FOREWORD

The final Technical Engineering Report covering all work performed under Contract AF 33(616)-6346 from 31 March 1959 to 31 March 1962 is divided into four volumes, as follows:

Volume 1 - Summary of mechanical and physical property data collected, including creep and fatigue.

Volume 2a - Details of data collection program. Test techniques and results for tension, compression, bearing, shear, crippling, joints and physical properties.

Volume 2b - Test techniques and results for creep and fatigue.

Volume 3 - Tables of data collected.

This work was primarily conducted by the Structural Research Department, Engineering Research Laboratory of Lockheed-Georgia Company, a Division of Lockheed Aircraft Corporation. The contract was initiated under Project No. 7381, "Materials Application." Task No. 738103, "Data Collection and Correlation." It was monitored by the Metals and Ceramics Laboratory, Directorate of Materials and Processes, Deputy for Technology, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Captain R. G. Henning and Mr. A. W. Brisbane were the project engineers.

Lockheed-Georgia Company supervision was provided by Mr. D. G. Cumro, Structural Research Department Engineer.

ABSTRACT

Mechanical and physical property data, necessary to fulfill the requirements of Phase II of the Department of Defense Titanium Alloy Sheet Rolling Program, were obtained for selected solution treated and aged titanium alloys in sheet form.

Four alloys were investigated: B120VCA (Ti-13V-11Cr-3Al), Ti-6Al-4V, Ti-2.5Al-16V and Ti-4Al-3Mo-1V. They were supplied by the producers in the heat treated condition from three or more heats and three thicknesses of each alloy. Static mechanical property data for tension, compression, bearing, shear and crippling; creep and rupture data for tension, compression, bearing and shear; and axial-load fatigue data were obtained at room and elevated temperatures. Fastener and weld joint data from -320°F to 80°F and physical properties from -420°F to 1200°F were obtained.

Volume 1 summarizes mechanical and physical properties in a form consistent with those given in MIL-HDBK-5. Experimental procedures and test results for static mechanical properties and physical properties are reported in Volume 2a. Volume 2b contains procedures and results for creep and fatigue tests and Volume 3 is a tabular compilation of all data obtained in the program.

This technical documentary report has been reviewed and is approved.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

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TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

INTRODUCTION

In the mid 1950's, the Department of Defense organized an integrated program to accelerate the development of high strength titanium alloy sheet for use in design of advanced aircraft and missile systems. This program, the Titanium Alloy Sheet Rolling Program, was coordinated and administered by the Bureau of Aeronautics, Department of the Navy. The Materials Advisory Board of the National Academy of Sciences was requested to establish a panel to act in an advisory capacity to the Bureau of Aeronautics, and did so with individuals selected from research organizations and academic institutions, from the titanium producing industry and from various aircraft companies. Liaison representatives were provided to the Panel by the various governmental agencies concerned with titanium alloy development. The first meeting of Materials Advisory Board Titanium Alloy Sheet Rolling Panel was held on June 5 and 6, 1956 in Washington, D. C. At this meeting a three phase program was outlined. Phases I and III were concerned with Manufacturing Development and Material Evaluation, respectively. Phase II, with which the present work is concerned, was defined as Design Data Accumulation and was directed toward the development of mechanical property data applicable to design uses for the heat treated titanium alloys. The initiation of work on Phase II was delayed in order for manufacturing development to progress sufficiently to establish consistent processing techniques which would make sheet material, having uniform properties, available for testing. Work commenced on Phase II of the DOD TASRP on 31 March 1959.

General

The program for collection of design data summarized in this report was divided into four basic phases as follows:

1. Phase I, "Static Properties" - room and elevated temperature data for short-time tension, compression, bearing, shear and crippling; effect of long-time temperature exposure on tensile properties.

2. Phase II, "Creep-Rupture Properties" - creep and rupture properties for tension and bearing, creep properties for compression, and rupture properties for shear.

3. Phase III, "Fatigue Properties" - axial-load tension-tension and tension-compression fatigue data at room and elevated temperatures for various stress ratios and stress concentration factors.

4. Phase IV, "Physical and Joint Properties" - measurement of specific heat, thermal coefficient of expansion and thermal conductivity from -420°F to 1200°F; strength data for mechanical and welded joints from -320°F to 80°F.

Four titanium alloys; B120VCA (Ti-13V-11Cr-3Al), Ti-6Al-4V, Ti-2.5Al-16V, and Ti-4Al-3Mo-1V, supplied by the producers in solution treated and aged condition from DOD stock were evaluated. The material was from three nominal thicknesses and several

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heats of each alloy and was specified to meet the requirements of quality, interstitial limits and strength established by the Materials Advisory Board. However, some of the required material was unavailable from producer's current supplies and it was necessary to substitute early DOD sheet, commercial sheet and reheat treated sheet. For certain test conditions requiring forming and welding,the material was received in the solution treated condition and was subsequently aged by Lockheed. The testing procedures employed in this program followed the recommendations of the MAB Subpanel on Uniform Procedures for Structural Design Data Collections as specified in Reference 1. Members of this subpanel acted in a consulting capacity during the course of data collection.

Volume 2a

The final engineering report is presented in four volumes. The scope of this volume, Volume 2a, encompasses a detailed description of equipment and techniques used to determine static mechanical properties and physical properties. Also, the property data obtained are summarized graphically, and tabulations are included for cases where graphical illustration was not practicable. Equipment and techniques common to all four alloys are discussed under general sections with appropriate headings. Following the discussion sections are results sections for each alloy containing summarized data. Generally, summary curves are presented which show the average variation with temperature of the property measured for each heat, thickness and grain direction investigated. For mechanical properties, which comprise most of the data, ten values at room temperature and three each at the other temperatures were averaged in establishing each curve.

Specific heat and low-temperature thermal conductivity data were obtained by Georgia Institute of Technology Engineering Experiment Station, Atlanta, Georgia. These data, along with descriptions of equipment and techniques, were taken in whole or in part from their final reports and included herein to reduce the number of volumes required. In most cases, a more detailed description of measurement techniques and data analysis procedures are in Georgia Tech's reports which are referenced.

Since the purpose of this program was primarily for collection of design data, no comment, observation or analysis was made as to the merits of one alloy with respect to another. Such an analysis of merit has been left for the users of these data as dictated by their particular applications.

II - SUMMARY

Approximately 250 sheets in three thicknesses of the four titanium alloys were supplied for material property evaluation. In general, heat treatment was conducted by the producers who furnished data on thermal conditioning, chemical analysis and tensile properties for each sheet. Additional chemical analyses were obtained by Lockheed. Problems were encountered by the producers in meeting strength specifications for some of the alloys, and reworking was required.

The various types of specimens for determination of material properties were taken, in most cases, from three heats of each thickness of each alloy. They were distributed throughout the sheets and were assigned to particular test conditions by random selection. Test specimen design and machining procedures conformed to specifications.

Subcontracts were awarded to Southern Research Institute, Georgia Institute of Technology and National Spectrographic Laboratories, Inc. for various parts of the program to expedite completion and profit by specialized equipment and experience.

The reduction of material property data from autographically recorded load-deformation curves was facilitated by programs utilizing an IBM Model 7090 Electronic Data Processing Machine and associated equipment. Considerable variation in mechanical properties was noted between heats and between sheets within a heat of a given thickness for the titanium alloys. Based on the longitudinal and transverse room-temperature ultimate tensile strengths, a limited analysis was made using the electronic data processing equipment to determine the significance of these variations.

Experimental techniques for static mechanical property tests and physical property measurements are detailed herein. Summarization of the design data program as to types of tests, the conditions under which they were conducted and the properties determined is accomplished in Table I. This table also gives the report volumes in which tabulated test results and summary plots of data can be found.

TABLE I SUMMARY OF TESTS CONDUCTED AND DATA REPORTED

(a) PHASE I

Alloys: B120VCA, 6Al-4V, 2.5Al-16V, 4Al-3Mo-1V Heats/Alloy - 3(1) Grain Direction - Longitudinal and Transverse	Thickness, In.			Temperature, °F							Reported in Volume
	0.020	0.063	0.125	80	200	400	600	800	900	1000	
TENSION											
1. Ultimate and yield strengths	X	X	X	X	X	X	X	X	X	X	1, 2a and 3
2. Elastic moduli	X	X	X	X	X	X	X	X	X	X	1, 2a and 3
3. Elongations	X	X	X	X	X	X	X	X	X	X	1, 2a and 3
4. Poisson's Ratio		X		X	X	X	X	X	X	X	2a
5. Tangent moduli	X	X	X	X	X	X	X	X	X	X	1
6. Stress-strain curves	X	X	X	X	X	X	X	X	X	X	1
COMPRESSION											
1. Yield strengths		X	X	X	X	X	X	X	X	X	1, 2a and 3
2. Elastic moduli		X	X	X	X	X	X	X	X	X	1, 2a and 3
3. Secant and tangent moduli		X	X	X	X	X	X	X	X	X	1
4. Stress-strain curves		X	X	X	X	X	X	X	X	X	1
5. Ramberg-Osgood parameters		X	X	X	X	X	X	X	X	X	3
BEARING (e/D = 1.5 and e/D = 2.0, D = 1/8 inch)											
1. Ultimate and yield strengths	X			X	X	X	X	X	X	X	2a and 3
BEARING (e/D = 1.5 and e/D = 2.0, D = 3/16 inch)											
1. Ultimate and yield strengths	X			X	X	X	X	X	X	X	2a and 3
BEARING (e/D = 1.5 and e/D = 2.0, D = 5/16 inch)											
1. Ultimate and yield strengths	X	X	X	X	X	X	X	X	X	X	1, 2a and 3
SINGLE SHEAR											
1. Ultimate strengths	X	X	X	X	X	X	X	X	X	X	1, 2a and 3
DOUBLE SHEAR											
1. Ultimate strengths			X	X	X	X	X	X	X	X	2a and 3
CRIPPLING											
1. Critical crippling stresses		X		X	X	X	X	X	X	X	2a
2. Compressive yield stresses		X		X	X	X	X	X	X	X	2a
3. Compressive elastic moduli		X		X	X	X	X	X	X	X	2a
4. Ramberg-Osgood parameters		X		X	X	X	X	X	X	X	2a

(b) PHASE II

Alloys: 6Al-4V, 2.5Al-16V, 4Al-3Mo-1V Grain Direction - Longitudinal (2)	Heats per Alloy	Thickness, In.	Temperature, °F					Reported in Volume
			500	600	700	800	900	
TENSILE CREEP-RUPTURE								
1. Strain-time curves	3	0.063	X	X	X	X	X	2b
2. Stress and time to rupture and to various strains	3	0.063	X	X	X	X	X	1, 2b and 3
3. Larson-Miller plots	3	0.063		X	X	X		2b
COMPRESSIVE CREEP								
1. Strain-time curves	1	0.063		X	X	X		2b
2. Stress and time to various strains	1	0.063		X	X	X		2b and 3
BEARING CREEP-RUPTURE								
1. Strain-time curves	1	0.063		X	X	X		2b
2. Stress and time to rupture and to various strains	1	0.063		X	X	X		2b and 3
SHEAR STRESS-RUPTURE								
1. Stress and time to rupture	3	0.063 0.125		X	X	X		2b and 3

(c) PHASE III

Alloys: 6Al-4V, 2.5Al-16, 4Al-3Mo-1V Heats/Alloy - 3 to 5 Grain Direction - Longitudinal Thickness, In. - 0.020, 0.063, 0.125	Stress Concentration		Temperature, °F					Reported in Volume
	1.0	2.82	80	400	600	800	900	
AXIAL-LOAD FATIGUE								
1. Cycles to failure at								
a. Stress Ratio = ∞	X	X	X	X	X	X	X	3
b. Stress Ratio = 1.0	X	X	X	X	X	X	X	3
c. Stress Ratio = 0.3	X	X	X	X	X	X	X	3
d. Stress Ratio = 0	X	X				X	X	2b
2. S-N Curves	X	X	X	X	X	X	X	2b
3. Alternating to mean stress diagrams	X	X	X	X	X	X	X	1

(d) PHASE IV

Alloys: B120VCA, 6Al-4V, 2.5Al-16V, 4Al-3Mo-1V Heats per alloy: 1 Grain Direction-Longitudinal and Transverse(3)	Thickness, In.		Temperature, °F					Reported in Volume
	0.063	0.125	-320	-200	-100	-65	80	
FASTENER JOINTS IN TENSION								
1. Ultimate and yield strengths	X		X	X	X	X	X	2a and 3
WELDED JOINTS IN TENSION								
1. Ultimate and yield strengths	X		X	X	X	X	X	2a and 3
2. Elastic moduli	X		X	X	X	X	X	2a and 3
3. Elongations	X		X	X	X	X	X	2a and 3
4. Joint efficiencies	X		X	X	X	X	X	3
TENSION								
1. Ultimate and yield strengths	X		X	X	X	X	X	2a and 3
2. Elastic moduli	X		X	X	X	X	X	2a and 3
3. Elongations	X		X	X	X	X	X	2a and 3
4. Stress-strain curves	X		X	X	X	X	X	2a
THERMAL EXPANSION		X	-453°F to 1200°F					2a and 3
THERMAL CONDUCTIVITY		X	-423°F to 1200°F					2a and 3
SPECIFIC HEAT		X	-423°F to 1200°F					2a

(1) Only one heat was tested for 0.020 inch Ti-6Al-4V.
(2) Tensile creep-rupture was conducted on one heat of each alloy in the transverse direction at 600, 700 and 800°F.
(3) Thermal expansion and thermal conductivity specimens were in the longitudinal direction only.

III - TEST PROGRAM

Material

Titanium alloy sheet material was supplied for evaluation by two of the DOD producers. Reactive Metals, Incorporated, Niles, Ohio (formerly Mallory-Sharon Metals Corporation) furnished Ti-6Al-4V and Ti-2.5Al-16V; and Crucible Steel Company of America, Pittsburg, Pennsylvania, furnished B120VCA and Ti-4Al-3Mo-1V. The producers conducted chemical analyses, mechanical property tests and flatness evaluations to verify conformity to MAB requirements prior to releasing the material. Based on these data, the Air Force laboratory responsible for monitoring the program approved shipment of acceptable material to Lockheed for testing. A total of 247 sheets, nominally 36 x 96 inches, were supplied and all but 21 were in the solution treated and aged condition. Aging of specimens from these twenty-one 0.063 inch thick solution treated sheets was accomplished by Lockheed after forming or welding operations had been performed. A complete breakdown of alloy, thickness, heat and sheet is given in Tables II through XVII for all material received. These tables include chemical composition, thermal treatment, physical dimensions and tensile properties reported by the producers with corresponding information by Lockheed, where applicable.

B120VCA

A total of nine sheets, 0.020 inch thick; 24 sheets, 0.063 inch thick; and nine sheets, 0.125 inch thick were received. Six of these sheets were solution treated material and were shipped to Lockheed from Metcut Research Association at the direction of the Air Force.

Two sheets of B120VCA, 0.063 inch thick, from heat R6392 had what appeared to be grind lines roughly parallel to the rolling direction; however, these were not evident in the third sheet of this heat. Photographs of the surfaces are shown in Figure 1 and surface roughness readings indicated that sheet 3BX4 had an RMS of 40 to 50 microinches and sheets 3BT6 and 3TX6 had values of 22 to 25 microinches. Crucible Steel Company was contacted as to the cause of this condition, and based on the verbal description given them, they indicated that such markings could be found in most B120VCA sheet in varying degrees. It was further stated that these were probably "ghost" grains which had been thoroughly broken up and recrystallized by working and annealing. Metallographic, X-Ray diffraction and mechanical property tests in Crucible's laboratory had failed to show any difference between these "lines" and surrounding material.

However, test results reported herein indicate some reduction in transverse tensile elongation at room temperature and in transverse bearing ultimate strength for this sheet of material as compared with the other sheets from the same heat.

Ti-6Al-4V

A total of four sheets, 0.020 inch thick; 34 sheets, 0.063 inch thick; and 20 sheets, 0.125 inch thick were received. Material from only one heat of the 0.020 inch sheet was available which made it necessary to eliminate this thickness entirely from portions of the test program.

Considerable difficulty was encountered by Reactive Metals in processing this alloy to fall within the limits of the MAB release properties for aged sheets. Reference 2 discusses these problems in some detail. Some of the material which was finally received was made from cross-rolled plate. The sheets obtained from the plate were divided into three groups and each group was solution treated and aged in a different heat treating facility and those meeting target properties were released to Lockheed.

Pronounced directionality as indicated by mechanical properties was observed in heat number 27039 of 0.063 inch thick Ti-6Al-4V and metallographic samples were examined to determine the cause. The micrographs for this heat and heat number 25671, which was relatively isotropic, are presented in Figure 2. The microstructure for heat number 25671 was of primary platelets of alpha in a matrix of aged acicular alpha plus beta; whereas, heat number 27039 showed bands of segregated primary alpha in a matrix of transformed beta which indicate preferred orientation and could be responsible for serrated failures, as shown in Figure 3, observed in mechanical tests. In an attempt to correlate structural differences with processing differences, histories of sheets from both heats were obtained from Reactive Metals and these are presented in Table XVIII. The processing sequence was generally the same for both heats, but individual sheets were given solution treatments other than those specified in Table XVIII, step number 15. The laboratory reports which were transmitted with the material showed that sheets 0742-8, 0742-10, 0743-2, 0743-5 and 0743-7 from heat number 27039 were solution heat treated at 1700°F for three minutes and water quenched, and only sheets 0744-6 and 0744-7 were as shown in Table XVIII. Also, all sheets which Lockheed received from heat number 25671 were solution heat treated at 1700°F for three minutes and water quenched as shown in the laboratory reports and in Reference 3. These sheets were resistance heated and spray quenched by Titanium Metals Corporation of America, Toronto, Ohio and aged by Reactive Metals at 950°F for four hours and air cooled.

Although two solution heat-treat methods, furnace and resistance, were represented in sheets of heat number 27039, both the producer's and Lockheed's mechanical property data indicated about ten percent more tensile strength in the transverse than in the longitudinal direction for all sheets. And in heat number 25671 there was only about three percent more transverse tensile strength than longitudinal.

Ti-2.5Al-16V

A total of 21 sheets, 0.020 inch thick; 37 sheets, 0.063 inch thick; and 21 sheets, 0.125 inch thick were received.

Ti-4Al-3Mo-1V

A total of 23 sheets, 0.020 inch thick; 26 sheets, 0.063 inch thick; and 19 sheets, 0.125 inch thick were received.

The availability of this alloy from DOD stock was limited and it was necessary to purchase twenty 0.063 inch and seven 0.125 inch thick sheets of commercial material to fulfill the program requirements. Ultimately, approved material was received but before the commercial sheet met strength properties it was necessary for Crucible Steel Company to deskin all of the 0.125 inch sheets and several of the 0.063 inch sheets originally processed for the order. Additionally, it was necessary to solution treat and age the remainder of the 0.063 inch sheet a second time before it was acceptable.

TABLE II—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.020 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Cr	H_2 PPM	SOLUTION		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
R6392	3TA2	CSC		.01	.019	.25	2.9	14.3	10.9	204	1450F	20 min. A.C.	900F	72 hrs A.C.	94	36	.025		T (1)	184.0	171.4	8.0
		LAC	A1																			
R6392	3BK2	CSC		.01	.019	.23	2.9	13.4	10.9	146	1450F	20 min. A.C.	900F	72 hrs A.C.	96	35	.025		T (1)	195.0	180.2	6.5
		LAC	A1															.0272 .0249 .0231	L	175	167	1.9
																			T	188	174	2.5
R6392	3BT1	CSC		.01	.019	.23	2.9	13.4	10.9	162	1450F	20 min. A.C.	900F	72 hrs A.C.	92	36	.025		T (1)	190.5	176.2	6.5
		LAC	A1															.0264 .0249 .0231	L	176	171	1.0
																			T	184	176	1.2
R6761	5TA1	CSC		.05	.031	.21	3.3	13.7	10.9	193	1450F	20 min. A.C.	900F	72 hrs A.C.	93	36	.025		T	183.0	168.4	6.5
		LAC	A4																			
R6761	5TT2	CSC		.03	.025	.22	3.4	13.6	11.2	201	1450F	20 min. A.C.	900F	72 hrs A.C.	93	36	.025		T (1)	194.0	178.2	6.2
		LAC	A4															.0253 .0234 .0213	L	185	177	2.3
																			T	192	183	1.7
R6761	5TA2	CSC		.05	.031	.21	3.3	13.7	10.9	185	1450F	20 min. A.C.	900F	72 hrs A.C.	90	36	.025		T (1)	191.4	172.2	5.8
		LAC	A4															.0253 .0234 .0213	L	175	168	1.2
																			T	178	168	2.5
R6788	7BT2	CSC		.03	.024	.26	3.2	13.8	11.6	234	1450F	20 min. A.C.	900F	72 hrs A.C.	90	36	.025		T	181.3	167.4	5.0
		LAC	A7																			
R6788	7BK1	CSC		.01	.028	.24	3.3	13.6	11.1	148	1450F	20 min. A.C.	900F	72 hrs A.C.	89	36	.025		T	189.2	175.2	5.5
		LAC	A7	.041	.026	.18	3.31	13.17	10.59	H_2 160 O_2 1000								.0258 .0245 .0213	L	191	178	4.1
																			T	194	184	3.0

TABLE II—CON'T.

0.020 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Cr	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6788	7TT1	CSC		.03	.024	.26	3.2	13.8	11.6	196	1450F	20 min. A.C.	900F	72 hrs A.C.	96	36	.025		T (1)	187.6	173.6	6.5
		IAC	A7															.0255 .0238 .0213	L	191	178	4.2
																			T	199	188	3.2

(1) Average of two tests.

IAC Thickness Measurements are for Maximum, Minimum, and Average.

TABLE III—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.063 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Cr	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6392	3BT6	CSC		.01	.019	.23	2.9	13.4	10.9	94	1450F	30 min. A.C.	900F	90 hrs	95	36	.063		T (1)	192.6	175.8	6.5
		LAC	A2	.027	.018	.18	3.04	12.96	11.22	H_2 140 O_2 720								.0655 .0642 .0617	L T	206 210	190 194	5.4 5.0
R6392	3TT1	CSC		.01	.019	.23	2.9	13.4	10.9	82	1450F	30 min. A. C.	900F	72 hrs	101	36	.063		T (1)	211.2	192.4	5.0
		LAC	A2																			
R6392	3BX3	CSC		.01	.019	.23	2.9	13.4	10.9	97	1450F	30 min. A. C.	900F	90 hrs	107	36	.063		T	198.1	178.0	4.5
		LAC	A2																			
R6392	3TX6	CSC		.01	.019	.23	2.9	13.4	10.9	143	1450F	30 min. A. C.	900F	72 hrs	96	36	.063		L T	192.1 195.0	174.2 177.3	8.5 7.5
		LAC	A2															.0680 .0657 .0620	L T	193 186	177 166	6.8 6.5
R6392	3TT2	CSC		.01	.019	.25	2.9	14.3	10.9	116	1450F	30 min. A. C.	900F	72 hrs	96	36	.063		L T	187.4 192.6	168.1 177.7	8.5 5.0
		LAC	(2) A2															.0682 .0644 .0593	L T	186 191	171 175	5.3 5.7
R6392	3BK4	CSC		.01	.019	.23	2.9	13.4	10.9	136	1450F	30 min. A. C.	900F	90 hrs	96	36	.063		L T	196.1 196.2	174.3 175.0	7.5 6.0
		LAC	A2															.0630 .0620 .0604	L T	180 179	165 167	5.2 3.2
R6761	5BX2	CSC		.03	.025	.23	3.4	13.7	11.2	140	1450F	30 min. A. C.	900F + 1000F	36 hrs. 10 min. A.C.	94	36	.063		T	193.8	183.9	6.0
		LAC	A5															.0634 .0605 .0585	L T	191 198	183 191	5.2 5.5
R6761	5BT7	CSC		.03	.025	.22	3.4	13.6	11.2	136	1450F	30 min. A. C.	900F + 1000F	36 hrs. 10 min. A. C.	94	36	.063		T	198.0	185.4	5.0
		LAC	A5															.0620 .0598 .0565	L T	195 198	189 191	4.8 5.0

TABLE III—CON'T.

0.063 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Cr	H_2 PPM	HEAT TREATMENT SOLUTION TEMP.	SOLUTION TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6761	5HT10	CSC		.03	.025	.22	3.4	13.6	11.2	143	1450F	30 min. A.C.	900F 1000F	36 hrs 10 min A.C.	94	36	.063		T	175.9	167.1	7.5
		LAC	A5																			
R6761	5TT6	CSC		.03	.025	.22	3.4	13.6	11.2	88	1450F	30 min. A.C.	900F	48 hrs	95	36	.063		T (1)	191.4	178.0	5.5
		LAC	A5																			
R6761	5TT5	CSC		.03	.025	.22	3.4	13.6	11.2	94	1450F	30 min. A.C.	900F	48 hrs	101	36	.063		T (1)	189.1	175.2	6.0
		LAC	A5																			
R6761	5BA5	CSC		.05	.031	.21	3.3	13.7	10.9	140	1450F	30 min. A. C.	900F	48 hrs	90	36	.063		L	216.6	190.8	5.5
																			T	223.2	203.0	5.0
		LAC	A5																			
R6788	7TT5	CSC		.03	.024	.26	3.2	13.8	11.6	76	1450F	30 min. A. C.	900F	72 hrs	101	36	.063		T (1)	202.0	182.6	5.0
		LAC	A8															.0655 .0638 .0628	L	189	173	5.6
																			T	198	181	3.6
R6788	7TA1	CSC		.02	.028	.26	3.4	13.7	10.9	87	1450F	30 min. A. C.	900F	72 hrs	107	36	.063		T (1)	201.6	182.0	5.2
		LAC	A8																			
R6788	7TA2	CSC		.02	.028	.26	3.4	13.7	10.9	84	1450F	30 min. A. C.	900F	72 hrs	101	36	.063		T (1)	202.8	185.6	5.0
		LAC	A8															.0628 .0608 .0569	L	186	170	6.6
																			T	201	178	4.7
R6788	7BK8	CSC		.01	.028	.24	3.3	13.6	11.1	110	1450F	30 min. A.C.	900F	72 hrs	90	36	.063		L	200.2	180.8	9.0
																			T	195.8	179.0	5.5
		LAC	A8																			

TABLE III—CON'T.

0.063 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Cr	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6788	7BK7	CSC		.01	.028	.24	3.3	13.6	11.1	222	1450F	30 min. A.C.	900F	72 hrs.	90	34	.063		L	197.2	176.9	7.0
																			T	197.8	180.6	6.0
		LAC	A8																			
R6788	7TT4	CSC		.03	.024	.26	3.2	13.8	11.6	114	1450F	30 min. A. C.	900F	72 hrs.	102	36	.063		L	209.7	190.4	7.0
																			T	210.1	195.2	6.0
		LAC	A8																			

(1) Average of two tests.
(2) Sheet assigned to cryogenic tests.

LAC Thickness Measurements are for Maximum, Minimum, and Average

TABLE IV—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.063in.

PRODUCER CRUCIBLE ALLOY B120VCA CONDITION SOLUTION TREATED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Cr	H_2 PPM	SOLUTION		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
F6794	BT-17	CSC									1450F	30 Min. A.C.	900F	72 hrs. A.C.	108	32	.063		L (1)	215.0	191.3	5.0
																			T (1)	226.2	212.5	3.0
		LAC	A11																			
F6794	BT-19	CSC									1450F	30 Min. A.C.	900F	72 hrs. A.C.	88	30	.063		L (1)	206.2	186.8	6.0
																			T (1)	203.1	195.0	7.0
		LAC	A11																			
F6799	BT-11	CSC									1450F	30 Min. A.C.	900F	72 hrs. A.C.	92	34	.063		L (1)	175.1	160.1	3.0
																			T (1)	185.3	167.6	3.0
		LAC	A14	.052	.019	.16	3.20	13.15	10.89	H_2 93 O_2 720			900F	90 hrs. A.C.				.0690 .0653 .0604	L	208	187	3.2
																			T	212	195	2.0
F6799	BX-17	CSC									1450F	30 Min. A.C.	900F	72 hrs. A.C.	94	32	.063		L (1)	171.8	153.2	8.0
																			T (1)	182.3	169.0	5.0
		LAC	A14																			
F6800	BX-9	CSC									1450F	30 Min. A.C.	900F	72 hrs. A.C.	96	36	.063		L (1)	202.8	182.5	6.0
																			T (1)	210.3	195.0	3.5
		LAC	A17										900F	72 hrs. A.C.				.0669 .0638 .0596	L	206	189	7.0
																			T	210	192	5.0
F6800	BX-11	CSC									1450F	30 Min. A.C.	900F	72 hrs. A.C.	80	34	.063		L (1)	201.4	181.4	6.0
																			T (1)	208.5	188.0	5.5
		LAC	A17	.043	.024	.12	3.33	12.87	10.59	H_2 120 O_2 870			900F	72 hrs. A.C.				.0663 .0633 .0581	L	207	186	6.8
																			T	210	192	4.2

(1) Properties are for labroatory aged samples.

TABLE V—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.125 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Cr	H_2 PPM	SOLUTION TEMP.	SOLUTION TIME	AGE TEMP.	AGE TIME	LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6759	9MA5	CSC		.04	.025	.25	3.5	13.9	10.4	94	1450F	20 min. A. C.	900F	60 hrs. A. C.	108	36	.125		L	209.7	191.0	4.0
																			T	203.9	185.7	3.0
		LAC	A3																			
R6759	9MB3	CSC		.04	.025	.25	3.5	13.9	10.4	114	1450F	20 min. A. C.	900F	60 hrs. A. C.	102	36	.125		L	215.4	195.6	4.5
																			T	205.2	187.3	3.5
		LAC	A3															.1308 .1292 .1268	L	210	190	5.1
																			T	213	197	3.8
R6759	9MB4	CSC		.04	.025	.25	3.5	13.9	10.4	89	1450F	20 min. A. C.	900F	60 hrs. A. C.	102	36	.125		L	212.0	193.2	4.0
																			T	210.5	193.7	3.5
		LAC	A3	.038	.025	.11	3.06	12.93	11.29	H_2 78 O_2 650								.1285 .1271 .1249	L	206	189	3.8
																			T	213	194	.2
R6761	5TT7	CSC		.03	.025	.22	3.4	13.6	11.2	117	1450F	20 min. A. C.	900F	60 hrs. A. C.	96	36	.125		T	194.7	175.9	6.0
		LAC	A6															.1299 .1271 .1242	L	184	167	8.7
																			T	187	171	6.9
R6761	5EA7	CSC		.05	.030	.21	3.3	13.7	10.9	137	1450F	20 min. A. C.	900F	60 hrs. A. C.	96	36	.125		T	185.8	168.1	7.0
		LAC	A6																			
R6761	5TA9	CSC		.04	.030	.21	3.3	13.7	10.9	91	1450F	20 min. A. C.	900F	60 hrs. A. C.	96	36	.125		T	198.2	181.7	5.0
		LAC	A6	.022	.019	.20	3.13	13.13	11.38	H_2 110 O_2 870								.1288 .1271 .1250	L	184	165	8.5
																			T	190	172	7.0
R6753	8TT3	CSC		.02	.019	.25	3.3	13.9	11.2	66	1450F	30 min. A. C.	900F	72 hrs.	114	36	.125		T (1)	199.8	183.2	5.2
		LAC	A9															.1231 .1200 .1151	L	195	180	6.0
																			T	196	184	3.8
R6753	8TT4	CSC		.02	.019	.25	3.3	13.9	11.2	68	1450F	30 min. A. C.	900F	72 hrs.	108	36	.125		T (1)	203.6	189.0	5.5
		LAC	A9	.047	.018	.17	3.24	13.04	11.04	H_2 73 O_2 720								.1312 .1265 .1218	L	199	181	6.5
																			T	198	183	4.7

TABLE V—CON'T.

0.125 in.

PRODUCER CRUCIBLE **ALLOY** B120VCA **CONDITION** SOLUTION TREATED AND AGED

				CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION		AGE				THICKNESS					
HEAT NO.	SHEET NO.	DATA BY	CODE	C	N_2	Fe	Al	V	Cr	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6392	3TT5	CSC		.01	.019	.25	2.9	14.3	10.9	151	1450F	30 min. A. C.	900F	60 hrs.	95	36	.125		T	206.5	188.3	3.5
		IAC	A12																			

(1) Average of two tests.

LAC Thickness Measurements are for Maximum, Minimum, and Average.

TABLE VI — PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.020 in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
24791	8335-14	RM		.02	.010	.18	6.11	3.86		135	1700 F	15 Min. W.Q.	950 F	4 Hrs. A.C.	84	36	.020		L	181.1	167.7	5.8
																			T	172.3	156.0	6.3
		LAC	B1															.0225 .0214 .0199	L	174	160	5.0
																			T	170	164	5.0
24791	8335-15	RM		.02	.010	.18	6.11	3.86		143	1700 F	15 Min. W.Q.	950 F	4 Hrs. A.C.	94	36	.020		L	174.1	155.4	5.7
																			T	173.6	160.4	5.5
		LAC	B1															.0243 .0215 .0181	L	177	162	4.1
																			T	181	168	5.1
24791	8335-16	RM		.02	.010	.18	6.11	3.86		137	1700 F	15 Min. W.Q.	950 F	4 Hrs. A.C.	84	36	.020		L	174.2	153.1	6.5
																			T	175.6	160.8	6.0
		LAC	B1																L			
																			T			
24791	8335-20	RM		.02	.010	.18	6.11	3.86		141	1700 F	15 Min. W.Q.	950 F	4 Hrs. A.C.	87	36	.020		L	171.3	159.2	9.0
																			T	176.2	167.0	9.8
		LAC	B1	.037	.012	.11	6.12	3.70		H_2 130 O_2 440								.0234 .0222 .0214	L	178	161	5.5
																			T	174	161	4.9

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

TABLE VII—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.063 in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION TEMP.	SOLUTION TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
27039	0743-2	RM		.03	.009	.21	5.88	3.95		77	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	101	34	.063		L	175.6	150.5	7.5
																			T	191.3	172.8	6.5
		LAC	B2															.0672 .0651 .0603	L	176	154	4.4
																			T	195	178	5.9
27039	0743-5	RM		.03	.009	.21	5.88	3.95		73	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	102	34	.063		L	175.2	156.6	6.2
																			T	190.2	174.2	7.5
		LAC	B2															.0653 .0631 .0607	L	178	154	4.5
																			T	196	177	6.2
27039	0743-7	RM		.03	.009	.21	5.88	3.95		67	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	101	34	.063		L	176.3	153.8	5.7
																			T	187.3	175.9	8.2
		LAC	B2															.0627 .0591 .0523	L	172	150	3.2
																			T	196	176	7.0
27039	0744-6	RM		.03	.009	.21	5.88	3.95		113	1675 F	20 Min. W.Q.	935 F	4 Hrs. A.C.	101	34	.063		L	170.0	152.3	6.2
																			T	183.5	171.1	8.2
		LAC	B2															.0674 .0644 .0607	L	174	154	5.8
																			T	186	175	4.6
27039	0744-7	RM		.03	.009	.21	5.88	3.95		138	1675 F	20 Min. W.Q.	935 F	4 Hrs. A.C.	99	34	.063		L	164.7	150.2	7.0
																			T	181.4	170.8	8.6
		LAC	B2	.016	.010	.18	5.75	4.00		H_2 96 O_2 580								.0649 .0623 .0594	L	166	148	6.4
																			T	183	172	5.4
27039	0742-8	RM		.03	.009	.21	5.88	3.95		71	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	87	34	.063		L	175.0	150.8	6.5
																			T	189.5	167.3	7.0
		LAC	B2																L			
																			T			
27039	0742-10	RM		.03	.009	.21	5.88	3.95		69	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	91	34	.063		L	170.7	150.9	5.0
																			T	187.7	173.0	8.5
		LAC	B2																L			
																			T			
25671	8361-3	RM		.03	.010	.19	6.03	3.80		76	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	84	34	.063		L	169.9	154.0	6.7
																			T	174.5	150.1	7.2
		LAC	B5	.015	.009	.14	6.18	3.95		H_2 62 O_2 580								.0705 .0666 .0615	L	170	148	5.0
																			T	176	152	5.6

LAC THICKNESS MEASUREMENTS ARE
FOR MAX., MIN. AND AVERAGE.

TABLE VII—CON'T. 0.063in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
25671	8361-4	RM		.03	.010	.19	6.03	3.80		76	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	79	34	.063		L	171.4	149.0	6.5
																			T	173.2	150.6	5.7
		LAC	B5															.0725 .0711 .0702	L	172	153	4.0
																			T	175	154	5.7
25671	8361-5	RM		.03	.010	.19	6.03	3.80		72	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	60	34	.063		L	170.6	147.4	6.7
																			T	180.8	161.1	8.0
		LAC	B5															.0753 .0732 .0703	L	169	152	4.8
																			T	178	158	6.0
25671	8361-6	RM		.03	.010	.19	6.03	3.80		89	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	88	34	.063		L	175.0	151.3	7.0
																			T	182.7	162.3	7.7
		LAC	B5															.0701 .0680 .0650	L	172	152	4.4
																			T	186	170	6.7
25671	8361-7	RM		.03	.010	.19	6.03	3.80		77	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	91	34	.063		L	170.6	149.2	6.0
																			T	173.4	152.8	6.0
		LAC	B5																L			
																			T			
25671	8361-9	RM		.03	.010	.19	6.03	3.80		90	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	86	34	.063		L	169.7	148.9	6.0
																			T	173.1	155.1	7.0
		LAC	B5															.0667 .0649 .0628	L	168	150	5.2
																			T	177	156	5.7
25671	8361-10	RM		.03	.010	.19	6.03	3.80		78	1700 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	87	34	.063		L	169.9	148.5	6.5
																			T	174.4	159.0	8.2
		LAC	B5															.0664 .0651 .0625	L	171	150	5.7
																			T	179	163	5.9
31372	1780AB-1	RM		.02	.010	.15	5.94	3.91		53	1675 F	20 Min. W.Q.	900 F	4 Hrs. A.C.	87	36	.063		L	173.5	159.5	9.2
																			T	171.0	151.5	8.5
		LAC	B8															.0685 .0669 .0643	L	177	167	8.8
																			T	174	158	9.0
31372	1780AB-2	RM		.02	.010	.15	5.94	3.91		60	1675 F	20 Min. W.Q.	900 F	4 Hrs. A.C.	89	36	.063		L	173.0	153.5	8.0
																			T	174.5	158.5	9.5
		LAC	B8	.022	.011	.14	5.90	3.85		H_2 58 O_2 720								.0690 .0668 .0637	L	176	167	8.4
																			T	174	161	7.6

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

TABLE VII—CON'T.

0.063 in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION TEMP.	SOLUTION TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
31372	1780 ABC-3	RM		.02	.010	.15	5.94	3.91		52	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	100	36	.063		L	182.0	164.0	8.5
																			T	177.0	154.0	8.0
		LAC	B8															.0718 .0674 .0617	L	179	164	8.8
																			T	178	161	7.7
31372	1780-7	RM		.02	.010	.15	5.94	3.91		68	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	94	36	.063		L	176.0	162.5	8.2
																			T	170.5	152.0	9.0
		LAC	(1) B2															.0690 .0653 .0612	L	175	160	7.8
																			T	-	-	-
31372	1780-8	RM		.02	.010	.15	5.94	3.91		79	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	94	36	.063		L	170.5	151.0	7.0
																			T	172.0	155.0	9.0
		LAC	(1) B2															.0696 .0658 .0605	L	182	166	8.7
																			T	-	-	-
31372	1780-9	RM		.02	.010	.15	5.94	3.91		75	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	94	36	.063		L	173.0	151.0	10.0
																			T	171.0	152.0	8.5
		LAC	(1) B2															.0712 .0680 .0631	L	182	166	8.0
																			T	-	-	-
31372	1780-10	RM		.02	.010	.15	5.94	3.91		73	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	98	36	.063		L	175.5	155.0	7.5
																			T	173.0	152.5	9.0
		LAC	(1) B2															.0679 .0652 .0610	L	180	162	8.3
																			T	-	-	-
31372	1780-12	RM		.02	.010	.15	5.94	3.91		89	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	99	36	.063		L	178.0	164.5	9.0
																			T	174.0	151.0	8.8
		LAC	(1) B2															.0680 .0658 .0622	L	179	164	9.5
																			T	-	-	-
31372	1780-14	RM		.02	.010	.15	5.94	3.91		100	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	100	36	.063		L	176.5	159.0	10.8
																			T	175.0	151.0	9.5
		LAC	(1) B2															.0688 .0654 .0600	L	182	167	8.5
																			T	-	-	-
31372	1780 AB-15	RM		.02	.010	.15	5.94	3.91		47	1675 F	20 Min. W.Q.	900 F	4 Hrs. A.C.	78	36	.063		L	186.5	169.5	6.8
																			T	182.5	164.5	7.6
		LAC	(1) B2															.0710 .0689 .0645	L	186	175	8.8
																			T	-	-	-

(1) SHEET ASSIGNED TO FATIGUE TESTS.

TABLE VII—CON'T.

0.063 in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION TEMP.	SOLUTION TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
31372	1780 AB-13	RM		.02	.010	.15	5.94	3.91		46	1675 F	20 Min. W.Q.	900 F	4 Hrs. A.C.	88	36	.063		L	180.5	162.5	7.3
																			T	182.0	164.5	7.0
		LAC	B8																L			
																			T			
32163	1776 ABCD-5	RM		.02	.016	.16	6.01	3.98		75	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	90	36	.063		L	178.5	161.0	8.5
																			T	177.5	158.5	6.0
		LAC	(1) B2															.0685 .0661 .0622	L	181	167	9.5
																			T	-	-	-
32163	1776A-6	RM		.02	.016	.16	6.01	3.98		86	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	99	36	.063		L	173.5	155.0	7.5
																			T	174.5	152.5	9.0
		LAC	(1) B2															.0648 .0616 .0577	L	186	167	8.8
																			T	-	-	-
32163	1776A-7	RM		.02	.016	.16	6.01	3.98		69	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	99	36	.063		L	180.0	164.0	8.0
																			T	177.0	156.0	7.0
		LAC	(1) B2															.0703 .0679 .0622	L	188	174	8.7
																			T	-	-	-
32163	1776A-8	RM		.02	.016	.16	6.01	3.98		71	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	102	36	.063		L	173.5	156.5	6.5
																			T	177.0	160.5	6.5
		LAC	(1) B2															.0725 .0692 .0649	L	184	169	8.7
																			T	-	-	-
32163	1776A-9	RM		.02	.016	.16	6.01	3.98		72	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	89	36	.063		L	176.5	157.0	7.2
																			T	173.5	153.0	7.8
		LAC	(1) B2															.0671 .0633 .0570	L	179	161	9.2
																			T	-	-	-
32163	1776 AB-1	RM		.02	.016	.16	6.09	3.98		46	1675 F	20 Min. W.Q.	900 F	4 Hrs. A.C.	79	36	.063		L	174.5	162.0	7.8
																			T	176.0	155.5	7.6
		LAC	(2)																L			
																			T			

(1) SHEET ASSIGNED TO FATIGUE TESTS. (2) SHEET OUT OF FLATNESS TOLERANCE.

TABLE VIII—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.063in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES*			
											SOLUTION		AGE*				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
31372	1780 ABCD-5	RM		.02	.010	.15	5.94	3.91		58	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	103	36	.063		L T	184.0 185.0	172.0 164.0	8.2 8.2
		LAC	B8															.0648 .0621 .0578	L T	175 174	163 160	6.3 5.8
32163	1776 ABC-4	RM		.02	.016	.16	6.09	3.98		49	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	99	36	.063		L T	186.0 184.0	166.0 165.0	8.8 6.5
		LAC	B11										900 F	4 Hrs. A.C.				.0659 .0629 .0608	L T	183 182	170 166	9.5 7.8
32163	1776 ABC-3	RM		.02	.016	.16	6.09	3.98		63	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	84	36	.063		L T	178.0 180.0	163.0 159.0	8.5 5.5
		LAC	B11										900F	4 Hrs. A.C.				.0622 .0594 .0568	L T	179 180	168 164	9.8 7.4

* AGING AND TESTING OF LABORATORY SAMPLE BY REACTIVE METALS, INC.

TABLE IX—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.125in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
22207	0785-6	RM		.01	.013	.17	5.98	3.97		65	1715 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	55	34	.125		L	173.6	159.9	6.0
																			T	190.3	180.2	5.7
		LAC	B3																L			
																			T			
22207	0785-7	RM		.01	.013	.17	5.98	3.97		61	1715 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	92	34	.125		L	177.9	167.7	5.7
																			T	191.6	171.3	6.0
		LAC	B3	.027	.017	.16	6.00	4.10		H_2 64 O_2 1000								.1287 .1276 .1264	L	177	162	4.7
																			T	190	177	5.9
23407	0746-2	RM		.01	.013	.18	6.11	3.95		52	1715 F	3 Min. W.Q.	950 F	4 Hrs. A.C.	97	34	.125		L	175.6	160.3	9.3
																			T	190.2	173.9	6.5
		LAC	B3	.022	.018	.16	5.75	4.00		H_2 59 O_2 650								.1230 .1209 .1108	L	170	154	5.5
																			T	188	175	7.3
32163	1775A-4	RM		.02	.016	.15	6.09	3.98		49	1665 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	92	36	.125		L	175.0	159.0	8.0
																			T	173.0	158.0	8.5
		LAC	B6	.011	.011	.16	6.10	4.10		H_2 63 O_2 720								.1306 .1274 .1219	L	174	155	7.9
																			T	176	161	6.6
32163	1775A-3	RM		.02	.016	.16	6.09	3.98		48	1665 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	88	36	.125		L	169.0	152.5	9.5
																			T	169.5	154.5	9.5
		LAC	B6															.1312 .1292 .1273	L	169	151	7.0
																			T	172	156	7.8
32167	1777A-2	RM		.02	.015	.15	5.89	3.87		56	1700 F	20 Min. O.Q.	900 F	4 Hrs. A.C.	86	36	.125		L	179.0	162.5	7.8
																			T	178.5	160.0	8.3
		LAC	B9															.1333 .1310 .1260	L	176	163	7.4
																			T	177	162	7.7
32167	1777A-1	RM		.02	.015	.15	5.89	3.87		50	1700 F	20 Min. O.Q.	900 F	4 Hrs. A.C.	90	36	.125		L	177.5	156.6	7.6
																			T	178.5	157.5	8.0
		LAC	B9	.043	.009	.15	6.03	4.00		H_2 63 O_2 800								.1315 .1263 .1219	L	176	162	7.8
																			T	177	163	7.2
32167	1777-4	RM		.02	.015	.15	5.89	3.87		91	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	97	36	.125		L	173.5	155.5	8.5
																			T	170.5	155.0	8.5
		LAC	(1) B3															.1302 .1278 .1235	L	168	153	9.5
																			T	-	-	-

(1) SHEET ASSIGNED TO FATIGUE TESTS.

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

TABLE IX—CON'T.

0.125in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
32167	1777-5	RM		.02	.015	.15	5.89	3.87		65	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	95	36	.125		L	170.5	156.5	8.5
																			T	171.0	158.5	9.8
		LAC	(1) B3															.1377 .1338 .1287	L	174	158	8.8
																			T	-	-	-
32167	1777-6	RM		.02	.015	.15	5.89	3.87		66	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	98	36	.125		L	176.0	164.0	8.0
																			T	172.0	158.0	6.5
		LAC	(1) B3															.1355 .1312 .1242	L	166	152	10.8
																			T	-	-	-
32167	1777-7	RM		.02	.015	.15	5.89	3.87		71	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	94	36	.125		L	171.5	156.5	10.0
																			T	172.0	156.5	5.5
		LAC	(1) B3															.1380 .1349 .1305	L	166	153	11.5
																			T	-	-	-
32167	1777-3	RM		.02	.015	.15	5.89	3.87		66	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	90	36	.125		L	172.0	159.5	8.0
																			T	175.0	158.0	8.0
		LAC	(1) B3															.1301 .1266 .1218	L	170	157	10.0
																			T	-	-	-
32167	1778 AB-1	RM		.02	.015	.15	5.89	3.87		54	1680 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	99	36	.125		L	171.5	151.5	7.8
																			T	172.0	156.5	7.5
		LAC	(1) B3															.1265 .1225 .1125	L	169	154	9.7
																			T	-	-	-
32167	1778 AB-2	RM		.02	.015	.15	5.89	3.87		60	1680 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	99	36	.125		L	177.5	158.0	6.8
																			T	172.5	154.0	8.2
		LAC	(1) B3															.1256 .1234 .1187	L	171	156	8.2
																			T	-	-	-
32167	1778 AB-3	RM		.02	.015	.15	5.89	3.87		51	1680 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	100	36	.125		L	170.5	154.5	7.5
																			T	170.0	150.5	8.0
		LAC	(1) B3															.1291 .1258 .1220	L	170	154	10.8
																			T	-	-	-
32167	1778 ABC-4	RM		.02	.015	.15	5.89	3.87		62	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	100	36	.125		L	170.0	155.0	8.8
																			T	167.0	151.0	8.5
		LAC	(1) B3															.1269 .1238 .1182	L	168	150	9.5
																			T	-	-	-

(1) SHEET ASSIGNED TO FATIGUE TESTS.

TABLE IX—CON'T.

0.125 in.

PRODUCER REACTIVE METALS **ALLOY** Ti-6Al-4V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
32167	1778 ABC-5	RM		.02	.015	.15	5.89	3.87		68	1690 F	12 Min. W.Q.	900 F	4 Hrs. A.C.	100	36	.125		L	171.5	158.0	6.3
																			T	170.0	154.5	8.8
		LAC	(1) B3															.1262 .1222 .1174	L	170	156	8.8
																			T	-	-	-
32167	1778A-10	RM		.02	.015	.15	5.89	3.87		50	1675 F	20 Min. W.Q.	950 F	4 Hrs. A.C.	94	36	.125		L	179.0	160.5	8.8
																			T	181.5	161.5	8.9
		LAC	(1) B3															.1208 .1175 .1120	L	180	164	9.0
																			T	-	-	-
32167	1778A-11	RM		.02	.015	.15	5.89	3.87		55	1675 F	20 Min. W.Q.	950 F	4 Hrs. A.C.	83	36	.125		L	180.5	157.5	8.8
																			T	178.0	160.0	8.0
		LAC	(1) B3															.1276 .1250 .1216	L	182	164	8.2
																			T	-	-	-
31372	1781A-1	RM		.02	.010	.15	5.94	3.91		55	1675 F	20 Min. W.Q.	900 F	4 Hrs. A.C.	89	36	.125		L	175.0	161.0	8.3
																			T	176.0	160.0	8.5
		LAC	B12																L			
																			T			

(1) SHEET ASSIGNED TO FATIGUE TESTS.

TABLE X—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM —0.020 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(2)		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
22093	3971-16	RM		.02	.013	.22	2.53	15.72		116	1390 F	15 Min.	975 F	6 Hrs.	101	36	.020		L	183.3	166.7	4.5
																			T	177.9	164.3	5.0
		LAC	C1															.0285 .0269 .0246	L	180	170	4.5
																			T	178	167	3.3
22093	3971-17	RM		.02	.013	.22	2.53	15.72		128	1390 F	15 Min.	975 F	6 Hrs.	103	36	.020		L	182.9	171.4	4.8
																			T	180.3	169.2	4.5
		LAC	C1															.0277 .0263 .0242	L	182	167	3.8
																			T	180	167	3.3
22093	(1) 3971-19	RM		.02	.013	.22	2.53	15.72		117	1390 F	15 Min.	975 F	6 Hrs.	93	36	.020		L	181.6	172.8	5.0
																			T	173.2	162.0	4.5
		LAC	C1															.0276 .0262 .0245	L	182	165	3.8
																			T	-	-	-
22093	(1) 3971-20	RM		.02	.013	.22	2.53	15.72		89	1400 F	20 Min.	990 F	6 Hrs.	93	35	.020		L	178.0	163.0	4.2
																			T	171.0	153.0	4.0
		LAC	C1															.0234 .0221 .0200	L	168	156	4.5
																			T	-	-	-
22093	(1) 3971-21	RM		.02	.013	.22	2.53	15.72		88	1400 F	20 Min.	990 F	6 Hrs.	88	35	.020		L	173.0	159.0	4.0
																			T	171.0	157.0	5.0
		LAC	C1															.0248 .0230 .0211	L	173	159	4.3
																			T	-	-	-
22093	(1) 3971-22	RM		.02	.013	.22	2.53	15.72		91	1400 F	20 Min.	990 F	6 Hrs.	88	35	.020		L	173.0	159.0	5.0
																			T	170.0	156.0	4.5
		LAC	C1															.0244 .0229 .0200	L	166	153	5.8
																			T	-	-	-
22093	(1) 3971-23	RM		.02	.013	.22	2.53	15.72		86	1400 F	20 Min.	990 F	6 Hrs.	89	35	.020		L	171.0	161.0	4.5
																			T	177.0	164.0	4.5
		LAC	C1															.0236 .0222 .0193	L	169	155	4.7
																			T	-	-	-
22093	(1) 3971-24	RM		.02	.013	.22	2.53	15.72		90	1400 F	20 Min.	990 F	6 Hrs.	92	35	.020		L	173.0	159.0	4.0
																			T	175.0	163.0	4.0
		LAC	C1															.0240 .0228 .0202	L	170	158	4.6
																			T	-	-	-

TABLE X—CON'T.

0.020 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION(2) TEMP.	SOLUTION(2) TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
22093	3971-25 (1)	RM		.02	.013	.22	2.53	15.72		86	1400 F	20 Min.	990 F	6 Hrs.	94	35	.020		L	170.0	156.0	4.0
																			T	170.0	156.0	4.5
		LAC	C1															.0253 .0238 .0218	L	171	156	5.0
																			T	-	-	-
22093	3971-26 (1)	RM		.02	.013	.22	2.53	15.72		123	1390 F	15 Min.	975 F	6 Hrs.	94	36	.020		L	178.9	166.7	4.5
																			T	172.4	157.7	4.5
		LAC	C1															.0277 .0261 .0240	L	176	162	3.8
																			T	-	-	-
22093	3971-27	RM		.02	.013	.22	2.53	15.72		123	1390 F	15 Min.	975 F	6 Hrs.	106	36	.020		L	180.0	167.6	4.5
																			T	170.1	154.3	4.0
		LAC	C1	.024	.016	.20	2.66	16.01		H_2 110 O_2 510								.0267 .0250 .0232	L	174	160	4.7
																			T	172	158	3.5
22093	3971-28 (1)	RM		.02	.013	.22	2.53	15.72		127	1390 F	15 Min.	975 F	6 Hrs.	127	36	.020		L	170.3	158.6	4.5
																			T	170.2	160.3	4.0
		LAC	C2															.0280 .0270 .0250	L	175	161	4.0
																			T	-	-	-
22093	3971-29 (1)	RM		.02	.013	.22	2.53	15.72		90	1400 F	20 Min.	990 F	6 Hrs.	79	35	.020		L	174.0	161.0	4.5
																			T	170.0	156.0	4.2
		LAC	C1															.0238 .0230 .0209	L	169	155	5.2
																			T	-	-	-
22093	3971-32 (1)	RM		.02	.013	.22	2.53	15.72		101	1400 F	20 Min.	990 F	6 Hrs.	94	36	.020		L	170.0	157.0	4.7
																			T	172.0	158.0	4.0
		LAC	C1															.0252 .0242 .0216	L	171	155	5.1
																			T	-	-	-
22093	3971-33 (1)	RM		.02	.013	.31	2.35	15.40		93	1400 F	20 Min.	990 F	6 Hrs.	95	35	.020		L	172.0	158.0	4.7
																			T	170.0	157.0	4.0
		LAC	C1															.0241 .0227 .0209	L	169	154	4.5
																			T	-	-	-
24990	05404-2	RM		.02	.013	.22	2.53	15.72		102	1390 F	15 Min.	975 F	6 Hrs.	114	36	.020		L	173.9	161.3	4.5
																			T	173.9	162.2	4.5
		LAC	C4															.0262 .0250 .0229	L	176	164	3.1
																			T	177	164	3.4

TABLE X—CON'T. 0.020 in.

PRODUCER REACTIVE METALS ALLOY 2.5Al-16V CONDITION SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(2) TEMP.	SOLUTION(2) TIME	AGE TEMP.	AGE TIME	LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
24990	0540A-3	RM		.02	.013	.31	2.35	15.40		102	1390 F	15 Min.	975 F	6 Hrs.	102	36	.020		L	173.7	165.4	4.5
																			T	176.3	153.3	4.0
		LAC	C4	.036	.018	.20	2.47	15.89		H_2 74 O_2 870								.0286 .0272 .0257	L	180	166	4.8
																			T	187	170	4.2
24990	0540A-4	RM		.02	.013	.31	2.35	15.40		91	1390 F	15 Min.	975 F	6 Hrs.	114	35	.020		L	174.1	163.0	4.0
																			T	173.1	158.8	4.0
		LAC	C4															.0254 .0227 .0216	L	179	165	3.0
																			T	182	167	4.1
24814	1508-1	RM		.02	.012	.18	2.63	15.30		97	1400 F	15 Min.	975 F	6 Hrs.	76	36	.025		L	181.9	170.9	4.0
																			T	183.9	167.8	4.7
		LAC	C7															.0285 .0278 .0269	L	174	164	3.3
																			T	172	159	3.3
24814	1508-2	RM		.02	.012	.18	2.63	15.30		95	1400 F	15 Min.	975 F	6 Hrs.	86	36	.025		L	176.8	160.1	5.0
																			T	179.9	165.5	5.0
		LAC	C7															.0286 .0280 .0273	L	176	162	4.0
																			T	176	164	4.5
24814	1508-3	RM		.02	.012	.16	2.63	15.30		109	1400 F	15 Min.	975 F	6 Hrs.	78	36	.025		L	186.7	172.3	5.5
																			T	177.3	159.6	5.2
		LAC	C7															.0289 .0278 .0263	L	179	167	3.3
																			T	176	165	3.8

(1) SHEET ASSIGNED TO FATIGUE TESTS.
LAC TENSILE PROPERTIES IN LONGITUDINAL DIRECTION ONLY.

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

(2) WATER QUENCHED.

TABLE XI—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM — 0.063 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(2)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
24806	1099-1	RM		.02	.015	.23	2.71	15.39		73	1410 F	25 Min.	990 F	4 Hrs.	95	36	.063		L	180.6	163.0	7.0
																			T	182.1	166.7	4.5
		LAC	C5															.0709 .0697 .0689	L	172	161	6.0
																			T	181	169	4.0
24806	1099-2	RM		.02	.015	.23	2.71	15.39		75	1410 F	25 Min.	990 F	4 Hrs.	97	36	.063		L	182.4	161.7	6.8
																			T	175.8	162.0	4.3
		LAC	C5															.0695 .0673 .0653	L	169	157	5.0
																			T	173	161	4.8
24806	1100-1	RM		.02	.015	.23	2.71	15.39		111	1410 F	25 Min.	975 F	4 Hrs.	102	36	.063		L	183.5	165.2	6.0
																			T	188.6	171.6	6.0
		LAC	C5	.01	.020	.18	2.57	15.96		H_2 74 O_2 1000								.0712 .0700 .0691	L	197	184	4.5
																			T	197	187	3.5
24806	1100-2	RM		.02	.015	.23	2.71	15.39		130	1410 F	25 Min.	975 F	4 Hrs.	103	36	.063		L	183.3	167.3	6.3
																			T	188.1	171.7	6.3
		LAC	C5															.0710 .0701 .0684	L	194	182	5.0
																			T	206	190	4.0
24806	(1) 1101-1	RM		.02	.015	.23	2.71	15.39		104	1410 F	25 Min.	990 F	4 Hrs.	95	36	.063		L	179.0	161.0	8.0
																			T	189.0	170.0	5.0
		LAC	C2															.0693 .0671 .0630	L	176	161	6.8
																			T	-	-	-
24806	(1) 1101-2	RM		.02	.015	.23	2.71	15.39		92	1410 F	25 Min.	990 F	4 Hrs.	81	36	.063		L	178.0	162.0	8.5
																			T	185.0	169.0	6.2
		LAC	C2															.0670 .0656 .0620	L	176	164	6.7
																			T	-	-	-
24806	(1) 1102-1	RM		.02	.015	.23	2.71	15.39		69	1400 F	20 Min.	990 F	6 Hrs.	70	36	.063		L	170.0	157.0	7.5
																			T	174.0	160.0	4.8
		LAC	C2															.0668 .0640 .0599	L	176	162	5.2
																			T	-	-	-
24806	(1) 1102-2	RM		.02	.015	.23	2.71	15.39		61	1400 F	20 Min.	990 F	6 Hrs.	90	36	.063		L	170.0	155.0	6.5
																			T	173.0	162.0	6.0
		LAC	C2															.0670 .0646 .0600	L	178	165	6.5
																			T	-	-	-

TABLE XI—CON'T.

0.063 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(2)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
24814	1509-1A	RM		.02	.012	.18	2.63	15.30		108	1400 F	25 Min.	975 F	6 Hrs.	27	36	.063		L	178.1	161.7	7.0
																			T	182.3	168.0	6.5
		LAC	C8																			
24814	1509-1	RM		.02	.012	.18	2.63	15.30		108	1400 F	25 Min.	975 F	6 Hrs.	27	36	.063		L	178.1	161.7	7.0
																			T	182.3	168.0	6.5
		LAC	C8																			
24814	1509-2	RM		.02	.012	.18	2.63	15.30		80	1400 F	25 Min.	975 F	6 Hrs.	71	36	.063		L	173.6	158.8	7.0
																			T	176.8	162.6	7.0
		LAC	C8															.0702 .0687 .0663	L	179	166	5.0
																			T	-	-	-
24814	1509-3	RM		.02	.012	.18	2.63	15.30		62	1400 F	25 Min.	975 F	6 Hrs.	77	36	.063		L	172.5	154.8	7.7
																			T	176.5	161.4	6.0
		LAC	C8															.0750 .0738 .0725	L	172	157	5.6
																			T	174	159	6.3
24814	1509-4	RM		.02	.012	.18	2.63	15.30		67	1400 F	25 Min.	975 F	6 Hrs.	75	36	.063		L	172.5	154.8	7.0
																			T	178.0	163.9	5.7
		LAC	C8															.0750 .0737 .0715	L	171	156	7.3
																			T	178	163	5.2
24814	1509-5	RM		.02	.012	.18	2.63	15.30		74	1400 F	25 Min.	975 F	6 Hrs.	70	36	.063		L	180.8	160.0	6.0
																			T	178.7	165.5	5.7
		LAC	C8																			
24814	1509-6	RM		.02	.012	.18	2.63	15.30		72	1400 F	25 Min.	975 F	6 Hrs.	75	36	.063		L	181.8	165.3	6.5
																			T	179.4	166.0	5.2
		LAC	C8	.035	.017	.17	2.67	15.83		H_2 78 O_2 440								.0733 .0718 .0699	L	178	161	6.3
																			T	181	167	5.0

(1) SHEET ASSIGNED TO FATIGUE TESTS.
LAC TENSILE PROPERTIES IN LONGITUDINAL DIRECTION ONLY.

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

(2) WATER QUENCHED.

TABLE XI—CON'T.

0.063 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION (2) TEMP.	SOLUTION (2) TIME	AGE TEMP.	AGE TIME	LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
24806	(1) 1102-3	RM		.02	.015	.23	2.71	15.39		107	1410 F	25 Min	990 F	4 Hrs.	105	36	.063		L	176.3	163.9	8.0
																			T	181.7	171.4	5.5
		LAC	C2															.0712 .0671 .0620	L	169	157	7.2
																			T	-	-	-
24806	(1) 1102-4	RM		.02	.015	.23	2.71	15.39		64	1400 F	20 Min	990 F	6 Hrs.	96	36	.063		L	172.0	157.0	8.0
																			T	177.0	163.0	5.2
		LAC	C2															.0670 .0645 .0605	L	180	166	7.5
																			T	-	-	-
24806	(1) 1102-5	RM		.02	.015	.23	2.71	15.39		102	1410 F	25 Min	990 F	4 Hrs.	104	36	.063		L	174.3	165.4	6.2
																			T	179.7	171.9	7.5
		LAC	C2															.0711 .0682 .0638	L	173	160	7.3
																			T	-	-	-
24806	(1) 1102-6	RM		.02	.015	.23	2.71	15.39		109	1410 F	25 Min	990 F	4 Hrs.	110	36	.063		L	173.1	163.8	7.2
																			T	178.3	171.6	7.7
		LAC	C2															.0710 .0671 .0620	L	172	160	6.8
																			T	-	-	-
24806	(1) 1102-7	RM		.02	.015	.23	2.71	15.39		98	1410 F	25 Min	990 F	4 Hrs.	104	36	.063		L	175.7	164.2	7.0
																			T	180.0	169.6	6.5
		LAC	C2															.0720 .0682 .0640	L	174	161	7.5
																			T	-	-	-
24806	(1) 1102-8	RM		.02	.015	.23	2.71	15.39		63	1400 F	20 Min	990 F	6 Hrs.	96	36	.063		L	173.0	157.0	7.0
																			T	178.0	169.0	5.5
		LAC	C2															.0679 .0654 .0590	L	177	164	7.2
																			T	-	-	-
24806	(1) 1102-9	RM		.02	.015	.23	2.71	15.39		105	1410 F	25 Min	990 F	4 Hrs.	101	36	.063		L	178.3	164.8	8.5
																			T	181.2	169.9	7.0
		LAC	C2															.0730 .0698 .0640	L	175	161	7.4
																			T	-	-	-
24806	(1) 1102-10	RM		.02	.015	.23	2.71	15.39		66	1400 F	20 Min	990 F	6 Hrs.	92	36	.063		L	172.0	157.0	8.0
																			T	176.0	164.0	5.0
		LAC	C2															.0700 .0666 .0620	L	184	166	6.4
																			T	-	-	-

TABLE XI—CON'T. 0.063in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION(2) TEMP.	SOLUTION(2) TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
24806	1104-1	RM		.02	.015	.23	2.71	15.39		99	1410 F	25 Min.	990 F	4 Hrs.	104	36	.063		L	181.9	164.8	7.0
																			T	186.6	173.0	7.3
		LAC	C5															.0716 .0700 .0697	L	177	164	6.0
																			T	182	169	6.5
24806	1104-2	RM		.02	.015	.23	2.71	15.39		105	1410 F	25 Min.	990 F	4 Hrs.	98	36	.063		L	183.8	167.3	6.3
																			T	189.8	171.4	5.0
		LAC	C5															.0717 .0698 .0668	L	166	152	6.3
																			T	-	-	-
22154	0083-1	RM		.02	.014	.27	2.56	15.79		165	1380 F	30 Min.	990 F	4 Hrs.	112	36	.063		L	176.8	162.3	4.7
																			T	176.1	165.0	5.5
		LAC	C2															.0645 .0611 .0530	L	184	164	5.4
																			T	186	170	5.5
22154	0083-3	RM		.02	.014	.27	2.56	15.79		142	1380 F	30 Min.	990 F	4 Hrs.	112	36	.063		L	178.9	159.6	6.2
																			T	178.8	165.2	5.1
		LAC	C2															.0684 .0661 .0630	L	176	157	7.5
																			T	178	163	5.8
22154	0083-4	RM		.02	.014	.27	2.56	15.79		155	1380 F	30 Min.	990 F	4 Hrs.	110	36	.063		L	173.2	160.2	6.6
																			T	175.1	162.9	4.7
		LAC	C2	.034	.021	.22	2.25	16.28		H_2 66 O_2 510								.0716 .0705 .0682	L	174	158	7.8
																			T	172	159	7.0
22154	0083-5	RM		.02	.014	.27	2.56	15.79		148	1380 F	30 Min.	990 F	4 Hrs.	109	36	.063		L	173.3	155.0	7.0
																			T	177.2	164.7	5.5
		LAC	C2															.0700 .0672 .0634	L	170	154	8.0
																			T	174	161	6.1
22154	0083-6	RM		.02	.014	.27	2.56	15.79		125	1380 F	30 Min.	990 F	4 Hrs.	116	36	.063		L	175.4	156.5	6.2
																			T	180.6	166.4	5.8
		LAC	C2															.0684 .0661 .0626	L	173	160	7.0
																			T	180	165	5.8
22154	0083-8	RM		.02	.014	.27	2.56	15.79		148	1380 F	30 Min.	990 F	4 Hrs.	110	36	.063		L	176.9	162.4	7.0
																			T	178.3	163.9	5.5
		LAC	C2															.0708 .0683 .0611	L	176	161	6.3
																			T	179	166	4.7

TABLE XII—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM 0.063 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION(2) TEMP.	SOLUTION(2) TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
T-24806	1503-15	RM		.02	.015	.23	2.71	15.39		126	1400 F	25 Min.	975 F	4 Hrs.	103	36	.063		L(1) T(1)	183.2 184.4	172.2 172.9	5.0 5.5
		LAC											975 F	4 Hrs.				.0736 .0699 .0568	L T	188 201	178 194	4.3 3.2
T-24806	1503-14	RM		.02	.015	.23	2.71	15.39		120	1400 F	25 Min.	975 F	4 Hrs.	94	36	.063		L(1) T(1)	175.4 182.6	167.8 174.2	6.0 5.0
		LAC											975 F	4 Hrs.				.0714 .0686 .0636	L T	190 198	181 189	4.2 2.5
M-23300	3896-7	RM		.02	.012	.21	2.57	15.92		80	1410 F	20 Min.	975 F	4 Hrs.	78	36	.063		L(1) T(1)	176.2 178.1	169.4 169.3	7.0 5.0
		LAC																				
M-23300	3896-6	RM		.02	.012	.21	2.57	15.92		61	1410 F	20 Min.	975 F	4 Hrs.	67	36	.063		L(1) T(1)	177.7 174.8	158.2 163.8	6.5 5.0
		LAC																				
M-22154	00844-6	RM		.02	.014	.27	2.56	15.79		86	1400 F	25 Min.	975 F	4 Hrs.	74	36	.063		L(1) T(1)	175.8 182.1	165.7 173.3	6.5 6.5
		LAC																				
M-22154	00844-5	RM		.02	.014	.27	2.56	15.79		100	1400 F	25 Min.	975 F	4 Hrs.	45	36	.063		L(1) T(1)	178.2 179.6	163.3 173.1	6.0 5.5
		LAC											975 F	4 Hrs.				.0678 .0654 .0626	L T	195 198	182 189	3.2 2.3

(1) PROPERTIES ARE FOR LABORATORY AGED SAMPLES.

(2) WATER QUENCHED.

TABLE XIII— PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM—0.125in

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(2)		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
23345	1149-3	RM		.03	.015	.21	2.75	14.95		66	1410 F	30 Min.	990 F	4 Hrs.	90	36	.125		L	171.6	149.2	9.5
																			T	184.5	166.8	7.8
		LAC	C9	.041	.018	.21	2.31	15.84		H_2 67 O_2 650								.1331 .1319 .1301	L	173	161	7.3
																			T	177	165	7.3
23345	1149-5	RM		.03	.015	.21	2.75	14.95		67	1410 F	30 Min.	990 F	4 Hrs.	102	36	.125		L	181.0	161.9	8.5
																			T	187.6	168.8	6.3
		LAC	C9															.1333 .1311 .1265	L	175	160	7.6
																			T	178	165	6.5
23345	(1) 1149-7	RM		.02	.015	.25	2.75	15.95		68	1410 F	30 Min.	975 F	4 Hrs.	95	36	.125		L	188.0	172.1	6.0
																			T	183.9	171.7	5.5
		LAC	C3															.1441 .1338 .1251	L	194	176	6.7
																			T	-	-	-
23345	(1) 1149-8	RM		.02	.015	.25	2.75	15.95		108	1410 F	30 Min.	975 F	4 Hrs.	96	36	.125		L	171.9	158.6	9.2
																			T	169.9	160.8	8.2
		LAC	C3															.1360 .1324 .1260	L	184	167	7.0
																			T	-	-	-
23345	(1) 1150-2	RM		.02	.015	.25	2.75	15.95		96	1410 F	30 Min.	975 F	4 Hrs.	105	36	.125		L	172.0	150.9	8.5
																			T	174.5	165.1	7.0
		LAC	C3															.1380 .1323 .1240	L	178	161	6.9
																			T	-	-	-
23345	(1) 1150-3	RM		.02	.015	.25	2.75	15.95		111	1410 F	30 Min.	975 F	4 Hrs.	107	36	.125		L	172.1	156.3	8.5
																			T	179.5	168.0	6.5
		LAC	C3															.1341 .1191 .1301	L	191	172	6.5
																			T	-	-	-
23345	(1) 1150-4	RM		.02	.015	.25	2.75	15.95		92	1410 F	30 Min.	975 F	4 Hrs.	110	36	.125		L	175.5	163.1	7.5
																			T	183.3	172.9	7.5
		LAC	C3															.1360 .1301 .1220	L	199	182	4.8
																			T	-	-	-
23345	(1) 1150-5	RM		.02	.015	.25	2.75	15.95		91	1410 F	30 Min.	975 F	4 Hrs.	111	36	.125		L	172.2	158.0	7.5
																			T	176.8	163.8	6.8
		LAC	C3															.1352 .1290 .1199	L	175	161	7.9
																			T	-	-	-

TABLE XIII—CON'T.

0.125in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(2) TEMP.	SOLUTION(2) TIME	AGE TEMP.	AGE TIME	LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
23345	1150-6 (1)	RM		.02	.015	.25	2.75	15.95		121	1410 F	30 Min.	975 F	4 Hrs.	113	36	.125		L	183.1	163.2	9.0
																			T	185.9	173.0	7.0
		LAC	C3															.1360 .1312 .1222	L	197	180	5.1
																			T	-	-	-
23345	1150-7 (1)	RM		.02	.015	.25	2.75	15.95		124	1410 F	30 Min.	975 F	4 Hrs.	102	36	.125		L	176.4	163.3	7.3
																			T	183.3	168.6	7.3
		LAC	C3															.1370 .1311 .1220	L	178	162	7.2
																			T	-	-	-
23345	1150-8 (1)	RM		.02	.015	.25	2.75	15.95		97	1410 F	30 Min.	975 F	4 Hrs.	101	36	.125		L	171.7	150.8	8.8
																			T	179.4	167.9	6.5
		LAC	C3															.1370 .1288 .1170	L	181	164	7.0
																			T	-	-	-
23345	1152A-2	RM		.02	.015	.25	2.75	15.95		66	1410 F	30 Min.	975 F	6 Hrs.	89	36	.125		L	183.9	170.5	7.5
																			T	183.0	170.2	6.0
		LAC	C9															.1429 .1403 .1374	L	180	167	7.0
																			T	-	-	-
23345	1152-5 (1)	RM		.02	.015	.25	2.75	15.95		76	1410 F	30 Min.	975 F	4 Hrs.	98	36	.125		L	174.6	158.7	10.0
																			T	176.7	165.6	8.5
		LAC	C3															.1350 .1298 .1204	L	178	161	7.0
																			T	-	-	-
23345	1152-6 (1)	RM		.02	.015	.25	2.75	15.95		90	1410 F	30 Min.	975 F	4 Hrs.	105	36	.125		L	181.4	166.0	8.5
																			T	180.5	166.9	7.0
		LAC	C3															.1340 .1294 .1204	L	179	159	7.7
																			T	-	-	-
23345	1152-7 (1)	RM		.02	.015	.25	2.75	15.95		98	1410 F	30 Min.	975 F	4 Hrs.	103	36	.125		L	170.8	155.3	10.0
																			T	171.4	158.1	8.3
		LAC	C3															.1370 .1329 .1220	L	168	153	7.8
																			T	-	-	-
23354	0559-2	RM		.02	.014	.25	2.39	15.98		80	1400 F	20 Min.	990 F	4 Hrs.	104	30	.125		L	170.6	169.9	7.0
																			T	170.4	161.4	7.0
		LAC	C3	.025	.018	.23	2.37	16.26		H_2 67 O_2 720								.1332 .1321 .1310	L	174	163	7.8
																			T	178	169	6.5

TABLE XIII—CON'T.

0.125 in.

PRODUCER REACTIVE METALS **ALLOY** 2.5Al-16V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(2)		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
23354	0559-4	RM		.02	.014	.25	2.39	15.98		92	1400 F	20 Min.	990 F	4 Hrs.	106	30	.125		L	171.2	166.2	7.0
																			T	181.6	166.8	5.5
		LAC	C3															.1316 .1268 .1216	L	179	169	6.8
																			T	183	173	5.7
23354	0559-5	RM		.02	.014	.25	2.39	15.98		94	1400 F	20 Min.	990 F	4 Hrs.	106	30	.125		L	177.3	166.1	6.4
																			T	181.3	172.6	7.9
		LAC	C3																			
23372	0073	RM		.02	.018	.21	2.51	15.85		108	1400 F	20 Min.	990 F	4 Hrs.	104	36	.125		L	181.8	166.2	6.6
																			T	177.3	165.7	5.5
		LAC	C6	.024	.022	.21	2.56	15.84		H_2 93 O_2 510								.1358 .1331 .1312	L	176	164	6.1
																			T	178	168	5.7
23372	0073-1	RM		.02	.018	.21	2.51	15.85		112	1400 F	20 Min.	990 F	4 Hrs.	108	36	.125		L	172.9	161.6	7.0
																			T	176.3	165.0	6.2
		LAC	C6															.1336 .1322 .1286	L	175.0	163.0	5.8
																			T	176.0	166.0	6.3
23372	0073-2	RM		.02	.018	.21	2.51	15.85		109	1400 F	20 Min.	990 F	4 Hrs.	107	36	.125		L	178.4	165.9	5.3
																			T	177.8	167.5	5.5
		LAC	C6															.1282 .1257 .1195	L	177	164	6.2
																			T	-	-	-

(1) SHEET ASSIGNED TO FATIGUE TESTS.
LAC TENSILE PROPERTIES IN LONGITUDINAL DIRECTION ONLY.

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

(2) WATER QUENCHED.

TABLE XIV—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.020 in.

PRODUCER CRUCIBLE				ALLOY 4Al-3Mo-1V											CONDITION SOLUTION TREATED AND AGED							
HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(2)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME(2)	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R4815	T4	CSC		.03	.022	.39	4.2	1.2	3.0	85	1655 F	15 - 30 Min.	925 F	12 Hrs.	93	35	.025		L	-	-	-
																			T	215.7	185.6	4.0
		LAC	D1															.0273 .0250 .0241	L	200	180	4.0
																			T	207	185	4.1
R4815	T1	CSC		.03	.022	.39	4.2	1.2	3.0	68	1655 F	15 - 30 Min.	925 F	12 Hrs.	92	36	.025		L	-	-	-
																			T	208.3	183.6	6.5
		LAC	D1															.0272 .0254 .0236	L	203	182	4.8
																			T	207	183	4.5
R4815	X3	CSC		.02	.024	.31	4.2	1.1	2.9	120	1655 F	15 - 30 Min.	925 F	12 Hrs.	88	36	.025		L	-	-	-
																			T	210.4	184.4	5.0
		LAC	D1															.0269 .0260 .0248	L	200	177	4.5
																			T	201	178	5.0
R4815	X2	CSC		.02	.024	.31	4.2	1.1	2.9	93	1655 F	15 - 30 Min.	925 F	12 Hrs.	91	36	.025		L	-	-	-
																			T	205.9	177.3	5.0
		LAC	(1) D1															.0270 .0254 .0230	L	198	172	5.7
																			T	-	-	-
R4815	X1	CSC		.02	.024	.31	4.2	1.1	2.9	67	1655 F	15 - 30 Min.	925 F	12 Hrs.	94	36	.025		L	-	-	-
																			T	216.5	189.7	3.0
		LAC	(1) D1															.0246 .0231 .0200	L	199	177	3.8
																			T	-	-	-
R4815	T2	CSC		.03	.022	.39	4.2	1.2	3.0	62	1655 F	15 - 30 Min.	925 F	12 Hrs.	84	36	.025		L	-	-	-
																			T	204.0	176.8	5.5
		LAC	(1) D1															.0247 .0230 .0207	L	207	181	3.0
																			T	-	-	-
R4815	T3	CSC		.03	.022	.39	4.2	1.2	3.0	87	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	206.3	178.7	-
																			T	200.0	175.7	5.0
		LAC	(1) D1															.0255 .0233 .0205	L	201	173	4.8
																			T	-	-	-
R4815	A4	CSC		.01	.025	.23	4.4	1.2	3.4	70	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	213.9	184.8	-
																			T	200.0	173.5	5.5
		LAC	(1) D1															.0262 .0243 .0227	L	203	177	5.0
																			T	-	-	-

TABLE XIV—CON'T.

0.020in.

PRODUCER CRUCIBLE **ALLOY** 4Al-3Mo-1V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(2)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R4815	X4	CSC		.02	.024	.31	4.2	1.1	2.9	57	1655 F	15 - 30 Min.	925 F	12 Hrs.	91	36	.025		L	-	-	-
																			T	204.2	182.1	4.0
		LAC	(1) D1															.0261 .0252 .0244	L	199	171	5.3
																			T	-	-	-
R4765	X11	CSC		.03	.014	.30	4.4	1.1	3.2	147	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	193.5	170.7	-
																			T	196.8	171.0	5.0
		LAC	D4															.0258 .0245 .0217	L	200	172	4.1
																			T	202	179	4.8
R4765	X10	CSC		.03	.014	.30	4.4	1.1	3.2	122	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	200.0	171.1	3.5
																			T	203.4	183.1	3.5
		LAC	D4															.0229 .0216 .0211	L	194	171	5.0
																			T	197	178	3.5
R4765	A9	CSC		.03	.021	.20	4.1	1.2	3.3	133	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	201.8	178.2	-
																			T	191.4	166.9	5.0
		LAC	D4															.0230 .0218 .0204	L	198	176	4.4
																			T	202	178	3.5
R4805	A5	CSC		.03	.026	.25	4.3	1.2	3.4	113	1655 F	15 - 30 Min.	925 F	12 Hrs.	95	36	.025		L	-	-	-
																			T	225.9	196.9	4.5
		LAC	D7															.0199 .0189 .0180	L	207	182	3.5
																			T	204	184	5.0
R4805	A6	CSC		.03	.026	.25	4.3	1.2	3.4	116	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	204.3	176.3	5.0
																			T	201.7	176.6	5.0
		LAC	D7															.0246 .0231 .0212	L	195	172	5.2
																			T	198	176	4.4
R4805	X5	CSC		.03	.024	.31	4.3	1.3	3.4	105	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	208.6	177.2	4.5
																			T	205.4	174.7	4.5
		LAC	D7	.016	.024	.18	4.05	.99	2.88	H_2 145 O_2 510								.0227 .0217 .0201	L	205	180	4.1
																			T	202	179	3.8
R4810	A7	CSC		.03	.022	.25	4.4	1.2	3.4	151	1655 F	15 - 30 Min.	925 F	12 Hrs	90	36	.025		L	213.8	184.2	-
																			T	209.7	176.5	4.0
		LAC	(1) D1	.038	.022	.24	4.2	.95	2.97	H_2 150 O_2 800								.0256 .0230 .0210	L	199	171	5.2
																			T	-	-	-

TABLE XIV—CON'T.

0.020in.

PRODUCER CRUCIBLE **ALLOY** 4Al-3Mo-1V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(2)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R4810	X11	CSC		.03	.021	.49	4.1	1.4	3.3	147	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	205.4	175.7	5.5
																			T	203.5	173.0	6.0
		LAC	(1) D1															.0240 .0231 .0221	L	208	178	3.2
																			T	-	-	-
R4810	X10	CSC		.03	.021	.49	4.1	1.4	3.3	80	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	207.4	178.2	4.5
																			T	206.2	173.3	3.5
		LAC	(1) D1															.0250 .0235 .0210	L	201	174	5.0
																			T	-	-	-
R4810	X9	CSC		.03	.021	.49	4.1	1.4	3.3	104	1655 F	15 - 30 Min.	925 F	12Hrs.	90	36	.025		L	209.5	186.1	2.0
																			T	217.1	193.2	-
		LAC	(1) D1															.0248 .0228 .0213	L	197	169	4.8
																			T	-	-	-
R4810	X8	CSC		.03	.021	.49	4.1	1.4	3.3	85	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	188.9	169.4	-
																			T	197.4	172.9	6.0
		LAC	(1) D1															.0240 .0234 .0220	L	190	166	3.8
																			T	-	-	-
R4810	X4	CSC		.03	.021	.49	4.1	1.4	3.3	93	1655 F	15 - 30 Min.	925 F	12 Hrs.	88	36	.025		L	-	-	-
																			T	216.0	186.1	5.5
		LAC	(1) D1															.0251 .0236 .0227	L	198	170	5.3
																			T	-	-	-
R4764	T8	CSC		.01	.033	.26	4.2	1.2	3.3	88	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.025		L	207.3	177.8	5.0
																			T	196.8	171.0	4.5
		LAC	D13																			
R4764	T7	CSC		.01	.033	.26	4.2	1.2	3.3	130	1655 F	15 - 30 Min.	925 F	12 Hrs.	92	36	.025		L	-	-	-
																			T	214.7	187.1	3.0
		LAC	D13																			

(1) SHEET ASSIGNED TO FATIGUE TESTS. LAC TENSILE PROPERTIES IN LONGITUDINAL DIRECTION ONLY.

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

(2) OIL QUENCHED.

TABLE XV—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM 0.063in.

PRODUCER CRUCIBLE **ALLOY** Ti-4Al-3Mo-1V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(2)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN.,%
P7653	TA14	CSC		.02	.01	.09	4.5	.96	2.9	62	1650F	15 Min.	925F	12 Hrs.	96	34	.063		L	197.9	167.2	5.0
																			T	192.5	166.8	5.0
		LAC	D2															.0601 .0585 .0547	L	196	164	6.0
																			T	196	172	6.2
P7653	TT16	CSC		.02	.01	.09	4.5	.96	2.9	51	1650F	15 Min.	925F	12 Hrs.	96	34	.063		L	189.3	158.1	5.0
																			T	182.5	160.2	6.0
		LAC	D2															.0579 .0563 .0540	L	193	159	6.2
																			T	189	166	7.5
P7653	TA11	CSC		.02	.01	.09	4.5	.96	2.9	45	1650F	15 Min.	925F	12 Hrs.	96	34	.063		L	193.7	160.3	6.0
																			T	193.0	166.6	5.5
		LAC	D2	.011	.020	.13	4.06	1.04	2.88	H_2 60 O_2 510								.0600 .0582 .0559	L	189	156	5.8
																			T	189	168	7.2
P7653	TT17	CSC		.02	.01	.09	4.5	.96	2.9	49	1650F	15 Min.	925F	12 Hrs.	98	34	.063		L	186.6	153.9	4.5
																			T	182.6	154.9	6.5
		LAC	(1) D2															.0602 .0586 .0564	L	196	161	6.5
																			T	-	-	-
P7653	TT-18	CSC		.02	.01	.09	4.5	.96	2.9	48	1650F	15 Min.	925F	12 Hrs.	98	34	.063		L	182.7	152.6	5.5
																			T	182.3	158.8	6.0
		LAC	(1) D2															.0609 .0588 .0582	L	195	161	6.0
																			T	-	-	-
P7653	TA-10	CSC		.02	.01	.09	4.5	.96	2.9	65	1650F	15 Min.	925F	12 Hrs.	95	36	.063		L	192.6	162.7	7.0
																			T	182.1	155.4	6.5
		LAC	(1) D2															.0630 .0613 .0592	L	197	164	6.8
																			T	-	-	-
P7653	TB8	CSC		.02	.01	.09	4.5	.96	2.9	61	1650F	15 Min.	925F	12 Hrs.	93	34	.063		L	187.9	154.6	6.7
																			T	186.0	160.6	7.5
		LAC	(1) D2															.0616 .0600 .0584	L	194	158	6.2
																			T	-	-	-
P7653	TB5	CSC		.02	.01	.09	4.5	.96	2.9	50	1650F	15 Min.	925F	12 Hrs.	92	34	.063		L	195.2	162.9	6.0
																			T	186.7	159.9	7.2
		LAC	(1) D2															.0630 .0611 .0590	L	194	159	6.8
																			T	-	-	-

TABLE XV—CON'T. 0.063in.

PRODUCER CRUCIBLE ALLOY Ti-4Al-3Mo-1V CONDITION SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(2)		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
P7653	TX1	CSC		.02	.01	.09	4.5	.96	2.9	55	1650F	15 Min.	925F	12 Hrs.	92	34	.063		L	193.7	158.9	6.7
																			T	187.6	160.6	7.0
		LAC	(1) D2															.0608 .0597 .0576	L	192	157	6.8
																			T	-	-	-
P7653	TB7	CSC		.02	.01	.09	4.5	.96	2.9	47	1650F	15 Min.	925F	12 Hrs.	95	34	.063		L	192.2	158.4	7.0
																			T	185.3	158.1	7.2
		LAC	(1) D2															.0612 .0599 .0582	L	192	152	6.5
																			T	-	-	-
P7653	TA12	CSC		.02	.01	.09	4.5	.96	2.9	46	1650F	15 Min.	925F	12 Hrs.	96	34	.063		L	194.4	160.3	6.5
																			T	188.4	162.7	6.0
		LAC	(1) D2															.0635 .0612 .0577	L	192	156	7.2
																			T	-	-	-
P7653	TA-9	CSC		.02	.01	.09	4.5	.96	2.9	59	1650F	15 Min.	925F	12 Hrs.	93	34½	.063		L	188.6	156.1	6.5
																			T	184.7	156.5	7.0
		LAC	(1) D2															.0642 .0625 .0590	L	193	155	7.8
																			T	-	-	-
P7653	TT-20	CSC		.02	.01	.09	4.5	.96	2.9	84	1650F	15 Min.	925F	12 Hrs.	93	34½	.063		L	189.5	157.0	5.0
																			T	184.8	158.2	6.5
		LAC	(1) D2															.0639 .0619 .0598	L	190	155	7.3
																			T	-	-	-
P7653	TT-19	CSC		.02	.01	.09	4.5	.96	2.9	77	1650F	15 Min.	925F	12 Hrs.	91	35 3/4	.062		L	188.7	152.1	6.5
																			T	176.2	150.4	8.0
		LAC	(1) D2															.0635 .0608 .0588	L	192	158	7.0
																			T	-	-	-
R4765	T2	CSC		.04	.018	.27	4.2	1.2	3.3	123	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.063		L	205.8	175.0	7.0
																			T	202.7	175.6	5.5
		LAC	D5	.038	.018	.18	4.12	.97	2.93	H_2 96 O_2 1000								.0648 .0634 .0600	L	199	171	6.0
																			T	204	181	6.6
R4765	T4	CSC		.04	.018	.27	4.2	1.2	3.3	157	1655 F	15 - 30 Min.	925 F	12 Hrs.	93	36	.063		L	-	-	-
																			T	213.3	188.0	6.0
		LAC	D5															.0682 .0651 .0608	L	209	181	6.0
																			T	-	-	-

TABLE XV—CON'T.

0.063 in.

PRODUCER CRUCIBLE **ALLOY** Ti-4Al-3Mo-1V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION(2) TEMP.	SOLUTION(2) TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R4765	X1	CSC		.03	.014	.30	4.4	1.1	3.2	76	1655 F	15 - 30 Min.	925 F	12 Hrs.	88	36	.063		L	-	-	-
																			T	207.2	177.6	5.5
		LAC	D5															.0676 .0645 .0610	L	195	169	6.1
																			T	203	175	6.1
R4815	T10	CSC		.03	.022	.39	4.2	1.2	3.0	93	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.063		L	204.4	175.0	7.0
																			T	203.5	179.6	7.0
		LAC	D8															.0707 .0668 .0603	L	204	177	6.0
																			T	205	180	5.8
R4815	X8	CSC		.02	.024	.31	4.2	1.1	2.9	97	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.063		L	198.7	171.5	6.5
																			T	193.7	170.2	7.5
		LAC	D8															.0690 .0670 .0660	L	205	178	6.9
																			T	205	181	6.6
R4815	T9	CSC		.03	.022	.39	4.2	1.2	3.0	90	1655 F	15 - 30 Min.	925 F	12 Hrs.	90	36	.063		L	206.8	178.8	6.5
																			T	202.2	179.0	7.5
		LAC	D8	.030	.019	.19	4.08	.99	3.03	H_2 120 O_2 580								.0673 .0653 .0615	L	205	180	6.1
																			T	205	184	6.2

(1) SHEET ASSIGNED TO FATIGUE TESTS.
LAC TENSILE PROPERTIES IN LONGITUDINAL DIRECTION ONLY.

LAC THICKNESS MEASUREMENTS ARE FOR
MAX., MIN. AND AVERAGE.

(2) OIL QUENCHED.

TABLE XVI—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.063 in.

PRODUCER CRUCIBLE **ALLOY** 4Al-3Mo-1V **CONDITION** SOLUTION TREATED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION(2) TEMP.	TIME	AGE TEMP.	TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
P7653	TA13	CSC		.02	.01	.09	4.5	.96	2.9	45	1650F	15 Min. O.Q.			98	35	.063		L(1)	184.9	154.3	4.0
																			T(1)	-	-	-
		LAC	D2										925F	12 Hrs.				.0651 .0632 .0610	L	186	151	7.2
																			T	181	166	1.8
P7653	TB3	CSC		.02	.01	.09	4.5	.96	2.9	68	1650F	15 Min. O.Q.			94	35	.063		L(1)	172.9	146.9	7.5
																			T(1)	-	-	-
		LAC	D2																			
P7653	TT15	CSC		.02	.01	.09	4.5	.96	2.9	42	1650F	15 Min. O.Q.			99	35	.063		L(1)	186.1	160.6	5.5
																			T(1)	-	-	-
		LAC	D2										925F	12 Hrs.				.0603 .0594 .0586	L	188	152	5.8
																			T	186	163	2.5
P7647	TX2	CSC		.02	.02	.09	4.5	1.0	2.9	39	1650F	25 Min. O.Q.			94	35	.063		L	178.2	155.2	5.5
																			T	-	-	-
		LAC	D11																			
P7647	TX1	CSC		.02	.02	.09	4.5	1.0	2.9	45	1650F	25 Min. O.Q.			93	35	.063		L(1)	182.2	157.0	8.0
																			T(1)	-	-	-
		LAC	D11										925F	12 Hrs.				.0615 .0591 .0565	L	185	150	5.5
																			T	186	160	6.0
P7647	TX3	CSC		.02	.02	.09	4.5	1.0	2.9	50	1650F	25 Min. O.Q.			98	35	.063		L(1)	181.0	155.3	5.0
																			T(1)	-	-	-
		LAC	D11																			

(1) PROPERTIES ARE FOR LABORATORY AGED SAMPLES.

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

(2) OIL QUENCHED.

TABLE XVII—PROPERTIES OF TITANIUM ALLOY SHEET FOR DOD DESIGN DATA PROGRAM

0.125in.

PRODUCER CRUCIBLE **ALLOY** 4Al-3Mo-1V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, % C	N_2	Fe	Al	V	Mo	H_2 PPM	HEAT TREATMENT SOLUTION(3) TEMP.	SOLUTION(3) TIME	AGE TEMP.	AGE TIME	SHEET DIMENSIONS, IN. LENGTH	WIDTH	THICKNESS NOMINAL	THICKNESS ACTUAL	TENSILE PROPERTIES GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
R6736	B32	CSC		.03	.011	.10	4.4	1.0	3.0	57	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	185.3	158.1	5.0
																			T	191.1	175.5	7.0
		LAC	D3															.1279 .1266 .1257	L	189	153	6.1
																			T	195	172	8.5
R6736	C12	CSC		.03	.011	.10	4.4	1.0	3.0	95	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	189.2	158.5	5.0
																			T	193.4	172.8	7.0
		LAC	D3	.022	.015	.11	4.04	.92	2.91	H_2 79 O_2 870								.1293 .1265 .1243	L	190	153	5.2
																			T	196	174	6.6
R6736	D1	CSC		.02	.008	.11	4.5	1.1	3.2	89	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	183.6	156.1	5.0
																			T	181.1	168.9	5.0
		LAC	(1) D3															.1265 .1235 .1208	L	184	151	6.0
																			T	-	-	-
R6736	B30	CSC		.03	.011	.10	4.4	1.0	3.0	114	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	187.5	156.2	5.5
																			T	185.0	165.8	6.5
		LAC	(1) D3															.1270 .1261 .1240	L	192	160	6.3
																			T	-	-	-
R6736	C10	CSC		.03	.011	.10	4.4	1.0	3.0	90	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	185.1	155.1	5.5
																			T	186.0	168.8	7.0
		LAC	(1) D3															.1285 .1264 .1227	L	186	155	6.0
																			T	-	-	-
R6736	D5	CSC		.02	.008	.11	4.5	1.1	3.2	104	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	186.0	154.0	5.0
																			T	187.4	171.4	2.0
		LAC	(1) D3															.1290 .1273 .1241	L	185	151	6.5
																			T	-	-	-
R6741	A30	CSC		.03	.016	.15	4.4	1.3	3.0	98	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	193.5	163.3	5.5
																			T	192.4	172.7	6.5
		LAC	D6															.1325 .1307 .1293	L	190	159	6.4
																			T	197	177	8.3
R6741	A27	CSC		.03	.016	.15	4.4	1.3	3.0	94	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	193.8	182.8	5.5
																			T	190.2	170.2	7.0
		LAC	D6	.032	.016	.09	4.05	.92	3.0	H_2 67 O_2 1100								.1318 .1282 .1256	L	188	155	6.8
																			T	198	173	7.1

TABLE XVII—CON'T.

0.125in.

PRODUCER CRUCIBLE ALLOY 4Al-3Mo-1V CONDITION SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
				C	N_2	Fe	Al	V	Mo	H_2 PPM	SOLUTION(3)		AGE		LENGTH	WIDTH	THICKNESS		GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
											TEMP.	TIME	TEMP.	TIME			NOMINAL	ACTUAL				
R6741	A25	CSC		.03	.016	.15	4.4	1.3	3.0	60	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	189.4	161.2	5.0
																			T	192.6	167.2	8.5
		LAC	(1) D3															.1287 .1266 .1229	L	192	167	6.8
																			T	-	-	-
R6741	C7	CSC		.01	.010	.08	4.4	1.0	3.2	114	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	194.3	160.9	5.0
																			T	196.4	174.4	4.0
		LAC	(1) D3															.1220 .1189 .1145	L	189	158	5.2
																			T	-	-	-
R6741	D5	CSC		.02	.011	.11	4.4	1.0	3.0	113	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	194.8	162.3	5.0
																			T	205.1	179.3	6.0
		LAC	(1) D3															.1220 .1197 .1159	L	188	157	5.5
																			T	-	-	-
R6741	C8	CSC		.01	.010	.08	4.4	1.0	3.2	103	1655 F	15 - 30 Min.	925 F	12 Hrs.	96	36	.125		L	188.8	158.4	5.0
																			T	190.6	170.8	2.5
		LAC	(1) D3															.1233 .1207 .1140	L	183	152	5.5
																			T	-	-	-
P7647	BA11	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	190.8	156.0	5.5
																			T	187.9	164.5	8.5
		LAC	D9															.1268 .1249 .1224	L	187	150	5.5
																			T	190	164	8.4
P7647	BB5	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	187.0	158.7	5.5
																			T	189.7	166.4	7.0
		LAC	D9	.016	.017	.09	4.30	.99	3.03	H_2 62 O_2 1200								.1255 .1234 .1203	L	190	151	5.4
																			T	191	167	7.2
P7647	BX7	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	192.8	158.2	6.0
																			T	193.0	172.6	6.0
		LAC	D9																			
P7647	BA9	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	189.6	155.6	5.0
																			T	187.9	163.4	9.0
		LAC	(1) D3															.1276 .1257 .1239	L	191	155	6.5
																			T	-	-	-

TABLE XVII—CON'T. 0.125in.

PRODUCER CRUCIBLE **ALLOY** 4Al-3Mo-1V **CONDITION** SOLUTION TREATED AND AGED

HEAT NO.	SHEET NO.	DATA BY	CODE	CHEMICAL COMPOSITION, %							HEAT TREATMENT				SHEET DIMENSIONS, IN.				TENSILE PROPERTIES			
											SOLUTION(3)		AGE				THICKNESS					
				C	N_2	Fe	Al	V	Mo	H_2 PPM	TEMP.	TIME	TEMP.	TIME	LENGTH	WIDTH	NOMINAL	ACTUAL	GRAIN DIR.	ULTIMATE KSI	YIELD KSI	ELONG. 2 IN., %
P7647	BA10	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	192.1	177.3	4.0
																			T	193.7	169.7	6.0
		LAC	(1) D3															.1290 .1271 .1241	L	191	156	6.2
																			T	-	-	-
P7647	BB6	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	187.9	155.2	5.0
																			T	191.9	169.1	7.0
		LAC	(1) D3															.1254 .1242 .1235	L	191	156	6.7
																			T	-	-	-
P7647	BB13	CSC		.02	.02	.09	4.5	1.0	2.9	(2) 64	1650F	25 Min.	925F	12 Hrs.	96	36	.125		L	193.0	170.7	5.5
																			T	193.9	172.1	6.0
		LAC	(1) D3															.1250 .1227 .1196	L	193	157	6.5
																			T	-	-	-

(1) SHEET ASSIGNED TO FATIGUE TESTS. LAC TENSILE PROPERTIES IN LONGITUDINAL DIRECTION ONLY.

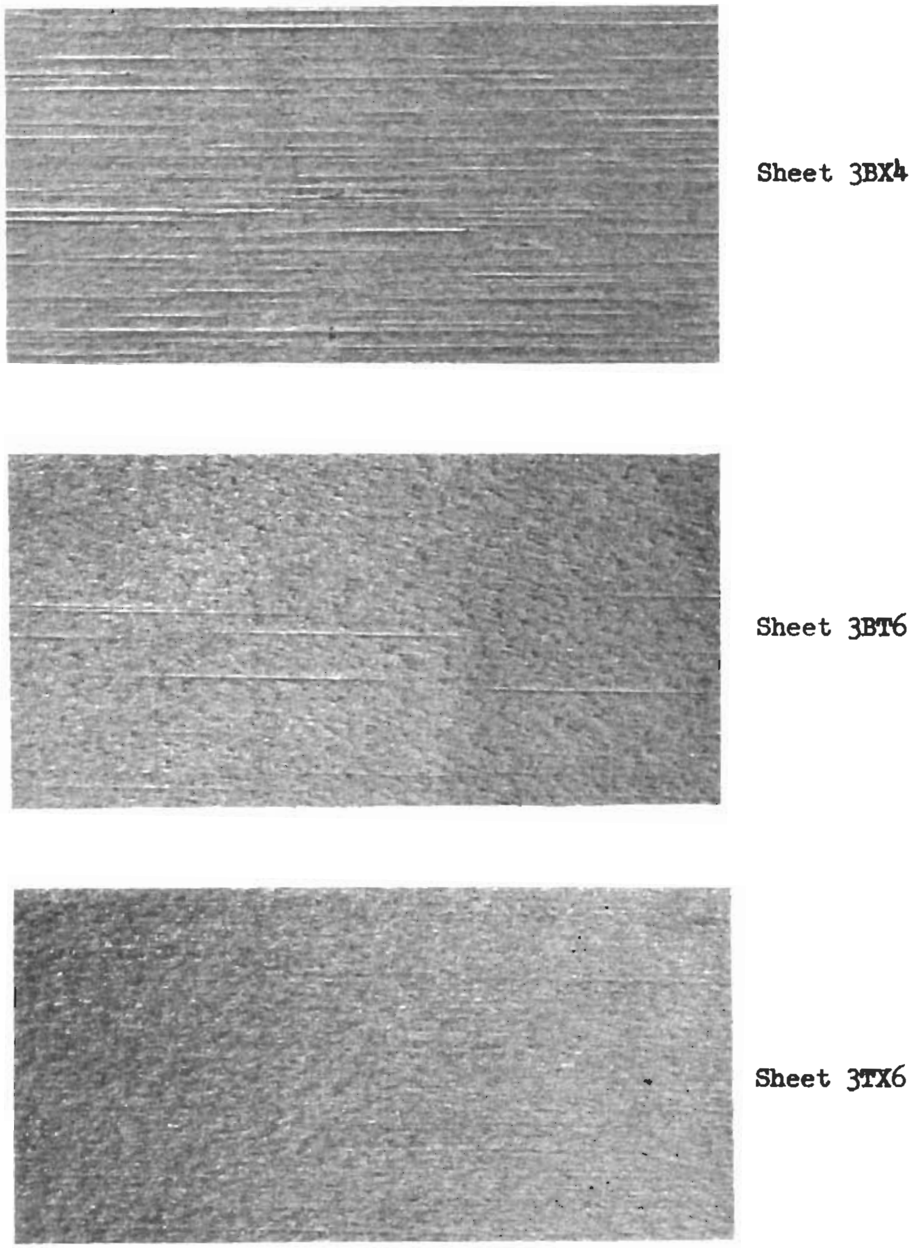
(2) PRODUCER GUARANTEED THAT NO SHEETS OF THIS HEAT EXCEEDED THIS H_2 CONTENT

LAC THICKNESS MEASUREMENTS ARE FOR MAX., MIN. AND AVERAGE.

(3) OIL QUENCHED.

TABLE XVIII PROCESSING HISTORY OF HEATS 25671 AND 27039 OF REACTIVE METALS STA Ti-6Al-4V (PRODUCER DATA)

PROCESS	HEAT 25671	HEAT 27039
1. Melt Ingot in Vacuo	x	x
2. Condition (Grind)	x	x
3. Forge to Slab (1850°F)	x	x
4. Condition Slab (Grind)	x	x
5. Roll Slab to Plate - 1850°F	x	x
6. Condition	Sand Blast and Pickle .002	Wheelabrate - Pickle .002
7. Roll Plate to Intermediate Size (1625°F)	x	x
8. Condition	Descale NaH and Pickle	-
9. Finish Roll (1625°F)	x	x
10. Shear	x	x
11. Condition	Descale NaH and Pickle	Wheelabrate and Pickle
12. Vac Anneal	x	x
13. Belt Grind	x	x
14. Pickle	x	x
15. Solution Treat	1700°F-20 min.W.Q.	1675°F-20 min.W.Q.
16. Sand Blast	x	x
17. Pickle	x	x
18. Test	x	x
19. Inspect	x	x



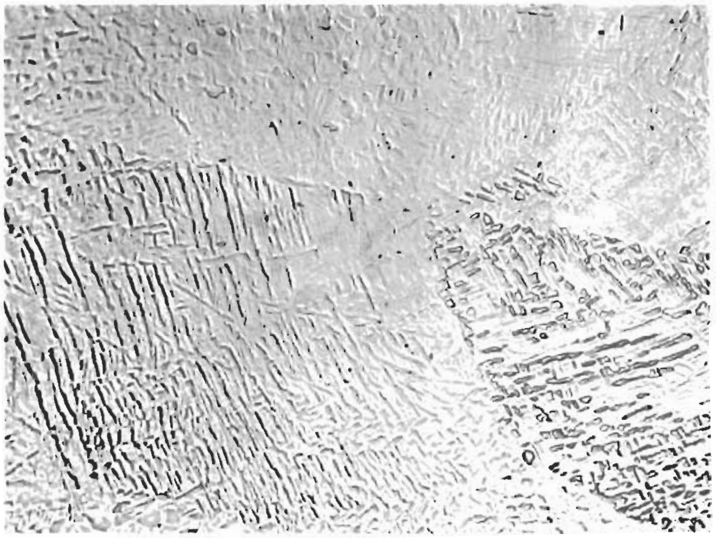
Sheet 3BX4

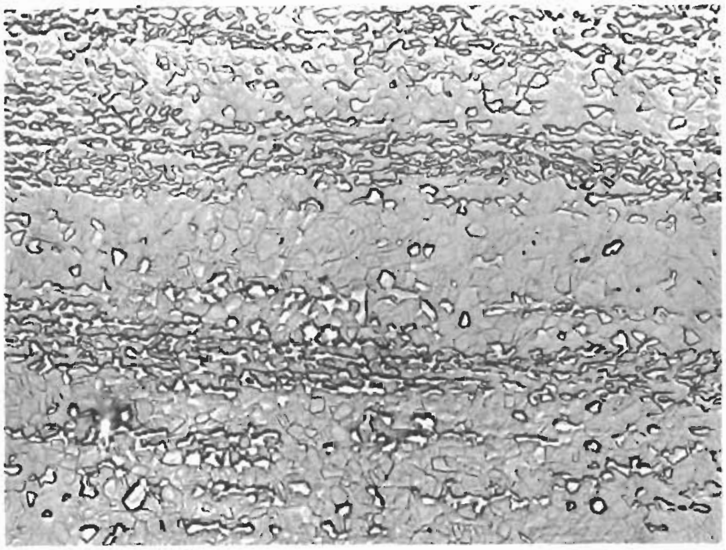
Sheet 3BT6

Sheet 3TX6

FIGURE 1- SURFACE CONDITION OF THREE SHEETS OF 0.063 INCH THICK B120VCA, HEAT NO. R6392 (Mag. 7x)

(a) HEAT NO. 25671, SHEET 8301-10 - SOLUTION TREATED AT 1700°F FOR 3 MINUTES, WATER QUENCHED, AND AGED AT 950°F FOR 4 HOURS

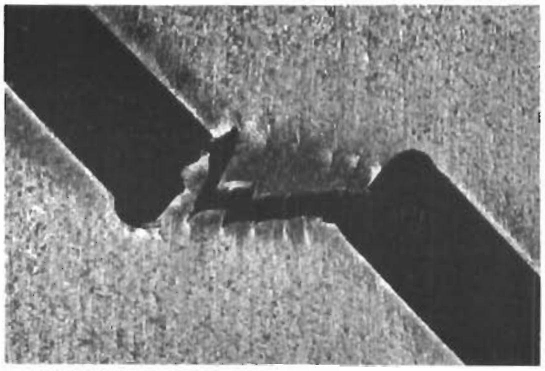




(b) HEAT NO. 27039, SHEET 0744-6 - SOLUTION TREATED AT 1675°F FOR 20 MINUTES, WATER QUENCHED, AND AGED AT 935°F FOR 4 HOURS

FIGURE 2 - MICROSTRUCTURE FROM TWO HEATS OF Ti-6Al-4V SUPPLIED FOR DESIGN DATA DETERMINATION (Mag 500x, $3HF-30HNO_3$ ETCH)

NORMAL SHEAR FAILURES
MAGNIFICATION 4x



TYPICAL SHEAR FAILURES FOR Ti-6Al-4V
FROM REACTIVE METALS HEAT NO. 27039

FIGURE 3 - NORMAL AND SERRATED SHEAR FAILURES FOR Ti-6Al-4V

Specimen Selection and Preparation

Two requirements for the design data program concerning specimen selection were specified. First, the material was to come from three separate heats of each thickness of each alloy; and secondly, tension, compression, bearing and shear specimens were to be taken in groups as close together as practicable. It was necessary, however, to expand the former during the course of the program and sample additional heats since sufficient sheets of material fulfilling the requirement were unavailable from DOD stock. Layout diagrams using a system of basic patterns for room-temperature specimens with dispersal of the basics throughout each sheet were designed to meet the latter requirement. A series of typical layout diagrams is shown in Figures 4 through 7 for the static and creep specimens of Phases I and II. These diagrams are described as typical since most sheets of material deviated from them to some extent because of retests and replacement of rejected specimens. All areas of the sheets were identified, however, and individual specimen location is a matter of record.

Layout diagrams are given in Figures 8 and 9 for crippling and in Figures 10 through 15 for the physical and joint specimens of Phase IV. Since fatigue specimens were of constant size and from the longitudinal grain direction only, they were marked off on the material in five columns of 12 specimens each. The resulting 60 specimens utilized an entire 36 x 96 inch sheet.

A full size stencil of each layout diagram was used to transfer specimen locations directly on the material. A marked sheet is shown in Figure 16. The coding system, shown in Table XIX, was devised for specimen identification. The appropriate code numbers indicating variables and defining location were written on each specimen blank with an electric etching pencil in a position well removed from the test section.

For each type of static mechanical property test of Phase I, ten specimens were required at room temperature and three at each of six elevated temperatures for each alloy, heat and thickness combination. One longitudinal and one transverse room-temperature specimen was taken from each of the dispersed basics. The eighteen elevated-temperature specimens were given sequential numbers determined by convenience of blank location but consistent for all sheets of a thickness. A particular specimen was then assigned a test temperature and any other necessary variable, such as e/D ratio in the case of bearing, by a system of random selection. Crippling, fatigue and creep specimens were also randomly selected for the particular variables involved in each case.

Specimen blanks were sheared from the sheets, and submitted for machining. With the aid of information of the type contained in Reference 4, machining practices for specimen fabrication were established. Specimens were rough machined to final dimensions plus approximately two thicknesses and then finished in several cuts to aid in elimination of cracks and severely worked material. No grinding was permitted. All finished specimens were carefully deburred, cleaned with methyl ethyl ketone and optically inspected under a microscope for edge cracks or other discontinuities that would make them unacceptable for testing.

TABLE XIX SPECIMEN IDENTIFICATION SYSTEM

ALLOY, THICKNESS AND HEAT NUMBER, FIRST AND SECOND SYMBOLS

ALLOY	NOMINAL THICKNESS INCH	HEAT NUMBER	FIRST TWO SYMBOLS	
			PHASES I, II AND IV	PHASE III
B120VCA	0.020	R6392	A1	
		R6761	A4	
		R6788	A7	
	0.063	R6392	A2	
		R6761	A5	
		R6788	A8	
		R6794	A11	
		R6799	A14	
		R6800	A17	
	0.125	R6759	A3	
		R6761	A6	
		R6753	A9	
		R6392	A12	
Ti-6Al-4V	0.020	24791	B1	
	0.063	27039	B2	
		25671	B5	
		31372	B8	B2
		32163		B2
	0.125	22207	B3	
		23407	B3	
		32163	B6	
		32167	B9	B3
		31372	B12	
Ti-2.5Al-16V	0.020	22093	C1	C1
		24990	C4	
		24814	C7	
	0.063	22154	C2	
		24806	C5	C2
		24814	C8	C2
		23300	C11	
	0.125	23354	C3	
		23372	C6	C3
		23345	C9	C3
Ti-4Al-3Mo-1V	0.020	R4815	D1	D1
		R4810		D1
		R4765	D4	
		R4805	D7	D1
		R4764	D13	
	0.063	P7653	D2	D2
		R4765	D5	D2
		R4815	D8	
		P7647	D11	
	0.125	R6736	D3	D3
		R6741	D6	D3
		P7647	D9	D3

GRAIN DIRECTION, THIRD SYMBOL

Longitudinal	L
Transverse	T

TYPE TEST, FOURTH SYMBOL

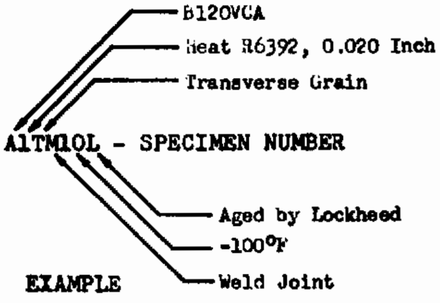
Tension	A
Compression	B
Crippling	C
Bearing	D
Shear	E
Tensile Creep	G
Compressive Creep	H
Bearing Creep	J
Shear Stress-Rupture	K
Fastener Joint	L
Weld Joint	M

TEST TEMPERATURE, FIFTH SYMBOL

80°F	1
200°F	2
400°F	3
600°F	4
700°F	5
800°F	6
900°F	7
1000°F	8
-65°F	9
-100°F	10
-200°F	11
-320°F	12

SPECIAL CONDITIONS, SIXTH SYMBOL

600°F Stress-Exposed	A
600°F Exposed	B
900°F Exposed	C
900°F Stress-Exposed	D
Crippling Configuration No. 1	E
Crippling Configuration No. 2	F
NAS675V-2 Screw	G
NAS2010V-2 Lockbolt	H
NAS663V-2 Screw	J
NAS2106V-2 Lockbolt	K
Aged by Lockheed	L
Single Shear	M
Double Shear	N
Poisson's Ratio	P
A=0 Fatigue, Stress-Rupture, $K_t=1.0$	R
A=0 Fatigue, Stress-Rupture, $K_t=2.82$	S



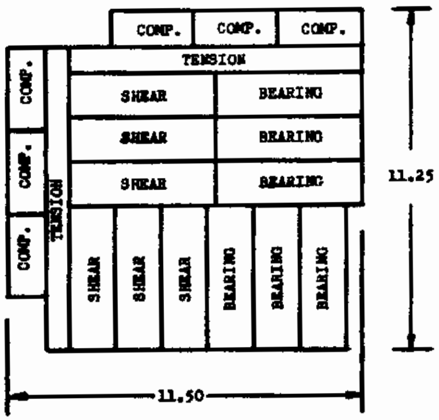


FIGURE 4—TYPICAL LAYOUT DIAGRAM FOR BASIC SAMPLE UNIT

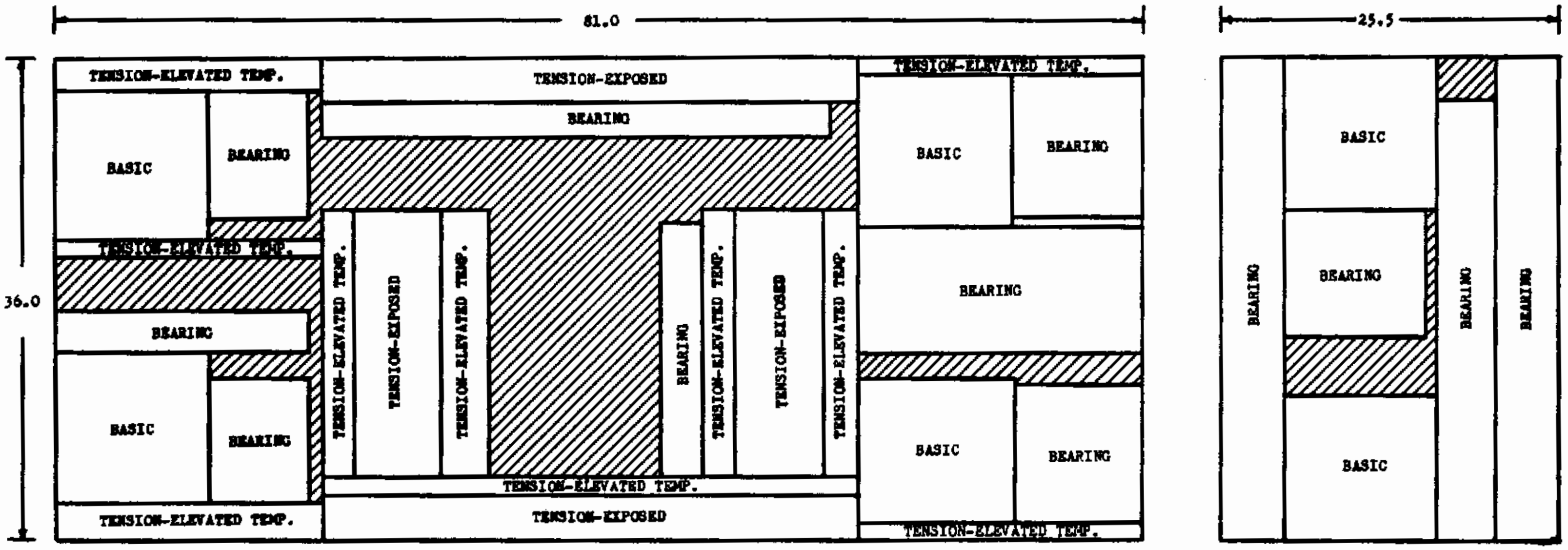


FIGURE 5—TYPICAL LAYOUT DIAGRAM FOR 0.020 INCH THICK MATERIAL

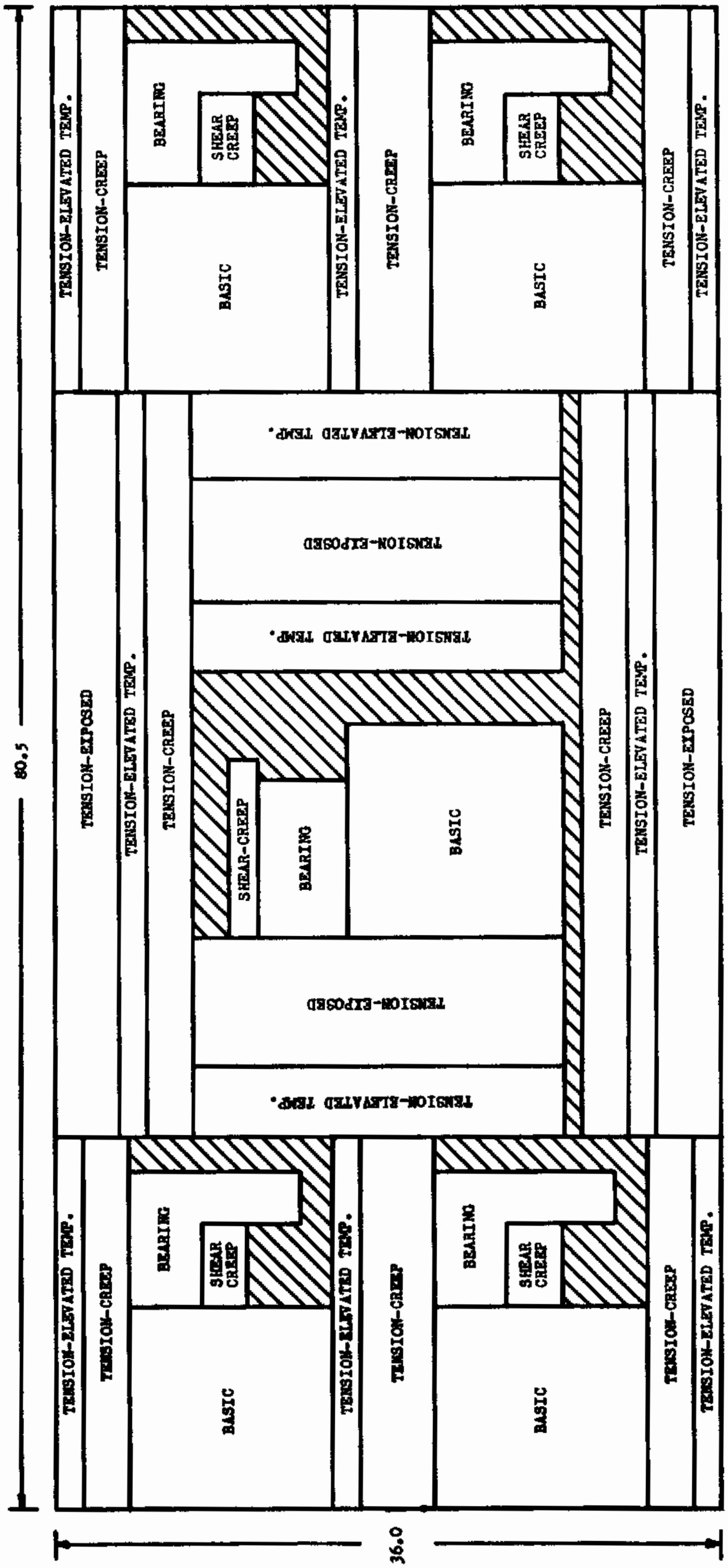


FIGURE 6-TYPICAL LAYOUT DIAGRAM FOR 0.063 INCH THICK MATERIAL

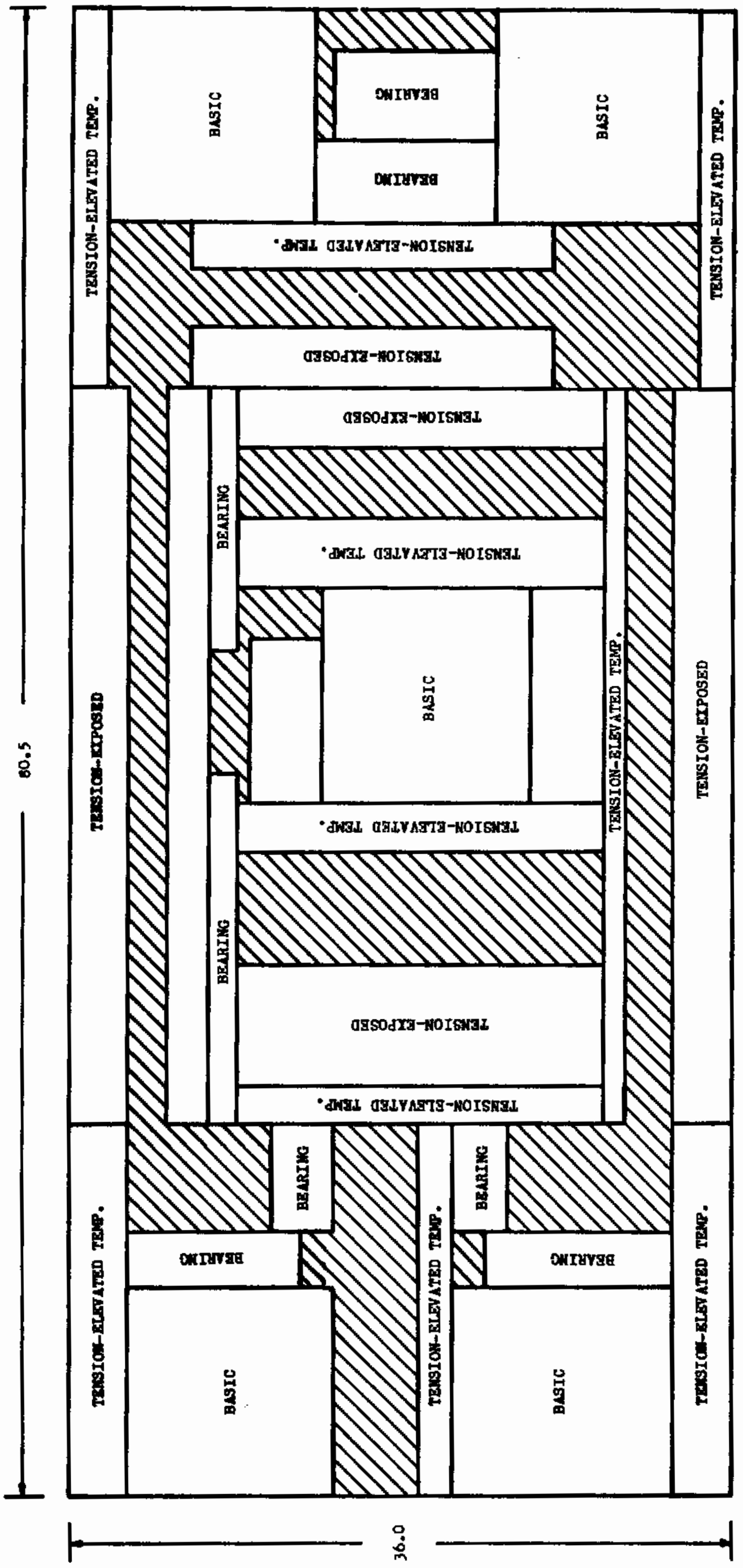
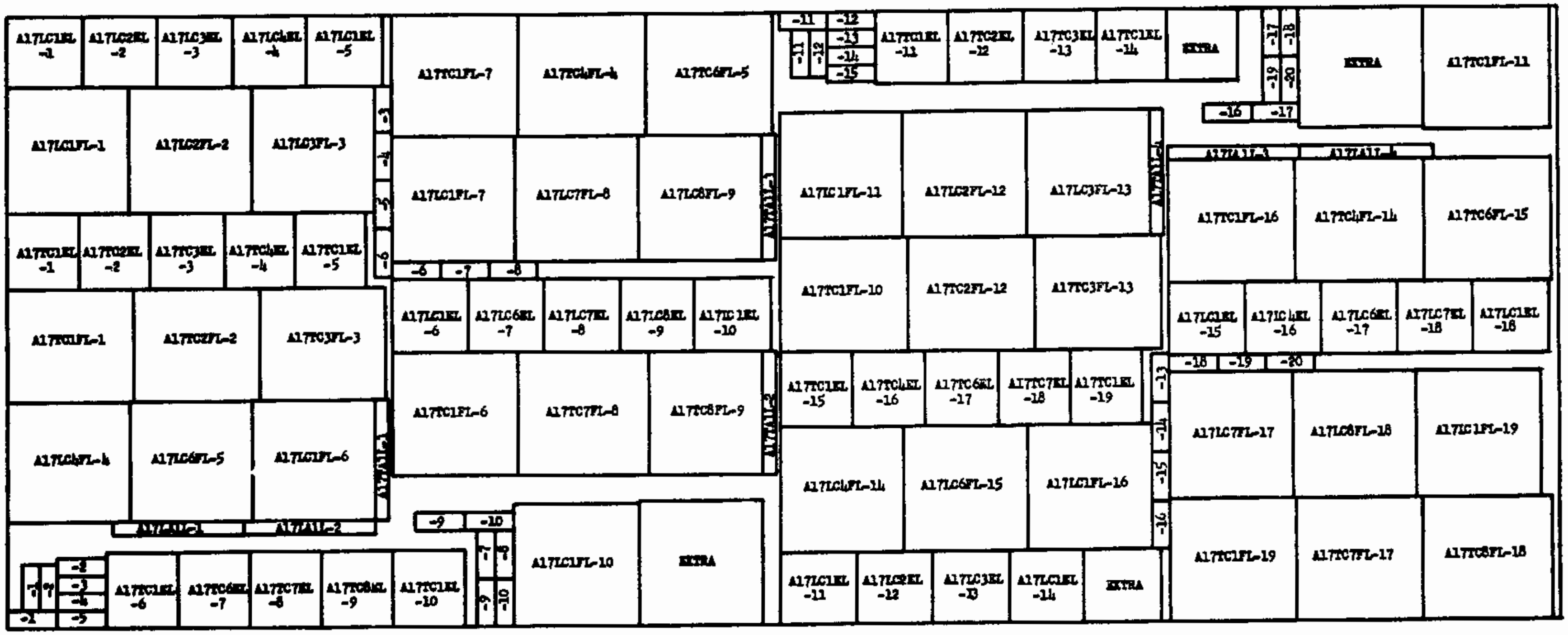
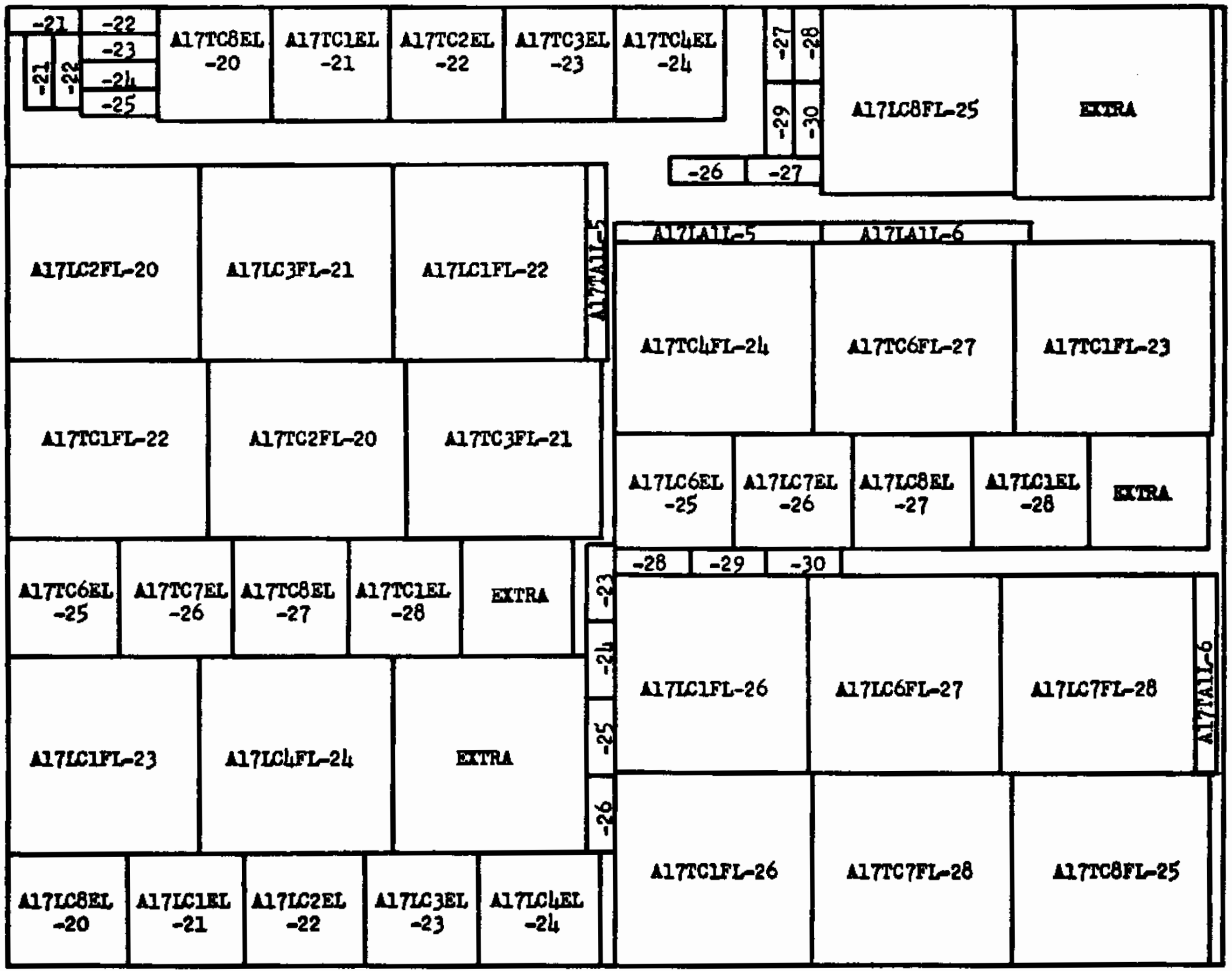


FIGURE 7—TYPICAL LAYOUT DIAGRAM FOR 0.125 INCH THICK MATERIAL



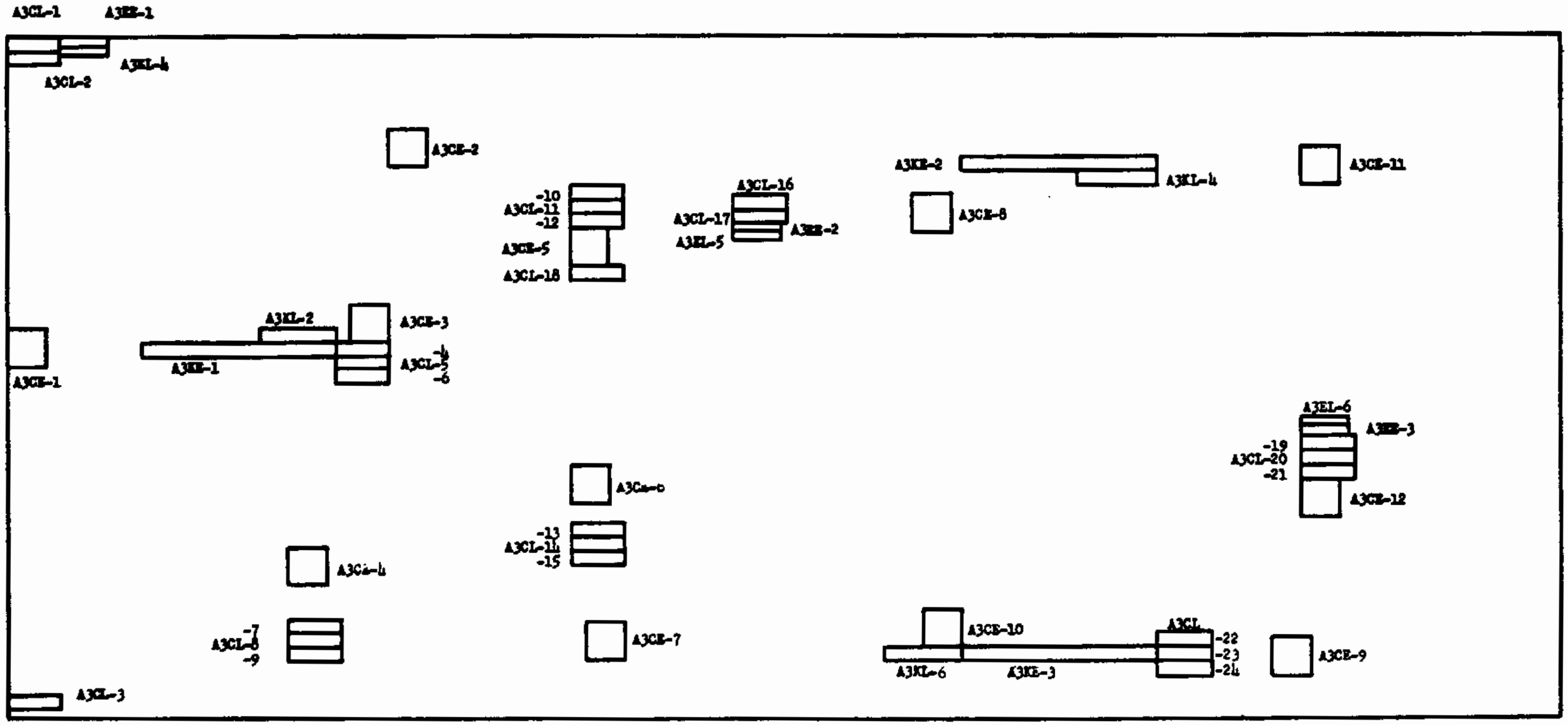
NOTE: 1 - See Table XIX for specimen coding system
2 - Small blanks having dash numbers are for longitudinal and transverse compressive specimens

FIGURE 8 - TYPES AND LOCATIONS OF TEST SPECIMENS IN 0.063 INCH THICK SOLUTION HEAT-TREATED SHEET FOR CRIPPLING EVALUATIONS, FIRST SHEET



NOTE: 1 - See Table XIX for specimen coding system
2 - Small blanks having dash numbers are for longitudinal and transverse compressive specimens.

