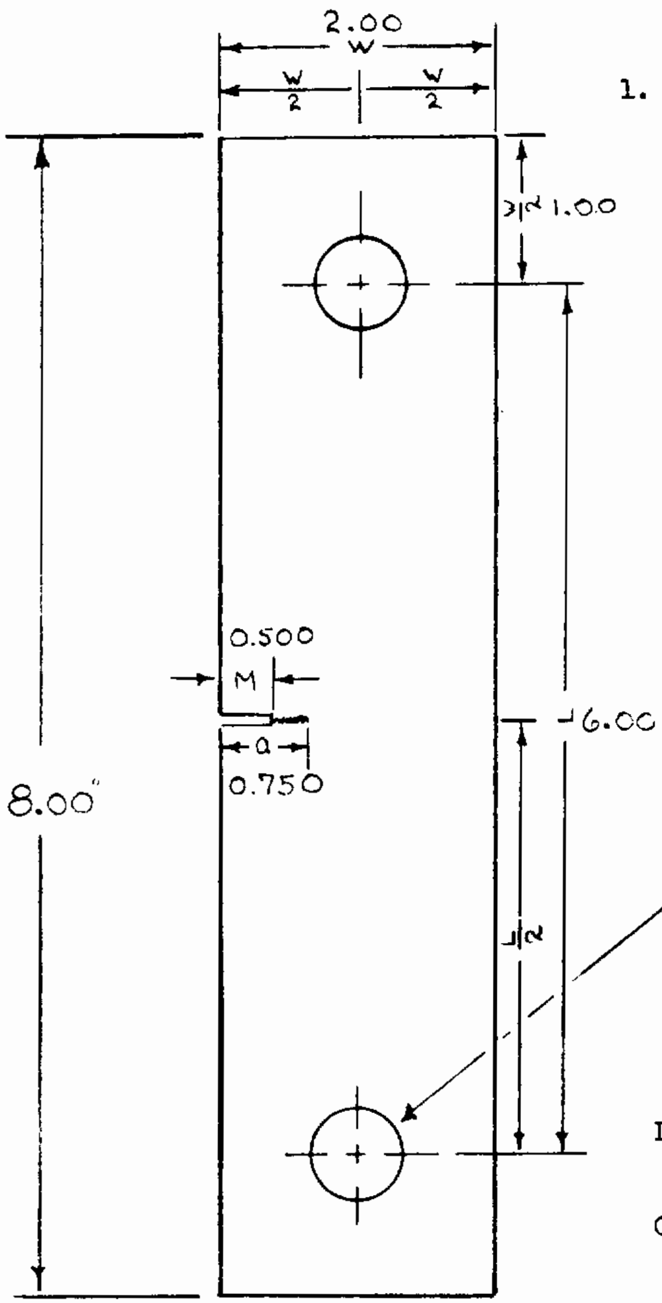

STMM ABOUT ℄
DIM FULL THDS
3/16 DIA MAX
SIZES
ENDS TO BE FLAT & PARALLEL
CHAMFER 45° X .030
THD PER SPEC MIL-S-7742
OPTIONAL CENTER HOLE SIZE 2 OR SMALLER, AS SHOWN
MUST BLEND SMOOTHLY WITH DIAMETER
TWICE SIZE
GRAIN DIRECTION
ACTUAL SIZE -3, -5, -7, -9, -11, -13
ACTUAL SIZE -15, -17, -19, -21, -23, -25
.138 ± .002 (REF)
.097 ± .002
ROOT RADIUS
DETAIL A 8 TIMES SIZE
-3, -5, -7, -9, -11, -13 NOTCH SHAPE
.195 ± .002 (REF)
.136 ± .002
DETAIL A 8 TIMES SIZE
-15, -17, -19, -21, -23, -25 NOTCH SHAPE
7. NOTCH TO BE MADE WITH LIGHT FINISHING CUTS, OR LIGHT GRIND WHEN SO SPECIFIED, & MUST HAVE CONTOUR SHOWN. TOOL CHATTER, METAL TEARING OR OTHER TOOL MARKS WILL BE CAUSE FOR REJECTION. DO NOT BUFF.
6. NO UNDERCUTTING OF DIMENSION RADIUS.
5. HEAT TREATMENT TO BE PERFORMED PRIOR TO FINISH MACHINING & THREADING.
4. SEE ATTACHED INSTRUCTION SHEET FOR THIS INFORMATION.
3. REDUCED SECTION MUST BE PARALLEL WITHIN .0015 T.I.R.
2. MACHINE PER NAA SPEC LA0103-004.
1. CONCENTRIC WITHIN .003 T.I.R.
NOTES: UNLESS OTHERWISE NOTED.
NORTH AMERICAN AVIATION, INC.
INTERNATIONAL AIRPORT LOS ANGELES 45, CALIF.
TT-15667

FIG. 3-11

FIG. 3-12



NOTES:

1. Coupons are nominally 0.25 in. thick. In order to meet the specimen thickness callout an equal amount of material shall be removed from both surfaces of the coupon

B = 0.230 ± .001 (see Note 1)

B = Specimen Thickness

D = Pin Hole Diameter

Clearance drill and ream for 0.625 Dia. Pin 2 holes as shown

$\frac{M}{a} = < 0.75$

$L/W > 3$

$2 < W/B < 12$

$0.20 < a/W < 0.40$

$$K_{IC}^2 = \left[\frac{1}{1-\nu^2}\right] \left(\frac{P}{B}\right)^2 \frac{1}{W} \left[7.59 \frac{a}{W} - 32 \left(\frac{a}{W}\right)^2 + 117 \left(\frac{a}{W}\right)^3\right]$$

$$a = a_o + \frac{K_{IC}^2}{6\pi\sigma_{YS}^2}$$ In All Cases

Figure 2 Recommanded Single-Edge-Notch Tensile Specimen Geometry

3.4 SPECIMEN PREPARATION

Every effort was made to insure that the variations in test results would be due to material properties, by requiring and holding close test specimen machining tolerances. The conditions for machining were carefully chosen to provide a minimum of distortion and surface defects which might influence the resulting test data. Additionally, care was exercised to insure that the material was not overheated during any of the cutting or machining operations.

Section IV

TEST EQUIPMENT

Contained within this section are the various pieces of test equipment used in this investigation.

Page

SECTION IV

TEST EQUIPMENT

4.1 STATIC TESTS

4.1.1 Loading Apparatus

The loading apparatus used in the performance of tension, compression, bearing, shear, fracture toughness, and stability tests, are as follows:

One Instron Univeral Testing Machine - 10,000 capacity
One Instron Universal Testing Machine - 20,000 capacity
One Baldwin-Lima-Hamilton Universal Testing Machine - 50,000 capacity
One Baldwin-Lima-Hamilton Universal Testing Machine - 120,000 capacity
One Riehle Universal Testing Machine - 120,000 capabity

All of the above mentioned machines are equipped with strain-rate pacers and autographic recorders.

4.1.2 Extensometers

Weideman Dual Range Extensometer, Model TSMD
Weideman Dual Range Extensometer, Model KSMD
Weideman Averaging Type Extensometer, Model PS-SM
Weideman Averaging Type Extensometer, Model PS-3MH
Instron Strain Gage Extensometer, Model G-51-12
Instron Strain Gage Extensometer, Model G-51-11
Baldwin Strain Beams, Model SB1E
Aminco-Tuckerman Optical Strain Gage System

With the exception of the Tuckerman optical strain gage system, the above listed extensometers and strain gage extensometers were used with autographic recording equipment which are built in to the various Universal testing machines to measure load versus deformation.

4.1.3 Furnaces

The furnaces used for achieving the static elevated test temperatures are as follows:

(1) Pacific Scientific Forced Air Furnace - 1400F capability
Honeywell-Brown "Electronik" recorder controller

(2) Hevi-Duty Split Tube Radiant Furnace - 2000F capability
Wheelco pyrometer controllers

(3) Messimers Circulating Air Chamber - 1000F capability
Brown proportional controller

(4) NR/LAD built Split Tube Radiant Furnaces - 2000F capability
Wheelco pryrometer controllers

The furnaces used for thermal stability exposure work were:

(1) Pacific Scientific Forced Air Furnaces - 1400F capability
Honeywell-Brown Pry-O-Vane controllers

(2) Arcweld Radiant Tube "Dial-O-Matic" Furnace - 2000F capability
Honeywell-Brown controllers

The furnaces used for heat treating the Ti-6Al-6V-2Sn material to Cond. STA are as follows:

(1) Hevi-Duty Radiant Furnace - 2100F capability
Leeds and Northrup controllers

(2) Pacific Scientific Forced Air Furnaces - 1400F capability
Honeywell-Brown controllers

4.2 FATIGUE TESTS

The fatigue test machines used to construct the Goodman Diagrams included:

(1) Amsler Vibraphone Fatigue Machine - 22,000 Lb. capacity, 60 - 300 CPS

(2) Baldwin-Sonntag Fatigue Machine - 10,000 Lb. capacity (has a 5:1 load multiplier 50,000 Lb.), 30 CPS

(3) Krouse Direct Stress Fatigue Machine - 5000 Lb. capacity (has a 2:1 load multiplier, 10,000 Lb.)

NOTE: The fracture toughness tests were pre-cracked using the above listed Krouse Direct Stress Fatigue Machine

Section V

TEST PROCEDURES

Contained within this section are the procedures utilized for the various mechanical property tests performed in this investigation

SECTION V

TEST PROCEDURES

5.1 TENSILE TESTS

Tensile tests on the subject program were performed using a Riehle, Baldwin-Lima-Hamilton, and Instron Universal test machines which are fully equipped with autographic recorders and automatic strain pacers. These machines are calibrated at least once each year to the appropriate ASTM Standard to ensure loading accuracy.

Tensile specimens tested at the indicated elevated temperatures were heated by means of a Pacific Scientific forced air furnace that has a capability of 1400F and tube radiant-type furnaces that have a temperature capability of 200F. All furnaces are capable of maintaining ± 5F over a 2-inch gage length.

Specimen temperature measurements were made by means of 20 A.W.G diameter chromel-alumel thermocouples attached to the center of the test specimen and calibrated potentiometers for obtaining emf readings.

All measurements of individual specimens for area determinations were made using a calibrated micrometer capable of measuring ± 0.0001 inch of the nominal specimen dimension. A minimum of five width and thickness measurements were taken over the individual specimens' gage length for the cross-sectional area determination.

Determination of the tensile yield strength and the elastic modulus of each individual specimen tested were performed by attaching a Baldwin-Lima-Hamilton or an Instron strain gage extensometer to the gage length of the test specimen.

An automatic strain pacer was used to monitor the induced strain to the tensile yield strength. A strain rate of 0.005 in./in./min. was maintained up to the yield strength. After yielding occurred, the loading rate was increased so as to produce failure of the specimen in approximately one minute.

In addition to the autographically recorded load-elongation graphs, a limited number of stress-strain plots were made, using Tuckerman optical strain gages. This instrument conforms to ASTM E83-57T, Class A, requirements which limit the maximum error of indicated strain to 0.00001 or 10 times as limiting as the requirements specified for Class B-1 extensometers. Data generated using this instrument serves as a base line for comparing subsequent test data obtained using the conventional autographic extensometers.

Typical full range stress-strain curves for each of the materials tested in conjunction with the precision elastic modulus obtained for the various materials are reported in Section VII of this report.

Typical room temperature and elevated temperature tensile setups are shown in Figures 5-1 and 5-2, respectively.

5.2 COMPRESSION TESTS

Compression testing of the four materials was accomplished by employing a compression subpress in conjunction with a Universal-type testing machine. One of the compression subpresses used was designed and built at NR/LAD, and employs a rigid frame containing a lower carbide loading anvil which is parallel to the bed of the testing machine. Within the frame, a sliding plunger is contained which accommodates the upper carbide loading anvil. The plunger is rigidly aligned within the support frame by the use of low-friction graphite plugs.

Specimen side support is provided by a plate assembly made up of small carbide balls backed up by a carbide plate with the balls protruding through a front retaining plate in which the holes for the balls are large enough to allow rotation and translation of each ball while, at the same time, retaining the ball within the plate. This method of support provides nearly frictionless contact even at high temperatures.

A special fixture is used to make gage mark indentations on each side of the specimen into which the hardened points of the extensometer arms fit. The extensometer arms pass through an access hole in the bottom of the subpress frame and, in turn, are connected to a common lineal differential transducer located in an ambient temperature zone. The extensometer system used meets ASTM Standard E83-57T, Class B-1, requirements.

The NR/LAD built compression subpress has proven to yield exceptionally reliable and highly reproducible compressive yield strengths as well as elastic moduli on a variety of materials tested in it from room temperature to 1800F. Materials with known moduli have been tested and the results obtained from the subpress agree remarkably well with the known values. The reproducibility of the subpress has been demonstrated time and again on large NR test programs where replication of test effort has been necessary.

Elevated temperature compression testing is provided for by a specially constructed resistance wound furnace, which is designed so that the elements are in close proximity to the subpress body. Temperature uniformity is measured by three thermocouples inserted in the side support plates adjacent to the specimen. The test machine employed, temperature measurement and specimen measurement techniques, as well as strain pacing, paralleling those described for the tensile. All compression tests were conducted in accordance with ASTM E 209-63T. Figure 5-3 shows the NR/LAD built compression subpress.

5.3 BEARING TESTS

Bearing tests on the program were performed using a Universal-type testing machine and a bearing fixture. One of the fixtures used, Figure 5.4, accommodates the bearing test specimen and is basically an adjustable clevis that contains the loading pin as well as providing for appropriate deformation measurements.

When the specimen is in place within the test fixture, the extension arms employing point contacts, locate on the sides of the bearing test specimen. When a load (tension) is applied, the relative displacement occurring between the pin, which is an integral part of the test fixture, and the pickup arms located on the sides of the test specimen is transferred to a linear differential transducer. The obtained signal is, in turn, fed into the test machine's autographic recorder, providing the necessary load-deformation plots necessary to obtain the 2 percent bearing yield strength.

The bearing fixture itself is made from Haynes 25 and contains carbide bushings that accommodate the loading pin. The loading pins themselves are fabricated from hot work die steels, heat-treated to the 280 - 300 Ksi range to resist brinelling during test.

Temperature measurements were made by attaching a thermocouple to the test specimen in the area of the pin.

Elevated test temperatures were achieved using a tube furnace previously described in the Tensile Test section.

All bearing tests were performed in accordance with ASTM E 234-64T.

5.4 SHEAR TESTS

Shear tests on the subject program were accomplished using an NR/LAD-built double shear subpress, shown in Figure 5-5. A Universal-type testing machine previously described provided the necessary loading requirements.

The shear subpress is basically a rigid frame containing the necessary load bearing edges which are carbide, and provides the required lateral restraint of the sheet shear specimen during test. Contained within the frame is a plunger which, in turn, is placed within the frame. By applying a compressive load, the subpress imparts a double-shear load condition to the restrained specimen. When the shear subpress is properly adjusted, the respective carbide load bearing edges, contained within the plunger and frame, pass within 1/100 of an inch of each other during tests. It has been NR/LAD experience that this subpress provides highly reproducible and reliable shear test data.

NR/LAD has tried a variety of shear test specimens and fixtures in an effort to obtain consistent and reliable shear property data. Methods tried and discarded after proving unsatisfactory have included the conventional single-shear tension sheet specimen as we well as fixtures which test specimens in single shear. The double-shear subpress described has proved superior to the various other methods explored so far as producing both reliable and reproducible shear test data.

Elevated test temperatures were achieved using a specially constructed resistance-wound furnace designed for use with the shear subpress. Temperature measurements were made from a thermocouple which is inserted into the subpress in very close proximity to the test specimen.

Since only ultimate load was determined, no deformation measurements were made.

Specimen measurement techniques paralleled those described for the tensile tests.

The single-shear ultimate strength was derived from the double shear load by merely taking half the failing load and dividing it by the cross-sectional area of the specimen.

The shear tests performed were in accordance with ARTC 13-S-1 detail requirements.

5.5 FRACTURE TOUGHNESS TESTS

The fracture toughness test used to obtain plane strain (K_{Ic}) values for the four titanium alloys employed the single-edge-notch tension-type specimen. Selection of this configuration was based on several considerations: First, and most important, specimens conforming to this configuration yield correct and consistent K_{Ic} values, References 1 and 2 . Secondly, while this configuration provided the necessary plane strain test data for the program, it also has the advantage of substantial material economy.

Precracking of the individual test specimens to the desired predetermined depth was accomplished using a fatigue machine. The total depth of the sawed crack, plus that induced by fatigue (natural crack), will equal approximately one third of the specimen width, with the sawed crack depth being equal to or less than 0.75 of the total crack depth. Crack growth induced by fatiguing was carefully monitored by means of a binocular microscope.

Tension testing of the precracked fracture toughness test specimens was performed using a Universal-type testing machine. Load deflection curves were obtained for each specimen tested using a Class B-1 extensometer applied to the edge of the specimen across the crack zone as a compliance gage. A cross-head speed of .05 In./Min. was used for the fracture toughness tests. Upon completion of testing, the load versus deflection plots were analyzed for "pop-in" load. K_{Ic} values were then determined by means of the following relationship:

$$K_{Ic} = \left[\frac{1}{1-\nu^2}\right] \left(\frac{P}{B}\right)^2 \frac{1}{W} \left[7.59 \frac{a}{W} - 32\left(\frac{a}{W}\right)^2 + 117\left(\frac{a}{W}\right)^3\right]$$

where:

B = specimen thickness
a = crack length at "pop-in" (in)
w = specimen width (in)
ν = Poisson's ratio

All of the fracture toughness testing was conducted at room temperature and was limited to the 1/4-inch thick materials.

5.6 METALLURGICAL STABILITY TESTS

The effect of exposure to selected elevated temperatures for prolonged periods of time was determined for the four selected alloys using tensile and fracture toughness tests as the measuring criteria.

Tensile test specimens of the appropriate configuration were exposed to elevated temperatures of 400F, 600F, and 800F for time durations of 10, 100, and 1000 hours. After exposure, some of the test specimens were tested at room temperature with the remaining being tested at the elevated temperatures at which they were exposed.

Fracture toughness test specimens were exposed at 400F, 600F and 800F for 10, 100, and 1000 hours, and tested at room temperature after elevated temperature exposure.

Test equipment, fixtures and procedures for each type of test are described in the preceding text.

5.7 FATIGUE TEST

Fatigue tests were performed on the subject program using the equipment described in Section IV. All tests were at room temperature, employing both smooth and notched ($K_t = 3.0$) fatigue test specimen configurations. Four minimum-to-maximum stress ratios (R factors) were used. These were R = -1.0, R = -0.3, R = 0 and R = +0.3. The stress levels were varied within a group of specimens so that S-N curves could be constructed. From the various S-N curves generated for the four R factors for a given alloy and K_t, constant life diagrams were then constructed. A photograph of one of the fatigue test machines employed in this investigation is shown in Figure 5-6.

Fig 5-1

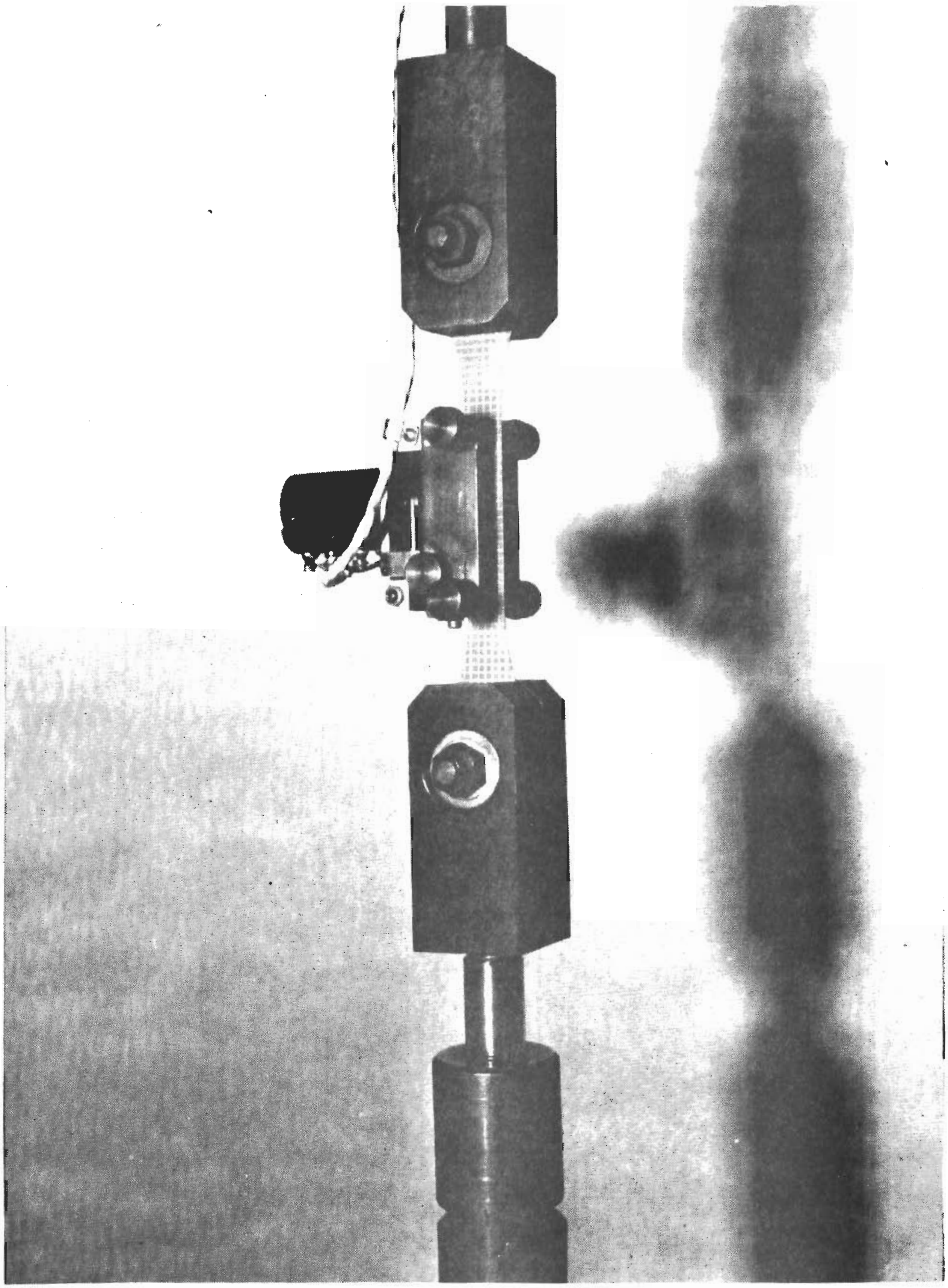


Fig 5-2

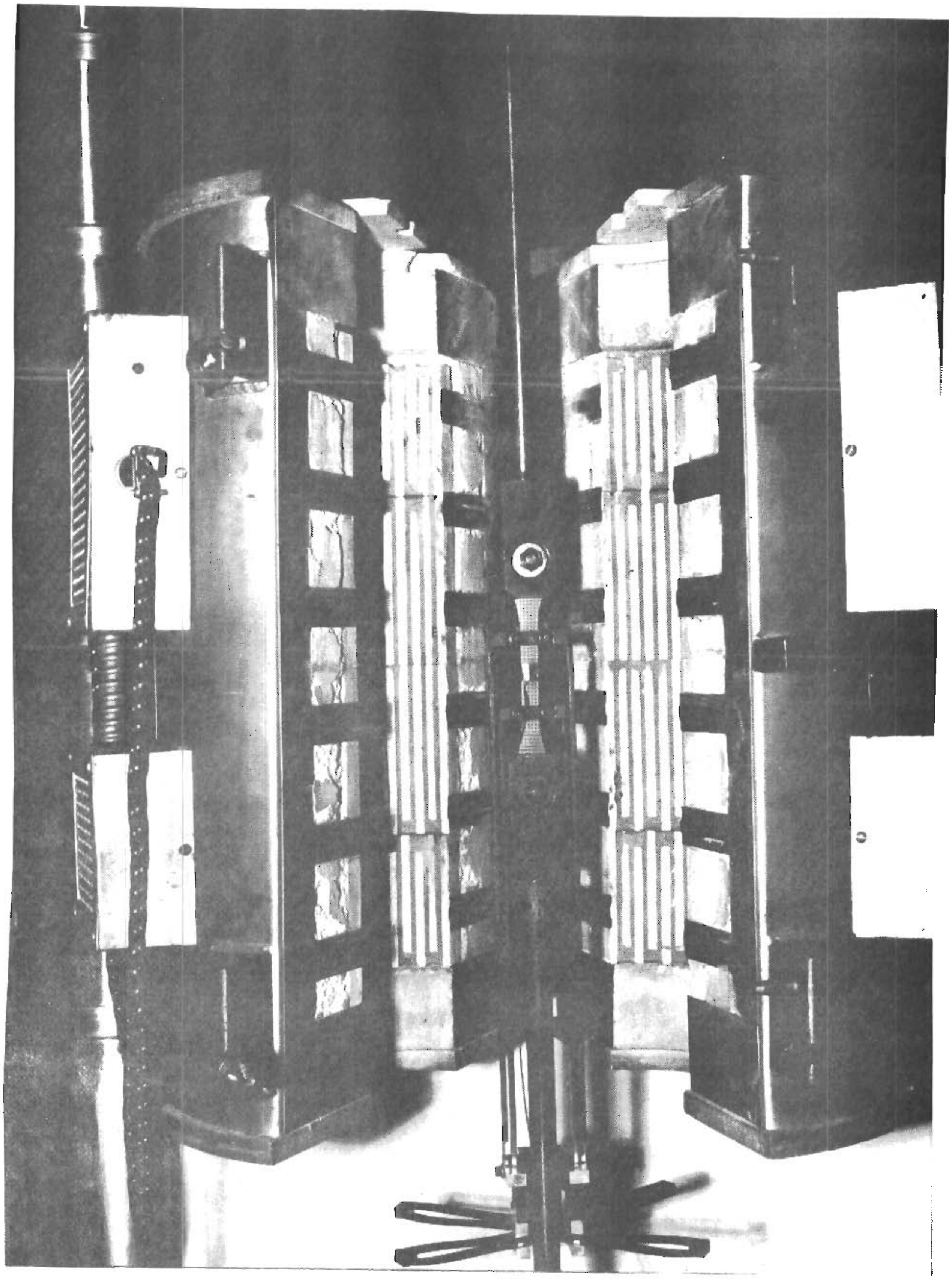


Fig 5-3

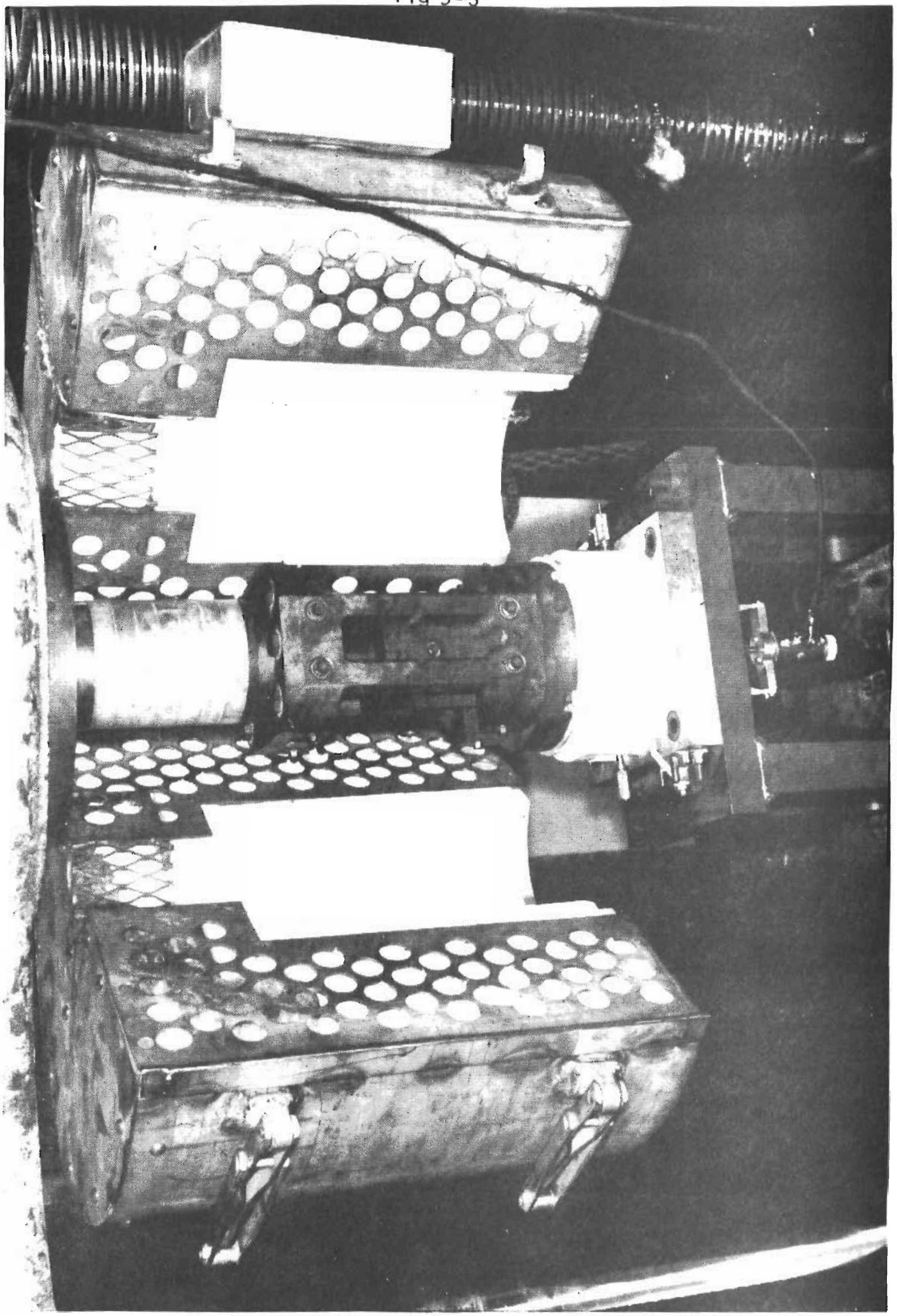


Fig 5-4

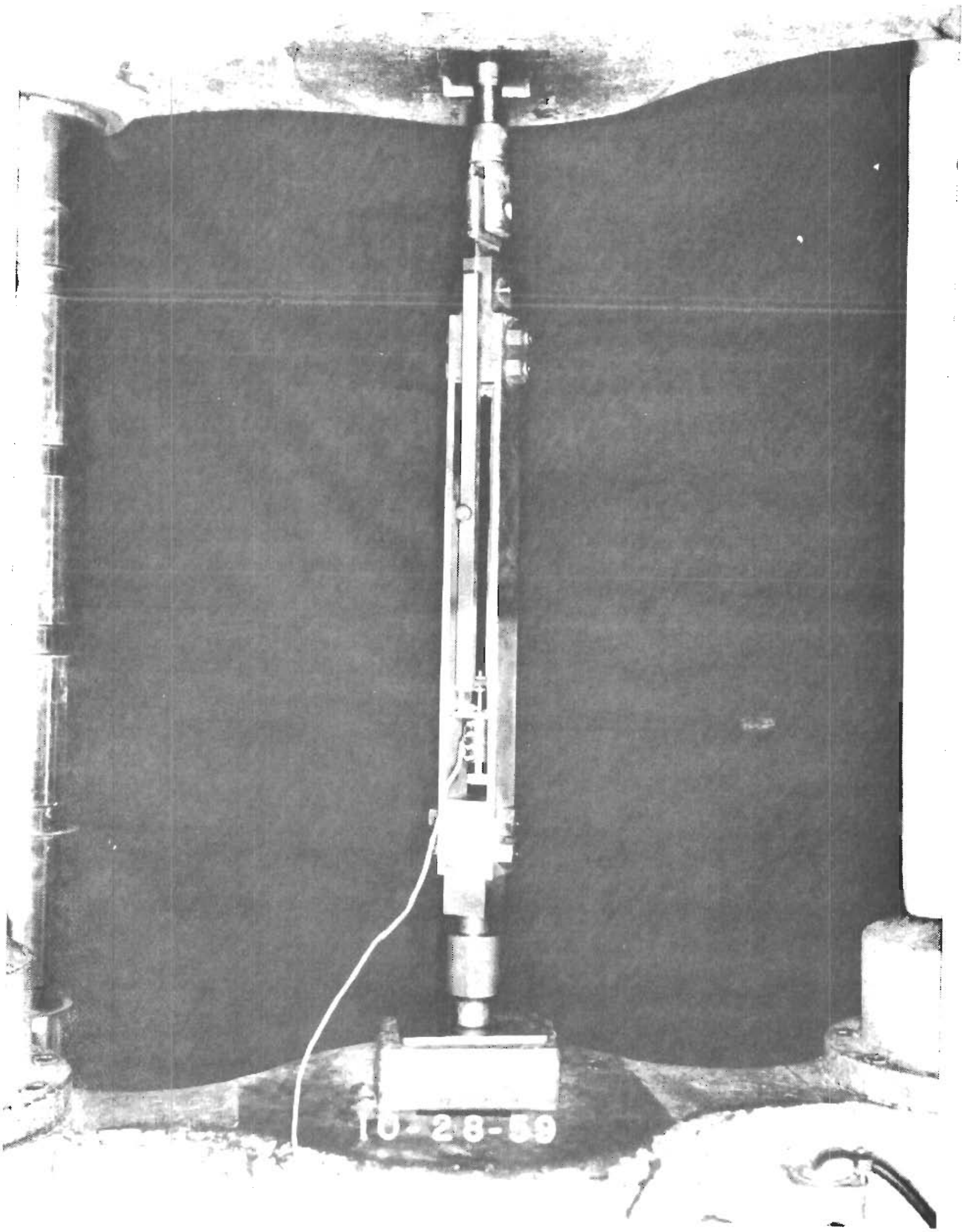


Fig 5-5

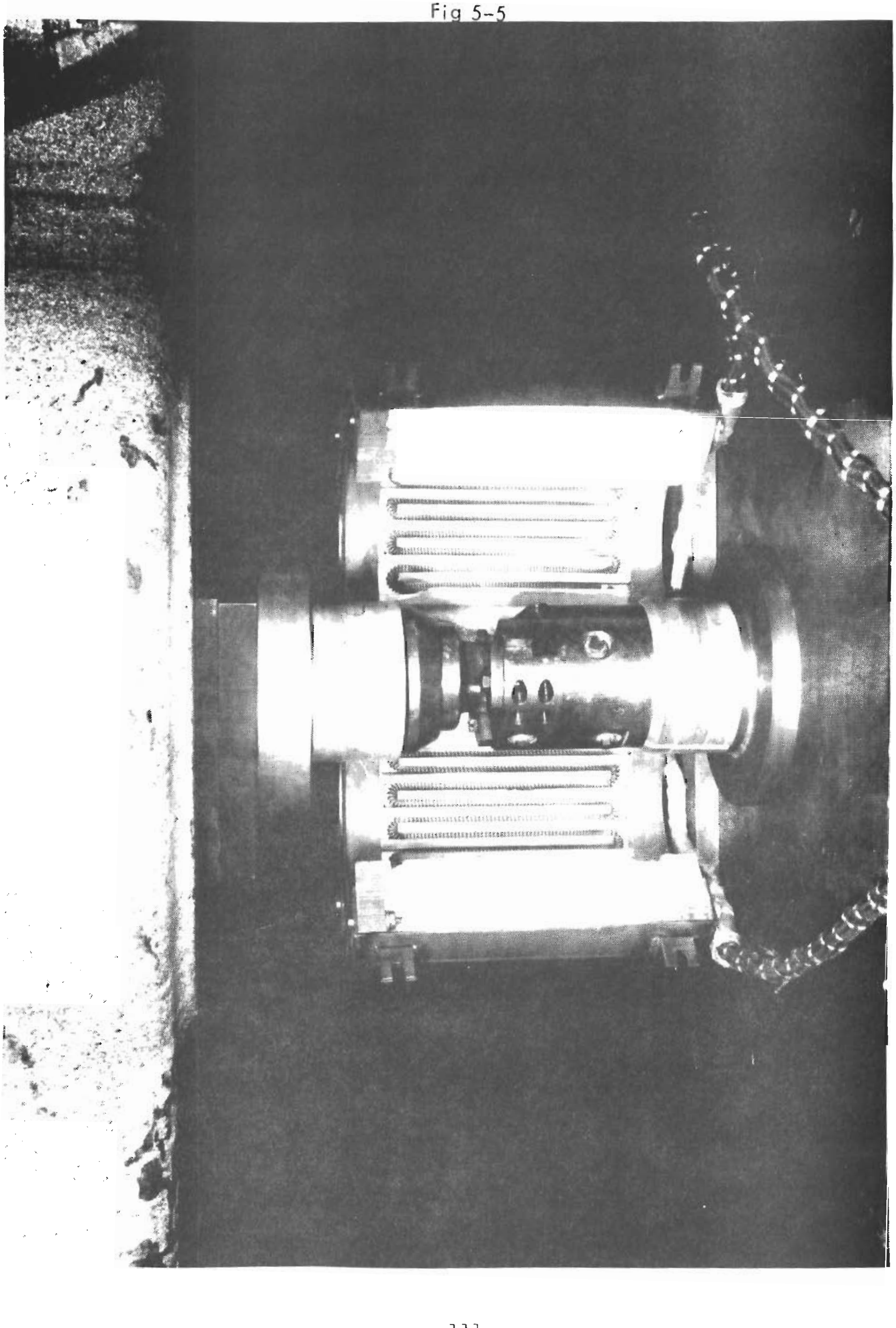
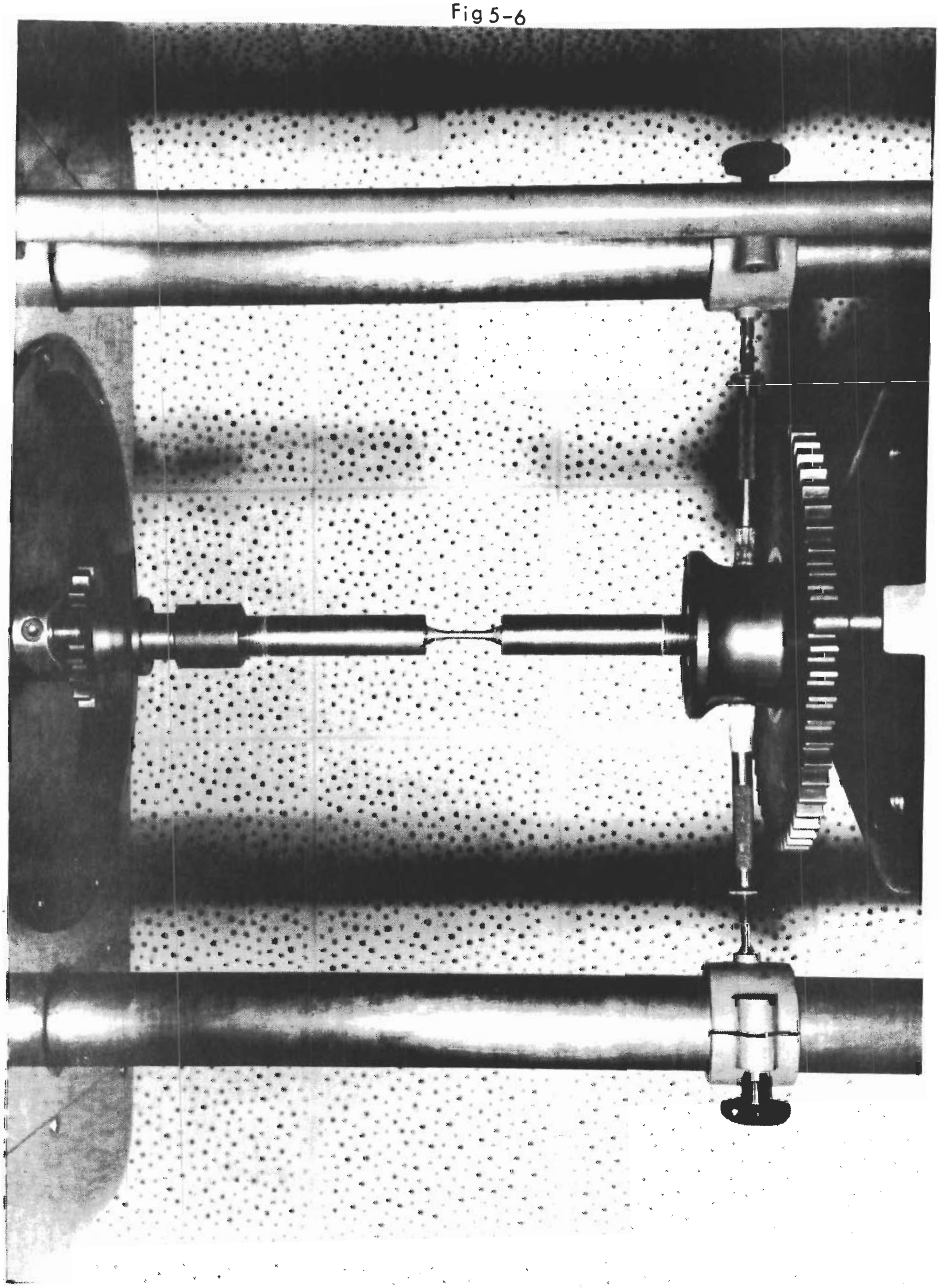


Fig 5-6



Section VI

SUMMARY AND ANALYSIS OF TEST RESULTS

Contained within this section are the statistical analysis procedures used to obtain the "A" and "B" Design Allowables, in addition to summary tables of the test results obtained in this investigation.

6.1 METHODS OF STATISTICAL ANALYSIS - R.T. DESIGN ALLOWABLES

This analysis was accomplished in accordance with "MIL'HDBK-5 Guidlines for the Presentation of Data", AFML TR-66-386 Battelle Memorial Institute.

The mechanical properties presented here are identified by a letter (i.e., A or B) to indicate the basis upon which they were established. An "A" value is the property above which 99 percent of the population is expected to fall with a confidence of 95 percent. A "B" value is the property above which 90 percent of the population is expected to fall with a confidence of 95 percent.

There are two methods of obtaining these values and they are:

1. Directly Calculated Values - The directly calculated "A" values are obtained as follows:

$$\text{"A" value} = \bar{x} - KS_x$$

$$\text{Where} \quad \bar{x} = \frac{\Sigma x}{n}$$

$$S_x = \sqrt{\frac{(x - \bar{x})^2}{(n - 1)}}$$

where $\bar{x}$ is the average value of individual measurements, S_x standard deviation of individual measurements, n the number of individual measurements and K, the one-sided tolerance factor for normal distribution and specified probability, confidence, and population (i.e., for "A", $K = K_{.99,\ .95,\ n}$).

The "B" values are calculated as follows:

$$\text{"B" value} = \bar{x} - KS_x$$

$$\text{Where } K - K_{.90,\ .95,\ n}.$$

The values of K were obtained from the table "One-Sided Tolerance Factors for the Normal Distribution and a Confidence of .95", in Tables of Normal Probability Functions in above referenced document.

An additional requirement is that the population, n, must consist of at least 100 points from a minimum of ten different heats of material. Because of the scarcity of available data, this requirement usually can be satisfied for room temperature tensile ultimate and yield only.

2. Derived Values - These values are established through their relationship to directly calculated "A" or "B" values of F_{tu} or F_{ty} as obtained in the foregoing section. This method consists of pairing individual ultimate strength values (i.e., F_{tu}, F_{su}, F_{bru}) with individual tensile ultimate strength values, or individual yield strength values (i.e., F_{ty}, F_{bry}) with individual tensile yield strength values, determining the mean ratio of these pairs with a probability of 95 percent and multiplying the directly calculated "A" or "B" values of F_{tu} or F_{ty} by this factor. Derived values are therefore equal to:

$$(\bar{r} - t_{.05} S_{\bar{r}})\ F_{tu}\ (A \text{ or } B)$$

or $$(\bar{r} - t_{.05} S_{\bar{r}})\ F_{ty}\ (A \text{ or } B)$$

where $$\bar{r} = \frac{\Sigma r}{n}$$

$$S_{\bar{r}} = \sqrt{\frac{\Sigma (r - \bar{r})^2}{n\ (n - 1)}}$$

and t .05 is the two-sided tolerance factor for the "t" distribution, a probability of 95 percent and the population, n, involved. The values of t .05 were obtained from a table in the referenced document. The derived values of the mechanical properties have the same validity (A or B) as the values of F_{tu} or F_{ty} used in equations (4) and (5). Ten pairs of measurements (n = 10) are the minimum for establishing a derived allowable.

LIST OF STATISTICAL SYMBOLS

A	"A" basis for mechanical property values
B	"B" basis for mechanical property values
K	One-sided tolerance factor for the normal distribution and the specified probability, confidence and population
n	The number of individual measurements or paired measurements - population
r	Ratio of two paired measurements
$\bar{r}$	ratio of two paired measurements
$S_{\bar{r}}$	Standard error of paired measurement ratios
S_x	Standard deviation of individual measurements
r	Two-sided tolerance factor for the "t" distribution and the specified probability and population
x	Value of an individual measurement
$\bar{x}$	The average value of individual measurements
Σ	The summation of

6.2 DISCUSSION OF ROOM TEMPERATURE ALLOWABLES

The values of all the mechanical properties for the Ti-4Al-3Mo-1V Cond. A sheet, Ti-6Al-4V Cond. STA plate, and Ti-6Al-6V-2Sn Cond. A and STA plate are presented as "S" values. This was a result of insufficient quantities of producers and users test data being supplied to NR/LAD during the solicitation of data phase of the subject contract. It should be noted that NR/LAD solicited the industry for test data applicable for the alloy covered in the scope of this contract. Much of the data obtained as a result of solicitation could not be used because of it not being the proper gage range, wrong condition, or inadequately identified to confidently be used.

The desired property values (i.e., all properties except F_{tu}, F_{ty} and e) for all alloys are limited because only five ratios were used to obtain each value, while a minimum of ten ratios is required by the MIL-HDBK-5 Guidelines.

The F_{tu}, F_{ty} and e values for the Ti-13V-11Cr-3Al sheet alloy are valid "A" and "B" values to the extent that sufficient number of test data were available to establish valid statictical values; however, all test data reflect one producer only. Additionally, much of the applicable data was obtained in summary form which did not show the distribution. Therefore, a test for normality could not be made.

Table VI-1 to VI-4 indicate the populations and other pertinent information used in calculation of the allowables.

6.3 DATA PRESENTATION

6.3.1 Effect of Temperature Curves

These curves are presented as Per Cent Strength at Room Temperature vs Test Temperature. The procedure used to obtain these curves is as follows:

a. Plot the individual values for the property at each temperature.

b. Indicate the average value at each temperature.

c. Draw the curve passing through the average at room temperature and either the average or 5 percent above minimum value, whichever is lowest, at each elevated temperature.

d. Obtain the curve value at each temperature as a percentage of the curve value at room temperature.

e. Plot the per cent values and fit the curve.

To obtain in a smooth curve in step (e), engineering judgement was used and the curves do not necessarily pass through the stated values at each temperature.

6.3.2 Effect of Exposure Curves

These curves are presented in "Per Cent Strength at Room Temperature vs Exposure Temperature"; they show the effect on the properties of specimens tested at room temperature after exposure to elevated temperature. These curves are drawn using the same technique described above.

The working curves (steps (a), (b), and (c)) can be found in the Appendix. Where aging has occurred and strength has increased with either temperature or exposure time, as in the case of Ti-13V-11Cr-3Al, a dashed line indicates this phenomena. In accordance with the MIL-HDBK-5 Guidelines, the working curve is drawn so that strength is not shown to increase with either temperature or exposure time.

6.3.3 Stress-Strain Curves

The method used to obtain these curves is as follows:

a. For each alloy and at each temperature, select several well defined typical curves.

b. Measure the plastic strains at different percentages of the yield strength and compute the average plastic strain at each percentage.

c. Select the modulus values to be used: at room temperature use the value obtained by precision modulus measurements made in this program; at elevated temperatures obtain a value from data contained in MIL-HDBK-5, where available, or from data generated in this program.

d. Use the average value for the yield strength at room temperature; find the elevated temperature average yield strengths using the appropriate "Effect of Temperature" curve and the room temperature value.

e. Draw the straight line portion of the curve using the selected modulus; add the plastic strain and the elastic strain at the percentages of the yield strength chosen in step (b) to obtain the remainder of the curve.

6.3.4 Constant Life Diagrams

The fatigue constant life diagrams presented in Section VII for the test materials were constructed from the S-N curves contained within the Appendix. Engineering judgement was exercised in the construction of constant life diagram to smooth out some of the humps.

6.3.5 Fracture Toughness Tests

The fracture toughness test results are presented in Section VII in tabular form. As there is no standardized treatment of these test data listed within the "Guidelines" for inclusion into MIL-HDBK-5, pertinent detail test data is included along with the computed fracture toughness values. No attempt was made to summarize either the fatigue or fracture toughness test data.

6.3.6 Summary of Room Temperature Test Results

A summary of room temperature test results for the various materials tested are presented in Table VI-5 to VI-9. The summary presents averaged test values for the various mechanical property tests performed with the exception of the fatigue tests and plane strain fracture toughness tests.

6.4 POPULATIONS USED TO OBTAIN ALLOWABLES

Table VI - 1

Ti 4Al-3Mo-1V Condition A

Material Form and Property	Direction	Values * Obtained	** Method	Pairs	Heats	Vendors	Specimens
Sheet							
F_{tu}	L	S	Direct		9	3	19
	LT	S	Direct		8	3	17
F_{ty}	L	S	Direct		9	3	19
	LT	S	Direct		8	3	17
F_{cy}	L	S	Derived	6	6	2	6
	LT	S	Derived	6	6	2	6
F_{su}	L	S	Derived	6	6	2	6
	LT				2	2	2
F_{Bru} (e/D=1.5)	L	S	Derived	6	6	2	6
	LT				2	2	2
(e/D=2.0)	L	S	Derived	6	6	2	6
	LT				2	2	2
F_{bry} (e/D=1.5)	L	S	Derived	6	6	2	6
	LT				2	2	2
e		S	Direct		9	3	36

* See 6.2 for discussion of the validity of these values.

** Direct "S" values were taken from MIL-T-9046.

6.4 (continued)

Table VI - 2

Ti 13V-11Cr-3Al Condition A

Material Form and Property	Direction	Values* Obtained	Method	Pairs	Heats	Vendors	Specimens
Sheet							
F_{tu}	L LT	A & B A & B	Direct Direct		Unknown Unknown	1 1	4385 2929
F_{ty}	L LT	A & B A & B	Direct Direct		Unknown Unknown	1 1	4385 2929
F_{cy}	L LT	A & B A & B	Derived Derived	4 5	4 5	1 1	4 5
F_{su}	L LT	A & B	Derived	5	5 1	1 1	5 1
F_{bru} (e/D=1.5)	L LT	A & B	Derived	5	5 1	1 1	5 1
(e/D-2.0)	L LT	A & B	Derived	5	5 1	1 1	5 1
F_{bry} (e/D=1.5)	L LT	A & B	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	A & B	Derived	5	5 1	1 1	5 1
e	L LT	A A	Direct Direct		Unknown Unknown	1 1	2828 2962

* See 6.2 for discussion of the validity of these values.

Table VI - 3

Ti 6Al-4V Condition STA

Material Form and Property	Direction	Values Obtained	** Method	Heats	Vendors	Specimens
Plate .250 to .300						
F_{tu}	L	S	Direct	15	2	33
	LT	S	Direct	13	2	29
F_{ty}	L	S	Direct	15	2	33
	LT	S	Direct	13	2	29
F_{cy}	L			3	2	3
	LT			3	2	3
F_{su}	L			3	2	3
	LT			2	2	3
F_{bru} (e/D=1.5)	L			3	2	3
	LT			2	2	2
(e/D=2.0)	L			3	2	3
	LT			2	2	2
F_{bry} (e/D=1.5)	L			3	2	3
	LT			2	2	2
(e/D=2.0)	L			3	2	3
	LT			2	2	2
e		S	Direct	15	2	62
Plate .500 to .630						
F_{tu}	L	S	Direct	20	2	35
	LT	S	Direct	11	2	21
F_{ty}	L	S	Direct	20	2	35
	LT	S	Direct	11	2	21
F_{cy}	L			3	2	3
	LT			3	2	3
F_{su}	L			3	2	3
	LT			1	1	1
F_{bru} (e/D=1.5)	L			3	2	3
	LT			1	1	1

** Direct "S" values were taken from MIL-T-9046.

Table VI-3 (Cont'd)

Ti 6Al-4V Condition STA

Material Form and Property	Direction	Values Obtained	** Method	Heats	Vendors	Specimens
(e/D=2.0)	L			3	2	3
	LT			1	1	1
F_{bry} (e/D=1.5)	L			3	2	3
	LT			1	1	1
(e/D=2.0)	L			3	2	3
	LT			1	1	1
e		S	Direct	20	2	56
Plate .750 to 1.000						
F_{tu}	L	S	Direct	5	2	27
	LT	S	Direct	5	2	27
F_{ty}	L	S	Direct	5	2	27
	LT	S	Direct	5	2	27
F_{cy}	L			2	2	2
	LT			2	2	2
F_{su}	L			2	2	2
	LT			1	1	1
F_{bru} (e/D=1.5)	L			2	2	2
	LT			1	1	1
(e/D=2.0)	L			2	2	2
	LT			1	1	1
F_{bry} (e/D=1.5)	L			2	2	2
	LT			1	1	1
(e/D=2.0)	L			2	2	2
	LT			1	1	1
e		S	Direct	5	2	54
Plate 1.200 to 1.500						
F_{tu}	L	S	Direct	9	2	16
	LT	S	Direct	9	2	16
F_{ty}	L	S	Direct	9	2	16
	LT	S	Direct	9	2	16
e		S	Direct	9	2	32

* Direct "S" values were taken from MIL-T-9046.

Table VI - 4

Ti 6Al-6V-2Sn Condition A

Material Form and Property	Direction	Values * Obtained	** Method	Pairs	Heats	Vendors	Specimens
Plate .250 to .300							
F_{tu}	L	S	Direct		7	1	15
	LT	S	Direct		7	1	15
F_{ty}	L	S	Direct		7	1	15
	LT	S	Direct		7	1	14
F_{cy}	L	S	Derived	5	5	1	5
	LT	S	Derived	5	5	1	5
F_{su}	L	S	Derived	5	5	1	5
	LT				1	1	1
F_{bru} (e/D=1.5)	L	S	Derived	5	5	1	5
	LT				1	1	1
(e/D=2.0)	L	S	Derived	5	5	1	5
	LT				1	1	1
F_{bry} (e/D=1.5)	L	S	Derived	5	5	1	5
	LT				1	1	1
(e/D=2.0)	L	S	Derived	5	5	1	5
	LT				1	1	1
e		S	Direct		7	1	30
Plate .500 to .630							
F_{tu}	L	S	Direct		6	1	12
	LT	S	Direct		6	1	12
F_{ty}	L	S	Direct		6	1	12
	LT	S	Direct		6	1	12
F_{cy}	L	S	Derived	5	5	1	5
	LT	S	Derived	5	5	1	5
F_{su}	L	S	Derived	5	5	1	5
	LT				1	1	1

* See 6.2 for discussion of the validity of these values

** Direct "S" values were taken from MIL-T-9046.

6.4 (cont'd)

Table VI - 4 (cont'd)

Ti 6Al-6V-2Sn Condition A

Material Form and Property	Direction	Values * Obtained	** Method	Pairs	Heats	Vendors	Specimens
Plate .500 to .630							
F_{bru} (e/D=1.5)	L LT	S	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	S	Derived	5	5 1	1 1	5 1
F_{bry} (e/D=1.5)	L LT	S	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	S	Derived	5	5 1	1 1	5 1
e		S	Direct		6	1	24
Plate ≥1.50							
F_{tu}	L LT	S S	Direct Direct		5 5	1 1	10 10
F_{ty}	L LT	S S	Direct Direct		5 5	1 1	10 10
F_{cy}	L LT	S S	Derived Derived	5 5	5 5	1 1	5 5
F_{su}	L LT	S	Derived	5	5 1	1 1	5 1
F_{bru} (e/D=1.5)	L LT	S	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	S	Derived	4	4 1	1 1	4 1
F_{bry} (e/D=1.5)	L LT	S	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	S	Derived	5	5 1	1 1	5 1
e		S	Direct		5	1	20

** Direct "S" values were taken from MIL-T-9046

* See 6.2 for discussion of the validity of these values

Table VI - 5

Ti-6Al-6V-2Sn Condition STA

Material Form and Property	Direction	Values * Obtained	** Method	Pairs	Heats	Vendors	Specimens
Plate .500 to .630							
F_{tu}	L	S	Direct		5	1	5
	LT	S	Direct		5	1	5
F_{ty}							
F_{ty}	L	S	Direct		5	1	5
	LT	S	Direct		5	1	5
F_{cy}	L	S	Derived	5	5	1	5
	LT	S	Derived	5	5	1	5
F_{su}	L	S	Derived	5	5	1	5
	LT				1	1	1
F_{bru} (e/D=1.5)	L	S	Derived	5	5	1	5
	LT				1	1	1
(e/D=2.0)	L	S	Derived	5	5	1	5
	LT				1	1	1
F_{bry} (e/D=1.5)	L	S	Derived	5	5	1	5
	LT				1	1	1
(e/D=2.0)	L	S	Derived	5	5	1	5
	LT				1	1	1
e		S	Direct		5	1	10
≥ 1.50							
F_{tu}	L	S	Direct	1	5	1	5
	LT	S	Direct		5	1	5
F_{ty}	L	S	Direct		5	1	5
	LT	S	Direct		5	1	5
F_{cy}	L	S	Derived	5	5	1	5
	LT	S	Derived	5	5	1	5
F_{su}	L	S	Derived	5	5	1	5
	LT				1	1	1

* See 6.2 for discussion of the validity of these values.

** Direct "S" values were taken from MIL-T-9046.

Table VI - 5 (continued)

Ti 6Al-6V-2Sn Condition STA

Material Form and Property	Direction	Values Obtained *	** Method	Pairs	Heats	Vendors	Specimens
F_{bru} (e/D=1.5)	L LT	S	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	S	Derived	5	5 1	1 1	5 1
F_{bry} (e/D=1.5)	L LT	S	Derived	5	5 1	1 1	5 1
(e/D=2.0)	L LT	S	Derived	5	5 1	1 1	5 1
e		S	Direct		5	1	10

* See 6.2 for discussion of the validity of these values.

** Direct "S" values were taken from MIL-T-9046.

Table VI-6

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 4Al-3Mo-1V   Annealed Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Tensile Ultimate Strength (KSI)	≤ .110	L	6	131.1
		LT	6	136.7
Tensile Yield Strength (KSI)	≤ .110	L	6	124.2
		LT	6	132.8
Compressive Yield Strength (KSI)	≤ .110	L	6	127.6
		LT	6	136.3
Bearing Ultimate Strength (KSI) e/D = 1.5	≤ .110	L	6	210.8
		LT	2	219.7
Bearing Ultimate Strength (KSI) e/D = 2.0	≤ .110	L	6	277.3
		LT	2	283.9
Bearing Yield Strength (KSI) e/D = 1.5	≤ .110	L	6	171.4
		LT	2	177.9
Bearing Yield Strength (KSI) e/D = 2.0	≤ .110	L	6	202.9
		LT	2	218.6
Shear Ultimate Strength (KSI)	≤ .110	L	6	82.8
		LT	2	84.2

* Average value for more than 1 test.

Table VI-7

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 13V-11Cr-3Al Annealed Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Tensile Ultimate Strength (KSI)	≤ .110	L	5	135.3
		LT	5	137.8
Tensile Yield Strength (KSI)	≤ .110	L	5	134.6
		LT	5	136.9
Compressive Yield Strength (KSI)	≤ .110	L	4	132.3
		LT	5	137.2
Bearing Ultimate Strength (KSI) e/D = 1.5	≤ .110	L	5	221.5
		LT	1	224.0
Bearing Ultimate Strength (KSI) e/D = 2.0	≤ .110	L	5	303.4
		LT	1	311.0
Bearing Yield Strength (KSI) e/D = 1.5	≤ .110	L	5	173.0
		LT	1	176.9
Bearing Yield Strength (KSI) e/D = 2.0	≤ .110	L	5	192.0
		LT	1	205.0
Shear Ultimate Strength (KSI)	≤ .110	L	5	96.8
		LT	1	98.2

* Average value for more than 1 test.

Table VI-8

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 6Al-4V STA Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Tensile Ultimate Strength (KSI)	.250 to .300	L	3	161.4
		LT	3	167.1
	.500 to .630	L	3	175.9
		LT	3	178.2
	≥ 1.00	L	2	152.9
		LT	2	159.0
		ST	2	152.9
Tensile Yield Strength (KSI)	.250 to .300	L	3	149.7
		LT	3	155.5
	.500 to .630	L	3	161.7
		LT	3	164.5
	≥ 1.00	L	2	146.2
		LT	2	151.4
		ST	2	145.0
Compressive Yield Strength (KSI)	.250 to .300	L	3	157.1
		LT	3	176.5
	.500 to .630	L	3	171.6
		LT	3	166.9
	≥ 1.00	L	2	156.8
		LT	2	158.7
		ST	2	153.2
Bearing Ultimate Strength (KSI) e/D = 1.5	.250 to .300	L	3	262.9
		LT	2	268.8
	.500 to .630	L	3	274.1
		LT	1	274.1
	≥ 1.00	L	2	250.9
		LT	1	267.3
		LE	1	233.8
		TE	1	224.0
Bearing Ultimate Strength (KSI) e/D = 2.0	.250 to .300	L	3	317.9
		LT	2	330.8
	.500 to .630	L	3	339.2
		LT	1	331.2
	≥ 1.00	L	2	315.7
		LT	1	334.3
		LE	1	310.8
		TE	1	299.4
Bearing Yield Strength (KSI) e/D = 1.5	.250 to .300	L	3	222.8
		LT	2	232.9
	.500 to .630	L	3	240.2
		LT	1	240.9
	≥ 1.00	L	2	215.9
		LT	1	217.8
		LE	1	214.0
		TE	1	207.7

* Average value for more than 1 test.

Table VI -8 (cont'd)

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 6Al-4V STA Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Bearing Yield Strength (KSI) e/D = 2.0	.250 to .300	L	3	256.0
		LT	2	279.3
	.500 to .630	L	3	283.8
		LT	1	271.7
	≥ 1.00	L	2	251.1
		LT	1	264.2
		LE	1	265.8
		TE	1	257.3
Shear Ultimate Strength (KSI)	.250 to .300	L	3	98.7
		LT	2	105.4
	.500 to .630	L	3	103.6
		LT	1	98.3
	≥ 1.00	L	2	95.2
		LT	1	102.0

* Average value for more than 1 test.

Table VI - 9

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 6Al-6V-2Sn   Annealed Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Tensile Ultimate Strength (KSI)	.250 to .300	L	5	161.2
		LT	5	171.2
	.500 to .630	L	5	160.9
		LT	5	163.5
	1.00	L	5	154.6
		LT	5	154.1
		ST	5	154.8
Tensile Yield Strength (KSI)	.250 to .300	L	5	158.8
		LT	5	166.6
	.500 to .630	L	5	158.3
		LT	5	160.2
	1.00	L	5	148.5
		LT	5	149.1
		ST	5	143.1
Compressive Yield Strength (KSI)	.250 to .300	L	5	162.6
		LT	5	184.3
	.500 to .630	L	5	170.6
		LT	5	173.2
	1.00	L	5	161.4
		LT	5	157.5
		ST	5	153.6
Bearing Ultimate Strength (KSI) e/D = 1.5	.250 to .300	L	5	261.8
		LT	1	274.6
	.500 to .630	L	5	275.5
		LT	1	264.4
	1.00	L	5	264.1
		LT	1	256.4
		LE	1	244.9
		TE	1	212.9
Bearing Ultimate Strength (KSI) e/D = 2.0	.250 to .300	L	5	330.8
		LT	1	354.3
	.500 to .630	L	5	344.7
		LT	1	392.9
	1.00	L	4	337.6
		LT	1	327.4
		LE	1	317.4
		TE	1	294.5

* Average value for more than 1 test.

Table VI- 9 (cont'd)

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 6Al-6V-2Sn Annealed Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Bearing Yield Strength (KSI) e/D = 1.5	.250 to .300	L	5	224.5
		LT	1	212.2
	.500 to .630	L	5	230.2
		LT	1	222.5
	1.00	L	5	218.4
		LT	1	217.3
		LE	1	215.6
		TE	1	200.6
Bearing Yield Strength (KSI) e/D = 2.0	.250 to .300	L	5	252.8
		LT	1	286.1
	.500 to .630	L	5	271.6
		LT	1	307.1
	1.00	L	5	264.0
		LT	1	253.4
		LE	1	267.7
		TE	1	256.4
Shear Ultimate Strength (KSI)	.250 to .300	L	5	99.6
		LT	1	108.7
	.500 to .630	L	5	106.0
		LT	1	108.2
	1.00	L	5	102.0
		LT	1	105.3

* Average value for more than 1 test.

Table VI - 10

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 6Al-6V-2Sn   STA Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Tensile Ultimate Strength (KSI)	.250 to .300	L	1	184.6
		LT	1	191.2
	.500 to .630	L	5	183.1
		LT	5	183.5
	≥ 1.00	L	5	187.4
		LT	5	188.3
		ST	5	182.3
Tensile Yield Strength (KSI)	.250 to .300	L	1	176.5
		LT	1	186.0
	.500 to .630	L	5	177.1
		LT	5	176.5
	≥ 1.00	L	5	176.2
		LT	5	179.0
		ST	5	167.6
Compressive Yield Strength (KSI)	.250 to .300	L	1	184.1
		LT	1	206.0
	.500 to .630	L	5	188.8
		LT	5	188.3
	≥ 1.00	L	5	195.4
		LT	5	191.4
		ST	5	194.4
Bearing Ultimate Strength (KSI) e/D = 1.5	.250 to .300	L	1	298.6
	.500 to .630	L	5	291.5
		LT	1	287.4
	≥ 1.00	L	5	295.4
		LT	1	289.0
		LE	1	261.1
		TE	1	251.7
Bearing Ultimate Strength (KSI) e/D = 2.0	.250 to .300	L	1	360.4
	.500 to .630	L	5	365.2
		LT	1	350.2
	≥ 1.00	L	5	360.6
		LT	1	343.7
		LE	1	350.3
		TE	1	342.5

* Average value for more than 1 test.

Table VI- 10 (cont'd)

SUMMARY OF ROOM TEMPERATURE TEST RESULTS

Ti 6Al-6V-2Sn STA Condition

Property	Thickness	Direction	No. of Tests	Property Value *
Bearing Yield Strength (KSI) e/D = 1.5	.250 to .300	L	1	277.7
	.500 to .630	L	5	263.5
		LT	1	265.1
	≥ 1.00	L	5	270.9
		LT	1	266.5
		LE	1	240.0
		TE	1	242.5
Bearing Yield Strength (KSI) e/D = 2.0	.250 to .300	L	1	296.7
	.500 to .630	L	5	298.3
		LT	1	298.1
	≥ 1.00	L	5	304.9
		LT	1	283.3
		LE	1	289.4
		TE	1	312.0
Shear Ultimate Strength (KSI)	.250 to .300	L	1	107.0
	.500 to .630	L	5	111.8
		LT	1	118.0
	≥ 1.00	L	5	114.6
		LT	1	111.0

* Average value for more than 1 test.

Section VII

TEST RESULTS

Contained within this section are the results of the various mechanical property tests performed in this investigation.

7.1 Ti 4Al-3Mo-1V Cond A

7.1.1 Tensile Tests

Ti 4Al-3Mo-1V ANNEALED CONDITION

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (oF)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
≤.110	Timet G 1596	TM1XLTR1	L	RT	126.2	133.6	12.0	-
		TM1XLT41	L	400	89.4	103.8	10.0	-
		TM1XLT61	L	600	81.9	96.9	7.5	-
		TM1XLT81	L	800	71.2	86.5	7.5	-
		TM1XTTR1	T	RT	125.2	134.7	11.0	-
		TM1XTT41	T	400	94.1	107.6	10.0	-
		TM1XTT61	T	600	81.8	97.6	7.0	-
	Timet G 1596	TM1XTT81	T	800	78.7	90.6	7.0	-
	Timet G 895	TM2X1TR1	L	RT	128.7	133.2	12.5	-
		TM2SLT41	L	400	100.4	106.4	12.5	-
		TM2XLT61	L	600	85.7	96.4	8.0	-
		TM2XLT81	L	800	75.0	87.1	7.5	-
	Timet G 895	TM2XTTR1	T	RT	132.8	135.4	11.5	-
	Timet G 2446	TM3XLTR1	L	RT	123.4	130.0	12.0	-
		TM3XLT41	L	400	93.8	102.2	12.5	-
		TM3XLT61	L	600	81.6	92.2	8.5	-
		TM3XLT81	L	800	74.1	85.6	9.5	-
	Timet G 2446	TM3XLTR1	T	RT	135.9	136.5	12.0	-
	Timet G 1523	TM4XLTR1	L	RT	120.9	128.1	12.0	-
		TM4XLT41	L	400	88.5	102.3	125.	-
		TM4XLT61	L	600	79.2	96.4	9.5	-
		TM4XLT81	L	800	71.2	88.4	8.5	-
	Timet G 1523	TM4XTTR1	T	RT	127.2	132.3	13.5	-
	Timet G 1401	TM5XLTR1	L	RT	121.2	130.4	12.0	-
		TM5XLT41	L	400	90.9	100.7	13.0	-
		TM5XLT61	L	600	79.4	90.8	9.0	-
		TM5XLT81	L	800	73.5	85.2	9.0	-
≤.110	Timet G 1401	TM5XTTR1	T	RT	139.4	142.2	12.0	-

7.1.1 Tensile Tests (continued) Ti 4Al-3Mo-1V ANNEALED CONDITION

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
≤.110	RMI 321055	RM6XLTR1	L	RT	124.8	131.5	13.0	-
↕	↕	RM6XLT41	L	400	88.7	99.3	16.0	-
		RM6XLT61	L	600	78.4	89.4	14.0	-
		RM6XLT81	L	800	70.5	81.9	15.0	-
		RM6XTTR1	T	RT	136.0	138.8	14.0	-
		RM6XTT41	T	400	100.1	106.0	15.0	-
		RM6XTT61	T	600	87.3	95.4	15.0	-
≤.110	RMI 321055	RM6XTT81	T	800	77.9	87.4	12.0	-

7.1.1 Tensile Stability Tests Ti 4Al-3Mo-IV ANNEALED CONDITION

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
≤ .110	Timet G 1596	TM1XLTW41	L	400	10	RT	122.6	133.7	13.0	-
		TM1XLTW42	L	400	100	RT	122.8	132.5	12.0	-
		TM1XLTW43	L	400	1000	RT	121.8	130.0	13.5	-
		TM1XLTW61	L	600	10	RT	121.0	131.7	13.0	-
		TM1XLTW62	L	600	100	RT	121.0	132.5	12.0	-
		TM1XLTW63	L	600	1000	RT	122.6	134.4	13.0	-
		TM1XLTW81	L	800	10	RT	120.4	131.1	12.0	-
		TM1XLTW82	L	800	100	RT	120.2	131.5	13.0	-
	Timet G 1596	TM1XLTW83	L	800	1000	RT	123.5	131.8	12.5	-
	Timet G 1596	TM1XLTX41	L	400	10	400	89.5	104.2	12*	-
		TM1XLTX42	L	400	100	400	90.6	105.1	13*	-
		TM1XLTX43	L	400	1000	400	89.3	104.2	14	-
		TM1XLTX61	L	600	10	600	78.2	94.9	8	-
		TM1XLTX62	L	600	100	600	79.9	95.1	8	-
		TM1XLTX63	L	600	1000	600	75.7	92.9	15	-
		TM1XLTX81	L	800	10	800	71.8	87.6	8*	-
		TM1XLTX82	L	800	100	800	72.7	89.1	8	-
≤ .110	Timet G 1596	TM1SLTX83	L	800	1000	800	73.2	89.1	8*	-

*Broke through guage mark or within specimen width of guage marks.

Ti-4Al-3Mo-1V COND. A

7.1.1.2 Tensile Tests - Precision Elastic Modulus (Tuckerman)

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature	Precision "E" x 10^6
$\leq .110$	Timet G 1596	TM1XLTR1	L	RT	16.2

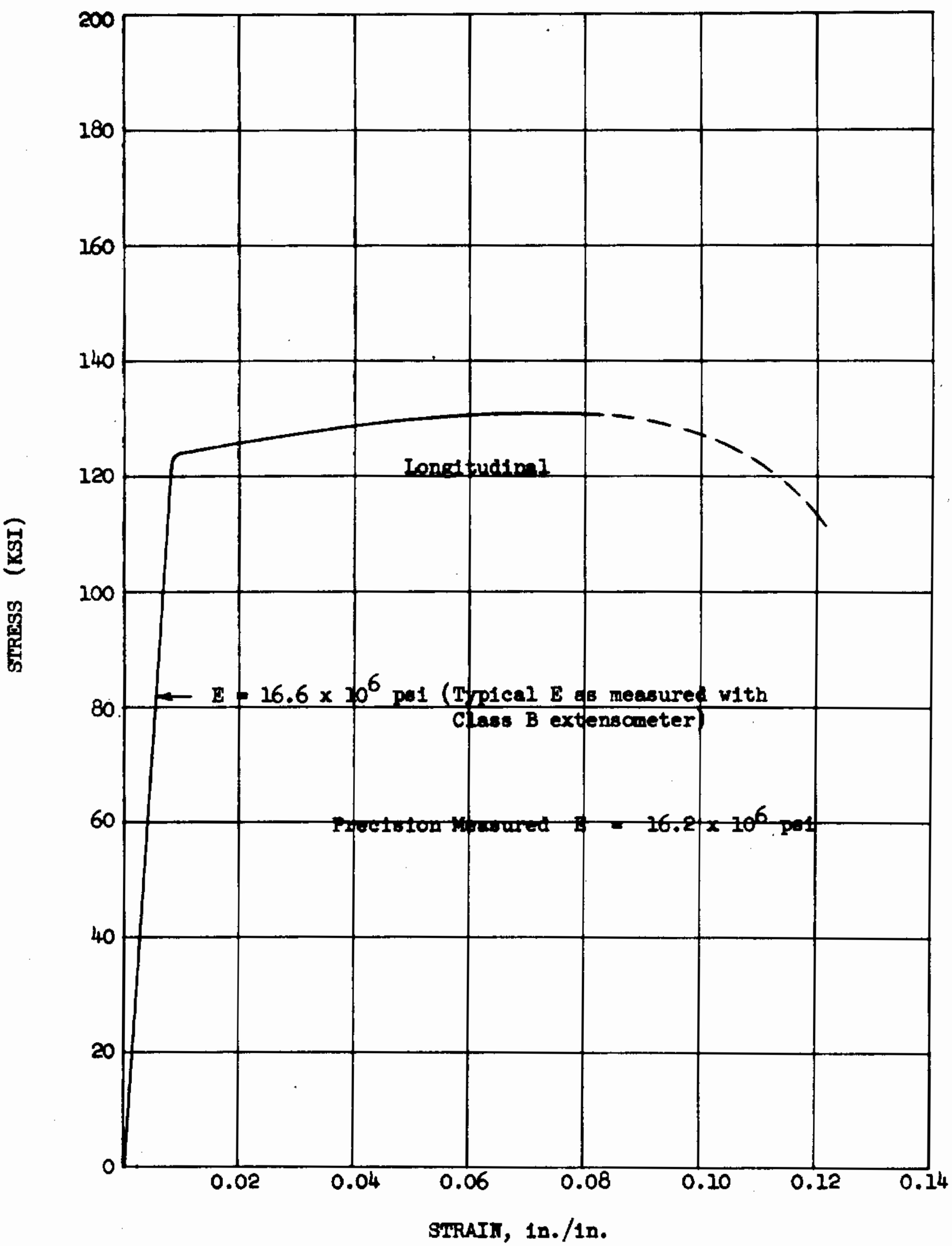


Figure 7-1 Typical Tensile Stress-Strain Curve (full-range) for Annealed Ti-4Al-3Mo-1V Alloy Sheet at Room Temperature

7.1.2 Compression Tests Ti 4Al-3Mo-1V ANNEALED CONDITION

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≤ .110	Timet G 1596	TM1XLCR1	L	RT	125.9
		TM1XLC41	L	400	91.5
		TM1XLC61	L	600	81.1
		TM1XLC81	L	800	72.7
		TM1XLCR1	T	RT	122.6
		TM1XTC41	T	400	90.6
		TM1XTC61	T	600	81.2
	Timet G 1596	TM1XTC81	T	800	72.9
	Timet G 895	TM2XLCR1	L	RT	131.2
	Timet G 895	TM2XLCR1	T	RT	131.5
	Timet G 2446	TM3XLCR1	L	RT	127.5
	Timet G 2446	TM3XTCR1	T	RT	133.3
	Timet G 1523	TM4XLCR1	L	RT	124.7
	Timet G 1523	TM4XTCR1	T	RT	129.6
	Timet G 1401	TM5XLCR1	L	RT	126.0
≤ .110	Timet G 1401	TM5XTCR1	T	RT	155.3

7.1.2 Compression Tests (continued)

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≤ .110	RMI 321055	RM6XLCR1	L	RT	129.1
↑	↑	RM6XLC41	L	400	93.5
│	│	RM6XLC61	L	600	82.1
│	│	RM6XLC81	L	800	75.7
│	│	RM6XTCR1	T	RT	145.7
│	│	RM6XTC41	T	400	104.2
↓	↓	RM6XTC61	T	600	91.9
≤ .110	RMI 321055	RM6XTC81	T	800	86.2

Ti 4Al-3Mo-1V ANNEALED CONDITION

7.1.3 Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (°F)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
≤ .110	Timet G1596	TM1XLB1R1	L	1.5	RT	162.4	201
		TM1XLB141	L	1.5	400	135.3	162.4
		TM1XLB161	L	1.5	600	134.1	154.1
		TM1XLB181	L	1.5	800	124.7	144.7
		TM1XTB1R1	T	1.5	RT	169.4	206
		TM1XTB141	T	1.5	400	133.0	161.4
		TM1XTB161	T	1.5	600	134.1	155.3
	Timet G1596	TM1XTB18	T	1.5	800	125.9	142.4
	Timet G1596	TM1XLB2R1	L	2.0	RT	198.8	279
		TM1XLB241	L	2.0	400	147.1	202.4
		TM1XLB261	L	2.0	600	143.5	191.8
		TM1XLB281	L	2.0	800	140.0	183.5
		TM1XTB2R1	T	2.0	RT	197.6	263
		TM1XTB241	T	2.0	400	163.5	204.7
		TM1XTB261	T	2.0	600	151.8	195.3
	Timet G1596	TM1XTB281	T	2.0	800	149.4	187.1
	Timet G 895	TM2XLB1R1	L	1.5	RT	170.0	208
	Timet G 895	TM2XLB2R1	L	2.0	RT	190.7	279
	Timet G 2446	TM3XLB2R1	L	1.5	RT	167.7	207
	Timet G2446	TM3XLB2R1	L	2.0	RT	208.9	280
	Timet G 1523	TM4XLB1R1	L	1.5	RT	168.0	206
	Timet G 1523	TM4XLB2R1	L	2.0	RT	189.1	276
	Timet G 1401	TM5XLB1R1	L	1.5	RT	178.5	214.2
≤ .110	Timet G 1401	TM5XLB2R1	L	2.0	RT	215.2	274.5

7.1.3 Bearing Tests (continued)

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
≤ .110	RMI 321055	RM6XLB1R1	L	1.5	RT	181.9	228.8
↓	↓	RM6XLB141	L	1.5	400	136.9	173.8
		RM6XLB161	L	1.5	600	132.6	159.2
		RM6XLB18	L	1.5	800	115.3	134.9
		RM6XTB1R1	T	1.5	RT	186.3	233.3
		RM6XTB141	T	1.5	400	140.9	183.7
		RM6XTB161	T	1.5	600	131.8	162.4
	RMI 321055	RM6XTB181	T	1.5	800	121.1	146.5
	RMI 321055	RM6XLB2R1	L	2.0	RT	214.7	275.0
	↓	RM6XLB241	L	2.0	400	159.3	233.5
		RM6XLB261	L	2.0	600	150.5	205.7
		RM6XLB281	L	2.0	800	139.5	186.8
		RM6XTB2R1	T	2.0	RT	239.6	304.7
		RM6XTB241	T	2.0	400	166.2	242.1
		RM6XTB261	T	2.0	600	159.8	213.8
≤ .110	RMI 321055	RM6XTB281	T	2.0	800	150.9	196.5

Ti 4Al-3Mo-1V ANNEALED CONDITION

7.1.4 Shear Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fsy (Ksi)
≤ .110	Timet G 1596	TM1XLSR1	L	RT	83.8
		TM1XLS41	L	400	65.0
		TM1XLS61	L	600	56.8
		TM1XLS81	L	800	51.5
		TM1XTSR1	L	RT	78.8
		TM1XTS41	T	400	63.4
		TM1XTS61	T	600	56.9
	Timet G 1596	TM1XTS81	T	800	51.9
	Timet G 895	TM2XLSR1	L	RT	82.2
	Timet G 2446	TM3XLSR1	L	RT	81.0
	Timet G 1523	TM4XLSR1	L	RT	82.7
	Timet G 1401	TM5XLSR1	L	RT	83.6
	RMI 321065	RM6XLSR1	L	RT	83.5
		RM6XLS41	L	400	68.5
		RM6XLS61	L	600	62.1
		RM6XLS81	L	800	58.4
		RM6XTSR1	T	RT	89.6
		RM6XTS41	T	400	74.0
		RM6XTS61	T	600	66.7
≤ .110	RMI 321065	RM6XTS81	T	800	61.6

Ti 4Al-3Mo-1V ANNEALED CONDITION

7.1.5 Fatigue Test F_{tu} - 131.5 Avg.

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≤ .110	RMI 321055	RM6XLVR25	L	1.0	-1.0	78,000	59.	51,000
		RM6XLVR26	L	1.0	-1.0	91,000	69.	20,000
		RM6XLVR27	L	1.0	-1.0	65,000	50	10,000,000 →
		RM6XLVR28	L	1.0	-1.0	72,800	55.	50,000
		RM6XLVR29	L	1.0	-1.0	70,200	53.	83,000
		RM6XLVR30	L	1.0	-1.0	67,000	51.	146,000
		RM6XLVR31	L	1.0	-1.0	66,000	50.	114,000
		RM6XLVR32	L	1.0	-1.0	65,500	50.	11,260,000 →
		RM6XLVR9	L	1.0	-0.3	97,500	74.	114,000
		RM6XLVR10	L	1.0	-0.3	91,000	69.	68,000
		RM6XLVR11	L	1.0	-0.3	84,500	64,	91,000
		RM6XLVR12 (1)	L	1.0	-0.3	104,000	79.	24,000
		RM6XLVR13	L	1.0	-0.3	78,000	59.	116,000
		RM6XLVR14	L	1.0	-0.3	65,000	50	10,000,000 →
		RM6XLVR15	L	1.0	-0.3	75,400	75.	14,307,000 →
≤ .110	RMI 321055	RM6XLVR16	L	1.0	-0.3	110,500	84.	23,000

(1) Specimen overstressed

→ No Failure

Ti 4Al-3Mo-1V ANNEALED CONDITION

7.1.5 Fatigue Tests

$F_{tu} = 131.5$

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≤ .110	RMI 321055	RM6XLVR 1 (1)	L	1.0	0	91,000	69	293,000 (1)
		RM6XLVR 2	L	1.0	0	104,000	79	65,000
		RM6XLVR 3	L	1.0	0	91,000	69	11,163,000 →
		RM6XLVR 4	L	1.0	0	97,500	74	93,000
		RM6XLVR 5	L	1.0	0	110,500	84	53,000
		RM6XLVR 6	L	1.0	0	94,900	72	15,600,000 →
		RM6XLVR 7	L	1.0	0	120,900	92	17,000
		RM6XLVR 8	L	1.0	0	96,200	73	164,000
		RM6XLVR17	L	1.0	+0.3	117,000	89	73,000
		RM6XLVR18	L	1.0	+0.3	104,000	79	24,400,000 →
		RM6XLVR19	L	1.0	+0.3	122,200	93	39,000
		RM6XLVR20	L	1.0	+0.3	114,400	87	212,000
		RM6XLVR21	L	1.0	+0.3	113,100	86	133,000
		RM6XLVR22	L	1.0	+0.3	110,500	84	10,000,000 →
		RM6XLVR23	L	1.0	+0.3	112,450	86	58,000
≤ .110	RMI 321055	RM6XLVR24	L	1.0	+0.3	126,750	97	46,000

(1) Grip Failure

→ No Failure

Ti 4Al-3Mo-1V ANNEALED CONDITION

7.1.5 Fatigue Tests

F_{tu} = 131.5

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
.110	RMI 321055	RM6XLVR41	L	3.0	-1.0	52,000	40	7,000
↑	↑	RM6XLVR42	L	3.0	-1.0	39,000	30	52,000
		RM6XLVR43	L	3.0	-1.0	32,500	25	94,000
		RM6XLVR44	L	3.0	-1.0	26,000	20	10,337,000→
		RM6XLVR45	L	3.0	-1.0	29,900	23	12,940,000→
		RM6XLVR46	L	3.0	-1.0	35,000	27	136,500
		RM6XLVR47	L	3.0	-1.0	32,000	24	5,441,000
		RM6XLVR48	L	3.0	-1.0	33,000	25	103,000
		RM6XLVR57	L	3.0	-0.3	65,000	49	7,000
		RM6XLVR58	L	3.0	-0.3	52,000	40	36,000
		RM6XLVR59	L	3.0	-0.3	45,500	34	68,000
		RM6XLVR60	L	3.0	-0.3	39,000	30	14,700,000→
		RM6XLVR61	L	3.0	-0.3	58,500	45	18,000
↓	↓	RM6XLVR63	L	3.0	-0.3	42,900	33	101,000
.110	RMI 321055	RM6XLVR64	L	3.0	-0.3	40,500	31	2,699,000

→ No Failure

7.1.5 Fatigue Tests

F_{tu} = 131.5

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≤ .110	RMI 321055	RM6XLVR33	L	3.0	0	104,000	79	2,000
↕	↕	RM6XLVR34	L	3.0	0	91,000	69	4,000
		RM6XLVR35	L	3.0	0	65,000	50	13,000
		RM6XLVR36	L	3.0	0	52,000	40	2,106,000
		RM6XLVR37	L	3.0	0	62,400	48	15,000
		RM6XLVR38	L	3.0	0	57,200	44	35,000
		RM6XLVR39	L	3.0	0	49,400	38	2,593,000
		RM6XLVR40	L	3.0	0	46,800	36	2,554,000
		RM6XLVR64	L	3.0	0	42,900	33	6,063,000
		RM6XLVR49	L	3.0	+0.3	65,000	50	41,000
		RM6XLVR50	L	3.0	+0.3	78,000	59	16,000
		RM6XLVR51	L	3.0	+0.3	58,500	45	99,000
		RM6XLVR52	L	3.0	+0.3	52,000	40	114,000
		RM6XLVR53	L	3.0	+0.3	45,500	35	10,210,000 →
		RM6XLVR54	L	3.0	+0.3	49,000	38	10,312,000 →
		RM6XLVR55	L	3.0	+0.3	50,700	39	10,000,000 →
≤ .110	RMI 321055	RM6XLVR56	L	3.0	+0.3	85,000	65.	11,000