FIGURE 9 - TYPES AND LOCATIONS OF TEST SPECIMENS IN 0.063 INCH THICK SOLUTION HEAT TREATED SHEET FOR CRIPPLING EVALUATIONS, SECOND SHEET

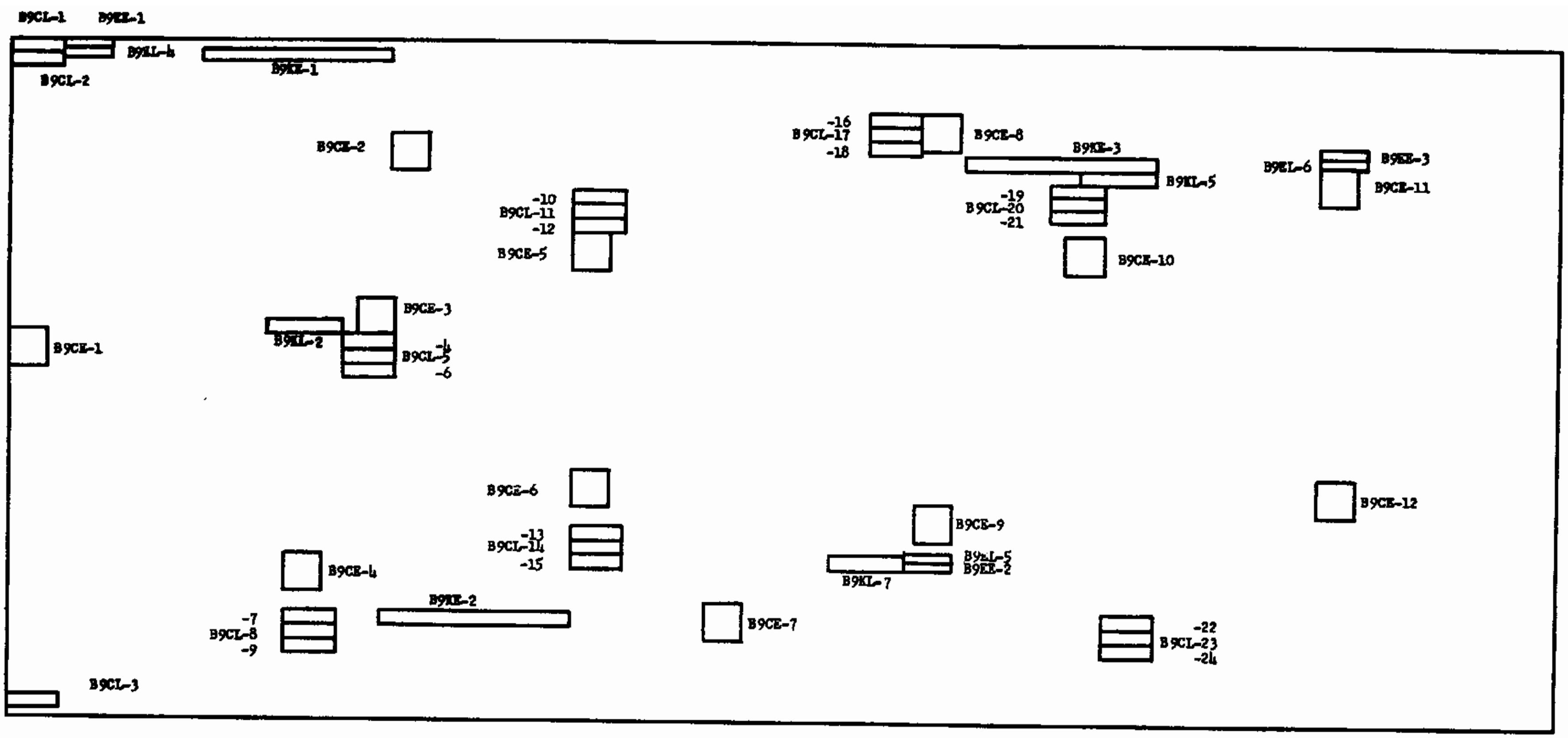


Specimen Code

First two symbols indicate alloy, heat and thickness

Third Symbol, Specimen Type	C - Specific Heat E - Thermal Coefficient of Expansion K - Thermal Conductivity
Fourth Symbol, Temperature	E - Elevated Temperature L - Low Temperature
Fifth Symbol, Specimen Number	

FIGURE 10 - TYPES AND LOCATIONS OF PHYSICAL PROPERTY SPECIMENS IN 0.125 INCH THICK SOLUTION HEAT TREATED AND AGED B120VCA TITANIUM ALLOY SHEET. CRUCIBLE HEAT NO. R6759, SHEET NO. 9MB3.



Specimen Code

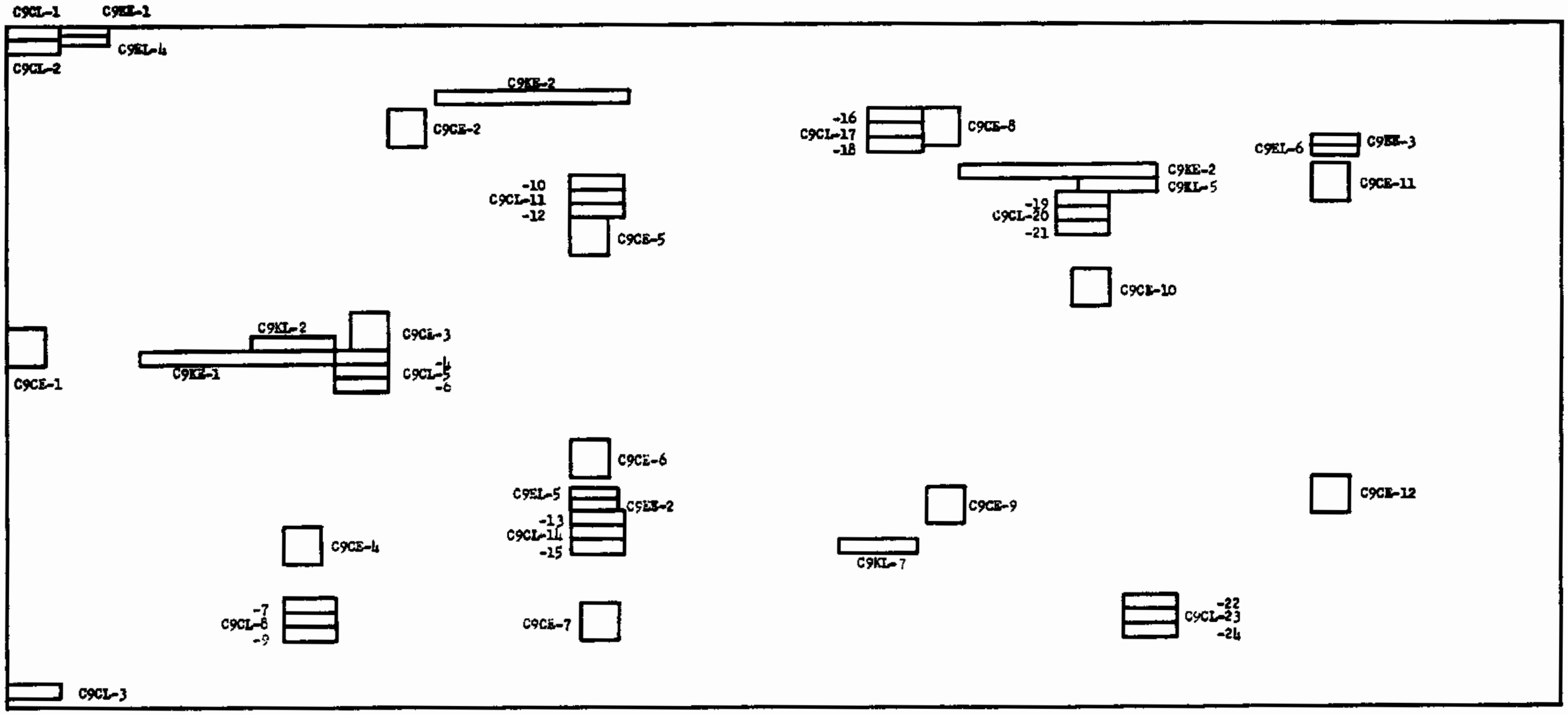
First two symbols indicate alloy, heat and thickness

Third Symbol, Specimen Type
C - Specific Heat
E - Thermal Coefficient of Expansion
K - Thermal Conductivity

Fourth Symbol, Temperature
E - Elevated Temperature
L - Low Temperature

Fifth Symbol, Specimen Number

FIGURE 11 - TYPES AND LOCATIONS OF PHYSICAL PROPERTY SPECIMENS IN 0.125 INCH THICK SOLUTION HEAT TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET. REACTIVE METALS HEAT NO. 32167, SHEET NO. 1777A-1.



Specimen Code

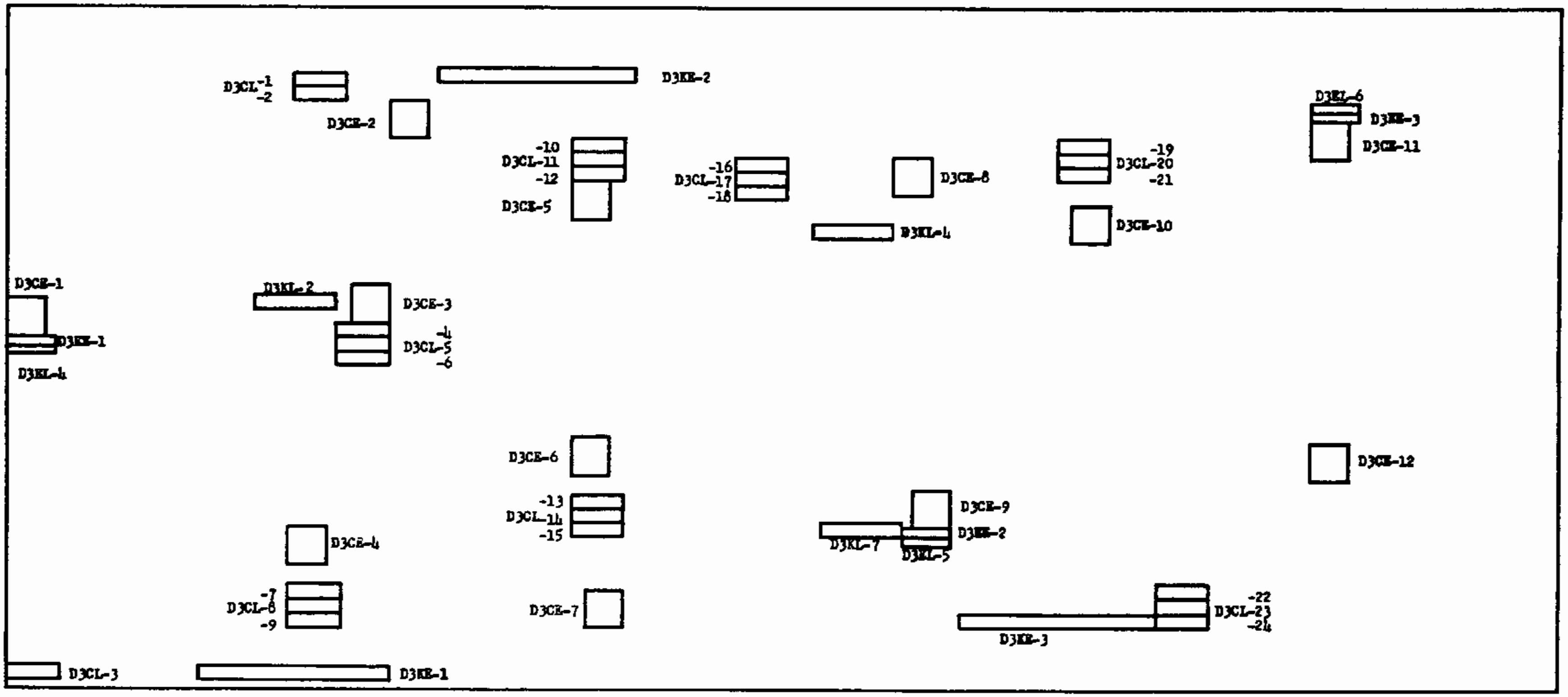
First two symbols indicate alloy, heat and thickness

Third Symbol, Specimen Type
C - Specific Heat
E - Thermal Coefficient of Expansion
K - Thermal Conductivity

Fourth Symbol, Temperature
E - Elevated Temperature
L - Low Temperature

Fifth Symbol, Specimen Number

FIGURE 12 - TYPES AND LOCATIONS OF PHYSICAL PROPERTY SPECIMENS IN 0.125 INCH THICK SOLUTION HEAT TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET. REACTIVE METALS HEAT NO. 23345, SHEET NO. 1149-3.

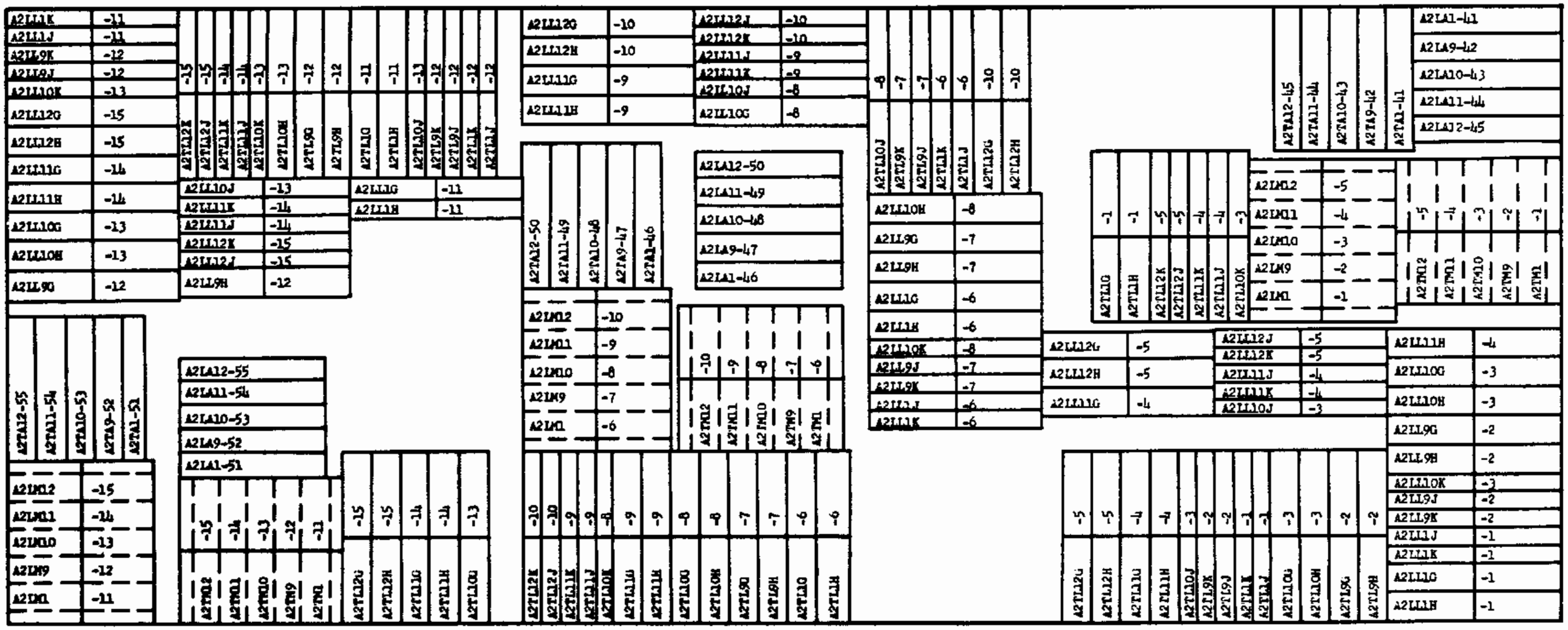


Specimen Code

First two symbols indicate alloy, heat and thickness

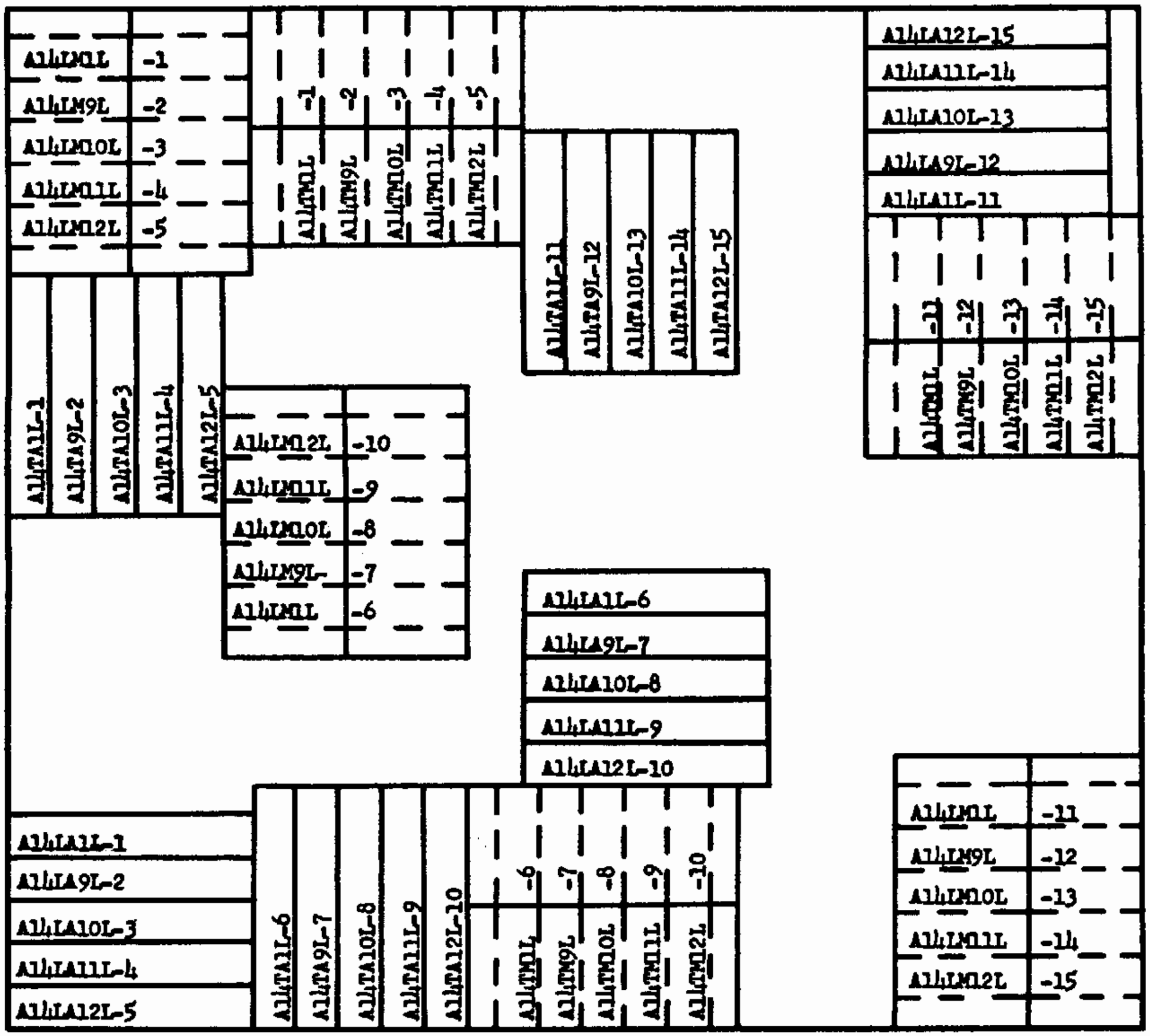
Third Symbol, Specimen Type	C - Specific Heat E - Thermal Coefficient of Expansion K - Thermal Conductivity
Fourth Symbol, Temperature	E - Elevated Temperature L - Low Temperature
Fifth Symbol, Specimen Number	

FIGURE 13 - TYPES AND LOCATIONS OF PHYSICAL PROPERTY SPECIMENS IN 0.125 INCH THICK SOLUTION HEAT TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET. CRUCIBLE HEAT NO. R6736, SHEET NO. B-32.



NOTE: 1- See Table XIX for specimen coding system
2- Omit weld specimens for 2.5Al-16V titanium alloy

FIGURE 14 - TYPES AND LOCATIONS OF TEST SPECIMENS IN 0.063 INCH THICK SOLUTION HEAT TREATED AND AGED SHEET FOR JOINT EVALUATIONS AT CRYOGENIC TEMPERATURES



NOTE: 1 - See Table XIX for specimen coding system

FIGURE 15 - TYPES AND LOCATIONS OF TEST SPECIMENS IN 0.063 INCH THICK SOLUTION HEAT TREATED SHEET FOR WELDED JOINT EVALUATIONS AT CRYOGENIC TEMPERATURES

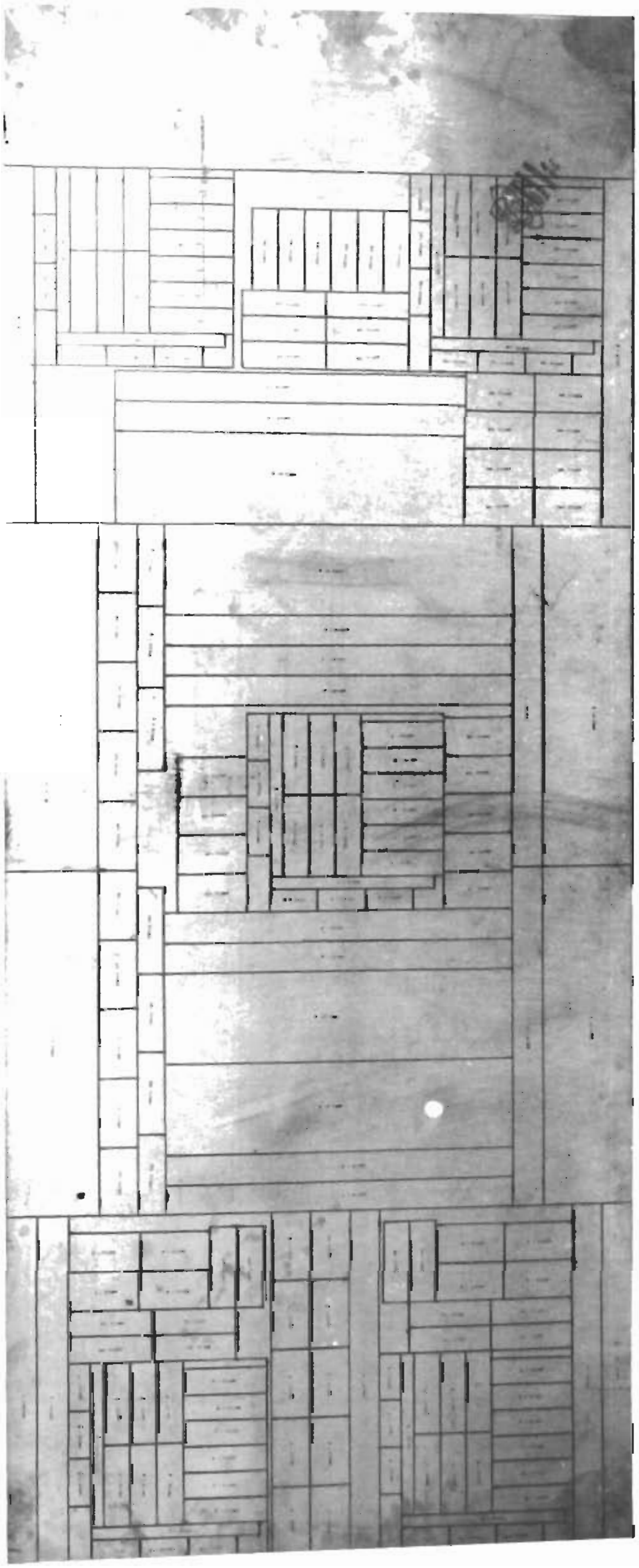


FIGURE 16 – TYPICAL SHEET MARKED AND CODED FOR SHEARING.

Subcontracts

Single and double shear stress-rupture, bearing creep-rupture and compressive creep tests for Phase II, "Creep-Rupture Properties", were subcontracted to Southern Research Institute, Birmingham, Alabama. In order to maintain complete test material control, identification, and random sampling, machined test specimens were supplied to the subcontractor. However, design of test fixtures and instrumentation necessary to perform the tests was accomplished by the subcontractor and complied with the specifications of Reference 1. Coordination between Lockheed and Southern Research Institute was maintained on test fixture designs to insure the acceptability of these designs for similar or identical specimens for determining creep and stress-rupture properties as were used for short-time static tests. Experimental procedures and results for these tests are included in Volume 2b of this report.

Georgia Institute of Technology, Atlanta, Georgia was the subcontractor performing all specific heat and low-temperature thermal conductivity measurements for the four titanium alloys. This work was conducted for Phase IV, "Physical and Joint Properties", and samples machined to the subcontractor's specification were supplied by Lockheed. Included herein are details of experimental techniques employed and physical property data obtained by Georgia Institute of Technology.

A chemical analysis was conducted for Lockheed on each heat of each alloy by National Spectrographic Laboratories, Inc., Cleveland, Ohio. These data are reported in Tables II through XVII.

Data Analysis

Design data desired from analog type load-deformation curves, autographically recorded for each tensile and compressive test, were obtained by an electronic data processing program. This program made possible the reduction of large volumes of data quickly and accurately.

For tensile and compressive tests, each autographically recorded curve was screened for recording errors, and a line drawn over the initial linear portion of the curve. A point was placed on the origin of the curve and on the proportional limit. Nine additional points were placed on the non-linear portion of the curve, the intervals of selection being arbitrary except for consideration of rate of curvature. Each curve was assigned a unique code number which contained specimen number, specimen area and instructions as to the type of data analysis required. The specimen code number and ten load-deformation coordinates were digitized and punched into an IBM card by a Model E-2 Analog to Digital Converter, and a Model 26 IBM Card Punch. The origin was used only for reference, and the coordinates of the ten points were digitized and punched in order of increasing load and deformation.

Information on the card was converted to binary coded decimal tape equivalents by an IBM 1401 Data Processing System. An IBM Electronic Data Processing Machine, Model 7090, which is a binary computer, performed the required data reduction from information supplied by the binary tape. Data from the computer were programmed on two separate binary coded tapes, one for tabulated data and one for data to be plotted. Tabulation from the tape was performed by the IBM 1401 and data to be plotted were punched into cards. Plotting was performed by a Model E Benson Lehner Electroplotter and a Model 514 IBM Reproducing Punch. Figure 17 shows a flow diagram of the data system.

The ten load values for each test specimen were reduced to stress readings and corresponding deformation values were scaled to strain to produce stress-strain curve coordinates. A third degree polynomial equation of the general form

$$Y = A + Bx + Cx^2 + Dx^3$$

was then selected; and the constants were solved for by the Model 7090 from the ten actual stress-strain points by means of the method of least squares, to produce a computed stress-strain curve. Ten stress values were computed from the equation of the curve using the actual strain values. The computed stress-strain curve was solved by the computer for the 0.2 percent yield stress, and the Ramberg-Osgood parameters, stress (F_1) at 0.70E and stress (F_2) at 0.85E. The shape factor, n, where

$$n = 1 + \frac{.3853}{\log_{10} F_1/F_2}$$

was also calculated. These data were collected on the binary tape and tabulated.

The ten coordinates taken from the actual stress-strain curve were collected on the second binary tape for plotting. Secant modulus values were computed for each of the ten actual stress-strain coordinates and collected on the same tape. These data were then punched into IBM cards and plotted by the Electroplotter.

Comparisons were made between actual stress-strain values and those computed using the polynomial. Deviation was on the order of one percent or less for the portion of the curve used to obtain mechanical property data.

Tangent moduli were obtained by taking the first derivative of the polynomial at each of the ten computed points. These moduli were then compared to values obtained graphically for the same points using the half-silvered mirror method. As previously stated the polynomial accurately described coordinates of the stress-strain curve, but comparison of computed and graphical tangent modulus values showed that it did not adequately describe the first derivative of the stress-strain curve. Large deviations were observed which in some cases were as great at 50 percent. Consequently, the graphical method employing a half-silvered mirror was used to construct lines normal to the stress-strain curve. Coordinates from these normal lines were then used to compute tangent modulus values.

Variation of Properties - The test program was designed using three heats and several sheets of each thickness of each alloy to allow the introduction of heat to heat and sheet to sheet variations into the total sample of mechanical properties. This resulted in average data more representative of the homogeneity, in terms of strength, to be expected in titanium alloy sheet produced for the DOD Program. Room-temperature data reflecting these variations are presented in the design tables of Volume I. In many cases, standard deviations for a particular property were quite large for a sample of combined heats and sheets, and it was apparent by observing the data that they were frequently ranked by sheet and/or heat. It was felt, consequently, that a statistical estimate of the significance of the differences between heats and sheets would be informative. Where the analysis utilized for the tabulated data of Volume I assumed a normal distribution, a distribution-free method was selected in the present case since sample size was small; of the order of five to ten items. A program was written for the IBM 7090 Electronic Data Processing Machine which compared data input in selected combinations of pairs of heats and sheets and gave the level of probability that the pairs were samples from the same population. If the computed probability for any pair of samples was 50 percent or greater, they were considered to be of the same population and, therefore, their differences were not statistically significant. For simplicity in the analysis, the data were compared for only a single strength property, ultimate tensile stress at room temperature, which was less subject to experimental error than other properties. Both longitudinal and transverse grain directions were investigated because of the directionality present in some sheets.

The results of this analysis are presented in Table XX. Generally, there was more dissimilarity between heats of an alloy-thickness combination than between pairs of sheets within a heat.

TABLE XX RESULTS OF AN ANALYSIS TO DETERMINE THE STATISTICAL SIGNIFICANCE OF THE DIFFERENCE IN ULTIMATE TENSILE STRESS FROM SHEET TO SHEET AND HEAT TO HEAT

B120VCA

Thickness - 0.020 Inch

Heat No. R6392 By Sheets

	3BX2
3BT1	L

Heat No. R6761 By Sheets

	5TA2
5TT2	L

Heat No. R6788 By Sheets

	7TT1
7BX1	0

0.020 Inch Thick Material By Heats

	R6761	R6788
R6392	T	0
R6761	▨	L

Thickness - 0.063 Inch

Heat No. R6392 By Sheets

	3BT6	3BX4
3BT6	▨	0
3BX4	0	▨
3TX6	L	L

Heat No. R6761 By Sheets

	5BT7
5BX2	L, T

Heat No. R6788 By Sheets

	7TA2
7TT5	L, T

0.063 Inch Thick Material By Heats

	R6761	R6788
R6392	L	T
R6761	▨	0

Thickness - 0.125 Inch

Heat No. R6759 By Sheets

	9MB4
9MB3	L, T

Heat No. R6761 By Sheets

	5TA9
5TT7	L, T

Heat No. R6753 By Sheets

	8TT4
8TT3	L, T

0.125 Inch Thick Material By Heats

	R6761	R6753
R6759	0	0
R6761	▨	0

Ti-6Al-4V

Thickness - 0.020 Inch

Thickness - 0.063 Inch

Heat No. 27039 By Sheets

	744-7	744-6	743-2	743-5
744-7	▨	T	T	T
744-6	T	▨	L	0
743-2	T	L	▨	L
743-5	T	0	L	▨
743-7	L	L	L	0

Heat No. 25671 By Sheets

	8361-6	8361-5	8361-10	8361-3
8361-6	▨	L	L	L
8361-5	L	▨	L, T	L
8361-10	L	L, T	▨	L
8361-3	L	L	L	▨
8361-9	L	L, T	L, T	L, T

Heat No. 31372 By Sheets

	1780AB-2
1780AB-1	L, T

0.063 Inch Thick Material By Heats

	27039	25671
27039	▨	L
25671	L	▨
31372	0	0

Thickness - 0.125 Inch

Heat No. 22207 By Sheets

	785-7
746-2	T

Heat No. 32163 By Sheets

	1775A-3
1775A-4	T

Heat No. 32167 By Sheets

	1777A-1
1777A-2	L, T

0.125 Inch Thick Material By Heats

	22207	32163
22207	▨	0
32163	0	▨
32167	0	0

Ti-2.5Al-16V

Thickness - 0.020 Inch

Heat No. 22093 By Sheets

	3971-17	3971-16	3971-27
3971-17	▨	L, T	0
3971-16	L, T	▨	0

Heat No. 24990 By Sheets

	540A-4	540A-2	540A-3
540A-4	▨	L, T	L, T
540A-2	L, T	▨	L

Heat No. 24814 By Sheets

	1508-3	1508-2	1508-1
1508-3	▨	L, T	T
1508-2	L, T	▨	T

0.020 Inch Thick Material By Heats

	22093	24990	24814
22093	▨	L, T	L
24990	L, T	▨	L

Thickness - 0.063 Inch

Heat No. 22154 By Sheets

	0083-1	0083-4	0083-5	0083-6
0083-1	▨	L	L	L
0083-4	L	▨	L, T	L
0083-5	L	L, T	▨	L
0083-6	L	L	L	▨
0083-3	L	0	0	T

Heat No. 24806 By Sheets

	1100-2	1100-1	1099-1	1099-2
1100-2	▨	L	0	0
1100-1	L	▨	0	0
1099-1	0	0	▨	L
1099-2	0	0	L	▨
1104-1	T	T	L, T	T

Heat No. 24814 By Sheets

	1509-3	1509-6
1509-3	▨	T
1509-6	T	▨
1509-4	L, T	L, T

0.063 Inch Thick Material By Heats

	22154	24806
22154	▨	0
24806	0	▨
24814	L, T	0

Thickness - 0.125 Inch

Heat No. 23354 By Sheets

	559-4
559-2	0

Heat No. 23372 By Sheets

	0073-1
0073-0	L, T

Heat No. 23345 By Sheets

	1149-3
1149-5	L, T

0.125 Inch Thick Material By Heats

	23354	23372	23345
23354	▨	L	L, T
23372	L	▨	L

Ti-4Al-3Mo-1V

Thickness - 0.020 Inch

Heat No. R4815 By Sheets

	T4	T1	X3
T1	L, T	▨	L, T
X3	L, T	L, T	▨

Heat No. R4765 By Sheets

	A9	X11	X10
X11	L, T	▨	L, T
X10	L, T	L, T	▨

Heat No. R4805 By Sheets

	X5	A6	A5
A6	T	▨	T
A5	L, T	T	▨

0.020 Inch Thick Material By Heats

	R4815	R4765	R4805
R4765	L, T	▨	L, T
R4805	0	L, T	▨

Thickness - 0.063 Inch

Heat No. P7653 By Sheets

	TA14	TT16	TA11
TT16	L, T	▨	L, T
TA11	L, T	L, T	▨

Heat No. R4765 By Sheets

	X1
T2	T

Heat No. R4815 By Sheets

	T9
X8	L, T

0.063 Inch Thick Material By Heats

	P7653	R4765
P7653	▨	0
R4765	0	▨
R4815	0	0

Thickness - 0.125 Inch

Heat No. R6736 By Sheets

	B32
C12	L, T

Heat No. R6741 By Sheets

	A27
A30	L, T

Heat No. P7647 By Sheets

	BA11
BB5	L, T

0.125 Inch Thick Material By Heats

	R6736	R6741	P7647
R6741	L, T	▨	L
P7647	L	L	▨

NOTE:

L and T - Denote pairs of sheets or heats that have a probability of 50 percent or greater of being from the same population for longitudinal and transverse grain directions, respectively.

O - Denotes pairs of sheets or heats that have a probability less than 50 percent of being from the same population for both longitudinal and transverse grain directions.

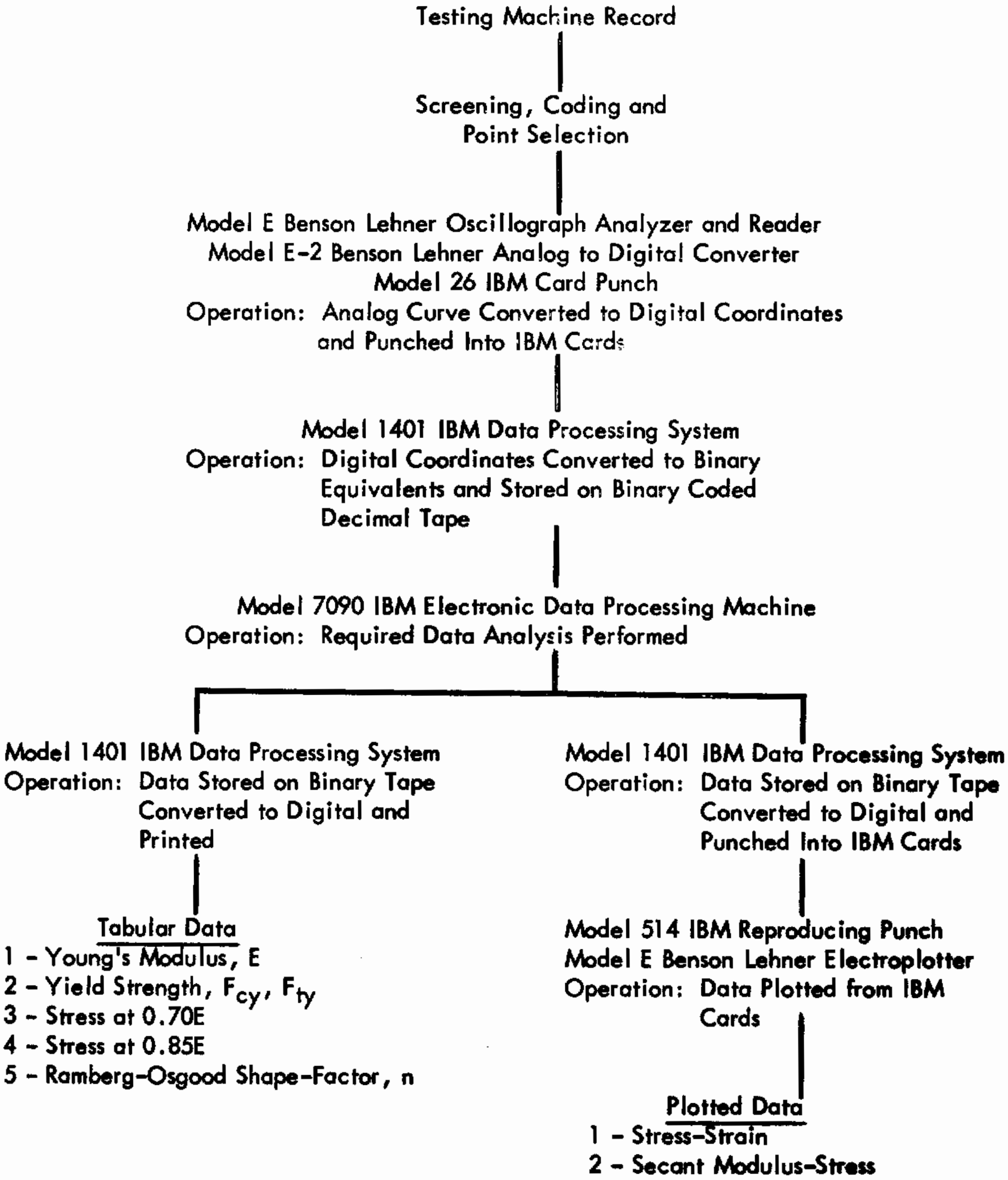


FIGURE 17 - DIAGRAM OF DATA PROCESSING PROGRAM

Experimental Techniques

Several items pertinent to all mechanical property tests are discussed in this general section in order to avoid repetition.

The short-time mechanical property tests at low, room and elevated temperatures were performed in universal testing machines of the appropriate capacity to most accurately measure the applied loads. Five such machines having combined load ranges from 10-pounds to 400,000-pounds full scale were used on this program. These machines were calibrated yearly with National Bureau of Standards certified proving rings to accuracies of ±0.5 percent of scale reading or 0.1 percent full range, whichever was greater. Check calibrations were performed at more frequent intervals with an NBS calibrated Baldwin-Lima-Hamilton SR-4 calibration kit. All of these machines were equipped with autographic load-deformation recorders, and load and strain rate pacers.

Commercial and Lockheed designed strainometers of various types were used for the program. The sensing elements on these devices utilized either differential transformer or SR-4 strain gage flexure members and the electrical outputs, which were linearly proportional to deformation, were recorded on null balance autographic recorders. Maximum strain sensitivity of these instruments was 500 microinches per inch of chart paper yielding a least strain reading of 50 microinches per inch with an estimated reading of approximately 1/4 of the least reading. However, the sensitivity selected for the various test types was chosen to yield load-deformation curves of the optimum proportion for data reduction. Strainometers in constant use were calibrated monthly to conform to ASTM Class B, Reference 5, or better accuracy using a Baldwin-Lima-Hamilton Portable Extensometer Comparator and precision gage blocks.

Except where otherwise stated, specimen temperature for the many elevated-temperature tests performed was measured by 28-gage Chromel-Alumel duplex thermocouple wire having asbestos and glass insulation. Rolls of wire were obtained from Leeds and Northrup Company to the following specifications: check calibrations to be performed at 600°F, 800°F and 1000°F and wire to be selected so that the error was within ±2°F of indicated for the 0°F to 530°F range and ±3/8 percent for the 530°F to 1300°F range. A tag containing correction data was attached to each roll. Application of the correction data resulted in error limits even less than those reported for selection. The selected and checked wire had half the tolerance limits of standard grade wire and very little difference in calibration from roll to roll.

Thermocouples were prepared by closely twisting the wires three turns and then fusing the twists into a bead. This bead formed the only junction between the two wires since care was taken to insure the absence of a twist or wire contact behind the bead. In most cases the thermocouple bead was placed in contact with the specimen surface, an asbestos pad was placed over the bead, and pressure was applied to the pad by a small metal clip containing a set screw. Chromel-Alumel thermocouple outputs were measured with multichannel Brown Type 153 ElectroniK recording potentiometers having a full scale millivolt range equivalent to 0°F to 1200°F. These potentiometers were completely calibrated to an accuracy of 1/5 percent of full scale every 12 weeks and checked at more frequent intervals with a Leeds and Northrup No. 8662 Portable Precision Potentiometer. Calibration data obtained were used to correct the indicated specimen temperature which was recorded continuously during the 30 minute stabilization-soak period and the test period. Temperature uniformity over the specimen test section was maintained to within ±5°F of that desired.

Thicknesses, widths and diameters of all test specimens were measured with mechanical type micrometers having a readability of 0.0001 inch. Ball contacts were used where conditions such as sheet flatness, surface finish or machined edges could possibly cause measurement errors when using flat anvils. Such micrometers, in continuous use, were calibrated every six weeks using precision gage blocks certified by the National Bureau of Standards.

In general, these items were common to all mechanical property tests; however, there were deviations. Such deviations are discussed under the appropriate sections.

Tensile Tests

Test Specimens

Room and elevated temperature tensile test specimens were machined to the configurations shown in Figure 18. In most cases, these specimens were machined in stacks of three or more dependent upon sheet thickness after which the machined edges of the test section were polished with No. 400 emery paper and inspected microscopically to insure the absence of edge cracks. Grid lines 1/8 inch apart for elongation measurements were applied to the test sections of these specimens using a silk screen process. Markal coating CR 8 was used for the grid lines except on room-temperature specimens where India ink was used. Figure 19 shows the Markal grid lines on a specimen immediately after application and after testing at 1000°F. In order to determine if the Markal coating reacted with the test material, a piece of 0.063 inch thick Ti-2.5Al-16V was coated and soaked at 1000°F for approximately one hour. Microscopic examination indicated no damage.

Dimensions of each specimen were determined by a minimum of five micrometer measurements each of width and thickness prior to application of the grid.

Specimens used for measuring Poisson's ratio and for determining effects of exposure were also shown in Figure 18.

Test Details

Three universal testing machines were used for loading the tensile specimens; a 30,000-pound capacity Riehle Model PS-30, a 50,000-pound capacity Baldwin Model FGT and a 120,000-pound capacity Tinius Olsen Super L. Load was transmitted to the room-temperature specimens through Templin grips which were spherically seated to insure proper alignment. Elevated-temperature specimens were loaded as shown in Figure 20 through a system of spherical seats and clevises which attached by pins through the holes in the specimen shoulders. Some difficulty was experienced with buckling of the 0.020 inch thick material around the attachment holes with subsequent tear-out and failure in the grip. This was true even though the attachment ends were at temperatures much lower than test temperature and clevises were designed to fit as snugly as possible within the limits of thickness variation. Failures of this type were virtually eliminated with the use of shims, which fitted tightly between clevis and specimen around the attachment hole, or intermediate load straps bolted tightly to the specimen shoulders.

Load-deformation curves were autographically recorded for each specimen on a drum type recorder using two inch gage length Baldwin Models SRE and P4M extensometers at room temperature and Baldwin Models PSH-8RS and PSH-8MS at elevated temperatures. The SRE and PSH-8RS models had electrical resistance strain gage measuring elements, and the P4M and PSH-8MS models employed differential transformers. The elevated-temperature extensometers employed standard commercial knife-edges and transfer arms as shown in Figure 21. No difficulty was experienced with slippage of the knife-edges up to the maximum test temperature of 1000°F. However, it was necessary to carefully adjust the initial clamping pressure to prevent specimen failure at the clamping point. Nevertheless, failure at the clamping point did occasionally occur.

During all tests a constant strain rate of 0.006 inch per inch per minute was maintained until 0.2 percent offset yield stress was reached. From yield to failure a head travel rate of 0.1 inch per minute was held. The instrument for controlling strain rate was of the pacing type actuated by a selsyn drive geared directly to the strain axis of the autographic recorder. By matching the motion of the strain against a reference disk rotating at constant velocity, a constant strain or deformation rate was accomplished.

Elevated-temperature test specimens were heated in cylindrical furnaces of the conventional type, manufactured by Marshall Products Company. Furnace temperature was monitored from a single Chromel-Alumel thermocouple and was controlled by a Marshall Control Panel which consisted of a Foxboro galvanometer and an autotransformer. The temperature gradient along the longitudinal axis of the furnace was adjusted to meet requirements by the application of shunts between the external winding taps provided. Actual specimen temperature was measured by three 28-gage Chromel-Alumel thermocouples, one mounted on each end of the reduced section immediately outside of the knife-edge and one at the center of the gage length. In the test arrangement, two furnaces and controllers were employed such that successive tests were conducted in different furnaces.

Poisson's Ratio - Lateral deformation during tensile testing, necessary for Poisson's ratio determinations, was measured using the strainometer shown in Figure 22. This instrument consisted of two arms connected by a flexure pivot to provide a mechanical advantage of approximately 2:1 and utilized a pair of flexure members with bonded wire strain gages from a Baldwin Model SRE two inch gage length extensometer as sensing elements. One end of the arms had knife-edges which contacted the specimen across the width at the center of the test section. Sufficient pressure was exerted to prevent slippage at the knife-edges by a compression spring placed between the arms at the opposite end. The transverse strainometer was calibrated using precision gage blocks and an extensometer comparator to have a maximum deviation of less than one percent of indicated strain with a readability of approximately 30 microinches per inch. The extensometer used to measure longitudinal deformation was a conventional Baldwin model utilizing strain gaged flexure members as sensing elements; however, the measuring head was modified to accept an additional pair of sensing elements as shown in Figure 23. The longitudinal extensometer having the dual elements was attached to the test specimen as described for a conventional tensile test, and the transverse strain follower was placed across the specimen width inside the gage length of the longitudinal extensometer. For elevated-temperature tests the transverse strainometer extended through a port cut in the furnace wall. Loose insulation was packed around the arms to prevent excessive heat loss; however, additional heat was required to reduce the conductive loss through the arms of the transverse strainometer. This was accomplished by wrapping the strainometer arms with Briskeat flexible heating tape as shown in Figure 24.

A load-longitudinal deformation curve was recorded for each specimen as in a conventional tensile test. Voltage outputs from the transverse strain follower and auxiliary sensing elements of the longitudinal extensometer were each amplified by a Kin Tel chopper stabilized D.C. amplifier. These amplified signals were then recorded by a Model 2, Mosely X-Y Autograf recorder having an 11 x 17 inch flat recorder bed. The resulting curve of transverse deformation versus longitudinal deformation was used to determine Poisson's ratio.

Exposure - A special fixture was used for exposing panels for 500 hours at 600°F and for 10 hours at 900°F while subjected to tensile load. Panels, 3.25 x 20 inches, were mounted in the loading fixture shown in Figures 25 and 26 which served as the door for a Lindberg furnace. This allowed the loading columns containing an exposure panel to project into the furnace. Panel temperature was increased to that desired and stabilized for about four hours. Furnace temperature was controlled and recorded with a Wheelco Capacilog having a range of 0°F to 1600°F. In addition, a Chromel-Alumel thermocouple was attached to the center of each panel and monitored with 16 channel Brown Type 153 ElectroniK Recorder. Results of temperature surveys at 600°F, Table XXI, indicated the exposure temperatures to be constant to within ±10°F except for one column. This column was eliminated from use since all attempts to improve its temperature tolerance failed to produce the desired effect. A similar survey made at 900°F showed the temperature to be uniform within ±10°F for columns one through eight only; consequently, columns nine through 12 were not used for exposure temperatures of 900°F. Results of this survey are also in Table XXI.

Exposure stresses were equal to 1/3 the ultimate tensile stress at the exposure temperature. The required load was applied to each column by torqueing the loading nut, identified in Figure 27, after temperature equilibrium was obtained. Panel stress, based on average area, was measured in each column by a load transducer instrumented with SR4 wire strain gages. The transducers were calibrated with a universal testing machine and a Baldwin-Lima-Hamilton Type M indicator. Conduction of heat through the loading linkage into the transducer was practically eliminated by the aluminum heat exchanger (Figure 25 and 27). At 600°F exposure temperature the transducer temperature remained at ambient or only slightly above, and stabilized at approximately 110°F after reaching equilibrium at 900°F exposure temperature.

Tensile load was monitored and maintained as closely as possible to the calculated value during the exposure period. Load was monitored on each column at frequent intervals to assure that it remained constant within ±2 percent.

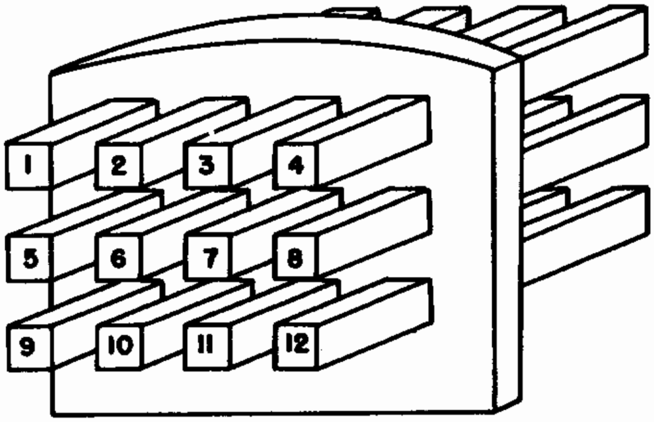
Similar panels were exposed to temperature only, for the same times and temperatures as those stress-exposed. These panels were placed in the Lindberg furnace and processed along with those being stress-exposed.

Data Analysis

Tensile load-deformation curves were processed by the IBM data analysis program previously described. This program computed and tabulated modulus of elasticity and yield stress at 0.2 percent offset for each specimen. Ulitmate tensile strength was obtained using the maximum load indicated by the testing machine. In all cases, average specimen area determined by five measurements each of width and thickness was used for computations.

TABLE XXI

TEMPERATURE DISTRIBUTION SURVEY FOR TEMPERATURE-STRESS EXPOSURE FIXTURE



Test Temp. °F	Time, Hours	Temp. in °F for Panel in Loading Column Number											
		1	2	3	4	5	6	7	8	9	10	11	12
600	0	602	601	600	600	600	600	599	599	597	598	(1)	596
	4	599	597	599	599	598	599	599	598	593	593	↓	593
	12	597	596	596	596	595	596	596	596	594	594	↓	594
	18	603	603	603	602	602	602	602	601	600	601	↓	601
	24	598	597	598	597	597	598	598	598	596	597	↓	595
900	1	894	895	895	895	895	895	895	895	(1)	(1)	(1)	(1)
	3	895	898	899	900	899	899	897	896	↓	↓	↓	↓
	5	905	906	906	906	906	905	905	904	↓	↓	↓	↓
	7	900	900	901	901	901	900	900	899	↓	↓	↓	↓
	9	900	900	901	901	901	901	901	900	↓	↓	↓	↓

(1) Column Not Loaded

To accurately evaluate elongation, specimens which failed within 1/4 inch of the point of tangency of the fillet and the reduced section were so indicated in the results. Also, those specimens which failed at the point of attachment of knife-edges were indicated. Values of elongation for 1/4 and 1/8 inch were only tabulated where fracture occurred between grid lines. If failures were across the width in the plane making an angle of approximately 30° with the longitudinal axis no deformation in 1/8 inch was measured and possibly none in 1/4 inch if several grid lines were traversed. The two types of failures most commonly observed are shown in Figure 28.

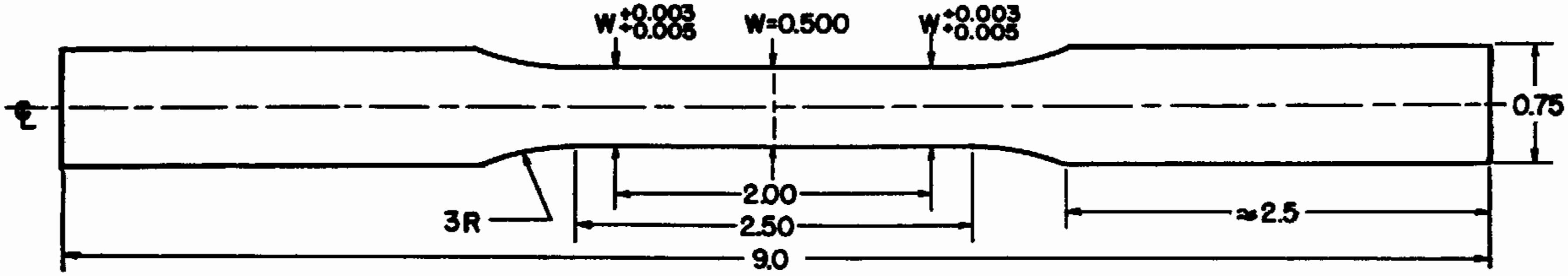
Elastic moduli obtained at room temperature for Ti-2.5Al-16V and Ti-4Al-3Mo-1V showed the values for Ti-2.5Al-16V to be considerably lower than expected and those for Ti-4Al-3Mo-1V to be higher than expected. To verify the results of autographic values, elastic tensile strain measurements were made using a two inch gage length Tuckerman optical strain gage on three tensile specimens from each of these alloys. Using incremental loads, strain measurements were made on both sides of each specimen during two runs. The elastic modulus was then computed for each specimen by the method of least squares. Results for the six specimens, which are in good agreement with autographic values, are tabulated in Table XXII.

TABLE XXII

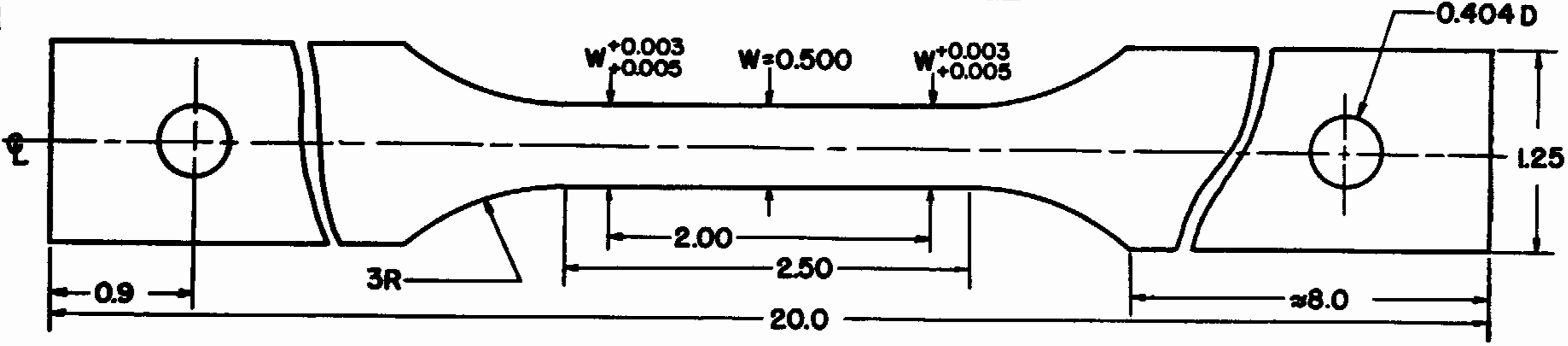
COMPARATIVE VALUES OF ELASTIC TENSILE MODULI

Alloy	Specimen Code	Elastic Tensile Modulus x 10^{-6} PSI	
		Optical Gage	Autographic(1)
Ti-2.5Al-16V	C1LA	15.33	15.0
	C5LA	14.39	15.0
	C9LA	14.47	14.8
Ti-4Al-3Mo-1V	D5LG	16.76	15.7
	D5TA	17.18	16.6
	D8TA	17.22	16.4

Note: (1) Average of 10 tests



SHEET TENSILE SPECIMEN (R.T.)



SHEET TENSILE SPECIMEN (Elev. Temp.)

FIGURE 18 - ROOM AND ELEVATED TEMPERATURE TENSILE SPECIMEN

(All Dimensions In Inches)

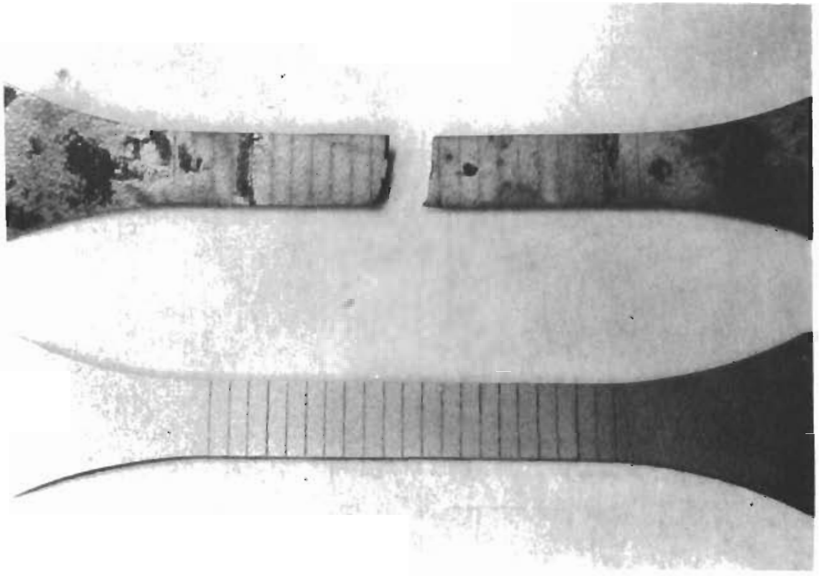


FIGURE 19 -

GRID MARKING ON ELEVATED TEMPERATURE TENSILE SPECIMENS AFTER TESTING AT 1000°F AND BEFORE HEATING; TOP TO BOTTOM, RESPECTIVELY

FIGURE 20 - TYPICAL ARRANGEMENT FOR TENSILE LOADING SHOWING FAILED SPECIMEN, LOADING CLEVIS, SPHERICALLY SEATED LOADING ROD AND WEDGE BLOCK

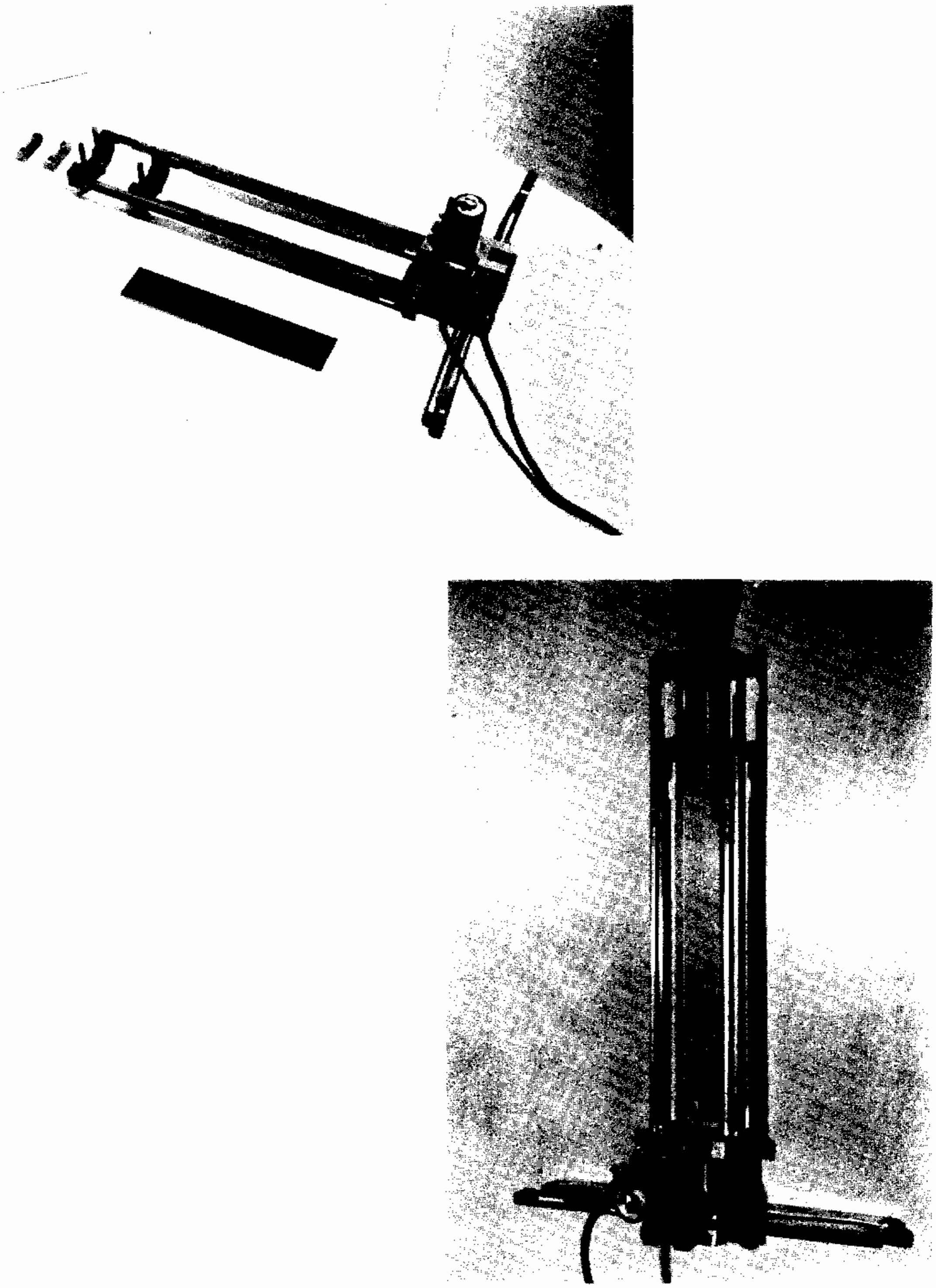
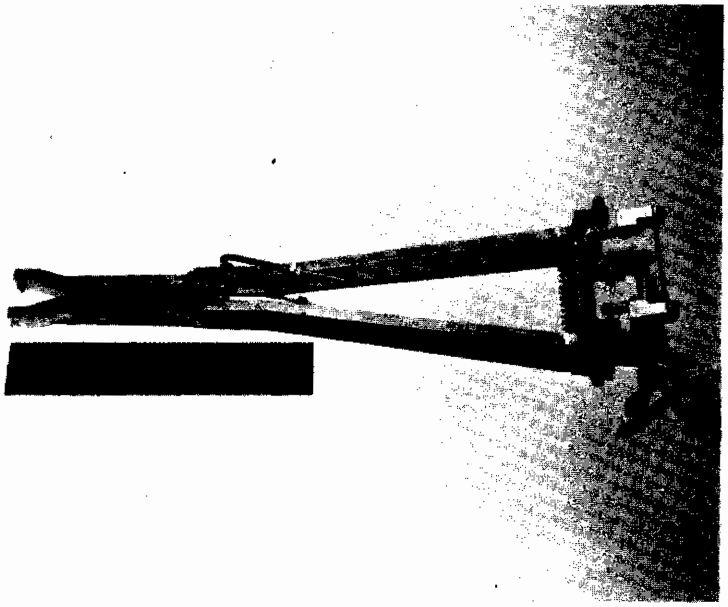


FIGURE 21- ELEVATED TEMPERATURE EXTENSOMETER



STRAINOMETER FOR
MEASUREMENT OF
LATERAL DEFORMATION

LATERAL STRAINOMETER
MOUNTED ON ELEVATED
TEMPERATURE SPECIMEN

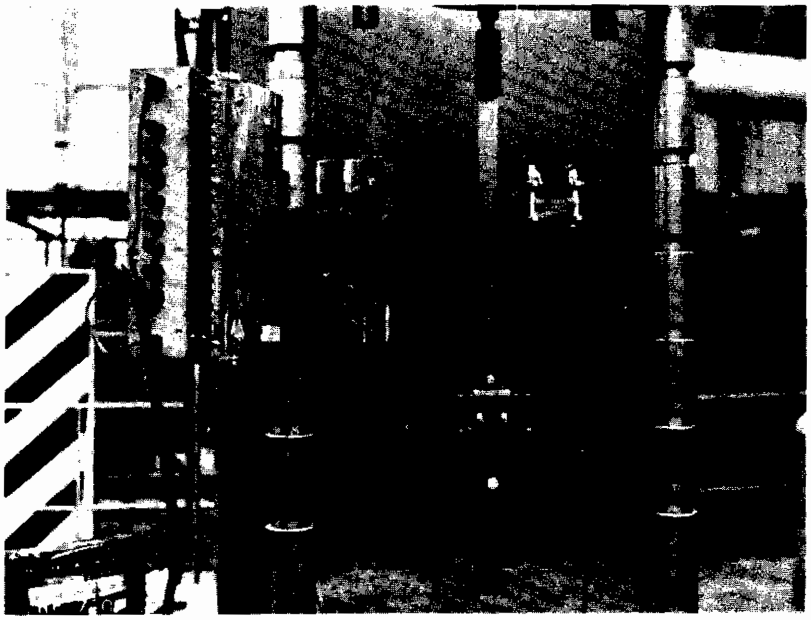


FIGURE 22 - STRAINOMETER USED FOR MEASUREMENT OF LATERAL DEFORMATION IN DETERMINATION OF POISSON'S RATIO

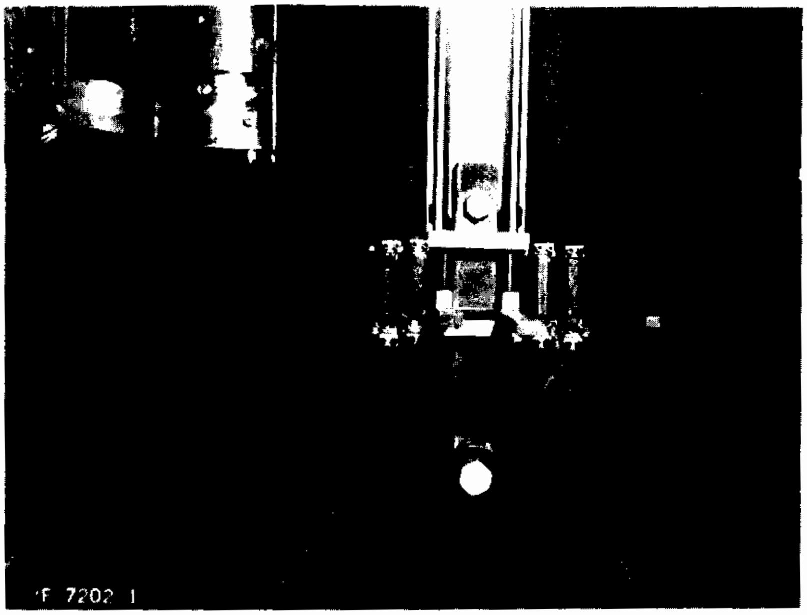


FIGURE 23- LONGITUDINAL AND TRANSVERSE STRAIN SENSING EQUIPMENT USED FOR THE DETERMINATION OF POISSON'S RATIO

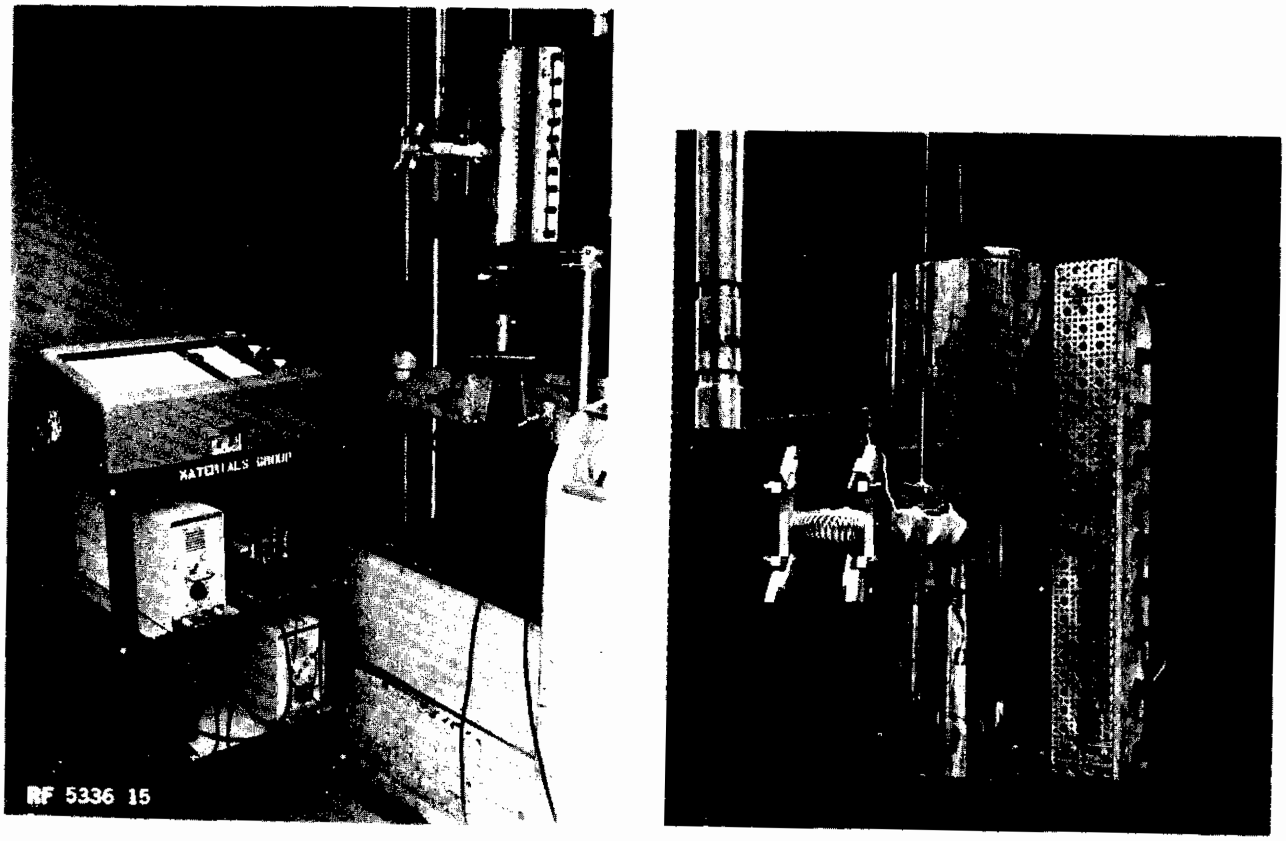
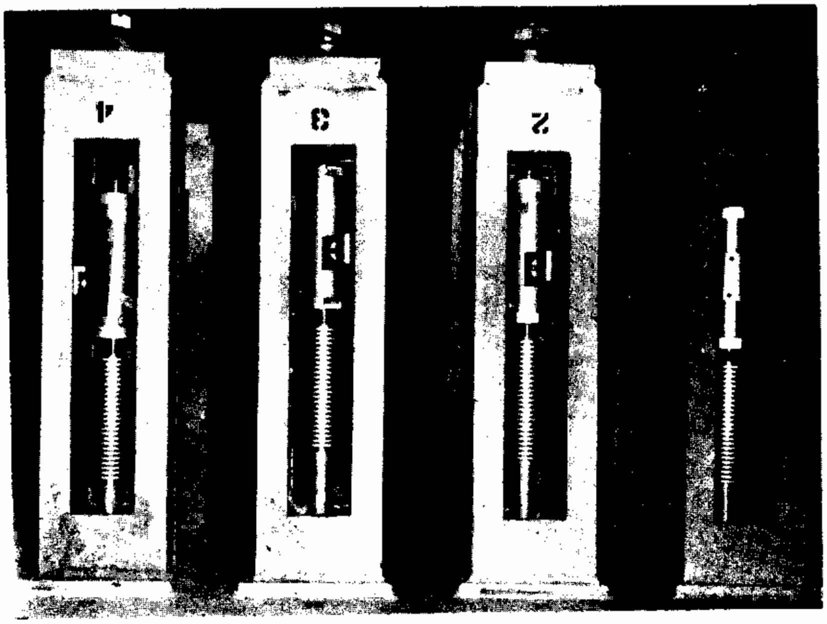


FIGURE 24 - ARRANGEMENT FOR MEASURING LATERAL DEFORMATION ON AN ELEVATED TEMPERATURE TENSILE SPECIMEN



External End of
Loading Columns

View of Fixture
Dismounted From
Furnace to Install
Specimens

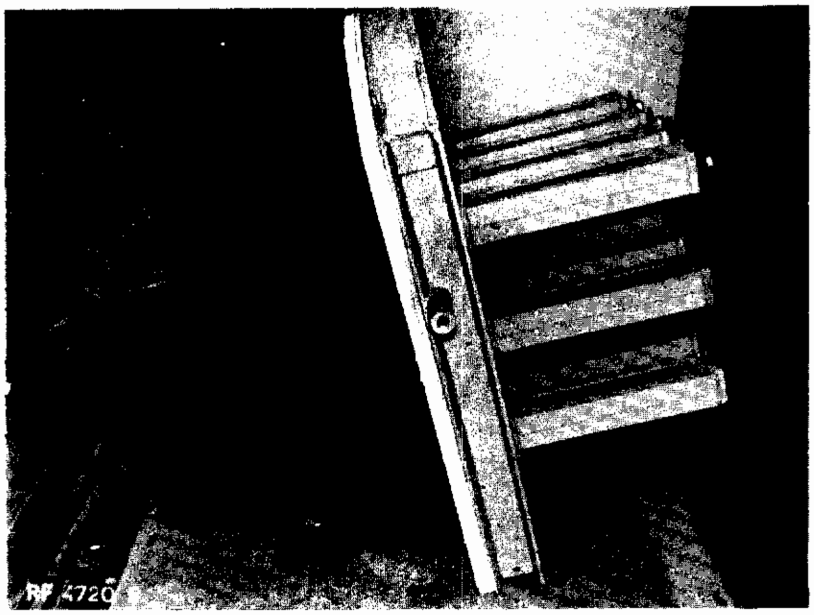


FIGURE 25- TEMPERATURE-STRESS EXPOSURE FIXTURE

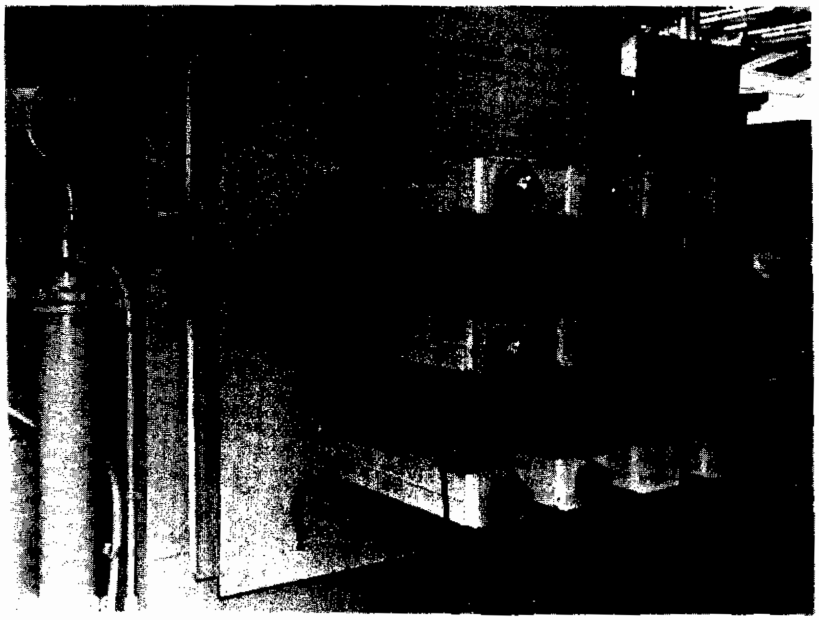
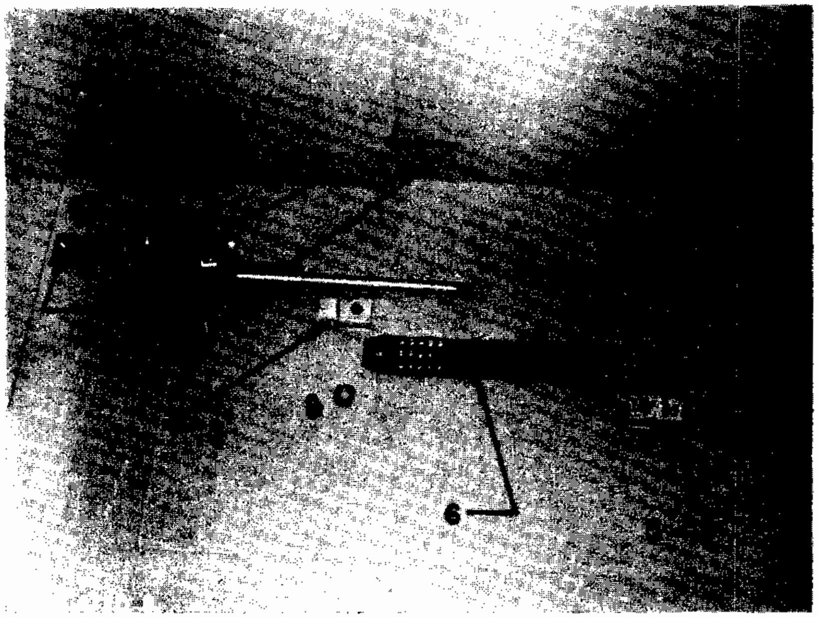


FIGURE 26 - TEMPERATURE-STRESS EXPOSURE FIXTURE MOUNTED ON FURNACE



(1) Loading Nut
(2) Thrust Bearing
(3) Load Transducer
(4) Heat Exchanger
(5) Clevis
(6) Test Panel

FIGURE 27- ASSEMBLY DETAILS OF TEMPERATURE-STRESS EXPOSURE LOADING LINKAGE

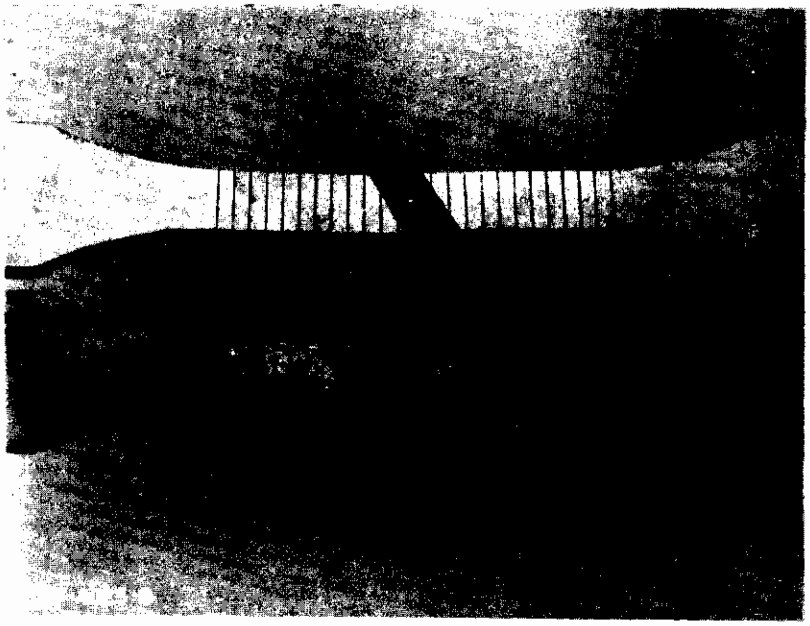


FIGURE 28- TYPICAL TENSILE FAILURES

Compressive Tests

Test Specimens

The compressive test specimen was designed to meet the requirements of DMIC Report No. 46D, Reference 1, and also be compatible with the Lockheed fixture. V-notches were incorporated to insure positive location of knife-edges and prevent slippage, as shown in Figure 29. This method was satisfactorily used by others as described in Reference 6.

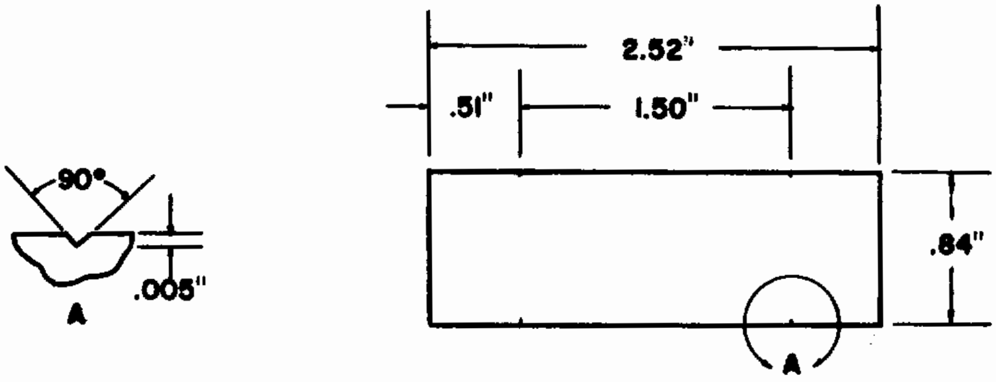


FIGURE 29 - COMPRESSIVE SPECIMEN

Test Details

Test specimens for determining compressive stress-strain properties were laterally supported from buckling by the fixture shown in Figure 30. Major components of the fixture were the support blocks, spacer, bearing block, spherical seat, lateral force wedge and housing as shown in Figure 31. All components were machined from Type 347 stainless steel with exception of the tool steel bearing block. The specimen support blocks had polished bearing faces which contained offset grooves. Machined into one support block was a spherical seat through which the lateral supporting force, necessary to prevent specimen buckling, was applied. The spherical seat facilitated uniformity of support over the specimen faces. The other support block contained three 0.18 inch diameter holes located 0.75 inch on centers along the vertical centerline of its face. They were line drilled with holes in the spacer and housing. One hole terminated at each end and one at the center of the specimen gage length and were used for thermocouple probes when testing at elevated temperatures.

In operation, the wedge was removed from the assembled fixture which allowed the grooved support block containing the spherical seat to be slipped back, thus leaving a space between the support blocks into which a specimen having both faces lubricated with Molykote was inserted. The wedge was then replaced. One end of the specimen rested on the bearing block, and the other end extended approximately 0.035 inch above the support blocks which represented an allowable compressive deformation of approximately 1.4 percent before the loading ram contacted the fixture. Lateral supporting forces were applied by driving the wedge a given amount between the housing and spherical seat which compressed the grooved support blocks against the specimen faces. These compressive loads were reacted by tensile loads in the housing. The assembled fixture is shown in Figures 30 and 32.

A measure of initial lateral restraint on specimen compressive load was made by installing a specimen as previously described, and then removing the bearing block. The wedge was tightened an amount which had been previously determined necessary to prevent specimen buckling, and the compressive force required to slide the specimen between the grooved blocks was measured. This force was approximately ten pounds.

Rams having ground bearing surfaces of Class VII tool steel were used to support the compressive fixture and transfer load to the specimen. These rams were approximately five inches in diameter and 16 inches long. The bearing surface of the lower ram contained a 0.25 inch diameter alloy steel dowel pin on its vertical centerline. This pin fitted in the positioning hole drilled in the bottom of the compressive fixture shown in Figure 31, Part 4. The lower ram shown in Figure 32 was positioned and aligned on the platen of the testing machine so that the steel dowel pin was on the vertical centerline of the machine. A heating element, the function of which is discussed later, was also built into the lower ram.

The upper ram, provided with a pair of leveling plates, was attached to the movable crosshead of the testing machine. Parallelism of the ram bearing surfaces was initially adjusted by removing the steel dowel pin and bringing the rams close together with the testing machine movable crosshead. The leveling screws were adjusted until the gap between the surfaces was approximately uniform as determined by feeler gages. Additional adjustments, discussed later, were made to further insure uniform specimen loading.

Compressive specimen deformation was measured with the 1.50 inch gage length compressometer shown in Figure 32. The compressometer was comprised of an upper and lower yoke, each containing a pair of opposing knife-edges, adjustable transfer rods and a lever system for magnifying deformation. Machined slots in the compressive fixture housing and recesses in the support blocks provided clearance for the yokes and knife-edges to be fitted around the fixture. Knife-edges on the upper and lower yokes fitted into the test specimen gage-length edge notches at top and bottom, respectively, and were held in place by spring action of the yokes. Each knife-edge had an extension arm to which was attached a transfer rod. These transfer rods extended vertically downward parallel to the lower loading ram and actuated the lever system which was located on the testing machine platen. Transfer rods from the upper and lower knife-edges on one side of the specimen actuated one lever unit and an identical lever unit was actuated by the rods on the opposing knife-edges. Each lever unit had two pivoted beams, and a transfer rod terminated on each beam as shown in Figure 32. A differential transformer coil was mounted on the opposite end of one of the beams with the core being attached to the other beam. Relative motion between the transfer rods, resulting from specimen deformation, displaced the beams with respect to each other, and also displaced the differential transformer core with respect to its coil. Voltages from the differential transformers were demodulated, electronically averaged and autographically recorded versus load by the testing machine recorder. The compressometer output had a readability of approximately 20 microinches per inch with a maximum deviation from the least squares slope of less than 100 microinches per inch as determined by calibration using an extensometer comparator and precision gage blocks.

Design of the differential transformer circuit included a switching arrangement which allowed separate recording of each differential transformer output. This feature was used to periodically check and make fine adjustments of loading ram bearing plate parallelism. A specimen was loaded within its elastic range and the strain on each edge was measured by switching from one differential transformer to the other. Significant inequality of edge strains indicated that ram adjustments were necessary to improve specimen load distribution.

Compressive tests were performed in a 30,000-pound capacity Riehle universal testing machine, Model PS-30. Load was applied to produce a specimen strain rate of 0.006 inch per inch per minute which was controlled by a strain rate pacer driven by the compressometer.

Elevated-temperature test details and equipment were the same as those for room temperature except for the addition of a furnace. The furnace utilized quartz lamp heating elements and had a heated zone approximately 12 inches long. The transverse cross-section of the heated zone was elliptical and had major and minor diameters of nine and six inches, respectively. The furnace was attached to the testing machine movable crosshead, and was fixed with respect to the upper loading ram. Horizontal and vertical positioning of the furnace was such that the compressive fixture was at the approximate center of the heated zone when the upper ram was lowered to contact the test specimen. This furnace is shown in Figure 32. Since the upper ram was always in the furnace and the lower ram and test fixture were exposed to ambient temperature between tests; a heating element, built into the lower ram and controlled manually by a variac, was used to prevent excessive cooling of the ram between tests. The lower ram heating element was also used as an aid in maintaining the test specimen temperature within the desired limits during test.

Test specimen temperature was measured at the center and each end of the gage length with Chromel-Alumel thermocouples made from 28-gage selected and checked wire. The thermocouple measuring junctions were held in contact with the specimen surface by ceramic tubes which fitted snugly in the holes drilled in the compressive fixture. The center thermocouple was considered control and power to the furnace heating elements and lower ram heating element was controlled manually by variacs to give the desired temperature.

In order to verify that the compressive testing system was suitable for determining compressive stress-strain properties of sheet materials, qualification tests as outlined in Reference 1 were performed using the previously described procedures. Six compressive specimens having a longitudinal grain direction were machined from a sheet of bare 0.070 inch thick 2024-T3 aluminum alloy. Compressive stress versus strain curves were recorded for each of the six specimens at room temperature, and the modulus of elasticity was determined for each by the least squares method using coordinates from the stress-strain curves. The moduli obtained were within ±3.8 percent of 10.6×10^6 psi which qualified the system at room temperature based on Reference 1 criterion of obtaining moduli of $10.6 \times 10^6 \pm 5$ percent. The modulus obtained for each specimen is in Table XXII. Elevated-temperature qualification specimens were machined from an 0.063 inch thick sheet of solution treated and aged Ti-4Al-3Mo-1V. Nine elevated-temperature tensile and nine compressive specimens were machined and three of each were tested at 400°F, 800°F, and 1000°F. Compressive and tensile moduli were determined by least squares method and compared at corresponding test temperatures. Compressive moduli obtained at 400°F and 1000°F were well within 5 percent of the average tensile modulus with no measured deviation at 400°F and 1.7 percent deviation at 1000°F. At 800°F only one of the three compressive moduli obtained was within the qualifying range of 5 percent; however, three other 800° compressive tests were selected at random from data obtained in the test program for 0.063 inch thick solution treated and aged Ti-2.5Al-16V and compared to corresponding tensile data. These comparisons showed a maximum compressive modulus deviation from the average tensile modulus of 3.2 percent. Moduli obtained for the elevated-temperature tensile and compressive tests are in Table XXII. Based upon the data obtained and the qualification criteria in Reference 1, the compressive testing system qualified for tests from room temperature to 1000°F.

Data Analysis

Compressive stress-strain data were obtained using the IBM data program described previously. All compressive data were computed using average specimen area determined from five measurements each of test section thickness and width.

The criteria used by Ramberg and Osgood in Reference 7 for selection of secant yield strength at 0.85 E and 0.70 E to compute the stress-strain curve shape factor, n, for aluminum alloys and chromium-nickel steels were not met for the four titanium alloys when using these secant yield strengths. Ramberg and Osgood found it desirable to select a secant yield strength at 0.70 E since this approximated the 0.2 percent offset yield strength for the aluminum and steel alloys. The 0.85 E value was selected since it was midway between 0.70 E and 1.0 E. For the titanium alloys the 0.85 E secant yield stress more nearly approximated the 0.2 percent offset yield strength for all test temperatures. This suggests that a secant value of approximately 0.85 E and a value approximately midway between 0.85 E and 1.0E be used for the titanium alloys; however, Ramberg and Osgood found it undesirable to use a secant slope greater than 0.90 E.

The 0.85 E and 0.70 E secant yield stresses and resulting shape factor may sufficiently define the titanium alloy stress-strain curves; however, comparisons were not made between experimental curves and curves computed using these parameters.

In some cases the shape factor, n, given in compressive tables of Volume 3, will not agree exactly with that which would be calculated by substituting the reported $F_{0.85}$ and $F_{0.70}$ values in the equation for n previously given. This condition exists because the computer used more significant figures than shown in the tables.

TABLE XXIII

QUALIFICATION OF COMPRESSIVE TEST EQUIPMENT

Material	Test Temp., °F	Test Type	Specimen No.	Modulus,(1) E, PSI x 10^{-6}	Qualification Range, PSI x 10^{-6}
2024-T3 Aluminum Alloy Sheet 0.070 Inch Thick	80	Compression	3 4 5 6 7 8	10.8 10.4 10.4 10.6 11.0 10.8	10.1 to 11.1
Solution Treated And Aged Ti-4Al-3Mo-1V 0.063 Inch Thick (Crucible Heat No. R4815)	400	Tension	QA1 QA2 QA3 Average	15.8 15.8 15.2 15.6	
		Compression	QB2 QB10 QB11	15.6 15.6 15.6	14.8 to 16.4
	800	Tension	QA4 QA5 QA6 Average	13.1 13.2 13.7 13.3	
		Compression	QB4 QB5 QB6	14.3 13.8 14.1	12.6 to 14.0
	1000	Tension	QA7 QA8 QA9 Average	12.1 12.2 11.6 12.0	
		Compression	QB7 QB8 QB9	12.1 11.8 11.9	11.4 to 12.6
Solution Treated and Aged Ti-2.5Al-16V 0.063 Inch Thick (Reactive Metals Heat No. 24814)	800	Tension	C8LA6-10 C8LA6-14 C8LA6-17 Average	12.6 12.5 12.4 12.5	
		Compression	C8LB6-4 C8LB6-10 C8LB6-12	12.8 12.2 12.8	11.9 to 13.1

(1) Average of least squares values for three loadings.

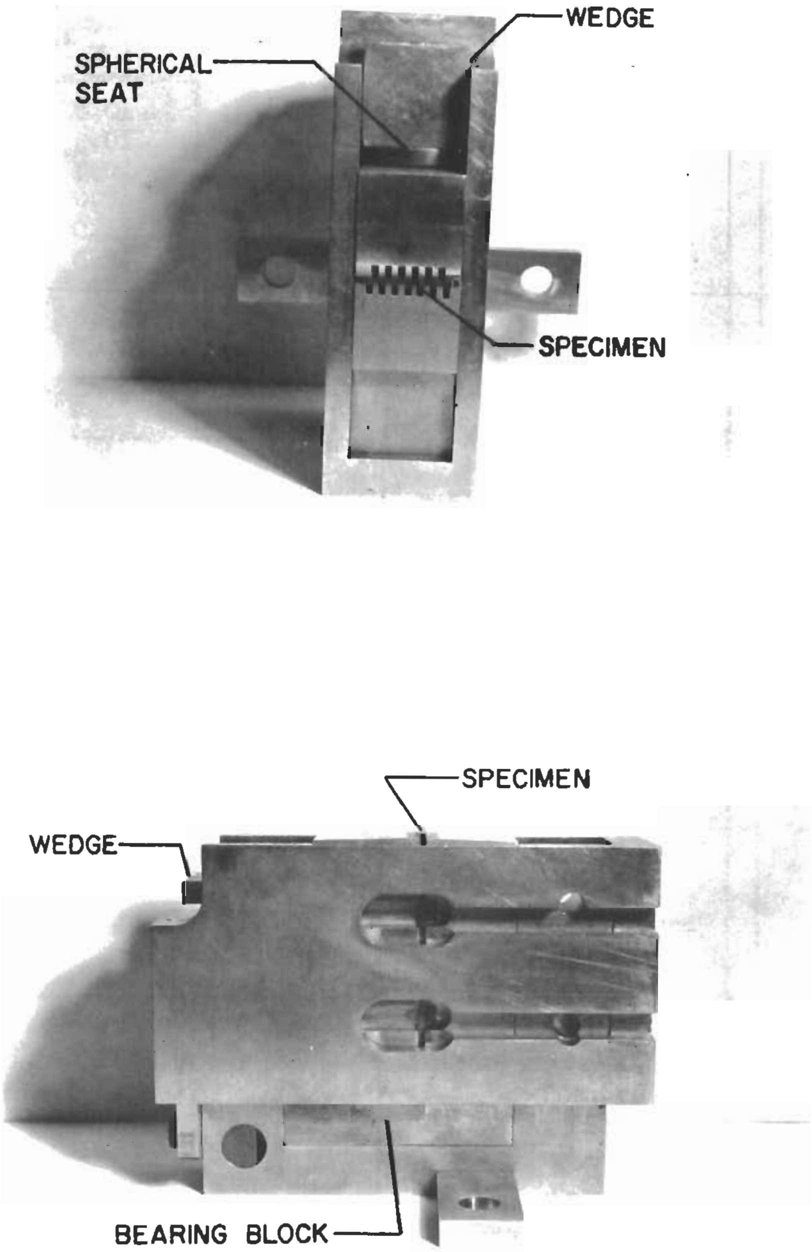
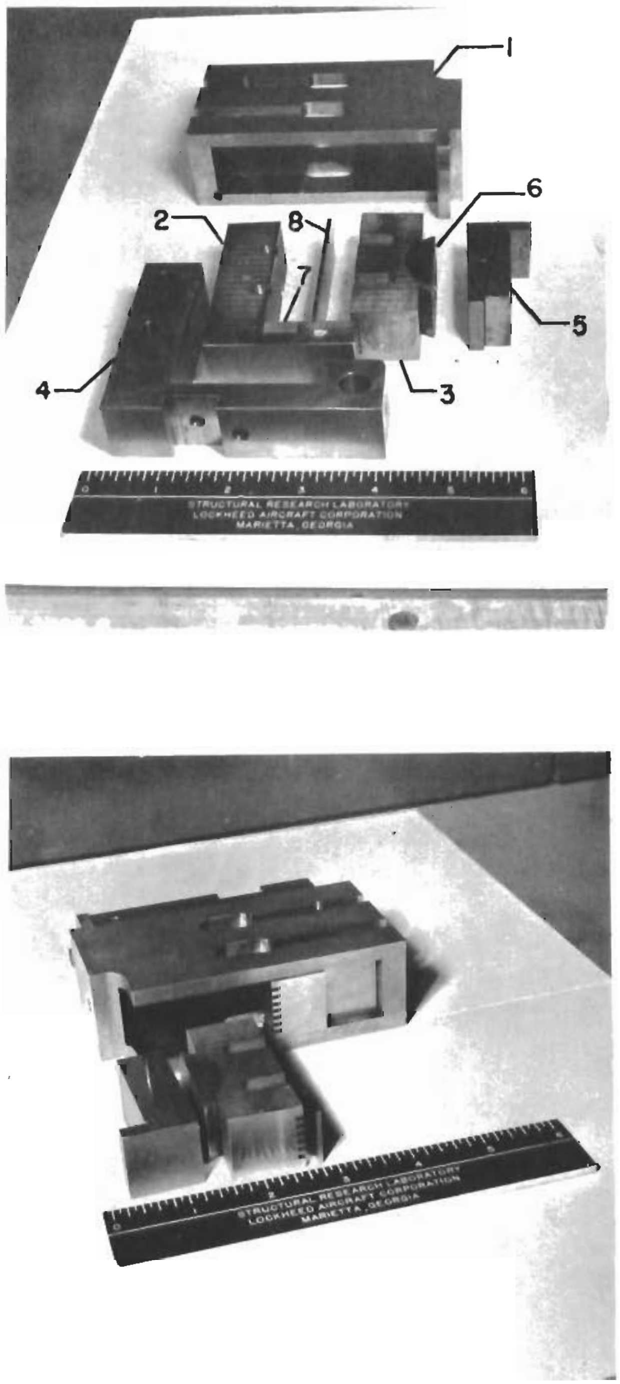


FIGURE 30- ASSEMBLED COMPRESSIVE TEST FIXTURE



1. Retainer
2, 3. Grooved Support Blocks
4. Spacer
5. Wedge
6. Spherical Seat
7. Bearing Block
8. Test Specimen

FIGURE 31 - COMPRESSIVE TEST FIXTURE COMPONENTS

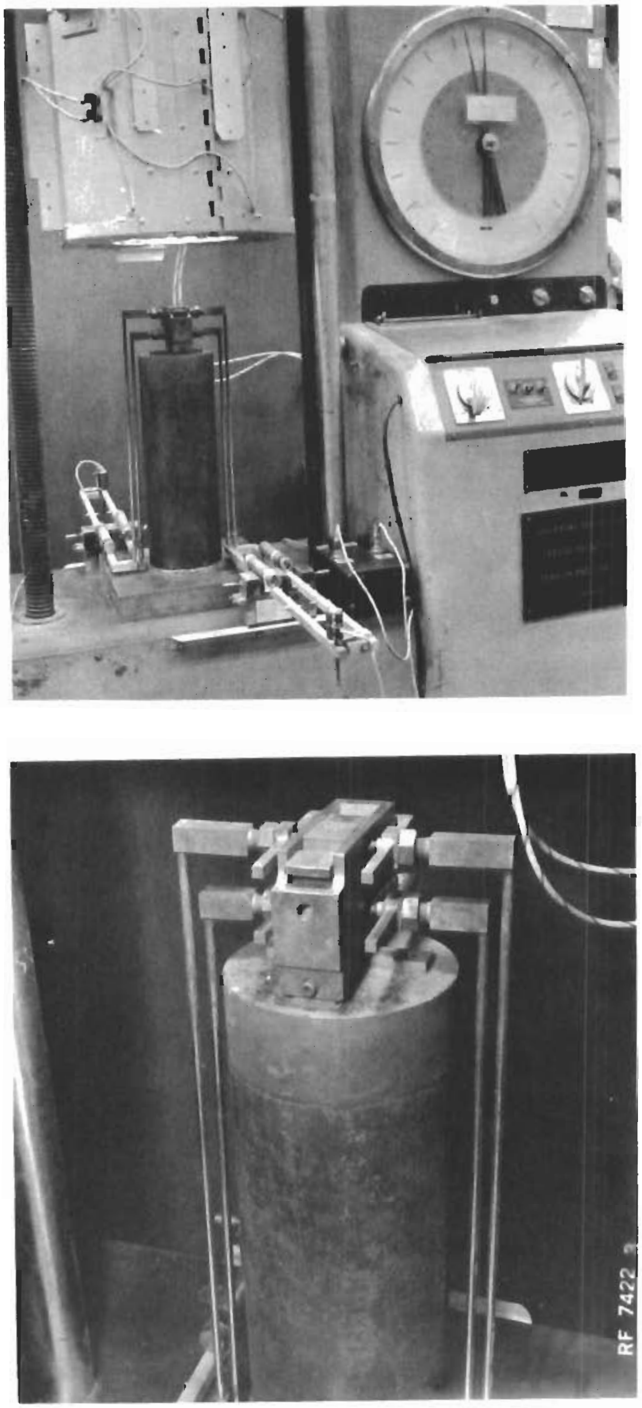


FIGURE 32- COMPRESSIVE TEST ARRANGEMENT

Crippling Tests

Test Specimens

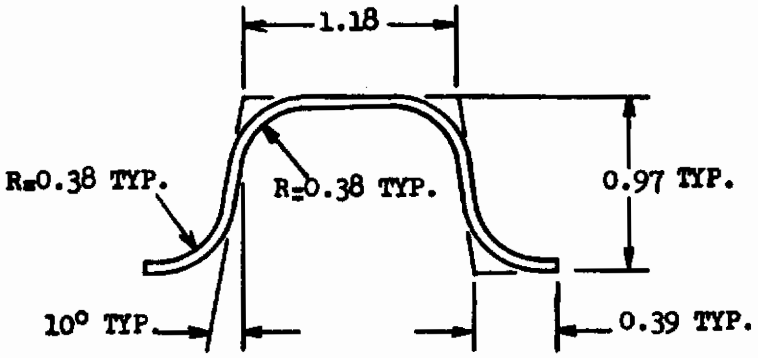
Preliminary evaluations necessary for forming crippling specimens were performed on 0.063 inch thick solution treated material for all four alloys. Two crippling specimen configurations, as shown in Figure 33, were used. Dimensions of these specimens were determined from those in Reference 1 by applying the ratio of the thicknesses; however, the flanges were turned out and the legs were formed at an angle to facilitate stacking during machining and aging. Longitudinal and tranverse bend tests were made in a conventional press brake on samples from each sheet of the four alloys to be used for crippling specimens. All alloys except Ti-6Al-4V were formable to radii in the 2t to 4t range. Results of the bend tests on Ti-6Al-4V indicated that a minimum radius of 6t was necessary to prevent excessive specimen rejection due to forming failures. In order to make crippling specimens of each configuration for all alloys as nearly identical as possible, a radius of 6t was used in the specimen designs.

After the specimens had been designed, evaluations were made for determining the blank widths required for forming each configuration. Longitudinal and transverse rectangular bend specimens approximately one inch wide by two inches long were machined from each sheet of the four alloys to be used for crippling specimens. These bend specimens were used to determine the bend factor for both grain directions of each alloy. The equation from Reference 8 relating bend factor, K, to width, L, of the specimen prior to forming is shown in Figure 34. L and t were measured for each specimen after which they were bent through an angle of approximately 90° in a conventional press brake. The dimensions shown in Figure 34 were measured for the bent specimens which provided sufficient information for determining the bend factor for each. Table XXIV gives the bend factors obtained for all four alloys. Each of the two crippling specimen configurations in Figure 33 was then divided into four segments, with each segment containing a bend. The equation in Figure 34 was solved for L for each segment using the appropriate bend factor from Table XXIV. Summation of L for the four segments gave the unbent width necessary to produce the desired specimen dimensions after forming.

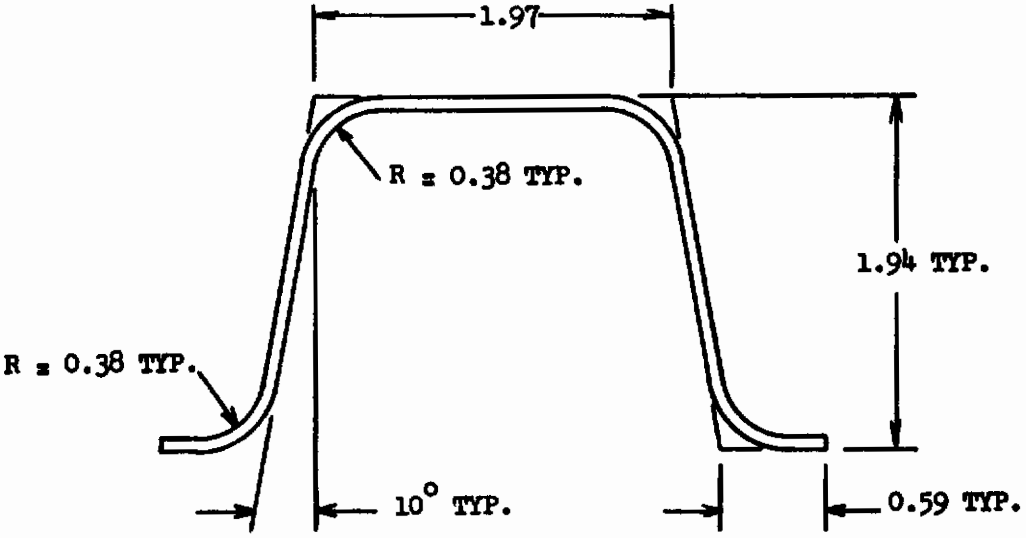
Several specimens of each configuration, alloy and grain direction were formed on a conventional press brake for preliminary studies on formability and spring back during aging. Some difficulty was encountered when forming the short outstanding element on the small crippling configuration. It was found necessary to first bend this element using a 0.750 inch diameter tool followed by a restrike with a 0.625 inch diameter tool in order to produce the desired shape.

Forming failures and cracks were experienced for all four alloys but more frequently for Ti-6Al-4V. Attempts were made to form acceptable replacement specimens for those that were rejected or broken during forming. As a result the available solution treated material, in some cases, was depleted before the desired number of specimens was obtained.

Investigation of spring-back during aging showed that formed specimens of all alloys except Ti-2.5Al-16V maintained their shape satisfactorily during the aging process without restraint or support being required. A restraining fixture was necessary for Ti-2.5Al-16V since spring-back during aging resulted in unusable specimens as shown in Figure 35. Several restraining methods were tried in resolving this problem and the one



CONFIGURATION 1, LENGTH = 4.13

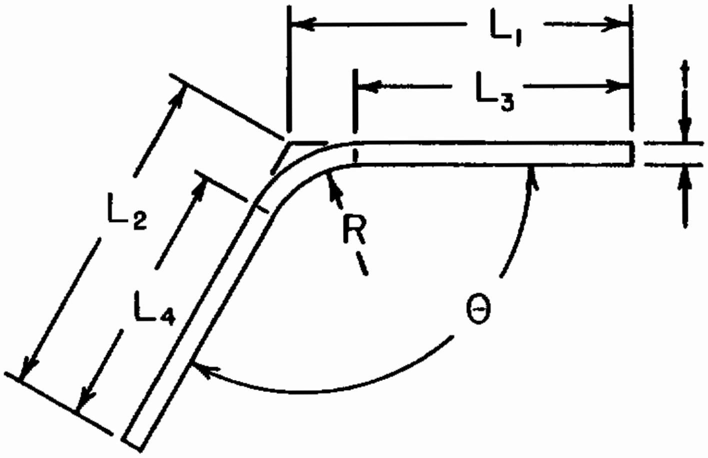


CONFIGURATION 2, LENGTH = 6.89

FIGURE 33 - CRIPPLING SPECIMENS FOR 0.063 INCH THICK SHEET

(All Dimensions In Inches)

used is shown in Figure 36. The shape obtained when using this fixture deviated somewhat from that desired since the section crown contained some curvature. This curvature shown in Figure 35 was measured for several specimens and was found to have a radius of approximately 2.5 inches.



$$L = L_1 + L_2 - 2(R + t)\cot\frac{\theta}{2} + \frac{\pi}{180}(R+Kt)(180-\theta)$$

FIGURE 34 - RELATIONSHIP OF WIDTH TO BEND FACTOR

Prior to aging, all formed specimens were cleaned in an aqueous solution of hydrofluoric and nitric acids, coated with Turco Pre-Treat to prevent surface contamination during aging, and placed in restraining fixtures where necessary. Aging was performed in a 2000°F capacity Leeds and Northrop forced air furnace. Aging times and temperatures used were those determined by the material producers on laboratory aged tensile specimens to give the desired properties and are in Tables IV, VIII, XII, and XVI. However, tensile and compressive specimens were aged along with the crippling material. After aging the protective coating was removed by an aqueous solution of Turco 4104 Activator and nitric acid.

Outstanding flange edges of the large sections were machined prior to forming. Flanges of the small sections were machined to size after forming since it was necessary that they be sufficiently wide during forming to prevent slipping from the brake die. All specimen ends were machined after aging, with those for the small section being machined individually. It was found that a faster machining rate and greater accuracy could be obtained for the larger sections by stacking several and then casting the ends in Cerrobend as shown in Figure 37. Milling of the entire group was then accomplished in one operation.

Tests Details

Crippling tests were performed in a 400,000-pound capacity Baldwin, Model BTE universal testing machine. The loading rams used were those previously described for compressive tests. Ram installation was identical to that for compressive tests, and parallelism of the bearing plates was checked and adjusted in the same manner. Since no extensometers were used, the deformation rate was maintained at 0.005 inch per minute per inch of specimen length to failure by monitoring testing machine head travel.

A Lockheed design furnace utilizing electrical resistance type heating elements and forced air was used for testing at elevated temperatures. Prior to performing elevated temperature tests, temperature distribution surveys were made for both specimen configurations. For these surveys, 28-gage Chromel-Alumel thermocouples were spot welded to the specimens at locations shown on the figure in Table XXV, where results of the surveys are presented. In order to obtain the temperature distribution reported, it was necessary to sandwich a fused quartz plate having parallel ground faces between each ram and its bearing plate. This reduced conductive heat loss from the specimen and allowed the specimen ends to be maintained at approximately the same temperature as the center.

Three 28-gage Chromel-Alumel thermocouples were mechanically attached to each specimen for testing at elevated temperatures, one on each flange at opposite ends and one on the crown at mid-length.

Data Analysis

The critical crippling load recorded for each specimen was that at which the specimen would sustain no additional load. Weight, length and cross-sectional dimensions were also recorded for each specimen. Critical crippling stress was determined using specimen area determined from weight, length and density measurements. Density was determined for each alloy at 77°F using compressive specimens weighed in air and in water by analytical balances.

Failure of the small specimens occurred primarily by crippling of one outstanding flange; however, some of these buckled across the entire section. Typical failures are shown in Figure 38. Most of the large specimens buckled across the crown as shown in Figure 39, with exception of Ti-2.5Al-16V which crippled in one or both outstanding flanges as shown in Figure 39.

TABLE XXIV

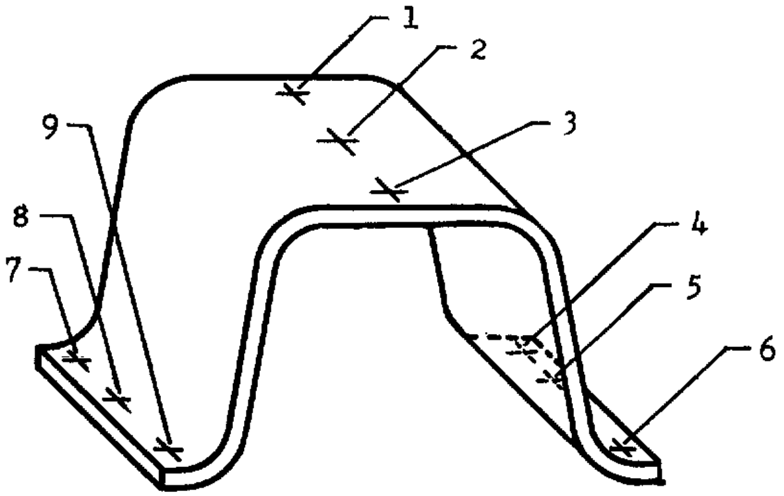
BEND FACTORS FOR 0.063 INCH THICK SOLUTION TREATED TITANIUM ALLOY SHEETS FOR CRIPPLING TESTS

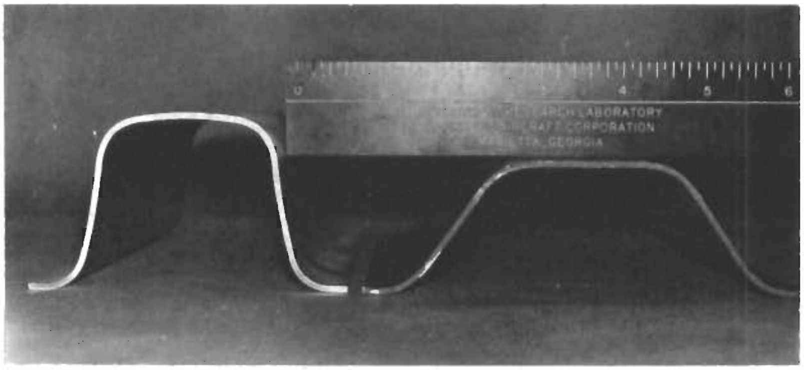
ALLOY	GRAIN DIRECTION	SPECIMEN NUMBER	BEND FACTOR, K
B120VCA	Longitudinal	A17L-1	0.226
		A17L-2	0.254
	Transverse	A17T-1	0.257
		A17T-2	0.250
Ti-6Al-4V	Longitudinal	B11L-1	0.291
		B11L-2	0.304
	Transverse	B11T-1	0.191
		B11T-2	0.357
Ti-2.5Al-16V	Longitudinal	C5L-1	0.202
		C5L-2	0.193
	Transverse	C5T-1	0.252
		C5T-2	0.184
Ti-4Al-3Mo-1V	Longitudinal	D2L-1	0.307
		D2L-2	0.315
	Transverse	D2T-1	0.248
		D2T-2	0.256

TABLE XXV

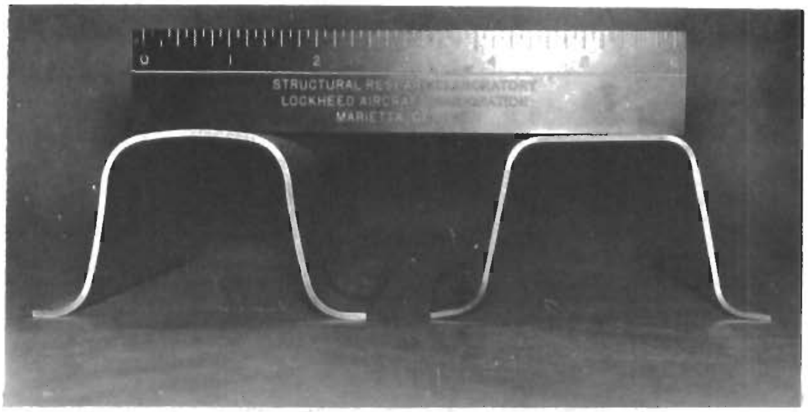
TEMPERATURE DISTRIBUTION SURVEY FOR CRIPPLING TESTS

Specimen Configuration	Control Temp. °F	Temperature, °F, at Diagram Location Number								
		1	2	3	4	5	6	7	8	9
1	200	201	202	203	197	198	199	201	203	196
	600	595	597	599	597	599	600	597	597	599
	800	800	805	805	796	800	800	797	800	803
	1000	1001	999	1000	999	999	1000	1000	1000	1005
2	200	200	200	200	200	199	200	201	200	198
	400	400	400	401	400	400	400	400	401	401
	600	602	602	602	602	600	602	602	601	602
	800	800	798	800	800	797	801	800	798	799
	900	905	905	905	905	903	905	905	904	904
	1000	995	995	995	994	995	995	996	995	994





Left to Right: Ti-2.5Al-16V Crippling Specimens Heat Treated With and Without Restraint.



Comparison of Heat Treated Ti-2.5Al-16V Crippling Specimen (Left) With That of Another Alloy. Note Curvature of Crown.

FIGURE 35 - CRIPPLING SPECIMENS AFTER AGING

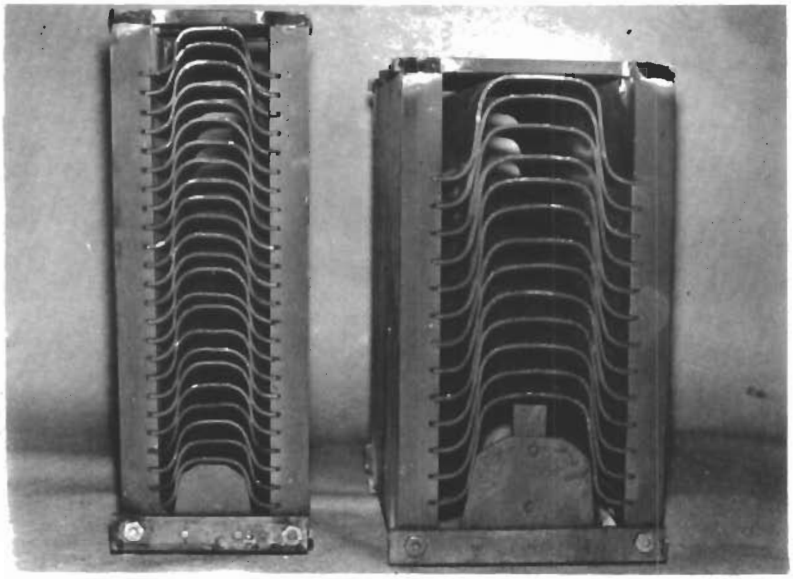
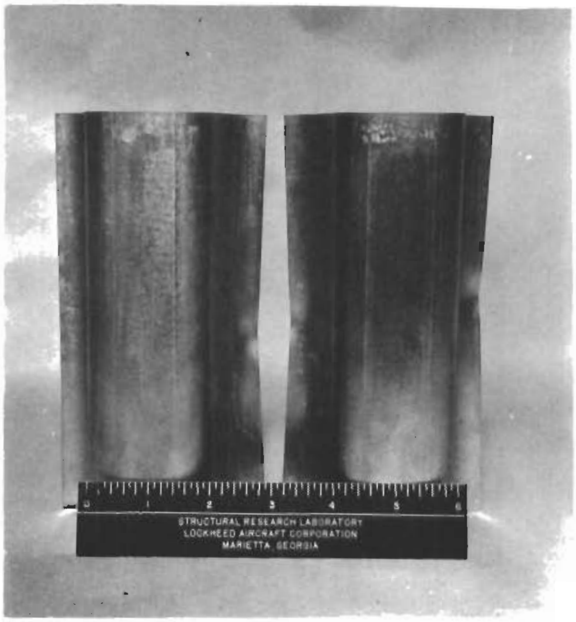


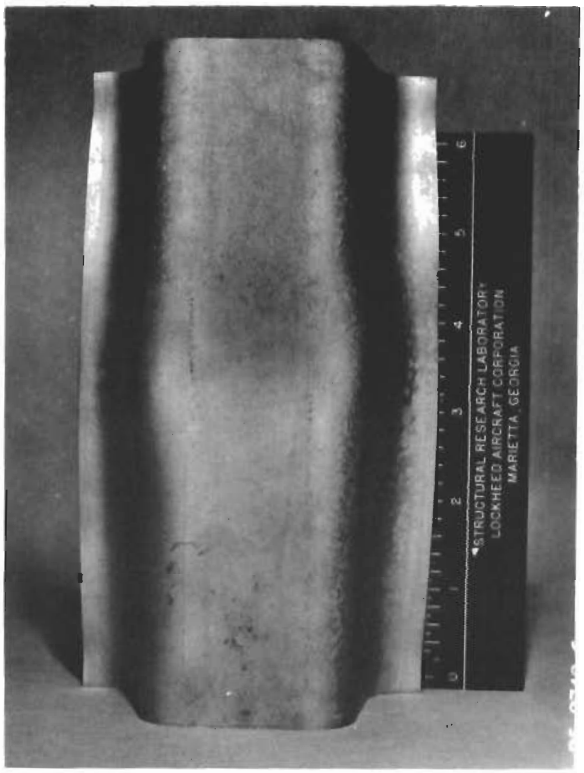
FIGURE 36 – RESTRAINING FIXTURE USED TO SUPPORT Ti-2.5Al-16V CRIPPLING SPECIMENS DURING AGING

FIGURE 37 – CRIPPLING SPECIMENS CAST IN CERROBEND FOR MACHINING

FIGURE 38 - TYPICAL FAILURES FOR CONFIGURATION 1 CRIPPLING SPECIMENS



Ti-2.5Al-16V



Ti-4Al-3Mo-1V, Ti-6Al-4V
and B120VCA

FIGURE 39 - TYPICAL FAILURES FOR CONFIGURATION 2 CRIPPLING SPECIMENS

Bearing Tests

Test Specimens

The standard bearing specimen is shown in Figure 40. It was modified slightly from that specified in Reference 1 to reduce the amount of machining and to increase the margin on the loading hole. Specimens were machined in a special jig in stacks of two or more depending on sheet thickness. The holes were line reamed and finished specimens were deburred and inspected for cracks or other imperfections before measuring. The bearing hole diameter was measured with precision drill blanks to tolerance using the blanks as "go", "no go" gages. Thickness was measured to 0.0001 inch in five locations in the region of the bearing hole and the average value was used in computing bearing area.

Deviation from flatness was checked on all specimens and the magnitude of the deviation was measured and recorded, but only the most severely bowed specimens were rejected since there were essentially none that were flat.

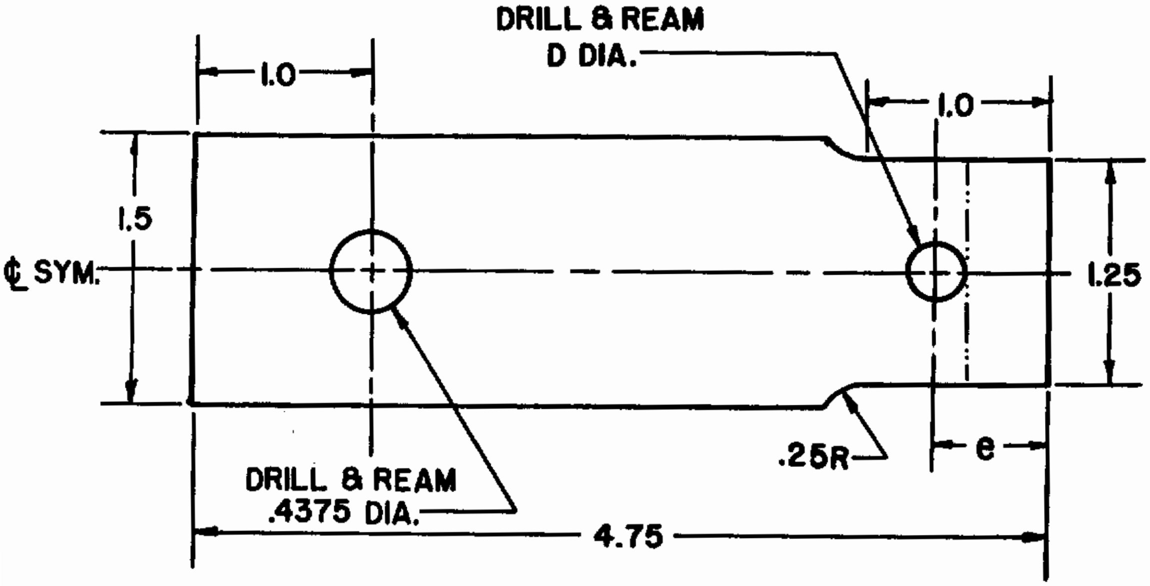


FIGURE 40 - BEARING SPECIMEN
(All Dimensions In Inches)

Test Details

Bearing tests were conducted in 30,000-pound capacity Riehle Model PS-30 and 120,000-pound capacity Tinius Olson universal testing machines using self-aligning type fixtures designed for use at both room and elevated temperatures. The photographs, Figure 41, give a general view of the device. It was constructed of high strength steel having good elevated-temperature properties and consisted of a pair of ground plates, 7/16 inch thick with a reamed bearing-pin hole, two clamping holes and an upper attachment hole. The specimen was snugly sandwiched between the plates with clamping bolts. A shim, equal to the specimen thickness, was also inserted between the plates to prevent excessive clamping, and the force required to withdraw the specimen was checked before mounting in the UTM and was not allowed to exceed approximately five pounds. The bearing pins were machined from different steels depending on the temperature range at which they were to serve. At the lower temperatures, 4340 steel pins heat treated to 160-180 ksi were used satisfactorily without the premature fracture which was experienced with some less ductile materials. At higher temperatures it was necessary to use pins machined from Vascojet 1000. All pins were made to tolerances consistent with those required for the bearing-pin hole diameter.

The bearing fixture was attached to the upper crosshead of the testing machine through a spherically seated clevis, and a similar arrangement attached the specimen directly to the lower crosshead.

Bearing deformation was measured using averaging, differential transformer extensometers (Baldwin-Lima-Hamilton Model PSH-8MS) with modified knife-edges and transfer arms. The output from the extensometer was autographically recorded on a null balance recorder. The instrument was calibrated to meet ASTM Class B requirements and was used with a readability of 50 microinches. In positioning the extensometer, the upper transfer arms attached to countersunk pivot points in the bearing jig and the lower arms were mounted on the edge of the specimen with "V"-notch knife-edges located on a line tangent to the loaded side of the bearing-pin hole in Figure 40. The total deformation measured by the extensometer included some elastic deformation of the jig and bearing pin.

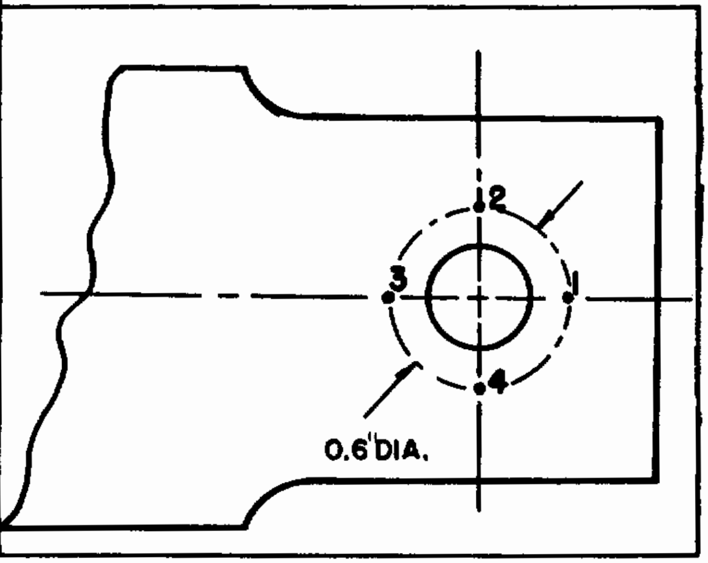
Bearing load was applied to give a constant deformation rate of approximately 0.008 inch per minute as controlled with a strain rate pacer driven by the extensometer. This value was selected since it resulted in reaching bearing yield stress in about the same lapsed time as was required to reach tensile yield stress. After bearing yield was reached, the head travel of the testing machine was readjusted to approximately 0.1 inch per minute.

Elevated-temperature tests were conducted in the same manner as the room-temperature tests with the addition of the furnace, control and temperature recording equipment. Lockheed designed, cylindrical furnaces having eight 500-watt quartz lamps as heating elements were used. Temperature was reached in approximately one-half the time required for the previously described resistance furnaces with equal precision of control. Furnace power was supplied and controlled by a Lindberg saturable core reactor and Wheelco controller, and the multiple furnace arrangement and temperature recording equipment, as described for tensile tests, were used. A preliminary, detailed examination of temperature distribution was conducted on a bearing specimen to verify compliance with requirements. Four 28-gage Chromel-Alumel thermocouples of calibrated wire were mounted in the locations indicated in the diagram in Table XXVI. The thermocouple beads were held in contact with the specimen surface by ceramic tubes which fit tightly in holes drilled through the bearing jig. The specimen was mounted in the furnace and a Leeds and Northrup No. 8662 Portable Precision Potentiometer was used to measure temperature after 1/2 hour stabilization. The results of the survey at six temperature levels are given in Table XXVI.

TABLE XXVI

TEMPERATURE DISTRIBUTION SURVEY FOR SHORT TIME BEARING TESTS

Control Temp., °F	Temperature, °F, at Diagram Location Number			
	1	2	3	4
200	198	198	199	199
400	402	401	400	401
600	596	595	592	596
800	799	798	798	799
900	900	898	897	899
1000	1002	1002	1001	1003



Based on the previous distribution, specimen temperature was measured by two thermocouples located at point 1 (diagram Table XXVI), one on each side of the specimen, inserted through the jig and held in place by ceramic tubes.

Data Analysis

The properties obtained were bearing yield stress (F_{bry}) and bearing ultimate stress (F_{bru}). Bearing area for the computation of stress was defined as the product of specimen thickness and bearing-pin diameter.

The autographically recorded load-deformation curves were used for the determination of bearing yield stress (F_{bry}) at a value of permanent deformation equal to two percent of the bearing-pin diameter.

In addition to F_{bru} and F_{bry} another value of stress, F'_{br}, was determined to quantify a type failure, described below, which was characteristic for some of the specimens.

Fracture of the specimens occurred primarily in shear tear-out (shown in Figure 42), tension across the minimum section or a combination of the two. In some cases, however, prior to final failure the load dropped abruptly, as much as 20 percent before increasing to ultimate. Figure 43 shows a typical curve exhibiting this phenomenon. In examination of the failed specimens, it was observed that fracture, characterized by a crescent shaped wedge of material being sheared from the bearing-pin hole at an angle of approximately 45° through the thickness, took place and resulted in the observed load decrease. The remaining bearing area was greatly reduced, approaching a knife-edge condition and in some instances caused pin failure by bending and cleavage. In other cases, the load increased beyond the load drop and a typical fracture pattern was noted with the value of F_{bru} obtained being consistent with normal failures. The magnitude of F'_{br} is, therefore, reported in the tabulated results of volume 3 since it demonstrates the value which would constitute effective failure of a joint.

Attempts at varying test technique to induce or inhibit this type failure were made and led to the conclusion that simple test parameters such as clamping pressure of bearing plates were not responsible. Examination of the data indicated that this type failure occurred most frequently in transverse specimens of Ti-6Al-4V at values of e/D = 2.0.

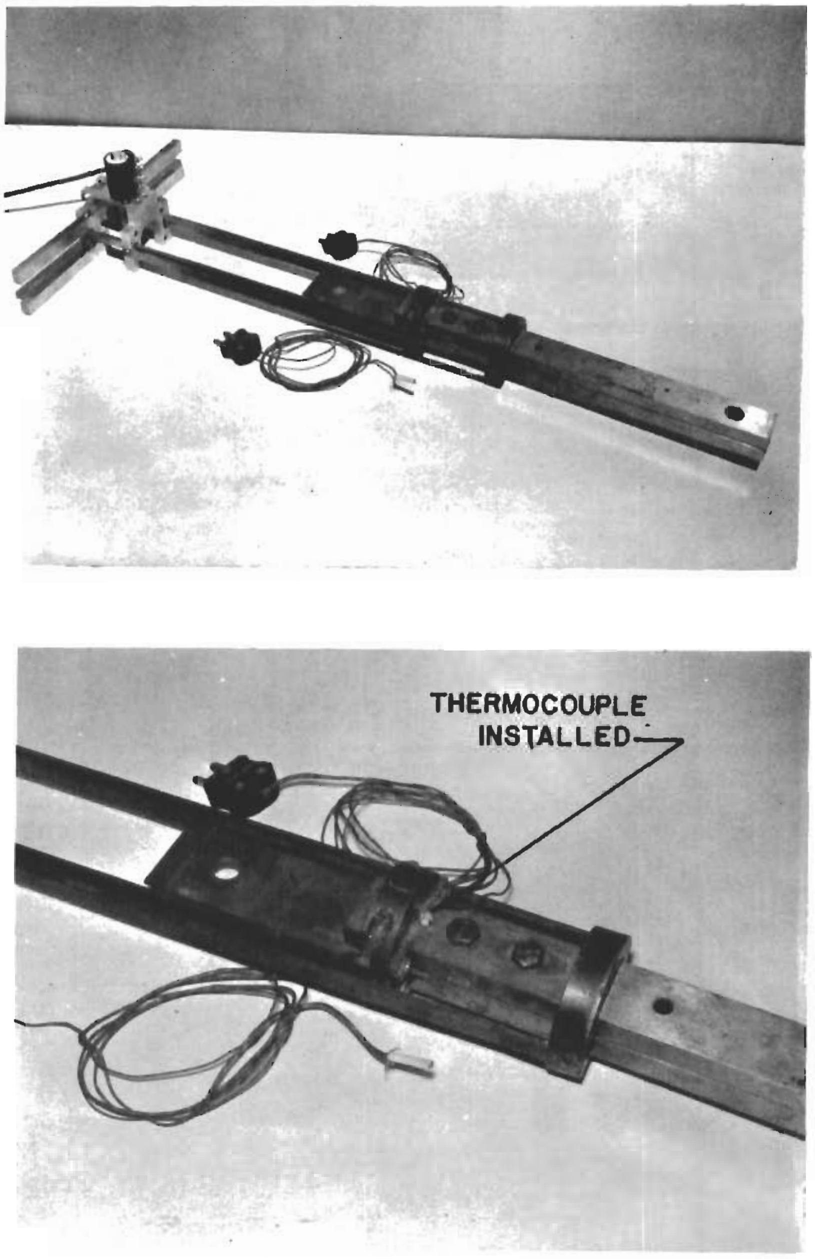
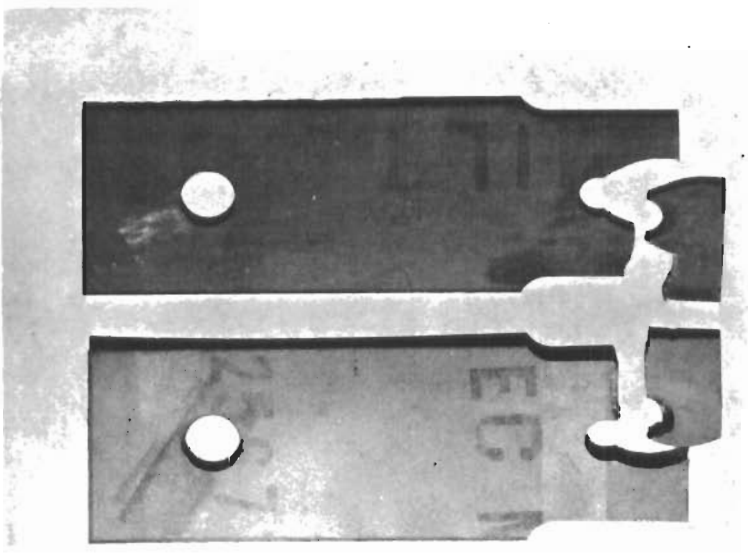
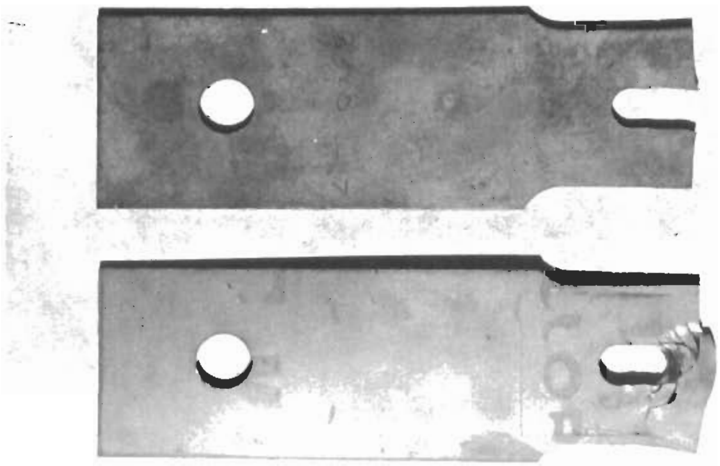


FIGURE 41 - ROOM AND ELEVATED TEMPERATURE BEARING TEST FIXTURE AND EXTENSOMETER



Longitudinal Sp. No. C2LD1-4, Ti-2.5Al-16V, tested at 80°F, with e/D = 2.0

Transverse Sp. No. B5TD1-41, Ti-6Al-4V, tested at 80°F, e/D = 2.0



Longitudinal Sp. No. B5LD8-7, Ti-6Al-4V, tested at 1000°F, e/D = 1.5

Transverse Sp. No. B2TD3-37, Ti-6Al-4V, tested at 400°F, e/D = 2.0. (Similar to shear failures from this heat, see 2nd Progress Report)

FIGURE 42 - ROOM AND ELEVATED TEMPERATURE BEARING FAILURES

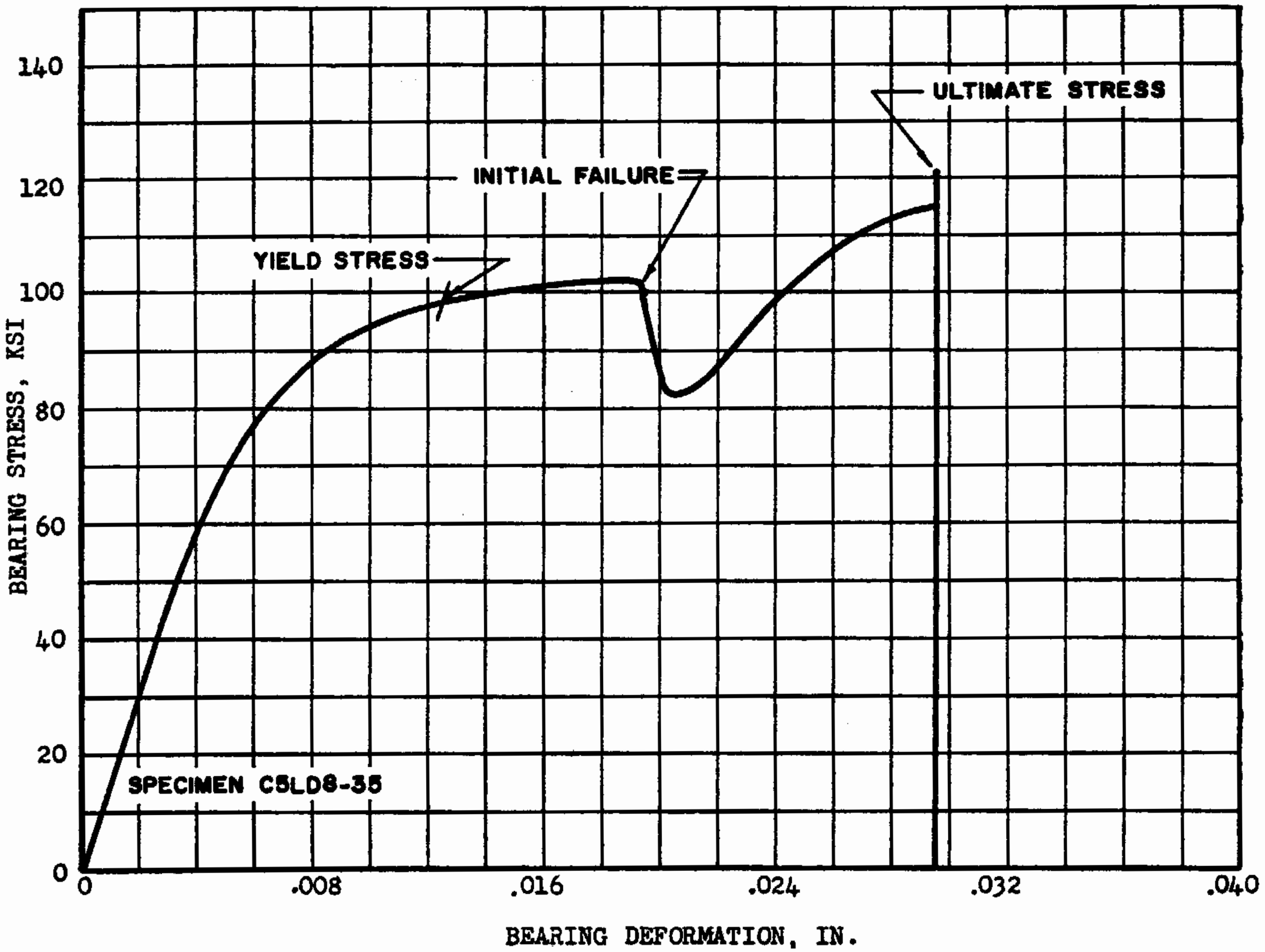


FIGURE 43 - BEARING STRESS-DEFORMATION CURVE SHOWING EFFECT OF EARLY FAILURE IN THE BEARING-PIN HOLE. Ti-2.5Al-16V, 0.063 INCH THICK, e/D = 1.5, TEST TEMPERATURE 1000°F.

Single Shear Tests

Test Specimens

Single shear specimens were machined to the configuration shown in Figure 44. Edges of these specimens were not machined, but were in the "as sheared" condition. Burrs were carefully removed from the shear-slot section terminal holes using No. 400 emery paper. After cleaning, these holes were inspected microscopically to determine if cracks existed around their circumference.

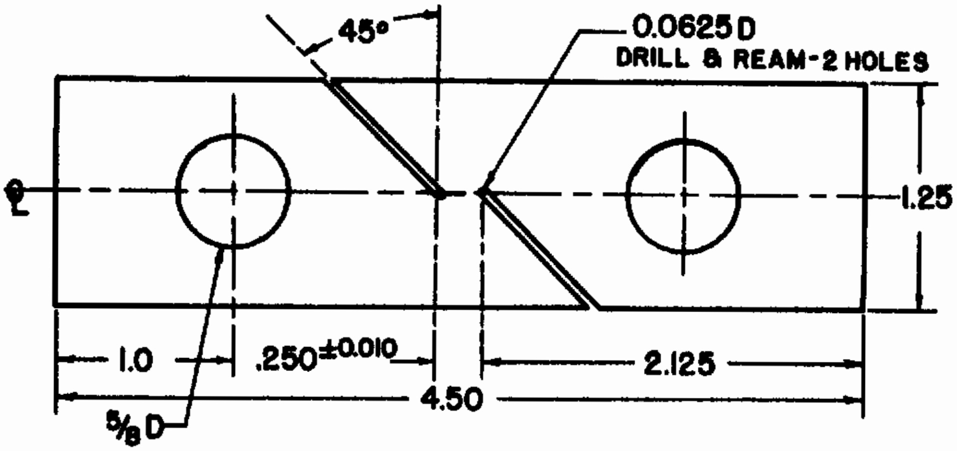


FIGURE 44 - SINGLE SHEAR SPECIMEN
(All Dimensions In Inches)

Specimen thickness was determined by averaging three micrometer measurements made across the test section. Test section length was measured on each side of the sheet using a Bausch and Lomb optical comparator. The average of these two measurements was used as the shear length. All measurements of test section dimensions were made with an accuracy of at least ±0.0005 inch.

Test Details

Two universal testing machines were used for single shear tests; a 30,000-pound capacity Riehle, Model PS-30, and a 50,000-pound capacity Baldwin, Model FGT. Load was transferred to the specimen by a pair of steel straps attached at each end of the specimen by tool steel pins. The other ends of these straps were pinned to clevises which were in turn attached to spherically seated, testing machine loading rods. All specimens were tested to failure at a constant rate of testing machine head travel of 0.1 inch per minute.

Elevated-temperature specimens were heated and tested in a cylindrical type Marshall furnace. Furnace power was supplied and controlled by a Lindberg saturable core reactor and Wheelco controller. Specimen temperature was measured by two 28-gage Chromel-Alumel thermocouples which were mechanically attached to opposite sides of the specimen. Figure 45 shows the attached thermocouples and general loading arrangement.

Two problems were encountered in single shear testing. First, it was found that 0.020 inch thick single shear specimens buckled under load as shown in Figure 46, and frequently failed by tension-tearing at the highly stressed edge of the terminal hole. Elimination of buckling could probably have been accomplished by changes in specimen geometry, but test specimens had been machined and were dimensionally fixed. Consequently, a method was sought to reduce the possibility of tensile failures due to buckling without requiring modification of specimen design. It was found that lateral support which prevented initial buckling deflection was sufficient to accomplish this. Support was supplied by 0.063 inch thick doublers clamped on each side of the specimen as shown in Figure 47a, and the doublers were discontinuous across the shear plane so as not to carry longitudinal load. Since these doublers were clamped with two C-clamps the arrangement would not fit in the furnace; so, a system was incorporated using a single doubler which extended from the test section to the gripping hole on each side but on opposite ends of the specimen, as shown in Figure 47b. This system was clamped by the small thermocouple clamps previously described. Few tensile failures were observed using this procedure, and stresses for clamped and unclamped specimens that failed in shear were in good agreement. Initial testing of unsupported specimens had resulted in an incidence of more than 50 percent unsuccessful tests. Supporting reduced the rejection rate to approximately 12 percent at room temperature.

The second problem was the high incidence of tensile failures at room temperature of the types shown in Figure 48 for 0.063 and 0.125 inch thick specimens of all alloys except Ti-2.5Al-16V. These failures were the result of the concentrated tensile stress at the shear-slot terminal holes, and buckling as described for the 0.020 inch thick material was not a factor. Similar failures were obtained by Battelle Memorial Institute and reported in Reference 6 for 0.090 inch thick Ti-4Al-3Mo-1V at room temperature. Although specimen design was obviously satisfactory for some materials since tests of Ti-2.5Al-16V of the same thicknesses were performed without difficulty, additional study is indicated before the present geometry can be used for the more brittle metals. Tensile type failures were also less prevalent in 0.063 inch thick Ti-6Al-4V than for B120VCA and Ti-4Al-3Mo-1V. All specimens performed satisfactorily at test temperatures greater than 200°F where increased ductility reduced notch sensitivity.

Several procedures were attempted to eliminate tensile failures but only limited success was achieved. Doublers attached in a manner similar to that described for the 0.020 inch thick sheet were used to redistribute the load path around the terminal holes. The doublers were clamped tightly onto the specimen with small C-clamps. For Ti-4Al-3Mo-1V, some increase was attained in the number of successful shear failures using this method, but B120VCA was not benefitted. However, doublers were used for most room-temperature tests of these alloys, but only after an investigation was conducted to determine if any measurable effect on ultimate shear strength was introduced. This was accomplished by testing ten specimens of 0.125 inch thick Ti-2.5Al-16V from each grain direction, five with doublers and five without doublers. Comparison of results showed no significant differences in strength.

Since some entire groups of tested room-temperature specimens were without a shear failure, it was decided to conduct some additional tests with a modified specimen geometry. As shown by Battelle in Reference 6, tensile failure was a function of the W/h ratio (where W is 1/2 the specimen width and h is the distance between the shear holes along the longitudinal axis). For the specimen specified for this program, W/h was equal to 4.0; so, several specimens of B120VCA were machined with W increased to give W/h = 5.7. All of these failed in tension. Finally, a group of B120VCA specimens 0.063 and 0.125 inch thick were machined with W/h made equal to 5.7 by decreasing h. A majority of these failed in shear, but no evaluation was made to determine the limiting minimum distance between the terminal holes before measurable effects on strength would be observed.

On most of the specimens that failed in tension, it was noted that the shear plane was plastically deformed, as shown in Figure 49, and observation of the testing machine loading rate indicated that load was approaching or had possibly reached the ultimate shear stress of the material before tensile fracture. In these cases, dividing the maximum load by the shear area usually resulted in a value of shear stress within the range of scatter of those specimens from the same group that failed in shear.

Data Analysis

Ultimate shear strength was determined by dividing the maximum load indicated by the testing machine by the product of average thickness and average shear length. Each specimen tested using doublers or having a W/h ratio different from that shown in Figure 44 is noted in the single shear tables of Volume 3.

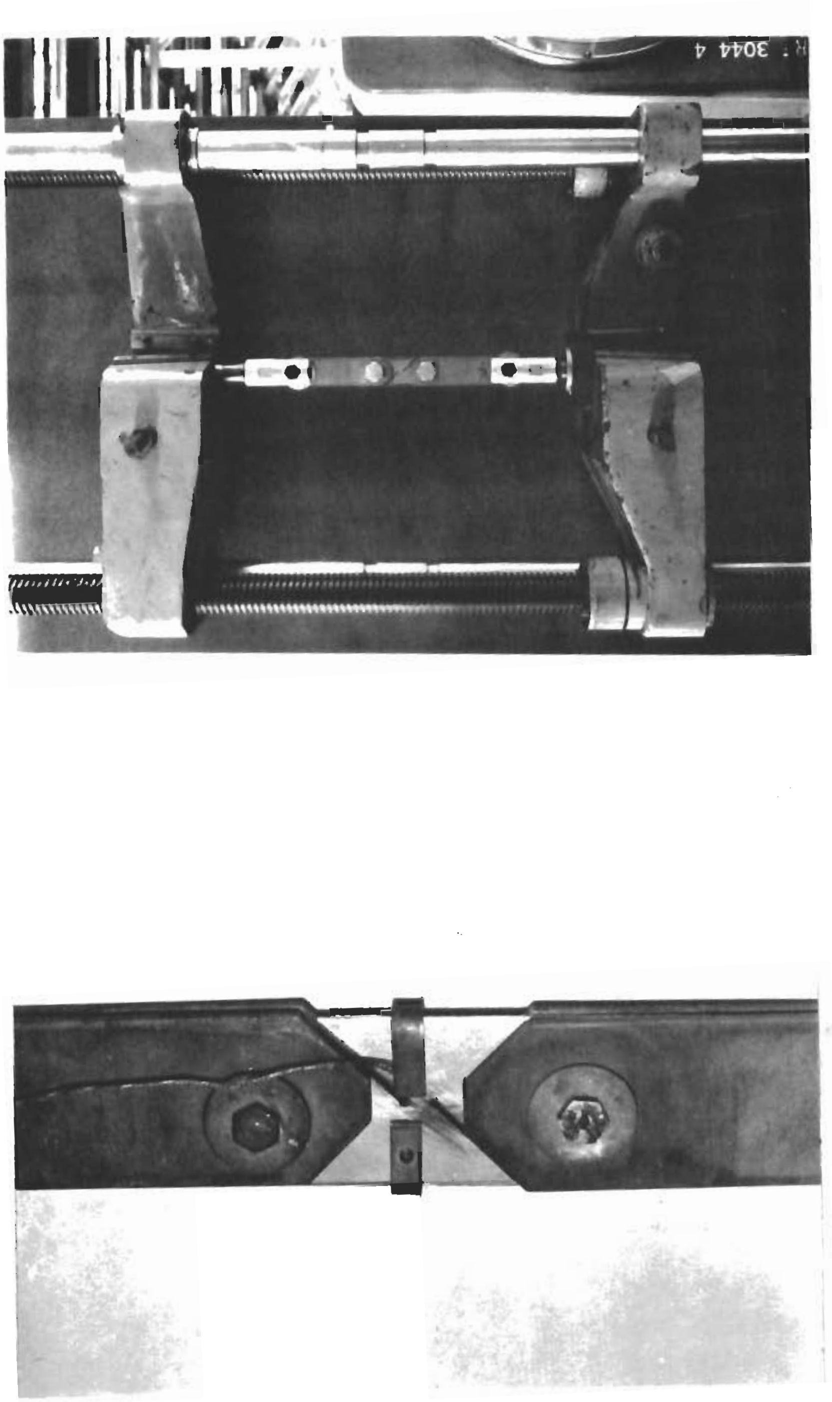


FIGURE 45 – SINGLE SHEAR LOADING ARRANGEMENT

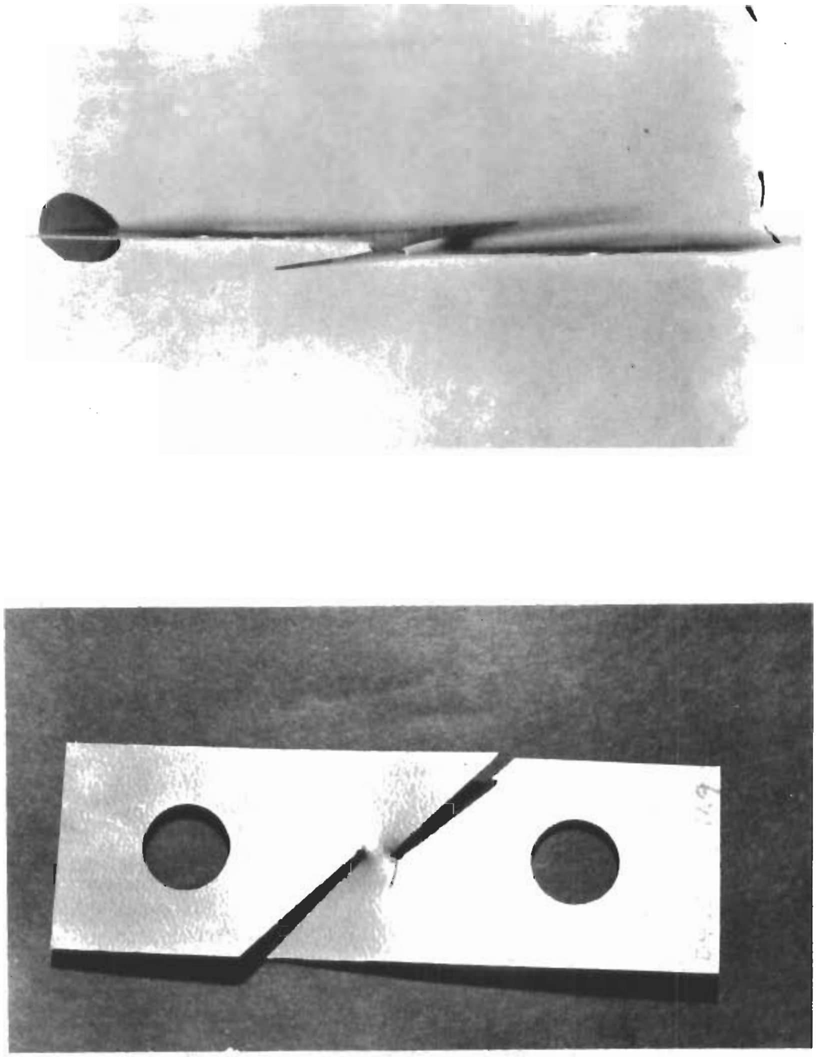
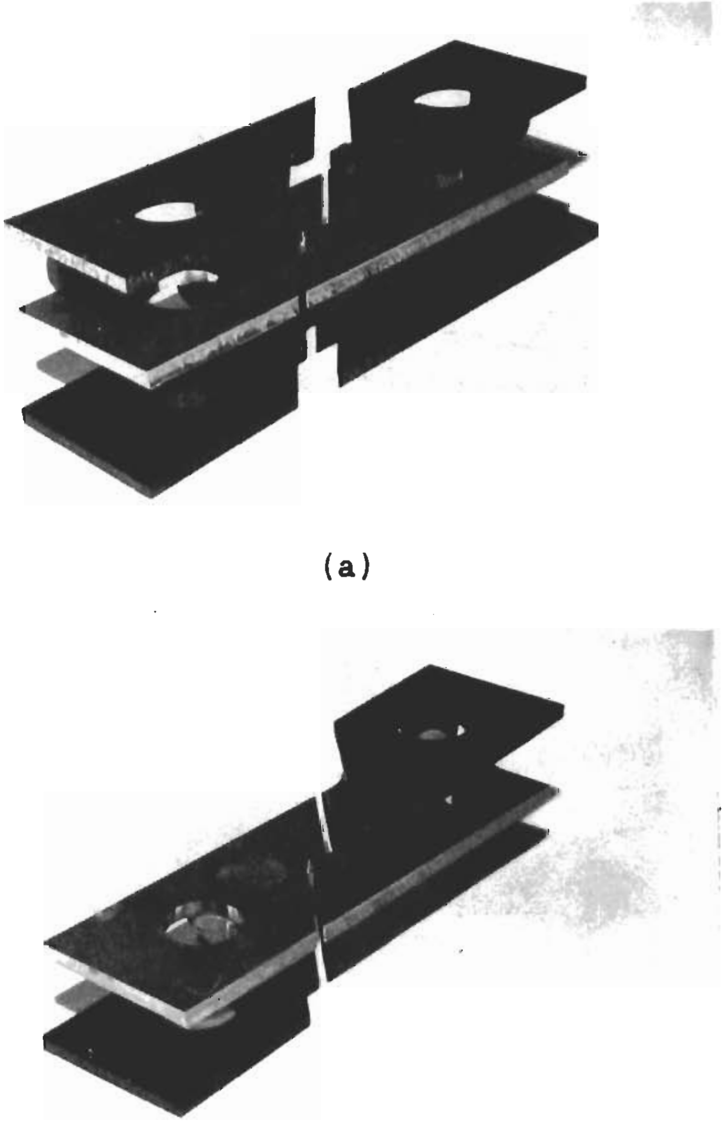


FIGURE 46 - BUCKLED SHEAR SPECIMEN, 0.020 INCH THICK WITH TENSION-TEARING FROM TERMINAL HOLES



(a)

(b)

FIGURE 47 - EXPLODED VIEW OF SHEAR SPECIMENS WITH TWO TYPES OF DOUBLERS

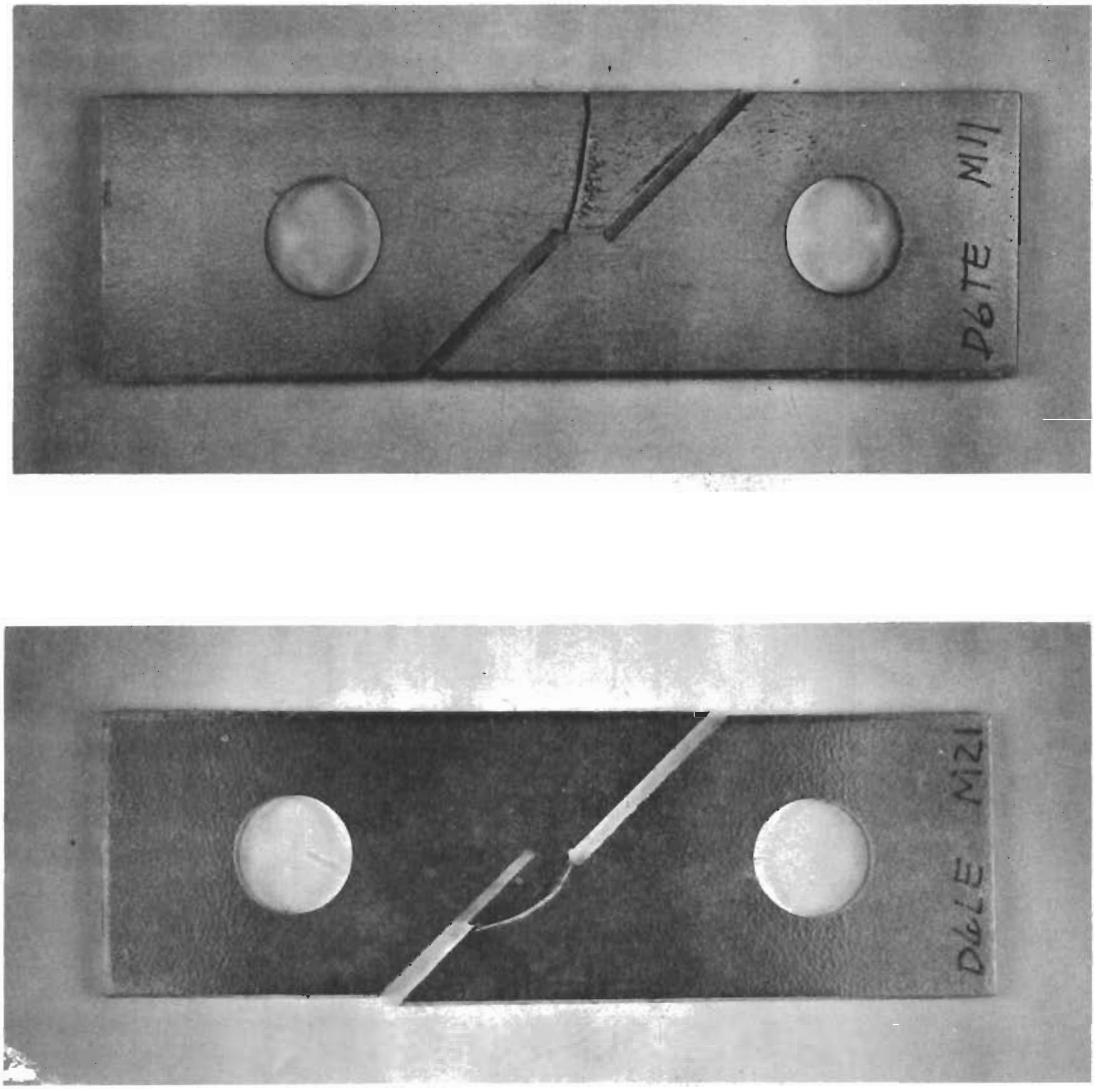
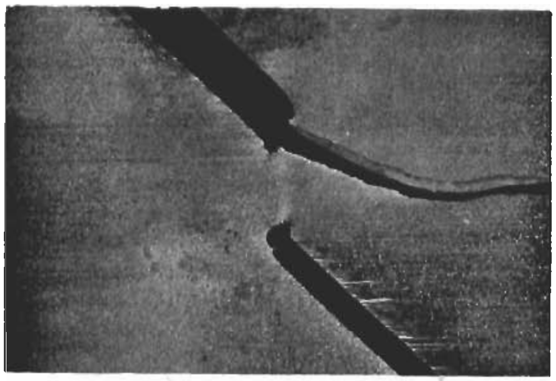


FIGURE 48 - TYPICAL TENSION-TEARING FAILURES OF 0.125 INCH THICK Ti-4Al-3MO-1V SINGLE SHEAR SPECIMENS



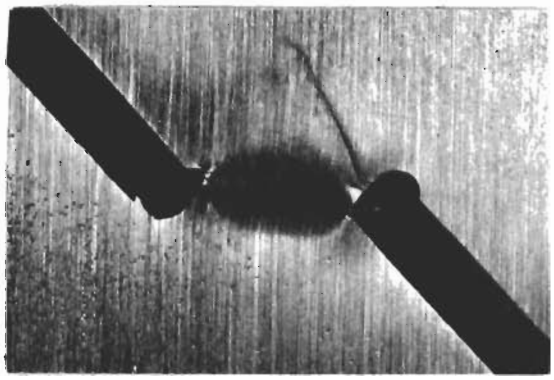


FIGURE 49 - PLASTIC DEFORMATION OCCURRING PRIOR TO TENSILE FRACTURE OF SINGLE SHEAR SPECIMENS

Double Shear Tests

Test Specimens

Figure 50 shows the cylindrical double shear test specimen which was machined from 0.125 inch thick sheet. A line was scribed on the end of each sheared blank so that orientation with respect to the thickness direction could be determined after machining the specimens. The sheared blanks were machined to within 0.001 inch of the required diameter and brought to final size by polishing with emery cloth.

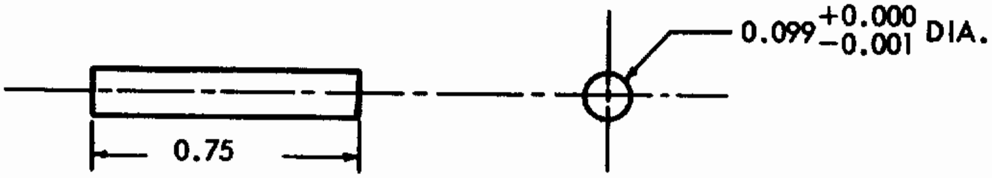


FIGURE 50 - DOUBLE SHEAR SPECIMEN

Identification was maintained by keeping each specimen in an individual, serialized envelope when not being measured or tested.

Microscopic inspection of the specimens was made and diameter for area determination was measured at three locations along the length and averaged.

Test Details

Double shear tests were performed in a 50,000-pound capacity Baldwin-Lima-Hamilton, Model FGT, universal testing machine. Load was applied to the double shear fixture shown in the photograph, Figure 51, and in sketch, Figure 52, through spherically seated clevises. Design of the fixture was such that three specimens could be soaked simultaneously at elevated temperature but loaded individually. This fixture, however, was used for room as well as elevated-temperature tests. Specimens were placed in the fixture and properly oriented with respect to the scribed line on the specimens ends so that the shear load was applied in the longitudinal or long transverse grain direction, depending upon orientation of the specimen with respect to the sheet. All specimens were tested to failure at a constant head travel rate of approximately 0.1 inch per minute.

Elevated-temperature specimens were heated and tested in a Marshall cylindrical furnace powered by a Lindberg saturable core reactor and controlled by a Model 407 Wheelco controller.

Specimen temperature was sensed by a 28-gage Chromel-Alumel thermocouple welded to the end of each of the loading plates adjacent to the specimen. The distance from the thermocouple bead to the center line of the specimen was approximately 0.25 inch. Figure 52 shows the location of the three thermocouples used during test and also the location of six other thermocouples that were used for a temperature distribution survey to verify uniformity. Results of this survey are given in Table XXVII.

Table XXVII

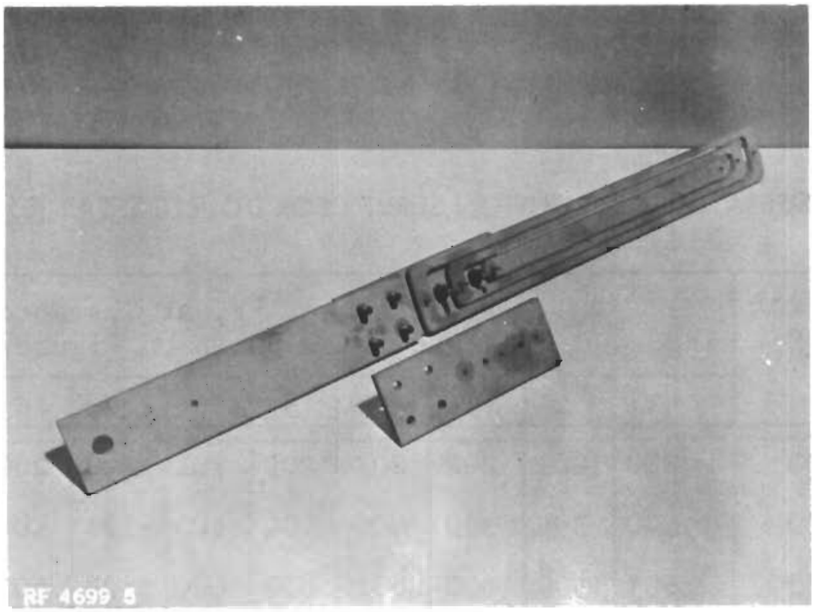
TEMPERATURE DISTRIBUTION SURVEY FOR DOUBLE SHEAR TESTS

Control Temp., °F	Temperature, °F, at Thermocouple Location Shown on Figure 4								
	1	2	3	4	5	6	7	8	9
200	200	201	202	201	201	201	200	200	200
400	400	398	399	400	400	400	398	400	401
600	603	599	600	602	600	600	598	601	601
800	801	799	799	801	800	801	797	800	801
900	901	898	901	901	899	900	898	901	900
1000	999	1000	1003	1000	999	998	1000	999	1001

Note: Test thermocouples were 2, 5, and 8.

Data Analysis

The ultimate shear stress for the double shear specimens was determined by dividing the maximum load indicated by the testing machine by twice the average area of the cylindrical specimen.



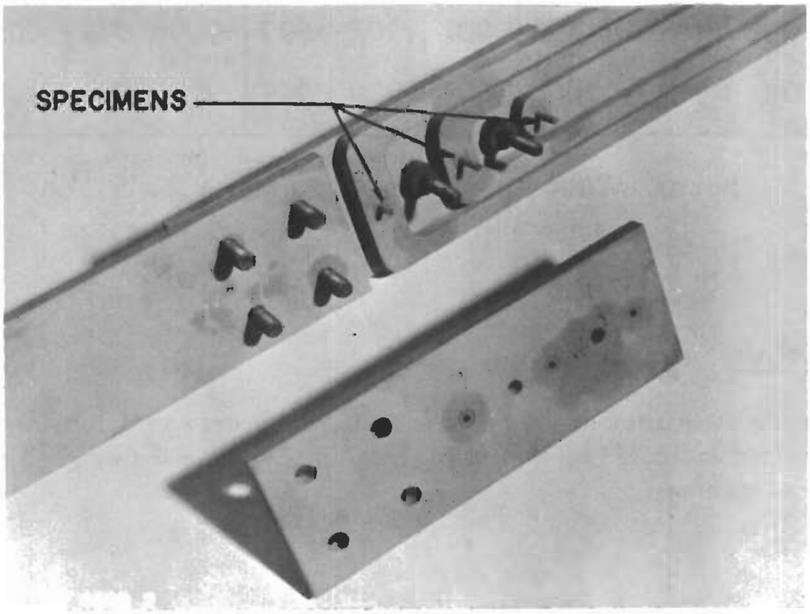


FIGURE 51 - ROOM AND ELEVATED TEMPERATURE DOUBLE SHEAR TEST FIXTURE

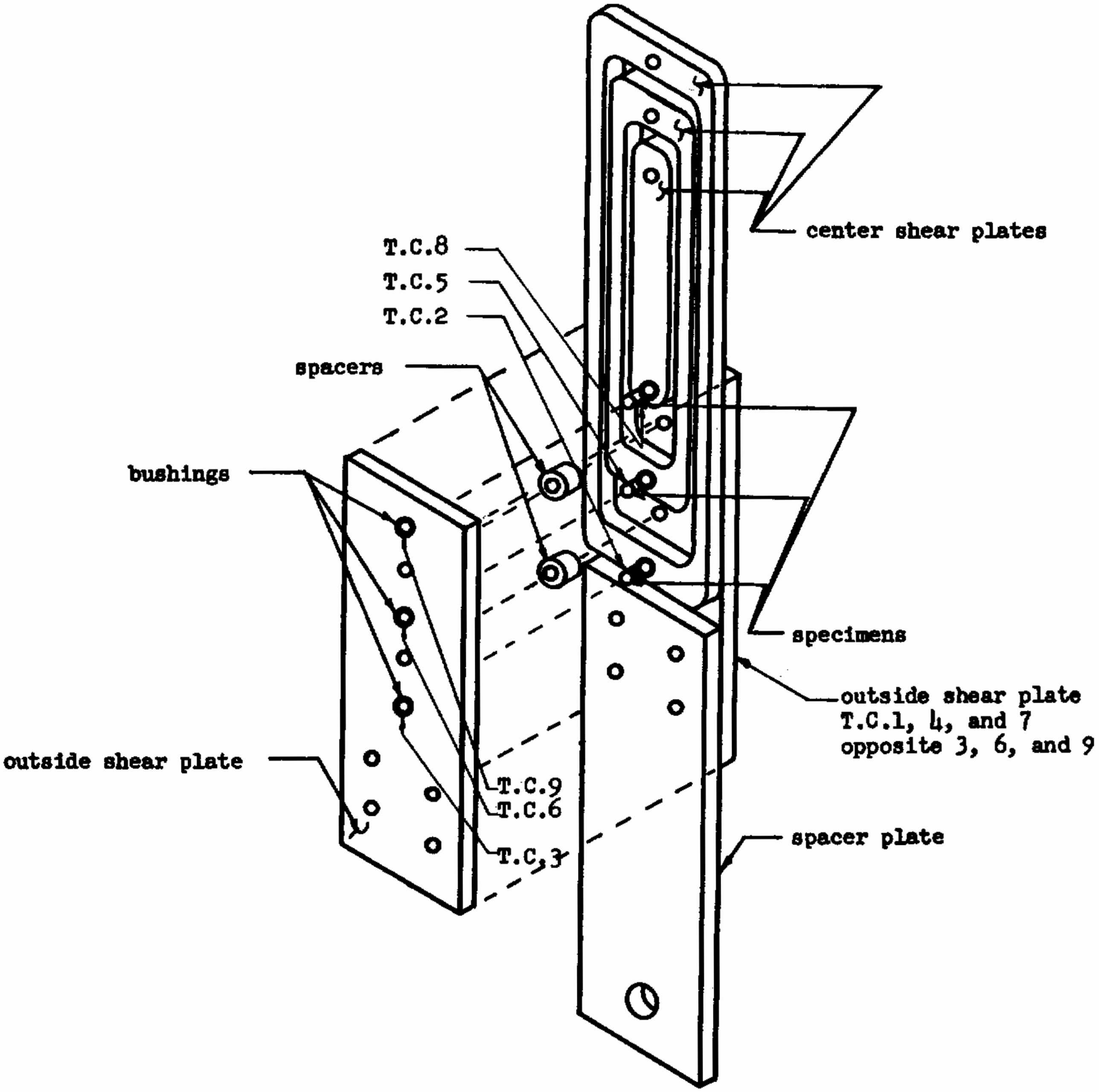


FIGURE 52 - DOUBLE SHEAR TEST FIXTURE

Fastener Joint Tests

Test Specimens

Joint specimen blanks were sheared from one 0.063 inch thick solution treated and aged sheet of each of the four alloys, and were systematically located to best sample the sheet as shown by the typical layout diagram in Figure 14.

Drawings of the joint specimens for 3/16 and 5/16 inch diameter fasteners are shown in Figure 53. These specimens had a W/D ratio of five (specimen width to fastener diameter ratio) whereas the bearing specimen in Figure 40, having a 5/16 inch hole diameter, had a W/D ratio of four. This ratio was increased for the joint specimens since many of the room-temperature bearing tests, predominantly for B120VCA, had tensile failures at the net section. It was expected that this condition would intensify as the test temperature was lowered, so the W/D ratio was increased to five for the joint specimens in an attempt to inhibit this type failure.

Machining of joint specimens was accomplished in a manner similar to that previously described for bearing specimens. Specimens were machined in special jigs in stacks of four in most cases, and the loading and fastener holes were line reamed. All 3/16 inch diameter fasteners were flush type and required a countersink. The 5/16 inch diameter fasteners were protruding head type; however, a small 90° countersink was required to insure proper head seating because of the close tolerance hole and the large fillet radius at the intersection of the fastener head and grip. This countersink is shown in Figure 53 on the specimen part labeled "Top" which was always in contact with the fastener head in the assembled joint. After machining was completed, the specimens were deburred, cleaned and inspected for cracks or other imperfections before the dimensions were measured. The fastener-hole diameters were checked to tolerance using precision drill blanks as "go" and "no go" gages. Specimen thickness was measured at four locations approximately equally spaced around the fastener-hole, and the average of these was recorded as being the actual sheet thickness.

All fasteners were Ti-6Al-4V purchased to NAS621 Procurement Specification. Table XXVIII contains information pertinent to all the fastener types used. Photographs of the fasteners along with the collar or nut used for each are shown in Figures 54 and 55.

Joint specimen assembly was performed in a tensile testing machine which had self-aligning loading rods and pinned clevises to fit the joint specimen loading holes. The two specimen parts were each attached to a clevis, the fastener was inserted and a load of approximately 50 pounds was applied. The NAS675-V2 bolts were then torqued to 180 inch-pounds, and the other fasteners were installed with a conventional lockbolt pull-gun or Hi-Lok gun depending upon the type of fastener. Both types of assembled 5/16 inch diameter joint specimens are shown in Figure 56.

Test Details

Fastener joints were evaluated at the cryogenic test facility which was remote from the main laboratory since special safety precautions were necessary when using liquified gases such as hydrogen, oxygen and nitrogen to create the desired temperature environment.

Tests were performed in a 50,000-pound capacity Baldwin-Lima-Hamilton universal testing machine, Model FGT. Load was applied to the specimen through spherically seated rods attached to pinned clevises at the specimen ends.

Joint deformation was measured using an averaging extensometer shown in Figure 57 which was especially designed for use at room and low temperatures. The extensometer design employed telescoping rods and tubes of stainless steel having removable knife-edges of hardened steel. Coil springs, attached across opposing knife-edges, provided a force sufficient to prevent knife-edge slippage. The instrument could be adjusted to have either a one or two inch gage length; however, a two inch gage length was used. Gage length was set by inserting a pin through holes drilled in each telescoping rod and tube. The pins were removed after the extensometer had been attached to the specimen. Joint deformation on each side of the specimen was measured with an SR-4 type strain gage transducer normally used with a Baldwin-Lima-Hamilton Model SRE extensometer, and the average was autographically recorded versus load. Calibration of the extensometer was performed to meet ASTM Class B requirements using an extensometer comparator and precision gage blocks.

Load was applied to the joints to give a constant deformation rate of approximately 0.015 inch per minute as controlled with a strain rate pacer driven by the extensometer. This rate was selected since it was comparable to the 0.008 inch per minute deformation rate used for the bearing tests. The loading arrangement for the joint specimens was such that at a given load the joint deformation was approximately twice that for a bearing specimen of equivalent hole size and edge distance. This rate was held constant until yield load for the joint was reached after which the head travel of the testing machine was adjusted to approximately 0.2 inch per minute.

Tests at -65°F, -100°F and -200°F were performed in the same manner as room-temperature tests with the addition of a system for cooling and controlling the test specimen temperature. Liquid nitrogen was employed as a coolant since the desired test temperature was equal to or greater than its boiling point. Safety precautions necessary for handling liquid nitrogen were not severe, and the liquid had a relatively high specific heat and low cost compared to other liquified gases capable of providing the required test temperatures.

A copper coil made from 1/4 inch diameter thin wall tubing was placed in a five liter capacity vacuum jacketed Dewar vessel filled with liquid nitrogen. The coil was approximately four inches in diameter and had ten turns. Dry nitrogen gas was passed through the coil and cooled. The cooled gas from the coil flowed into a specially designed test chamber where it was diffused and impinged upon the test specimen. The test chamber was slotted top and bottom for the specimen and had holes in the bottom for the extensometer rods. Several views of the test chamber are shown in Figures 57 and 58. The nitrogen gas line had a pressure regulator, solenoid valve and needle valve between the gas supply bottle and cooling coil. With the regulator set at a given pressure, gas flow was varied to provide the desired specimen temperature by adjusting the needle valve. Once this valve was set for a given temperature, subsequent tests were performed for this temperature by turning the solenoid valve off and on between tests with only small changes necessary in the needle valve setting. There was also a valve in the liquid nitrogen supply line to the Dewar vessel containing the coil. The Dewar vessel was refilled periodically to insure that the entire coil would remain submerged during the test. A schematic diagram of the system is shown in Figure 59. The lowest controllable temperature attainable with this system was approximately -300°F.

A survey was made to determine the temperature uniformity of a specimen at -65°F, -100°F and -200°F. A joint specimen for a 5/16 inch diameter fastener was machined for this purpose and instrumented with ten copper-constantan thermocouples of 28-gage selected and checked wire. The joint was assembled with an NAS675-V2 bolt in which a 1/32 inch diameter hole had been drilled in the center of the threaded end parallel to the bolt centerline. Termination of the hole was at the approximate center of the bolt grip. Four thermocouples were spotwelded symmetrically around the fastener hole on each side of the specimen at locations shown on the diagram in Table XXIX. One thermocouple was mechanically attached for control and one was inserted in the hole drilled in the fastener. Locations of these are also shown in Table XXIX. The thermocouple located inside the fastener and sealed from the test chamber atmosphere was used to aid in determining necessary soak time and determining if any appreciable temperature difference existed between the surface and center of the largest section of the fastener. Thermocouple EMF's were measured with a 24 channel Brown ElectroniK recorder having a measuring range of 100°F to -350°F and a readability of 1°F. This recorder was calibrated using a Leeds and Northrup No. 8662 potentiometer immediately prior to making the temperature survey.

Results of the temperature survey are in Table XXIX. Specimen temperature was easily controlled within ±3°F, and the temperatures at the nine locations were within ± 3°F of control. Recordings of temperature versus time showed the above temperature conditions were met after soaking five minutes at test temperature; however, a soak time of approximately ten minutes was used for the tests. A thermocouple of the type and size described for the survey was mechanically attached at the position indicated by ten on the diagram in Table XXIX for monitoring temperature during the tests. Design of the low-temperature test chamber was such that the specimen was located at approximately the same position with respect to the test chamber from one test to the next as can be seen in Figures 57 and 58. After completion of the temperature distribution survey, the instrumented specimen was shifted with respect to the test chamber by amounts expected to occur from one specimen installation to the next to determine if this changed the temperature distribution. Results showed no measurable change at -65°F which was the only temperature investigated because it was the most difficult to control.

The previously described loading arrangement and extensometer were used for tests performed at -320°F, the boiling point of liquid nitrogen; however, the test chamber was replaced by a Dewar vessel which allowed the specimen to be tested while submerged in the liquid. The extensometer was used in the inverted position from that previously described. Inversion of the extensometer allowed the ends of the telescoping rods and tubes containing the strain gage transducers to extend above the liquid nitrogen level when the specimen was submerged. Specimen temperature was not measured, but the specimen was submerged for approximately five minutes prior to beginning the test. Additional liquid was supplied to the Dewar vessel during test as required to keep the specimen submerged.

Data Analysis

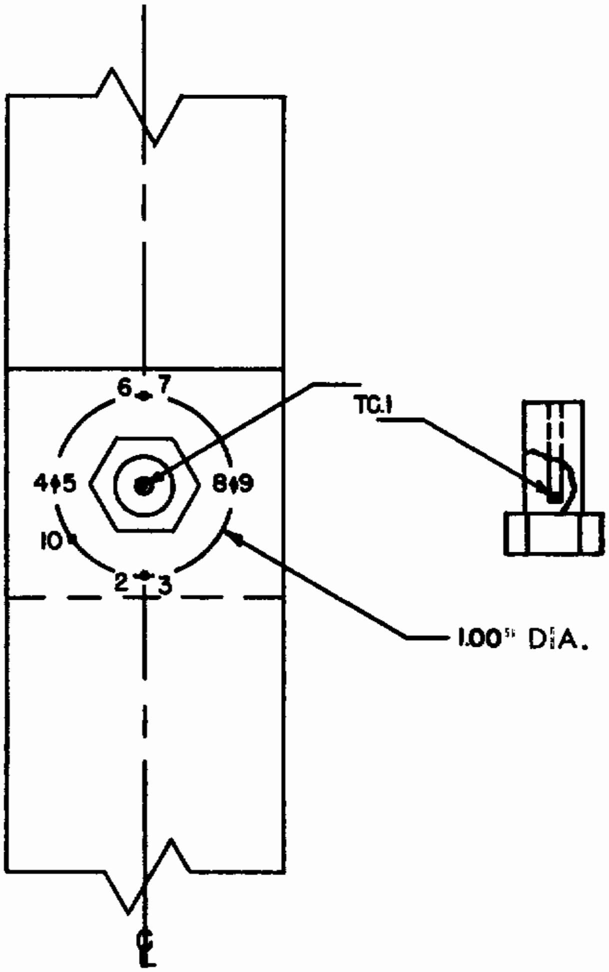
Ultimate load was recorded for each joint as indicated by the testing machine. A load deformation curve was autographically recorded for each specimen from which yield load was determined. An offset of 0.012 inch parallel to the linear portion of the load deformation curve was used for determining yield on specimens having 3/16 inch diameter fasteners, and a value of four percent of the fastener diameter (0.0125 inch) was used for specimens having 5/16 inch diameter fasteners. Actual specimen thickness was recorded and the type failure was noted for each specimen.

TABLE XXVIII

FASTENERS USED FOR THE PHASE IV FASTENER JOINT EVALUATIONS

Fastener	Type	Nominal Diameter	Head Type	Manufacturer's Heat No.	Manufacturer
HL11V-6-3	Hi-Lok Pin	3/16	100° Flush	HL94	Hi-Shear Corporation
NAS2506-3	Lockbolt	3/16	100° Flush	BD880W, Lot 1	Standard Pressed Steel
NAS675-V2	Bolt	5/16	Protruding	G7243 B-16	Briles Manufacturing Co.
NAS2010-V2	Lockbolt	5/16	Protruding	BD394U, Lot 1	Standard Pressed Steel

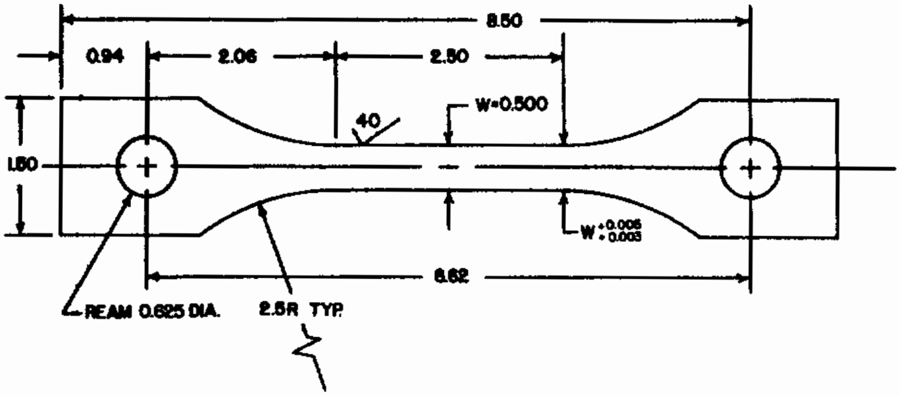
TABLE XXIX
TEMPERATURE DISTRIBUTION SURVEY FOR FASTENER JOINT TESTS

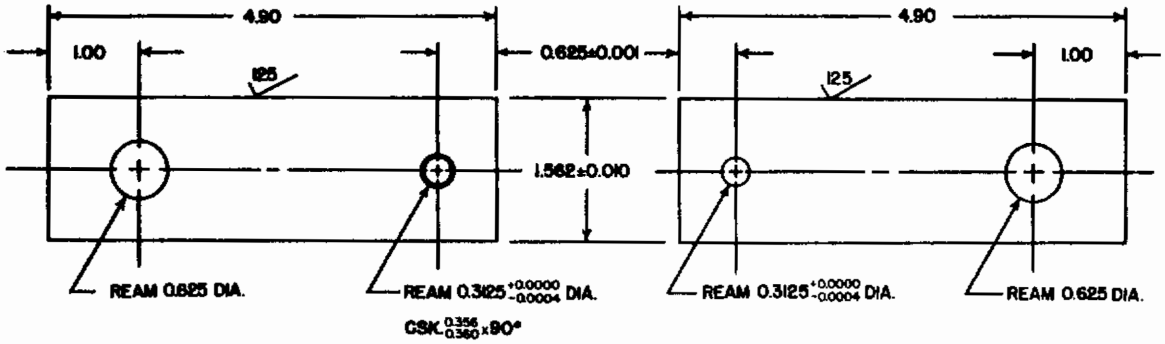


Control Temp., ^{o}F T.C. No. 10	Temperature, ^{o}F, at Locations Shown on Above Diagram								
	1	2	3	4	5	6	7	8	9
-65	-67	-63	-63	-65	-65	-66	-66	-66	-66
-100	-102	-97	-98	-100	-100	-101	-101	-101	-101
-200	-203	-198	-199	-201	-201	-202	-201	-201	-201

NOTE: Odd numbered thermocouples were on front side and even numbered ones were on reverse.

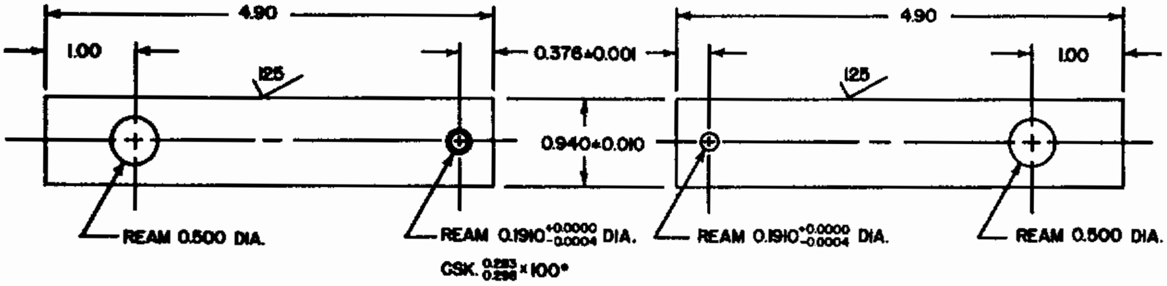
Thermocouples 2 through 9 were spot welded to the specimen, number 10 was mechanically attached as control and number 1 was in a hole drilled in the fastener.





TOP SHEET

BOTTOM SHEET



TOP SHEET

BOTTOM SHEET

FIGURE 53 – LOW TEMPERATURE TENSILE AND JOINT SPECIMENS
(All Dimensions In Inches)

FIGURE 54 - 3/16 INCH DIAMETER FASTENERS USED FOR JOINT EVALUATIONS

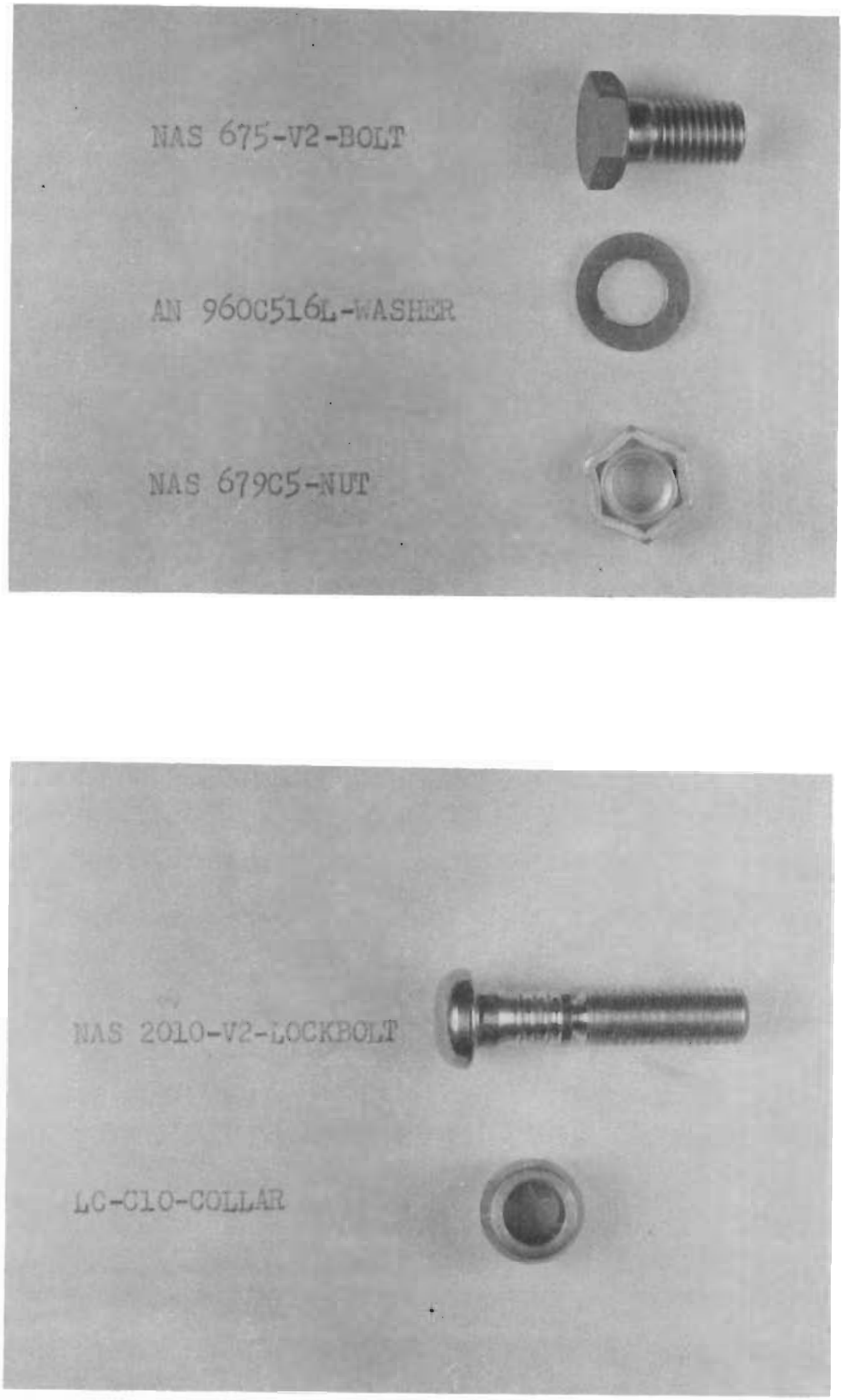
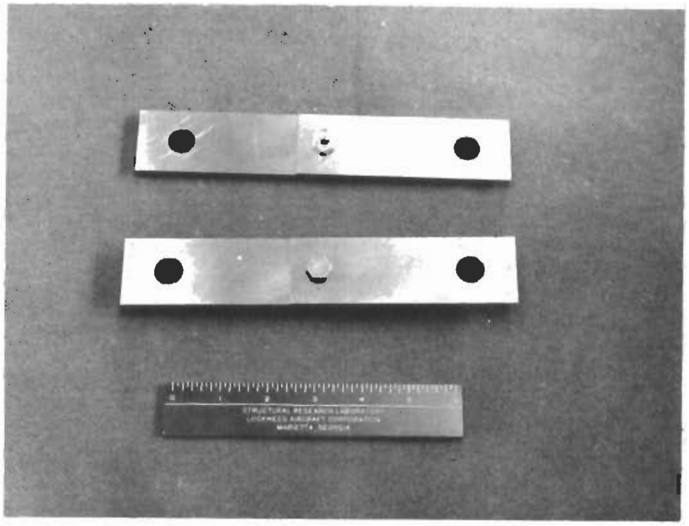


FIGURE 55 – 5/16 INCH DIAMETER FASTENERS USED FOR JOINT EVALUATIONS



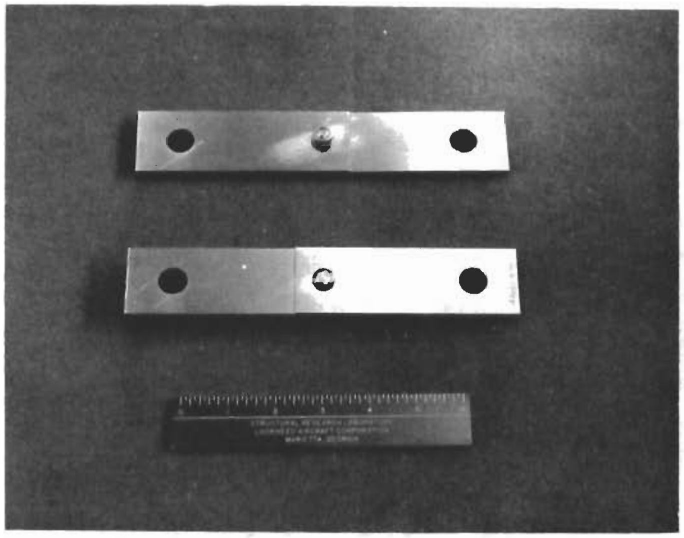


FIGURE 56 - **TYPICAL FASTENER JOINT SPECIMENS CONTAINING 5/16 INCH DIAMETER FASTENERS**

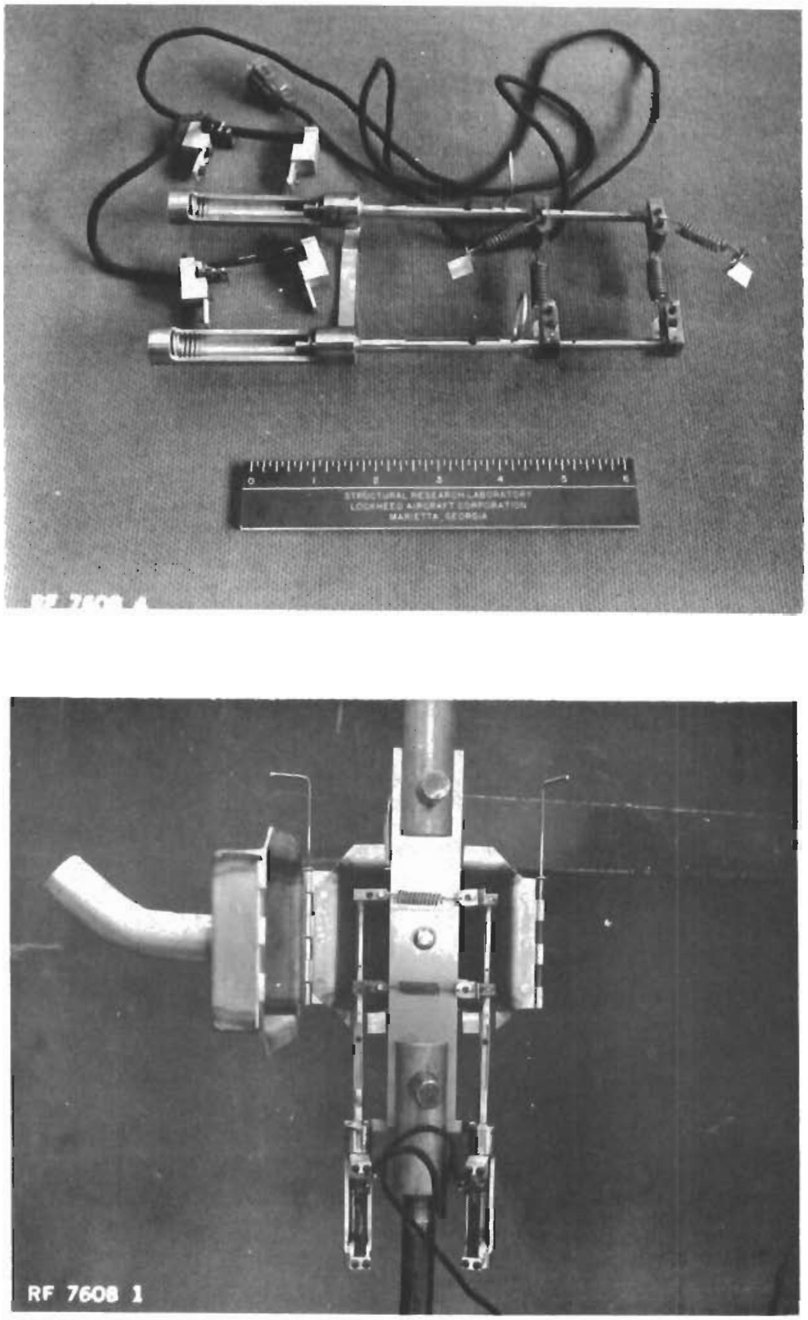


FIGURE 57 - LOW TEMPERATURE EXTENSOMETER AND TEST CHAMBER

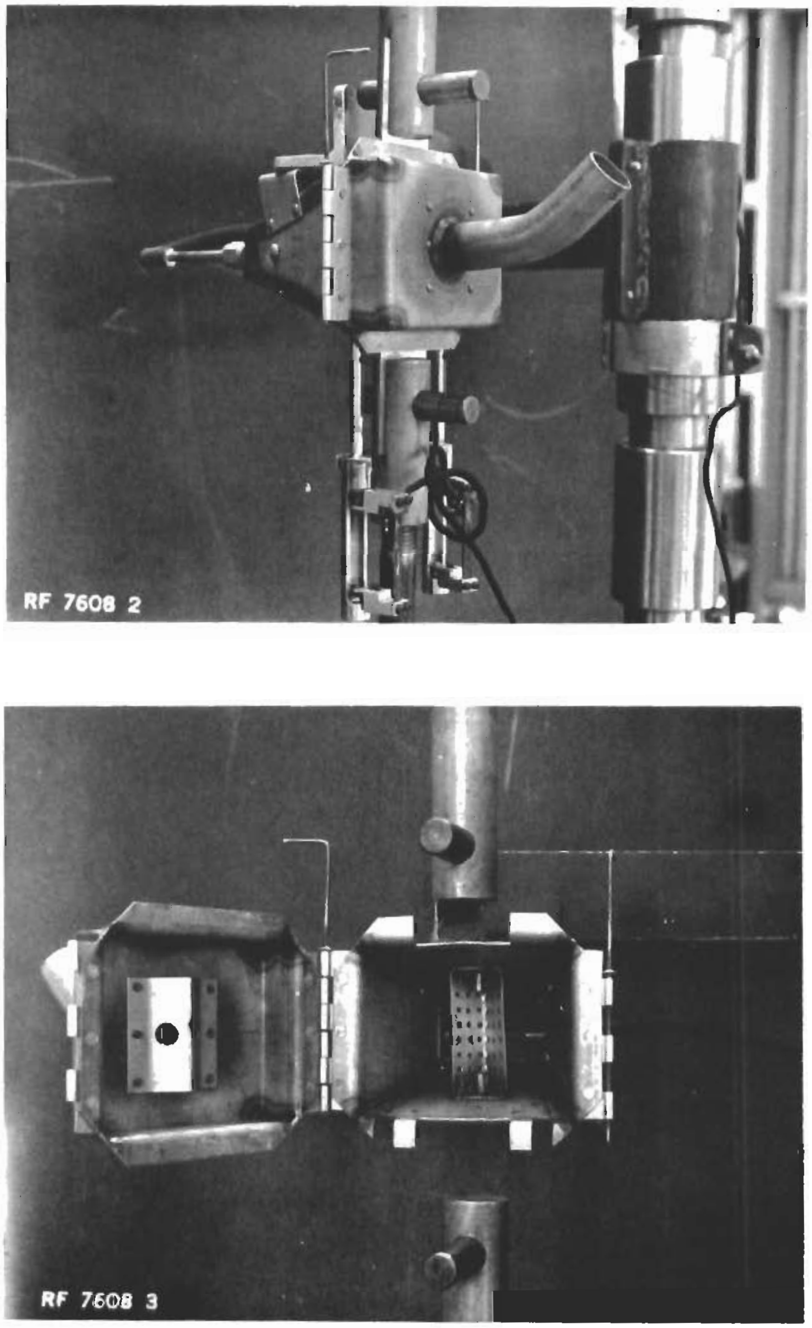


FIGURE 58 - LOW TEMPERATURE EXTENSOMETER AND TEST CHAMBER

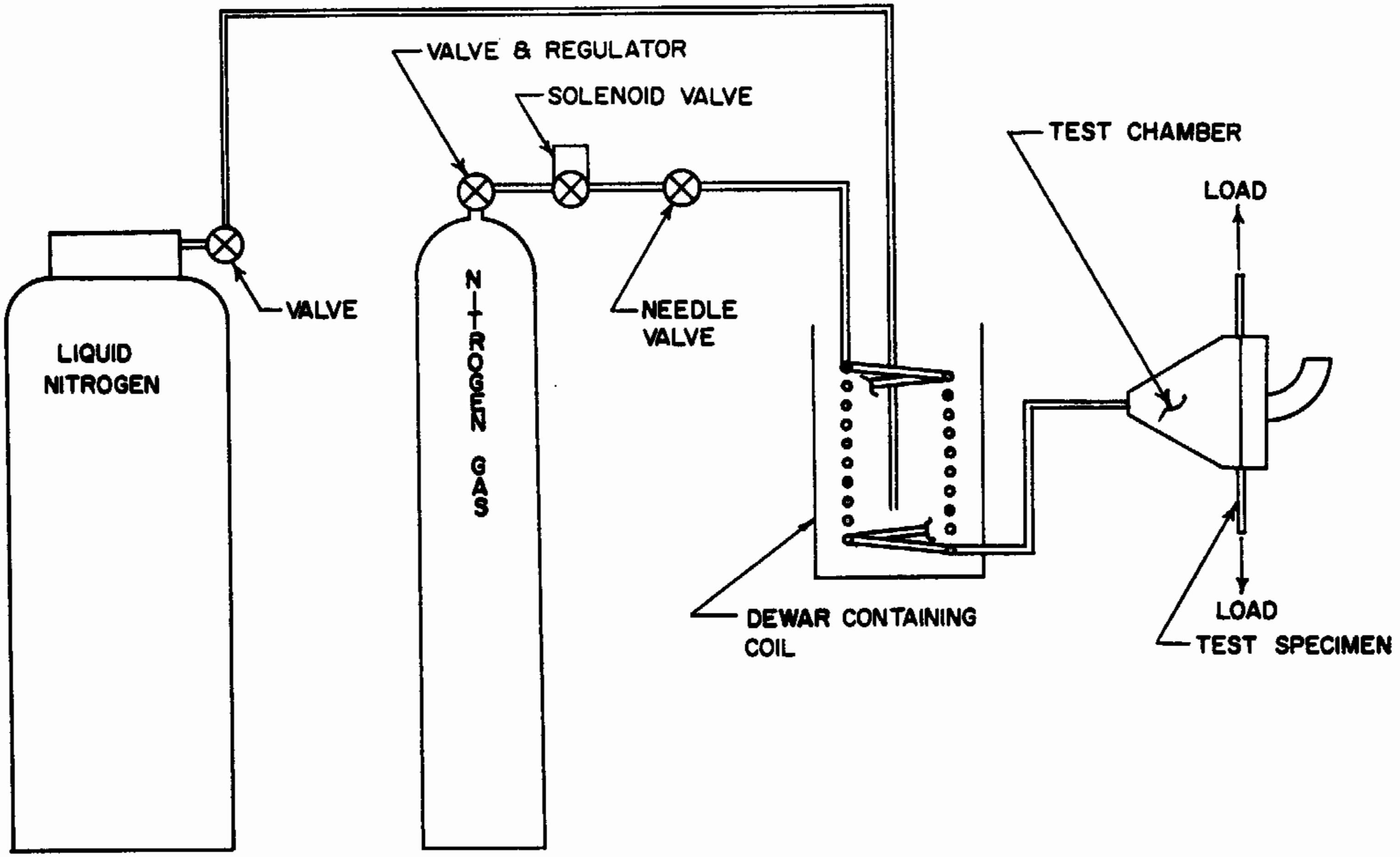


FIGURE 59 - SCHEMATIC OF LOW TEMPERATURE TEST ARRANGEMENT

Weld Joint Tests

Test Specimens

Panels for weld joint evaluations were sheared from one 0.063 inch thick sheet each of solution treated and solution treated and aged material for each alloy except Ti-2.5Al-16V where only solution treated sheet was used. The panels were sheared in pairs with mating panels being taken side by side from the sheet and identified so they could be welded together at the adjacent edge. This was done to eliminate variations in properties and sheet thickness across the weld. Six pairs of 4.5 x 9.5 inch panels were taken from each sheet; three pairs for each grain direction as shown in the typical layout diagrams, Figures 14 and 15. Edges of the panels to be fusion welded were machined to provide square butt-joint fit-up. All panels were cleaned in an aqueous solution of hydrofluoric and nitric acids, rinsed in cold water and dried. Edges to be welded were cleaned with acetone immediately prior to welding.

Mating panels with starting and run-off tabs were assembled in a welding fixture which had clamping bars and a backup plate of stainless steel. When assembled the butted joint was centered over a 1/16 inch deep by 3/8 inch wide groove in the backup plate. During welding argon gas was flowed through the groove at a rate of three cubic feet per hour. Welding was performed without filler wire by an automatic gas tungsten-arc process using a 1/16 inch diameter electrode of 98 percent tungsten and two percent thorium. Cup gas was extra dry helium supplied at a rate of 30 cubic feet per hour and adequate gas coverage was obtained by argon at 30 cubic feet per hour through a six inch long trailing shield equipped with porous bronze diffusers. Welding current was 111 to 124 amperes, arc voltage was 12 to 14 and welding speed was 20 to 28 inches per minute. The particular settings within these ranges used for welding each test panel were dependent upon the alloy and panel thickness as determined by preliminary evaluations. Panels were removed from the welding fixture immediately after welding. The front and back of a typical welded panel is shown in Figure 60.

Panels welded in the solution treated condition were recleaned subsequent to welding and then coated with Turco Pre-Treat to prevent surface contamination during aging. Aging was performed in a 2000°F capacity Leeds and Northrup forced air furnace. Aging times and temperatures used were those determined by the material producers from laboratory aged tensile specimens to give the desired properties and are given in Tables IV, VIII, XII and XVI. Tensile specimens were also included for aging as described in the following section, Low-Temperature Tensile Tests. After aging the protective coating was removed by an aqueous solution of Turco 4104 Activator and nitric acid.

No thermal treatment subsequent to welding was given the panels which were welded in the solution treated and aged condition.

All welded test panels were inspected radiographically to verify soundness of the welds. Even though tabs were used for starting and run-off, some panels showed unsound welds near the panel edges. Such areas were marked on the welded panels using their respective radiographs as a guide, and were not used for test specimens. In general, all welds were clean and sound except those for Ti-2.5Al-16V which contained many small gas holes in the fusion zone. Prints of typical radiographs for each alloy are shown in Figure 61.

The welded and inspected panels were sheared into blanks from which low-temperature tensile specimens of the type shown in Figure 53 were machined. Room-temperature specimens were as shown in Figure 18. The weld was transverse to and at the center of the test section. Longitudinal specimens were defined as those having welds perpendicular to the grain direction and loaded in a direction parallel to the grain. The converse of this defined transverse specimens. In some cases, it was necessary to reduce the test section width of the specimen from the standard 0.500 inch to 0.400 inch. This was done primarily for specimens tested at -320°F since the material became more notch sensitive at low temperatures resulting in failure across the loading hole rather than in the test section.

Averages of five width measurements and four thickness measurements were used to determine area for each specimen. Thickness of the fusion zone was not considered in the area determination. A grid for determining elongation was silk screened on each specimen using India ink as previously described for tensile tests.

Test Details

Weld joint tests were performed in a 50,000-pound capacity Baldwin universal testing machine, Model FGT. Load was applied to the room-temperature specimens through spherically seated Templin grips, and a load-deformation curve was recorded for each specimen using a two inch gage length Baldwin Model SRE extensometer and autographic recorder, as described for tensile tests.

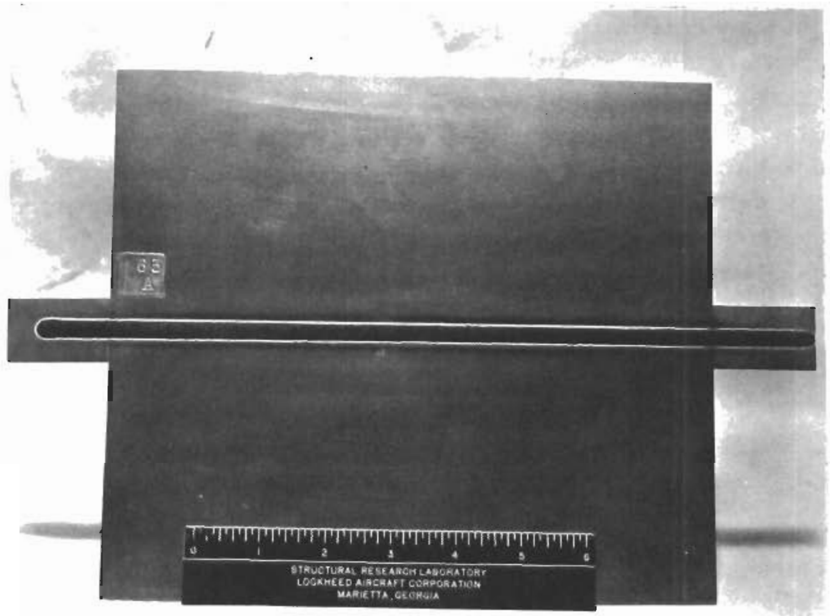
Equipment and procedures used for testing welded joint specimens at low temperatures were the same as those described for fastener joint tests with exception of temperature and strain measurements. A 28-gage copper-constantan thermocouple was mechanically attached at the center and each end of the specimen test section to monitor and control temperature during test, and a Baldwin Model PSH-8RS extensometer was used to measure specimen deformation. The low-temperature test arrangement is shown in Figure 62. Test temperature was maintained to ±3°F and was recorded continuously during the ten minute soak and test periods.

Tests at -320°F were performed in the Dewar vessel described for fastener joint tests, and the Model PSH-8RS extensometer was used in the inverted position from that shown in Figure 62. Strain rate for all weld joint tests was paced at 0.006 inch per minute to yield stress after which testing machine head travel was increased to 0.1 inch per minute.

Data Analysis

Modulus of elasticity, yield stress at 0.2 percent strain offset and ultimate tensile stress were obtained for each test. Specimen failure location with respect to the weld was also recorded. Joint efficiencies for ultimate and yield strength were determined by the ratio of the weld specimen strength values, tensile ultimate and tensile yield, to the respective values of average unwelded strengths at each temperature.

Percent elongation in 1/8 inch, 1/4 inch and two inches was obtained, where possible, as described for tensile tests. As test temperature was decreased the material became less ductile and in some cases there was no measurable elongation in two inches. The minimum elongation measurable by the method used was approximately 0.3 percent, and such values were highly questionable because of the difficulty in completely refitting the fractured surfaces. Where elongation was not measurable it was reported as being less than 0.3 percent and assumed to be zero for determining average values. This assumption was valid for many cases since the deformation obtained was insufficient to allow yield strength at 0.2 percent offset to be determined.



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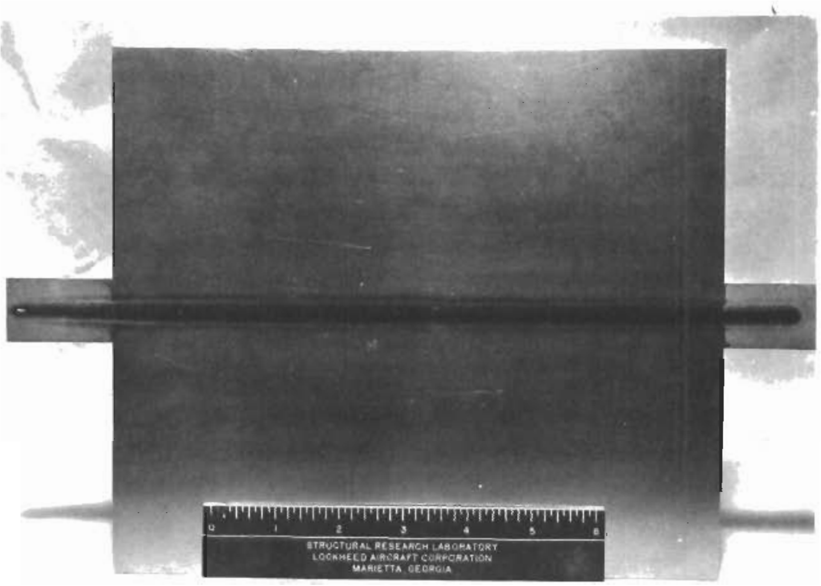

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FIGURE 60 – TYPICAL WELDED PANEL WITH TABS

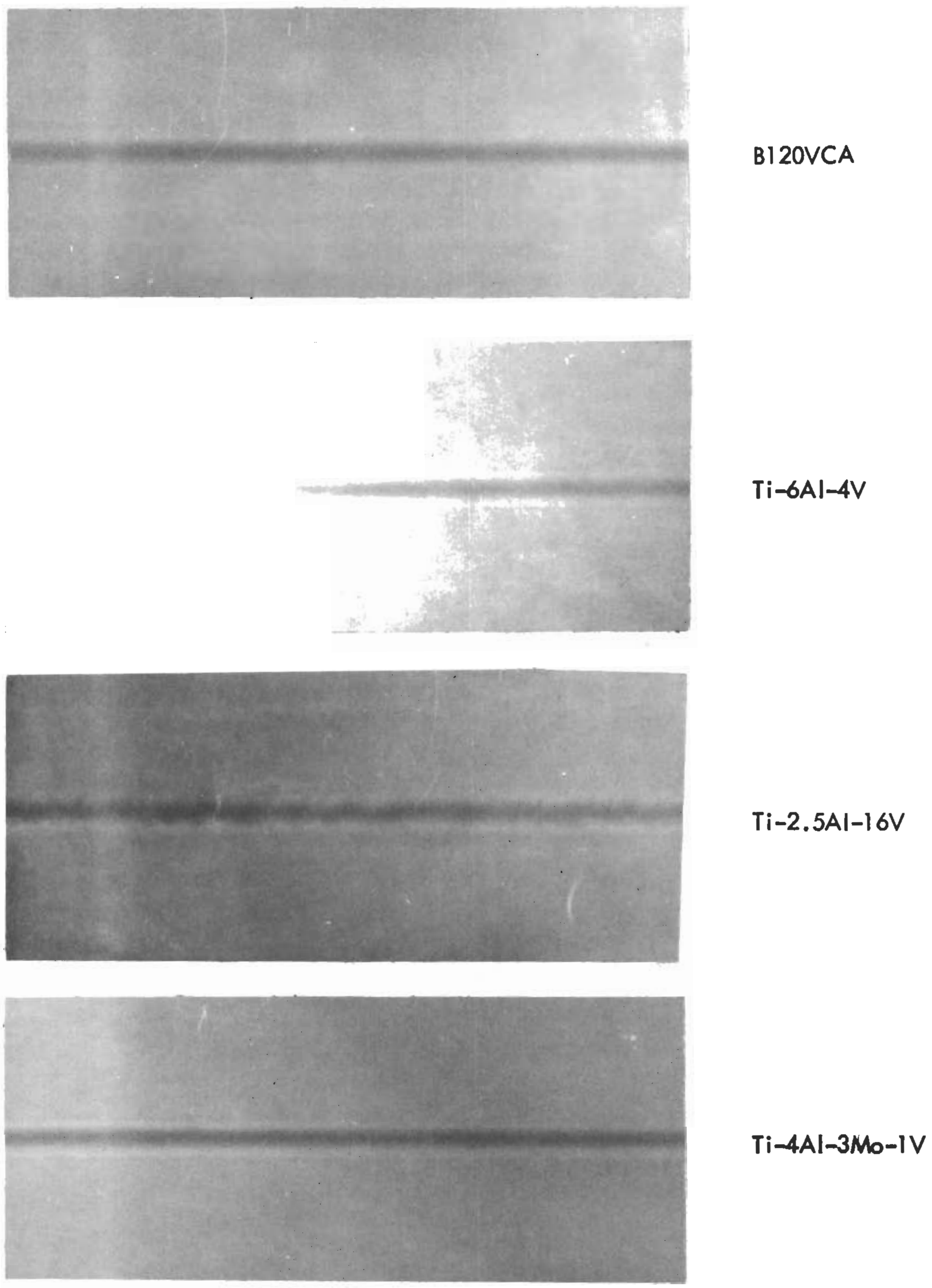


FIGURE 61 – PRINTS OF TYPICAL RADIOGRAPHS FOR EACH ALLOY

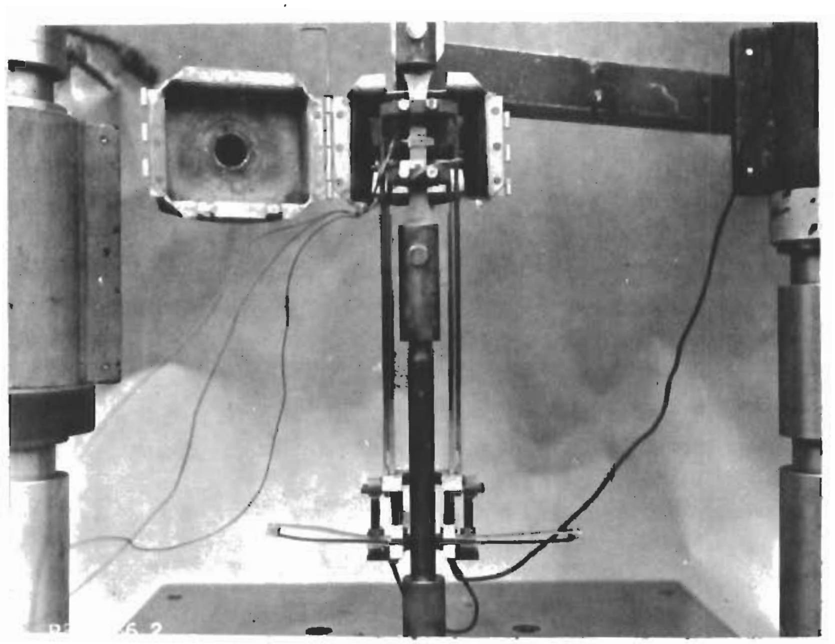


FIGURE 62 - ARRANGEMENT FOR WELD JOINT AND TENSILE TESTS AT LOW TEMPERATURE

Low-Temperature Tensile Tests

Test Specimens

Tensile specimen blanks were sheared from one 0.063 inch thick sheet each of solution treated and solution treated and aged material for each of the four alloys. These were the same sheets used for fastener and weld joint specimens previously described, and typical layout diagrams are shown in Figures 14 and 15. Tensile specimens from solution treated material were primarily for comparative evaluation with welded joints, and the blanks were processed and heat treated in the same manner and along with the panels which were welded in the solution treated condition and subsequently aged. Room and low temperature specimens were machined to the configurations shown in Figures 18 and 53, respectively. Gage marking and measurement of specimens were as previously described for tensile tests.

Test Details

Test details were identical to those described for weld joint tests.

Data Analysis

Modulus of elasticity, yield stress at 0.2 percent offset and ultimate tensile stress were obtained for each test. These strength data were used as a basis for computing weld joint efficiency.

Percent elongation in 1/8 inch, 1/4 inch and two inches was also obtained where possible. The same low ductility problems as described for weld joint tests were also encountered for the low-temperature tensile tests.

Thermal Expansion Measurements

Test Specimens

These measurements were made and analyzed by the Chemical and Metallurgical Research Department of the Engineering Research Laboratory. Cylindrical specimens as shown in Figure 63 were used for both the low and elevated temperature thermal expansion measurements. These specimens were machined from 0.125 inch thick solution treated and aged sheet with their longer dimension parallel to the grain direction. In most cases, the low and elevated temperature measurements required three specimens each for each of the four alloys or a total of six specimens per alloy. Selection of specimens for a given alloy was made at three different locations from the same sheet with one low and one elevated temperature specimen being taken from each location. Spare material from a sheet utilized in Phase I, "Static Mechanical Properties", was used for specimen selection for each alloy. Test specimen locations within a sheet for each alloy, respectively, are shown in Figures 10 through 13.

Details of Measurement at Elevated Temperature

Elevated-temperature expansion measurements were made using a Lietz, Model HTV, dilatometer. This instrument employed an optical-mechanical measuring system which traced on photographic sheet film the expansion of a calibrated material versus expansion of the titanium alloy specimen.

The calibrated material was an iron-chromium-nickel alloy for which thermal expansion versus temperature was accurately known. The dilatometer had two quartz tubes each containing a quartz push rod cantilevered from the optical-mechanical measuring head and extending into the furnace parallel to its center-line, as shown in Figure 64. One end of each tube was closed but had a diametrical slot approximately 2.5 inches long for inserting either the titanium or calibrated specimen. During operation one tube contained the calibrated material and the other contained the specimen for which expansion measurements were to be made. As the two materials were heated, the expansion of each translated its respective push rod which resulted in proportional rotation of a mirror in the measuring head. A light beam was reflected from the mirror onto sheet film where the resultant expansion of the two materials was recorded. The optical-mechanical measuring system was arranged so that expansion of the calibrated material rotated the mirror about a vertical axis and moved the light beam horizontally across the film. Expansion of the test specimen moved the light beam vertically. Resistance to expansion was negligible since each push rod had a force resistance of approximately 0.025 pound. The magnification of the system was 197 to 1 for both axes.

Calibration of the instrument was accomplished using a special optical calibrator supplied with the dilatometer. Simulated expansion was applied to each axis in increments of approximately 200 microinches per inch over the measuring range. After each calibration expansion, the light beam intensity was momentarily increased to produce a spot on the film. Calibration results indicated the accuracy of the instrument to be within ±1 percent of the measured value at each point.

The furnace supplied with the dilatometer was an insulated ceramic tube wound with electrical resistance wire. The ceramic tube also served as a vacuum chamber in which the pressure was maintained at a maximum of 30 microns of mercury to prevent specimen oxidation. A calibrated 30-gage noble metal thermocouple was attached to the center of the calibrated specimen to monitor measurement temperature. Output of the thermocouple was measured with a Leeds and Northrup No. 8662 potentiometer. Specimen heating rate during expansion measurements varied from 2°F per minute at low temperatures to 4.5°F per minute at high temperatures. This was accomplished by automatically increasing the heating element current with a motor driven potentiometer. At approximately 100°F intervals, the light beam intensity was momentarily increased to provide a temperature reference spot on the film trace. This procedure provided temperature check points by the monitoring thermocouple since expansion versus temperature was accurately known for the calibrated specimen. Comparisons at such points were in agreement within the temperature readability of the film or approximately ±1.5°F. Specimen contraction on cooling was measured in the same manner as expansion to determine if metallurgical changes had occurred which would cause the expansion curve to be irreversible.

Prior to making expansion measurements, a survey was made to determine specimen temperature distribution. A Leeds and Northrup No. 8662 potentiometer was used to measure outputs from 30-gage noble metal thermocouples attached at the center and each end of the specimen. Results of this survey showed the temperature to be uniform within ± 2°F over the range of room temperature to 1200°F. The temperature difference between the center thermocouples of the calibrated and titanium specimens was less than 1°F.

Details of Measurements at Low Temperature

Expansion measurements at low temperature were made using the previously described Lietz, Model HTV, dilatometer; however, changes were made in the temperature measurement method and the furnace was replaced by a helium cryostat.

Since the iron-chromium-nickel alloy used in one quartz tube specimen holder for elevated-temperature measurements was not calibrated at low temperatures, a titanium alloy specimen was placed in each of the two specimen holders. This allowed expansion of two specimens to be measured at the same time. Specimen temperature was measured with a four lead platinum resistance thermometer which was placed between and just above the two test specimens as shown in Figure 65. Thermometer resistance was measured by a Rubicon Meuller Bridge and a Honeywell ElectroniK Null Indicator. The resistance thermometer was calibrated over the temperature range of 10°K to 500°K (-442°F to 440°F) by the National Bureau of Standards. Accuracy of the temperature measuring systems was approximately 0.2°F.

The cryostat was designed especially for use with the dilatometer, and was manufactured by Hofman Laboratories, Inc. to Lockheed specifications. Basically, the unit was made up of three concentric cylinders as shown schematically in Figure 66. The outside cylinder served as a vacuum insulating jacket and contained laminar type insulation. The middle cylinder was designed to contain the coolant and had a capacity of approximately 1.6 liters. The inside wall of the coolant cylinder formed the cylindrical test chamber into which the quartz tubes containing the test specimens extended. During expansion measurements the coolant surrounded but did not contact the specimens. Figure 65 shows the liquid helium Dewar vessel and dilatometer with cryostat attached.

Prior to beginning expansion measurements the insulating jacket and helium transfer tube were evacuated, and the coolant chamber was purged with helium gas. The test chamber was evacuated to approximately five microns of mercury and then back pressured with helium gas to approximately 100 microns of mercury to facilitate heat transfer between the coolant chamber and test specimens. This pressure was monitored and maintained during measurement. The samples were then cooled at a rate of approximately 10°F per minute by slowly admitting helium vapor into the coolant chamber until the specimen temperature was approximately -380°F. The coolant chamber was then filled with liquid helium which lowered the specimen temperature to -440°F. The specimens remained at this temperature until the liquid helium had evaporated which took approximately 15 minutes. Cooling from ambient to -440°F required approximately one hour, and returning to ambient required approximately three hours. Specimen temperature was monitored with the resistance thermometer during the cooling and warming periods. The light beam intensity was momentarily increased at temperature intervals of approximately 50°F to provide temperature points on the film trace of specimen expansion.

Data Analysis

Values of specimen expansion versus temperature were determined from the dilatometer film traces using reference temperatures of 100°F for the 80°F to 1200°F range and 35°F for the 80°F to -453°F range. The different systems used for low and elevated temperature measurements resulted in a 65°F difference in reference temperature. In order to present these data as a smooth curve over the entire temperature range, the low-temperature data were adjusted to 100°F. This adjustment was made using the average expansion coefficient for the 100°F to 200°F and 35°F to -10°F ranges. Except over the specimen length, the error introduced by expansion of the quartz tubes was compensated by expansion of the quartz push rods. Over the 80°F to 1200°F range a correction of one microinch per inch per °F was used for the uncompensated length of quartz tube. Since expansion of quartz deviates considerably from a linear function over the low-temperature range, data from Scheel and Heuse, Reference 9, were used to correct over the 80°F to -453°F range. The corrected values of specimen expansion versus temperature for each temperature range were then fitted by least squares to a polynomial using an IBM Model 7090 computer. The resulting polynomials were then solved to obtain thermal expansion values at the desired temperatures. Since -440°F was the lowest specimen temperature attainable by the cyrostat, the values at -453°F were obtained by extrapolation.

Experimental errors for the expansion measurements were estimated to be less than three percent and less than five percent for the elevated and low temperature measurements, respectively.

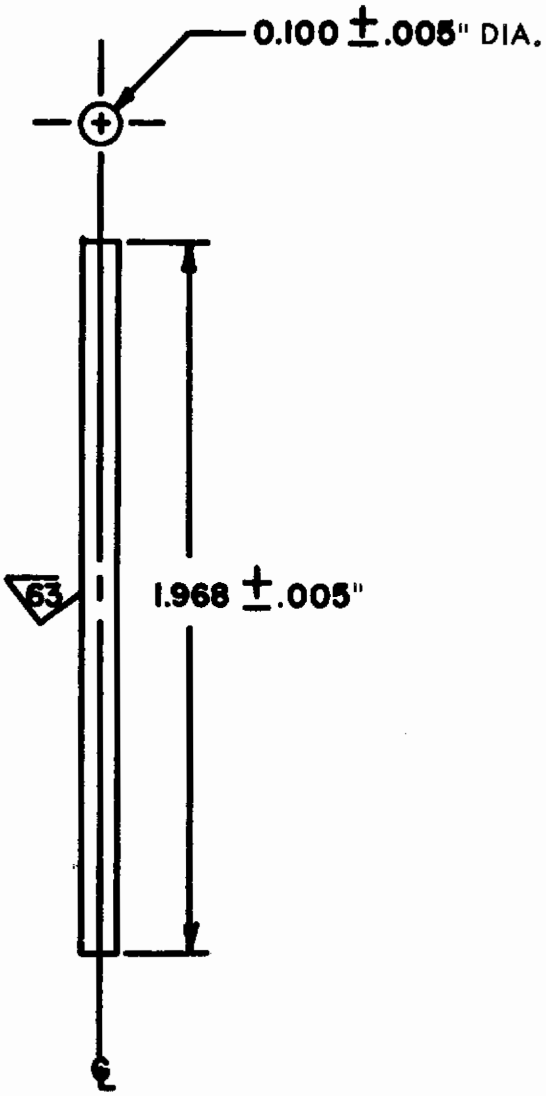
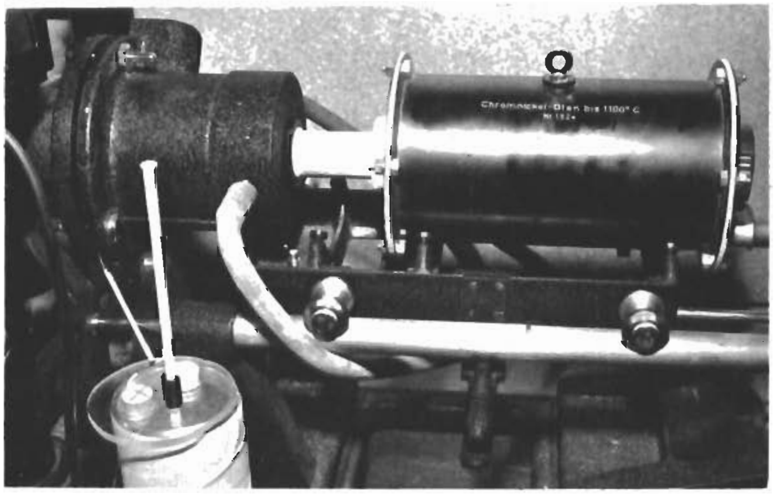
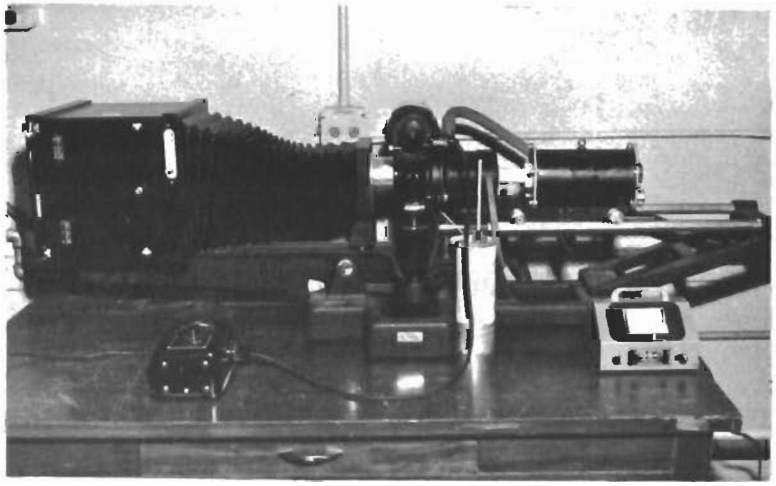


FIGURE 63 - THERMAL COEFFICIENT OF EXPANSION SPECIMEN FOR 0.125 INCH THICK SHEET

Quartz Tube Specimen Holders



Furnace and Vacuum Tube in Operating Position



Overall view of Dilatometer

FIGURE 64 - DILATOMETER USED FOR THERMAL EXPANSION MEASUREMENTS

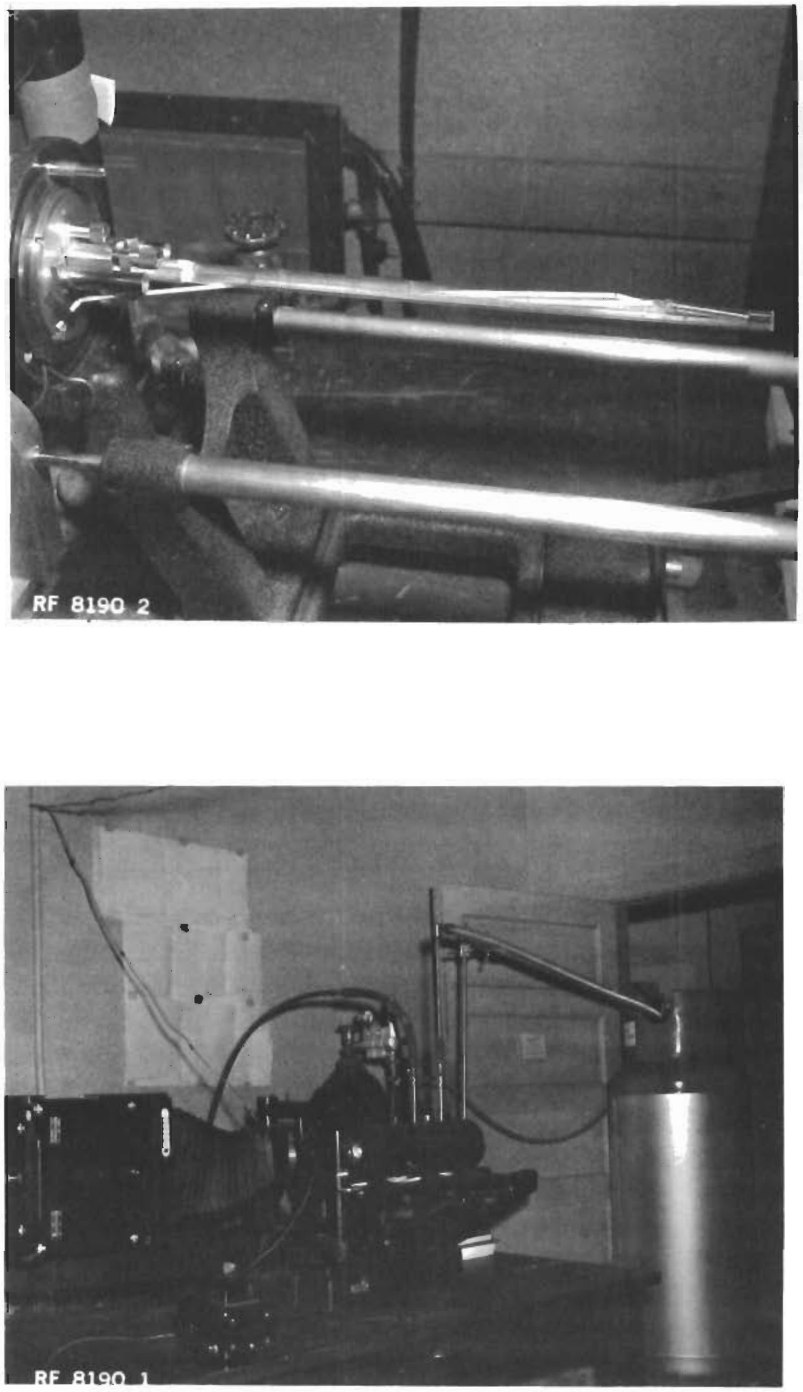


FIGURE 65 - ARRANGEMENT FOR MEASURING LOW TEMPERATURE THERMAL EXPANSION PROPERTIES

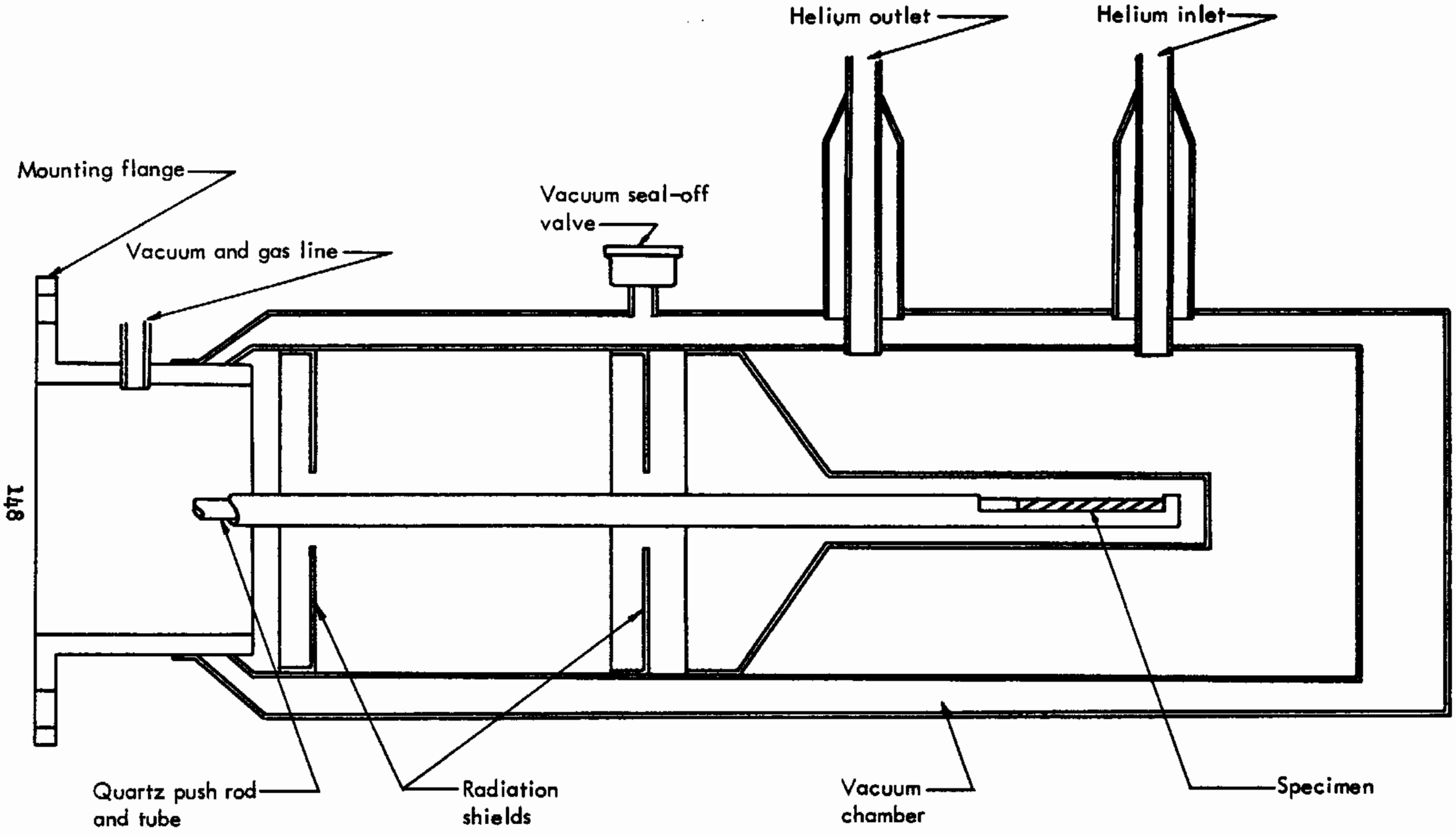


FIGURE 66 - SCHEMATIC OF EXPANSION CRYOSTAT

Thermal Conductivity Measurements

Test Specimens

Low temperature specimens machined to the configuration shown in Figure 67 were supplied to the subcontractor by Lockheed. The combined conductivity of three specimens was measured for each of the four alloys. The specimen used for thermal conductivity measurements at elevated temperatures is shown in Figure 68. Individual measurements were made on three such specimens for each alloy.

All specimens of a given alloy were machined from the same 0.125 inch thick solution treated and aged sheet, and were selected from spare material of a sheet utilized in Phase I, "Static Mechanical Properties." Specimens were selected as randomly as possible from the spare material in order for the data to be representative of the entire sheet. Specimen locations within a sheet for each alloy, respectively, are shown in Figures 10 through 13.

Details of Measurements at Low Temperature

Low-temperature thermal conductivity measurements were made by Georgia Institute of Technology Engineering Experiment Station. The cryostat used for these measurements is shown schematically in Figure 69 and was suitable for making measurements from about 15°K to 300°K. The apparatus was similar in a number of respects to one described in References 10 and 11 for measurement of the thermal conductivity of the titanium alloy RC-130B (4Al-4.7Mn) over the same temperature range, as well as to an apparatus developed for measurement of the thermal conductivity of brass near 80°K, Reference 12.

With reference to Figure 69, construction and operation of the cryostat used in the present measurements is as follows: the brass container, C, housed the specimens to be measured and was immersed in a coolant bath contained in Dewar vessel, D. Thermal conditions inside C were controlled either by evacuation of the container through vent V to about 1×10^{-5} mm. mercury or by adding helium gas to serve as a heat exchange medium to cool the contents of C to the desired initial temperature.

The container was four inches in diameter and 20 inches long with the test specimen assembly (Plate P3 and its associated radiation shields) occupying approximately the bottom third of the vacuum space. All tubing entering C was thin-walled (0.010 inch) monel or copper-nickel alloy (70 percent Cu, 30 percent Ni) tubing to reduce heat leak.

All wires entered container C through two wax (Apiezon W) wire seals W (only one is shown). The wires were brought into thermal equilibrium with their surroundings by cementing them to the surfaces of E, D and P3, where appropriate, using General Electric Company insulating varnish No. 7031.

The titanium alloy test specimen, A, whose thermal conductivity was to be measured, consisted of three 4 x 3/8 x 1/8 inch strips held between two copper end-pieces by means of an epoxy cement. The test assembly is shown in place in Figure 69 and in greater detail in Figure 70. The upper end of this assembly was attached to copper plate P3 by four screws.

A thin film of Vaseline was used between these surfaces to provide good heat transfer. The heater, H1, for supplying heat to the test specimen was mounted on a copper block which was attached by four screws to the test specimen end-piece at the lower end, the mating surfaces being covered with a thin layer of Vaseline. This heater was wrapped loosely with aluminum foil to minimize radiation transfer.

Three single-junction constantan (Advance)-Chromel P (90 percent Ni, 10 percent Cr) thermocouples (TC4, TC7, TC9) served to measure the temperature gradient along the test specimens. They were attached to U-shaped copper pieces made of heavy copper wire which had been inserted between the specimens and cemented to them by means of G.E. No. 7031 varnish. Two single-junction copper-constantan thermocouples (TC6 and TC8) served to measure the temperature of the copper end-pieces of the test assembly thus providing a measure of the temperature drop across the epoxy joints. Details concerning construction and calibration of these and other thermocouples mentioned below are in Reference 13.

Radiation losses from the test specimens were reduced by surrounding the specimens with an Inconel radiation shield, S1, the temperature gradient along which was very nearly the same as that along the specimens. The temperature gradient along S1 was controlled manually by adjusting the current in the H2 heater (mounted on a copper block) to give a zero reading of the three-junction copper-constantan difference-thermocouple, D1. A second copper radiation shield, S2, provided additional protection against radiation transfer from S1. Both radiation shields (S1 and S2) were attached to P3 by means of four screws, the mating surfaces being coated with Vaseline. Two single-junction copper-constantan thermocouples (TC5 and TC10) permitted the temperatures of S1 and S2 to be monitored. In certain experiments thermocouple TC10 was attached to the center of the Inconel tube of S2, thus permitting the temperature gradient to be examined.

Single-junction copper-constantan thermocouples TC0, TC1 and TC3 permitted the temperature of plates P1, P2 and P3, respectively, to be monitored. An auxiliary single-junction constantan-Chromel P thermocouple, TC2, also permitted the temperature of P2 to be determined.

The temperature of copper plate P3, to which the upper ends of the test specimens were attached, was controlled by means of heater H3. Heat conduction between this plate and the hydrogen pot, D, was provided by three 2 3/4 inch long by 1/4 inch diameter copper rods, R, positioned 120° apart. Thus, appropriate control of heaters H1 and H3 permitted the mean temperature of the test specimen to be varied. Provision was also made in the design of the cryostat for replacing these rods, if desired, by rods of much lower thermal conductance or for substituting similar rods between plates P1 and P3 for those between P2 and P3. This last arrangement converted the cryostat into one which was identical in principle with that described in References 10 and 11. A more detailed discussion of cryostat construction is in Reference 13.

After assembly of the test specimens was completed, distances L_{4-7}, L_{7-9} and L_{4-9} were measured. These were the distances between the centers of the copper bridges to which thermocouples TC4, TC7 and TC9 were attached. The distances L_{6-4} and L_{9-8} from the point of attachment of thermocouple pairs TC6-TC4 and TC9-TC8, respectively, were also measured.

Heat conduction to and from the test specimens and heater H1 was minimized by cementing the four copper leads from H1 and the copper lead from the three-junction difference-thermocouple, D1, to the copper block on which heater H2 was mounted. In normal operation of the equipment, no heat flow presumably occurred along these leads when H1 and H2 were at the same temperature. The thermocouples TC4, TC7 and TC9 were constructed of 32-gage constantan and 30-gage Chromel P wire. Heat conduction between the test specimens and plate P3 along the 20 centimeter lengths of wire involved was negligible. Heat conduction along the copper lead of thermocouple TC8 between P3 and H1 was small since the lead consisted of 19 centimeters 32-gage and 25 centimeters 40-gage copper wire. Correction for this heat loss was made in computing the heat input to the test specimen.

All voltage measurements were made using a Leeds and Northrup Type K2 potentiometer which permitted measurements reproducible to ±0.3 microvolts. Heaters H1, H2 and H3 were powered by a 16 volt high-capacity Edison battery. All lead wires were single strand 34-gage with cotton enamel insulation.

Measurement of the thermal conductivity of a given alloy was carried out in a high vacuum (pressure usually less than 1×10^{-5} mm. mercury) using external baths of (1) water at room temperature, (2) ice-water mixture, (3) ethyl alcohol-solid carbon dioxide mixture, and (4) liquid nitrogen. Measurements near -420°F were made using an external liquid nitrogen bath and liquid hydrogen in pot D.

The alloy test assembly, as well as the supporting copper plate, P3, (see Figures 69 and 70) and surrounding radiation shields S1 and S2, was usually first cooled to the desired temperature by admitting helium gas to container C which was immersed in one of the baths previously mentioned. When the desired low temperature had been reached, the helium gas was removed by evacuation to a pressure of about 1×10^{-5} mm. mercury.

A temperature gradient of 4°C to 8°C was then established along the test specimens by suitable control of heaters H1, H2 and H3. The achievement of a steady-state condition required that the temperatures of H1, H2 and H3 (P3) be constant. This was accomplished by first heating P3 by means of H3 to a temperature a few degrees less than the desired final mean temperature of the test specimens, while simultaneously heating H1 and H2. Since H1, H2 and H3 were cemented to copper pieces which had very high thermal conductivities relative to the test specimens, these pieces could be heated quickly to the final desired temperatures.

After the desired gradient had been established between the copper end-pieces holding the test specimens, the power input to H1, H2 and H3 was adjusted manually to maintain the copper end-pieces at constant temperatures. As equilibrium was approached, indicated both by a constant power input requiring no adjustment of either H1, H2 or H3 and by a constant voltage reading of TC4, TC7 and TC9, the temperature of the copper end-pieces could be maintained essentially constant with a drift of less than 0.08°K per hour for measurements above 77°K. At hydrogen temperatures no drift could be detected. By adjusting the temperatures of the copper end-pieces in this manner, equilibrium was normally established within two hours for temperatures above 77°K. Near 20°K less than one hour was required because of the increased thermal diffusivity. When a steady state was considered to have been reached, readings were taken of all thermocouples and the voltage across H1 and the one-ohm standard resistor. A second reading was taken approximately 20 minutes later and a comparison made with the first set of readings. If the apparent thermal conductivity calculated from the heat input to the specimens, uncorrected for wire losses, and the temperature drop along the specimens between TC4 and TC9 showed no change greater than that attributed to spatter in the voltages of the thermocouples, the specimens were assumed to be in equilibrium and the data from the last readings used to compute the thermal conductivity. If any doubt existed as to the state of equilibrium reached, further readings were taken.

Data Analysis

The experimental values for thermal conductivity for each alloy were computed from steady-state measurements of the temperature gradient along the test assembly (TC4, TC7 and TC9), the known energy input rate, Q, together with the total cross-sectional area, A, of the specimens and the measured distances between the centers of the copper bridges to which thermocouples TC4, TC7 and TC9 were attached. The relation used to compute the thermal conductivity was

$$K = \frac{QL}{A \quad \Delta T}, \quad \text{BTU/Ft-hr-}^{\circ}\text{F}$$

Where L and ΔT refer to the distance and temperature difference, respectively, between the appropriate pair of thermocouples.

The heat flow along the three specimens was assumed to be one-dimensional. The heat input rate, Q, was obtained from the energy input to heater H1 after correcting for a small loss of energy from H1 due to conduction along the copper lead wire of thermocouple TC8. This correction never amounted to more than 0.5 percent except at liquid hydrogen temperatures where the correction amounted to as much as three percent. No correction was applied to Q for any radiation effects which may have been present. Computation of the effect of thermal contraction on the dimensions of the specimens, using thermal expansion data supplied by Lockheed-Georgia Company, showed this effect to be less than 0.3 percent; it was neglected in calculation of thermal conductivity.

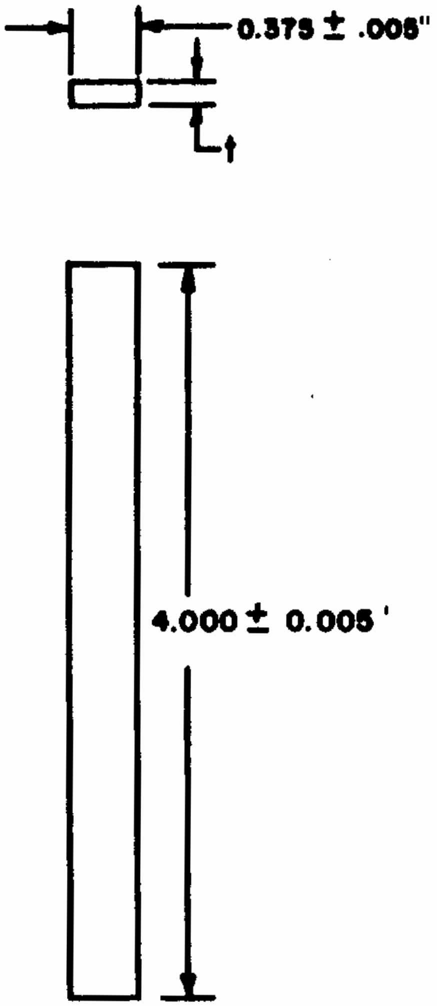
It can readily be shown that if the thermal conductivity varies linearly with temperature over a given temperature interval then the mean thermal conductivity given by the equation is equal to the true thermal conductivity at the mid-point temperature of that interval. Since the temperature gradients used in these experiments were small, the assumption that the thermal conductivity varies linearly with temperature over the intervals used was considered to be satisfactory.

The thermal conductivities were computed from the measurements of thermocouples TC4 and TC9 and the length L_{4-9} between these thermocouples. These thermocouples were chosen rather than the pairs TC4-TC7 and TC7-TC9 to minimize errors in length and temperature difference measurements.

The experimental values of thermal conductivity were plotted for each alloy and a smooth curve drawn through the data points. This smooth curve was used to obtain, by interpolation, values of thermal conductivity at four of the desired temperatures, namely: 70°F, -65°F, -110°F and -320°F. These temperatures were all close to the temperatures used in the actual measurements. The smoothed values at -415°F and -420°F were obtained by a different procedure described below which involved extrapolation from -415°F to -420°F.

In the liquid hydrogen region the experimental measurements for the four alloys were all made with gradients of 4°K to 8°K, the measurements being centered about 25°K (-415°F). Extrapolation of these data to -420°F presented something of a problem because of the limited temperature range (about 2°K) over which the measurements were made. An examination of published data for a number of other alloys such as stainless steel, References 14 through 17; Monel, References 14 and 17; Inconel, Reference 14; nickel steels, Reference 18; and the titanium alloy 4Al-4.7Mn, Reference 10, showed the thermal conductivity versus T (°K) curve in the liquid hydrogen region to be approximately linear, with a slope somewhat greater than would be computed from the simple relation $K = aT$. The limited experimental data obtained near 25°K for Ti-6Al-4V, Ti-4Al-3Mo-1V and Ti-2.5Al-16V show a slope characteristic similar to that of the alloys mentioned above. Accordingly, it was felt that linear extrapolation to -420°F was justified and has introduced little uncertainty for these alloys. Extrapolation of the data for B120VCA presented more of a problem since the measured slope, dk/dT, appeared to be excessively large. Extrapolation to -420°F for this alloy was made by assuming the slope to be very nearly the same as for Ti-2.5Al-16V.