→ No Failure

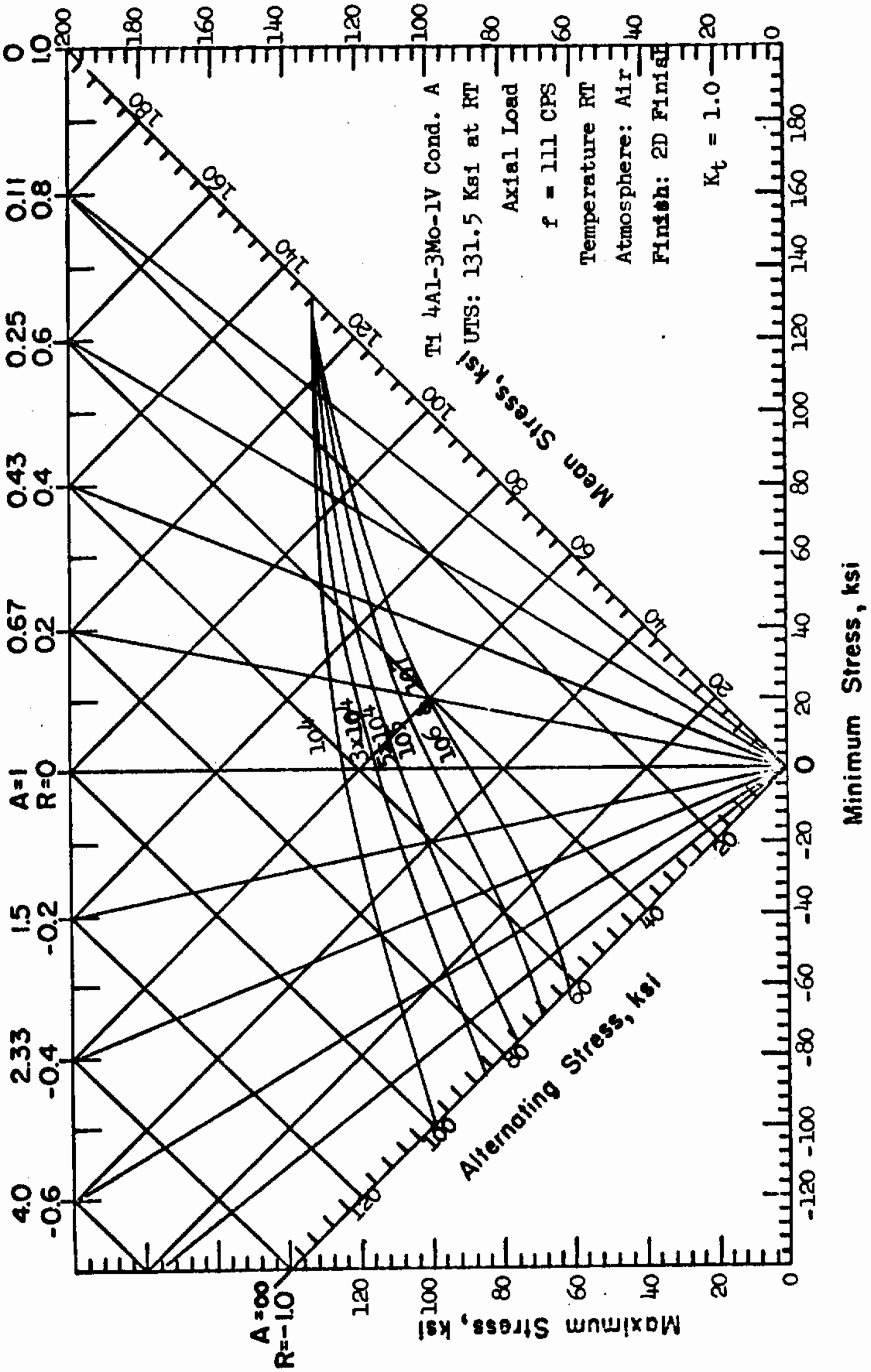

Ti 4Al-3Mo-1V Cond. A
UTS: 131.5 Ksi at RT
Axial Load
f = 111 CPS
Temperature RT
Atmosphere: Air
Finish: 2D Finish
K_t = 1.0
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=∞
R=-1.0
A=1
R=0
10^4
3×10^4
10^5
10^6
10^7

Figure 7-2

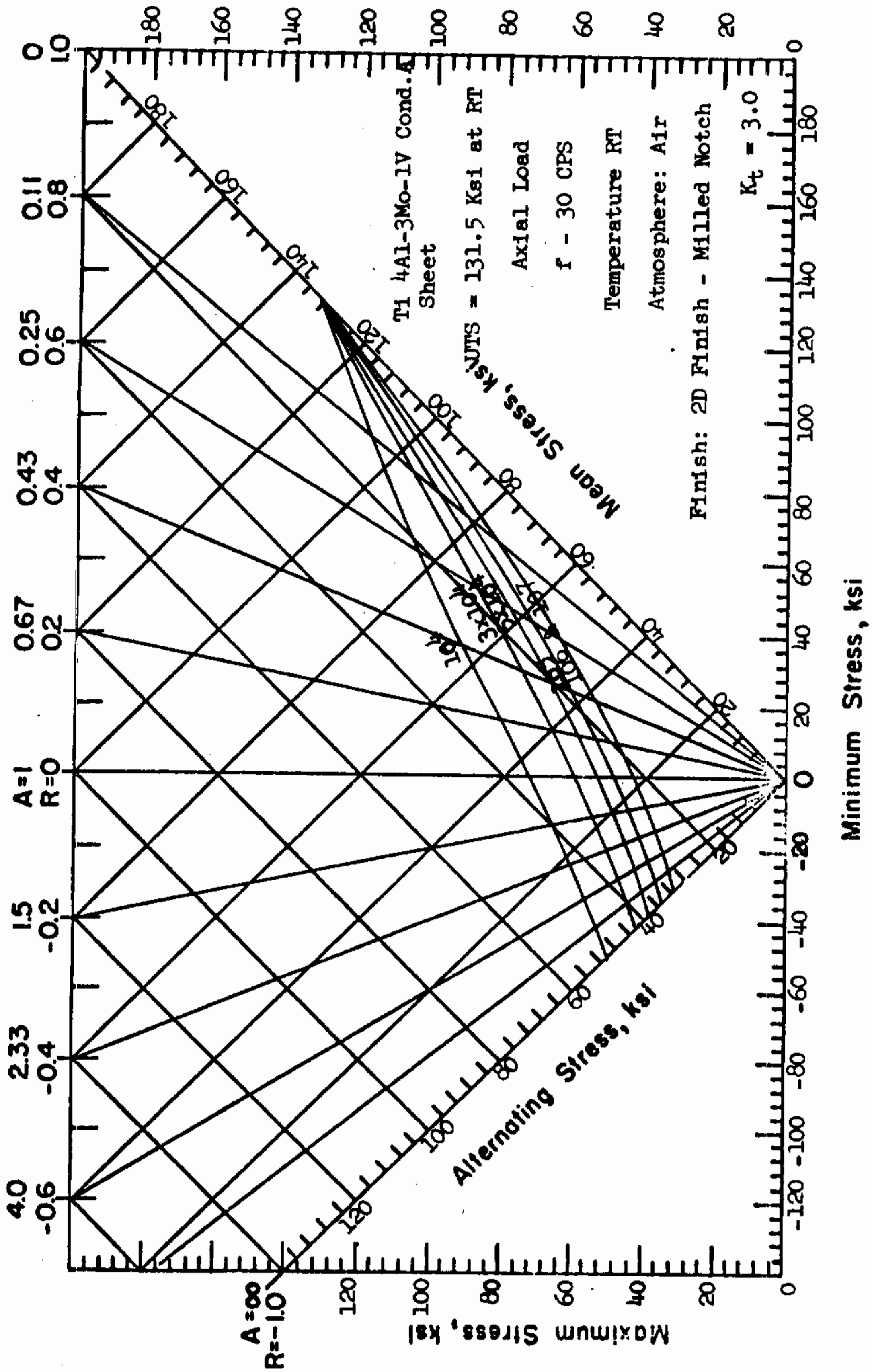

Ti 4Al-3Mo-1V Cond.A
Sheet
UTS = 131.5 Ksi at RT
Axial Load
f - 30 CPS
Temperature RT
Atmosphere: Air
Finish: 2D Finish - Milled Notch
K_t = 3.0
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=1
R=0
A=∞
R=-1.0
10^4
3×10^4
10^7

Figure 7-3

7.2 Ti 13V-11Cr-3Al Cond. A(or ST)

7.2.1 Tensile Tests

TI 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
≤ .110	Timet D 7855	TC1XLTR1	L	RT	131.8	133.6	12	-
		TC1XLT41	L	400	100.8	110.3	22.5	-
		TC1XLT61	L	600	96.2	108.1	22.5	-
		TC1XLT81	L	800	95.2	112.4	16.5	-
		TC1XTTR1	T	RT	141.0	143.7	13.0	-
		TC1XTT41	T	400	108.0	113.9	19.5	-
		TC1XTT61	T	600	105.5	113.6	16.5	-
	Timet D 7855	TC1XTT81	T	800	100.0	115.9	14.0	-
	Timet D 7770	TC2XLTR1	L	RT	135.8	135.8	22.5	-
		TC2XLT41	L	400	103.4	114.7	22.0	-
		TC2XLT61	L	600	101.1	113.7	22.5	-
		TC2XLT81	L	800	98.4	115.8	15.0	-
	Timet D 7770	TC2XTTR1	T	RT	134.7	135.0	16.0	-
	Timet D 7107	TC3XLTR1	L	RT	137.1	137.1	22.5	-
		TC3XLT41	L	400	101.1	111.9	27.0	-
		TC3XLT61	L	600	98.9	111.1	25.0	-
		TC3XLT81	L	800	92.8	111.7	18.0	-
≤ .110	Timet D 7107	TC3XTTR1	T	RT	132.4	132.8	17.0	-

7.2.1 **Tensile Tests** TI 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
≤ .110	Timet D 7639	TC4XLTR1	L	RT	137.4	137.4	20.0	-
↕	↕	TC4XLT41	L	400	103.4	117.1	16.0	-
		TC4XLT61	L	600	103.7	115.3	22.5	-
		TC4XLT81	L	800	101.6	116.3	16.5	-
	Timet D 7639	TC4XTTR1	T	RT	139.1	140.0	19.0	-
	Timet D 7110	TC5XLTR1	L	RT	131.1	131.1	24.0	-
	↕	TC5XLT41	L	400	104.5	113.4	28.0	-
		TC5XLT61	L	600	100.0	113.2	26.5	-
		TC5XLT81	L	800	48.9	116.3	18.0	-
≤ .110	Timet D 7110	TC5XTTR1	T	RT	137.4	137.4	20.5	-

7.2.1.1 Tensile Stability Tests

TI 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
≤.110	Timet D 7855	TC1XLTW41	L	400	10	RT	129.0	132.4	18.0	-
		TC1XLTW42	L	400	100	RT	132.5	134.0	15.0	-
		TC1XLTW43	L	400	1000	RT	132.4	132.9	22.0	-
		TC1XLTW61	L	600	10	RT	132.4	137.7	14.0	-
		TC1XLTW62	L	600	100	RT	137.1	138.1	17.0	-
		TC1XLTW63	L	600	1000	RT	184.8	202.9	4.0	-
		TC1XLTW81	L	800	10	RT	142.4	148.1	15.5	-
		TC1XLTW82	L	800	100	RT	210.1	226.7	5.0	-
		TC1XLTW83	L	800	1000	RT	232.9	241.9	0.5	-
		TC1XLTX41	L	400	10	400	102	111	21	-
		TC1XLTX42	L	400	100	400	104	114	28	-
		TC1XLTX43	L	400	1000	400	104	112	23	-
		TC1XLTX61	L	600	10	600	101	111	22	-
		TC1XLTX62	L	600	100	600	104.1	114.5	20.5	-
		TC1XLTX63	L	600	1000	600	148.4	177.7	7.0	-
		TC1XLTX81	L	800	10	800	106.4	125.0	12.5	-
		TC1XLTX82	L	800	100	800	160.5	187.3	5.0	-
≤.110	Timet D 7855	TC1XLTX83	L	800	1000	800	173.6	197.7	2.5	-

Ti 13V-11CR-3AL COND. A

7.2.1.2 Tensile Tests - Precision Elastic Modulus (Tuckerman)

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature	Precision "E" x 10^6
$\leq$.110	Timet D 7855	TC1XLTR1	L	RT	14.6

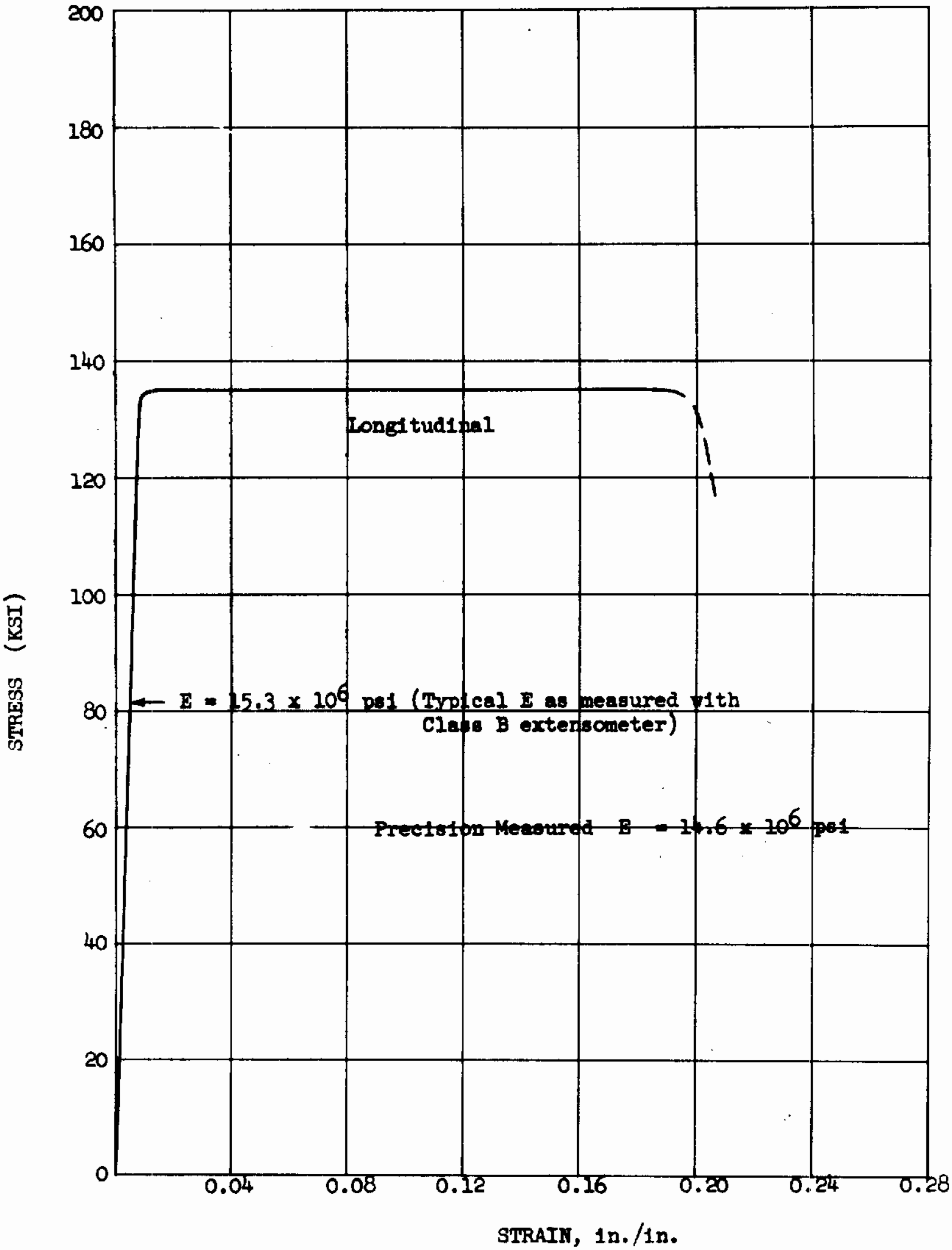


Figure 7-4 Typical Tensile Stress-Strain Curve (full-range) for Annealed Ti-13V-11Cr-3Al Alloy Sheet at Room Temperature

7.2.2 Compression Tests TI 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≤ .110	Timet D 7855	TC1XLCR1	L	RT	132.1
↕	Timet D 7855	TC1XLC41	L	400	105.8
	Timet D 7855	TC1XLC61	L	600	97.2
	Timet D 7855	TC1XLC81	L	800	99.9
	Timet D 7855	TC1XTCR1	T	RT	134.9
	Timet D 7855	TC1XTC41	T	400	113.9
	Timet D 7855	TC1XTC61	T	600	107.4
	Timet D 7855	TC1XTC81	T	800	105.7
	Timet D 7770	TC2XLCR1	L	RT	134.2
	Timet D 7770	TC2XTCR1	T	RT	140.0
	Timet D 7107	TC3XLCR1	L	RT	131.4
	Timet D 7107	TC3XTCR1	T	RT	141.7
	Timet D 7639	TC4XLCR1	L	RT	131.5
↕	Timet D 7634	TC4XTCR1	T	RT	133.6
≤ .110	Timet D 7110	TC5XLCR1	L	RT	116.1 (1)
	Timet D 7110	TC5XTCR1	T	RT	135.7

(1) Stress - Strain Curve Erratic - Specimen Probably not seated Test invalid

7.2.3 Bearing Tests Ti 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
≤ .110	Timet D 7855	TC1XLB1R1	L	1.5	RT	172.2	221
	Timet D 7855	TC1XLB141	L	1.5	400	149.1	198.2
	Timet D 7855	TC1XLB161	L	1.5	600	153.7	200.0
	Timet D 7855	TC1XLB181	L	1.5	800	155.5	200.0
	Timet D 7855	TC1XTB1R1	T	1.5	RT	176.9	224
	Timet D 7855	TC1XTB141	T	1.5	400	142.6	200.9
	Timet D 7855	TC1XTB161	T	1.5	600	150.9	195.4
	Timet D 7855	TC1XTB181	T	1.5	800	170.4	205.6
	Timet D 7855	TC1XLB2R1	L	2.0	RT	191.7	300
	Timet D 7855	TC1XLB241	L	2.0	400	179.6	265.7
	Timet D 7855	TC1XLB261	L	2.0	600	176.4	263.6
	Timet D 7855	TC1XLB281	L	2.0	800	188.2	258.2
	Timet D 7855	TC1XTB2R1	T	2.0	RT	205	311
	Timet D 7855	TC1XTB241	T	2.0	400	165.0	262.1
	Timet D 7855	TC1XTB261	T	2.0	600	182.0	263.0
≤ .110	Timet D 7855	TC1XTB281	T	2.0	800	200.0	266.0

7.2.3 Bearing Tests

Ti 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (°F)	F_{bry} (Ksi) (2% Offset)	F_{bru} (Ksi)
≤ .110	Timet D 7770	TC2XLBIR1	L	1.5	RT	176.0	215.6
	Timet D 7770	TC2XLB2R1	L	2.0	RT	188.8	300
	Timet D 7107	TC3XLBIR1	L	1.5	RT	172.7	224
	Timet D 7107	TC3XLB2R1	L	2.0	RT	192.0	303
	Timet D 7639	TC4XLBIR1	L	1.5	RT	169.4	221
	Timet D 7639	TC4XLB2R1	L	2.0	RT	193.9	306
	Timet D 7110	TC5XLBIR1	L	1.5	RT	174.7	226
≤ .110	Timet D 7110	TC5XLB2R1	L	2.0	RT	193.7	308

7.2.4 Shear Tests Ti 13V-11Cr-3Al ANNEALED

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fsy (Ksi)
≤ .110	Timet D 7855	TC1XLSR1	L	RT	96.1
		TC1XLS41	L	400	81.9
		TC1XLS61	L	600	82.8
		TC1XLS81	L	800	76.7
		TC1XTSR1	T	RT	98.2
		TC1XTS41	T	400	84.0
		TC1XTS61	T	600	82.1
	Timet D 7855	TC1XTS81	T	800	78.2
	Timet D 7770	TC2XLSR1	L	RT	99.4
	Timet D 7107	TC3XLSR1	L	RT	94.4
	Timet D 7639	TC4XLSR1	L	RT	95.8
≤ .110	Timet D 7110	TC5XLSR1	L	RT	98.2

7.3 Ti 6Al-4V COND. STA

7.3.1 Tensile Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
.250 to .300	Timet G 4956	TA1XLTR1	L	RT	155.6	170.2	9	-
		TA1XLT41	L	400	115.7	135.1	10	-
		TA1XLT61	L	600	105.0	127.2	10	-
		TA1XLT81	L	800	87.5	109.1	12	-
		TA1XTTR1	T	RT	169.0	182.5	8	-
		TA1XTT41	T	400	135.6	153.2	12	-
		TA1XTT61	T	600	126.0	143.8	10	-
	Timet G 4956	TA1XTT81	T	800	118.4	138.1	10	-
	Timet G 4796	TA2XLTR1	L	RT	140.0	146.9	13	-
		TA2XLT41	L	400	100.9	116.8	18	-
		TA2XLT61	L	600	86.0	105.6	17	-
		TA2XLT81	L	800	80.8	98.6	17	-
	Timet G 4796	TA2XTTR1	T	RT	146.0	152.1	14	-
	RMI X 53788	RA6XLTR1	L	RT	153.6	167.2	7	-
		RA6XLT41	L	400	112.5	133.7	13*	-
		RA6XLT61	L	600	95.4	124.0	12	-
		RA6XLT81	L	800	108.5	133.1	11	-
		RA6XTTR1	T	RT	151.4	166.7	7	-
		RA6XTT41	T	400	106.9	132.3	12**	-
		RA6XTT61	T	600	92.8	121.7	11	-
.250 to .300	RMI X 53788	RA6XTT81	T	800	87.1	114.4	13	-

*Broke through guage mark or within spec. width of guage mark
**Broke through Extensometer placement

7.3.1   Tensile Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
.500 to .630	Timet G 6539	TA1YLTR1	L	RT	164.9	178.7	12	36
		TA1YLT41	L	400	125.5	146.4	17	52
		TA1YLT61	L	600	107.8	134.3	5	51
		TA1YLT81	L	800	101.0	123.5	15	57
		TA1YTTR1	T	RT	158.4	173.8	11	28
		TA1YTT41	T	400	120.3	142.7	15	44
		TA1YTT61	T	600	97.8	126.9	13	43
	Timet G 6539	TA1YTT81	T	800	97.4	122.3	16	55
	Timet G 7278	TA2YLTR1	L	RT	164.7	177.0	10	32
	Timet G 7278	TA2YTTR1	T	RT	178.0	188.5	11	33
	RMI 302634	RA7YLTR1	L	RT	155.6	172.0	7	16
.500 to .630	RMI 302634	RA7YTTR1	T	RT	157.2	172.4	7	14
≥ 1.00	Timet G 7021	TA2ZLTR1	L	RT	142.3	152.0	12	22
		TA2ZTTR1	T	RT	157.6	166.7	12	25
≥ 1.00	Timet G 7021	TA2ZSTR1	ST	RT	141.9	147.6	10	25

7.3.1 Tensile Tests

Ti 6Al-4V Cond. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
≥ 1.00	RMI 293504	RAZLTR1	L	RT	150.1	153.7	13	40
↕	↕	RA6ZLT41	L	400	104.6	116.4	18	54
		RA6ZLT61	L	600	91.0	104.7	17	57
		RA6ZLT81	L	800	84.2	97.0	17	57
		RA6ZTTR1	T	RT	145.2	151.2	13	37
		RA6ZTT41	T	400	107.0	118.6	17	49
		RA6ZTT61		600	93.2	105.8	15	53
		RA6ZTT81	T	800	85.7	99.4	16	50
		RA6ZSTR1	ST	RT	148.1	158.2	11	21
		RA6ZST41	ST	400	112.8	123.4	13	28
		RA6ZST61	ST	600	96.3	112.4	16	34
≥ 1.00	RMI 293504	RA6ZST81	ST	800	89.2	102.3	13	42

7.3.1.1 Tensile Stability Tests

Ti 6Al-4V Cond. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
.250 to .300	Timet G 4956	TA1XLTW41	L	400	10	RT	157.0	170.7	8	-
		TA1XLTW42	L	400	100	RT	157.0	170.6	6	-
		TA1XLTW43	L	400	1000	RT	156.7	171.0	8	-
		TA1XLTW61	L	600	10	RT	155.7	170.8	7	-
		TA1XLTW62	L	600	100	RT	157.7	170.9	6	-
		TA1XLTW63	L	600	1000	RT	158.0	171.6	8	-
		TA1XLTW81	L	800	10	RT	158.2	171.4	7	-
		TA1XLTW82	L	800	100	RT	159.8	172.2	8	-
		TA1XLTW83	L	800	1000	RT	161.0	174.5	7	-
		TA1XLTX41	L	400	10	400	115.6	137.0	9	-
		TA1XLTX42	L	400	100	400	118.2	136.8	10	-
		TA1XLTX43	L	400	1000	400	117.2	136.6	10	-
		TA1XLTX61	L	600	10	600	105.9	128.0	9*	-
		TA1XLTX62	L	600	100	600	104.4	127.2	8	-
		TA1XLTX63	L	600	1000	600	105.6	126.1	9	-
		TA1XLTX81	L	800	10	800	100.2	121.0	8	-
		TA1XLTX82	L	800	100	800	100.3	121.8	5*	-
.250 to .300	Timet G 4956	TA1XLTX83	L	800	1000	800	99.0	122.2	9	-

*Indicates broke through gage mark or within specimen width of guage marks.

7.3.1.1 Tensile Stability Tests

Ti 6Al-4V Cond. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
.500 to 630	Timet G 6539	TA1YLTW41	L	400	10	RT	164.7	175.5	12	25
↕	↕	TA1YLTW42	L	400	100	RT	160.5	177.4	11	31
		TA1YLTW43	L	400	1000	RT	162.1	174.1	13	30
		TA1YLTW61	L	600	10	RT	160.9	172.3	12	31
		TA1YLTW62	L	600	100	RT	160.5	172.6	12	32
		TA1YLTW63	L	600	1000	RT	167.0	177.6	12	38
		TA1YLTW81	L	800	10	RT	161.5	173.6	12	28
		TA1YLTW82	L	800	100	RT	162.6	172.5	12	30
.500 to .630	Timet G 6539	TA1YLTW83	L	800	1000	RT	163.1	175.9	13	33

Ti-6AL-4V COND. STA

7.3.1.2 Tensile Tests - Precision Elastic Modulus (Tuckerman)

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature	Precision "E" x 10^6
.250-.300	Timet G 4956	TA1XLTR1	L	RT	16.2

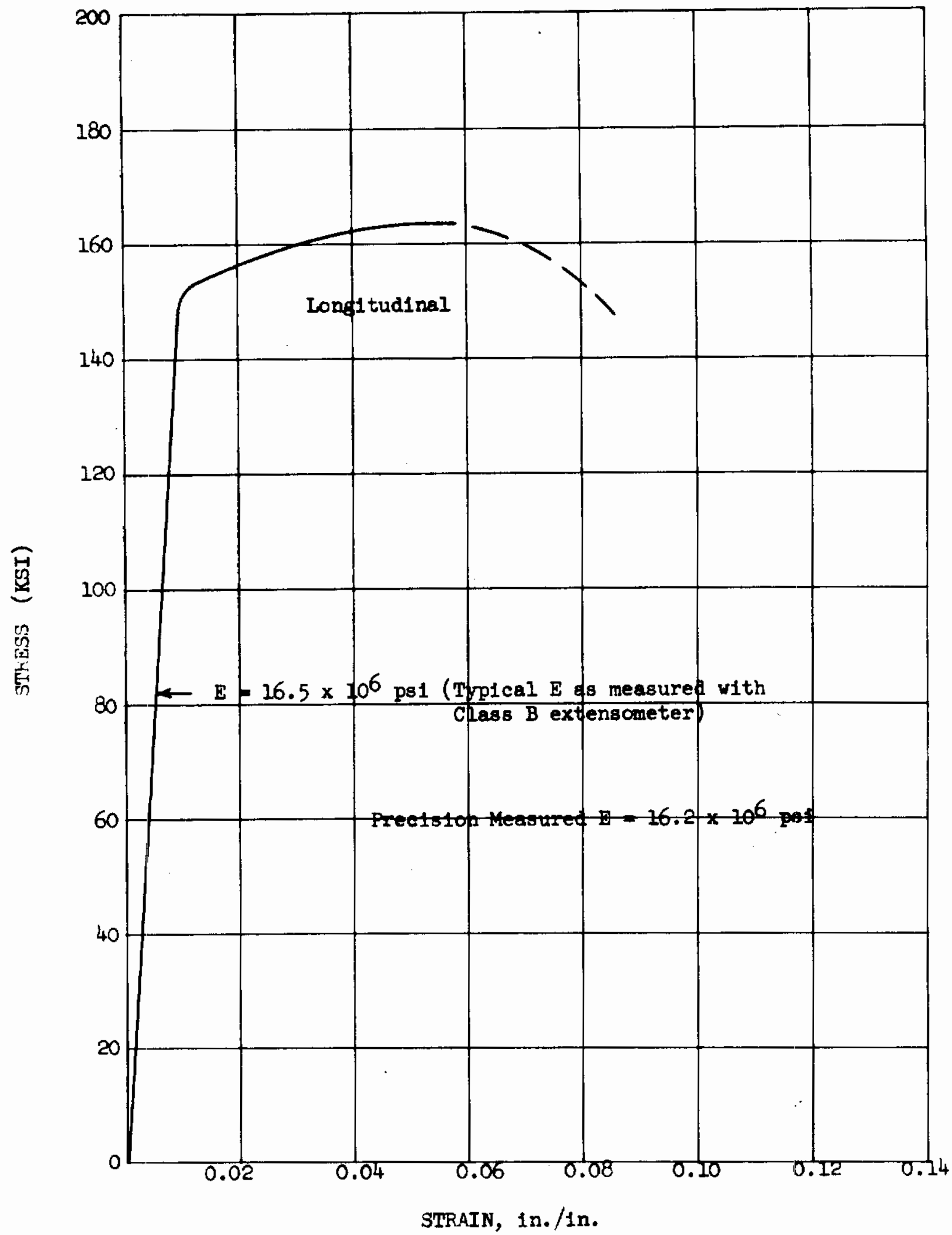


Figure 7-5 Typical tensile stress-strain curve (full-range) for solution treated and aged Ti-6Al-4V alloy sheet at room temperature.

7.3.2 Compression Tests

Ti 6Al-4V COND. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
.250 to .300	Timet G 4956	TA1XLCR1	L	RT	154.2
		TA1XLC41	L	400	118.7
		TA1XLC61	L	600	113.0
		TA1XLC81	L	800	99.8
		TA1XTCR1	T	RT	186.9
		TA1XTC41	T	400	150.2
		TA1XTC61	T	600	143.2
	Timet G 4956	TA1XTC81	T	800	132.0
	Timet G 4796	TA2XLCR1	L	RT	150.8
	Timet G 4796	TA2XLCR1	T	RT	187.2
	RMI X 53788	RA6XLCR1	L	RT	166.4
		RA6XLC41	L	400	117.3
		RA6XLC61	L	600	103.4
		RA6XLC81	L	800	102.7
		RA6XTCR1	T	RT	155.3
		RA6XTC41	T	400	115.8
		RA6XTC61	T	600	99.9
.250 to .300	RMI X 53788	RA6XTC81	T	800	93.1

7.3.2 Compression Tests

Ti 6Al-4V Cond. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
.500 to .630	Timet G 6539	TA1YLCR1	L	RT	173.5
↕	↕	TA1YLC41	L	400	127.7
↕	↕	TA1YLC61	L	600	114.6
↕	↕	TA1YLC81	L	800	102.0
↕	↕	TA1YTCR1	T	RT	165.7
↕	↕	TA1YTC41	T	400	125.4
↕	↕	TA1YTC61	T	600	108.4
↕	Timet G 6539	TA1YTC81	T	800	107.8
↕	Timet G 7278	TA2YLCR1	L	RT	177.2
↕	Timet G 7278	TA2YTCR1	T	RT	163.8
↕	RMI 302634	RA7YLCR1	L	RT	164.1
.500 to .630	RMI 302634	RA7YTCR1	T	RT	171.3
≥ 1.00	Timet G 7021	TA2ZLCR1	L	RT	156.0
↕	Timet G 7021	TA2ZTCR1	T	RT	157.6
≥ 1.00	Timet G 7021	TA2ZSCR1	ST	RT	148.7

7.3.2 Compression Tests

Ti 6Al-4V Cond. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≥ 1.00	RMI 293504	RA6ZLCR1	L	RT	157.5
↕	↕	RA6ZLC41	L	400	114.4
		^6ZLC61	L	600	96.4
		RA6ZLC81	L	800	95.4
		RA6ZTCR1	T	RT	159.7
		RA6ZTC41	T	400	117.1
		RA6ZTC61	T	600	101.5
		RA6ZTC81	T	800	98.7
		RA6ZSCR1	ST	RT	157.7
		RA6ZSC41	ST	400	112.0
		RA6ZSC61	ST	600	96.1
≥ 1.00	RMI 293504	RA6ZSC81	ST	800	89.1

Ti 6Al-4V Cond. STA

7.3.3 Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.250 to .300	Timet G 4956	TA1XLB1R1	L	1.5	RT	241.2	256.8
		TA1XLB141	L	1.5	400	197.6	214.1
		TA1XLB161	L	1.5	600	190.5	196.8
		TA1XLB181	L	1.5	800	176.7	185.6
		TA1XTB1R1	T	1.5	RT	237.5	278.1
		TA1XTB141	T	1.5	400	196.4	229.4
		TA1XTB161	T	1.5	600	183.9	213.0
		TA1XTB181	T	1.5	800	173.5	198.1
		TA1XLB2R1	L	2.0	RT	265.2	324.5
		TA1XLB241	L	2.0	400	219.2	251.9
		TA1XLB261	L	2.0	600	215.7	231.5
		TA1XLB281	L	2.0	800	206.4	234.8
		TA1XTB2R1	T	2.0	RT	289.3	344.0*
		TA1XTB241	T	2.0	400	240.3	263.7
		TA1XTB261	T	2.0	600	232.0	270.8
	Timet G 4956	TA1XTB281	T	2.0	800	211.5	257.4
.250 to .300	Timet G 4796	TA2XLB1R1	L	1.5	RT	199.7	242.6
	Timet G 4796	TA2XLB2R1	L	2.0	RT	225.6	294.9

*Pin broke – specimen retested

7.3.3 Bearing Tests

Ti 6Al-4V Cond. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.250 to .300	RMI X53788	RA6XLB1R1	L	1.5	RT	227.4	269.2
		RA6XLB141	L	1.5	400	179.0	216.8
		RA6XLB161	L	1.5	600	165.7	200.6
		RA6XLB181	L	1.5	800	155.8	186.2
		RA6XTB1R1	T	1.5	RT	228.3	259.4
		RA6XTB141	T	1.5	400	179.0	212.9
		RA6XTB161	T	1.5	600	165.6	198.7
		RA6XTB181	T	1.5	800	158.5	184.1
		RA6XLB2R1	L	2.0	RT	277.1	334.3
		RA6XLB241	L	2.0	400	208.9	274.9
		RA6XLB261	L	2.0	600	195.2	251.5
		RA6XLB281	L	2.0	800	194.6	243.2
		RA6XTB2R1	T	2.0	RT	269.3	317.6
		RA6XTB241	T	2.0	400	215.2	264.5
		RA6XTB261	T	2.0	600	189.0	238.7
.250 to .300	RMI X 53788	RA6XTB281	T	2.0	800	177.3	228.6
.500 to .630	Timet G 6539	TA1YLB1R1	L	1.5	RT	240.9	278.6
		TA1Y1B141	L	1.5	400	192.0	236.8
		TA1YLB161	L	1.5	600	175.0	214.0
		TA1YLB181	L	1.5	800	177.7	206.7
.500 to .630	Timet G 6539	TA1YTB1R1	T	1.5	RT	240.9	274.1

Ti 6Al-4V Cond. STA

7.3.3 Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.500 to .630	Timet G 6539	TA1YLB2R1	L	2.0	RT	293.2	351.0
		TA1YLB241	L	2.0	400	228.4	276.7
		TA1YLB261	L	2.0	600	209.7	266.0
		TA1YLB281	L	2.0	800	208.2	239.0
	Timet G 6539	TA1YTB2R1	T	2.0	RT	271.7	331.2
	Timet G 7278	TA2YLB1R1	L	1.5	RT	238.6	281.3
	Timet G 7278	TA24LB2R1	L	2.0	RT	276.0	336.4
	RMI 302634	RA7YLB1R1	L	1.5	RT	241.2	262.5
.500 to .630	RMI 302634	RA7YLB2R1	L	2.0	RT	275.1	330.1
≥ 1.00	Timet G 7021	TA2ZLB1R1	L	1.5	RT	212.2	247.8
	Timet G 7021	TA2ZLB2R1	L	2.0	RT	247.0	306.7
	RMI 293504	RA6ZLB1R1	L	1.5	RT	219.5	253.9
		RA6ZLB141	L	1.5	400	168.8	209.6
		RA6ZLB161	L	1.5	600	156.8	189.7
		RA6ZLB181	L	1.5	800	150.4	177.9
		RA6ZTB1R1	T	1.5	RT	217.8	267.3
		RA6ZLEB1R1	LE	1.5	RT	214.0	233.8
≥ 1.00	RMI 293504	RA6ZTEB1R1	TE	1.5	RT	207.7	224.0

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7.3.3 Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (°F)	F_{bry} (Ksi) (2% Offset)	F_{bru} (Ksi)
≥ 1.00	RMI 293504	RA6ZLB2R1	L	2.0	RT	255.1	324.6
↕	↕	RA6ZLB241	L	2.0	400	213.4	258.6
		RA6ZLB261	L	2.0	600	179.9	234.0
		RA6ZLB281	L	2.0	800	166.2	219.5
		RA6ZTB2R1	T	2.0	RT	264.2	334.3
		RA6ZLEB2R1	LE	2.0	RT	265.8	310.8
≥ 1.00	RMI 293504	RA6ZTEB2R1	TE	2.0	RT	257.3	299.4

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7.3.4 Shear Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{su} (Ksi)
.250 to .300	Timet G 4956	TA1XLSR1	L	RT	101.0
		TA1XLS41	L	400	86.0
		TA1XLS61	L	600	74.8
		TA1XLS81	L	800	64.1
		TA1XTSR1	T	RT	113.0
		TA1XTS41	T	400	89.7
		TA1XTS61	T	600	85.3
	Timet G 4956	TA1XTS81	T	800	79.2
	Timet G 4796	TA2XLSR1	L	RT	93.2
	RMI X53788	RA6XLSR1	L	RT	102.0
		RA6XLS41	L	400	87.3
		RA6XLS61	L	600	71.6
		RA6XLS81	L	800	73.2
		RA6XTSR1	T	RT	47.7
		RA6XTS41	T	400	84.0
		RA6XTS61	T	600	76.8
.250 to .300	RMI X53788	RA6XTS81	T	800	72.0
.500 to .630	Timet G 6539	TA1YLSR1	L	RT	96.3
		TA1YLS41	L	400	88.3
		TA1YLS61	L	600	74.7
		TA1YLS81	L	800	77.4
.500 to .630	Timet G 6539	TA1YTSR1	T	RT	98.3

7.3.4 Shear Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{su} (Ksi)
.500 to .630	Timet G 7278	TA2YLSR1	L	RT	106.0
.500 to .630	RMI 302634	TA7YLSRI	L	RT	108.0
≥ 1.00	Timet G 7021	TA2ZLSR1	L	RT	88.3
	RMI 293504	RA6ZLSR1	L	RT	102.0
		RA6ZLS41	L	400	77.6
		RA6ZLS61	L	600	70.0
		RA6ZLS81	L	800	73.5
≥ 1.00	RMI 293504	RA6ZTSR1	T	RT	102.0

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7.3.5 Fracture Toughness Tests

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temp. (°F)	Exposure Time (Hrs.)	Test Temp.	Load Pop-in (lbs)	a Crack Depth	K F actor	K_{Ic} Ksi$\sqrt{in}$	Net Fracture Strength, σ_n	Load at Failure (lbs)
.250 - .300	Timet G 4956	TA1XLFR1	L	-	-	RT	6400	.800	6.96	44.5	31.7	7530
↕	↕	TA1XLFW41	L	400	10	RT	6850	.760	6.48	44.4	44.4	8330
		TA1XLFW42	L	400	100	RT	5480	.600	4.79	26.2	17.5	5680
		TA1XLFW43	L	400	1000	RT	6400	.790	6.84	43.7	35.4	7520
		TA1XLFW61	L	600	10	RT	6500	.790	6.84	46.5	37.1	7420
		TA1XLFW62	L	600	100	RT	6500	.800	6.96	45.7	35.6	7570
		TA1XLFW63	L	600	1000	RT	5500	.820	7.20	39.6	38.2	7160
		TA1XLFW81	L	800	10	RT	4500	.820	7.20	32.4	45.5	7980
		TA1XLFW82	L	800	100	RT	5600	.800	6.96	39.0	34.2	6840
		TA1XLFW83	L	800	1000	RT	4950	.880	7.96	39.4	26.6	5730
	Timet G 4956	TA1XTFR1	T	-	-	RT	5000	.740	8.32	40.0	44.3	8160
	Timet G 4796	TA2XLFR1	L	-	-	RT	7200	.700	7.416	53.4	38.8	8030
	RMI X53788	RA6XLFR1	L	-	-	RT	10200	.760	6.48	66.0	48.5	10960
.250-.300	RMI X53788	RA6XTFR1	T	-	-	RT	9300	.770	6.604	61.5	47.1	11780

7.3.6 Fatigue Tests

F_{tu} = 153.7

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	RMI 293504	RA6ZLVR19	L	1.0	-1.0	120,000	78	13,000
		RA6ZLVR20	L	1.0	-1.0	100,000	65	81,000
		RA6ZLVR21	L	1.0	-1.0	90,000	59	72,000
		RA6ZLVR22	L	1.0	-1.0	80,000	52	608,000
		RA6ZLVR23	L	1.0	-1.0	65,000	42	5,768,000
		RA6ZLVR24	L	1.0	-1.0	62,000	40	10,000,000 →
		RA6ZLVR13	L	1.0	-0.3	130,000	84	20,000
		RA6ZLVR14	L	1.0	-0.3	110,000	73	16,000
		RA6ZLVR15	L	1.0	-0.3	90,000	58	2,716,000
		RA6ZLVR16	L	1.0	-0.3	100,000	65	955,000
		RA6ZLVR17	L	1.0	-0.3	85,000	55	1,699,000
		RA6ZLVR18	L	1.0	-0.3	78,000	54	1,362,000
		RA6ZLVR 7	L	1.0	0	130,000	84	343,000
		RA6ZLVR 8	L	1.0	0	145,000	94	8,000
		RA6Z1VR 9	L	1.0	0	125,000	81	198,000
		RA6ZLVR10	L	1.0	0	118,000	77	362,000
		RA6ZLVR11	L	1.0	0	110,000	73	522,000
≥ 1.00	RMI 293504	RA6ZLVR12	L	1.0	0	95,000	62	1,429,000

→ No Failure

Ti 6Al-4V **Cond.** STA

7.3.6 Fatigue Tests

F_{tu} = 153.7

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥1.00	RMI 293504	RA6ZLVR-1	L	1.0	+ 0.3	120.0	78	459,000
		RA6ZLVR-2	L	1.0	+ 0.3	130.0	85	487,000
		RA6ZLVR-3	L	1.0	+ 0.3	110.0	73	1,101,000
		RA6ZLVR-4	L	1.0	+ 0.3	140.0	91	205,000
		RA6ZLVR-5	L	1.0	+ 0.3	100.0	65	2,237,000
		RA6ZLVR-6	L	1.0	+ 0.3	90.0	59	4,186,000
		RA6ZLVR-6A	L	1.0	+ 0.3	80.0	52	9,274,000
		RA6ZLVR-43	L	3.0	- 1.0	60.0	39	10,000
		RA6ZLVR-44	L	3.0	- 1.0	45.0	29	40,000
		RA6ZLVR-45	L	3.0	- 1.0	30.0	19	210,000
		RA6ZLVR-46	L	3.0	- 1.0	15.0	10	15,700,000 →
		RA6ZLVR-47	L	3.0	- 1.0	24.0	16	838,000
		RA6ZLVR-48	L	3.0	- 1.0	37.5	24	53,000
		RA6ZLVR-37	L	3.0	- 0.3	60.0	39	15,000
		RA6ZLVR-38	L	3.0	- 0.3	37.5	24	10,000,000 →
		RA6ZLVR-39	L	3.0	- 0.3	52.5	34	20,000
		RA6ZLVR-40	L	3.0	- 0.3	45.0	29	39,000
		RA6ZLVR-41	L	3.0	- 0.3	42.0	27	37,000
≥1.00	RMI 293504	RA6ZLVR-42	L	3.0	- 0.3	39.0	25	146,000

→ No Failure

Ti 6Al-4V Cond. STA

7.3.6 Fatigue Tests

F_{tu} = 153.7

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	RMI 293504	RA6ZLVR25	L	3.0	0	60.0	39	77,000
		RA6ZLVR26	L	3.0	0	75.0	49	27,000
		RA6ZLVR27	L	3.0	0	90.0	58	10,000
		RA6ZLVR28	L	3.0	0	45.0	29	102,000
		RA6ZLVR29	L	3.0	0	35.0	23	2,074,000
		RA6ZLVR30	L	3.0	0	30.0	19	4,407,000
		RA6ZLVR31	L	3.0	+ 0.3	45.0	29	1,109,000
		RA6ZLVR32	L	3.0	+ 0.3	90.0	58	18,000
		RA6ZLVR33	L	3.0	+ 0.3	75.0	49	32,000
		RA6ZLVR34	L	3.0	+ 0.3	60.0	39	74,000
		RA6ZLVR35	L	3.0	+ 0.3	39.0	25	9,800,000→
≥ 1.00	RMI 293504	RA6ZLVR36	L	3.0	+ 0.3	52.5	34	377,000

→ No Failure

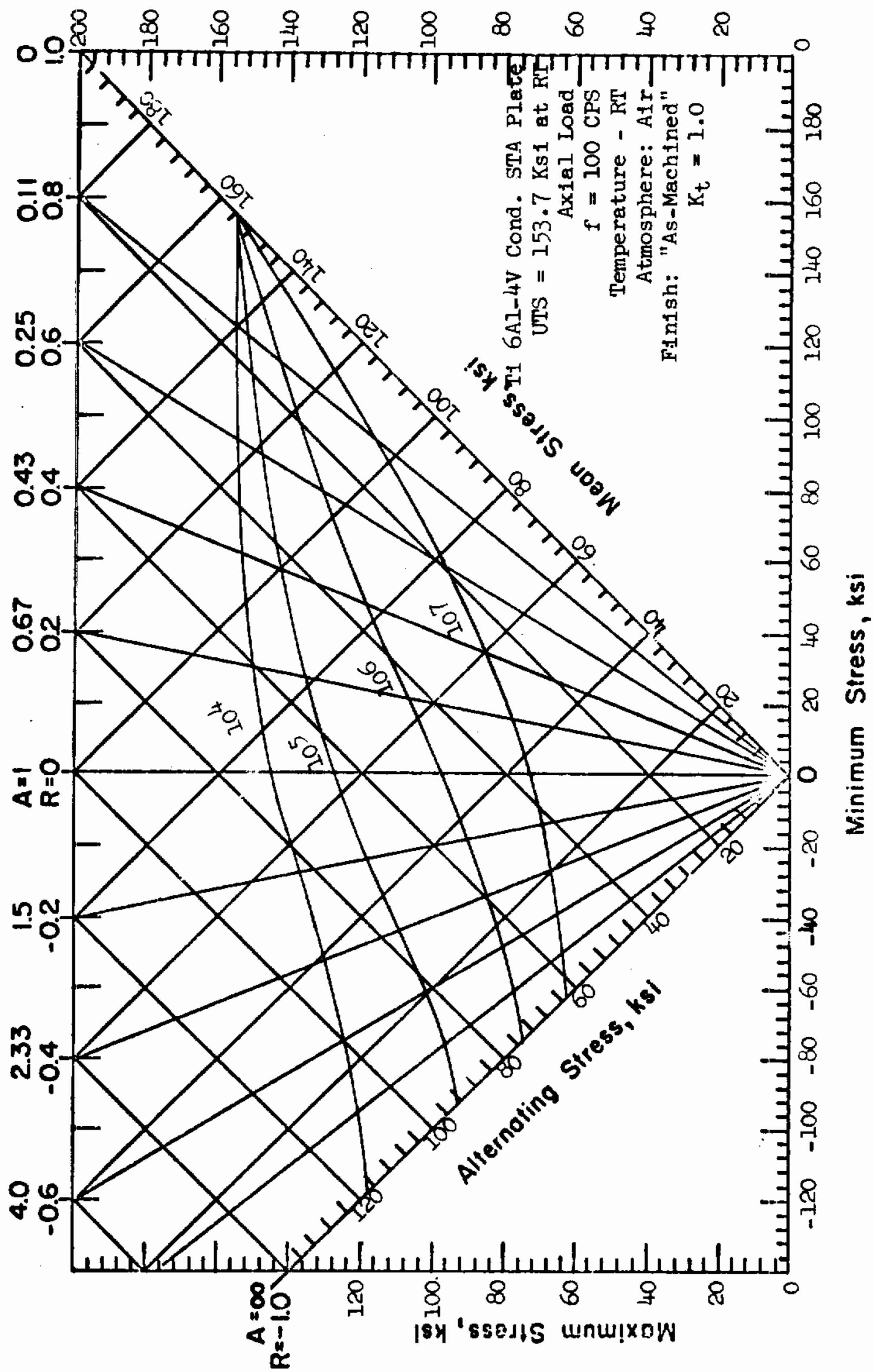

Ti 6Al-4V Cond. STA Plate
UTS = 153.7 Ksi at RT
Axial Load
f = 100 CPS
Temperature - RT
Atmosphere: Air
Finish: "As-Machined"
$K_t = 1.0$
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=1
R=0
A=∞
R=-1.0
10^4
10^5
10^6
10^7

Figure 7-6

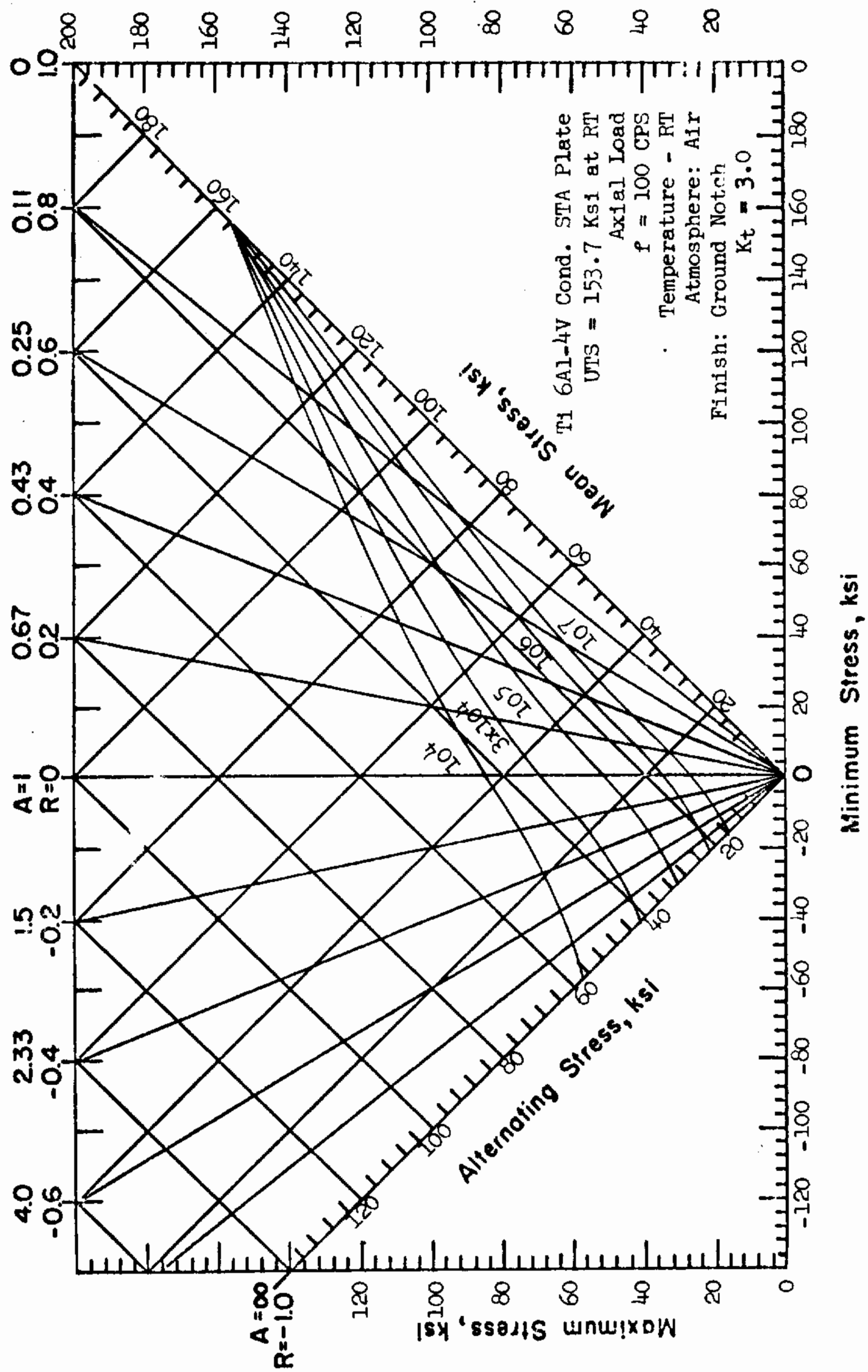

Ti 6Al-4V Cond. STA Plate
UTS = 153.7 Ksi at RT
Axial Load
f = 100 CPS
Temperature - RT
Atmosphere: Air
Finish: Ground Notch
K_t = 3.0
Mean Stress, ksi
Alternating Stress, ksi
Maximum Stress, ksi
Minimum Stress, ksi
A=1
R=0
A=∞
R=-1.0
10^4
$3x10^4$
10^5
10^6
10^7

Figure 7-7

7.4 Ti-6Al-6V-2Sn

7.4.1 Ti-6Al-6V-2Sn Cond. A

7.4.1 Annealed

7.4.1.1 Tensile Test

Ti-6Al-6V-2Sn **Cond. A**

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
.250 to .300	Timet G3105	TV1XLTR1	L	RT	157.3	159.1	9.0	-
		TV1XLT41	L	400	118.9	131.0	12.5	-
		TV1XLT61	L	600	107.9	122.2	10.0	-
		TV1XLT81	I	800	97.3	109.9	13.0	-
		TV1XTTR1	T	RT	171.0	176.9	16.5	-
		TV1XTT41	T	400	134.6	150.7	12.0	-
		TV1XTT61	T	600	131.7	145.4	9.0	-
	Timet G3105	TV1XTT81	T	800	116.0	127.0	14.0	-
	Timet G3212	TV2XLTR1	L	RT	162.1	164.6	8.5	-
		TV2XLT41	L	400	123.4	134.7	12.5	-
		TV2XLT61	L	600	109.6	126.3	11.0	-
		TV2XLT81	L	800	99.8	111.6	13.0	-
	Timet G3212	TV2XTTR1	T	RT	164.2	167.2	12.0	-
	Timet G3211	TV3XLTR1	L	RT	159.0	161.4	13.0	-
		TV3XLT41	L	400	126.4	139.0	11.0	-
		TV3XLT61	L	600	112.0	127.3	13.5	-
		TV3XLT81	L	800	102.9	116.3	11.0	-
.250 to .300	Timet G3211	TV3XTTR1	T	RT	164.5	167.1	16.0	-

7.4.1.1 Annealed - Tensile Tests Ti-6Al-6V-2Sn **Cond. A**

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
.250 to .300	Timet G 881	TV4XLTR1	L	RT	158.3	161.1	11.0	-
		TV4XLT41	L	400	124.8	136.8	12.0	-
		TV4XLT61	L	600	108.4	124.1	11.0	-
		TV4XLT81	L	800	99.5	112.0	13.0	-
	Timet G 881	TV4XTTR1	T	RT	164.3	169.5	15.0	-
	Timet G 1537	TV5XLTR1	L	RT	158.6	160.5	12.0	-
		TV5XLT41	L	400	127.1	139.5	10.0	-
		TV5XLT61	L	600	114.7	130.2	10.5	-
		TV5XLT81	L	800	107.2	121.2	13.0	-
.250 to .300	Timet G 1537	TV5XTTR1	T	RT	169.0	175.1	15.0	-
.500 to .630	Timet G 393	TV1YLTR1	L	RT	154.1	156.4	17.5	40.1
		TV1YLT41	L	400	123.9	136.0	18.5	50.6
		TV1YLT61	L	600	112.4	127.9	17.0	50.9
		TV1YLT81	L	800	102.5	115.1	20.5	56.9
		TV1YTTR1	T	RT	153.8	159.9	17.5	34.4
		TV1YTT41	T	400	123.5	136.8	18.0	43.1
		TV1YTT61	T	600	111.3	127.5	18.5	40.7
.500 to .630	Timet G 393	TV1YTT81	T	800	103.1	117.1	19.0	47.5

7.4.1.1 Annealed Tensile Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
.500 to .630	Timet G 2443	TV2YLTR1	L	RT	157.2	158.6	17.5	40.4
	Timet G 2443	TV2YTTR1	T	RT	159.0	161.6	17.0	32.9
	Timet G 1971	TV3YLTR1	L	RT	159.2	162.2	16.5	34.9
	Timet G 1971	TV3YTTR1	T	RT	160.4	162.6	16.0	33.1
	Timet G 2504	TV4YLTR1	L	RT	161.8	165.1	17.5	35.7
	Timet G 2504	TV4YTTR1	T	RT	163.7	166.9	16.5	37.4
	Timet G 3106	TV5YLTR1	L	RT	159.2	161.9	17.0	35.4
.500 to .630	Timet G 3106	TV5YTTR1	T	RT	164.3	166.7	17.5	37.4
≥ 1.00	Timet G 3023	TV1ZLTR1	L	RT	149.0	158.0	17.0	31.6
		TV1ZLT41	L	400	117.0	132.8	18.5	49.2
		TV1ZLT61	L	600	100.8	118.6	19.0	45.8
		TV1ZLT81	L	800	86.6	105.7	19.0	54.7
		TV1ZTTR1	T	RT	149.0	158.0	17.0	31.6
		TV1ZTT41	T	400	109.3	126.3	19.0	45.7
		TV1ZTT61	T	600	96.5	114.7	19.0	41.2
		TV1ZTT81	T	800	86.9	104.3	21.0	49.2
		TV1ZSTR1	ST	RT	138.2	156.7	10.0	27.8
		TV1ZST41	ST	400	111.6	132.1	15.0	27.0
		TV1ZST61	ST	600	93.6	117.9	15.0	41.9
≥ 1.00	Timet G 3023	TV1ZST81	ST	800	84.5	107.9	20.0	41.6

Ti 6Al-6V-2Sn Cond. A

7.4.1.1 Annealed Tensile Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	% Elongation	% Reduction Area
≥ 1.00	Timet G 3214	TV2ZLTR1	L	RT	151.6	158.8	17.5	31.7
		TV2ZTTR1	T	RT	153.4	156.2	17.0	36.8
	Timet G 3214	TV2ZSTR1	ST	RT	145.7	157.8	2.5 (*)	11.5
	Timet G 2070	TV3ZLTR1	L	RT	147.4	152.0	16.0	36.8
		TV3ZTTR1	T	RT	155.1	160.1	14.5	24.9
	Timet G 2070	TV3ZSTR1	ST	RT	143.6	152.9	7.5	34.0
	Timet G 1971	TV4ZLTR1	L	RT	147.2	151.8	20.0	29.1
		TV4ZTTR1	T	RT	151.0	154.3	14.0	32.6
	Timet G 1971	TV4ZSTR1	ST	RT	144.8	154.8	15.0	35.6
	Timet G 3024	TV5ZLTR1	L	RT	147.2	152.6	16.0	32.3
		TV5ZTTR1	T	RT	149.8	154.0	18.0	35.4
≥ 1.00	Timet G 3024	TV5ZSTR1	ST	RT	143.2	151.8	2.5	0.97

(*) Failed in Gage Mark

Ti-6Al-6V-2Sn Cond. A

7.4.1.1.1 Annealed Tensile Stability Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
.250 to .300	Timet G 3105	TV1XLTW41	L	400	10	RT	157	160	11	—
↑	↑	TV1XLTW42	L	400	100	RT	158	162	6*	—
		TV1XLTW43	L	400	1000	RT	154	158	11	—
		TV1XLTW61	L	600	10	RT	153	157	13	—
		TV1XLTW62	L	600	100	RT	153	157	12	—
		TV1XLTW63	L	600	1000	RT	155	158	11	—
		TV1XLTW81	L	800	10	RT	153	156	12	—
		TV1XLTW82	L	800	100	RT	154	158	11	—
		TV1XLTW83	L	800	1000	RT	162	163	5**	—
		TV1XLTX41	L	400	10	400	123.8	133.3	14	—
		TV1XLTX42	L	400	100	400	121.3	131.4	13	—
		TV1XLTX43	L	400	1000	400	120.3	131.4	12*	—
		TV1XLTX61	L	600	10	600	107.6	122.4	11	—
		TV1XLTX62	L	600	100	600	108.3	122.9	12	—
		TV1XLTX63	L	600	1000	600	107.9	122.8	11*	—
		TV1XLTX81	L	800	10	800	95.1	108.1	16	—
↓	↓	TV1XLTX82	L	800	100	800	99.4	113.9	13	—
.250 to .300	Timet G 3105	TV1XLTX83	L	800	1000	800	105.9	120.3	11	—

* Broke through gage mark.

** Retested after pin hole failure w/reduced width.

7.4.1.1.1 Annealed Tensile Stability

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
.500 to 630	Timet G 393	TV1YLTW41	L	400	10	RT	144	150	17	40
↕	↕	TV1YLTW42	L	400	100	RT	156	160	17	37
		TV1YLTW43	L	400	1000	RT	152	157	17	40
		TV1YLTW61	L	600	10	RT	154	158	18	41
		TV1YLTW62	L	600	100	RT	154	158	17	37
		TV1YLTW63	L	600	1000	RT	154	158	18	40
		TV1YLTW81	L	800	10	RT	157	162	17	39
		TV1YLTW82	L	800	100	RT	158	165	16	33
.500 to .630	Timet G 393	TV1YLTW83	L	800	1000	RT	162	165	11	17
≥ 1.00	Timet G 3023	TV1ZLTW41	L	400	10	RT	145	152	18	34
↕	↕	TV1ZLTW42	L	400	100	RT	146	152	17	33
		TV1ZLTW43	L	400	1000	RT	145	151	16	32
		TV1ZLTW61	L	600	10	RT	147	153	17	31
		TV1ZLTW62	L	600	100	RT	145	151	17	33
		TV1ZLTW63	L	600	1000	RT	147	154	16	29
		TV1ZLTW81	L	800	10	RT	148	154	16	28
		TV1ZLTW82	L	800	100	RT	149	156	15	27
≥ 1.00	Timet G 3023	TV1ZLTW83	L	800	1000	RT	152	156	8	14

Ti-6AL-6V-2Sn COND A

7.4.1.1.2 Tensile Tests - Precision Elastic Modulus (Tuckerman)

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature	Precision "E" x 10^6
.250-.300	Timet G 3105	TV1XLTR1	L	RT	15.6

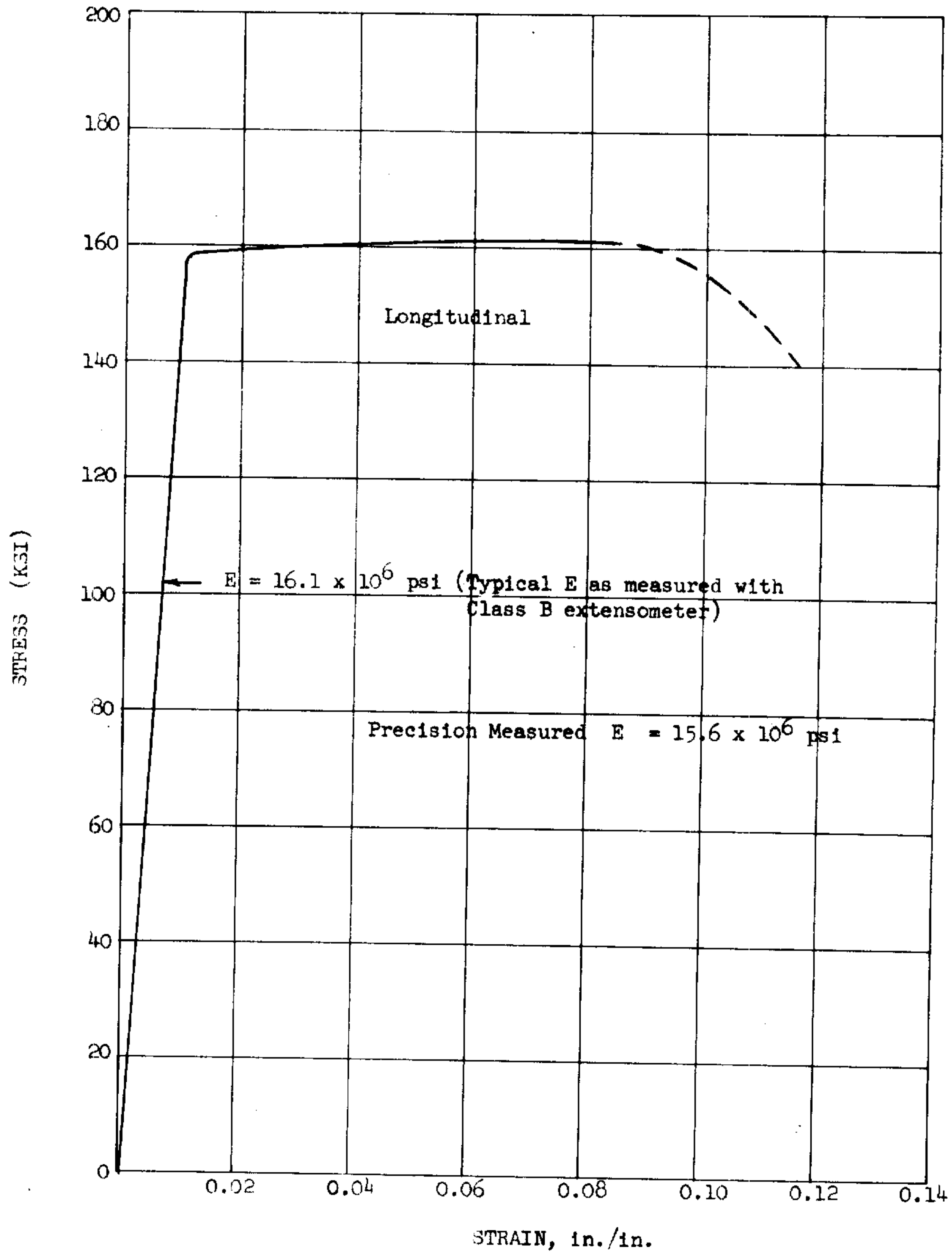


Figure 7-8 Typical Tensile Stress-Strain Curve (full-range) for Annealed Ti-6Al-6V-2Sn Alloy Plate at Room Temperature.

7.4.1.2 Annealed Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
.250 to .300	Timet G 3105	TV1XLCR1	L	RT	157.1
		TV1XLC41	L	400	120.9
		TV1XLC61	L	600	105.3
		TV1XLC81	L	800	97.2
		TV1XTCR1	T	RT	195.3
		TV1XTC41	T	400	149.7
		TV1XTC61	T	600	135.2
	Timet G 3105	TV1XTC81	T	800	129.2
	Timet G 3212	TV2XLCR1	L	RT	163.5
	Timet G 3212	TV2XTCR1	T	RT	177.5
	Timet G 3211	TV3XLCR1	L	RT	163.8
	Timet G 3211	TV3XTCR1	T	RT	179.9
	Timet G 881	TV4XLCR1	L	RT	163.9
	Timet G 881	TV4XTCR1	T	RT	183.4
	Timet G 1537	TV5XLCR1	L	RT	164.9
.250 to .300	Timet G 1537	TV5XTCR1	T	RT	185.4

Ti-6Al-6V-2Sn Cond. A

7.4.1.2 Annealed Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{cy} (Ksi)
.500 to .630	Timet G 393	TV1YLCR1	L	RT	167.4
↕	Timet G 393	TV1YLC41	L	400	125.1
	Timet G 393	TV14LC61	L	600	118.2
	Timet G 393	TV1YLC81	L	800	106.1
	Timet G 393	TV1YTCR1	T	RT	167.2
	Timet G 393	TV1YTC41	T	400	127.9
	Timet G 393	TV1YTC61	T	600	117.7
	Timet G 393	TV1YTC81	T	800	105.3
	Timet G 2443	TV2YLCR1	L	RT	170.4
	Timet G 2443	TV2YTCR1	T	RT	173.7
	Timet G 1971	TV3YLCR1	L	RT	171.0
	Timet G 1971	TV3YTCR1	T	RT	174.3
	Timet G 2504	TV4YLCR1	L	RT	172.3
	Timet G 2504	TV4YTCR1	T	RT	180.2
	Timet G 3106	TV5YLCR1	L	RT	172.0
.500 to .630	Timet G 3106	TV5YTCR1	T	RT	170.8

7.4.1.2 Annealed Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≥ 1.00	Timet G 3023	TV1ZLCR1	L	RT	148.9
	Timet G 3023	TV1ZLC41	L	400	120.2
	Timet G 3023	TV1ZLC61	L	600	105.5
	Timet G 3023	TV1ZLC81	L	800	96.7
	Timet G 3023	TV1ZTCR1	T	RT	150.5
	Timet G 3023	TV1ZTC41	T	400	115.3
	Timet G 3023	TV1ZTC61	T	600	103.4
	Timet G 3023	TV1ZTC81	T	800	93.4
	Timet G 3023	TV1ZSCR1	ST	RT	153.0
	Timet G 3023	TV1ZSC41	ST	400	116.2
	Timet G 3023	TV1ZSC61	ST	600	99.4
	Timet G 3023	TV1ZSC81	ST	800	90.9
	Timet G 3214	TV2ZLCR1	L	RT	162.4
	Timet G 3214	TV2ZTCR1	T	RT	167.1
	Timet G 3214	TV2ZSCR1	ST	RT	156.7
	Timet G 2070	TV3ZLCR1	L	RT	162.4
	Timet G 2070	TV3ZTCR1	T	RT	157.5
≥ 1.00	Timet G 2070	TV3ZSCR1	ST	RT	156.3

Ti-6Al-6V-6Sn Cond. A

7.4.1.2 Annealed Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{su} (Ksi)
≥1.00	Timet G 1971	TV4ZLCRL	L	RT	168.2
↕	↕	TV4ZTCRL	T	TR	155.4
	Timet G 1971	TV4ZSCR1	ST	RT	157.7
	Timet G 3024	TV5ZLCR1	L	RT	166.3
	↕	TV5ZTCR1	T	RT	157.0
≥1.00	Timet G 3024	TV5ZSCR1	ST	RT	144.5

7.4.1.3 Annealed Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.250 to .300	Timet G 3105	TV1XLB1R1	L	1.5	RT	224.0	252.5
	Timet G 3105	TV1XLB141	L	1.5	400	186.4	213.2
	Timet G 3105	TV1XLB161	L	1.5	600	169.3	187.3
	Timet G 3105	TV1XLB181	L	1.5	800	148.0	180.0
	Timet G 3105	TV1XTB1R1	T	1.5	RT	212.2	274.6
	Timet G 3105	TV1XTB141	T	1.5	400	184.1	231.3
	Timet G 3105	TV1XTB161	T	1.5	600	177.4	218.7
	Timet G 3105	TV1XTB181	T	1.5	800	150.0	193.3
	Timet G 3105	TV1XLB2R1	L	2.0	RT	247.1	314.1
	Timet G 3105	TV1XLB241	L	2.0	400	217.6	276.9
	Timet G 3105	TV1XLB261	L	2.0	600	202.8	237.2
	Timet G 3105	TV1XLB281	L	2.0	800	168.4	232.6
	Timet G 3105	TV1XTB2R1	T	2.0	RT	286.1	354.3
	Timet G 3105	TV1XTB241	T	2.0	400	238.3	297.1
	Timet G 3105	TV1XTB261	T	2.0	600	215.4	267.3
	Timet G 3105	TV1XTB281	T	2.0	800	198.5	253.8
	Timet G 3212	TV2XLB1R1	L	1.5	RT	228.0	273.7
	Timet G 3212	TV2XLB2R1	L	2.0	RT	249.2	329.6
	Timet G 3211	TV3XLB1R1	L	1.5	RT	222.2	266.0
.250 to .300	Timet G 3211	TV3XLB2R1	L	2.0	RT	244.7	331.6

Ti-6Al-6V-2Sn Cond. A

7.4.1.3 Annealed Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.250 to .300	Timet G 881	TV4XLB1R1	L	1.5	RT	221.7	250.0
	Timet G 881	TV3XLB2R1	L	2.0	RT	255.7	323.9
	Timet G 1537	TV5XLB1R1	L	1.5	RT	226.4	266.8
.250 to .300	Timet G 1537	TV5XLB2R1	L	2.0	RT	267.3	354.7
.500 to .630	Timet G 393	TV1YLB1R1	L	1.5	RT	221.6	267.8
	Timet G 393	TV1YLB141	L	1.5	400	193.7	238.1
	Timet G 393	TV1YLB161	L	1.5	600	176.9	212.3
	Timet G 393	TV1YLB181	L	1.5	800	160.0	200.4
	Timet G 393	TV1YTB1R1	T	1.5	RT	222.5	264.4
	Timet G 393	TV1YLB2R1	L	2.0	RT	259.1	330.1
	Timet G 393	TV1YLB241	L	2.0	400	229.6	288.1
	Timet G 393	TV1YLB261	L	2.0	600	202.9	255.5
	Timet G 393	TV1YLB281	L	2.0	800	176.4	235.0
	Timet G 393	TV1YTB2R1	T	2.0	RT	307.1	392.9
	Timet G 2443	TV2YLB1R1	L	1.5	RT	230.4	277.9
	Timet G 2443	TV2YLB2R1	L	2.0	RT	252.2	318.9
	Timet G 1971	TV3YLB1R1	L	1.5	RT	234.3	274.5
.500 to .630	Timet G 1971	TV3YLB2R1	L	2.0	RT	296.2	376.2

Ti-6Al-6V-2Sn Cond. A

7.4.1.3 Annealed Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.500 to .630	Timet G 2504	TV4YLB1R1	L	1.5	RT	235.1	276.2
	Timet G 2504	TV4YLB2R1	L	2.0	RT	284.0	356.0
	Timet G 3106	TV3YLB1R1	L	1.5	RT	229.7	281.1
.500 to .630	Timet G 3106	TV5YLB2R1	L	2.0	RT	266.4	342.1
≥ 1.00	Timet G 3023	TV1ZLB1R1	L	1.5	RT	224.9	265.4
	Timet G 3023	TV1ZLB141	L	1.5	400	182.1	225.0
	Timet G 3023	TV1ZLB161	L	1.5	600	163.2	202.5
	Timet G 3023	TV1ZLB181	L	1.5	800	154.3	185.9
	Timet G 3023	TV1ZTB1R1	T	1.5	RT	217.3	256.4
	Timet G 3023	TV1ZLEB1R1	LE	1.5	RT	215.6	244.9
	Timet G 3023	TV1ZTEB1R1	TE	1.5	RT	200.6	212.9
	Timet G 3023	TV1ZLB2R1	L	2.0	RT	277.5	340.0
	Timet G 3023	TV1ZLB241	L	2.0	400	209.1	280.1
	Timet G 3023	TV1ZLB261	L	2.0	600	199.5	252.0
	Timet G 3023	TV1ZLB281	L	2.0	800	178.0	231.8
	Timet G 3023	TV1ZTB2R1	T	2.0	RT	253.4	327.4
	Timet G 3023	TV1ZLEB2R1	LE	2.0	RT	267.7	317.4
≥ 1.00	Timet G 3023	TV1ZTEB2R1	TE	2.0	RT	256.4	294.5

Ti-6Al-6V-2Sn Cond. A

7.4.1.3 Annealed Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
≥ 1.00	Timet G 3214	TV2ZLB1R1	L	1.5	RT	211.8	263.9
	Timet G 3214	TV2ZLB2R1	L	2.0	RT	275.0	(1)
	Timet G 2070	TV3ZLB1R1	L	1.5	RT	220.0	265.5
	Timet G 2070	TV3ZLB2R1	L	2.0	RT	264.1	338.0
	Timet G 1471	TV4ZLB1R1	L	1.5	RT	214.8	259.0
	Timet G 1471	TV4ZLB2R1	L	2.0	RT	247.7	320.7
≥ 1.00	Timet G 3023	TV5ZLB1R1	L	1.5	RT	220.7	266.7
	Timet G 3024	TV5ZLB2R1	L	2.0	RT	255.5	350.8

(1) Pin Failure

Ti-6Al-6V-2Sn **Cond. A**

7.4.1.4 Annealed Shear Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{su} (Ksi)
.250 to .300	Timet G 3105	TV1XLSR1	L	RT	95.5
		TV1XLs41	L	400	80.0
		TV1XLS61	L	600	72.5
		TV1XLS81	L	800	68.8
		TV1XTSR1	T	RT	108.7
		TV1XTS41	T	400	92.3
		TV1XTS61	T	600	85.7
	Timet G 3105	TV1XTS81	T	800	80.7
	Timet G 3212	TV2XLSR1	L	RT	100.0
	Timet G 3211	TV3XLSR1	L	RT	102.4
	Timet G 881	TV4XL3R1	L	RT	101.1
.250 to .300	Timet G 1537	TV3XLSR1	L	RT	98.8
.500 to .630	Timet G 393	TV1YLSR1	L	RT	105.7
		TV1YLS41	L	400	92.5
		TV1YLS61	L	600	74.8
		TV1YLS81	L	800	78.5
	Timet G 393	TV1YTSR1	T	RT	
	Timet G 2443	TV2YLSR1	L	RT	110.7
	Timet G 1471	TV3YLSR1	L	RT	100.7
	Timet G 2504	TV4YLSR1	L	RT	113.0
.500 to .630	Timet G 3106	TV5YLSR1	L	RT	99.8

Ti-6Al-6V-2Sn Cond. A

7.4.1.4 Annealed Shear Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	F_{su} (Ksi)
≥ 1.00	Timet G 3023	TV1ZLSR1	L	RT	104.2
		TV1ZLS41	L	400	86.3
		TV1ZLS61	L	600	77.8
		TV1ZLS81	L	800	72.9
	Timet G 3023	TV1ZTSR1	T	RT	
	Timet G 3214	TV2XLSR1	L	RT	100.6
	Timet G 2070	TV3ZLSR1	L	RT	102.3
	Timet G 1971	TV4ZLSR1	L	RT	102.7
≥ 1.00	Timet G 3024	TV5ZLSR1	L	RT	100.0

Ti-6Al-6V-2Sn Cond. A

7.4.1.5 Fracture Toughness Tests

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temp. (°F)	Exposure Time (Hrs.)	Test Temp.	Load Pop-in (lbs)	a Crack Depth	K Factor	K_{Ic} Ksi $\sqrt{in}$	Net Fracture Strength, a_n (Ksi)	Load at Failure (lbs)
.250 - .300	Timet G 3105	TV1XLFR1	L	-	-	RT	5300	.800	6.96	36.8	55.0	13720
		TV1XLFW41	L	400	10	RT	5900	.730	6.132	36.0	51.0	9580
		TV1XLFW42(1)	L	400	100	RT	1070	.330	32.506	35.0	59.0	2010
		TV1XLFW43	L	400	1000	RT	5600	.770	6.604	37.0	70.6	14100
		TV1XLFW61	L	600	10	RT	5200	.770	6.604	34.4	76.0	14250
		TV1XLFW62(1)	L	600	100	RT	1640	.270	24.509	40.0	71.0	2710
		TV1XLFW63	L	600	1000	RT	5100	.760	6.48	33.0	53.8	13420
		TV1XLFW81	L	800	10	RT	5000	.780	6.72	33.6	58.0	11660
		TV1XLFW82	L	800	100	RT	1140	.350	35.457	40.0	62.0	1870
		TV1XLFW83	L	800	1000	RT	5800	.760	6.48	37.6	37.4	9340
	Timet G 3105	TV1XTFR1	T	-	-	RT	4400	.830	7.31	32.0	58.2	13100
	Timet G 3212	TV2XLFR1	L	-	-	RT	5350	.780	6.72	36.0	48.5	9700
	Timet G 3211	TV3XLFR1	L	-	-	RT	4620	.750	6.34	29.4	38.5	8620
	Timet G 881	TV4XLFR1	L	-	-	RT	4900	.770	6.604	32.2	41.6	8350
.250 - .300	Timet G 1537	TV5XLFR1	L	-	-	RT	6400	.800	6.96	40.0	32.0	8000

(1) Subsize Specimen

7.4.1.6 Annealed Fatigue Tests

Ti 6Al-6V-2Sn **Cond. A** F_{tu} = 158.0

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV1ZLVR49	L	3.0	-1	70.0	44	5,000
		TV1ZLVR50	L	3.0	-1	52.5	33	11,000
		TV1ZLVR51	L	3.0	-1	35.0	22	104,000
		TV1ZLVR52	L	3.0	-1	26.25	17.	225,000
		TV1ZLVR53	L	3.0	-1	17.5	11	10,000,000 →
		TV1ZLVR54	L	3.0	-1	43.75	28	21,000
		TV1ZLVR55	L	3.0	-1	22.750	14	1,982,000
		TV1ZLVR56	L	3.0	-1	38.0	24	38,000
		TV1ZLVR57	L	3.0	-0.3	35.0	22	288,000
		TV1ZLVR58	L	3.0	-0.3	61.25	39	20,000
		TV1ZLVR59	L	3.0	-0.3	52.5	33	24,000
		TV1ZLVR60	L	3.0	-0.3	43.75	28	16,000
		TV1ZLVR61	L	3.0	-0.3	31.5	20	1,361,000
		TV1ZLVR62	L	3.0	-0.3	28.0	18	9,700,000 →
		TV1ZLVR63	L	3.0	-0.3	78.75	50	6,000
≥ 1.00	Timet G 3023	TV1ZLVR64	L	3.0	-0.3	45.5	29	126,000

→ No Failure

Ti 6Al-6V-2Sn Cond. A

7.4.1.6 Annealed Fatigue Tests

F_{tu} = 158.0

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV1XLVR33	L	3.0	0	87.5	55	7,000
		TV1XLVR34	L	3.0	0	70.0	44	14,000
		TV1XLVR35	L	3.0	0	52.5	33	68,000
		TV1XLVR36	L	3.0	0	35.0	22	3,706,000
		TV1XLVR37	L	3.0	0	31.5	20	1,883,000
		TV1XLVR38	L	3.0	0	28.0	18	4,841,000
		TV1XLVR39	L	3.0	0	21.0	13	7,850,000 →
		TV1XLVR40	L	3.0	0	45.5	29	112,000
		TV1ZLVR41	L	3.0	+0.3	96.25	61	13,000
		TV1ZLVR42	L	3.0	+0.3	78.75	50	8,000
		TV1ZLVR43	L	3.0	+0.3	70.0	44	42,000
		TV1ZLVR44	L	3.0	+0.3	52.5	33	144,000
		TV1ZLVR45	L	3.0	+0.3	43.75	28	393,000
		TV1ZLVR46	L	3.0	+0.3	35.0	22	9,600,000 →
		TV1ZLVR47	L	3.0	+0.3	87.5	55	18,000
≥ 1.00	Timet G 3023	TV1ZLVR48	L	3.0	+0.3	113.75	72	4,000

→ No Failure

Ti-6Al-6V-2Sn Cond. A

7.4.1.6 Annealed Fatigue Tests F_{tu} = 158.0

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥1.00	Timet G 3023	TV1ZLVR17	L	1.0	-1	130.	82	5,000
		TV1ZLVR18	L	1.0	-1	100.	64	51,000
		TV1ZLVR19	L	1.0	-1	85.	58	97,000
		TV1ZLVR20	L	1.0	-1	78.75	50	374,000
		TV1ZLVR21	L	1.0	-1	70.	44	260,000
		TV1ZLVR22	L	1.0	-1	122.5	78	12,000
		TV1ZLVR23	L	1.0	-1	113.75	76	15,000
		TV1ZLVR24	L	1.0	-1	60.	38	10,000,000→
		TV1ZLVR25	L	1.0	-0.3	120.	76	161,000
		TV1ZLVR26	L	1.0	-0.3	55.	35	11,200,000→
		TV1ZLVR27	L	1.0	-0.3	100.	63	143,000
		TV1ZLVR28	L	1.0	-0.3	70.	44	3,351,000
		TV1ZLVR29	L	1.0	-0.3	100.	63	245,000
		TV1ZLVR30	L	1.0	-0.3	140.	89	47,000
		TV1ZLVR31	L	1.0	-0.3	155.	98	6,000
≥1.00	Timet G 3023	TV1ZLVR32	L	1.0	-0.3	80.	51	3,232,000

→ No Failure

Ti 6Al-6V-2Sn Cond. A

7.4.1.6 Annealed Fatigue Tests

F_{tu} = 158.0

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV1ZLVR-1	L	1.0	0	160,000	101	8,000
		TV1ZLVR-2	L	1.0	0	145,000	92	17,000
		TV1ZLVR-3	L	1.0	0	130,000	82	194,000
		TV1ZLVR-4	L	1.0	0	135,000	35	70,000
		TV1ZLVR-5	L	1.0	0	125,000	79	268,000
		TV1ZLVR-6	L	1.0	0	115,000	73	339,000
		TV1ZLVR-7	L	1.0	0	105,000	66	583,000
		TV1ZLVR-8	L	1.0	0	80,000	51	1,164,000
		TV1ZLVR-71	L	1.0	0	60,000	38	31,706,000 →
		TV1ZLVR-9	L	1.0	+0.3	155,000	98	29,000
		TV1ZLVR-10	L	1.0	+0.3	145,000	72	178,000
		TV1ZLVR-11	L	1.0	+0.3	140,000	89	59,000
		TV1ZLVR-12	L	1.0	+0.3	135,000	85	207,000
		TV1ZLVR-13	L	1.0	+0.3	125,000	79	619,000
		TV1ZLVR-14	L	1.0	+0.3	120,000	75	384,000
		TV1ZLVR-15	L	1.0	+0.3	110,000	69	585,000
≥ 1.00	Timet G 3023	TV1ZLVR-16	L	1.0	+0.3	95,000	60	738,000