The thermal conductivity values reported are believed to be accurate to about five percent except at -420°F where the uncertainty may be as large as ten percent. A detailed discussion of the possible sources of error and comparisons of the data obtained with other published data are in Reference 13.



THREE REQUIRED PER SAMPLE

FIGURE 67 LOW TEMPERATURE THERMAL CONDUCTIVITY SPECIMEN FOR 0.125 INCH THICK SHEET

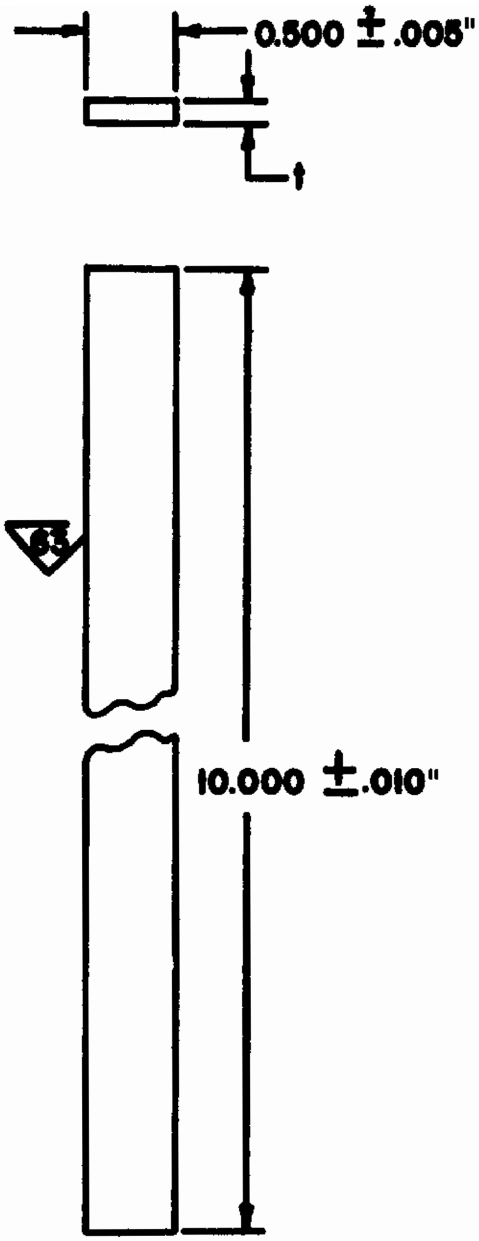


FIGURE 68 ELEVATED TEMPERATURE THERMAL CONDUCTIVITY SPECIMEN FOR 0.125 INCH THICK SHEET

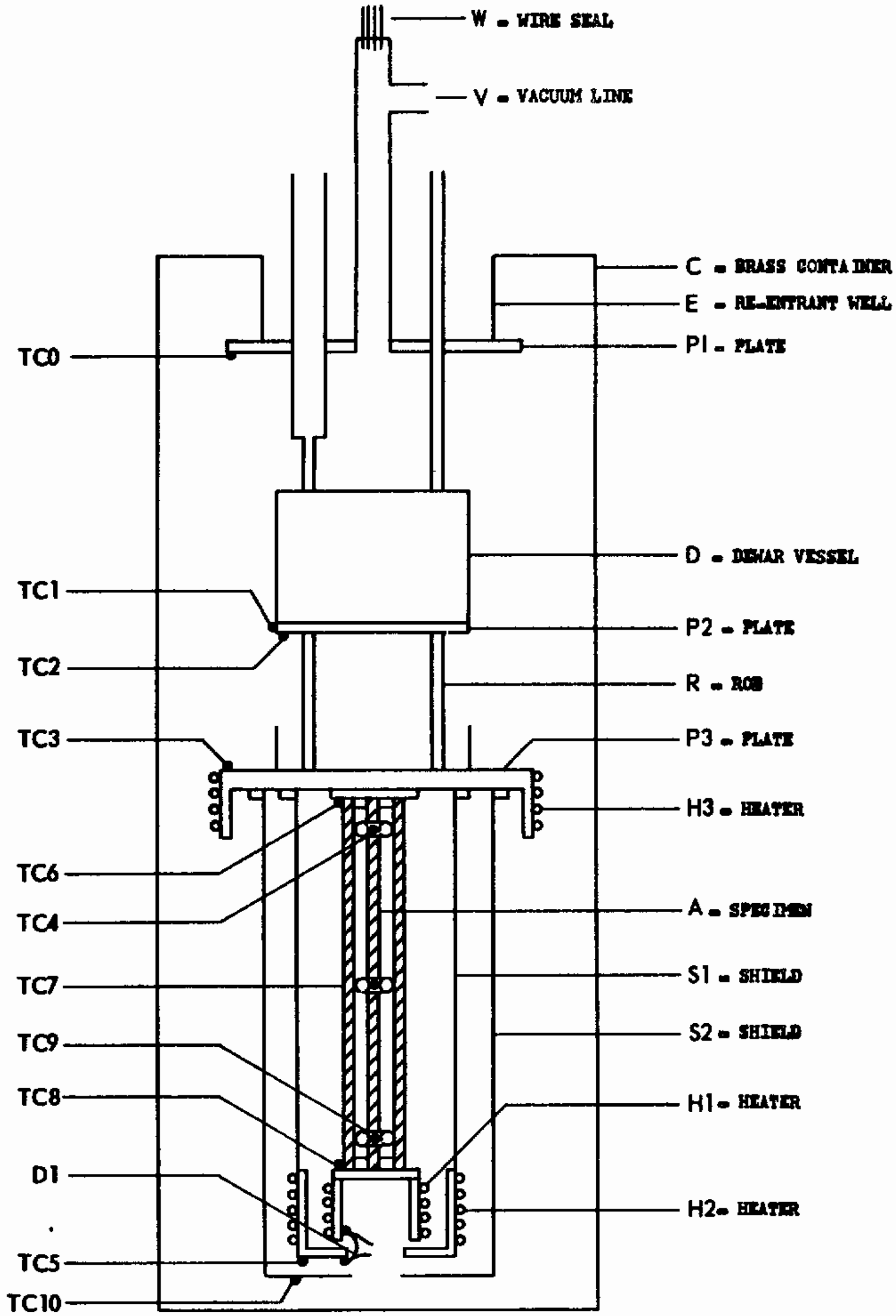


FIGURE 69 - SCHEMATIC DIAGRAM OF THERMAL CONDUCTIVITY CRYOSTAT

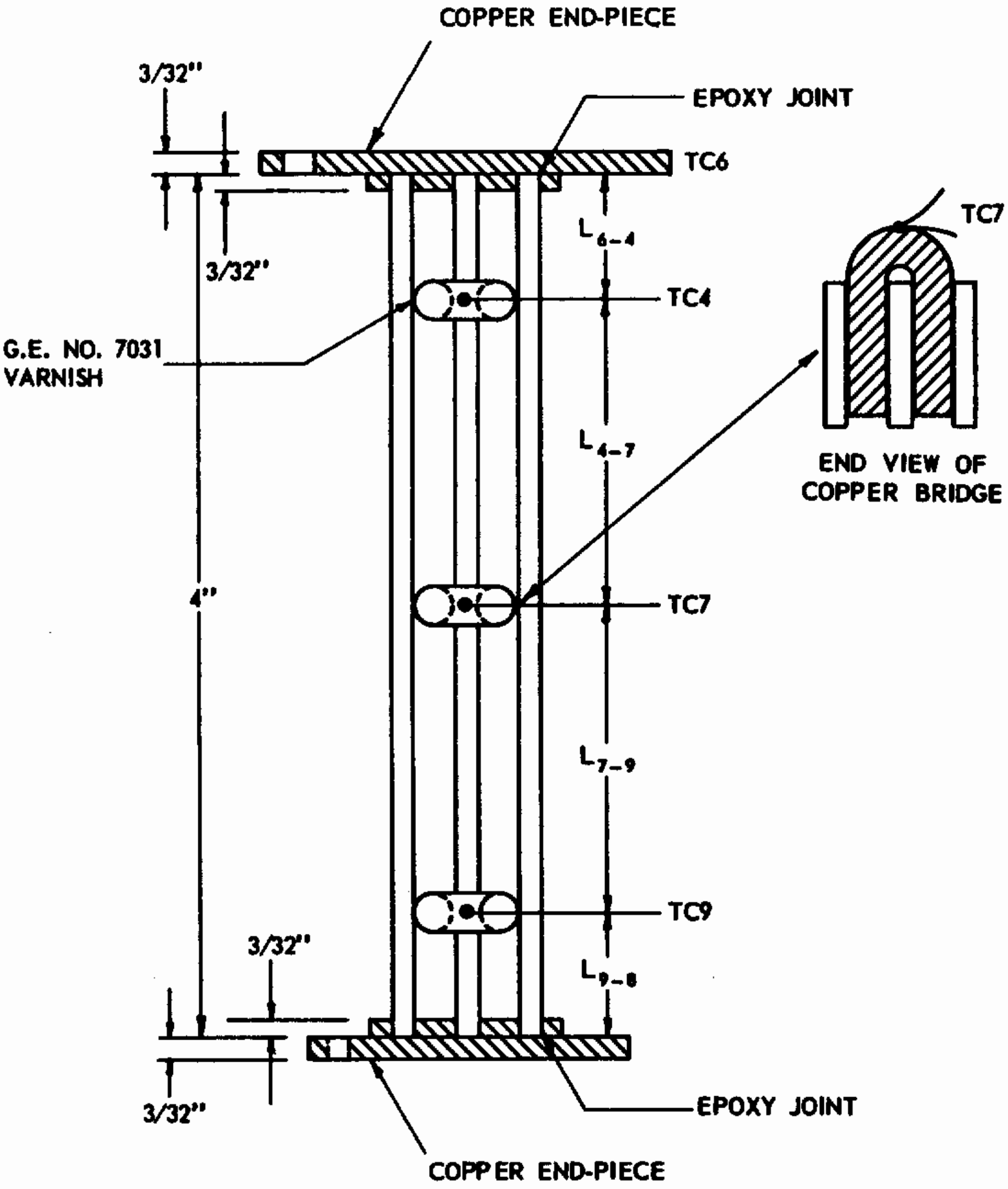


FIGURE 70 - DETAILED SKETCH OF SPECIMEN ASSEMBLY SHOWING ATTACHMENT OF THERMOCOUPLES

Details of Measurements at Elevated Temperature

Experimental techniques, conductivity measurements and data analyses described for elevated temperatures were submitted by the Chemical and Metallurgical Research Department of the Engineering Research Laboratory. The direct method was used for measuring thermal conductivity at elevated temperature. The ten inch long specimen which was heated at one end was cooled at the other end by a calorimeter to provide an approximate 900°F temperature difference over the length. Heat flux, determined by the calorimeter, and specimen temperature, measured at several stations along its length, provided data necessary to compute the conductivity over the 300°F to 1200°F temperature range.

A cross-section of the thermal conductivity apparatus which consisted of several concentric cylinders instrumented with heaters and thermocouples is shown in Figure 71. The steel container or outer cylinder was ten inches in diameter and 23 inches long and was positioned on a one inch thick block of Johns-Manville Superex insulation. Laminar insulation consisting of alternate layers of aluminum foil and micro glass-fiber mats was attached to the outside surface of the steel container. A 5 1/2 inch diameter by one inch thick ceramic disk was attached to the Superex block inside and concentric with the steel container. Fitted around the ceramic disk was a resistance heater for the 12 inch long stainless steel shield tubes. Two such tubes were used with the heater being sandwiched between them.

A 2 5/8 inch diameter stainless steel guard tube having a wall thickness of 0.020 inch fitted inside and concentric with the shield arrangement and was properly positioned by a circular groove machined in the ceramic disk. The guard tube had eight Chromel-Alumel thermocouples spaced one inch apart along seven inches of its 12 inch length, and a 1/4 inch diameter copper ring-shaped tube was soldered to the top end of the guard tube. Guard tube design was similar to that described in Reference 19. A second electrical resistance heater was employed which heated the lower end of the guard tube and a heat collector attached to one end of the specimen. This heater fitted inside the guard tube and was positioned in a circular groove machined in the ceramic disk. Both heaters used were helically wound with No. 22 Nichrome wire on alumina tubing and had a maximum rating of approximately 500 watts each.

The specimen for conductivity measurements along with a heat collector and calorimeter fitted inside the guard tube.

The heat collector was a 1/2 inch diameter stainless steel tube having a one inch deep by 1/8 inch wide slot in one end. The specimen was inserted in this slot and was held in place by friction.

The calorimeter, shown in Figure 72, was constructed of 0.070 inch thick copper and consisted primarily of two closed chambers each being semicircular in cross-section and two inches long. Radius of the cross-section was one inch. Except for 1/4 inch at one end, each chamber contained an internal separator at mid-radius parallel to the rectangular face. The separators were also copper and served to direct the flow of water through the assembled calorimeter. The two chambers were interconnected at one end by a copper tube which, when assembled, spaced the rectangular faces parallel and approximately 1/8 inch apart. One inch of specimen length and a slotted copper spacer were clamped between the

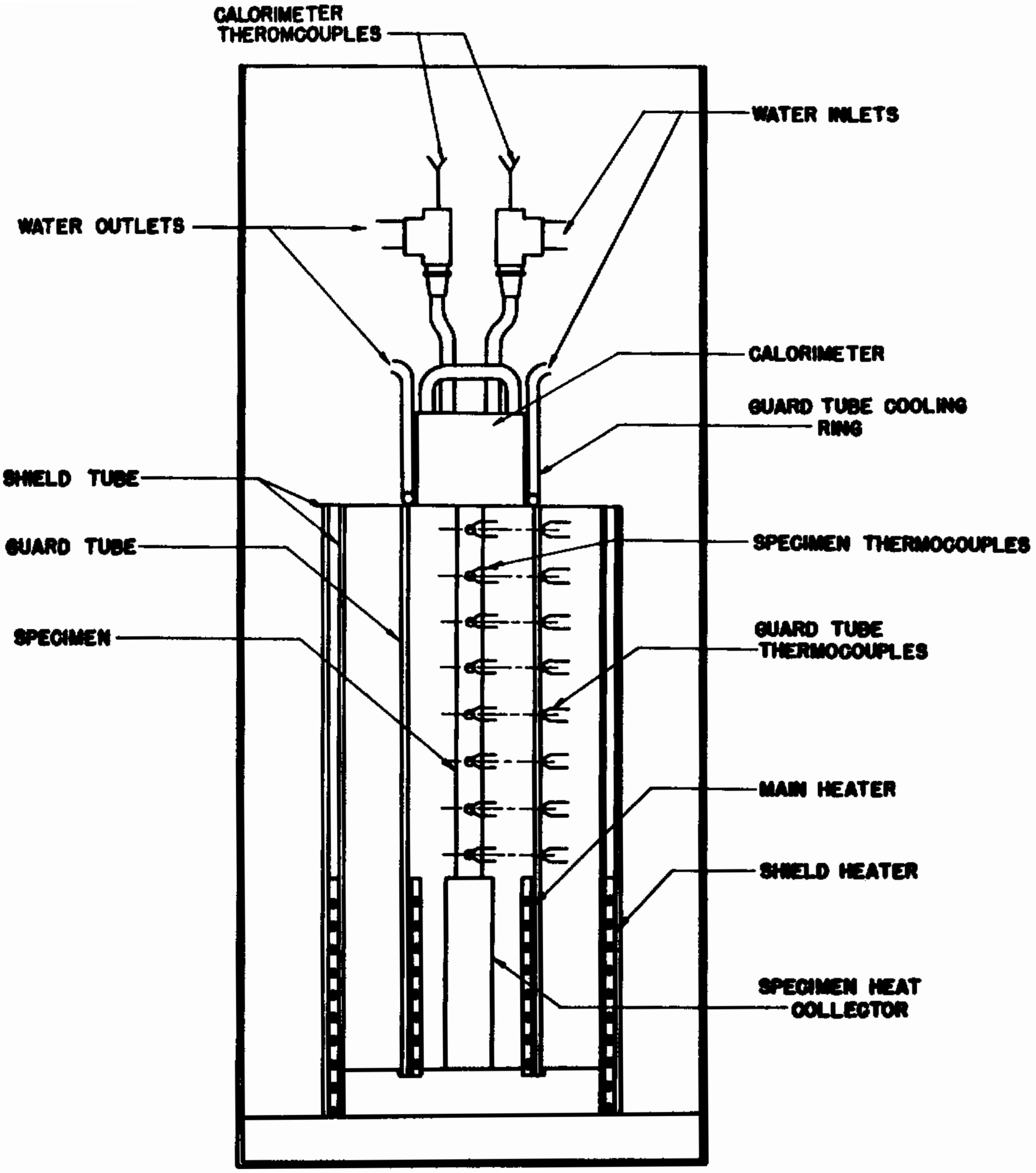


FIGURE 71 - CROSS-SECTION OF ELEVATED TEMPERATURE THERMAL CONDUCTIVITY APPARATUS

rectangular faces of the chambers, thus providing one square inch of specimen area to transfer heat to the calorimeter. The spacer was the same thickness as the specimen, and the slot which fitted around the specimen was 1/2 inch wide by one inch deep. Each rectangular face extended beyond the vessel wall along its length on each side to form a flange. Screw fasteners through opposing holes in these flanges provided the necessary clamping force for the specimen and spacer. Each chamber had an inlet or exit tube in the same end mentioned for the interconnecting tube. Spacing of these tubes was such that water through the inlet tube passed between the rectangular face and separator in one chamber, around the separator at the bottom and up through the interconnecting tube. The interconnecting tube directed the water flow through both sections of the chamber clamped to the other side of the specimen, and out through the exit tube. Each inlet or exit tube was fitted with a Conax Midget thermocouple gland, each containing an iron-constantan thermocouple with the measuring junction immersed in the water circulating through the calorimeter. All calorimeter parts were silver plated.

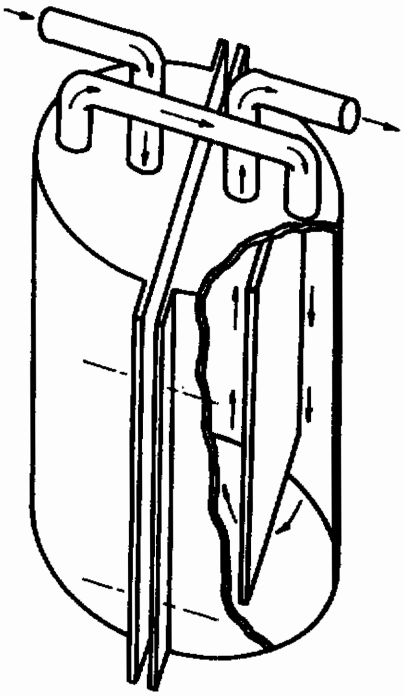


FIGURE 72 - CALORIMETER

Prior to installing a specimen for measurement, locations for eight 28-gage calibrated Chromel-Alumel thermocouples were lightly scribed on the specimen surface. The first reference mark was located 1 1/2 inches from the bottom or heat collector end of the specimen, and the remaining seven were spaced along the specimen toward the top end at one inch increments. The specimen was then cleaned in an aqueous solution of hydrofluoric and nitric acids, and the eight thermocouples, which had been previously beaded by fusion welding, were spot welded to the specimen at the marked locations. Turco Pre-Treat was applied to the specimen and thermocouple assembly to prevent surface contamination with resultant scaling at elevated temperature. After attaching the calorimeter and heat collector, the specimen was placed inside the guard tube. Thermocouple lead wires from each junction were brought out perpendicular from the specimen to the guard tube wall then along the inside of the guard tube and out the top. Design of the apparatus was such that each thermocouple on the guard tube was at the same elevation as one attached to the specimen. There was 1/2 inch between the heat collector or calorimeter and the nearest specimen thermocouple. Since there was some distortion of the isotherms near the heat collector and calorimeter, this 1/2 inch allowed space for the isotherms to become relatively straight and parallel to those along the remaining length of specimen.

After installing the specimen, the steel container and spaces between all tubes were filled with Santocel granular insulation. Insulation was carefully maintained at a constant elevation with respect to the calorimeter for all samples measured. A temperature gradient was then established along the specimen and guard tube by heat supplied from the specimen and guard tube heater. The desired gradient was obtained by varying heater power and flow of water through the calorimeter. At the same time power to the shield heater and flow of water to the guard tube cooling ring were varied to produce,as nearly as possible,the same temperature distribution along the guard tube as determined by the opposing thermocouples on specimen and guard tube. The temperature gradient established along the seven inch metered length of specimen and guard tube was from approximately 1250°F at the heated end to 250°F at the cooled end. Maximum variation between specimen and guard tube temperatures at equal elevations was less than 5°F and occurred at the heated end, while the difference near the cooled end was less than 1°F.

Steady state was considered to exist when the temperature indicated by the specimen thermocouples nearest the heat collector and calorimeter, respectively, changed at a rate less than 2°F per hour. A further consideration for steady state, as well as for parallel isotherms, was that the temperature difference between specimen and guard tube at the heated end be less than 5°F and the difference at the cooled end be less than 1°F. Temperature measurements were made hourly for at least four hours to assure that a steady state existed. Water flow rate through the calorimeter was monitored every 15 minutes during the four hour period.

Water was supplied to the guard tube cooling ring and calorimeter at constant pressure from a supply tank. The circulating system, which was controlled by a float actuated mercury switch, maintained the water level to within 1/4 inch of five feet above the calorimeter, at all times. An immersion heater in the tank maintained the water temperature constant within ±1°F.

Needle valves were used to control the flow of water to the guard tube cooling ring and calorimeter. A Hawshaw Model H-24890-4 flowrator was used to visually monitor the water flow through the calorimeter. The flowrator was calibrated by measuring the volume of water per unit time that flowed through it and the calorimeter while both were in the operating position.

A Leeds and Northrup Type K3 potentiometer and an ElectroniK Null Indicator which had a combined error of less than 0.001 MV were used to measure EMF output from the thermocouples. Mercury junctions in an ice-water bath were used as reference.

Three measurements, as previously described, were made for each of the four alloys. In addition, measurements were made of heat conducted to the calorimeter from sources other than the specimen. Several measurements were made without a specimen, but with thermocouples and other instrumentation properly positioned. These measurements were made for the same temperature range that the thermocouples nearest the calorimeter and guard tube cooling ring had indicated during measurements of specimens.

Data Analysis

The measured flow of water through the calorimeter along with the temperature difference of water entering and leaving the calorimeter were used to compute the heat flux, Q, through the specimen. The value was corrected by an amount determined by measurements made without a specimen. The mean temperatures were determined using the measured specimen temperatures at the eight equally spaced locations and assuming a linear gradient between each location. Specimen area, A, was also required and was determined from specimen dimensions measured with micrometers to the nearest 0.0001 inch. Thermal conductivity was then computed using the relation

$$K = \frac{QL}{A\ \Delta T}$$

Where L was the distance between thermocouples and ΔT was temperature difference between a particular pair of adjacent thermocouples.

Since the conductivity values determined were not at the exact desired temperatures, a smooth curve was drawn through the experimental points for each specimen. This curve was then used to obtain conductivity values at the desired temperatures.

The experimental error was estimated to be less than ten percent. This was determined by considering the possible error that each physically measured quantity contributed to a thermal conductivity calculation.

Specific Heat Measurements

Test Specimens

In order to control material and sampling, specimens for specific heat measurements were machined by Lockheed and supplied to the subcontractor, Georgia Institute of Technology Engineering Experiment Station. The apparatus used for measurements at elevated temperature differed from that used for low temperature; consequently, different specimen designs were required for each as shown in Figure 73. Disk type specimens were used for elevated temperature with 12 disks being required for each alloy sample. Twenty-four of the rectangular specimens comprised each alloy sample for low-temperature measurements. All specimens of a given alloy were machined from the same 0.125 inch thick solution treated and aged sheet, and were selected from spare material of a sheet utilized in Phase I, "Static Mechanical Properties." Specimen selection was made as randomly as possible from the spare material in order for the alloy sample to be representative of the entire sheet. Specimen locations within a sheet are shown for each alloy in Figures 10 through 13.

Details of Measurements at Low Temperature

The Kelvin and centigrade temperature scales are used for discussion of specific heat measurement details since calibration of all thermometers was based on these scales.

The apparatus used for low-temperature heat capacity measurements was a precision adiabatic-shield type high-vacuum calorimeter suitable for measurements from 15°K to 350°K, and was similar to one described in Reference 20. This apparatus was used previously in Georgia Tech's laboratory and was described in detail in Reference 21.

A schematic diagram of the apparatus is shown in Figure 74. Briefly, the apparatus consisted of a copper calorimeter can, C, (in which the sample of the alloy to be studied was sealed) surrounded by a vacuum tight case, V, which was immersed in a suitable cryogenic bath contained in the Dewar vessel, D. The vacuum case could be evacuated through the line, L, or helium gas could be admitted when it was desired to cool the calorimeter can to the temperature of the bath. The calorimeter can was surrounded by a lightweight copper shield, S, the temperature of which was adjustable to the same temperature as the calorimeter can, thus eliminating radiation transfer between the calorimeter can and its surroundings. The temperature difference between calorimeter can and adiabatic shield was sensed by four three-junction difference-thermocouples, and was controlled to within about 0.01°C and 0.001°C at 20°K and 300°K, respectively. Manual control of the temperature difference was achieved by regulation of the power supplied to three electrical resistance heaters wound on the top, sides and bottom of the shield.

Energy input to the calorimeter can was accomplished by measurement of electrical power to a heater, H, located in the re-entrant well, W. This well also contained a calibrated precision platinum resistance thermometer, T, which was used to measure the temperature of the calorimeter can.

All leads to the thermocouples, heaters and thermometer were wrapped around a tempering ring, R, the temperature of which was controlled by an electrical resistance heater and a difference-thermocouple between the ring and the adiabatic shield. The leads then were wrapped around the adiabatic shield. The calorimeter can, adiabatic shield and tempering ring were suspended by fine Nichrome wires to minimize heat transfer.

The pot, P, was used only when liquid hydrogen measurements were being made, in which case P was filled with liquid nitrogen to decrease heat leak along the vacuum line, along wires and through the mouth of the Dewar.

Measurement of specific heat was accomplished by noting the energy required to heat the carefully weighed calorimeter can and its contents through a known temperature interval. During this heating period the adiabatic shield and tempering ring were controlled so as to eliminate energy loss from or gain by the calorimeter can. A series of such measurements were made from 21°K to 300°K on each alloy. A similar set of measurements were made for the empty calorimeter can. After appropriate corrections for the slightly different mass of 50-50 lead-tin solder used to seal the calorimeter can for each alloy, the corrected thermal capacity of the empty can for each temperature interval was determined. The specific heat of the alloy for each temperature interval could then be computed by difference.

The primary temperature measurements were made with a Leeds and Northrup, capsule-type, precision, platinum resistance thermometer (25.5 ohms at 25°C) which was calibrated by the National Bureau of Standards on the International Temperature Scale down to the normal boiling point of oxygen (-182.970°C). Below this point the thermometer was calibrated to 10°K on the provisional temperature scale of the National Bureau of Standards, Reference 22, which was based on an assigned oxygen point of 90.19°K. The ice point was taken to be 273.16°K. All measurements with this thermometer were made with a Leeds and Northrup Mueller G-2 resistance bridge which permitted the temperature of the calorimeter can to be determined to about 0.001°K (0.0001 ohm) except near 20°K where the sensitivity of the thermometer decreased to 0.005°K.

Energy measurements were made by accurately measuring the current through and potential across the calorimeter heater during the heating interval by means of a Leeds and Northrup 100,000-microvolt White double potentiometer. The standard resistors and standard cells used were calibrated by the National Bureau of Standards. The heating time, which was controlled manually, was determined with a 110-volt, 60-cycle type S-10 electric timer manufactured by The Standard Electric Timer Company, Springfield, Massachusetts. A previous analysis, Reference 21, of the accuracy of this timer and manual operation of the switches indicated that the time of the heating interval could be determined to ±0.1 second.

Prior to beginning measurements the calorimetric sample consisting of 24 specimens was cleaned with acetone, dried, accurately weighed and placed in the calorimeter can which was then sealed with a 50-50 weight lead-tin solder. However, just prior to final sealing the can was evacuated, filled with helium gas to the existing barometric pressure of approximately 740 mm. of mercury, sealed off and, finally, accurately weighed. During these operations care was taken to keep an exact inventory of the solder added to the can so that appropriate corrections could be made for any change in the mass of the empty can.

The calorimeter can was suspended in the cryostat, vacuum case V was sealed, and the system evacuated to about five microns of mercury to ensure a vacuum-tight system. Helium gas was then admitted to the vacuum case and the calorimeter, and its contents were cooled to the temperature of the bath in the surrounding Dewar vessel, D. Four different baths were used to cover the desired temperature ranges as follows:

Bath	Temperature Range Covered (°K)
Liquid Hydrogen	20 to 80
Liquid Nitrogen	77 to 200
Solid CO_2-ethanol	198 to 275
Ice-water Mixture	273.2 to 305

In each instance, the measurements with a given bath were carried out so as to overlap measurements from an adjacent temperature range. Different baths were necessary to improve the stability of the shield control and to minimize heat leaks along leads.

Once the calorimeter can had reached the bath temperature the helium was pumped off and a high vacuum of approximately one micron of mercury re-established. The system was now ready for calorimetric measurements.

Specific heat measurements were made by first observing the temperature of the calorimeter as a function of time, while at the same time establishing an essenticlly zero temperature difference between the adiabatic shield and the can. This established the initial temperature. The calorimeter heater was now energized and the timer started simultaneously. The shield operator immediately began adjustment of the energy input to the shield heaters to maintain the desired adiabatic conditions. Measurements of the current and potential of the calorimeter heater were made during the heating interval, which varied from 400 to 1300 seconds. At the end of the heating interval, a small time, about 200 seconds, was allowed for dissipation of thermal gradients in the calorimeter can, after which the final temperature was reached, as shown by the fact that the temperature drift rate became essentially constant as in the fore period. About 50 measurements of the type just described were made for each alloy over the temperature range covered by the four baths, namely, 20°K to 305°K.

Control of the adiabatic shield presented no difficulty in the range below about 200°K. Above this temperature, control was somewhat more difficult because of the fact that the amount of energy lost from the shield to the bath increased, since the principal energy transfer was due to radiation. Near room temperature a small correction was applied to the observed temperature rise of the can because of a small heat leak of undetermined origin which occurred even when the temperatures of the can and shield were the same to 0.001°C.

This correction was determined experimentally and never amounted to more than 0.3 percent of the specific heat.

Analysis of Low-Temperature Data

The experimentally measured quantities: thermometer resistances, potential measurements acrosss the standard resistor and across the heater resistor, and the measured time interval, were used to determine the heat capacity of the empty can or of the can plus sample. These quantities were processed on an IBM 650 digital computer using the Bell general purpose interpretive system.

Heat capacity measurements were made on the empty calorimeter can over the entire temperature range from 20°K to 305°K. These results were combined with previous data obtained from Reference 21. Data for the specific heat of the empty can were fitted by least squares procedures as fourth-degree polynomials with temperature (°K) as the independent variable covering the ranges 20°K to 90°K, 90°K to 240°K, and 240°K to 305°K. These polynomials were corrected slightly for differences in the weight of solder used to close the can in each series of alloy measurements. The solder corrections were made using polynomials for (50-50) lead-tin solder assuming that the specific heat of the solder could be represented as a weight fraction average of published specific heat data of the pure substances. Subsequent measurement of the specific heat of the lead-tin solder indicated that this assumption led to no appreciable error in the final reported specific heat for the alloys.

The mass of the calorimeter can was 188.613 grams. The ratio of the total heat capacity of each sample to that of the empty can was approximately 1.6 at 300°K, and decreased to about 1.3 at 80°K. At 21°K the ratio was approximately 0.6 for the low vanadium content alloys and approximately 0.9 for the high vanadium content alloys.

The results in the temperature regions where overlap of measurements was possible were in good agreement with one another; the maximum deviation in specific heat never amounted to more than 0.3 percent.

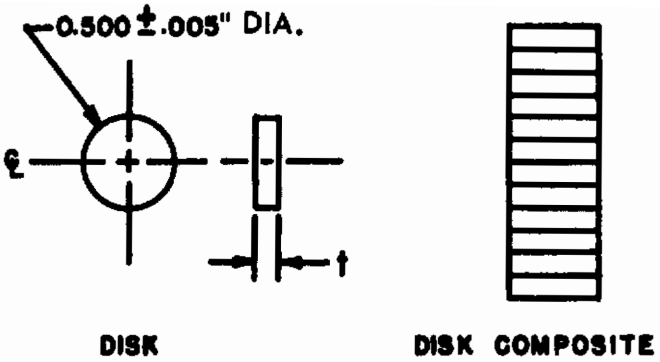
No thermal anomalies were noted in any of the alloys.

The accuracy of the measured specific heat from 300°K to 80°K was estimated to be 0.5 percent. Below 80°K the accuracy decreased to about two percent at 21°K.

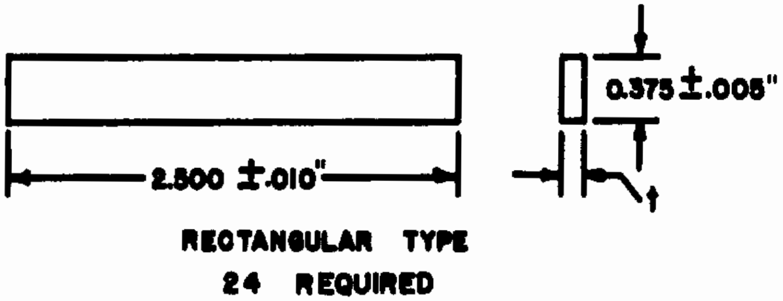
In order to obtain values of specific heat at even temperature intervals, the experimentally determined specific heats were least squared to obtain polynomials of the form

$$C_p = A_o + A_1T + A_2T^2 + A_3T^3 + A_4T^4$$

To obtain a good fit, three polynomials were used for each sample covering the ranges 20°K to 50°K, 50°K to 150°K, and 150°K to 305°K. In the range 20°K to 50°K, values of C_p/T were least squared against temperature, therefore, the constant A_o was identically zero in this range for each alloy.



ELEVATED TEMPERATURE DISK COMPOSITE SPECIMEN



LOW TEMPERATURE SPECIMEN

FIGURE 73 - SPECIFIC HEAT SPECIMENS FOR 0.125 INCH THICK SHEET

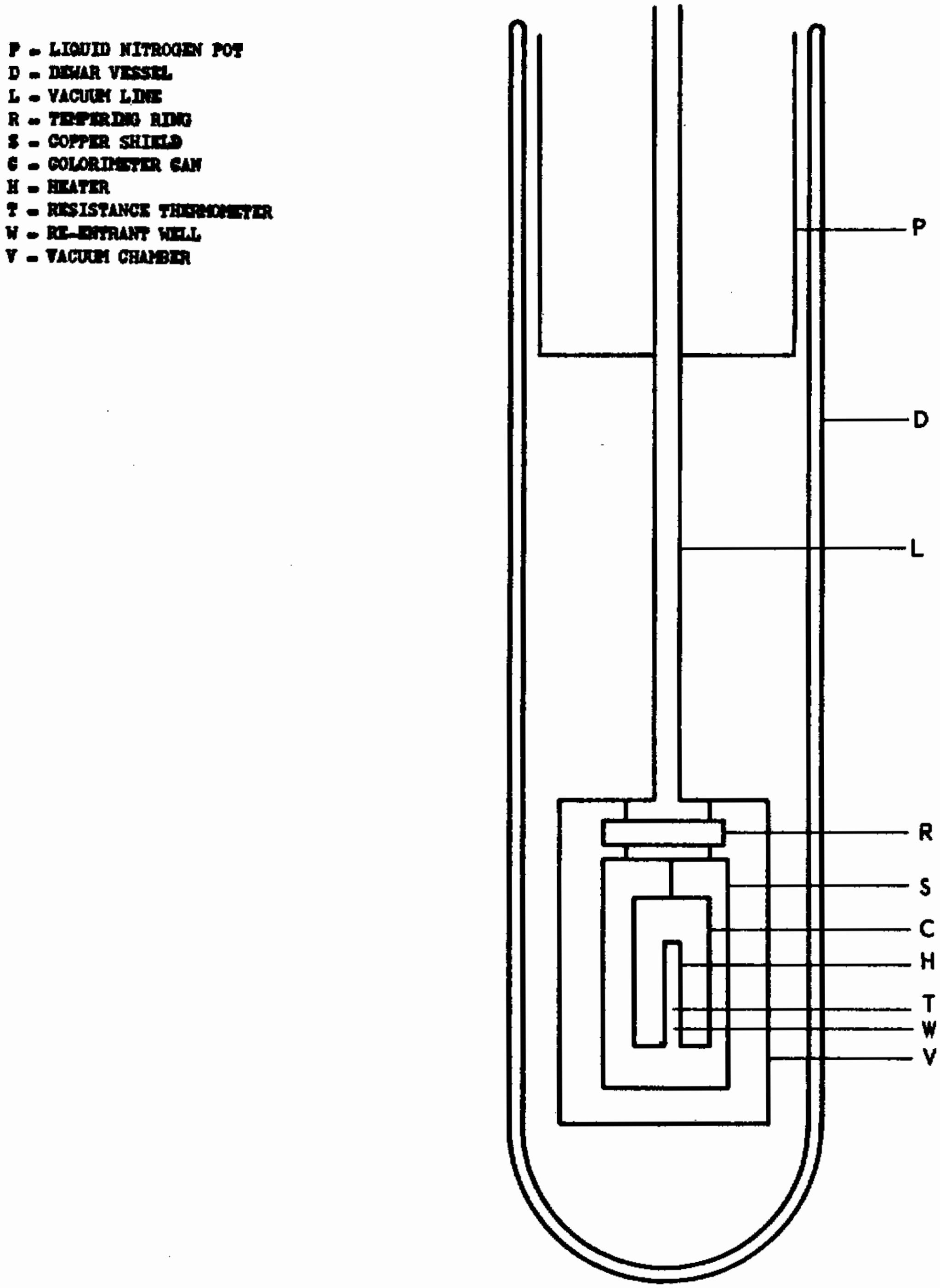


FIGURE 74 - SCHEMATIC DIAGRAM OF LOW-TEMPERATURE CALORIMETER

Details of Measurements at Elevated Temperatures

The apparatus used for specific heat measurements at elevated temperatures was a "drop type" copper block calorimeter similar to the one described in Reference 23. It was originally constructed for specific heat measurements of rare earth oxides over the 30°C to 900°C temperature range as described in References 24 and 25.

Figure 75 shows the apparatus schematically. The sample, consisting of 12 carefully cleaned and weighed disk specimens for specific heat measurements, was enclosed in an Inconel container, C, and the container was suspended by a Nichrome wire in the tube furnace, F. After the sample had reached equilibrium with the furnace temperature, the latch, L, holding the wire in place was released and the Inconel container fell into the massive copper block, B. Fall time was approximately two seconds, and was cushioned near its end by the plunger, P, which was slowed down by compression of the gas in the lower section of the guide tube, I. Immediately after the fall was completed, the gates G1 and G2, operated manually by a common handle, H, were closed. Gate G1 was water-cooled which prevented radiation transfer to the top of the calorimeter block, B. Gate G2 closed the top of the block and prevented loss of energy by convection and radiation from the opening in the block.

The copper block was surrounded by a water-tight container, K, which was immersed in a large water thermostat, W, the temperature of which was maintained at 30.00 ±0.02°C. The copper block was equipped with a copper resistance thermometer, having a resistance of about 105 ohms, which was readable to approximately ±0.00002°C by means of a Leeds and Northrup Mueller G-2 precision resistance bridge. The copper block was also equipped with a constantan heater which was used to accurately determine the thermal equivalent of the block. This thermal equivalent was 1120.7 calories per °C over the 30°C to 35°C range, and was determined during a previous investigation, Reference 25, by observing the block temperature rise when known amounts of electrical energy were applied to the constantan heater.

An inert atmosphere was provided in the entire assembly, including the furnace, by an argon gas flow of 31 cubic centimeters per minute which entered the system through the thermostated bath as shown in Figure 75.

Since the position of the isothermal zone in the furnace varied with temperature level, it was necessary to determine the position of this zone with respect to the Inconel container. A separate study was made from which a correction curve was obtained showing the relation between the true Inconel container temperature, as measured by a thermocouple placed inside the empty container, and the furnace thermocouple. Since the isothermal zone of the furnace shifted upward with an increase in temperature, the thermocouple and Inconel container were located at a higher position for temperature greater than about 425°C. The use of these two fixed positions for the thermocouple and container minimized the required temperature corrections. These corrections, which amounted in some instances to as much as 4°C, were applied to all temperatures measured with the furnace thermocouple during the actual specific heat measurements.

During measurement, the furnace temperature was first adjusted to approximately the desired value, during which time the sample container was located in block B. When the desired furnace temperature was approximately constant, the sample container was raised to its proper position in the furnace and allowed to come to equilibrium with the furnace during a period of two to four hours. Shortly before the sample was dropped, a time versus temperature record was made for the copper block. At the instant of drop, the furnace temperature, as determined with platinum-platinum (10 percent rhodium) thermocouple, was measured. This thermocouple had been calibrated by the National Bureau of Standards and was believed to be correct to ± 0.5°C. The temperature of the copper block, B, now began to rise and was followed until an equilibrium cooling rate, due to loss of energy from the block to the colder surrounding water thermostat, was reached. This equilibrium state was reached in approximately 40 minutes for the empty Inconel container and 75 minutes for the container plus sample. The temperature rise of the copper block varied from about 0.053°C for the empty Inconel container initially at 100°C to 2.2°C for a sample plus container initially at 650°C. Temperature rise of the copper block was corrected for heat loss to the water thermostat using data from a separate series of measurements from which the rate of change of the block temperature was determined as a function of temperature difference between the block and the water thermostat. Enthalpy change of the sample plus Inconel container between the furnace temperature and final base temperature of 30°C was obtained using this corrected temperature rise and the block thermal equivalent since the enthalpy change of sample and container was equal to that of the copper block. In most cases, six to eight such enthalpy measurements were made at successively higher temperatures over the 200°F to 1200°F range for each sample plus Inconel container and for the Inconel container without a sample. Differences between those yielded enthalpy of the sample versus temperature from which specific heat values were determined. Since the final block temperature was different for each drop, it was necessary to correct all enthalpy changes to a common base temperature. A base temperature of 30.00°C was selected since it was previously used with the equipment, References 24 and 25. This correction required an approximate value for the specific heat of each alloy which was obtained in the course of subsequent calculations or from the low-temperature specific heat measurements.

Analysis of Elevated-Temperature Data

The difference between the two measured enthalpy changes divided by the mass of the alloy in grams gave the enthalpy change, Δh^t_{30}, for the alloy in calories per gram between 30°C and t°C.

$$\Delta h^t_{30} = \frac{\Delta H^t_{30}\,(\text{sample} + \text{container}) - \Delta H^t_{30}\,(\text{container})}{\text{mass of sample}} \tag{1}$$

Δh^t_{30} = Enthalpy change for sample in calories per gram between 30°C and t°C

ΔH^t_{30} = Enthalpy change in calories between 30°C and t°C

Since measurements of ΔH^t_{30} for the container were not made at exactly the same temperatures as those for the sample plus container, it was necessary to develop an interpolating function for the container enthalpy measurements in order to determine Δh^t_{30} in Equation (1). This was done by making a least squares fit of the measured container enthalpies to a third degree polynomial. This function was adequate since the mean percentage deviation between the 12 measured values and corresponding values from solution of the polynomial was 0.37 percent. The deviation for any one of the 12 values was less than one percent.

Specific heat of the sample was then determined using the $\Delta h^t{}_{30}$ versus temperature data from Equation (1), since specific heat at a desired temperature was equal to the slope of the enthalpy curve at that temperature. This slope was determinable either graphically or analytically. For these data, specific heats were determined analytically by assuming the enthalpy difference to be of the following form.

$$\Delta h^T{}_{303.16} = h_T - h_{303.16} = aT + bT^2 + c/T + d \qquad (2)$$

where $\Delta h^T{}_{303.16} = \Delta h^t{}_{30}$

$T = {}^\circ K$

a, b, c, d = constants

The corresponding heat capacity equation obtained by differentiating Equation (2) with respect to temperature was

$$C_p = a + 2bT - c/T^2 \qquad (3)$$

which is of the form

$$C_p = A + BT + C/T^2 \qquad (4)$$

Equations of the same form as (3) and (4) were used in Reference 26 to represent elevated-temperature enthalpy and specific heat data for chromium and vanadium, and the simple linear form of Equation (4) with C set equal to zero was used for alpha titanium over the 290°K to 1155°K range.

The "drop-type" calorimeter inherently gives less accurate results near its base temperature. For this reason the more accurately known specific heat values at 30°C ($C_{p303.16}$) obtained from the low-temperature measurements were used to fix the lower end of the elevated-temperature specific heat curve. Making use of the fact that $\Delta h^T{}_{303.16}$ becomes zero at T = 303.16°K (30°C), Equation (2) was expressed as

$$\Delta h^T{}_{303.16} - C_{p303.16}(T-303.16)\,T/(T-303.16)^2 = c/(303.16)^2 + bT \qquad (5)$$

which is of the form

$$Y = A + B x \qquad (6)$$

Values for x and y in Equation (6) were computed for each experimental value of $\Delta h^T{}_{303.16}$, and the constants A and B were determined by method of least squares for each alloy. The constants a, b, c, and d in Equations (2) and (3) were then evaluated as follows:

$$a = C_{P303.16} - 2B(303.16) + A$$

$$b = B$$

$$c = A(303.16)^2$$

$$d = \left[-C_{P303.16} + B(303.16) - 2A\right] \times (303.16)$$

Specific heat values at the desired temperatures were then computed from Equation (3) using the above constants. The ratio of total heat capacity of the sample to that of the Inconel container was about four over the entire temperature range.

Equation (2) was also solved for $\Delta h^{T}_{303.16}$ at the measurement temperatures and compared to the experimentally determined values. The mean percent deviation between the calculated and measured values of $\Delta h^{T}_{303.16}$ varied from 0.14 percent for Ti-4Al-3Mo-IV to 0.91 percent for Ti-2.5Al-16V. A more detailed comparison of computed values and experimental values is presented in Reference 27. This reference also gives details of the interpolating function used for the sample container enthalpy change.

In order to check the overall accuracy of the calorimeter, specific heat measurements were made on a coarsely crystalline sample (12.30 gm) of synthetic sapphire (Al_2O_3) which had been used in earlier measurements with this equipment. This material was originally obtained from the National Bureau of Standards for use as a standard sample for calibration of calorimeters in the region 0°C to 900°C. Careful measurements of enthalpy changes, Δh^{t}_{0} (referred to 0°C), of this material have been published, Reference 28. The results of the present experimental measurements are shown in Table XXX together with the corresponding values of Δh^{t}_{30} obtained by appropriate interpolation of the results in Reference 28. The percentage deviation between the results for the ten measured points is also in Table XXX. The mean deviation from the published values for the ten temperatures measured was 0.53 percent. Excluding the two points H-6 and H-7 at 100.8°C the mean deviation was 0.21 percent. No systematic trend in the deviations was noted. The measurements 0-1 and 0-2 in Table XXX were made after all measurements on the four titanium alloys were completed.

Accuracy of the elevated-temperature specific heat measurements for the four alloys was estimated to be one to two percent.

Corrosion was minimized by the use of an argon atmosphere in the furnace. The Inconel sample container used was not hermetically sealed and some diffusion of gaseous impurities from the furnace atmosphere presumably occurred. The observed weight increase amounted to less than 0.25 percent for all alloys except for a few points for Ti-2.5Al-16V for which a weight increase of 0.75 percent was observed. These weight increases occurred only at the higher temperatures. It was felt that this did not affect the measured specific heats outside the stated accuracy.

A more serious complication, which was not adequately studied, arose from the fact that specific heat measured at 1000°F and higher required heating for two to four hours at temperatures exceeding the aging temperatures given for the alloys. The occurrence of aging effects may be expected as cited in Reference 29. It should be noted that with the "drop-type" calorimeter used, the heated sample was cooled to room temperature within 10 to 20 minutes, a process which was equivalent to an air-quench.

Some specific heat measurements were made on Ti-2.5Al-16V in the temperature range of 100°F to 600°F subsequent to making measurements above 900°F. It was found that the specific heat was two to three percent smaller than the specific heat of the material which had been held above 900°F for a number of hours; this indicated that aging effects had occurred. Unfortunately, time did not permit further study of this alloy nor any studies of possible aging effects in the other alloys. The specific heats of the Ti-6Al-4V, Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were all made by heating the specimens to successively higher temperatures.

TABLE XXX

COMPARISON OF MEASURED AND PUBLISHED ENTHALPY CHANGES FOR A STANDARD Al_2O_3 SAMPLE, WEIGHING 12.30 GRAMS

Sequential Order of Measurement	Corrected Furnace Temp., t, °C	Δh_{30}^{t}, Cal./Gm. Measured	Δh_{30}^{t}, Cal./Gm. From Ref. (28)	Percent Deviation
H-1	499.3	116.8	116.66	-0.12
H-3	597.5	144.7	144.49	-0.15
H-4	651.3	159.9	159.97	0.04
H-5	435.0	99.12	98.80	-0.32
H-6	100.8	14.61	14.40	-1.46
H-7	100.8	14.71	14.40	-2.15
H-10	330.2	70.36	70.52	0.23
H-11	430.8	97.08	97.65	0.58
O-1(1)	178.9	32.29	32.27	0.06
O-2(1)	265.0	53.47	53.58	0.21
			Mean	0.53

(1) These measurements were made after completion of all high temperature measurements on the titanium alloys.

L - LATCH
P - PLUNGER
N - NICHROME WIRE
I - GUIDE TUBE
R - REFRACTORY PLUG
TC - THERMOCOUPLE
C - SPECIMEN CONTAINER
F - FURNACE
G1 - GATE
H - GATE HANDLE
W - WATER THERMOSTAT
K - WATER-TIGHT CONTAINER
G2 - GATE
B - COPPER BLOCK

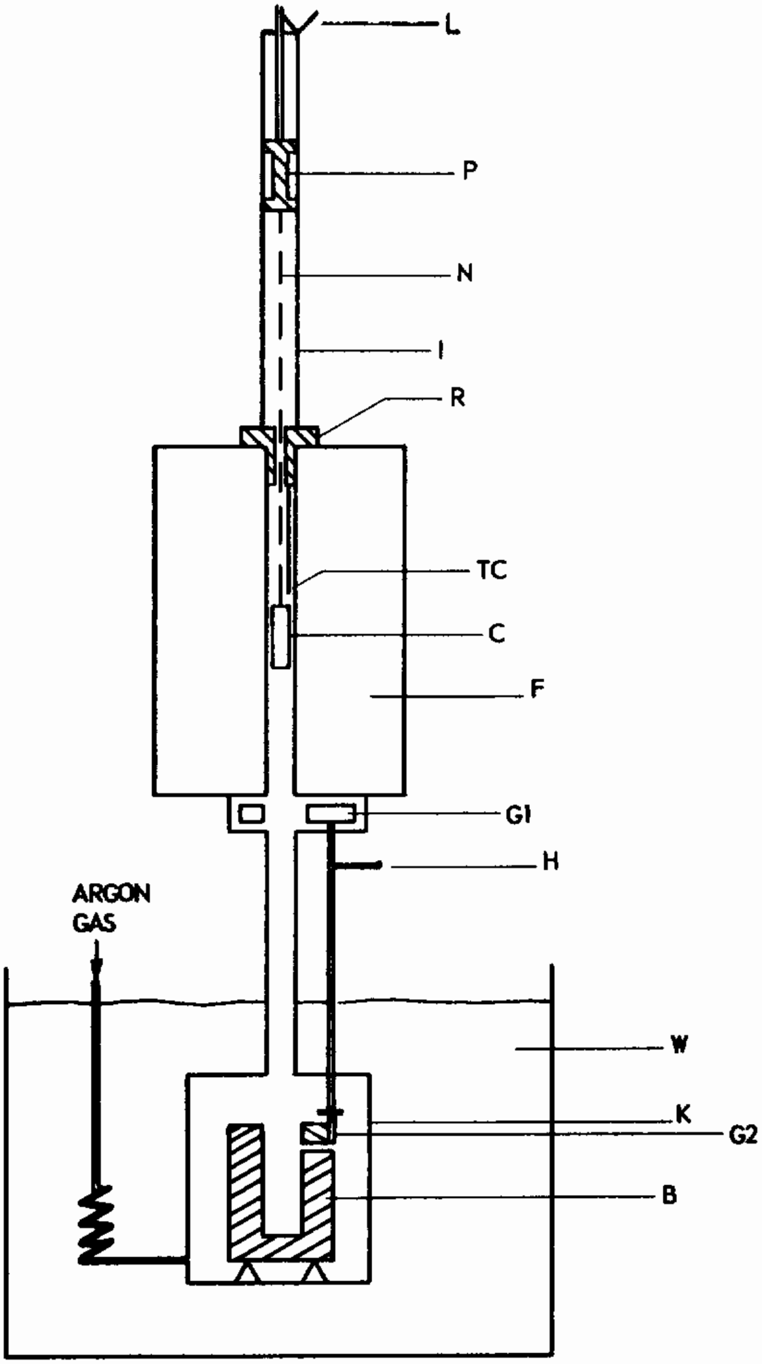


FIGURE 75 - SCHEMATIC DIAGRAM OF ELEVATED-TEMPERATURE CALORIMETER

IV - RESULTS FOR B120VCA TITANIUM ALLOY

Tensile Test Results – B120VCA

Summary plots for B120VCA tensile data showing average variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature are presented in Figures 76 through 84. A total of approximately 500 tests representing five heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch is summarized by these plots for a temperature range of 80°F to 1000°F. Tabulations of these data and percent elongation in 1/8 inch and 1/4 inch are in Tables I through IX, pages 6 through 14 of Volume 3.

A complete stress versus strain curve is in Figure 85 and typical families of longitudinal and transverse stress versus strain curves and stress versus tangent modulus curves for each thickness are in Volume 1. Also in Volume 1 are statistically determined "B" design values for each thickness at room temperature as well as design curves for elevated temperature.

Curves showing variation of Poisson's ratio with tensile strain for longitudinal and transverse grain directions for one heat of 0.063 inch thick sheet are in Figures 86 through 89. Additional elastic values of Poisson's ratio for two heats are in Table XXXI.

Results for longitudinal and transverse tensile specimens from five heats and three thicknesses of B120VCA after being temperature exposed and temperature-stress exposed are in Tables XXXII through XL. These data included exposure temperatures of 600°F and 900°F for 500 hours and ten hours, respectively, and exposure stresses equal to 1/3 the ultimate tensile stress at the exposure temperatures. Volume 1 summarizes these data in a manner more convenient for design use.

Compressive Test Results – B120VCA

Summary curves showing average compressive yield stress and elastic modulus versus temperature for five heats and for thicknesses of 0.063 inch and 0.125 inch are in Figures 90 through 95. These curves represent approximately 350 tests for the 80°F to 1000°F temperature range. Tabulations of these data along with the Ramberg-Osgood shape factor and secant stresses at 0.85 E and 0.70 E are in Tables X through XV, pages 15 through 20 of Volume 3.

Typical families of longitudinal and transverse compressive stress-strain curves, stress versus tangent modulus curves and stress versus secant modulus curves for the two thicknesses are in Volume 1. Statistically determined "B" design values at room temperature,as well as design curves for elevated temperature,are also in Volume 1.

Bearing Test Results – B120VCA

Curves summarizing approximately 1700 bearing tests for e/D ratios of 1.5 and 2.0 and bearing hole diameters of 1/8 inch, 3/16 inch and 5/16 inch are in Figures 96 through 125. These curves show longitudinal and transverse ultimate bearing stress and yield stress versus temperature for the 80°F to 1000°F temperature range, and represent five heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch. Tabulations of the data are in Tables XVI through XLV, pages 21 through 50 of Volume 3.

Statistically determined "B" design values at room temperature are presented in Volume 1 for both e/D ratios and a 5/16 inch hole diameter. Design curves for elevated temperature are also presented in Volume 1 for these same conditions.

Single Shear Test Results - B120VCA

Summary plots showing variation of longitudinal and transverse single shear strength with temperature are shown in Figures 126 through 134. An approximate total of 500 tests representing five heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch is summarized by these plots for a temperature range of 80°F to 1000°F. These data are in Tables XLVI through XLVIII, pages 51 through 53 of Volume 3.

Statistically determined "B" design values for room temperature and design curves for elevated temperatures are in Volume 1 for each thickness.

Double Shear Test Results - B120VCA

Curves showing variation of longitudinal and transverse double shear strength with temperature for three heats of 0.125 inch thick B120VCA are in Figures 135, 136 and 137. These data, representing approximately 175 tests for the 80°F to 1000°F temperature range, are in Table XLIX, page 54, Volume 3.

Crippling Test Results - B120VCA

Longitudinal and transverse crippling data obtained for two specimen sizes over the 80°F to 1000°F temperature range are in Tables XLI through XLIV. The data are for specimens formed from one heat of 0.063 inch thick solution treated B120VCA which was aged subsequent to forming. Compressive properties, including Ramberg-Osgood parameters, for specimens from the same solution treated sheets as the crippling specimens and aged at the same time are in Table XLV.

Fastener Joint Test Results - B120VCA

Single fastener lap joint properties obtained for one heat of 0.063 inch thick B120VCA over the -320°F to 80°F temperature range are summarized in Figures 138 through 141. These data are for screw type and lockbolt type Ti-6Al-4V fasteners of 3/16 inch and 5/16 inch nominal diameters. The summary curves represent specimens having an e/D ratio of two and W/D ratio of five. Tabulations of the data are in Tables L through LIII, pages 55 through 58 of Volume 3.

Tensile data obtained from the same heat and temperature range are summarized under Low-Temperature Tensile Test Results.

Weld Joint Test Results - B120VCA

Figure 142 summarizes tensile data obtained for longitudinal and transverse specimens of 0.063 inch thick B120VCA which were fusion welded in the solution treated and aged condition. A similar plot is shown in Figure 143 for specimens from a different heat which were welded in the solution treated condition and subsequently aged. Tabulations of the summarized data, along with joint efficiencies for the -320°F to 80°F temperature range, are in Tables LIV and LV, pages 59 and 60 of Volume 3.

Tensile data obtained for the same heats and temperature range and used as a basis for computing joint efficiency are summarized under Low-Temperature Tensile Test Results.

Low-Temperature Tensile Test Results - B120VCA

Summary plots for longitudinal and transverse tensile data showing average variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature are presented in Figures 144 and 145. Two heats of 0.063 inch thick sheet are represented by these plots and are the same as those used for fastener and weld joints. Families of typical longitudinal and transverse stress-strain curves are shown in Figures 146 and 147 for the heat which was aged by the producer. Tabulations of the data obtained for the -320°F to 80°F temperature range are in Tables LVI and LVII, pages 61 and 62 of Volume 3.

Thermal Expansion Measurement Results - B120VCA

Thermal expansion data obtained for longitudinal specimens from one 0.125 inch thick sheet of B120VCA are summarized by the curve of average expansion versus temperature in Figure 148. Also in this figure are mean linear thermal expansion coefficients for several temperatures in the -453°F to 1200°F temperature range. These data represent measurements for three specimens at low temperatures and two at elevated temperatures. Elevated-temperature measurements for a third specimen were considerably different from the other two in that it showed a change in length upon cooling from 1200°F. This indicated a phase change had occurred which made the expansion curve irreversible. Results of each measurement are in Tables LVII and LIX, pages 63 and 64, Volume 3. The curve in Figure 148 was obtained from these measurements by adjusting all data to a reference of 100°F.

Thermal Conductivity Measurement Results - B120VCA

Thermal conductivity data obtained for specimens from one 0.125 inch thick sheet of B120VCA are summarized by the curve in Figure 149. Conductivity values at several temperatures for the -420°F to 1200°F range are also in this figure. Elevated-temperature measurements were made by Lockheed on three specimens, and the average of these is represented by the curve in Figure 149. Results of individual measurements are in Table LX, page 65, Volume 3.

Low-temperature measurements were made by Georgia Tech, and the method employed measured the combined conductivity of three specimens. Additional results are in Georgia Tech's report, Reference 13.

Specific Heat Measurement Results - B120VCA

Specific heat data obtained for specimens from one 0.125 inch thick sheet of B120VCA are summarized by the curve in Figure 150. Specific heat values at several temperatures for the –420°F to 1200°F range are also in this figure. The measurements were made by Georgia Tech, and the sampling method used resulted in average values for the sheet. Additional results are in Georgia Tech's report, Reference 27.

TABLE XXXI

ELASTIC POISSON'S RATIO DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK

Grain Direction	Tensile Specimen Number	Test Temp., °F	Poisson's Ratio
Longitudinal	A8LA1P-2 *	80	.335
	A2LA2-6	200	.291
	A2LA2-13	200	.286
	A2LA2-15	200	.294
	A2LA3-8	400	.310
	A2LA3-16	400	.287
	A2LA3-18	400	.299
	A8LA3P-1 *	400	.345
	A2LA4-9	600	.340
	A2LA4-12	600	.365
	A8LA4P-2 *	600	.341
	A2LA6-4	800	.331
	A2LA6-10	800	.342
	A2LA6-17	800	.307
	A8LA6P-3 *	800	.340
	A2LA7-3	900	.380
	A8LA7P-4 *	900	.373
	A2LA8-2	1000	.338
	A2LA8-7	1000	.372
	A2LA8-14	1000	.329
	A8LA8P-5 *	1000	.298
Transverse	A8TA1P-1 *	80	.335
	A8TA1P-2 *	80	.329
	A2TA2-6	200	.309
	A2TA2-13	200	.307
	A2TA2-15	200	.331
	A8TA2P-6 *	200	.330
	A2TA3-16	400	.315
	A2TA3-18	400	.288
	A8TA3P-1 *	400	.298
	A2TA4-1	600	.302
	A2TA4-9	600	.327
	A2TA4-12	600	.312
	A8TA4P-2 *	600	.334
	A2TA6-3	800	.363
	A8TA6P-3 *	800	.346
	A2TA7-2	900	.379
	A2TA7-5	900	.336
	A2TA7-10	900	.334
	A8TA7P-4 *	900	.362
	A2TA8-7	1000	.372
	A2TA8-11	1000	.311

* Curves are plotted for indicated specimens

TABLE XXXII- EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6392 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $X10^{-6}$, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A1LA1B-1	189,000	173,000	16.0	5.0	10	-
					-2	188,000	171,000	15.7	5.5	10	20
					-3	191,000	178,000	15.9	4.0	8	16
					Average	189,000	174,000	15.9	4.8	9	18
				T	A1TA1B-1	185,000	174,000	16.7	5.0	10	20
					-2	186,000	175,000	16.6	5.0	12	24
					-3	192,000	179,000	16.7	3.5	10	16
					Average	188,000	176,000	16.7	4.5	11	20
			600	L	A1LA4B-1	163,000	136,000	14.7	4.0	-	-
					-2	168,000	153,000	14.0	3.8	-	-
					-3	169,000	133,000	13.5	4.3	-	-
					Average	167,000	141,000	14.1	4.0		
				T	A1TA4B-1	172,000	144,000	15.0	6.0	12	20
					-2	174,000	149,000	14.9	3.0	-	-
					-3	177,000	151,000	14.7	3.5	-	-
					Average	174,000	148,000	14.9	4.2		
		54,300	80	L	A1LA1A-1	195,000	178,000	16.1	4.0	12	16
					-2	196,000	179,000	16.1	4.5	12	20
					-3	193,000	177,000	15.6	5.0	16	20
					Average	195,000	178,000	15.9	4.5	13	19
		54,300		T	A1TA1A-1	177,000	160,000	15.0	4.5	12	20
					-2	179,000	168,000	16.3	-	-	-(1)
					-3	181,000	170,000	16.4	3.5	8	20
					Average	179,000	166,000	15.9	4.0	10	20
		54,300	600	L	A1LA4A-1	174,000	142,000	13.7	-	-	-(1)
					-2	171,000	144,000	14.9	4.0	10	16
					-3	172,000	144,000	13.5	3.5	8	16
					Average	172,000	143,000	14.0	3.8	9	16
		54,300		T	A1TA4A-1	158,000	133,000	13.8	6.0	14	24
					-2	181,000	155,000	15.0	4.0	-	-
					-3	182,000	154,000	15.7	4.0	-	-
					Average	174,000	147,000	14.8	4.7		
900	10	ZERO	80	L	A1LA1C-1	178,000	175,000	16.4	1.0	8	16
					-2	201,000	184,000	16.4	3.5	8	12
					-3	199,000	176,000	15.8	3.0	6	12
					Average	193,000	176,000	16.2	2.5	7	13
				T	A1TA1C-1	177,000	173,000	17.0	1.0	4	12
					-2	173,000	168,000	16.6	1.8	10	24
					-3	187,000	185,000	17.8	1.5	10	16
					Average	179,000	175,000	17.1	1.4	8	17
			900	L	A1LA7C-1	150,000	118,000	12.3	20.0	46	52
					-2	155,000	124,000	11.5	16.0	40	-
					-3	150,000	116,000	12.4	18.0	-	-
					Average	152,000	119,000	12.1	18.0	43	
				T	A1TA7C-1	150,000	128,000	13.0	8.0	26	44
					-2	148,000	135,000	12.8	-	-	-
					-3	163,000	134,000	12.3	1.0	26	40
					Average	154,000	132,000	12.7	9.0	26	42
		48,000	80	L	A1LA1D-1	167,000	-	16.4	0.2	6	12(2)
					-2	174,000	-	15.9	-	-	-(2)
					-3	189,000	-	16.4	0.2	10	16(2)
					Average	177,000		16.2	0.2	8	14
		47,700		T	A1TA1D-1	170,000	-	16.3	0.5	8	12(2)
					-2	178,000	176,000	16.8	1.0	8	12
					-3	187,000	-	16.4	0.5	8	12(2)
					Average	178,000		16.5	0.7	8	12
		48,000	900	L	A1LA7D-1	150,000	129,000	13.4	12.5	32	52
					-2	161,000	138,000	12.7	6.5	24	40
					-3	161,000	136,000	12.6	-	-	-
					Average	157,000	134,000	12.9	9.5	28	46
		47,700		T	A1TA7D-1	153,000	132,000	14.0	10.0	30	48
					-2	160,000	142,000	11.6	11.0	20	24
					-3	154,000	141,000	13.1	10.0	30	52
					Average	156,000	138,000	12.9	10.3	27	41

(1) Specimen failed within 1/4" of fillet.
(2) Specimen failed prior to attaining yield deformation.

TABLE XXXIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6392 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	ELONGATION, % in .25 IN.	ELONGATION, % in .125 IN.
600	500	ZERO	80	L	A2LA1B-1	210,000	194,000	16.6	5.0	16	20
					-2	210,000	194,000	16.6	5.0	14	28
					-3	196,000	176,000	16.5	7.0	16	36
					Average	205,000	188,000	16.6	5.7	15	28
				T	A2TA1B-1	210,000	194,000	16.9	4.0	6	12
					-2	210,000	192,000	17.0	4.0	12	16
					-3	187,000	170,000	16.8	4.0	6	12
					Average	202,000	185,000	16.9	4.0	8	13
			600	L	A2LA4B-1	187,000	160,000	14.5	5.0	16	24
					-2	176,000	143,000	14.7	7.0	16	20
					-3	174,000	140,000	14.6	6.5	20	32
					Average	179,000	148,000	14.6	6.2	17	25
				T	A2TA4B-1	188,000	162,000	15.7	5.0	18	-
					-2	163,000	137,000	15.3	6.3	24	36
					-3	167,000	137,000	15.2	8.0	20	32
					Average	173,000	145,000	15.4	6.4	21	34
		56,600	80	L	A2LA1A-1	205,000	192,000	16.0	2.0	8	16
					-2	205,000	192,000	16.3	3.0	8	16
					-3	171,000	160,000	16.1	2.0	10	16
					Average	194,000	181,000	16.1	2.3	9	16
		58,300		T	A2TA1A-1	201,000	190,000	16.7	1.0	6	16
					-2	202,000	188,000	16.7	1.5	8	16
					-3	172,000	164,000	17.3	6.0	10	-
					Average	192,000	181,000	16.9	2.8	8	16
		56,600	600	L	A2LA4A-1	188,000	162,000	15.1	4.5	16	20
					-2	150,000	130,000	12.7	7.5	24	32
					-3	157,000	129,000	14.1	7.5	24	40
					Average	165,000	140,000	14.0	6.5	21	31
		58,300		T	A2TA4A-1	188,000	161,000	15.3	5.5	22	32
					-2	157,000	-	-	5.5	12	-(1)
					-3	155,000	126,000	14.9	8.0	20	28
					Average	167,000	144,000	15.1	6.3	18	30
900	10	ZERO	80	L	A2LA1C-1	209,000	190,000	16.6	4.5	10	-
					-2	183,000	-	-	0.5	4	8(1)
					-3	186,000	166,000	16.4	4.0	8	-
					Average	193,000	178,000	16.5	3.0	7	
				T	A2TA1C-1	200,000	190,000	16.7	1.0	6	10
					-2	200,000	189,000	16.5	1.0	4	-
					-3	171,000	159,000	16.6	1.5	6	8
					Average	190,000	179,000	16.6	1.2	5	9
			900	L	A2LA7C-1	159,000	140,000	12.4	9.0	32	68
					-2	146,000	123,000	12.5	12.0	36	52
					-3	148,000	121,000	12.9	12.0	36	68
					Average	151,000	128,000	12.6	11.0	35	63
				T	A2TA7C-1	162,000	-	-	10.0	36	-(1)
					-2	141,000	121,000	13.4	12.0	32	36
					-3	140,000	121,000	12.9	15.0	48	76
					Average	148,000	121,000	13.2	12.0	39	56
		50,700	80	L	A2LA1D-1	202,000	189,000	16.5	3.5	8	-
					-2	203,000	190,000	16.5	3.0	8	12
					-3	198,000	182,000	16.5	4.5	10	16
					Average	201,000	187,000	16.5	3.7	9	14
		51,700		T	A2TA1D-1	204,000	200,000	17.2	1.0	4	8
					-2	202,000	201,000	17.3	1.0	6	8
					-3	176,000	174,000	17.2	1.0	6	8
					Average	194,000	192,000	17.2	1.0	5	8
		50,700	900	L	A2LA7D-1	159,000	142,000	11.8	13.0	48	84
					-2	156,000	137,000	12.0	13.0	44	68
					-3	152,000	131,000	11.7	14.0	40	56
					Average	156,000	137,000	11.8	13.0	44	69
		51,700		T	A2TA7D-1	162,000	140,000	13.4	13.0	54	-
					-2	150,000	130,000	11.8	14.0	46	-
					-3	149,000	131,000	12.0	16.0	54	-
					Average	154,000	134,000	12.4	14.0	51	

(1) Unusable load-deformation curve.

TABLE XXXIV - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6759 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^6 PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A3LA1B-1	214,000	198,000	16.8	3.5	4	8
					-2	214,000	196,000	16.5	4.5	10	12
					-3	217,000	201,000	17.1	3.0	8	12
					Average	215,000	198,000	16.8	3.7	7	11
				T	A3TA1B-1	212,000	199,000	17.3	3.0	6	8
					-2	211,000	197,000	17.1	2.0	4	-
					-3	206,000	196,000	17.5	3.5	8	12
					Average	210,000	197,000	17.3	2.8	6	10
			600	L	A3LA4B-1	192,000	159,000	15.4	5.5	20	32
					-2	196,000	166,000	15.2	4.5	14	20
					-3	199,000	168,000	14.7	4.5	22	32
					Average	196,000	164,000	15.1	4.8	19	28
				T	A3TA4B-1	190,000	161,000	15.6	5.0	20	28
					-2	187,000	157,000	15.5	-	14	20
					-3	187,000	156,000	15.3	5.0	20	28
					Average	188,000	158,000	15.5	5.0	18	25
		63,300	80	L	A3LA1A-1	223,000	210,000	16.5	3.5	10	24
					-2	223,000	205,000	16.5	4.0	8	20
					-3	221,000	205,000	16.5	3.5	14	28
					Average	222,000	207,000	16.5	3.7	11	24
		62,300		T	A3TA1A-1	201,000	187,000	17.4	2.5	6	12
					-2	202,000	183,000	17.6	3.0	12	20
					-3	225,000	-	-	3.5	12	24(1)
					Average	209,000	185,000	17.5	3.0	10	19
		63,300	600	L	A3LA4A-1	200,000	174,000	13.8	5.0	16	28
					-2	197,000	171,000	14.3	4.8	18	28
					-3	199,000	170,000	13.9	5.0	20	36
					Average	199,000	172,000	14.0	4.9	18	31
		62,300		T	A3TA4A-1	184,000	156,000	16.0	6.5	20	28
					-2	194,000	166,000	16.0	5.5	20	36
					-3	193,000	166,000	15.4	6.0	22	36
					Average	190,000	163,000	15.8	6.0	21	33
900	10	ZERO	80	L	A3LA1C-1	212,000	195,000	16.0	2.0	6	8
					-2	213,000	192,000	16.9	2.5	4	6
					-3	214,000	198,000	16.3	2.5	4	8
					Average	213,000	195,000	16.4	2.3	5	7
				T	A3TA1C-1	191,000	-	17.1	1.0	4	8(2)
					-2	205,000	191,000	16.9	2.0	4	8
					-3	212,000	202,000	17.3	2.0	6	8
					Average	203,000	196,000	17.1	1.7	5	8
			900	L	A3LA7C-1	168,000	141,000	12.9	12.0	52	68
					-2	167,000	139,000	11.9	13.0	52	-
					-3	169,000	143,000	12.7	15.0	56	92
					Average	168,000	141,000	12.5	13.0	53	80
				T	A3TA7C-1	165,000	140,000	12.5	12.0	30	-(3)
					-2	169,000	141,000	13.0	12.0	28	-(3)
					-3	171,000	139,000	13.1	7.5	24	-(3)
					Average	168,000	140,000	12.9	10.0	27	
		52,700	80	L	A3LA1D-1	210,000	195,000	16.7	1.0	-	-(3)
					-2	210,000	195,000	16.8	-	-	-(3)
					-3	220,000	207,000	16.6	-	-	-(3)
					Average	213,000	199,000	16.7			
		53,000		T	A3TA1D-1	202,000	191,000	16.4	-	-	-(3)
					-2	-	-	-	-	-	-(4)
					-3	211,000	198,000	17.2	3.0	6	8
					Average	206,000	194,000	16.8			
		52,700	900	L	A3LA7D-1	168,000	145,000	12.4	9.0	60	92
					-2	165,000	143,000	12.4	14.0	64	92
					-3	169,000	148,000	11.8	12.0	54	-
					Average	167,000	145,000	12.2	12.0	59	92
		53,000		T	A3TA7D-1	167,000	145,000	12.8	7.5	42	100
					-2	167,000	144,000	12.6	12.0	52	92
					-3	164,000	138,000	12.3	13.0	52	-
					Average	166,000	142,000	12.6	11.0	49	96

(1) Unusable load-deformation curve.
(2) Specimen failed prior to attaining yield deformation.
(3) Failed within 1/4" of fillet.
(4) Failed outside test section.

TABLE XXXV - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE M6761 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A4LA1B-1	183,000	167,000	16.2	6.0	16	24
					-2	183,000	167,000	16.4	5.5	10	16
					-3	201,000	184,000	16.7	5.0	10	20
					Average	189,000	173,000	16.4	5.5	12	20
				T	A4TA1B-1	179,000	165,000	16.7	5.0	10	16
					-2	179,000	166,000	16.6	3.5	8	12
					-3	191,000	174,000	16.5	2.5	8	12
					Average	183,000	168,000	16.6	3.7	9	13
			600	L	A4LA4B-1	161,000	135,000	14.1	5.5	16	20
					-2	177,000	149,000	14.5	5.0	14	16
					-3	177,000	150,000	14.9	5.0	14	20
					Average	172,000	145,000	14.5	5.2	15	19
				T	A4TA4B-1	160,000	136,000	15.0	8.0	20	32
					-2	171,000	146,000	15.0	4.5	-	-
					-3	173,000	146,000	16.5	5.0	-	-
					Average	168,000	143,000	15.5	5.8		
		54,300	80	L	A4LA1A-1	196,000	181,000	16.0	5.0	8	12
					-2	192,000	176,000	15.8	5.0	10	12
					-3	195,000	178,000	16.1	6.0	16	20
					Average	194,000	178,000	16.0	5.3	11	15
		54,300		T	A4TA1A-1	185,000	172,000	16.4	3.5	8	20
					-2	182,000	170,000	16.6	3.5	8	20
					-3	191,000	180,000	16.6	3.0	8	20
					Average	186,000	174,000	16.5	3.3	8	20
		54,300	600	L	A4LA4A-1	169,000	141,000	13.0	-	-	(1)
					-2	180,000	163,000	15.9	4.0	10	16
					-3	-	142,000	13.4	-	-	(2)
					Average	174,000	149,000	14.1			
		54,300		T	A4TA4A-1	168,000	140,000	15.7	6.0	10	20
					-2	175,000	148,000	15.0	4.5	10	16
					-3	177,000	151,000	15.8	4.5	10	16
					Average	173,000	146,000	15.5	5.0	10	17
900	10	ZERO	80	L	A4LA1C-1	180,000	179,000	16.6	0.5	4	8
					-2	188,000	179,000	16.0	2.0	6	16
					-3	-	173,000	16.6	0.5	4	8(4)
					Average	184,000	177,000	16.4	1.5	5	11
				T	A4TA1C-1	177,000	168,000	16.2	-	-	-
					-2	174,000	164,000	16.5	1.5	10	24
					-3	186,000	177,000	17.0	1.5	10	20
					Average	179,000	170,000	16.6	1.5	10	22
			900	L	A4LA7C-1	156,000	128,000	12.7	9.0	30	44
					-2	156,000	123,000	12.4	16.0	32	48
					-3	158,000	129,000	11.0	8.0	24	-
					Average	157,000	127,000	12.0	11.0	29	46
				T	A4TA7C-1	150,000	124,000	13.0	12.0	28	44
					-2	155,000	129,000	12.8	12.0	40	52
					-3	159,000	133,000	13.6	7.0	24	-
					Average	155,000	129,000	13.1	10.0	31	48
		47,700	80	L	A4LA1D-1	157,000	-	-	1.0	6	8(3)
					-2	127,000	-	-	-	-	-(3)
					-3	146,000	-	-	0.5	4	8(3)
					Average	143,000			0.8	5	8
		47,000		T	A4TA1D-1	185,000	178,000	16.8	1.0	6	12
					-2	186,000	178,000	16.4	2.0	6	12
					-3	184,000	175,000	16.5	1.5	6	12
					Average	185,000	177,000	16.6	1.5	6	12
		47,700	900	L	A4LA7D-1	150,000	131,000	12.1	11.0	28	-
					-2	154,000	136,000	11.6	9.0	22	32
					-3	157,000	135,000	13.8	14.0	30	44
					Average	154,000	134,000	12.5	11.0	27	38
		47,000		T	A4TA7D-1	149,000	127,000	11.4	9.0	32	60
					-2	151,000	130,000	12.6	10.0	28	36
					-3	150,000	129,000	13.1	14.0	44	52
					Average	150,000	129,000	12.4	11.0	35	49

(1) Failed within 1/4" of fillet.
(2) Failed in loading hole.
(3) Specimen failed prior to attaining yield deformation.
(4) Failed under extensometer attachment.

TABLE XXXVI - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.**— CRUCIBLE R6761 **SHEET THICKNESS**— 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP. °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $X10^6$, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A5LA1B-1	202,000	194,000	15.8	5.0	10	12
					-2	203,000	195,000	16.2	4.5	10	12
					-3	201,000	191,000	16.3	5.0	10	-
					Average	202,000	193,000	16.1	4.8	10	12
				T	A5TA1B-1	211,000	202,000	16.3	5.0	12	12
					-2	213,000	204,000	16.7	4.5	12	-
					-3	209,000	200,000	16.1	2.5	8	8
					Average	211,000	202,000	16.3	4.0	11	10
			600	L	A5LA4B-1	176,000	160,000	13.7	4.5	-	-
					-2	178,000	159,000	13.7	4.5	16	32
					-3	177,000	154,000	14.5	5.0	22	28
					Average	177,000	158,000	14.0	4.7	19	30
				T	A5TA4B-1	186,000	167,000	15.7	3.0	16	28
					-2	186,000	166,000	15.8	4.0	20	36
					-3	184,000	166,000	15.0	4.5	18	24
					Average	185,000	166,000	15.5	3.8	18	29
		59,000	80	L	A5LA1A-1	206,000	195,000	15.6	5.5	10	20
					-2	179,000	178,000	15.8	1.0	4	8
					-3	176,000	-	15.2	0.3	2	4(1)
					Average	187,000	186,000	15.5	2.3	5	11
		59,000		T	A5TA1A-1	200,000	192,000	16.4	1.0	6	12
					-2	202,000	193,000	16.4	1.0	6	12
					-3	204,000	192,000	16.4	1.0	6	8
					Average	202,000	192,000	16.4	1.0	6	11
		59,000	600	L	A5LA4A-1	178,000	159,000	14.1	6.0	24	36
					-2	179,000	160,000	13.2	6.0	24	36
					-3	172,000	152,000	14.2	6.0	20	32
					Average	176,000	157,000	13.8	6.0	23	35
		59,000		T	A5TA4A-1	180,000	155,000	14.8	4.5	16	28
					-2	181,000	157,000	14.2	4.0	16	24
					-3	179,000	160,000	14.6	4.5	16	36
					Average	180,000	157,000	14.5	4.3	16	29
900	10	ZERO	80	L	A5LA1C-1	215,000	203,000	16.7	4.0	10	12
					-2	217,000	205,000	16.3	3.0	4	8
					-3	213,000	200,000	16.4	3.0	6	-
					Average	215,000	203,000	16.5	3.3	7	10
				T	A5TA1C-1	200,000	186,000	16.4	1.5	4	4
					-2	216,000	207,000	16.1	1.0	4	8
					-3	215,000	205,000	16.8	4.5	10	12
					Average	210,000	199,000	16.4	2.3	6	8
			900	L	A5LA7C-1	162,000	142,000	11.8	22.0	52	-
					-2	161,000	138,000	12.3	18.0	50	68
					-3	159,000	139,000	11.5	18.0	46	76
					Average	161,000	140,000	11.9	19.0	49	72
				T	A5TA7C-1	155,000	139,000	11.8	7.0	14	-
					-2	156,000	143,000	12.8	12.0	34	-
					-3	161,000	145,000	12.2	12.0	40	52
					Average	157,000	142,000	12.3	10.0	29	
		49,700	80	L	A5LA1D-1	218,000	212,000	16.1	3.0	12	20
					-2	217,000	210,000	16.2	4.0	12	20
					-3	213,000	204,000	16.7	4.0	10	-
					Average	216,000	209,000	16.3	3.7	11	20
		49,300		T	A5TA1D-1	222,000	212,000	16.4	2.0	6	12
					-2	213,000	208,000	16.3	1.0	2	4
					-3	209,000	-	17.1	0.5	2	4(2)
					Average	215,000	210,000	16.6	1.2	3	7
		49,700	900	L	A5LA7D-1	164,000	138,000	12.8	12.0	44	84
					-2	163,000	141,000	11.4	10.0	44	68
					-3	163,000	144,000	11.8	12.0	40	76
					Average	163,000	141,000	12.0	11.0	43	76
		49,300		T	A5TA7D-1	165,000	134,000	11.8	13.0	50	-
					-2	167,000	141,000	11.4	11.0	-	-
					-3	167,000	143,000	12.3	12.0	32	60
					Average	166,000	139,000	11.8	12.0	41	

(1) Specimen failed prior to attaining yield deformation.
(2) Unusable load deformation curve beyond the proportional limit.

TABLE XXXVII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6761 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A6LA1B-1	173,000	166,000	16.3	9.0	24	28
					-2	176,000	164,000	16.1	10.0	20	-
					-3	178,000	173,000	16.3	9.5	20	24
					Average	176,000	168,000	16.2	9.5	21	26
				T	A6TA1B-1	207,000	188,000	18.6	8.5	16	28
					-2	202,000	185,000	17.9	7.0	16	28
					-3	198,000	180,000	17.8	8.0	16	-
					Average	202,000	184,000	18.1	7.8	16	28
			600	L	A6LA4B-1	169,000	136,000	14.4	8.5	24	40
					-2	171,000	141,000	13.9	8.0	24	28
					-3	172,000	140,000	15.0	8.0	24	36
					Average	170,000	139,000	14.4	8.2	24	35
				T	A6TA4B-1	174,000	146,000	15.0	6.0	20	20
					-2	170,000	140,000	14.9	7.0	24	44
					-3	171,000	141,000	15.5	8.5	20	20
					Average	172,000	142,000	15.1	7.2	21	27
		56,000	80	L	A6LA1A-1	189,000	172,000	15.9	6.5	16	20
					-2	188,000	171,000	16.4	7.0	16	-
					-3	185,000	168,000	16.2	9.0	18	24
					Average	187,000	170,000	16.2	7.5	17	22
		57,000		T	A6TA1A-1	194,000	178,000	16.6	6.0	16	20
					-2	194,000	178,000	16.5	5.0	12	20
					-3	187,000	173,000	16.5	7.0	20	28
					Average	192,000	176,000	16.5	6.0	16	23
		56,000	600	L	A6LA4A-1	165,000	138,000	14.4	-	-	-
					-2	171,000	141,000	17.2	8.0	24	28
					-3	169,000	139,000	14.3	8.0	24	32
					Average	168,000	140,000	15.3	8.0	24	30
		57,000		T	A6TA4A-1	168,000	140,000	14.1	8.5	34	52
					-2	171,000	143,000	13.3	8.0	32	-
					-3	171,000	145,000	14.8	8.0	32	-
					Average	170,000	143,000	14.1	8.2	33	
900	10	ZERO	80	L	A6LA1C-1	193,000	174,000	16.0	8.0	16	-
					-2	192,000	173,000	16.1	8.0	16	28
					-3	189,000	171,000	15.9	8.5	-	-
					Average	191,000	173,000	16.0	8.2	16	
				T	A6TA1C-1	195,000	175,000	16.5	4.5	16	20
					-2	195,000	176,000	16.8	5.5	12	20
					-3	191,000	173,000	16.3	5.5	8	12
					Average	194,000	175,000	16.5	5.2	12	17
			900	L	A6LA7C-1	155,000	130,000	12.0	17.0	64	-
					-2	150,000	124,000	12.7	16.0	60	88
					-3	148,000	126,000	13.2	15.0	54	92
					Average	151,000	127,000	12.6	16.0	59	90
				T	A6TA7C-1	156,000	129,000	13.4	12.0	50	76
					-2	153,000	127,000	12.8	14.0	58	100
					-3	155,000	128,000	12.5	15.0	54	92
					Average	155,000	129,000	12.9	14.0	54	89
		47,300	80	L	A6LA1D-1	194,000	181,000	16.4	7.0	14	-
					-2	194,000	180,000	16.6	8.0	12	20
					-3	193,000	179,000	15.9	8.5	20	28
					Average	194,000	180,000	16.3	7.8	15	24
		49,000		T	A6TA1D-1	198,000	185,000	16.4	5.0	16	28
					-2	198,000	187,000	16.5	5.0	8	12
					-3	192,000	181,000	16.2	5.0	14	20
					Average	196,000	184,000	16.4	5.0	13	20
		47,300	900	L	A6LA7D-1	151,000	130,000	13.0	13.0	52	68
					-2	146,000	123,000	11.8	18.0	68	-
					-3	150,000	132,000	11.9	12.0	50	72
					Average	149,000	128,000	12.2	14.0	57	70
		49,000		T	A6TA7D-1	157,000	136,000	12.8	16.0	60	100
					-2	153,000	132,000	12.8	16.0	72	-
					-3	154,000	132,000	14.3	4.0	18	36
					Average	155,000	133,000	13.3	12.0	50	68

TABLE XXXVIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6786 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A7LA1B-1	184,000	177,000	16.2	0.5	2	2
					-2	180,000	176,000	16.1	0.5	4	4
					-3	176,000	168,000	15.8	0.5	8	-
					Average	180,000	174,000	16.0	0.5	5	3
				T	A7TA1B-1	170,000	168,000	16.4	-	-	-
					-2	163,000	-	16.7	-	-	(1)(2)
					-3	184,000	180,000	17.1	0.5	4	4
					Average	172,000	174,000	16.7			
			600	L	A7LA4B-1	176,000	148,000	13.8	3.5	8	12
					-2	167,000	143,000	12.5	3.0	12	20
					-3	171,000	145,000	14.8	4.0	8	12
					Average	171,000	145,000	13.7	3.5	9	15
				T	A7TA4B-1	166,000	139,000	13.8	4.5	12	36
					-2	170,000	142,000	13.8	5.5	12	20
					-3	178,000	153,000	15.8	-	-	-
					Average	171,000	145,000	14.5	5.0	12	28
		54,300	80	L	A7LA1A-1	148,000	-	-	-	-	-(1)
					-2	174,000	-	16.8	0.5	2	4(1)
					-3	166,000	-	16.2	0.5	2	4(1)
					Average	163,000		16.5	0.5	2	4
		55,600		T	A7TA1A-1	170,000	168,000	16.2	-	-	-
					-2	166,000	-	16.8	-	4	4(1)
					-3	178,000	-	16.8	-	-	-(1)
					Average	171,000		16.6			
		54,300	600	L	A7LA4A-1	160,000	150,000	15.2	2.0	-	20
					-2	170,000	-	-	2.0	8	28(3)
					-3	175,000	149,000	13.0	4.0	12	-
					Average	168,000	150,000	14.1	2.7	10	24
		55,600		T	A7TA4A-1	167,000	141,000	14.1	3.5	12	-
					-2	180,000	153,000	14.5	3.0	12	-
					-3	179,000	152,000	15.9	4.0	16	20
					Average	175,000	149,000	14.8	3.5	13	
900	10	ZERO	80	L	A7LA1C-1	185,000	184,000	16.6	1.0	10	16
					-2	177,000	-	15.6	1.0	8	16(1)
					-3	169,000	-	15.7	-	-	-(1)
					Average	177,000		16.0	1.0	9	16
				T	A7TA1C-1	181,000	176,000	16.4	-	-	-
					-2	168,000	167,000	16.7	1.0	10	20
					-3	187,000	186,000	17.2	-	-	-
					Average	179,000	176,000	16.8			
			900	L	A7LA7C-1	152,000	126,000	14.0	2.0	4	8
					-2	161,000	138,000	12.4	8.0	24	40
					-3	154,000	131,000	12.7	6.0	14	-
					Average	156,000	132,000	13.0	5.3	14	24
				T	A7TA7C-1	153,000	125,000	13.8	9.0	28	44
					-2	162,000	140,000	13.3	-	-	-
					-3	161,000	133,000	13.9	4.0	12	24
					Average	159,000	133,000	13.7	6.5	20	34
		47,700	80	L	A7LA1D-1	198,000	184,000	16.0	3.0	10	12
					-2	198,000	184,000	15.9	3.0	10	12
					-3	168,000	-	15.4	0.5	6	12(1)
					Average	188,000	184,000	15.8	2.2	9	12
		48,700		T	A7TA1D-1	188,000	177,000	16.9	1.0	4	8
					-2	188,000	176,000	16.4	2.0	4	8
					-3	204,000	191,000	16.4	2.0	4	8
					Average	193,000	181,000	16.6	1.7	4	8
		47,700	900	L	A7LA7D-1	152,000	126,000	11.5	8.5	24	36
					-2	157,000	128,000	13.6	8.0	26	44
					-3	156,000	131,000	12.2	4.5	18	28
					Average	155,000	128,000	12.4	7.0	23	36
		48,700		T	A7TA7D-1	152,000	124,000	13.0	10.0	20	28
					-2	161,000	131,000	13.0	7.0	24	44
					-3	160,000	133,000	11.8	13.0	36	52
					Average	158,000	129,000	12.6	10.0	27	41

(1) Specimen failed prior to attaining yield deformation.
(2) Ftu for this specimen not included in the average.
(3) Unusable load deformation curve.

TABLE XXXIX - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6788 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6} PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A8LA1B-1	217,000	203,000	16.5	3.0	6	-
					-2	221,000	206,000	16.6	3.5	12	12
					-3	204,000	193,000	16.5	3.5	12	-
					Average	214,000	201,000	16.5	3.3	10	
				T	A8TA1B-1	188,000	173,000	16.8	3.5	14	20
					-2	188,000	173,000	16.7	3.0	10	20
					-3	201,000	183,000	16.8	3.0	16	-
					Average	192,000	176,000	16.8	3.2	13	20
			600	L	A8LA4B-1	200,000	178,000	15.3	2.5	14	24
					-2	193,000	162,000	14.8	4.5	16	20
					-3	188,000	159,000	15.1	4.5	20	28
					Average	194,000	166,000	15.1	3.8	17	24
				T	A8TA4B-1	170,000	143,000	15.0	4.5	16	28
					-2	179,000	152,000	14.9	5.0	20	28
					-3	179,000	153,000	15.2	6.0	22	28
					Average	176,000	149,000	15.0	5.2	19	28
		64,300	80	L	A8LA1A-1	209,000	208,000	16.4	1.0	4	-
					-2	206,000	204,000	16.6	1.0	6	8
					-3	186,000	181,000	16.0	2.0	6	12
					Average	200,000	198,000	16.3	1.3	5	10
		58,300		T	A8TA1A-1	199,000	185,000	16.4	2.0	6	12
					-2	198,000	185,000	16.4	2.0	6	16
					-3	195,000	180,000	16.6	3.0	8	20
					Average	197,000	183,000	16.5	2.3	7	16
		64,300	600	L	A8LA4A-1	197,000	176,000	14.3	-	-	-
					-2	169,000	144,000	14.3	7.5	24	36
					-3	171,000	145,000	14.3	7.5	24	36
					Average	179,000	155,000	14.3	7.5	24	36
		58,300		T	A8TA4A-1	170,000	156,000	14.3	1.5	10	20
					-2	176,000	148,000	14.7	6.0	22	36
					-3	176,000	147,000	14.4	5.5	18	20
					Average	174,000	150,000	14.5	4.3	17	25
900	10	ZERO	80	L	A8LA1C-1	212,000	206,000	16.4	1.5	4	8
					-2	212,000	204,000	16.3	1.5	8	12
					-3	196,000	194,000	17.2	1.0	2	4
					Average	207,000	201,000	16.6	1.3	5	8
				T	A8TA1C-1	196,000	174,000	15.8	1.0	4	4
					-2	184,000	164,000	15.1	4.0	20	-
					-3	196,000	178,000	17.7	1.5	4	4
					Average	192,000	172,000	16.2	2.2	9	4
			900	L	A8LA7C-1	168,000	149,000	12.6	12.0	44	68
					-2	158,000	140,000	12.9	10.0	32	36
					-3	160,000	145,000	12.3	12.0	36	60
					Average	162,000	145,000	12.6	11.0	37	55
				T	A8TA7C-1	157,000	136,000	12.2	8.5	28	46
					-2	157,000	135,000	12.4	13.0	14	52
					-3	153,000	133,000	13.3	12.0	46	72
					Average	156,000	135,000	12.6	11.0	29	57
		54,000	80	L	A8LA1D-1	195,000	185,000	16.5	1.0	8	20
					-2	222,000	213,000	16.7	2.0	6	12
					-3	211,000	200,000	16.4	3.5	10	16
					Average	209,000	199,000	16.5	2.2	8	16
		52,000		T	A8TA1D-1	193,000	181,000	16.8	2.5	6	12
					-2	189,000	184,000	15.8	1.0	6	12
					-3	200,000	188,000	16.3	3.0	10	20
					Average	194,000	184,000	16.3	2.2	7	15
		54,000	900	L	A8LA7D-1	161,000	139,000	11.0	11.0	56	72
					-2	163,000	144,000	12.3	12.0	48	80
					-3	159,000	137,000	11.5	8.5	34	52
					Average	161,000	140,000	11.6	10.0	46	68
		52,000		T	A8TA7D-1	152,000	129,000	10.7	14.0	54	76
					-2	159,000	141,000	12.0	12.0	48	60
					-3	159,000	141,000	12.9	10.0	36	60
					Average	157,000	137,000	11.9	12.0	46	65

TABLE XL - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— B120VCA **HEAT NO.—** CRUCIBLE R6753 **SHEET THICKNESS—** 0.125 in.

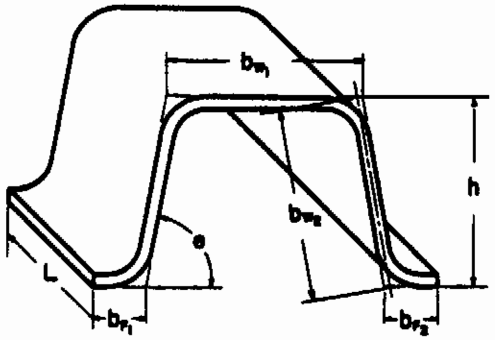
EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP. °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{6} PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	A9LA1B-1	212,000	197,000	16.7	5.3	10	16
					-2	211,000	196,000	16.7	12.0	16	20
					-3	215,000	203,000	16.8	4.0	12	16
					Average	213,000	199,000	16.7	7.1	13	17
				T	A9TA1B-1	191,000	178,000	16.4	9.5	12	20
					-2	193,000	178,000	15.7	4.0	12	20
					-3	189,000	176,000	16.4	3.5	12	16
					Average	191,000	177,000	16.2	5.7	12	19
			600	L	A9LA4B-1	191,000	165,000	14.9	5.5	24	36
					-2	193,000	158,000	14.7	6.0	-	-
					-3	194,000	172,000	15.0	6.5	26	-
					Average	193,000	165,000	14.9	6.0	25	
				T	A9TA4B-1	173,000	148,000	14.7	6.0	24	-
					-2	167,000	146,000	15.7	5.5	32	48
					-3	171,000	150,000	14.3	5.8	28	-
					Average	170,000	148,000	14.9	5.8	28	
		60,700	80	L	A9LA1A-1	216,000	-	-	4.0	8	12(1)
					-2	218,000	207,000	15.9	4.0	8	12
					-3	214,000	201,000	16.2	3.5	8	-
					Average	216,000	204,000	16.0	3.8	8	12
		56,000		T	A9TA1A-1	200,000	188,000	16.6	4.0	8	12
					-2	196,000	183,000	16.4	1.5	4	8
					-3	186,000	173,000	16.2	3.0	8	12
					Average	194,000	181,000	16.4	2.8	7	11
		60,700	600	L	A9LA4A-1	191,000	167,000	14.5	5.0	18	32
					-2	193,000	165,000	14.4	-	-	-
					-3	195,000	170,000	14.4	-	24	44
					Average	193,000	167,000	14.4		21	38
		56,000		T	A9TA4A-1	181,000	153,000	15.6	6.0	20	24
					-2	167,000	143,000	14.7	7.5	24	36
					-3	161,000	143,000	14.7	7.5	26	36
					Average	170,000	146,000	15.0	7.0	23	32
900	10	ZERO	80	L	A9LA1C-1	212,000	198,000	16.2	5.0	10	12
					-2	210,000	196,000	16.1	5.0	10	12
					-3	209,000	197,000	15.8	4.5	10	12
					Average	210,000	197,000	16.0	4.8	10	12
				T	A9TA1C-1	197,000	186,000	16.7	4.5	12	12
					-2	196,000	182,000	16.2	3.0	8	-
					-3	201,000	176,000	15.9	4.5	10	12
					Average	198,000	181,000	16.3	4.0	10	12
			900	L	A9LA7C-1	160,000	138,000	12.7	18.0	70	112
					-2	158,000	134,000	12.2	20.0	76	116
					-3	160,000	137,000	12.2	-	-	-
					Average	159,000	136,000	12.4	19.0	73	114
				T	A9TA7C-1	151,000	128,000	13.3	18.0	70	-
					-2	149,000	124,000	12.6	14.0	70	100
					-3	151,000	130,000	13.2	14.0	64	112
					Average	150,000	127,000	13.0	15.0	68	106
		50,300	80	L	A9LA1D-1	215,000	207,000	16.4	2.5	8	-
					-2	214,000	205,000	16.5	-	-	-(2)
					-3	216,000	199,000	16.6	-	-	-(2)
					Average	215,000	204,000	16.5			
		48,700		T	A9TA1D-1	198,000	190,000	16.4	2.5	8	8
					-2	198,000	190,000	16.4	4.0	8	14
					-3	198,000	190,000	16.7	4.5	8	8
					Average	198,000	190,000	16.5	3.7	8	10
		50,300	900	L	A9LA7D-1	164,000	144,000	12.9	16.0	76	120
					-2	160,000	139,000	12.5	14.0	70	124
					-3	161,000	140,000	11.7	16.0	66	-
					Average	162,000	141,000	12.4	15.0	71	122
		48,700		T	A9TA7D-1	157,000	138,000	13.4	14.0	56	92
					-2	156,000	135,000	13.2	17.0	64	108
					-3	154,000	132,000	12.4	25.0	90	-
					Average	156,000	135,000	13.0	19.0	70	100

(1) Unusable load-deformation curve.
(2) Failed within 1/4 inch of fillet.

TABLE XLI - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - B120VCA
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE R6800

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	A17LC1EL-11	0.37	0.37	76.0	1.24	0.98	0.94	.0618	.1943	27600	142
	-19	0.40	0.40	76.3	1.22	0.98	0.94	.0651	.2052	30050	146
	-25	0.44	0.42	79.8	1.24	0.97	0.96	.0627	.2015	25150	125
	-31	0.44	0.43	79.5	1.25	1.02	1.00	.0632	.2128	37150	171
	-34	0.46	0.43	81.2	1.35	0.98	0.97	.0642	.2108	36100	174
	-35	0.42	0.42	77.8	1.23	1.00	0.98	.0636	.2101	36600	174
	Average										155
200	A17LC2EL-12	0.37	0.37	76.5	1.23	1.00	0.98	.0629	.1991	28050	141
	-15	0.37	0.37	78.0	1.28	1.00	0.97	.0648	.2061	30400	148
	-28	0.36	0.36	75.2	1.22	0.97	0.93	.0654	.2049	29800	145
	Average										145
400	A17LC3EL-5	0.40	0.41	77.0	1.26	0.96	0.95	.0673	.2172	31050	143
	-10	0.39	0.38	77.0	1.25	1.00	0.97	.0616	.1982	27250	137
	-19	0.36	0.37	77.5	1.27	0.97	0.96	.0634	.1963	27450	138
	Average										139
600	A17LC4EL-14	0.36	0.36	74.0	1.21	0.98	0.95	.0631	.1970	24500	124
	-16	0.42	0.42	80.2	1.21	1.00	0.99	.0652	.2083	28250	136
	-22	0.39	0.39	78.2	1.27	0.96	0.94	.0623	.1965	26050	133
	Average										131
800	A17LC6EL-7	0.39	0.41	77.2	1.22	1.00	0.98	.0645	.2068	26200	127
	-17	0.38	0.39	78.0	1.29	0.98	0.96	.0709	.2098	27400	131
	-25	0.39	0.39	79.0	1.30	0.98	0.97	.0676	.2171	29325	135
	Average										131
900	A17LC7EL-8	0.39	0.39	77.0	1.19	1.03	1.01	.0631	.2066	19700	95.4
	-18	0.38	0.40	77.5	1.23	0.98	0.95	.0659	.2098	24900	119
	-26	0.36	0.37	75.2	1.27	0.97	0.94	.0669	.2126	25550	120
	Average										111
1000	A17LC8EL-9	0.37	0.36	77.0	1.27	0.98	0.95	.0624	.1962	17825	90.8
	-20	0.39	0.39	79.0	1.25	0.96	0.96	.0628	.2141	17400	81.3
	-21	0.38	0.38	78.5	1.27	0.98	0.96	.0629	.1995	17350	87.0
	Average										86.4

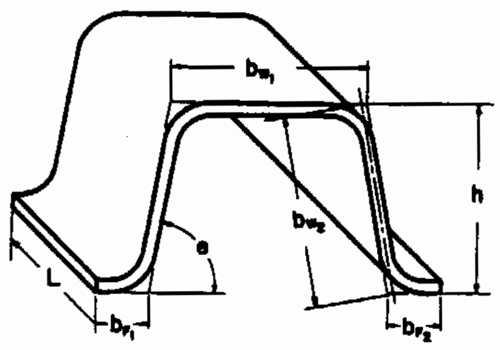


CONFIGURATION 1, LENGTH = 4.13"

TABLE XLII - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - B120VCA
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE R6800

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	A17TC1EL-10	0.37	0.37	75.5	1.18	1.00	0.98	.0657	.2112	33350	158
	-23	0.37	0.40	75.0	1.21	1.03	1.01	.0631	.2050	31750	155
	-32	0.45	0.45	74.5	1.22	0.98	0.94	.0605	.2025	36550	180
	-33	0.37	0.39	75.5	1.22	0.97	0.94	.0624	.2040	34600	170
	-34	0.41	0.47	77.0	1.23	0.98	0.97	.0618	.1980	36000	182
	-35	0.42	0.40	78.2	1.24	0.98	0.96	.0606	.1956	32400	166
	-36	0.41	0.41	75.5	1.22	0.98	0.95	.0639	.2018	35250	175
	-37	0.42	0.41	77.0	1.23	1.00	0.97	.0641	.2138	36250	170
	-38	0.41	0.40	77.2	1.22	1.00	0.97	.0634	.2048	34050	166
	Average										169
200	A17TC2EL-2	0.35	0.35	70.0	1.15	1.00	0.95	.0654	.2067	29750	144
	-12	0.36	0.36	72.0	1.15	0.97	0.93	.0603	.1885	26950	143
	-30	0.33	0.34	78.8	1.18	0.98	0.95	.0640	.2088	34000	163
	Average										150
400	A17TC3EL-3	0.32	0.32	70.0	1.14	1.02	0.95	.0650	.2049	27200	133
	-28	0.33	0.33	72.0	1.18	1.02	0.97	.0669	.2122	28350	134
	-29	0.44	0.45	75.0	1.21	0.98	0.94	.0625	.2096	33200	158
	Average										142
600	A17TC4EL-16	0.33	0.34	72.3	1.18	1.04	0.99	.0680	.2014	26650	132
	-21	0.34	0.34	72.5	1.12	1.04	1.00	.0637	.2063	26850	130
	-31	0.43	0.42	77.0	1.27	0.98	0.96	.0632	.2062	30800	149
	Average										137
800	A17TC6EL-1	0.39	0.35	79.3	1.20	1.00	0.99	.0648	.2149	21900	102
	-17	0.35	0.35	76.0	1.17	0.98	0.95	.0625	.1980	24775	125
	-25	0.37	0.37	73.0	1.16	1.02	0.98	.0688	.2207	29150	132
	Average										120
900	A17TC7EL-14	0.33	0.33	71.5	1.19	0.95	0.90	.0620	.1920	22200	116
	-16	0.35	0.36	72.5	1.19	0.99	0.95	.0680	.2138	27300	128
	-18	0.34	0.34	78.2	1.00	1.06	1.00	.0623	.2050	17900	87.3
	Average										110
1000	A17TC8EL-11	0.34	0.34	75.2	1.20	1.04	1.00	.0599	.2043	16800	82.2
	-13	0.34	0.37	70.4	1.11	1.06	1.02	.0609	.2034	15100	74.2
	-20	0.39	0.36	76.5	1.16	1.00	0.96	.0637	.2029	19000	93.6
	Average										83.3

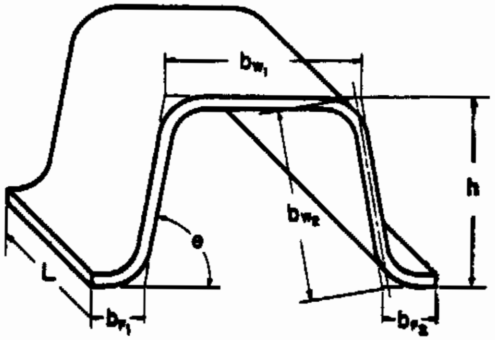


CONFIGURATION 1, LENGTH = 4.13"

TABLE XLIII – LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - B120VCA
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE R6800

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	A17LC1FL-1	0.62	0.60	77.5	2.02	1.98	1.96	.0689	.4356	48100	110
	-7	0.59	0.57	76.2	2.03	1.99	1.95	.0631	.3987	37900	95.0
	-10	0.59	0.60	76.0	2.02	1.97	1.93	.0652	.4133	43050	104
	-19	0.59	0.60	76.0	2.02	1.97	1.93	.0624	.3946	38750	98.2
	-22	0.61	0.59	77.0	2.02	1.99	1.94	.0682	.4317	48050	111
	-23	0.59	0.59	77.5	2.03	1.98	1.93	.0646	.4087	41700	102
	Average										103
200	A17LC2FL-2	0.62	0.61	77.5	2.02	1.98	1.93	.0694	.4298	47150	110
	-12	0.58	0.57	76.8	1.99	1.99	1.94	.0670	.4217	44600	106
	-20	0.59	0.60	75.0	2.01	1.99	1.93	.0679	.4279	43050	101
	Average										106
400	A17LC3FL-3	0.59	0.59	77.5	2.01	2.00	1.98	.0681	.4246	43150	102
	-13	0.59	0.57	78.8	2.01	2.01	1.97	.0666	.4154	40300	97.0
	-21	0.59	0.57	75.0	2.00	1.99	1.94	.0669	.4125	41050	99.5
	Average										99.5
600	A17LC4FL-4	0.59	0.60	75.2	2.03	1.96	1.92	.0624	.3910	32300	82.6
	-14	0.59	0.57	76.5	2.02	1.97	1.94	.0660	.4184	38000	90.8
	-16	0.61	0.57	77.8	2.02	1.96	1.94	.0659	.4183	39050	93.4
	Average										88.9
800	A17LC6FL-5	0.59	0.60	76.5	2.03	1.96	1.92	.0627	.3969	30950	78.0
	-15	0.61	0.59	77.5	2.02	1.96	1.93	.0667	.4229	36375	86.0
	-27	0.65	0.58	80.0	2.02	1.95	1.94	.0648	.4104	35650	86.9
	Average										83.6
900	A17LC7FL-6	0.59	0.58	80.0	2.08	1.99	1.94	.0659	.4181	34850	83.4
	-17	0.58	0.56	77.0	2.07	1.99	1.95	.0628	.3970	29350	73.9
	-28	0.59	0.56	75.0	2.01	1.97	1.93	.0593	.3736	26500	70.9
	Average										76.1
1000	A17LC8FL-9	0.66	0.62	76.6	2.01	1.91	1.88	.0646	.4098	30950	75.5
	-18	0.63	0.59	79.0	1.96	1.99	1.95	.0642	.4053	30100	74.3
	-29	0.59	0.57	79.0	2.08	1.97	1.93	.0618	.3893	26350	67.7
	Average										72.5

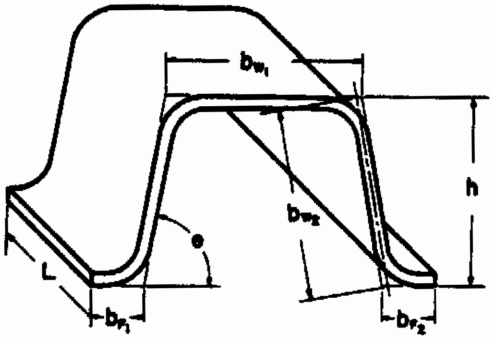


CONFIGURATION 2, LENGTH = 6.89"

TABLE XLIV - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - B120VCA
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE R6800

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	A17TC1FL-6	0.62	0.60	77.5	2.04	1.93	1.90	.0670	.4238	46750	110
	-7	0.59	0.61	76.8	2.03	1.95	1.92	.0664	.4208	46000	109
	-16	0.59	0.56	79.8	2.11	1.94	1.93	.0637	.4033	40850	101
	-19	0.59	0.59	76.4	2.03	1.94	1.88	.0649	.4108	44050	107
	-51	0.58	0.59	77.5	2.02	1.94	1.91	.0648	.4091	41900	102
	-52	0.58	0.60	77.8	2.00	1.95	1.91	.0636	.3981	40250	101
	-53	0.59	0.59	75.2	1.90	1.98	1.93	.0613	.3849	36350	94.4
	-55	0.58	0.58	78.0	2.02	1.95	1.91	.0642	.4020	36250	90.2
	-56	0.59	0.56	78.0	2.07	1.98	1.94	.0623	.3924	35250	89.8
	Average										100
200	A17TC2FL-2	0.60	0.59	75.0	2.03	2.01	1.84	.0680	.4196	43050	102
	-12	0.59	0.59	76.0	1.94	1.97	1.91	.0658	.4114	41600	101
	-20	0.61	0.61	74.0	1.95	1.94	1.87	.0680	.4200	45700	109
	Average										104
400	A17TC3FL-3	0.58	0.56	75.0	2.02	1.93	1.88	.0671	.4139	42750	103
	-10	0.59	0.61	76.0	2.07	1.90	1.85	.0622	.3797	36000	94.8
	-13	0.57	0.57	74.0	2.01	1.96	1.90	.0658	.4119	40000	97.1
	Average										98.3
600	A17TC4FL-1	0.58	0.58	74.5	2.02	1.94	1.88	.0680	.4289	40450	94.3
	-4	0.59	0.59	74.5	2.01	1.96	1.89	.0680	.4308	43000	99.8
	-14	0.59	0.59	77.0	2.07	1.92	1.87	.0622	.3923	35200	89.7
	Average										94.6
800	A17TC6FL-15	0.56	0.55	75.8	2.08	1.95	1.90	.0633	.4010	33100	82.5
	-23	0.56	0.56	73.5	2.06	1.94	1.86	.0655	.4116	36400	88.4
	-26	0.59	0.59	74.5	2.00	1.92	1.85	.0638	.4039	35100	86.9
	Average										85.9
900	A17TC7FL-5	0.59	0.59	75.2	1.98	1.94	1.88	.0678	.4303	37300	86.7
	-11	0.55	0.56	74.0	1.96	1.99	1.92	.0644	.4058	33000	81.3
	-28	0.56	0.57	73.0	2.03	1.93	1.85	.0626	.3960	31350	79.2
	Average										82.4
1000	A17TC8FL-9	0.59	0.57	77.5	2.06	1.98	1.94	.0664	.4101	32750	79.8
	-18	0.61	0.59	77.3	2.03	1.94	1.89	.0640	.4051	29350	72.4
	-25	0.61	0.59	75.5	1.96	1.99	1.94	.0596	.3774	24800	65.7
	Average										72.6



CONFIGURATION 2, LENGTH = 6.89"

TABLE XIV

LONGITUDINAL COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6800)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
A17LB1L-2	80	196,000	16.2	196,000	202,000	28.1
-5	80	193,000	16.3	193,000	198,000	36.0
-8	80	194,000	16.2	194,000	200,000	32.6
-11	80	187,000	16.4	187,000	193,000	26.1
-14	80	187,000	16.4	187,000	195,000	21.8
-17	80	186,000	16.8	186,000	194,000	22.8
-20	80	195,000	16.7	195,000	201,000	31.4
-23	80	191,000	16.5	191,000	198,000	28.0
-26	80	190,000	16.7	190,000	195,000	36.1
-29	80	188,000	16.7	188,000	193,000	34.6
Average		191,000	16.5	191,000	197,000	29.8
A17LB2L-7	200	179,000	15.8	179,000	185,000	28.0
-19	200	182,000	16.2	182,000	189,000	23.6
-22	200	179,000	16.1	178,000	184,000	28.9
Average		180,000	16.0	180,000	186,000	26.8
A17LB3L-13	400	164,000	14.9	164,000	180,000	10.8
-24	400	166,000	15.4	166,000	180,000	11.4
-27	400	166,000	15.2	166,000	178,000	13.4
Average		165,000	15.2	165,000	179,000	11.9
A17LB4L-15	600	157,000	15.0	156,000	171,000	10.9
-18	600	162,000	13.2	163,000	174,000	13.8
-25	600	155,000	12.7	155,000	-	-
Average		158,000	13.6	158,000	172,000	12.4
A17LB6L-4	800	155,000	14.0	155,000	169,000	11.3
-10	800	152,000	13.9	151,000	163,000	12.7
-12	800	128,000	13.7	120,000	147,000	5.4
Average		145,000	13.9	142,000	160,000	9.8
A17LB7L-3	900	147,000	13.0	147,000	157,000	14.5
-16	900	147,000	12.7	147,000	162,000	9.9
-28	900	142,000	12.9	142,000	156,000	9.5
Average		145,000	12.9	145,000	158,000	11.3
A17LB8L-1	1000	106,000	11.5	103,000	115,000	8.8
-6	1000	105,000	7.4	107,000	115,000	13.8
-21	1000	103,000	12.0	100,000	110,000	10.6
Average		105,000	10.3	103,000	113,000	11.1

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

TRANSVERSE COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6800)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
A17TB1L-2	80	199,000	17.0	199,000	206,000	26.8
-5	80	200,000	17.1	200,000	209,000	21.8
-8	80	199,000	17.0	199,000	206,000	27.2
-11	80	200,000	16.8	201,000	208,000	24.5
-14	80	200,000	17.2	200,000	208,000	25.6
-17	80	202,000	16.4	202,000	210,000	23.6
-20	80	200,000	17.1	200,000	208,000	24.0
-23	80	196,000	16.7	196,000	204,000	22.6
-26	80	195,000	16.9	195,000	205,000	13.6
-29	80	196,000	16.6	197,000	204,000	24.2
Average		199,000	16.9	199,000	207,000	23.9
A17TB2L-7	200	184,000	16.4	183,000	190,000	23.9
-19	200	184,000	16.8	184,000	192,000	21.6
-22	200	180,000	16.5	179,000	186,000	23.0
Average		183,000	16.6	182,000	189,000	22.8
A17TB3L-6	400	177,000	15.7	177,000	191,000	12.1
-13	400	175,000	16.1	175,000	186,000	15.5
-24	400	171,000	15.3	171,000	181,000	16.0
Average		174,000	15.7	174,000	186,000	14.5
A17TB4L-15	600	166,000	15.5	165,000	177,000	13.3
-18	600	166,000	15.6	165,000	178,000	12.7
-25	600	163,000	14.9	162,000	176,000	11.8
Average		165,000	15.3	164,000	177,000	12.6
A17TB6L-4	800	161,000	15.1	160,000	172,000	13.3
-10	800	151,000	14.4	149,000	162,000	11.4
-12	800	158,000	13.8	158,000	169,000	13.4
Average		157,000	14.4	156,000	168,000	12.7
A17TB7L-3	900	152,000	14.2	151,000	159,000	17.8
-28	900	152,000	14.2	151,000	163,000	13.1
-30	900	149,000	13.4	149,000	165,000	15.3
Average		151,000	13.9	150,000	162,000	15.4
A17TB8L-1	1000	108,000	12.5	106,000	-	-
-9	1000	116,000	11.9	114,000	119,000	20.6
-21	1000	103,000	9.93	103,000	110,000	13.5
Average		109,000	11.4	108,000	114,000	17.0

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

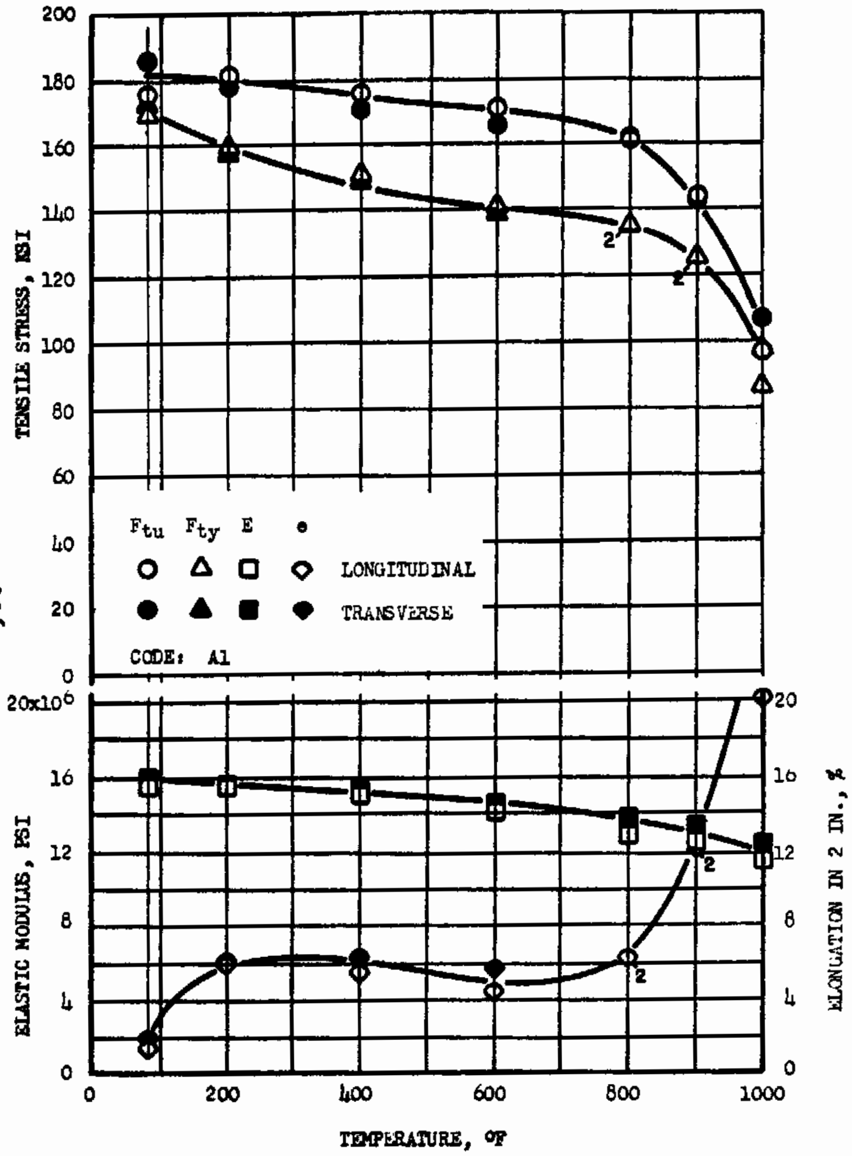


FIGURE 76 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R6392)

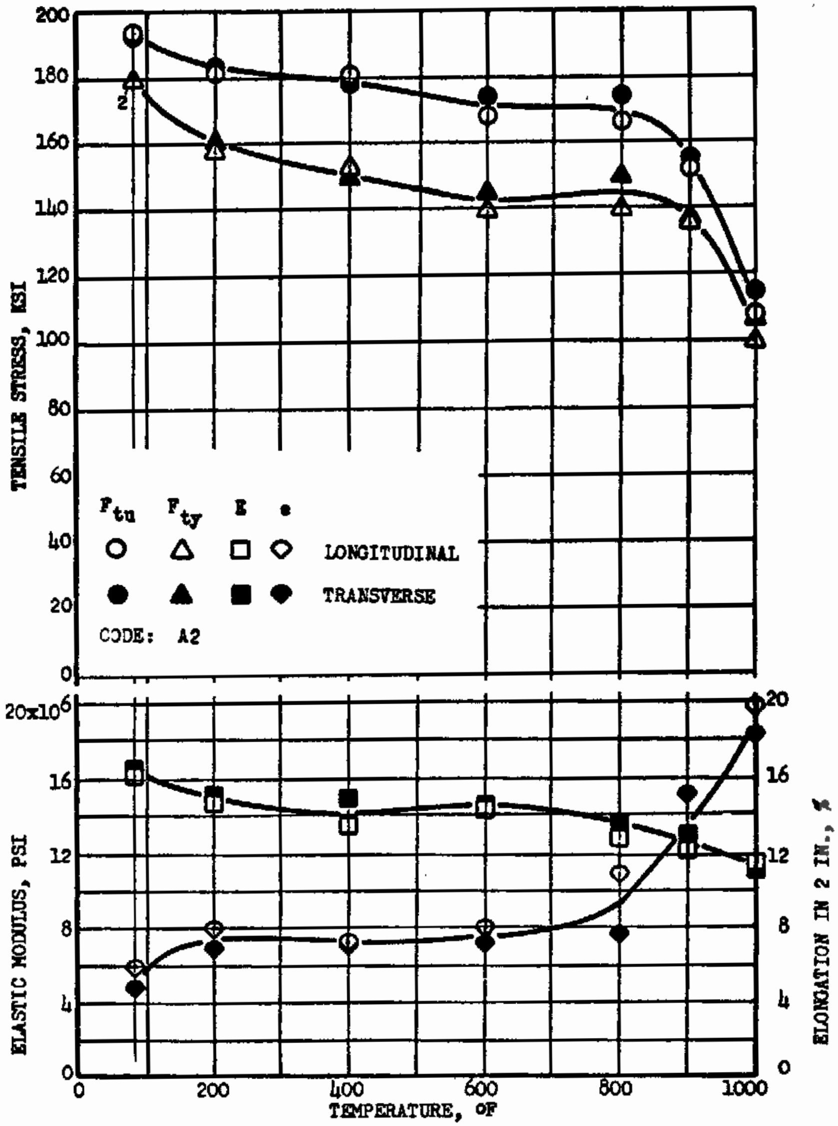


FIGURE 77 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6392)

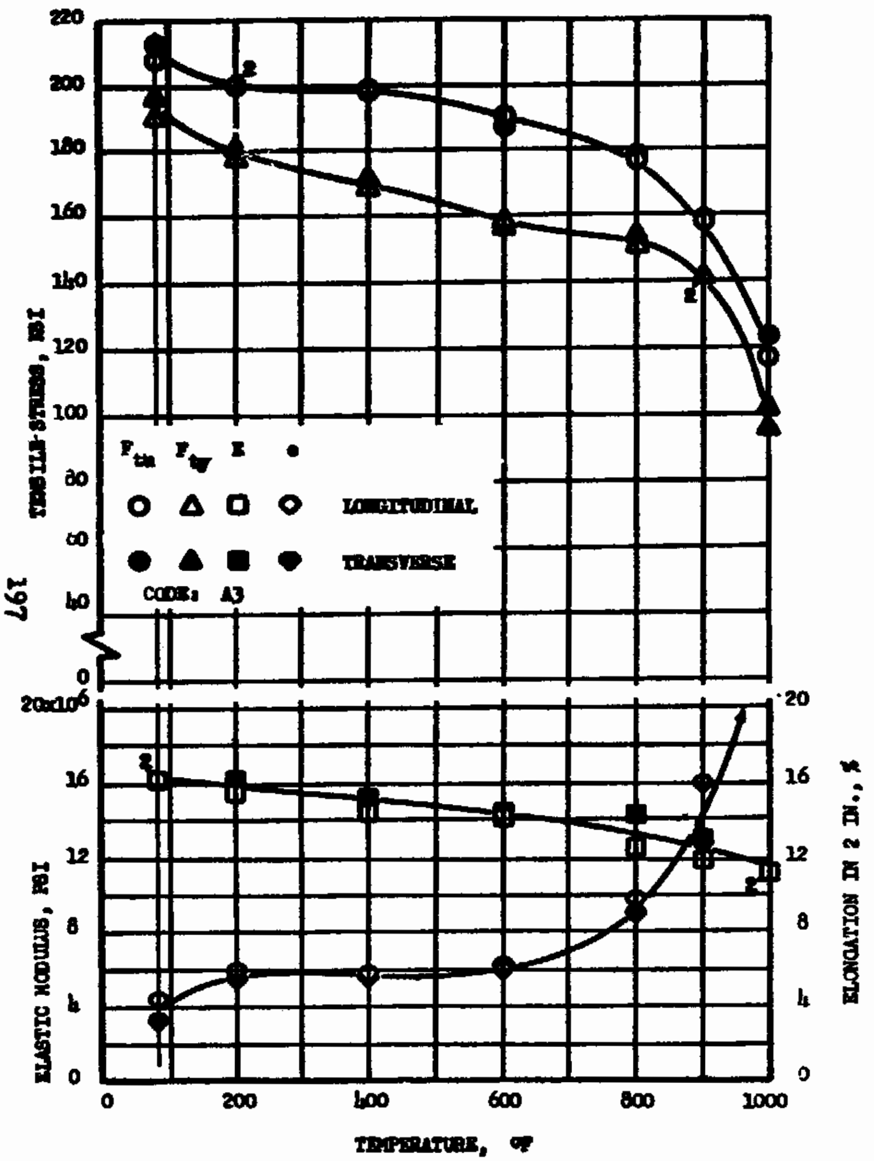


FIGURE 78 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6759)

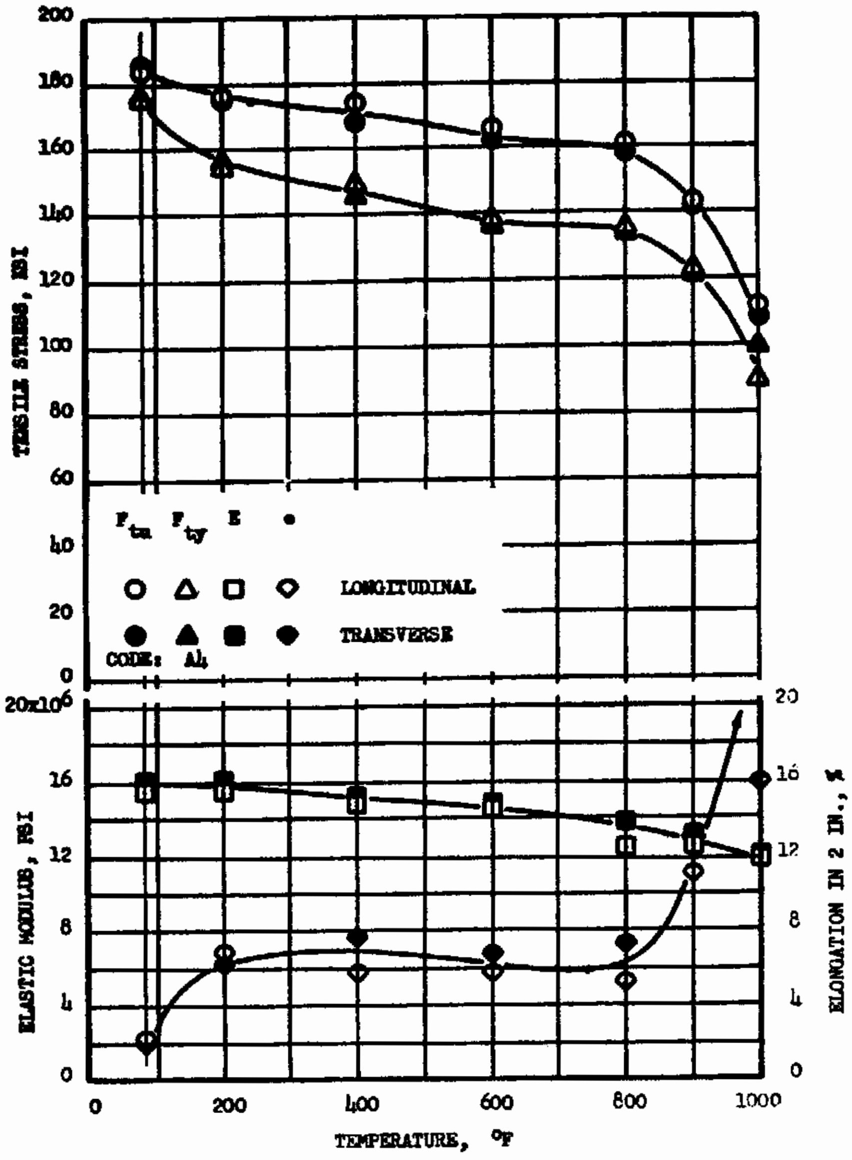


FIGURE 79 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, .020 INCH THICK (CRUCIBLE HEAT NO. R6761)

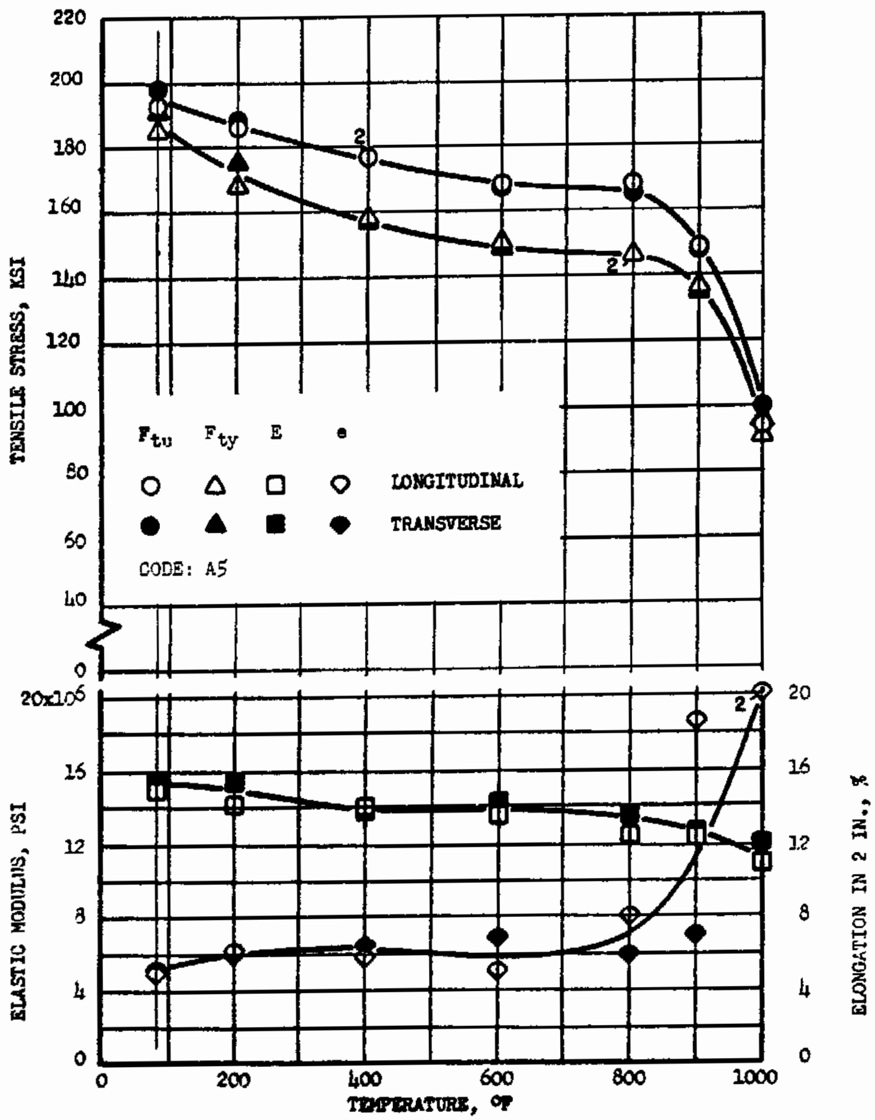


FIGURE 80 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6761)

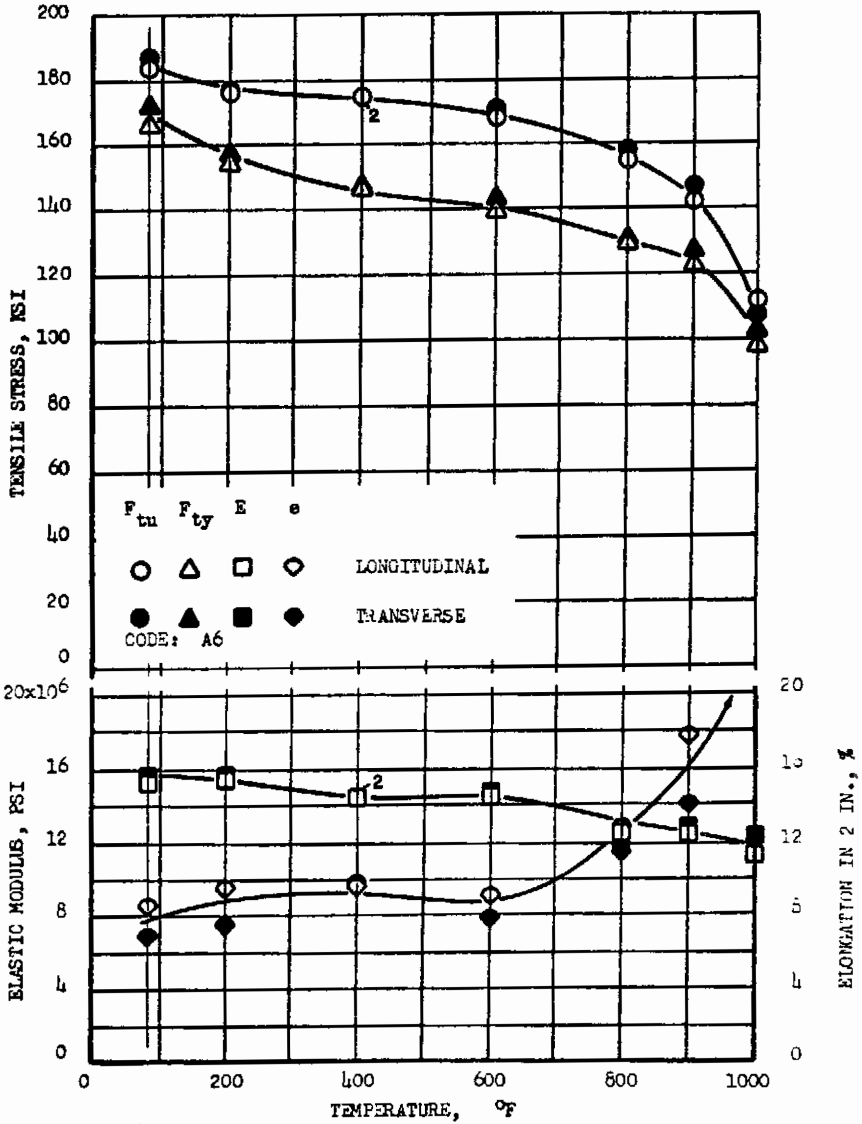


FIGURE 81 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6761)

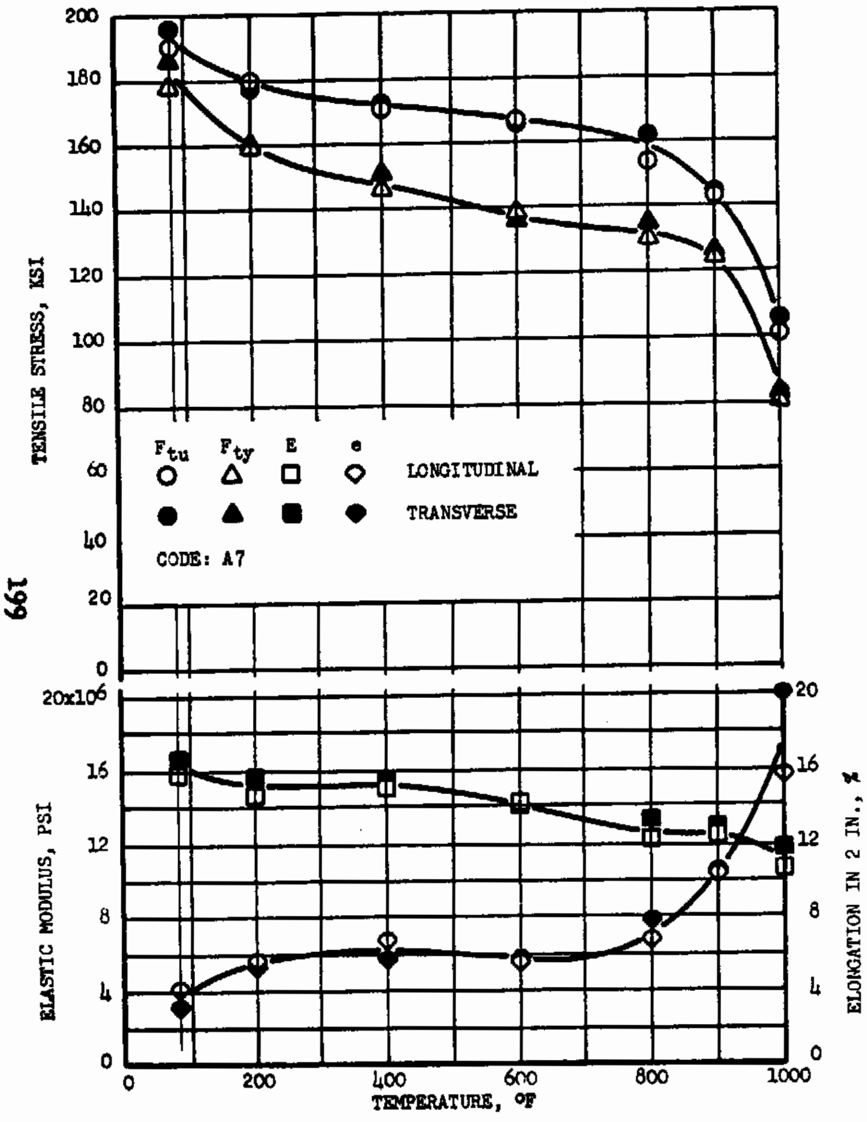


FIGURE 82 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R6788)

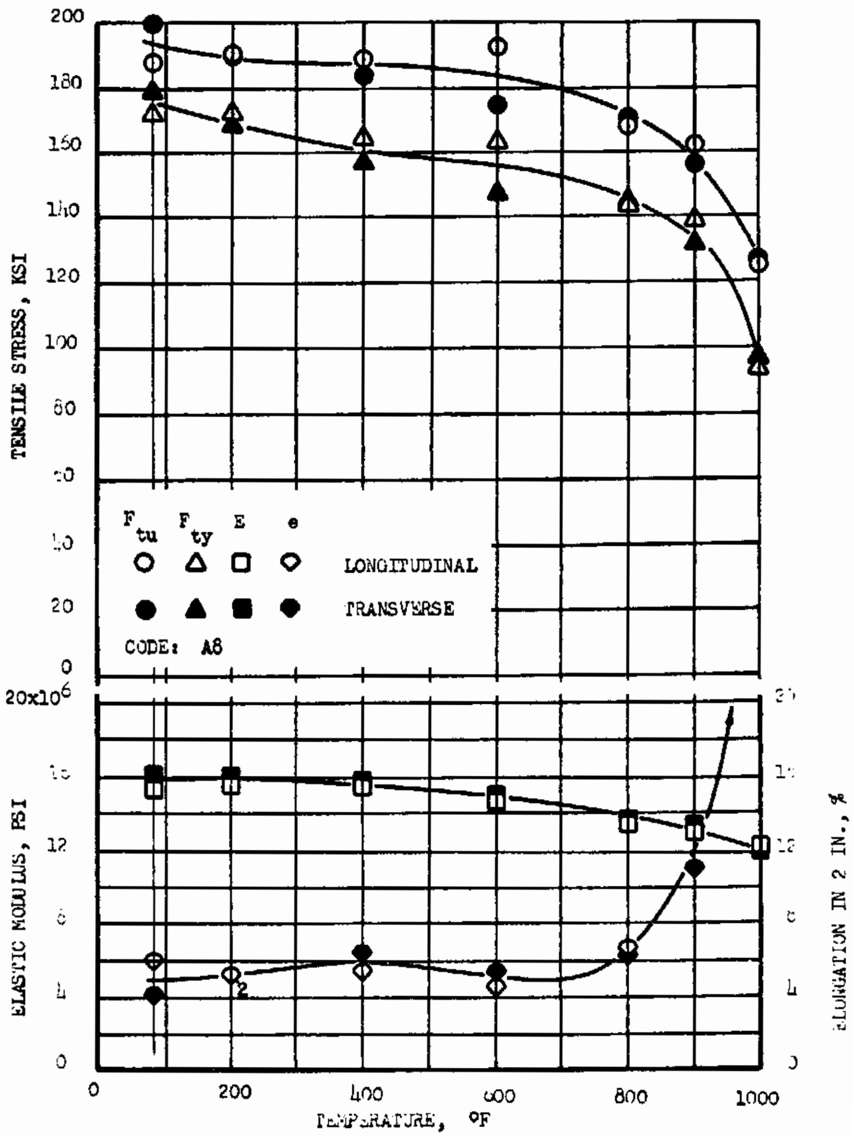


FIGURE 83 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6788)

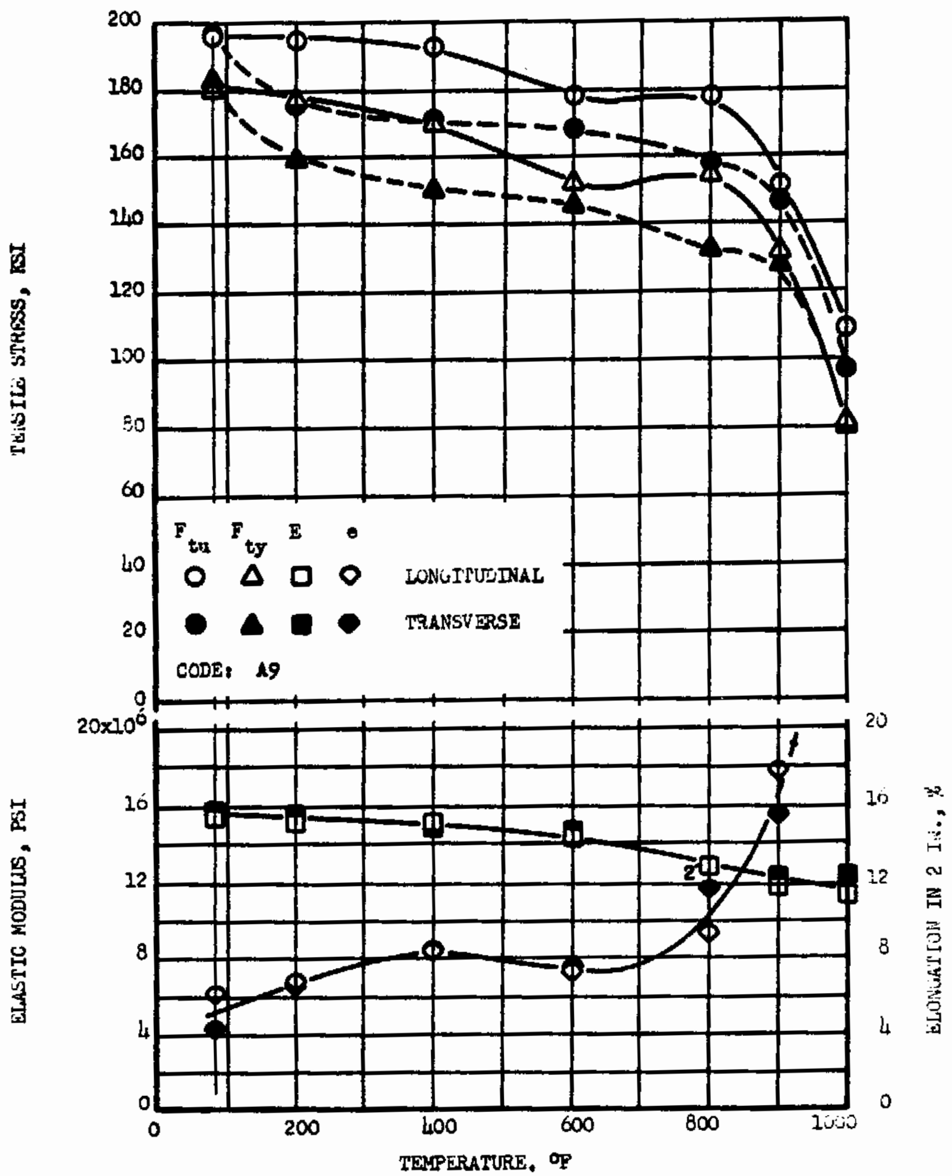


FIGURE 84 – SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6753)

FIGURE 85 - COMPLETE ROOM TEMPERATURE TENSILE STRESS-STRAIN CURVE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (SPECIMEN NO. A2LA1-22)

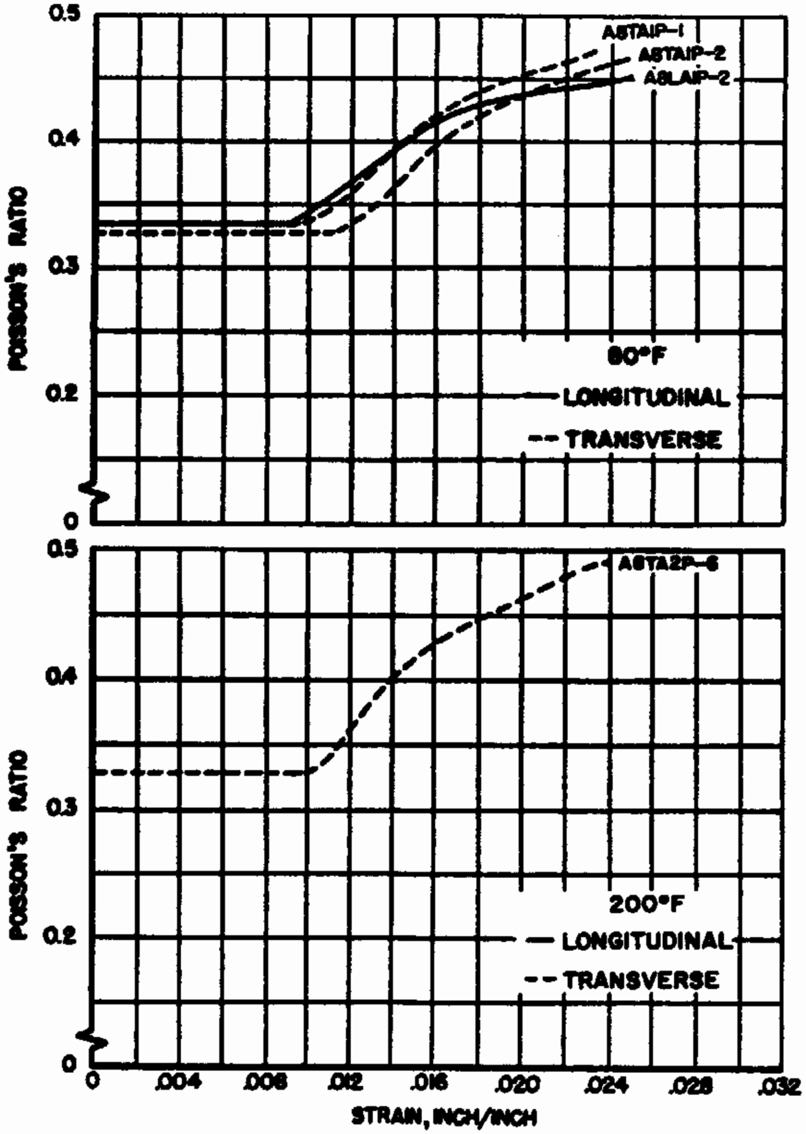


FIGURE 86 – VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK

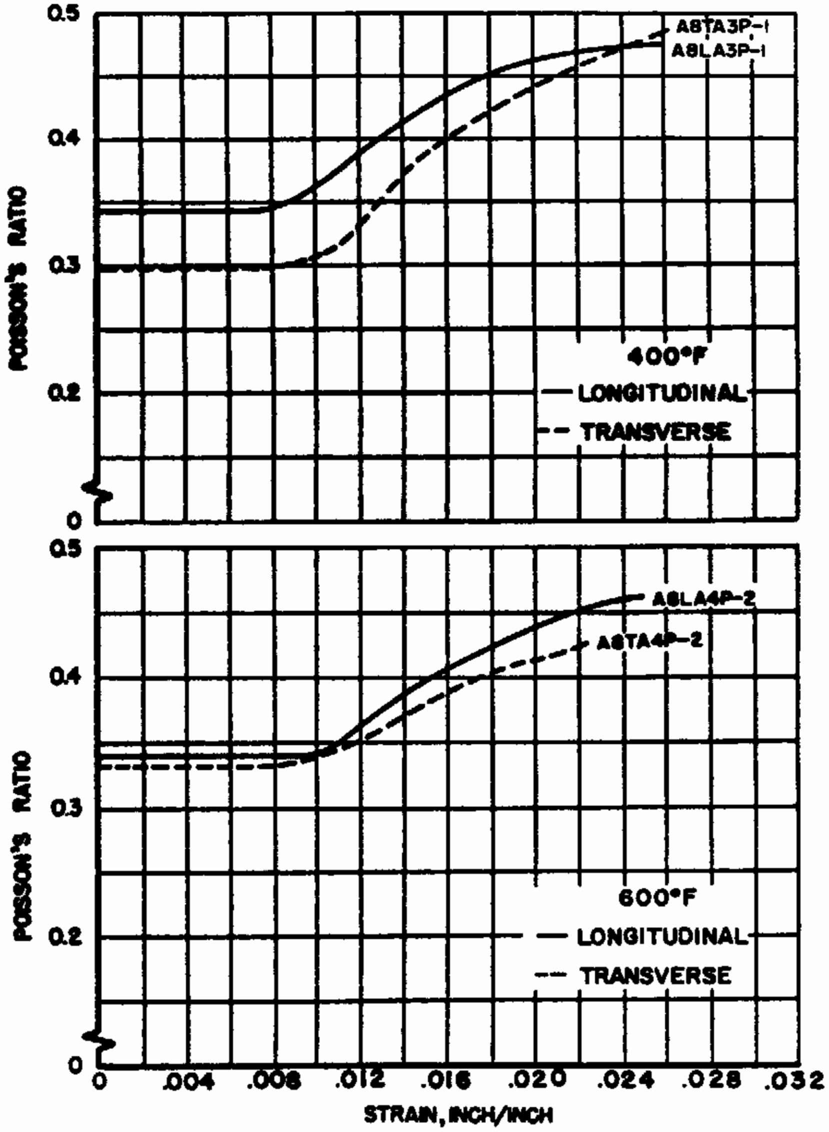


FIGURE 87 – VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK

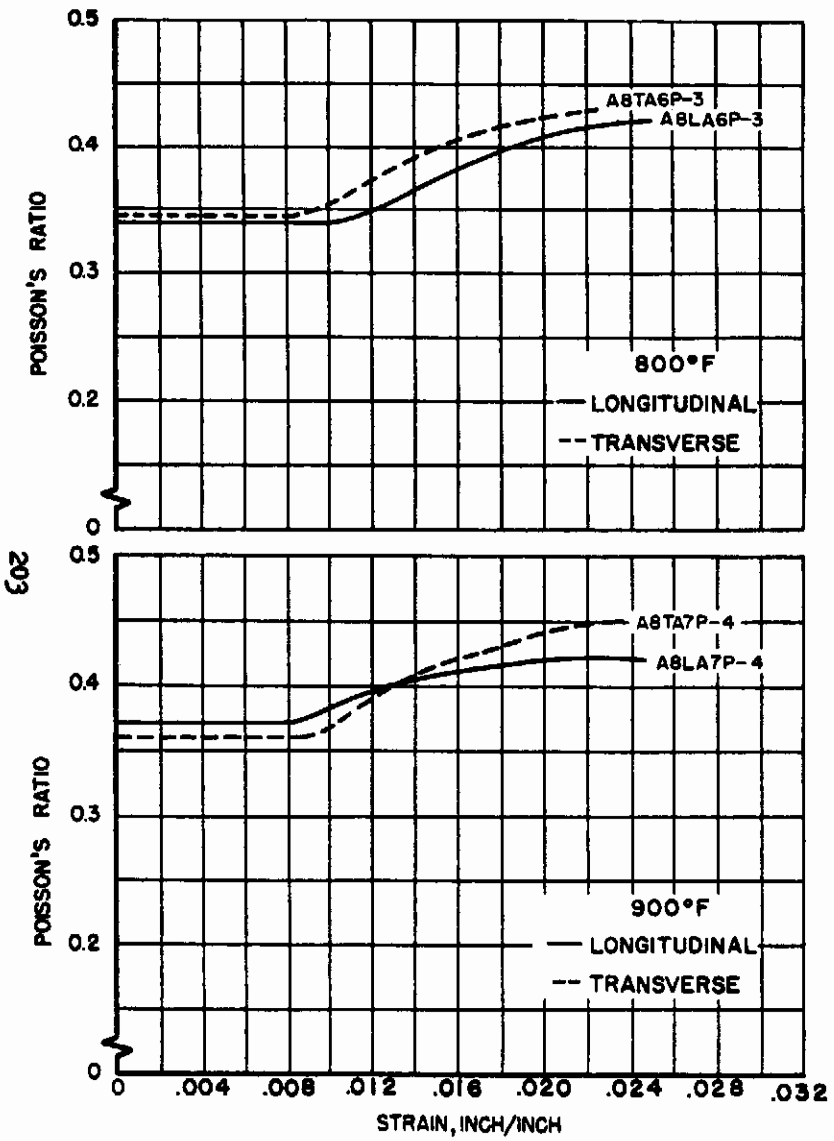


FIGURE 88 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK

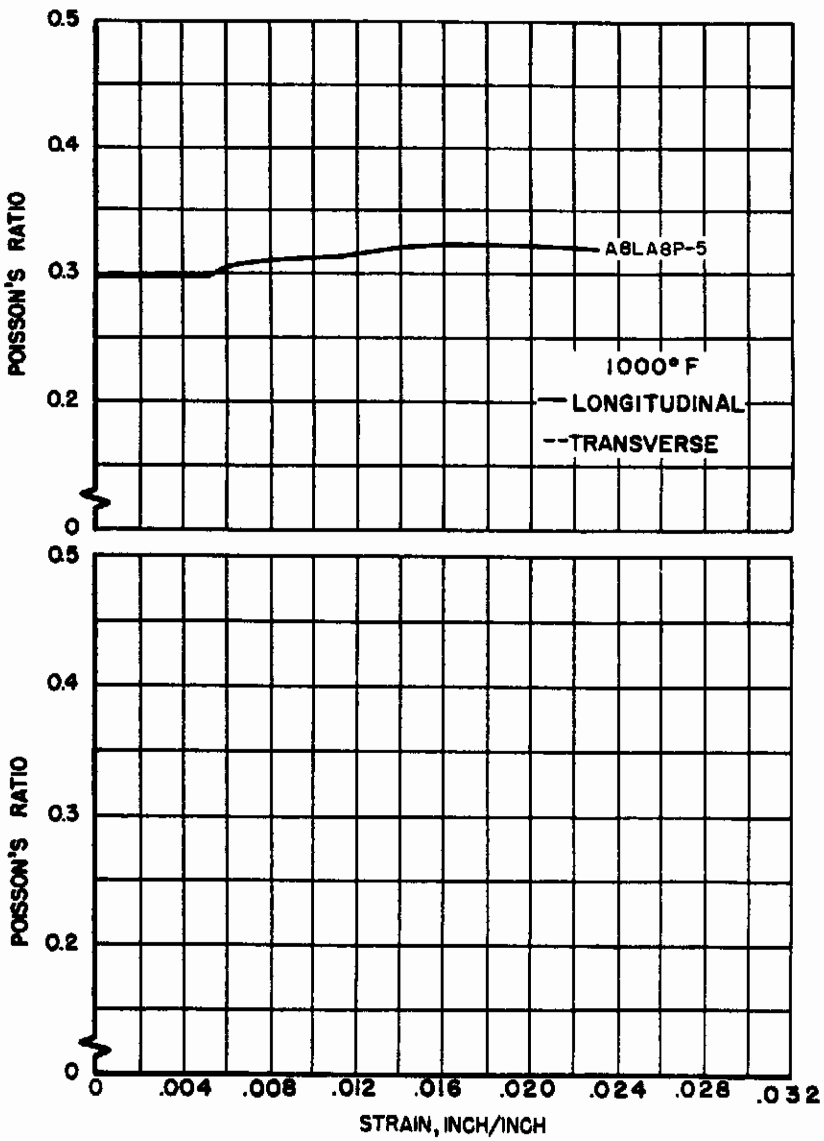


FIGURE 89 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK

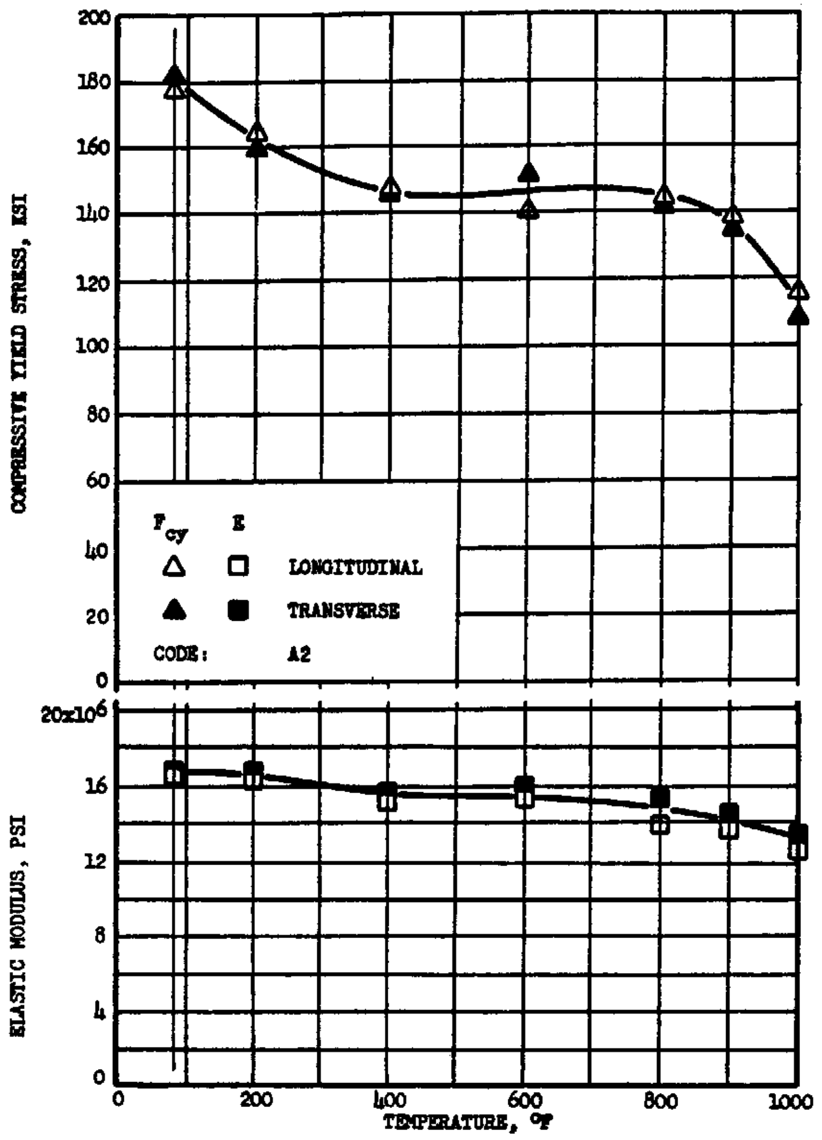


FIGURE 90 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6392)

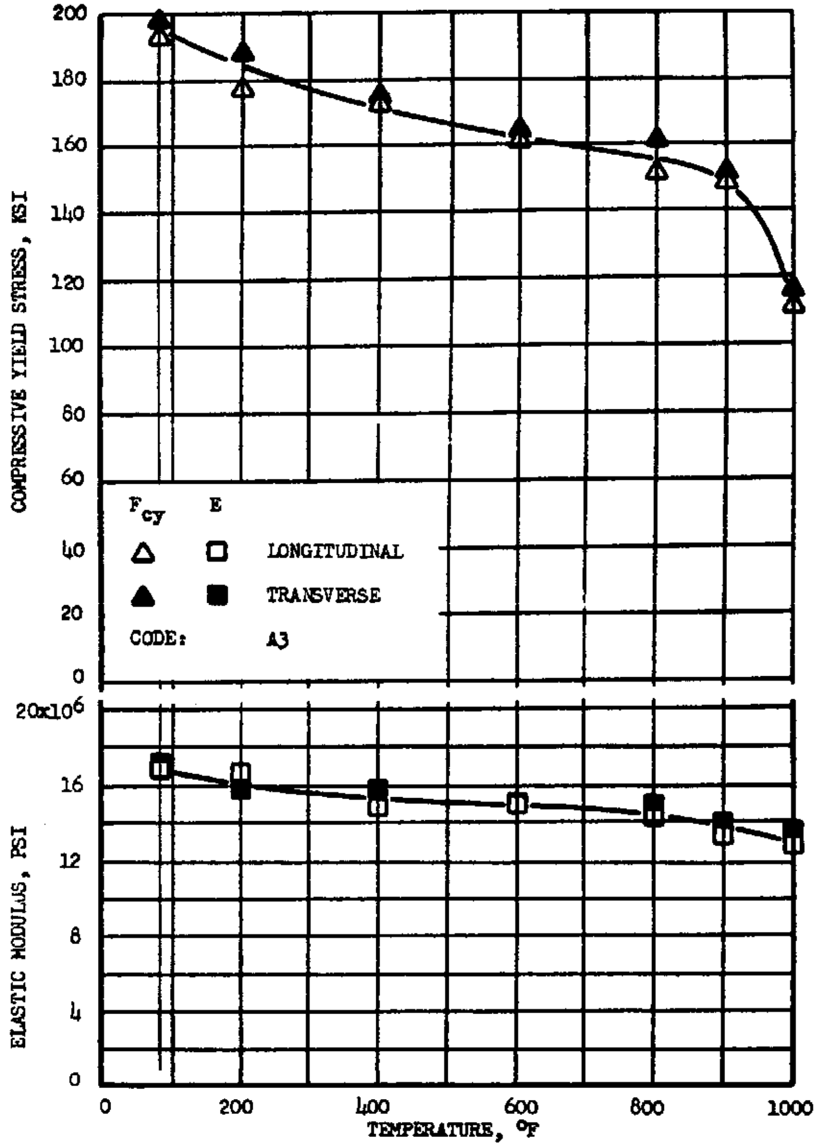


FIGURE 91 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6759)

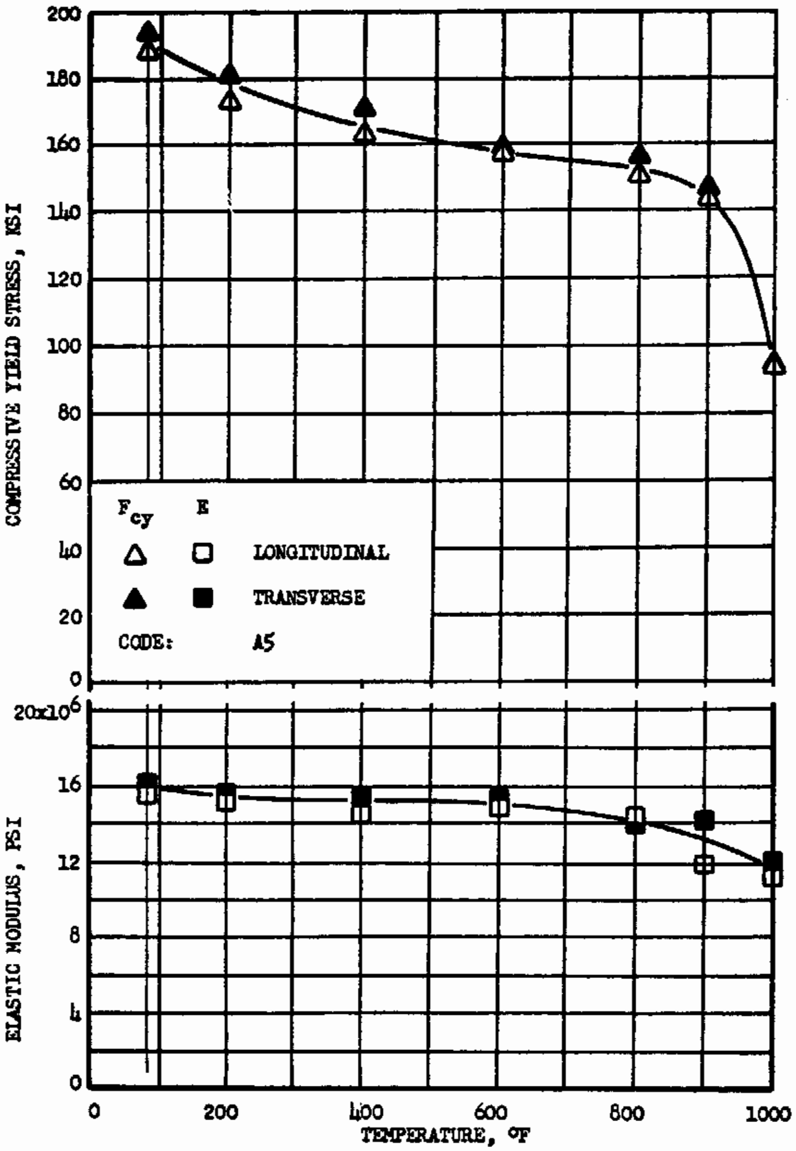


FIGURE 92 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6761)

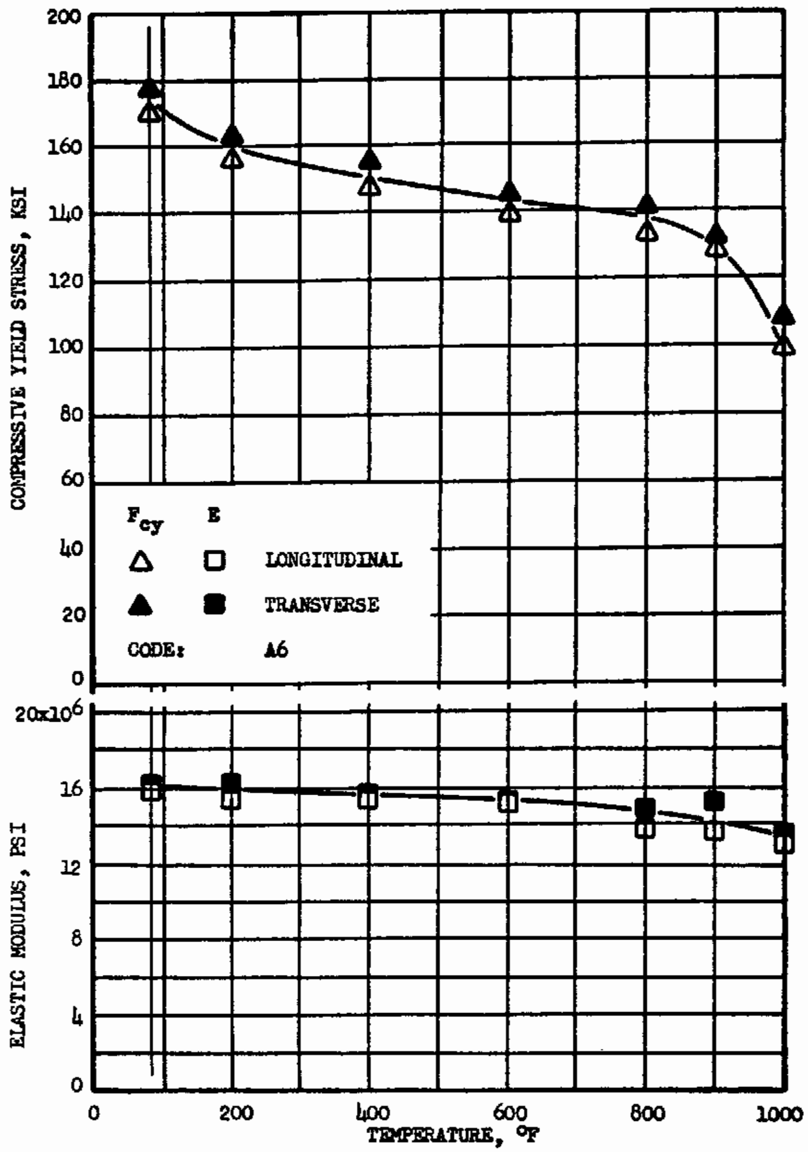


FIGURE 93 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6761)

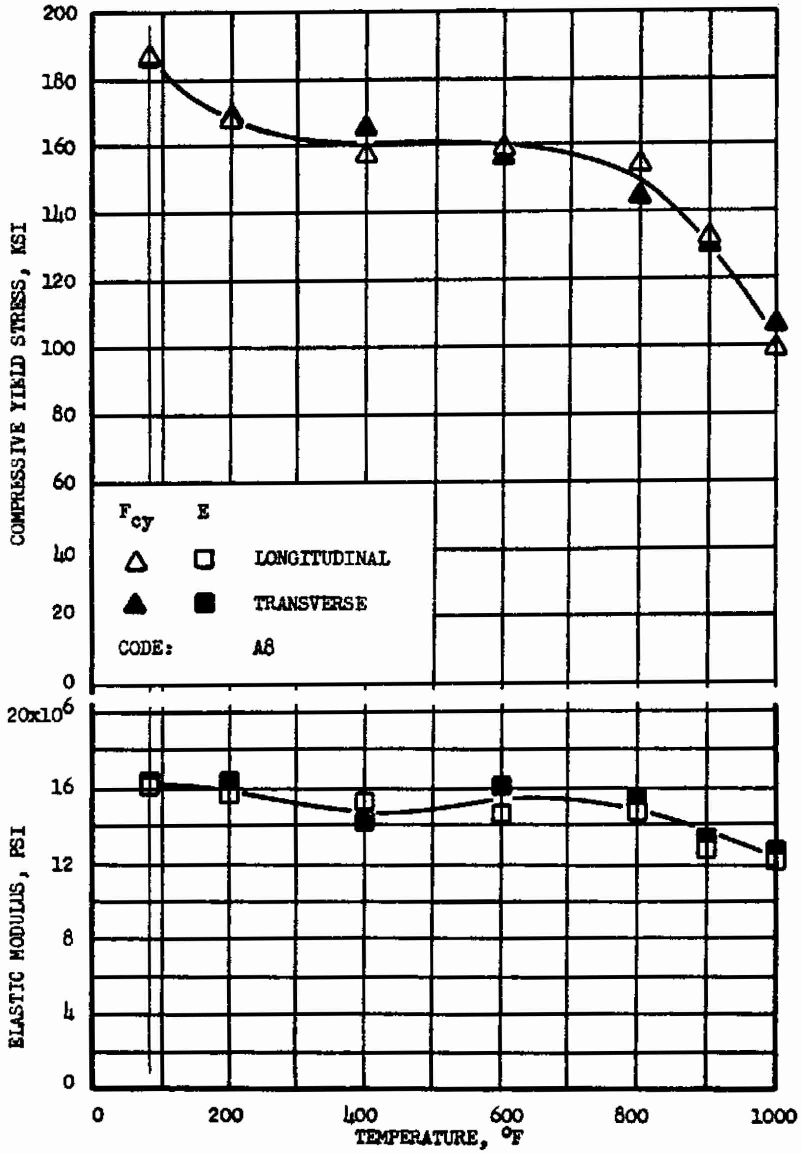


FIGURE 94 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6788)

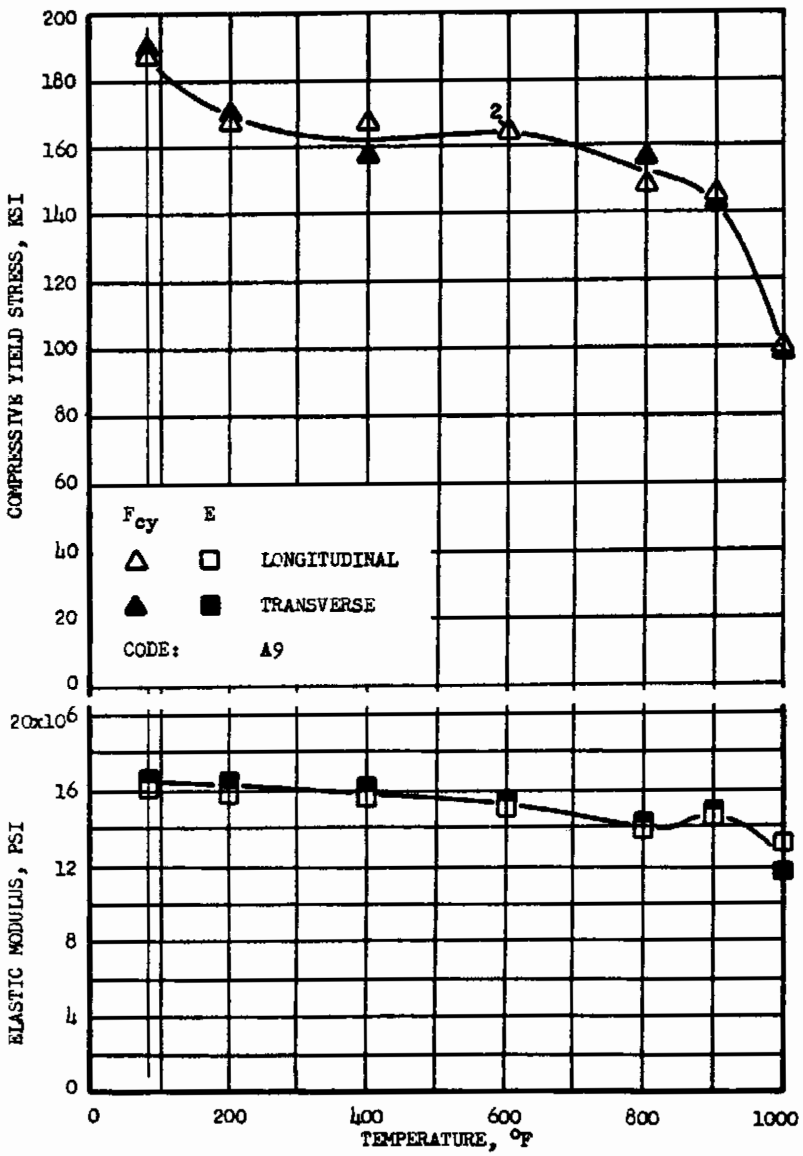


FIGURE 95 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6753)

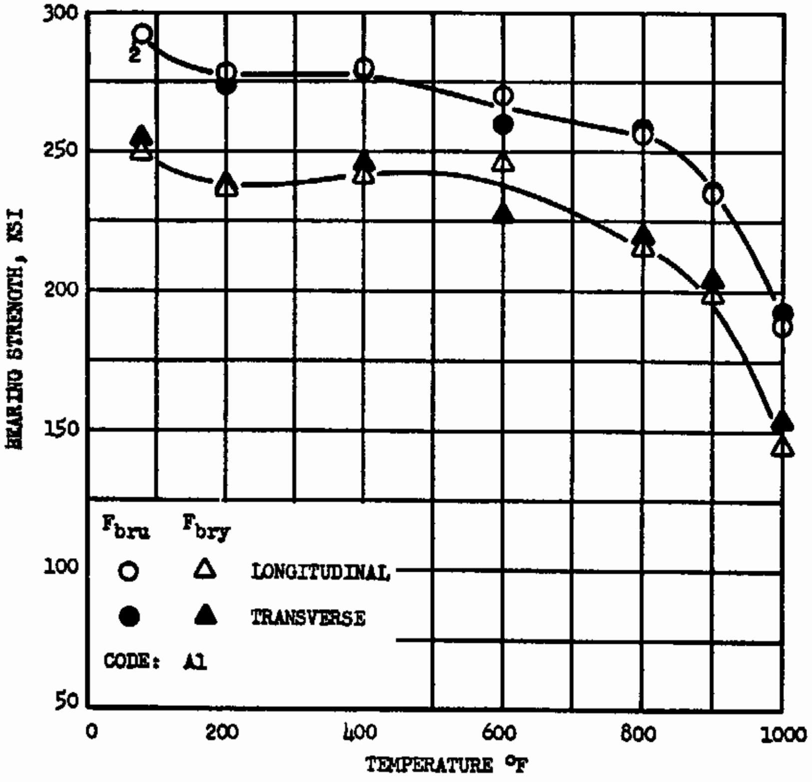


FIGURE 96 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R6392)

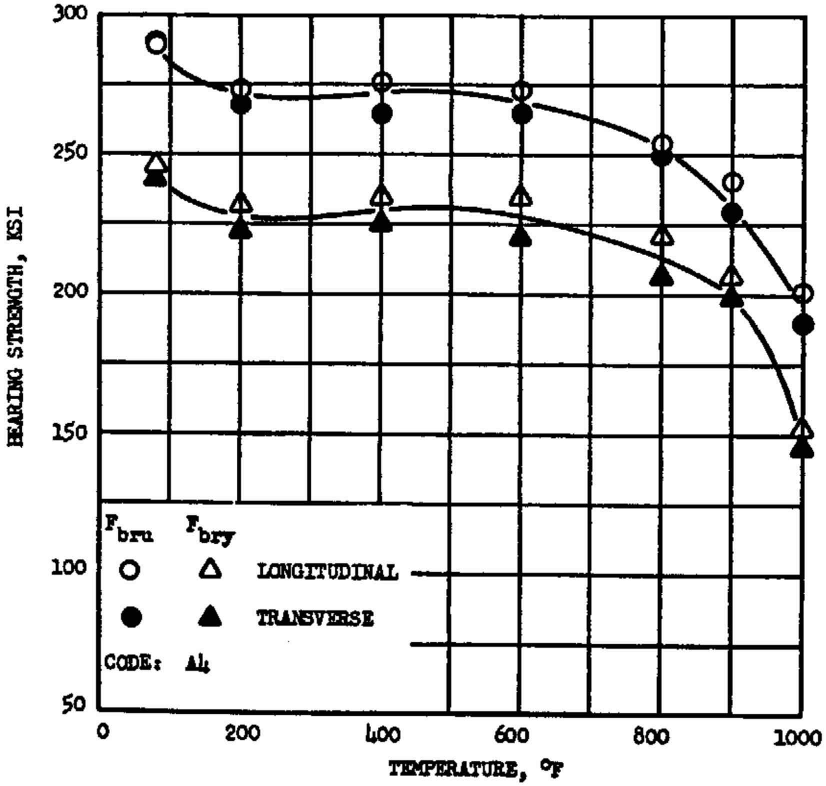


FIGURE 97 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R6761)

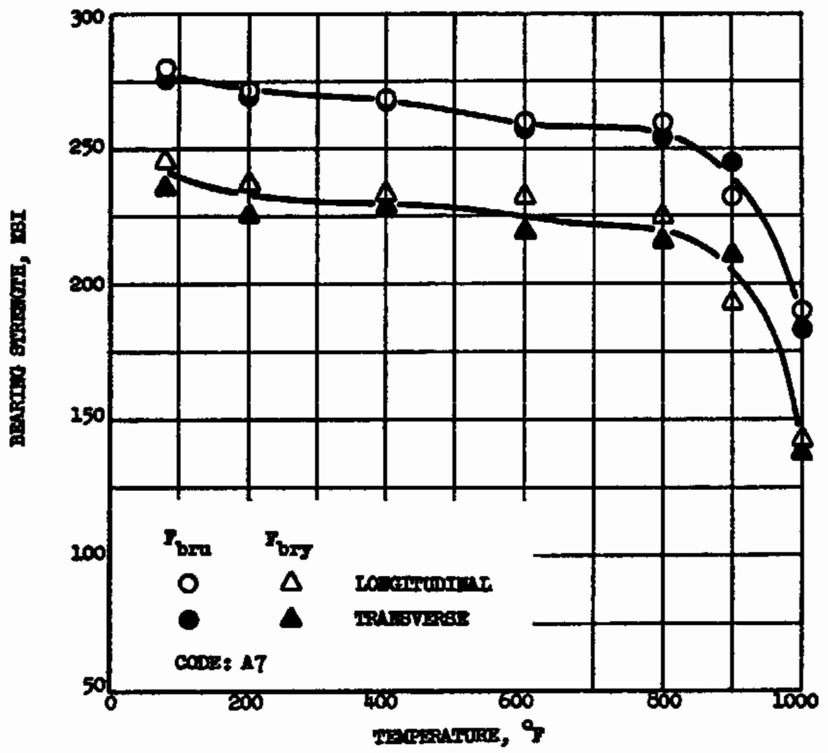


FIGURE 98 - **AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R6788)**

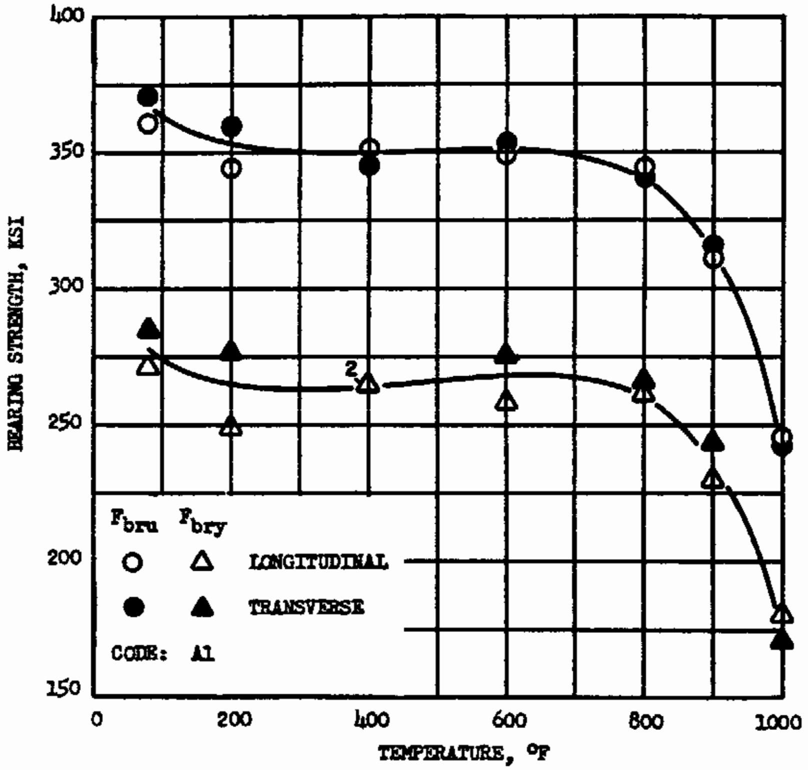


FIGURE 99 - **AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R6392)**

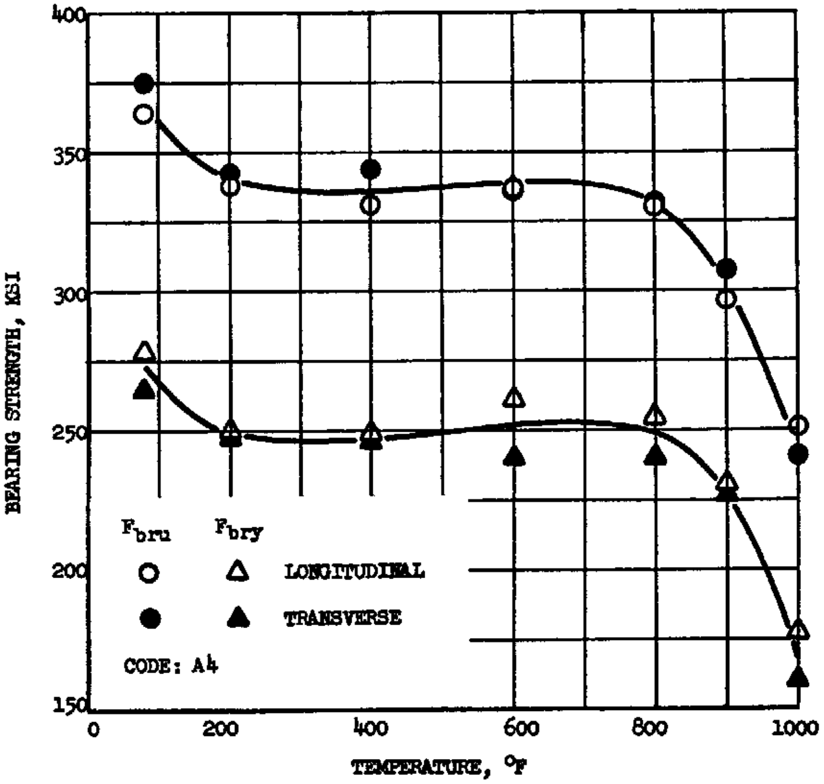


FIGURE 100 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R6761)

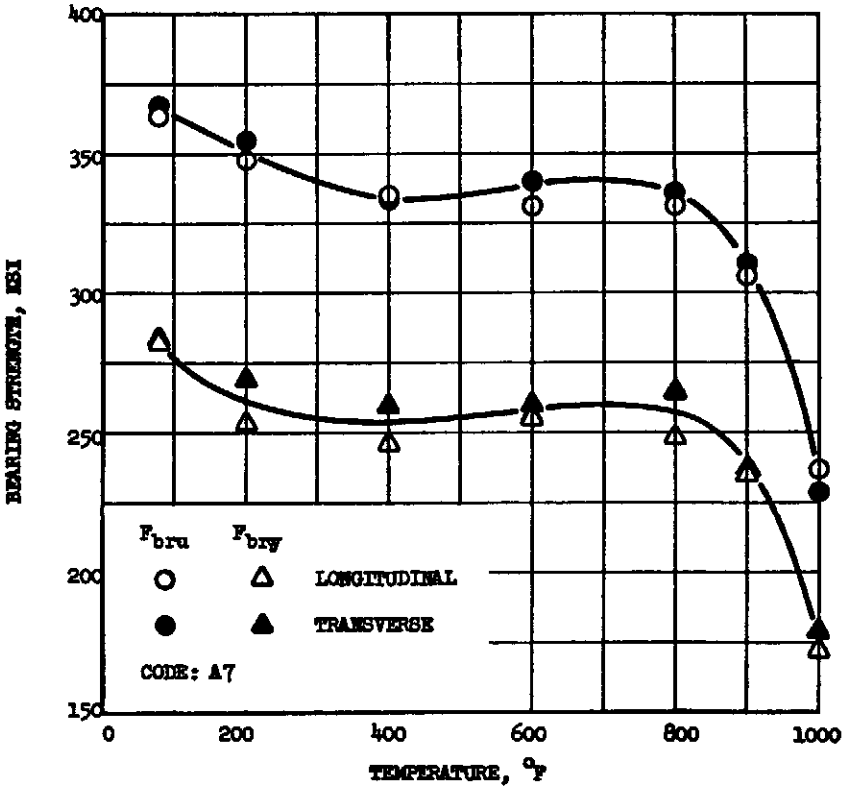


FIGURE 101 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R6788)

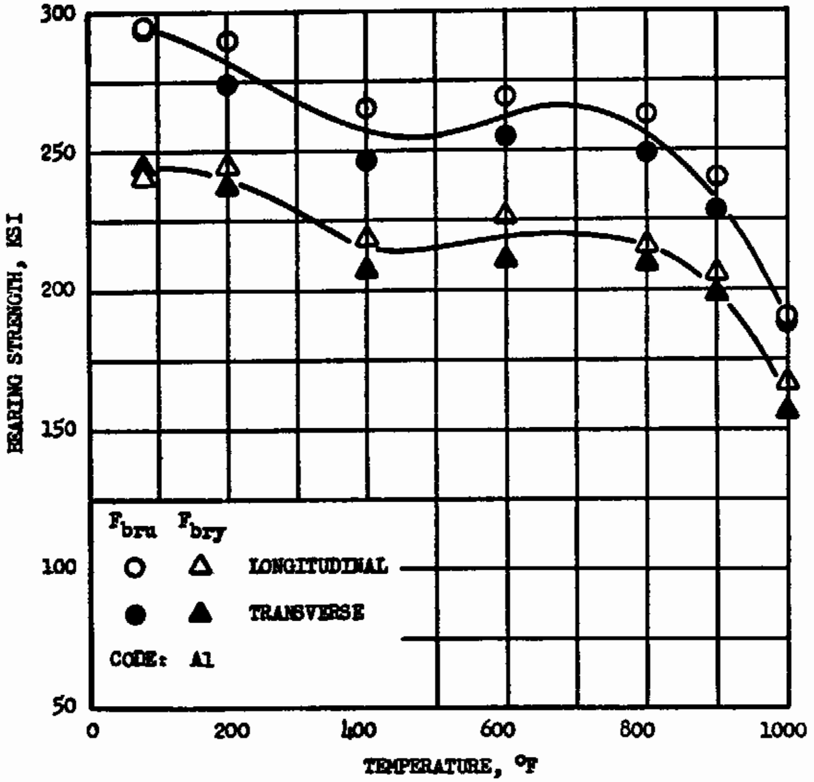


FIGURE 102 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R6392)

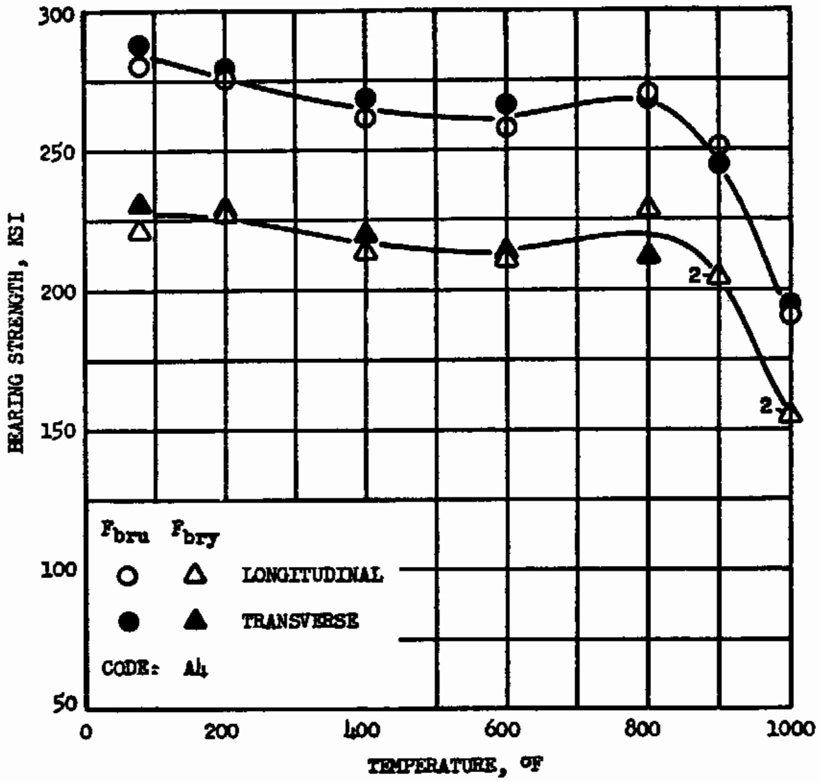


FIGURE 103 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R6761)

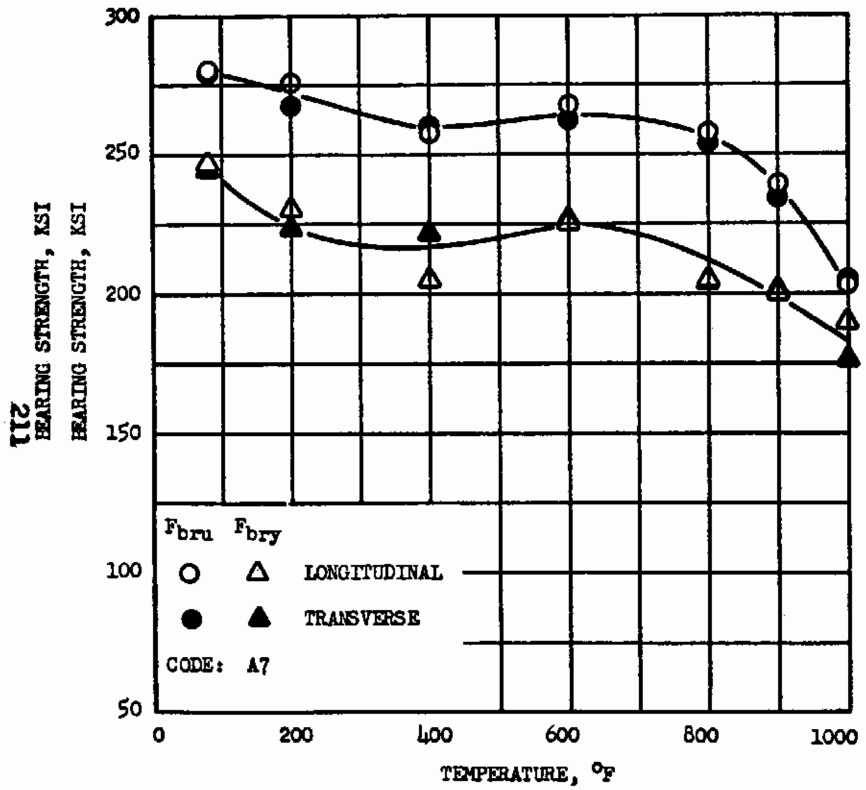


FIGURE 104 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R6788)

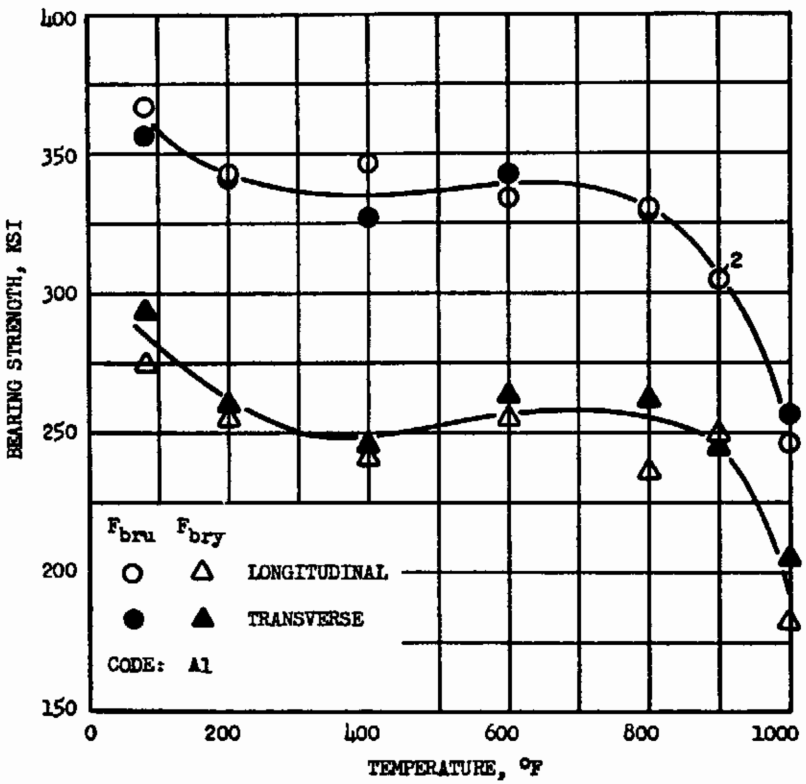


FIGURE 105 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R6392)

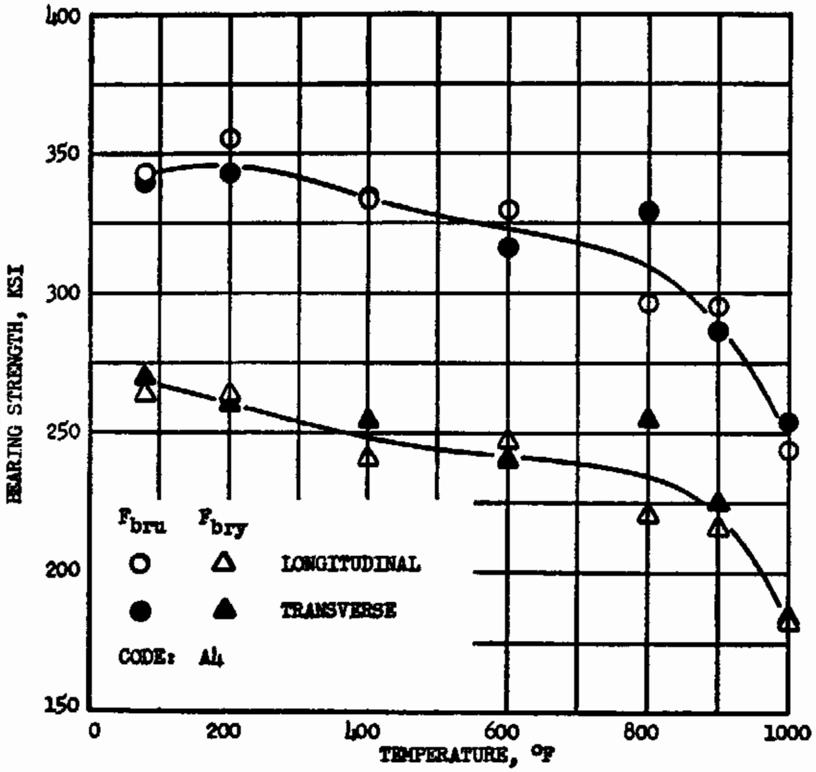


FIGURE 106 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R6761)

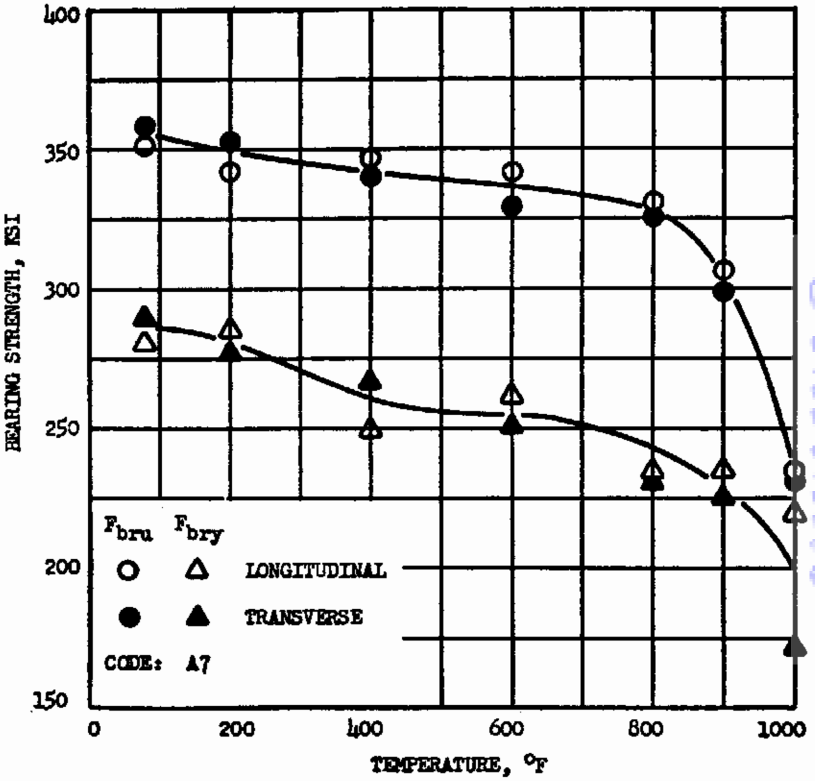


FIGURE 107 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R6788)

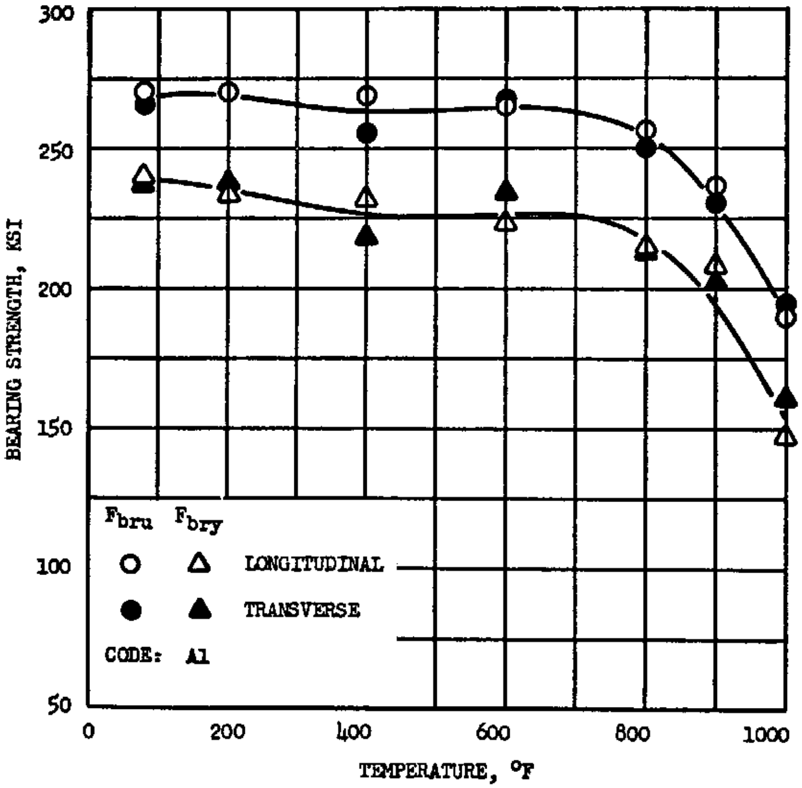


FIGURE 108 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6392)

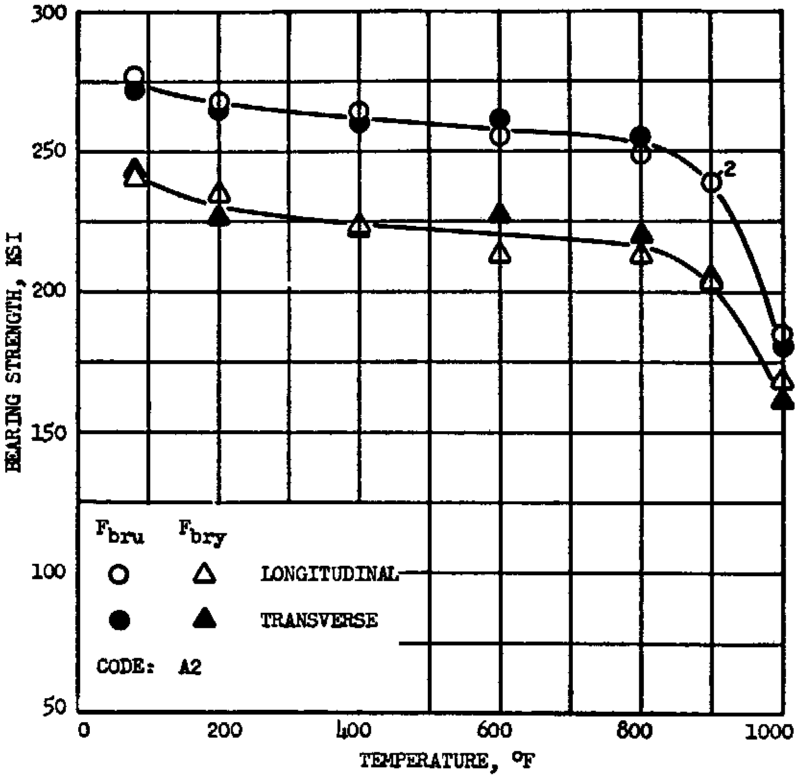


FIGURE 109 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6392)

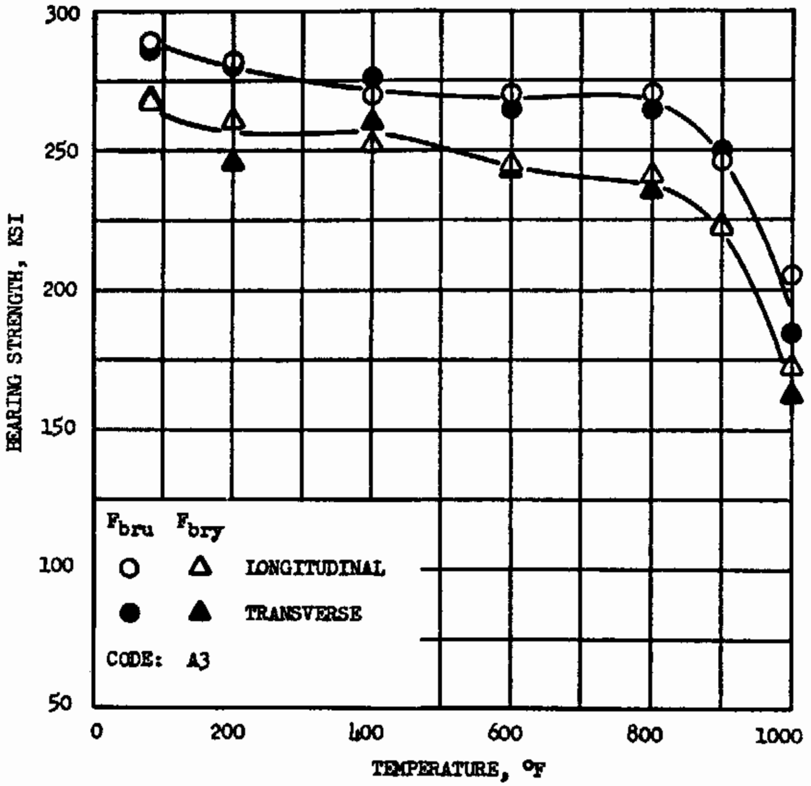


FIGURE 110 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6759)

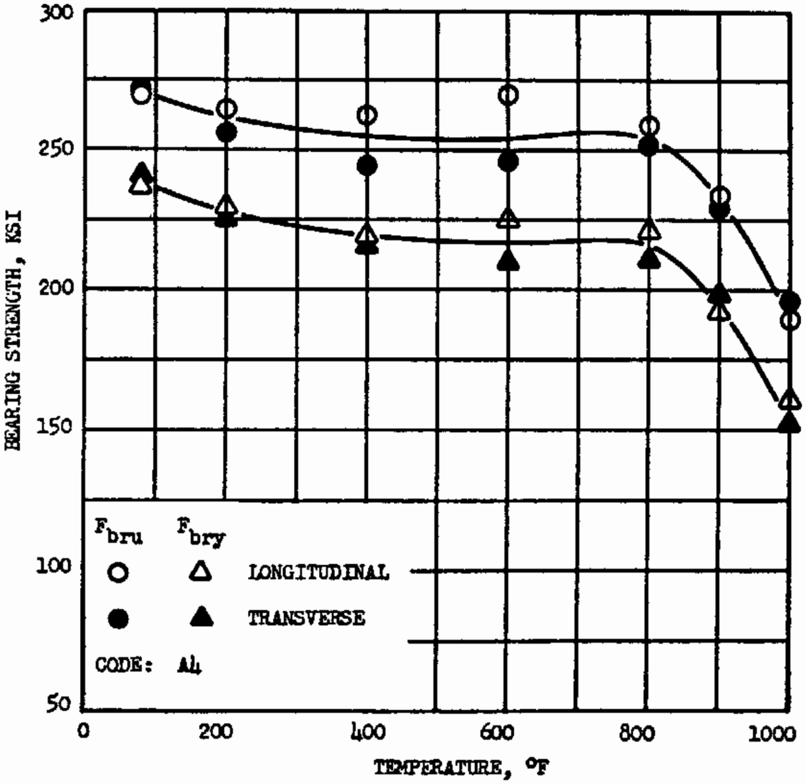


FIGURE 111 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R 6761)

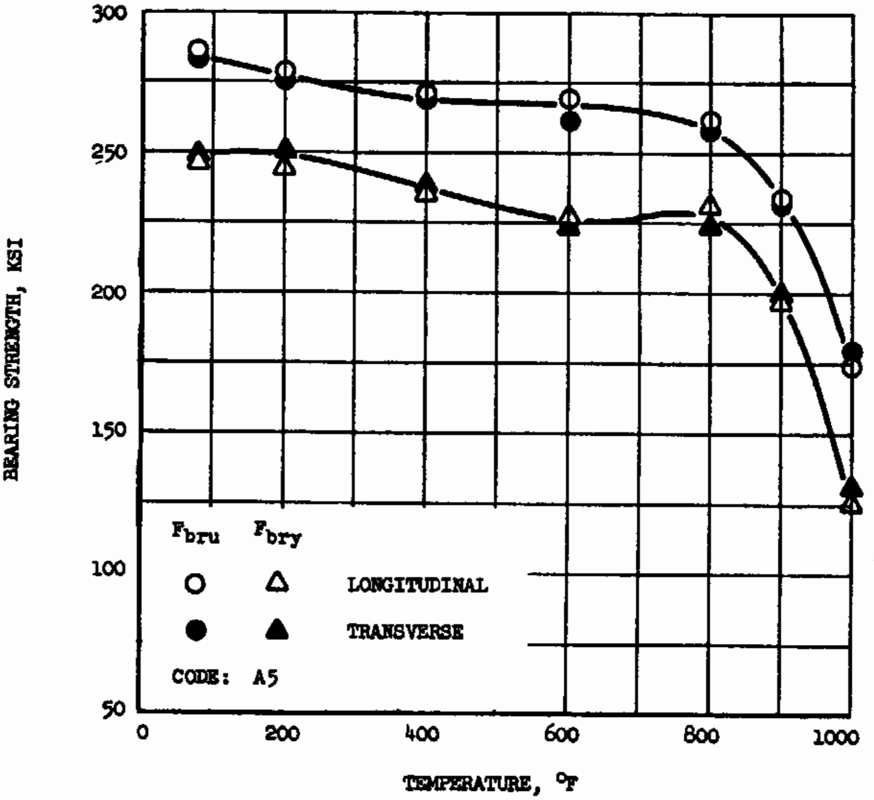


FIGURE 112 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER =0.3125 INCH (CRUCIBLE HEAT NO. R6761)

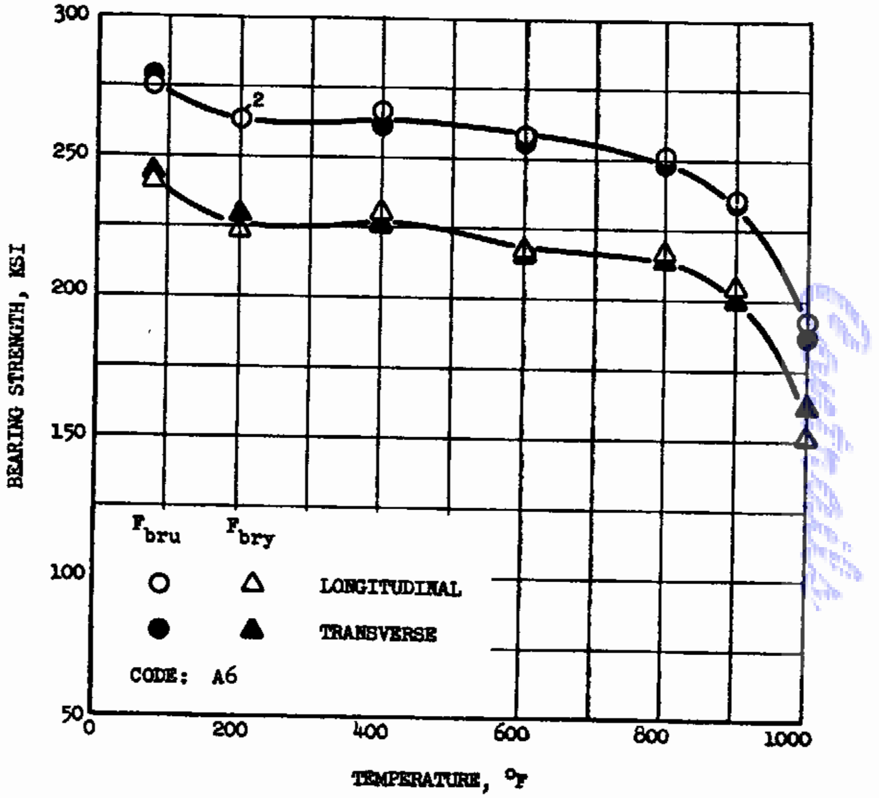


FIGURE 113 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6761)

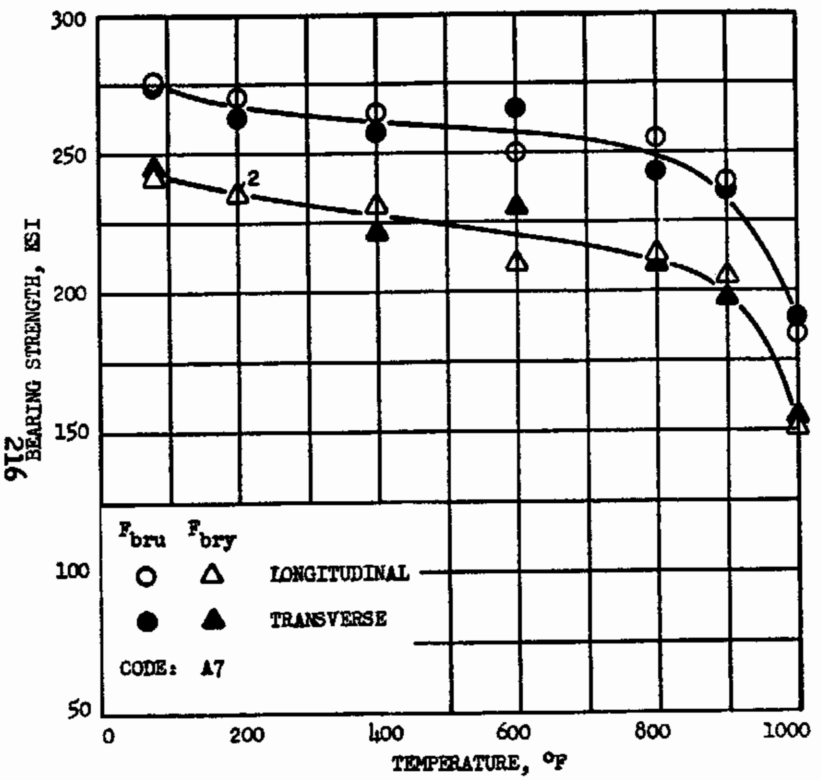


FIGURE 114 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6788)

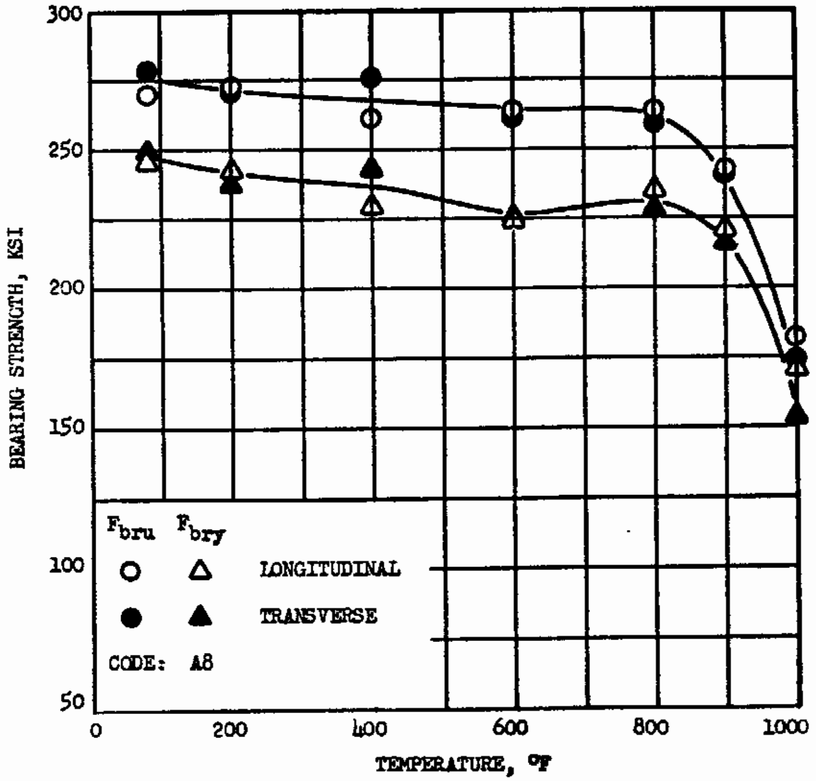


FIGURE 115 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6788)

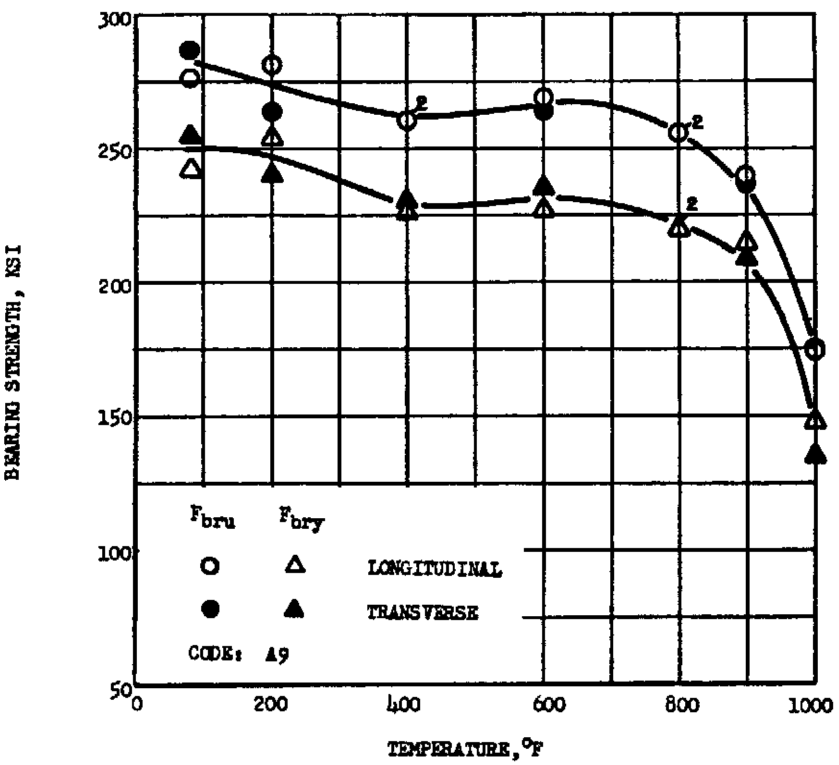


FIGURE 116 – AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6753)

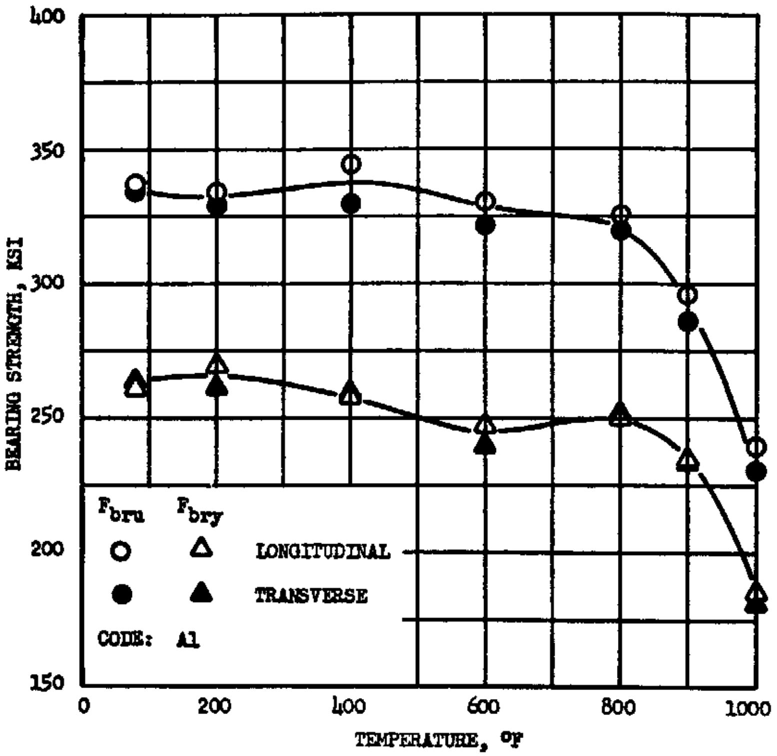


FIGURE 117 – AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6392)

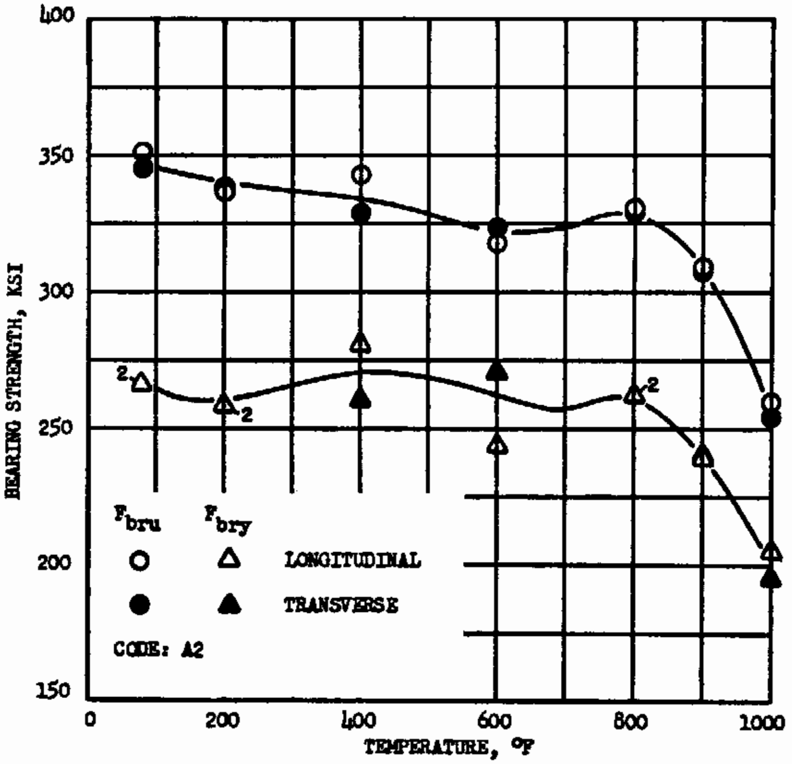


FIGURE 118 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6392)

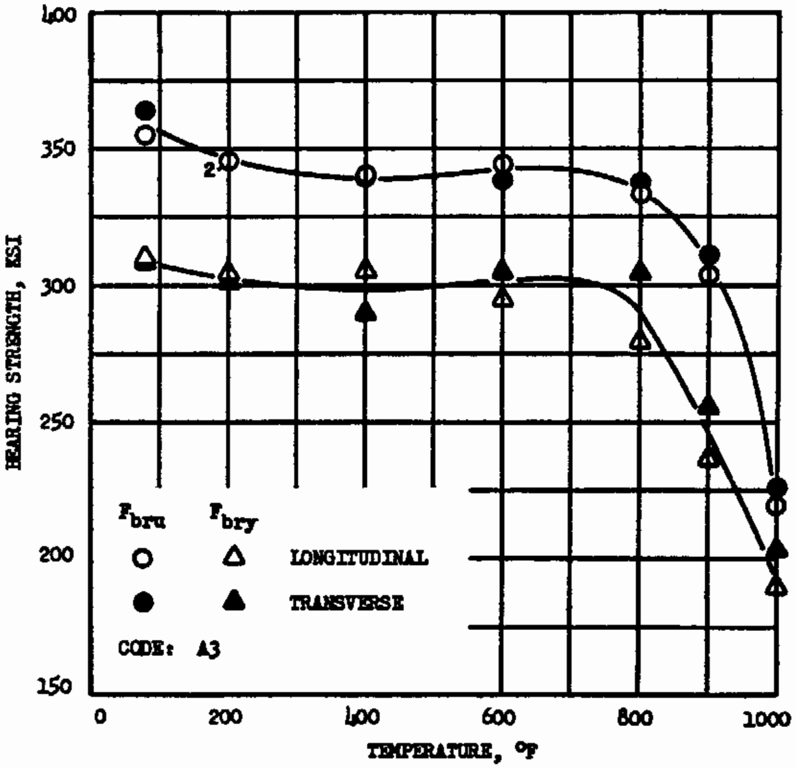


FIGURE 119 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6759)

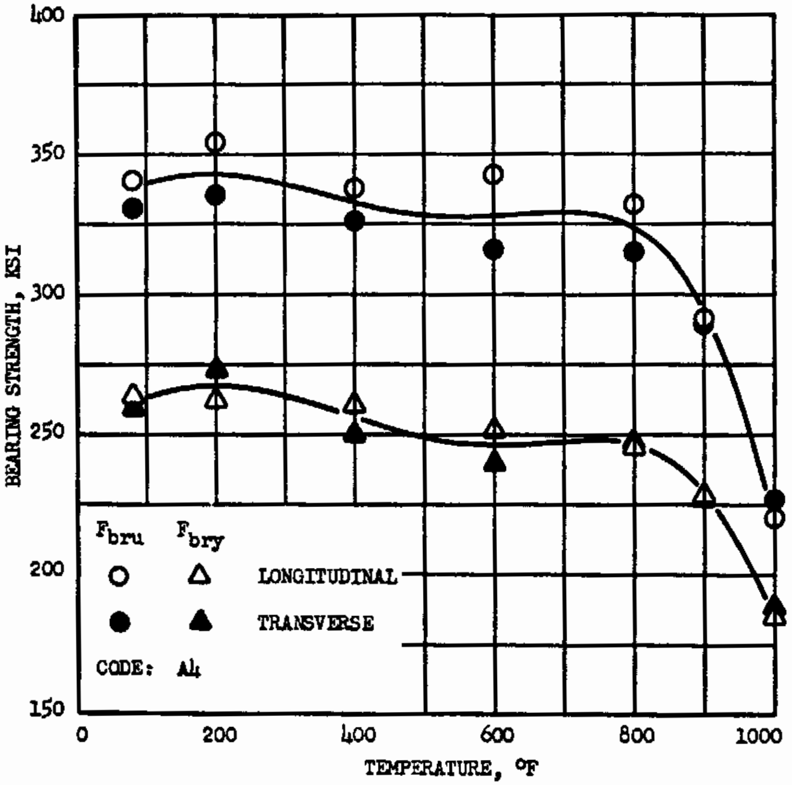


FIGURE 120 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6761)

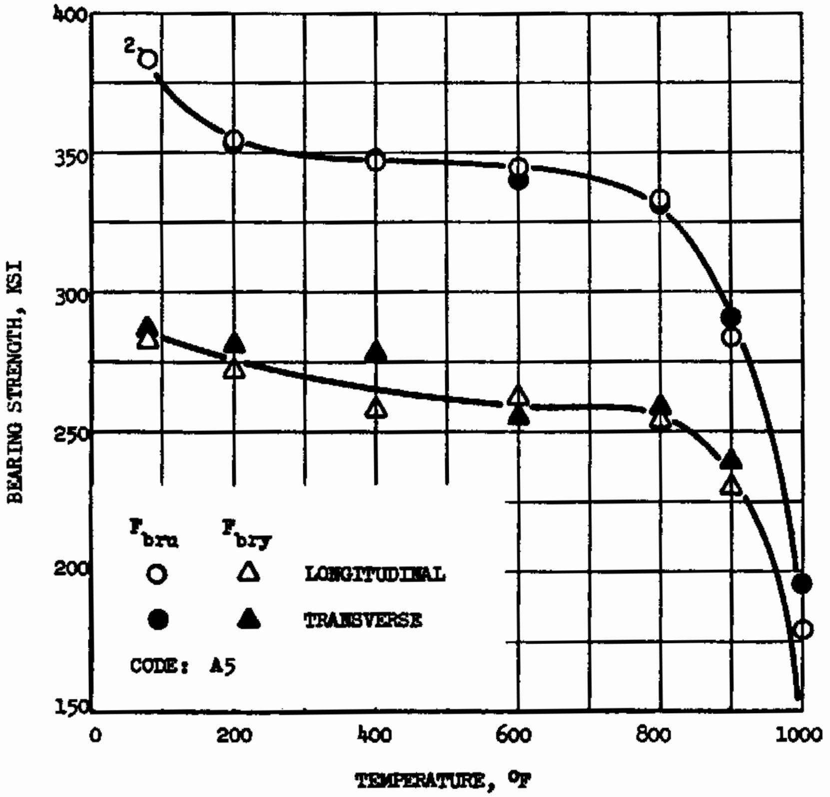


FIGURE 121 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6761)

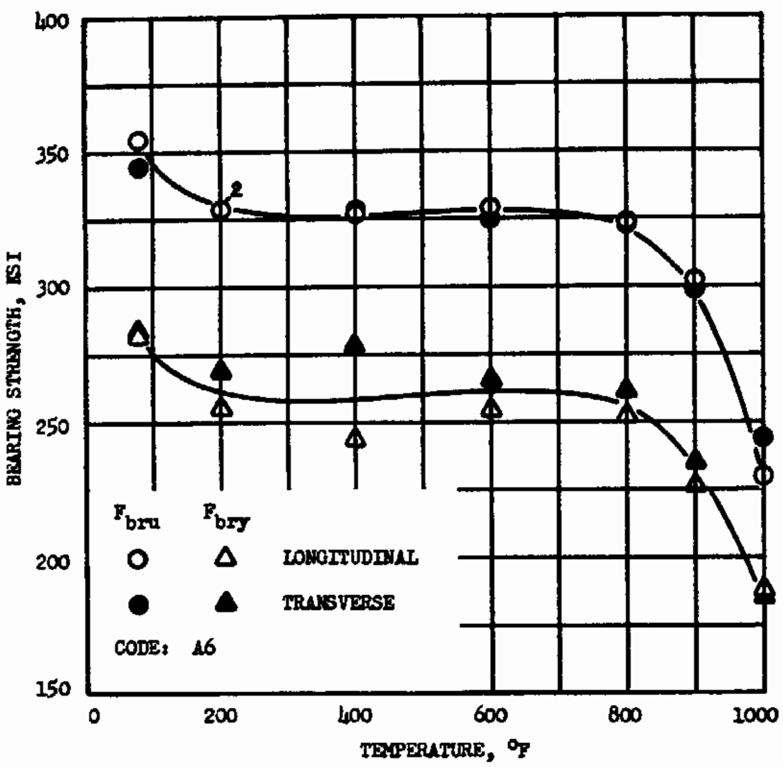


FIGURE 122 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6761)

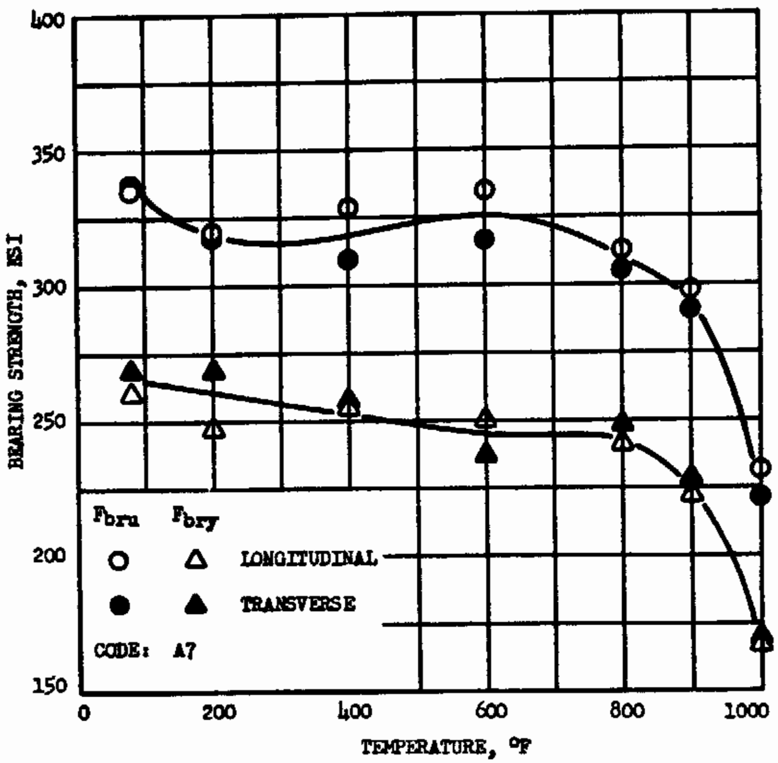


FIGURE 123 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6788)

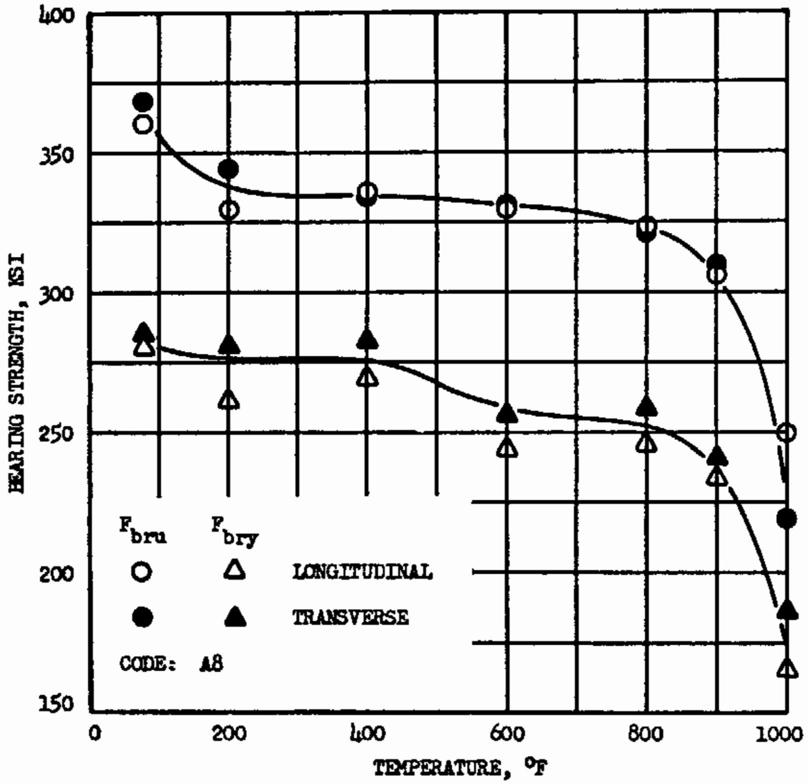


FIGURE 124 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6788)

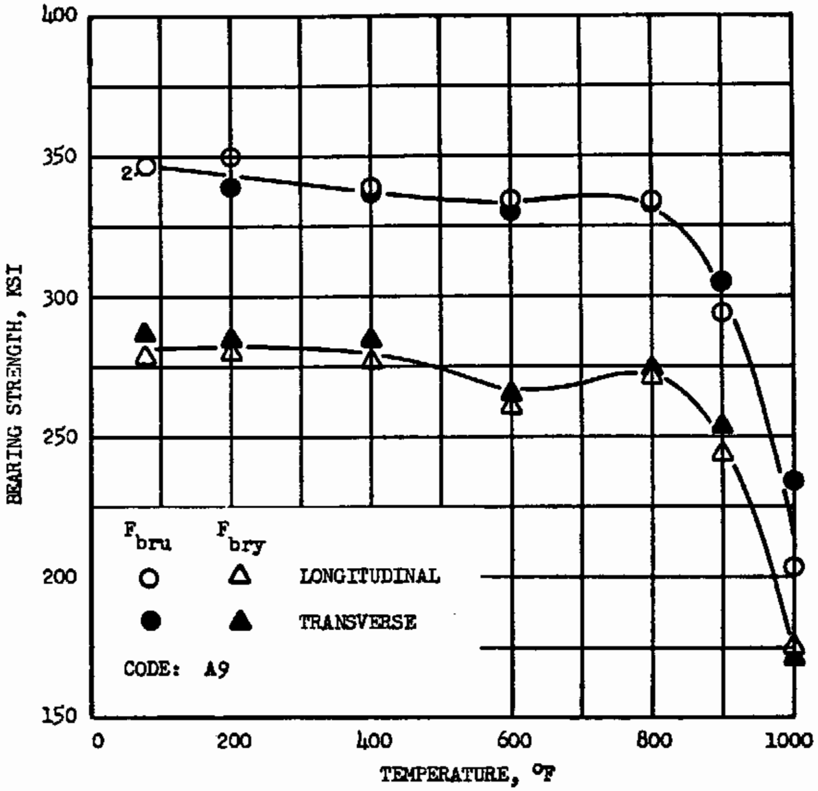


FIGURE 125 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6753)

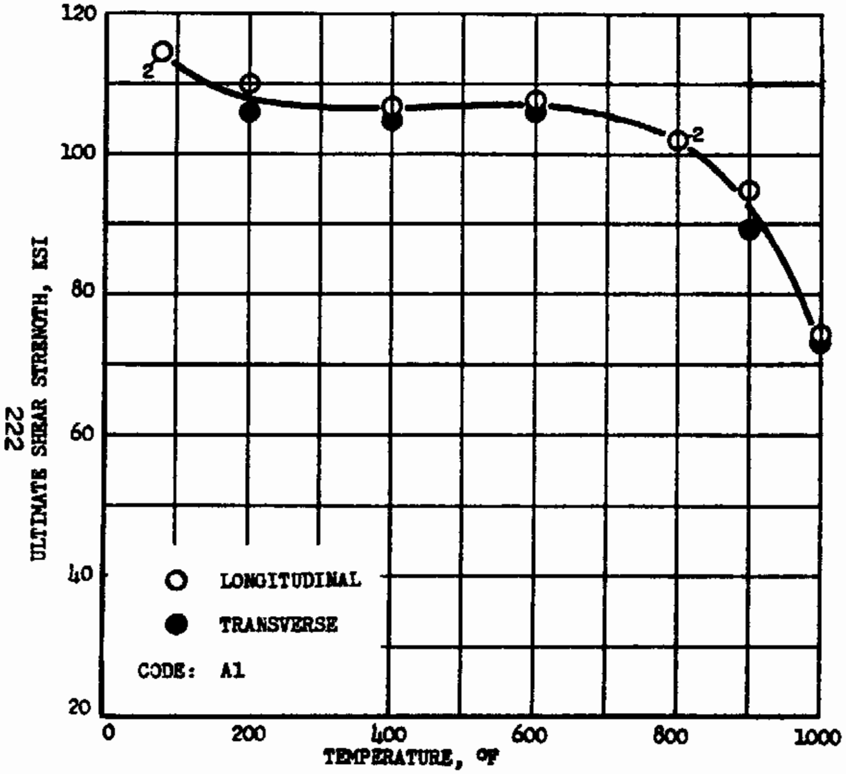


FIGURE 126 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R6392)

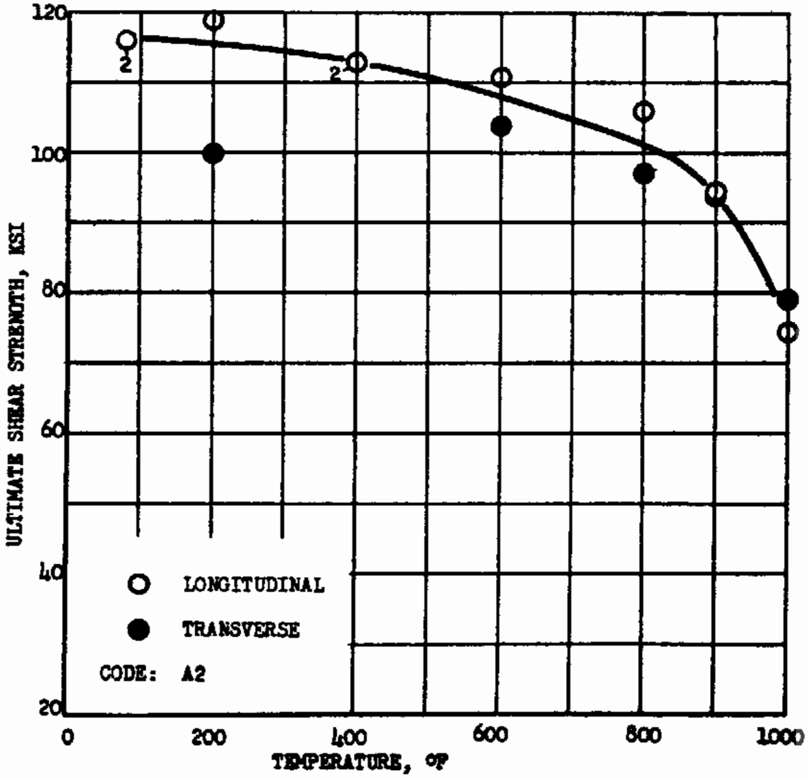


FIGURE 127 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6392)

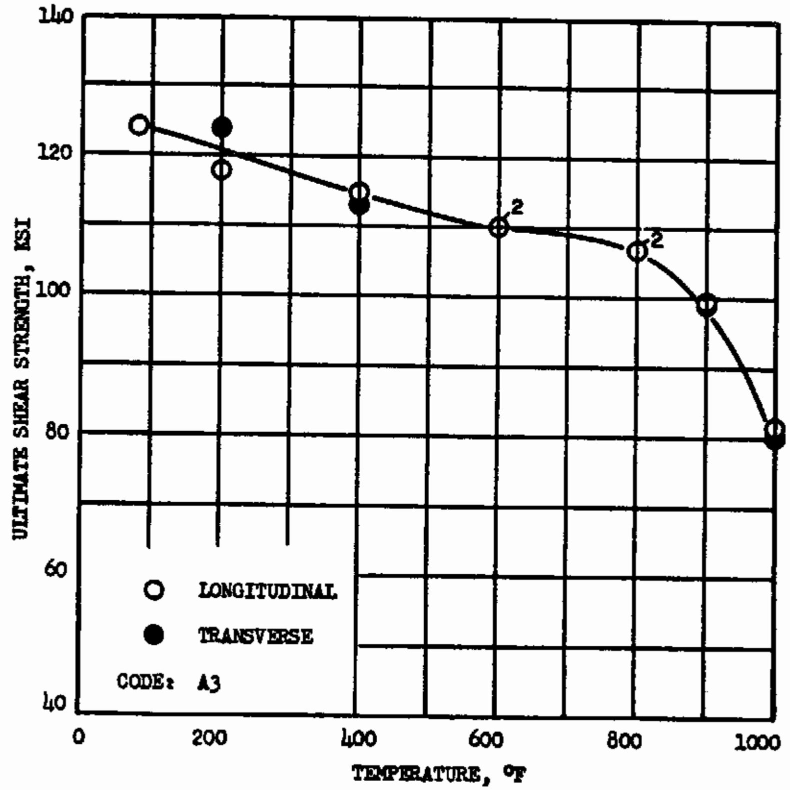


FIGURE 128 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. B6759)

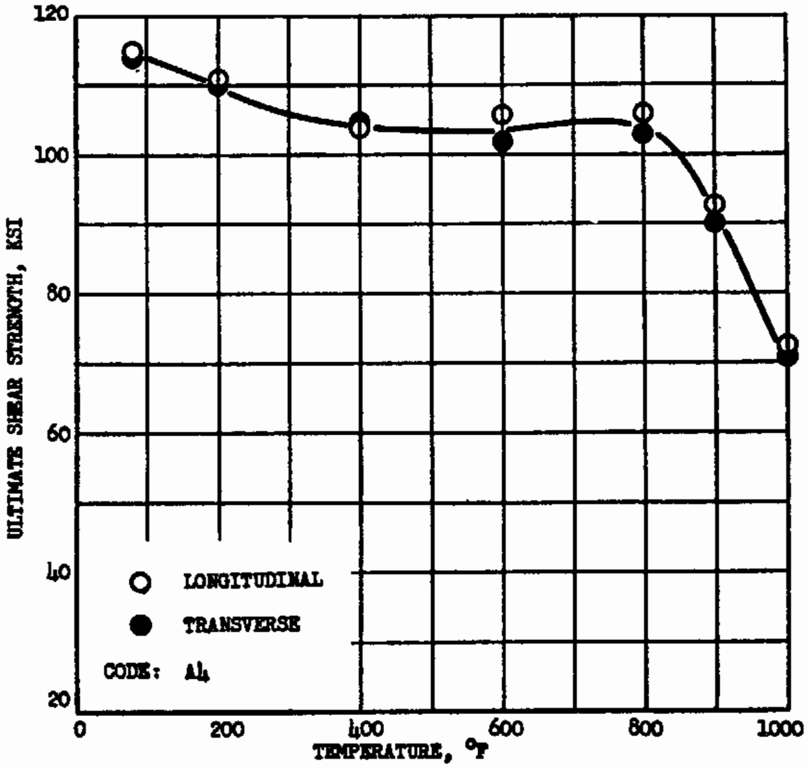


FIGURE 129 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. B6761)

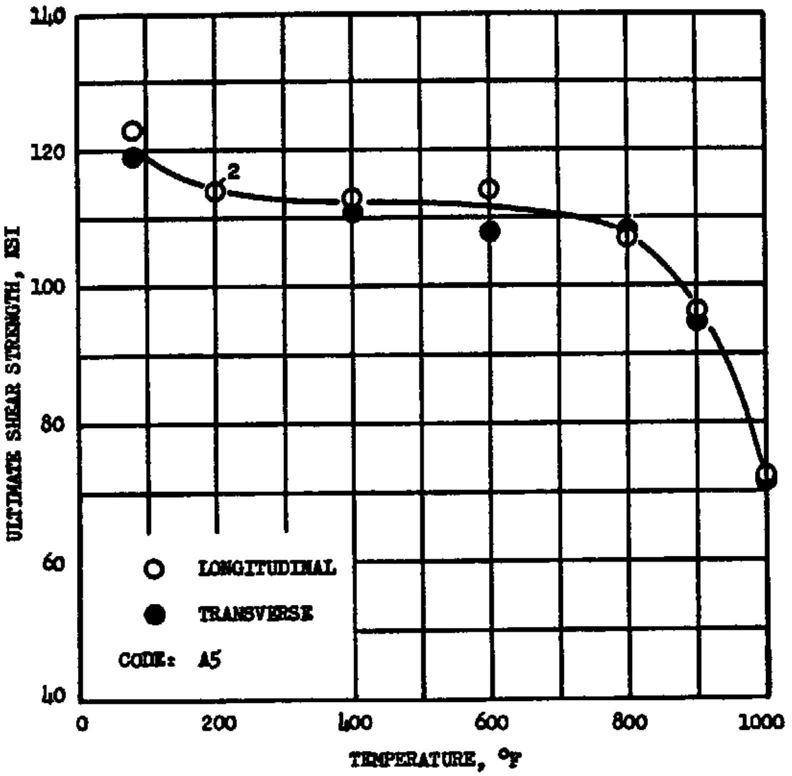


FIGURE 130 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6761)

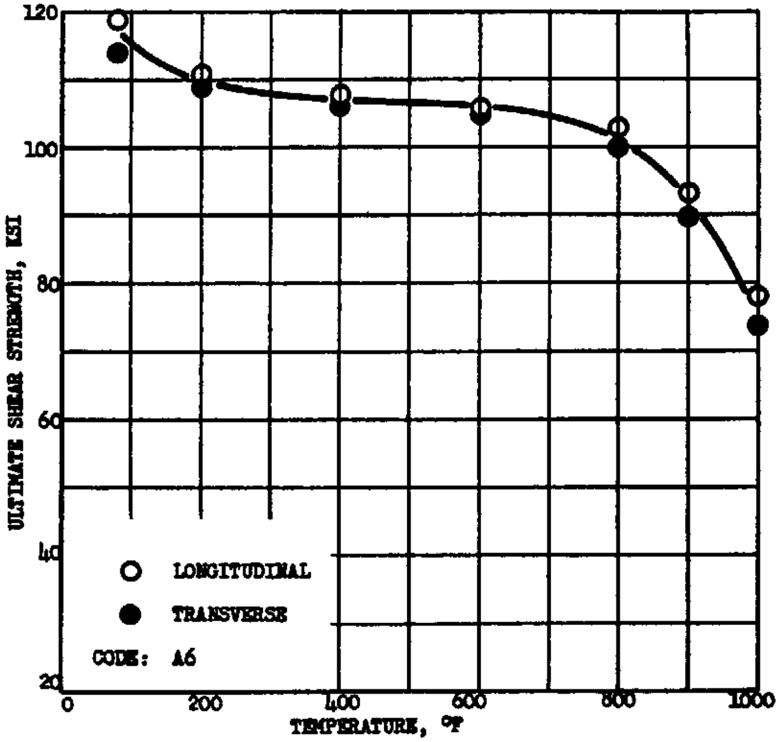


FIGURE 131 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6761)

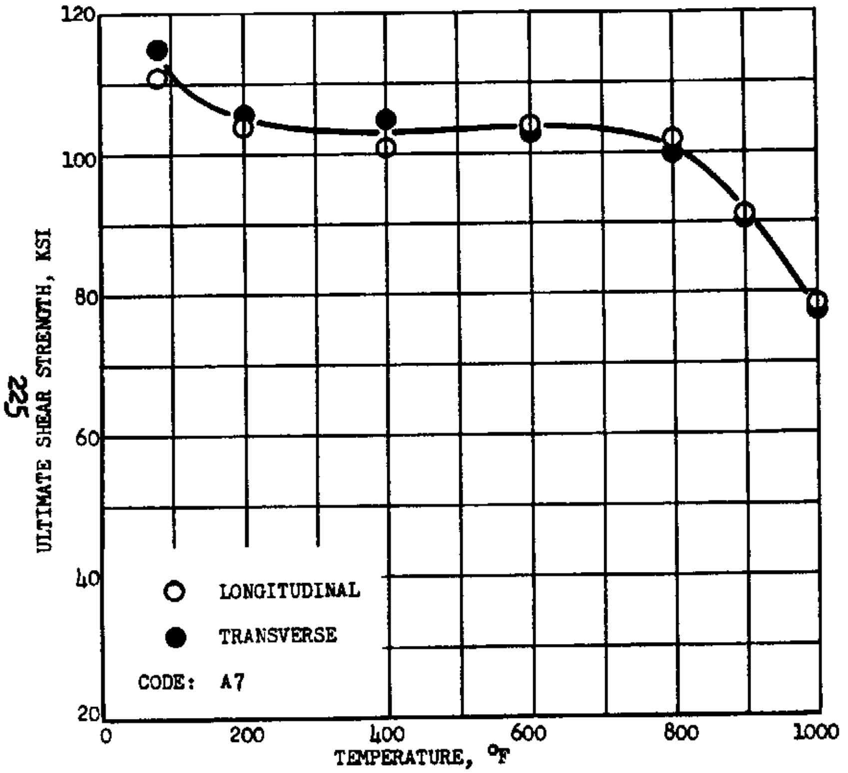


FIGURE 132 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R6788)

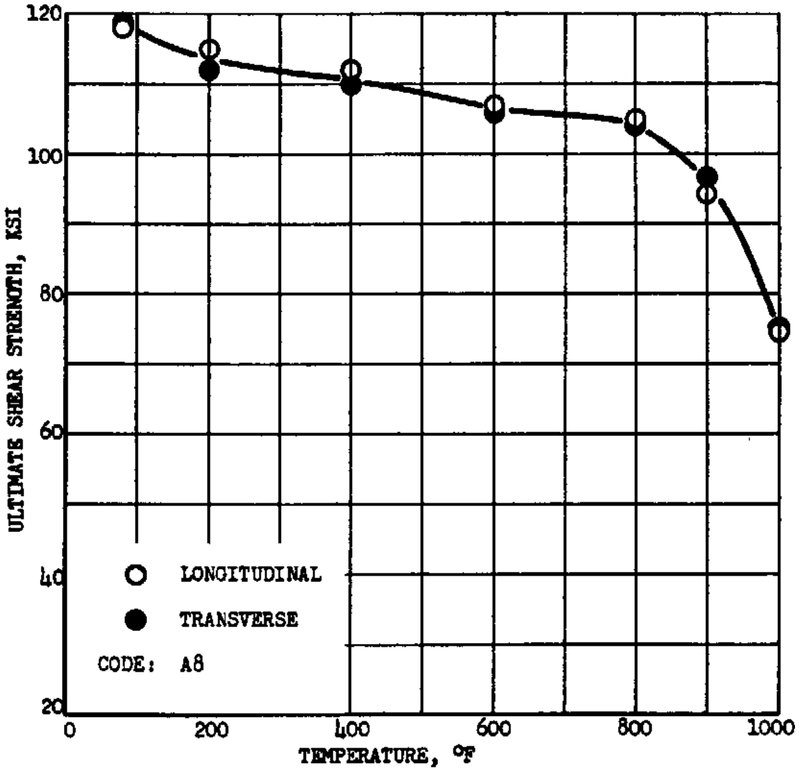


FIGURE 133 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6788)

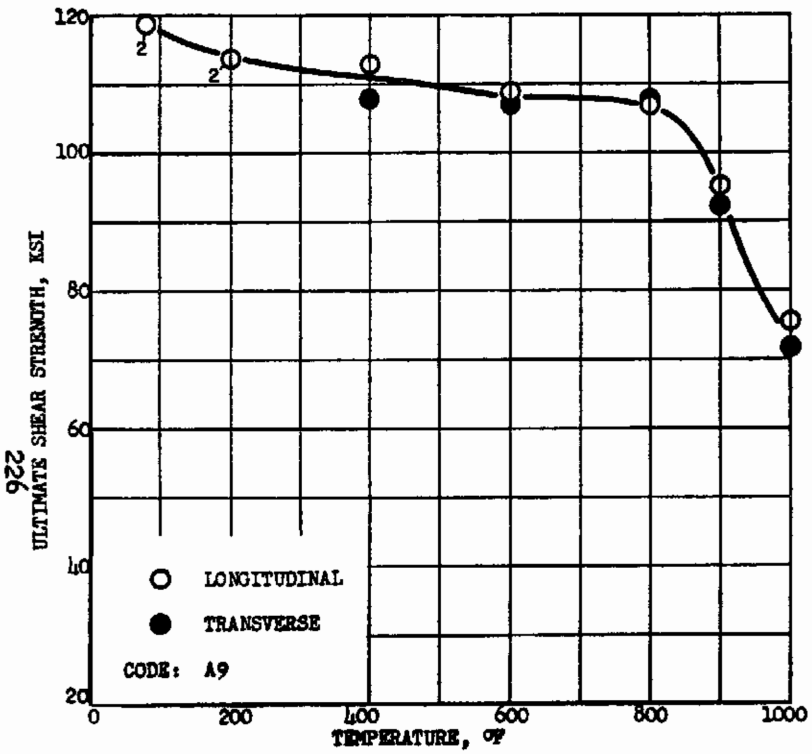


FIGURE 134 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6753)

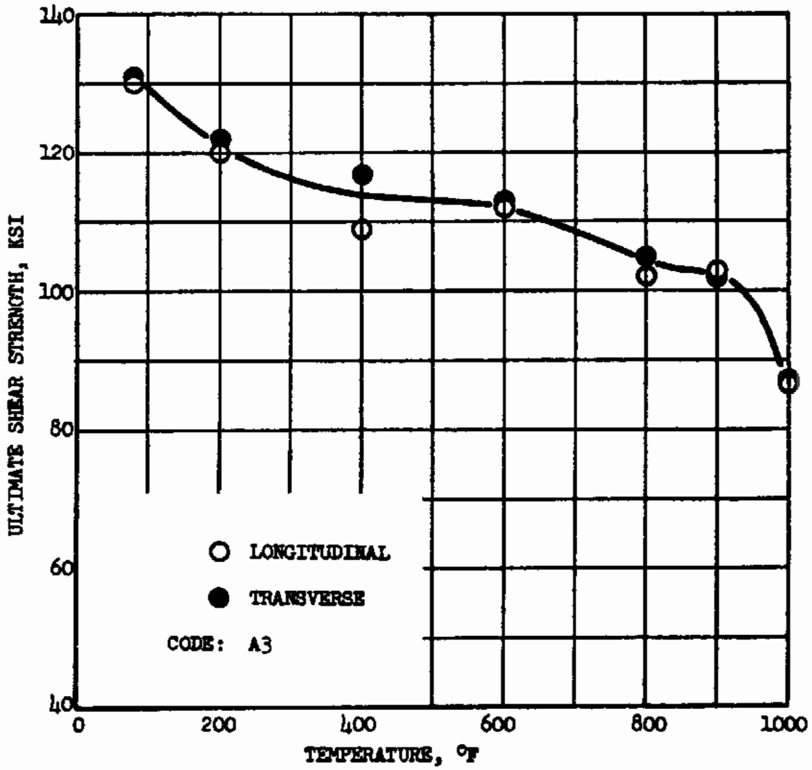


FIGURE 135 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATUPE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6759)

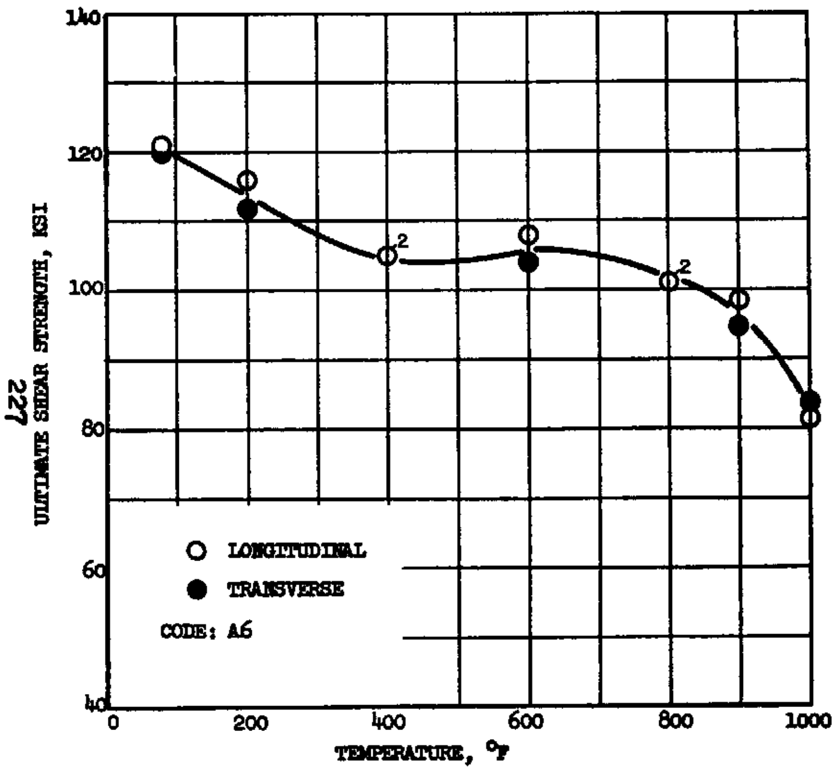


FIGURE 136 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6761)