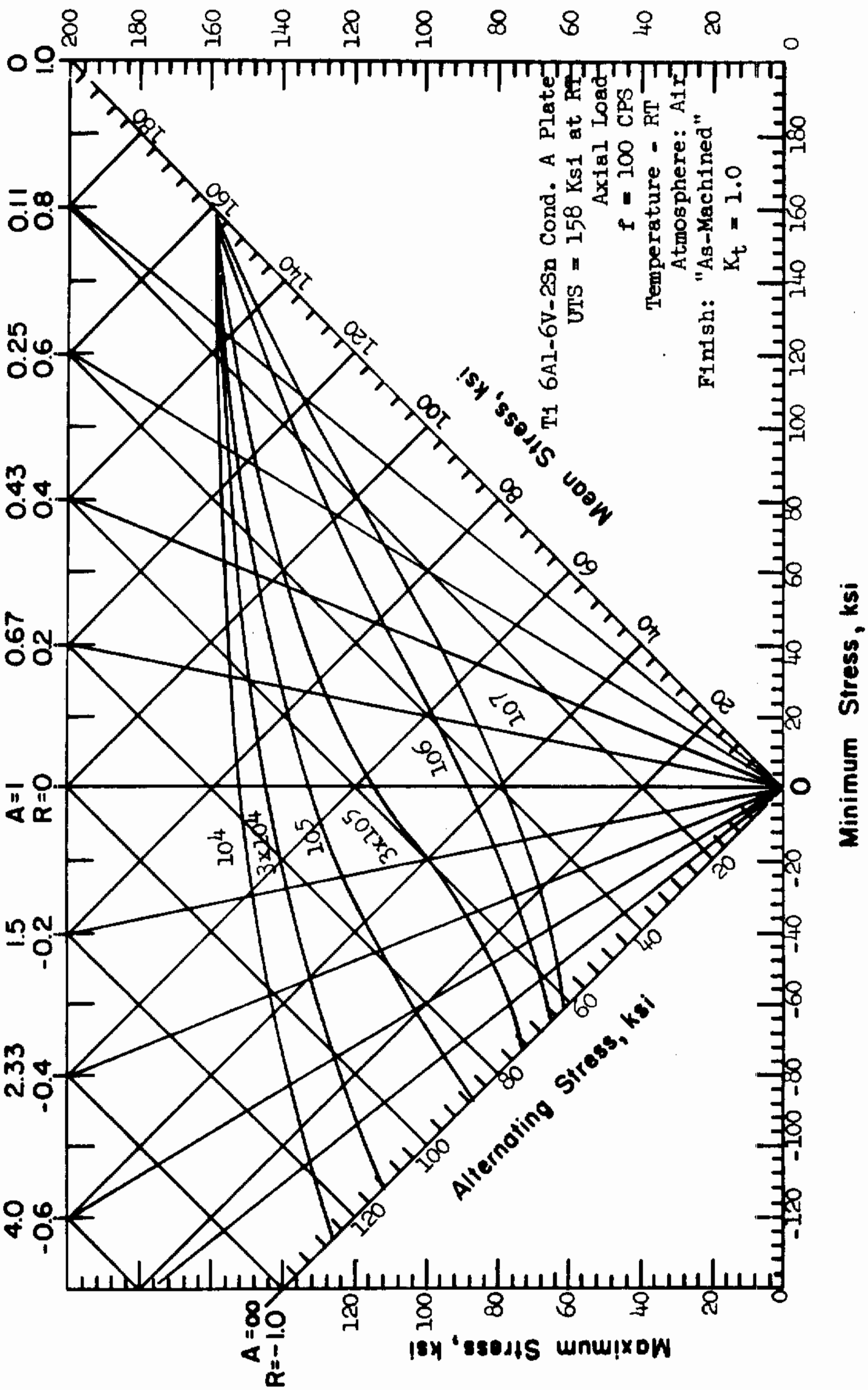

Ti 6Al-6V-2Sn Cond. A Plate
UTS = 158 Ksi at RT
Axial Load
f = 100 CPS
Temperature - RT
Atmosphere: Air
Finish: "As-Machined"
K_t = 1.0
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=1
R=0
A=∞
R=-1.0
10^4
$3x10^4$
10^5
$3x10^5$
10^6
10^7

Figure 7-9

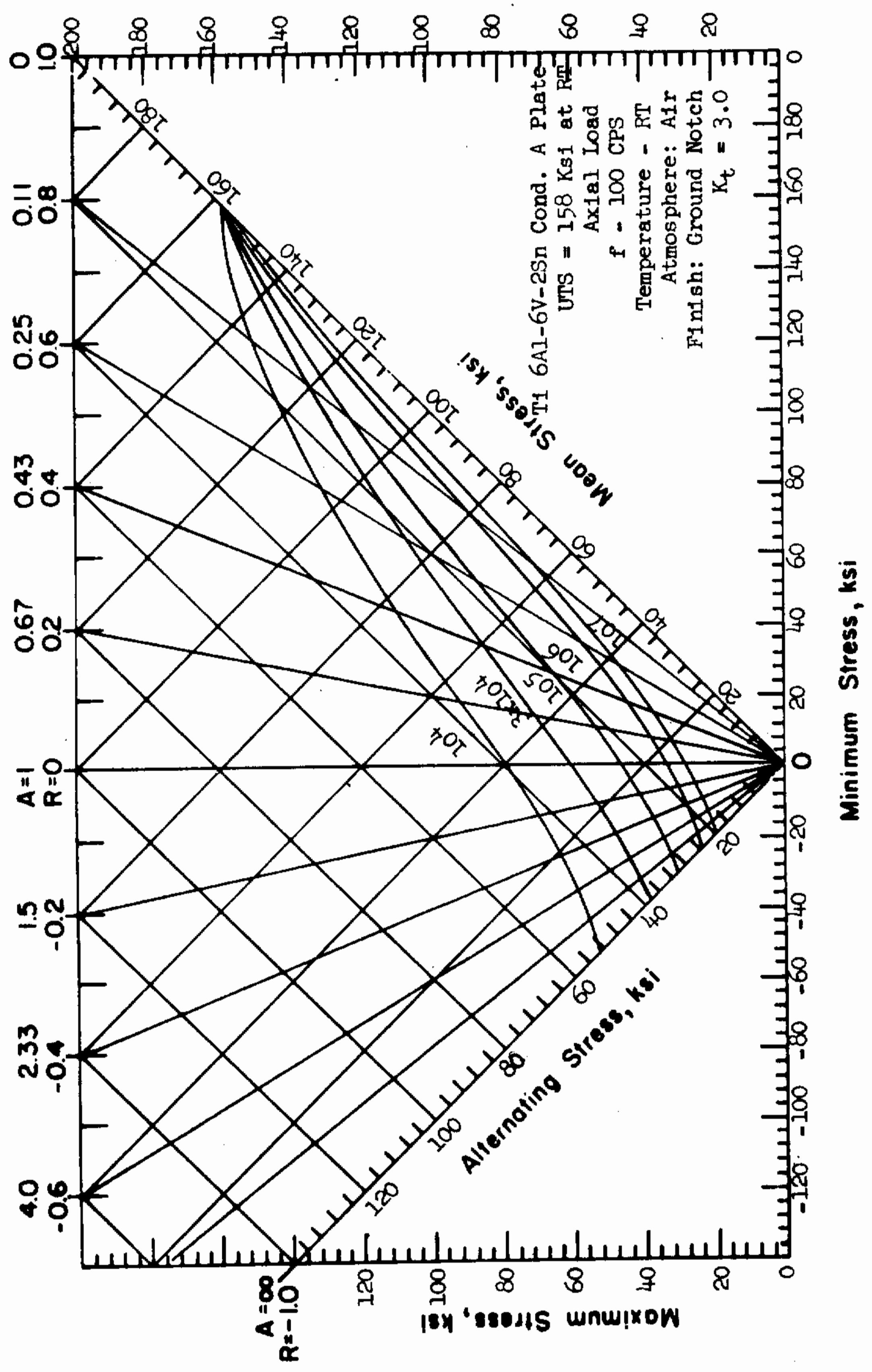

Ti 6Al-6V-2Sn Cond. A Plate
UTS = 158 Ksi at RT
Axial Load
f - 100 CPS
Temperature - RT
Atmosphere: Air
Finish: Ground Notch
K_t = 3.0
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=∞
R=-1.0
A=1
R=0
10^4
10^5
10^6
10^7

Figure 7-10

7.4.2 Ti 6Al-6V-2Sn Cond. STA

7.4.2.1 STA Tensile Tests   Ti 6Al-6V-2Sn **Cond.** STA

Thickness (Inches)	**Manufacturer and Heat No.**	**Specimen Number**	**Test Direction**	**Test Temperature (°F)**	**F_{ty} (Ksi)**	**F_{tu} (Ksi)**	**% Elongation**	**% Reduction Area**
.250 to .300	Timet G 3105	TV7XLTR1	L	RT	176.5	184.0	8	-
		TV7XLT41	L	400	139.7	153.8	9	-
		TV7XLT61	L	600	123.6	142.6	9	-
		TV7XLT81	L	800	117.9	133.1	12	-
.250 to .300	Timet G 3105	TV7XTTR1	T	RT	186.0	191.2	10	-
.500 to .630	Timet G 393	TV6YLTR1	L	RT	174.0	181.0	10	28
		TV6YLT41	L	400	143.5	158.6	12	38
		TV6YLT61	L	600	133.0	148.8	12	42
		TV6YLT81	L	800	123.3	141.6	17	63
		TV6YTTR1	T	RT	174.3	182.6	7	20
		TV6YTT41	T	400	145.6	160.3	12	39
		TV6YTT61	T	600	133.0	149.6	11	31
	Timet G 393	TV6YTT81	T	800	122.9	140.8	12	45
	Timet G 2443	TV7YLTR2	L	RT	178.0	181.0	9	32
	Timet G 2443	TV7YLTR1	L	RT	178.2	183.8	8	20
	Timet G 2443	TV76TTR1	T	RT	182.6	188.0	8	19
	Timet G 1971	TV8YLTR1	L	RT	178.0	183.0	9	24
	Timet G 1971	TV8YLTR1	L	RT	175.9	184.0	11	30
	Timet G 1971	TV8YTTR1	T	RT	174.0	180.8	12	34
	Timet G 2504	TV9YLTR2	L	RT	183.0	188.0	8	26
	Timet G 2504	TV9YLTR1	L	RT	176.8	188.5	10	24
.500 to .630	Timet G 2504	TV9YTTR1	T	RT	180.8	187.7	10	31

7.4.2.1 STA Tensile

Ti 6Al-6V-2Sn **Cond. STA**

Thickness (Inches)	**Manufacturer and Heat No.**	**Specimen Number**	**Test Direction**	**Test Temperature (°F)**	**F_{ty} (Ksi)**	**F_{tu} (Ksi)**	**% Elongation**	**% Reduction Area**
	Timet G 3106	TV10YLTR2	L	RT	176.0	182.0	12	26
.500 to .630	Timet G 3106	TV10YLTR1	L	RT	170.8	178.2	12	39
	Timet G 3106	TV10YTTR1	T	RT	170.8	178.6	13	41
≥ 1.00	Timet G 3023	TV6ZLTR1	L	RT	175.3	186.4	10	32
		TV6ZLTR2	L	RT	182.0	190.0	7	19
		TV6ZLT41	L	400	138.5	153.1	15	54
		TV6ZLT61	L	600	125.3	145.6	15	59
		TV6ZLT81	L	800	120.1	137.9	17	70
		TV6ZTTR1	T	RT	178.6	187.8	10	29
		TV6ZTT41	T	400	138.3	155.2	12	42
		TV6ZTT61	T	600	124.1	144.8	13	45
		TV6ZTT81	T	800	113.0	134.3	14	59
		TV6ZSTR1	ST	RT	159.6	173.7	8	33
		TV6ZST41	ST	400	132.5	146.5	10	46
		TV6ZST61	ST	600	114.3	133.9	12	49
	Timet G 3023	TV6ZST81	ST	800	103.5	120.6	12	43
	Timet G 3214	TV7ZLTR1	L	RT	181.0	191.0	8	23
		TV7ZLTR2	L	RT	181.0	191.0	9	25
		TV7ZTTR1	T	RT	179.9	188.8	8	17
≥ 1.00	Timet G 3214	TV7ZSTR1	ST	RT	171.1	186.6	10	33

7.4.2.1 STA Tensile Ti 6Al-6V-2Sn **Cond. STA**

Thickness (Inches)	**Manufacturer and Heat No.**	**Specimen Number**	**Test Direction**	**Test Temperature (oF)**	**F_{ty} (Ksi)**	**F_{tu} (Ksi)**	**% Elongation**	**% Reduction Area**
≥ 1.00	Timet G 2070	TV8ZLTR1	L	RT	180.0	191.3	8	18
↕	↕	TV8ZLTR2	L	RT	181.0	192.0	7	23
		TV8ZTTR1	T	RT	179.0	187.0	7	17
	Timet G 2070	TV8ZSTR1	ST	RT	165.3	180.5	7	26
	Timet G 1971	TV9ZLTR1	L	RT	174.8	185.6	10	32
	↕	TV9ZLTR2	L	RT	182.0	190.0	11	41
		TV9ZTTR1	T	RT	175.8	186.7	10	31
	Timet G 1971	TV9ZSTR1	ST	RT	173.8	186.3	8	18
	Timet G 3024	TV10ZLTR1	L	RT	180.0	192.1	7	22
	↕	TV10ZLTR2	L	RT	180.0	194.0	6	22
		TV10ZTTR1	T	RT	181.5	191.2	10	30
≥ 1.00	Timet G 3024	TV10ZSTR1	ST	RT	168.0	184.6	4	9

7.4.2.1.1 STA Tensile Stability Tests Ti 6Al-6V-2Sn Cond.. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
.500 to .630	Timet G 393	TV6YLTW41	L	400	10	RT	174.7	179.8	8	29
↕	↕	TV6YLTW42	L	400	100	RT	169.2	180.4	8	20
		TV6ULTW43	L	400	1000	RT	174.4	182.5	8	23
		TV6YLTW61	L	600	10	RT	175.3	181.6	9	27
		TV6YLTW62	L	600	100	RT	172.0	180.0	9	25
		TV6YLTW63	L	600	1000	RT	175.6	181.3	9	27
		TV6YLTW81	L	800	10	RT	177.8	184.7	8	25
		TV6YLTW82	L	800	100	RT	183.8	189.0	7	15
.500 to .630	Timet G 393	TV6YLTW83	L	800	1000	RT	183.8	192.2	8	22

7.4.2.1.1 STA Tensile Stability Tests Ti 6Al-6V-2Sn Cont. STA

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temperature (°F)	Exposure Time (Hrs.)	Test Temperature (°F)	F_{ty} (Ksi)	F_{tu} (Ksi)	Percent Elongation	% Reduction Area
≥ 1.00	Timet G 3023	TV6ZLTW41	L	400	10	RT	175.6	182.8	8	21
↕	↕	TV6ZLTW42	L	400	100	RT	175.0	185.9	7	20
		TV6ZLTW43	L	400	1000	RT	181.0	188.8	8	28
		TV6ZLTW61	L	600	10	RT	176.2	183.0	9	25
		TV6ZLTW62	L	600	100	RT	174.7	180.8	9	24
		TV6ZLTW63	L	600	1000	RT	176.4	186.0	10	31
		TV6ZLTW81	L	800	10	RT	181.2	187.0	8	19
		TV6ZLTW82	L	800	100	RT	181.5	192.8	9	29
≥ 1.00	Timet G 3023	TV6ZLTW83	L	800	1000	RT	185.1	192.2	8	21

Ti-6AL-6V-2Sn COND. STA

7.4.2.1.2 Tensile Tests - Precision Elastic Modulus (Tuckerman)

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature	Precision "E" $\times 10^6$
.250-.300	Timet G 3105	TVTXLTR1	L	RT	16.1

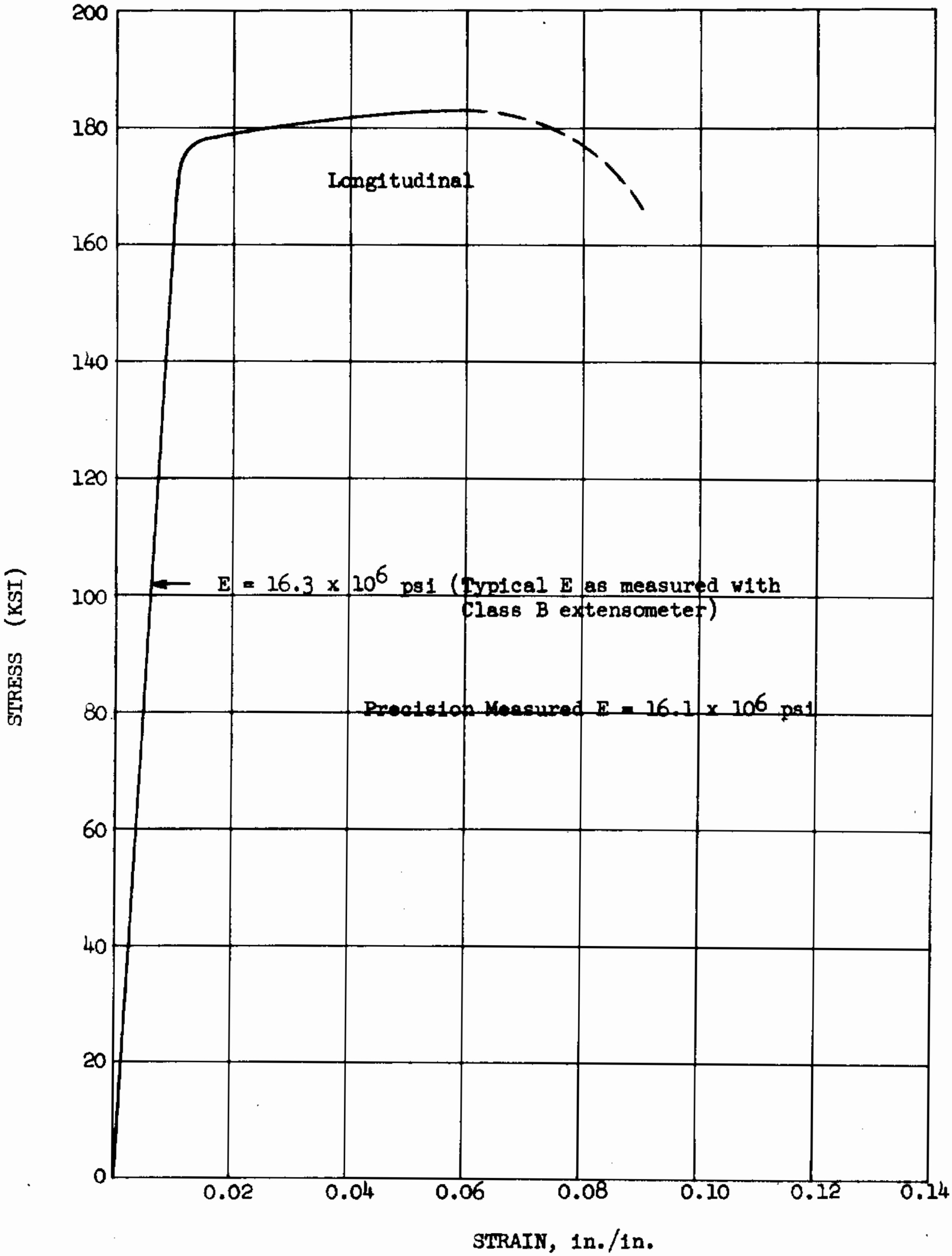


Figure 7-11 Typical Tensile Stress-Strain Curve (full-range) for Solution Treated and Aged Ti-6Al-6V-2Sn Alloy Plate at Room Temperature

Ti 6Al-6V-2Sn **Cond. STA**

7.4.2.2 STA Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
.250 to .300	Timet G 3105	TV7XLCR1	L	RT	184.1
.250 to .300	Timet G 3105	TV7XTCR1	T	RT	206.0
.500 to .630	Timet G 393	TV6YLCR1	L	RT	182.3
		TV6YLC41	L	400	149.2
		TV6YLC61	L	600	141.0
		TV6YLC81	L	800	125.7
		TV6YTCR1	T	RT	187.0
		TV6YTC41	T	400	154.0
		TV6YTC61	T	600	139.4
	Timet G 393	TV6YTC81	T	800	126.3
	Timet G 2443	TV7YLCR1	L	RT	188.3
	Timet G 2443	TV7YTCR1	T	RT	194.6
	Timet G 1971	TV8YLCR1	L	RT	190.7
	Timet G 1971	TV8YTCR1	T	RT	187.8
	Timet G 2504	TV9YLCRL	L	RT	195.5
	Timet G 2504	TV9YTCR1	T	RT	191.0
	Timet G 3106	TV10YLCR1	L	RT	187.0
.500 to .630	Timet G 3106	TV10YTCR1	T	RT	183.3

7.4.2.2 STA Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≥ 1.00	Timet G 3023	TV6ZLCR1	L	RT	208.2
		TV6ZLC41	L	400	153.3
		TV6ZLC61	L	600	133.6
		TV6ZLC81	L	800	121.9
		TV6ZTCR1	T	RT	194.2
		TV6ZTC41	T	400	150.7
		TV6ZTC61	T	600	134.6
		TV6ZTC81	T	800	119.7
		TV6ZSCR1	ST	RT	182.7
		TV6ZSC41	ST	400	140.3
		TV6ZSC61	ST	600	131.2
	Timet G 3023	TV6ZSC81	ST	800	126.5
	Timet G 3214	TV7ZLCR1	L	RT	191.5
		TV7ZTCR1	T	RT	191.2
	Timet G 3214	TV7ZSCR1	ST	RT	193.1
	Timet G 2070	TV8ZLCR1	L	RT	195.7
		TV8ZTCR1	T	RT	185.0
≥ 1.00	Timet G 2070	TV8ZSCR1	ST	RT	190.3

Ti 6Al-6V-2Sn **Cond.** STA

7.4.2.2 STA Compression Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
≥ 1.00	Timet G 1971	TV9ZLCR1	L	RT	183.3
		TV9ZTCR1	T	RT	192.0
	Timet G 1971	TV9ZSCR1	ST	RT	200.5
	Timet G 3024	TV10ZLCR1	L	RT	198.2
		TV10ZTCR1	T	RT	194.5
≥ 1.00	Timet G 3024	TV10ZSCR1	ST	RT	205.3

7.4.2.3 STA Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.250 to .300	Timet G 3105	TV7XLB1R1	L	1.5	RT	277.7	298.6
.250 to .300	Timet G 3105	TV7XLB2R1	L	2.0	RT	296.7	360.4
.500 to .630	Timet G 393	TV6YLB1R1	L	1.5	RT	252.5	276.7
↕	↕	TV6YLB141	L	1.5	400	218.4	250.8
		TV6YLB161	L	1.5	600	222.2	238.1
		TV6YLB181	L	1.5	800	187.9	213.3
		TV6YTB1R1	T	1.5	RT	265.1	287.4
		TV6YLB2R1	L	2.0	RT	298.8	343.3
		TV6YLB241	L	2.0	400	254.5	300.3
		TV6YLB261	L	2.0	600	254.2	296.5
		TV6YLB281	L	2.0	800	242.9	292.0
	Timet G 393	TV6YTB2R1	T	2.0	RT	298.1	350.2
	Timet G 2443	TV7YLB1R1	L	1.5	RT	268.1	293.6
	Timet G 2443	TV7YLB2R1	L	2.0	RT	302.4	366.3
	Timet G 2070	TV8YLB1R1	L	1.5	RT	264.0	302.5
	Timet G 2070	TV8YLB2R1	L	2.0	RT	295.0	371.8
	Timet G 1971	TV9YLB1R1	L	1.5	RT	277.5	293.0
.500 to .630	Timet G 1971	TV9YLB2R1	L	2.0	RT	299.3	373.4

Ti 6Al-6V-2Sn Cond. STA

7.4.2.3 STA Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (oF)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
.500 to .630	Timet G 3106	TV10YLB1R1	L	1.5	RT	255.4	291.6
.500 to .630	Timet G 3106	TV10YLB2R1	L	2.0	RT	295.8	371.4
≥ 1.00	Timet G 3023	TV6ZLB1R1	L	1.5	RT	258.0	288.6
↓	↓	TV6ZLB141	L	1.5	400	226.9	256.1
↓	↓	TV6ZLB161	L	1.5	600	201.4	227.1
↓	↓	TV6ZLB181	L	1.5	800	200.0	228.5
↓	↓	TV6ZTB1R1	T	1.5	RT	266.5	289.0
↓	↓	TV6ZLEB1R1	LE	1.5	RT	240.0	261.1
↓	↓	TV6ZTEB1R1	TE	1.5	RT	242.5	251.7
↓	↓	TV6ZLB2R1	L	2.0	RT	299.0	353.2
↓	↓	TV6ZLB241	L	2.0	400	253.3	306.9
↓	↓	TV6ZLB261	L	2.0	600	234.4	282.2
↓	↓	TV6ZLB281	L	2.0	800	226.5	285.2
↓	↓	TV6ZTB2R1	T	2.0	RT	283.3	343.7
↓	↓	TV6ZLEB2R1	LE	2.0	RT	289.4	350.3
↓	Timet G 3023	TV6ZTEB2R1	TE	2.0	RT	312.0	342.5
↓	Timet G 3214	TV7ZLB1R1	L	1.5	RT	272.5	295.0
≥ 1.00	Timet G 3214	TV7ZLB2R1	L	2.0	RT	325.4	372.1

Ti 6Al-6V-2Sn **Cond.** STA

7.4.2.3 STA Bearing Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	e/D	Test Temperature (°F)	F_{BRY} (Ksi) (2% Offset)	F_{BRU} (Ksi)
≥ 1.00	Timet G 2070	TV8ZLB1R1	L	1.5	RT	267.9	291.3
↑	Timet G 2070	TV8ZLB2R1	L	2.0	RT	284.0	347.7
|	Timet G 1971	TV9ZLB1R1	L	1.5	RT	277.2	303.9
|	Timet G 1971	TV9ZTB1R1	L	2.0	RT	304.3	361.4
↓	Timet G 3024	TV10ZLB1R1	L	1.5	RT	279.0	298.2
≥ 1.00	Timet G 3024	TV10ZLB2R1	L	2.0	RT	312.0	368.6

Ti 6Al-6V-2Sn Cond. STA

7.4.2.4 STA Shear Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Test Temperature (°F)	Fcy (Ksi)
.250 to .300	Timet G 3105	TV7XLSR1	L	RT	107.0
.500 to .630 ↓	Timet G 393 ↓	TV6YLSR1	L	RT	108.0
		TV6YLS41	L	400	93.7
		TV6YLS61	L	600	89.8
		TV6YLS81	L	800	83.6
	Timet G 393	TV6YTSR1	T	RT	118.0
	Timet G 2443	TV7YLSR1	L	RT	106.0
	Timet G 1971	TV8YLSR1	L	RT	115.0
	Timet G 2504	TV9YLSR1	L	RT	115.0
.500 to .630	Timet G 3106	TV10YLSR1	L	RT	115.0
≥ 1.00 ↓	Timet G 3023 ↓	TV6ZLSR1	L	RT	111.0
		TV6ZLS41	L	400	96.3
		TV6ZLS61	L	600	89.7
		TV6ZLS81	L	800	87.3
	Timet G 3023	TV6ZTSR1	T	RT	111.0
	Timet G 3214	TV7ZLSR1	L	RT	116.0
	Timet G 2070	TV8ZLSR1	L	RT	114.0
	Timet G 1971	TV9ZLSR1	L	RT	116.0
≥ 1.00	Timet G 3024	TV10ZLSR1	L	RT	116.0

Ti-6Al-6V-2Sn Cond. STA

7.4.2.5 Fracture Toughness Tests

Thickness (inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	Exposure Temp. (°F)	Exposure Time (Hrs.)	Test Temp.	Load Pop-in (lbs)	a Crack Depth	K Factor	K_{Ic} Ksi $\sqrt{in}$	Net Fracture Strength, σ_n (Ksi)	Load at Failure (lbs)
.250 - .300	Timet G 3105	TV7XLFR1	L	-	-	RT	4900	.750	6.34	31.0	34.3	6860

F_{tu} = 186.4

7.4.2.6 STA Fatigue Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV6ZLVR25	L	1.0	-1	152.0	81.	10,000
		TV6ZLVR26	L	1.0	-1	142.5	76	21,000
		TV6ZLVR27	L	1.0	-1	133.0	71	26,000
		TV6ZLVR28	L	1.0	-1	114.0	61	68,000
		TV6ZLVR29	L	1.0	-1	95.0	51	9,224,000
		TV6ZLVR30	L	1.0	-1	108.3	58	108,000
		TV6ZLVR31	L	1.0	-1	102.6	55	3,105,000
		TV6ZLVR32	L	1.0	-1	161.5	87	7,000
		TV6ZLVR17	L	1.0	-0.3	152.0	82	141,000
		TV6ZLVR18	L	1.0	-0.3	161.5	87	66,000
		TV6ZLVR19	L	1.0	-0.3	142.5	76	430,000
		TV6ZLVR20	L	1.0	-0.3	171.1	92	8,000
		TV6ZLVR21	L	1.0	- 0.3	123.5	66	1,041,000
		TV6ZLVR22	L	1.0	-0.3	104.5 (1)	56	(1) 591,000
		TV6ZLVR23	L	1.0	-0.3	104.5 (1)	56	(1) 327,000
		TV6ZLVR24	L	1.0	-0.3	104.5 (1)	56	(1) 1,066,000
≥ 1.00	Timet G 3023	TV6ZLVR24A	L	1.0	-0.3	100.0	54	997,000

(1) Grip Failure

Ti 6Al-6V-2Sn Cond. STA

7.4.2.6 STA Fatigue Tests

F_{tu} = 186.4

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV6ZLVR1	L	1.0	0	161.5	87	310,000
		TV6ZLVR2	L	1.0	0	171.0	92	21,000
		TV6ZLVR3	L	1.0	0	152.0	81	36,000
		TV6ZLVR4	L	1.0	0	133.0	71	1,041,000
		TV6ZLVR5	L	1.0	0	114.0	61	4,723,000
		TV6ZLVR6	L	1.0	0	142.5	76	405,000
		TV6ZLVR7	L	1.0	0	104.5	56	15,050,000
		TV6ZLVR8	L	1.0	0	152.0	81	(1) 99,000
		TV6ZLVR9	L	1.0	+0.3	180.5	97	17,000
		TV6ZLVR10	L	1.0	+0.3	161.5	87	370,000
		TV6ZLVR11	L	1.0	+0.3	171.0	92	29,000
		TV6ZLVR12	L	1.0	+0.3	152.0	81	693,000
		TV6ZLVR13	L	1.0	+0.3	142.5	76	949,000
		TV6ZLVR14	L	1.0	+0.3	123.5	66	6,880,000
		TV6ZLVR15	L	1.0	+0.3	167.2	90	622,000
≥ 1.00	Timet G 3023	TV6ZLVR16	L	1.0	+0.3	184.3	99	13,000

(1) Grip Failure

Ti 6Al-6V-2Sn Cond. STA

7.4.2.6 STA Fatigue Tests

F_{tu} = 186.4

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV6ZLVR49	L	3.0	-1	57.0	30	4,000
		TV6ZLVR50	L	3.0	-1	47.5	25	20,000
		TV6ZLVR51	L	3.0	-1	38.0	20	81,000
		TV6ZLVR52	L	3.0	-1	28.5	15	154,000
		TV6ZLVR53	L	3.0	-1	19.0	10	10,000,000 →
		TV6ZLVR54	L	3.0	-1	24.7	13	175,000
		TV6ZLVR55	L	3.0	-1	41.8	22	14,000
		TV6ZLVR56	L	3.0	-1	53.2	28	15,000
		TV6ZLVR57	L	3.0	-0.3	57.54	31	20,000
		TV6ZLVR58	L	3.0	-0.3	47.5	25	40,000
		TV6ZLVR59	L	3.0	-0.3	38.0	20	46,000
		TV6ZLVR60	L	3.0	-0.3	28.5	15	10,000,000 →
		TV6ZLVR61	L	3.0	-0.3	34.2	18	10,000,000 →
		TV6ZLVR62	L	3.0	-0.3	76.0	41	7,000
		TV6ZLVR63	L	3.0	-0.3	38.0	20	112,000
≥ 1.00	Timet G 3023	TV6ZLVR64	L	3.0	-0.3	66.5	35	10,000
→	No Failure							

Ti 6Al-6V-2Sn Cond. STA

F_{tu} = 186.4

7.4.2.6 STA Fatigue Tests

Thickness (Inches)	Manufacturer and Heat No.	Specimen Number	Test Direction	K_t	R	Max. (Ksi)	% F_{tu}	N (Cycles to Failure)
≥ 1.00	Timet G 3023	TV6ZLVR33	L	3.0	0	76 *	-	-
		TV6ZLVR34	L	3.0	0	83.0	44	4,000
		TV6ZLVR35	L	3.0	0	57.0	31	24,000
		TV6ZLVR36	L	3.0	0	47.5	25	114,000
		TV6ZLVR37	L	3.0	0	28.5	15	25,000,000 →
		TV6ZLVR38	L	3.0	0	53.2	28	28,000
		TV6ZLVR39	L	3.0	0	66.5	36	27,000
		TV6ZLVR40	L	3.0	0	43.7	23	7,213,000
		TV6ZLVR41	L	3.0	+0.3	76.0	41	24,000
		TV6ZLVR42	L	3.0	+0.3	57.0	31	223,000
		TV6ZLVR43	L	3.0	+0.3	66.5	36	11,000
		TV6ZLVR44	L	3.0	+0.3	47.5	25	140,000
		TV6ZLVR45	L	3.0	+0.3	34.2	18	10,000,000 →
		TV6ZLVR46	L	3.0	+0.3	95.0	51	14,000
		TV6ZLVR47	L	3.0	+0.3	104.5	56	3,000
≥ 1.00	Timet G 3023	TV6ZLVR48	L	3.0	+0.3	41.8	22	10,000,000 →

→ No Failure

* Overstressed

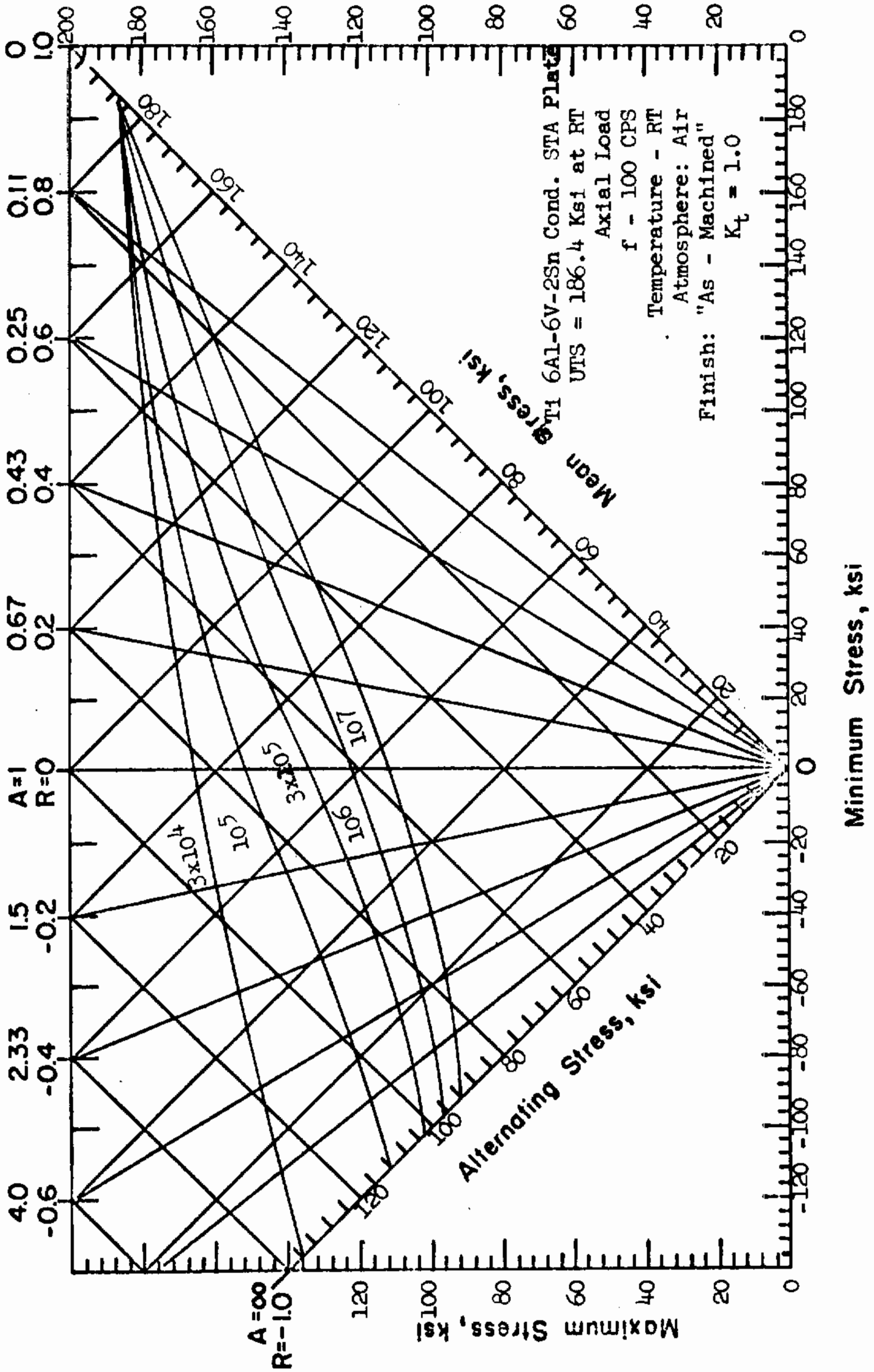
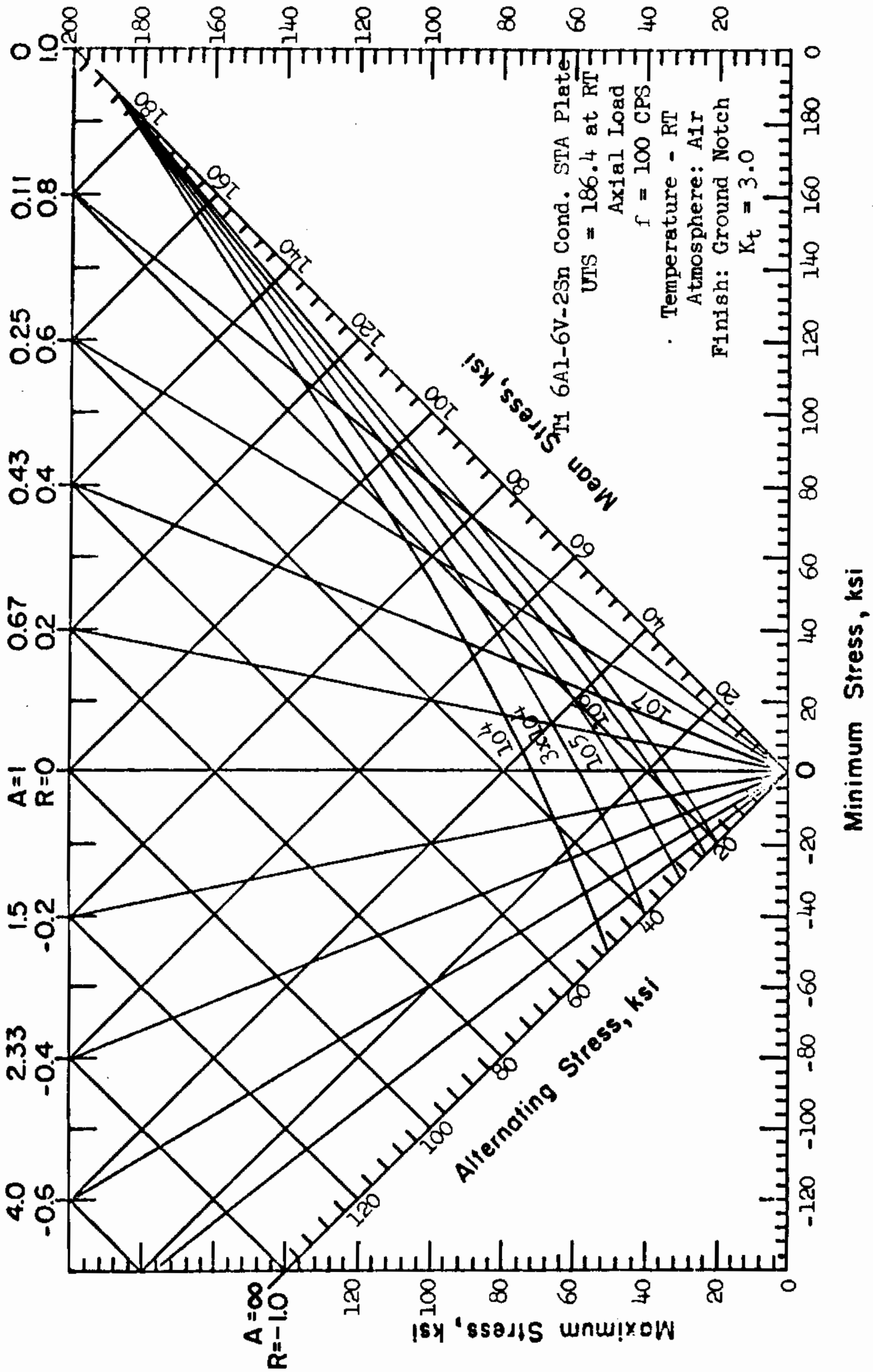

Ti 6Al-6V-2Sn Cond. STA Plate
UTS = 186.4 Ksi at RT
Axial Load
f - 100 CPS
Temperature - RT
Atmosphere: Air
Finish: "As - Machined"
Kt = 1.0
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=1
R=0
A=∞
R=-1.0
3x10^4
10^5
3x10^5
10^6
10^7

Figure 7-12



Ti 6Al-6V-2Sn Cond. STA Plate
UTS = 186.4 at RT
Axial Load
f = 100 CPS
Temperature - RT
Atmosphere: Air
Finish: Ground Notch
K_t = 3.0
Mean Stress, ksi
Alternating Stress, ksi
Minimum Stress, ksi
Maximum Stress, ksi
A=1
R=0
A=∞
R=-1.0

Figure 7-13

SECTION VIII

MIL-HDBK-5 DATA PRESENTATION

Contained in this section are the room temperature design allowables, effect of temperature curves, and stress-strain curves, for Ti 4Al-3Mo-1V Cond. A, Ti 13V-11Cr-3Al Cond. A, Ti 6Al-4V Cond. STA, and Ti 6Al-6V-2Sn Cond. A and Ti 6Al-6V-2Sn Cond. STA. Refer to Section VI for a discussion of the limitations of the allowables contained herein.

Table VIII-1

8.1 **Design Mechanical and Physical Properties of Ti-4Al-3Mo-1V**

Alloy	MIL-T-4046 Type III Comp. B
Form	Sheet and Strip
Condition	Annealed
Thickness or diameter, in.	$\leq$ .110
Basis	S
Mechanical properties:	
F_{tu}, ksi	125
L	
LT	
F_{ty}, ksi	115
L	
LT	
F_{cy}, ksi	112
L	
LT	
F_{su}, ksi	77
F_{bru}, ksi	
(e/D = 1.5)	191
(e/D = 2.0)	260
F_{bry}, ksi:	
(e/D = 1.5)	150
(e/D = 2.0)	175
e, per cent:	
In 2 in.	10
In 4 D	
E, 10^6 psi	16.2
E_c, 10^6 psi	
G, 10^6 psi	
Physical properties:	
, lb/in.^{3}	
C, Btu/(lb)(F)	
K, Btu/ (hr)(ft^2)(F)/ft	
, 10^{-6} in./in./F	

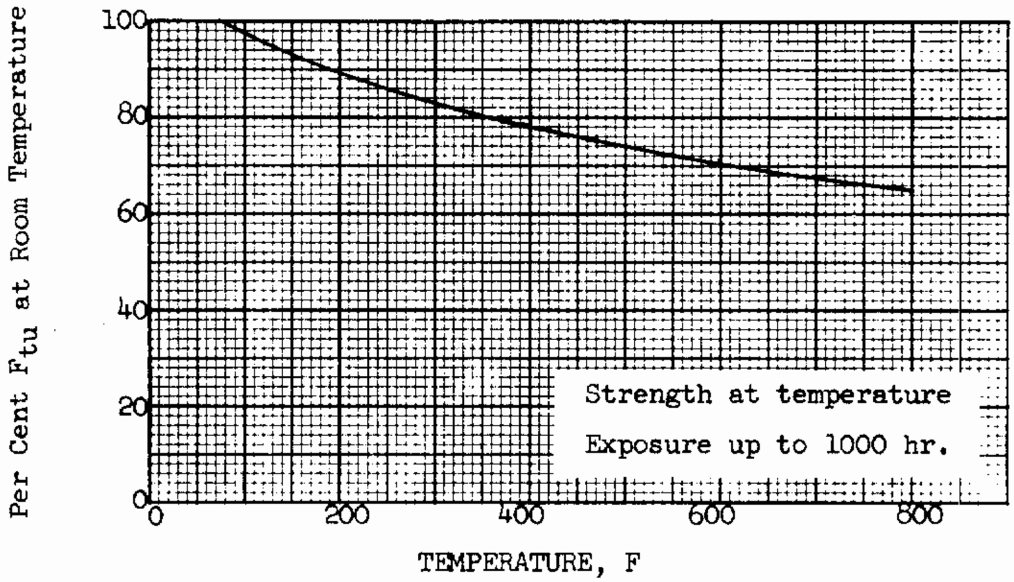


Figure 8.1.1 Effect of Temperature on the ultimate tensile strength (F_{tu}) of annealed Ti-4Al-3Mo-1V alloy sheet.

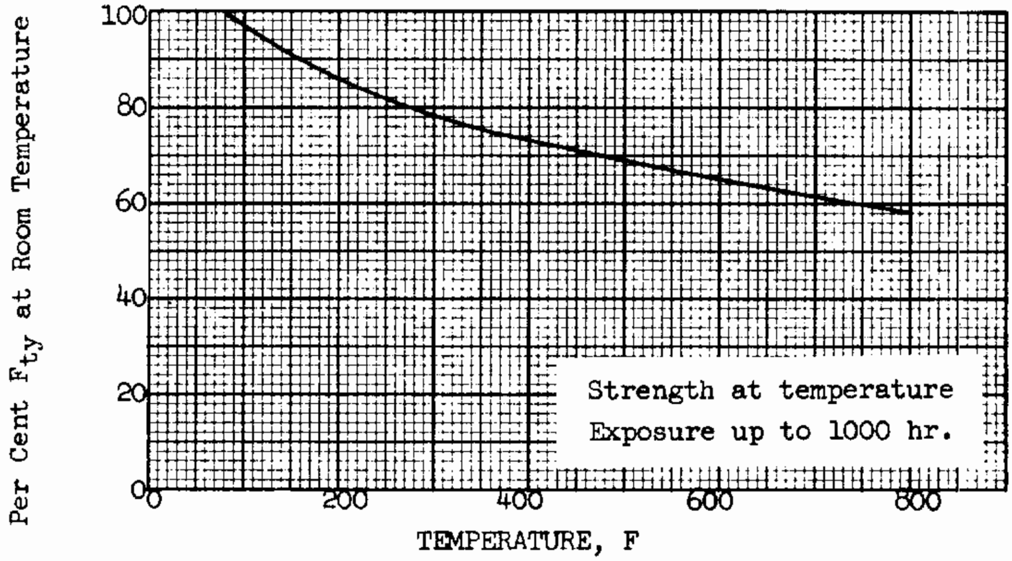


Figure 8.1.2 Effect of Temperature on the tensile yield strength (F_{ty}) of annealed Ti-4Al-3Mo-1V alloy sheet.

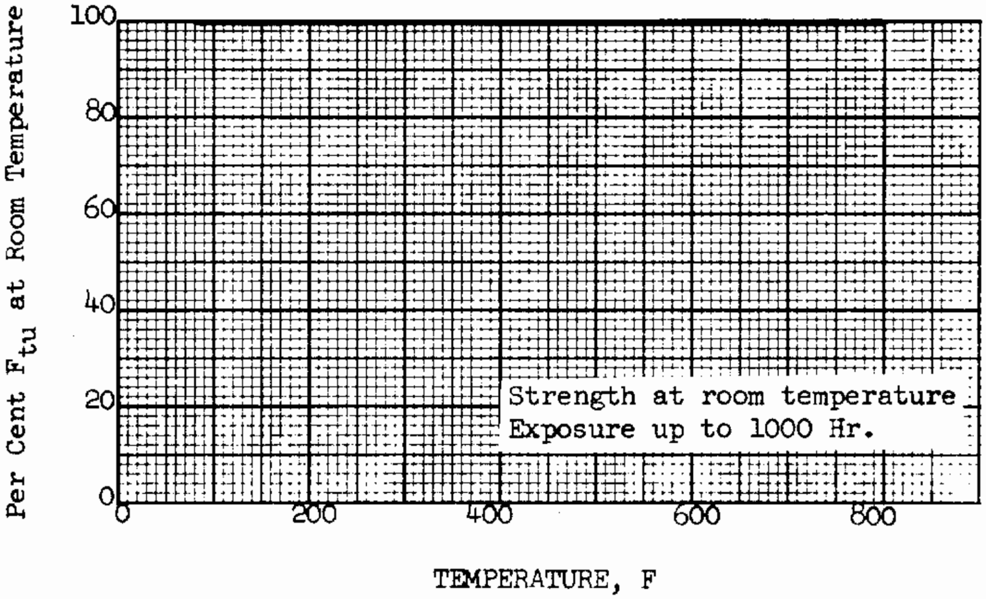


Figure 8.1.3 Effect of Exposure at elevated temperature on the room-temperature ultimate tensile strength (F_{tu}) of annealed Ti-4Al-3Mo-1V alloy sheet.

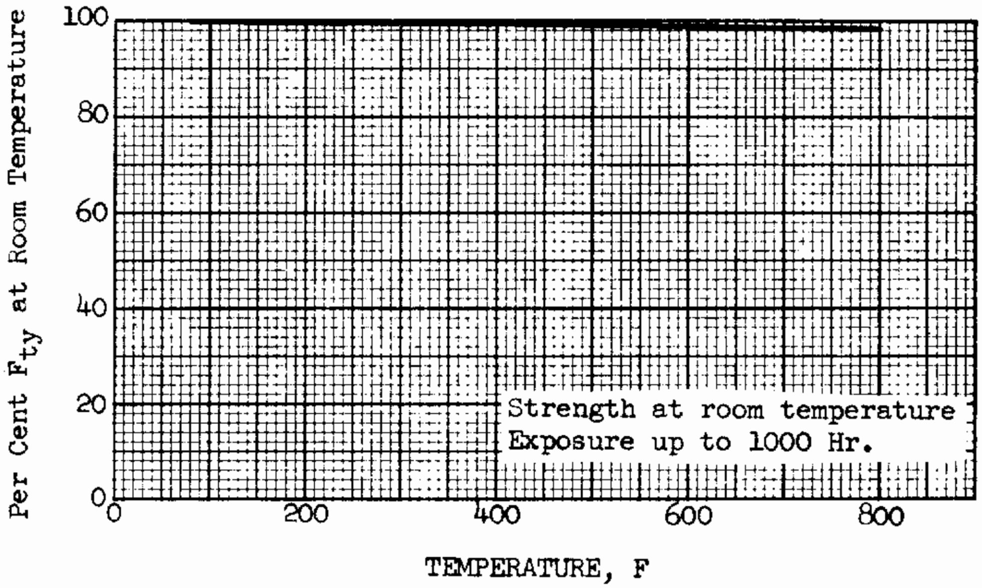


Figure 8.1.4 Effect of exposure at elevated temperature on the room-temperature tensile yield strength (F_{ty}) of annealed Ti-4Al-3Mo-1V alloy sheet.

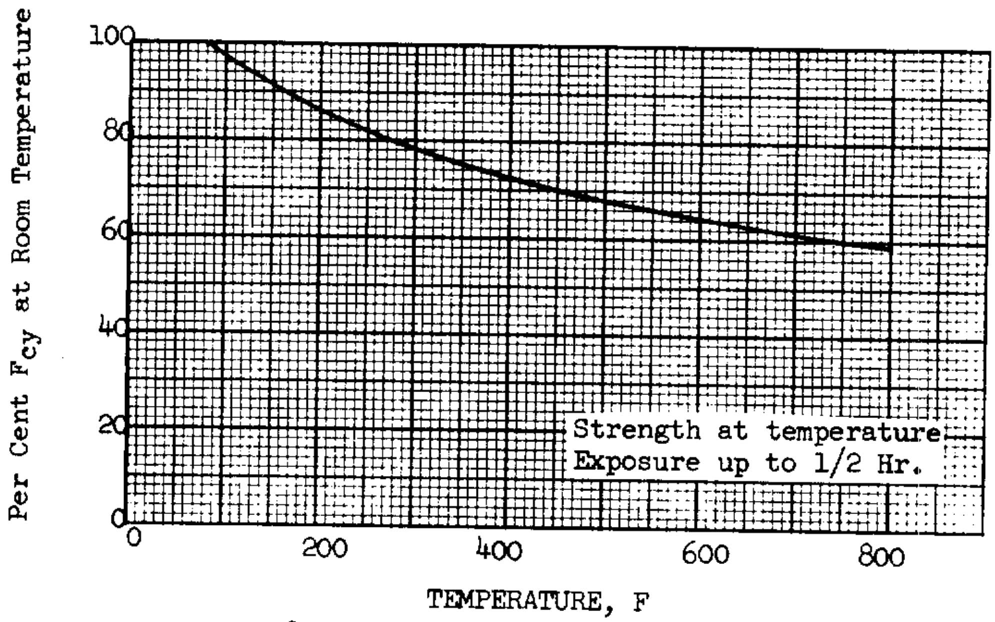


Figure 8.1.5 Effect of temperature on the compressive yield strength (F_{cy}) of annealed Ti-4Al-3Mo-1V alloy sheet.

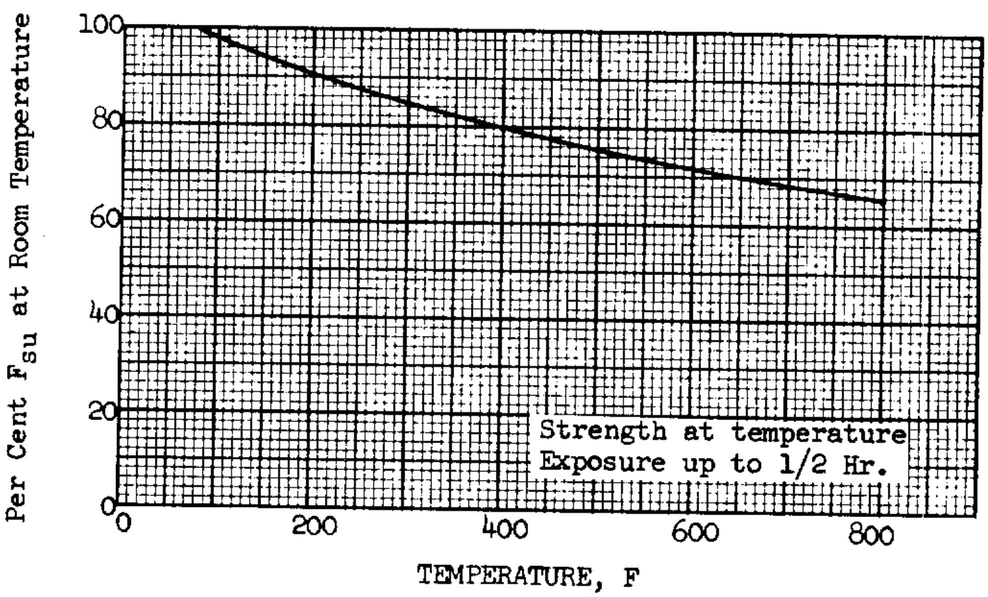


Figure 8.1.6 Effect of temperature on ultimate shear strength (F_{su}) of annealed Ti-4Al-3Mo-1V alloy sheet.

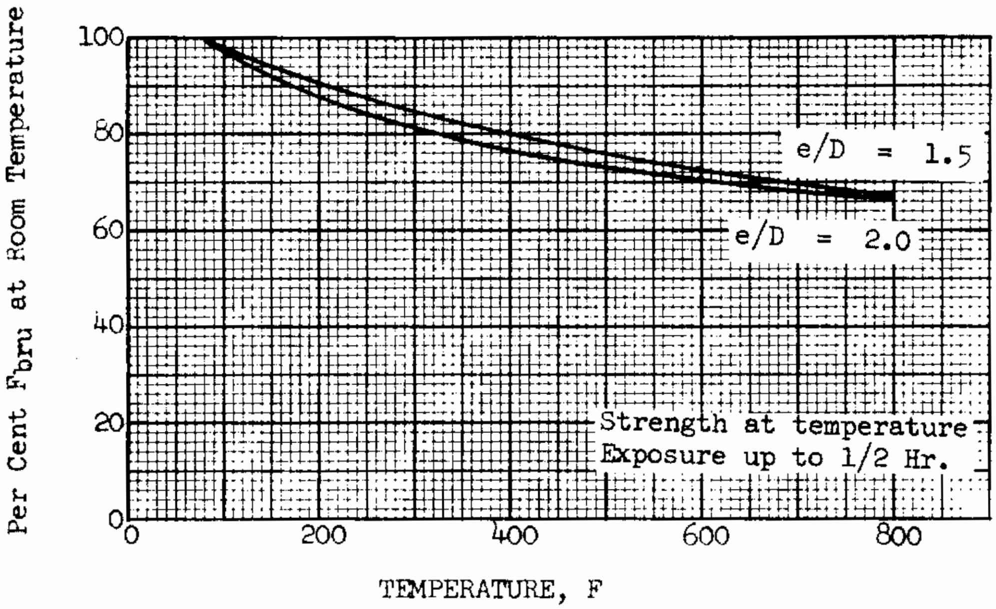


Figure 8.1.7 Effect of Temperature on ultimate bearing strength (F_{bru}) of annealed Ti-4Al-3Mo-1V alloy sheet.

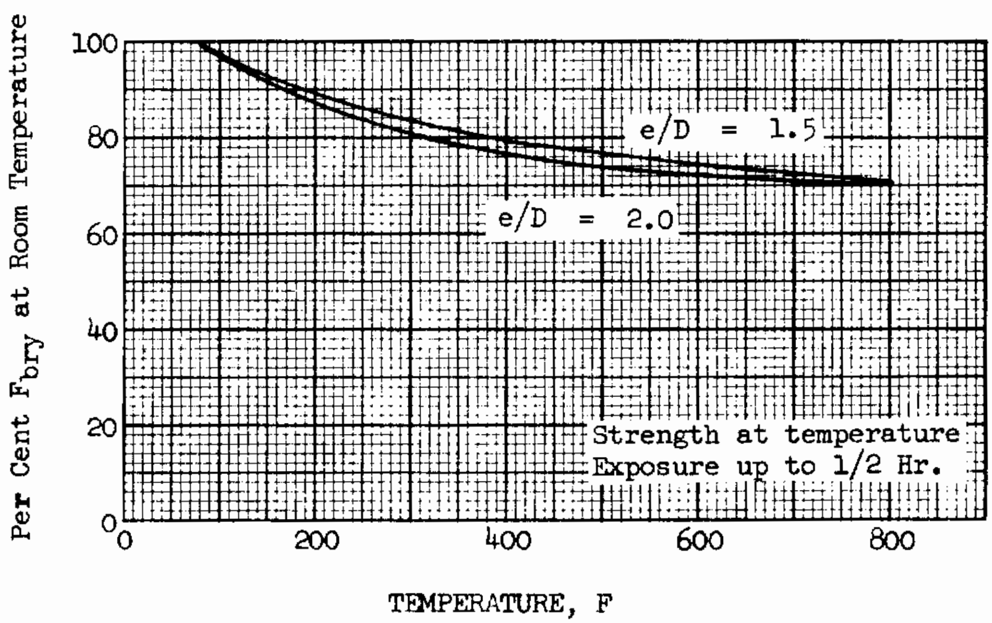


Figure 8.1.8 Effect of Temperature on bearing yield strength (F_{bry}) of annealed Ti-4Al-3Mo-1V alloy sheet.

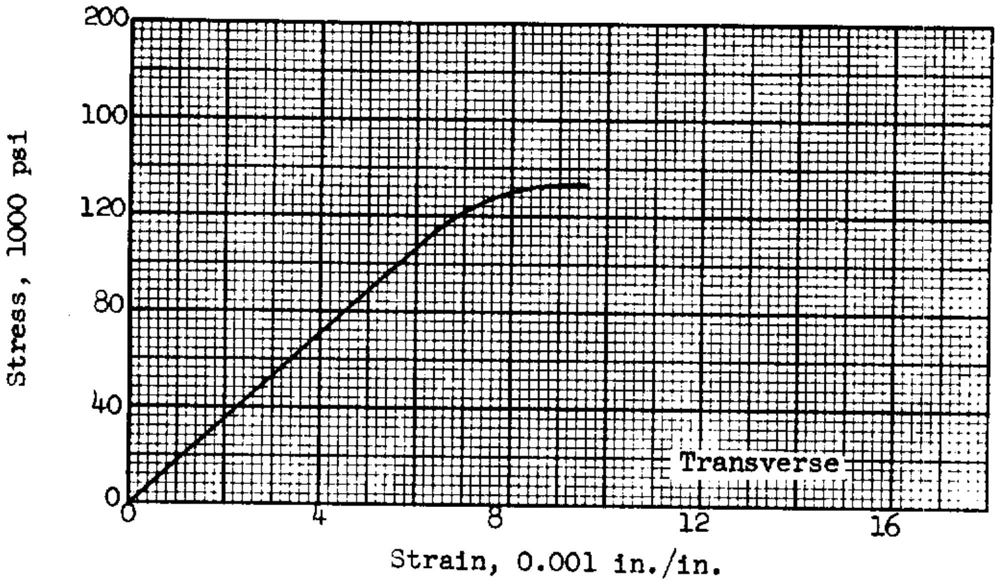


Figure 8.1.9 Typical tensile stress-strain curve for annealed Ti-4Al-3Mo-1V alloy sheet at room temperature.

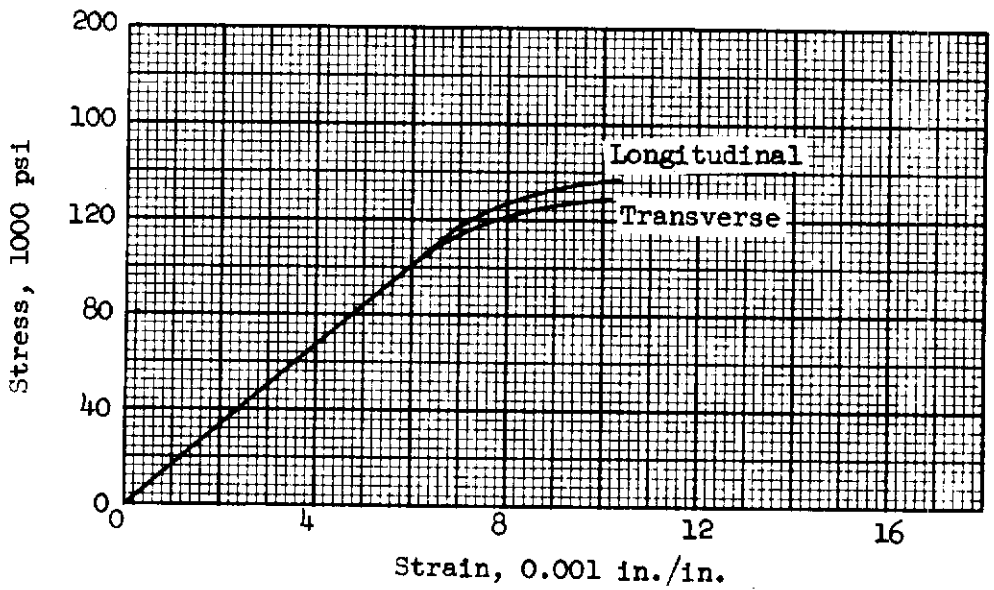


Figure 8.1.10 Typical compressive stress-strain curves for annealed Ti-4Al-3Mo-1V alloy sheet at room temperature.

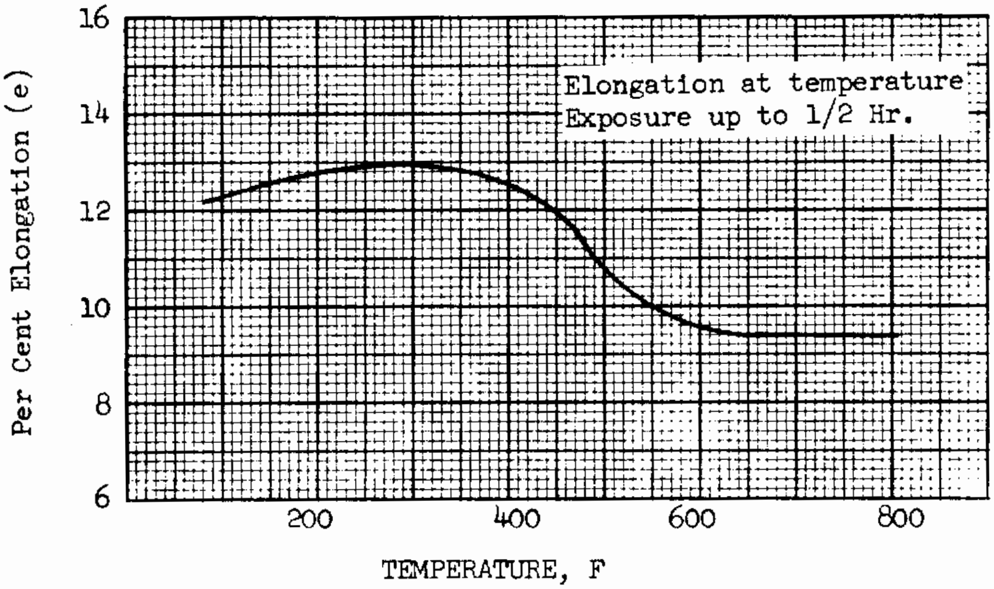


Figure 8.1.11 Effect of temperature on the elongation (e) of annealed Ti-4Al-3Mo-1V alloy sheet.

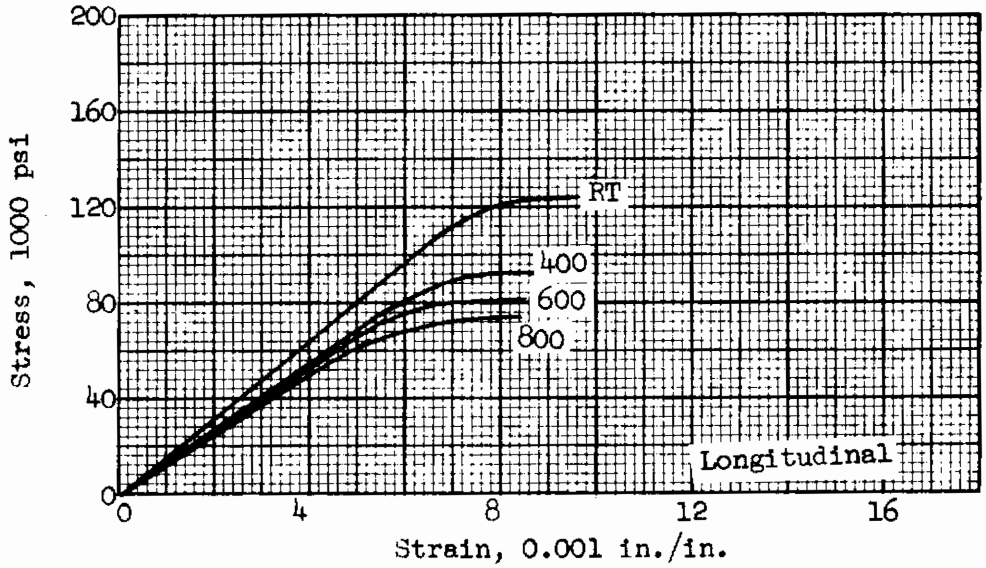


Figure 8.1.12 Typical tensile stress-strain curves for annealed Ti-4Al-3Mo-1V alloy sheet at room and elevated temperatures.

Table VIII-2

8.2 Design Mechanical and Physical Properties of Ti 13V-11Cr-3Al

Alloy	MIL-T-9046 Type IV Comp. A			
Form	Sheet and Strip			
Condition	Annealed			
Thickness or diameter, in.	≤ .110			
			Tentative	
Basis	A	B	A	B
Mechanical properties:				
F_{tu}, ksi				
L	132	134		
LT	136	139		
F_{ty}, ksi				
L	126	129		
LT	131	134		
F_{cy}, ksi				
L			119	122
LT			123	126
F_{su}, ksi			90	92
F_{bru}, ksi				
(e/D = 1.5)			207	212
(e/D = 2.0)			286	292
F_{bry}, ksi:				
(e/D = 1.5)			156	160
(e/D = 2.0)			174	178
e, per cent:				
In 2 in. L	11			
LT	7			
E, 10^6 psi	14.6			
E_c, 10^6 psi				
G, 10^6 psi				
Physical properties:				
, lb/in.^{3}				
C, Btu/(lb)(F)				
K, Btu/ (hr)(ft^2)(F)/ft				
, 10^{-6} in./in./F				

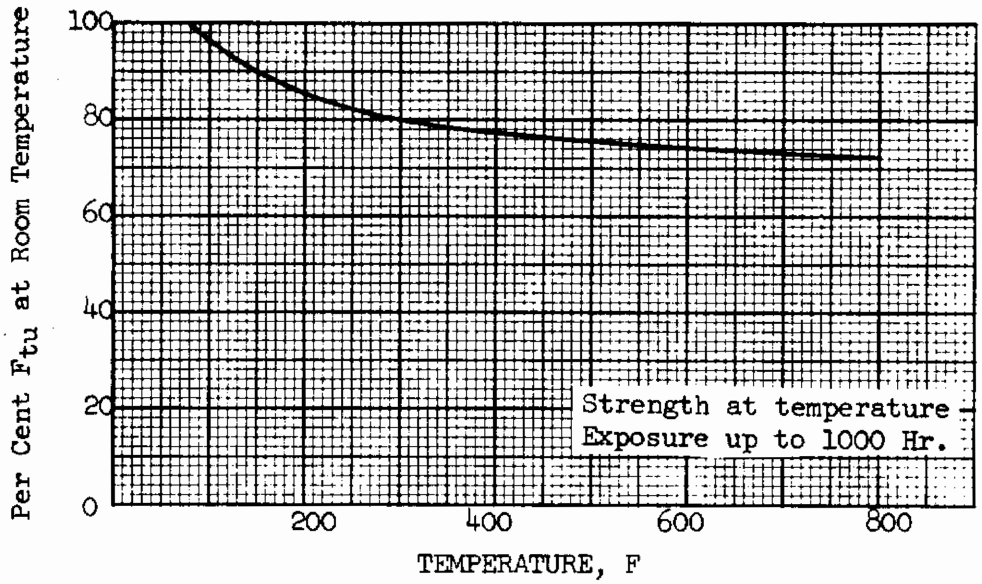


Figure 8.2.1 Effect of temperature on the ultimate tensile strength (F_{tu}) of annealed Ti-13V-11Cr-3Al alloy sheet.

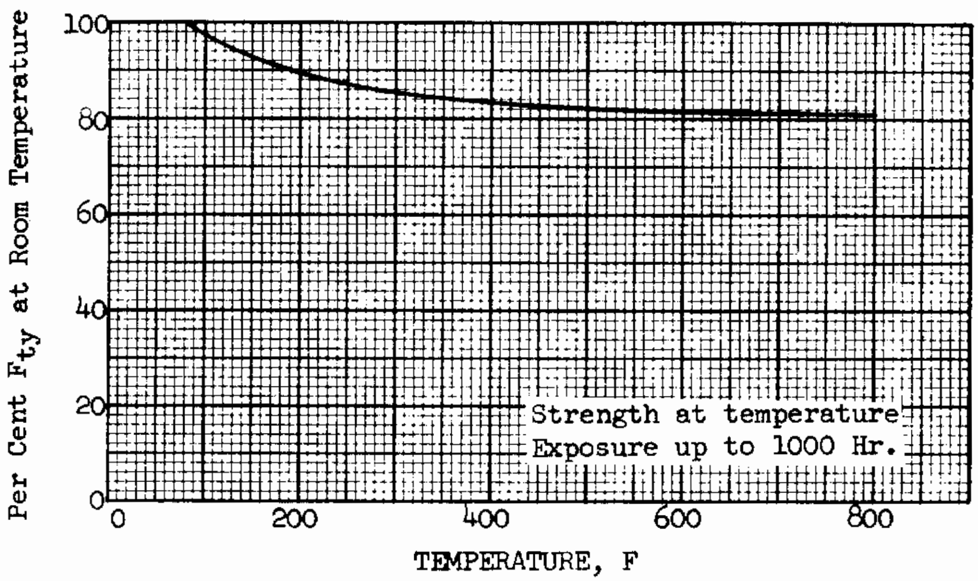


Figure 8.2.2 Effect of temperature on the tensile yield strength (F_{ty}) of annealed Ti-13V-11Cr-3Al alloy sheet.

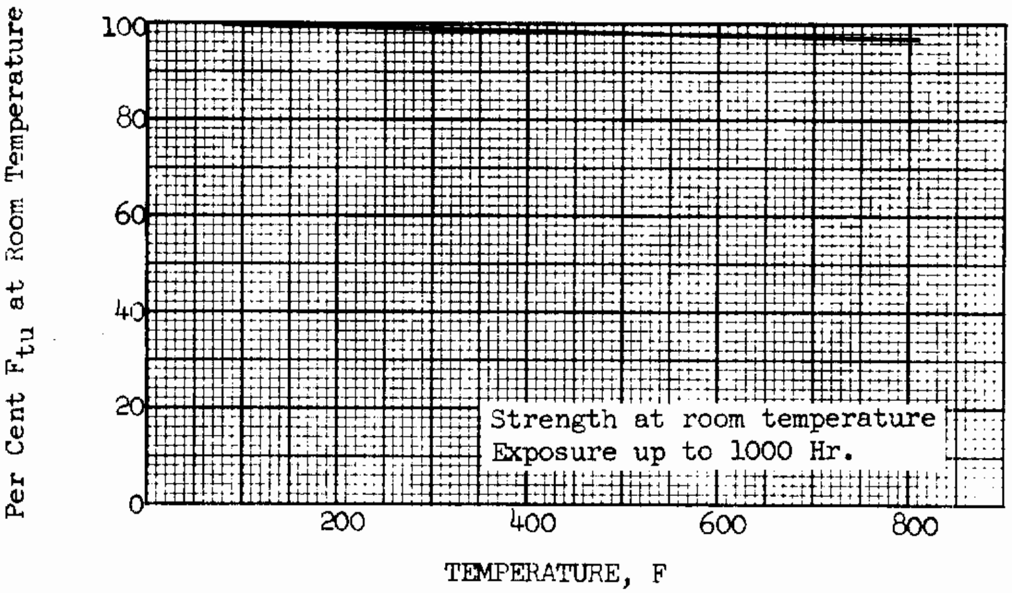


Figure 8.2.3 Effect of exposure at elevated temperature on the room-temperature ultimate tensile strength (F_{tu}) of annealed Ti-13V-11Cr-3Al alloy sheet.

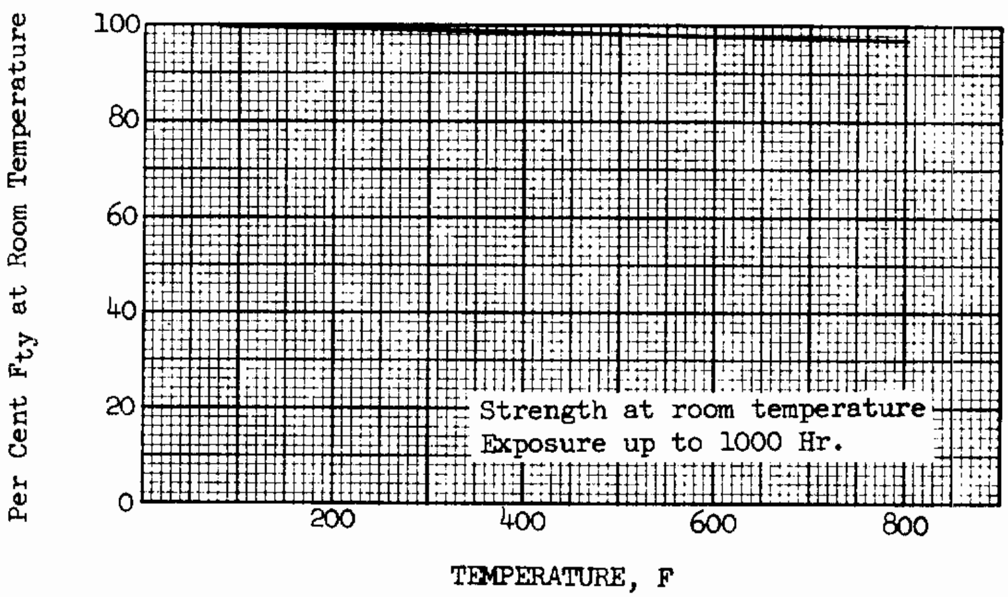


Figure 8.2.4 Effect of exposure at elevated temperature on the tensile yield strength (F_{ty}) of annealed Ti-13V-11Cr-3Al alloy sheet.

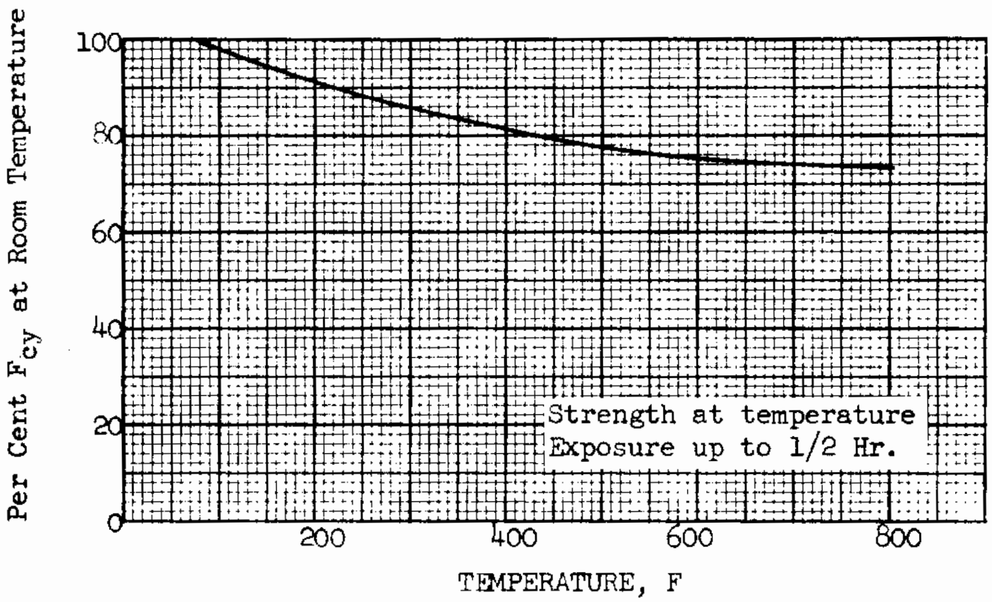


Figure 8.2.5 Effect of temperature on the compressive yield strength (F_{cy}) of annealed Ti-13V-11Cr-3Al alloy sheet.

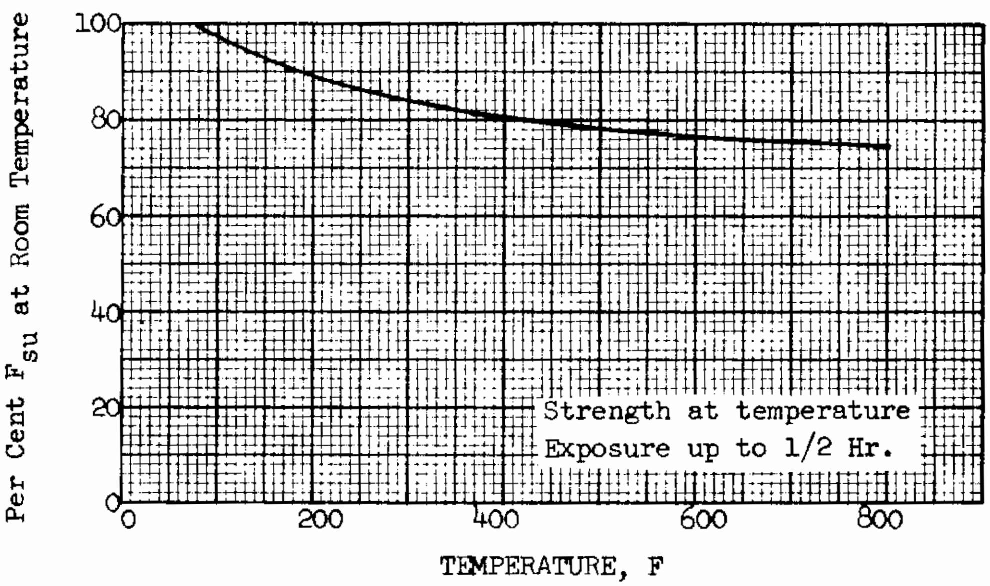


Figure 8.2.6 Effect of temperature on the ultimate shear strength (F_{su}) of annealed Ti-13V-11Cr-3Al alloy sheet.

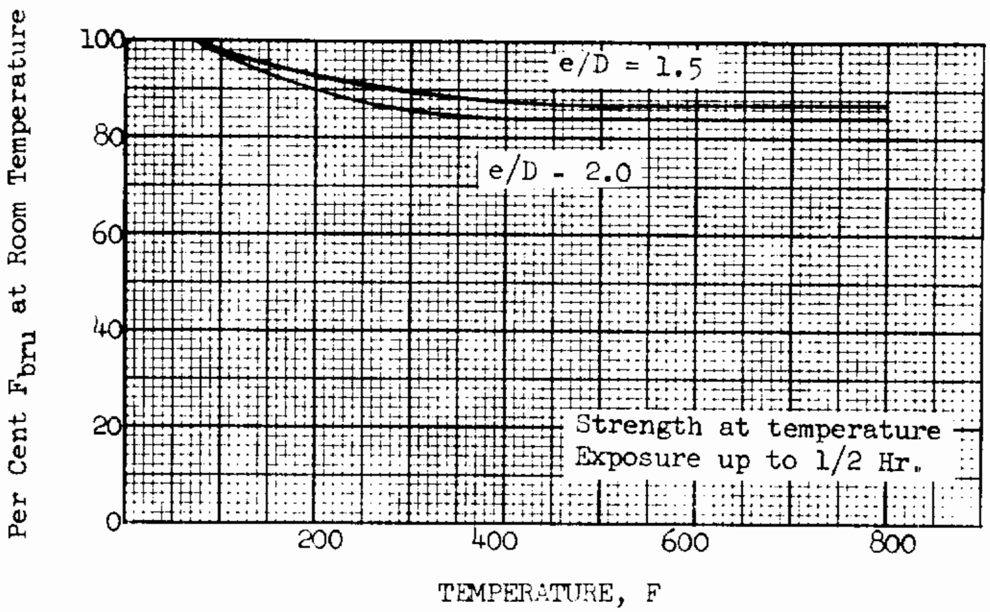


Figure 8.2.7 Effect of temperature on the ultimate bearing strength (F_{bru}) of annealed Ti-13V-11Cr-3Al alloy sheet

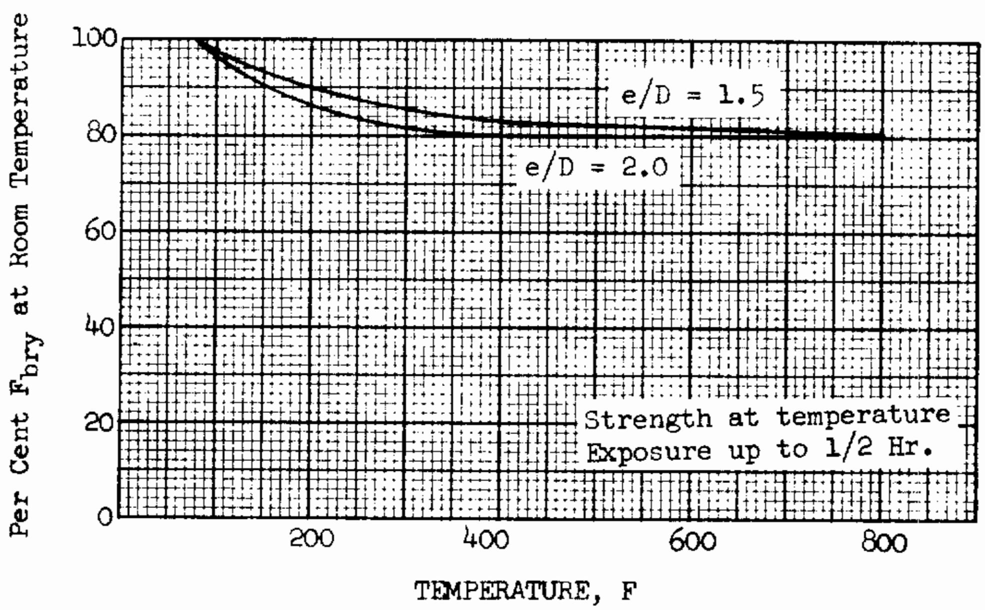


Figure 8.2.8 Effect of temperature on the bearing yield strength (F_{bry}) of annealed Ti-13V-11Cr-3Al alloy sheet.

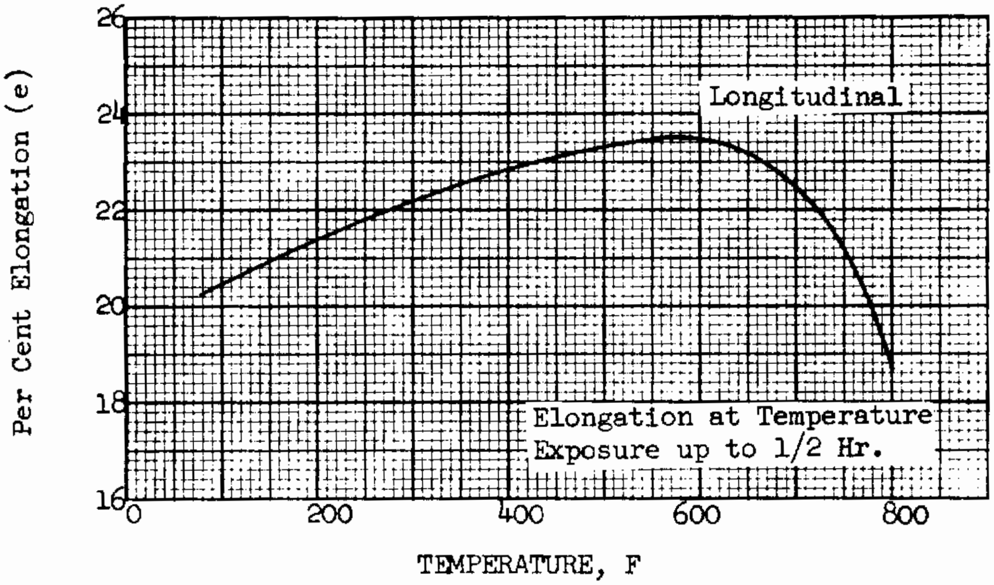


Figure 8.2.9 Effect of temperature on the elongation (e) of annealed Ti-13V-11Cr-3Al alloy sheet.