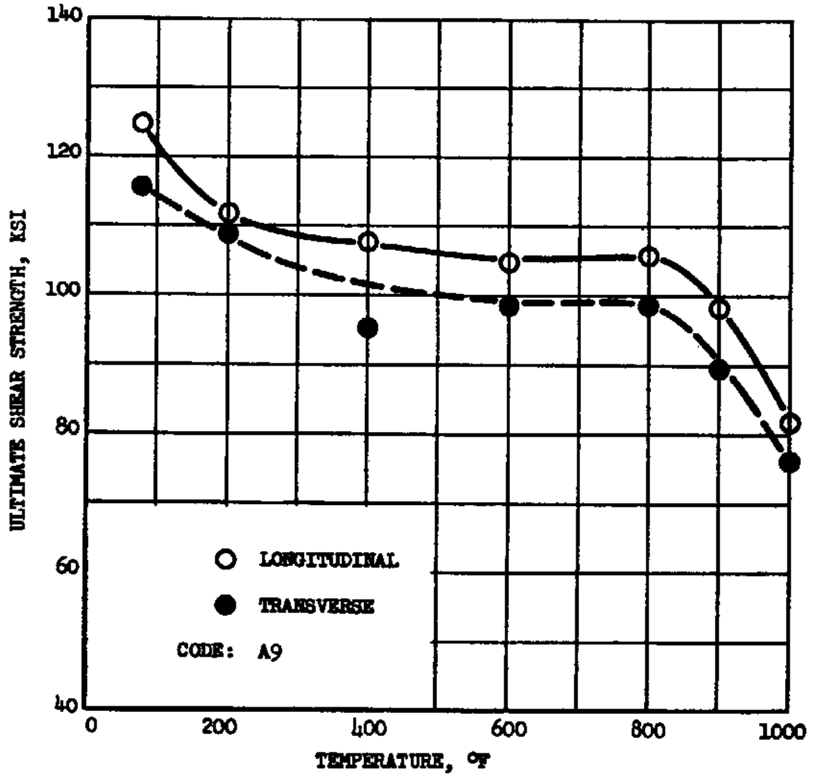


FIGURE 137 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6753)

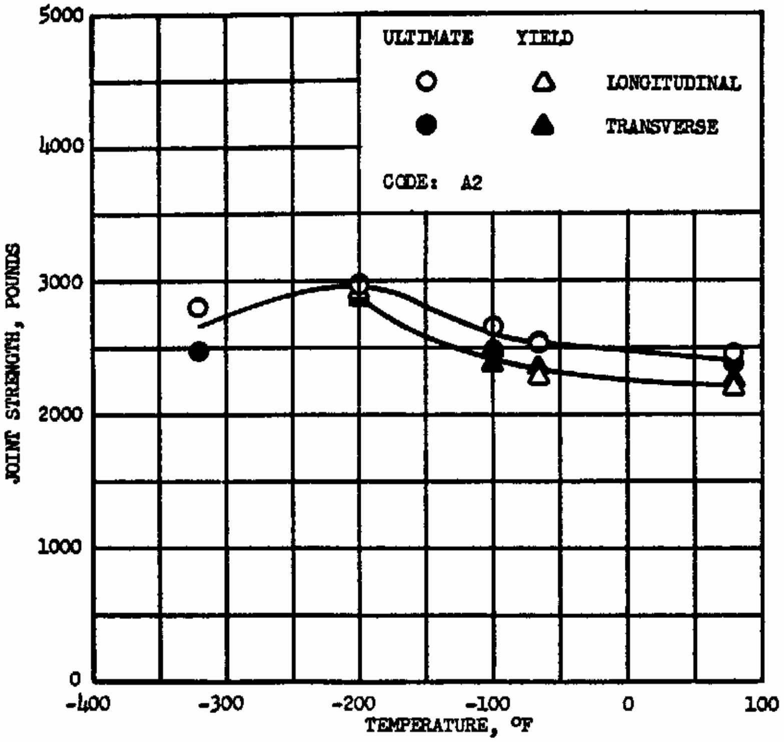


FIGURE 138 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER NAS2506-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R6392)

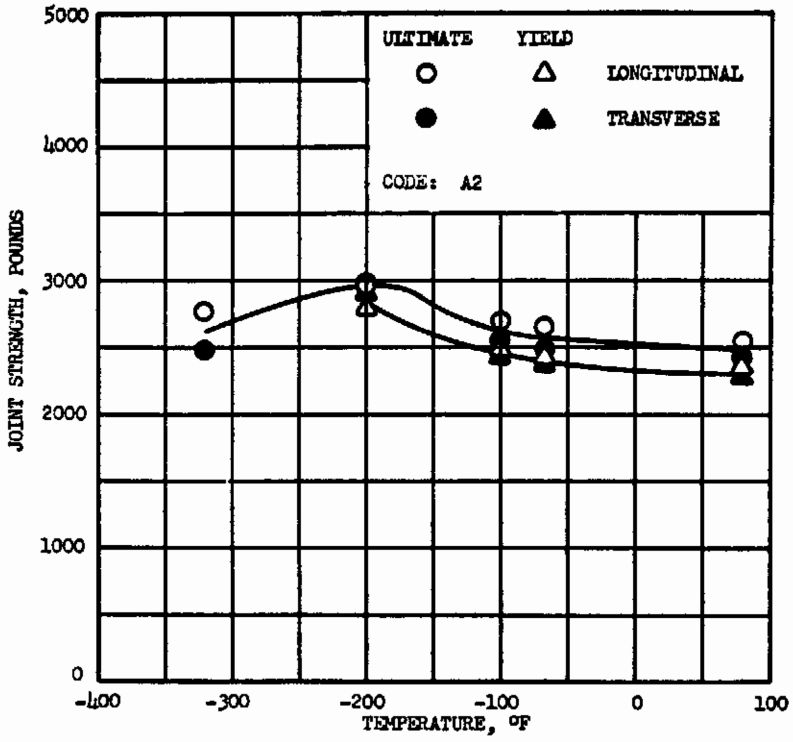


FIGURE 139 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER HL11V-6-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R6392)

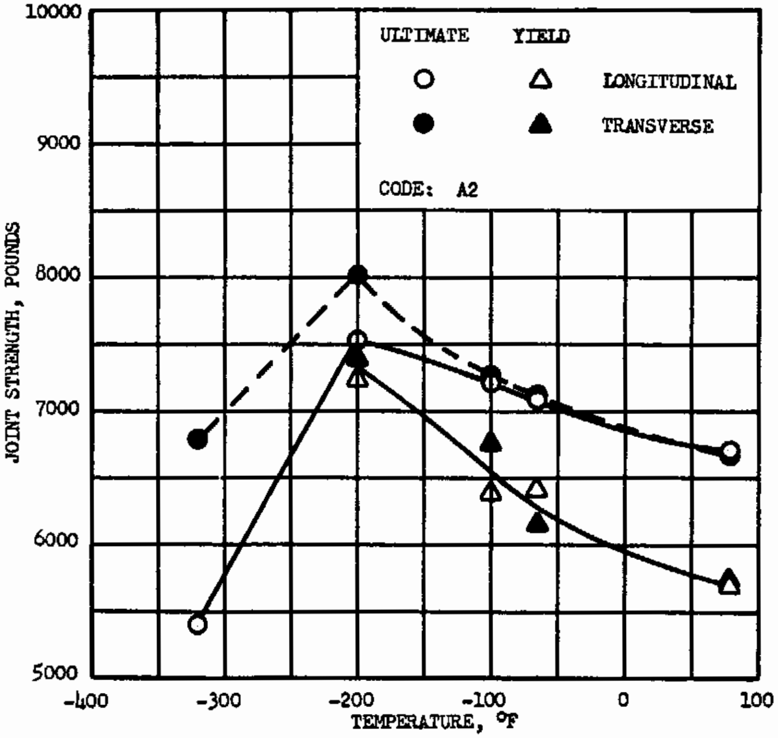


FIGURE 140 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS2010-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R6392)

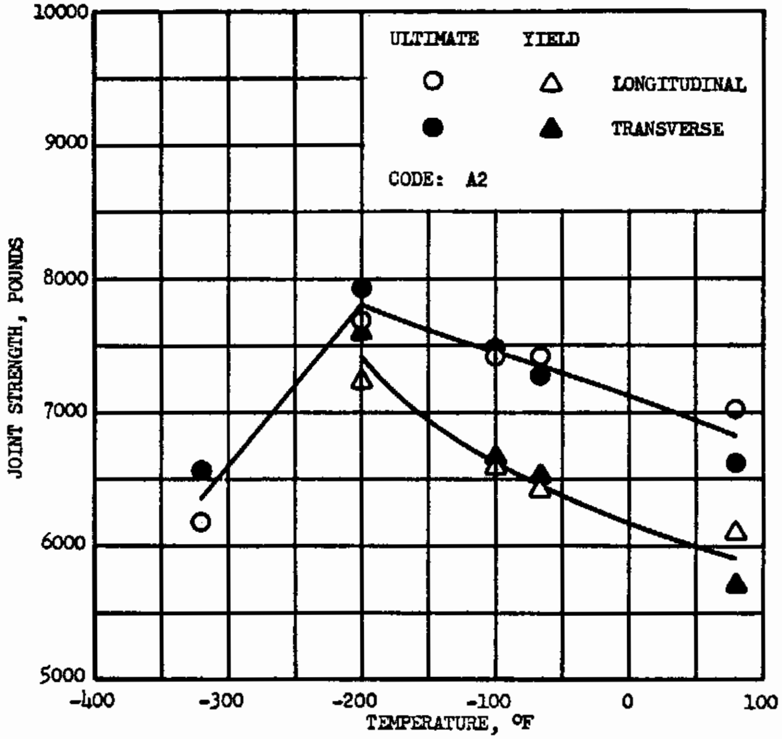


FIGURE 141 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS675-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R6392)

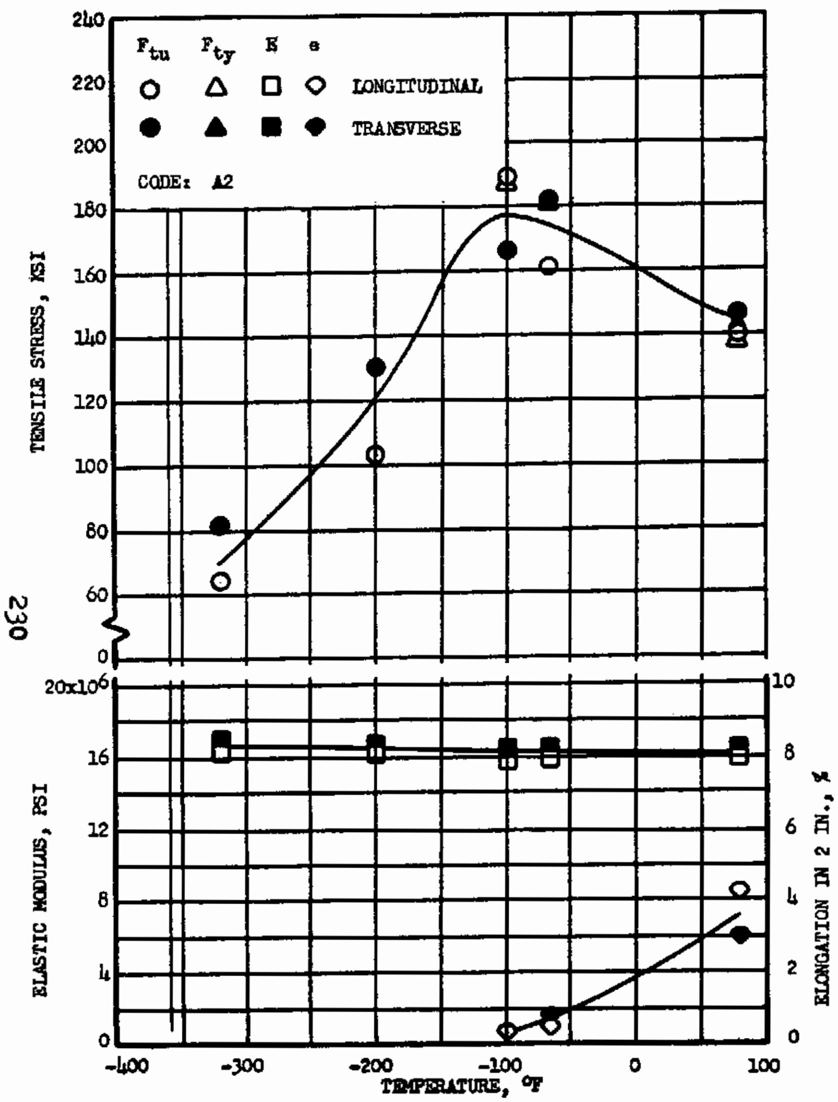


FIGURE 142 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK B120VCA TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED IN AGED CONDITION (CRUCIBLE HEAT NO. R6392)

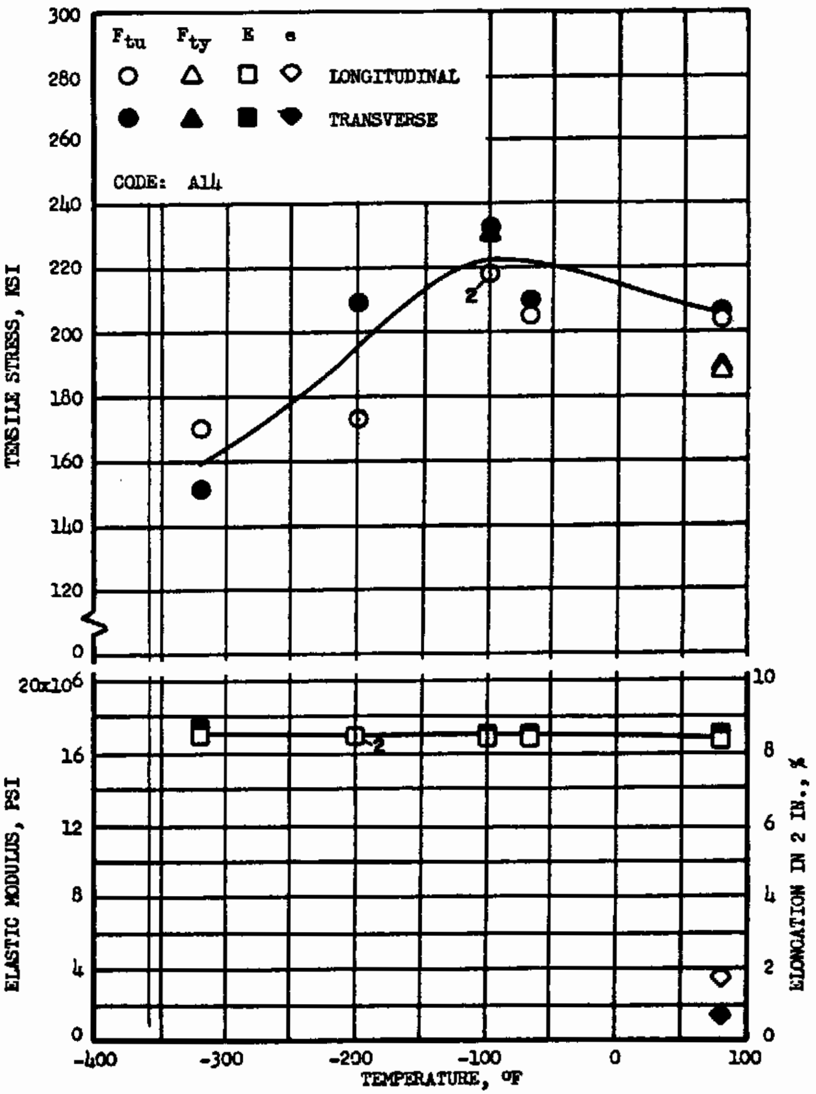


FIGURE 143 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK B120VCA TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED PRIOR TO AGING (CRUCIBLE HEAT NO. R6799)

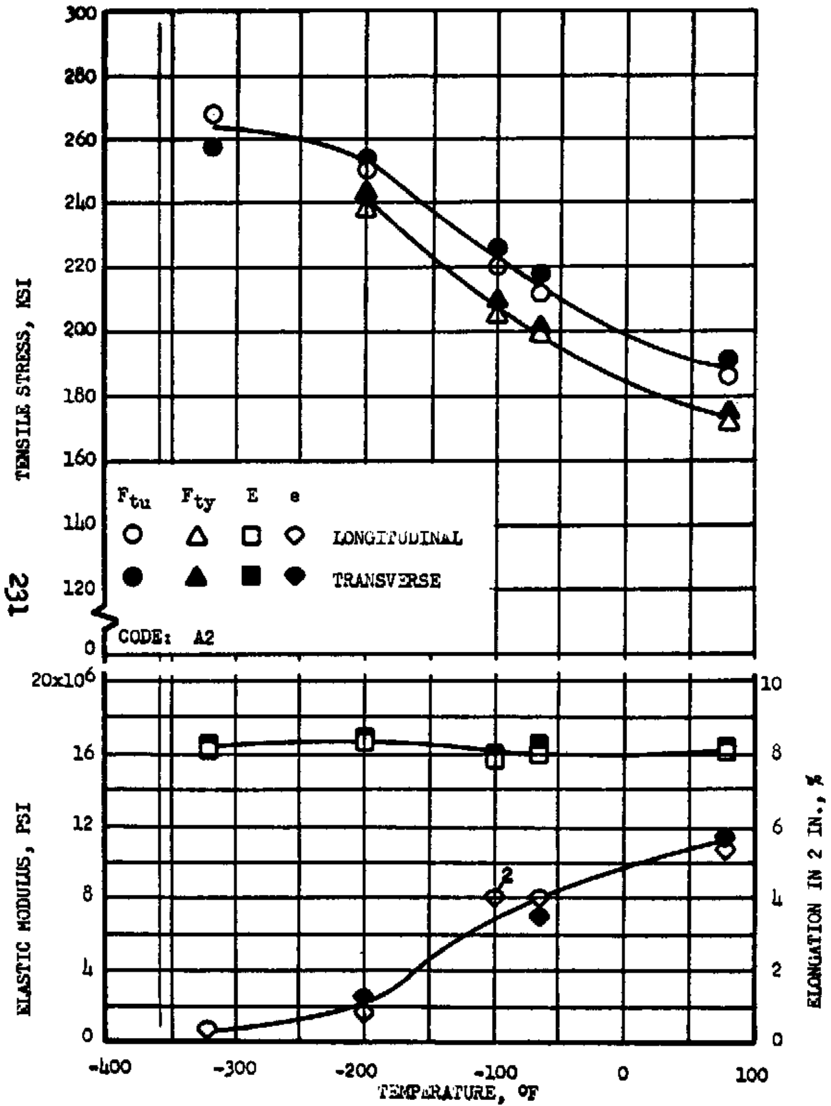


FIGURE 144 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6392)

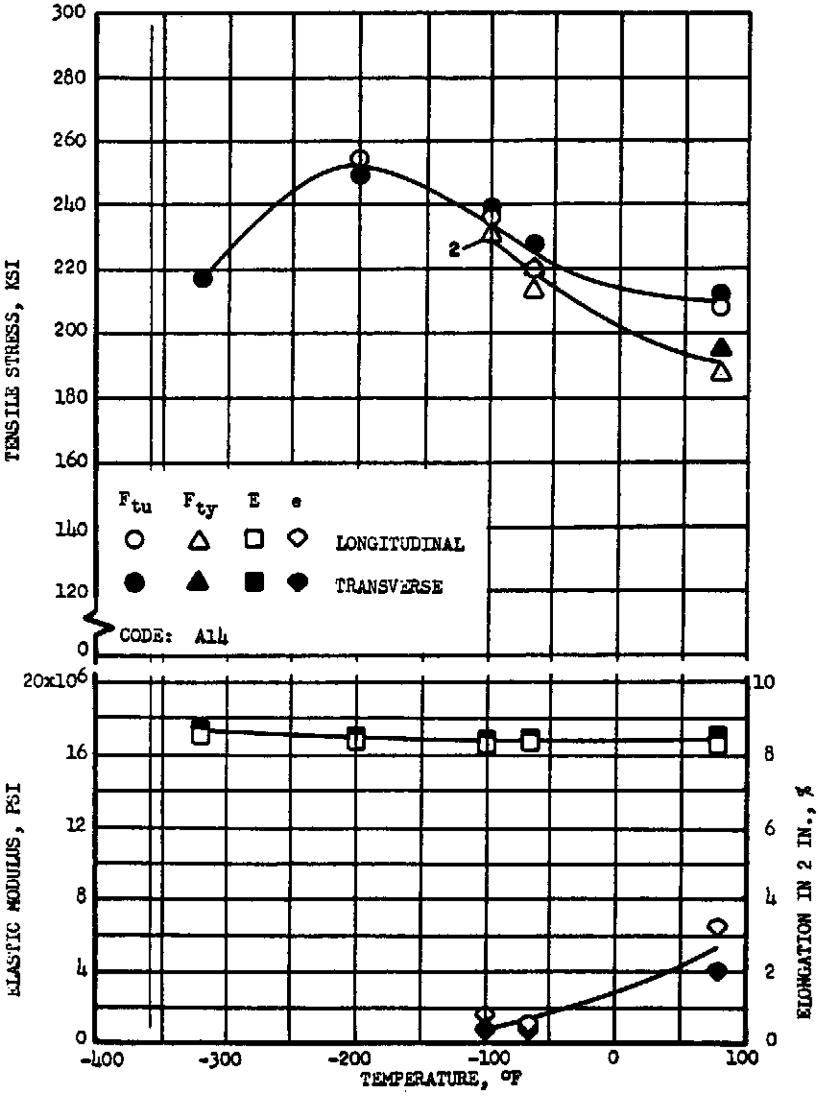


FIGURE 145 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK, AGED BY LOCKHEED (CRUCIBLE HEAT NO. R6799)

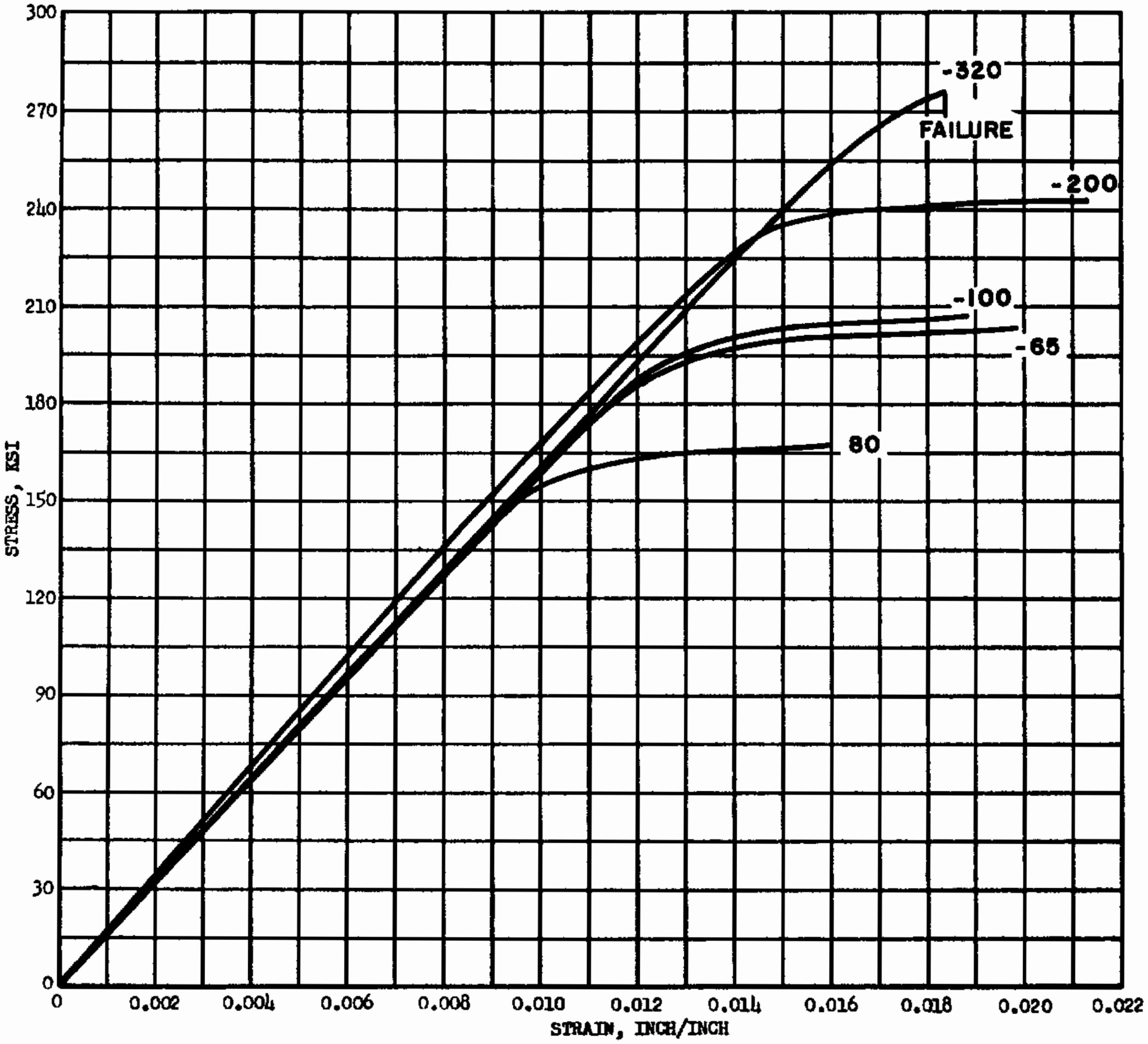


FIGURE 146 - TYPICAL LONGITUDINAL TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6392)

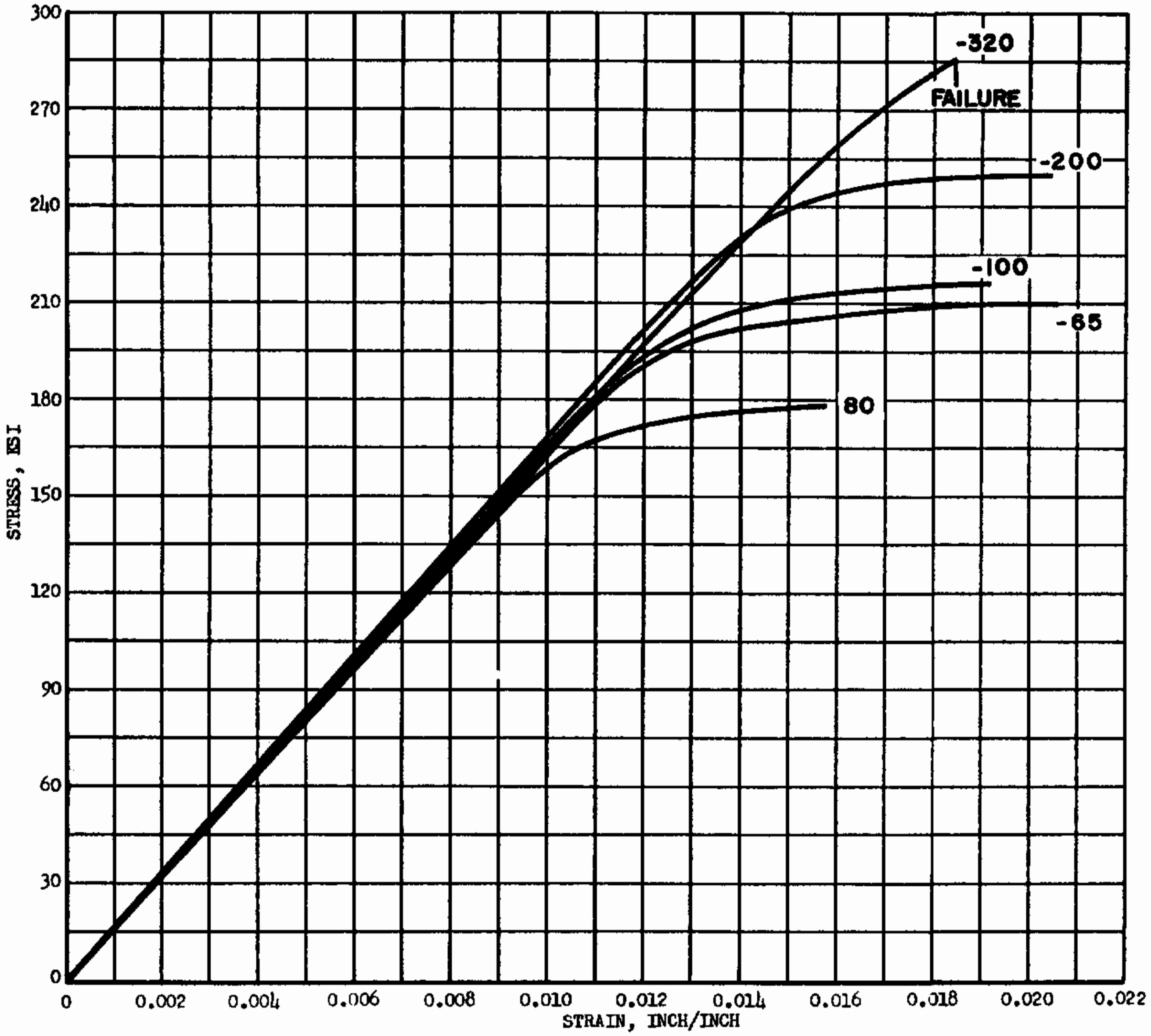
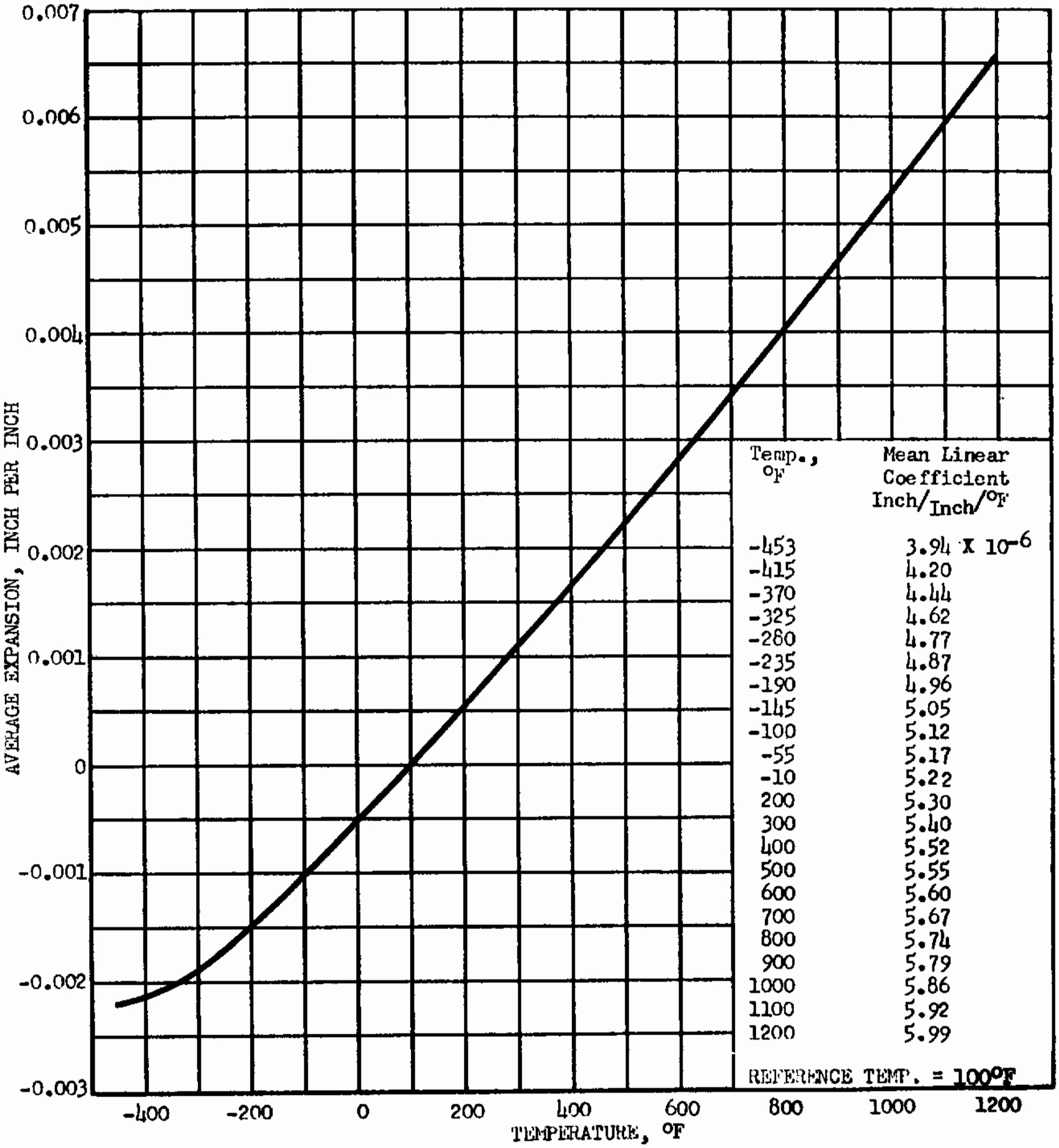


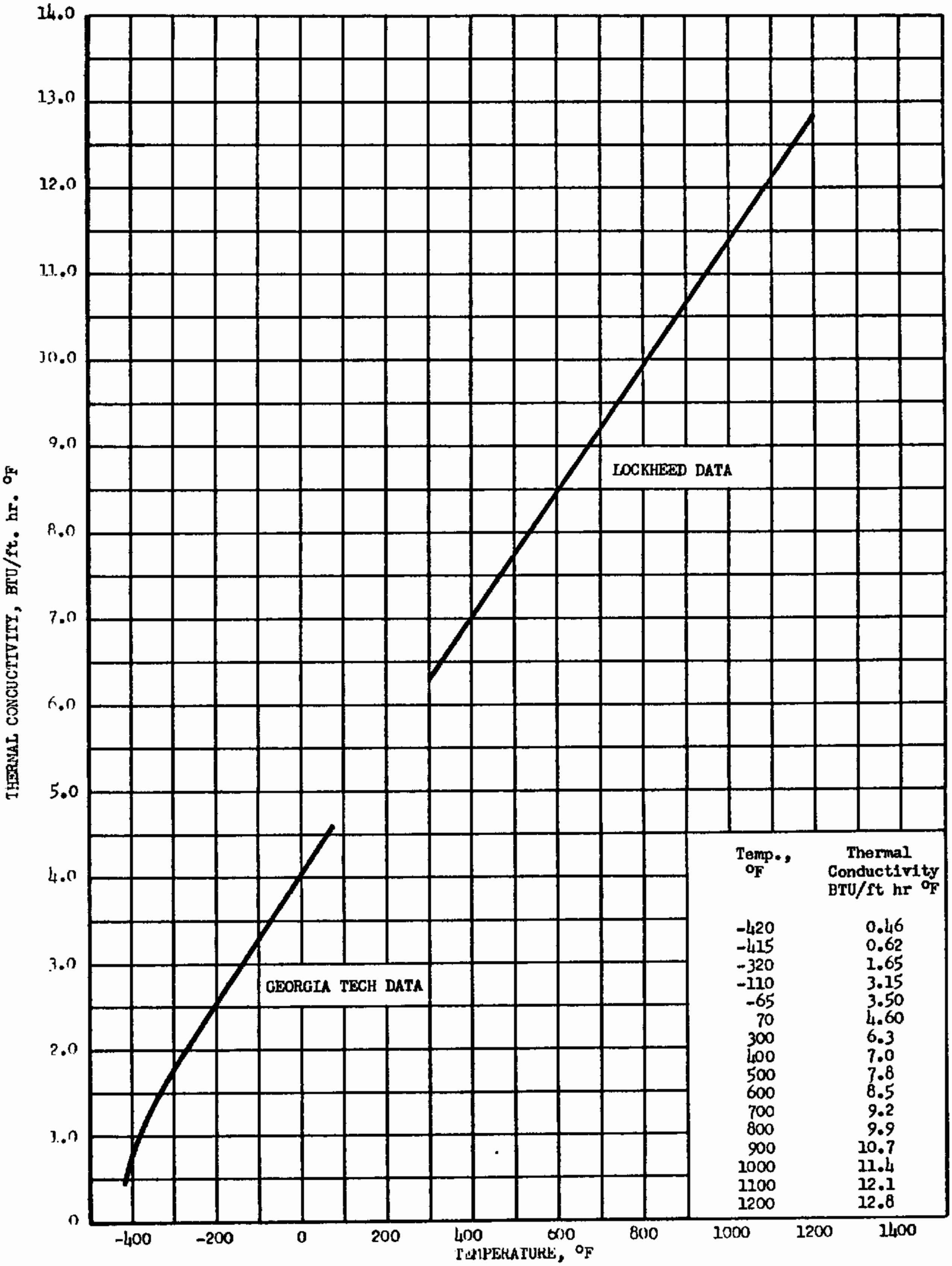
FIGURE 147 - TYPICAL TRANSVERSE TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R6392)



Temp., °F	Mean Linear Coefficient Inch/Inch/°F
-453	3.94×10^{-6}
-415	4.20
-370	4.44
-325	4.62
-280	4.77
-235	4.87
-190	4.96
-145	5.05
-100	5.12
-55	5.17
-10	5.22
200	5.30
300	5.40
400	5.52
500	5.55
600	5.60
700	5.67
800	5.74
900	5.79
1000	5.86
1100	5.92
1200	5.99

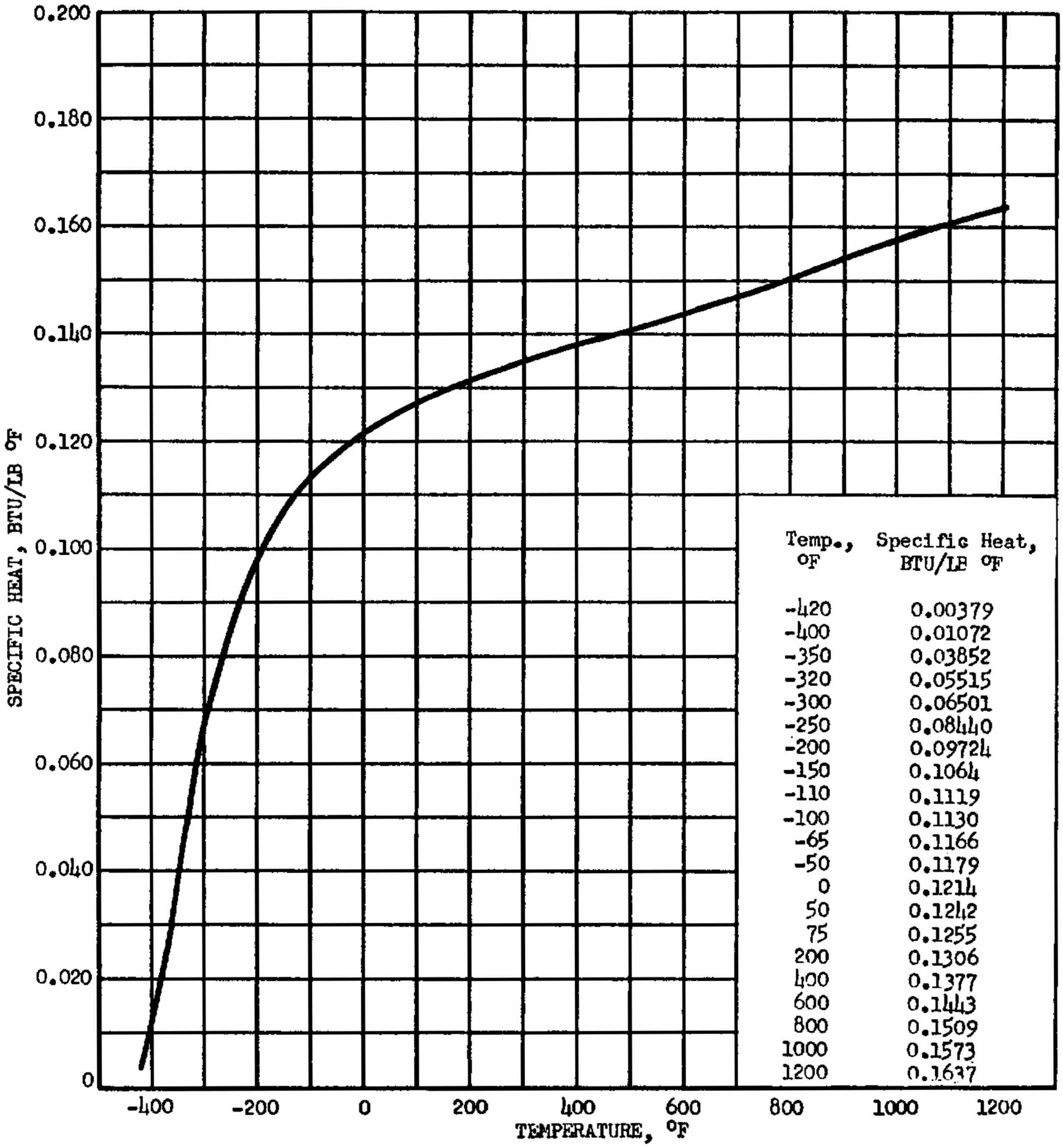
REFERENCE TEMP. = 100°F

FIGURE 148 - AVERAGE EXPANSION VERSUS TEMPERATURE FOR 0.125 INCH THICK B120VCA TITANIUM ALLOY SHEET (CRUCIBLE HEAT NO. R6759, SHEET NO. 9MB3)



Temp., °F	Thermal Conductivity BTU/ft hr °F
-420	0.46
-415	0.62
-320	1.65
-110	3.15
-65	3.50
70	4.60
300	6.3
400	7.0
500	7.8
600	8.5
700	9.2
800	9.9
900	10.7
1000	11.4
1100	12.1
1200	12.8

FIGURE 149 --THERMAL CONDUCTIVITY VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET (CRUCIBLE HEAT NO. R6759, SHEET NO. 9MB3)



Temp., °F	Specific Heat, BTU/LB °F
-420	0.00379
-400	0.01072
-350	0.03852
-320	0.05515
-300	0.06501
-250	0.08440
-200	0.09724
-150	0.1064
-110	0.1119
-100	0.1130
-65	0.1166
-50	0.1179
0	0.1214
50	0.1242
75	0.1255
200	0.1306
400	0.1377
600	0.1443
800	0.1509
1000	0.1573
1200	0.1637

FIGURE 150 - SPECIFIC HEAT VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED B120VCA TITANIUM ALLOY SHEET (CRUCIBLE HEAT NO. R6759, SHEET NO. 9MB3)

V – RESULTS FOR 6Al–4V TITANIUM ALLOY

Tensile Test Results - Ti-6Al-4V

Longitudinal and transverse tensile data for Ti-6Al-4V are summarized in Figures 151 through 157 by curves which show average variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature. These curves represent approximately 400 tests from eight heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch for the 80°F to 1000°F temperature range. Tabulations of the summarized data and percent elongation in 1/8 and 1/4 inch are in Tables LXI through LXVII, pages 67 through 73 of Volume 3.

A complete room-temperature stress-strain curve is shown in Figure 158 and typical families of longitudinal and transverse stress-strain curves and stress versus tangent modulus curves for each thickness are in Volume 1. Volume 1 also contains statistically determined "B" design values for each thickness at room temperature as well as design curves for elevated temperature.

Figures 159 through 162 show the variation of Poisson's ratio with tensile strain for longitudinal and transverse grain directions for one heat of 0.063 inch thick sheet. Additional elastic values of Poisson's ratio for several heats are in Table XLVI.

Tables XLVII through LIII contain results for longitudinal and transverse tensile specimens from eight heats and three thicknesses after being temperature exposed and temperature-stress exposed. Exposure temperatures of 600°F and 900°F for 500 hours and ten hours, respectively, and exposure stresses equal to 1/3 the tensile ultimate at the exposure temperatures are represented. These data are summarized in a manner more usable for design purposes in Volume 1.

Compressive Test Results - Ti-6Al-4V

Average compressive yield stress and elastic modulus versus temperature, summarizing data for seven heats and thicknesses of 0.063 inch and 0.125 inch, are in Figures 163 through 168. These curves represent approximately 350 tests for the 80°F to 1000°F temperature range. The summarized data along with the Ramberg-Osgood shape factor and secant stresses at 0.85 E and 0.70 E are in Tables LXVIII through LXXIII, pages 74 through 79 of Volume 3.

Families of typical longitudinal and transverse compressive stress-strain curves, stress versus tangent modulus curves and stress versus secant modulus curves for the two thicknesses are in Volume 1. Statistically determined "B" design values at room temperature, as well as design curves for elevated temperature, are also in Volume 1.

Bearing Test Results - Ti-6Al-4V

Data for approximately 950 bearing tests for e/D ratios of 1.5 and 2.0 and bearing hole diameters of 1/8 inch, 3/16 inch and 5/16 inch are summarized in Figures 169 through 186. These curves show longitudinal and transverse bearing ultimate and yield stresses versus temperature for the 80°F to 1000°F range, and represent eight heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch. Data tabulations are in Tables LXXIV through XCI, pages 80 through 97, Volume 3.

Design curves for elevated temperature and statistically determined "B" design values at room temperature for both e/D ratios with a 5/16 inch bearing hole diameter are in Volume 1.

Single Shear Test Results - Ti-6Al-4V

Longitudinal and transverse single shear data are summarized by Figures 187 through 193 which show ultimate shear strength variation with temperature for the 80°F to 1000°F range. Approximately 400 tests representing eight heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch are summarized by these plots. Tabulations of the data are in Tables XCII through XCIV, pages 98 through 100 of Volume 3.

Statistically determined "B" design values for room temperature and design curves for elevated temperatures for each thickness are in Volume 1.

Double Shear Test Results - Ti-6Al-4V

Curves showing variation of longitudinal and transverse double shear strength with temperature for four heats of 0.125 inch thick sheet are in Figures 194, 195 and 196. These data, representing approximately 175 tests for the 80°F to 1000°F temperature range, are in Table XCV, page 101, Volume 3.

Crippling Test Results - Ti-6Al-4V

Longitudinal and transverse crippling data obtained for two specimen sizes over the 80°F to 1000°F temperature range are in Tables LIV through LVII. The data are for specimens formed, primarily, from one heat of 0.063 inch thick solution treated Ti-6Al-4V which was aged subsequent to forming. Compressive properties, including Ramberg-Osgood parameters, for specimens from the same solution treated sheets as the crippling specimens and aged at the same time are in Table LVIII.

Fastener Joint Test Results - Ti-6Al-4V

Figures 197 through 200 summarize longitudinal and transverse single fastener lap joint data obtained for one heat of 0.063 inch thick sheet over the -320°F to 80°F temperature range. Screw type and lockbolt type Ti-6Al-4V fasteners of 3/16 inch and 5/16 inch nominal diameters are represented by these data. The data are for specimens having an e/D ratio of two and a W/D ratio of five. Tabular data are in Tables CXXIII through CXXVI, pages 129 through 132, Volume 3.

Tensile data obtained for the same heat and temperature range are summarized under Low-Temperature Tensile Test Results.

Weld Joint Test Results - Ti-6Al-4V

Data obtained for longitudinal and transverse specimens from a 0.063 inch thick sheet which was fusion welded in the solution treated and aged condition are summarized in Figure 201. A similar plot is shown in Figure 202 for tests from a sheet of a different heat, welded in the solution treated condition and subsequently aged. These curves show variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature for the -320°F to 80°F range. Tabulations of these test values along with joint efficiencies and percent elongation in 1/8 inch and 1/4 inch are in Tables CXXVII and CXXVIII, pages 133 and 134, Volume 3.

Tensile data obtained for the same heats and temperature range and used as a basis for computing joint efficiency are summarized under Low-Temperature Tensile Test Results.

Low-Temperature Tensile Test Results - Ti-6Al-4V

Summary plots for longitudinal and transverse tensile data showing average variations of ultimate tensile strength, tensile yield strength, elastic modulus and percent elongation in two inches with temperature for the -320°F to 80°F range are presented in Figures 203 and 204. Two heats of 0.063 inch thick sheet are included in these plots and are the same as those used for fastener and weld joints. Typical families of longitudinal and transverse stress-strain curves are shown in Figures 205 and 206 for the heat which was aged by the producer. Tabulations of the data obtained are in Tables CXXIX and CXXX, pages 135 and 136 of Volume 3.

Thermal Expansion Measurement Results - Ti-6Al-4V

Figure 207 summarizes thermal expansion data obtained for longitudinal specimens from one 0.125 inch thick sheet. Mean linear thermal expansion coefficients for several temperatures in the -453°F to 1200°F range are also in this figure. These data represent measurements made for six specimens, three each for the low and elevated temperature ranges. As shown by the figure, the expansion curve was irreversible at elevated temperature indicating a phase change had occurred. Measurement results for each specimen are in Tables CXXXI and CXXXII, pages 137 and 138 of Volume 3. The curve in Figure 207 was obtained from these measurements by adjusting the low-temperature data to a reference of 100°F.

Thermal Conductivity Measurement Results - Ti-6Al-4V

Figure 208 summarizes thermal conductivity data obtained for specimens from one 0.125 inch thick sheet. Tabulated conductivity values at several temperatures for the -420°F to 1200°F range are also included in the figure. The elevated-temperature curve represents the average of measurements made by Lockheed for three specimens. Results of the individual measurements are in Table CXXXIII, page 139, Volume 3.

Measurements for the low-temperature curve were made by Georgia Tech, and the method employed measured the combined conductivity of three specimens. Additional data are in Georgia Tech's report, Reference 13.

Specific Heat Measurement Results - Ti-6Al-4V

Measurements of specific heat made by Georgia Tech for one 0.125 inch thick sheet are summarized in Figure 209. Also in this figure are values of specific heat at several temperatures in the −420°F to 1200°F range. These data give typical values for the sheet since a specimen for measurement consisted of several samples from different locations within the sheet. Additional data are in Georgia Tech's report, Reference 27.

TABLE XLVI

ELASTIC POISSON'S RATIO DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK

Grain Direction	Tensile Specimen Number	Test Temp., °F	Poisson's Ratio
Longitudinal	B5LA1-2	80	.300
	B5LA1-3	80	.311
	B5LA1-10	80	.338
	B8LA1-30 *	80	.323
	B5LA1P-1 *	80	.329
	B5LA1P-2 *	80	.322
	B2LA2-6	200	.319
	B2LA2-15	200	.306
	B5LA2P-1 *	200	.295
	B2LA3-8	400	.337
	B2LA3-13	400	.305
	B2LA3-21	400	.302
	B5LA3P-6 *	400	.302
	B5LA4P-2 *	600	.329
	B5LA6P-3 *	800	.326
	B2LA7-11	900	.334
	B5LA7P-4 *	900	.339
	B2LA8-14	1000	.330
	B5LA8P-5 *	1000	.333
Transverse	B2TA1-1	80	.314
	B2TA1-3	80	.328
	B2TA1-6	80	.320
	B5TA1-1	80	.326
	B5TA1-2	80	.311
	B5TA1-4	80	.315
	B7TA1P-1 *	80	.322
	B5TA1P-2 *	80	.322
	B8TA2-1	200	.349
	B8TA2-9	200	.332
	B5TA2P-1 *	200	.331
	B2TA3-1	400	.368
	B8TA3-8	400	.287
	B8TA3-16	400	.324
	B8TA3-18	400	.293
	B5TA3P-6 *	400	.319
	B5TA4P-2 *	600	.383
	B5TA6P-3 *	800	.317
	B5TA7P-4 *	900	.326
	B8TA8-7	1000	.347
	B5TA8P-5 *	1000	.380

* Curves are plotted for indicated specimens

TABLE XLVII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.—** REACTIVE METALS 24791 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	B1LA1B-1	183,000	169,000	16.6	5.0	14	24
					-2	183,000	169,000	16.3	4.5	12	12
					-3	183,000	168,000	16.1	3.5	12	20
					Average	183,000	169,000	16.3	4.3	13	20
				T	B1TA1B-1	186,000	172,000	17.9	5.0	16	28
					-2	187,000	172,000	18.0	5.5	10	16
					-3	184,000	172,000	17.3	1.5	8	12
					Average	186,000	172,000	17.7	4.0	11	19
			600	L	B1LA4B-1	137,000	114,000	14.3	3.0	10	16
					-2	140,000	116,000	14.7	3.0	12	16
					-3	138,000	111,000	15.6	3.5	10	16
					Average	138,000	114,000	14.9	3.2	11	16
				T	B1TA4B-1	141,000	120,000	14.0	3.0	8	16
					-2	138,000	116,000	14.6	3.0	8	16
					-3	154,000	115,000	13.7	3.5	14	20
					Average	144,000	117,000	14.1	3.2	10	17
		45,300	80	L	B1LA1A-1	186,000	173,000	15.6	10.1	24	-
					-2	185,000	172,000	16.1	5.0	20	-
					-3	183,000	171,000	15.6	5.0	20	24
					Average	185,000	172,000	15.8	6.7	21	
		46,600		T	B1TA1A-1	189,000	179,000	17.1	4.5	-	-
					-2	190,000	182,000	16.8	4.0	18	-
					-3	187,000	178,000	17.2	5.0	22	-
					Average	189,000	180,000	17.0	4.5	20	
		45,300	600	L	B1LA4A-1	137,000	101,000	14.2	3.0	8	12
					-2	132,000	108,000	12.5	3.0	10	16
					-3	135,000	109,000	14.3	3.5	10	16
					Average	135,000	106,000	13.7	3.2	9	15
		46,600		T	B1TA4A-1	142,000	120,000	14.0	4.2	10	-
					-2	138,000	113,000	14.2	3.2	10	16
					-3	138,000	-	-	3.5	12	20(1)
					Average	139,000	116,000	14.1	4.0	11	18
900	10	ZERO	80	L	B1LA1C-1	185,000	171,000	15.6	5.0	20	36
					-2	188,000	173,000	16.0	5.0	16	28
					-3	183,000	169,000	16.1	3.0	10	20
					Average	185,000	171,000	15.9	4.3	15	28
				T	B1TA1C-1	188,000	176,000	17.2	4.0	16	24
					-2	188,000	175,000	16.9	5.0	18	28
					-3	184,000	172,000	17.0	3.5	14	28
					Average	187,000	174,000	17.0	4.2	16	27
			900	L	B1LA7C-1	121,000	89,500	11.4	5.0	18	28
					-2	118,000	85,000	10.7	7.5	18	28
					-3	122,000	92,800	9.75	5.0	18	32
					Average	120,000	89,100	10.6	5.8	18	29
				T	B1TA7C-1	125,000	94,500	11.5	5.0	16	28
					-2	123,000	95,000	11.1	5.0	14	24
					-3	120,000	88,900	9.33	5.0	16	28
					Average	123,000	92,800	10.6	5.0	15	27
		37,700	80	L	B1LA1D-1	184,000	170,000	16.4	6.5	20	28
					-2	184,000	170,000	15.9	5.5	16	24
					-3	181,000	167,000	16.3	5.5	20	28
					Average	183,000	169,000	16.2	5.8	19	27
		39,700		T	B1TA1D-1	183,000	170,000	17.5	4.5	18	28
					-2	183,000	171,000	17.7	4.5	18	28
					-3	181,000	171,000	16.7	4.0	16	28
					Average	182,000	171,000	17.3	4.3	17	28
		37,700	900	L	B1LA7D-1	121,000	91,300	11.0	9.0	28	32
					-2	116,000	86,200	11.7	8.0	16	-
					-3	115,000	83,900	10.9	4.5	14	20
					Average	117,000	87,100	11.2	7.2	19	26
		39,700		T	B1TA7D-1	123,000	91,700	13.3	6.5	16	20
					-2	122,000	95,200	10.4	5.5	14	24
					-3	121,000	93,300	9.45	6.0	12	12
					Average	122,000	93,400	11.1	6.0	14	19

(1) Unusable load-deformation curve.

TABLE XLVIII- EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.**— REACTIVE METALS 27039 **SHEET THICKNESS**— 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^6, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	B2LA1B-1	179,000	159,000	14.6	4.5	16	28
					-2	178,000	157,000	15.2	4.0	14	-
					-3	168,000	149,000	15.0	5.0	20	-
					Average	175,000	155,000	14.9	4.5	17	
				T	B2TA1B-1	185,000	175,000	18.5	3.0	-	-
					-2	185,000	174,000	18.7	3.0	16	20
					-3	176,000	160,000	16.8	8.0	32	44
					Average	182,000	170,000	18.0	6.3	24	32
			600	L	B2LA4B-1	137,000	109,000	14.3	3.0	12	28
					-2	125,000	102,000	13.1	4.5	16	28
					-3	129,000	102,000	13.8	5.5	16	28
					Average	130,000	104,000	13.7	4.3	15	28
				T	B2TA4B-1	147,000	126,000	16.3	6.0	20	36
					-2	156,000	131,000	16.1	5.0	20	28
					-3	153,000	130,000	16.2	4.0	12	24
					Average	152,000	129,000	16.2	5.0	17	29
		43,000	80	L	B2LA1A-1	167,000	148,000	15.1	6.0	16	28
					-2	166,000	154,000	14.6	5.0	16	28
					-3	176,000	150,000	15.4	3.5	14	-
					Average	170,000	151,000	15.0	4.8	15	28
		52,300		T	B2TA1A-1	189,000	175,000	18.3	5.5	18	32
					-2	188,000	176,000	17.8	6.0	20	32
					-3	188,000	171,000	17.3	5.5	20	32
					Average	188,000	174,000	17.8	5.7	19	32
		43,000	600	L	B2LA4A-1	133,000	97,100	12.6	3.5	16	20
					-2	133,000	110,000	12.7	4.0	26	-
					-3	122,000	108,000	13.0	-	-	-
					Average	129,000	105,000	12.8	3.8	21	
		52,300		T	B2TA4A-1	151,000	130,000	16.4	5.0	24	40
					-2	153,000	120,000	16.9	3.5	22	36
					-3	154,000	126,000	14.6	4.5	20	36
					Average	153,000	125,000	16.0	4.3	22	37
900	10	ZERO	80	L	B2LA1C-1	174,000	162,000	16.1	3.5	14	24
					-2	174,000	162,000	16.0	3.0	12	20
					-3	178,000	164,000	16.0	4.5	16	20
					Average	175,000	163,000	16.0	3.7	14	21
				T	B2TA1C-1	186,000	175,000	18.5	5.0	12	16
					-2	187,000	176,000	18.9	5.0	14	20
					-3	195,000	186,000	17.1	5.5	22	28
					Average	189,000	179,000	18.2	5.2	16	21
			900	L	B2LA7C-1	112,000	80,600	10.2	9.0	20	32
					-2	113,000	78,800	9.76	9.0	28	44
					-3	112,000	79,900	9.45	9.0	36	52
					Average	112,000	79,800	9.80	9.0	28	43
				T	B2TA7C-1	133,000	109,000	13.8	6.5	24	44
					-2	137,000	112,000	11.8	4.5	-	-
					-3	136,000	112,000	12.3	-	-	-
					Average	135,000	111,000	12.6	5.0		
		38,300	80	L	B2LA1D-1	174,000	160,000	16.0	4.0	14	24
					-2	174,000	157,000	15.9	3.5	16	20
					-3	208,000	-	16.5	0.5	2	4(1)
					Average	185,000	158,000	16.1	2.7	11	16
		44,000		T	B2TA1D-1	192,000	182,000	17.4	7.0	20	28
					-2	192,000	182,000	17.2	6.0	10	24
					-3	193,000	184,000	17.4	6.0	20	28
					Average	192,000	183,000	17.3	6.3	17	27
		38,300	900	L	B2LA7D-1	113,000	89,200	10.1	9.0	30	52
					-2	111,000	84,600	10.3	8.0	28	48
					-3	112,000	87,700	10.0	7.5	22	40
					Average	112,000	87,200	10.1	8.2	27	47
		44,000		T	B2TA7D-1	134,000	103,000	12.0	8.0	24	48
					-2	139,000	112,000	12.8	7.0	24	52
					-3	139,000	107,000	13.1	8.0	24	60
					Average	137,000	107,000	12.6	7.7	24	53

(1) Specimen failed prior to attaining yield deformation.

TABLE XLIX - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.**— REACTIVE METALS 22207 **SHEET THICKNESS**— 0.125 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	B3LA1B-1	178,000	162,000	16.2	6.5	32	-
					-2	172,000	-	-	-	-	-(1)
					-3	176,000	162,000	15.8	4.5	16	20
					Average	175,000	162,000	16.0	5.0	24	
				T	B3TA1B-1	190,000	180,000	18.1	7.0	32	48
					-2	191,000	181,000	16.4	4.5	24	40
					-3	194,000	181,000	17.2	7.5	32	52
					Average	192,000	181,000	17.2	6.3	29	47
			600	L	B3LA4B-1	126,000	111,000	14.6	6.0	28	72
					-2	129,000	113,000	13.2	3.5	22	40
					-3	129,000	115,000	13.8	4.5	30	48
					Average	128,000	113,000	13.9	4.7	27	53
				T	B3TA4B-1	151,000	132,000	15.0	6.5	32	64
					-2	153,000	137,000	15.2	5.5	34	56
					-3	156,000	138,000	15.4	6.0	34	64
					Average	153,000	136,000	15.2	6.0	33	61
		43,900	80	L	B3LA1A-1	182,000	171,000	16.1	6.0	32	52
					-2	181,000	170,000	16.5	4.5	26	40
					-3	173,000	161,000	16.3	5.5	26	44
					Average	179,000	167,000	16.3	5.3	28	45
		50,230		T	B3TA1A-1	196,000	184,000	17.3	5.0	16	28
					-2	196,000	184,000	17.2	6.0	16	36
					-3	193,000	184,000	17.1	5.5	30	48
					Average	195,000	184,000	17.2	5.5	21	37
		43,900	600	L	B3LA4A-1	136,000	116,000	13.2	6.4	34	64
					-2	126,000	108,000	13.9	-	-	-
					-3	125,000	106,000	12.9	7.0	40	56
					Average	129,000	110,000	13.3	6.7	37	60
		50,230		T	B3TA4A-1	151,000	136,000	15.7	6.5	40	72
					-2	156,000	138,000	15.2	6.3	36	56
					-3	154,000	137,000	14.4	6.5	38	68
					Average	154,000	137,000	15.1	6.4	38	65
900	10	ZERO	80	L	B3LA1C-1	171,000	158,000	15.8	6.0	28	40
					-2	182,000	171,000	16.3	5.0	20	28
					-3	170,000	159,000	15.8	3.0	16	20
					Average	174,000	163,000	16.0	4.7	21	29
				T	B3TA1C-1	191,000	181,000	16.6	3.5	16	24
					-2	191,000	179,000	17.7	5.0	24	28
					-3	191,000	181,000	17.0	5.0	20	24
					Average	191,000	180,000	17.1	4.5	20	25
			900	L	B3LA7C-1	120,000	85,400	12.5	9.0	40	60
					-2	109,000	83,200	10.7	7.5	32	76
					-3	114,000	88,200	11.4	5.5	34	60
					Average	114,000	85,600	11.5	7.3	35	65
				T	B3TA7C-1	133,000	96,300	12.8	9.0	32	64
					-2	136,000	101,000	13.4	7.0	32	52
					-3	135,000	103,000	13.1	8.0	40	68
					Average	135,000	99,100	13.1	8.0	35	61
		39,700	80	L	B3LA1D-1	175,000	161,000	16.2	6.5	28	44
					-2	173,000	159,000	15.8	6.5	32	40
					-3	170,000	155,000	15.4	4.5	22	32
					Average	173,000	158,000	15.8	5.8	27	39
		43,700		T	B3TA1D-1	190,000	178,000	16.4	7.0	20	24
					-2	190,000	179,000	16.7	7.0	24	36
					-3	190,000	178,000	16.9	5.5	16	24
					Average	190,000	178,000	16.7	6.5	20	28
		39,700	900	L	B3LA7D-1	117,000	88,700	10.5	14.0	40	72
					-2	112,000	86,400	11.2	5.5	38	52
					-3	112,000	82,900	10.2	5.0	40	60
					Average	114,000	86,000	10.6	8.2	39	61
		43,700		T	B3TA7D-1	130,000	96,500	12.6	9.5	38	72
					-2	132,000	100,000	10.7	9.0	34	52
					-3	134,000	97,400	12.6	11.0	40	88
					Average	132,000	98,000	12.0	9.8	37	71

(1) Unusable load-deformation curve.

TABLE L - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.—** REACTIVE METALS 25671 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $X10^{6}$, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	B5LA1B-1	175,000	154,000	16.1	4.0	18	40
					-2	176,000	154,000	16.2	4.5	20	32
					-3	171,000	151,000	16.2	5.0	24	32
					Average	174,000	153,000	16.1	4.5	21	35
				T	B5TA1B-1	185,000	171,000	16.8	6.0	20	28
					-2	187,000	173,000	17.4	6.3	20	28
					-3	181,000	159,000	16.7	4.5	16	-
					Average	184,000	168,000	17.0	5.6	19	28
			600	L	B5LA4B-1	132,000	105,000	14.0	4.5	26	-
					-2	130,000	106,000	14.7	6.0	30	-
					-3	130,000	108,000	14.1	5.0	26	44
					Average	131,000	106,000	14.3	5.2	27	
				T	B5TA4B-1	141,000	121,000	15.0	5.8	-	-
					-2	136,000	112,000	15.1	5.8	-	-
					-3	137,000	115,000	14.3	5.3	-	-
					Average	138,000	116,000	14.8	5.6		
		43,500	80	L	B5LA1A-1	174,000	152,000	16.5	5.0	24	40
					-2	174,000	155,000	16.2	6.0	28	44
					-3	170,000	153,000	16.3	6.0	28	52
					Average	173,000	153,000	16.3	5.7	27	45
		47,000		T	B5TA1A-1	180,000	160,000	17.1	5.0	24	28
					-2	181,000	160,000	16.9	6.0	24	-
					-3	185,000	167,000	16.9	6.0	28	52
					Average	182,000	162,000	17.0	5.7	25	40
		43,500	600	L	B5LA4A-1	132,000	100,000	14.1	5.0	24	44
					-2	134,000	105,000	13.5	5.0	20	36
					-3	132,000	105,000	14.0	4.5	22	-
					Average	133,000	103,000	13.9	4.8	22	40
		47,000		T	B5LA4A-1	137,000	113,000	13.8	5.5	28	52
					-2	143,000	112,000	14.9	5.0	24	44
					-3	141,000	115,000	13.8	5.5	-	-
					Average	140,000	113,000	14.2	5.3	26	48
900	10	ZERO	80	L	B5LA1C-1	171,000	157,000	16.0	4.5	22	28
					-2	170,000	158,000	15.6	4.5	22	28
					-3	175,000	157,000	16.1	4.0	12	20
					Average	172,000	157,000	15.9	4.3	19	25
				T	B5TA1C-1	184,000	173,000	16.8	4.5	20	24
					-2	182,000	173,000	16.8	3.0	20	24
					-3	174,000	158,000	16.1	3.5	20	24
					Average	180,000	168,000	16.6	3.7	20	24
			900	L	B5LA7C-1	114,000	93,100	11.2	-	-	-(1
					-2	115,000	104,000	12.1	6.0	28	52
					-3	116,000	98,000	9.88	5.5	24	44
					Average	115,000	98,400	11.1	5.8	26	48
				T	B5TA7C-1	127,000	104,000	11.6	7.0	28	-
					-2	120,000	96,400	12.1	6.0	28	48
					-3	120,000	101,000	10.9	7.5	32	44
					Average	122,000	100,000	11.5	6.8	29	46
		39,300	80	L	B5LA1D-1	168,000	157,000	16.3	5.0	12	-
					-2	169,000	155,000	15.8	4.5	24	40
					-3	168,000	156,000	15.6	3.5	22	28
					Average	168,000	156,000	15.9	4.3	19	34
		41,000		T	B5TA1D-1	178,000	163,000	17.0	8.5	28	48
					-2	177,000	162,000	17.5	8.0	30	44
					-3	171,000	161,000	16.5	4.5	14	16
					Average	175,000	162,000	17.0	7.0	24	36
		39,300	900	L	B5LA7D-1	110,000	82,700	10.5	8.0	28	52
					-2	118,000	96,900	11.0	6.0	28	52
					-3	116,000	91,000	10.6	9.5	44	52
					Average	115,000	90,200	10.7	7.8	33	52
		41,000		T	B5TA7D-1	121,000	91,400	12.7	10.0	40	68
					-2	124,000	98,200	10.8	8.5	36	52
					-3	123,000	97,600	10.5	10.0	44	64
					Average	123,000	95,700	11.3	9.5	40	61

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(1) Failed at knife edge.

TABLE LI - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.—** REACTIVE METALS 32163 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS TEMP., °F	EXPOSURE CONDITIONS TIME, HRS.	EXPOSURE CONDITIONS STRESS, PSI	TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	ELONGATION, % in .25 IN.	ELONGATION, % in .125 IN.
600	500	ZERO	80	L	B6LA1B-1	178,000	165,000	16.7	6.0	32	44
					-2	176,000	165,000	16.7	9.0	36	52
					-3	171,000	157,000	16.4	8.0	32	52
					Average	175,000	162,000	16.6	7.7	33	49
				T	B6TA1B-1	173,000	161,000	16.9	7.0	34	-
					-2	175,000	164,000	16.8	6.0	24	32
					-3	171,000	159,000	16.8	6.5	36	52
					Average	173,000	161,000	16.8	6.5	31	42
			600	L	B6LA4B-1	129,000	107,000	14.3	9.0	44	72
					-2	126,000	102,000	15.0	9.0	40	68
					-3	126,000	101,000	14.7	10.0	50	72
					Average	127,000	103,000	14.7	9.3	45	71
				T	B6TA4B-1	128,000	108,000	13.0	8.5	44	76
					-2	125,000	107,000	13.4	9.0	48	80
					-3	126,000	106,000	13.3	8.0	44	76
					Average	126,000	107,000	13.2	8.5	45	77
		42,900	80	L	B6LA1A-1	176,000	164,000	16.0	7.5	24	40
					-2	175,000	164,000	17.0	7.0	26	40
					-3	172,000	157,000	16.6	8.0	32	52
					Average	174,000	162,000	16.5	7.5	27	44
		42,300		T	B6TA1A-1	175,000	162,000	16.8	6.5	34	52
					-2	174,000	161,000	16.9	8.0	32	48
					-3	174,000	160,000	16.7	7.5	32	40
					Average	174,000	161,000	16.8	7.3	33	47
		42,900	600	L	B6LA4A-1	129,000	106,000	14.6	8.5	44	80
					-2	125,000	100,000	14.6	10.0	52	80
					-3	128,000	101,000	15.0	10.0	46	88
					Average	127,000	102,000	14.7	9.5	47	83
		42,300		T	B6TA4A-1	128,000	106,000	14.2	9.5	52	76
					-2	125,000	106,000	14.5	9.0	48	84
					-3	127,000	105,000	14.9	9.5	48	88
					Average	127,000	106,000	14.5	9.3	49	83
900	10	ZERO	80	L	B6LA1C-1	176,000	167,000	16.4	7.5	28	44
					-2	170,000	161,000	16.0	7.5	32	44
					-3	169,000	160,000	16.6	9.0	28	44
					Average	172,000	163,000	16.3	8.0	29	44
				T	B6TA1C-1	172,000	164,000	16.8	7.0	24	28
					-2	172,000	166,000	17.0	6.0	20	28
					-3	170,000	160,000	17.0	7.0	22	28
					Average	171,000	163,000	16.9	6.7	22	28
			900	L	B6LA7C-1	114,000	84,200	12.5	13.0	66	-
					-2	113,000	85,000	12.5	14.0	68	-
					-3	111,000	86,500	11.7	14.0	64	112
					Average	113,000	85,200	12.2	14.0	66	
				T	B6TA7C-1	113,000	88,500	13.1	14.0	54	-
					-2	110,000	84,600	13.3	12.0	54	-
					-3	112,000	84,500	12.2	11.0	52	-
					Average	112,000	85,900	12.9	12.0	53	
		36,700	80	L	B6LA1D-1	175,000	164,000	16.3	9.0	34	40
					-2	174,000	165,000	16.6	10.0	32	52
					-3	169,000	158,000	16.1	9.5	36	48
					Average	173,000	162,000	16.3	9.5	34	47
		36,700		T	B6TA1D-1	170,000	161,000	16.5	6.5	22	28
					-2	170,000	160,000	16.7	5.5	26	32
					-3	168,000	159,000	17.1	9.5	38	44
					Average	169,000	160,000	16.8	7.2	29	35
		36,700	900	L	B6LA7D-1	114,000	84,000	11.6	15.0	56	80
					-2	112,000	78,900	12.2	13.0	52	76
					-3	111,000	80,900	11.7	12.0	50	84
					Average	112,000	81,300	11.8	13.0	53	80
		36,700		T	B6TA7D-1	114,000	90,400	10.8	11.0	64	108
					-2	112,000	84,800	12.1	10.1	58	100
					-3	110,000	84,800	10.7	10.0	64	96
					Average	112,000	86,700	11.2	10.0	62	101

TABLE LII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.—** REACTIVE METALS 31372 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $X10^{-6}$ PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	B8LA1B-1	178,000	164,000	17.0	7.5	30	48
					-2	179,000	168,000	16.6	8.5	32	52
					-3	178,000	164,000	16.6	7.0	26	44
					Average	178,000	165,000	16.7	7.7	29	48
				T	B8TA1B-1	177,000	158,000	16.2	8.0	28	40
					-2	177,000	156,000	16.4	8.0	30	44
					-3	169,000	151,000	16.0	8.0	28	40
					Average	174,000	155,000	16.2	8.0	29	41
			600	L	B8LA4B-1	132,000	103,000	13.9	6.5	28	44
					-2	129,000	103,000	14.5	7.0	30	52
					-3	128,000	103,000	14.8	6.5	28	52
					Average	130,000	103,000	14.4	6.7	29	49
				T	B8TA4B-1	132,000	101,000	14.0	8.0	-	-
					-2	131,000	105,000	13.6	7.0	-	-
					-3	131,000	103,000	14.7	7.5	-	-
					Average	131,000	103,000	14.1	7.5		
		43,500	80	L	B8LA1A-1	183,000	168,000	16.8	8.0	28	40
					-2	177,000	171,000	17.5	9.0	34	60
					-3	178,000	170,000	16.8	8.5	34	48
					Average	179,000	170,000	17.0	8.5	32	49
		47,000		T	B8TA1A-1	175,000	157,000	16.1	8.0	36	52
					-2	175,000	158,000	16.2	8.0	34	36
					-3	177,000	162,000	16.6	7.5	30	44
					Average	176,000	159,000	16.3	7.8	33	44
		43,500	600	L	B8LA4A-1	127,000	100,000	11.5	8.0	30	48
					-2	125,000	99,600	13.2	6.0	28	52
					-3	125,000	98,300	14.1	7.5	26	52
					Average	126,000	99,300	12.9	7.2	28	51
		47,000		T	B8TA4A-1	126,000	98,200	13.3	6.5	32	44
					-2	125,000	97,600	14.8	7.5	30	48
					-3	125,000	100,000	12.9	8.0	28	52
					Average	125,000	98,600	13.7	7.3	30	48
900	10	ZERO	80	L	B8LA1C-1	175,000	165,000	17.0	9.0	30	52
					-2	175,000	167,000	16.8	-	-	-
					-3	175,000	166,000	16.5	9.0	32	56
					Average	175,000	166,000	16.8	9.0	31	54
				T	B8TA1C-1	173,000	159,000	16.8	10.0	36	40
					-2	173,000	160,000	16.6	9.0	28	-
					-3	177,000	164,000	16.8	7.5	24	28
					Average	174,000	161,000	16.7	8.8	29	34
			900	L	B8LA7C-1	106,000	81,000	11.5	12.0	36	68
					-2	109,000	90,200	11.4	11.0	44	68
					-3	106,000	79,600	12.7	14.0	40	68
					Average	107,000	83,600	11.9	12.0	40	68
				T	B8TA7C-1	109,000	86,200	11.0	8.5	36	60
					-2	109,000	86,400	10.4	10.0	24	48
					-3	106,000	82,000	10.9	12.0	36	64
					Average	108,000	84,900	10.8	10.0	32	57
		37,000	80	L	B8LA1D-1	174,000	163,000	17.0	8.5	34	-
					-2	172,000	162,000	17.2	9.0	-	-
					-3	172,000	159,000	17.2	9.0	-	-
					Average	173,000	161,000	17.1	8.8		
		36,300		T	B8TA1D-1	174,000	152,000	16.5	7.5	30	44
					-2	174,000	154,000	16.4	9.5	28	48
					-3	174,000	156,000	16.3	8.5	26	48
					Average	174,000	154,000	16.4	8.5	28	48
		37,000	900	L	B8LA7D-1	107,000	82,100	11.8	11.0	40	52
					-2	106,000	77,500	11.8	14.0	36	52
					-3	105,000	80,400	11.8	12.0	30	-
					Average	106,000	80,000	11.8	13.0	35	52
		36,300		T	B8TA7D-1	103,000	81,900	10.2	16.0	38	76
					-2	104,000	79,000	12.2	15.0	44	68
					-3	107,000	79,200	12.0	17.0	44	52
					Average	105,000	80,000	11.5	16.0	42	65

TABLE LIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-6Al-4V **HEAT NO.—** REACTIVE METALS 32167 **SHEET THICKNESS—** 0.125 in.

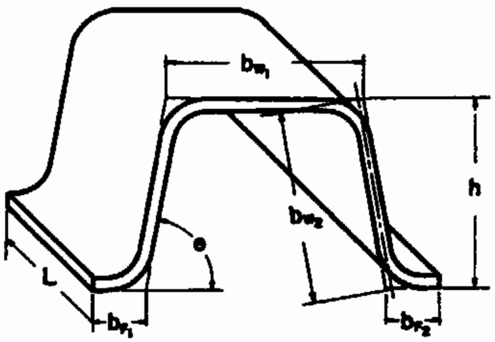
EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	B9LA1B-1	173,000	164,000	17.3	10.0	36	48
					-2	174,000	162,000	16.8	9.0	36	52
					-3	176,000	166,000	17.2	7.0	20	36
					Average	174,000	164,000	17.1	8.7	31	45
				T	B9TA1B-1	174,000	162,000	17.4	6.5	26	36
					-2	174,000	163,000	17.3	9.5	28	48
					-3	178,000	165,000	17.8	8.0	28	44
					Average	175,000	163,000	17.5	8.0	27	43
			600	L	B9LA4B-1	131,000	105,000	13.8	8.5	36	-
					-2	132,000	106,000	14.4	8.5	44	-
					-3	130,000	105,000	13.7	8.8	46	-
					Average	131,000	105,000	14.0	8.6	42	
				T	B9TA4B-1	130,000	107,000	13.9	8.0	44	72
					-2	133,000	106,000	14.3	8.0	40	68
					-3	133,000	108,000	14.6	7.0	36	60
					Average	132,000	107,000	14.3	7.7	40	67
		43,000	80	L	B9LA1A-1	173,000	160,000	16.6	7.5	32	52
					-2	171,000	163,000	16.6	8.5	28	40
					-3	176,000	164,000	17.1	9.5	36	60
					Average	173,000	162,000	16.8	8.5	32	51
		44,200		T	B9TA1A1-1	177,000	165,000	16.4	4.5	20	36
					-2	171,000	159,000	16.7	5.5	20	32
					-3	176,000	162,000	16.8	5.5	26	40
					Average	175,000	162,000	16.6	5.2	22	36
		43,000	600	L	B9LA4A-1	129,000	105,000	14.6	8.5	44	72
					-2	132,000	111,000	15.3	10.0	46	80
					-3	136,000	111,000	14.1	8.5	44	76
					Average	132,000	109,000	14.7	9.0	45	76
		44,200		T	B9TA4A-1	135,000	110,000	11.3	4.0	44	76
					-2	131,000	107,000	13.2	6.0	40	68
					-3	133,000	108,000	14.2	8.0	48	84
					Average	133,000	108,000	12.9	6.0	44	76
900	10	ZERO	80	L	B9LA1C-1	169,000	159,000	17.3	7.5	28	52
					-2	170,000	159,000	17.1	8.0	28	52
					-3	172,000	163,000	16.3	8.5	26	32
					Average	170,000	160,000	16.9	8.0	27	45
				T	B9TA1C-1	177,000	165,000	17.0	4.0	16	20
					-2	176,000	174,000	18.0	4.0	12	20
					-3	174,000	163,000	16.5	8.0	20	20
					Average	176,000	167,000	17.2	5.3	16	20
			900	L	B9LA7C-1	107,000	81,400	10.4	14.0	56	100
					-2	114,000	87,500	11.2	14.0	56	92
					-3	111,000	84,000	12.3	17.0	64	100
					Average	111,000	84,300	11.3	15.0	59	97
				T	B9TA7C-1	116,000	90,400	12.0	16.0	64	84
					-2	112,000	84,600	11.7	16.0	56	88
					-3	112,000	82,200	12.8	13.0	60	-
					Average	113,000	85,700	12.2	15.0	60	86
		36,700	80	L	B9LA1D-1	170,000	159,000	16.7	10.0	36	60
					-2	170,000	157,000	16.2	10.0	30	48
					-3	175,000	161,000	16.2	9.0	30	40
					Average	172,000	159,000	16.4	9.7	32	49
		37,700		T	B9TA1D-1	172,000	-	-	-	-	-(1)(2)
					-2	172,000	156,000	16.7	6.5	18	20
					-3	174,000	158,000	16.6	6.5	16	28
					Average	173,000	157,000	16.6	6.5	17	24
		36,700	900	L	B9LA7D-1	110,000	81,300	11.0	16.0	54	92
					-2	109,000	76,700	12.2	20.0	-	-
					-3	109,000	78,000	9.72	19.0	66	116
					Average	109,000	78,700	11.0	18.0	60	104
		37,700		T	B9TA7D-1	111,000	82,500	12.0	12.0	60	100
					-2	111,000	76,000	9.1	14.0	60	100
					-3	112,000	77,900	10.8	12.0	56	88
						111,000	78,800	10.6	13.0	59	96

(1) Failed within 1/4 inch of fillet.
(2) Unusable load-deformation curve.

TABLE LIV - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-6Al-4V
THICKNESS - 0.063 INCH
HEAT NUMBER - REACTIVE METALS 32163

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA in.^{2}		
80	B11LC1EL-1	0.42	0.42	76.0	1.19	0.96	0.93	.0634	.1975	27000	137
	-11	0.45	0.44	78.3	1.20	0.96	0.94	.0600	.1902	24300	128
	-14	0.45	0.44	79.5	1.20	0.96	0.94	.0606	.1916	27200	142
	-21	0.42	0.42	80.0	1.18	1.00	0.97	.0573	.1814	21700	120
	-25	0.42	0.41	79.0	1.22	0.97	0.95	.0610	.1950	29000	149
	-36	0.43	0.42	79.0	1.19	0.96	0.94	.0613	.1941	27100	140
	Average										136
200	B11LC2EL-12	0.43	0.43	80.0	1.20	0.98	0.97	.0606	.1928	25600	133
	-22	0.43	0.42	79.7	1.23	0.97	0.96	.0576	.1863	23800	128
	-24	0.42	0.42	80.0	1.27	0.97	0.96	.0575	.1832	24500	134
	Average										132
400	B11LC3EL-13	0.41	0.41	79.2	1.24	1.00	0.98	.0605	.1922	20000	104
	-23	0.43	0.42	78.2	1.22	0.96	0.94	.0575	.1814	21000	116
	-30	0.42	0.43	77.2	1.21	0.97	0.95	.0587	.1847	21300	115
	Average										112
600	B11LC4EL-2	0.42	0.42	81.2	1.23	1.00	0.99	.0630	.2009	21400	106
	-4	0.44	0.44	81.5	1.28	1.00	0.99	.0629	.2018	20350	101
	-17	0.42	0.43	81.8	1.25	1.00	0.99	.0645	.2062	23000	112
	Average										106
800	B11LC6EL-7	0.44	0.44	83.0	1.27	1.01	1.01	.0594	.1916	19150	99.9
	-31	0.44	0.44	81.6	1.24	0.95	0.94	.0628	.2014	21100	105
	-34	0.43	0.44	79.5	1.20	0.98	0.97	.0608	.1948	20050	103
	Average										103
900	B11LC7EL-8	0.44	0.44	82.7	1.26	0.96	0.95	.0609	.1945	17400	89.5
	-19	0.42	0.42	80.0	1.26	1.00	0.98	.0637	.2060	18750	91.0
	-35	0.42	0.42	80.0	1.22	0.99	0.98	.0618	.1942	18000	92.7
	Average										91.1
1000	B11LC8EL-9	0.42	0.42	80.0	1.28	0.97	0.96	.0617	.1959	12750	65.1
	-20	0.44	0.44	81.0	1.25	0.97	0.96	.0572	.1801	12550	69.7
	-27	0.43	0.42	82.0	1.23	1.00	0.99	.0612	.1963	13500	68.8
	Average										67.9

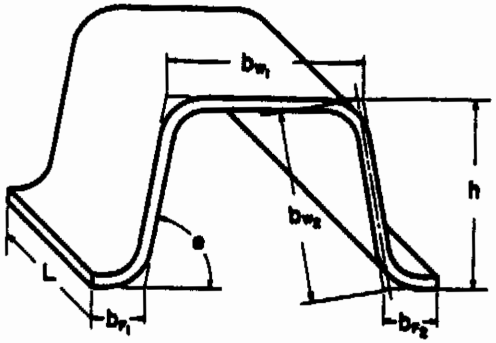


CONFIGURATION 1, LENGTH = 4.13"

TABLE LV - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-6Al-4V
THICKNESS 0.063 INCH
HEAT NUMBER - REACTIVE METALS 32163

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	B11TC1EL-1	0.42	0.42	79.2	1.20	0.96	0.95	.0591	.1878	23200	124
	-5	0.42	0.43	80.0	1.25	0.96	0.95	.0597	.1899	26250	138
	-11	0.42	0.41	82.0	1.26	0.97	0.96	.0604	.1967	28050	143
	Average										135
200	B11TC2EL-10	0.41	0.42	80.0	1.25	0.98	0.96	.0643	.2054	27600	134
	-30	0.41	0.41	79.0	1.23	0.97	0.96	.0611	.1938	24500	126
	-34	0.44	0.43	80.0	1.20	0.98	0.97	.0615	.1951	26550	136
	Average										132
400	B11TC3EL-3	0.43	0.43	81.0	1.26	0.95	0.94	.0596	.1899	22600	119
	-21	0.41	0.42	82.2	1.32	0.98	0.97	.0575	.1828	18400	101
	-23	0.43	0.43	82.0	1.30	0.97	0.96	.0678	.1849	21600	117
	Average										112
600	B11TC4EL-4	0.42	0.42	80.8	1.22	1.00	0.98	.0605	.1893	19300	102
	-24	0.41	0.41	83.0	1.26	0.97	0.96	.0580	.1840	19000	103
	-40	0.42	0.42	76.0	1.15	0.97	0.95	.0615	.1924	19400	101
	Average										102
800	B11TC6EL-6	0.42	0.43	82.4	1.29	1.00	0.99	.0644	.2051	19500	95.1
	-7	0.43	0.44	85.0	1.31	1.00	0.99	.0648	.2079	21250	102
	012	0.41	0.40	84.2	1.29	0.98	0.97	.0593	.1887	18600	98.5
	Average										98.5
900	B11TC7EL-2	0.41	0.42	77.2	1.23	0.98	0.97	.0602	.1935	16900	87.3
	-8	0.43	0.43	79.0	1.23	0.95	0.94	.0648	.2050	18000	87.8
	-18	0.41	0.42	81.5	1.24	0.97	0.96	.0650	.2070	17200	83.1
	Average										86.1
1000	B11TC8EL-9	0.42	0.43	83.5	1.26	0.99	0.98	.0642	.2049	13050	63.7
	-38	0.43	0.43	76.0	1.25	0.96	0.94	.0618	.1947	12900	66.2
	-41	0.41	0.41	76.0	1.20	0.96	0.93	.0603	.1894	13200	69.7
	Average										66.5



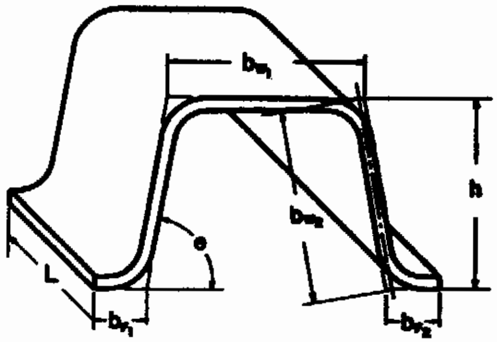
CONFIGURATION 1, LENGTH = 4.13"

TABLE LVI - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-6Al-4V
THICKNESS - 0.063 INCH
HEAT NUMBER - REACTIVE METALS 32163 & 31372

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	B11LC1FL-10	0.63	0.61	80.2	2.00	1.98	1.97	.0648	.4067	43650	107
	-11	0.62	0.60	83.5	2.18	1.96	1.96	.0611	.3810	37550	98.6
	-23	0.64	0.60	82.0	2.09	1.99	1.98	.0604	.3797	37000	97.4
	-26	0.63	0.63	79.0	2.00	1.96	1.94	.0586	.3660	33650	91.9
	B8LC1FL-3*	0.60	0.57	80.0	2.06	2.01	1.96	.0595	.3723	36550	98.2
	-14*	0.60	0.59	80.8	2.08	2.04	2.02	.0619	.3864	40450	105
	Average										99.7
200	B11LC2FL-16	0.60	0.62	82.0	2.07	1.98	1.94	.0645	.4066	37150	91.4
	-30	0.59	0.59	79.5	2.10	1.90	1.89	.0616	.3868	35800	92.6
	Average										92.0
400	B11LC3FL-13	0.63	0.62	80.0	1.98	2.00	1.98	.0651	.4076	36150	88.7
	-28	0.63	0.62	81.0	2.06	1.97	1.97	.0579	.3626	30250	83.4
	Average										86.0
600	B11LC4FL-14	0.64	0.58	80.2	2.02	1.96	1.95	.0650	.4090	32600	79.7
	-19	0.62	0.58	83.0	2.18	1.95	1.93	.0620	.3885	30400	78.2
	Average										79.0
800	B11LC6FJ-9	0.62	0.58	82.0	2.14	1.96	1.96	.0639	.4005	31750	79.3
	-25	0.64	0.56	83.5	2.14	1.98	1.98	.0583	.3599	24400	67.8
	Average										73.6
900	B11LC7FL-5	0.62	0.62	84.2	2.13	1.95	1.94	.0623	.3917	25750	65.7
	-15	0.64	0.60	81.5	2.14	1.95	1.94	.0645	.4085	27800	68.0
	Average										66.8
1000	B11LC8FL-4	0.62	0.62	82.5	2.08	1.97	1.96	.0640	.3837	21850	56.9
	-8	0.59	0.56	80.8	2.14	1.97	1.95	.0610	.4037	23500	58.2
	Average										57.6

*Heat No. 31372.



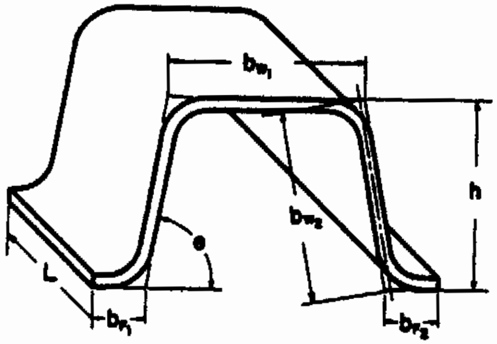
CONFIGURATION 2, LENGTH = 6.89"

TABLE LVII - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-6Al-4V
THICKNESS - 0.063 INCH
HEAT NUMBER REACTIVE METALS 32163 & 31372

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	B11TC1FL-6	0.64	0.62	81.0	2.07	1.97	1.96	.0637	.3993	42450	106
	-7	0.60	0.60	81.0	2.08	1.97	1.96	.0640	.3994	40800	102
	-16	0.62	0.63	80.8	2.07	1.98	1.96	.0634	.3975	41600	105
	-19	0.64	0.65	80.7	2.03	1.99	1.96	.0647	.4043	44650	110
	B8TC1FL-1*	0.59	0.60	77.8	2.03	2.01	1.96	.0607	.3810	38950	102
	-2*	0.60	0.63	81.5	2.02	2.01	1.99	.0635	.4049	43750	108
	-5*	0.62	0.60	81.2	2.00	2.02	2.00	.0644	.4051	44850	111
	-6*	0.60	0.60	77.2	2.10	2.01	1.94	.0599	.3775	37750	100
	-7*	0.61	0.62	79.8	1.99	2.02	2.00	.0633	.3991	43600	109
	Average										106
200	B11TC2FL-2	0.61	0.62	80.2	2.10	1.99	1.93	.0621	.3882	37100	95.6
	-12	0.61	0.62	76.2	2.07	2.00	1.98	.0635	.3964	39450	99.5
	-20	0.61	0.64	79.2	2.06	1.98	1.95	.0605	.3769	35000	92.9
	Average										96.0
400	B11TC3FL-3	0.62	0.65	83.0	2.05	2.00	1.98	.0628	.3916	34700	88.6
	-13	0.62	0.65	84.0	2.08	2.01	1.99	.0634	.3985	36850	92.5
	-21	0.61	0.62	80.8	2.07	1.98	1.96	.0598	.3766	31200	82.8
	Average										88.0
600	B11TC4FL-10	0.61	0.63	82.2	2.08	2.00	1.98	.0618	.3871	31900	82.4
	-23	0.62	0.62	83.0	2.07	1.96	1.94	.0602	.3767	29300	77.8
	-24	0.58	0.60	80.8	2.09	1.98	1.95	.0602	.3777	28850	76.4
	Average										78.9
800	B11TC6FL-15	0.62	0.64	81.0	2.05	1.98	1.97	.0634	.3972	30750	77.4
	-27	0.61	0.63	80.5	2.06	1.97	1.96	.0602	.3768	27300	72.4
	-28	0.61	0.61	80.0	2.06	1.97	1.96	.0603	.3782	26500	70.1
	Average										73.3
900	B11TC7FL-8	0.60	0.61	82.0	2.02	2.03	2.00	.0635	.3988	27400	68.7
	-11	0.62	0.62	82.0	2.08	1.97	1.96	.0628	.3922	28150	71.8
	-17	0.62	0.64	81.9	2.07	1.95	1.95	.0639	.4017	29150	72.6
	Average										71.0
1000	B11TC8FL-9	0.62	0.64	80.0	2.00	2.00	1.95	.0634	.3974	22350	56.2
	-18	0.64	0.62	83.8	2.12	1.99	1.97	.0646	.4064	24500	60.3
	-30	0.60	0.61	80.0	2.10	1.96	1.93	.0612	.3808	19200	50.4
	Average										55.6

*Heat No. 31372



CONFIGURATION 2, LENGTH = 6.89"

TABLE LVIII

LONGITUDINAL COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 32163)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
B11LB1L-5	80	189,000	15.3	189,000	203,000	13.4
-8	80	185,000	15.1	186,000	199,000	13.7
-11	80	182,000	16.5	182,000	190,000	22.4
-14	80	182,000	17.4	182,000	188,000	26.0
-17	80	181,000	16.9	180,000	188,000	22.7
-20	80	184,000	16.3	184,000	193,000	21.2
-23	80	189,000	15.6	190,000	202,000	15.5
-26	80	184,000	17.9	183,000	195,000	15.3
-29	80	191,000	17.4	191,000	200,000	20.8
-30	80	192,000	16.6	192,000	203,000	16.8
Average		186,000	16.5	186,000	196,000	18.8
B11LB2L-7	200	162,000	16.2	161,000	166,000	30.0
-22	200	158,000	16.0	157,000	-	-
Average		160,000	16.1	159,000		
B11LB3L-13	400	134,000	15.6	132,000	138,000	19.9
-24	400	138,000	15.7	136,000	143,000	19.2
-27	400	129,000	14.8	127,000	134,000	15.9
Average		134,000	15.4	132,000	138,000	18.3
B11LB4L-6	600	121,000	12.9	120,000	128,000	14.8
-15	600	118,000	14.1	116,000	123,000	16.1
-18	600	120,000	14.5	117,000	127,000	11.6
Average		120,000	13.8	118,000	126,000	14.2
B11LB6L-4	800	110,000	11.8	108,000	-	-
-10	800	107,000	13.3	104,000	113,000	11.3
-12	800	109,000	12.9	106,000	118,000	9.4
Average		109,000	12.7	106,000	116,000	10.4
B11LB7L-3	900	98,500	12.8	93,900	105,000	8.7
-16	900	93,600	12.5	88,500	98,800	9.1
-28	900	99,600	12.7	95,000	107,000	8.6
Average		97,200	12.7	92,500	104,000	8.8
B11LB8L-1	1000	69,400	8.75	65,000	75,000	7.2
-9	1000	68,400	8.58	64,700	74,100	7.5
-21	1000	73,800	10.9	67,600	77,900	7.2
Average		70,500	9.41	65,800	75,700	7.3

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

TRANSVERSE COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 32163)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
B11TB1L-2	80	184,000	17.2	184,000	195,000	16.1
-5	80	181,000	17.1	180,000	189,000	20.9
-8	80	180,000	17.0	179,000	193,000	12.8
-11	80	180,000	17.0	180,000	187,000	23.8
-14	80	181,000	17.4	180,000	189,000	20.4
-17	80	180,000	16.9	179,000	185,000	27.3
-20	80	179,000	17.2	178,000	186,000	20.9
-23	80	173,000	16.6	173,000	180,000	26.2
-26	80	178,000	16.6	178,000	186,000	22.5
-29	80	178,000	16.5	178,000	184,000	20.2
Average		179,000	17.0	179,000	187,000	21.7
B11TB2L-7	200	159,000	16.5	158,000	165,000	19.9
-19	200	157,000	16.0	156,000	162,000	24.8
-22	200	157,000	14.4	156,000	165,000	17.0
Average		158,000	15.6	157,000	164,000	20.6
B11TB3L-13	400	132,000	14.8	131,000	137,000	20.8
-24	400	129,000	15.0	127,000	133,000	19.5
-27	400	122,000	15.1	121,000	124,000	34.7
Average		128,000	15.0	126,000	131,000	25.0
B11TB4L-12	600	118,000	14.4	115,000	124,000	12.9
-15	600	119,000	14.5	116,000	125,000	13.9
-25	600	115,000	13.9	113,000	121,000	13.8
Average		117,000	14.3	115,000	123,000	13.5
B11TB6L-4	800	109,000	12.9	105,000	117,000	8.9
-10	800	106,000	13.1	102,000	114,000	9.6
-18	800	107,000	13.0	104,000	116,000	9.4
Average		107,000	13.0	104,000	116,000	9.3
B11TB7L-3	900	94,600	11.7	91,200	100,000	10.1
-16	900	90,600	12.3	84,800	96,100	8.1
-28	900	94,900	11.4	91,600	101,000	9.8
Average		93,400	11.8	89,200	99,000	9.3
B11TB8L-1	1000	62,800	11.6	52,200	64,900	5.1
-9	1000	67,600	10.5	61,500	70,800	7.3
-21	1000	74,000	10.9	69,000	77,600	8.5
Average		68,100	11.0	60,900	71,100	7.0

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

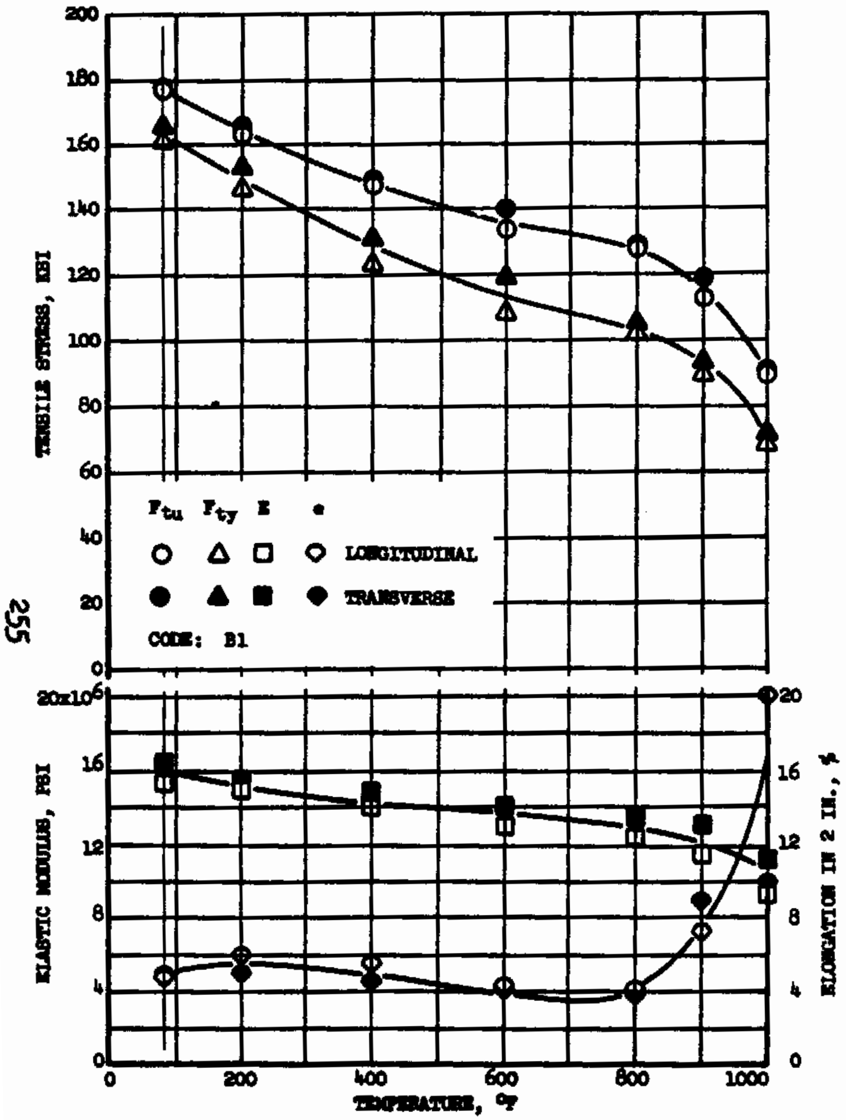


FIGURE 151 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO.24791)

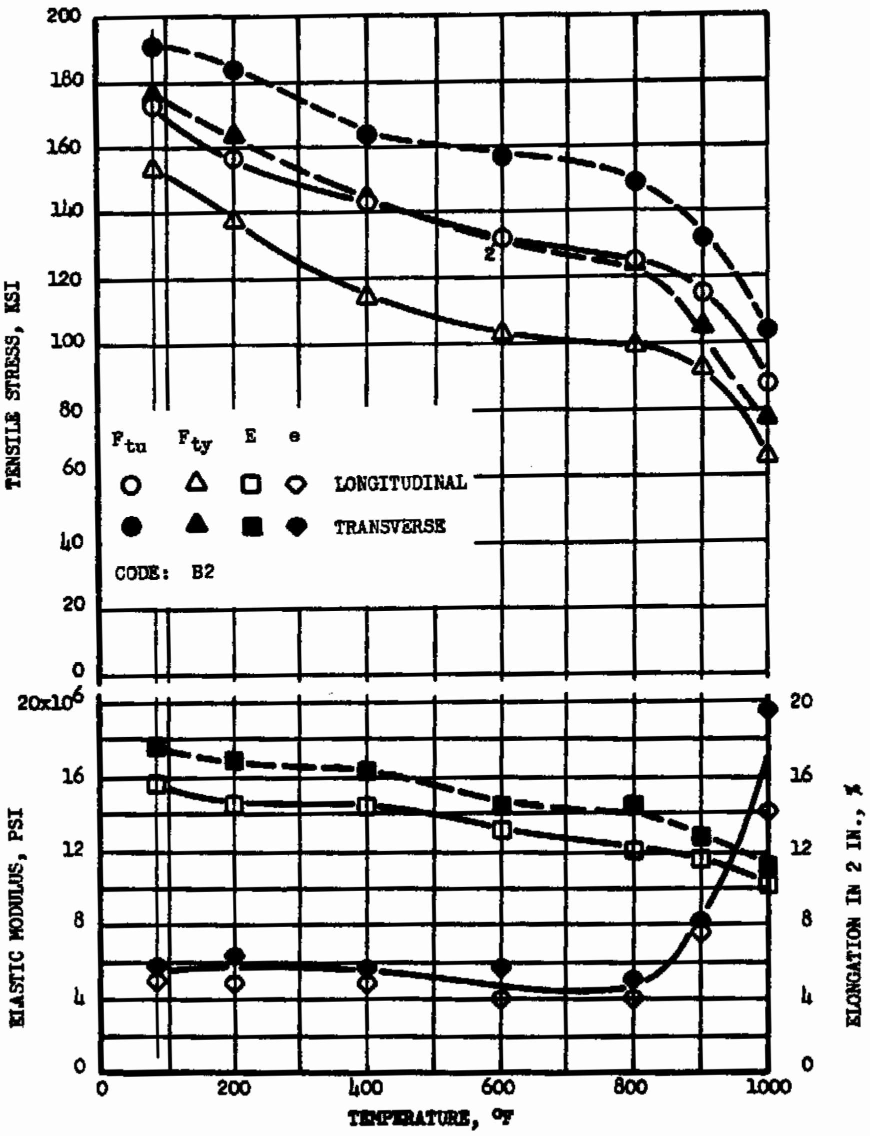


FIGURE 152 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 27039)

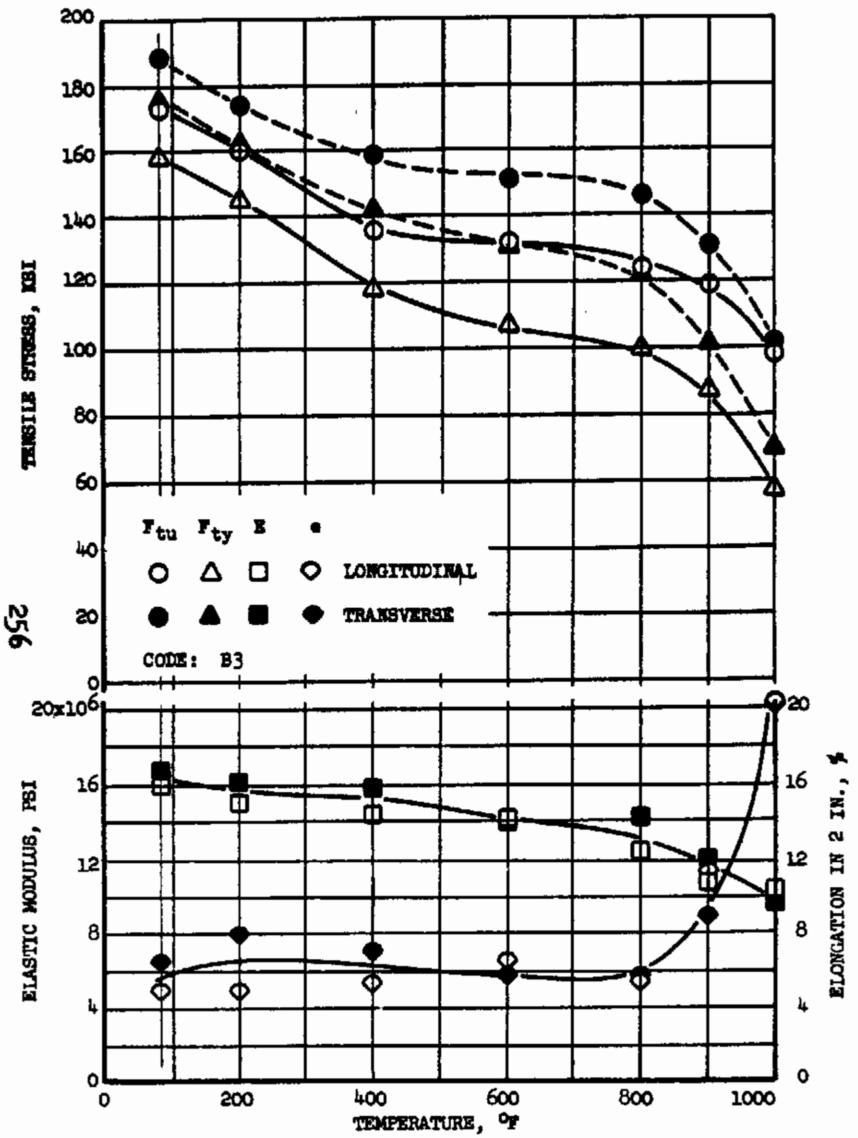


FIGURE 153 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 22207)

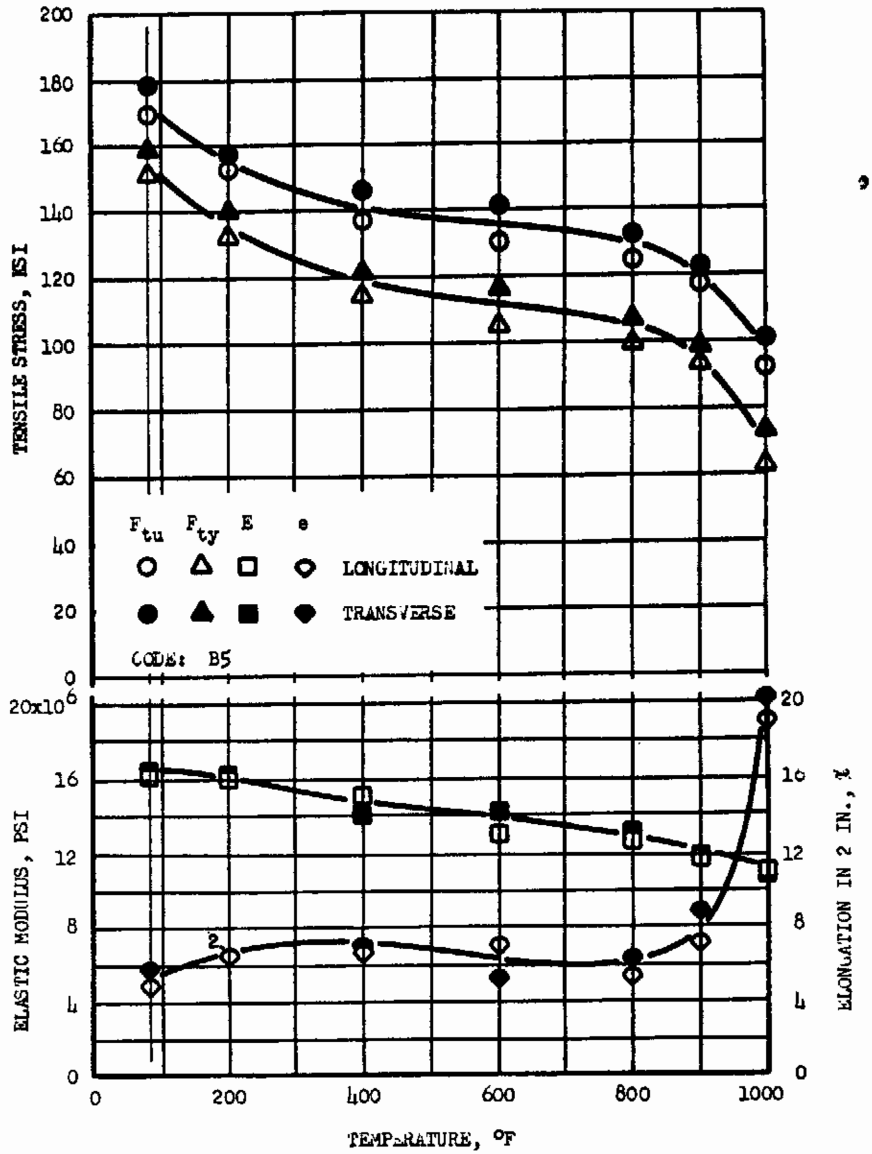


FIGURE 154 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (MALLORY-SHARON HEAT NO. 25671)

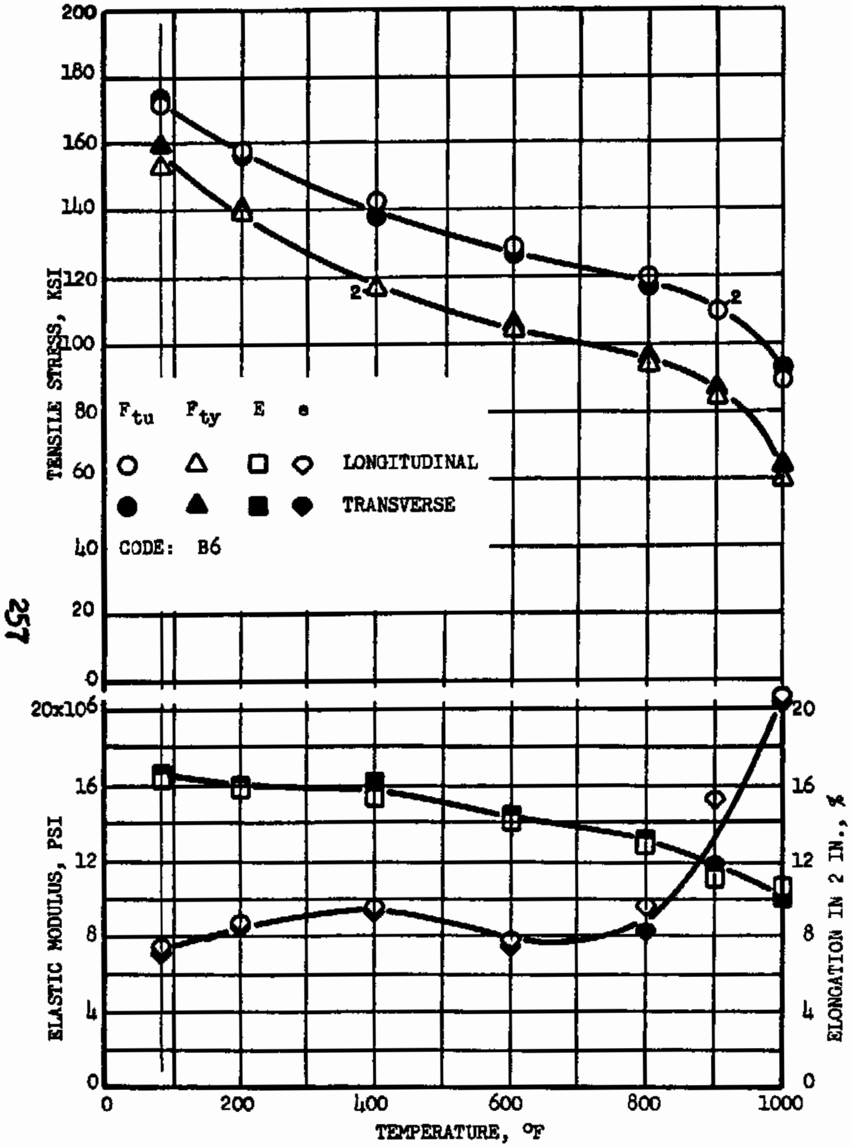


FIGURE 155 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 32163)

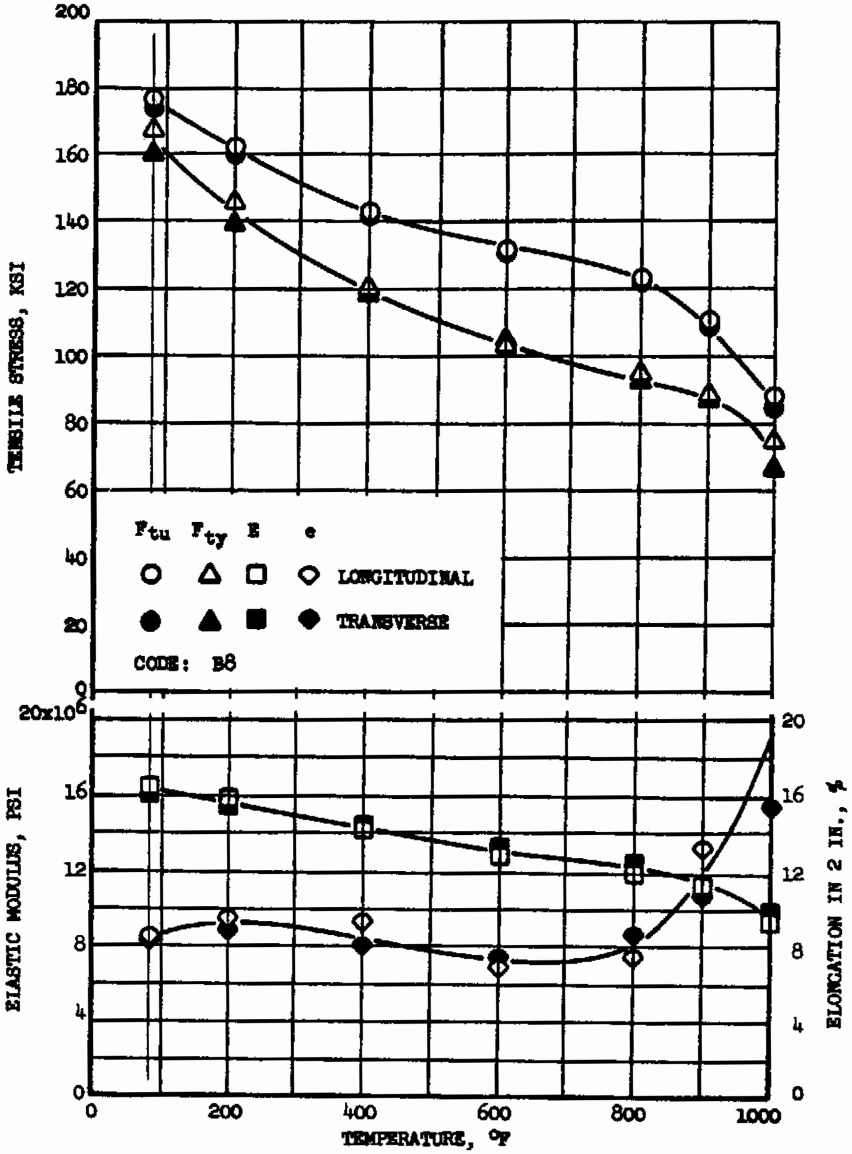


FIGURE 156 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 31372)

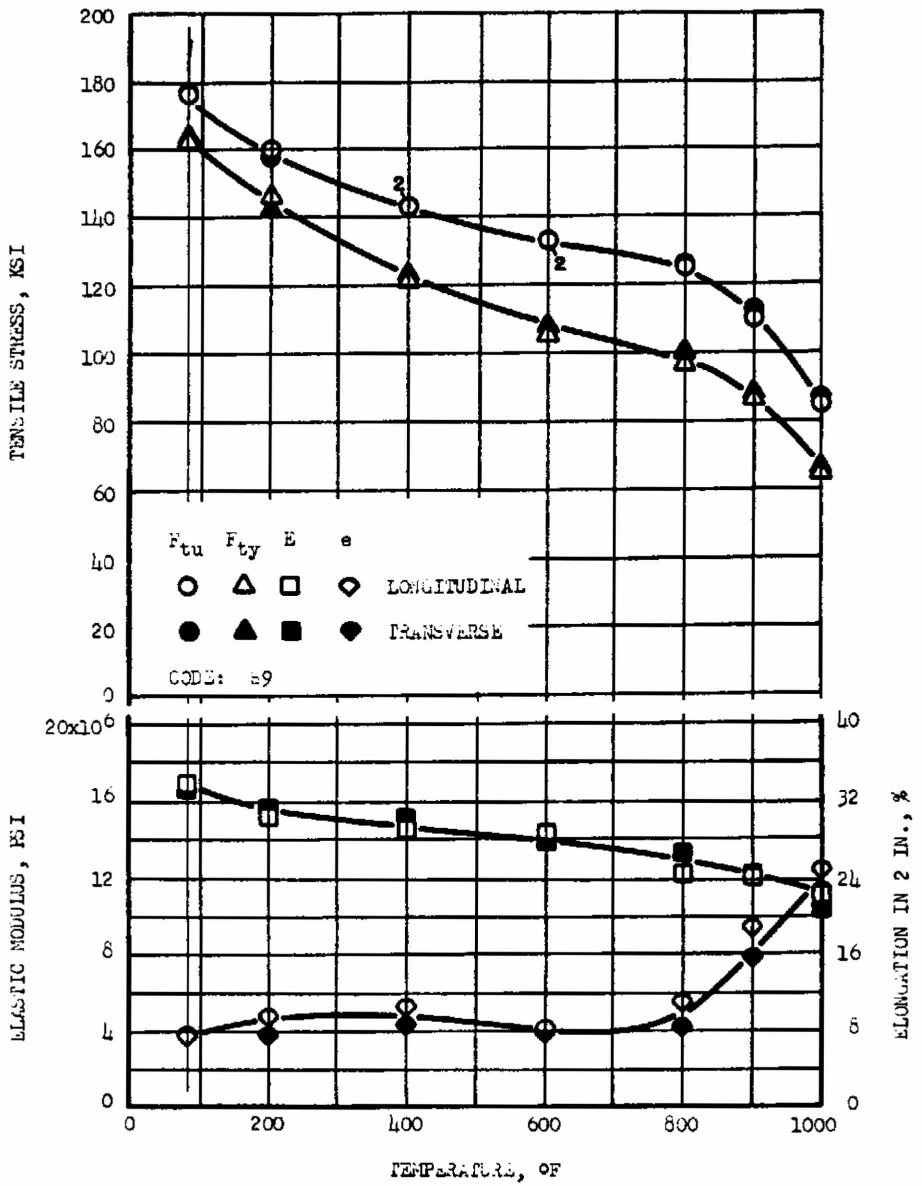


FIGURE 157 – SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (MALLORY-SHARON HEAT NO. 32167)

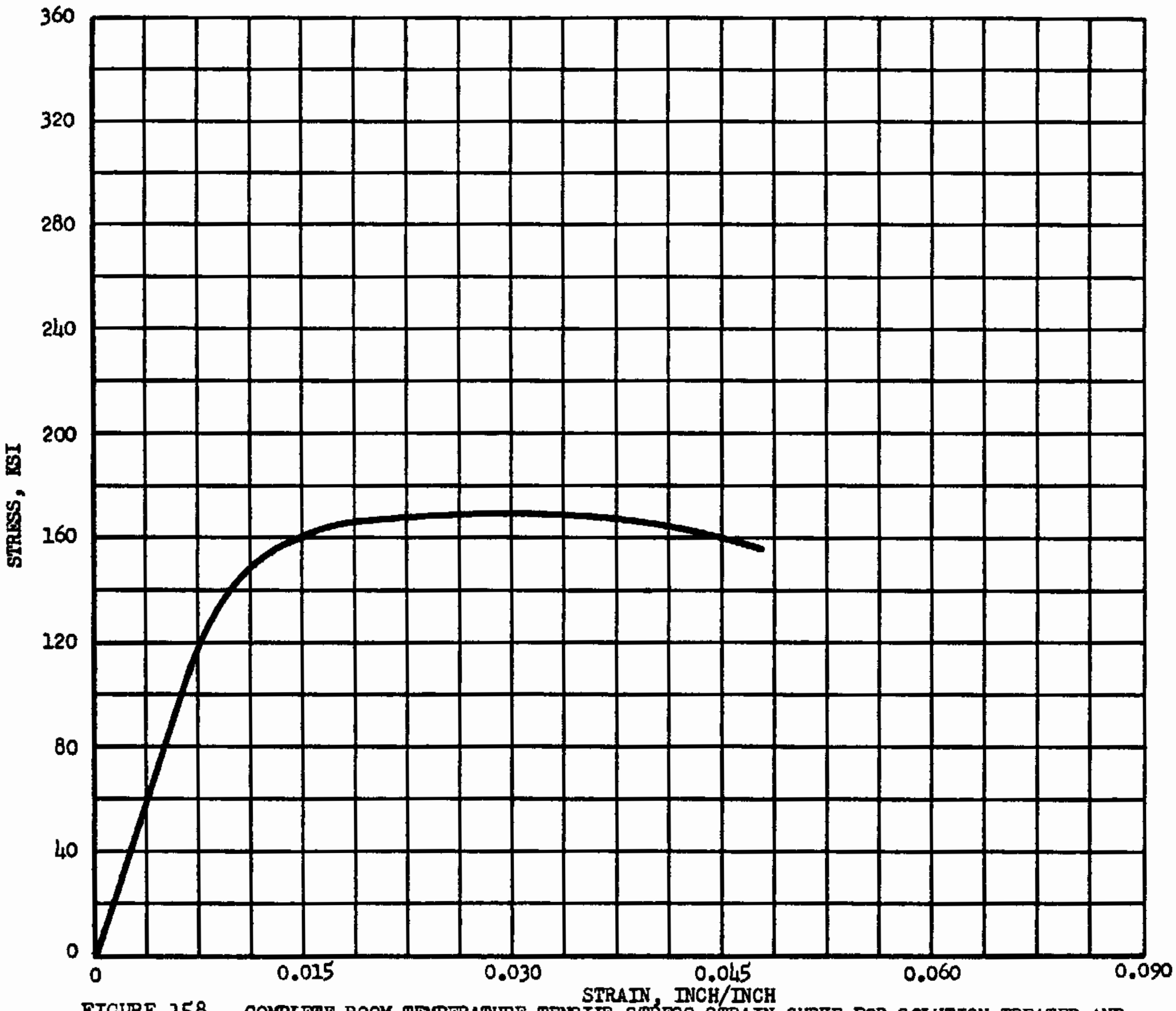


FIGURE 158 - COMPLETE ROOM TEMPERATURE TENSIIE STRESS-STRAIN CURVE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (SPECIMEN NO. B5LA1P-2)

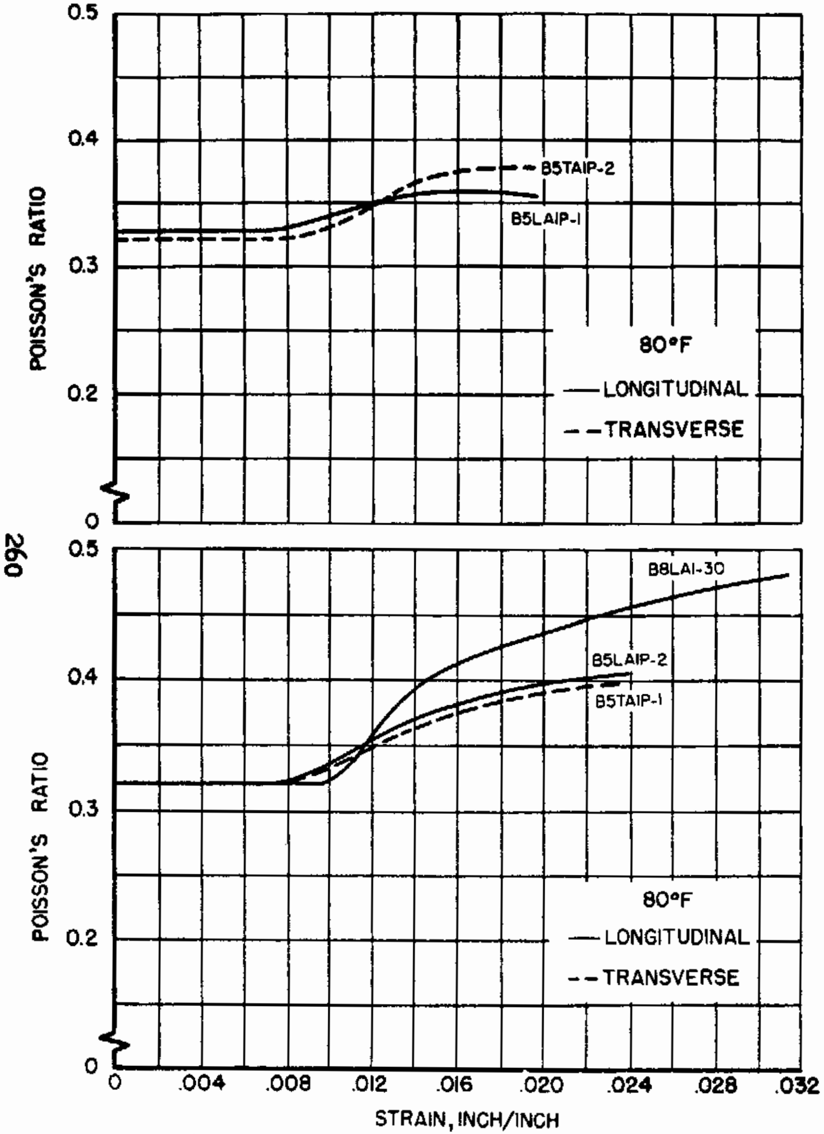


FIGURE 159 – VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 6A1-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK

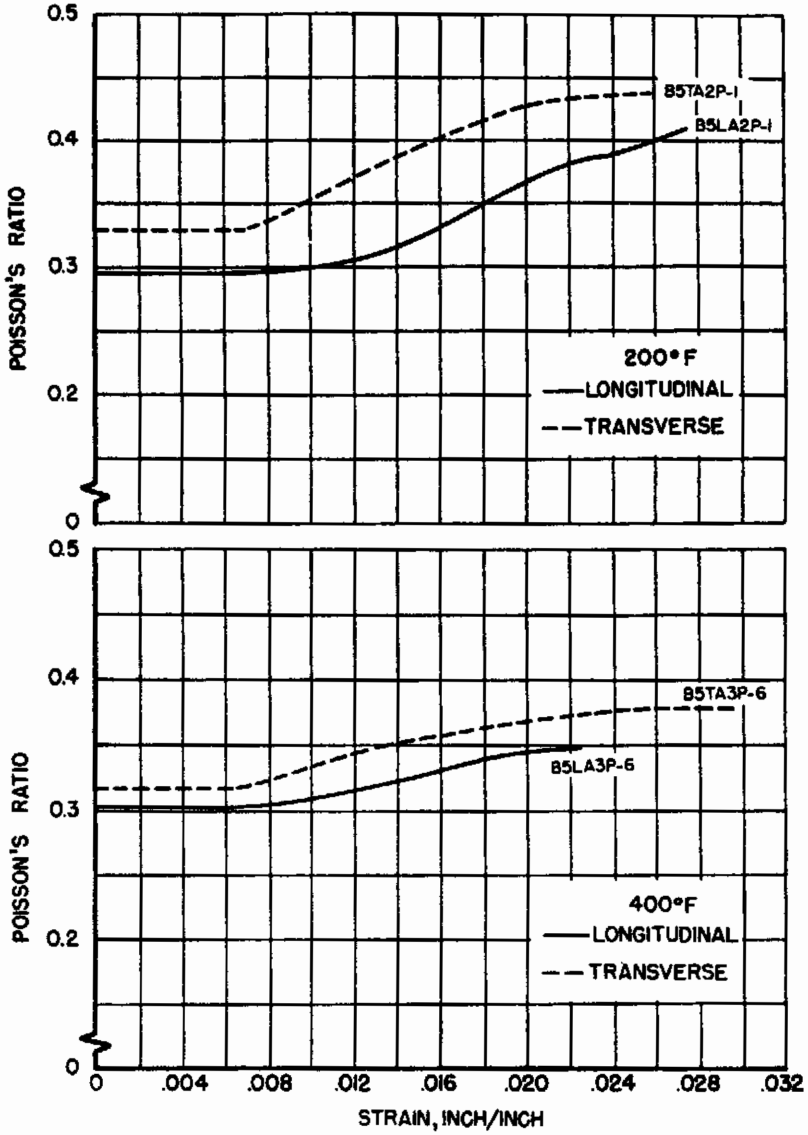


FIGURE 160 – VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 6A1-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK

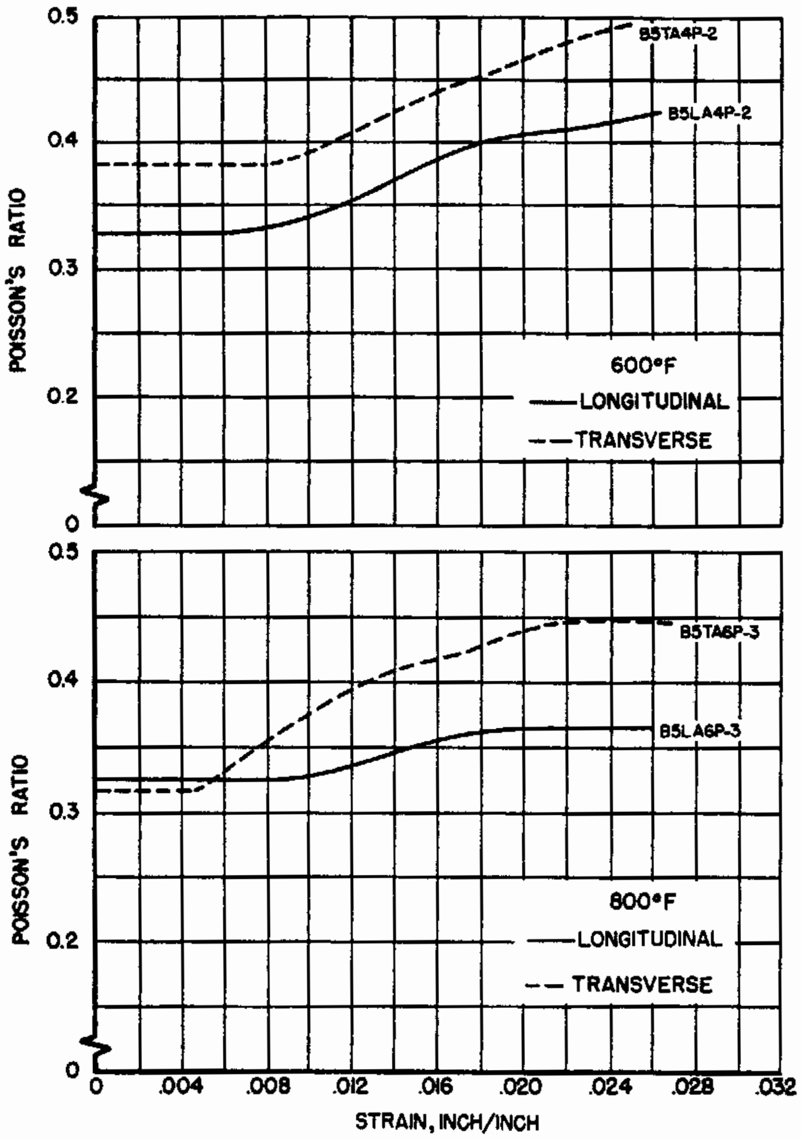


FIGURE 161 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK

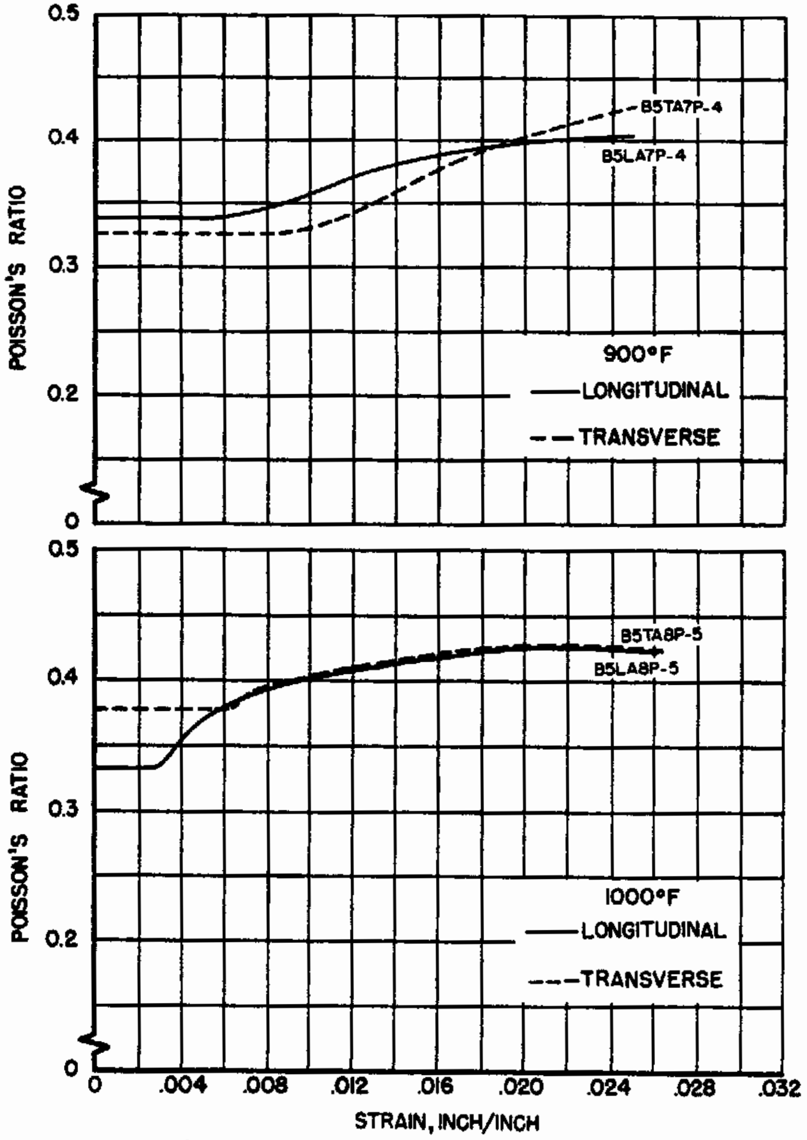
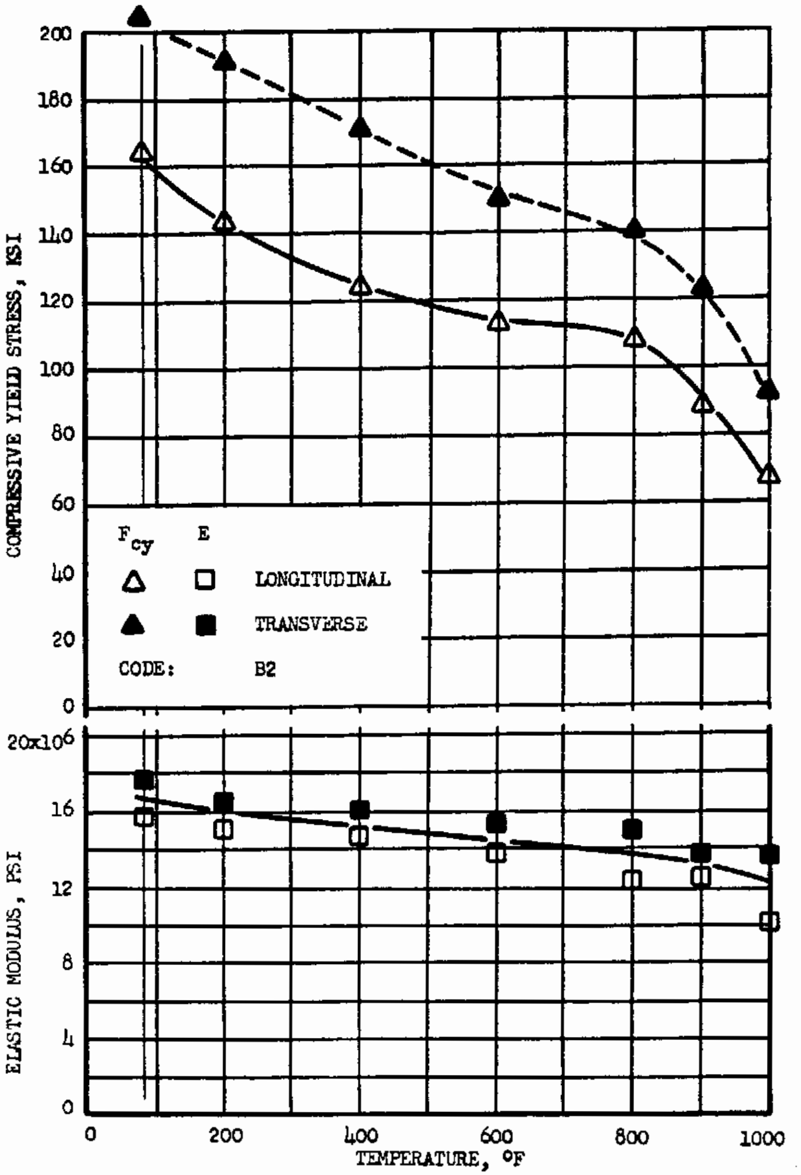


FIGURE 162 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK



IGURE 163 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 27039)

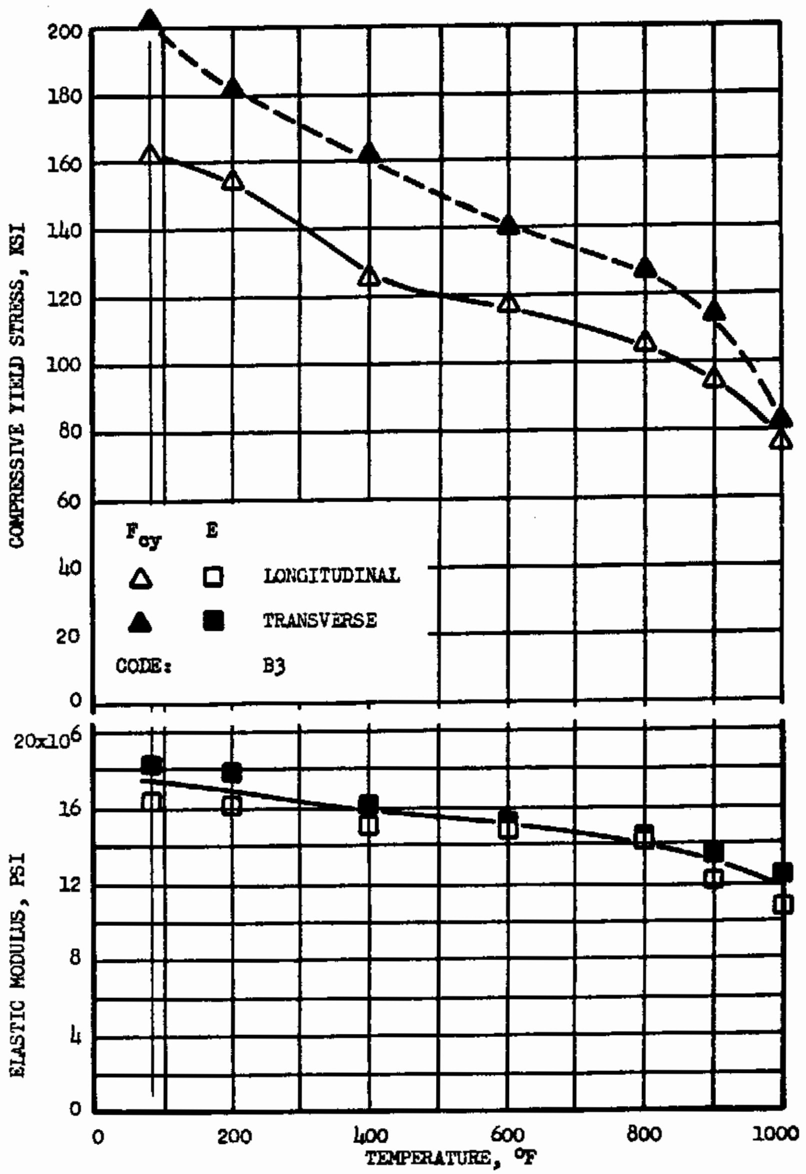


FIGURE 164 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 22207)

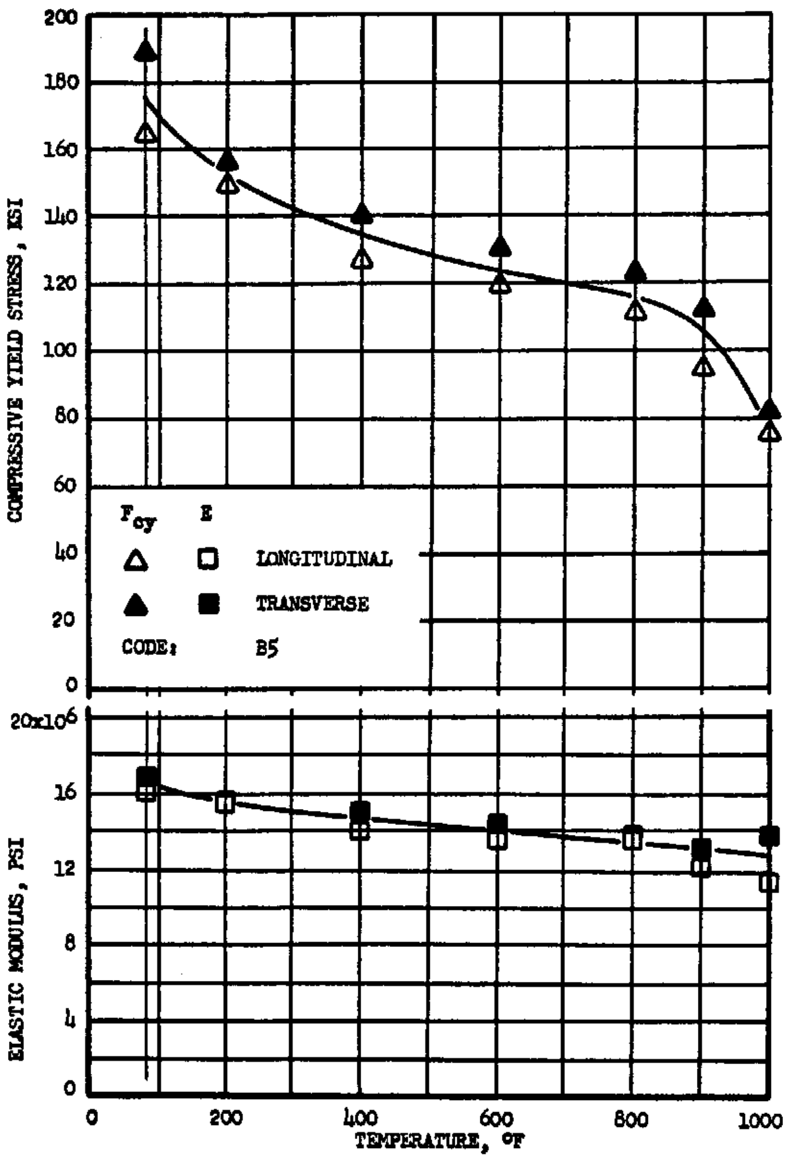


FIGURE 165 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 25671)

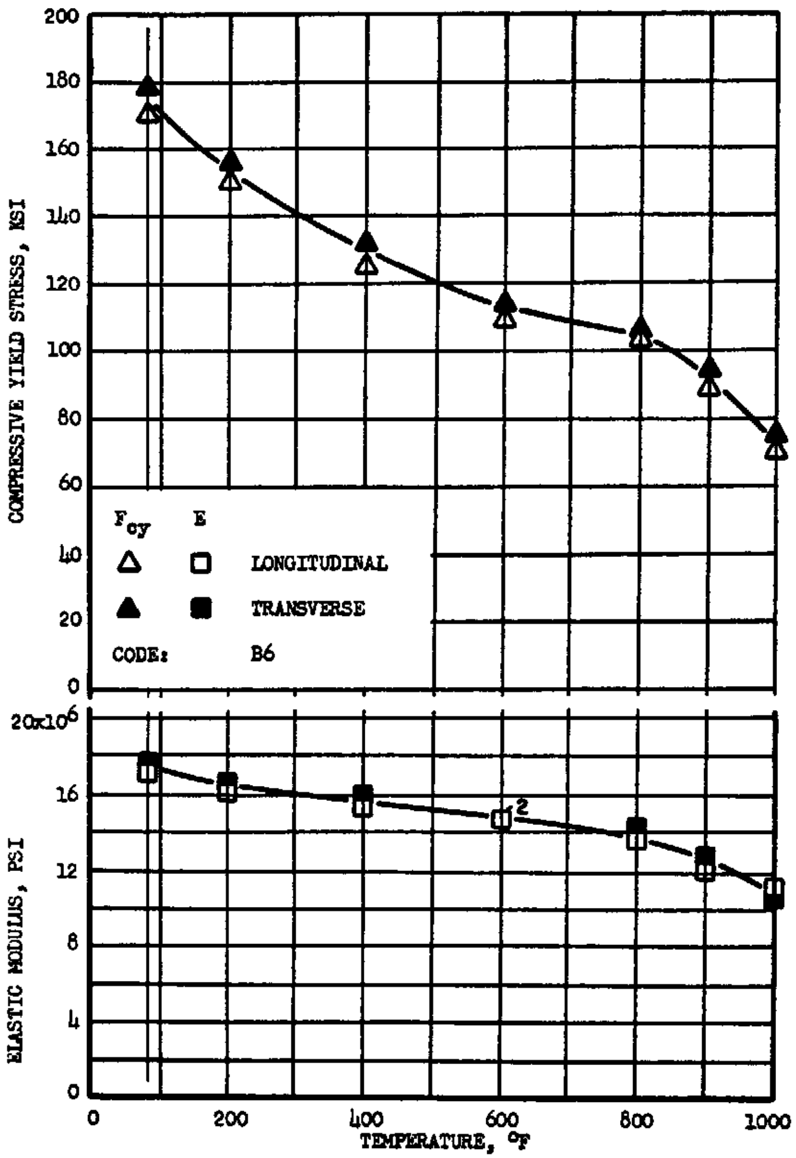


FIGURE 166 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 32163)

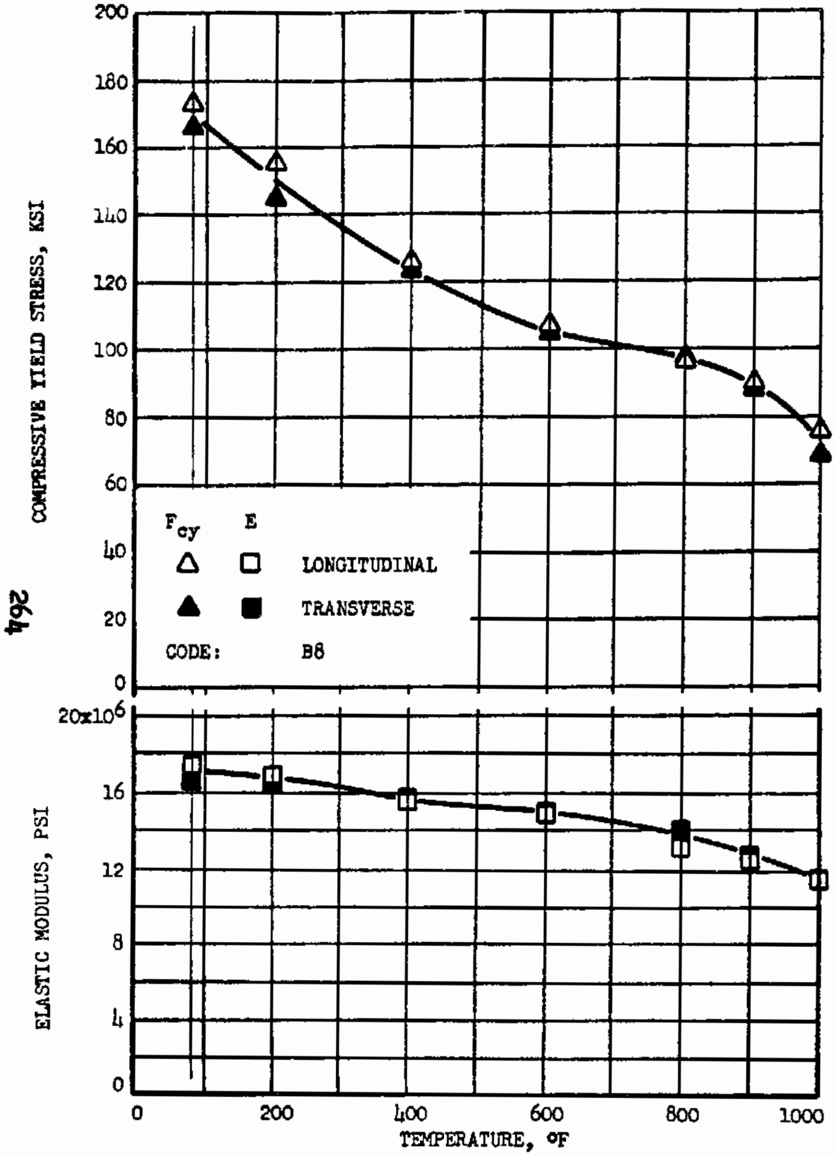


FIGURE 167 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 31372)

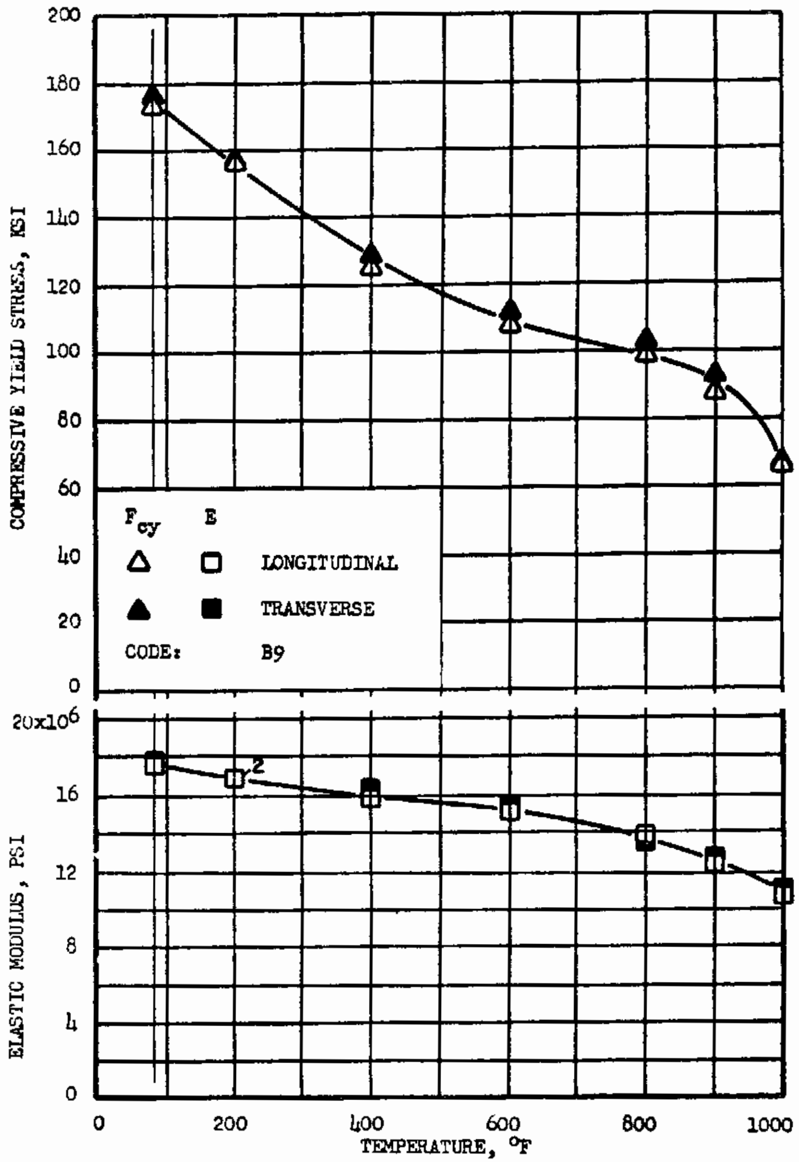


FIGURE 168 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 32167)

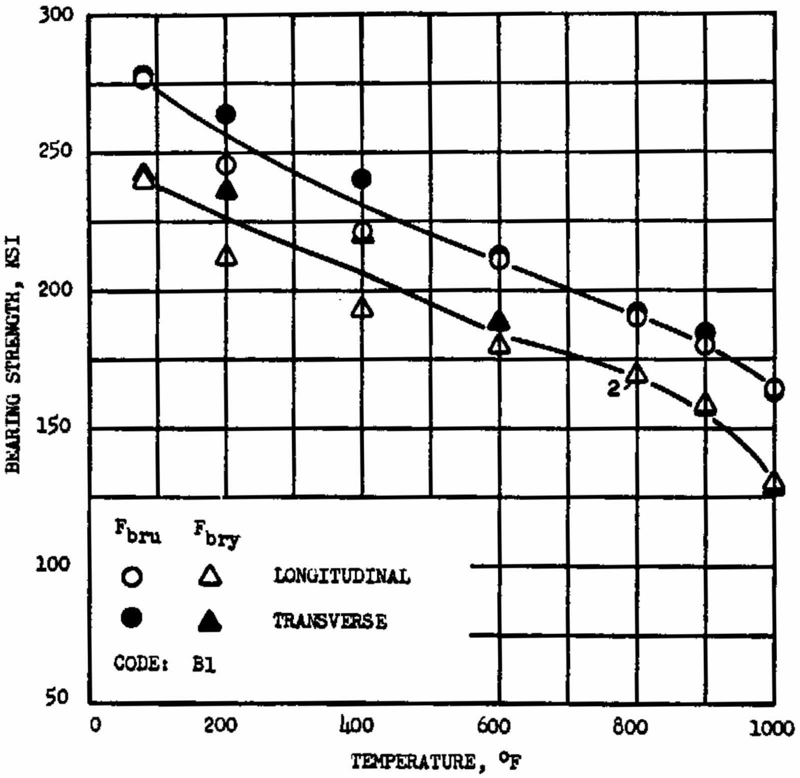


FIGURE 169 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1250 INCH (REACTIVE METALS HEAT NO. 24791)

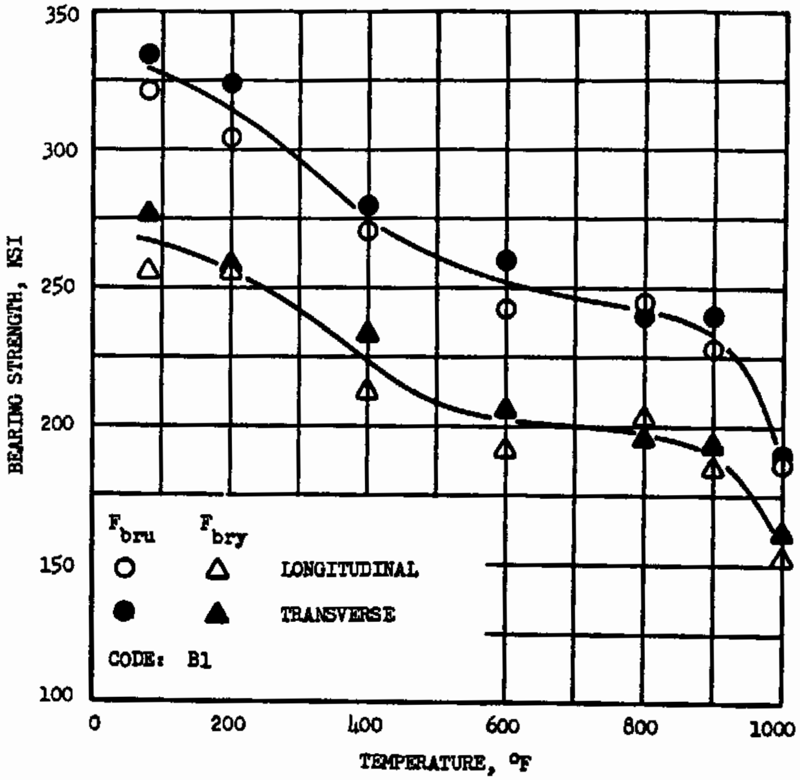


FIGURE 170 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1250 INCH (REACTIVE METALS HEAT NO. 24791)

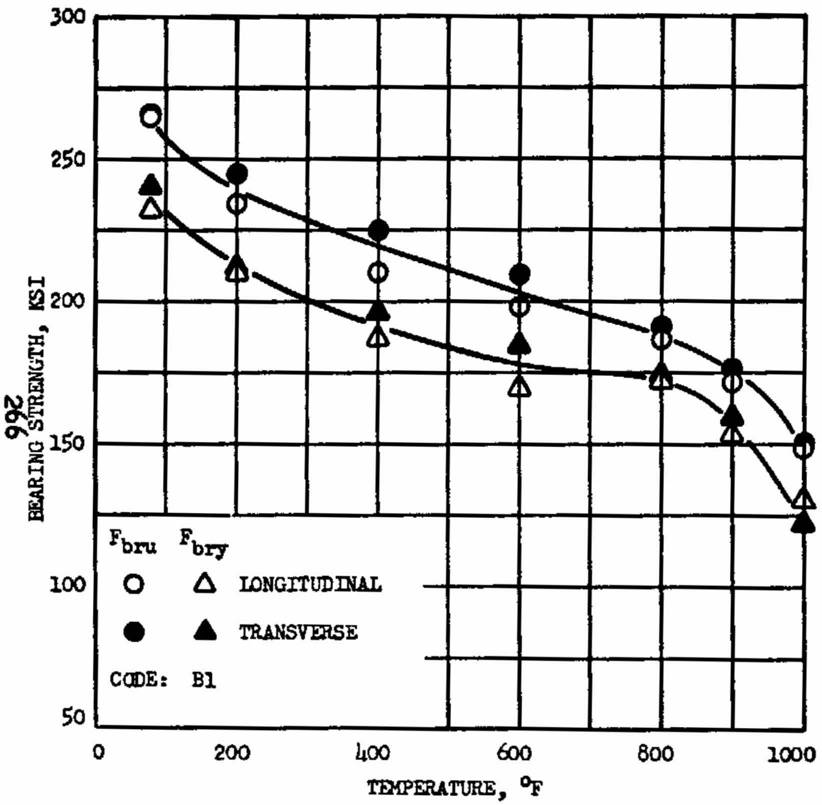


FIGURE 171 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 24791)

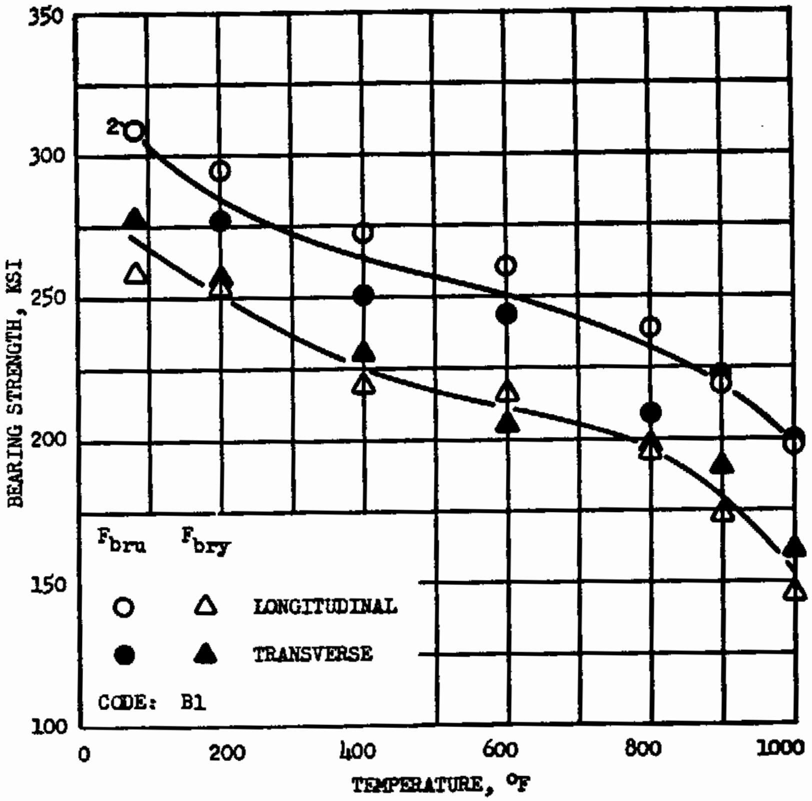


FIGURE 172 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 24791)

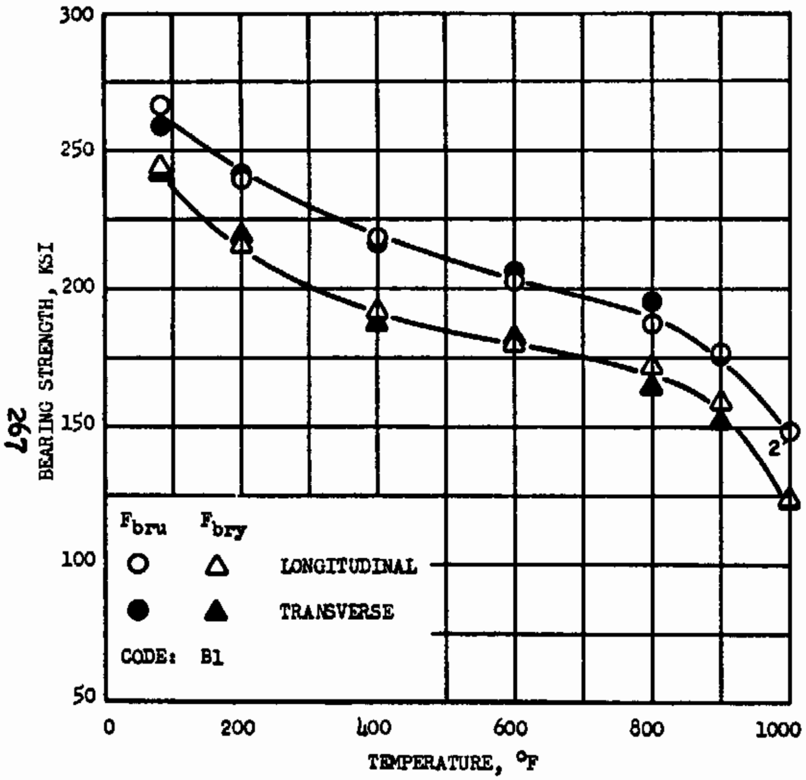


FIGURE 173 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24791)

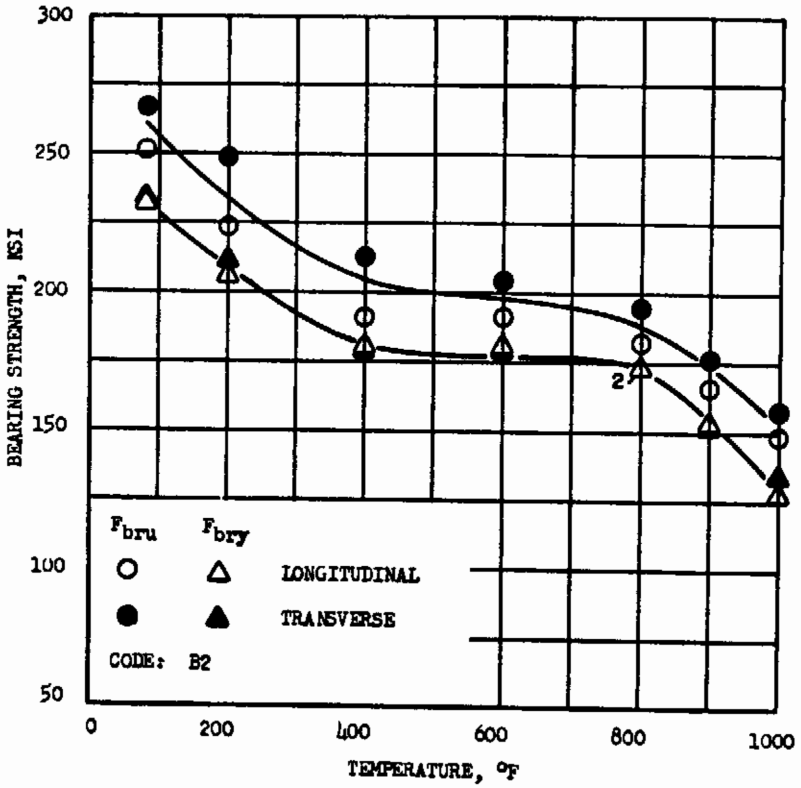


FIGURE 174 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 27039)

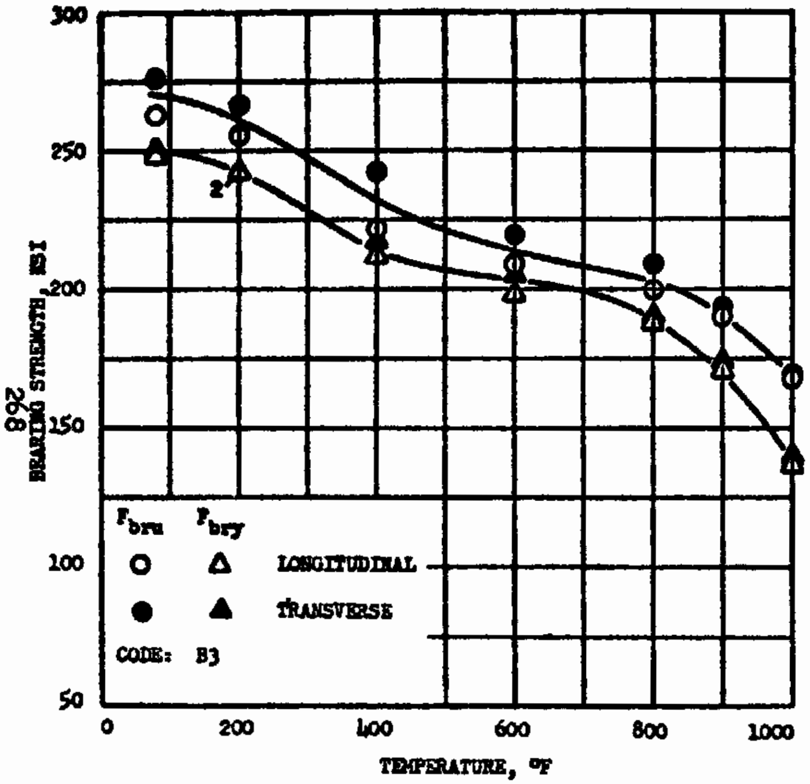


FIGURE 175 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 22207 AND 23407)

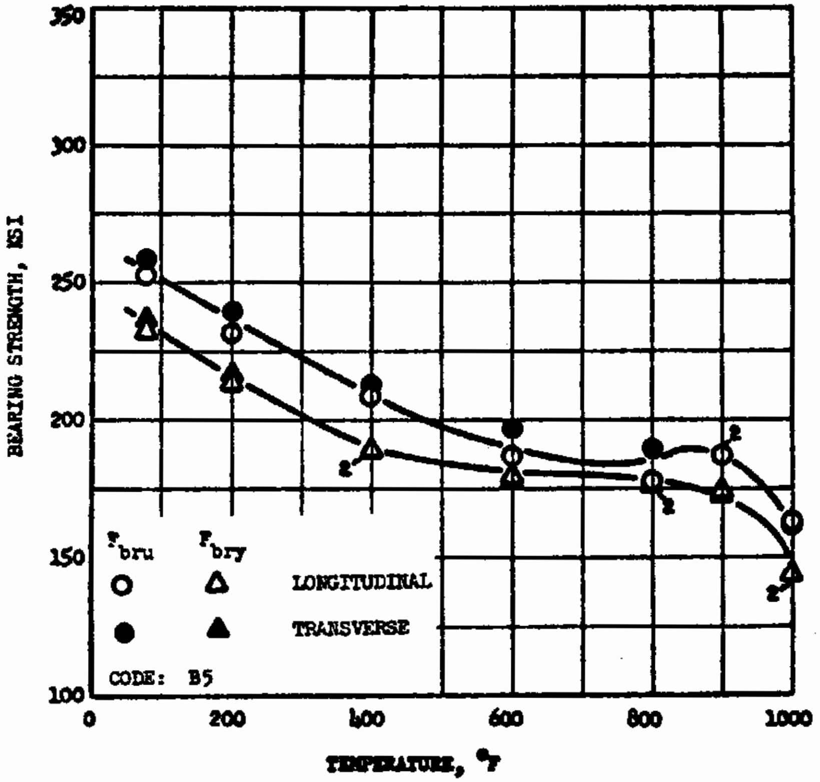


FIGURE 176 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 25671)

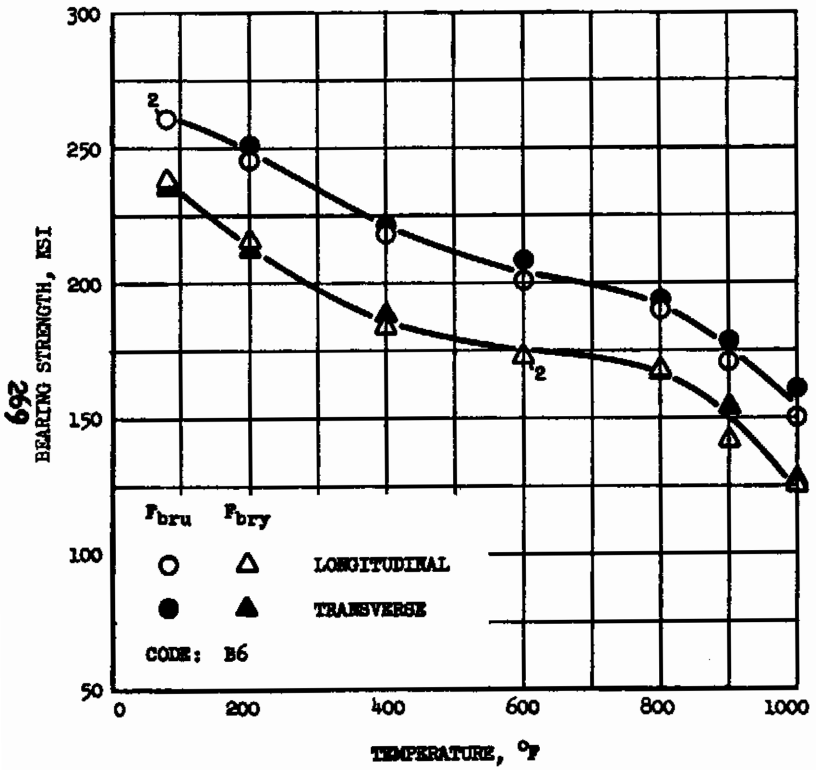


FIGURE 177 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 32163)

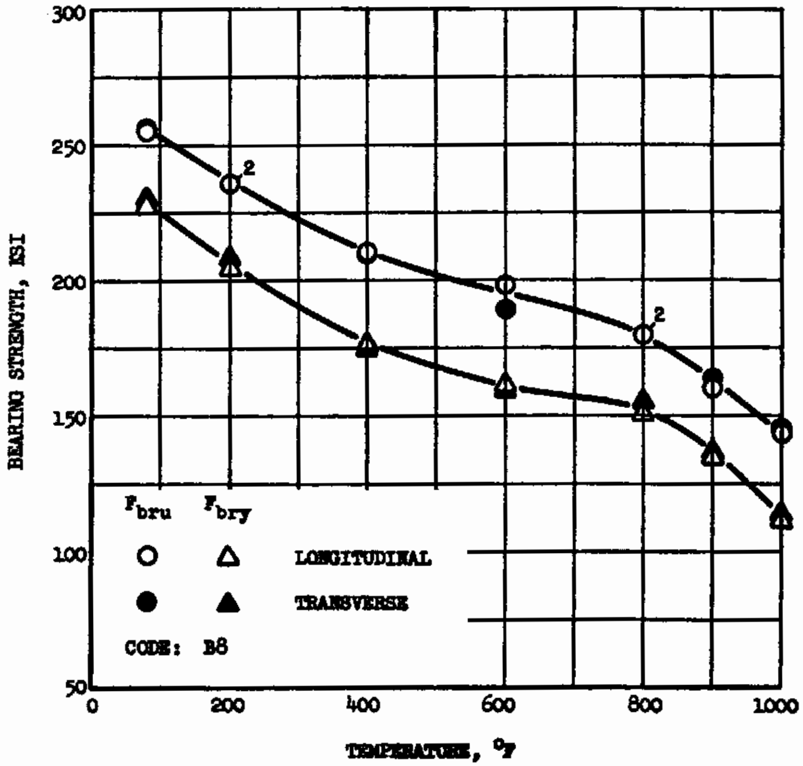


FIGURE 178 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 31372)

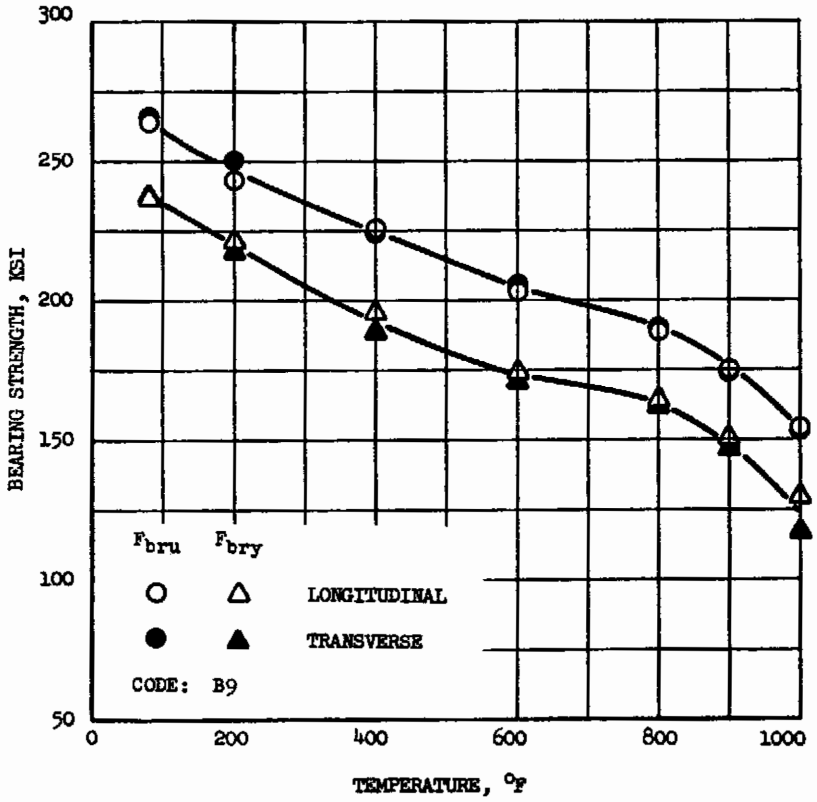


FIGURE 179 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER =0.3125 INCH (REACTIVE METALS HEAT NO. 32167)

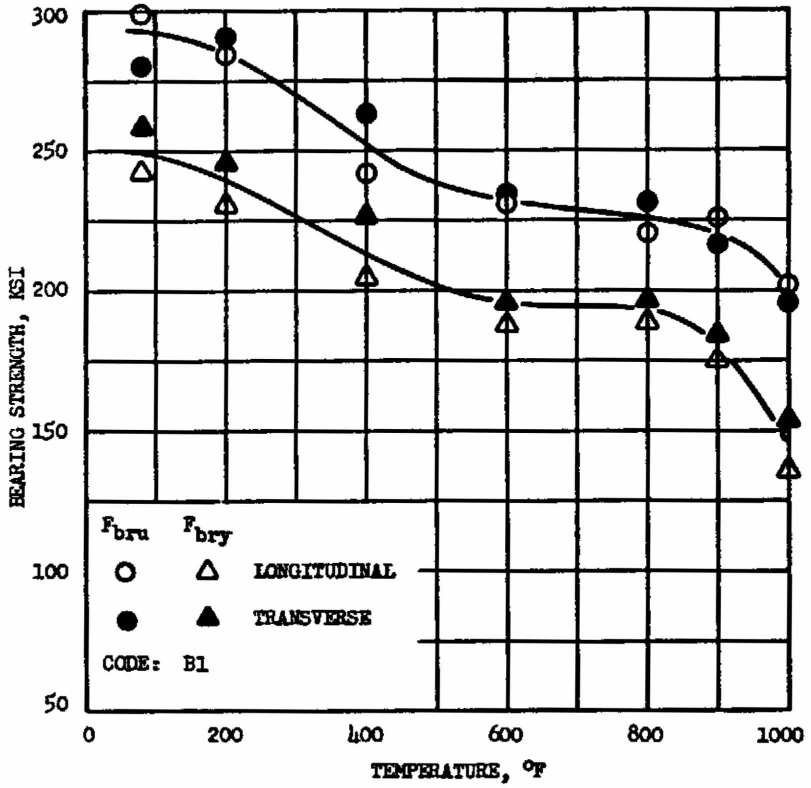


FIGURE 180 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24791)

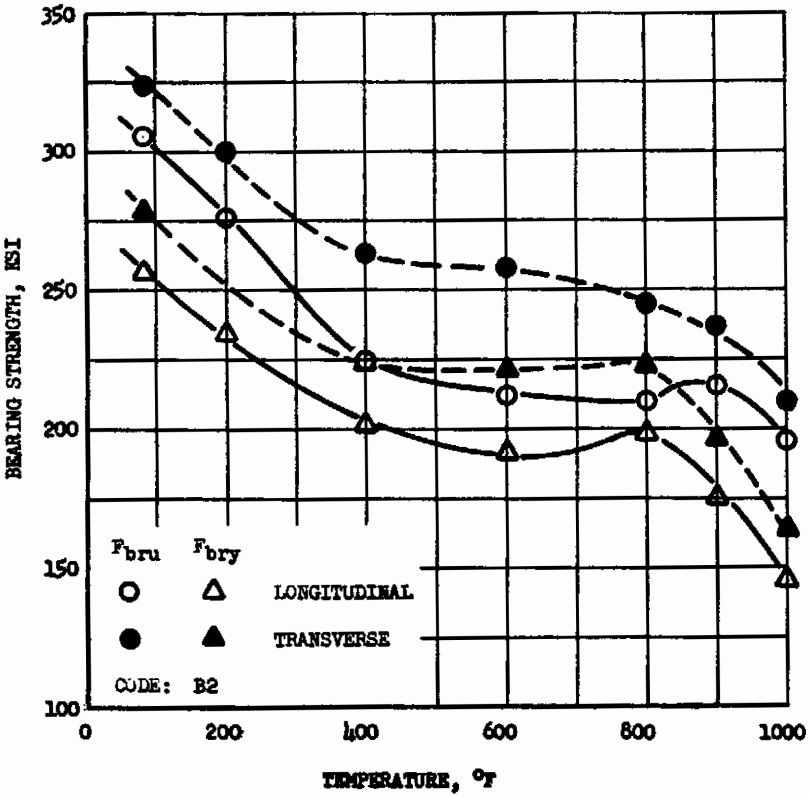


FIGURE 181 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 27039)

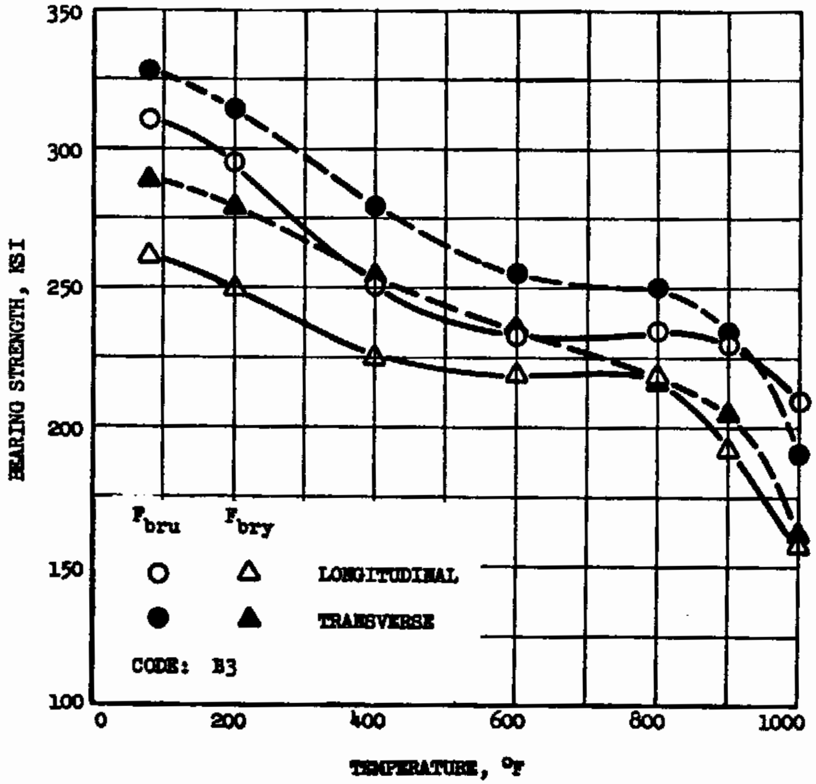


FIGURE 182 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NOS. 22207 AND 23407)

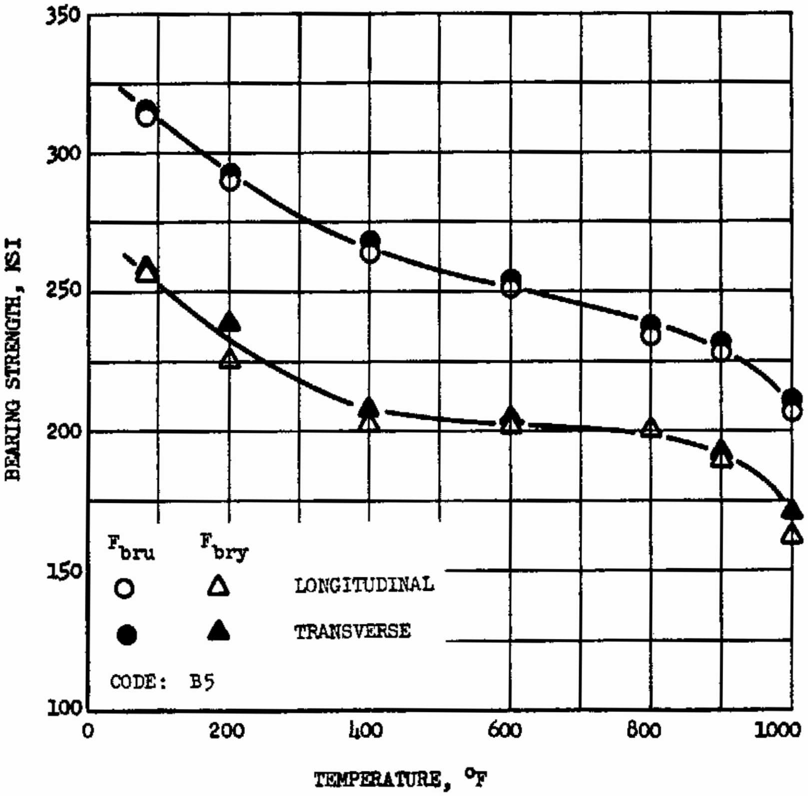


FIGURE 183 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 25671)

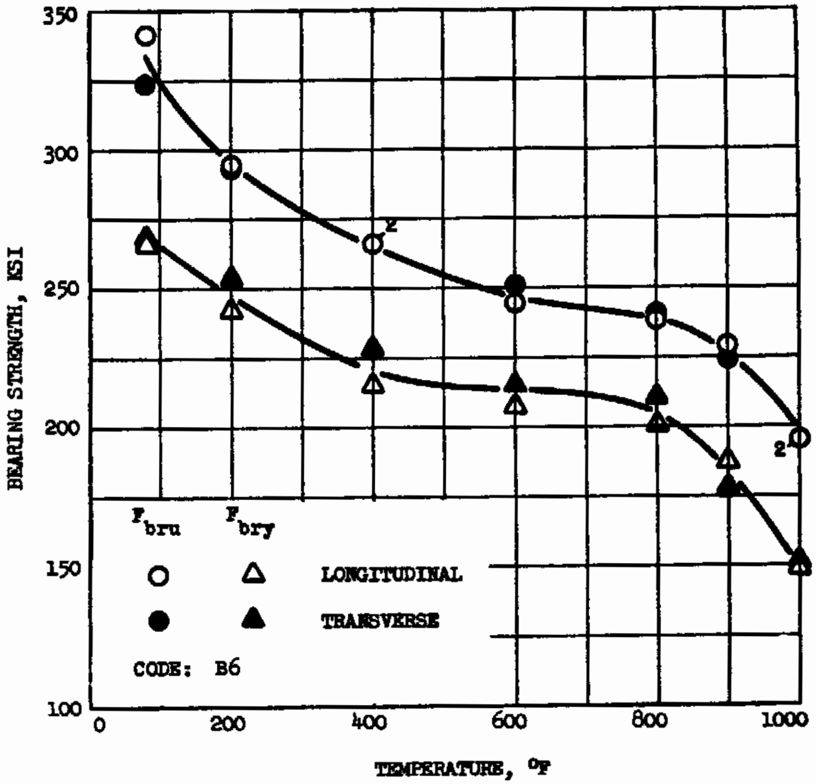


FIGURE 184 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, .125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 32163)

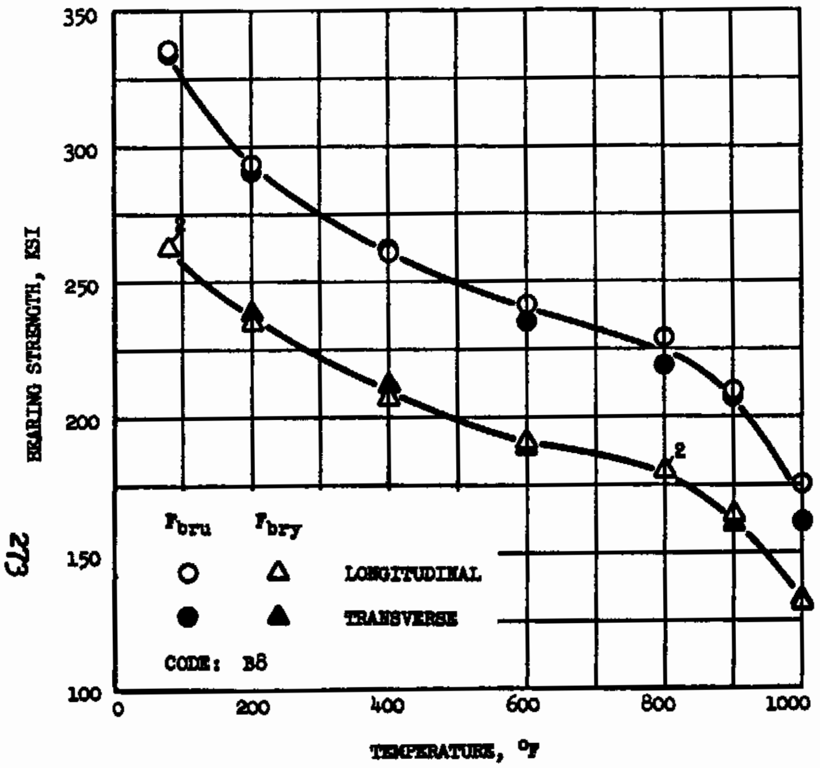


FIGURE 185 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 31372)

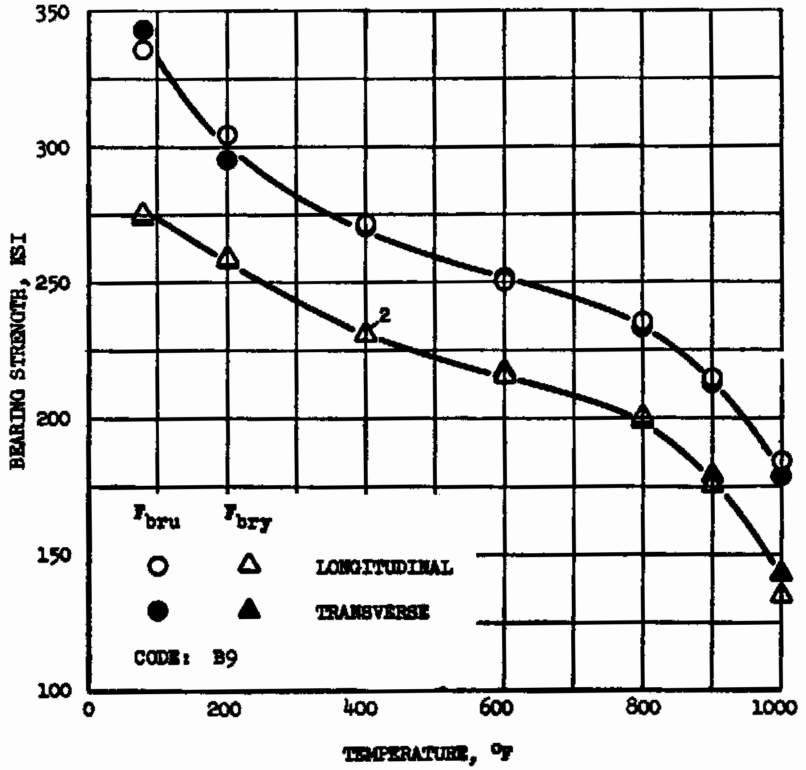


FIGURE 186 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 32167

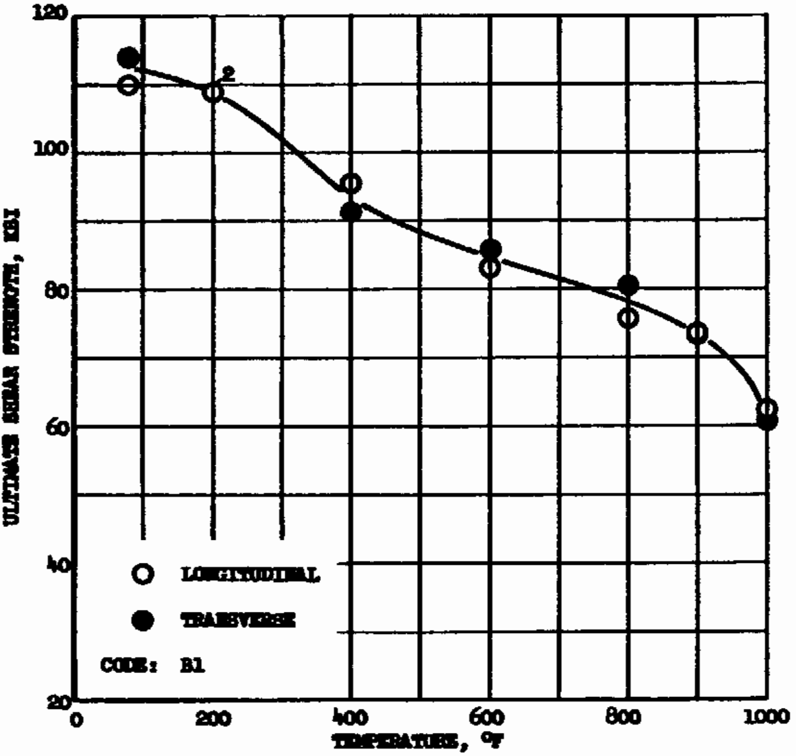


FIGURE 187 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO. 24791)

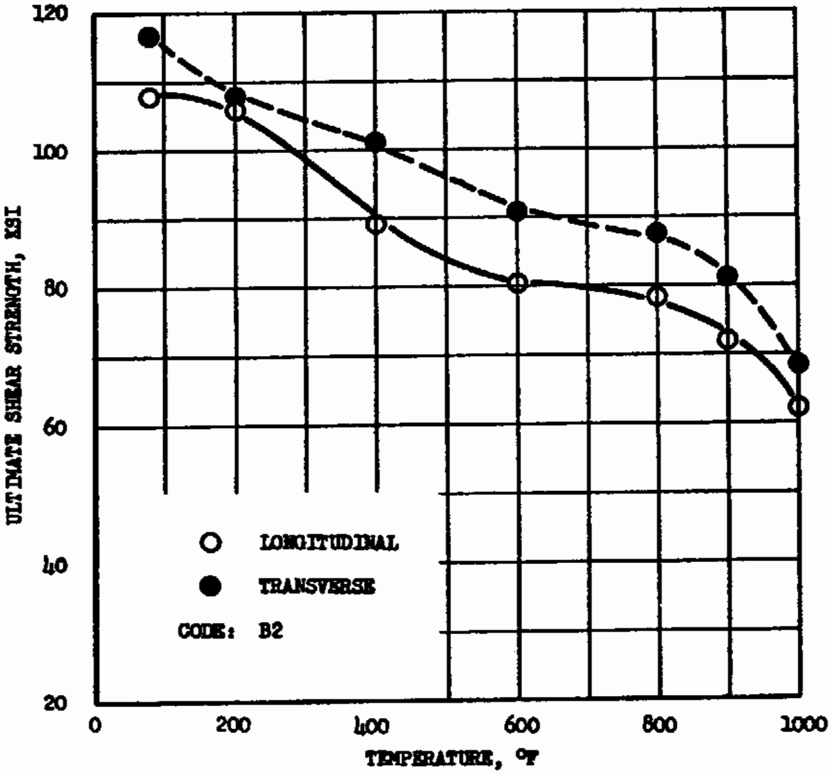


FIGURE 188 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 27039)

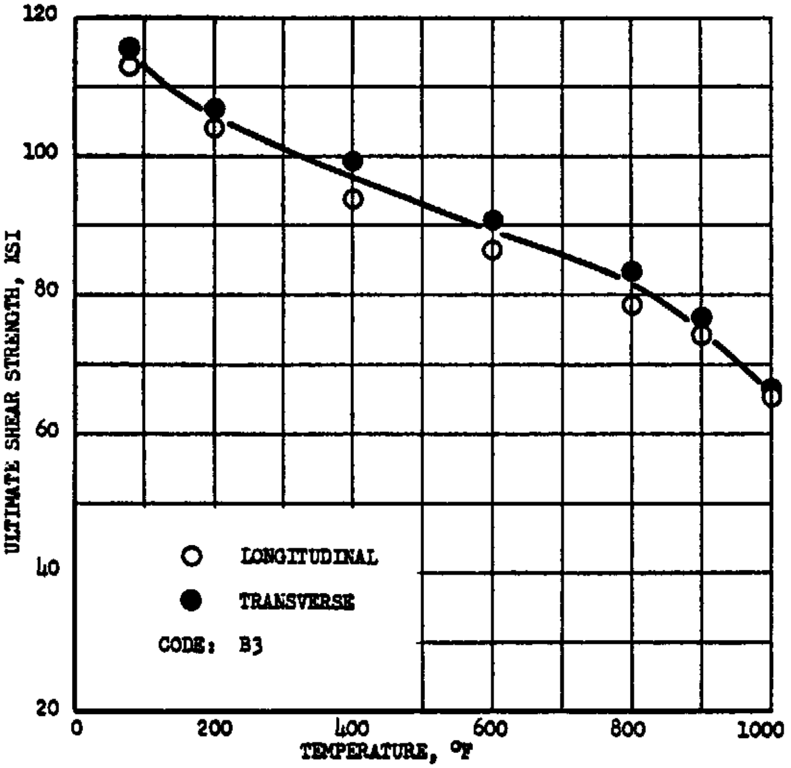


FIGURE 189 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NOS. 22207 AND 23407)

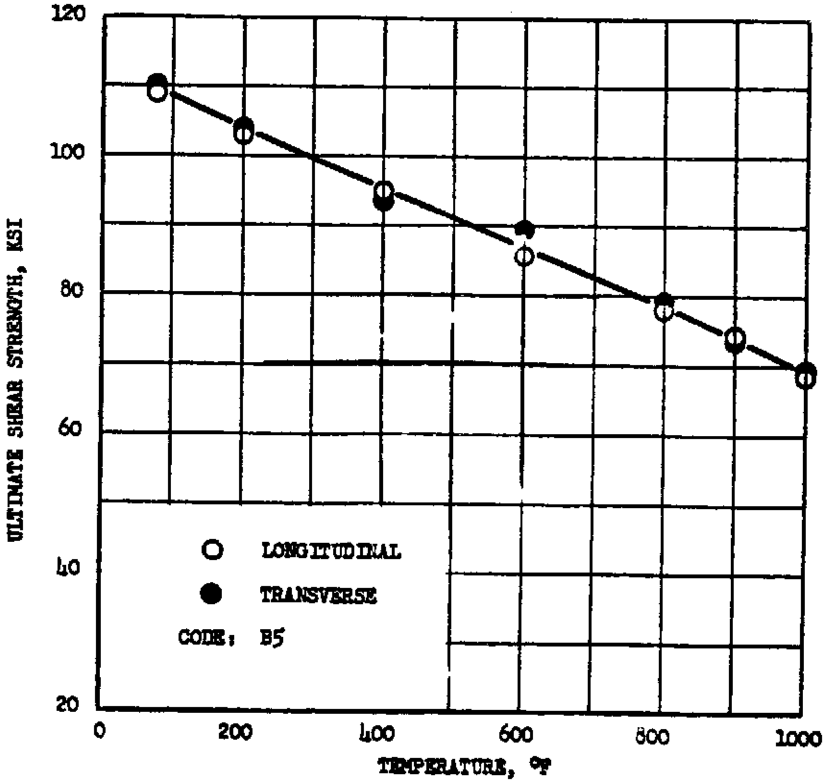


FIGURE 190 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 25671)

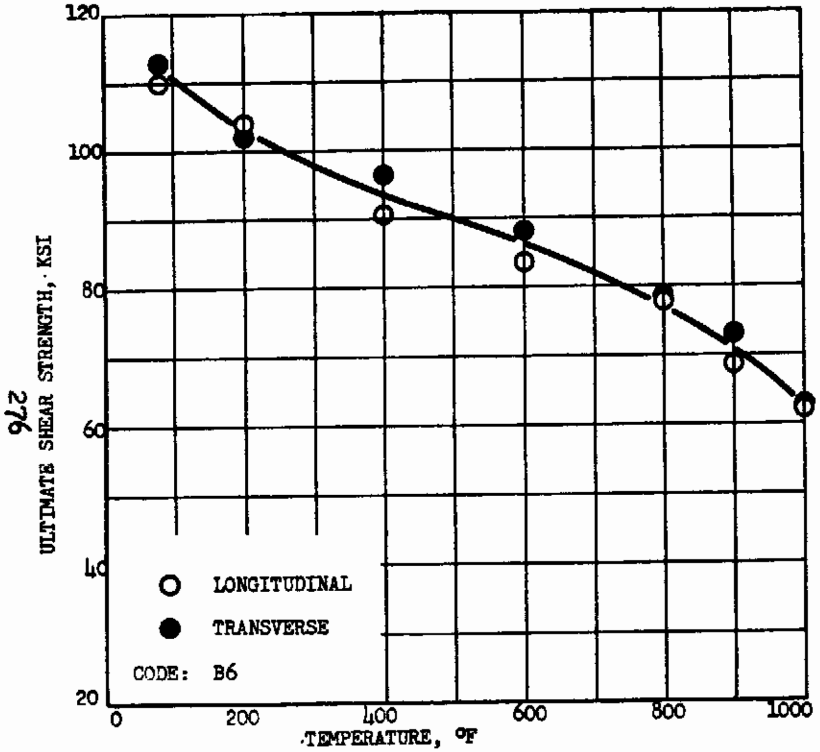


FIGURE 191 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METAL HEAT NO. 32163)

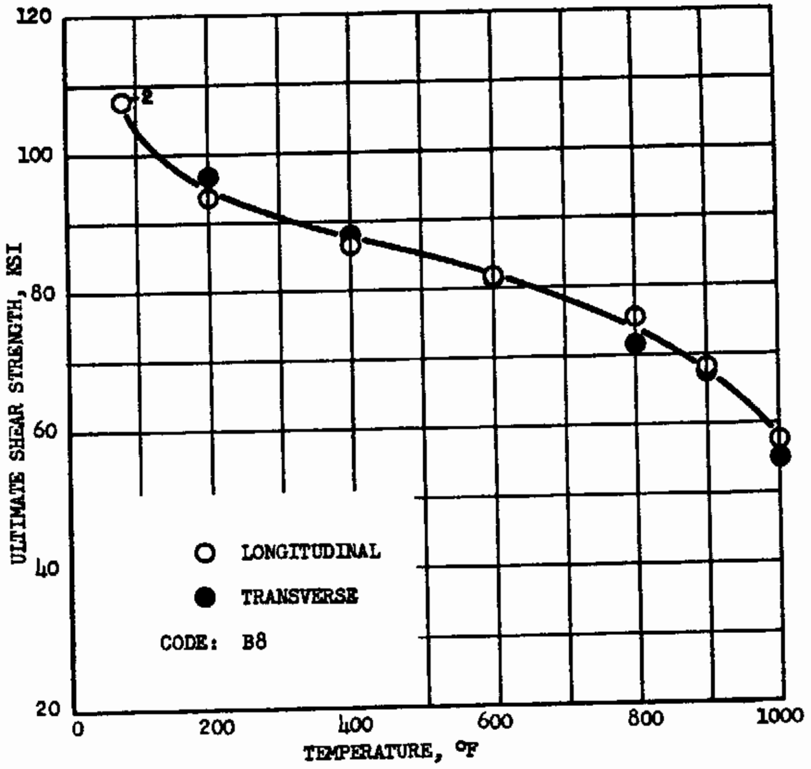


FIGURE 192 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 31372)

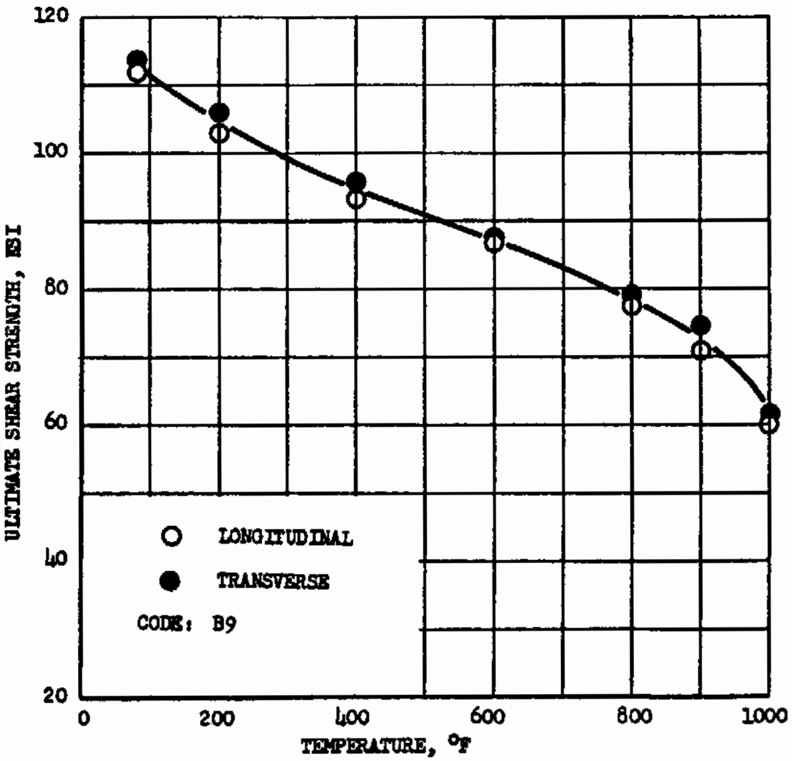


FIGURE 193 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6A1-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 32167)

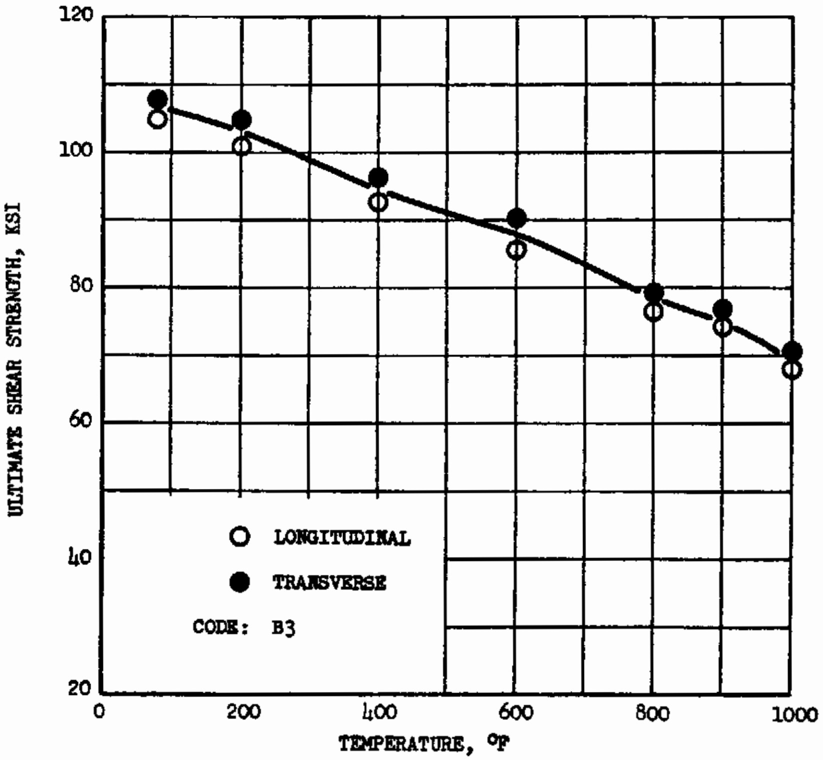


FIGURE 194 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6A1-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NOS. 22207 AND 23407)

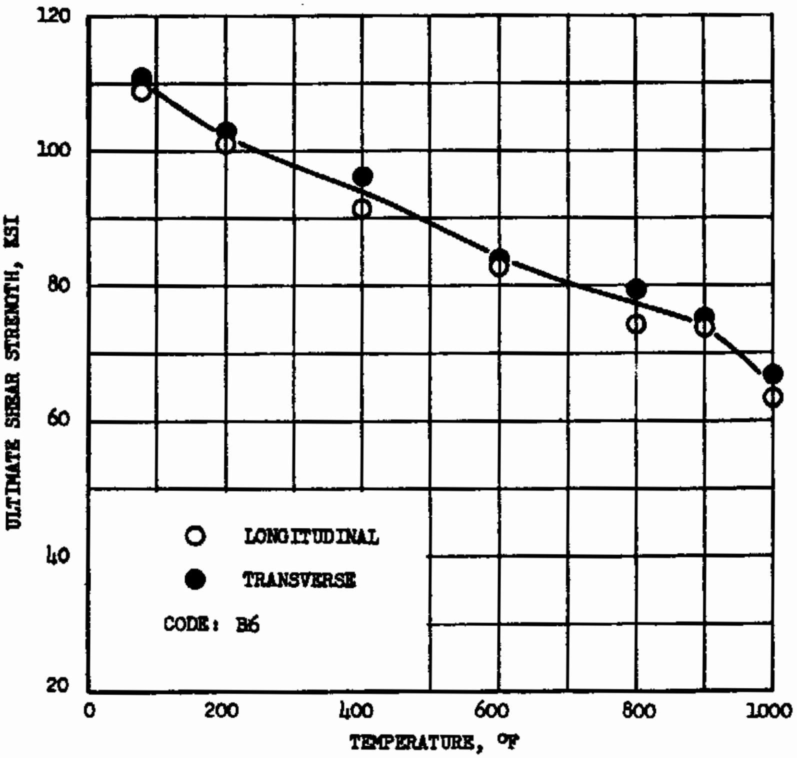


FIGURE 195 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 32163)

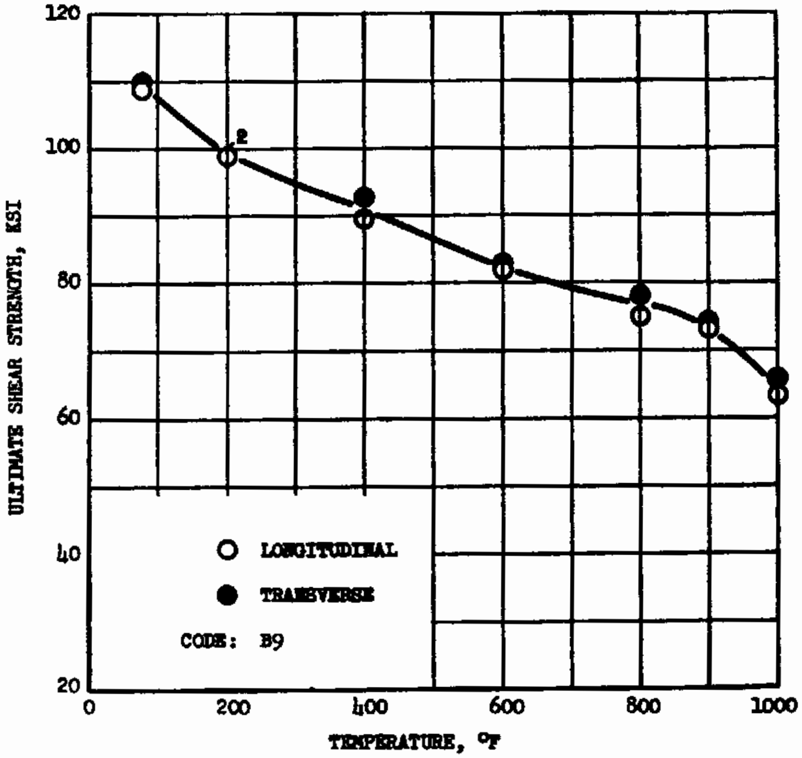


FIGURE 196 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 32167)

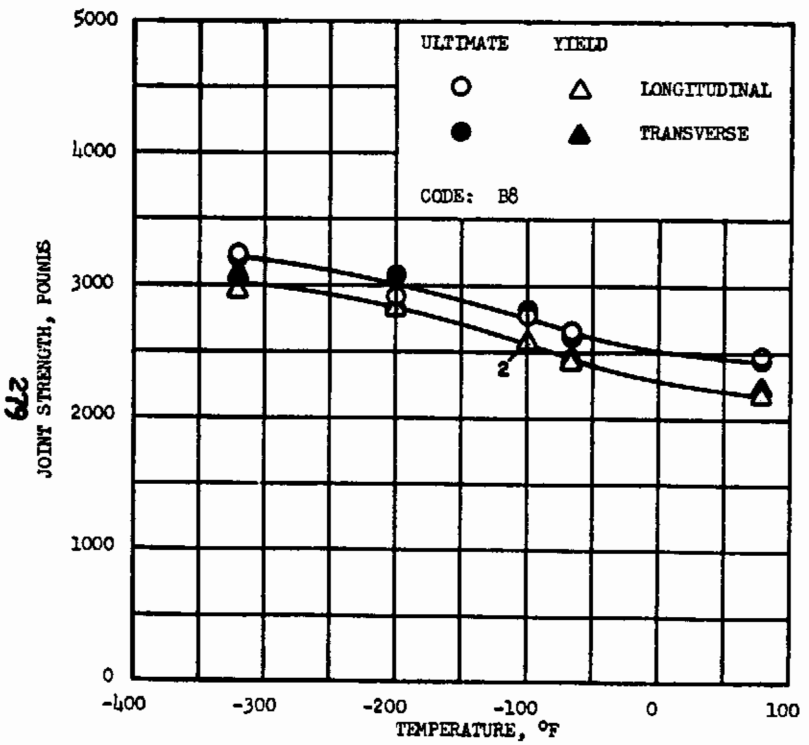


FIGURE 197 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER NAS2506-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 31372)

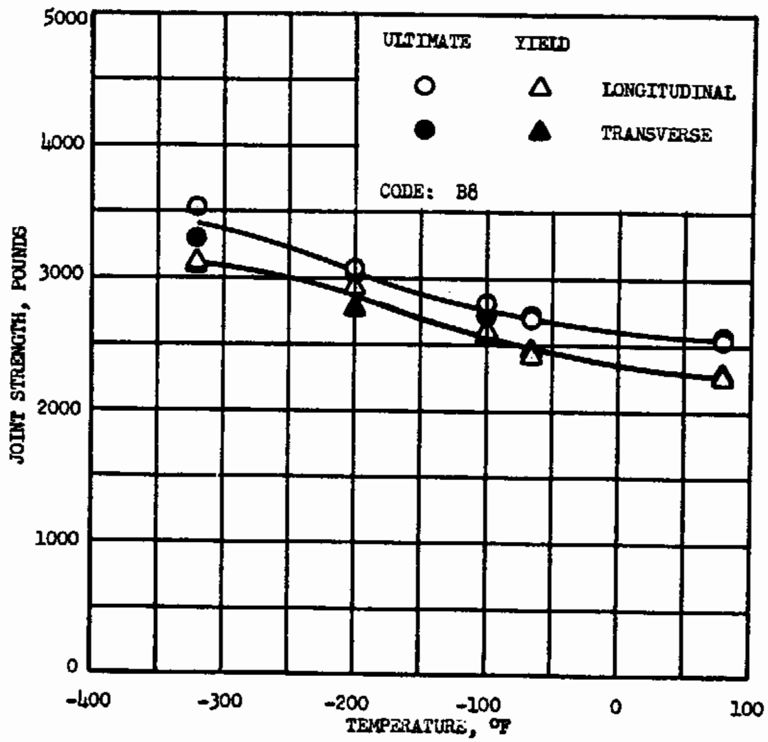


FIGURE 198 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER HL11V-6-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 31372)

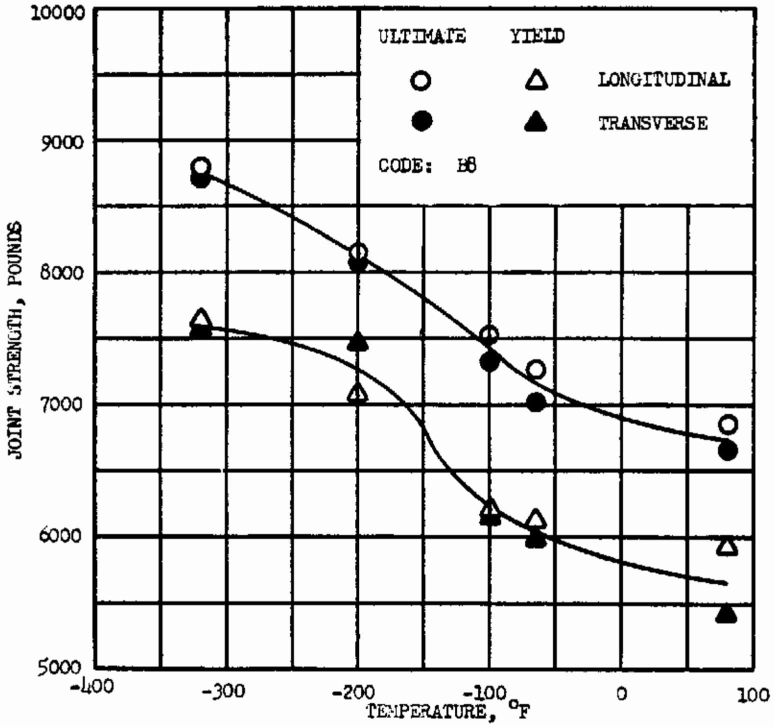


FIGURE 199 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS2010-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 31372)

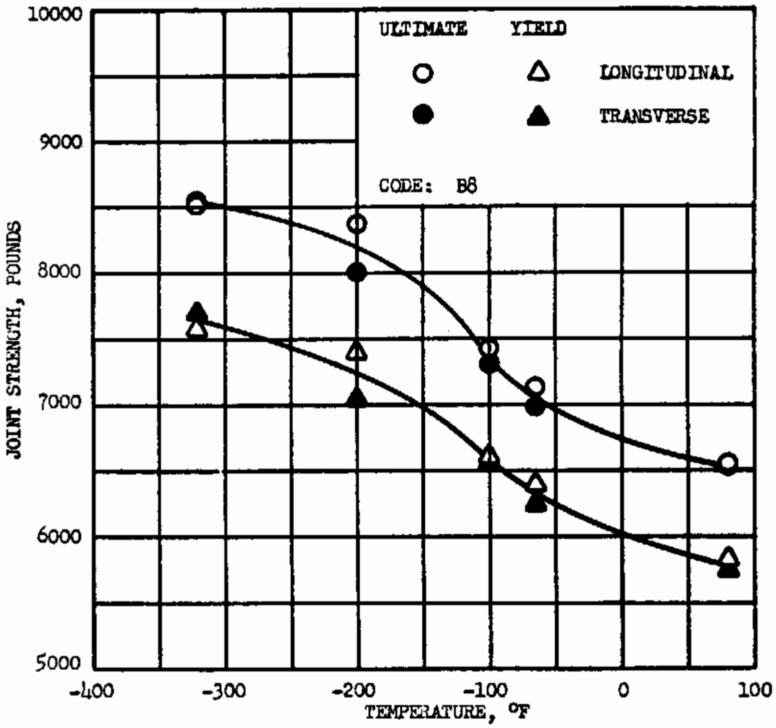


FIGURE 200 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS675-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 31372)

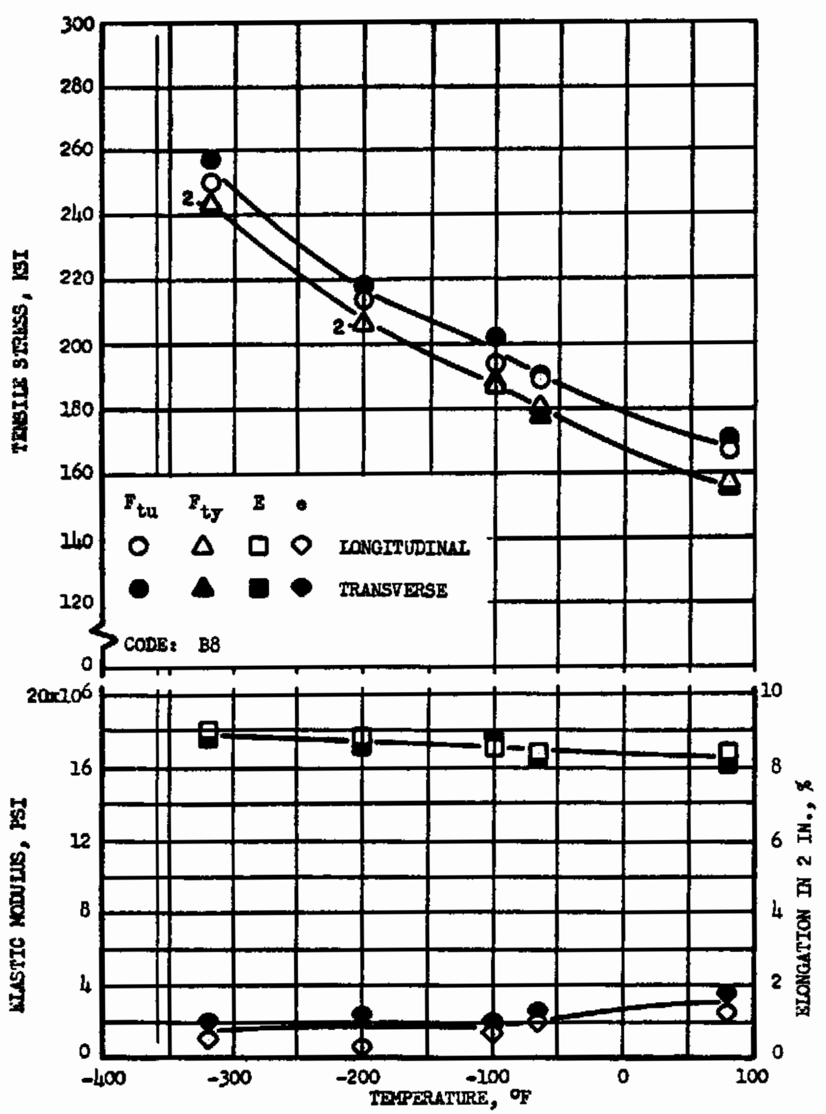


FIGURE 201 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK 6Al-4V TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED IN AGED CONDITION (REACTIVE METALS HEAT NO. 31372)

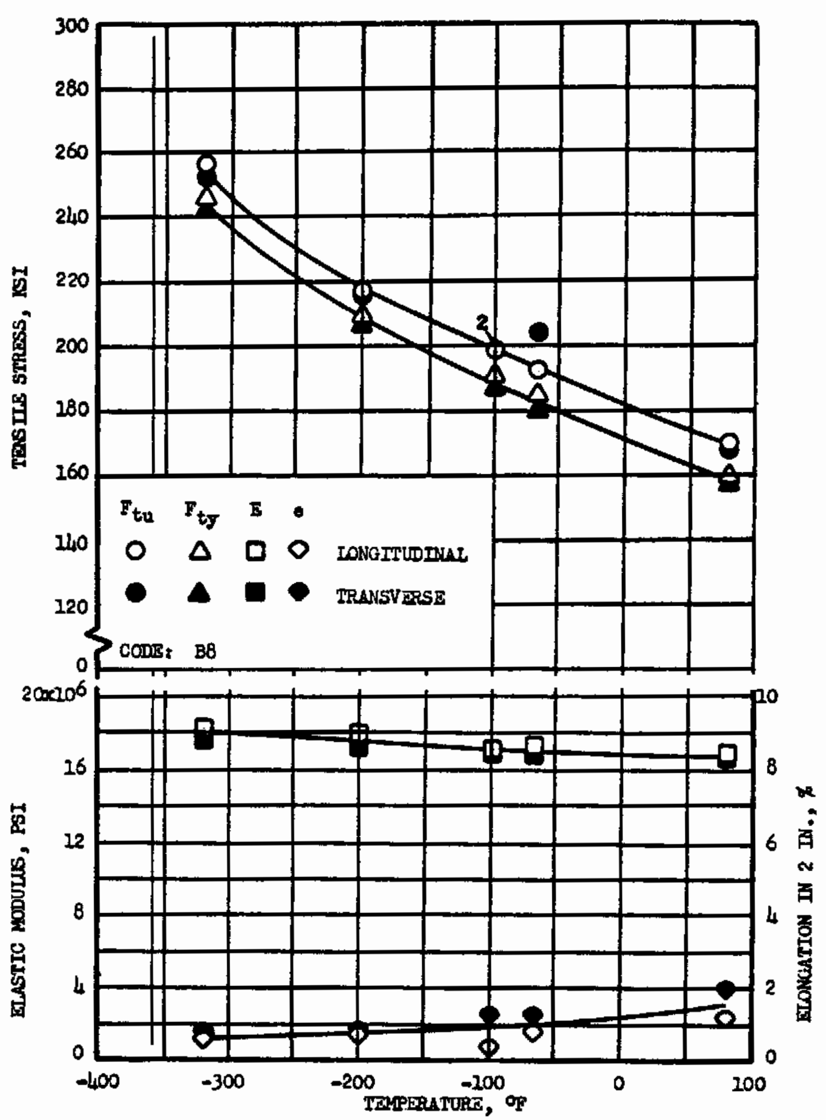


FIGURE 202 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK 6Al-4V TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED PRIOR TO AGING (REACTIVE METALS HEAT NO. 31372)

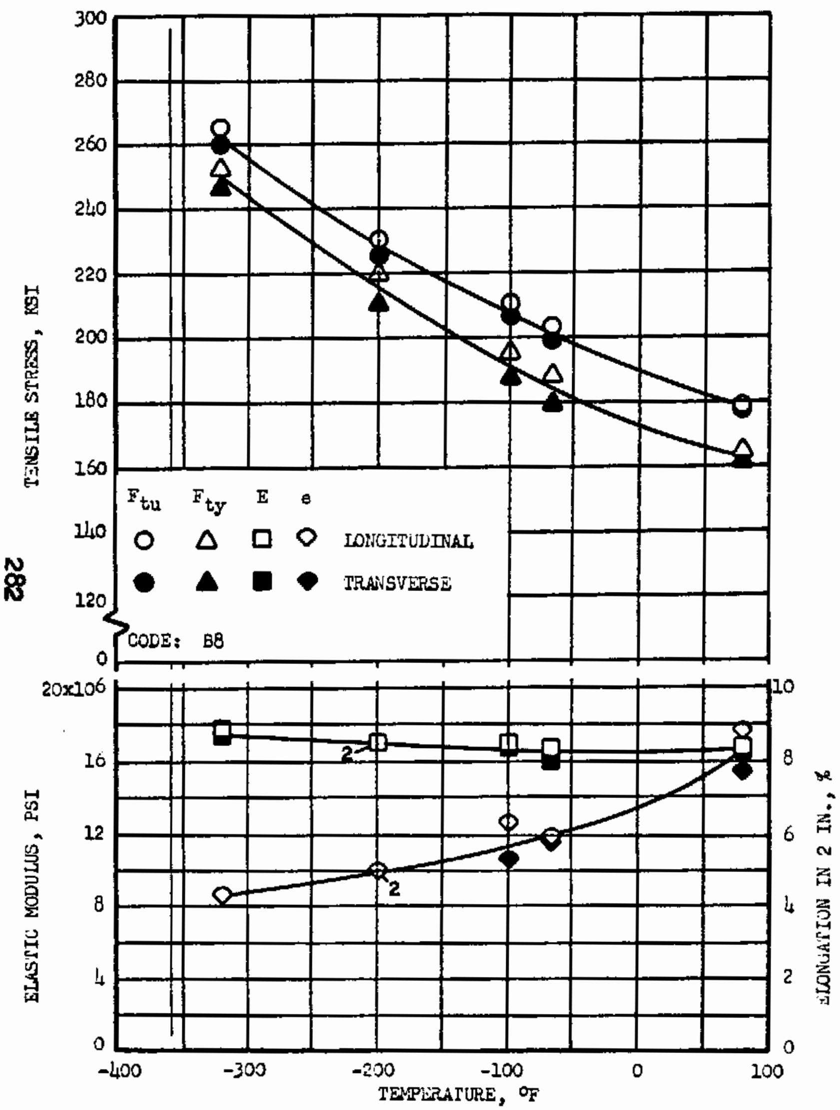


FIGURE 203 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 31372)

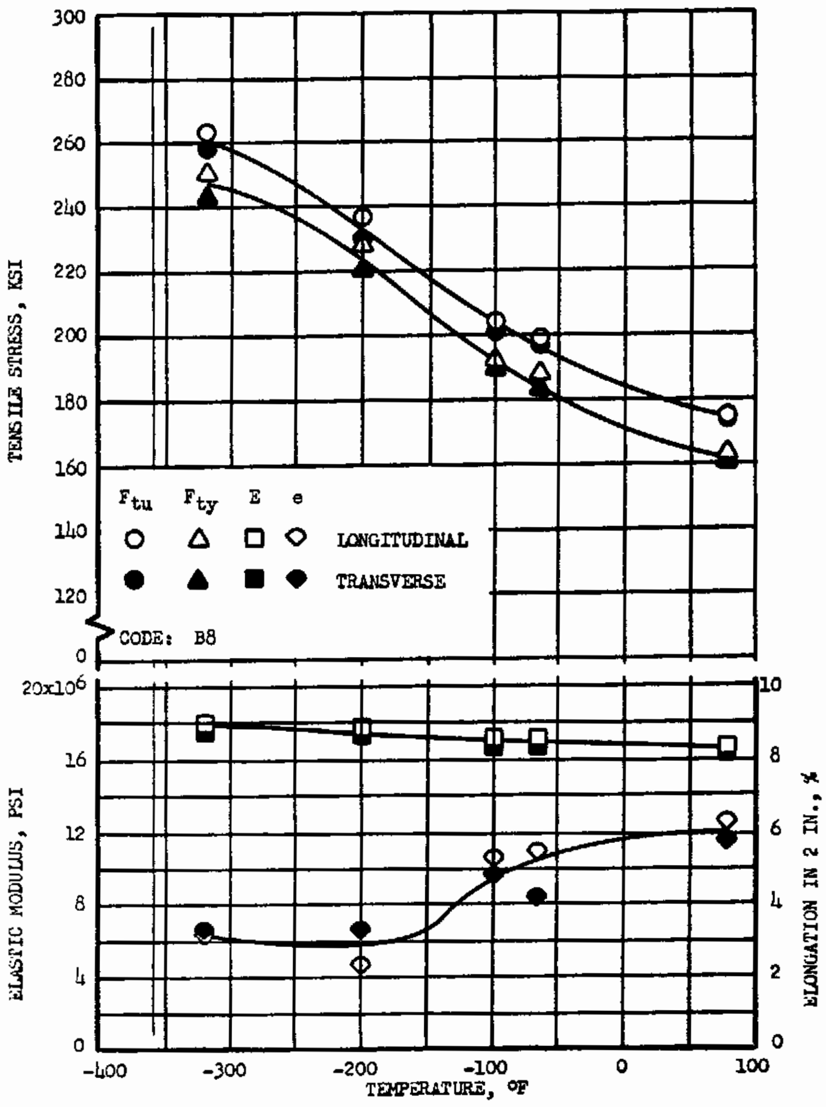


FIGURE 204 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK, AGED BY LOCKHEED (REACTIVE METALS HEAT NO. 31372)

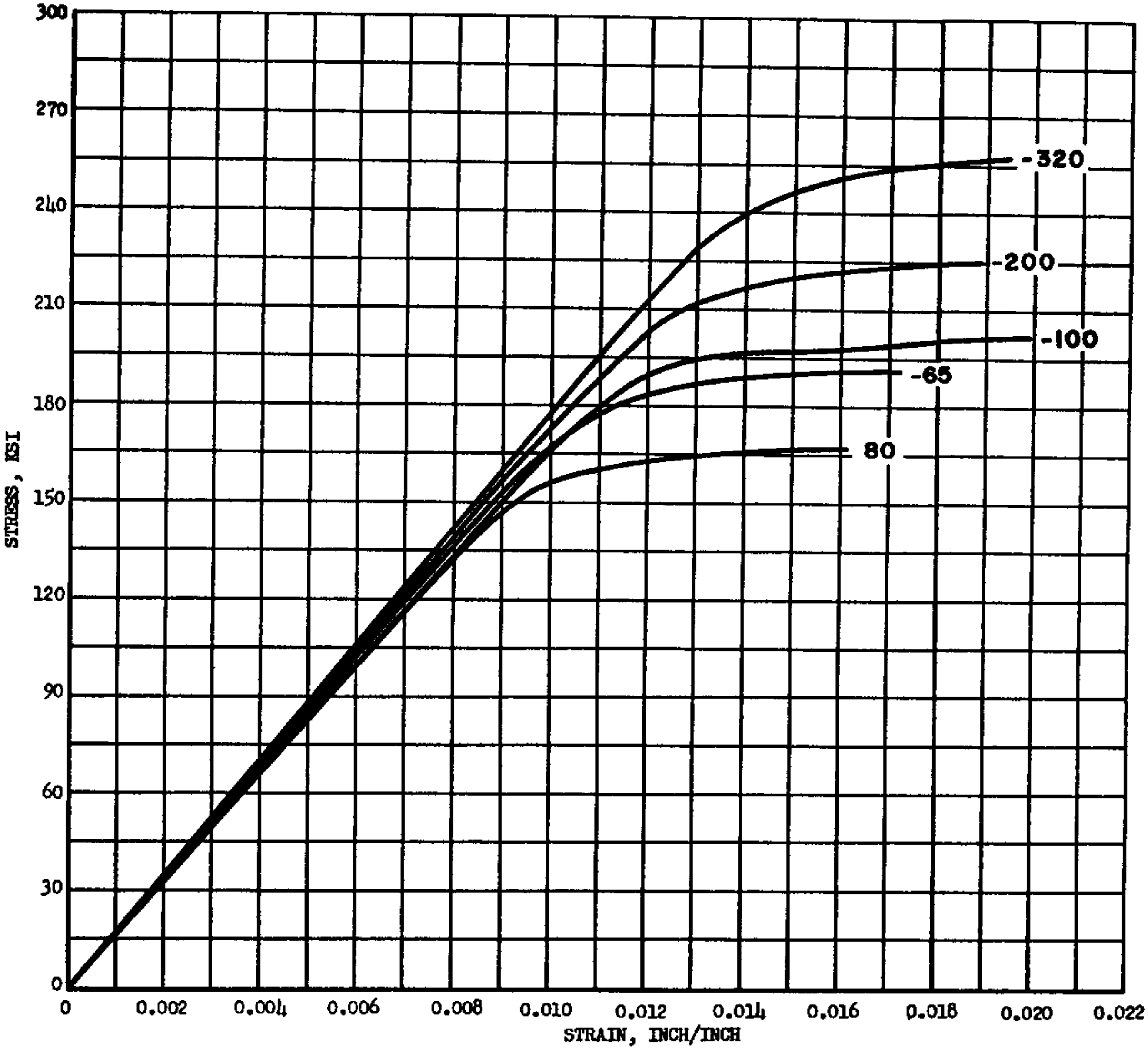


FIGURE 205 - TYPICAL LONGITUDINAL TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 31372)

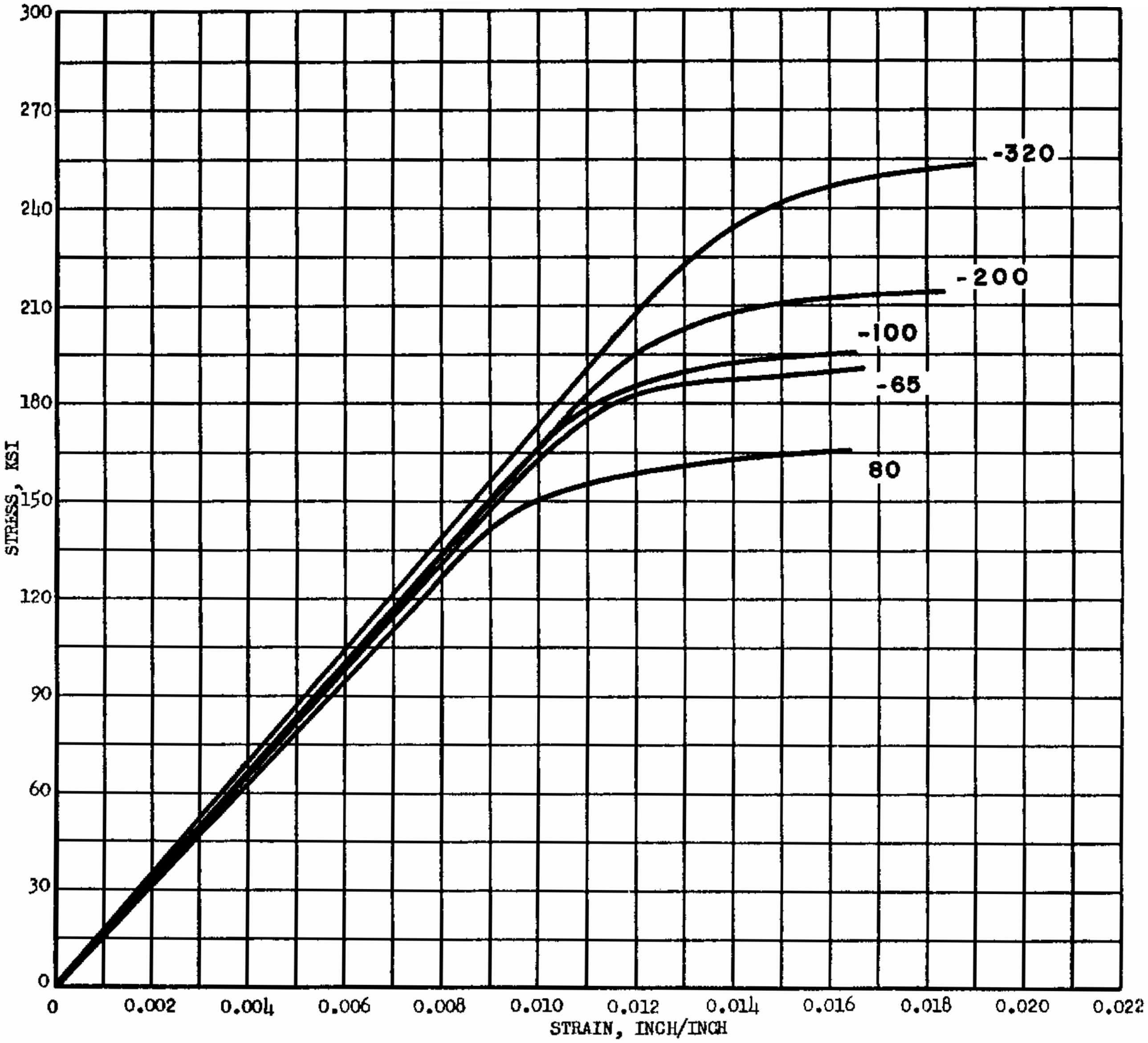
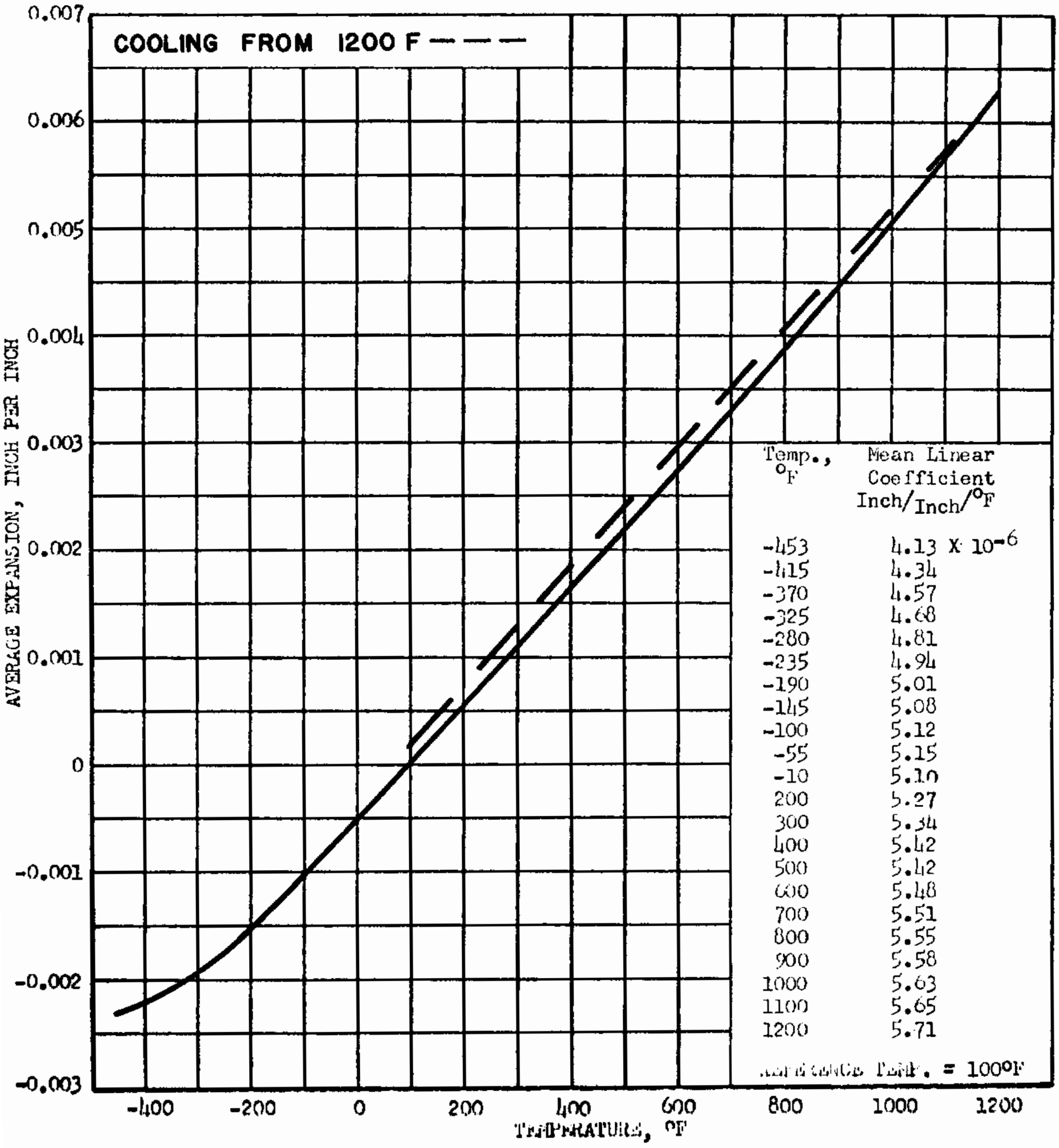


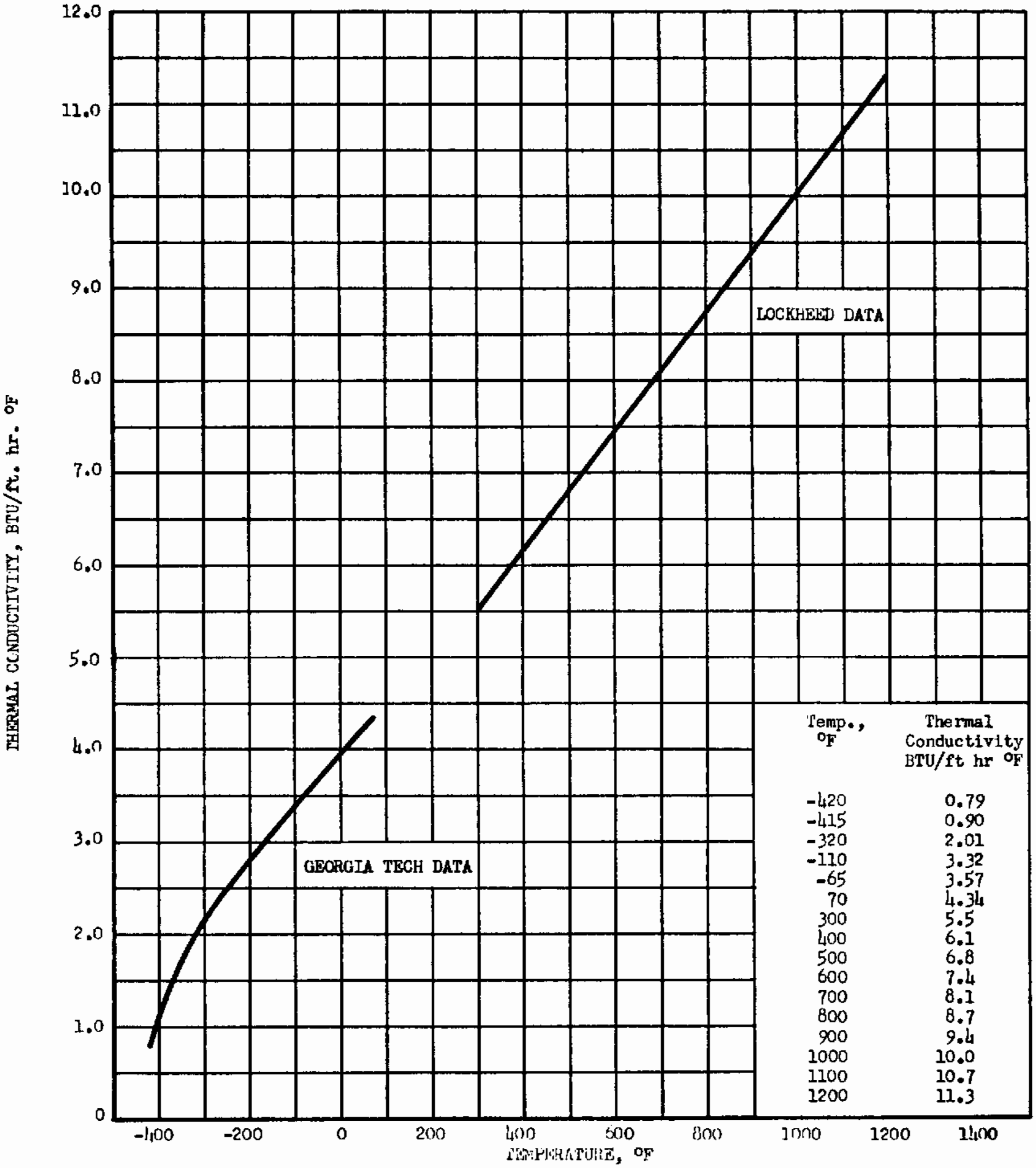
FIGURE 206 - TYPICAL TRANSVERSE TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 31372)



Temp., °F	Mean Linear Coefficient Inch/Inch/°F
-453	4.13 X 10^{-6}
-415	4.34
-370	4.57
-325	4.68
-280	4.81
-235	4.94
-190	5.01
-145	5.08
-100	5.12
-55	5.15
-10	5.10
200	5.27
300	5.34
400	5.42
500	5.42
600	5.48
700	5.51
800	5.55
900	5.58
1000	5.63
1100	5.65
1200	5.71

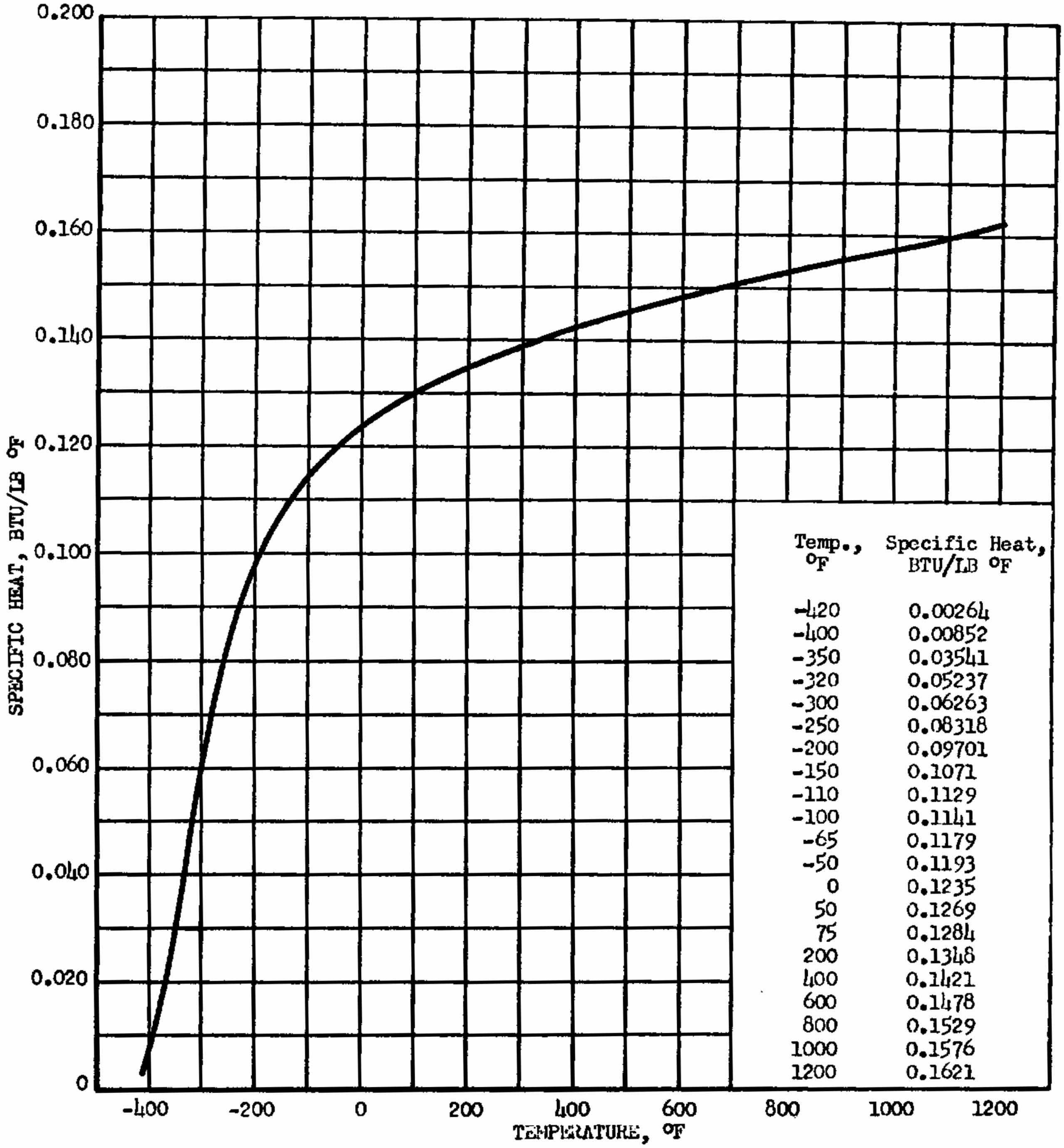
REFERENCE TEMP. = 100°F

FIGURE 207 - AVERAGE EXPANSION VERSUS TEMPERATURE FOR 0.125 INCH THICK 6Al-4V TITANIUM ALLOY SHEET (REACTIVE METALS HEAT NO. 32167, SHEET NO. 1777A-1)



Temp., °F	Thermal Conductivity BTU/ft hr °F
-420	0.79
-415	0.90
-320	2.01
-110	3.32
-65	3.57
70	4.34
300	5.5
400	6.1
500	6.8
600	7.4
700	8.1
800	8.7
900	9.4
1000	10.0
1100	10.7
1200	11.3

FIGURE 208 - THERMAL CONDUCTIVITY VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET (REACTIVE METALS HEAT NO. 32167, SHEET NO. 1777A-1)



Temp., °F	Specific Heat, BTU/LB °F
-420	0.00264
-400	0.00852
-350	0.03541
-320	0.05237
-300	0.06263
-250	0.08318
-200	0.09701
-150	0.1071
-110	0.1129
-100	0.1141
-65	0.1179
-50	0.1193
0	0.1235
50	0.1269
75	0.1284
200	0.1348
400	0.1421
600	0.1478
800	0.1529
1000	0.1576
1200	0.1621

FIGURE 209 - SPECIFIC HEAT VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED 6Al-4V TITANIUM ALLOY SHEET (REACTIVE METALS HEAT NO. 32167, SHEET NO. 1777A-1)

VI - RESULTS FOR 2.5Al-16V TITANIUM ALLOY

Tensile Test Results – Ti-2.5Al-16V

Summary curves for tensile data showing average variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature are presented in Figures 210 through 218. Approximately 500 tests representing seven heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch are summarized by these plots for a temperature range of 80°F to 1000°F. Tabulations of the summarized data along with percent elongation in 1/8 and 1/4 inch are in Tables CXXXIV through CXLII, pages 141 through 149 of Volume 3.

A complete room-temperature stress-strain curve is in Figure 219 and families of typical longitudinal and transverse stress-strain curves and stress versus tangent modulus curves for each thickness are in Volume 1. Volume 1 also contains statistically determined "B" design values for each thickness at room temperature, as well as design curves for elevated temperature.

Variation of Poisson's ratio with longitudinal and transverse tensile strain is shown in Figures 220 through 223 for one heat of 0.063 inch thick sheet. Table LIX contains some additional elastic values of Poisson's ratio for two heats.

Longitudinal and transverse tensile data for approximately 430 specimens from seven heats and three thicknesses which were temperature exposed and temperature-stress exposed are in Tables LX through LXVIII. Included in these data are exposure temperatures of 600°F and 900°F for 500 hours and ten hours, respectively, and exposure stresses equal to 1/3 the ultimate tensile stress at the exposure temperatures. Volume 1 summarizes these data in a manner more practicable for design use.

Compressive Test Results – Ti-2.5Al-16V

Compressive data for six heats from sheets 0.063 inch and 0.125 inch thick are summarized by the curves in Figures 224 through 229 showing average compressive yield stress and elastic modulus versus temperature for the 80°F to 1000°F range. Tabulations of these data, representing approximately 350 tests, along with the Ramberg-Osgood parameters and shape factors are in Tables CXLIII through CXLVIII, pages 150 through 155 of Volume 3.

Typical arrays of longitudinal and transverse compressive stress-strain curves, stress versus tangent modulus curves and stress versus secant modulus curves for the two thicknesses are in Volume 1. Statistically determined "B" design values at room temperature as well as design curves for elevated temperature are also in Volume 1.

Bearing Test Results – Ti-2.5Al-16V

Curves summarizing approximately 1700 bearing tests for e/D ratios of 1.5 and 2.0 and bearing hole diameters of 1/8 inch, 3/16 inch and 5/16 inch are in Figures 230 through 259. These curves show longitudinal and transverse bearing ultimate stress and bearing yield stress versus temperature for the 80°F to 1000°F temperature range, and represent seven heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch. Tabulations of the data are in Tables CXLIX through CLXXVIII, pages 156 through 185 of Volume 3.

Statistically determined "B" design values at room temperature are presented in Volume 1 for both e/D ratios with a 5/16 inch diameter bearing hole. Design curves for elevated temperatures are also in Volume 1 for these same conditions.

Single Shear Test Results - Ti-2.5Al-16V

Single shear data are summarized in Figures 261 through 269 which show variation of longitudinal and transverse ultimate shear strength with temperature for the 80°F to 1000°F range. Data for approximately 500 tests are summarized for seven heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch. Tabulations of the data are in Tables CLXXIX through CLXXXI, pages 186 through 188, Volume 3.

Statistically determined "B" design values for room temperature and design curves for elevated temperatures for each thickness are in Volume 1.

The ductility of Ti-2.5Al-16V at 900°F and 1000°F was of considerable magnitude. Some tests were stopped prior to failure but after the load had dropped almost to zero, and it was found that deformation, as shown in Figure 260, had occurred without fracture. The other alloys did not show evidence of this much deformation in shear.

The micrograph, Figure 260, View B, gives some indication of the width, along the shear plane, of material loaded in shear. The band of deformed grains is on the order of about 1/2 the diameter of the shear-slot terminal holes.

Double Shear Test Results - Ti-2.5Al-16V

Variation of longitudinal and transverse double shear strength with temperature for three heats of 0.125 inch thick sheet is shown by the curves in Figures 270, 271 and 272. The data summarized are for approximately 175 tests for the 80°F to 1000°F temperature range and are in Table CLXXXII, page 189, Volume 3.

Crippling Test Results - Ti-2.5Al-16V

Crippling data obtained over the 80°F to 1000°F temperature range for longitudinal and transverse specimens of two sizes are in Tables LXIX through LXXII. These data represent specimens formed from one heat of 0.063 inch thick solution treated sheet which was aged subsequent to forming. Compressive properties over this temperature range, including Ramberg-Osgood parameters, for specimens from the same solution treated sheets and aged at the same time as the crippling specimens are in Table LXXIII.

Fastener Joint Test Results - Ti-2.5Al-16V

Curves summarizing single fastener lap joint properties obtained for one heat of 0.063 inch thick sheet over the -320°F to 80°F temperature range are in Figures 273 through 276. Screw type and lockbolt type Ti-6Al-4V fasteners of 3/16 inch and 5/16 inch nominal diameters for specimens having an e/D ratio of two and a W/D ratio of five are represented by these data. Tables CCXVI through CCXIX, pages 223 through 226 of Volume 3, contain data tabulations.

Summarized under Low-Temperature Tensile Test Results are tensile data obtained for the same heat and temperature range.

Weld Joint Test Results - Ti-2.5Al-16V

Curves summarizing tensile data obtained for longitudinal and transverse specimens of 0.063 inch thick sheet which was fusion welded in the solution treated condition and subsequently aged are in Figure 277. Variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature for the -320°F to 80°F range are shown by these curves. Tabulations of strength and modulus along with joint efficiencies and percent elongation in 1/8 inch and 1/4 inch are in Table CCXX, page 227, Volume 3.

Tensile data, used as a basis for computing joint efficiency, for the same heat and temperature range are summarized under Low-Temperature Tensile Test Results.

Low-Temperature Tensile Test Results - Ti-2.5Al-16V

Longitudinal and transverse tensile data are summarized in Figures 278 and 279 by curves showing average variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature for the -320°F to 80°F range. Data for two heats of 0.063 inch thick sheet are summarized and are the same heats used for fastener and weld joints. Arrays of typical stress-strain curves for the heat which was aged by the producer are in Figures 280 and 281. Tabulated data are in Tables CCXXI and CCXXII, pages 228 and 229, Volume 3.

Thermal Expansion Measurement Results - Ti-2.5Al-16V

A curve of average expansion versus temperature for the -453°F to 1200°F range is shown in Figure 282 along with mean linear thermal expansion coefficients for several temperatures within the range. Measurements for six specimens are represented, three each for the low and elevated temperature ranges. The expansion curve was irreversible at elevated temperature indicating a phase change had occurred. Results of measurements for each specimen are in Tables CCXXIII and CCXXIV, pages 230 and 231 of Volume 3. The curve in Figure 282 was obtained from these measurements by adjusting the low-temperature data to a reference of 100°F.

Thermal Conductivity Measurement Results - Ti-2.5Al-16V

Variation of thermal conductivity with temperature for the -420°F to 1200°F range is shown in Figure 283 which represents one 0.125 inch thick sheet. Also in this figure are conductivity values at several temperatures in the -420°F to 1200°F range. Elevated-temperature measurements were made by Lockheed and the average of these is represented by the curve in Figure 283. Results obtained for each specimen are in Table CCXXV, page 232, Volume 3.

Measurements for the low-temperature curve were made by Georgia Tech, and the method employed measured the combined conductivity of three specimens. Additional data are in Georgia Tech's report, Reference 13.

Specific Heat Measurement Results - Ti-2.5Al-16V

A curve showing specific heat versus temperature for one 0.125 inch thick sheet is shown in Figure 284. Values of specific heat at several temperatures in the -420°F to 1200°F range are tabulated in this figure. These data are typical for the sheet since a specimen for measurement consisted of several samples from different locations within the sheet. The measurements were made by Georgia Tech, and additional results are in their report, Reference 27.