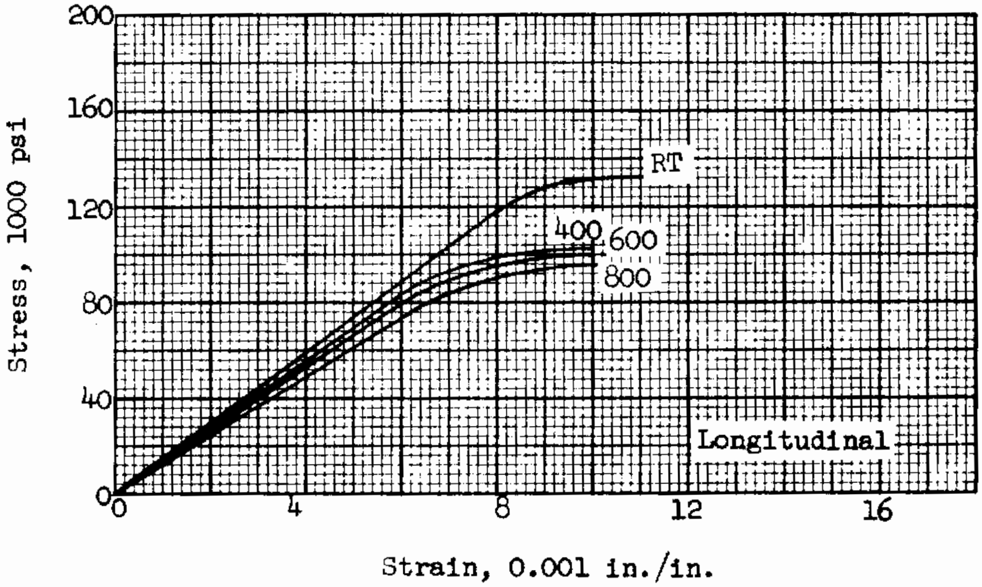


Figure 8.2.10 Typical tensile stress-strain curves for annealed Ti-13V-11Cr-3Al alloy sheet at room and elevated temperatures.

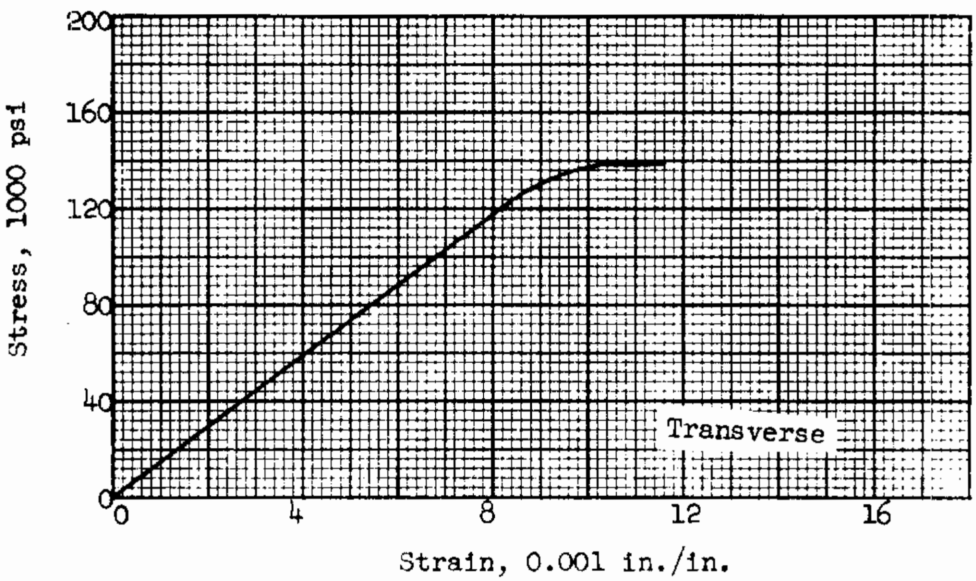


Figure 8.2.11 Typical tensile stress-strain curve for annealed Ti-13V-11Cr-3Al alloy sheet at room temperature.

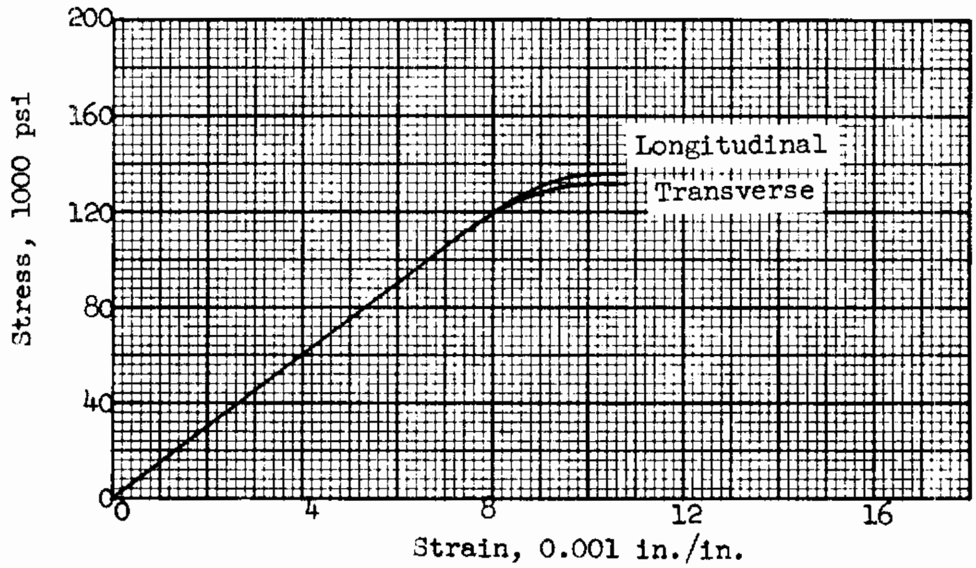


Figure 8.2.12 Typical compressive stress-strain curve for annealed Ti-13V-11Cr-3Al alloy sheet at room temperature.

Table VIII-3

8.3 **Design Mechanical and Physical Properties of** Ti-6Al-4V

Alloy	MIL-T-9046 Type III Comp. C	
Form	Plate	
Condition	Solution Treated and Aged	
Thickness or diameter, in.	.188 to .750	.751 to 1.000
Basis	S	S
Mechanical properties:		
F_{tu}, ksi		
L	160	150
LT		
F_{ty}, ksi		
L	145	140
LT		
F_{cy}, ksi		
L		
LT		
F_{su}, ksi		
F_{bru}, ksi		
(e/D = 1.5)		
(e/D = 2.0)		
F_{bry}, ksi:		
(e/D = 1.5)		
(e/D = 2.0)		
e, per cent:		
In 2 in.		
In 4 D	8	6
E, 10^6 psi	16.2	
E_c, 10^6 psi		
G, 10^6 psi		
Physical properties:		
, lb/in.^{3}		
C, Btu/(lb)(F)		
K, Btu/ (hr)(ft^2)(F)/ft		
, 10^{-6} in./in./F		

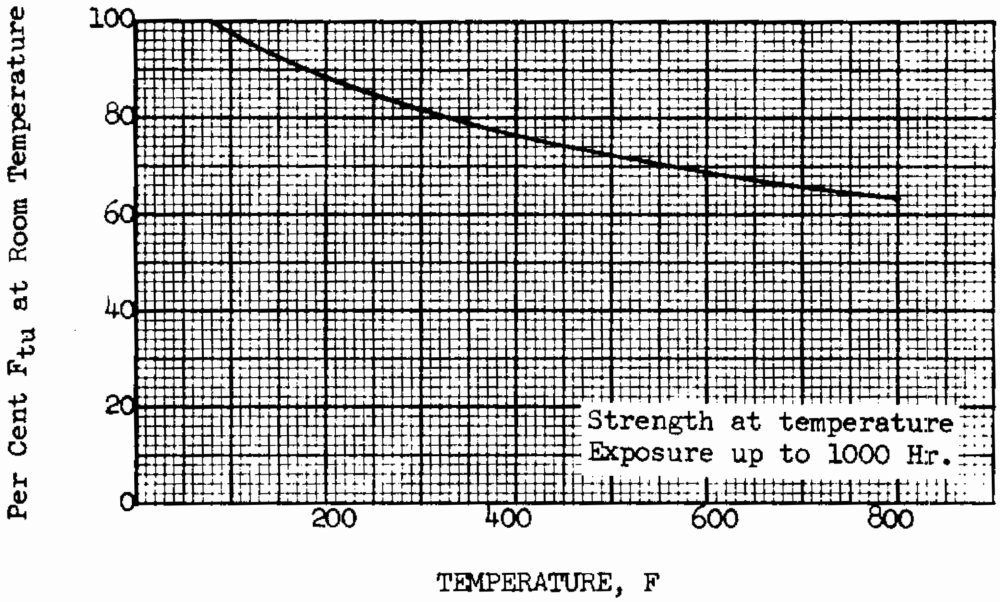


Figure 8.3.1 Effect of temperature on the ultimate tensile strength (F_{tu}) of solution treated and aged Ti-6Al-4V alloy plate.

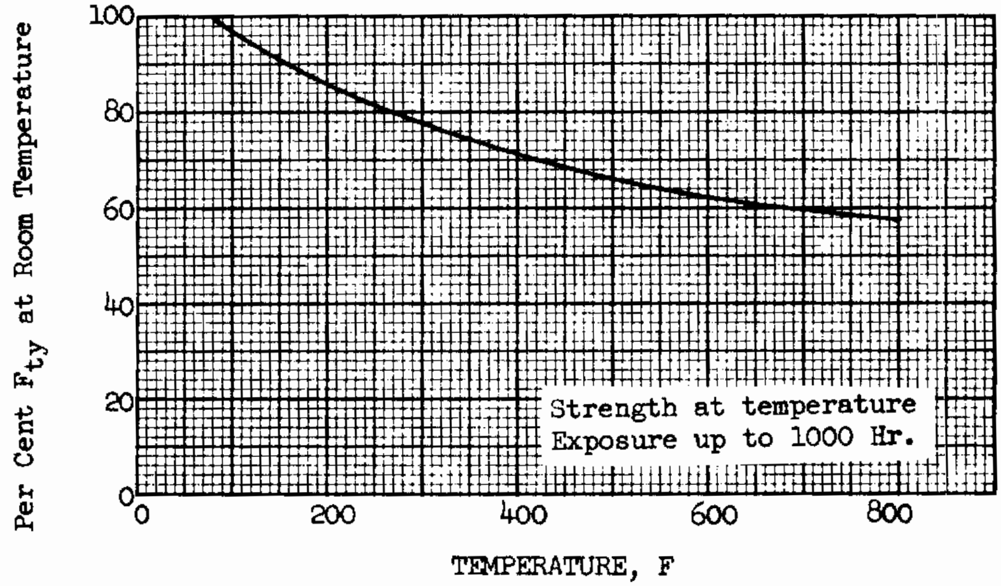


Figure 8.3.2 Effect of temperature on the tensile yield strength (F_{ty}) of solution treated and aged Ti-6Al-4V alloy plate.

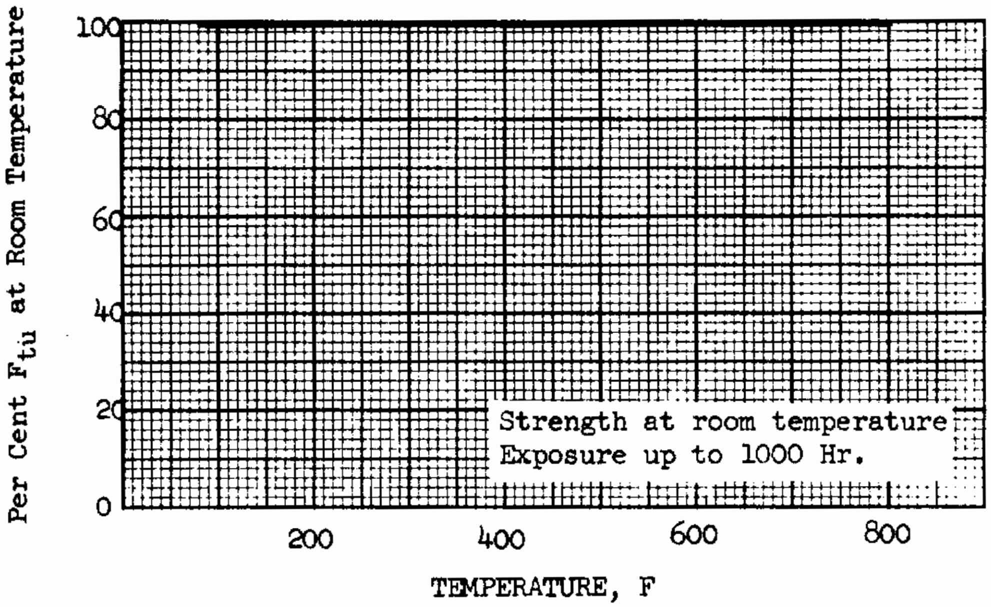


Figure 8.3.3 Effect of exposure at elevated temperature on the room temperature ultimate tensile strength (F_{tu}) of solution treated and aged Ti-6Al-4V alloy plate.

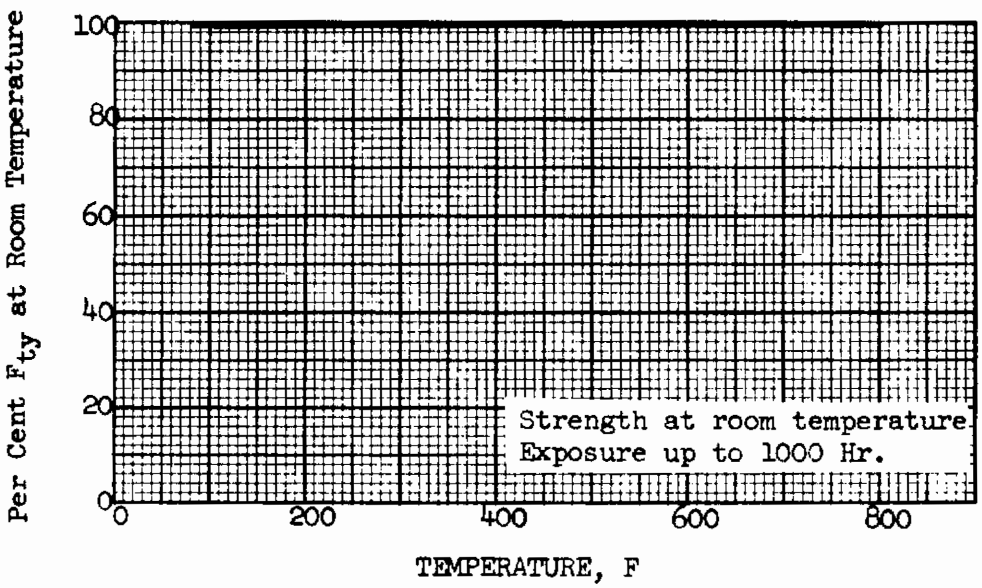


Figure 8.3.4 Effect of exposure at elevated temperature on the room temperature tensile yield strength (F_{ty}) of solution treated and aged Ti-6Al-4V alloy plate.

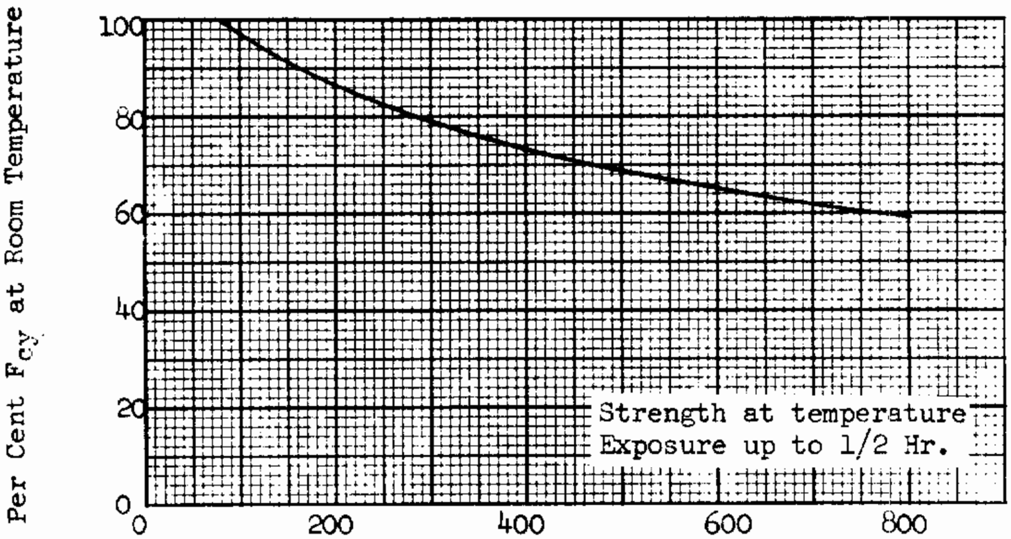


Figure 8.3.5 Effect of temperature on the compressive yield strength (F_{cy}) of solution treated and aged Ti-6Al-4V alloy plate.

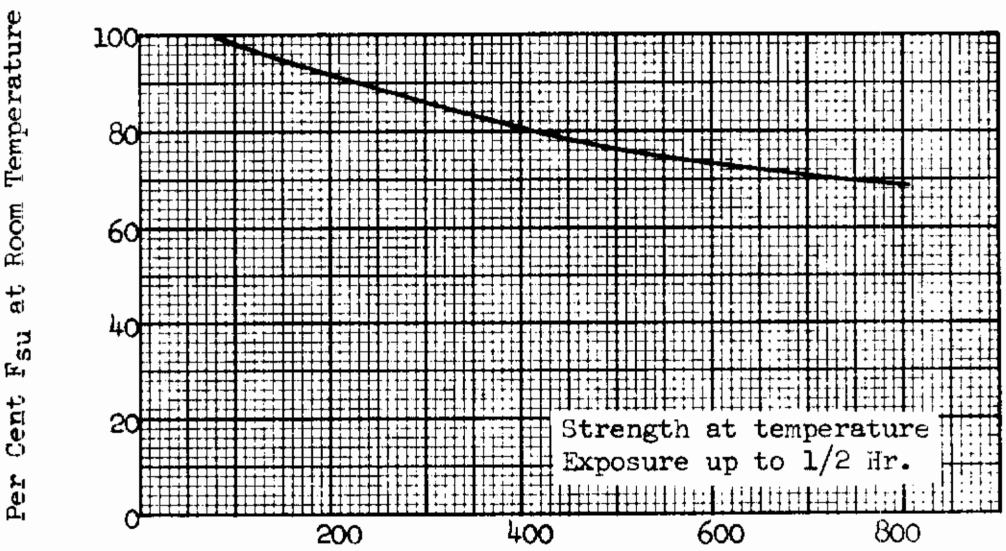


Figure 8.3.6 Effect of temperature on the ultimate shear strength (F_{su}) of solution treated and aged Ti-6Al-4V alloy plate.

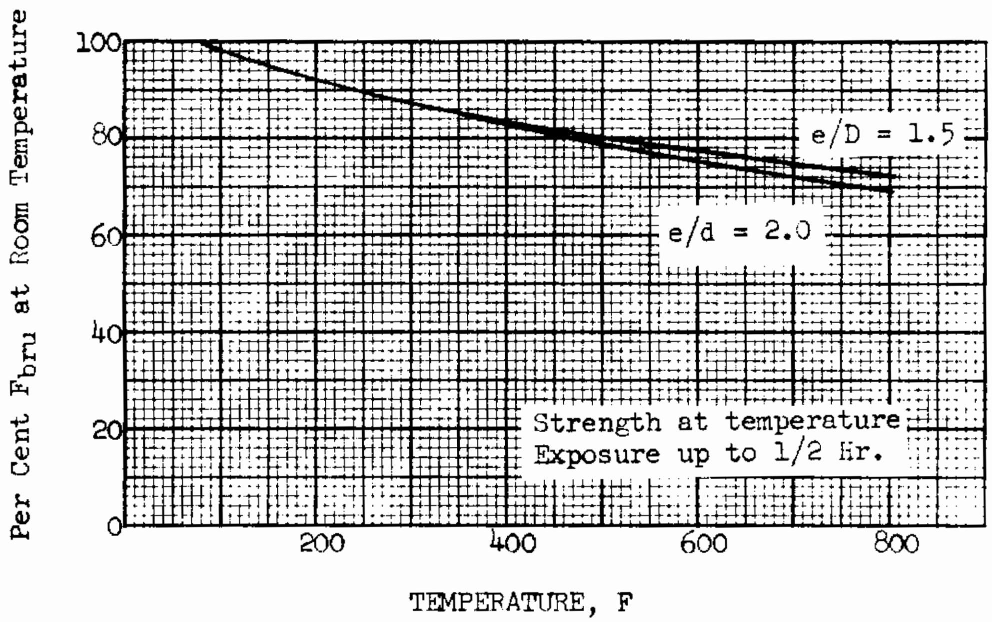


Figure 8.3.7 Effect of temperature on the ultimate bearing strength (F_{bru}) of solution treated and aged Ti-6Al-4V alloy plate.

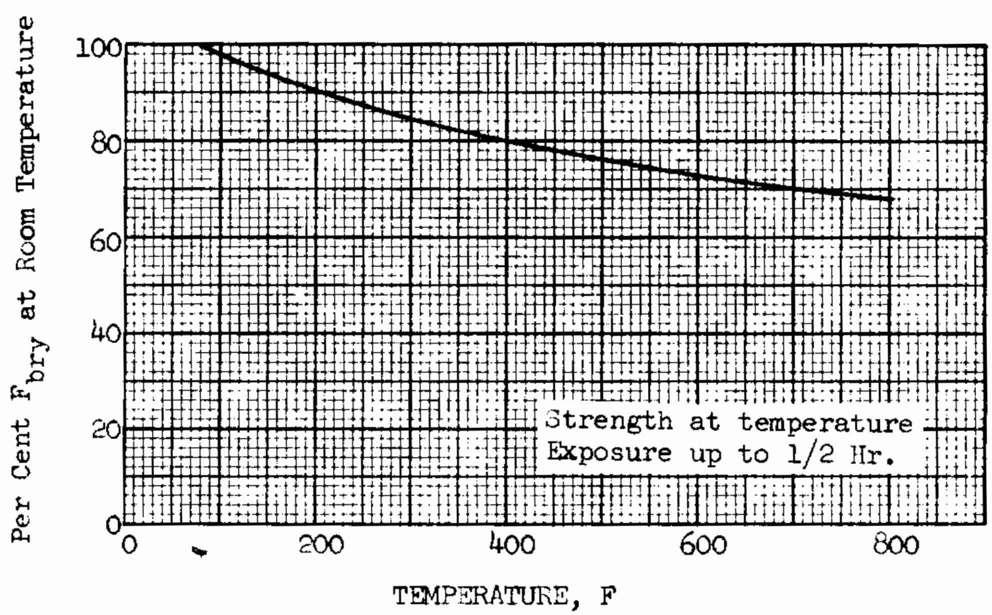


Figure 8.3.8 Effect of temperature on the bearing yield strength (F_{bry}) of solution treated and aged Ti-6Al-4V alloy plate.

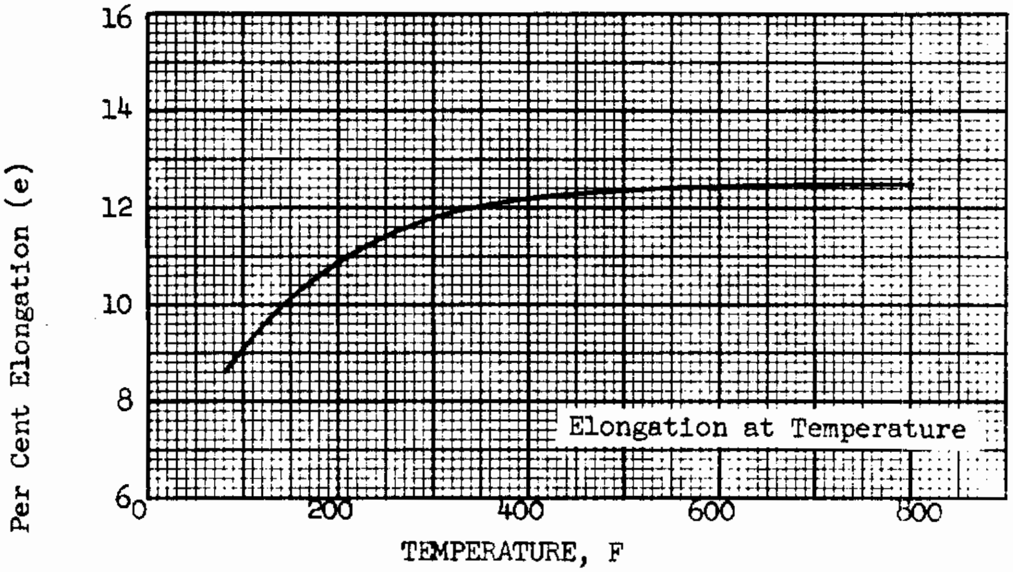


Figure 8.3.9 Effect of temperature on the elongation (e) of solution treated and aged Ti-6Al-4V alloy plate

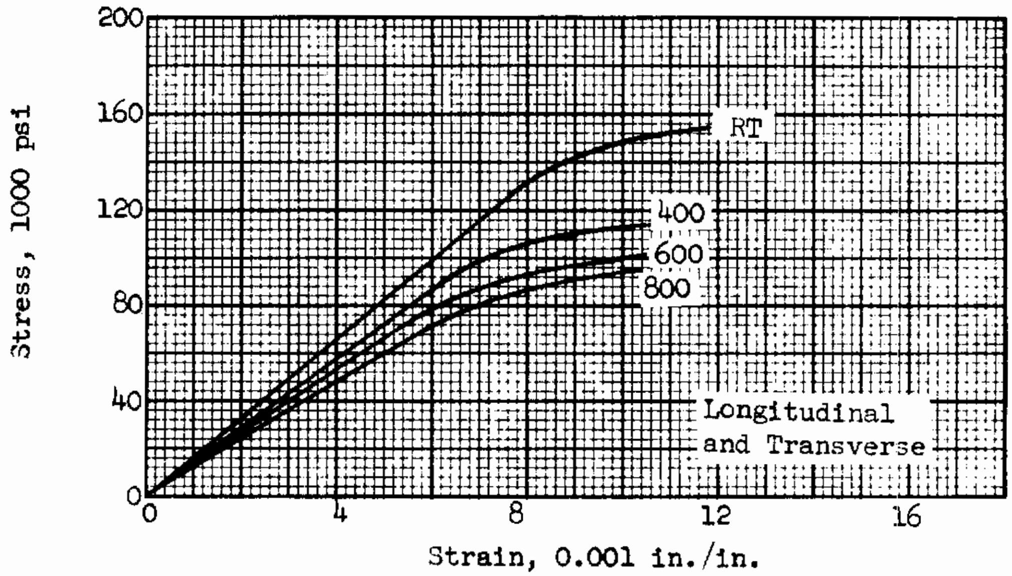


Figure 8.3.10 Typical tensile stress-strain curves for solution treated and aged Ti-6Al-4V alloy plate ate room and elevated temperatures

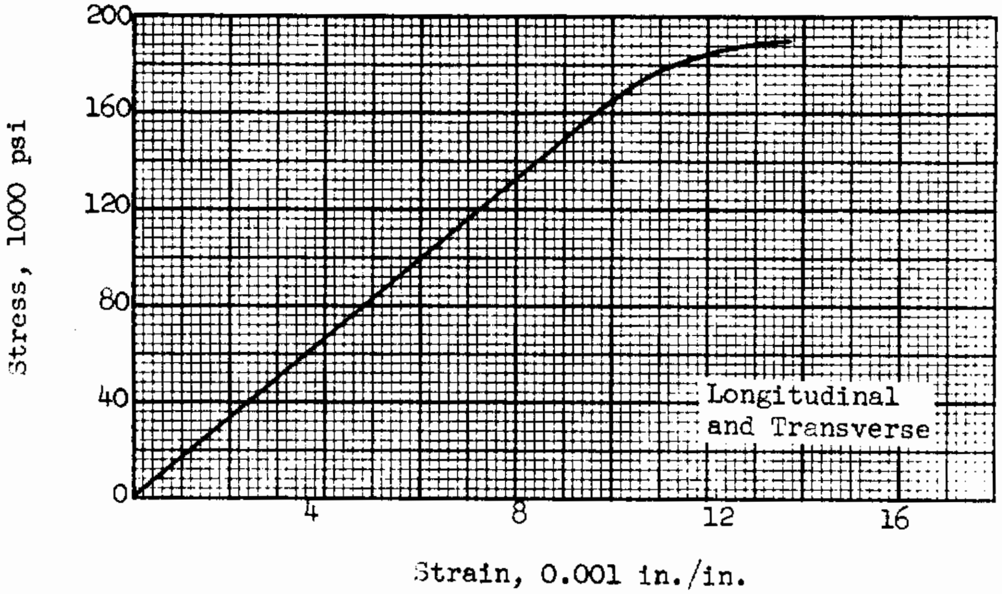


Figure 8.3.11 Typical compressive stress-strain curve for solution treated and aged Ti-6Al-4V alloy plate at room temperature.

Table VIII-4

8.4 **Design Mechanical and Physical Properties of Ti-6Al-6V-2Sn**

Alloy	MIL-T-9046 Type III Comp. E		
Form	Plate		
Condition	Annealed		
Thickness or diameter, in.	.250 to .300	.500 to .630	1.50
Basis	S	S	S
Mechanical properties:			
F_{tu}, ksi	150	150	150
L			
LT			
F_{ty}, ksi	140	140	140
L			
LT			
F_{cy}, ksi	141	147	142
L			
LT			
F_{su}, ksi	90	92	95
F_{bru}, ksi			
(e/D = 1.5)	234	251	249
(e/D = 2.0)	275	301	310
F_{bry}, ksi:			
(e/D = 1.5)	195	201	198
(e/D = 2.0)	212	223	237
e, per cent:			
In 2 in.	10		
In 4 D		10	10
E, 10^6 psi		15.6	
E_c, 10^6 psi			
G, 10^6 psi			
Physical properties:			
, lb/in.^{3}			
C, Btu/(lb)(F)			
K, Btu/ (hr)(ft^2)(F)/ft			
, 10^{-6} in./in./F			

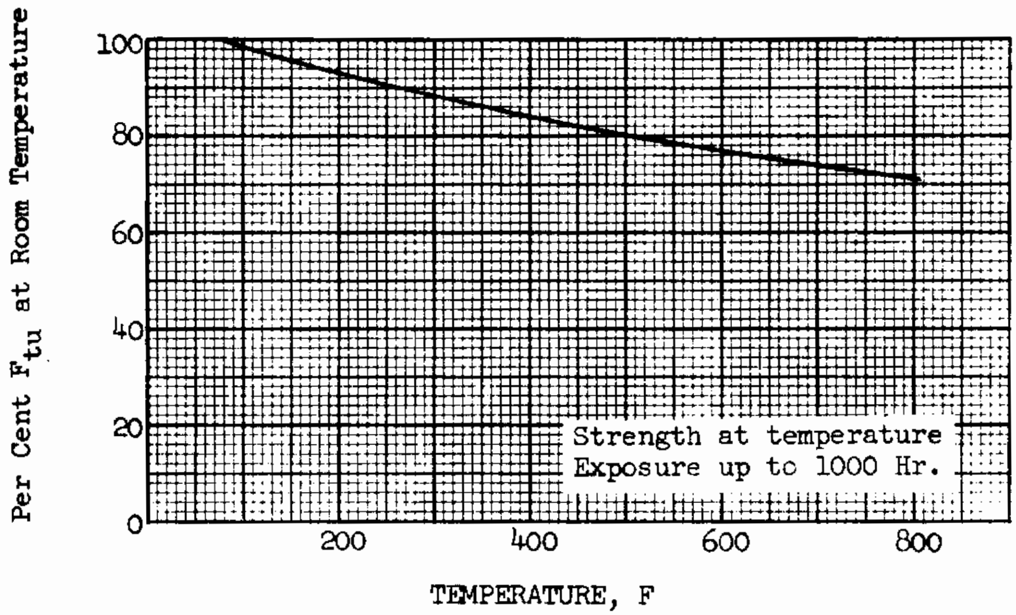


Figure 8.4.1 Effect of temperature on the ultimate tensile strength (F_{tu}) of annealed Ti-6Al-6V-2Sn alloy plate.

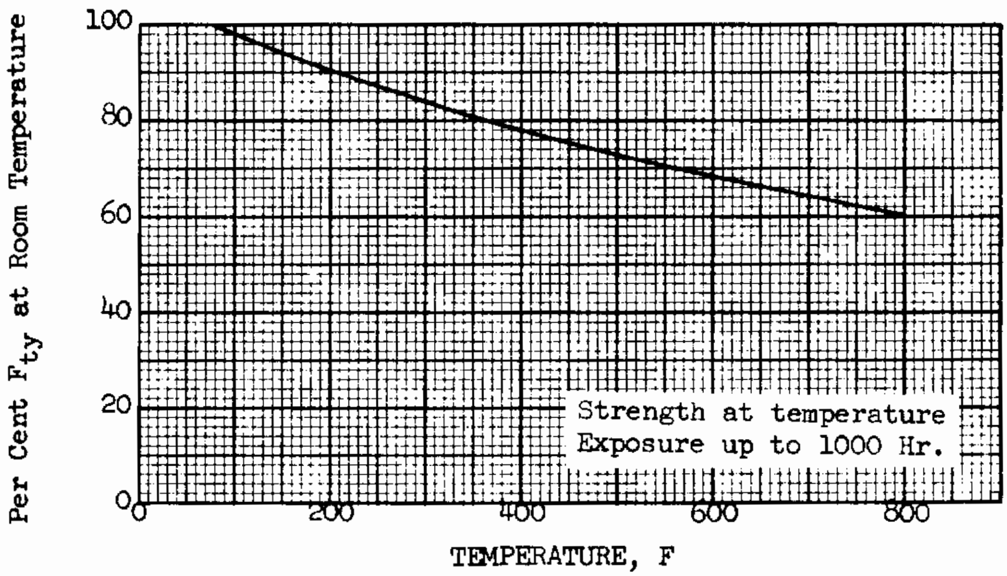


Figure 8.4.2 Effect of temperature on the tensile yield strength (F_{ty}) of annealed Ti-6Al-6V-2Sn alloy plate.

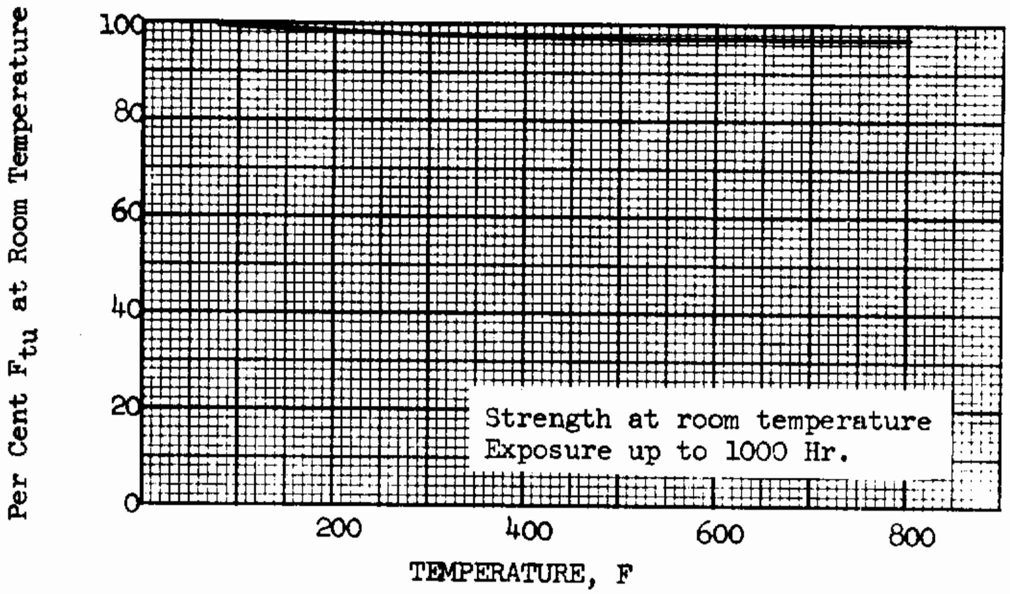


Figure 8.4.3 Effect of exposure at elevated temperature on the room-temperature ultimate tensile strength (F_{tu}) of annealed Ti-6Al-6V-2Sn alloy plate.

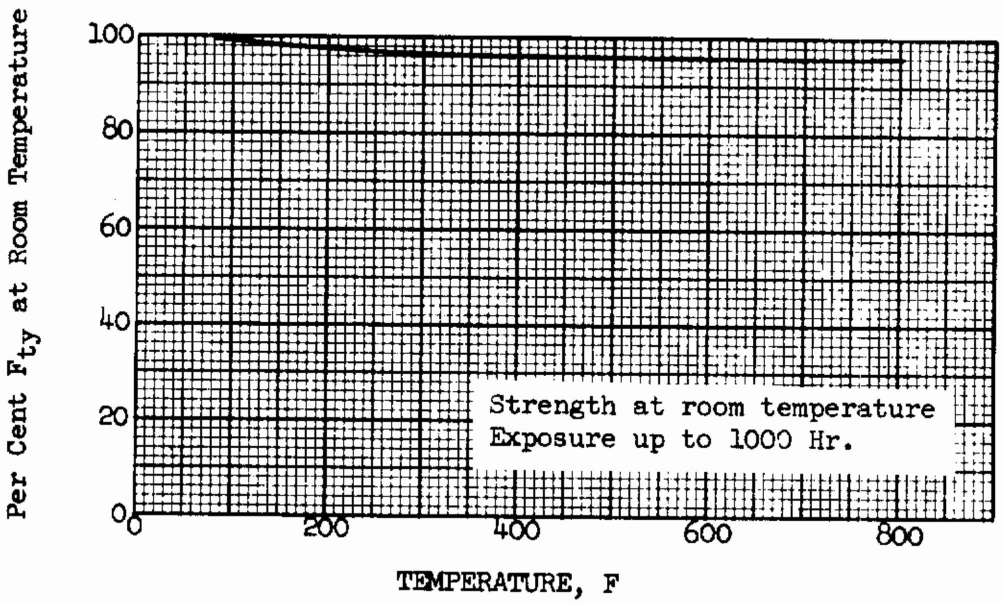


Figure 8.4.4 Effect of exposure at elevated temperature on the room temperature tensile yield strength (F_{ty}) of annealed Ti-6Al-6V-2Sn alloy plate.

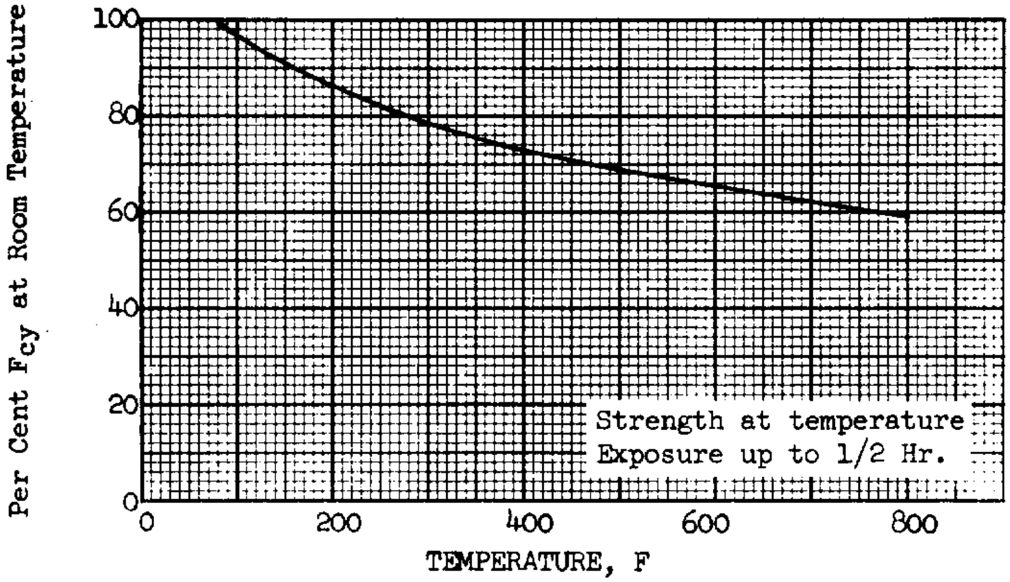


Figure 8.4.5 Effect of temperature on the compressive yield strength (F_{cy}) of annealed Ti-6Al-6V-2Sn alloy plate.

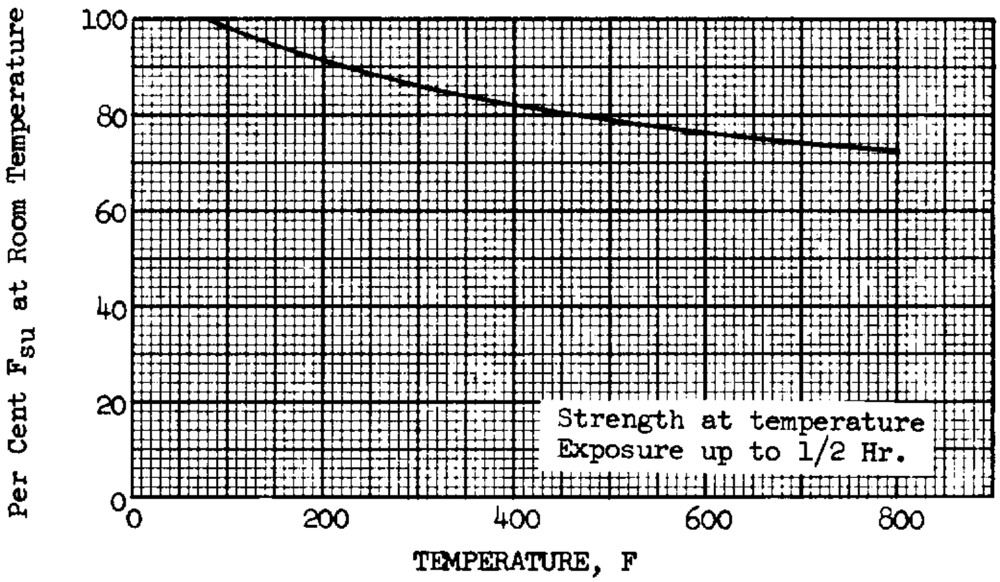


Figure 8.4.6 Effect of temperature on the ultimate shear strength (F_{su}) of annealed Ti-6Al-6V-2Sn alloy plate.

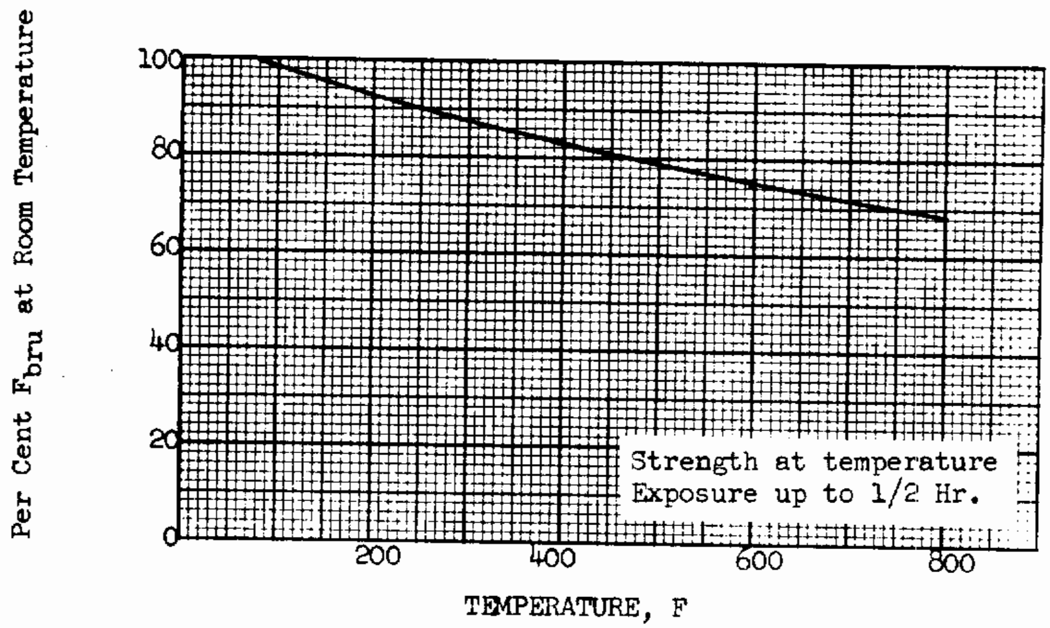


Figure 8.4.7 Effect of temperature on the ultimate bearing strength (F_{bru}) of annealed Ti-6Al-6V-2Sn alloy plate.

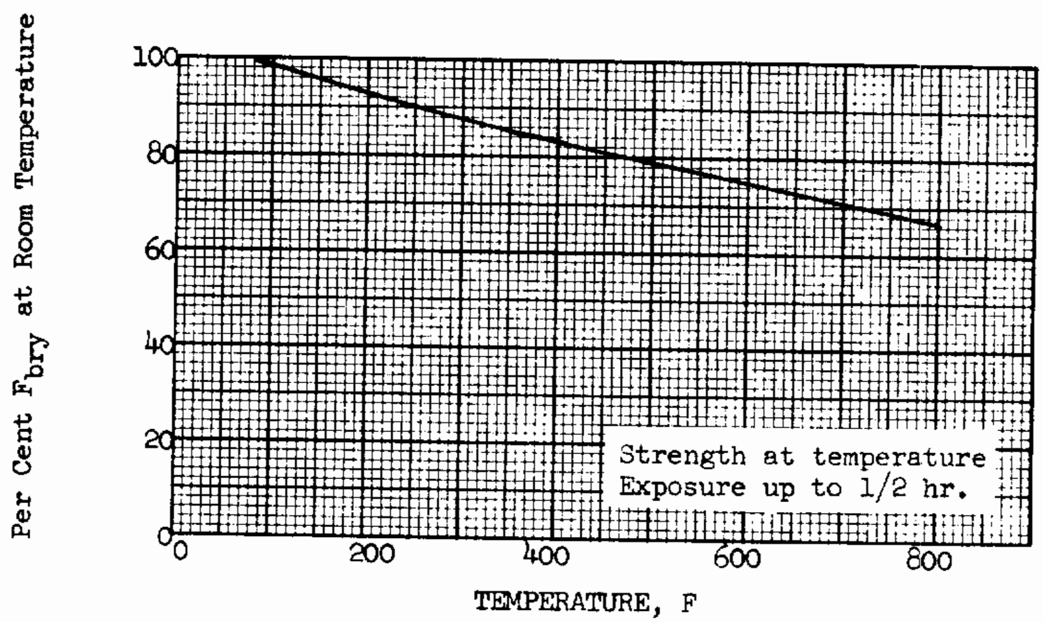


Figure 8.4.8 Effect of temperature on the bearing yield strength (F_{bry}) of annealed Ti-6Al-6V-2Sn alloy plate.

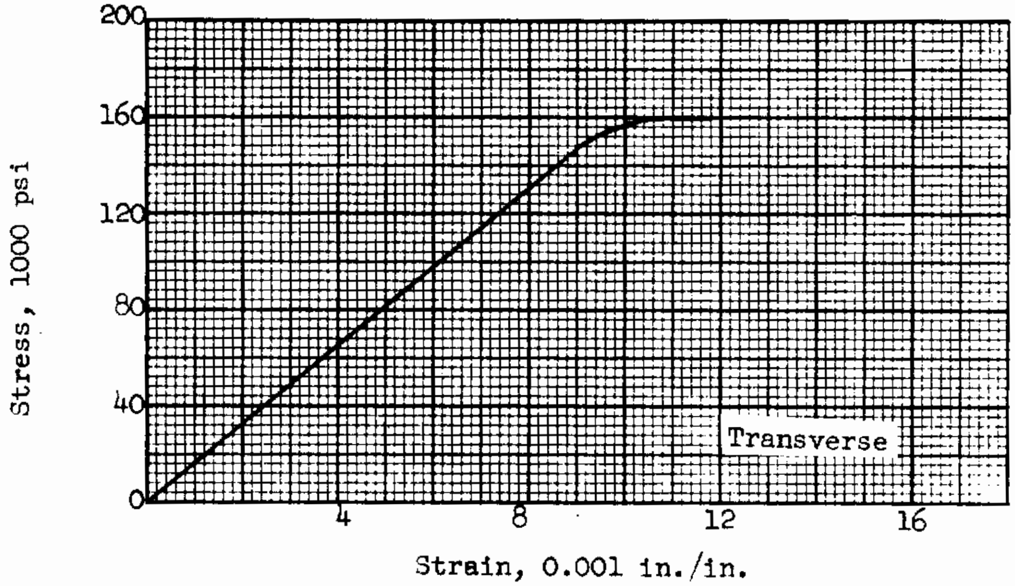


Figure 8.4.9 Typical tensile stress-strain curve for annealed Ti-6Al-6V-2Sn alloy plate at room temperature.

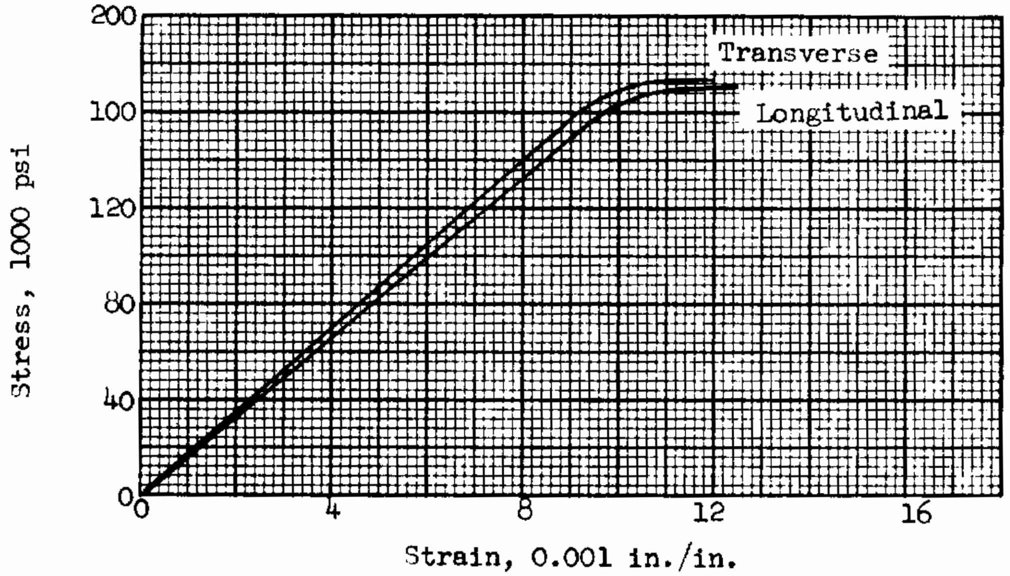


Figure 8.4.10 Typical compressive stress-strain curves for annealed Ti-6Al-6V-2Sn alloy plate at room temperature.

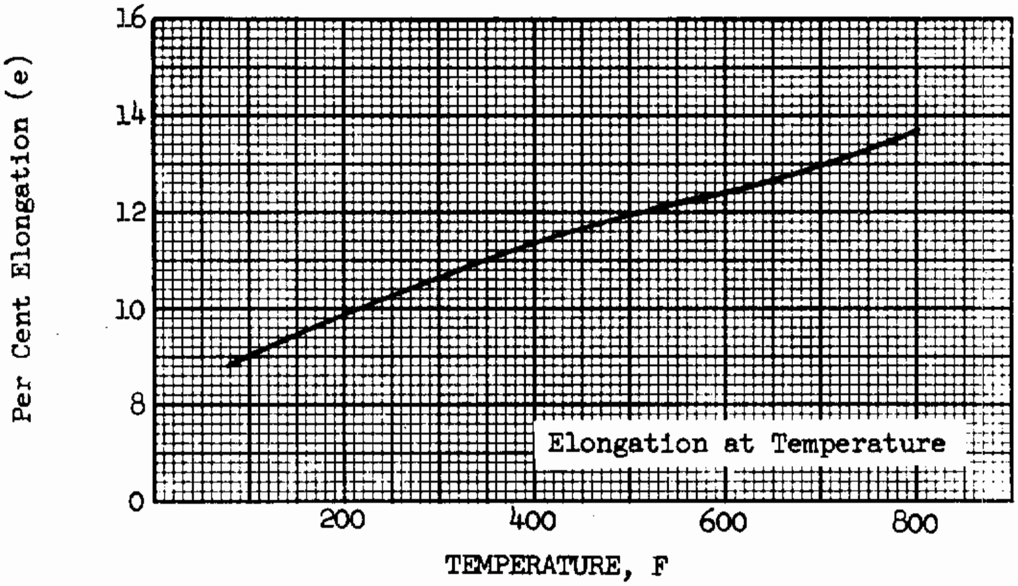


Figure 8.4.11 Effect of temperature on the elongation (e) of annealed Ti-6Al-6V-2Sn alloy plate.

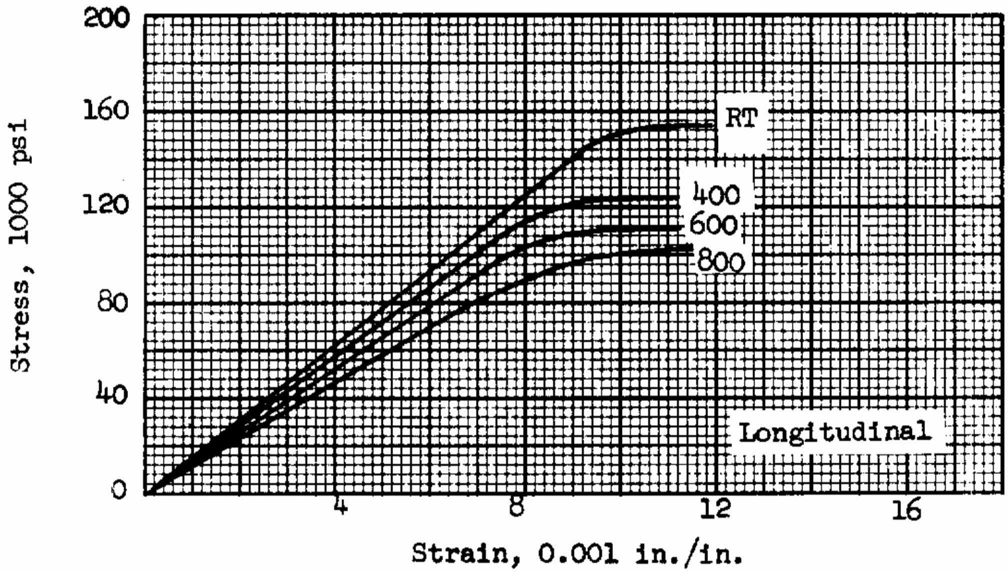


Figure 8.4.12 Typical tensile stress-strain curves for annealed Ti-6Al-6V-2Sn alloy plate at room and elevated temperatures.

8.5 Design Mechanical and Physical Properties of Ti-6Al-6V-2Sn

Alloy	MIL-T-9046 Type III Comp. E	
Form	Plate	
Condition	Solution Treated and Aged	
Thickness or diameter, in.	.500 to .630	1.50
Basis	S	S
Mechanical properties:		
F_{tu}, ksi	170	160
L		
LT		
F_{ty}, ksi	160	150
L		
LT		
F_{cy}, ksi	167	156
L		
LT		
F_{su}, ksi	98	94
F_{bru}, ksi		
(e/D = 1.5)	260	242
(e/D = 2.0)	325	290
F_{bry}, ksi:		
(e/D = 1.5)	232	220
(e/D = 2.0)	268	238
e, per cent:		
In 2 in.		
In 4 D	8	6
E, 10^6 psi	16.1	
E_c, 10^6 psi		
G, 10^6 psi		
Physical properties:		
, lb/in.^{3}		
C, Btu/(lb)(F)		
K, Btu/ (hr)(ft^2)(F)/ft		
, 10^{-6} in./in./F		

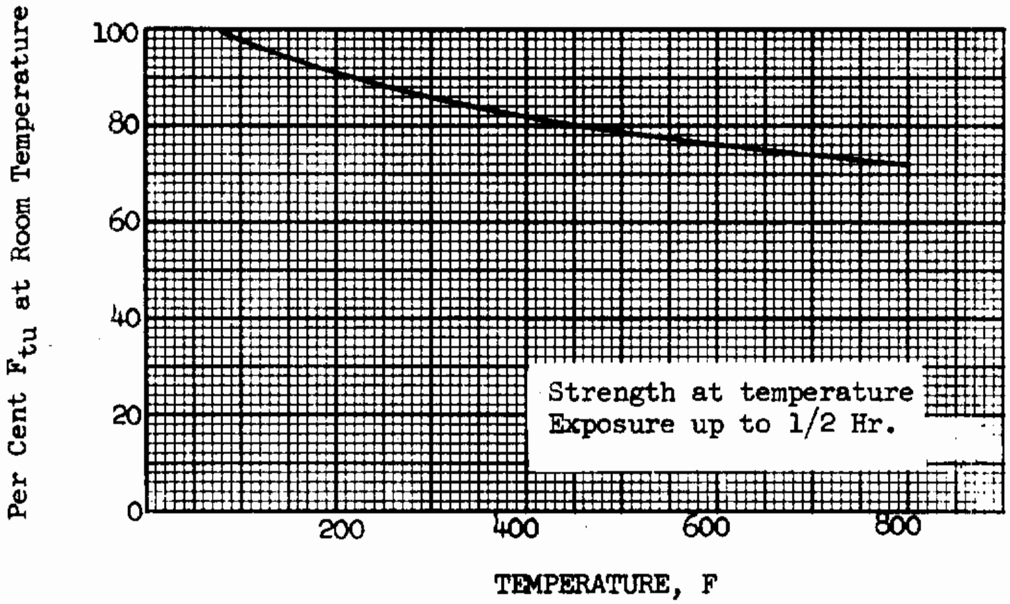


Figure 8.5.1 Effect of temperature on the ultimate tensile strength (F_{tu}) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

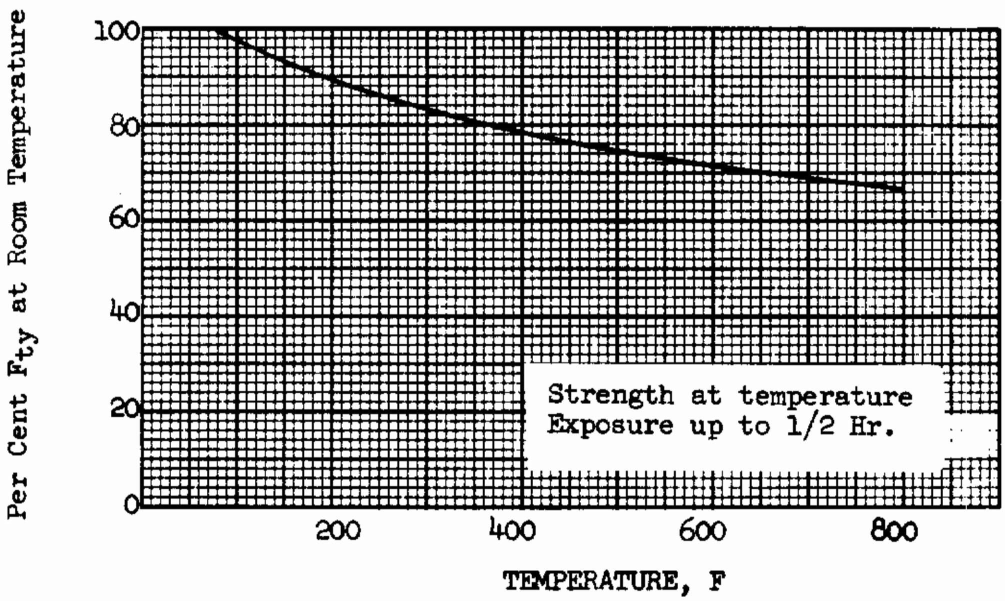


Figure 8.5.2 Effect of temperature on the tensile yield strength (F_{ty}) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

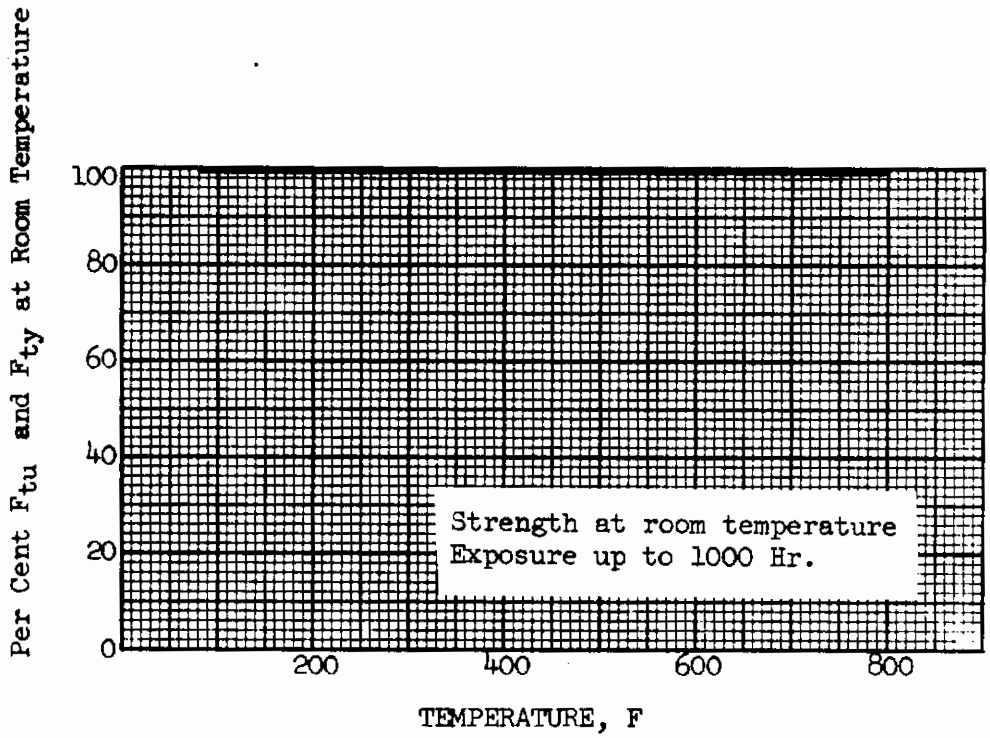


Figure 8.5.3 Effect of exposure at elevated temperature on the room temperature tensile yield and ultimate strength (F_{ty} and F_{tu}) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

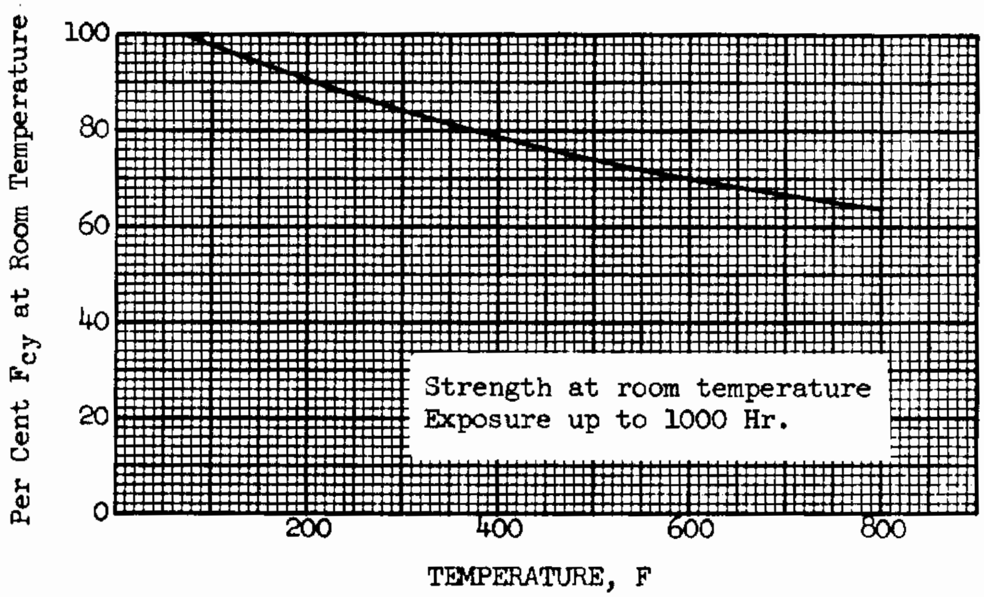


Figure 8.5.4 Effect of temperature on the compressive yield strength (F_{cy}) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

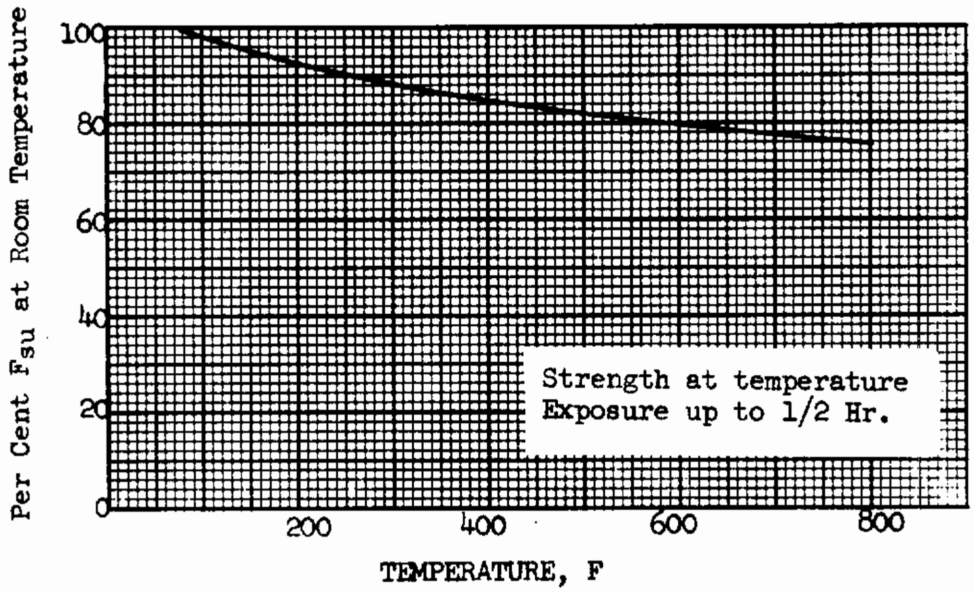


Figure 8.5.5 Effect of temperature on the ultimate shear strength (F_{su}) of solution treated and aged Ti-6Al-6V-2Sn

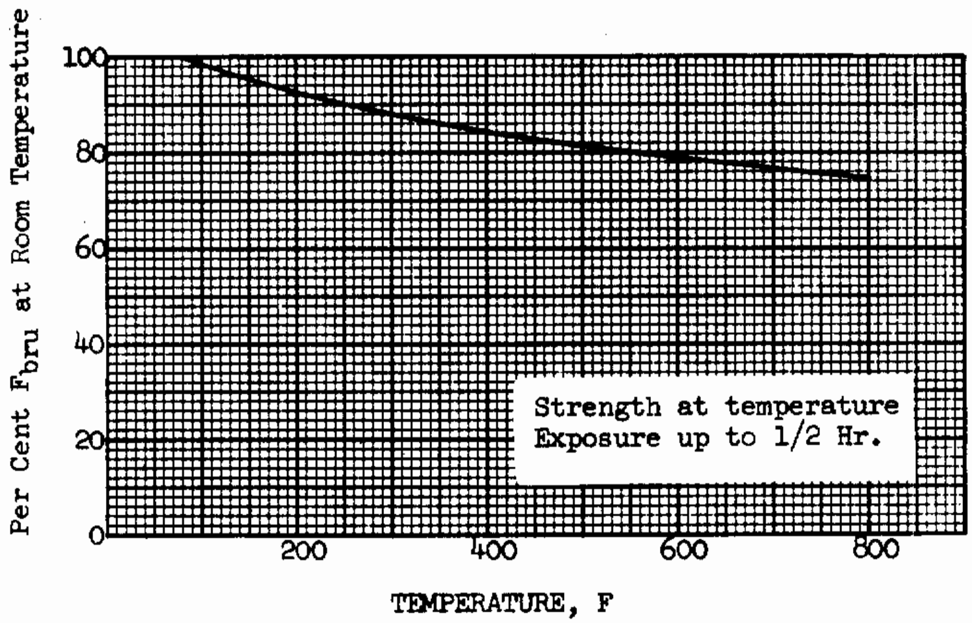


Figure 8.5.6 Effect of temperature on the ultimate bearing strength (F_{bru}) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

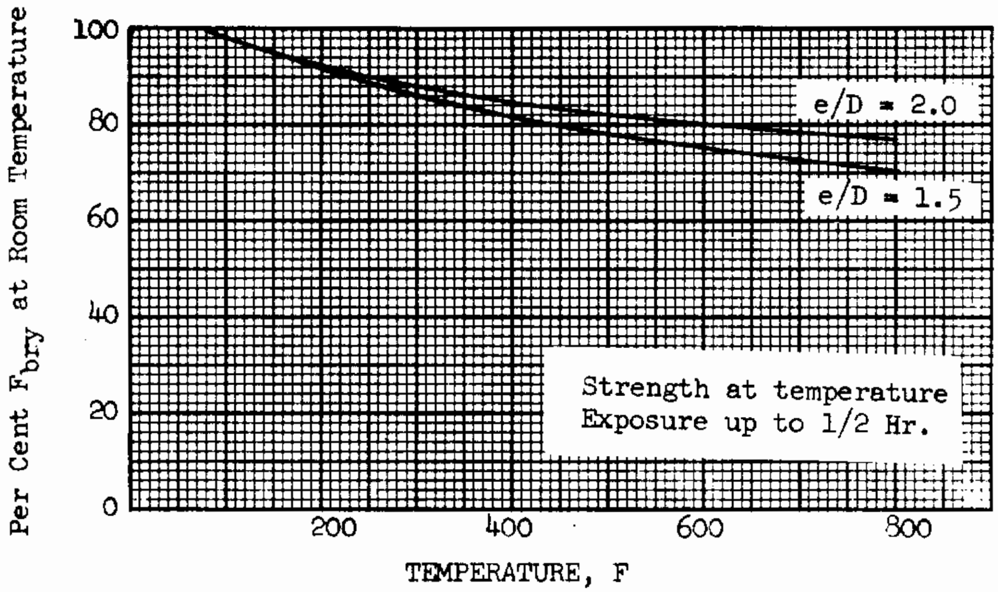


Figure 8.5.7 Effect of temperature on the bearing yield strength (F_{bry}) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

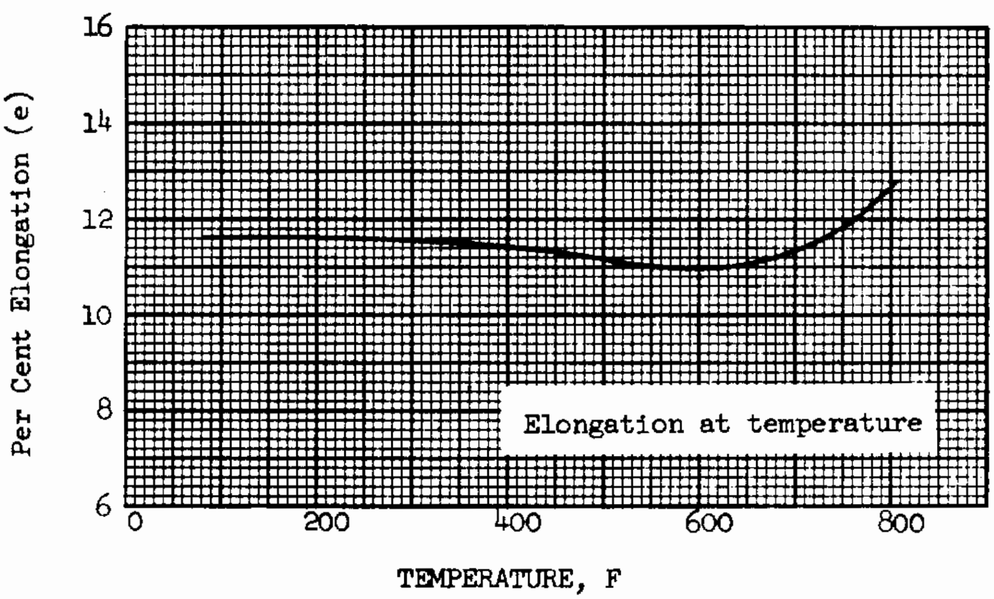


Figure 8.5.8 Effect of temperature on the elongation (e) of solution treated and aged Ti-6Al-6V-2Sn alloy plate.

SECTION IX - REFERENCES

1. AFML-TR-65-213, "Development of Standardized Test Methods to Determine Plane Strain Fracture Toughness", G. L. Hanna and E. A. Steigerwald.

2. ASTM STP 410, "Plane Strain Crack Toughness Testing of High Strength Metallic Materials", W. F. Brown Jr., and J. E. Srawley.

APPENDIX

Contained within this Appendix are the; (1) Mechanical property working curves, and, (2) Fatigue S-N curves.

A. WORKING CURVES

1.1 Ti-4Al-3Mo-1V Cond. A Figures 1.1.1 to 1.1.13

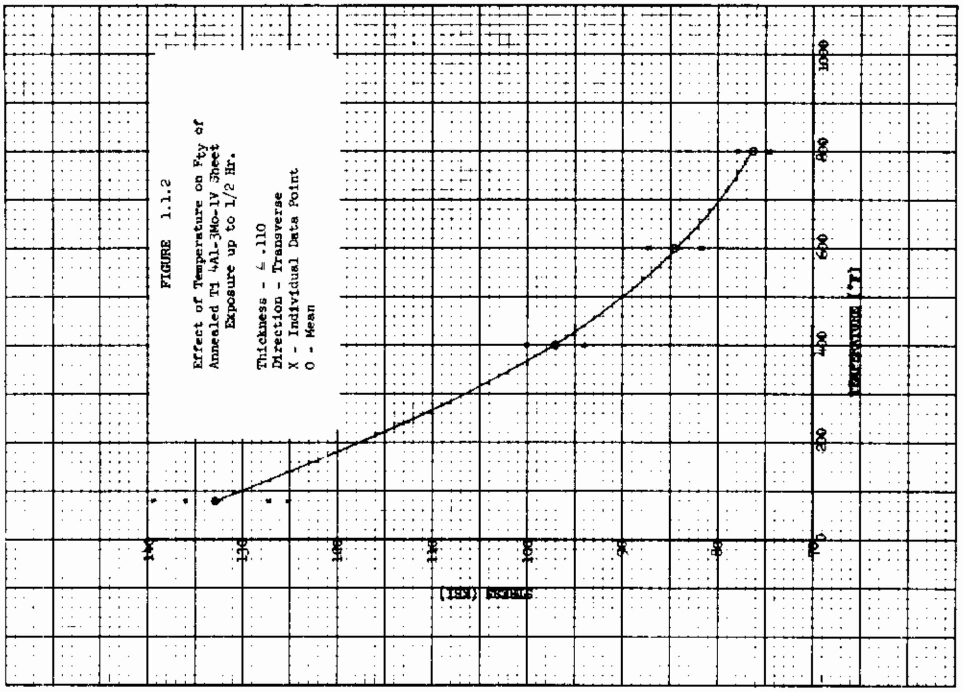


FIGURE 1.1.2
Effect of Temperature on Fty of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.
Thickness - ≤ .110
Direction - Transverse
X - Individual Data Point
O - Mean
STRESS (KSI)
TEMPERATURE (°F)
140
130
120
110
100
90
80
70
0
200
400
600
800
1000

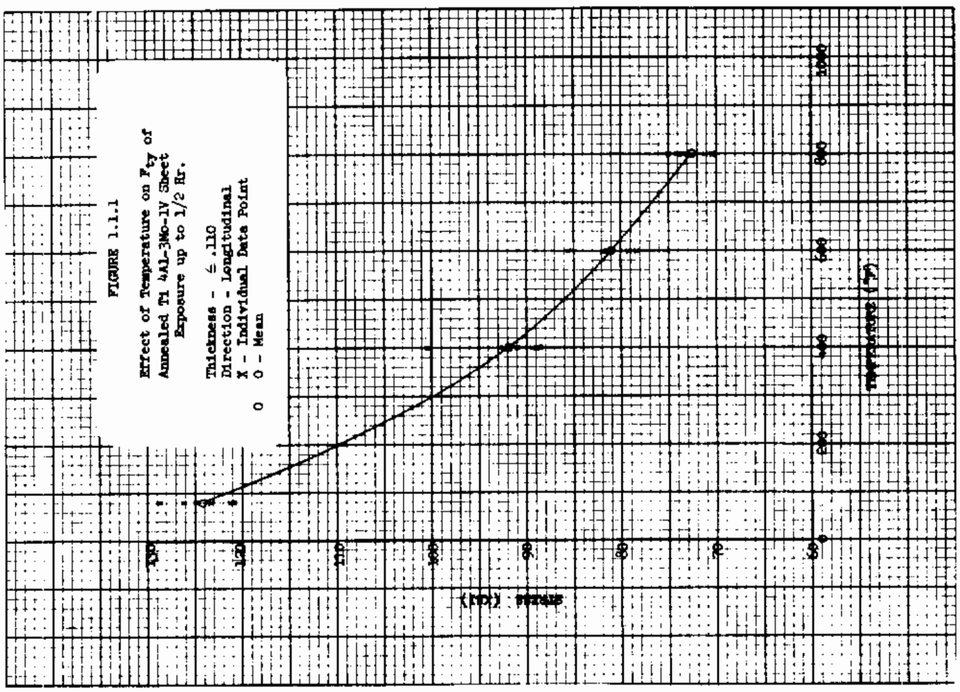


FIGURE 1.1.1
Effect of Temperature on F_{ty} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.
Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
O - Mean
STRESS (KSI)
TEMPERATURE (°F)
130
120
110
100
90
80
70
60
0
200
400
600
800
1000

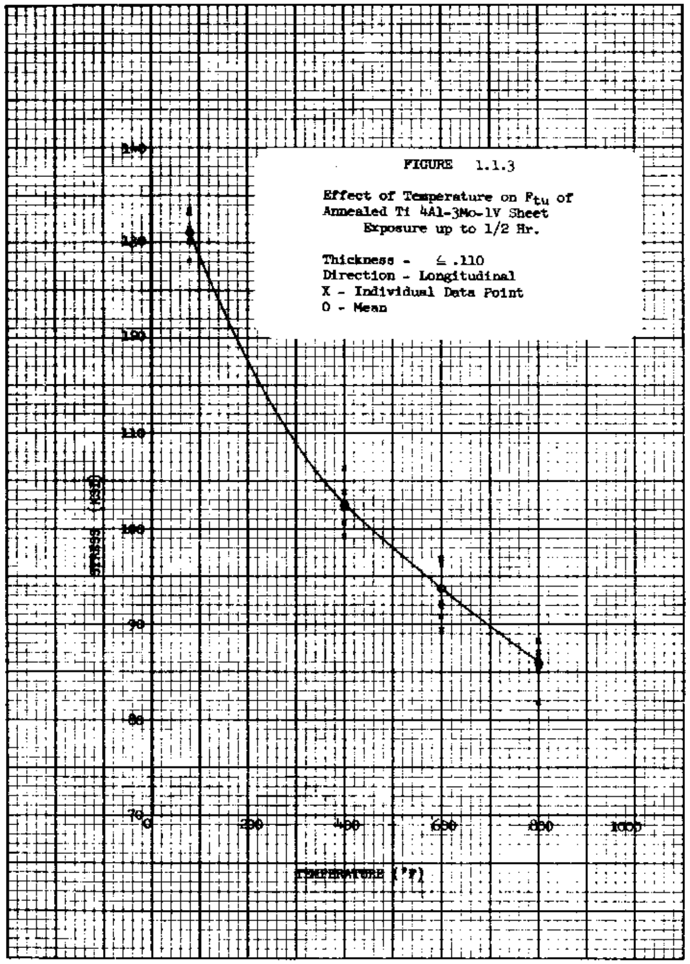


FIGURE 1.1.3

Effect of Temperature on F_{tu} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
O - Mean

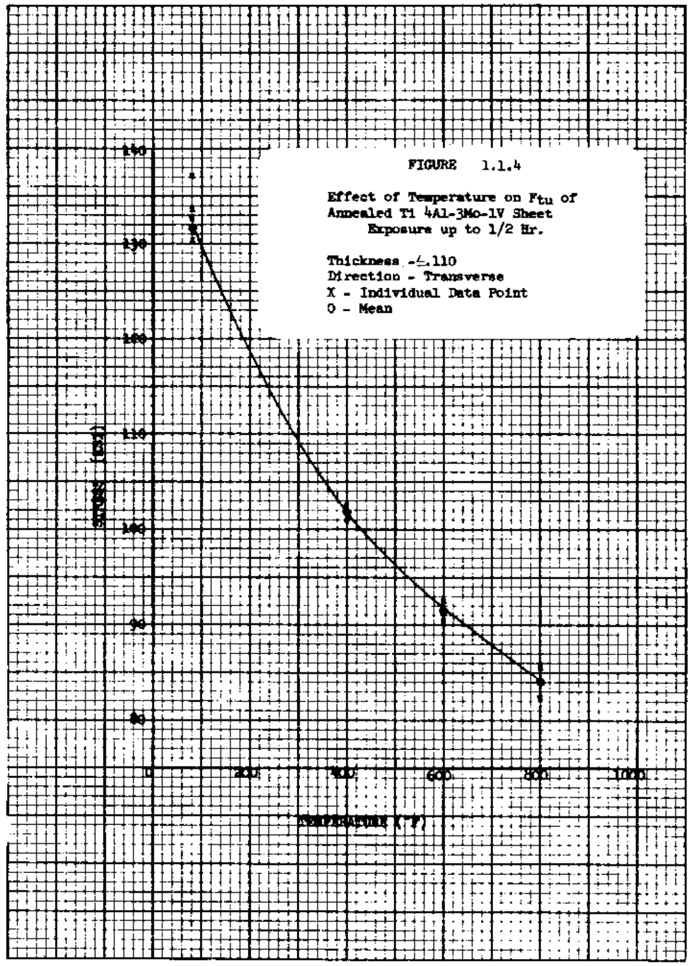


FIGURE 1.1.4

Effect of Temperature on F_{tu} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Transverse
X - Individual Data Point
O - Mean

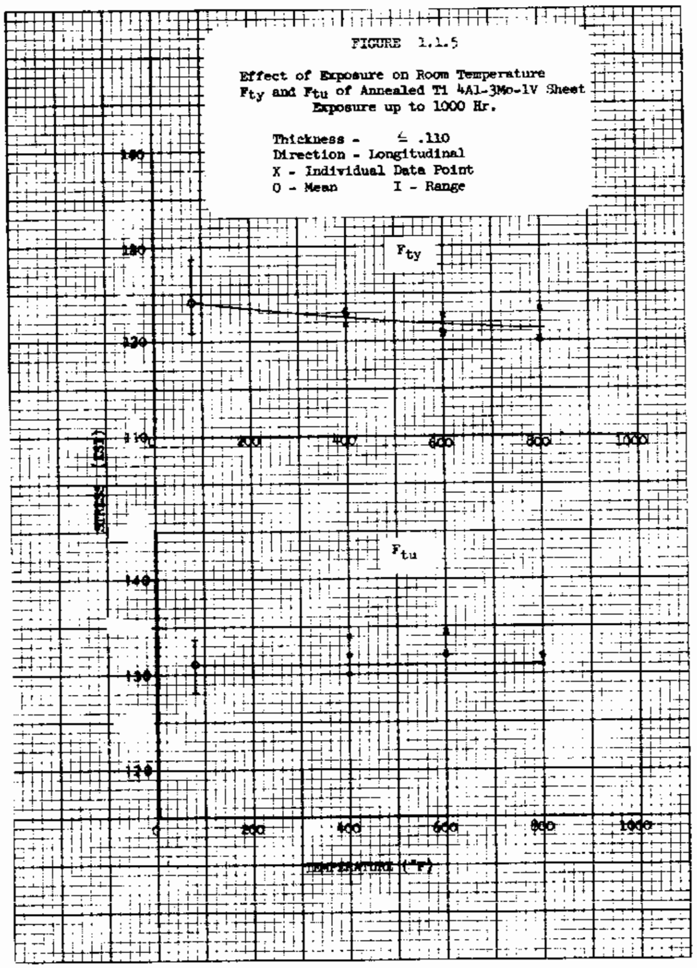


FIGURE 1.1.5

Effect of Exposure on Room Temperature F_{ty} and F_{tu} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1000 Hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
O - Mean I - Range

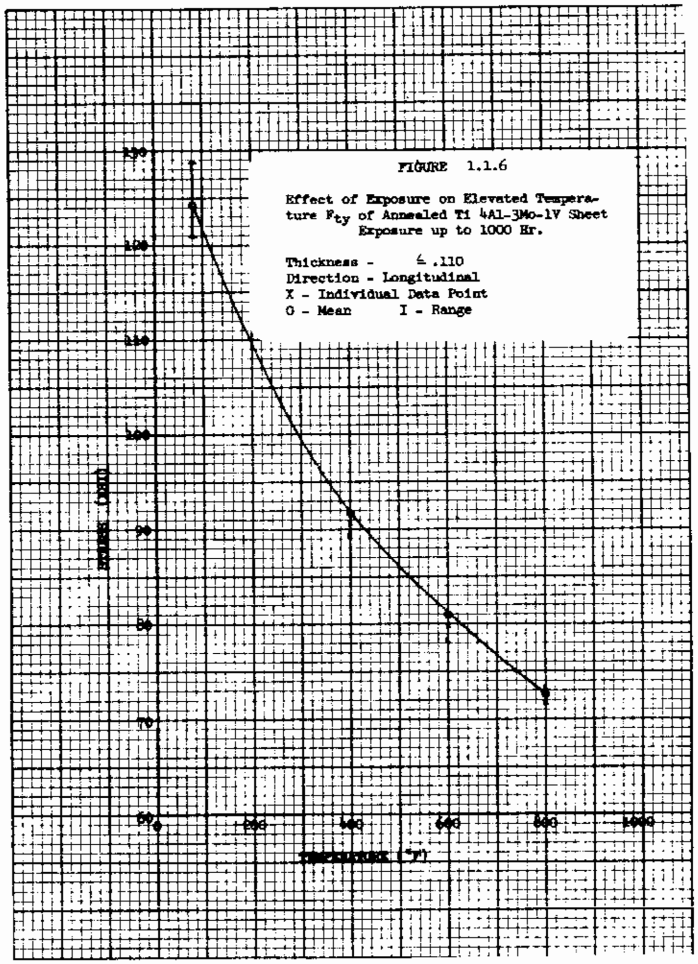


FIGURE 1.1.6

Effect of Exposure on Elevated Temperature F_{ty} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1000 Hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
O - Mean I - Range

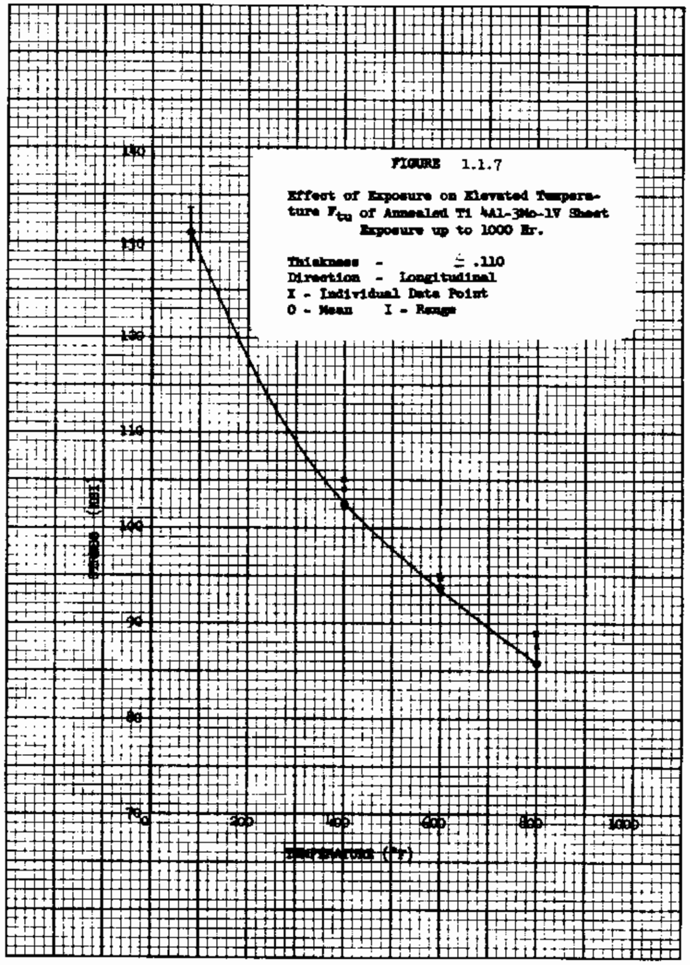


FIGURE 1.1.7

Effect of Exposure on Elevated Temperature F_{tu} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1000 Hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
0 - Mean   I - Range

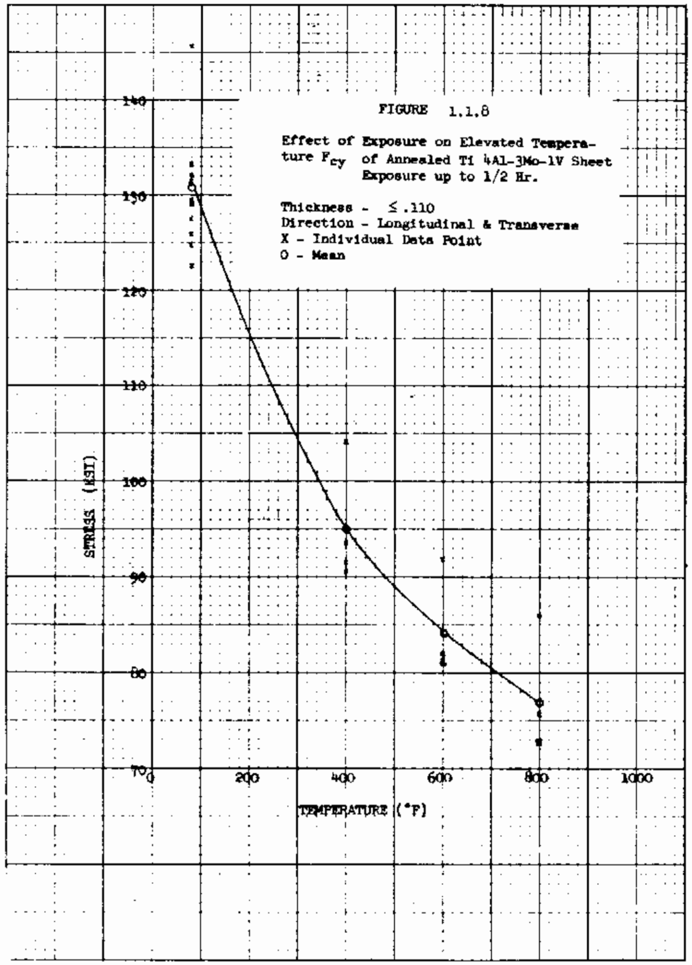


FIGURE 1.1.8

Effect of Exposure on Elevated Temperature F_{cy} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal & Transverse
X - Individual Data Point
0 - Mean

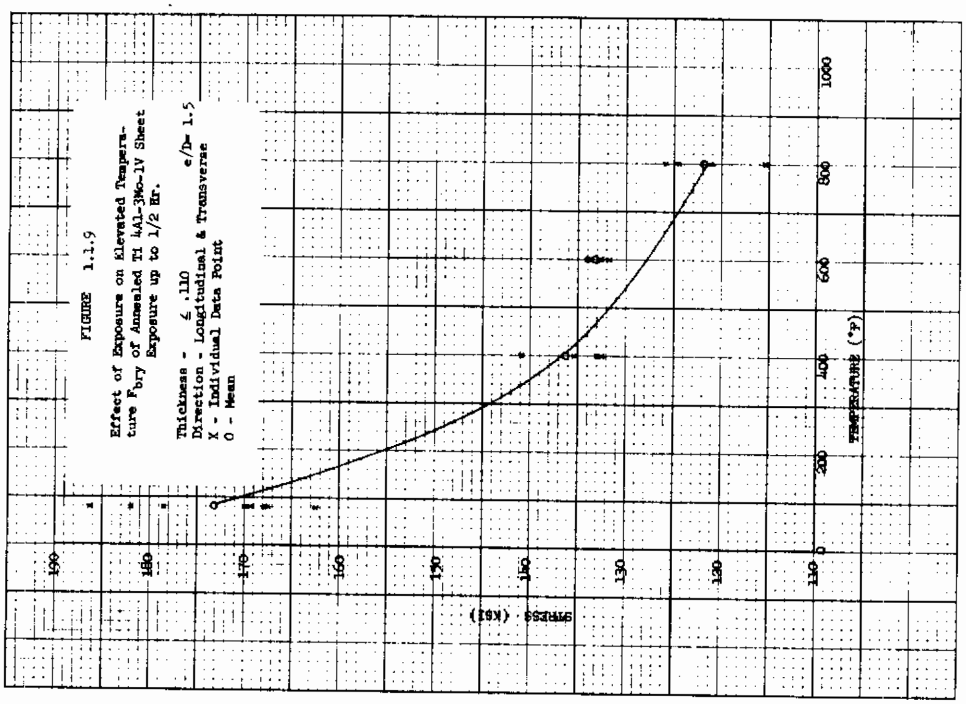


FIGURE 1.1.9

Effect of Exposure on Elevated Temperature F_{bry} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110 e/D= 1.5
Direction - Longitudinal & Transverse
X - Individual Data Point
O - Mean

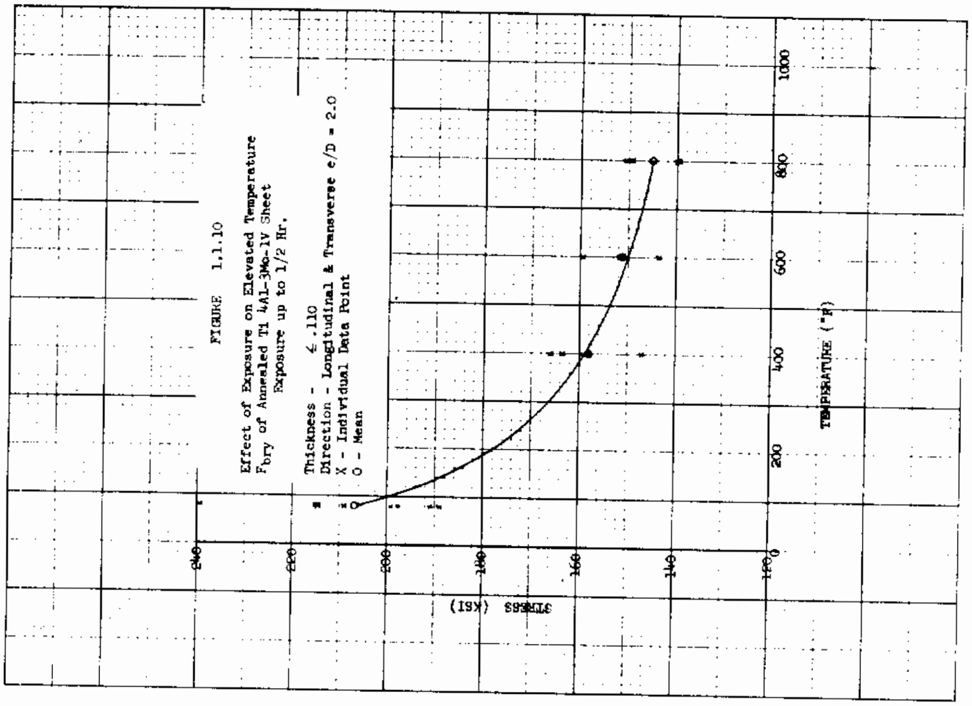


FIGURE 1.1.10

Effect of Exposure on Elevated Temperature F_{bry} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal & Transverse e/D = 2.0
X - Individual Data Point
O - Mean

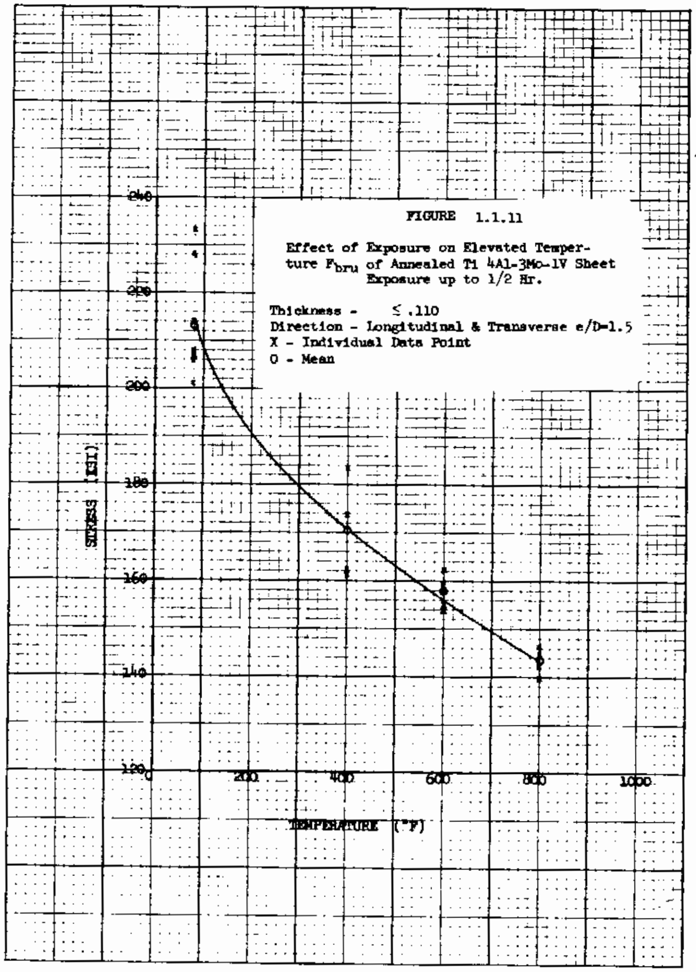


FIGURE 1.1.11

Effect of Exposure on Elevated Temperature F_{bru} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal & Transverse e/D=1.5
X - Individual Data Point
O - Mean

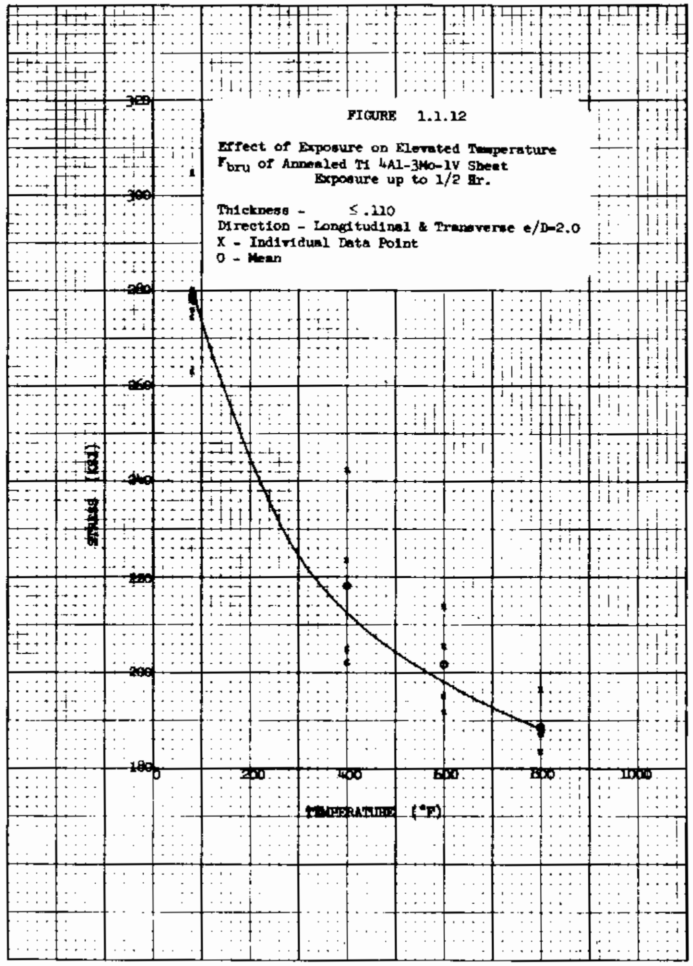


FIGURE 1.1.12

Effect of Exposure on Elevated Temperature F_{bru} of Annealed Ti 4Al-3Mo-1V Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal & Transverse e/D=2.0
X - Individual Data Point
O - Mean

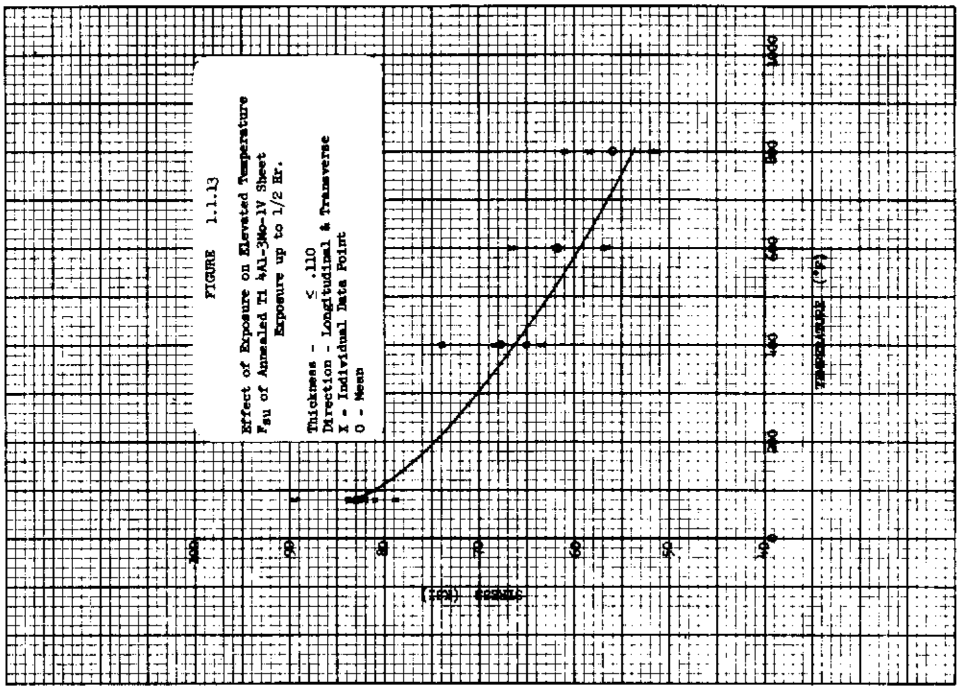


FIGURE 1.1.13
Effect of Exposure on Elevated Temperature
F_{su} of Annealed Ti 4Al-3Mo-1V Sheet
Exposure up to 1/2 Hr.
Thickness - ≤ .110
Direction - Longitudinal & Transverse
X - Individual Data Point
O - Mean
STRESS (KSI)
100
90
80
70
60
50
40
0
200
400
600
800
1000
TEMPERATURE (°F)

A. WORKING CURVES (Continued)

1.2 Ti-13V-11Cr-3Al Cond. A Figures 1.2.1 to 1.2.18

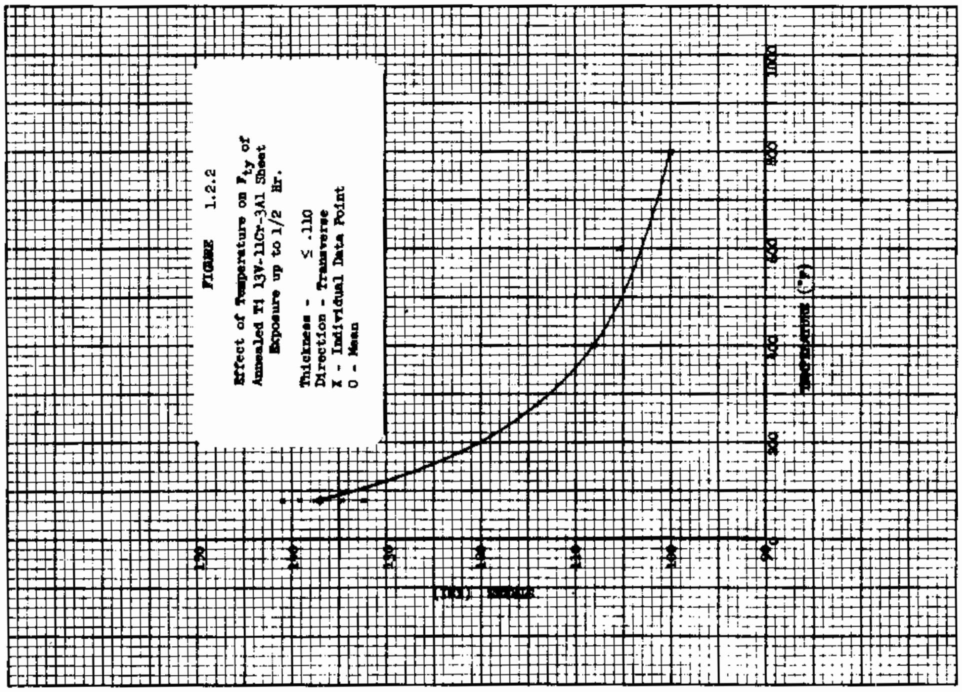


FIGURE 1.2.2
Effect of Temperature on F_{ty} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Transverse
X - Individual Data Point
O - Mean

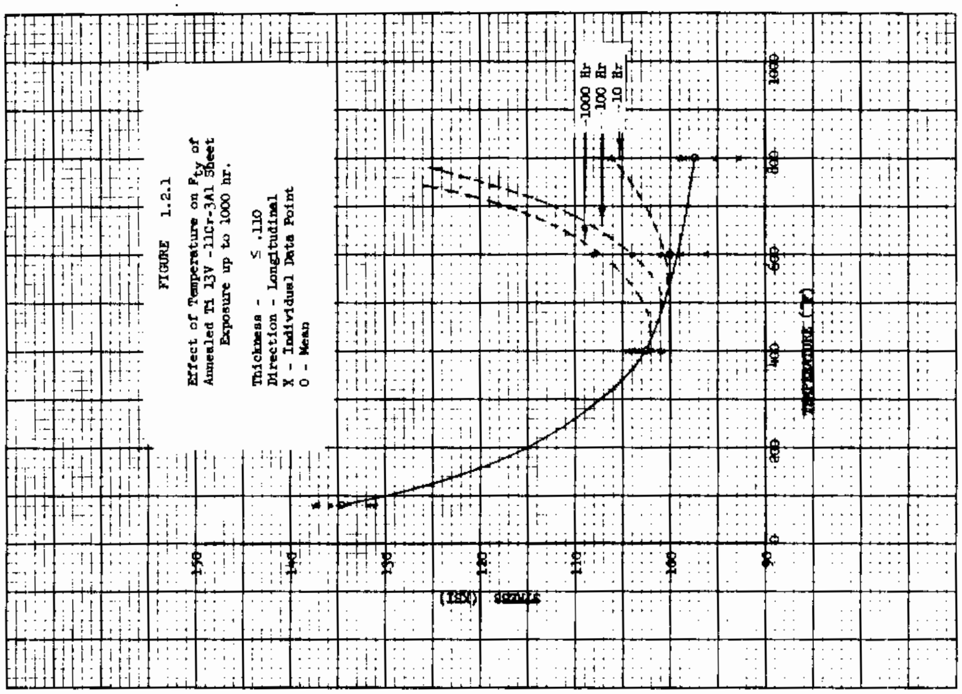


FIGURE 1.2.1
Effect of Temperature on F_{ty} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1000 hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
O - Mean

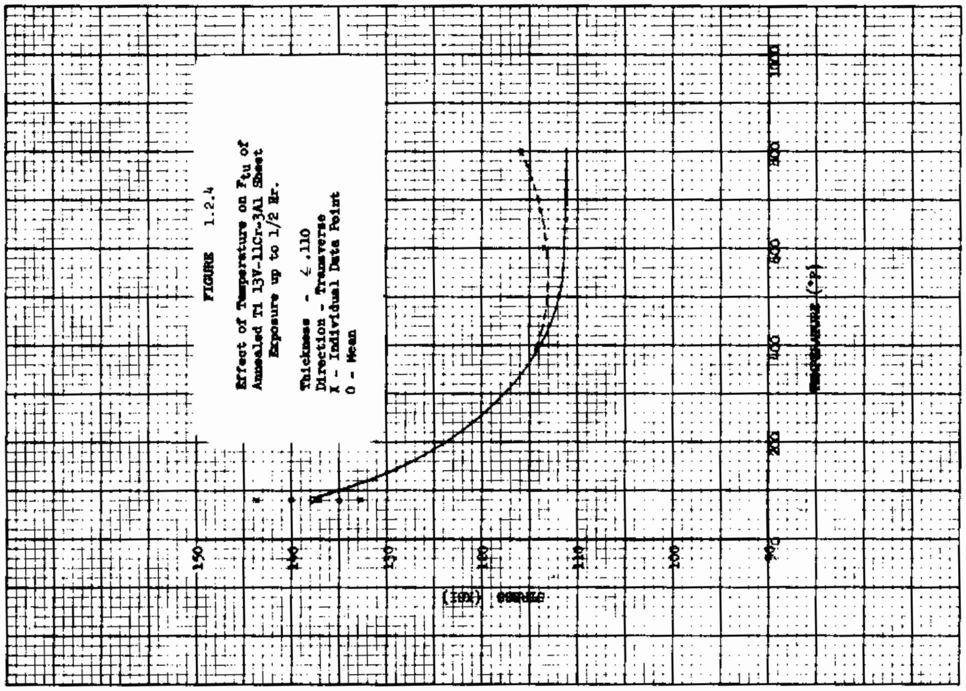


FIGURE 1.2.4
Effect of Temperature on Ftu of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.
Thickness - ≤ .110
Direction - Transverse
X - Individual Data Point
0 - Mean
Ftu (KSI)
150
140
130
120
110
100
90
0
200
400
600
800
1000
TEMPERATURE (°F)

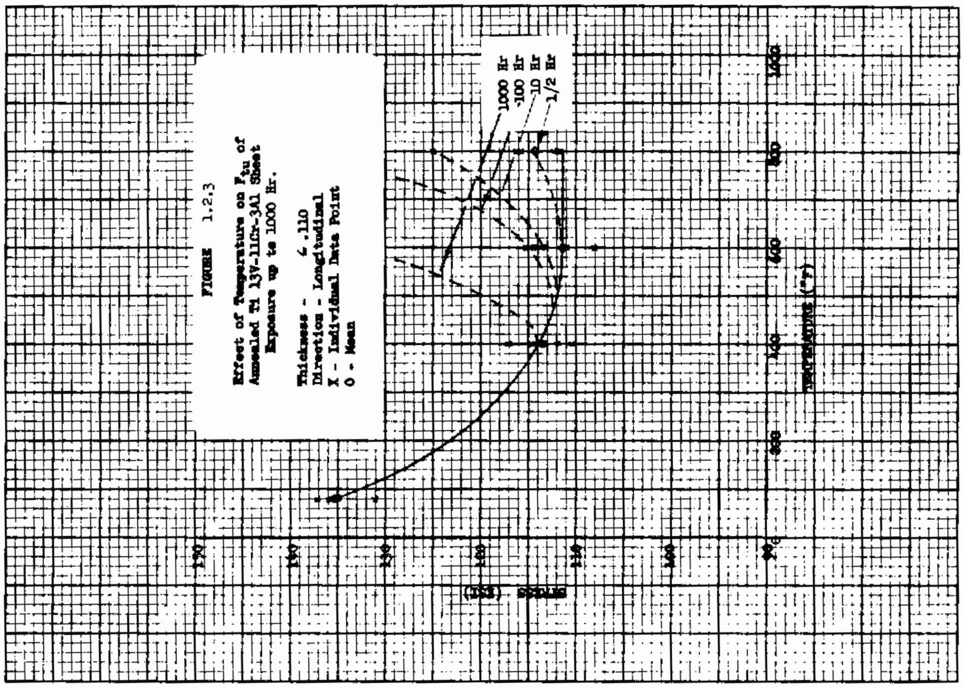


FIGURE 1.2.3
Effect of Temperature on Ftu of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1000 Hr.
Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
0 - Mean
1000 Hr
100 Hr
10 Hr
1/2 Hr
Ftu (KSI)
150
140
130
120
110
100
90
0
200
400
600
800
1000
TEMPERATURE (°F)

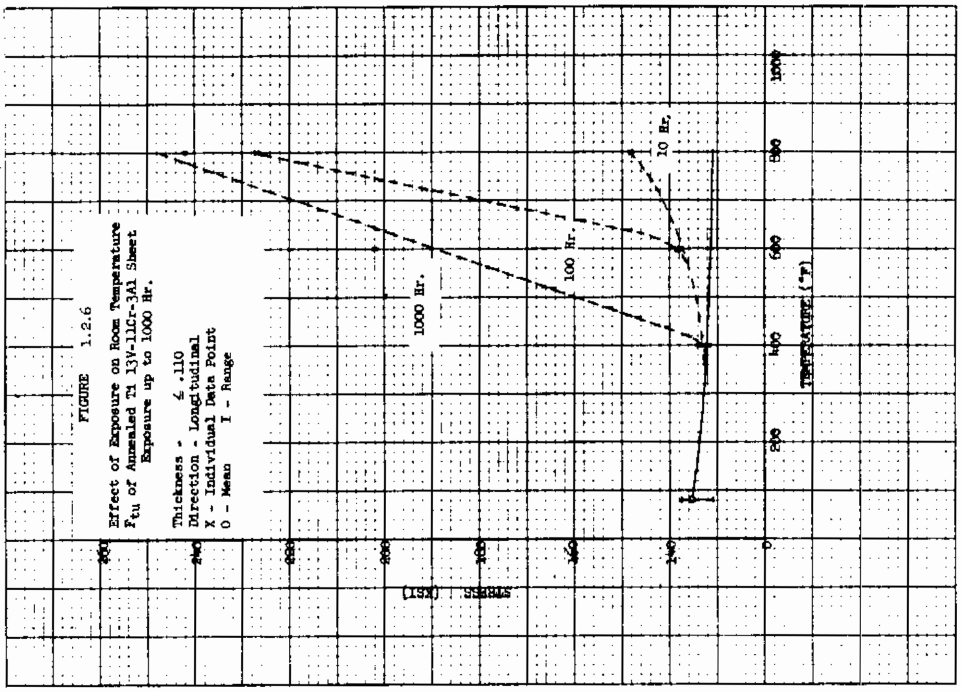


FIGURE 1.2.6

Effect of Exposure on Room Temperature F_{tu} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1000 Hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
0 - Mean I - Range

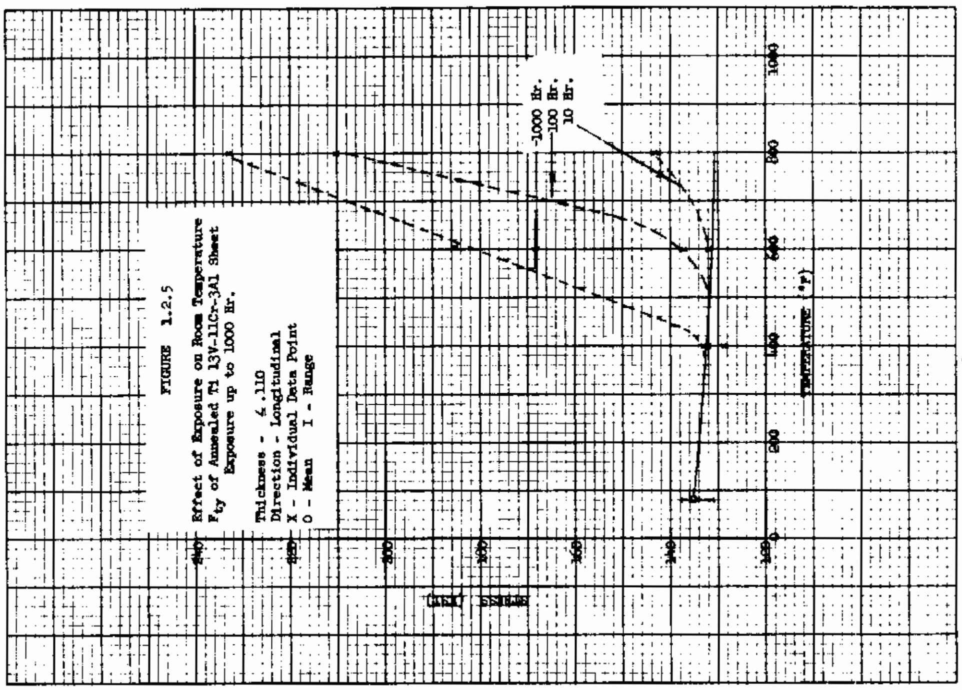


FIGURE 1.2.5

Effect of Exposure on Room Temperature F_{ty} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1000 Hr.

Thickness - ≤ .110
Direction - Longitudinal
X - Individual Data Point
0 - Mean I - Range

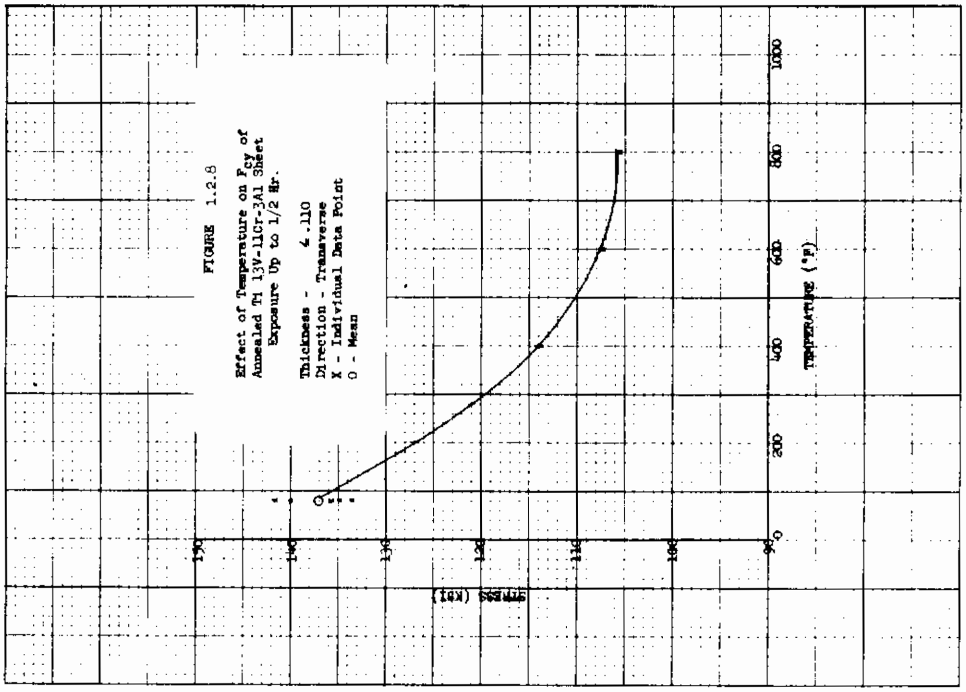


FIGURE 1.2.8

Effect of Temperature on F_{cy} of Annealed Ti 13V-11Cr-3Al Sheet Exposure Up to 1/2 Hr.

Thickness - .110
Direction - Transverse
X - Individual Data Point
0 - Mean

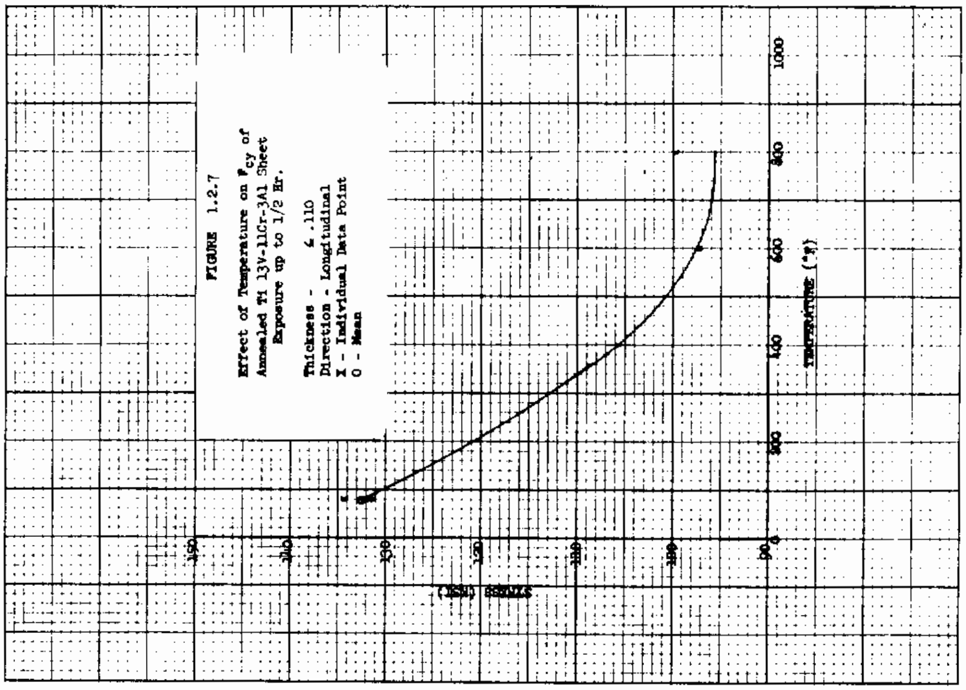


FIGURE 1.2.7

Effect of Temperature on F_{cy} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - .110
Direction - Longitudinal
X - Individual Data Point
0 - Mean

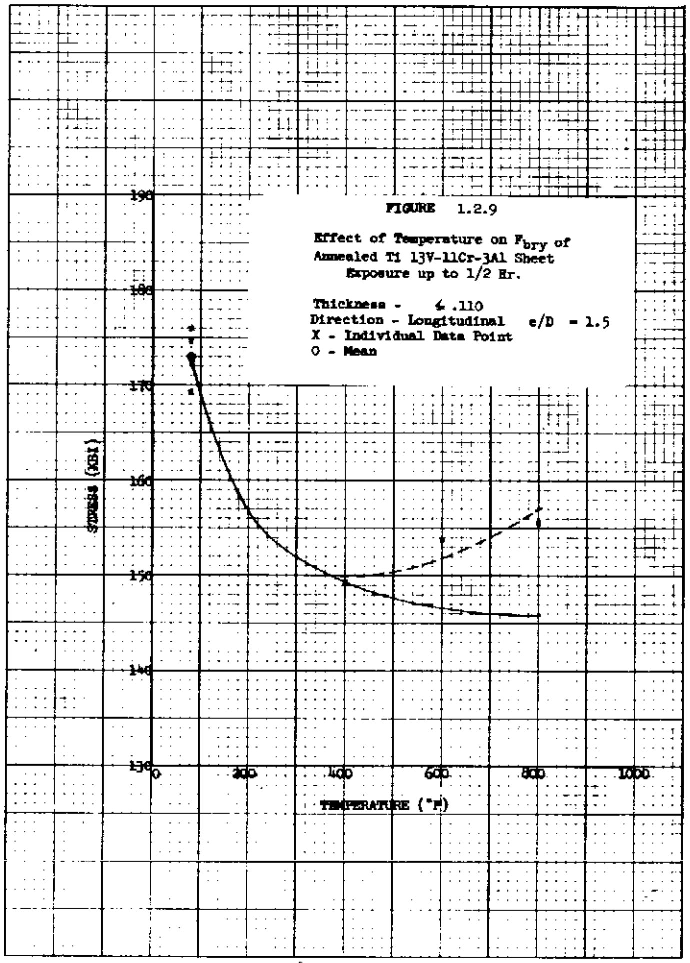


FIGURE 1.2.9

Effect of Temperature on F_{bry} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

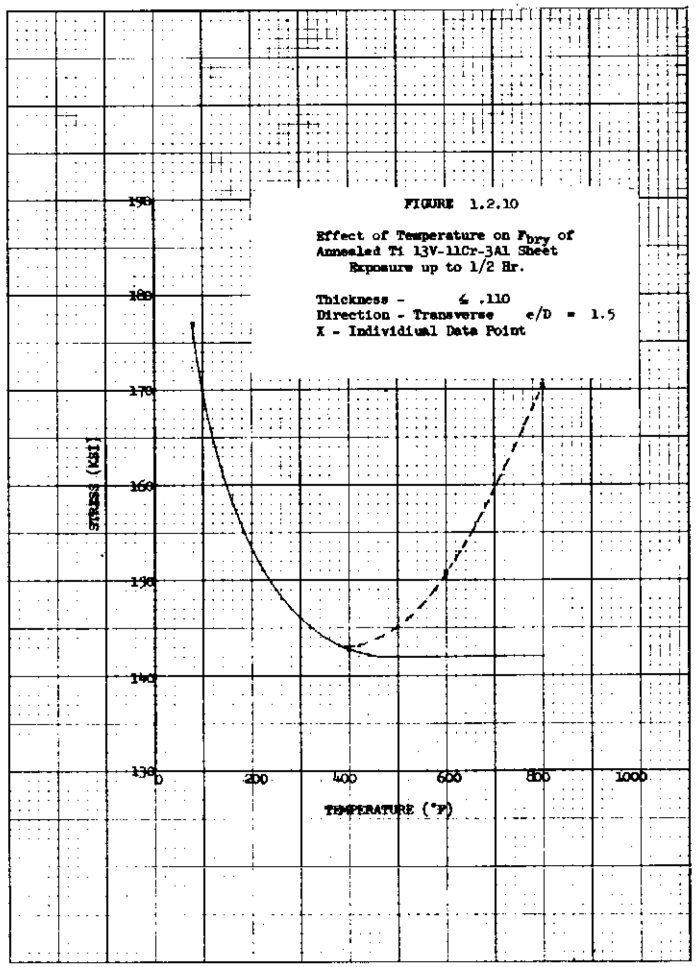


FIGURE 1.2.10

Effect of Temperature on F_{bry} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Transverse e/D = 1.5
X - Individual Data Point

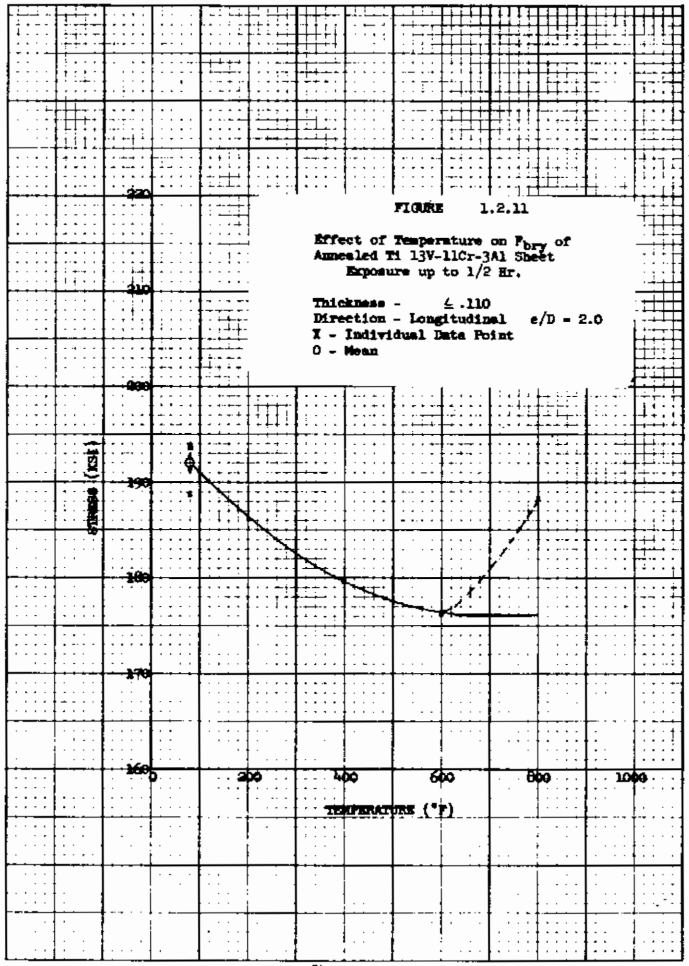


FIGURE 1.2.11
Effect of Temperature on F_{bry} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.
Thickness - ≤ .110
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
0 - Mean
STRESS (KSI)
TEMPERATURE (°F)
160
170
180
190
200
210
220
0
200
400
600
800
1000

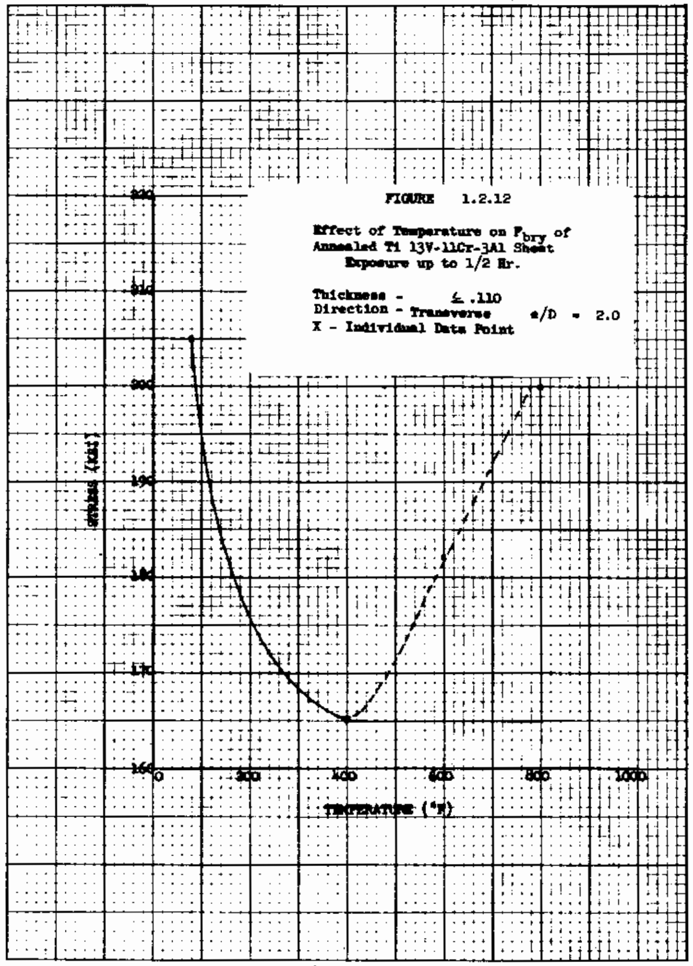


FIGURE 1.2.12
Effect of Temperature on F_{bry} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.
Thickness - ≤ .110
Direction - Transverse e/D = 2.0
X - Individual Data Point
STRESS (KSI)
TEMPERATURE (°F)
160
170
180
190
200
210
220
0
200
400
600
800
1000

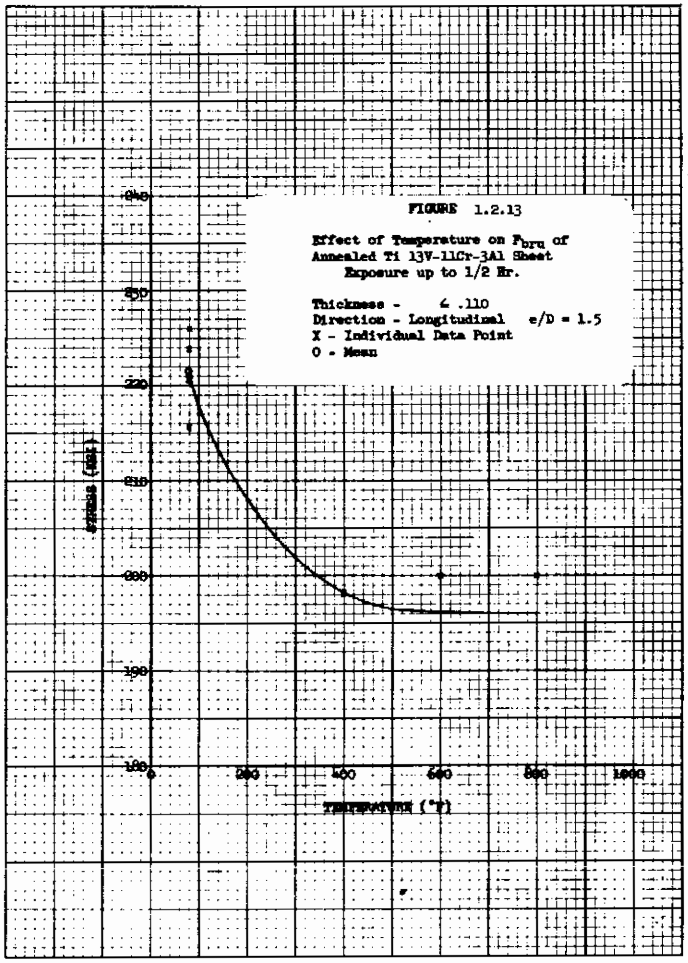


FIGURE 1.2.13

Effect of Temperature on F_{bru} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
0 - Mean

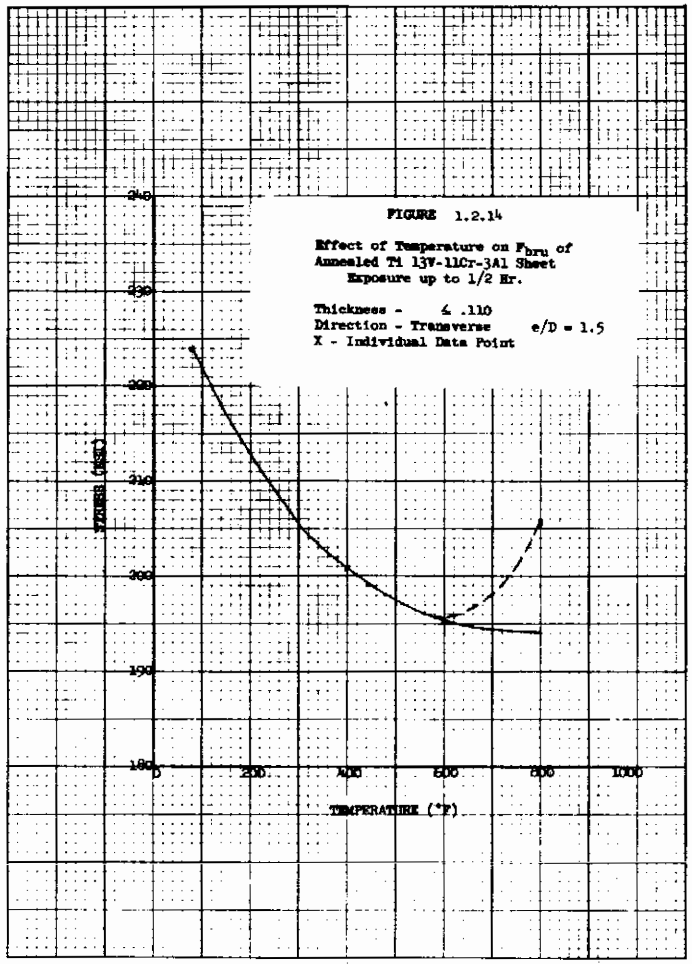


FIGURE 1.2.14

Effect of Temperature on F_{bru} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ≤ .110
Direction - Transverse e/D = 1.5
X - Individual Data Point

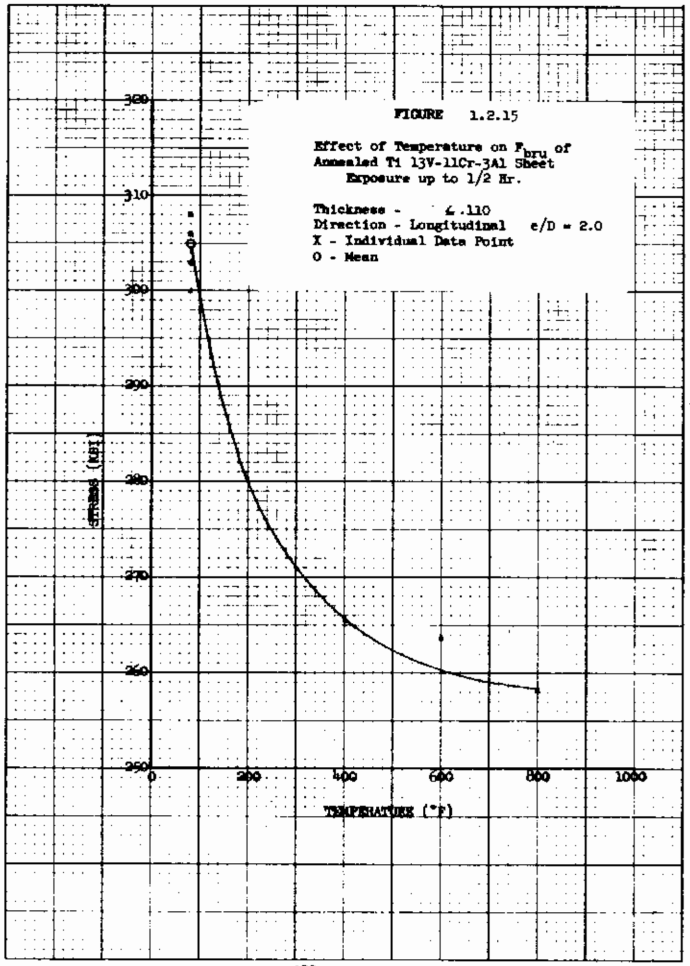


FIGURE 1.2.15

Effect of Temperature on F_{bru} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ∠.110
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

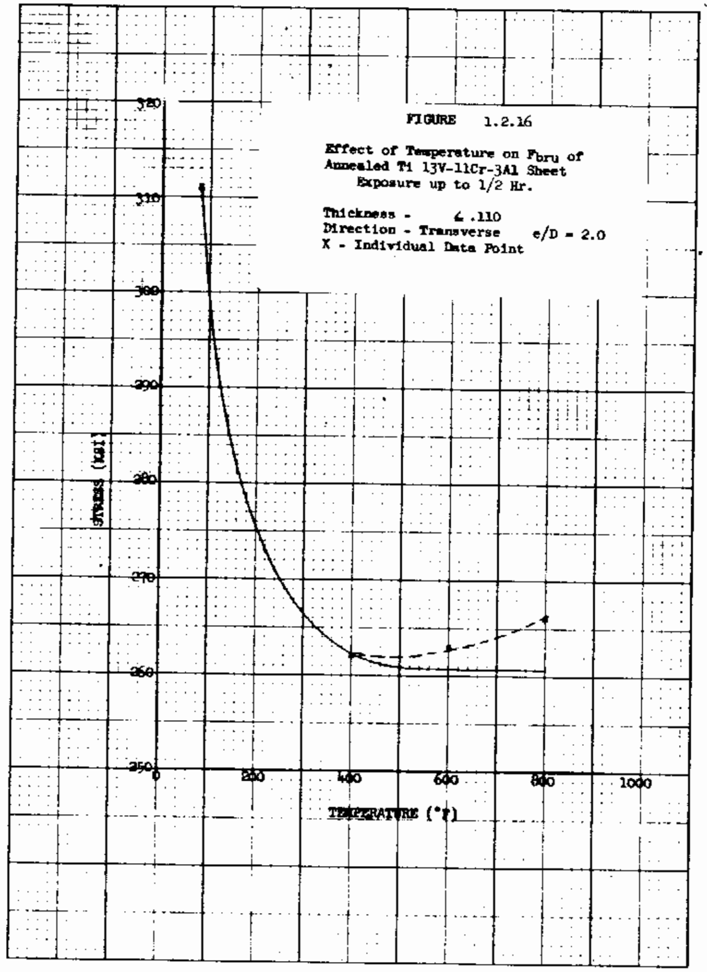


FIGURE 1.2.16

Effect of Temperature on F_{bru} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - ∠.110
Direction - Transverse e/D = 2.0
X - Individual Data Point

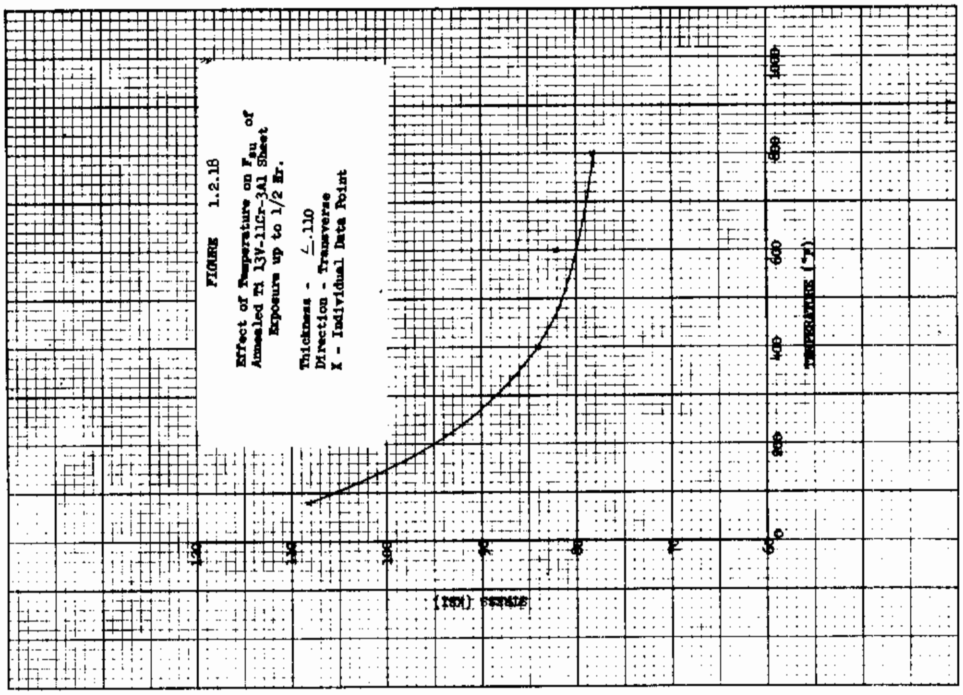


FIGURE 1.2.18

Effect of Temperature on F_{su} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - < .110
Direction - Transverse
X - Individual Data Point

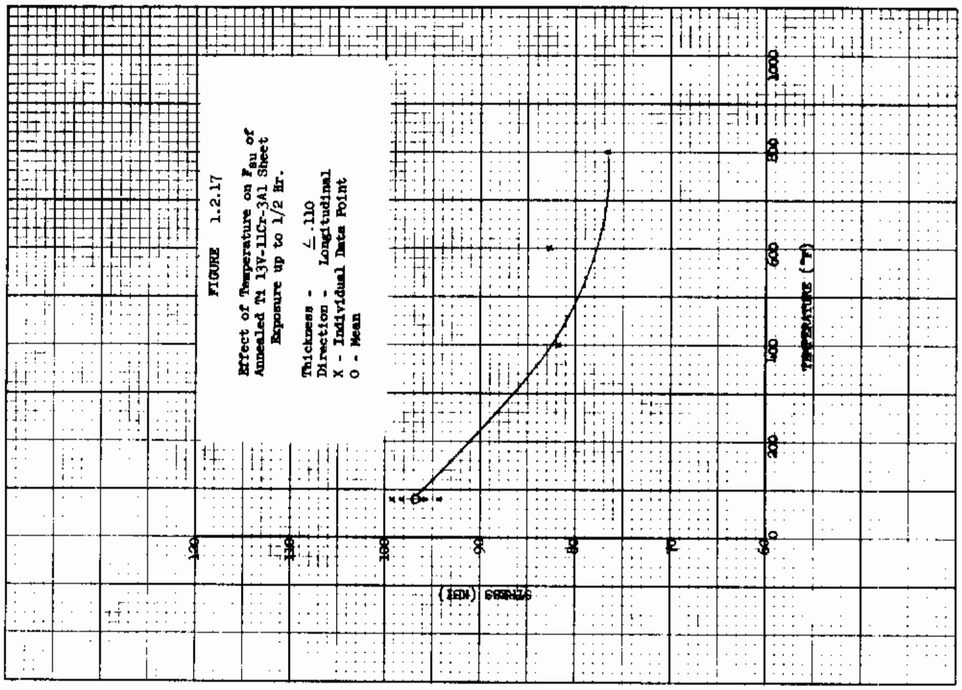


FIGURE 1.2.17

Effect of Temperature on F_{su} of Annealed Ti 13V-11Cr-3Al Sheet Exposure up to 1/2 Hr.

Thickness - < .110
Direction - Longitudinal
X - Individual Data Point
O - Mean

A. WORKING CURVES (continued)

1.3 Ti-6Al-4V Cond. STA Figures 1.3.1 to 1.3.43

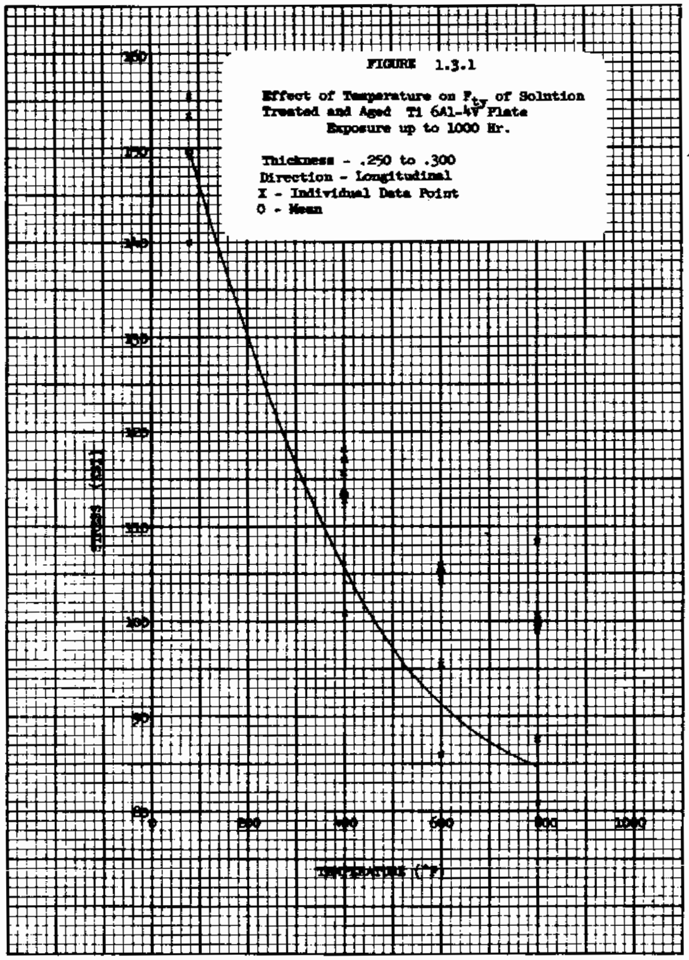


FIGURE 1.3.1
Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1000 Hr.
Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
O - Mean
STRESS (KSI)
160
150
140
130
120
110
100
90
80
0
200
400
600
800
1000
TEMPERATURE (°F)

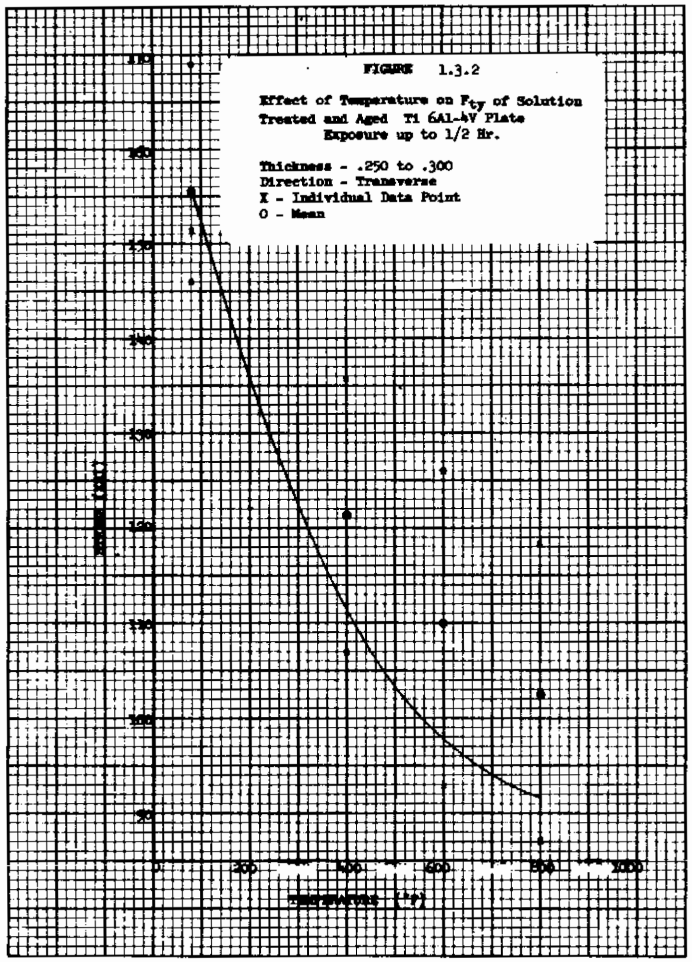


FIGURE 1.3.2
Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
O - Mean
STRESS (KSI)
170
160
150
140
130
120
110
100
90
0
200
400
600
800
1000
TEMPERATURE (°F)

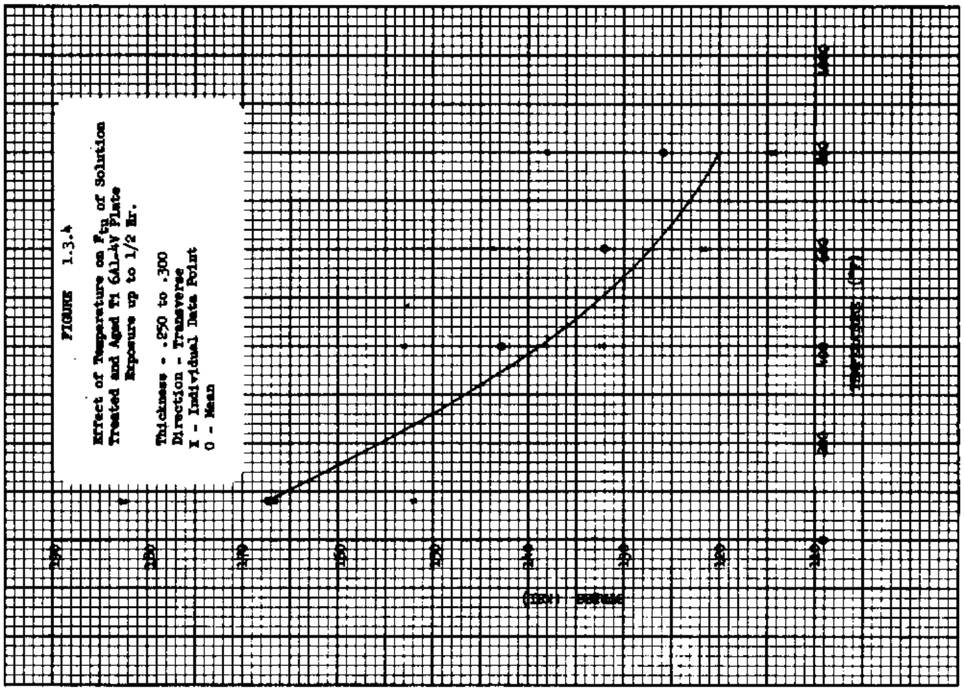


FIGURE 1.3.4
Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
0 - Mean
STRESS (KSI)
TEMPERATURE (°F)

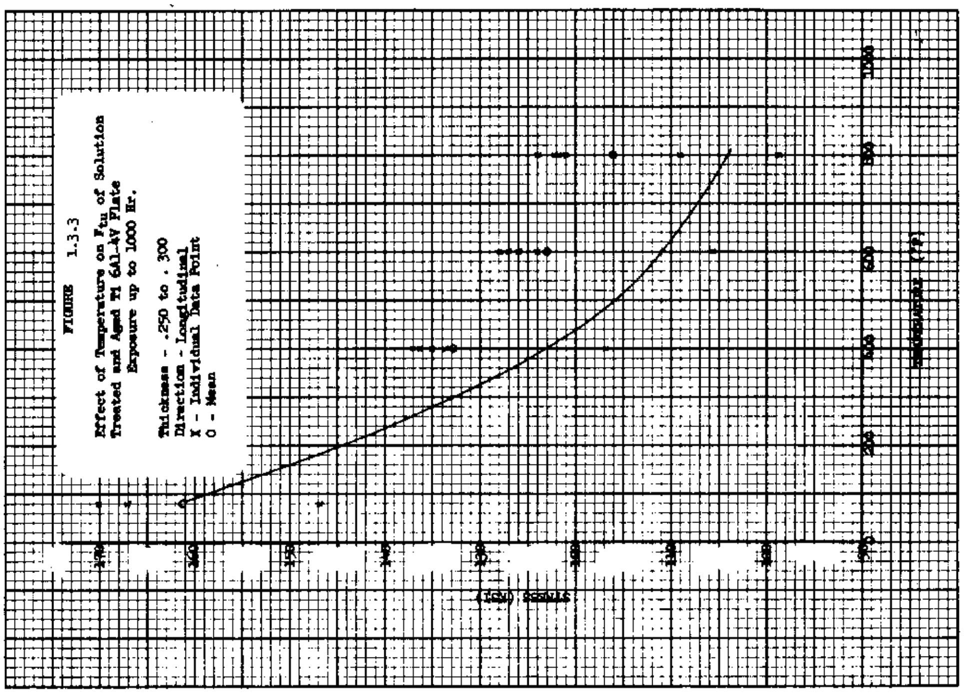


FIGURE 1.3.3
Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1000 Hr.
Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
0 - Mean
STRESS (KSI)
TEMPERATURE (°F)

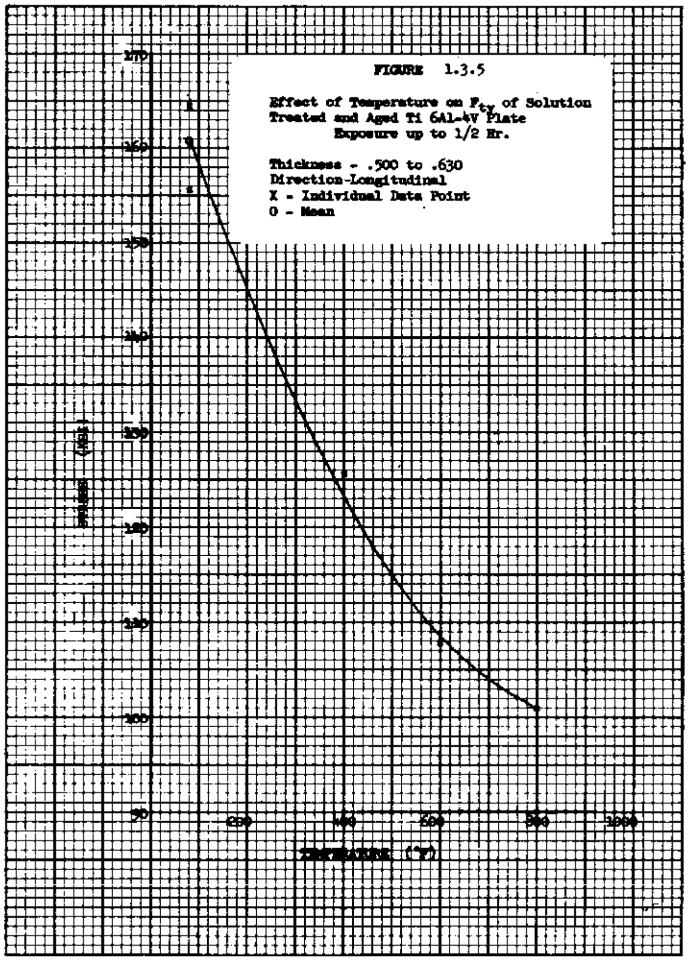


FIGURE 1.3.5

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction-Longitudinal
X - Individual Data Point
0 - Mean

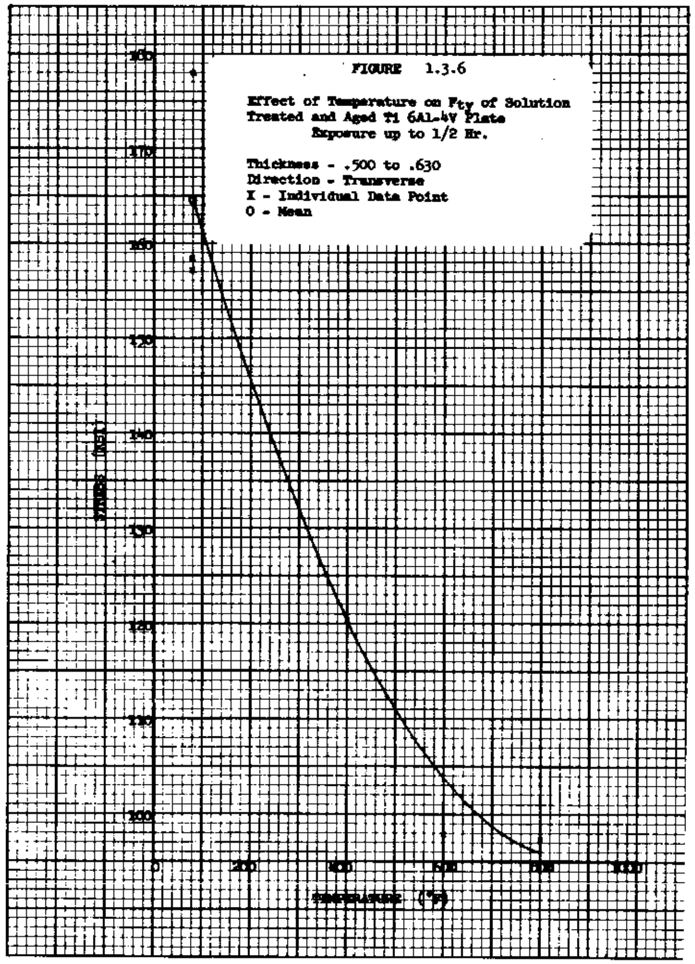


FIGURE 1.3.6

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
0 - Mean

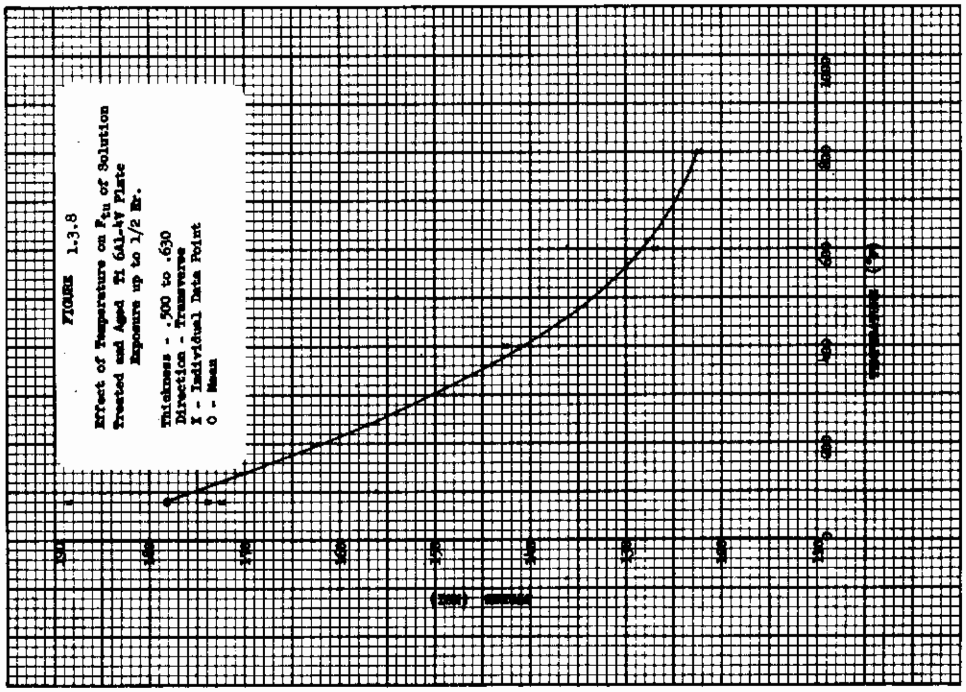


FIGURE 1.3.8
Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
O - Mean
STRESS (KSI)
TEMPERATURE (°F)

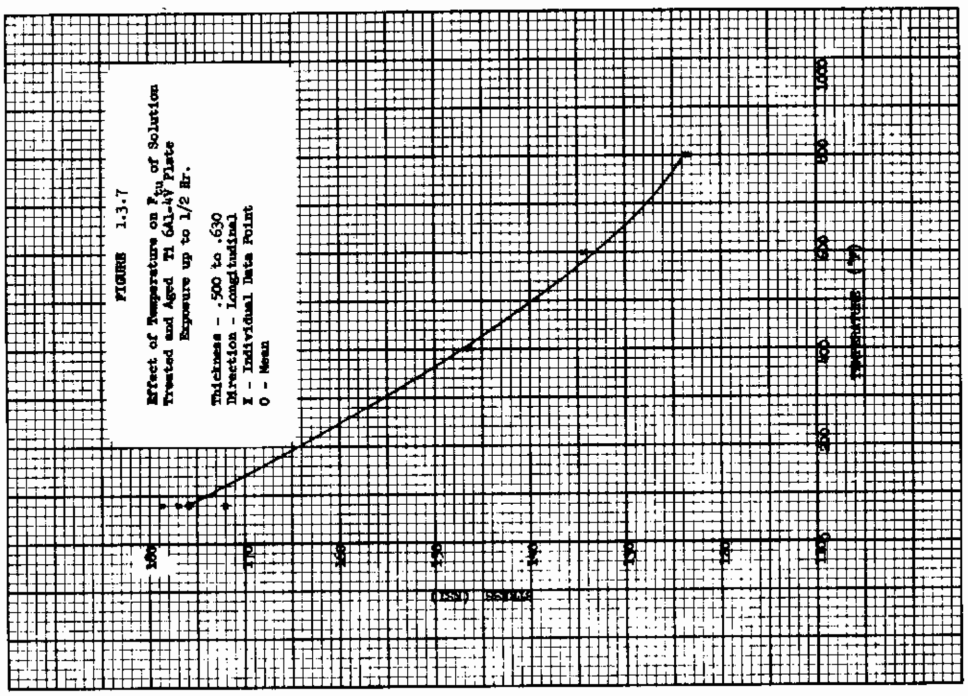


FIGURE 1.3.7
Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean
STRESS (KSI)
TEMPERATURE (°F)

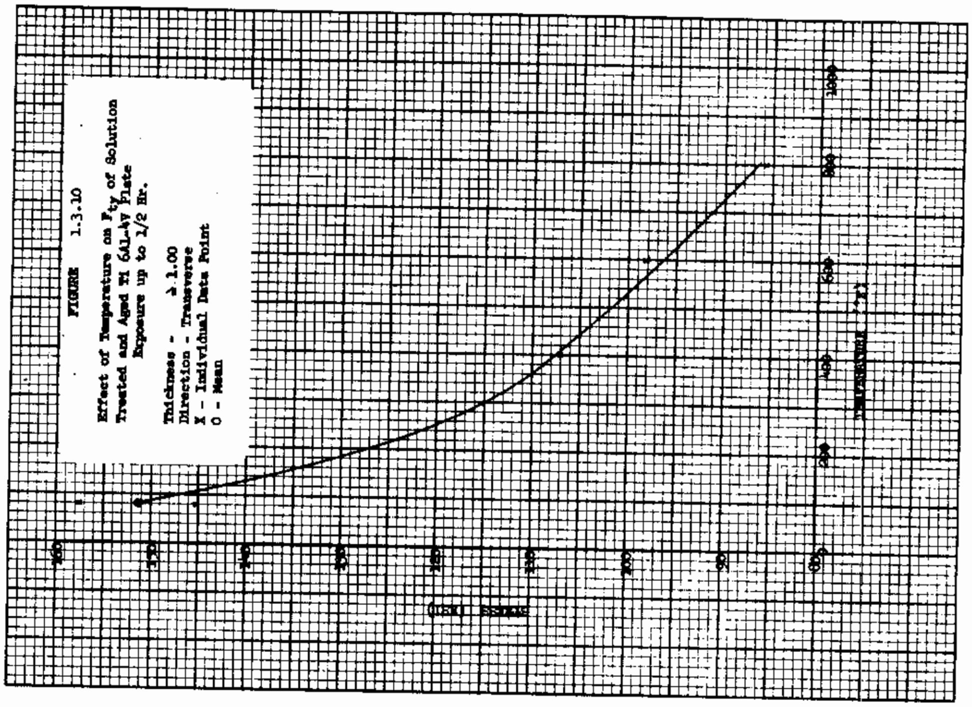


FIGURE 1.3.10
Effect of Temperature on F_{ty} of Solution
Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean
160
150
140
130
120
110
100
90
80
0
200
400
600
800
1000

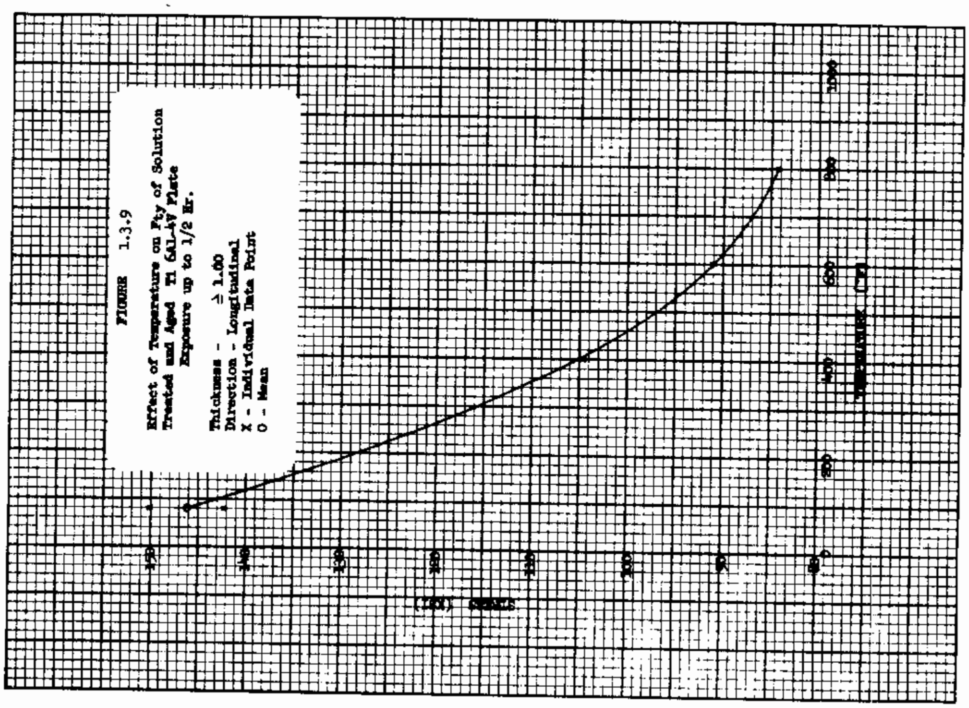


FIGURE 1.3.9
Effect of Temperature on Fty of Solution
Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean
150
140
130
120
110
100
90
80
200
400
600
800
1000

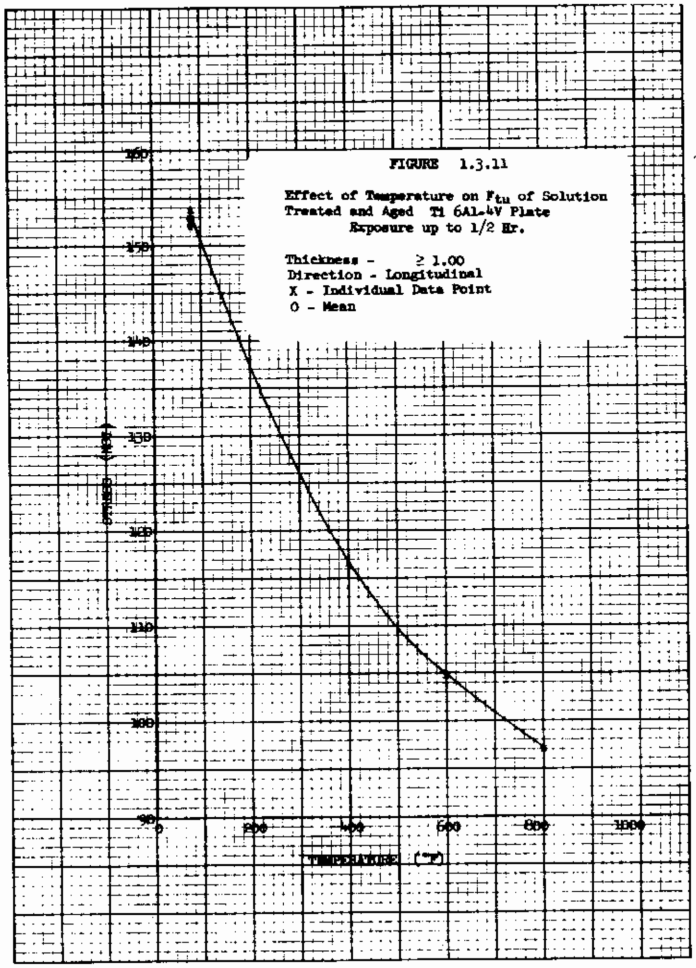


FIGURE 1.3.11

Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
0 - Mean

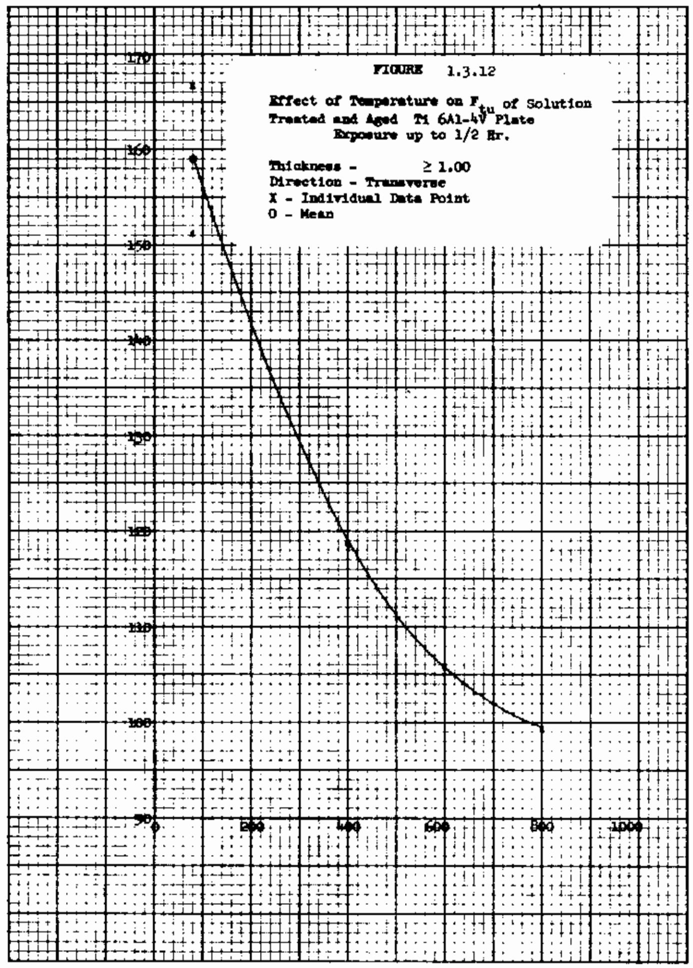


FIGURE 1.3.12

Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
0 - Mean

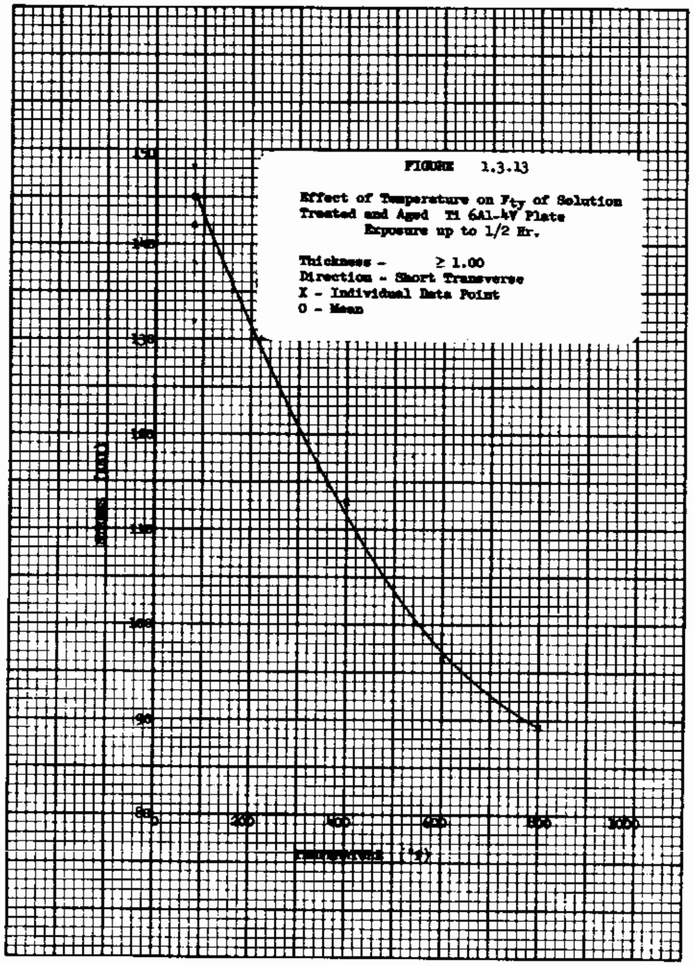


FIGURE 1.3.13

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - $\geq$ 1.00
Direction - Short Transverse
X - Individual Data Point
0 - Mean

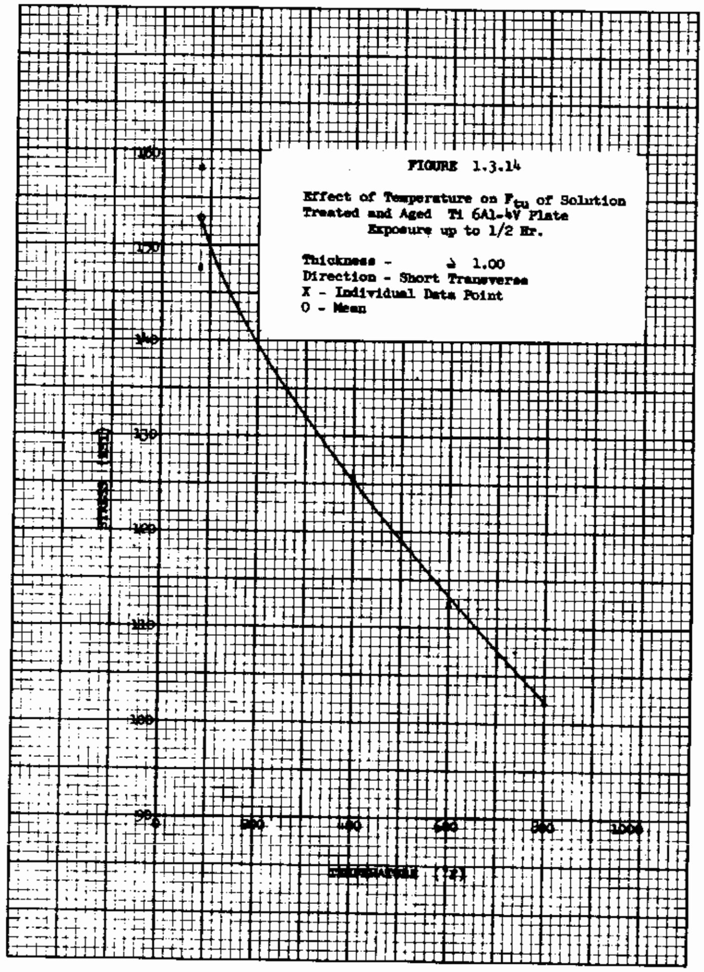


FIGURE 1.3.14

Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - $\geq$ 1.00
Direction - Short Transverse
X - Individual Data Point
0 - Mean

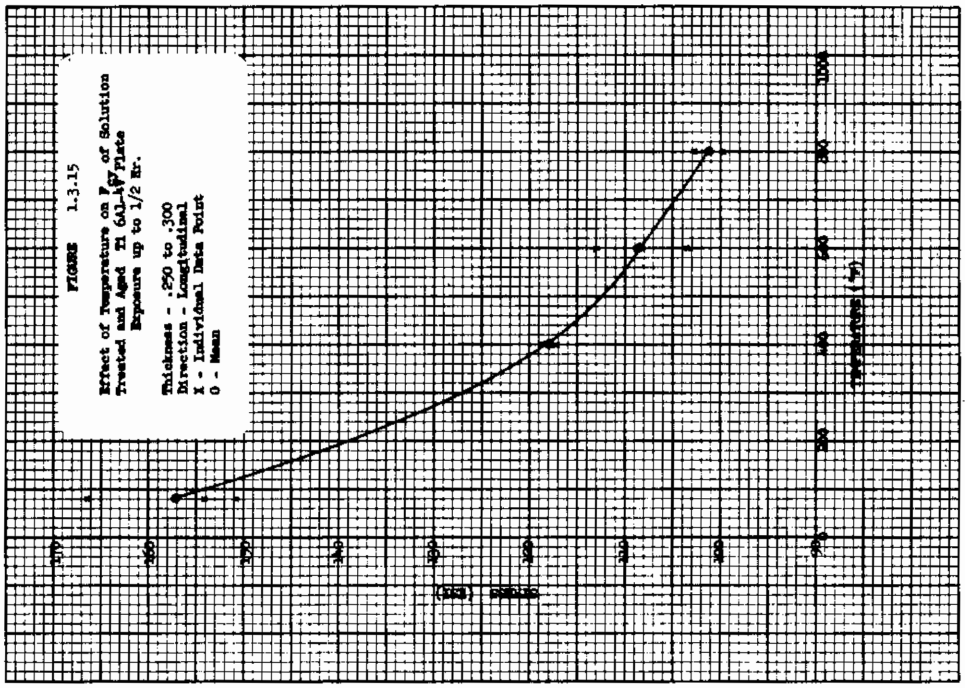


FIGURE 1.3.15

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
O - Mean

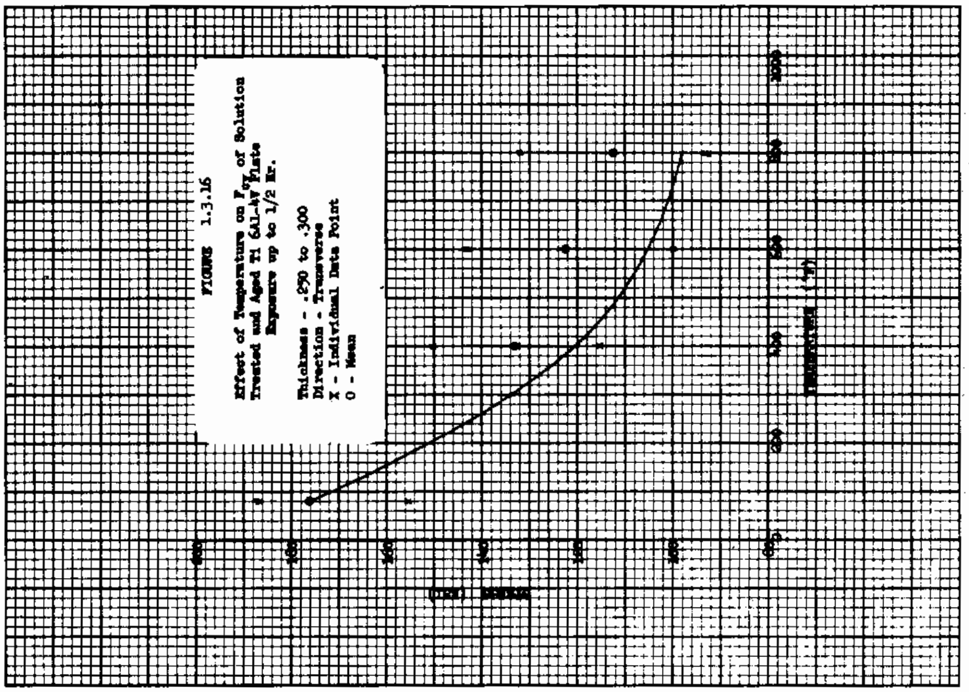


FIGURE 1.3.16

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
O - Mean

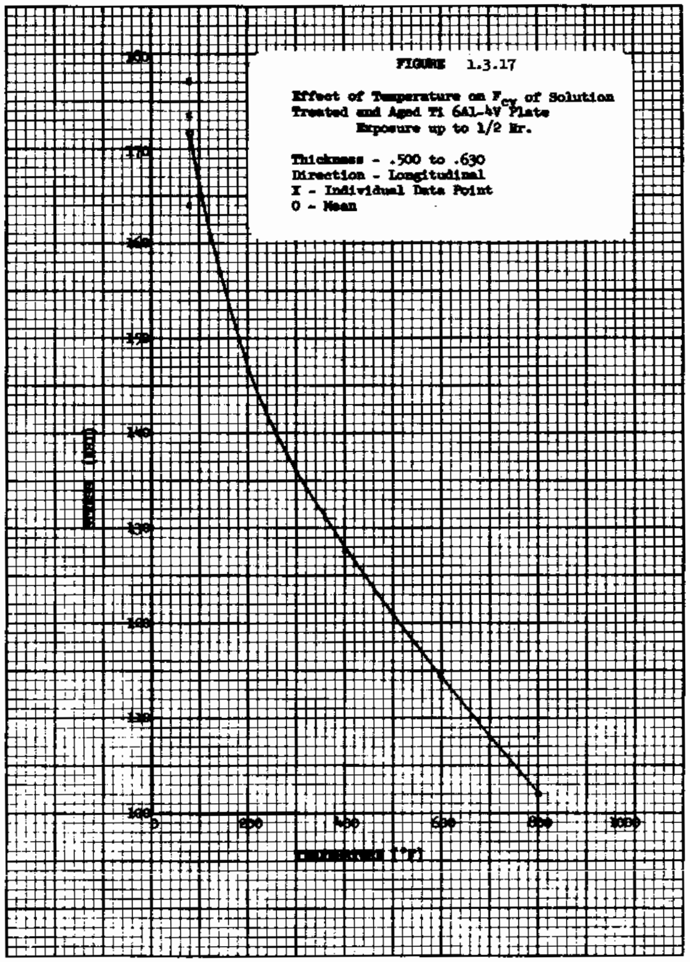


FIGURE 1.3.17
Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean
180
170
160
150
140
130
120
110
100
0
200
400
600
800
1000

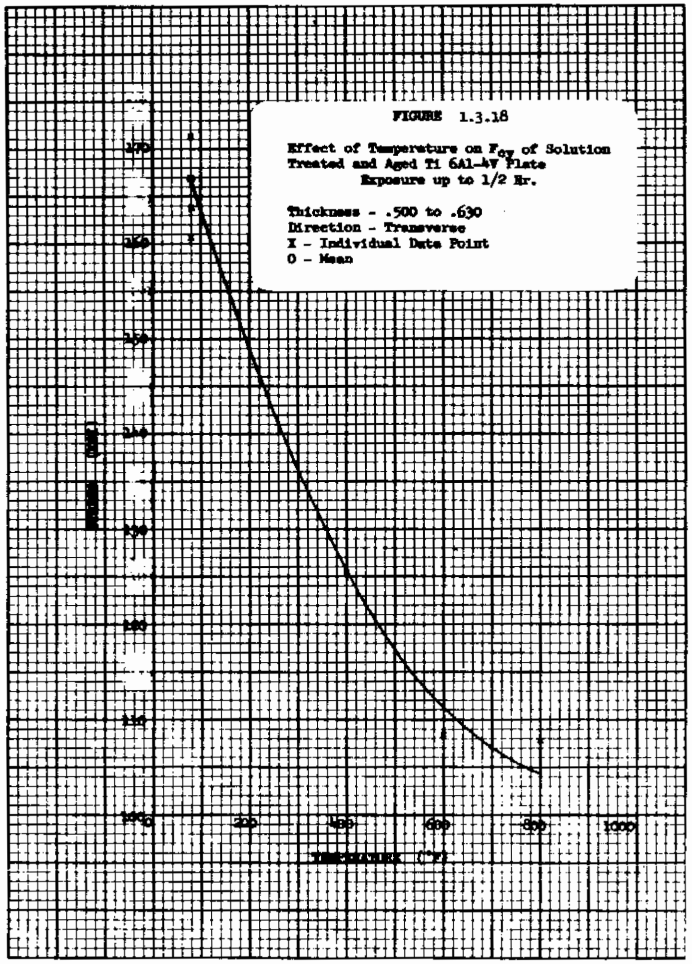


FIGURE 1.3.18
Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
O - Mean
170
160
150
140
130
120
110
100
0
200
400
600
800
1000

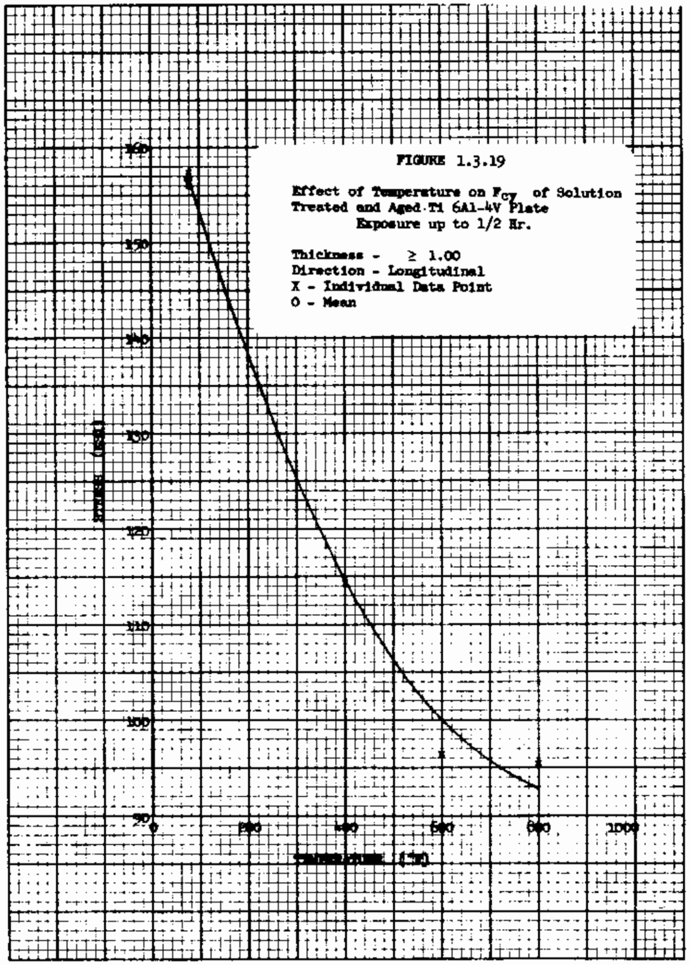


FIGURE 1.3.19

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
0 - Mean

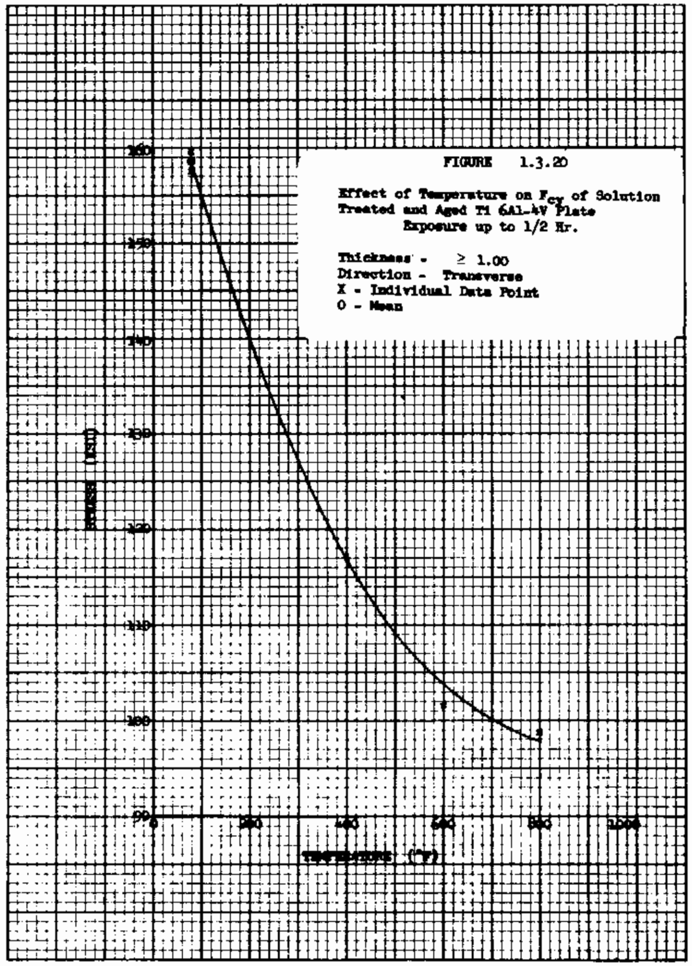


FIGURE 1.3.20

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
0 - Mean

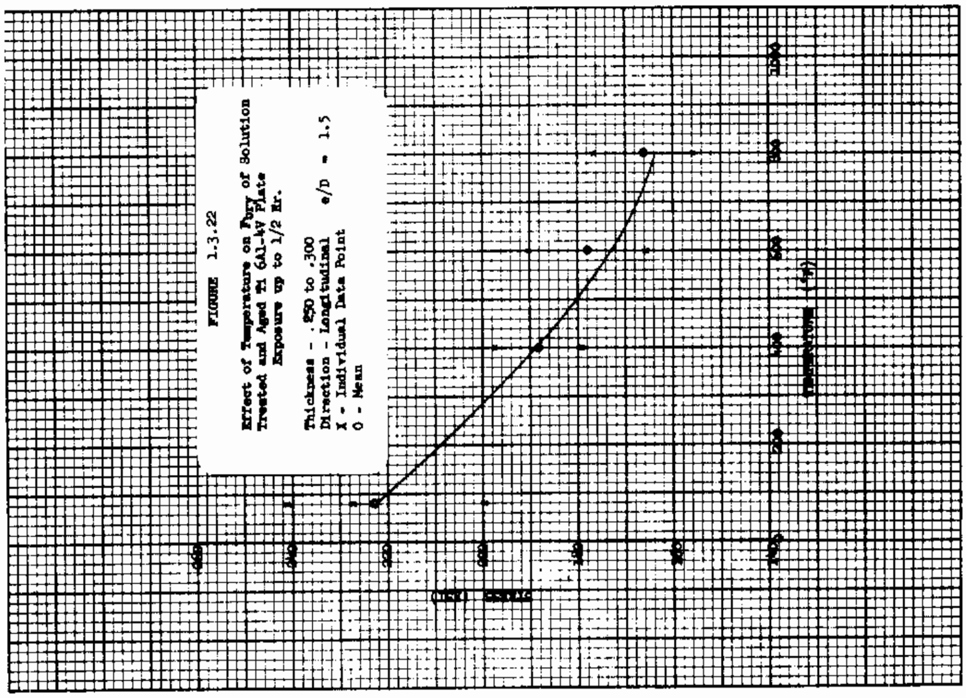


FIGURE 1.3.22
Effect of Temperature on Fbry of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Longitudinal
e/D = 1.5
X - Individual Data Point
O - Mean
260
240
220
200
180
160
140
200
400
600
800
1000
TEMPERATURE (°F)

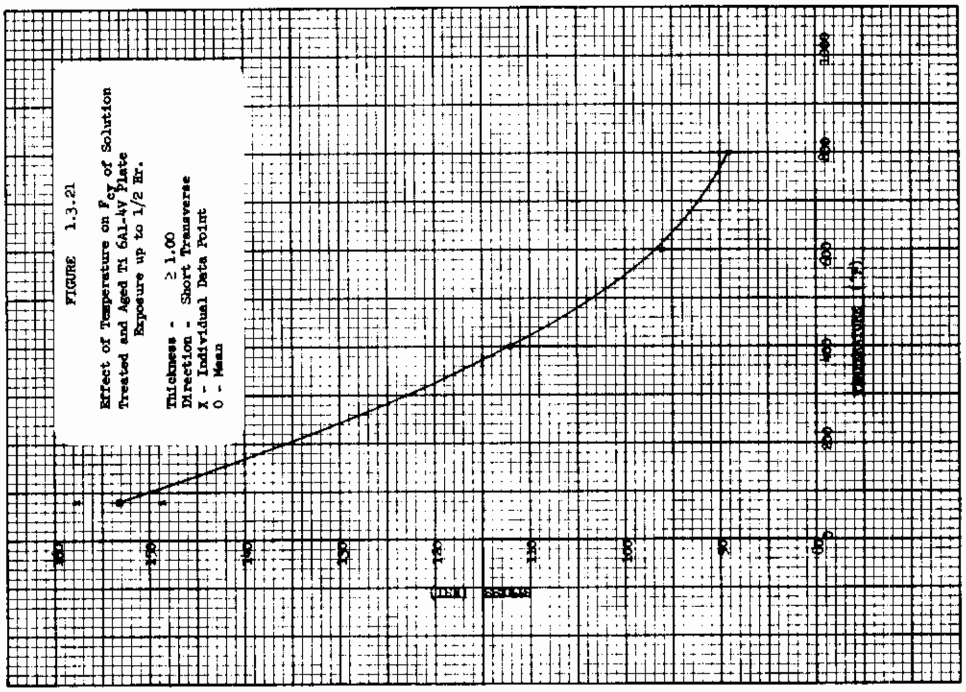


FIGURE 1.3.21
Effect of Temperature on Fcy of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Short Transverse
X - Individual Data Point
O - Mean
160
150
140
130
120
110
100
90
80
200
400
600
800
1000
TEMPERATURE (°F)

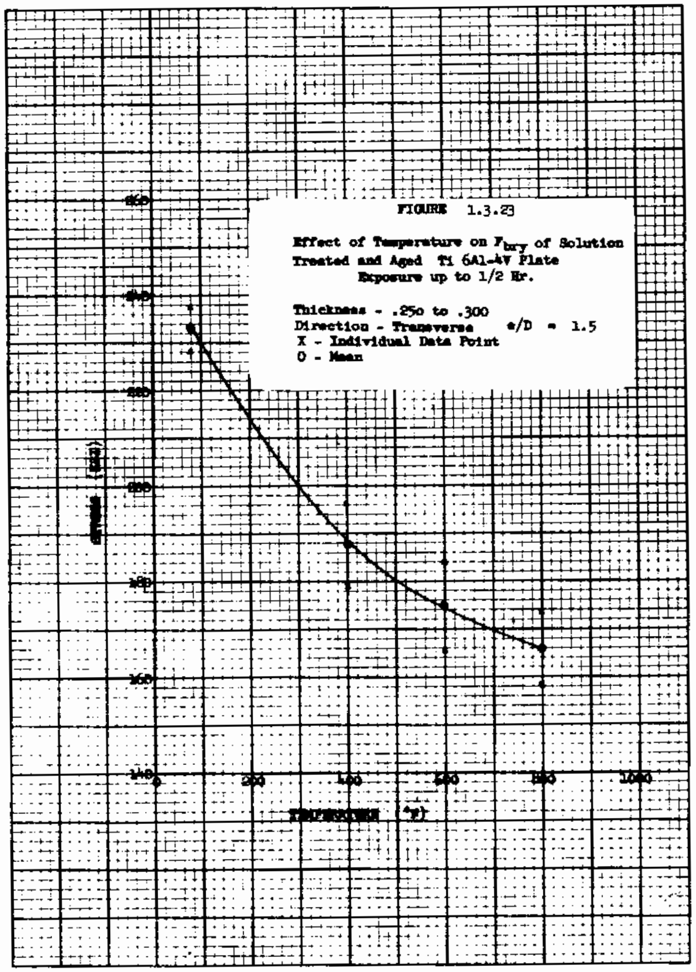


FIGURE 1.3.23
Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Transverse e/D = 1.5
X - Individual Data Point
0 - Mean
STRESS (KSI)
260
240
220
200
180
160
140
0
200
400
600
800
1000
TEMPERATURE (°F)

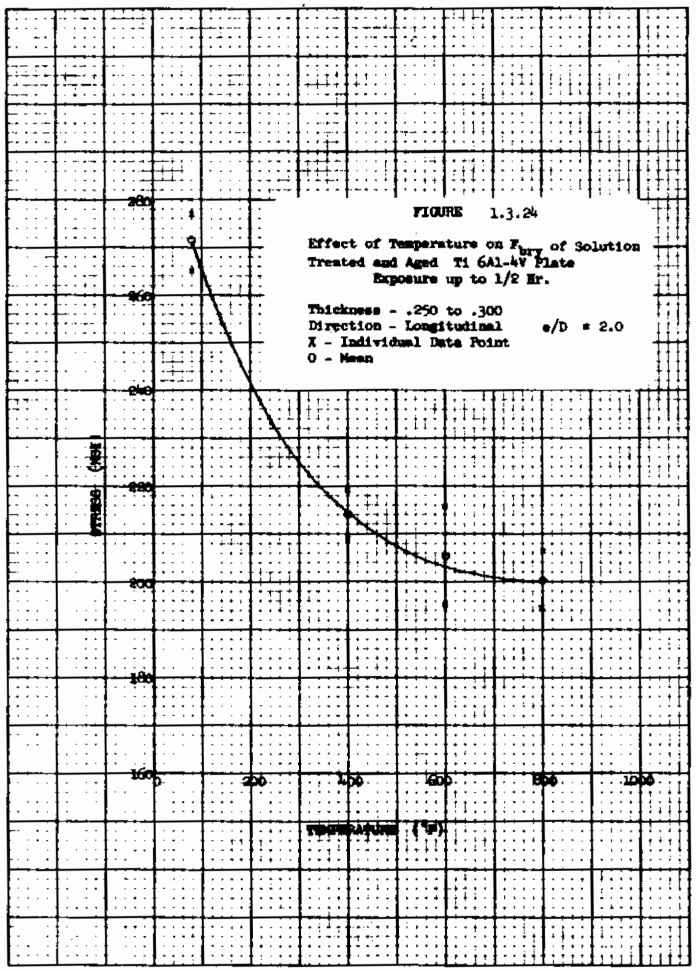


FIGURE 1.3.24
Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
0 - Mean
STRESS (KSI)
280
260
240
220
200
180
160
0
200
400
600
800
1000
TEMPERATURE (°F)

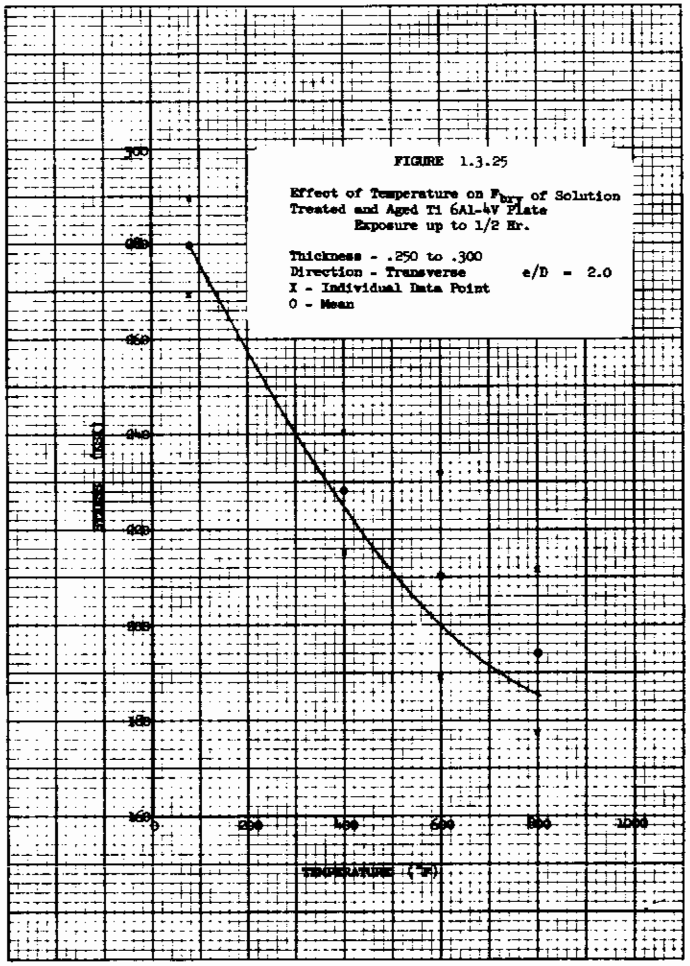


FIGURE 1.3.25

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse   e/D = 2.0
X - Individual Data Point
O - Mean

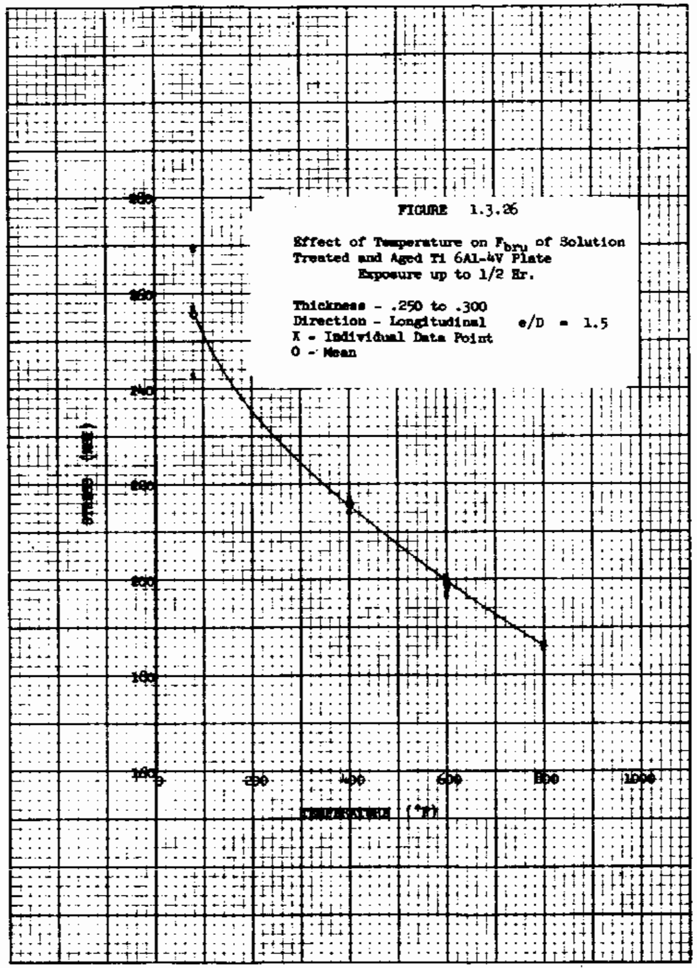


FIGURE 1.3.26

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal   e/D = 1.5
X - Individual Data Point
O - Mean

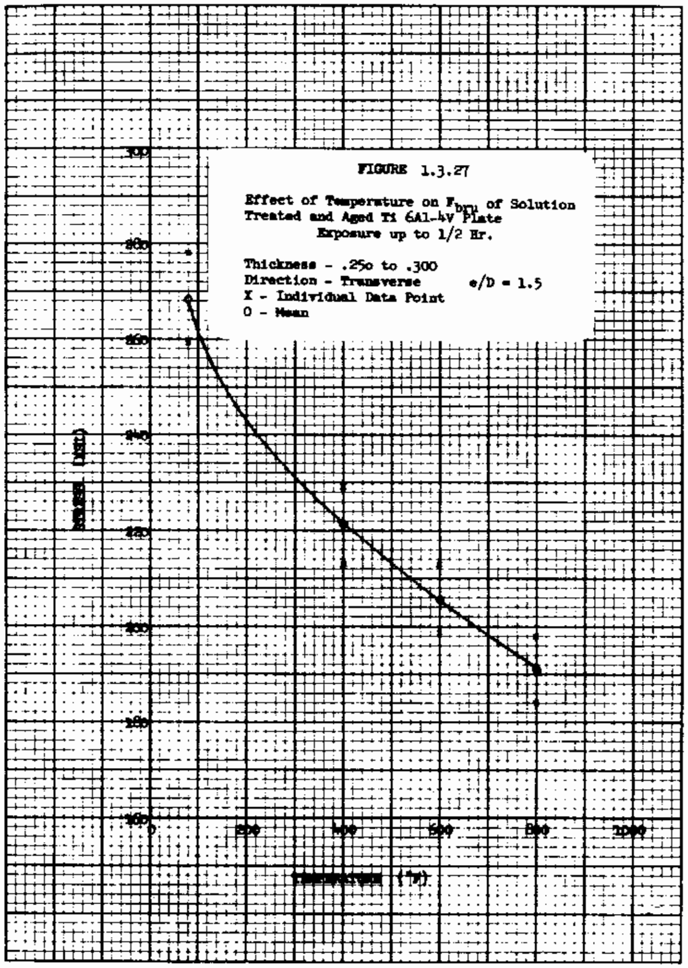


FIGURE 1.3.27

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .25o to .300
Direction - Transverse e/D = 1.5
X - Individual Data Point
0 - Mean

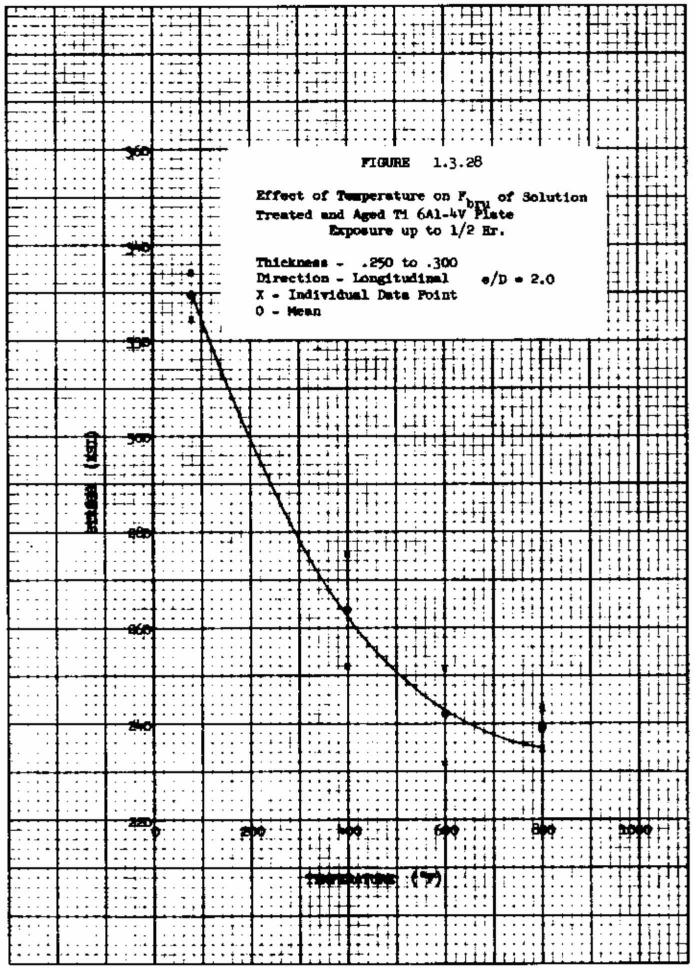


FIGURE 1.3.28

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
0 - Mean

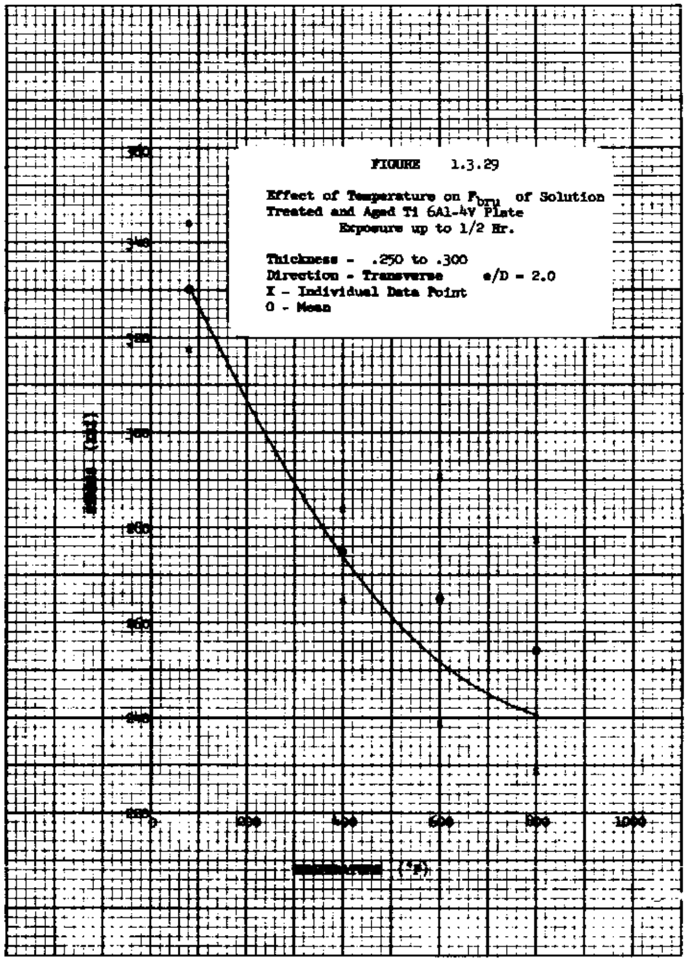


FIGURE 1.3.29

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse e/D = 2.0
X - Individual Data Point
O - Mean

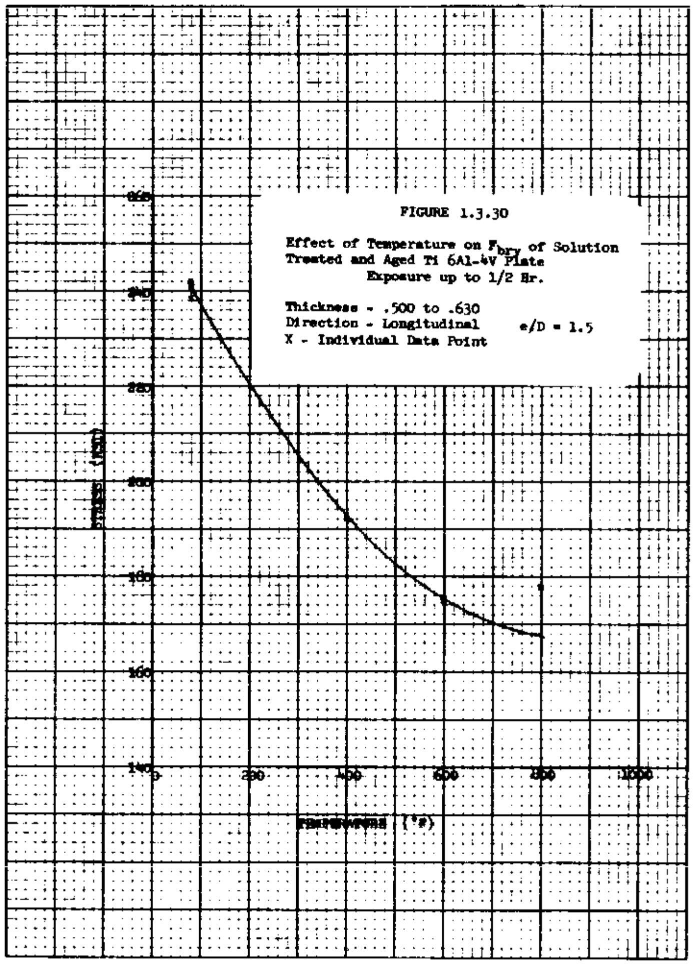


FIGURE 1.3.30

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 1.5
X - Individual Data Point

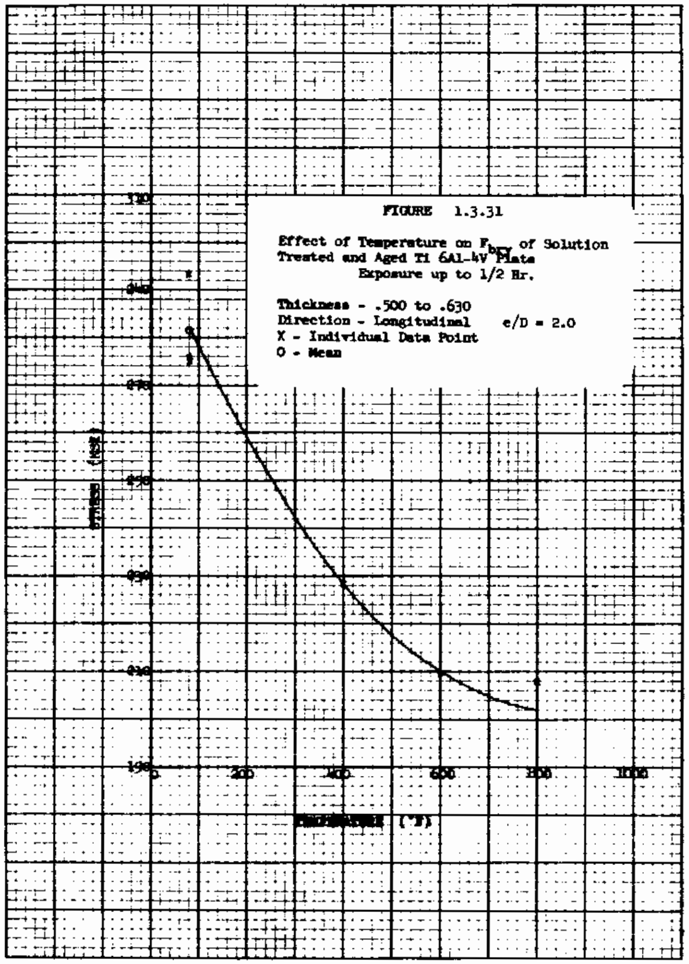


FIGURE 1.3.31

Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

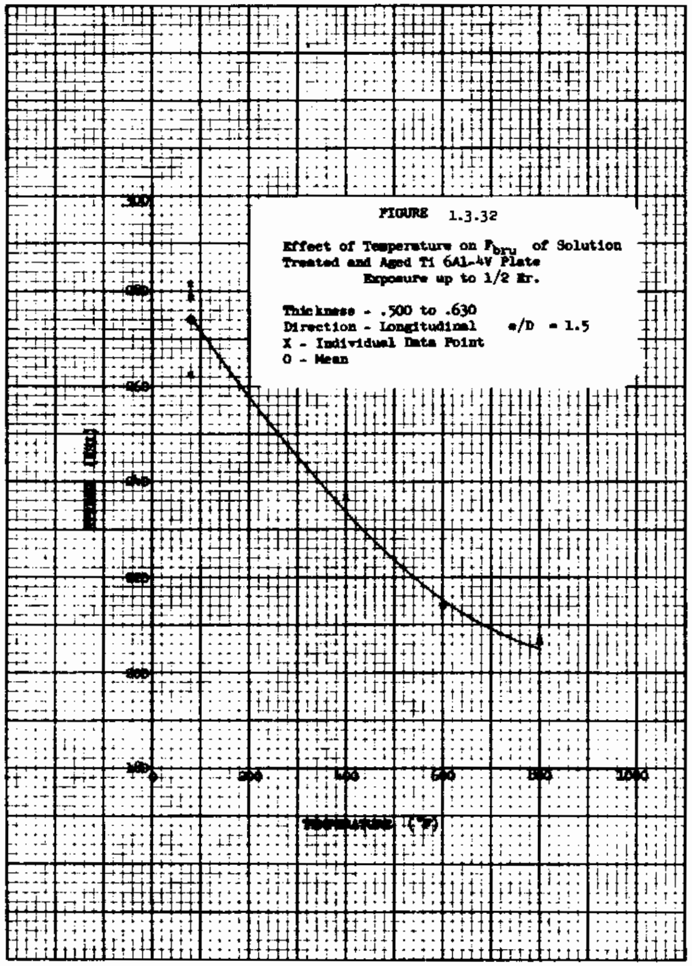


FIGURE 1.3.32

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

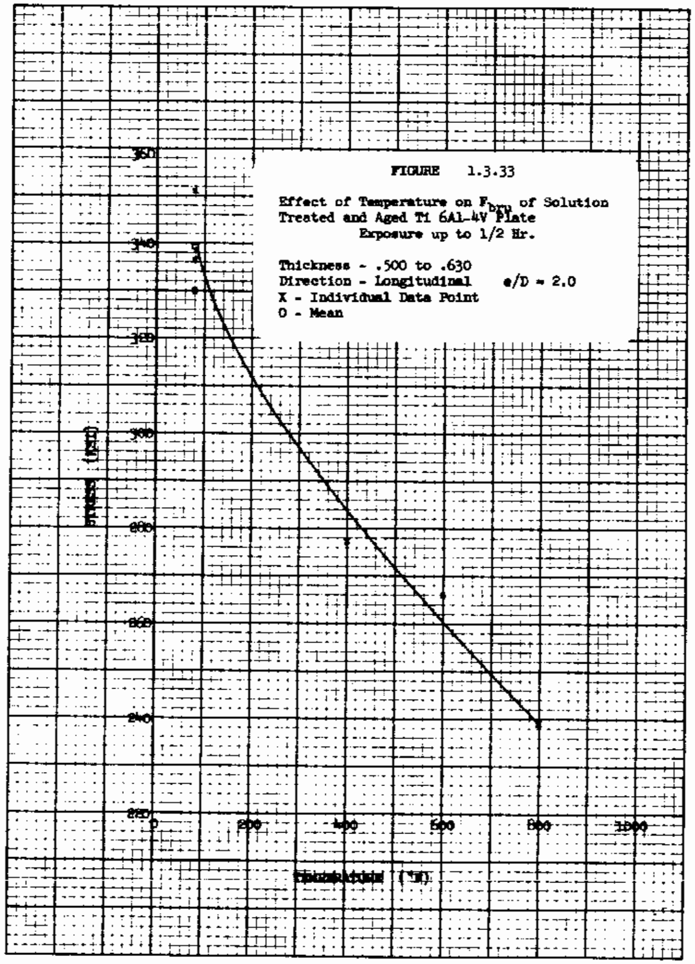


FIGURE 1.3.33
Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean
360
340
320
300
280
260
240
220
0
200
400
600
800
1000
STRESS (KSI)
TEMPERATURE (°F)

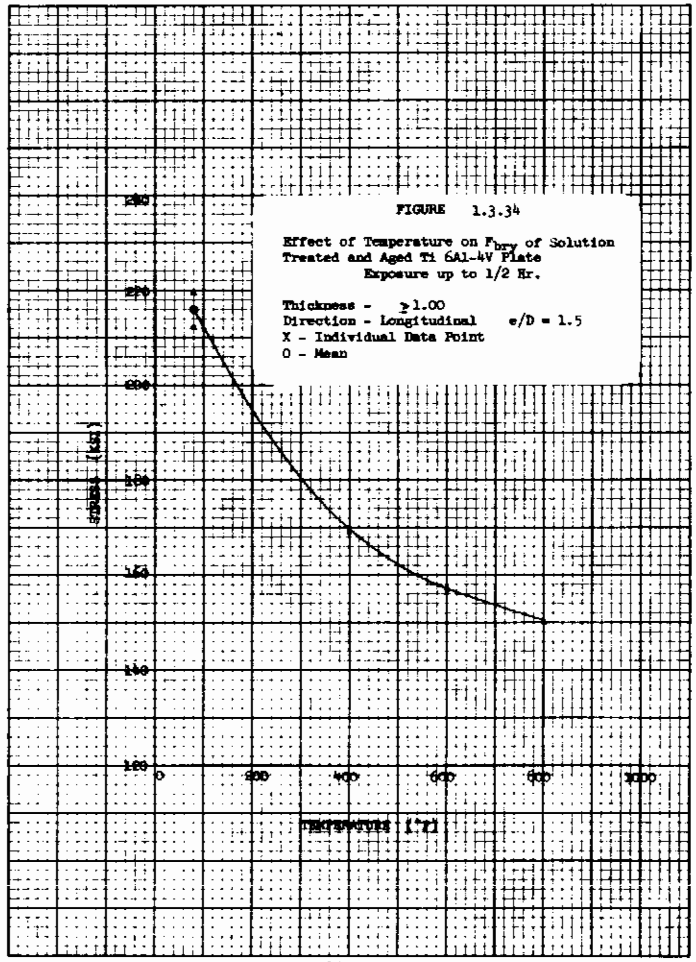


FIGURE 1.3.34
Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.
Thickness - ≥1.00
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean
240
220
200
180
160
140
120
0
200
400
600
800
1000
STRESS (KSI)
TEMPERATURE (°F)

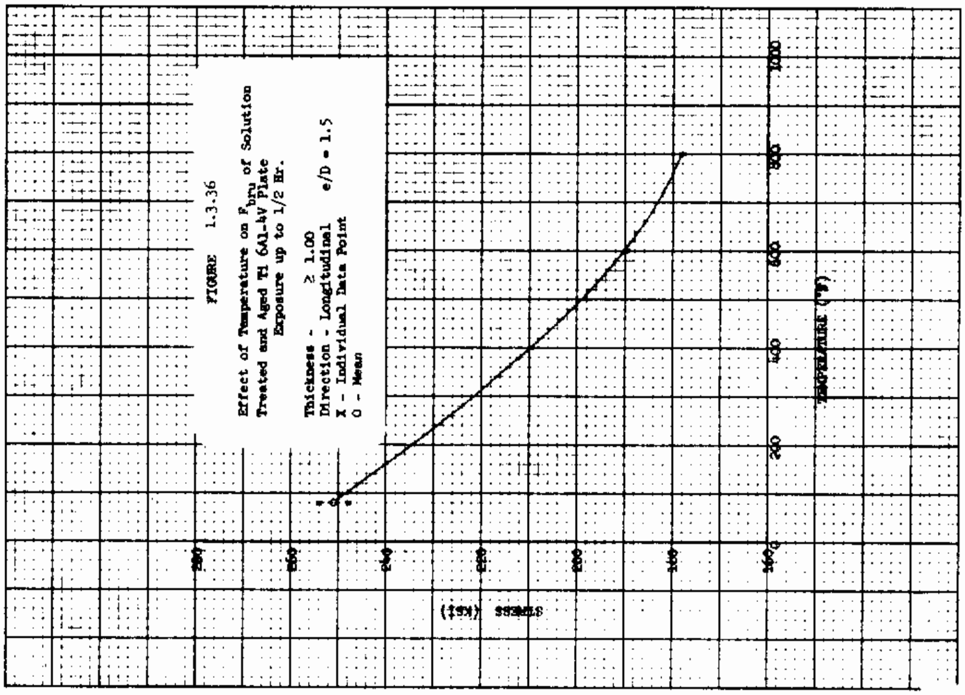


FIGURE 1.3.36
Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
0 - Mean
STRESS (KSI)
TEMPERATURE (°F)
280
260
240
220
200
180
160
200
400
600
800
1000

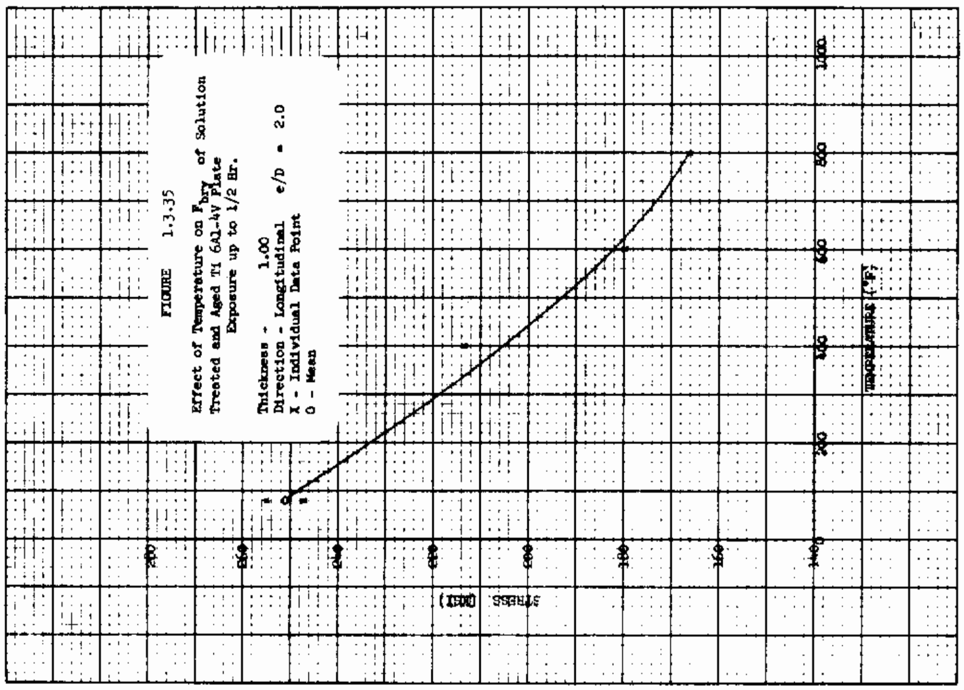


FIGURE 1.3.35
Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - 1.00
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
0 - Mean
STRESS (KSI)
TEMPERATURE (°F)
200
400
600
800
1000

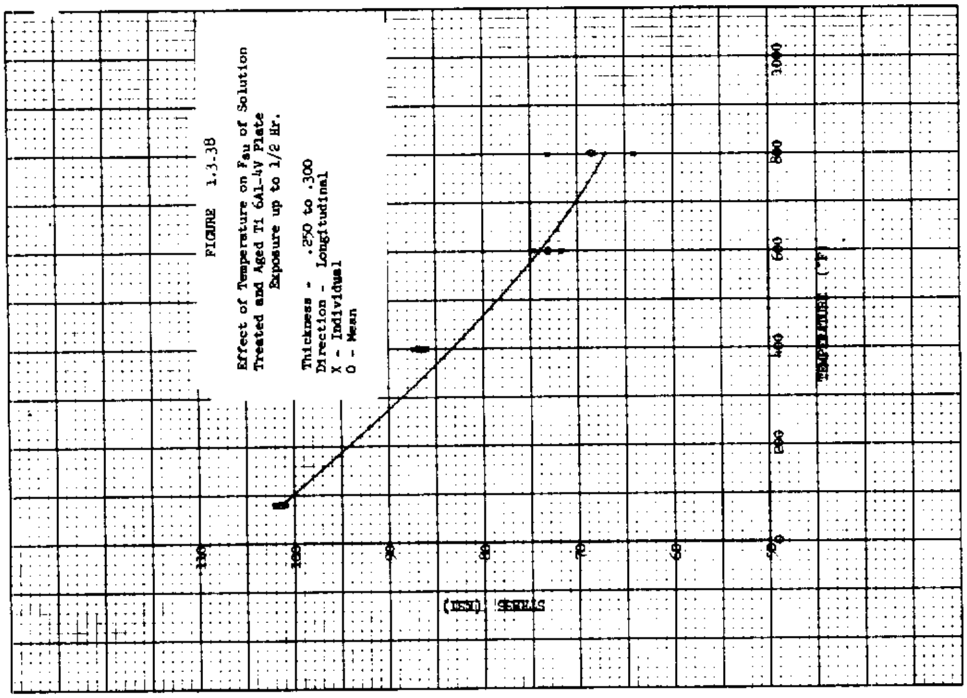


FIGURE 1.3.38
Effect of Temperature on F_{su} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Longitudinal
X - Individual
O - Mean
STRESS (KSI)
110
100
90
80
70
60
50
TEMPERATURE (°F)
0
200
400
600
800
1000

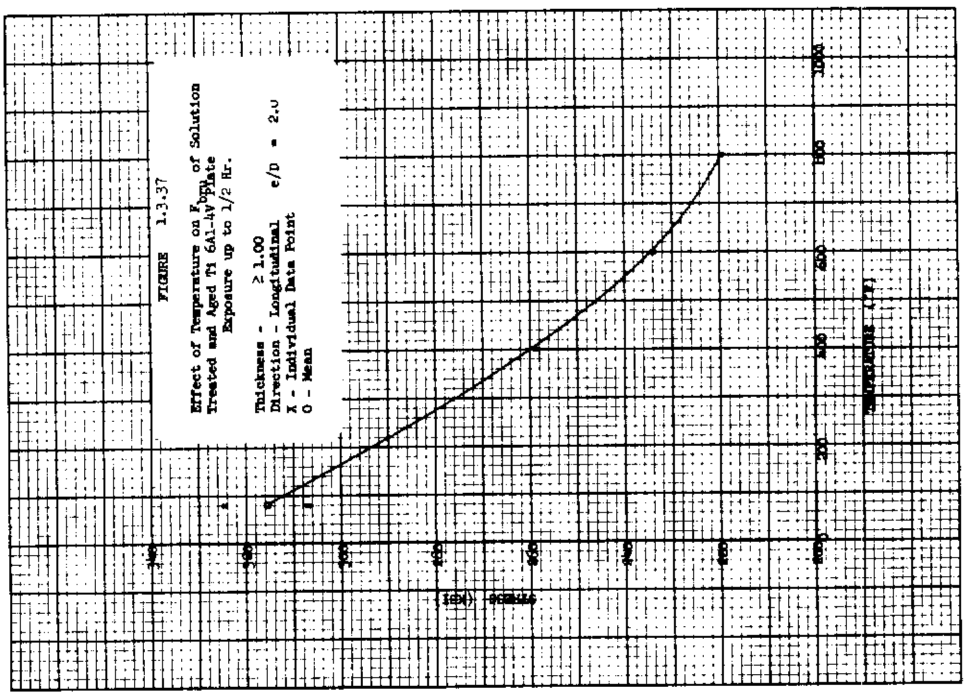


FIGURE 1.3.37
Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean
STRESS (KSI)
TEMPERATURE (°F)
0
200
400
600
800
1000

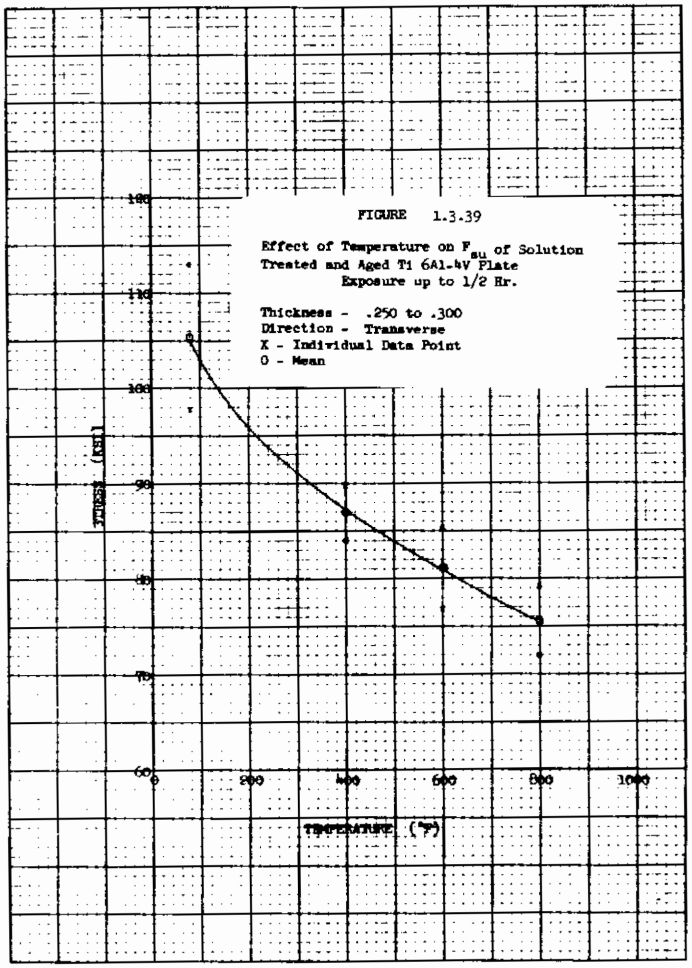


FIGURE 1.3.39

Effect of Temperature on F_{su} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
0 - Mean

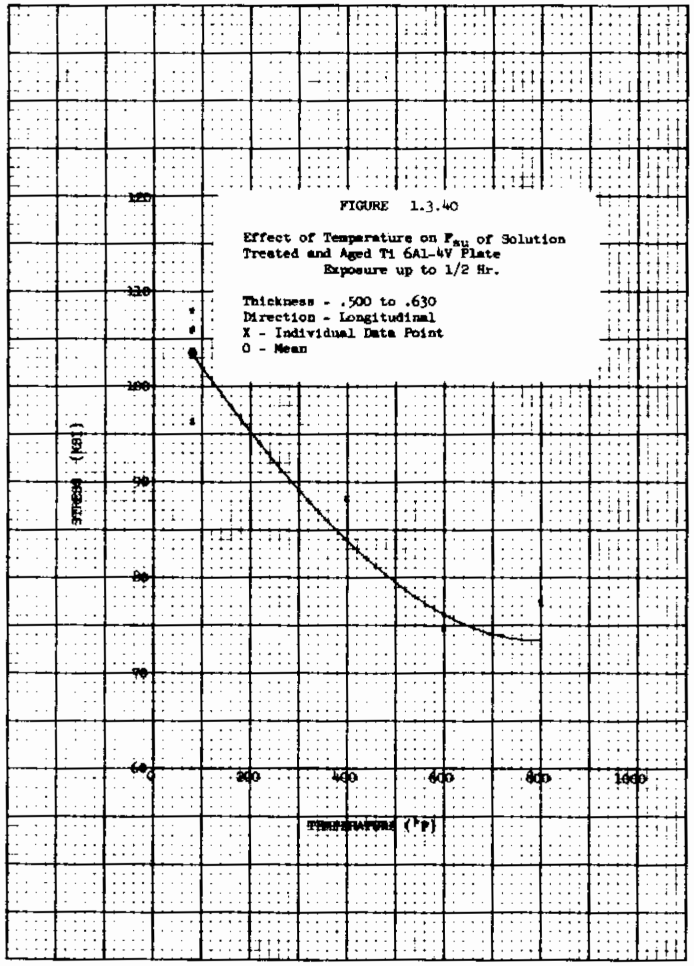


FIGURE 1.3.40

Effect of Temperature on F_{su} of Solution Treated and Aged Ti 6Al-4V Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
0 - Mean

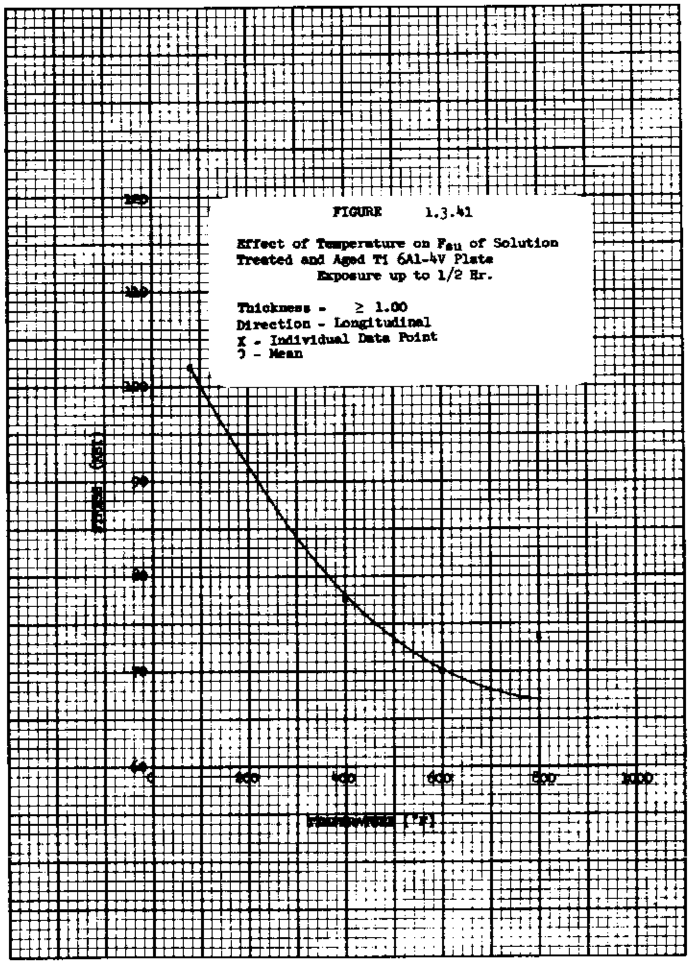


FIGURE 1.3.41

Effect of Temperature on F_{su} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
ↄ - Mean

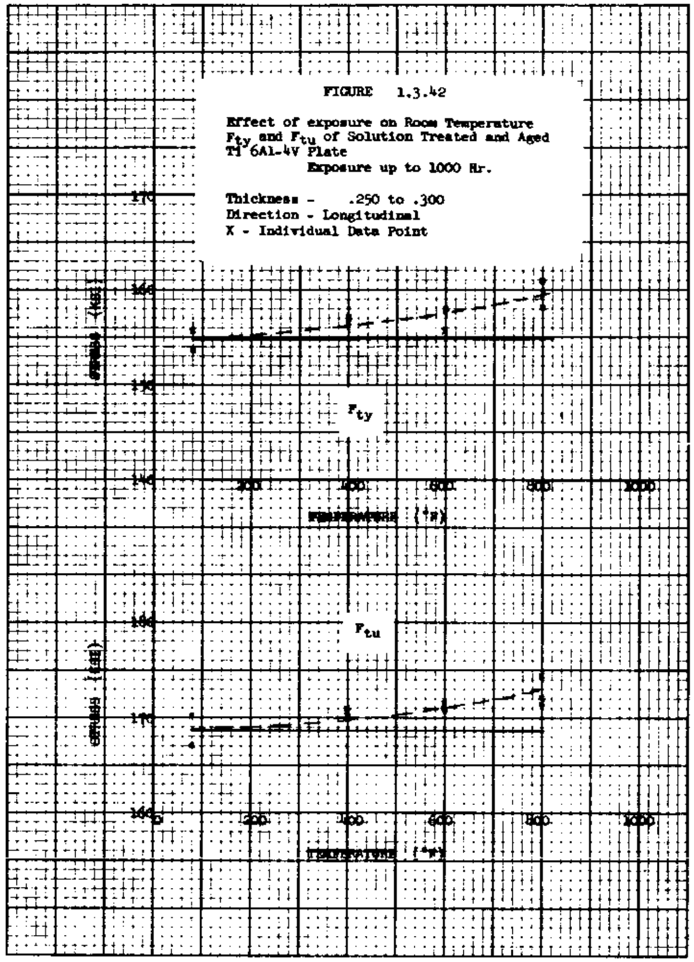


FIGURE 1.3.42

Effect of exposure on Room Temperature F_{ty} and F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1000 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point

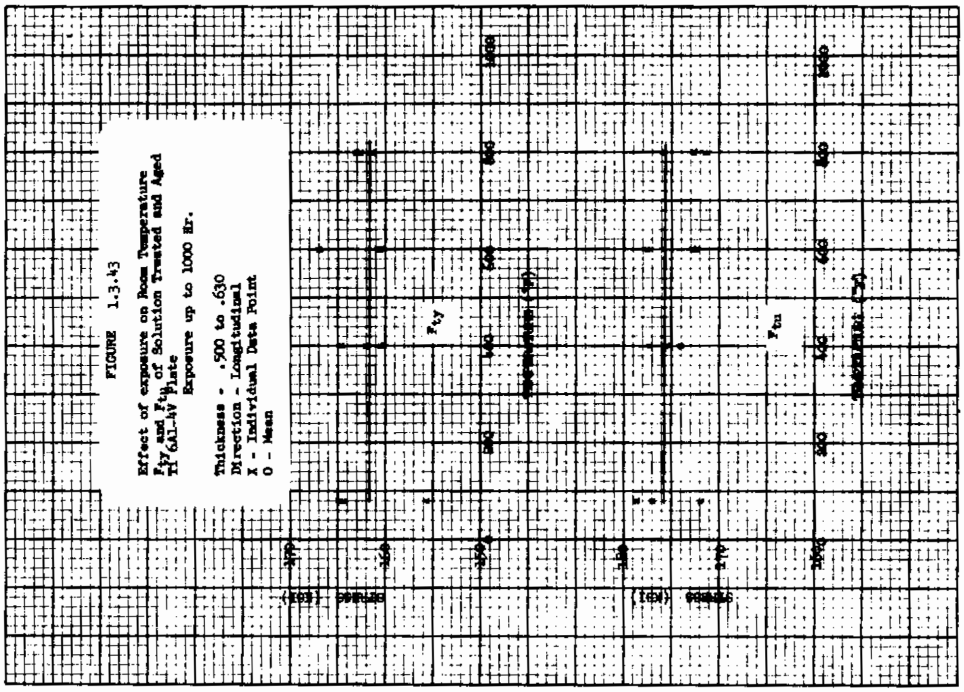


FIGURE 1.3.43

Effect of exposure on Room Temperature F_{ty} and F_{tu} of Solution Treated and Aged Ti 6Al-4V Plate
Exposure up to 1000 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

A WORKING CURVES (continued)

1.4 Ti-6Al-6V-2Sn Cond. A Figures 1.4.1 to 1.4.44

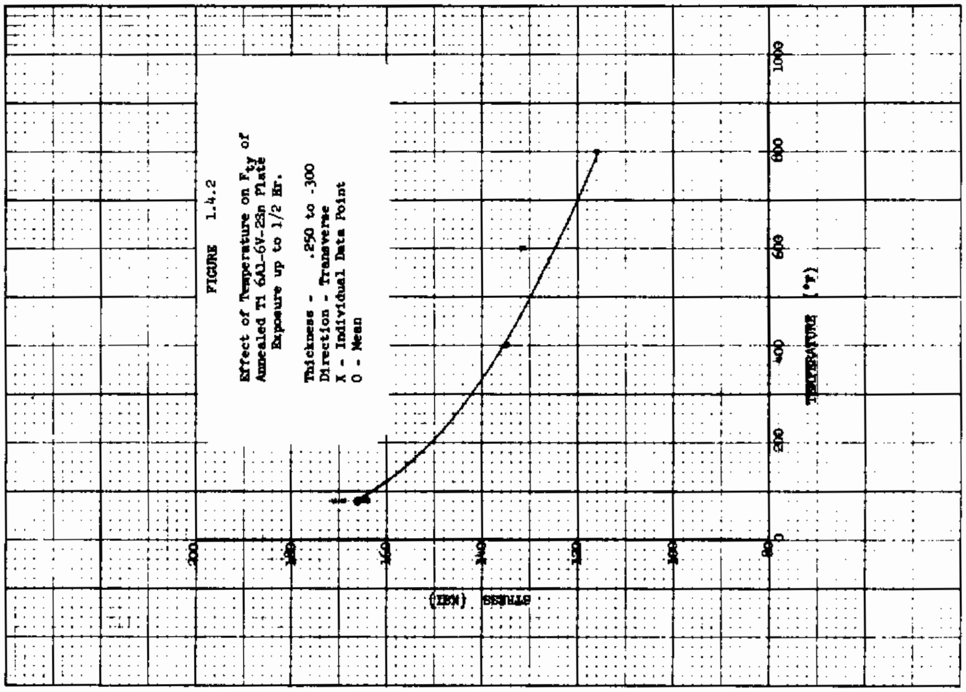


FIGURE 1.4.2
Effect of Temperature on F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
0 - Mean
STRESS (KSI)
200
180
160
140
120
100
80
TEMPERATURE (°F)
0
200
400
600
800
1000

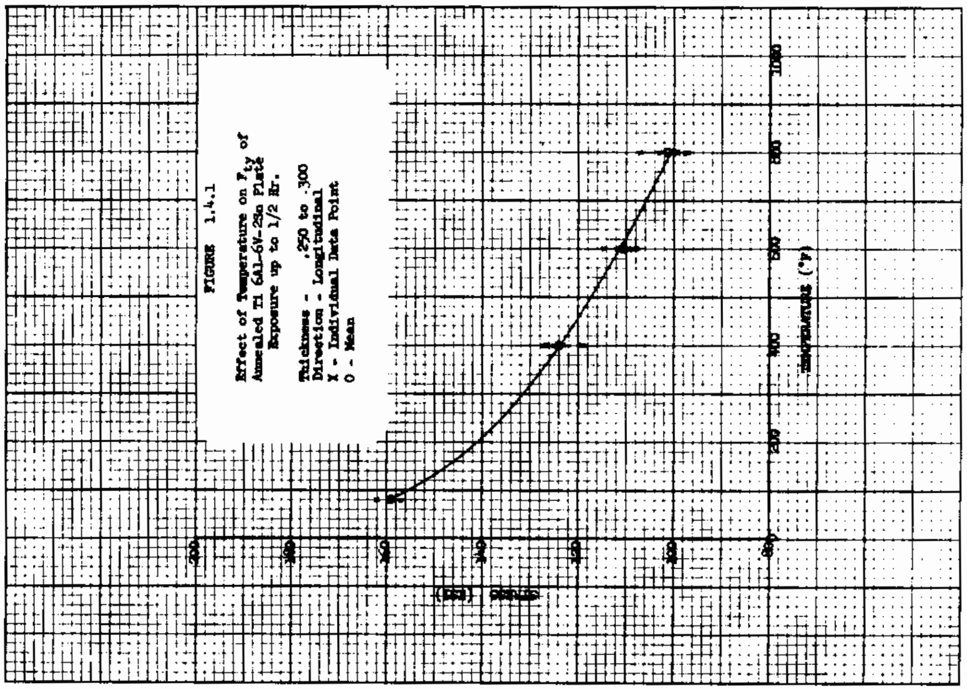


FIGURE 1.4.1
Effect of Temperature on F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
0 - Mean
STRESS (KSI)
200
180
160
140
120
100
80
TEMPERATURE (°F)
200
400
600
800
1000

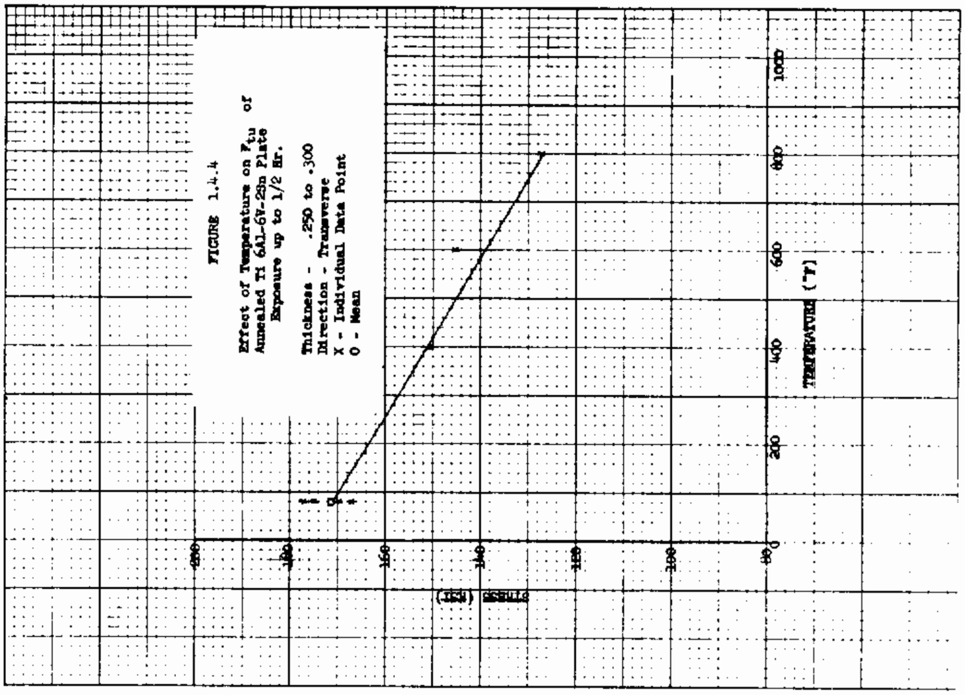


FIGURE 1.4.4

Effect of Temperature on F_{tu} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
0 - Mean

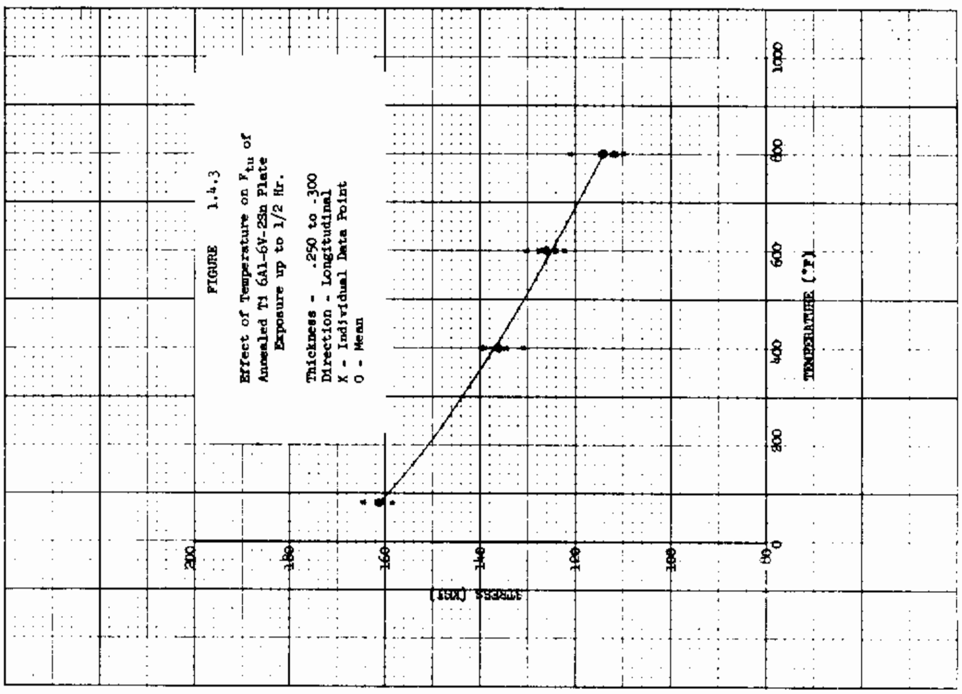


FIGURE 1.4.3

Effect of Temperature on F_{tu} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
0 - Mean

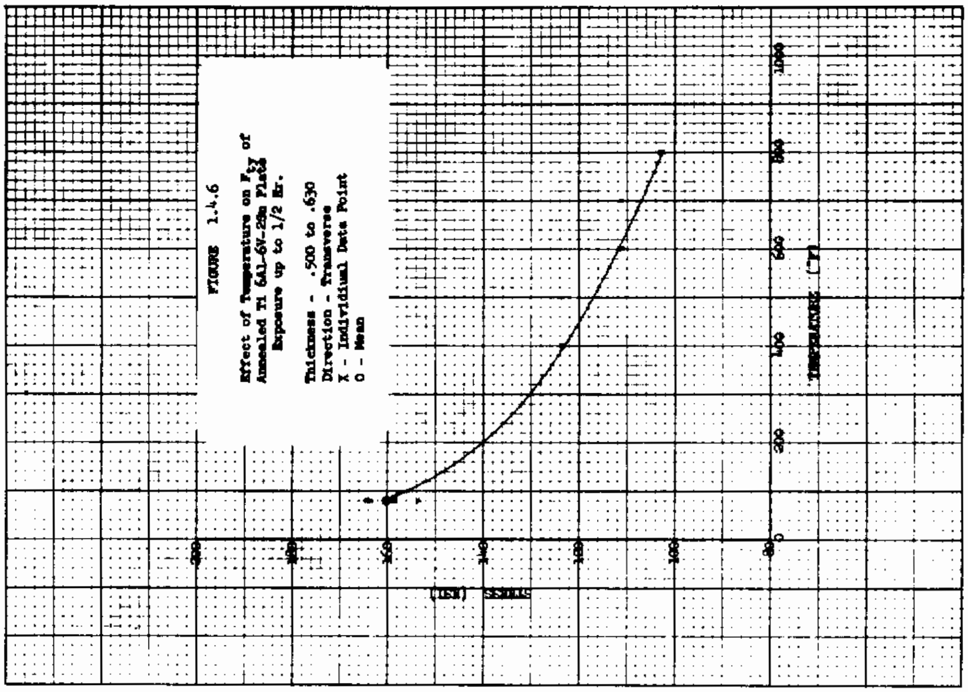


FIGURE 1.4.6
Effect of Temperature on F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
0 - Mean
STRESS (KSI)
200
180
160
140
120
100
80
TEMPERATURE (°F)
0
200
400
600
800
1000

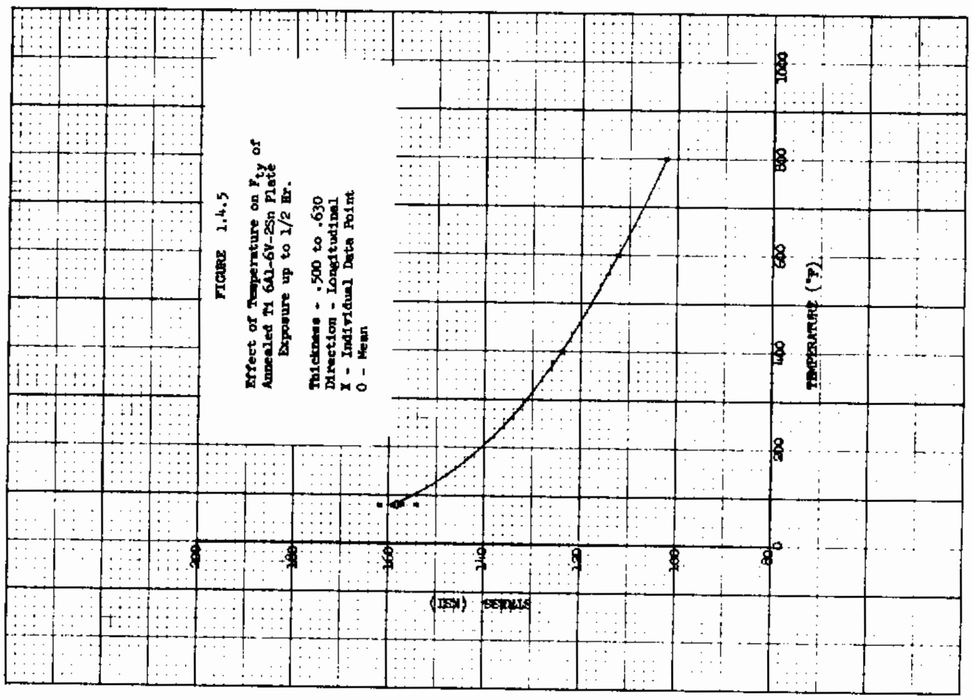


FIGURE 1.4.5
Effect of Temperature on F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
0 - Mean
STRESS (KSI)
200
180
160
140
120
100
80
TEMPERATURE (°F)
0
200
400
600
800
1000

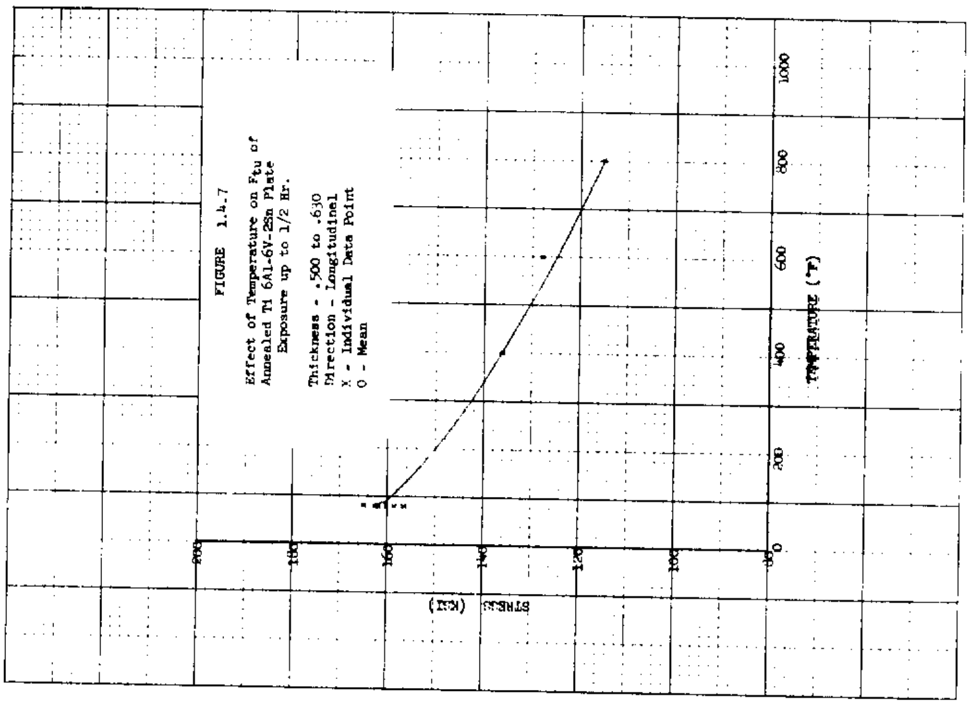


FIGURE 1.4.7
Effect of Temperature on Ftu of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean
STRESS (KSI)
200
180
160
140
120
100
80
TEMPERATURE (°F)
0
200
400
600
800
1000

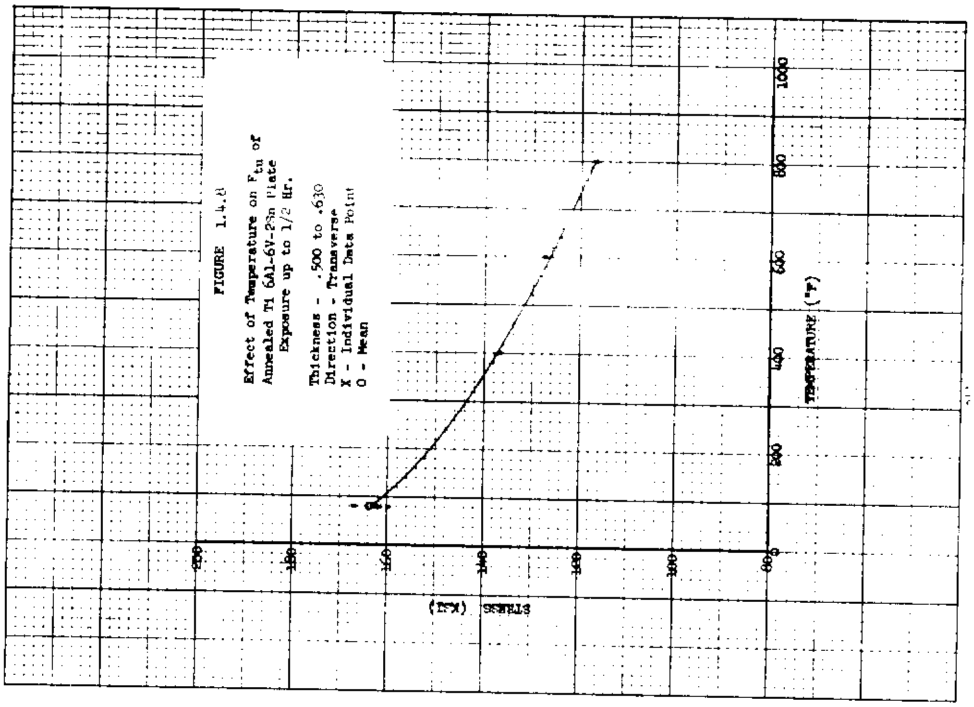


FIGURE 1.4.8
Effect of Temperature on F_{tu} of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
O - Mean
STRESS (KSI)
200
180
160
140
120
100
80
TEMPERATURE (°F)
0
200
400
600
800
1000

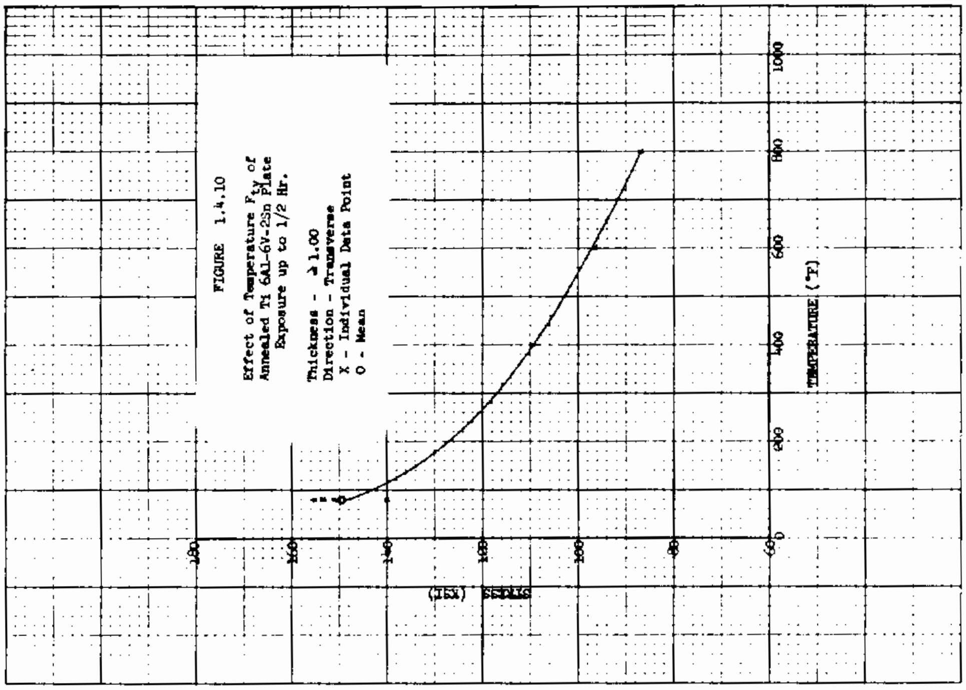


FIGURE 1.4.10

Effect of Temperature F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean

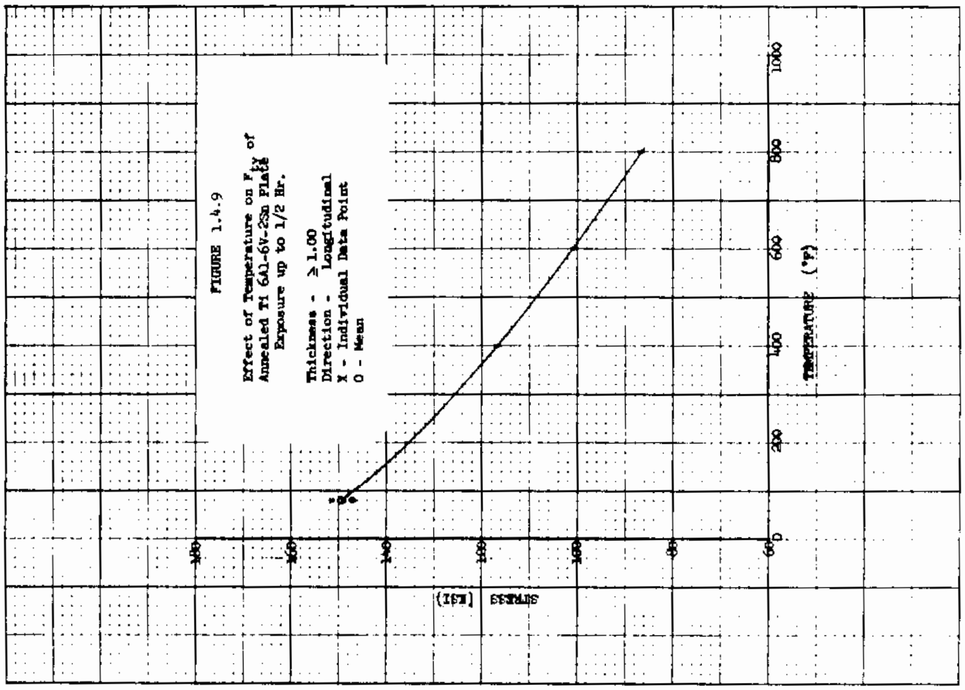


FIGURE 1.4.9

Effect of Temperature on F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

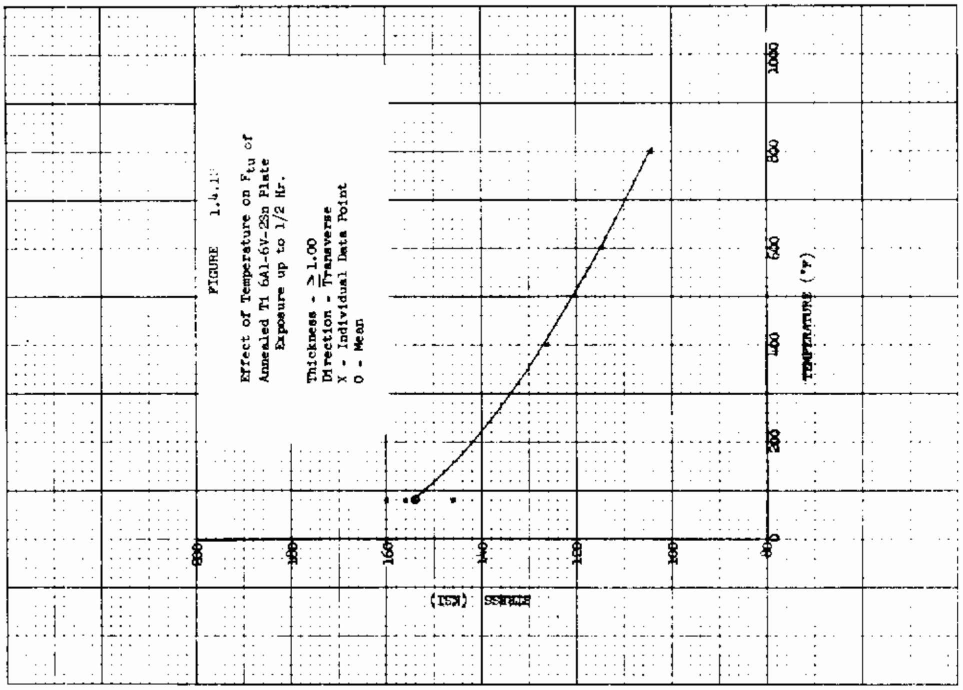


FIGURE 1.4.1[illegible]

Effect of Temperature on F_{tu} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - $\geq$ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean

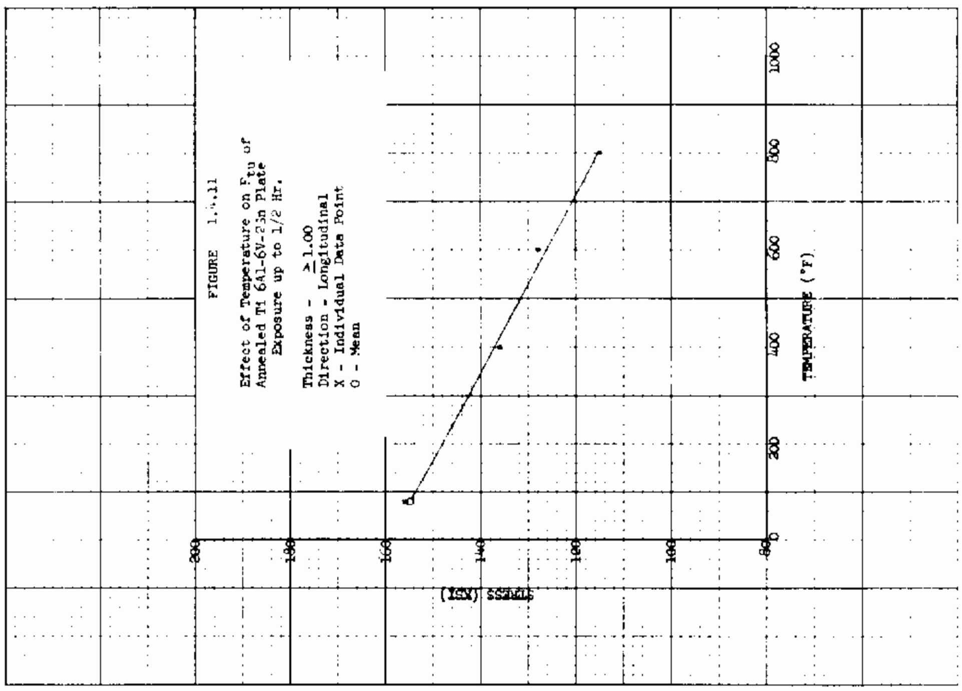


FIGURE 1.4.11

Effect of Temperature on F_{tu} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - $\geq$ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

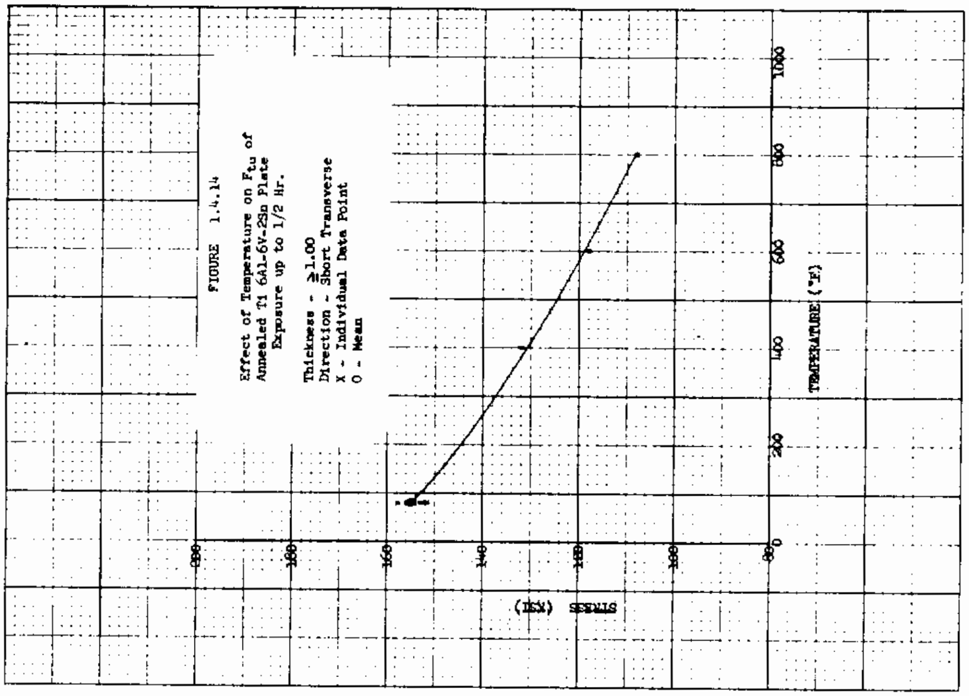


FIGURE 1.4.14

Effect of Temperature on F_{tu} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

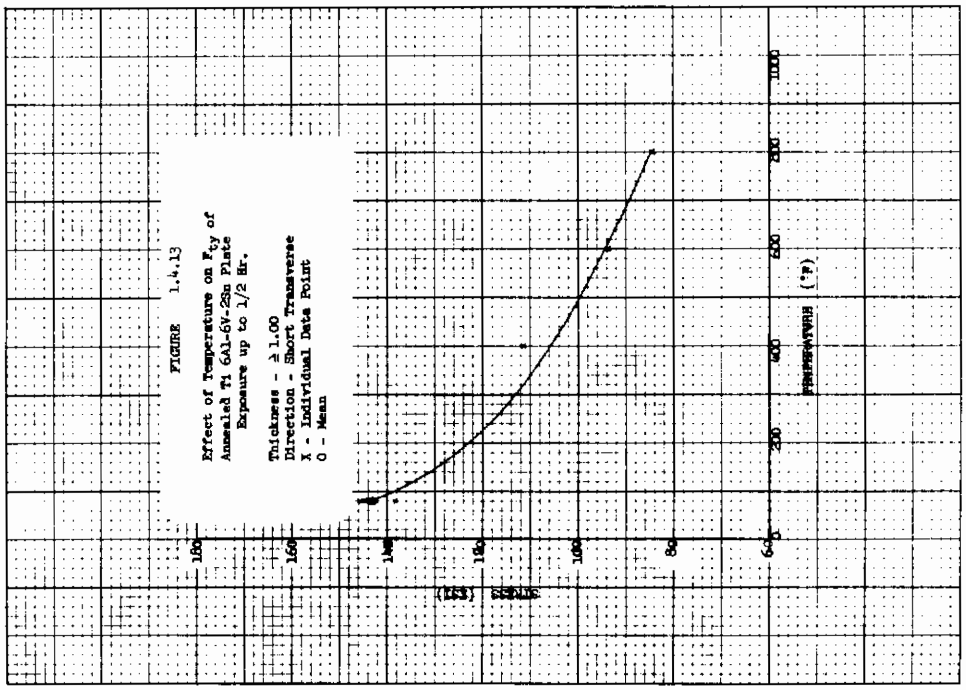


FIGURE 1.4.13

Effect of Temperature on F_{ty} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

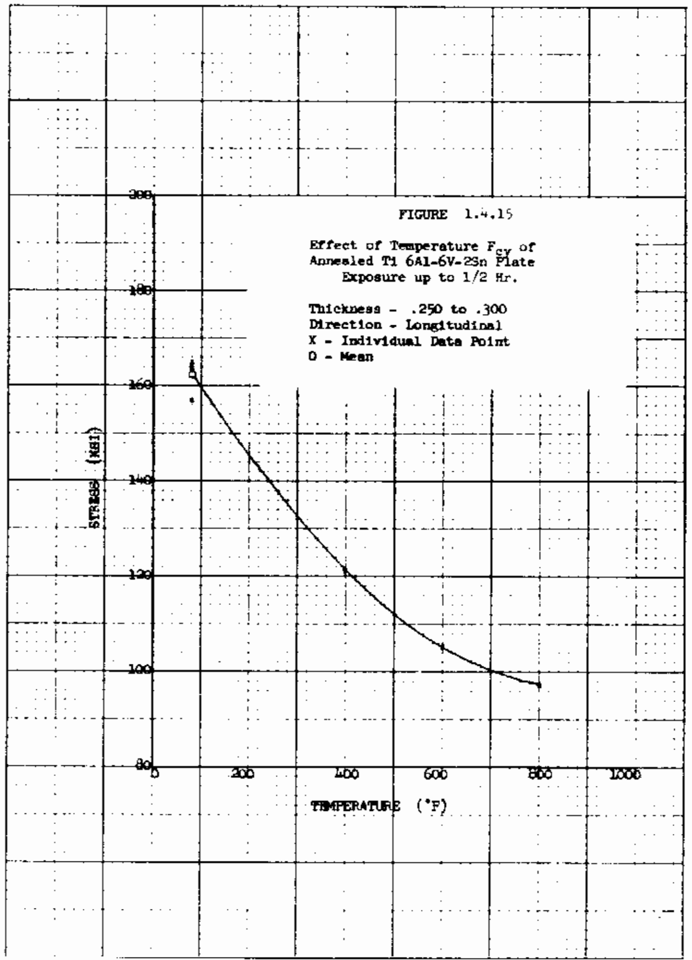


FIGURE 1.4.15

Effect of Temperature F_{cy} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
O - Mean

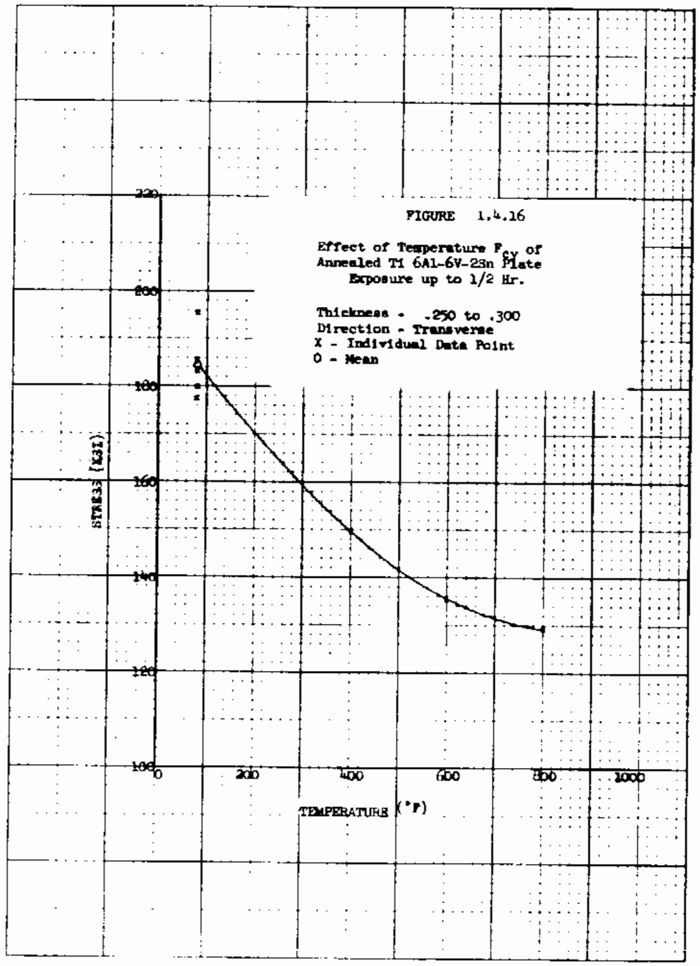


FIGURE 1.4.16

Effect of Temperature F_{cy} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
O - Mean

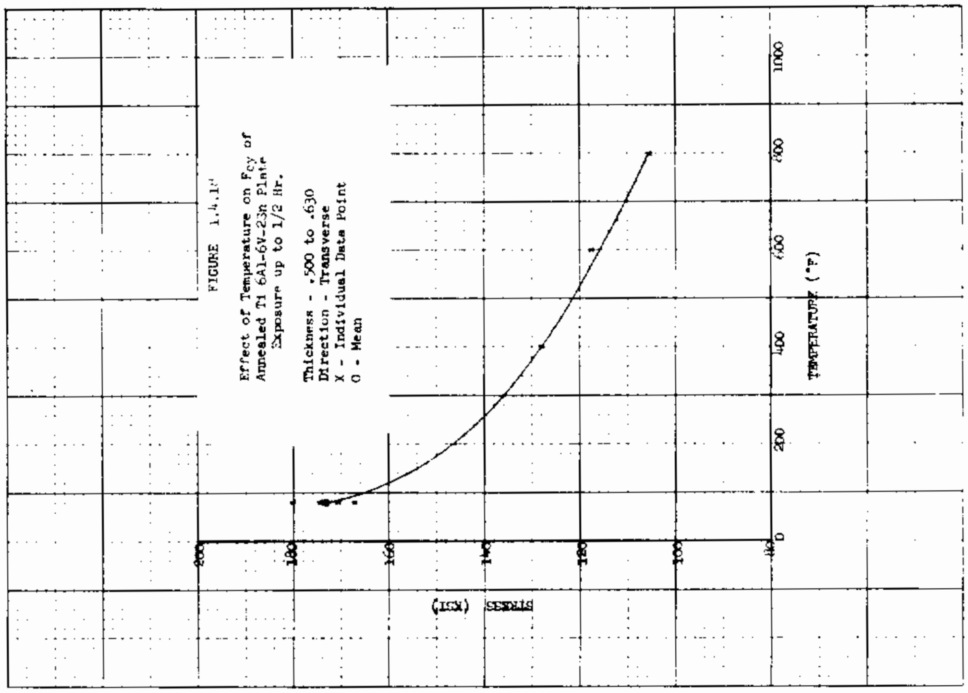


FIGURE 1.4.1[illegible]

Effect of Temperature on F_{cy} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
O - Mean

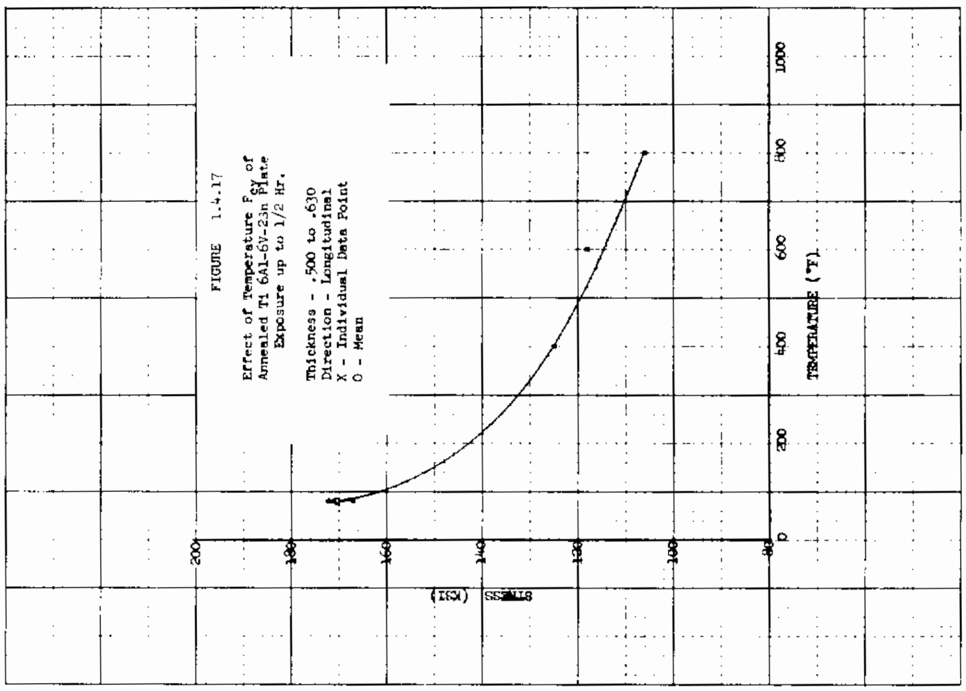


FIGURE 1.4.17

Effect of Temperature F_{cy} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

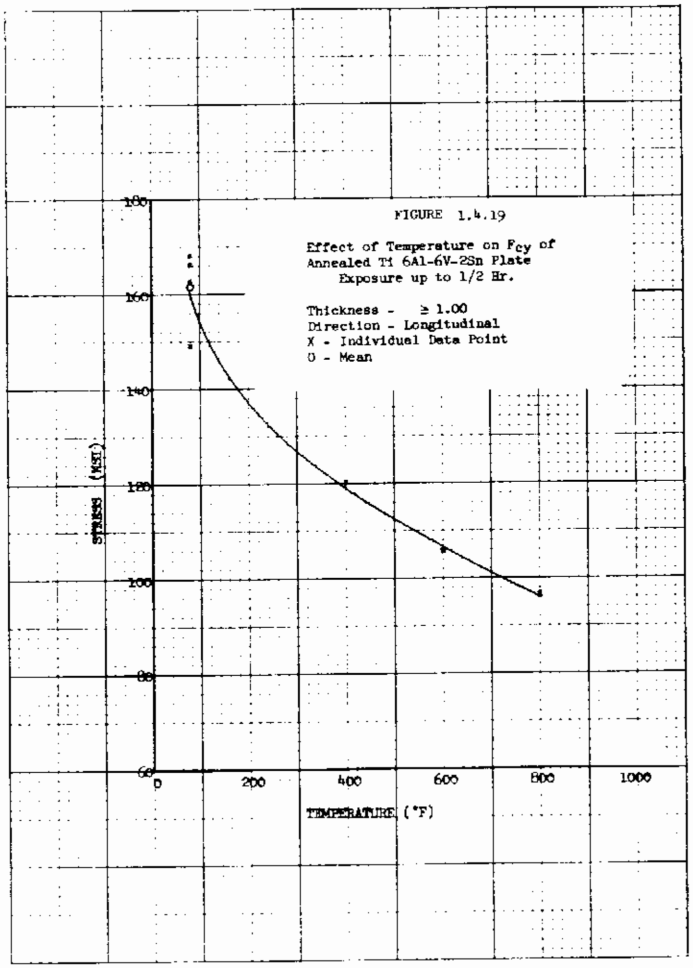


FIGURE 1.4.19

Effect of Temperature on F_{cy} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

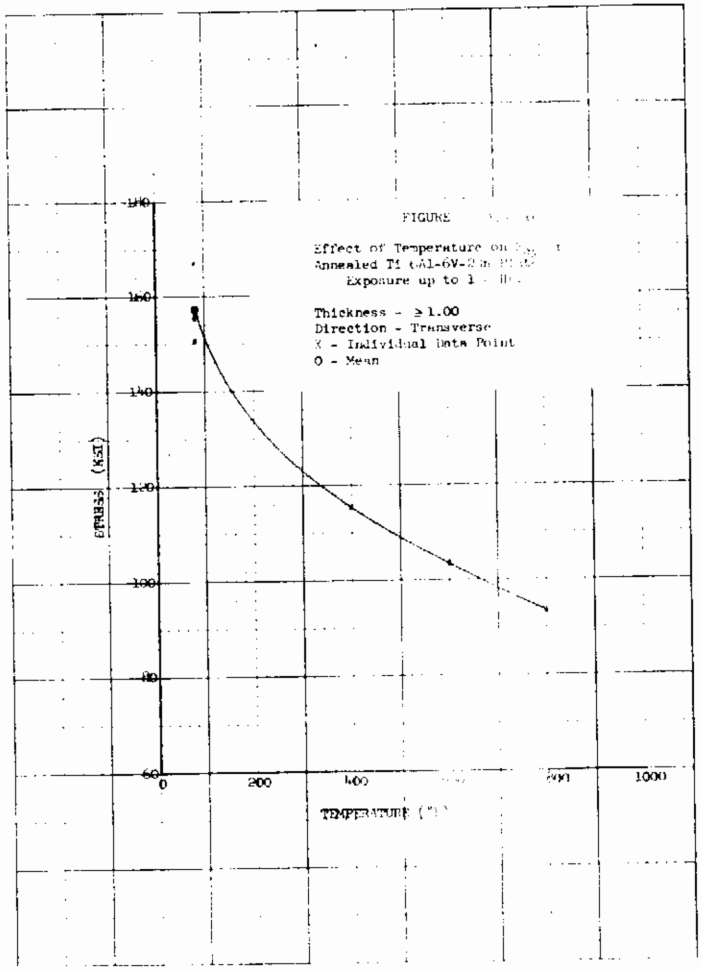


FIGURE [illegible]

Effect of Temperature on [illegible] Annealed Ti 6Al-6V-2Sn [illegible] Exposure up to 1 [illegible]

Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean

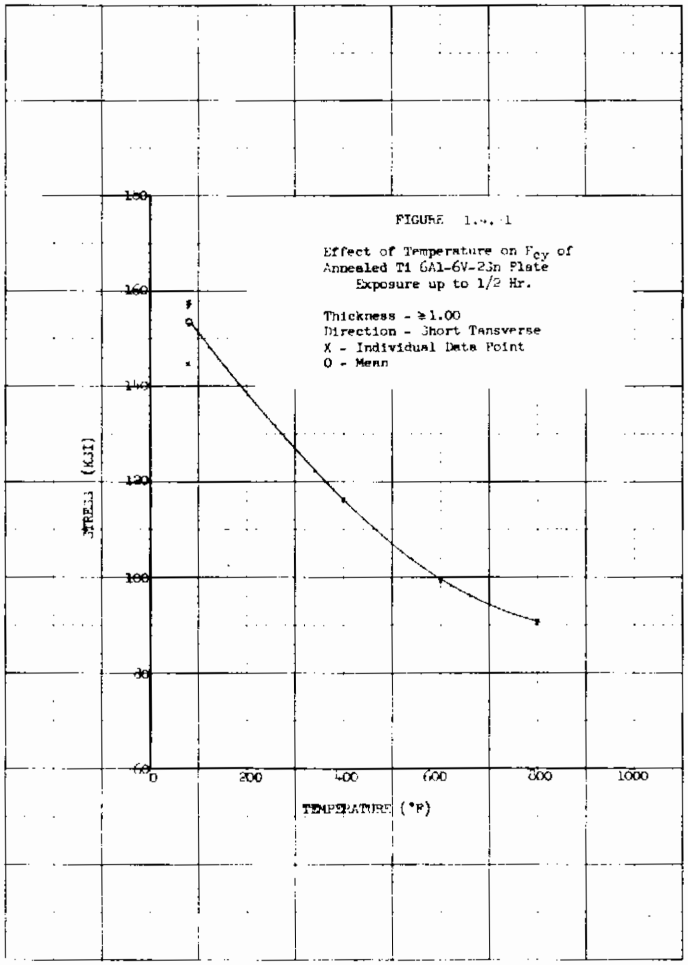


FIGURE 1.[illegible]1
Effect of Temperature on F_{cy} of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - ≥1.00
Direction - Short Tansverse
X - Individual Data Point
O - Mean
STRESS (KSI)
180
160
140
120
100
80
60
0
200
400
600
800
1000
TEMPERATURE (°F)

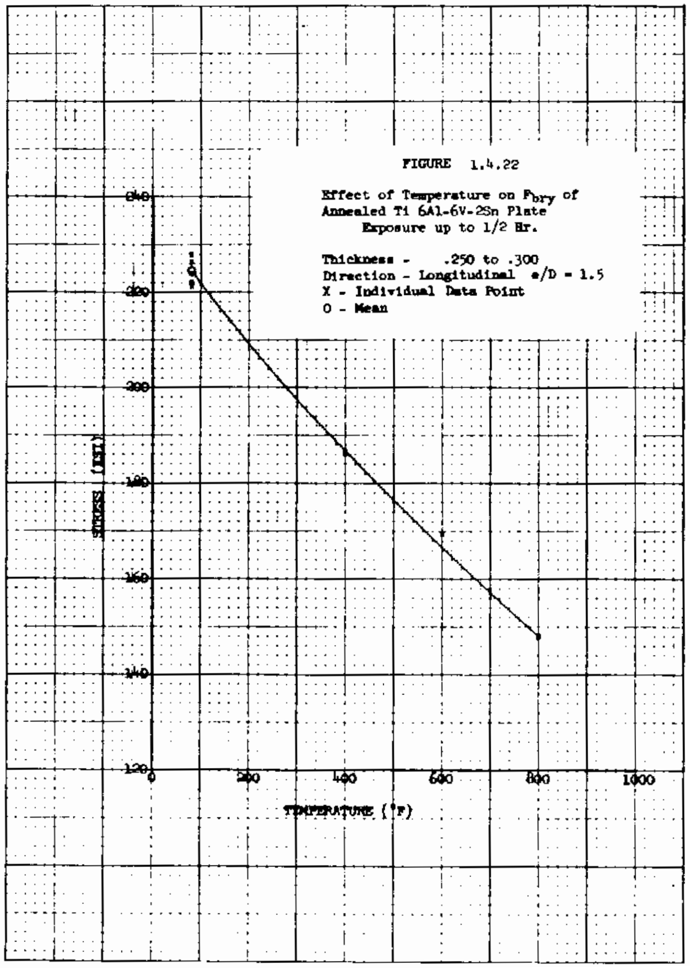


FIGURE 1.4.22
Effect of Temperature on F_{bry} of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean
STRESS (KSI)
240
220
200
180
160
140
120
0
200
400
600
800
1000
TEMPERATURE (°F)

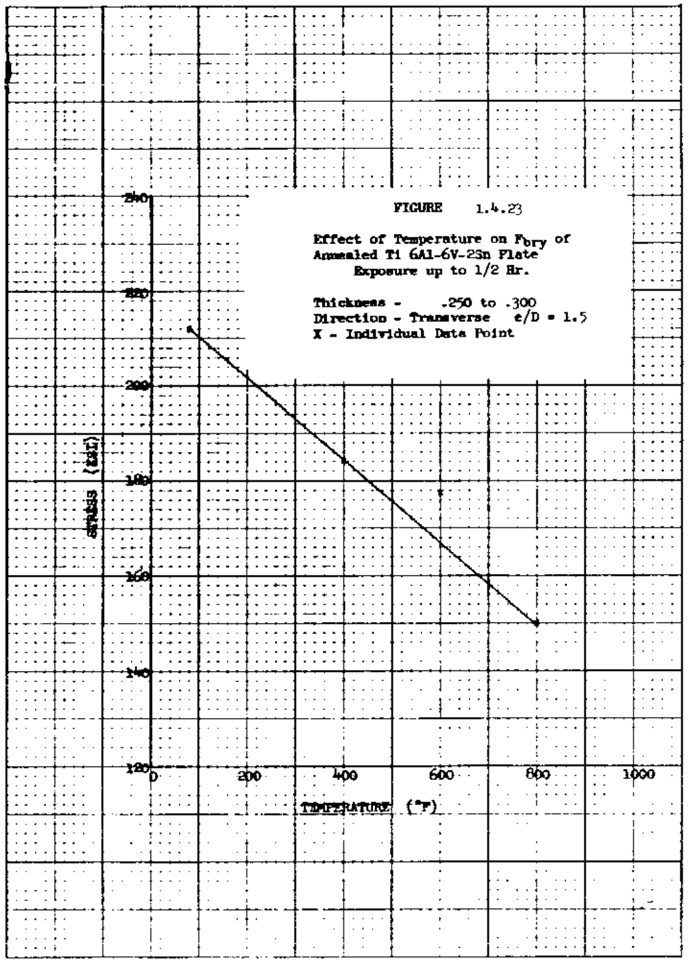


FIGURE 1.4.23

Effect of Temperature on F_{bry} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse e/D = 1.5
X - Individual Data Point

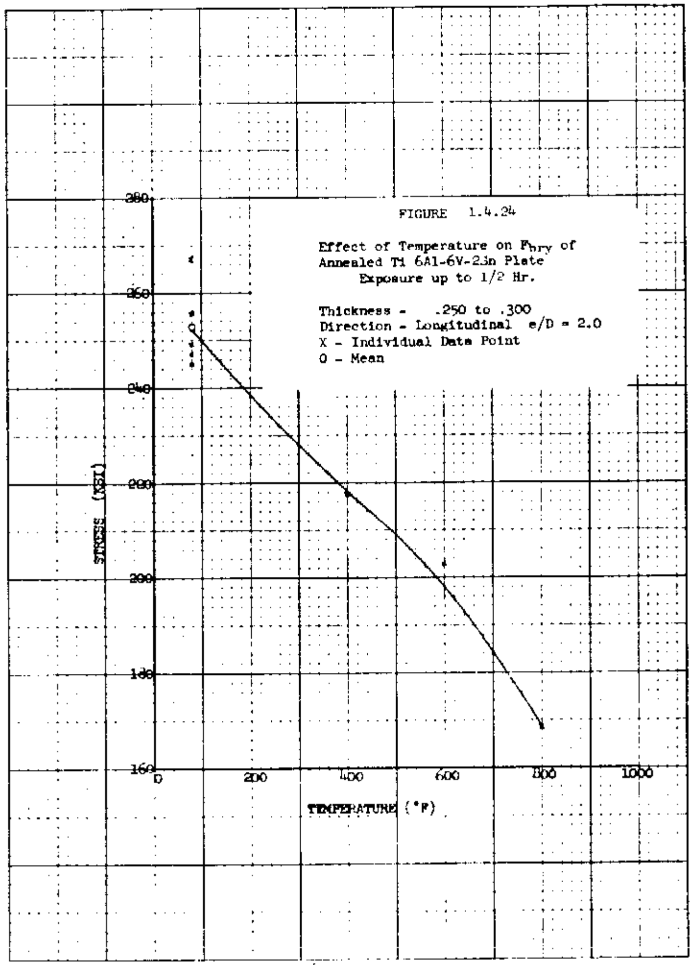


FIGURE 1.4.24

Effect of Temperature on F_{bry} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

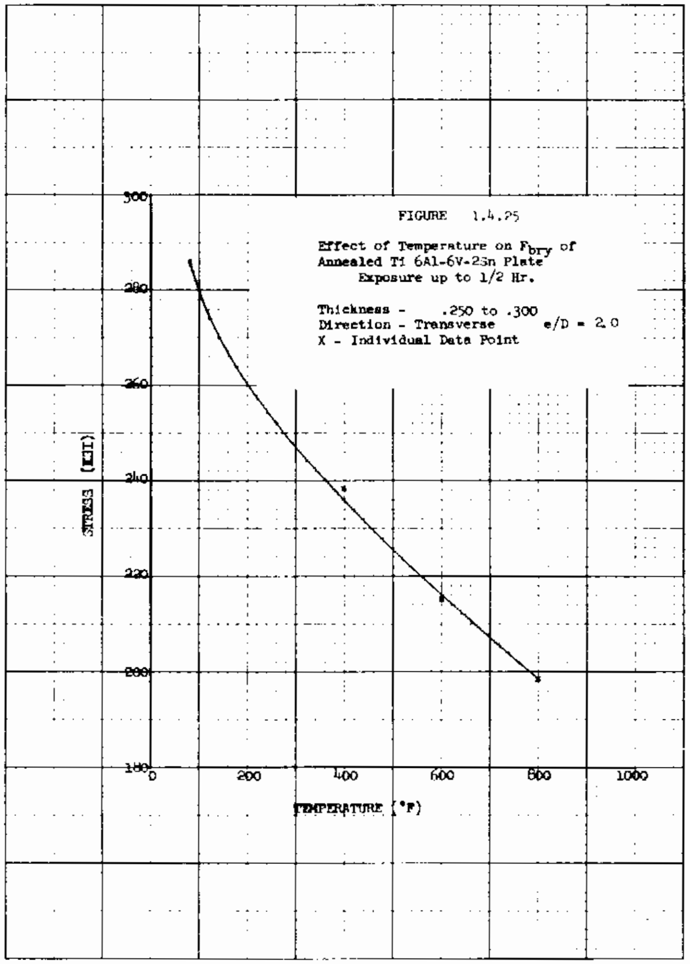


FIGURE 1.4.25

Effect of Temperature on F_{bry} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse e/D = 2.0
X - Individual Data Point

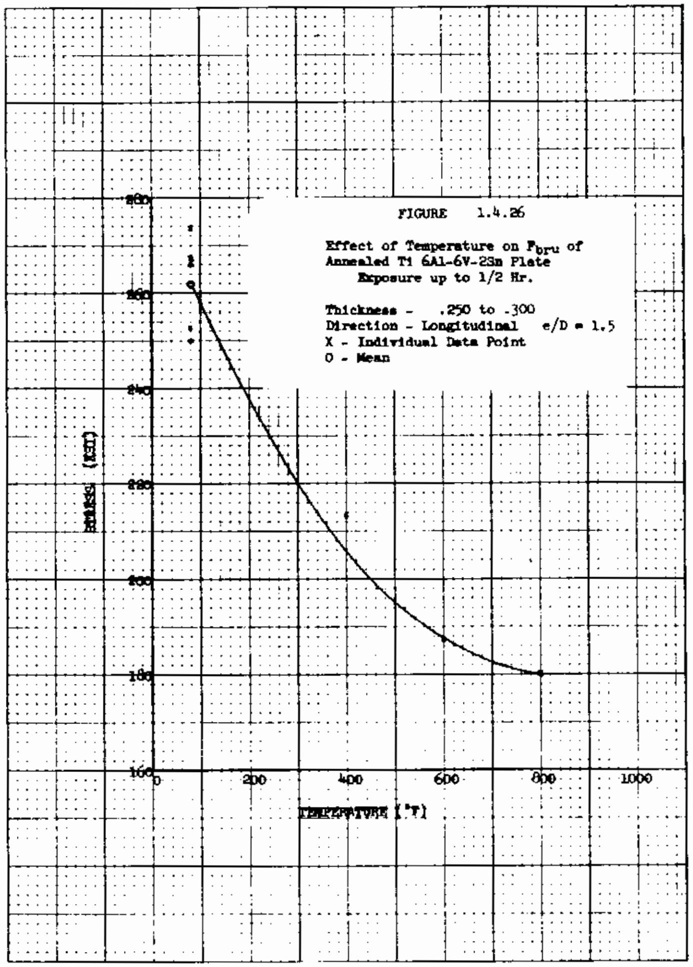


FIGURE 1.4.26

Effect of Temperature on F_{bru} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

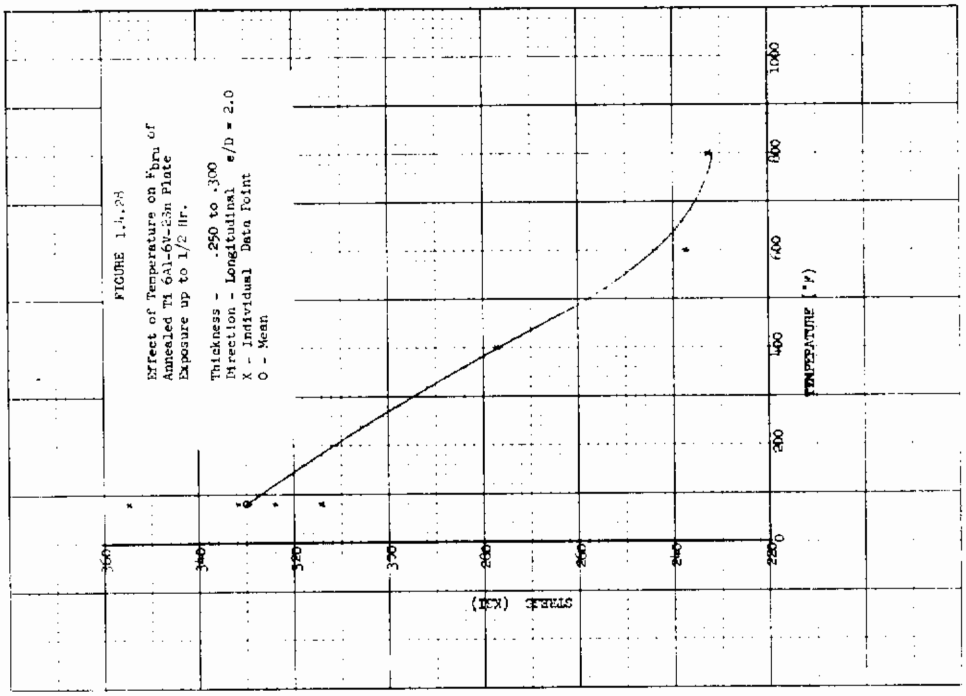


FIGURE 1.4.28

Effect of Temperature on F_{bru} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

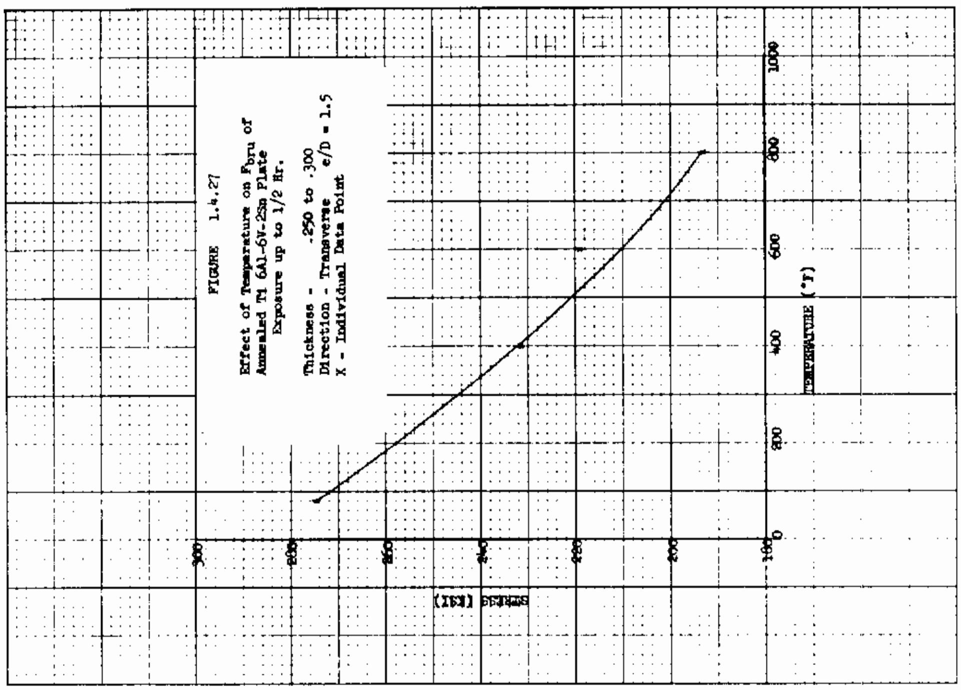


FIGURE 1.4.27

Effect of Temperature on F_{bru} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Transverse e/D = 1.5
X - Individual Data Point

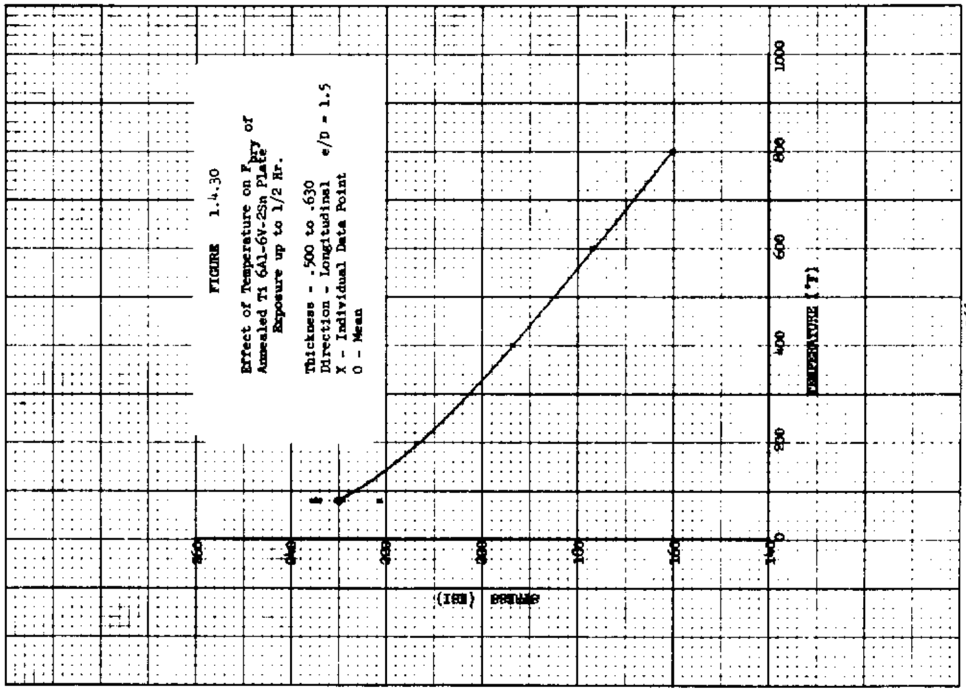


FIGURE 1.4.30
Effect of Temperature on Fbry of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean
0
200
400
600
800
1000
TEMPERATURE (°F)

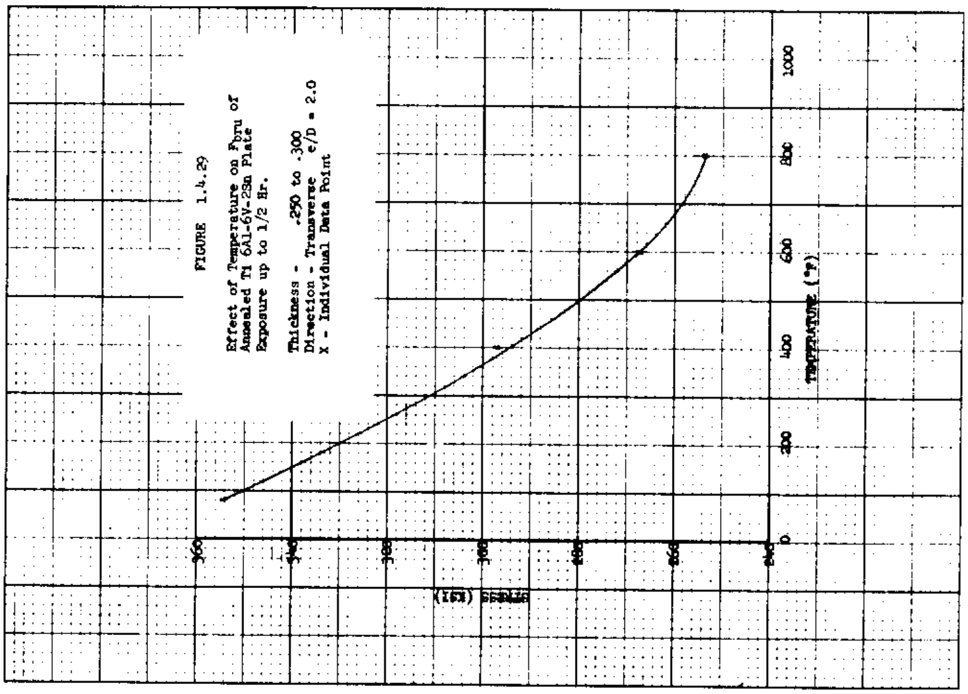


FIGURE 1.4.29
Effect of Temperature on Fbru of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Transverse e/D = 2.0
X - Individual Data Point
0
200
400
600
800
1000
TEMPERATURE (°F)

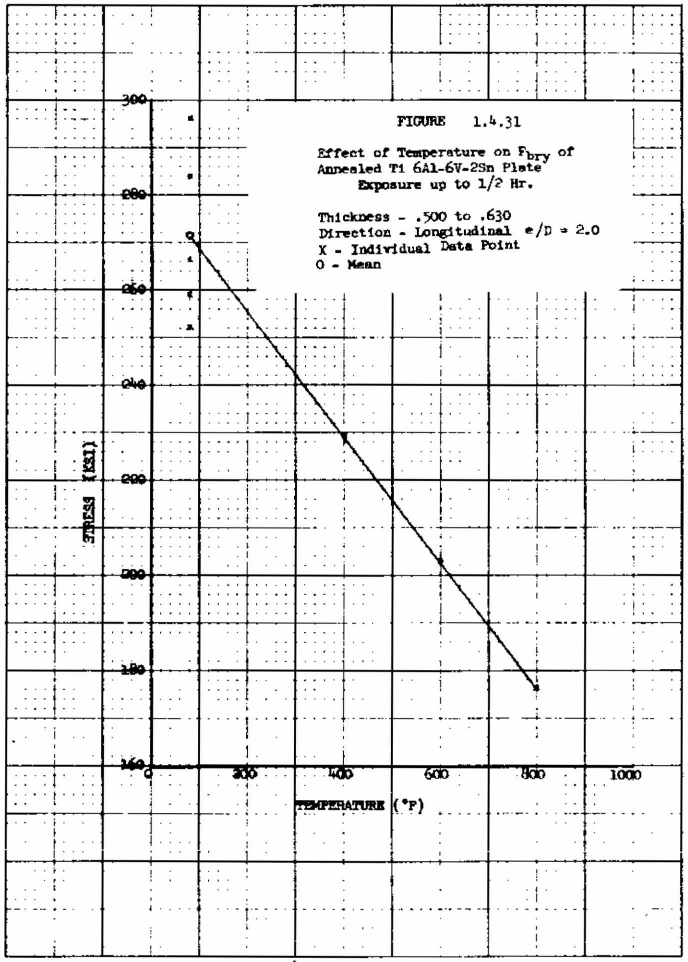


FIGURE 1.4.31

Effect of Temperature on F_{bry} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

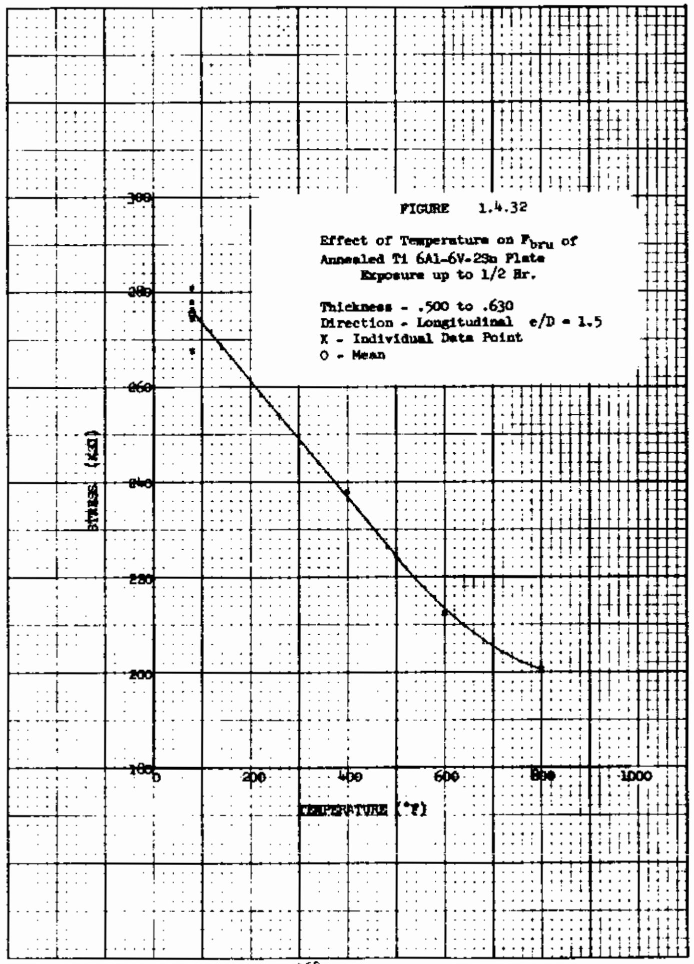


FIGURE 1.4.32

Effect of Temperature on F_{bru} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

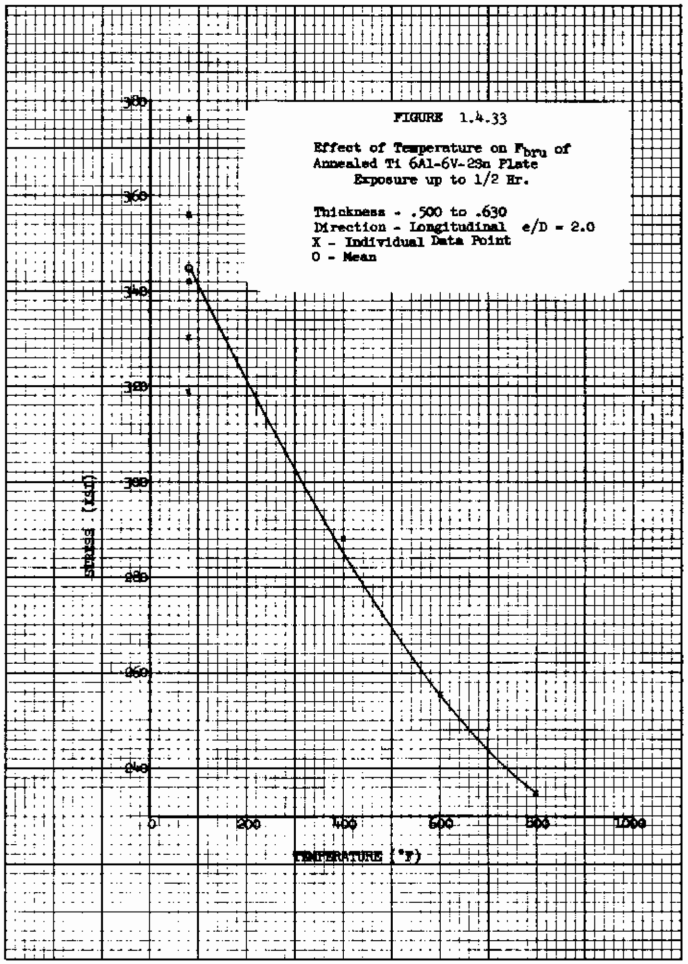


FIGURE 1.4.33

Effect of Temperature on F_{bru} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

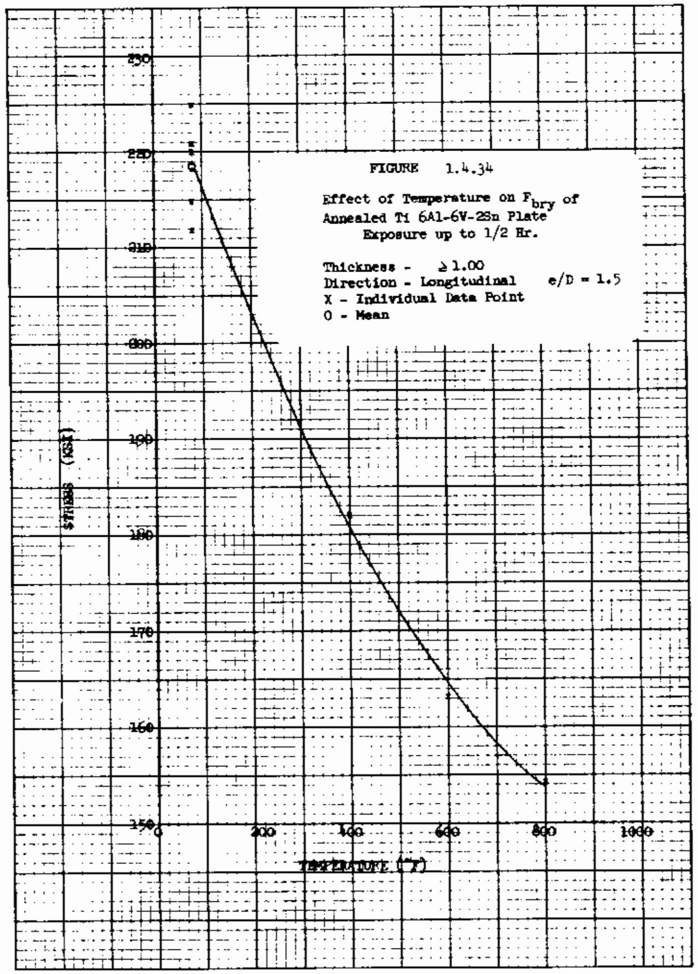


FIGURE 1.4.34

Effect of Temperature on F_{bry} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥1.00
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

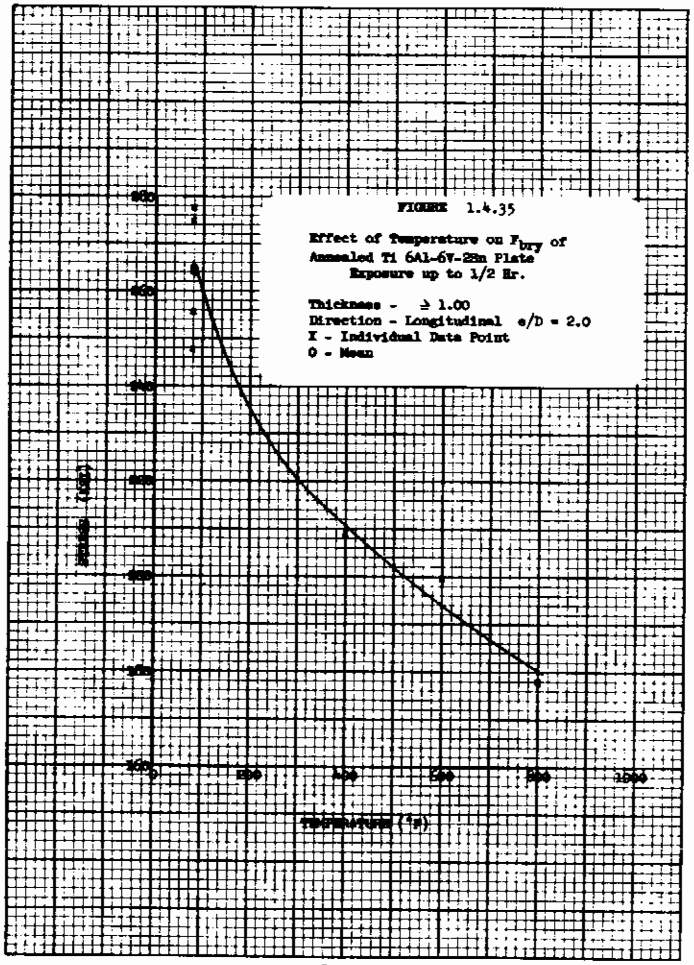


FIGURE 1.4.35

Effect of Temperature on F_{bry} of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

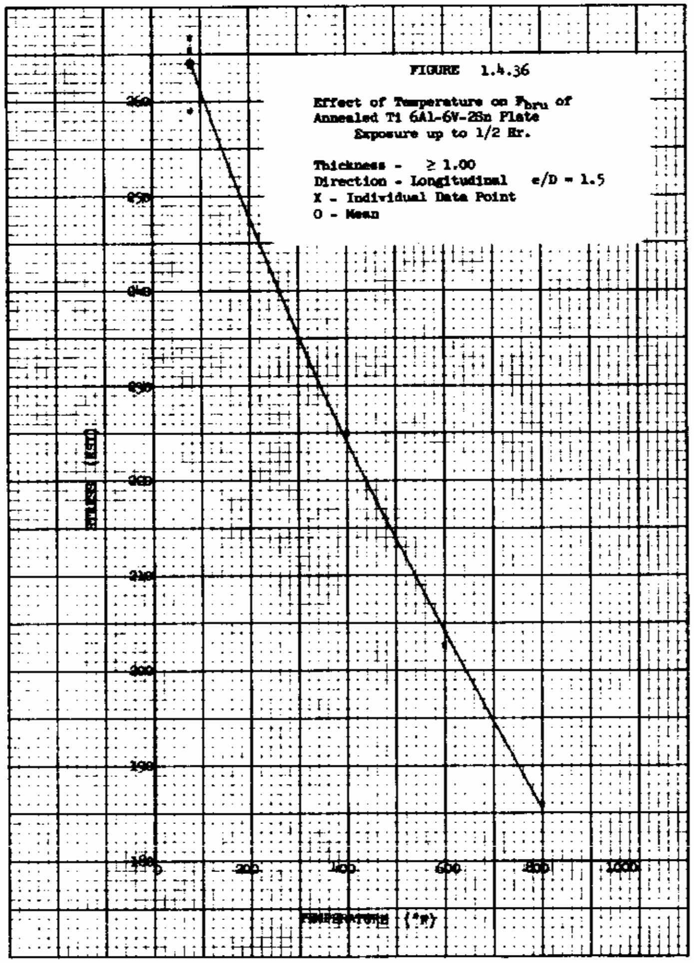


FIGURE 1.4.36

Effect of Temperature on F_{bru} of
Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

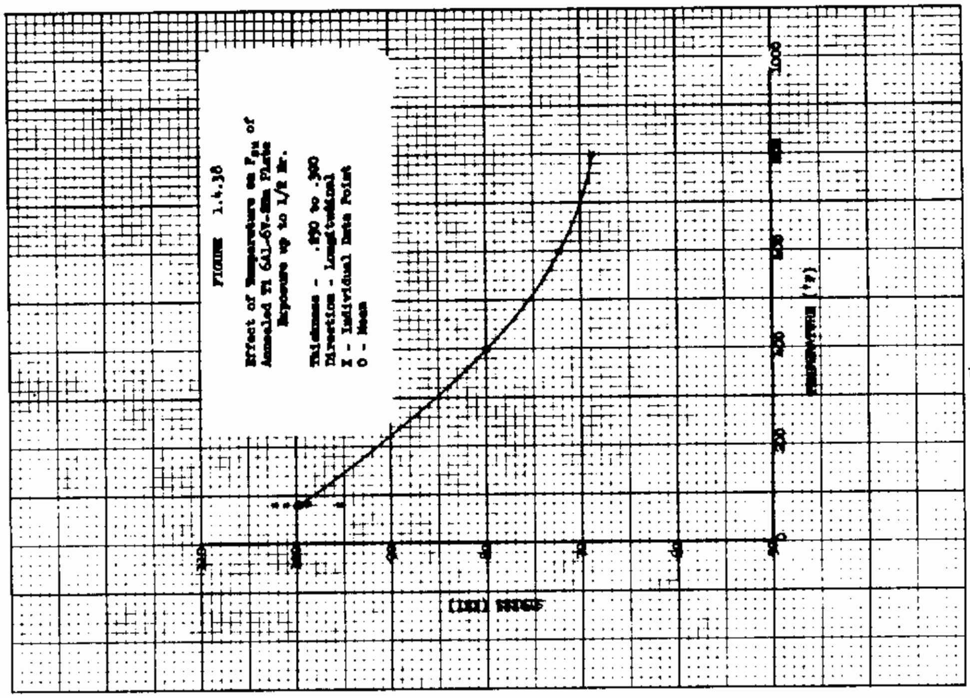


FIGURE 1.4.38
Effect of Temperature on F_{su} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .190 to .380
Direction - Longitudinal
X - Individual Data Point
O - Mean
TEMPERATURE (°F)
F_{su} (KSI)

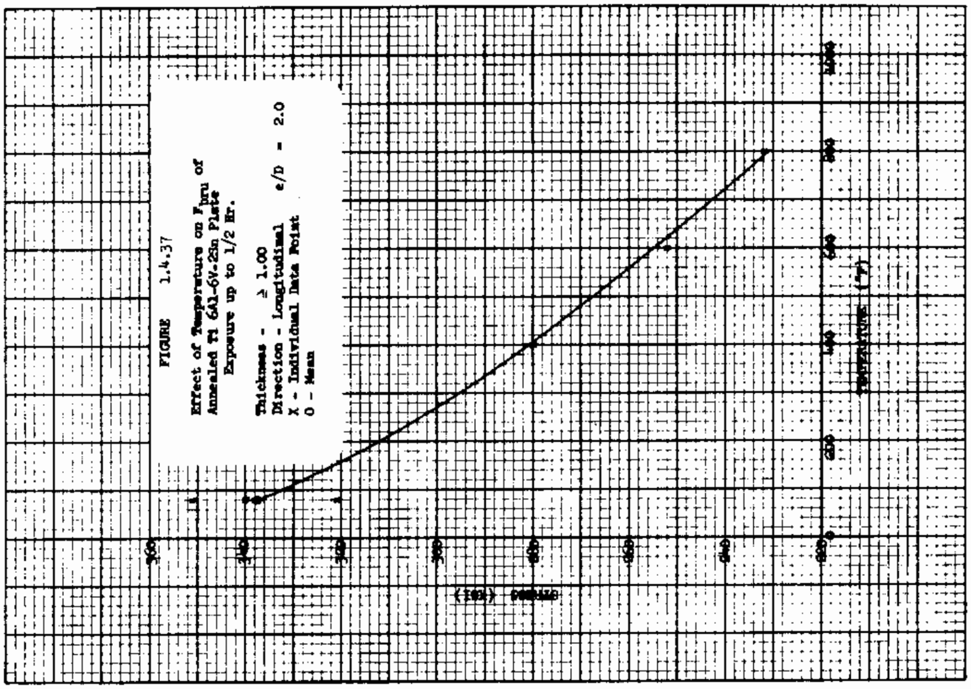


FIGURE 1.4.37
Effect of Temperature on F_{bru} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean
TEMPERATURE (°F)
F_{bru} (KSI)

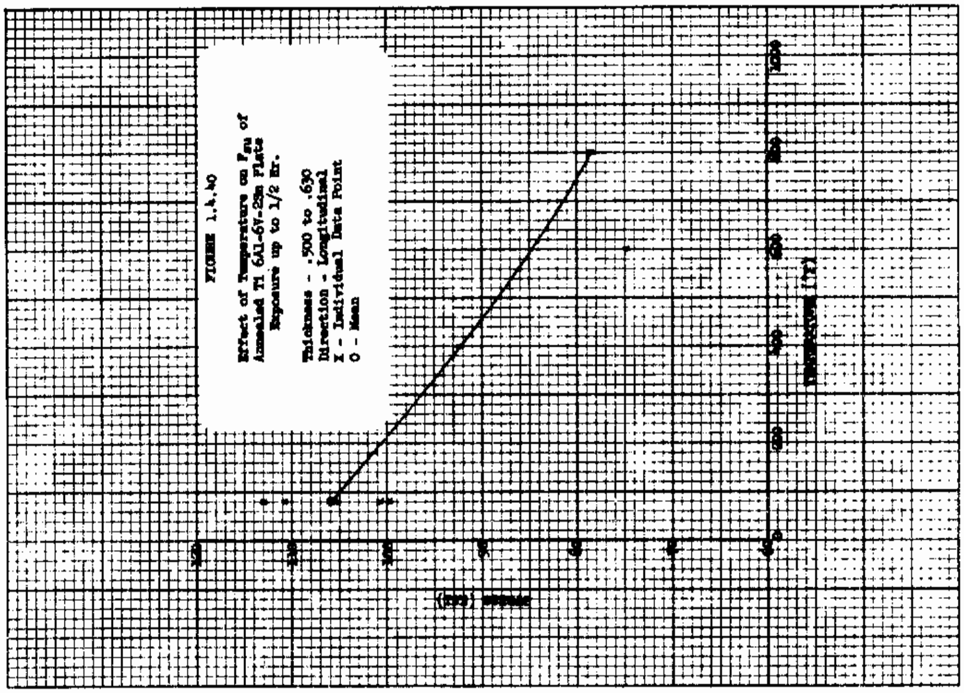


FIGURE 1.4.40
Effect of Temperature on F_{su} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean
TEMPERATURE (°F)
STRESS (KSI)

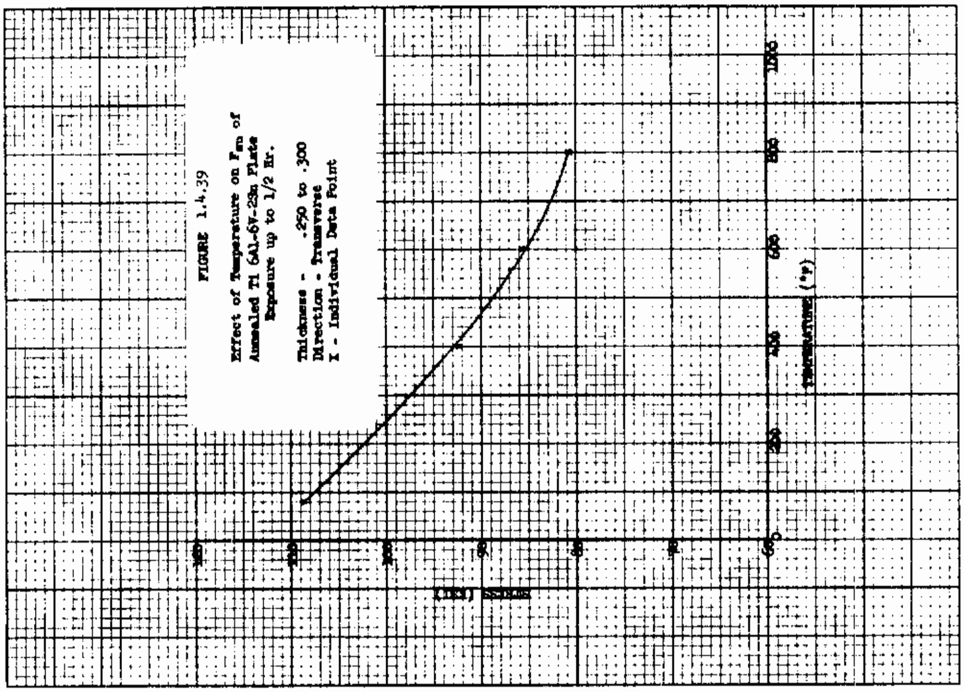


FIGURE 1.4.39
Effect of Temperature on F_{su} of Annealed Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - .250 to .300
Direction - Transverse
X - Individual Data Point
TEMPERATURE (°F)
STRESS (KSI)

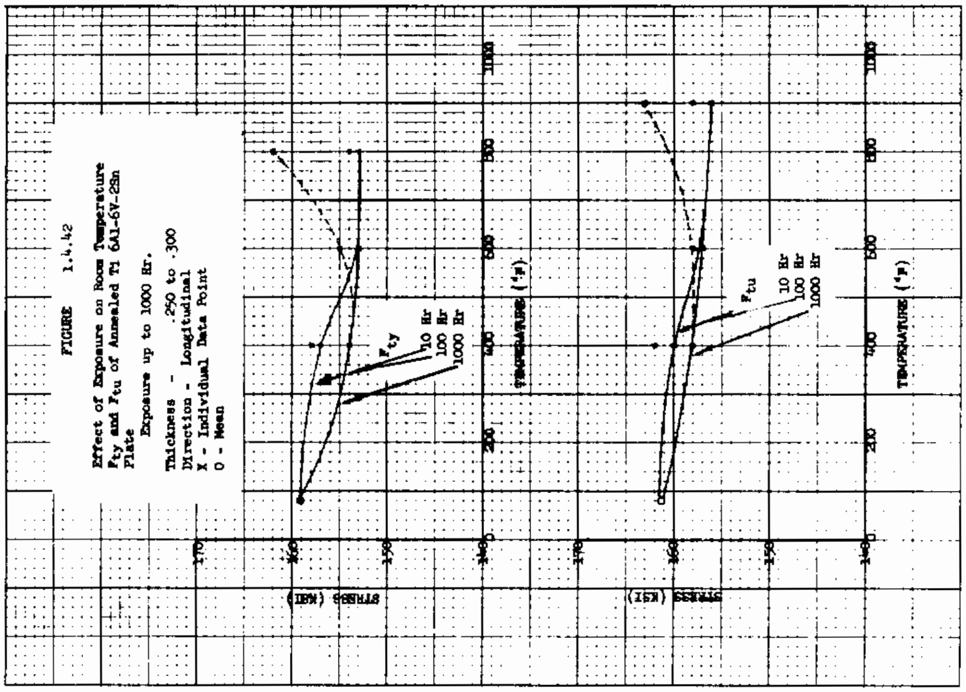


FIGURE 1.4.42

Effect of Exposure on Room Temperature F_{ty} and F_{tu} of Annealed Ti 6Al-6V-2Sn Plate

Exposure up to 1000 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point
O - Mean

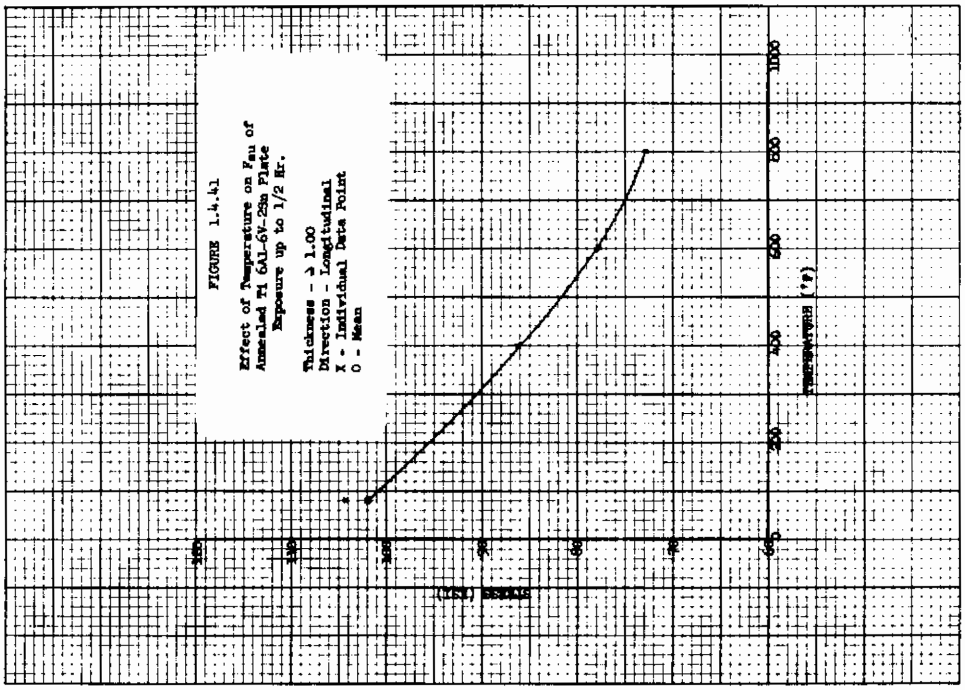


FIGURE 1.4.41

Effect of Temperature on F_{su} of Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

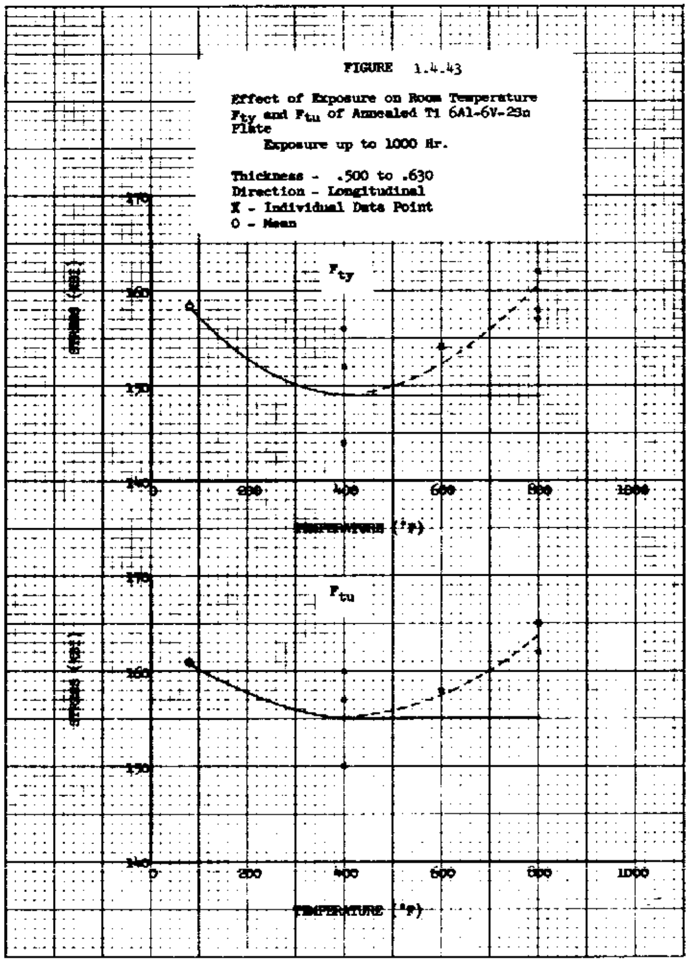


FIGURE 1.4.43

Effect of Exposure on Room Temperature F_{ty} and F_{tu} of Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1000 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

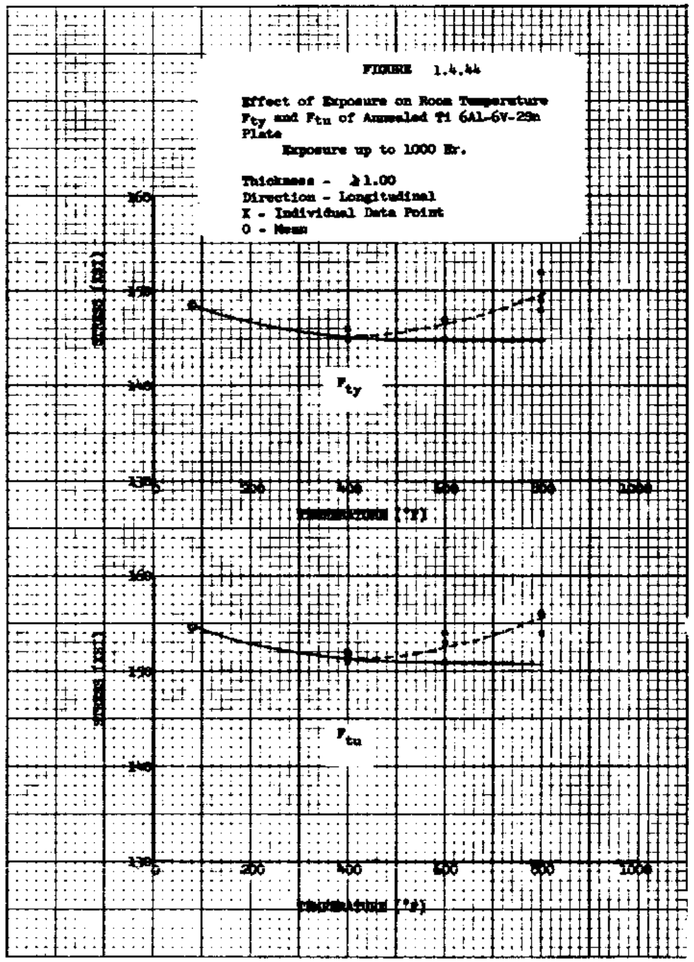


FIGURE 1.4.44

Effect of Exposure on Room Temperature F_{ty} and F_{tu} of Annealed Ti 6Al-6V-2Sn Plate
Exposure up to 1000 Hr.

Thickness - ≥1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

B. WORKING CURVES

1.4 Ti 6Al-6V-2Sn Cond. STA Figures 1.5.1 to 1.5.29

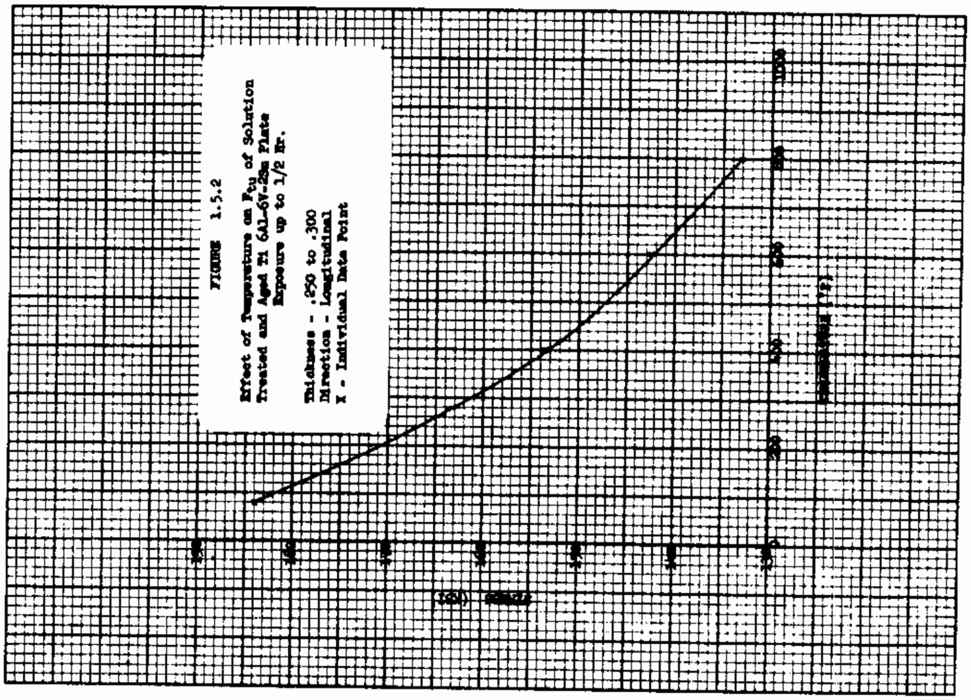


FIGURE 1.5.2

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point

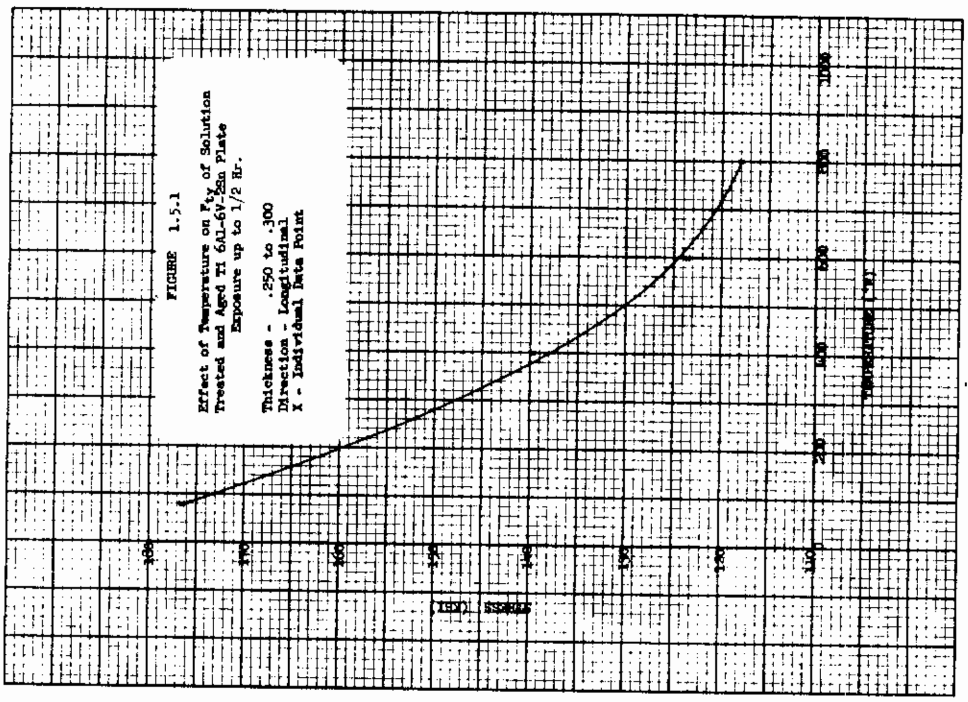


FIGURE 1.5.1

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .250 to .300
Direction - Longitudinal
X - Individual Data Point

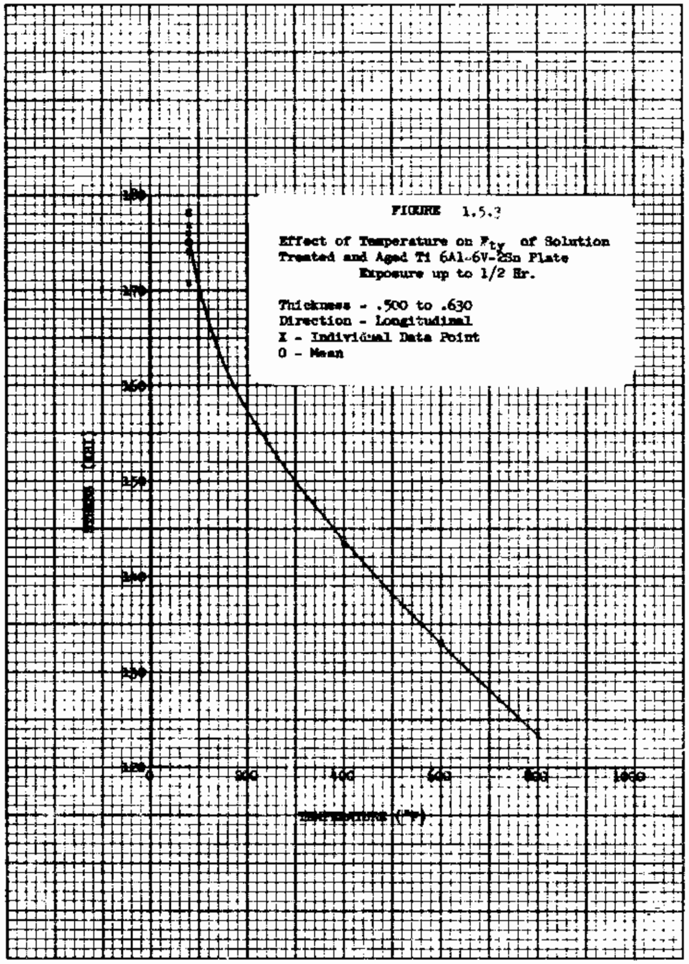


FIGURE 1.5.3

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
0 - Mean

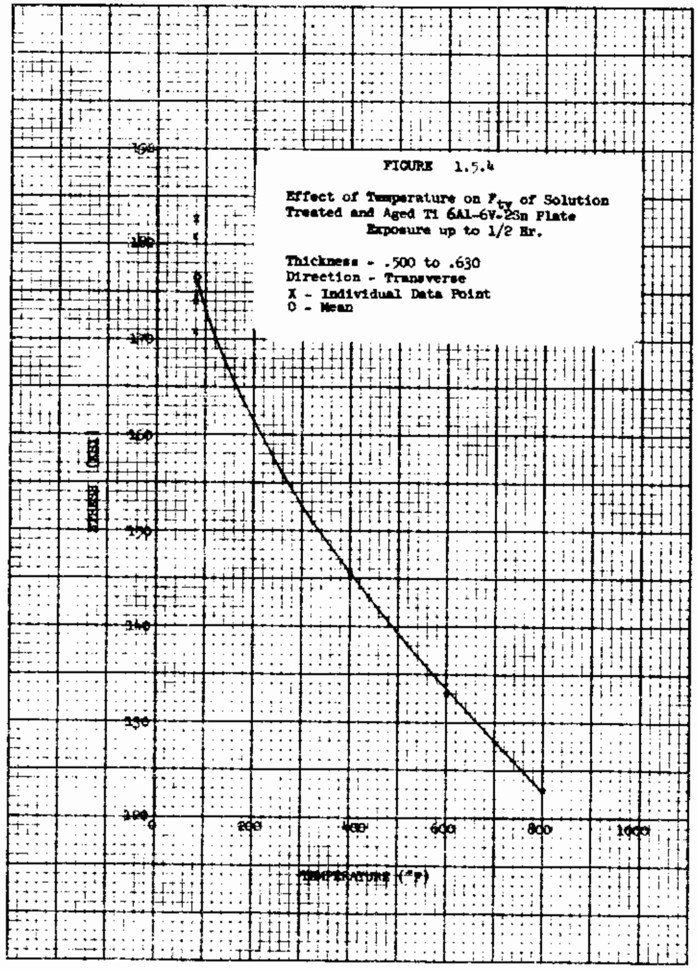


FIGURE 1.5.4

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
0 - Mean

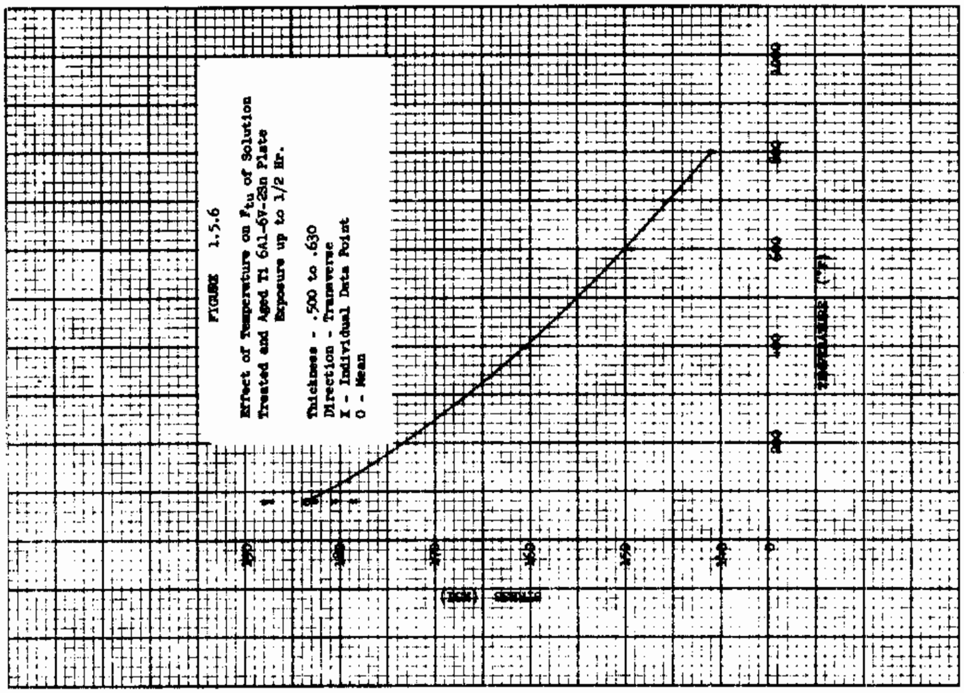


FIGURE 1.5.6
Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
O - Mean

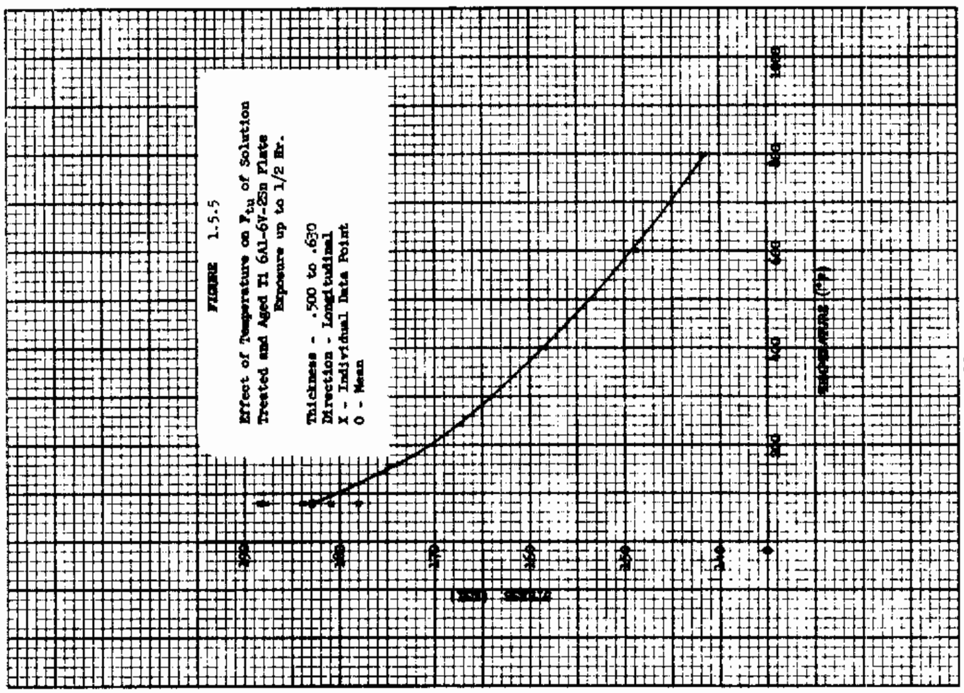


FIGURE 1.5.5
Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.
Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

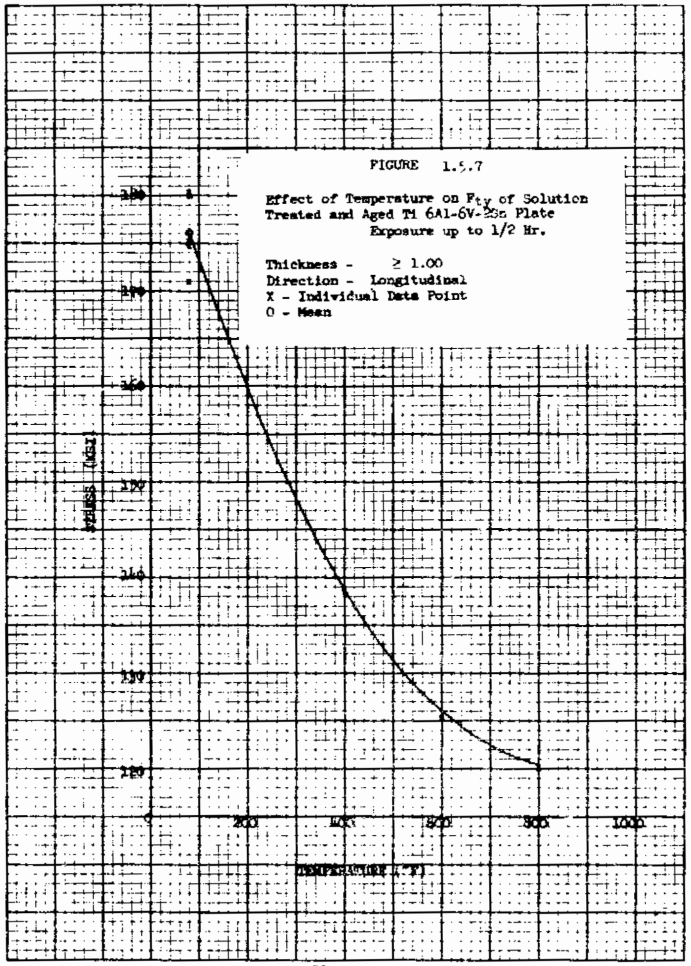


FIGURE 1.5.7

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

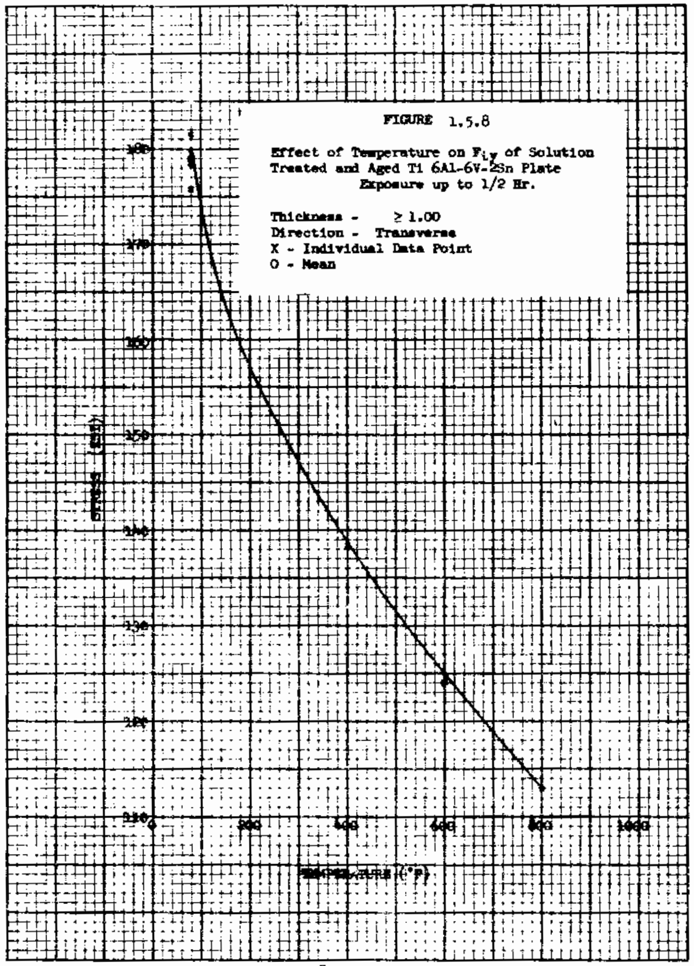


FIGURE 1.5.8

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean

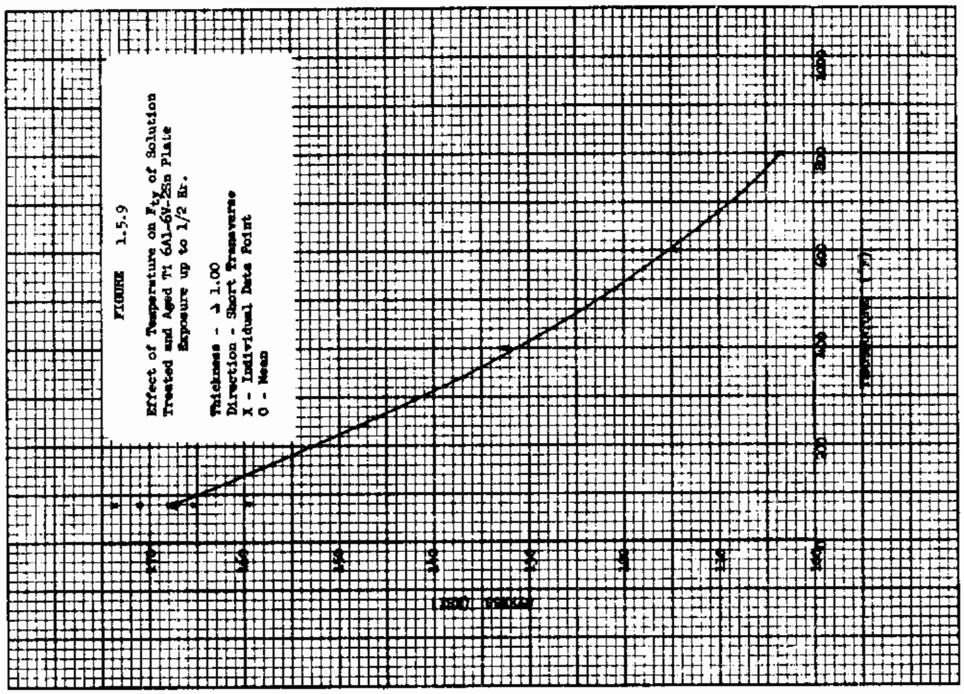


FIGURE 1.5.9

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Short Transverse
X - Individual Data Point
O - Mean

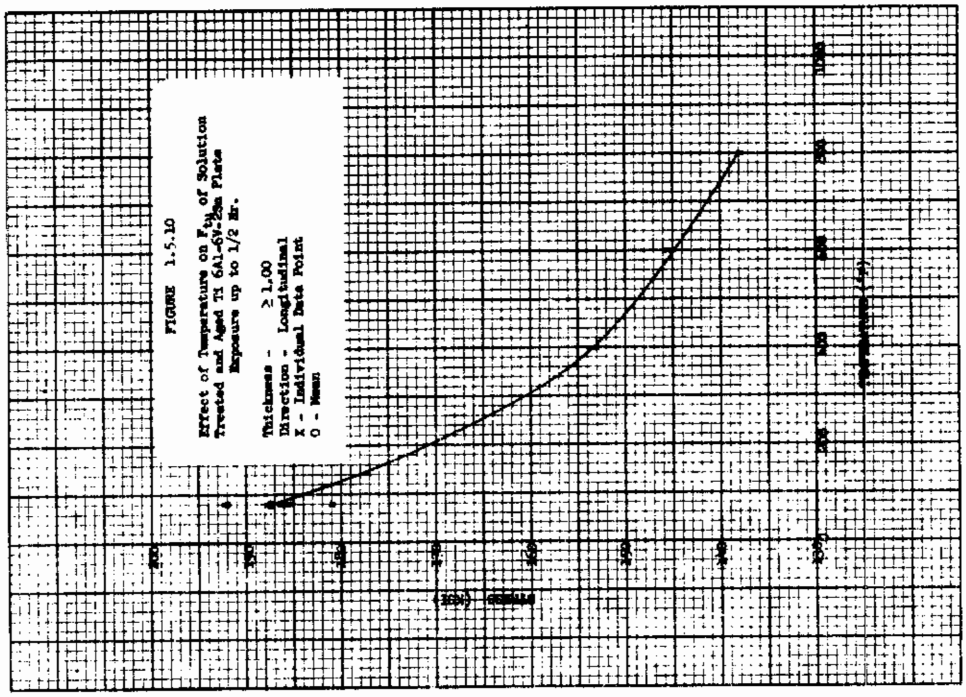


FIGURE 1.5.10

Effect of Temperature on F_{ty} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

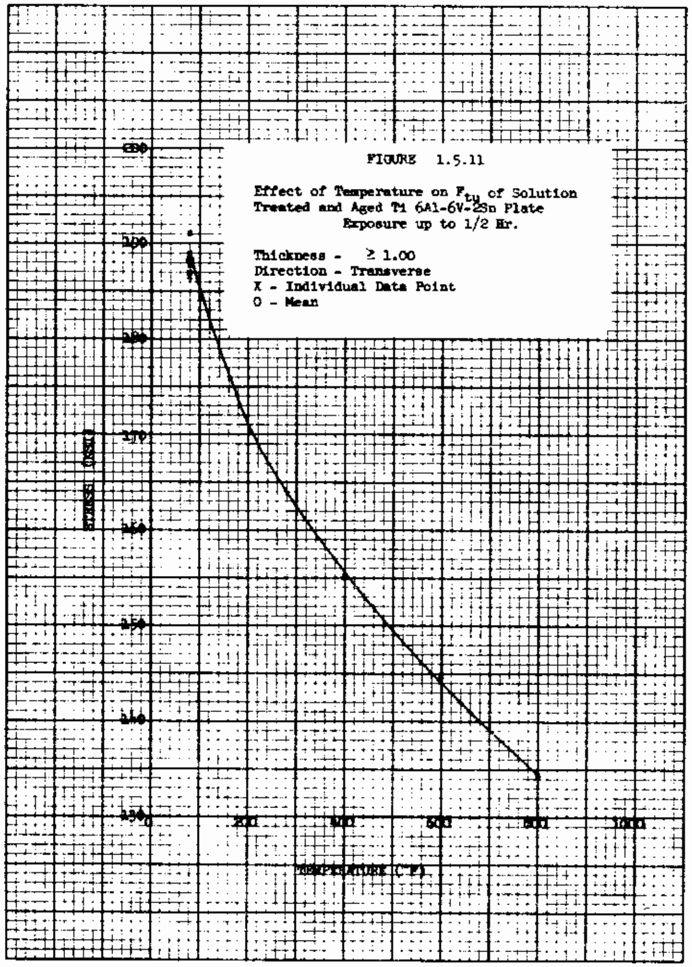


FIGURE 1.5.11

Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean

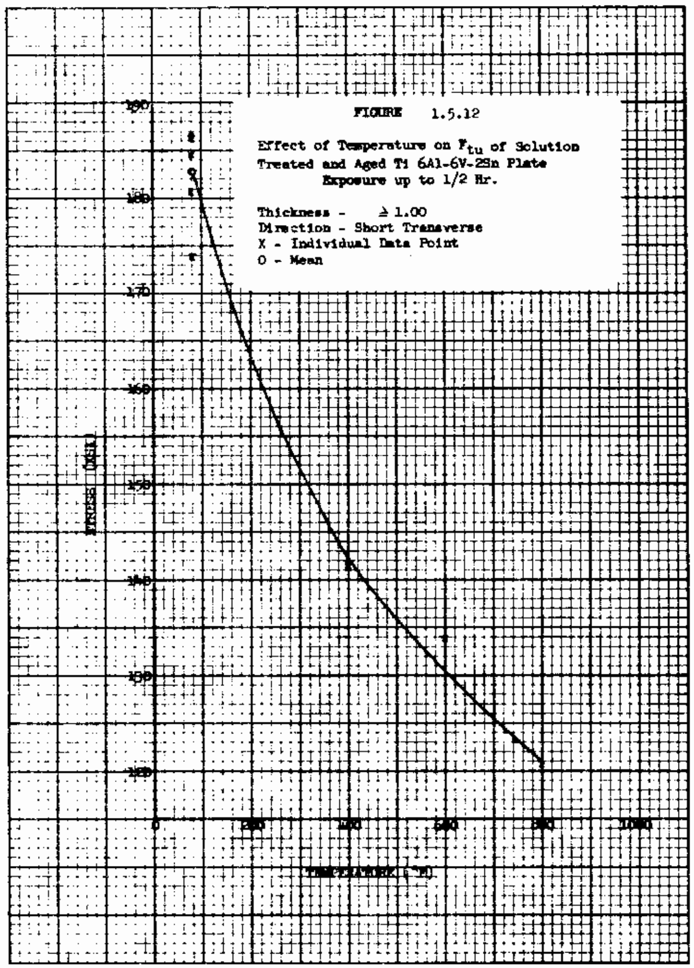


FIGURE 1.5.12

Effect of Temperature on F_{tu} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Short Transverse
X - Individual Data Point
O - Mean

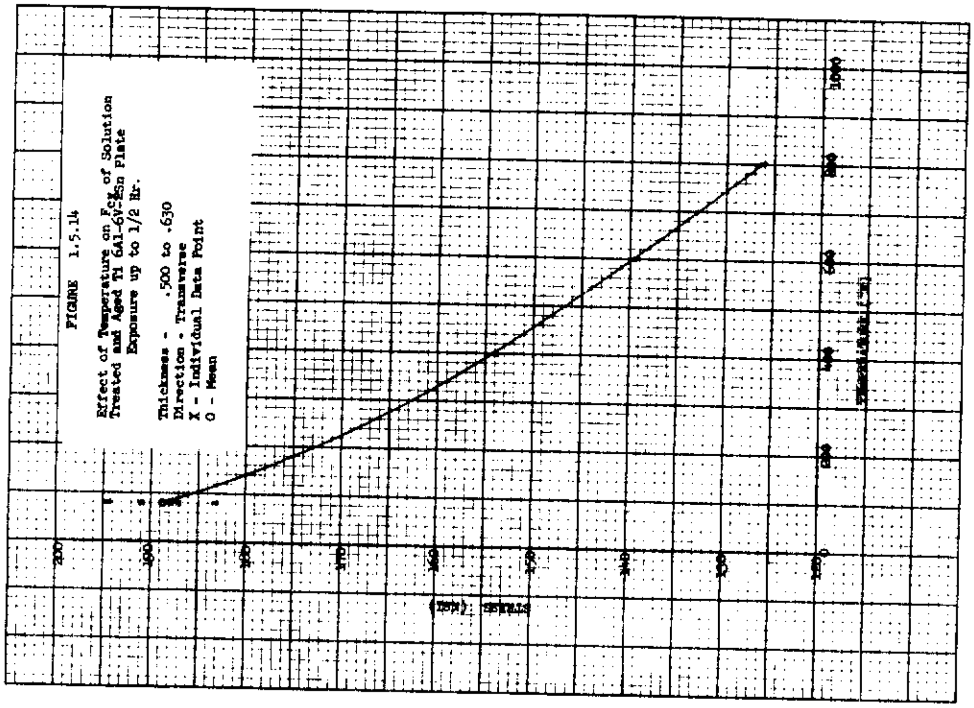


FIGURE 1.5.14

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Transverse
X - Individual Data Point
O - Mean

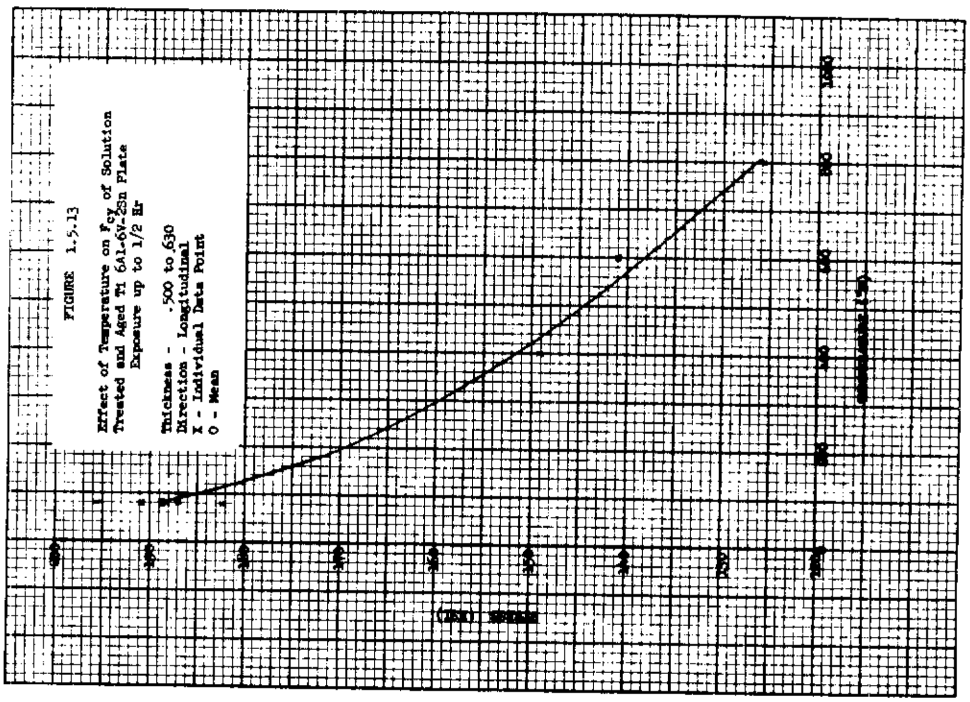


FIGURE 1.5.13

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

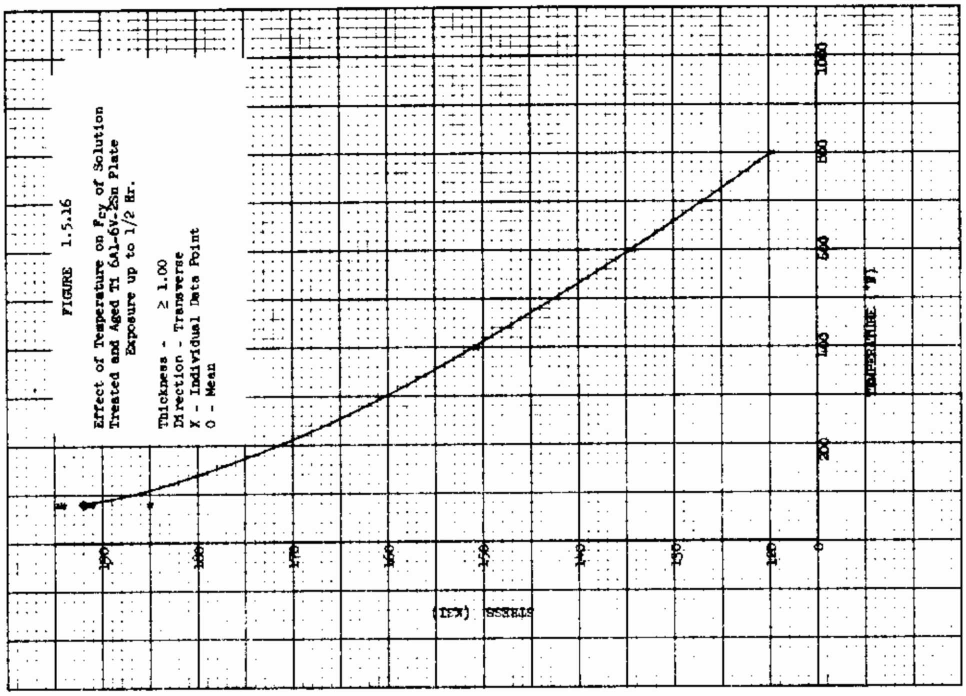


FIGURE 1.5.16
Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Transverse
X - Individual Data Point
O - Mean
TEMPERATURE °F
STRESS (KSI)
0
200
400
600
800
1000
120
130
140
150
160
170
180
190

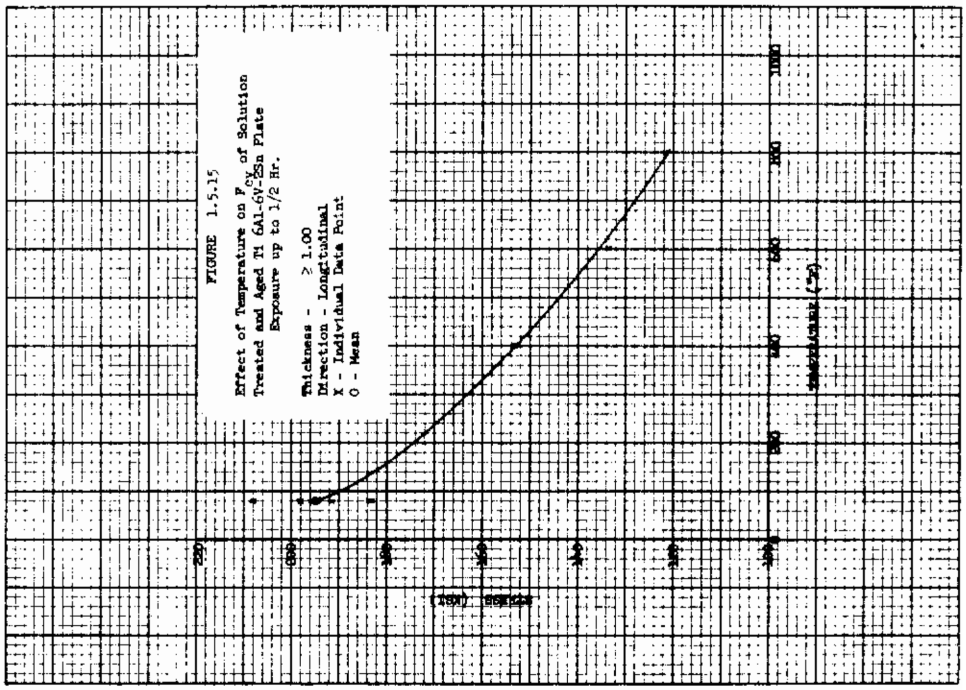


FIGURE 1.5.15
Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.
Thickness - ≥ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean
TEMPERATURE (°F)
STRESS (KSI)
200
400
600
800
1000
100
120
140
160
180
200
220

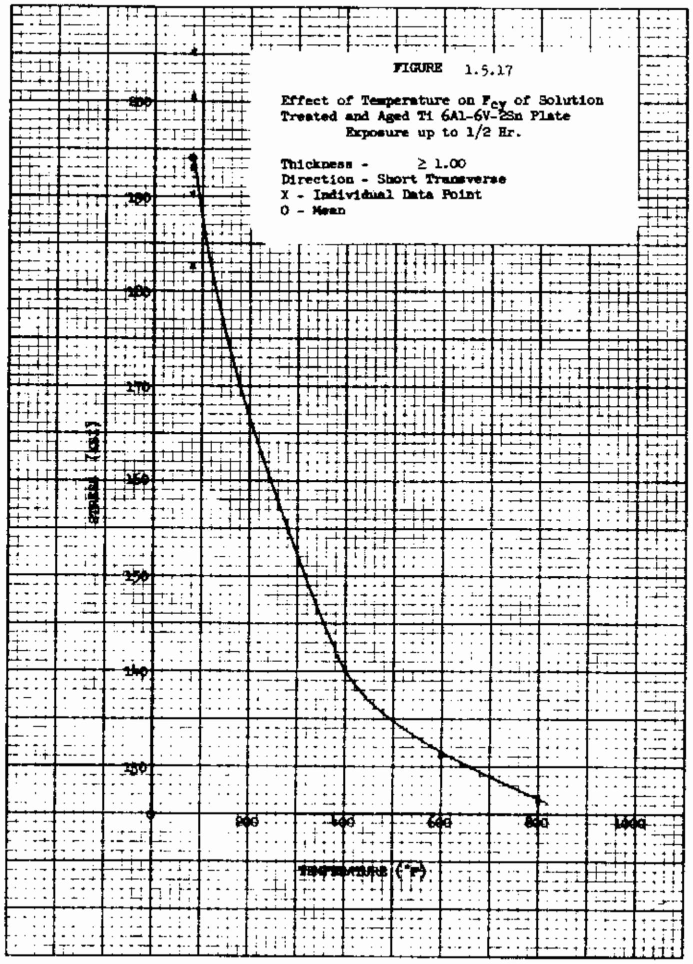


FIGURE 1.5.17

Effect of Temperature on F_{cy} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Short Transverse
X - Individual Data Point
O - Mean

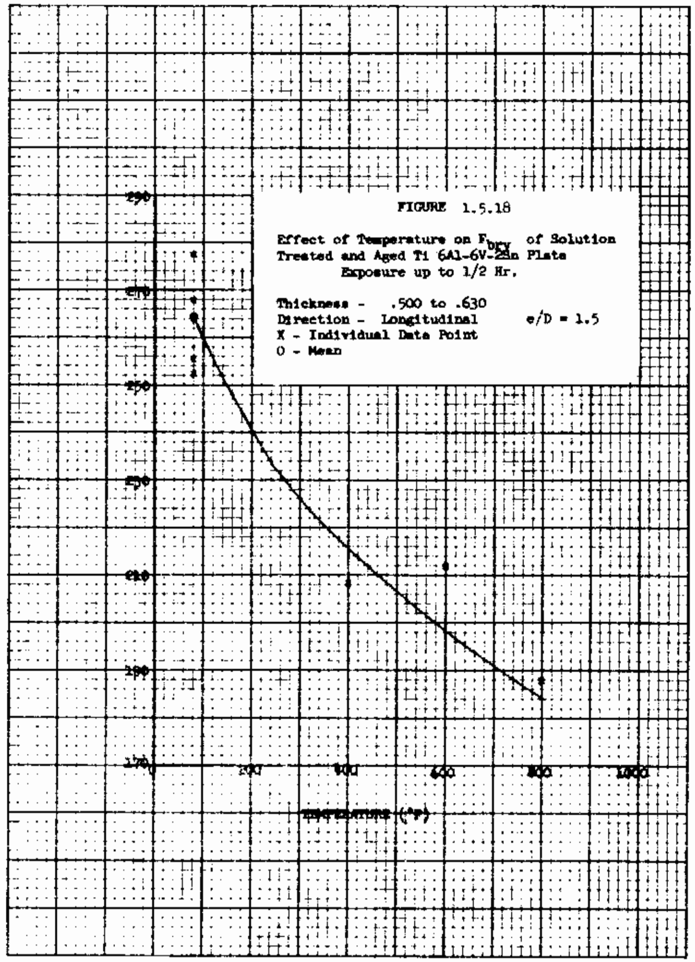


FIGURE 1.5.18

Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

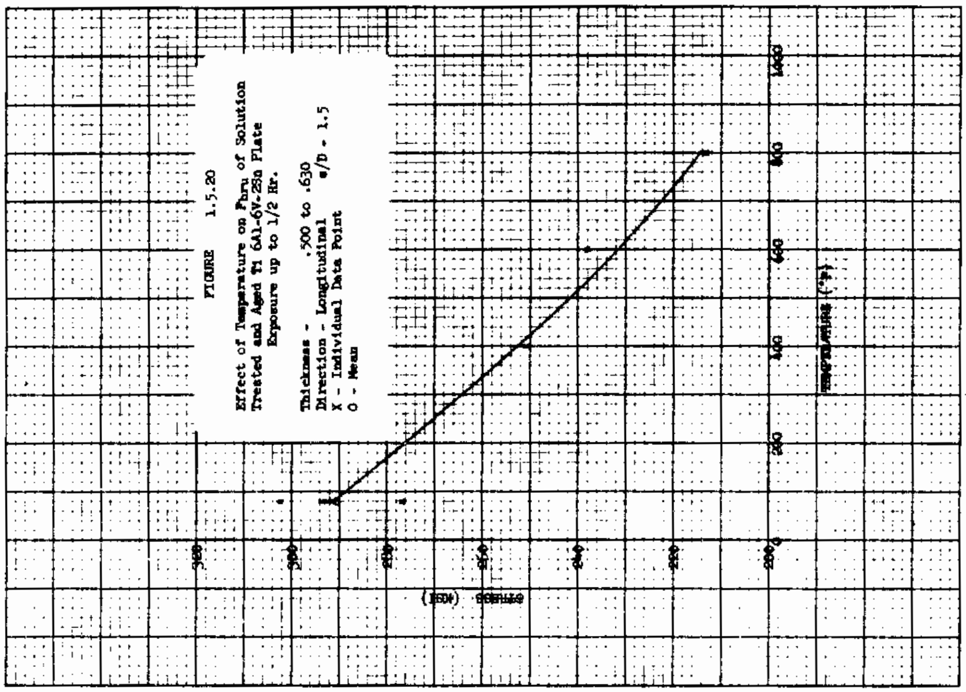


FIGURE 1.5.20

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

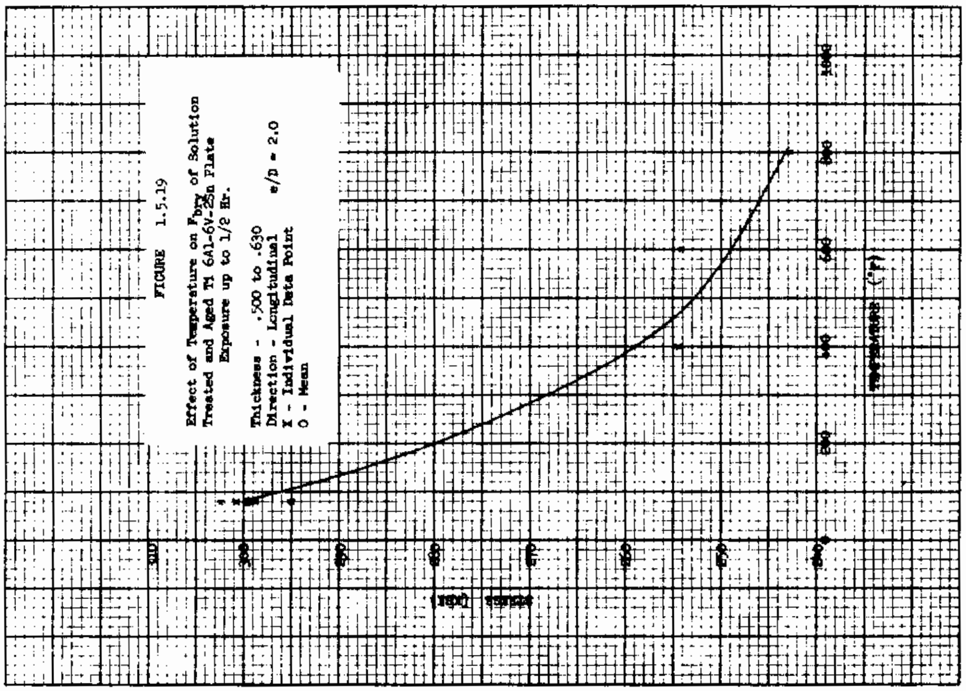


FIGURE 1.5.19

Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

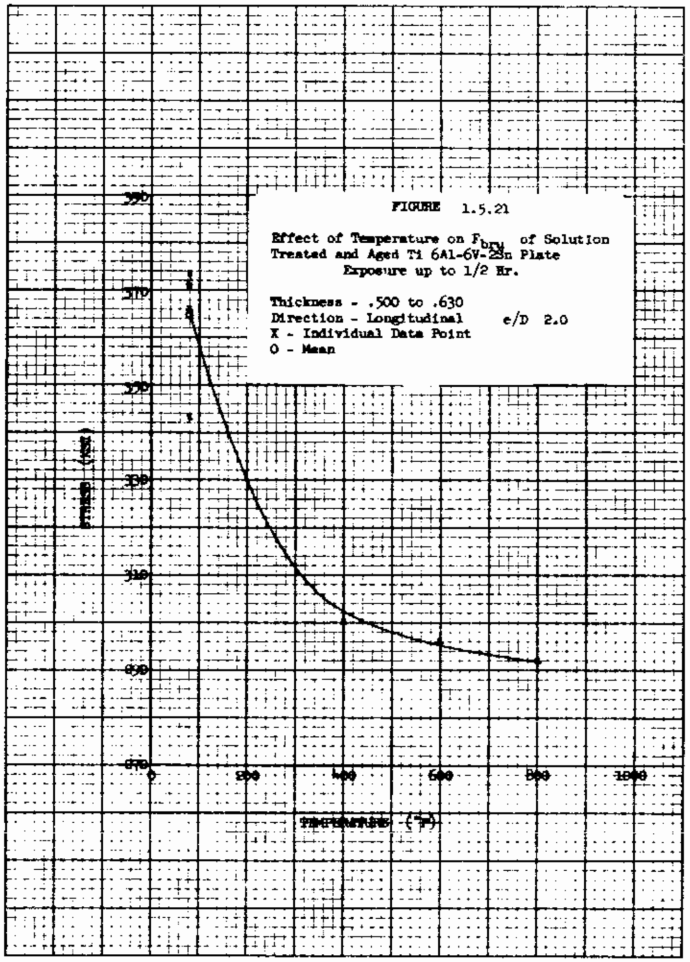


FIGURE 1.5.21

Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal e/D 2.0
X - Individual Data Point
O - Mean

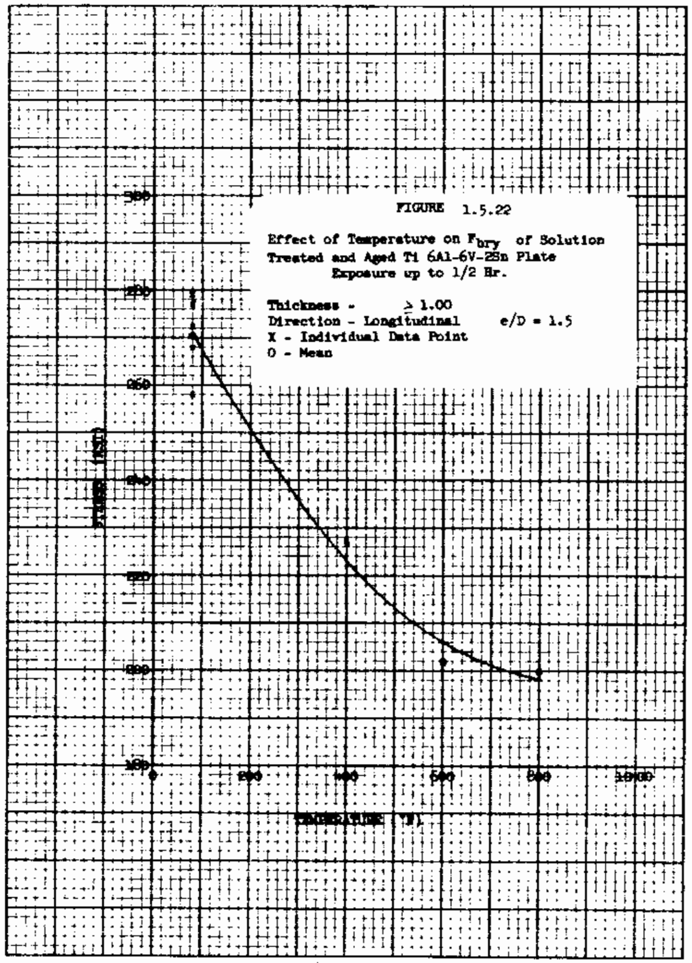


FIGURE 1.5.22

Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal e/D = 1.5
X - Individual Data Point
O - Mean

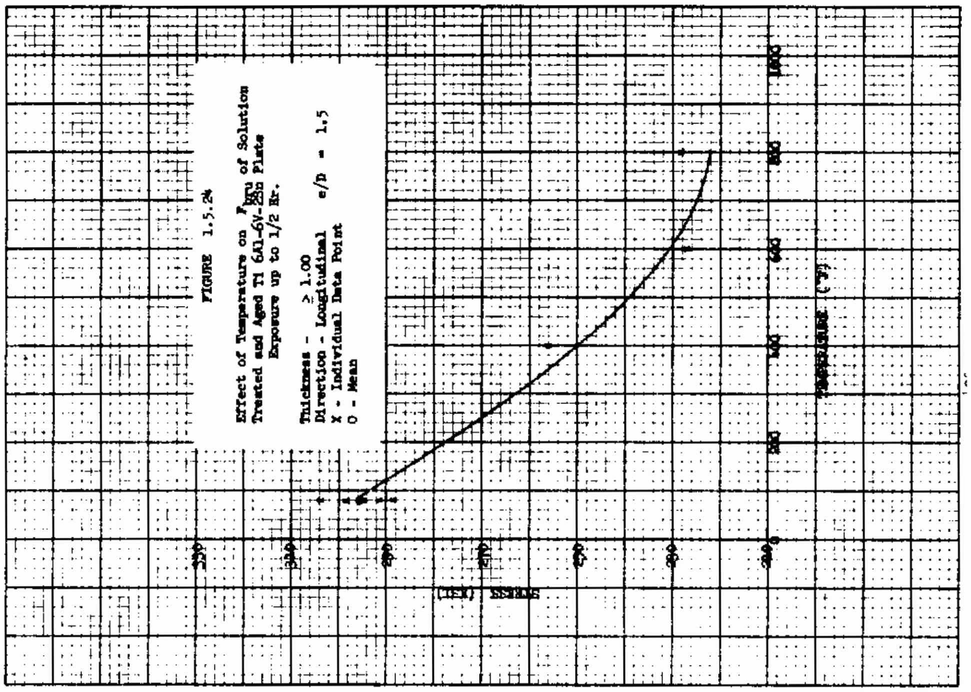


FIGURE 1.5.24

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal   e/D = 1.5
X - Individual Data Point
O - Mean

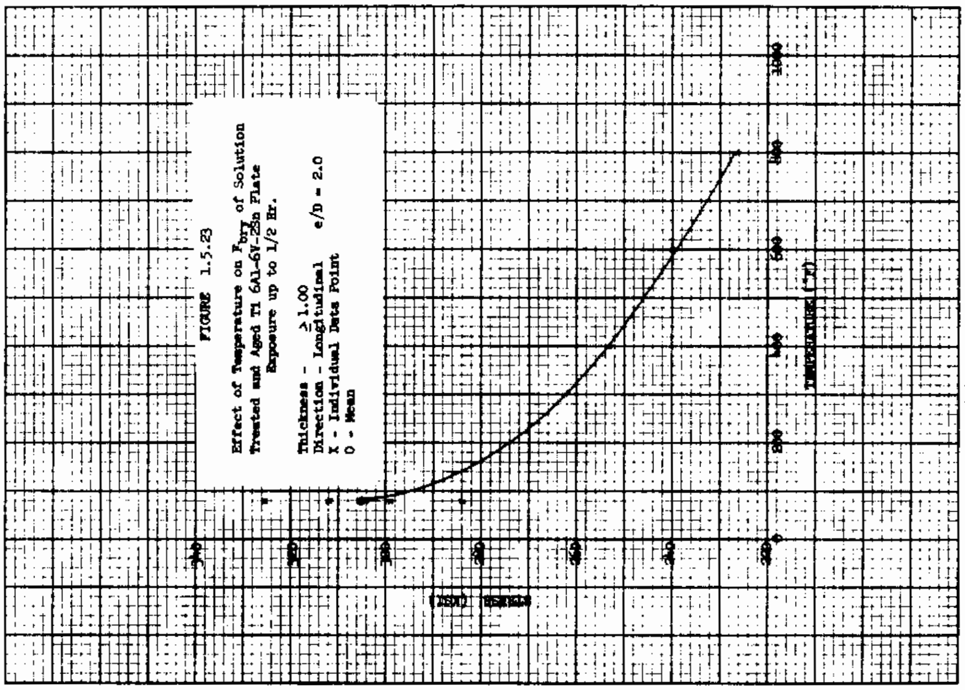


FIGURE 1.5.23

Effect of Temperature on F_{bry} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal   e/D = 2.0
X - Individual Data Point
O - Mean

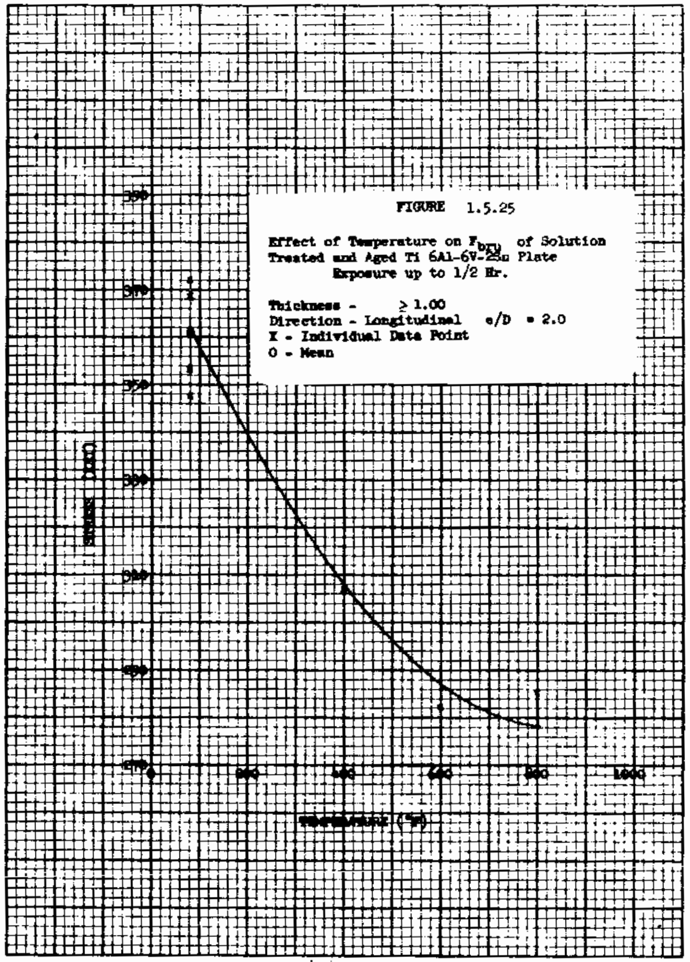


FIGURE 1.5.25

Effect of Temperature on F_{bru} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.

Thickness - ≥ 1.00
Direction - Longitudinal e/D = 2.0
X - Individual Data Point
O - Mean

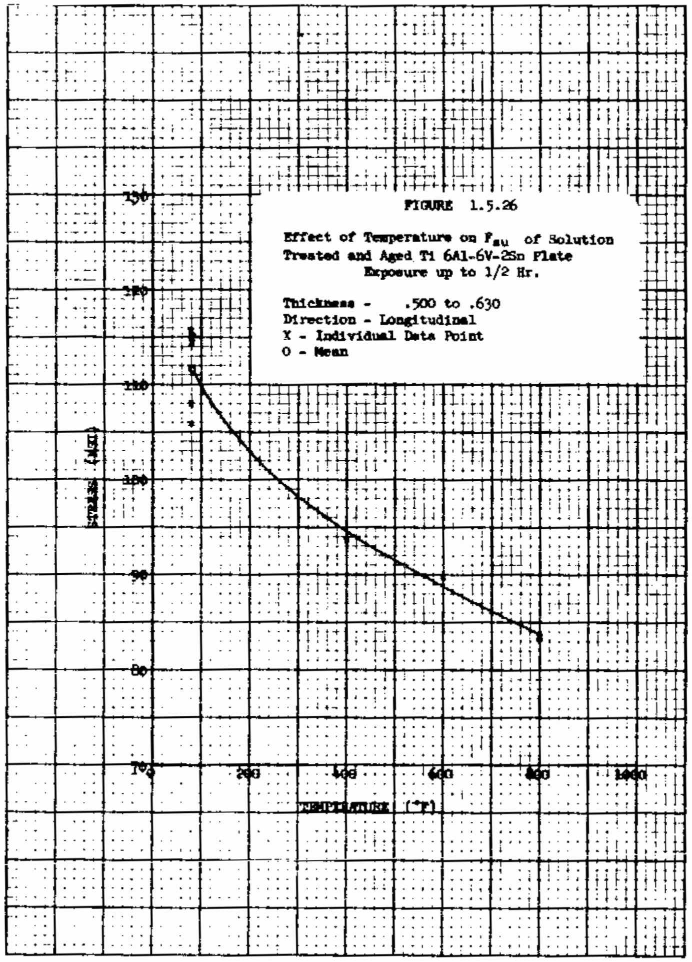


FIGURE 1.5.26

Effect of Temperature on F_{su} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate
Exposure up to 1/2 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

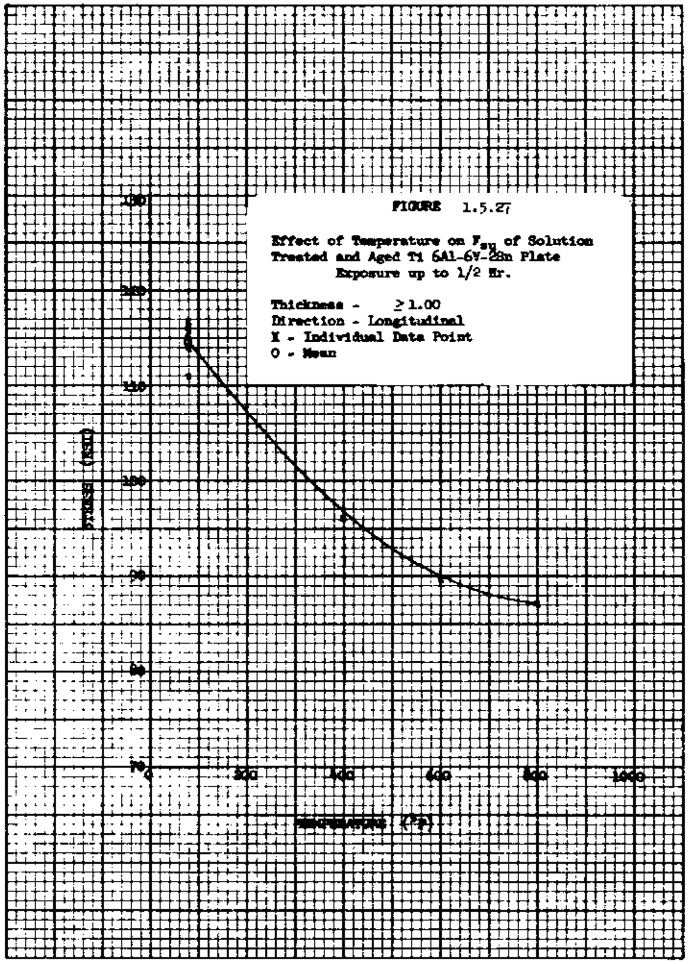


FIGURE 1.5.27

Effect of Temperature on F_{su} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1/2 Hr.

Thickness - $\geq$ 1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

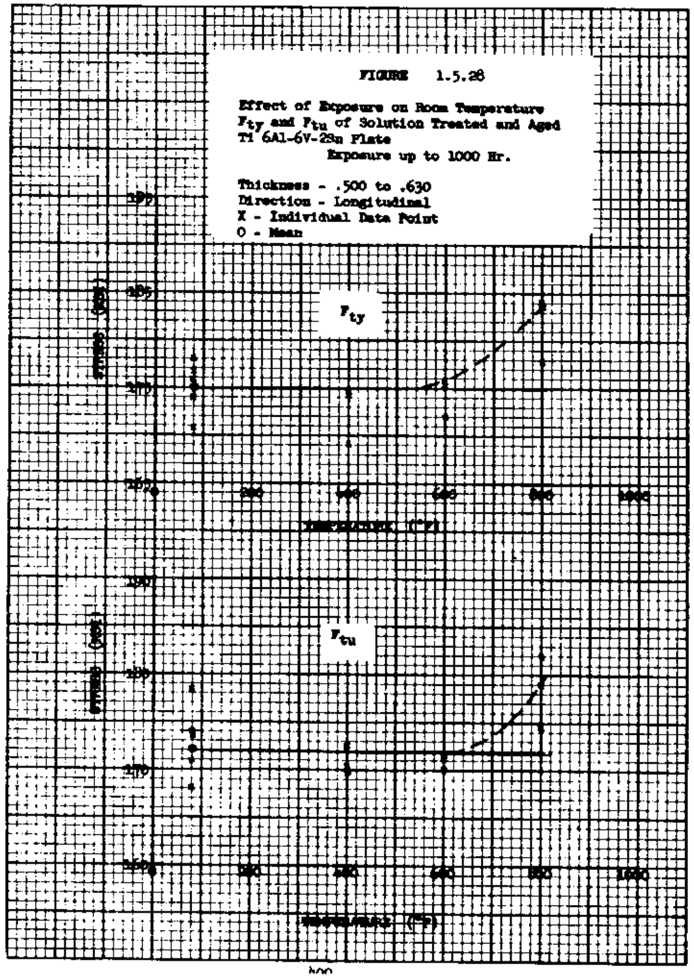


FIGURE 1.5.28

Effect of Exposure on Room Temperature F_{ty} and F_{tu} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate Exposure up to 1000 Hr.

Thickness - .500 to .630
Direction - Longitudinal
X - Individual Data Point
O - Mean

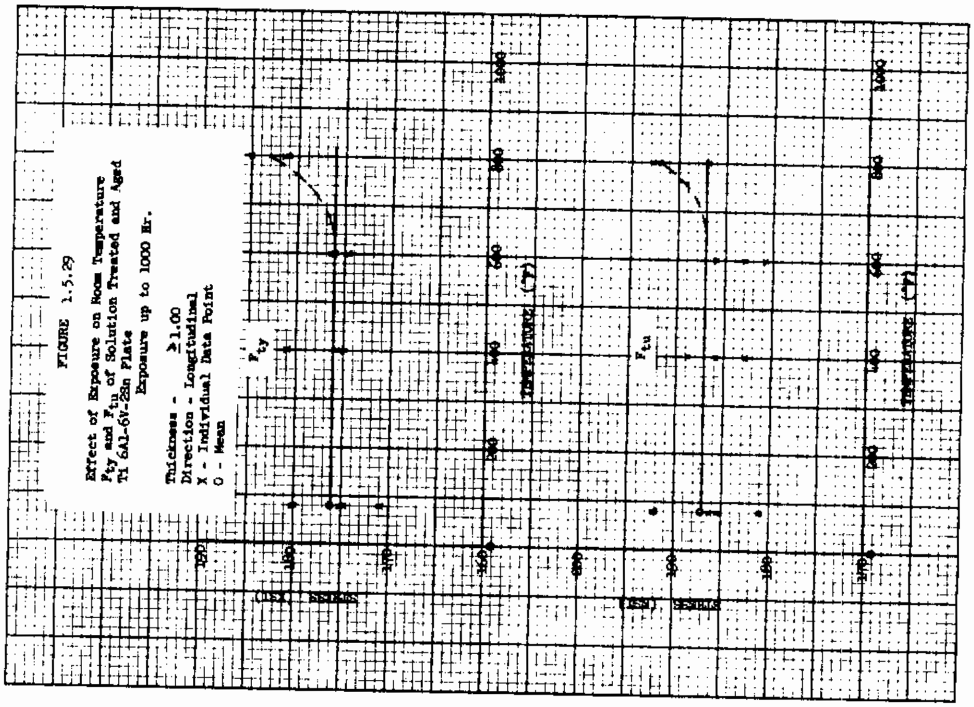


FIGURE 1.5.29

Effect of Exposure on Room Temperature F_{ty} and F_{tu} of Solution Treated and Aged Ti 6Al-6V-2Sn Plate
Exposure up to 1000 Hr.

Thickness - ≥1.00
Direction - Longitudinal
X - Individual Data Point
O - Mean

B. FATIGUE S-N CURVES

2.1 Ti-4Al-3Mo-1V Cond. A Figures 2.1.1 to 2.1.2

Figure 2.1.1

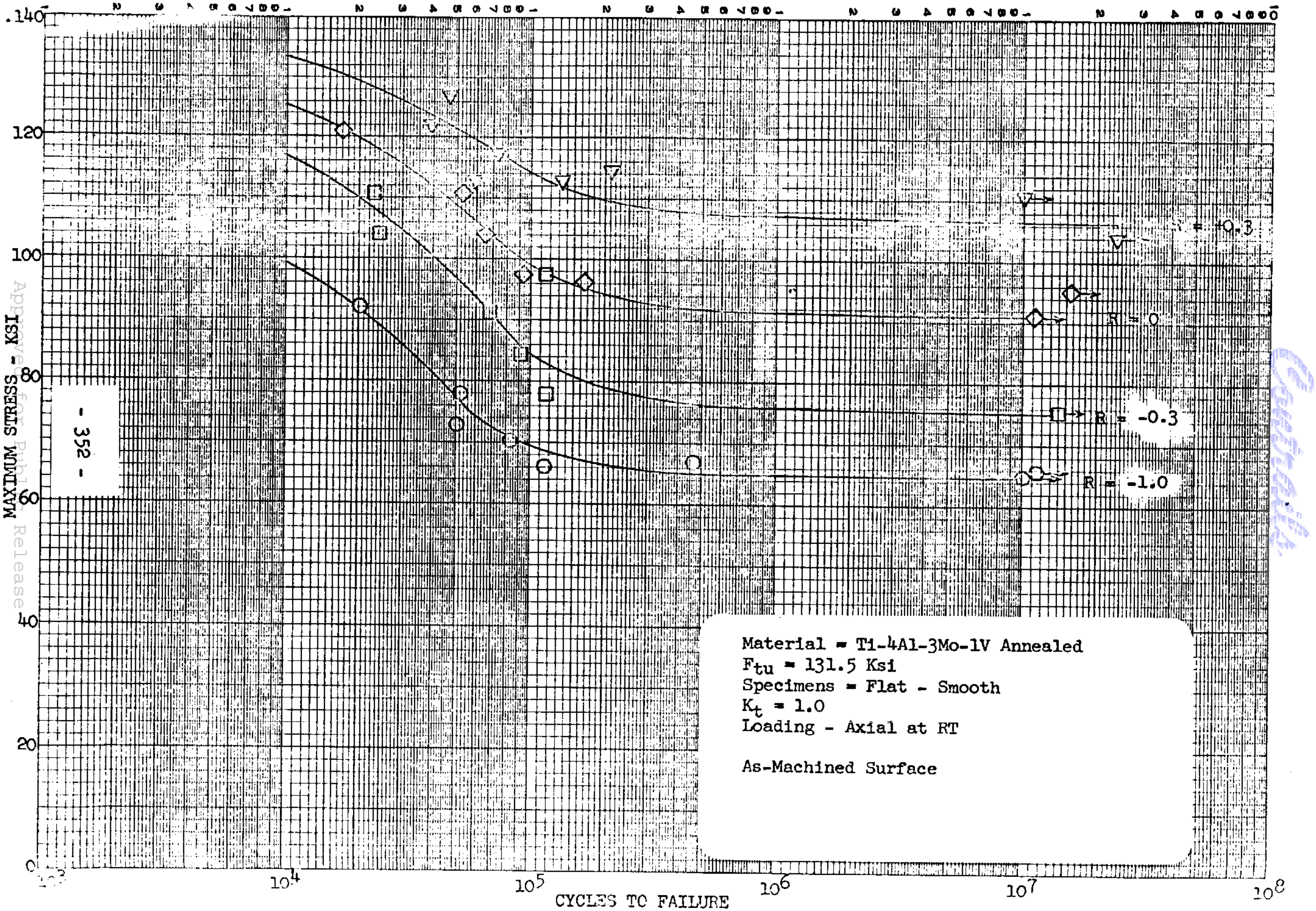
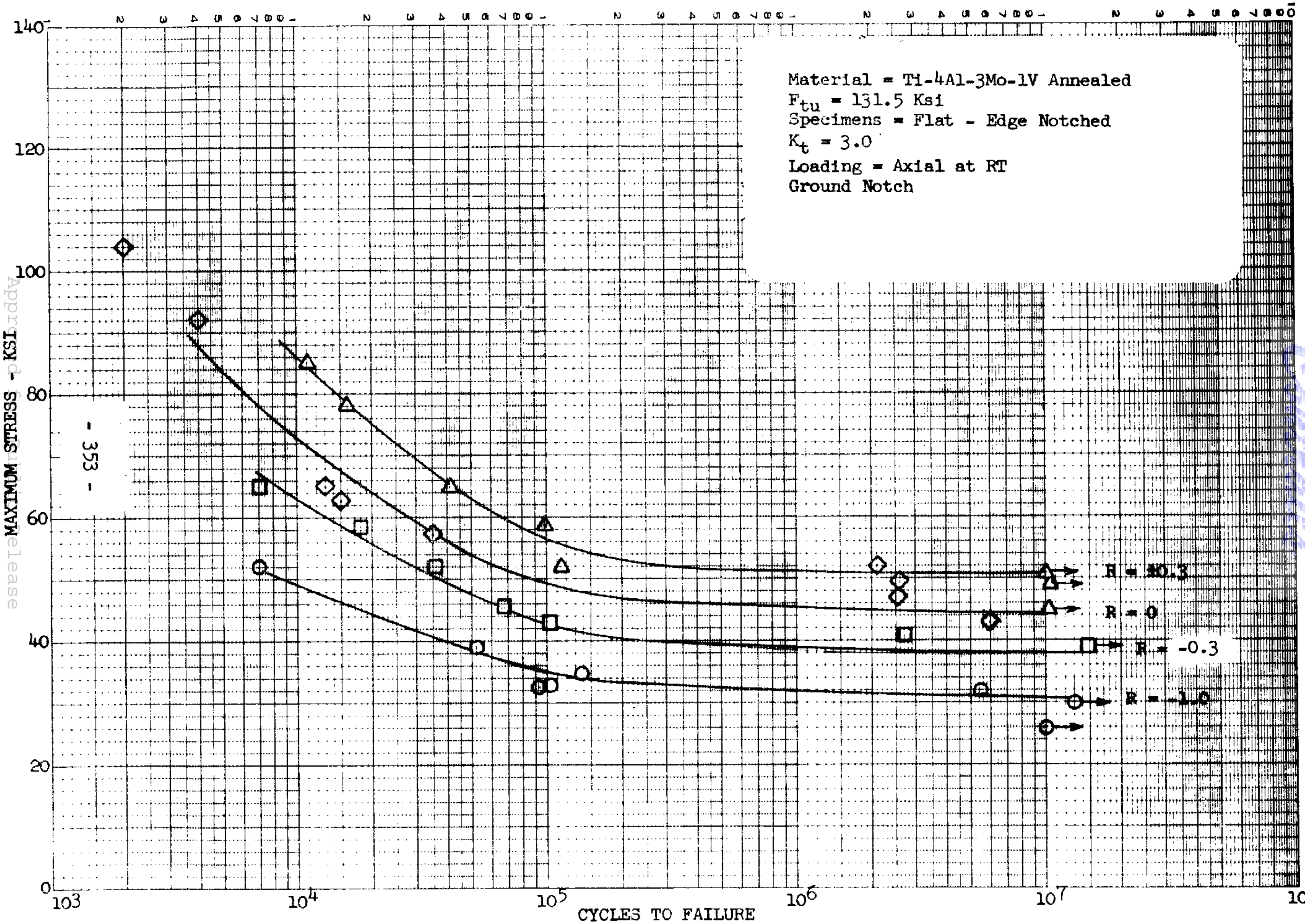

MAXIMUM STRESS - KSI
140
120
100
80
60
40
20
0
10^3
10^4
10^5
10^6
10^7
10^8
CYCLES TO FAILURE
R = +0.3
R = 0
R = -0.3
R = -1.0
Material = Ti-4Al-3Mo-1V Annealed
F_{tu} = 131.5 Ksi
Specimens = Flat - Smooth
K_t = 1.0
Loading - Axial at RT
As-Machined Surface

Figure 2.1.2


Material = Ti-4Al-3Mo-1V Annealed
F_{tu} = 131.5 Ksi
Specimens = Flat - Edge Notched
K_t = 3.0
Loading = Axial at RT
Ground Notch
R = +0.3
R = 0
R = -0.3
R = -1.0
MAXIMUM STRESS - KSI
CYCLES TO FAILURE
0
20
40
60
80
100
120
140
10^3
10^4
10^5
10^6
10^7
10^8

B. FATIGUE S-N CURVES

2.2 Ti-6Al-4V Cond. STA Figures 2.2.1 to 2.2.2

Figure 2.2.1

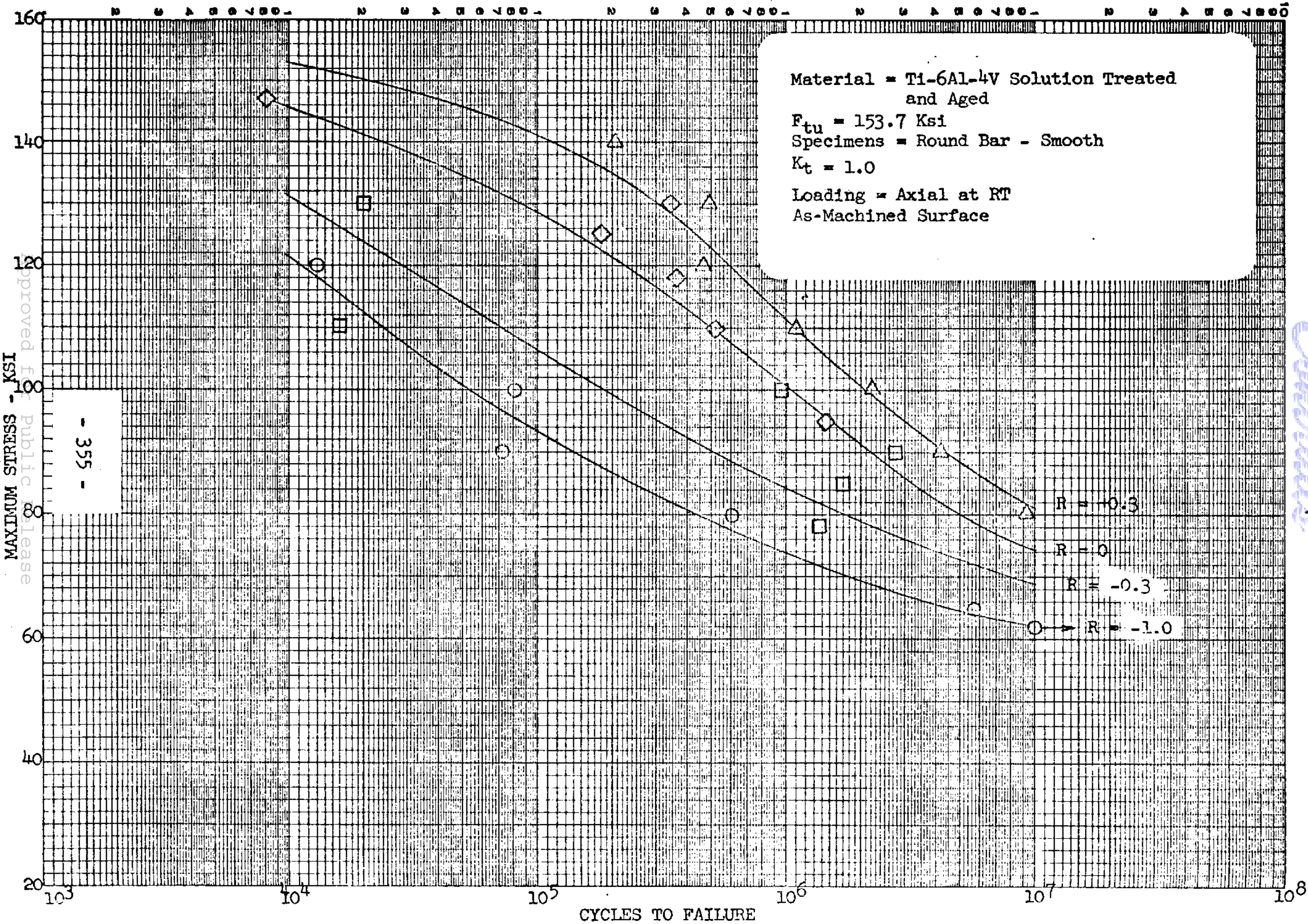
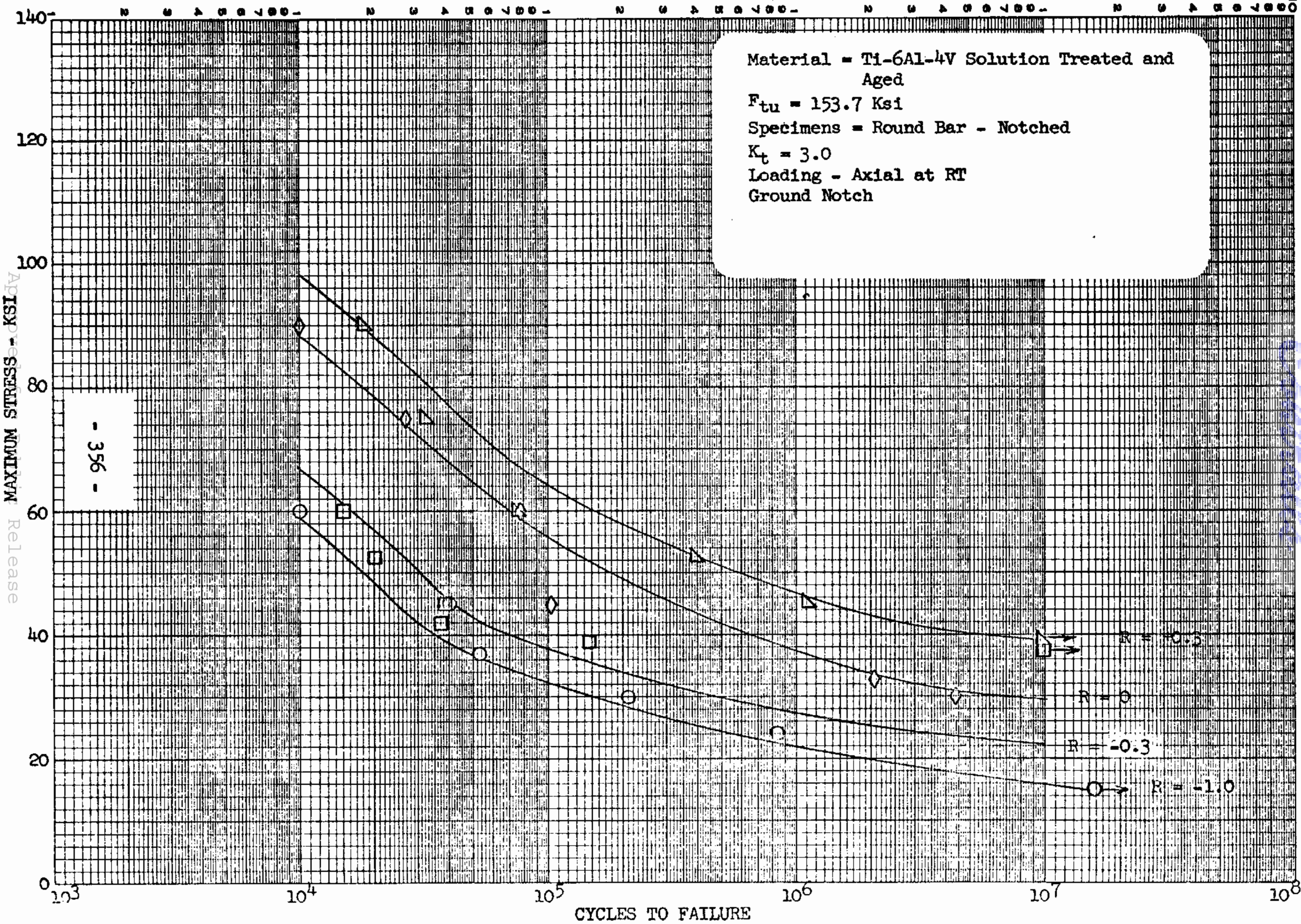

Material = Ti-6Al-4V Solution Treated
and Aged
Ftu = 153.7 Ksi
Specimens = Round Bar - Smooth
Kt = 1.0
Loading = Axial at RT
As-Machined Surface
R = +0.3
R = 0
R = -0.3
R = -1.0
MAXIMUM STRESS - KSI
CYCLES TO FAILURE
160
140
120
100
80
60
40
20
10^3
10^4
10^5
10^6
10^7
10^8

Figure 2.2.2



Material = Ti-6Al-4V Solution Treated and Aged
F_{tu} = 153.7 Ksi
Specimens = Round Bar - Notched
K_t = 3.0
Loading - Axial at RT
Ground Notch
MAXIMUM STRESS - KSI
CYCLES TO FAILURE
140
120
100
80
60
40
20
0
10^3
10^4
10^5
10^6
10^7
10^8
R = +0.5
R = 0
R = -0.3
R = -1.0

B FATIGUE S-N CURVES

2.3 Ti-6Al-6V-2Sn Cond. A Figures 2.3.1 to 2.3.2

Figure 2.3.1

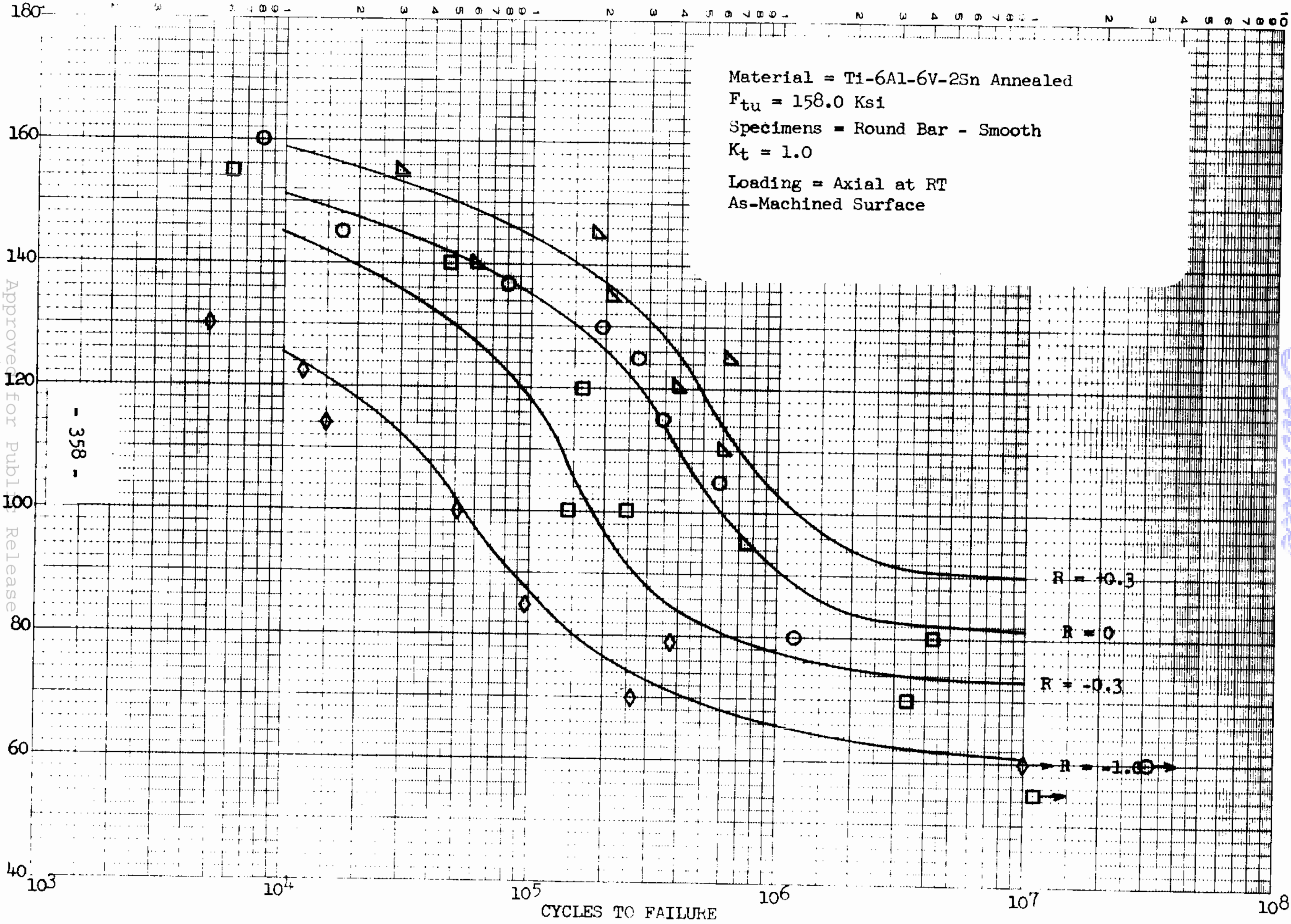
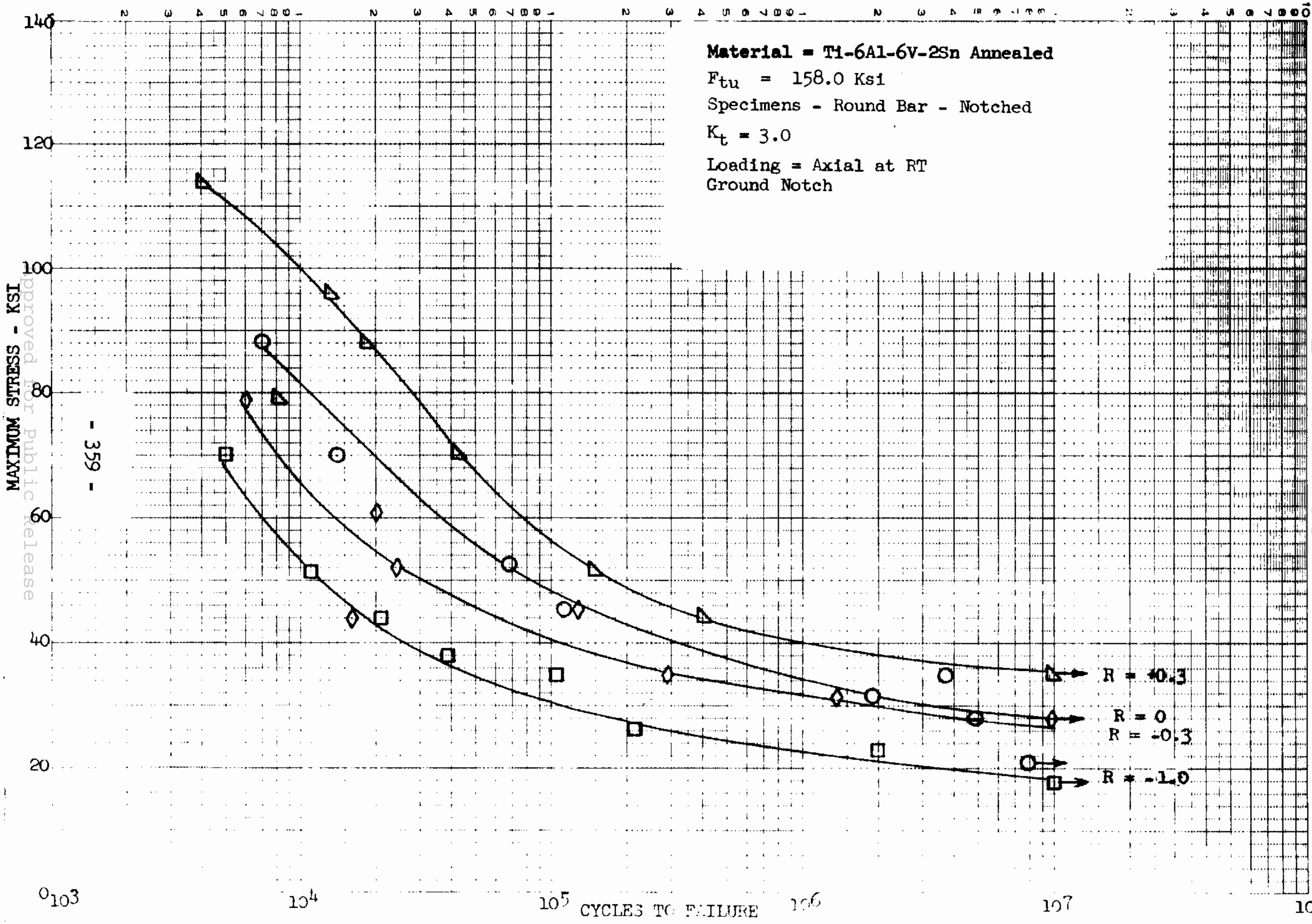

Material = Ti-6Al-6V-2Sn Annealed
F_{tu} = 158.0 Ksi
Specimens = Round Bar - Smooth
K_t = 1.0
Loading = Axial at RT
As-Machined Surface
R = +0.3
R = 0
R = -0.3
R = -1.0
MAXIMUM STRESS - KSI
CYCLES TO FAILURE

Figure 2.3.2


5 CYCLES X 10 DIVISIONS PER INCH
Material = Ti-6Al-6V-2Sn Annealed
Ftu = 158.0 Ksi
Specimens - Round Bar - Notched
Kt = 3.0
Loading = Axial at RT
Ground Notch
R = +0.3
R = 0
R = -0.3
R = -1.0
MAXIMUM STRESS - KSI
CYCLES TO FAILURE
0
20
40
60
80
100
120
140
10^3
10^4
10^5
10^6
10^7
10^8

B. FATIGUE S-N CURVES

2.4 Ti-6Al-6V-2Sn Cond. STA Figures 2.4.1 to 2.4.2

Figure 2.4.1

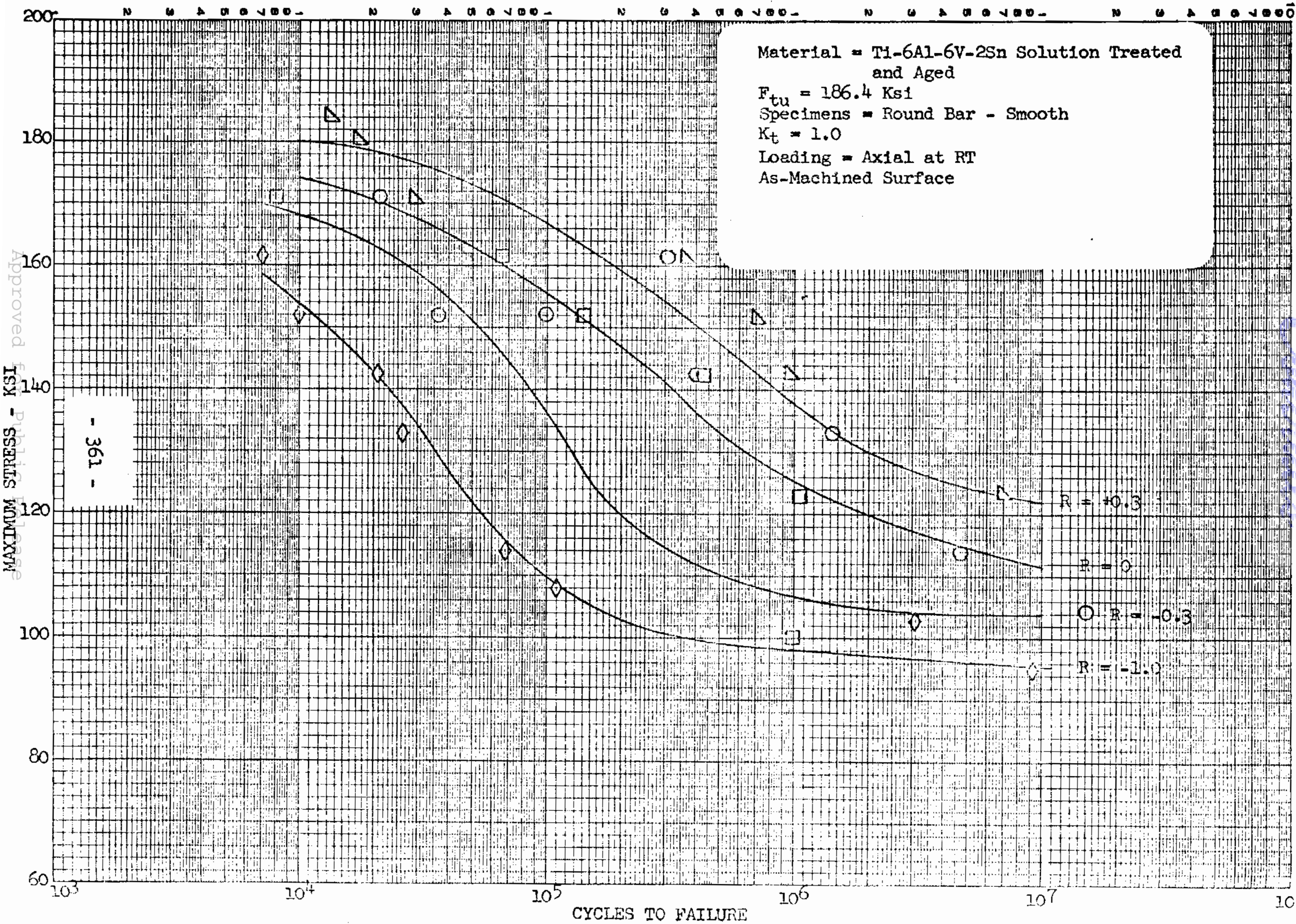
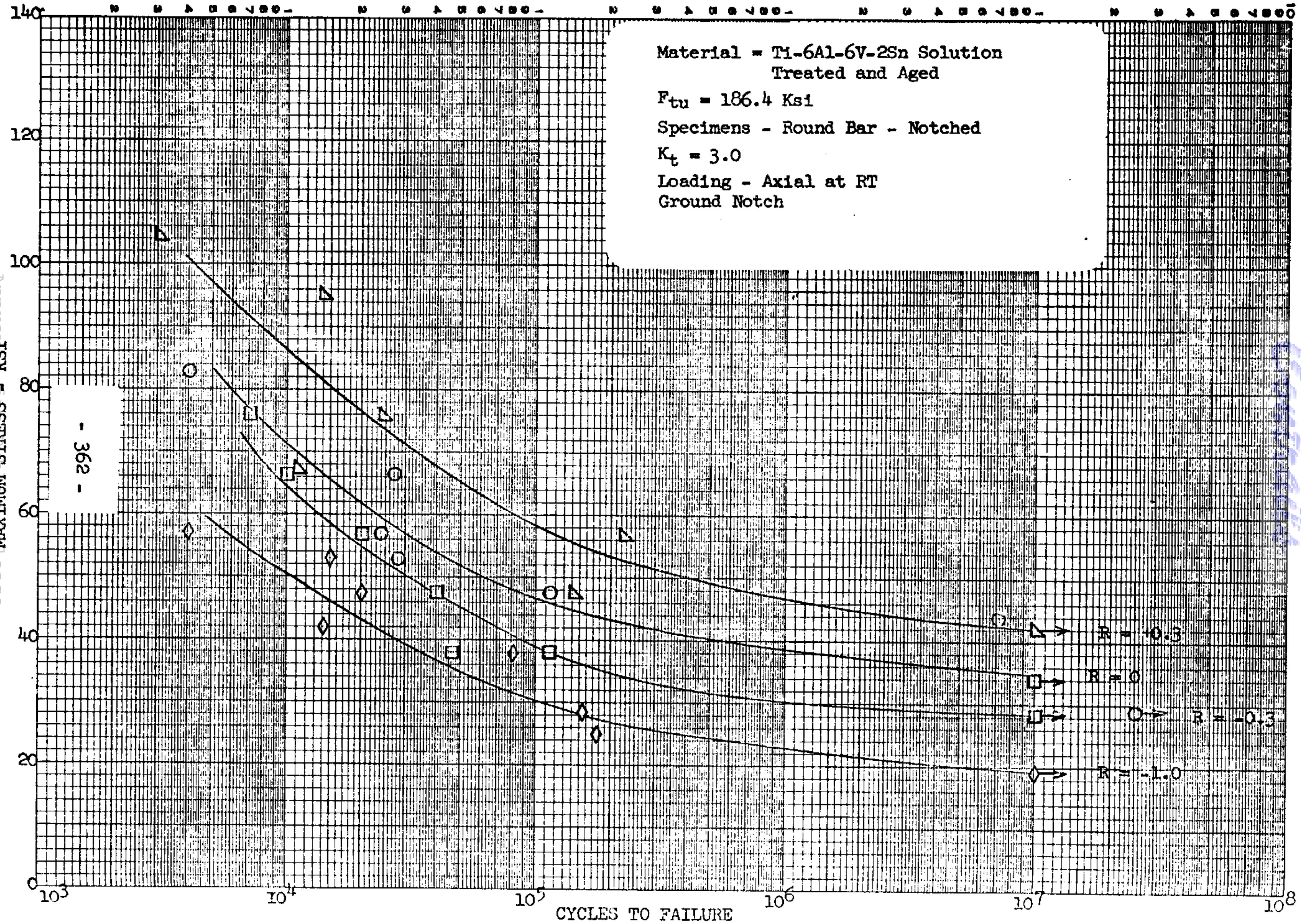

Material = Ti-6Al-6V-2Sn Solution Treated and Aged
F_{tu} = 186.4 Ksi
Specimens = Round Bar - Smooth
K_t = 1.0
Loading = Axial at RT
As-Machined Surface
R = +0.3
R = 0
R = -0.3
R = -1.0
MAXIMUM STRESS - KSI
200
180
160
140
120
100
80
60
CYCLES TO FAILURE
10^3
10^4
10^5
10^6
10^7
10^8

Figure 2.4.2


Material = Ti-6Al-6V-2Sn Solution Treated and Aged
F_{tu} = 186.4 Ksi
Specimens - Round Bar - Notched
K_t = 3.0
Loading - Axial at RT
Ground Notch
R = +0.3
R = 0
R = -0.3
R = -1.0
MAXIMUM STRESS - KSI
CYCLES TO FAILURE
0
20
40
60
80
100
120
140
10^3
10^4
10^5
10^6
10^7
10^8

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13. ABSTRACT

The purpose of this program was to develop design information on four titanium alloys for inclusion into Military Handbood-5. The alloys investigated were Ti-6Al-4V Condition STA, Ti-4Al-3Mo-1V Annealed Condition, Ti-13V-11Cr-3Al Annealed Condition, and Ti-6Al-6V-2Sn Annealed Condition and Condition STA. The mechanical properties investigated were tensile, compression, shear, bearing, fracture toughness and fatigue.

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