TABLE LIX

ELASTIC POISSON'S RATIO DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK

Grain Direction	Tensile Specimen Number	Test Temp., °F	Poisson's Ratio
Longitudinal	C5LA1P-1 *	80	.330
	C5LA2P-6 *	200	.299
	C2LA3-13	400	.303
	C5LA3P-1 *	400	.326
	C2LA4-14	600	.309
	C5LA4P-2 *	600	.343
	C2LA6-17	800	.323
	C5LA6P-3 *	800	.334
	C2LA7-5	900	.328
	C2LA7-11	900	.373
	C5LA7P-4 *	900	.349
	C2LA8-2	1000	.358
	C5LA8P-5 *	1000	.362
Transverse	C5TA1P-1 *	80	.328
	C5TA1P-2 *	80	.333
	C2TA2-6	200	.352
	C2TA2-13	200	.311
	C2TA2-15	200	.310
	C5TA2P-6 *	200	.328
	C2TA3-8	400	.322
	C2TA3-16	400	.310
	C2TA3-18	400	.365
	C5TA3P-1 *	400	.308
	C2TA4-1	600	.308
	C2TA4-7	600	.336
	C2TA4-12	600	.336
	C5TA4P-2 *	600	.280
	C2TA6-9	800	.318
	C2TA6-10	800	.326
	C2TA6-17	800	.302
	C2TA7-3	900	.349
	C5TA7P-4 *	900	.344
	C5TA8P-5 *	1000	.363

* Curves are plotted for indicated specimens

TABLE LX - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.—** REACTIVE METALS 22093 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP. °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10⁻⁶, PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	C1LA1B-1 -2 -3 Average	186,000 185,000 193,000 188,000	169,000 168,000 176,000 171,000	15.8 15.8 16.2 15.9	3.0 3.5 3.0 3.2	10 12 6 9	16 16 8 13
				T	C1TA1B-1 -2 -3 Average	184,000 184,000 193,000 187,000	169,000 170,000 178,000 172,000	15.8 16.0 15.9 15.9	2.5 2.0 2.0 2.2	6 8 6 7	8 12 8 9
			600	L	C1LA4B-1 -2 -3 Average	151,000 150,000 156,000 152,000	129,000 131,000 136,000 132,000	13.4 13.8 13.5 13.6	2.5 2.5 2.0 2.3	6 6 6 6	12 12 12 12
				T	C1TA4B-1 -2 -3 Average	150,000 156,000 158,000 155,000	130,000 140,000 137,000 136,000	13.2 13.4 13.2 13.3	2.5 3.0 3.0 2.8	10 12 - 11	- - -
		48,400	80	L	C1LA1A-1 -2 -3 Average	188,000 189,000 194,000 190,000	173,000 - 180,000 176,000	15.7 15.7 15.6 15.7	4.5 3.5 4.5 4.2	12 8 14 11	20 12(1) 24 19
		50,300		T	C1TA1A-1 -2 -3 Average	198,000 200,000 195,000 198,000	185,000 182,000 181,000 183,000	15.8 16.3 15.8 16.0	2.5 2.5 2.0 2.3	12 10 4 9	16 16 8 13
		48,400	600	L	C1LA4A-1 -2 -3 Average	152,000 157,000 156,000 155,000	131,000 135,000 136,000 134,000	15.3 13.8 13.9 14.3	1.5 2.5 3.5 2.5	10 12 10 11	- - -
		50,300		T	C1TA4A-1 -2 -3 Average	160,000 150,000 - 155,000	140,000 135,000 133,000 136,000	13.0 12.5 12.5 12.7	3.0 5.0 - 4.0	10 12 - 11	16 20 -(2) 18
900	10	ZERO	80	L	C1LA1C-1 -2 -3 Average	188,000 188,000 180,000 185,000	176,000 174,000 168,000 173,000	15.6 15.2 15.4 15.4	3.0 3.5 4.5 3.7	10 10 16 12	- - 16
				T	C1TA1C-1 -2 -3 Average	183,000 187,000 183,000 184,000	171,000 180,000 172,000 174,000	15.5 15.9 15.7 15.7	4.0 3.0 4.5 3.8	18 12 16 15	28 28 24 27
			900	L	C1LA7C-1 -2 -3 Average	115,000 116,000 117,000 116,000	70,500 70,300 75,400 72,100	11.6 10.8 7.15 9.8	- - 4.0	- - 18	-(3) - 36
				T	C1TA7C-1 -2 -3 Average	119,000 118,000 115,000 117,000	71,100 77,000 70,800 73,000	8.59 8.54 9.76 8.96	5.0 8.0 7.5 6.8	12 20 10 14	20 28 12 20
		36,000	80	L	C1LA1D-1 -2 -3 Average	186,000 185,000 183,000 185,000	176,000 173,000 173,000 174,000	16.0 15.6 15.6 15.7	3.5 3.5 4.5 3.8	12 14 12 13	24 24 20 23
		37,700		T	C1TA1D-1 -2 -3 Average	181,000 182,000 190,000 184,000	170,000 174,000 182,000 175,000	15.7 15.7 15.6 15.7	3.0 3.0 3.0 3.0	10 10 12 11	12 12 20 15
		36,000	900	L	C1LA7D-1 -2 -3 Average	111,000 114,000 111,000 112,000	73,200 74,600 89,400 79,100	7.15 9.99 8.52 8.55	11.0 5.5 8.0 8.2	24 16 16 19	36 28 20 28
		37,700		T	C1TA7D-1 -2 -3 Average	112,000 115,000 118,000 115,000	83,000 82,100 88,200 84,400	8.74 10.4 9.11 9.42	4.0 2.0 8.0 4.7	4 16 24 15	- 20 32 26

(1) Unusable load-deformation curve beyond elastic portion.
(2) Failed in loading hole.
(3) Failed outside gage marks.

TABLE LXI - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.**— REACTIVE METALS 22154 **SHEET THICKNESS**— 0.063 in.

EXPOSURE CONDITIONS						TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI	TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	ELONGATION, % in .25 IN.	ELONGATION, % in .125 IN.
600	500	ZERO	80	L	C2LA1B-1	182,000	170,000	14.8	6.5	22	32
					-2	173,000	155,000	14.6	7.0	28	36
					-3	182,000	170,000	15.2	5.5	20	28
					Average	179,000	165,000	14.9	6.3	23	32
				T	C2TA1B-1	186,000	174,000	15.2	3.5	20	36
					-2	188,000	177,000	15.2	4.0	20	28
					-3	188,000	178,000	15.8	3.5	18	24
					Average	187,000	176,000	15.4	3.7	19	29
			600	L	C2LA4B-1	151,000	133,000	12.0	5.0	22	36
					-2	142,000	121,000	14.9	5.5	28	48
					-3	154,000	138,000	13.3	5.0	20	36
					Average	149,000	131,000	13.4	5.2	23	40
				T	C2TA4B-1	154,000	138,000	12.7	4.0	20	32
					-2	154,000	136,000	13.2	3.5	16	28
					-3	154,000	139,000	12.5	4.0	20	28
					Average	154,000	138,000	12.8	3.8	19	29
		47,400	80	L	C2LA1A-1	194,000	182,000	15.3	4.5	20	28
					-2	194,000	183,000	15.7	4.5	16	24
					-3	193,000	182,000	15.8	4.5	18	22
					Average	194,000	182,000	15.6	4.5	18	25
		49,600		T	C2TA1A-1	210,000	199,000	15.7	2.5	10	20
					-2	209,000	198,000	15.4	2.5	10	20
					-3	184,000	175,000	15.5	3.0	18	24
					Average	201,000	191,000	15.5	2.7	13	21
		47,400	600	L	C2LA4A-1	159,000	144,000	13.3	3.5	16	36
					-2	147,000	135,000	12.7	5.0	28	-
					-3	147,000	116,000	12.0	5.5	22	40
					Average	151,000	132,000	12.7	4.7	22	38
		49,600		T	C2TA4A-1	148,000	138,000	13.3	5.0	22	44
					-2	149,000	139,000	13.4	4.8	22	36
					-3	149,000	140,000	13.3	5.3	22	40
					Average	149,000	139,000	13.3	5.0	22	40
900	10	ZERO	80	L	C2LA1C-1	194,000	178,000	15.5	5.0	22	36
					-2	187,000	178,000	15.8	5.0	22	36
					-3	176,000	171,000	15.8	6.0	22	36
					Average	186,000	176,000	15.7	5.3	22	36
				T	C2TA1C-1	191,000	181,000	16.1	3.5	20	28
					-2	192,000	183,000	15.2	4.0	20	28
					-3	183,000	176,000	15.7	4.5	22	32
					Average	189,000	180,000	15.7	4.0	21	29
			900	L	C2LA7C-1	114,000	85,000	6.79	13.0	42	-
					-2	101,000	75,700	7.36	20.0	68	92
					-3	114,000	71,200	9.85	13.0	40	56
					Average	110,000	77,300	8.00	15.0	50	74
				T	C2TA7C-1	111,000	87,700	8.05	15.0	44	52
					-2	110,000	87,800	7.90	10.0	38	52
					-3	114,000	89,100	7.96	12.0	34	56
					Average	112,000	88,200	7.97	12.0	39	53
		35,000	80	L	C2LA1D-1	178,000	169,000	15.8	5.0	22	24
					-2	177,000	170,000	15.8	5.5	24	40
					-3	174,000	162,000	15.3	6.0	28	44
					Average	176,000	167,000	15.6	5.5	25	36
		37,700		T	C2TA1D-1	183,000	176,000	15.4	5.5	20	36
					-2	179,000	175,000	15.4	5.0	22	32
					-3	174,000	168,000	15.5	5.5	20	32
					Average	179,000	173,000	15.4	5.3	21	33
		35,000	900	L	C2LA7D-1	109,000	85,000	7.29	13.0	60	80
					-2	102,000	85,600	8.85	13.0	56	72
					-3	104,000	91,600	8.60	-	-	-
					Average	105,000	87,400	8.25	13.0	58	76
		37,700		T	C2TA7D-1	114,000	80,200	8.85	14.0	44	60
					-2	112,000	79,800	8.33	14.0	52	64
					-3	109,000	78,100	8.10	16.0	44	64
					Average	112,000	79,400	8.43	15.0	47	63

TABLE LXII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.—** REACTIVE METALS 23354 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $\times 10^{-6}$, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	C3LA1B-1	189,000	177,000	16.0	3.5	12	28
					-2	188,000	175,000	14.8	5.0	20	24
					-3	189,000	178,000	15.4	4.5	20	28
					Average	189,000	177,000	15.4	4.3	17	27
				T	C3TA1B-1	192,000	179,000	14.8	5.0	18	24
					-2	192,000	178,000	14.7	5.0	20	24
					-3	195,000	182,000	15.0	4.5	16	28
					Average	193,000	180,000	14.8	4.8	18	25
			600	L	C3LA4B-1	158,000	141,000	11.4	4.0	26	28
					-2	158,000	141,000	13.0	5.0	24	40
					-3	159,000	141,000	12.5	4.5	20	40
					Average	158,000	141,000	12.3	4.5	23	36
				T	C3TA4B-1	159,000	143,000	12.9	4.5	20	36
					-2	160,000	140,000	13.2	5.0	20	40
					-3	159,000	142,000	13.6	5.5	24	40
					Average	159,000	142,000	13.2	5.0	21	39
		50,300	80	L	C3LA1A-1	193,000	183,000	14.8	-	-	-
					-2	190,000	182,000	14.7	-	-	-
					-3	196,000	191,000	16.0	3.0	12	12
					Average	193,000	185,000	15.2			
		52,300		T	C3TA1A-1	200,000	187,000	15.2	3.5	12	-
					-2	200,000	189,000	15.0	4.0	-	-
					-3	196,000	184,000	15.5	5.0	20	32
					Average	199,000	187,000	15.2	4.2	16	
		50,300	600	L	C3LA4A-1	162,000	147,000	13.3	3.0	24	36
					-2	166,000	153,000	13.1	3.0	24	-
					-3	164,000	151,000	13.1	-	-	-
					Average	164,000	150,000	13.2	3.0	24	
		52,300		T	C3TA4A-1	167,000	150,000	13.2	5.0	20	28
					-2	164,000	150,000	13.1	5.0	20	36
					-3	171,000	-	13.2	6.0	18	36(1)
					Average	167,000	150,000	13.2	5.3	19	33
900	10	ZERO	80	L	C3LA1C-1	178,000	164,000	14.6	5.5	22	28
					-2	176,000	166,000	15.7	4.5	24	28
					-3	179,000	168,000	14.9	6.5	16	20
					Average	178,000	166,000	15.1	5.5	21	25
				T	C3TA1C-1	190,000	180,000	15.3	4.5	16	28
					-2	190,000	180,000	15.7	4.0	16	28
					-3	186,000	176,000	15.6	4.5	18	20
					Average	189,000	179,000	15.5	4.3	17	25
			900	L	C3LA7C-1	109,000	66,400	7.83	25.0	100	160
					-2	105,000	73,900	8.16	18.0	70	100
					-3	108,000	76,800	8.77	18.0	76	116
					Average	107,000	72,400	8.25	20.0	82	125
				T	C3TA7C-1	118,000	77,000	9.09	22.0	76	112
					-2	115,000	71,100	8.48	22.0	80	-
					-3	119,000	76,700	7.94	20.0	76	112
					Average	118,000	74,900	8.50	21.0	77	112
		34,300	80	L	C3LA1D-1	184,000	177,000	15.3	5.5	16	24
					-2	186,000	180,000	15.2	5.0	20	36
					-3	-	-	-	-	-	-(2)
					Average	185,000	178,000	15.2	5.2	18	30
		35,700		T	C3TA1D-1	193,000	187,000	15.2	3.5	12	16
					-2	193,000	186,000	15.2	3.0	16	24
					-3	192,000	185,000	15.3	3.5	14	20
					Average	193,000	186,000	15.2	3.3	14	20
		34,300	900	L	C3LA7D-1	107,000	86,000	8.72	8.0	46	74
					-2	106,000	81,500	9.00	16.0	60	76
					-3	99,400	76,200	8.06	17.0	68	-
					Average	104,000	81,200	8.59	14.0	58	75
		35,700		T	C3TA7D-1	114,000	76,900	8.84	17.0	64	84
					-2	118,000	75,400	8.62	19.0	90	160
					-3	116,000	74,500	9.48	23.0	100	156
					Average	116,000	75,600	8.98	20.0	85	133

(1) Unusable load-deformation curve beyond proportional limit.
(2) Specimen rejected on inspection.

TABLE LXIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V HEAT NO.— REACTIVE METALS 24990 SHEET THICKNESS— 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{6}, PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	C4LA1B-1	178,000	162,000	15.3	3.5	10	12
					-2	189,000	170,000	16.0	4.0	8	12
					-3	184,000	168,000	16.2	3.5	8	12
					Average	184,000	167,000	15.8	3.7	9	12
				T	C4TA1B-1	193,000	176,000	16.2	3.0	8	12
					-2	193,000	180,000	16.5	3.5	8	12
					-3	184,000	170,000	16.6	3.5	8	12
					Average	190,000	175,000	16.4	3.3	8	12
			600	L	C4LA4B-1	154,000	133,000	13.2	2.0	8	12
					-2	150,000	127,000	14.5	2.5	8	12
					-3	150,000	128,000	13.8	2.0	8	12
					Average	151,000	129,000	13.8	2.2	8	12
				T	C4TA4B-1	155,000	135,000	13.6	3.5	-	-
					-2	149,000	128,000	13.5	3.5	14	-
					-3	150,000	129,000	14.6	2.5	12	-
					Average	151,000	131,000	13.9	3.2	13	
		50,300	80	L	C4LA1A-1	194,000	177,000	16.1	4.0	16	-
					-2	189,000	174,000	15.5	3.5	12	20
					-3	188,000	176,000	15.6	3.0	8	12
					Average	190,000	176,000	15.7	3.5	12	16
		50,700		T	C4TA1A-1	190,000	178,000	15.7	4.0	10	12
					-2	188,000	175,000	15.4	3.0	11	20
					-3	186,000	172,000	15.6	4.5	12	-
					Average	188,000	175,000	15.6	3.8	11	16
		50,300	600	L	C4LA4A-1	156,000	135,000	13.9	3.5	-	-
					-2	150,000	132,000	13.0	2.0	12	-
					-3	151,000	132,000	13.3	2.5	10	-
					Average	152,000	133,000	13.4	2.7	11	
		50,700		T	C4TA4A-1	151,000	129,000	13.6	2.5	10	-
					-2	152,000	131,000	13.9	3.0	12	-
					-3	151,000	129,000	12.9	2.5	12	20
					Average	151,000	130,000	13.5	2.7	11	
900	10	ZERO	80	L	C4LA1C-1	183,000	169,000	15.4	4.5	14	20
					-2	182,000	168,000	15.3	5.5	10	16
					-3	178,000	169,000	15.6	5.0	10	20
					Average	181,000	169,000	15.4	5.0	11	19
				T	C4TA1C-1	180,000	168,000	15.4	5.5	16	28
					-2	181,000	169,000	15.2	4.5	10	12
					-3	183,000	171,000	15.5	4.5	12	20
					Average	181,000	169,000	15.4	4.8	13	20
			900	L	C4LA7C-1	118,000	72,400	8.95	8.0	16	24
					-2	116,000	79,300	9.65	4.0	14	20
					-3	116,000	69,700	9.43	4.0	10	20
					Average	117,000	73,800	9.34	5.3	13	21
				T	C4TA7C-1	115,000	75,400	8.60	9.5	26	44
					-2	115,000	73,900	10.0	9.0	26	36
					-3	121,000	79,500	10.8	5.0	16	28
					Average	117,000	76,300	9.80	7.8	23	36
		38,000	80	L	C4LA1D-1	183,000	173,000	16.1	4.0	14	16
					-2	184,000	173,000	15.6	4.0	12	16
					-3	181,000	173,000	16.4	4.0	14	20
					Average	183,000	173,000	16.0	4.0	13	17
		37,000		T	C4TA1D-1	188,000	177,000	15.8	4.0	12	16
					-2	188,000	177,000	15.9	4.0	12	16
					-3	182,000	170,000	15.9	5.0	12	16
					Average	186,000	174,000	15.9	4.3	12	16
		38,000	900	L	C4LA7D-1	115,000	83,500	9.19	9.0	12	36
					-2	116,000	83,700	9.12	7.0	16	28
					-3	112,000	83,200	8.88	9.0	16	32
					Average	114,000	83,500	9.06	8.3	15	32
		37,000		T	C4TA7D-1	119,000	87,800	8.45	9.0	16	20
					-2	116,000	87,300	8.65	7.0	12	16
					-3	115,000	84,500	9.54	10.0	16	16
					Average	117,000	86,500	8.88	8.66	15	17

TABLE LXIV - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.—** REACTIVE METALS 24806 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10-6, PSI	ELONGATION, % in 2 IN.	ELONGATION, % in .25 IN.	ELONGATION, % in .125 IN.
600	500	ZERO	80	L	C5LA1B-1	212,000	198,000	15.7	5.0	18	28
					-2	211,000	200,000	15.2	4.0	16	24
					-3	220,000	208,000	15.8	2.8	14	24
					Average	214,000	202,000	15.6	3.9	16	25
				T	C5TA1B-1	214,000	202,000	15.7	4.0	14	40
					-2	213,000	200,000	15.2	3.3	20	36
					-3	192,000	180,000	15.0	5.0	20	32
					Average	206,000	194,000	15.3	4.1	18	36
			600	L	C5LA4B-1	168,000	152,000	14.1	4.5	12	20
					-2	166,000	147,000	13.0	4.0	20	28
					-3	166,000	148,000	11.0	4.5	16	20
					Average	167,000	149,000	12.7	4.3	16	23
				T	C5TA4B-1	175,000	160,000	12.9	-	-	-
					-2	171,000	155,000	13.3	3.5	16	28
					-3	167,000	150,000	12.4	3.5	20	36
					Average	171,000	155,000	12.9	3.5	18	32
		50,700	80	L	C5LA1A-1	222,000	211,000	16.4	2.5	12	-
					-2	214,000	203,000	15.7	3.0	6	16
					-3	202,000	192,000	15.6	3.5	14	20
					Average	213,000	202,000	15.9	3.0	11	18
		51,600		T	C5TA1A-1	215,000	203,000	16.0	-	-	-
					-2	215,000	204,000	16.0	6.0	12	20
					-3	208,000	196,000	15.7	3.5	16	20
					Average	213,000	201,000	15.9	4.8	14	20
		50,700	600	L	C5LA4A-1	175,000	161,000	13.5	3.0	16	24
					-2	165,000	149,000	13.5	4.0	20	28
					-3	171,000	148,000	12.8	3.5	20	40
					Average	170,000	153,000	13.3	3.5	19	31
		51,600		T	C5TA4A-1	171,000	162,000	12.9	1.5	34	-
					-2	165,000	154,000	13.7	3.5	-	-
					-3	163,000	148,000	12.7	4.0	-	-
					Average	166,000	155,000	13.1	3.0		
900	10	ZERO	80	L	C5LA1C-1	183,000	174,000	15.5	7.0	28	48
					-2	204,000	191,000	15.1	3.5	12	20
					-3	183,000	173,000	15.0	6.0	-	-
					Average	190,000	179,000	15.2	4.8	20	34
				T	C5TA1C-1	206,000	193,000	15.3	3.0	18	20
					-2	206,000	195,000	15.0	3.0	18	24
					-3	182,000	171,000	15.6	6.0	22	28
					Average	198,000	186,000	15.3	4.0	19	24
			900	L	C5LA7C-1	120,000	82,800	7.94	14.0	46	56
					-2	109,000	83,100	7.27	18.0	62	92
					-3	110,000	82,900	7.67	16.0	52	76
					Average	113,000	82,900	7.63	16.0	53	75
				T	C5TA7C-1	116,000	82,800	8.15	14.0	44	60
					-2	110,000	85,100	8.44	12.0	28	-
					-3	113,000	85,100	8.74	12.0	46	60
					Average	113,000	84,300	8.44	13.0	39	60
		39,000	80	L	C5LA1D-1	179,000	173,000	15.6	8.0	46	74
					-2	177,000	173,000	16.1	16.0	60	76
					-3	182,000	173,000	15.8	17.0	68	-
					Average	179,000	173,000	15.8	14.0	58	75
		36,700		T	C5TA1D-1	188,000	182,000	15.8	3.5	18	32
					-2	181,000	182,000	15.8	4.5	18	36
					-3	189,000	178,000	16.0	5.5	22	40
					Average	186,000	181,000	15.9	4.5	19	39
		39,000	900	L	C5LA7D-1	110,000	76,600	7.30	19.0	66	106
					-2	113,000	73,400	8.08	18.0	60	84
					-3	111,000	74,600	6.99	17.0	56	92
					Average	111,000	74,900	7.46	18.0	61	94
		36,700		T	C5TA7D-1	113,000	79,600	8.25	13.0	46	60
					-2	113,000	71,400	7.52	20.0	66	92
					-3	110,000	63,600	10.5	24.0	84	120
					Average	112,000	71,500	8.76	19.0	65	91

TABLE LXV - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.—** REACTIVE METALS 23372 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS						TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI	TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10⁻⁶, PSI	ELONGATION, % in 2 IN.	ELONGATION, % in .25 IN.	ELONGATION, % in .125 IN.
600	500	ZERO	80	L	C6LA1B-1	200,000	174,000	14.7	6.0	22	-
					-2	186,000	175,000	14.6	6.0	22	32
					-3	185,000	177,000	14.6	5.5	20	24
					Average	190,000	175,000	14.6	5.8	21	28
				T	C6TA1B-1	188,000	177,000	14.8	5.0	20	24
					-2	183,000	173,000	14.1	5.5	18	28
					-3	188,000	179,000	14.8	5.0	18	28
					Average	186,000	176,000	14.6	5.2	19	27
			600	L	C6LA4B-1	154,000	137,000	14.0	6.0	30	40
					-2	158,000	140,000	14.1	5.5	26	40
					-3	-	-	-	-	-	-(1)
					Average	156,000	138,000	14.0	5.8	28	40
				T	C6TA4B-1	155,000	141,000	13.1	5.5	28	40
					-2	151,000	137,000	13.3	6.0	26	40
					-3	152,000	135,000	11.9	5.0	32	40
					Average	153,000	138,000	12.8	5.5	29	40
		49,300	80	L	C6LA1A-1	196,000	187,000	14.8	2.5	16	-
					-2	194,000	184,000	14.9	3.0	-	-
					-3	193,000	184,000	14.8	3.5	20	28
					Average	194,000	185,000	14.8	3.0	18	
		49,300		T	C6TA1A-1	198,000	190,000	14.8	3.0	12	20
					-2	198,000	191,000	14.4	3.0	12	22
					-3	183,000	175,000	14.9	4.5	24	28
					Average	193,000	185,000	14.7	3.5	16	23
		49,300	600	L	C6LA4A-1	163,000	151,000	12.3	4.0	20	32
					-2	162,000	147,000	13.4	4.0	26	44
					-3	160,000	149,000	12.0	4.0	20	32
					Average	162,000	149,000	12.6	4.0	22	36
		49,300		T	C6TA4A-1	161,000	147,000	12.8	4.5	22	32
					-2	150,000	137,000	12.4	5.5	36	48
					-3	151,000	137,000	11.4	5.0	28	44
					Average	154,000	140,000	12.4	5.0	29	41
900	10	ZERO	80	L	C6LA1C-1	171,000	162,000	14.8	7.5	28	40
					-2	180,000	170,000	14.7	7.5	22	28
					-3	183,000	174,000	14.8	5.5	24	32
					Average	178,000	169,000	14.8	6.8	25	33
				T	C6TA1C-1	180,000	171,000	15.2	5.5	24	28
					-2	180,000	173,000	15.1	6.0	22	36
					-3	186,000	175,000	15.2	4.0	16	24
					Average	182,000	173,000	15.2	5.2	21	29
			900	L	C6LA7C-1	107,000	67,900	7.43	19.0	84	116
					-2	107,000	-	-	20.0	84	132(2)
					-3	111,000	67,600	8.11	15.0	60	76
					Average	108,000	67,800	7.77	18.0	76	108
				T	C6TA7C-1	109,000	73,400	8.83	20.0	80	132
					-2	111,000	79,100	9.12	18.0	72	-
					-3	104,000	85,400	9.34	17.0	60	92
					Average	108,000	79,300	9.10	18.0	71	112
		35,300	80	L	C6LA1D-1	179,000	173,000	15.1	5.0	22	32
					-2	180,000	174,000	15.3	5.5	18	24
					-3	181,000	178,000	14.7	5.0	20	28
					Average	181,000	175,000	15.0	5.2	20	28
		35,000		T	C6TA1D-1	186,000	179,000	15.1	4.5	16	28
					-2	187,000	181,000	15.3	5.0	18	28
					-3	183,000	175,000	15.0	5.5	26	32
					Average	185,000	178,000	15.1	5.0	20	29
		35,300	900	L	C6LA7D-1	104,000	84,400	9.06	12.0	56	92
					-2	102,000	80,700	7.68	-	-	-
					-3	116,000	102,000	10.0	16.0	56	80
					Average	107,000	89,000	8.91	14.0	56	86
		35,000		T	C6TA7D-1	118,000	74,600	8.28	16.0	92	132
					-2	114,000	-	-	20.0	96	188(2)
					-3	114,000	74,500	9.67	20.0	84	-
					Average	115,000	74,600	8.98	19.0	91	160

(1) Failed outside test section.
(2) Unusable load-deformation curve.

TABLE LXVI - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.**— REACTIVE METALS 24814 **SHEET THICKNESS**— 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	C7LA1B-1	186,000	170,000	16.2	4.0	8	12
					-2	186,000	169,000	15.8	4.0	12	16
					-3	189,000	169,000	16.2	3.0	10	12
					Average	187,000	169,000	16.1	3.7	10	13
				T	C7TA1B-1	194,000	173,000	16.5	3.0	8	12
					-2	190,000	173,000	16.2	3.5	12	12
					-3	188,000	169,000	16.1	4.0	12	16
					Average	191,000	172,000	16.3	3.5	11	13
			600	L	C7LA4B-1	151,000	131,000	14.1	2.0	6	12
					-2	149,000	133,000	12.3	2.0	6	8
					-3	152,000	133,000	14.5	2.0	8	16
					Average	151,000	132,000	13.6	2.0	7	12
				T	C7TA4B-1	155,000	134,000	12.8	3.0	12	16
					-2	154,000	132,000	13.6	2.5	8	16
					-3	152,000	128,000	13.4	2.5	8	16
					Average	154,000	131,000	13.3	2.7	9	16
		50,000	80	L	C7LA1A-1	189,000	175,000	16.1	3.0	8	12
					-2	190,000	175,000	16.4	3.5	8	12
					-3	197,000	177,000	16.2	3.5	12	16
					Average	192,000	176,000	16.2	3.3	9	13
		50,000		T	C7TA1A-1	195,000	178,000	16.6	4.0	12	20
					-2	195,000	177,000	16.2	3.5	8	12
					-3	190,000	173,000	16.3	2.5	12	12
					Average	193,000	176,000	16.4	3.3	11	15
		50,000	600	L	C7LA4A-1	157,000	136,000	12.5	2.0	10	20
					-2	152,000	135,000	14.1	-	-	-
					-3	154,000	134,000	14.0	2.0	6	8
					Average	154,000	135,000	13.5	2.0	8	14
		50,000		T	C7TA4A-1	157,000	136,000	13.8	2.0	6	12
					-2	154,000	133,000	13.4	3.5	12	16
					-3	151,000	131,000	13.4	3.0	10	20
					Average	154,000	133,000	13.5	2.8	9	16
900	10	ZERO	80	L	C7LA1C-1	181,000	169,000	15.8	3.5	14	24
					-2	182,000	169,000	15.6	4.5	10	12
					-3	182,000	168,000	16.0	3.5	10	16
					Average	182,000	169,000	15.8	3.8	11	17
				T	C7TA1C-1	180,000	169,000	15.8	4.5	16	28
					-2	180,000	173,000	15.1	6.0	14	20
					-3	205,000	168,000	16.0	4.5	14	28
					Average	188,000	170,000	15.6	5.0	15	25
			900	L	C7LA7C-1	118,000	79,200	9.71	9.0	24	32
					-2	118,000	79,500	9.78	6.0	20	36
					-3	119,000	82,000	10.4	4.5	20	28
					Average	118,000	80,200	9.96	6.5	21	32
				T	C7TA7C-1	123,000	82,500	9.51	10.0	22	44
					-2	120,000	78,800	8.90	-	-	-
					-3	124,000	80,200	10.5	6.0	16	28
					Average	122,000	80,500	9.64	8.0	19	36
		36,000	80	L	C7LA1D-1	180,000	170,000	15.7	3.5	10	12
					-2	180,000	169,000	15.7	4.0	12	24
					-3	176,000	166,000	15.9	4.0	12	24
					Average	179,000	168,000	15.8	3.8	11	20
		35,300		T	C7TA1D-1	179,000	169,000	16.0	5.0	12	24
					-2	179,000	168,000	15.8	3.0	12	24
					-3	178,000	169,000	16.0	4.0	14	24
					Average	179,000	169,000	15.9	4.0	13	24
		36,000	900	L	C7LA7D-1	112,000	82,100	9.46	10.0	20	20
					-2	109,000	84,200	8.24	5.5	6	20
					-3	-	-	-	-	-	-(1)
					Average	110,000	83,200	8.85	7.8	4	20
		35,300		T	C7TA7D-1	110,000	76,000	9.31	8.0	16	-
					-2	111,000	76,100	10.7	10.0	24	28
					-3	109,000	-	-	9.5	16	28(2)
					Average	110,000	76,000	10.0	9.2	19	28

(1) Specimen rejected on inspection.
(2) Unusable load-deformation curve.

TABLE LXVII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.—** REACTIVE METALS 24814 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	ELONGATION, % in .25 IN.	ELONGATION, % in .125 IN.
600	500	ZERO	80	L	C8LA1B-1	185,000	173,000	15.0	6.0	18	24
					-2	185,000	172,000	14.9	5.5	24	28
					-3	179,000	163,000	15.8	6.0	24	32
					Average	183,000	169,000	15.2	5.8	22	28
				T	C8TA1B-1	196,000	183,000	15.6	4.5	20	24
					-2	195,000	183,000	15.2	4.0	14	28
					-3	197,000	185,000	15.4	4.0	10	16
					Average	196,000	184,000	15.4	4.2	15	23
			600	L	C8LA4B-1	145,000	125,000	12.5	5.5	26	44
					-2	148,000	127,000	12.9	5.0	24	36
					-3	149,000	129,000	13.3	5.0	24	44
					Average	147,000	127,000	12.9	5.2	25	41
				T	C8TA4B-1	149,000	127,000	13.0	4.0	24	36
					-2	148,000	132,000	11.7	5.0	24	44
					-3	147,000	120,000	11.3	4.5	24	44
					Average	148,000	126,000	12.0	4.5	24	41
		50,300	80	L	C8LA1A-1	185,000	172,000	15.2	5.5	22	32
					-2	184,000	171,000	15.3	4.5	20	36
					-3	192,000	178,000	15.4	4.0	20	28
					Average	187,000	174,000	15.3	4.7	21	32
		50,000		T	C8TA1A-1	190,000	177,000	15.5	3.5	14	24
					-2	190,000	176,000	15.1	4.0	24	40
					-3	190,000	174,000	15.0	4.0	18	-
					Average	190,000	176,000	15.2	3.8	19	32
		50,300	600	L	C8LA4A-1	149,000	130,000	13.5	5.0	26	44
					-2	151,000	132,000	13.0	5.0	22	32
					-3	149,000	135,000	12.3	6.0	24	40
					Average	150,000	132,000	12.9	5.3	24	39
		50,000		T	C8TA4A-1	153,000	133,000	12.7	4.0	24	28
					-2	149,000	-	-	4.0	20	28(1)
					-3	152,000	132,000	13.7	4.0	18	28
					Average	151,000	132,000	13.2	4.0	21	28
900	10	ZERO	80	L	C8LA1C-1	178,000	167,000	15.2	5.5	16	32
					-2	180,000	168,000	15.0	6.0	24	32
					-3	178,000	167,000	14.9	7.0	30	36
					Average	179,000	167,000	15.0	6.2	23	33
				T	C8TA1C-1	181,000	170,000	16.0	6.5	22	32
					-2	180,000	169,000	15.1	5.0	20	20
					-3	178,000	167,000	15.3	7.5	24	40
					Average	180,000	169,000	15.5	6.3	22	31
			900	L	C8LA7C-1	115,000	74,000	7.66	18.0	64	108
					-2	104,000	83,500	8.12	-	-	-
					-3	111,000	69,200	8.75	16.0	62	93
					Average	110,000	75,600	8.18	17.0	63	100
				T	C8TA7C-1	113,000	83,000	8.37	14.0	40	-
					-2	116,000	85,200	8.48	14.0	38	64
					-3	116,000	85,000	7.88	11.0	44	56
					Average	115,000	84,400	8.24	13.0	41	60
		40,000	80	L	C8LA1D-1	178,000	171,000	15.1	7.0	22	32
					-2	178,000	170,000	14.9	7.0	26	36
					-3	171,000	163,000	15.0	7.0	26	40
					Average	176,000	168,000	15.0	7.0	25	36
		39,000		T	C8TA1D-1	172,000	167,000	15.1	6.5	26	36
					-2	173,000	167,000	15.0	6.5	26	40
					-3	178,000	174,000	14.9	5.0	24	24
					Average	174,000	169,000	15.0	6.0	25	33
		40,000	900	L	C9LA7D-1	113,000	79,800	8.08	14.0	40	68
					-2	109,000	81,800	7.54	18.0	68	128
					-3	101,000	75,900	8.92	17.0	-	-
					Average	108,000	79,200	8.18	16.0	54	98
		39,000		T	C8TA7D-1	118,000	90,900	8.27	-	52	84
					-2	113,000	77,200	9.21	17.0	54	76
					-3	116,000	75,300	8.80	17.0	70	-
					Average	116,000	81,100	8.76	17.0	59	80

(1) Unusable load-deformation curve.

TABLE LXVIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-2.5Al-16V **HEAT NO.—** REACTIVE METALS 23345 **SHEET THICKNESS—** 0.125 in.

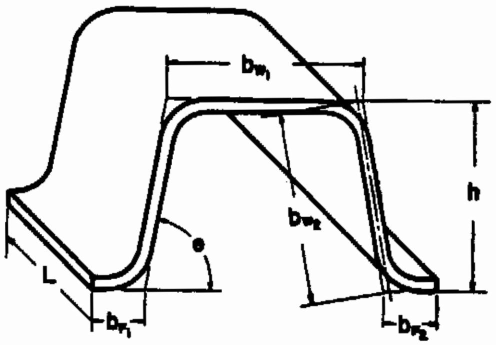
EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP. °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $X10^{-6}$ PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	C9LA1B-1	183,000	163,000	14.8	7.0	-	-
					-2	183,000	162,000	15.1	6.5	16	28
					-3	188,000	165,000	14.6	7.0	24	40
					Average	185,000	163,000	14.8	6.8	20	34
				T	C9TA1B-1	192,000	184,000	16.2	5.0	16	-
					-2	192,000	178,000	15.4	5.5	18	24
					-3	193,000	184,000	15.5	5.0	20	28
					Average	192,000	182,000	15.7	5.2	18	26
			600	L	C9LA4B-1	145,000	120,000	10.8	6.0	-	-
					-2	142,000	121,000	12.4	6.3	26	36
					-3	150,000	124,000	12.2	6.8	22	36
					Average	146,000	122,000	11.8	6.4	24	36
				T	C9TA4B-1	158,000	136,000	14.2	6.5	24	36
					-2	165,000	141,000	13.5	6.0	12	28
					-3	154,000	133,000	12.8	6.0	26	44
					Average	159,000	137,000	13.5	6.2	21	36
		47,300	80	L	C9LA1A-1	181,000	165,000	15.4	6.0	22	36
					-2	181,000	166,000	14.6	6.5	22	36
					-3	188,000	172,000	14.5	6.5	22	36
					Average	183,000	168,000	14.8	6.3	22	36
		50,300		T	C9TA1A-1	186,000	168,000	15.0	6.0	22	-
					-2	185,000	168,000	14.8	5.0	20	28
					-3	196,000	182,000	15.5	5.0	20	28
					Average	189,000	173,000	15.1	5.3	21	28
		47,300	600	L	C9LA4A-1	149,000	130,000	14.1	7.5	32	56
					-2	151,000	128,000	14.2	-	-	-
					-3	152,000	130,000	12.5	6.0	28	36
					Average	151,000	129,000	13.6	6.8	30	46
		50,300		T	C9TA4A-1	152,000	135,000	13.8	5.0	20	32
					-2	162,000	-	-	4.5	24	36(1)
					-3	159,000	141,000	13.5	6.0	20	32
					Average	158,000	138,000	13.6	5.2	21	33
900	10	ZERO	80	L	C9LA1C-1	174,000	162,000	14.9	7.0	24	28
					-2	179,000	162,000	15.1	5.5	24	-
					-3	188,000	174,000	15.2	7.0	16	20
					Average	180,000	166,000	15.1	6.5	21	24
				T	C9TA1C-1	181,000	171,000	15.7	6.0	24	28
					-2	181,000	169,000	15.5	6.0	20	20
					-3	193,000	181,000	15.4	5.0	16	20
					Average	185,000	174,000	15.5	5.7	20	23
			900	L	C9LA7C-1	100,000	75,500	8.72	15.0	52	-
					-2	108,000	84,400	8.95	26.0	80	112
					-3	114,000	74,600	9.21	21.0	64	116
					Average	107,000	78,200	8.96	21.0	65	114
				T	C9TA7C-1	101,000	82,800	9.47	1.0	12	20
					-2	116,000	88,400	9.14	13.0	48	68
					-3	111,000	87,600	8.74	-	-	-
					Average	109,000	86,300	9.12	7.0	30	44
		35,700	80	L	C9LA1D-1	177,000	165,000	15.2	8.0	28	48
					-2	171,000	161,000	14.6	7.5	30	48
					-3	180,000	169,000	15.2	6.0	20	28
					Average	176,000	165,000	15.0	7.1	26	41
		38,300		T	C9TA1D-1	194,000	177,000	15.4	7.0	24	32
					-2	180,000	170,000	14.7	5.5	24	28
					-3	193,000	184,000	15.8	5.5	18	32
					Average	189,000	177,000	15.3	6.0	22	31
		35,700	900	L	C9LA7D-1	107,000	70,800	7.22	23.0	86	120
					-2	110,000	73,900	8.67	18.0	88	148
					-3	112,000	73,800	9.97	18.0	68	100
					Average	110,000	72,800	8.62	20.0	81	123
		38,300		T	C9TA7D-1	116,000	80,900	9.83	15.0	36	120
					-2	123,000	-	-	12.0	50	-(1)
					-3	115,000	76,300	7.65	22.0	84	140
					Average	118,000	78,600	8.74	16.0	57	130

(1) Unusable load-deformation curve.

TABLE LXIX - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-2.5Al-16V
THICKNESS - 0.063 INCH
HEAT NUMBER - REACTIVE METALS 24806

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	C5LC1EL-1	0.37	0.34	78.0	1.28	0.97	0.95	.0708	.2214	30550	138
	-5	0.36	0.33	80.8	1.30	0.96	0.94	.0691	.2149	29750	138
	-10	0.41	0.41	81.5	1.24	0.99	0.98	.0677	.2140	30050	140
	-11	0.38	0.42	79.0	1.24	1.02	1.00	.0653	.2089	28250	135
	-18	0.42	0.38	81.0	1.30	0.97	0.98	.0666	.2150	30000	140
	-28	0.42	0.39	80.5	1.30	1.00	0.99	.0714	.2318	35300	152
	Average										140
200	C5LC2EL-2	0.49	0.47	83.0	1.26	1.02	1.01	.0685	.2295	31500	137
	-12	0.49	0.47	82.3	1.32	0.99	0.97	.0636	.2139	28250	132
	-22	0.43	0.42	83.5	1.26	1.06	1.05	.0668	.2227	29950	134
	Average										134
400	C5LC3EL-3	0.36	0.35	82.5	1.29	1.08	1.08	.0678	.2198	24725	112
	-13	0.40	0.39	80.0	1.30	0.98	0.97	.0641	.2061	22100	107
	-23	0.41	0.38	81.0	1.25	0.96	0.95	.0680	.2144	25600	119
	Average										113
600	C5LC4EL-4	0.39	0.37	80.0	1.27	1.01	1.00	.0671	.2129	23550	111
	-16	0.38	0.39	81.0	1.31	0.96	0.95	.0702	.2233	25675	115
	-24	0.38	0.40	81.6	1.26	1.09	1.08	.0660	.2164	23000	106
	Average										111
800	C5LC6EL-7	0.40	0.41	80.0	1.25	1.01	0.99	.0681	.2246	24000	107
	-17	0.41	0.40	81.8	1.30	1.01	0.99	.0704	.2285	25000	109
	-25	0.37	0.36	78.2	1.26	1.02	0.99	.0713	.2294	24800	108
	Average										108
900	C5LC7EL-8	0.40	0.38	75.0	1.28	0.94	0.93	.0672	.2132	17750	83.2
	-19	0.47	0.44	83.0	1.30	1.05	1.04	.0690	.2265	19900	87.8
	-26	0.39	0.42	77.8	1.25	1.04	1.02	.0719	.2316	22050	95.2
	Average										88.7
1000	C5LC8EL-9	0.36	0.34	75.5	1.26	0.96	0.93	.0680	.2119	9550	45.1
	-20	0.44	0.40	83.0	1.25	1.09	1.08	.0680	.2235	10700	47.9
	-27	0.40	0.37	78.5	1.26	1.07	1.05	.0723	.2327	11850	50.9
	Average										48.0

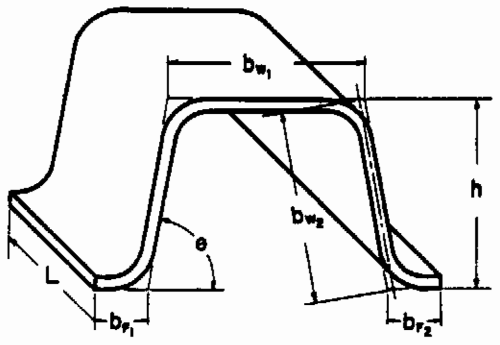


CONFIGURATION 1, LENGTH = 4.13"

TABLE LXX - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-2.5Al-16V
THICKNESS - 0.063 INCH
HEAT NUMBER - REACTIVE METALS 24806

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf$_1$, in.	bf$_2$, in.	θ, degree	bw$_1$, in.	bw$_2$, in.	h, in.	t, in.	AREA, in.^{2}		
80	C5TC1EL-10	0.40	0.40	81.0	1.28	0.99	0.98	.0691	.2179	29350	125
	-14	0.40	0.40	78.2	1.27	0.97	0.96	.0686	.2214	33050	149
	-15	0.39	0.40	76.5	1.21	1.02	1.01	.0660	.2139	31500	147
	-30	0.46	0.50	82.8	1.29	1.06	1.05	.0708	.2426	38750	160
	Average										148
200	C5TC2EL-3	0.43	0.44	76.5	1.16	1.02	0.99	.0648	.2141	30250	141
	-22	0.46	0.43	77.0	1.15	1.02	0.99	.0694	.2203	29700	135
	-31	0.45	0.45	79.0	1.18	1.04	1.02	.0714	.2374	36000	152
	Average										143
400	C5TC3EL-12	0.42	0.41	80.0	1.29	0.99	0.97	.0677	.2177	27200	125
	-13	0.38	0.39	83.0	1.26	1.11	1.10	.0678	.2225	25700	116
	-29	0.49	0.49	83.0	1.25	1.04	1.04	.0697	.2352	31500	134
	Average										125
600	C5TC4EL-6	0.40	0.36	79.0	1.28	0.95	0.93	.0685	.2173	24800	114
	-16	0.41	0.38	84.5	1.25	1.06	1.05	.0657	.2120	23400	110
	-23	0.43	0.37	79.2	1.29	0.99	0.97	.0684	.2244	27400	122
	Average										115
800	C5TC6EL-17	0.45	0.46	79.5	1.20	1.03	1.02	.0664	.2130	24350	114
	-21	0.40	0.39	81.5	1.27	0.97	0.97	.0694	.2246	24900	111
	-25	0.42	0.41	77.5	1.19	1.00	0.99	.0568	.2168	24600	113
	Average										113
900	C5TC7EL-8	0.41	0.39	86.0	1.30	1.13	1.13	.0692	.2264	18350	81.0
	-11	0.42	0.41	79.0	1.19	0.96	0.94	.0679	.2103	17400	82.7
	-28	0.41	0.40	81.0	1.31	0.98	0.97	.0659	.2130	16450	77.2
	Average										80.3
1000	C5TC8EL-7	0.40	0.37	83.5	1.21	1.05	1.04	.0690	.2197	10350	47.1
	-9	0.42	0.38	76.5	1.24	0.95	0.94	.0692	.2227	11425	51.3
	-27	0.36	0.38	79.5	1.18	1.08	1.07	.0659	.2134	9950	46.6
	Average										48.3

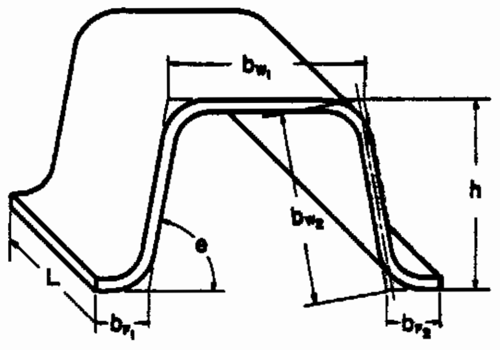


CONFIGURATION 1, LENGTH = 4.13"

TABLE LXXI - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-2.5Al-16V
THICKNESS - 0.063 INCH
HEAT NUMBER - REACTIVE METALS 24806

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	C5LC1FL-6	0.61	0.59	81.5	1.93	2.13	2.12	.0702	.4427	50350	114
	-11	0.58	0.59	85.0	1.96	2.13	2.12	.0671	.4214	40350	95.8
	-16	0.66	0.64	84.8	1.99	2.10	2.09	.0704	.4418	49350	112
	-19	0.63	0.64	82.2	1.95	2.12	2.10	.0683	.4322	46450	107
	-22	0.66	0.67	81.6	1.99	2.06	2.04	.0736	.4625	58450	127
	Average										111
200	C5LC2FL-2	0.65	0.62	82.0	1.92	2.13	2.09	.0692	.4376	51000	116
	-20	0.65	0.64	80.2	1.94	2.05	2.03	.0735	.4623	55700	120
	-26	0.65	0.63	81.0	1.93	2.12	2.09	.0714	.4515	51000	113
	Average										116
400	C5LC3FL-29	0.60	0.64	82.0	1.96	2.19	2.17	.0706	.4460	47350	106
	-30	0.66	0.66	82.0	1.91	2.09	2.07	.0708	.4466	51050	114
	Average										110
600	C5LC4FL-4	0.60	0.67	83.0	2.01	2.08	2.07	.0684	.4277	41600	97.3
	-14	0.75	0.70	83.0	1.96	2.02	2.02	.0700	.4410	43800	99.3
	-23	0.60	0.62	83.5	1.99	2.11	2.09	.0724	.4551	41350	90.8
	Average										95.8
800	C5LC6FL-10	0.72	0.60	84.0	1.93	2.13	2.12	.0710	.4488	42300	94.3
	-27	0.65	0.65	84.5	2.08	2.08	2.07	.0718	.4512	40300	89.3
	-28	0.67	0.66	83.5	1.97	2.12	2.11	.0708	.4472	41850	93.6
	Average										92.4
900	C5LC7FL-24	0.67	0.63	80.5	1.96	2.05	2.02	.0698	.4412	34400	78.0
	-31	0.59	0.59	81.0	1.92	2.13	2.09	.0715	.4445	36300	81.7
	Average										79.8
1000	C5LC8FL-9	0.59	0.60	82.0	1.97	2.15	2.13	.0689	.4331	14600	33.7
	-18	0.61	0.65	85.0	2.01	2.15	2.14	.0709	.4461	20350	45.6
	-25	0.68	0.66	81.5	1.90	2.08	2.06	.0718	.4534	20800	45.9
	Average										41.7



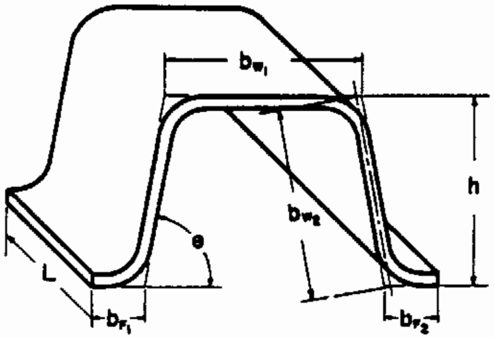
CONFIGURATION 2, LENGTH = 6.89"

TABLE LXXII - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-2.5Al-16V
THICKNESS - 0.063 INCH
HEAT NUMBER - REACTIVE METALS 24806

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf$_1$, in.	bf$_2$, in.	θ, degree	bw$_1$, in.	bw$_2$, in.	h, in.	t, in.	AREA, in.^{2}		
80	C5TC1FL-1	0.74	0.65	82.5	1.93	2.04	2.02	.0691	.4376	50300	115
	-15	0.61	0.62	78.0	1.99	1.99	1.94	.0700	.4430	47600	107
	-30	0.60	0.60	83.0	1.93	2.19	2.18	.0706	.4466	45600	102
	-32	0.74	0.72	84.0	1.91	2.07	2.06	.0711	.4503	57500	128
	-36	0.72	0.66	87.0	1.98	2.14	2.13	.0695	.4409	55750	126
	-39	0.69	0.69	83.0	1.90	2.09	2.08	.0713	.4510	55150	122
	-40	0.60	0.59	84.0	2.10	2.06	2.05	.0695	.4393	35000	79.7(1)
	Average										117
200	C5TC2FL-10	0.73	0.61	83.5	1.97	2.10	2.09	.0683	.4314	50850	118
	-26	0.66	0.67	84.0	1.98	2.11	2.09	.0723	.4567	53200	116
	-30	0.62	0.54	81.8	1.97	2.20	2.19	.0681	.4308	50550	117
	Average										117
400	C5TC3FL-21	0.68	0.67	82.6	1.98	2.07	2.06	.0725	.4572	47400	104
	-34	0.66	0.63	84.0	1.90	2.12	2.11	.0714	.4514	52450	116
	-35	0.62	0.63	81.0	1.89	2.15	2.13	.0701	.4417	45400	103
	Average										108
600	C5TC4FL-4	0.65	0.56	84.0	1.96	2.14	2.13	.0686	.4322	39850	92.2
	-14	0.63	0.63	85.5	2.03	2.17	2.16	.0698	.4406	43500	98.7
	-37	0.60	0.63	83.0	1.87	2.18	2.16	.0702	.4434	46200	104
	Average										98.3
800	C5TC6FL-5	0.62	0.69	84.0	2.05	2.08	2.07	.0684	.4322	41200	95.3
	-27	0.63	0.64	81.2	1.92	2.09	2.07	.0722	.4564	43200	94.6
	-31	0.68	0.67	86.0	2.06	2.08	2.07	.0715	.4520	42200	93.4
	Average										94.4
900	C5TC7FL-8	0.56	0.62	80.5	1.92	2.13	2.10	.0703	.4454	24650	55.3
	-29	0.58	0.62	83.0	1.90	2.20	2.19	.0684	.4306	32050	74.4
	-38	0.66	0.65	84.0	1.93	2.10	2.09	.0722	.4548	37400	82.2
	Average										70.6
1000	C5TC8FL-9	0.66	0.66	81.5	1.93	2.08	2.05	.0702	.4427	20200	45.6
	-11	0.61	0.60	84.5	1.99	2.15	2.13	.0694	.4359	24050	55.2
	-19	0.72	0.66	81.2	1.87	2.10	2.07	.0714	.4496	25800	57.4
	Average										52.7

(1) Not included in average.



CONFIGURATION 2, LENGTH = 6.89"

TABLE LXXIII

LONGITUDINAL COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24806)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
C5LB1L-5	80	190,000	15.4	191,000	196,000	34.4
-11	80	189,000	14.9	187,000	199,000	15.3
-14	80	192,000	15.3	193,000	197,000	39.8
-17	80	191,000	15.3	192,000	197,000	32.5
-20	80	184,000	15.5	184,000	194,000	17.6
-23	80	190,000	15.4	191,000	196,000	34.4
-26	80	188,000	14.4	189,000	198,000	18.6
-29	80	188,000	15.6	189,000	196,000	24.1
Average		189,000	15.2	190,000	197,000	27.1
C5LB2L-7	200	169,000	13.6	170,000	180,000	17.2
-19	200	177,000	13.3	179,000	188,000	17.7
-22	200	168,000	14.4	168,000	179,000	15.0
Average		171,000	13.8	172,000	182,000	16.6
C5LB3L-13	400	164,000	14.4	164,000	174,000	15.0
-24	400	161,000	14.4	161,000	172,000	15.3
-27	400	156,000	14.2	155,000	167,000	12.6
Average		160,000	14.3	160,000	171,000	14.3
C5LB4L-6	600	147,000	13.3	147,000	157,000	14.8
-15	600	151,000	13.6	149,000	156,000	20.3
-30	600	149,000	12.4	150,000	-	-
Average		149,000	13.1	149,000	156,000	17.6
C5LB6L-4	800	121,000	12.0	120,000	131,000	11.1
-10	800	130,000	11.9	-	-	-
-12	800	127,000	12.1	-	-	-
Average		126,000	12.0			
C5LB7L-3	900	68,300	11.5	54,000	74,500	3.8
-16	900	74,600	10.4	66,700	83,000	5.0
-28	900	67,900	10.2	57,200	76,000	4.1
Average		70,300	10.7	59,300	77,800	4.3
C5LB8L-2	1000	43,500	7.66	38,400	44,500	7.0
-9	1000	37,400	7.70	30,200	38,300	4.7
-21	1000	42,200	7.53	38,100	43,200	8.1
Average		41,000	7.63	35,600	42,000	6.6

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

TRANSVERSE COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24806)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
C5TB1L-2	80	192,000	14.3	193,000	-	-
-5	80	197,000	15.4	198,000	206,000	23.1
-8	80	192,000	15.3	193,000	-	-
-11	80	192,000	15.3	193,000	203,000	19.6
-14	80	199,000	15.5	200,000	209,000	20.8
-17	80	194,000	15.6	194,000	200,000	33.5
-20	80	195,000	15.3	196,000	205,000	20.9
-23	80	194,000	14.3	197,000	-	-
-26	80	194,000	15.9	195,000	203,000	22.7
-29	80	196,000	16.0	197,000	207,000	19.7
Average		194,000	15.3	196,000	205,000	22.9
C5TB2L-7	200	185,000	14.2	186,000	-	-
-19	200	186,000	14.6	187,000	192,000	36.4
-22	200	181,000	15.0	182,000	189,000	24.8
Average		184,000	14.6	185,000	190,000	30.6
C5TB3L-13	400	165,000	14.5	165,000	177,000	13.6
-24	400	163,000	14.6	163,000	173,000	16.8
-27	400	166,000	14.9	166,000	172,000	26.1
Average		165,000	14.7	165,000	174,000	18.8
C5TB4L-15	600	161,000	12.3	162,000	163,000	15.7
-18	600	159,000	14.2	159,000	-	-
-25	600	160,000	13.4	160,000	-	-
Average		160,000	13.3	160,000		
C5TB6L-10	800	130,000	11.4	130,000	140,000	13.0
-12	800	128,000	12.0	126,000	136,000	13.3
Average		129,000	11.7	128,000	138,000	13.2
C5TB7L-6	900	82,500	10.4	73,800	93,400	4.8
-16	900	62,000	10.7	45,700	-	-
-28	900	80,700	7.86	78,800	94,000	6.0
Average		75,100	9.65	66,100	93,700	5.4
C5TB8L-9	1000	50,900	8.00	45,400	53,600	6.3
-21	1000	49,500	6.23	45,700	55,400	5.6
-30	1000	49,000	7.76	42,600	52,400	5.3
Average		49,800	7.33	44,600	53,800	5.7

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

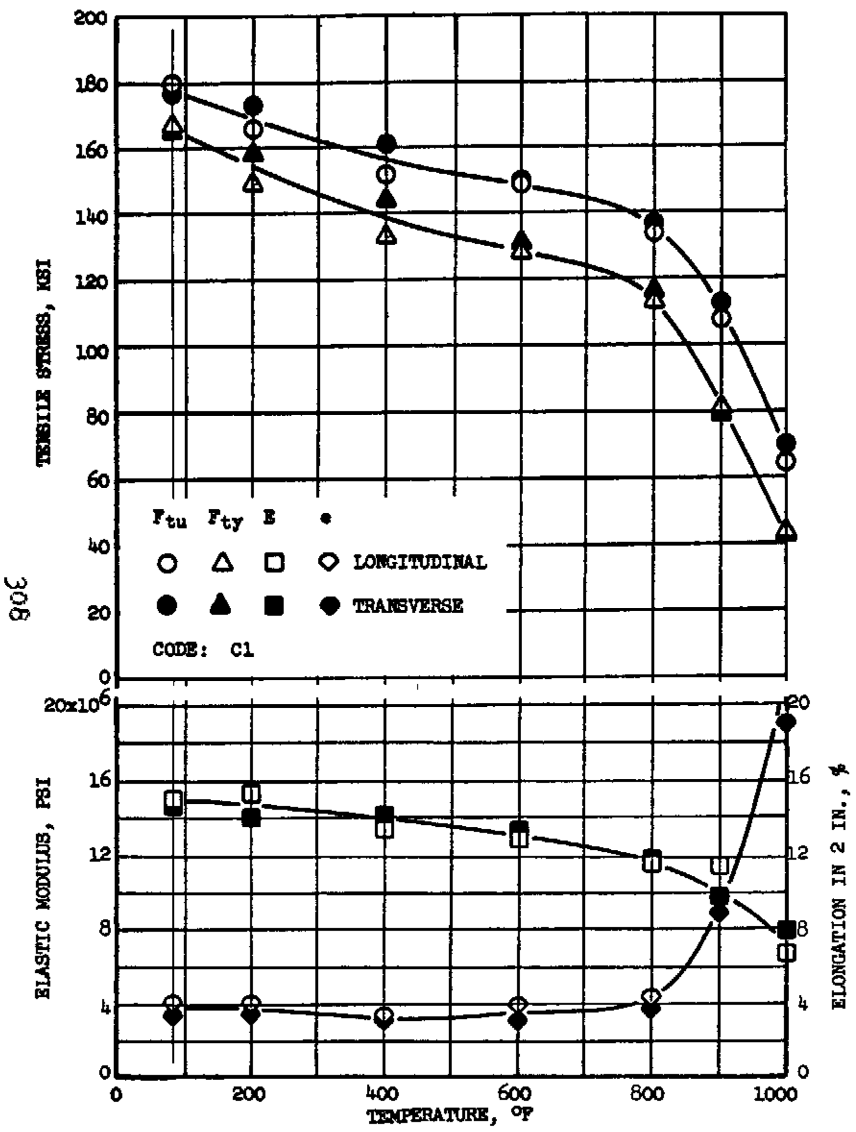


FIGURE 210 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO. 22093)

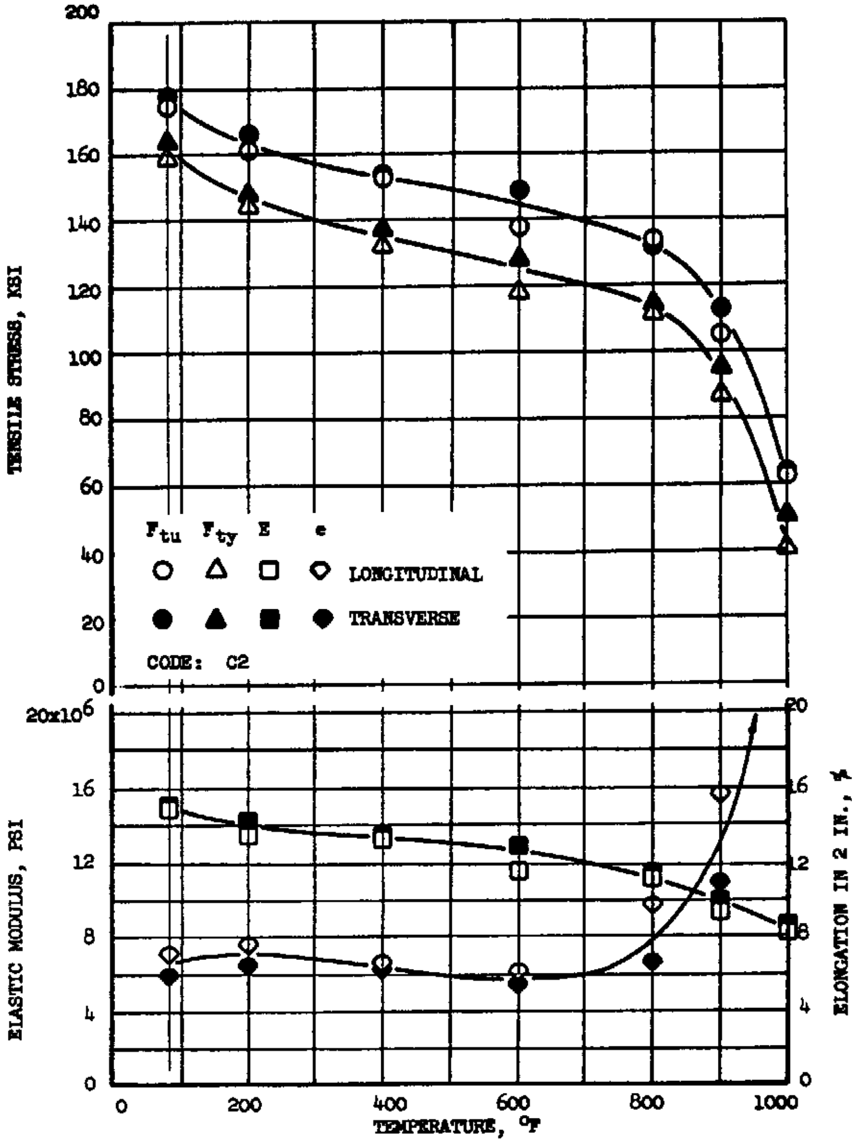


FIGURE 211 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 22154)

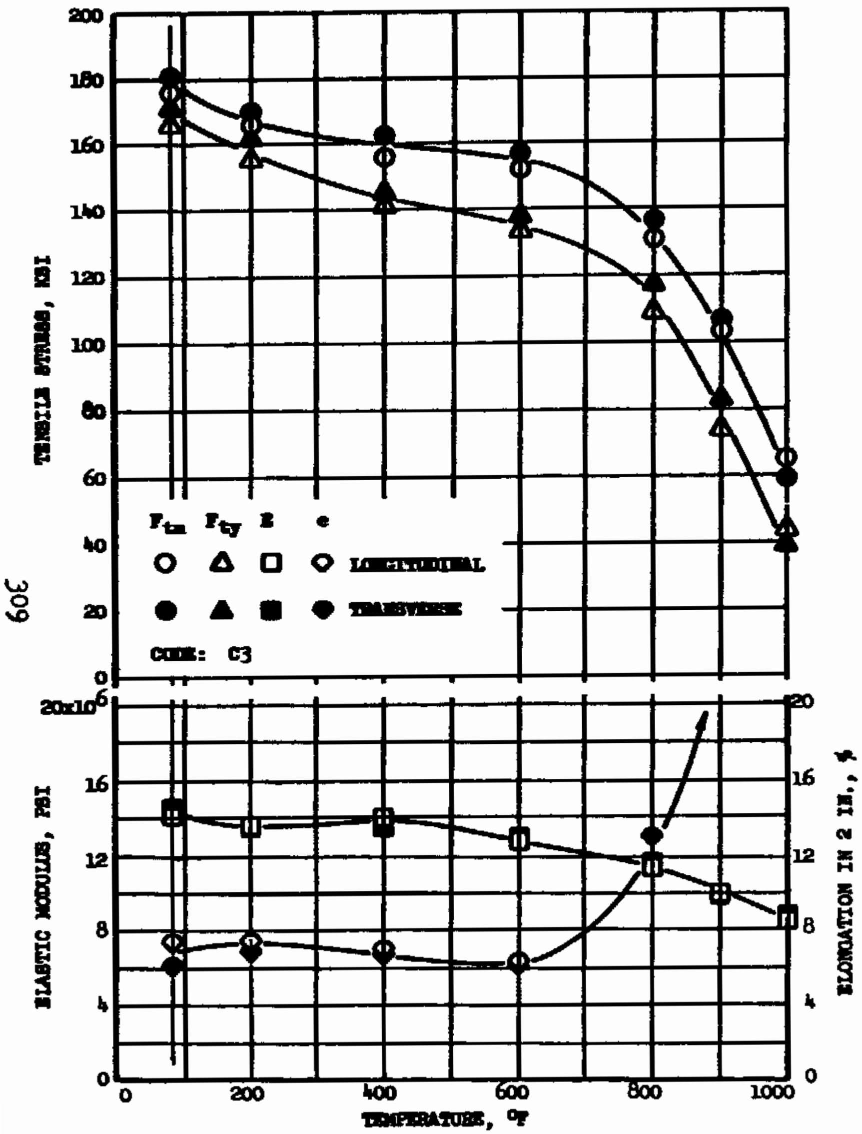


FIGURE 212 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23354)

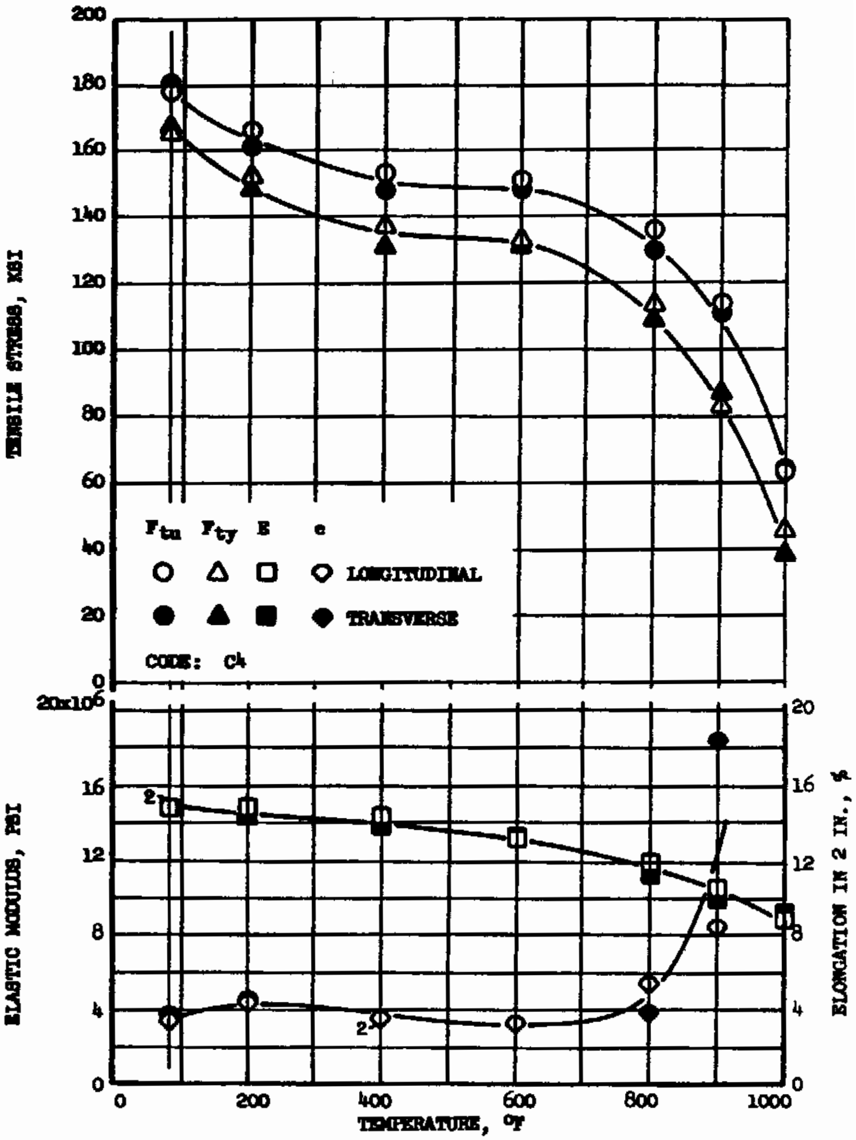


FIGURE 213 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO. 24990)

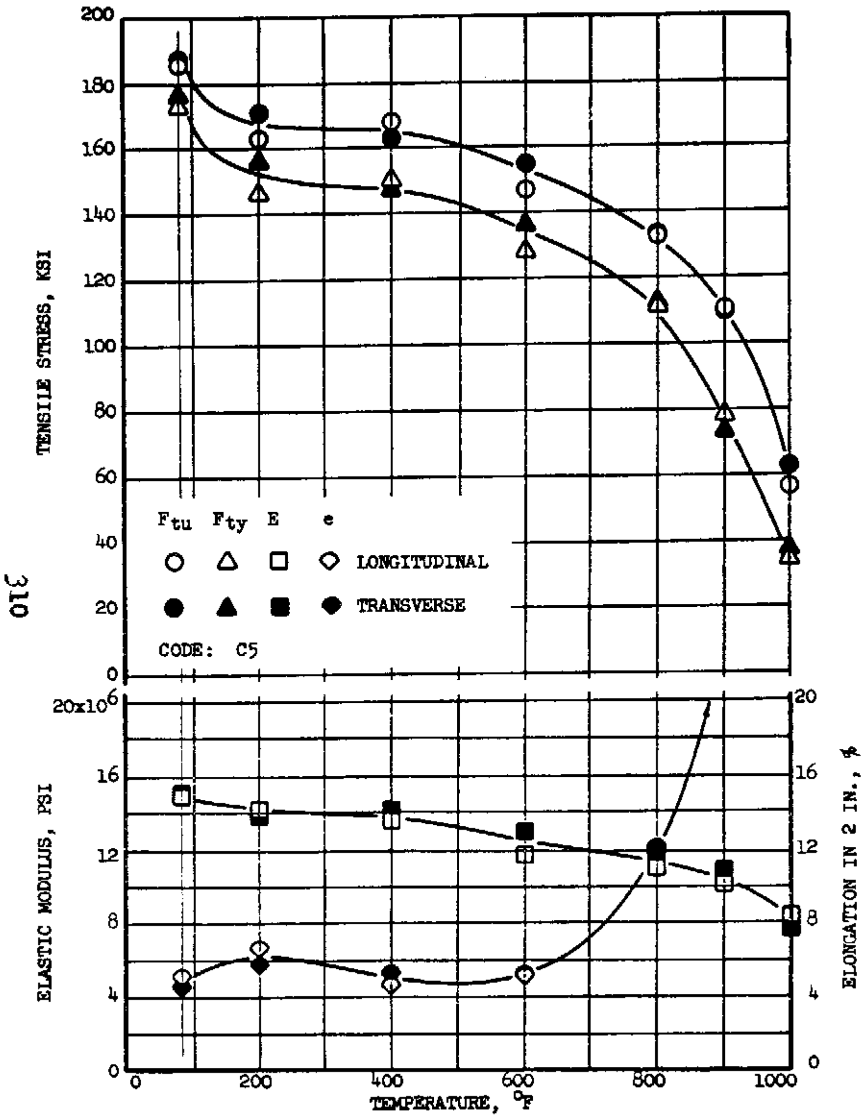


FIGURE 214 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24806)

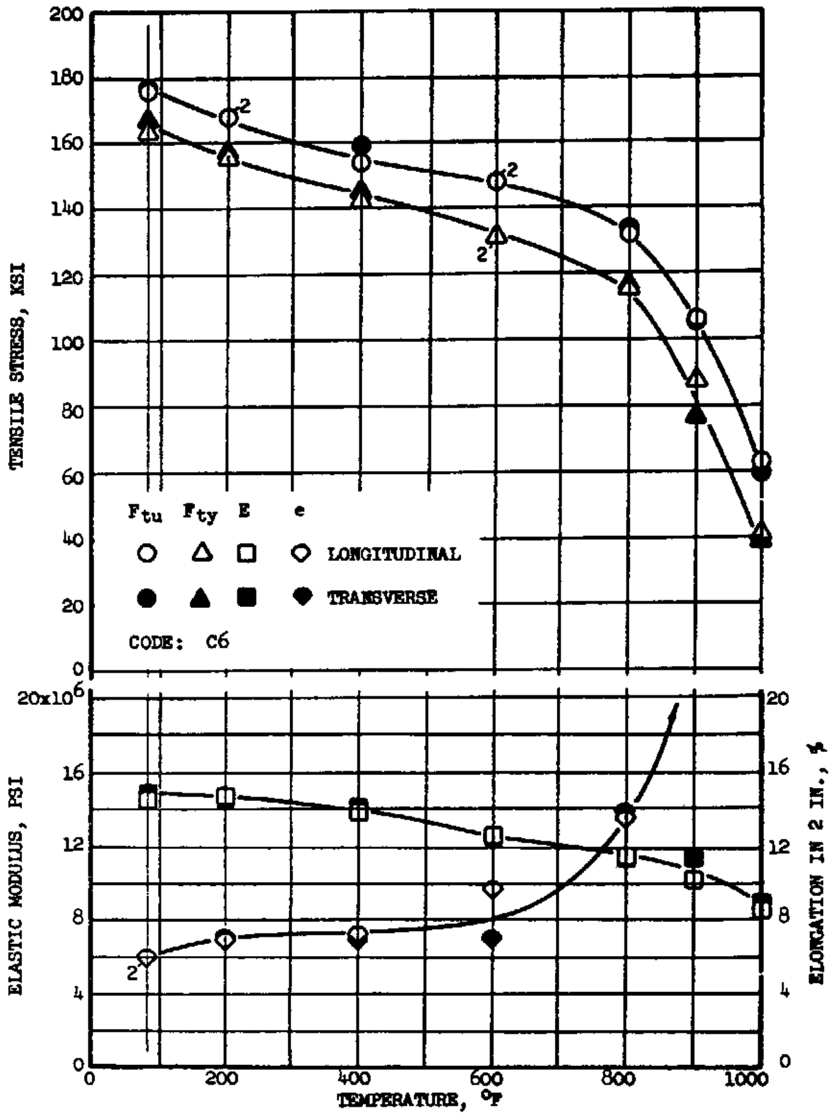


FIGURE 215 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23372)

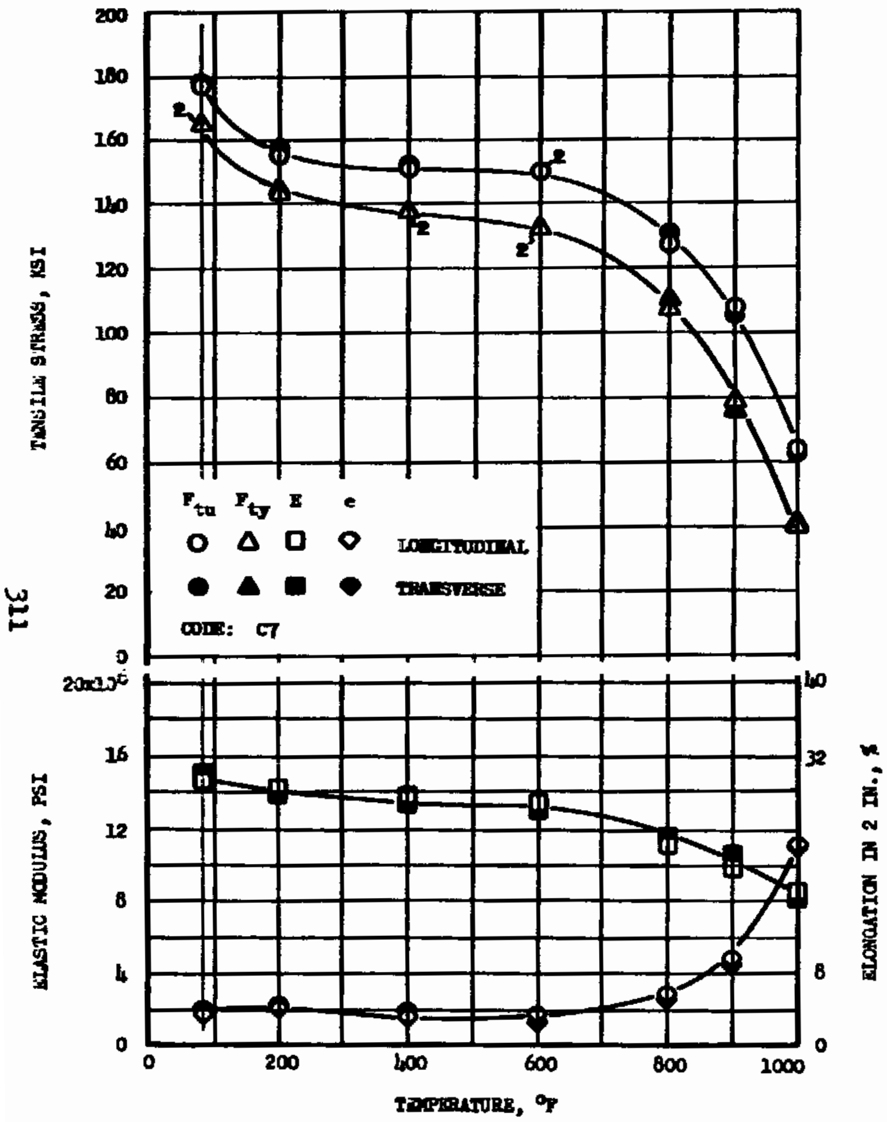


FIGURE 216 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (MALLORY-SHARON HEAT NO. 24814)

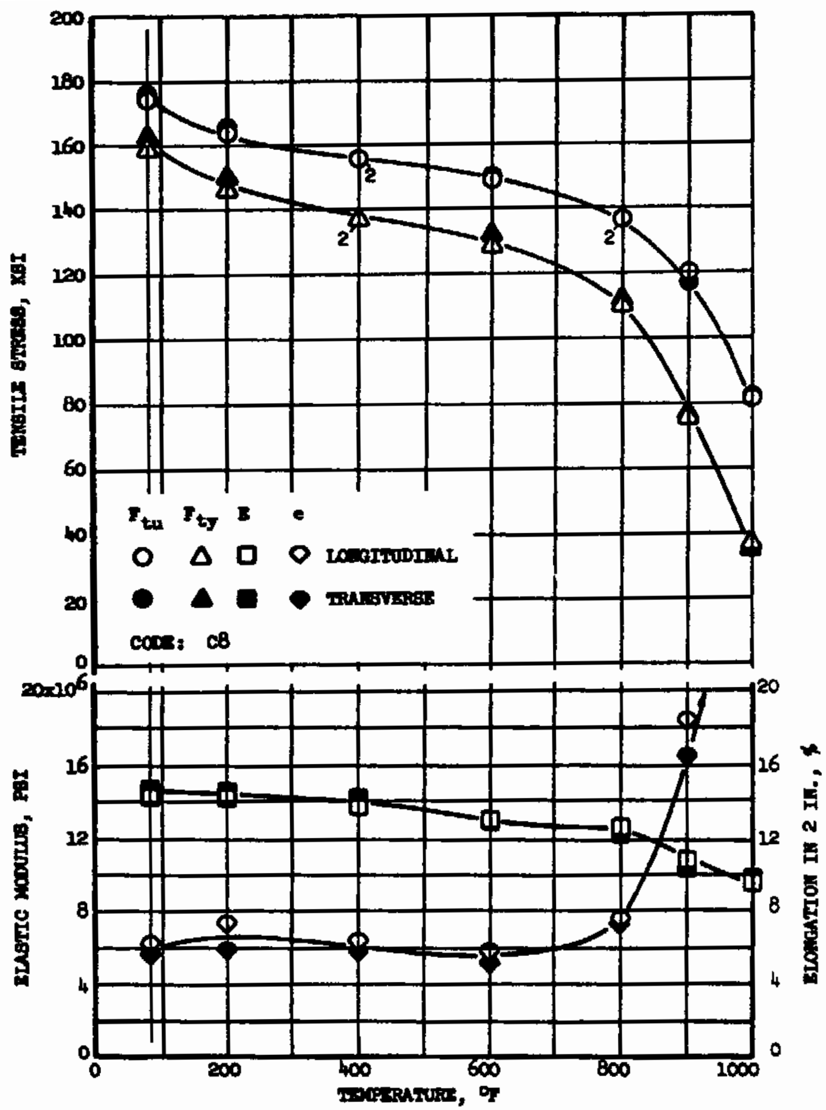


FIGURE 217 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24814)

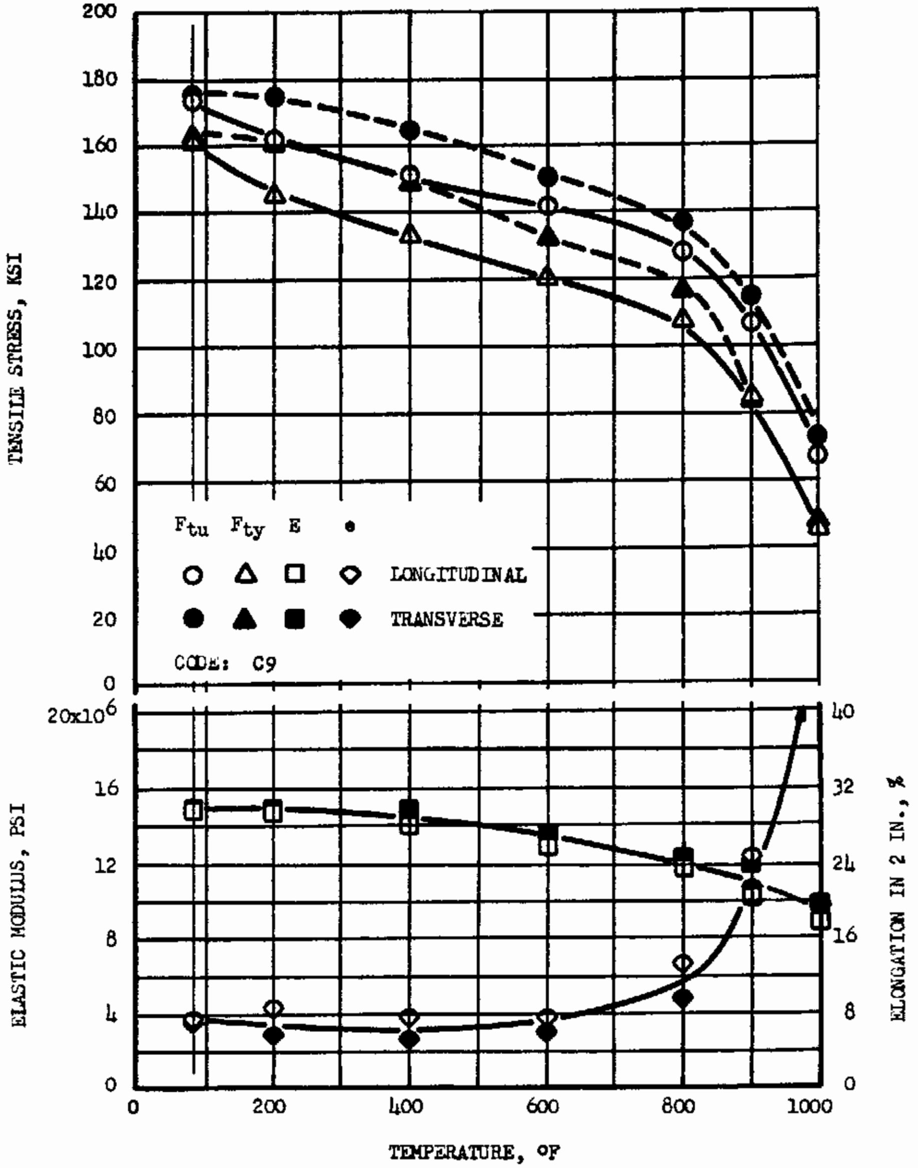


FIGURE 218 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (MALLORY-SHARON HEAT NO. 23345)

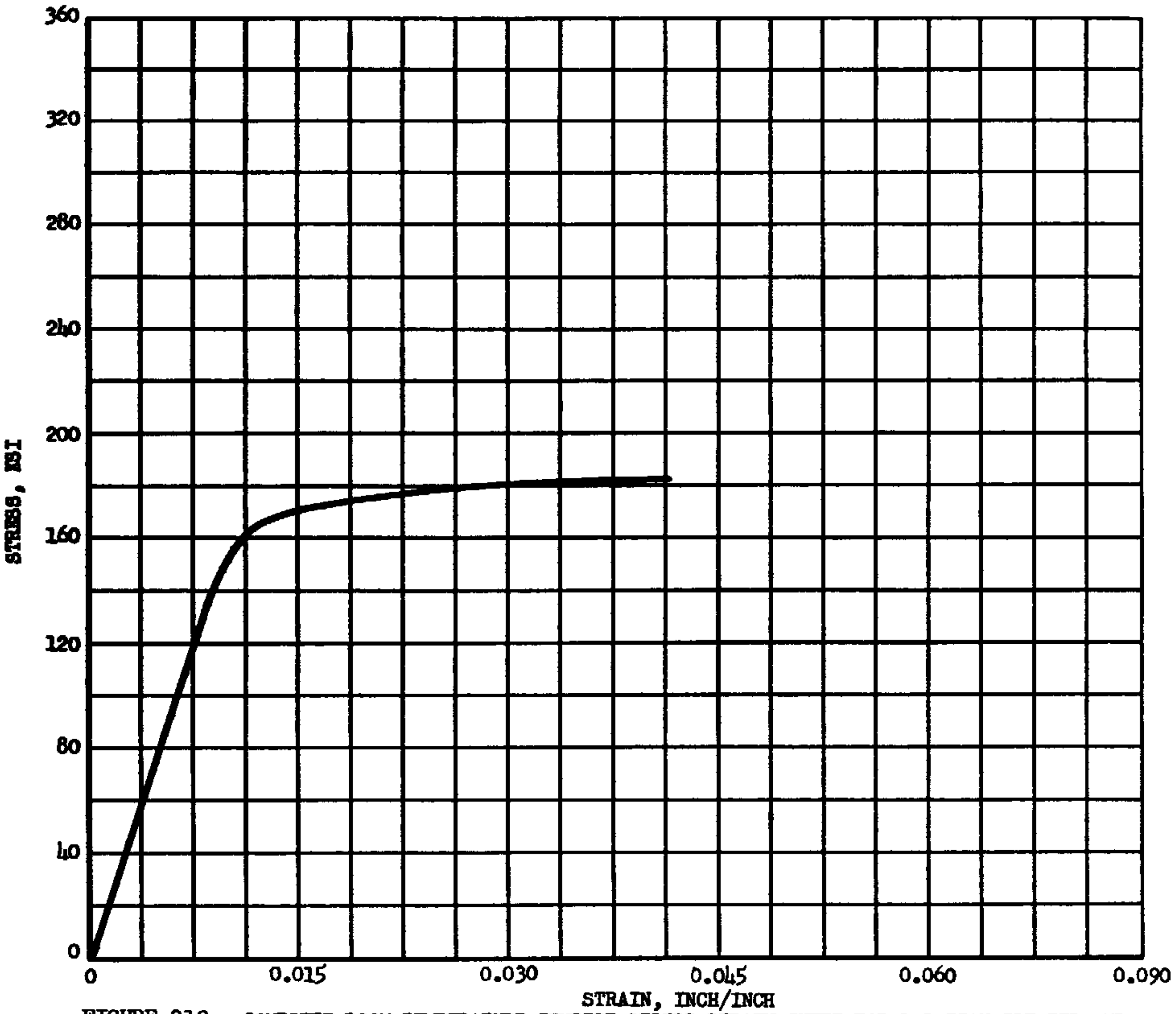


FIGURE 219 - COMPLETE ROOM TEMPERATURE TENSILE STRESS-STRAIN CURVE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (SPECIMEN NO. C4LA1-13)

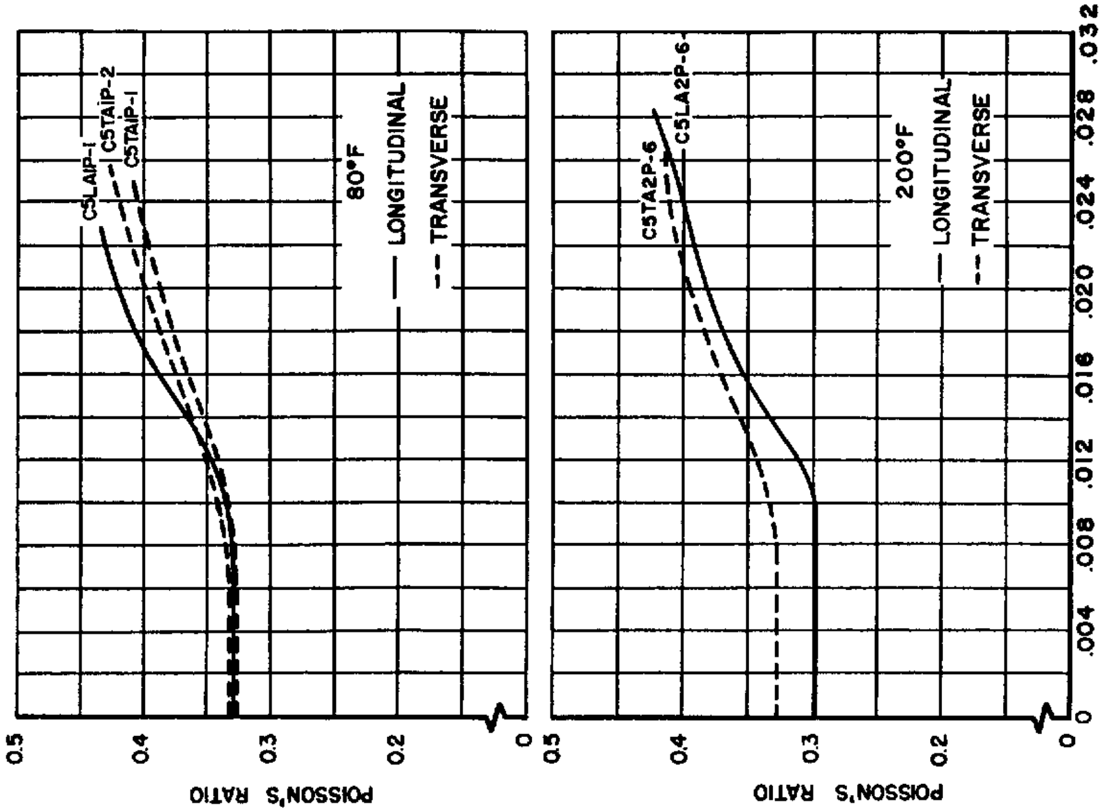


FIGURE 220 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK

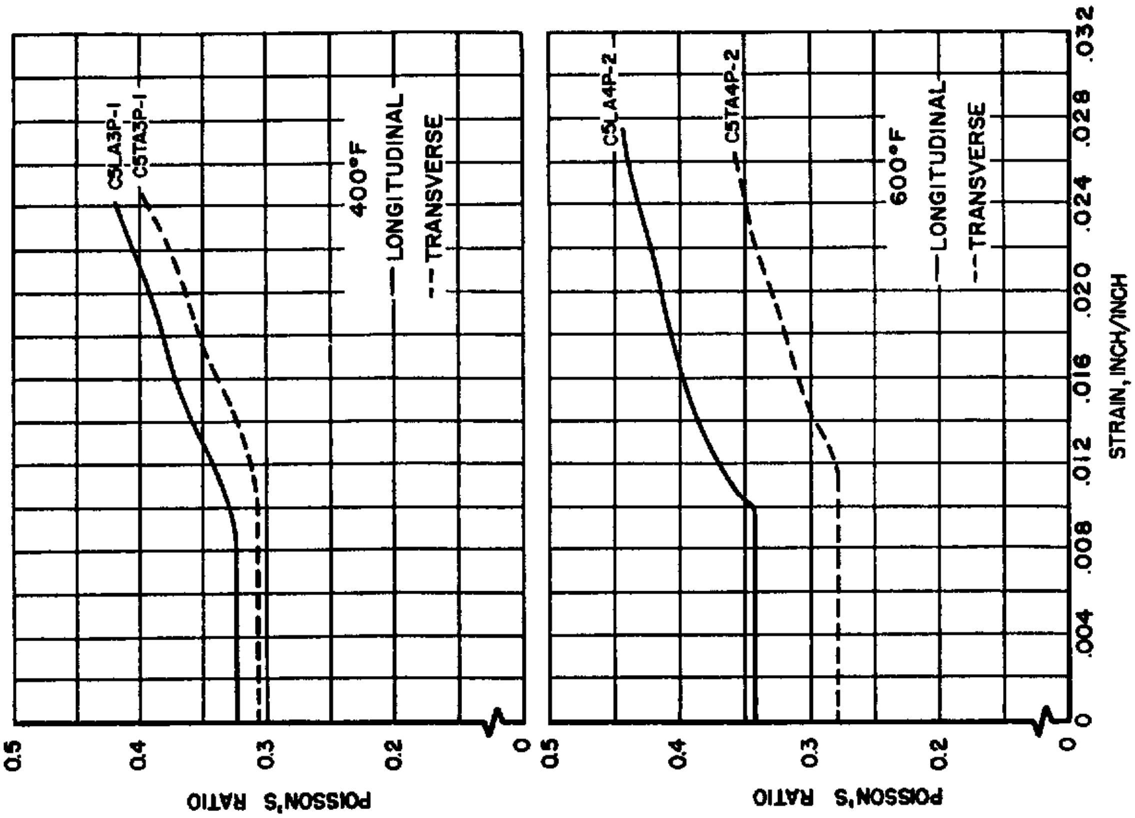


FIGURE 221 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK

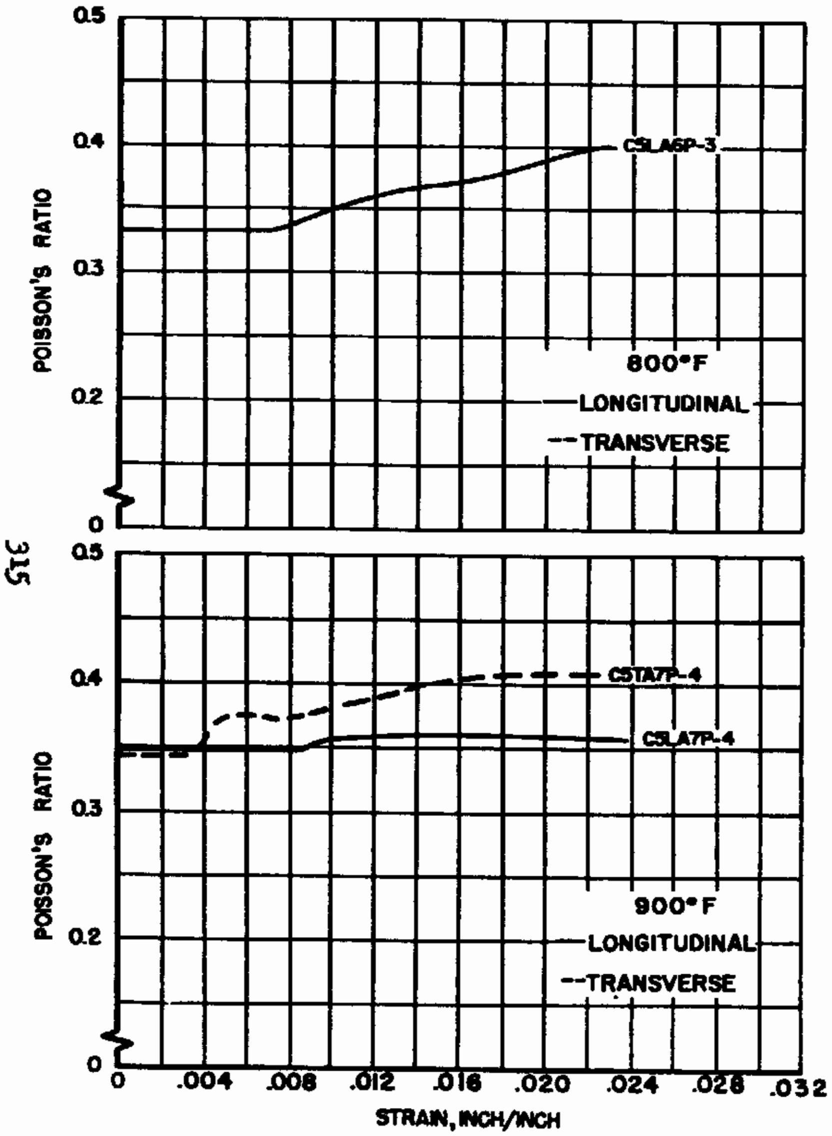


FIGURE 222 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK

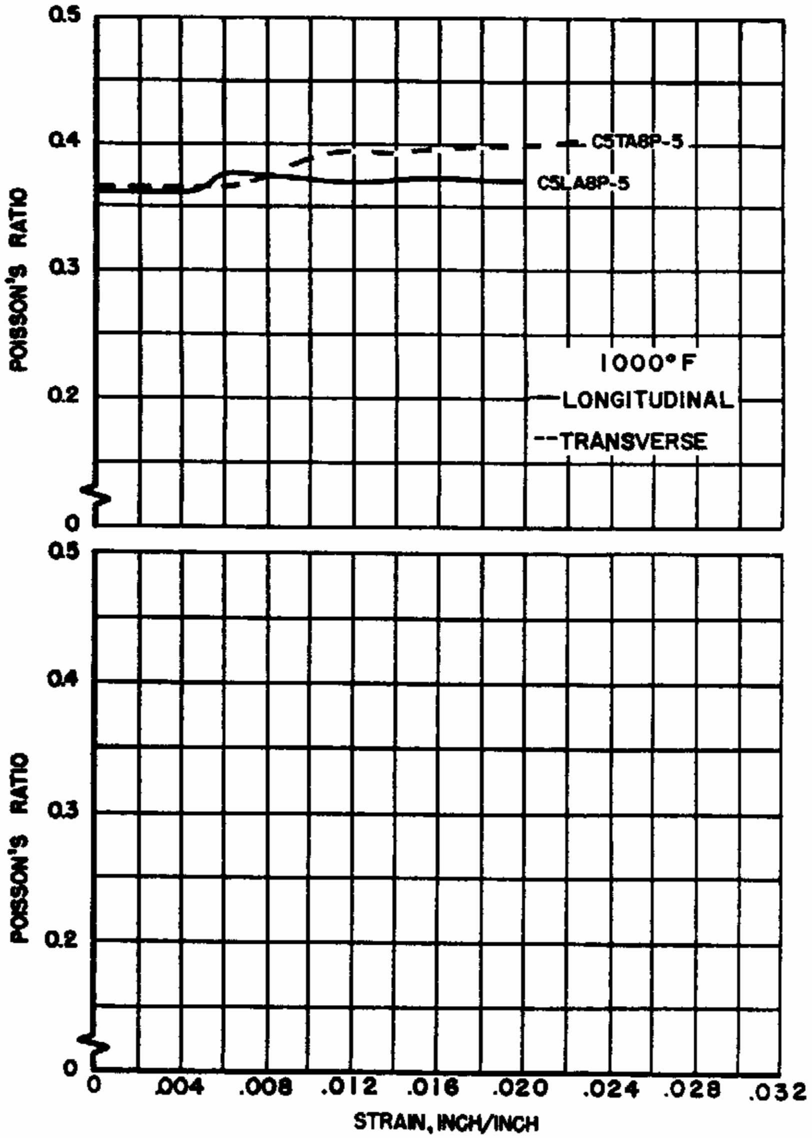


FIGURE 223 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK

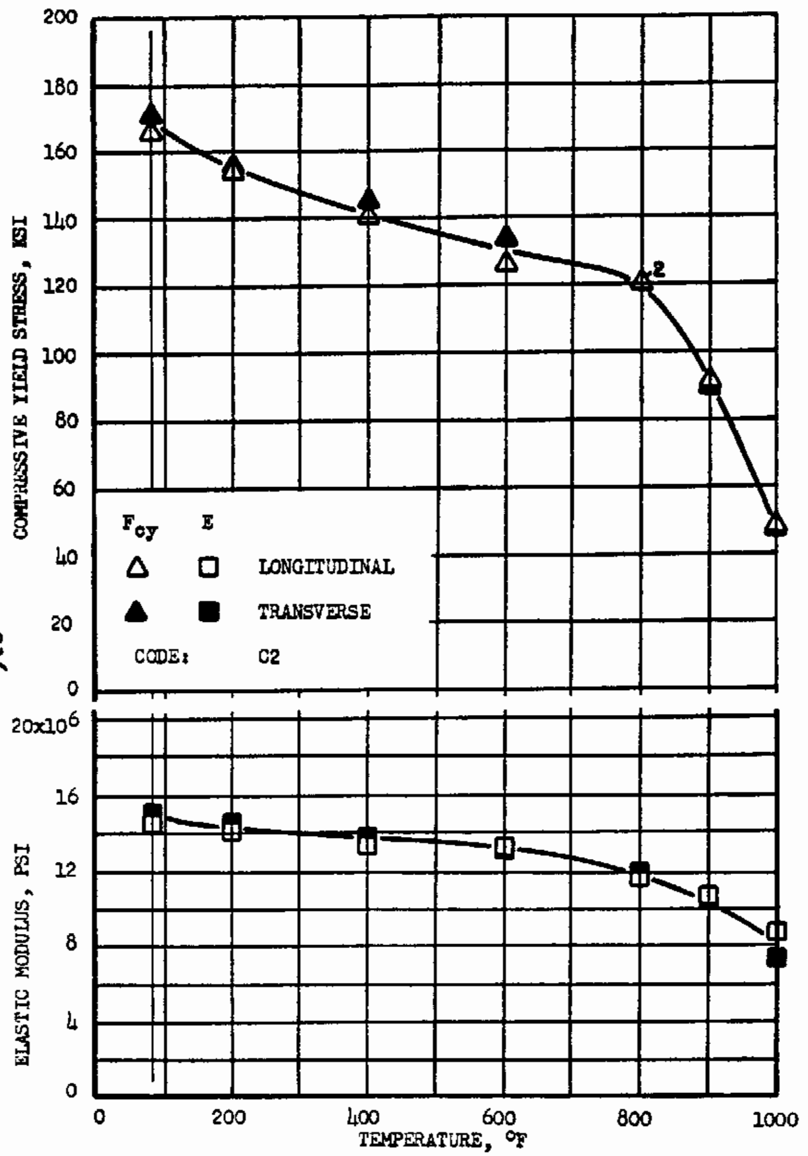


FIGURE 224 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 22154)

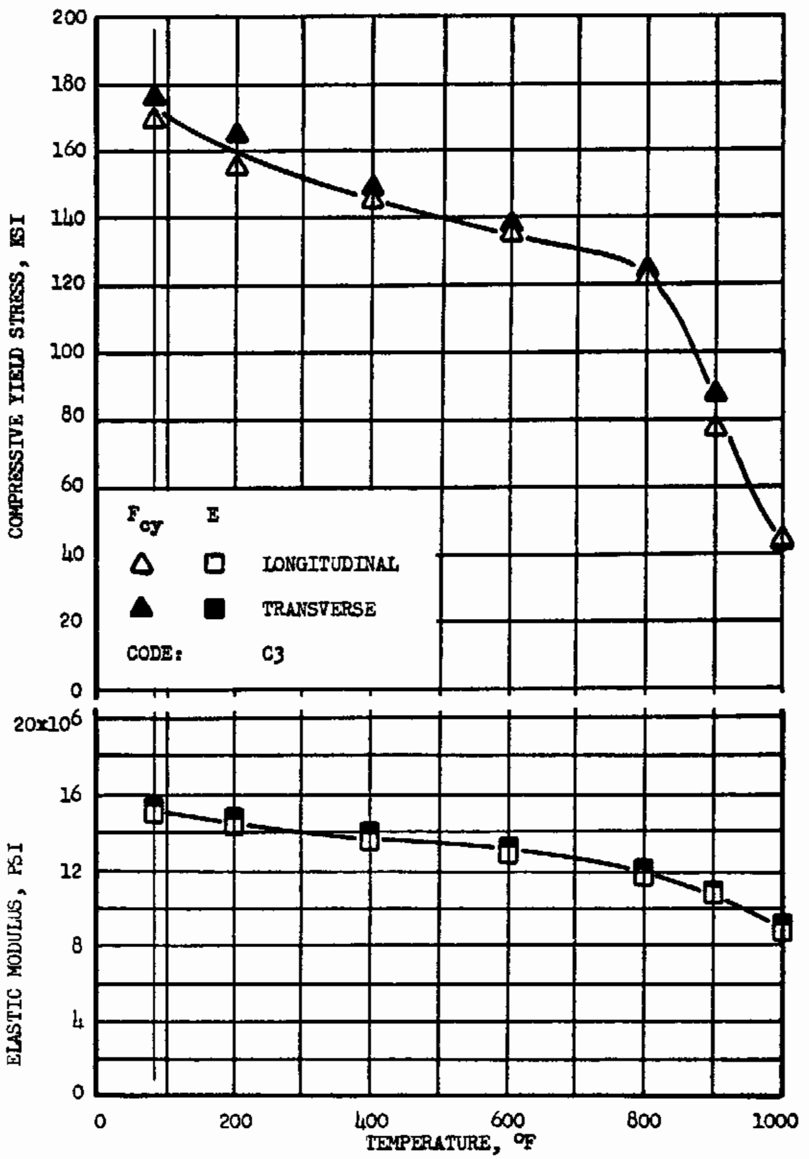


FIGURE 225 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23354)

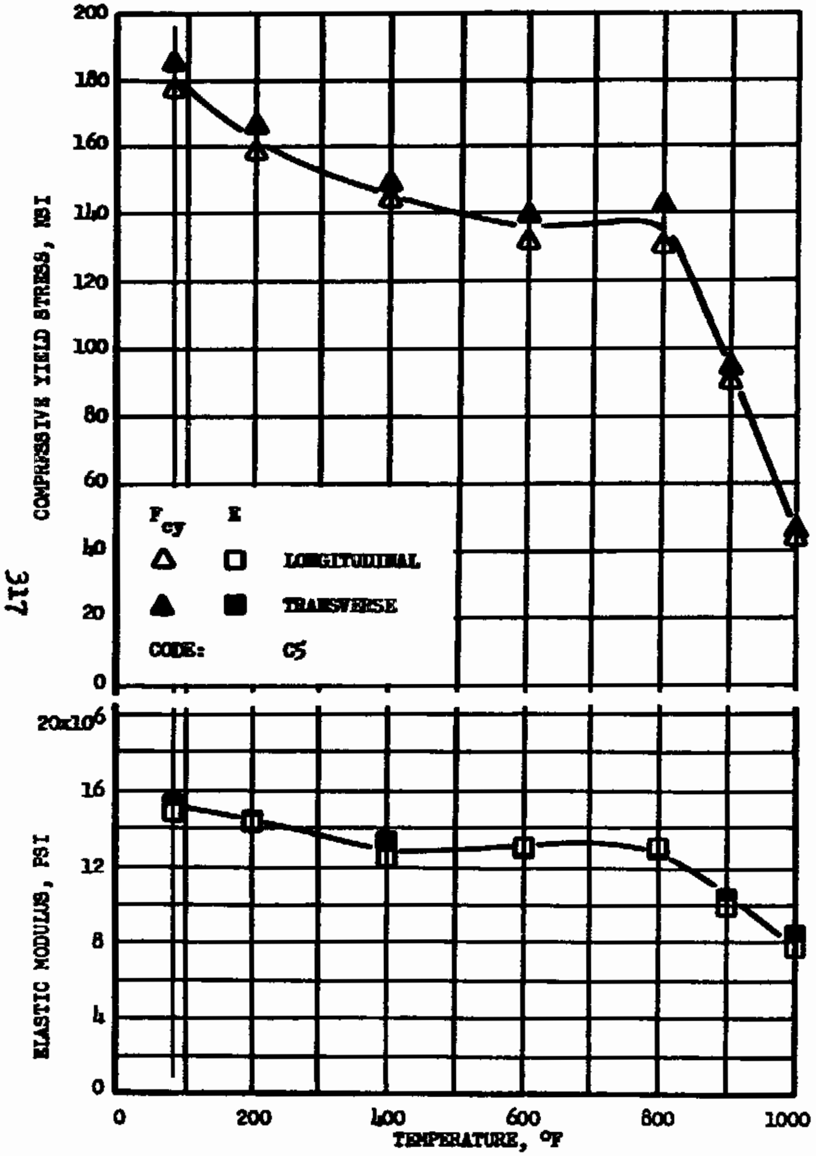


FIGURE 226 – SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24806)

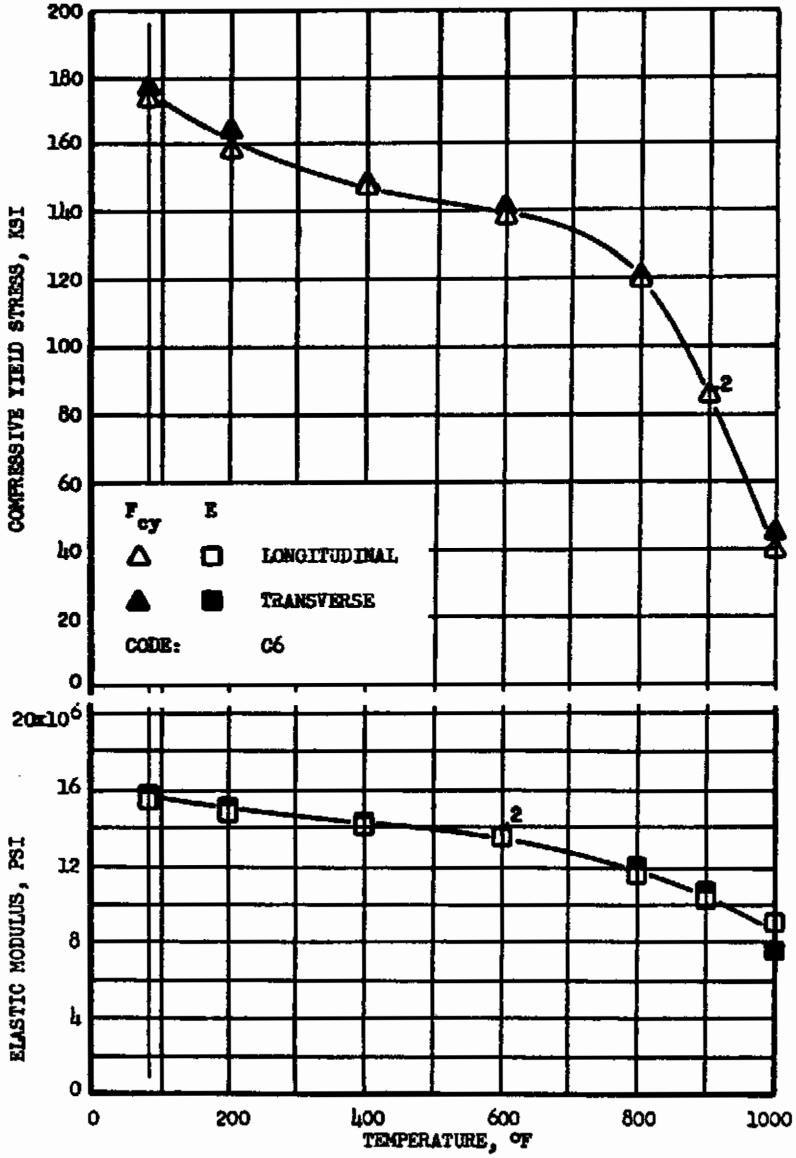


FIGURE 227 – SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23372)

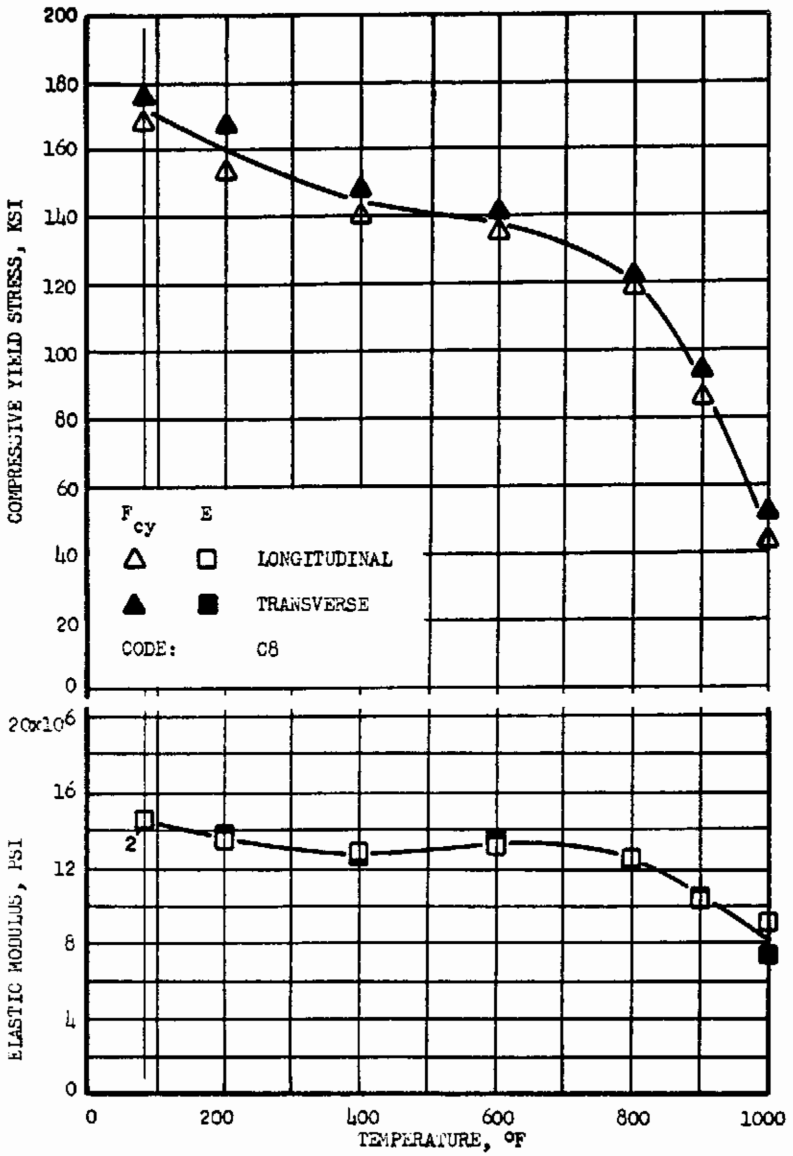


FIGURE 228 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24814)

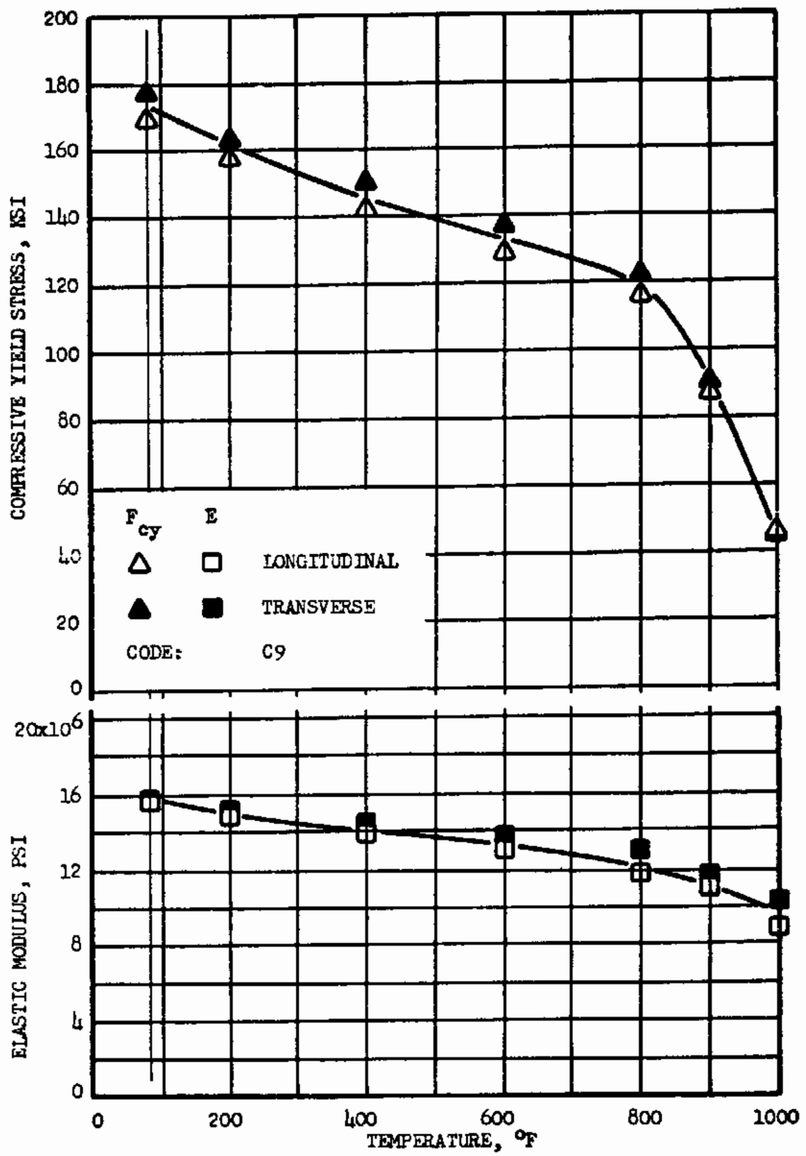


FIGURE 229 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23345)

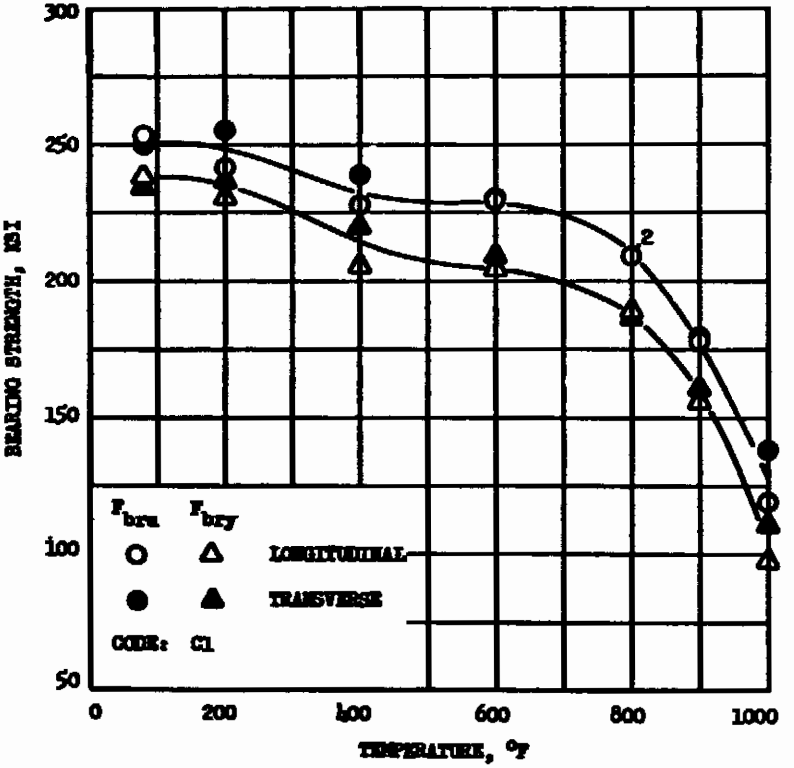


FIGURE 230 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (REACTIVE METALS HEAT NO. 22093)

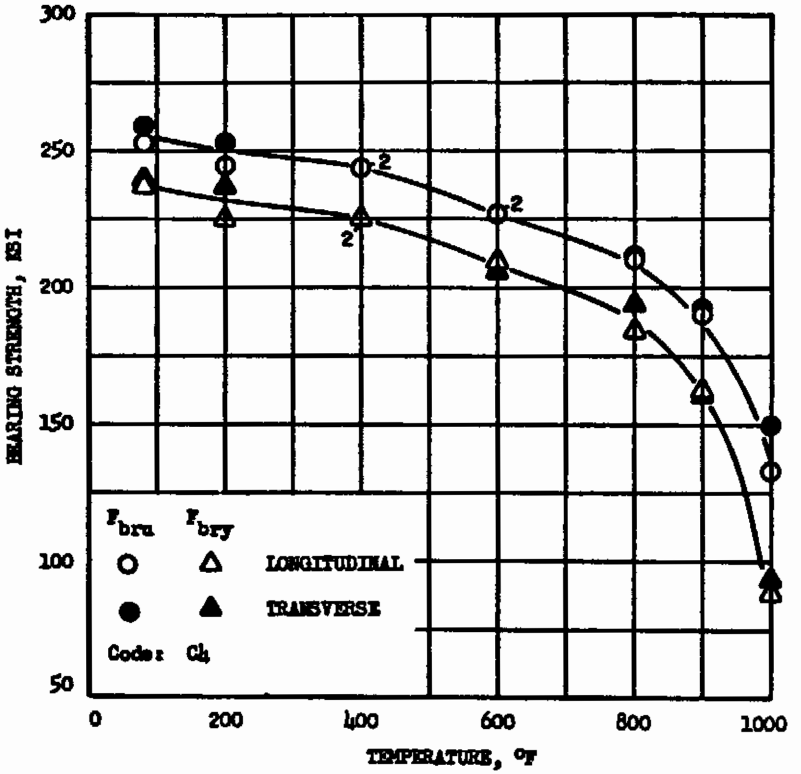


FIGURE 231 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (REACTIVE METALS HEAT NO. 24990)

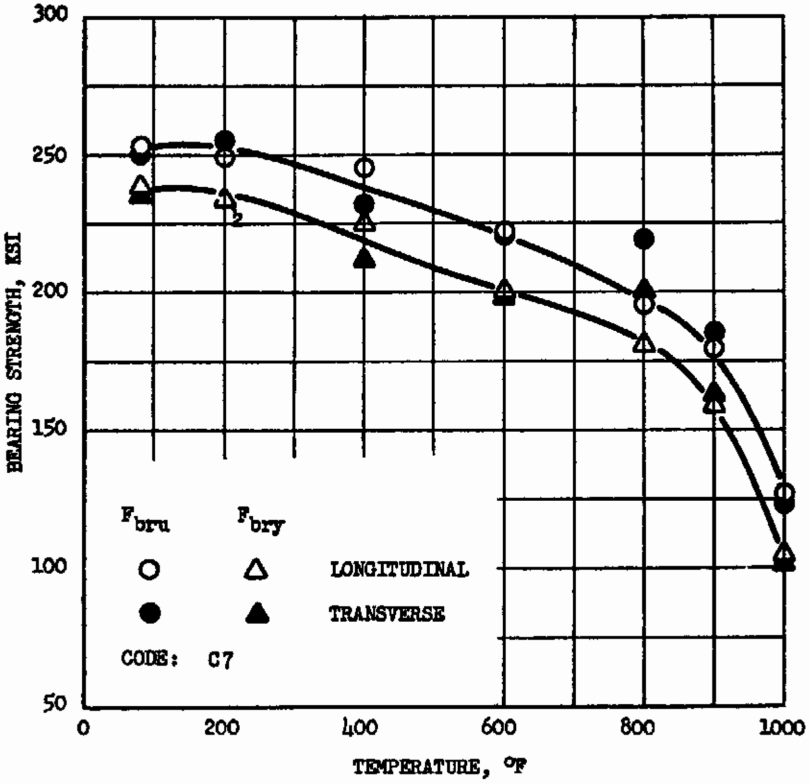


FIGURE 232 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (REACTIVE METALS HEAT NO. 24814)

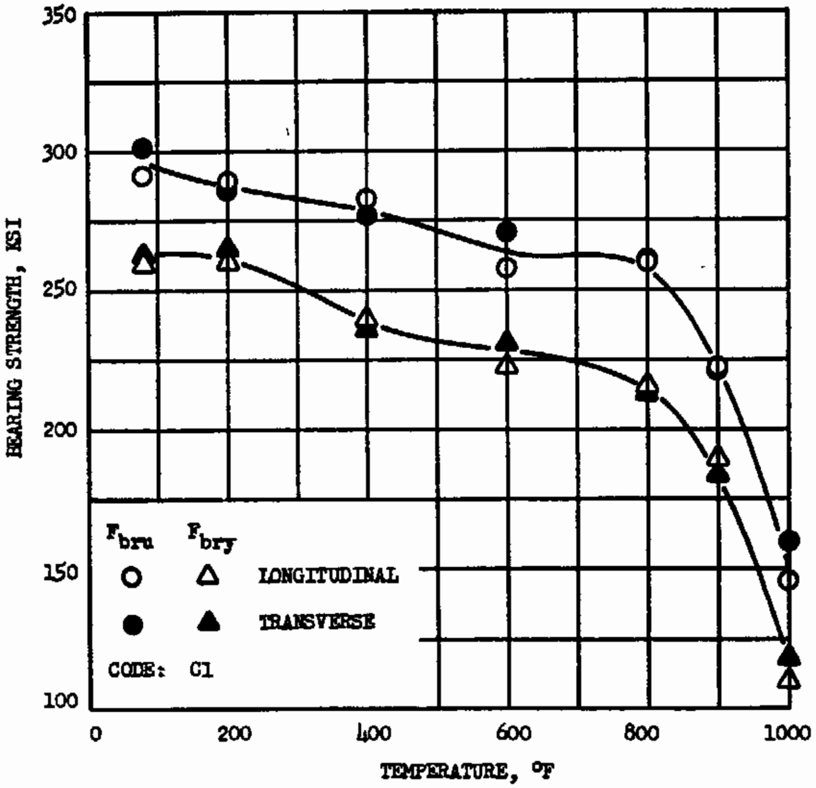


FIGURE 233 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (REACTIVE METALS HEAT NO. 22093)

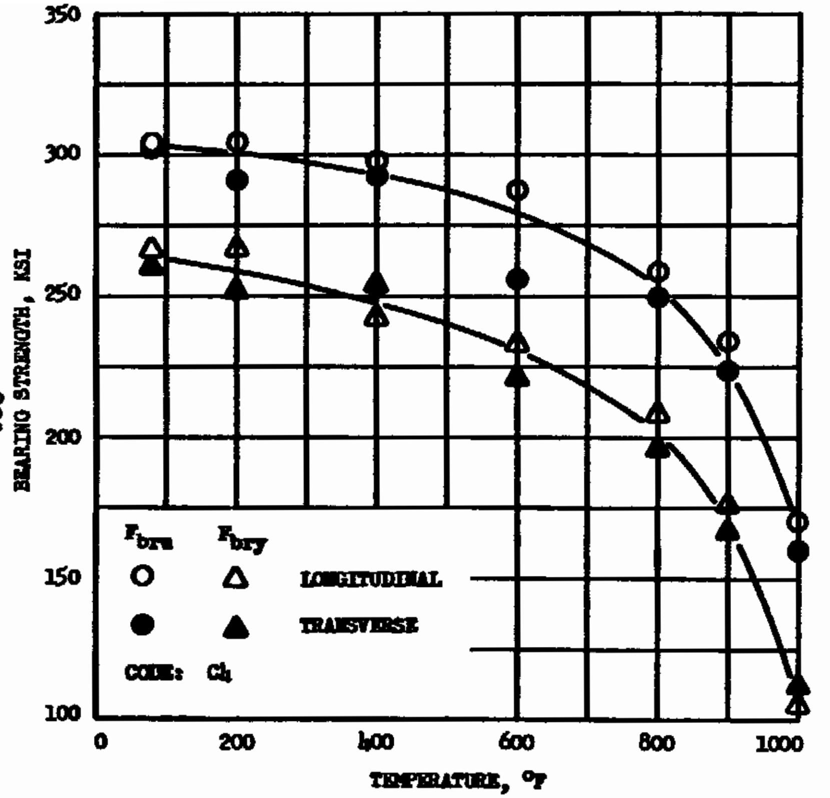


FIGURE 234 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1250 INCH (REACTIVE METALS HEAT NO. 24990)

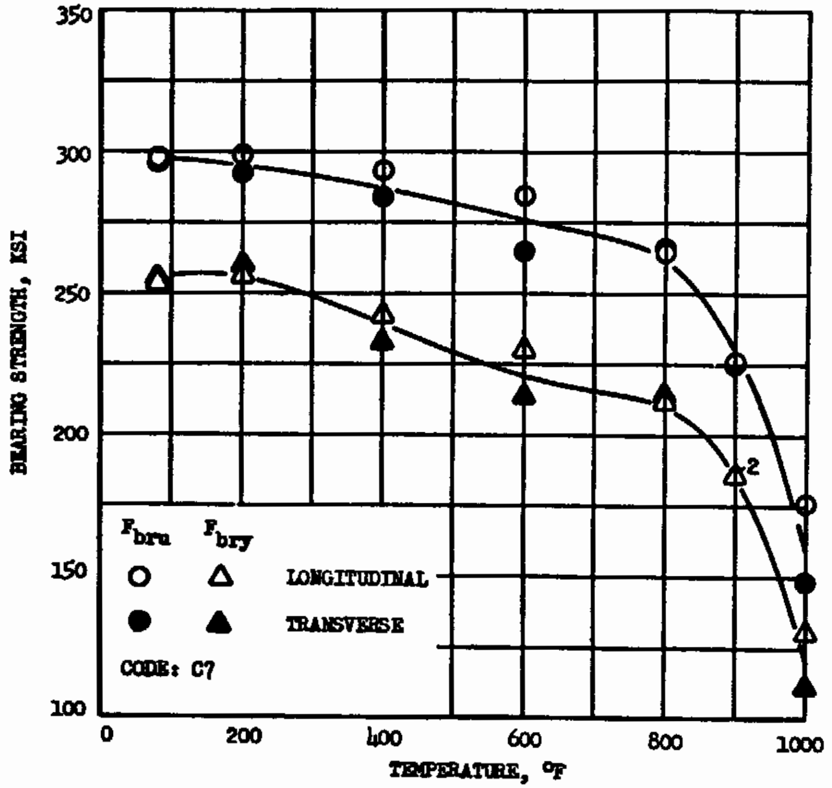


FIGURE 235 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1250 INCH (REACTIVE METALS HEAT NO. 24814)

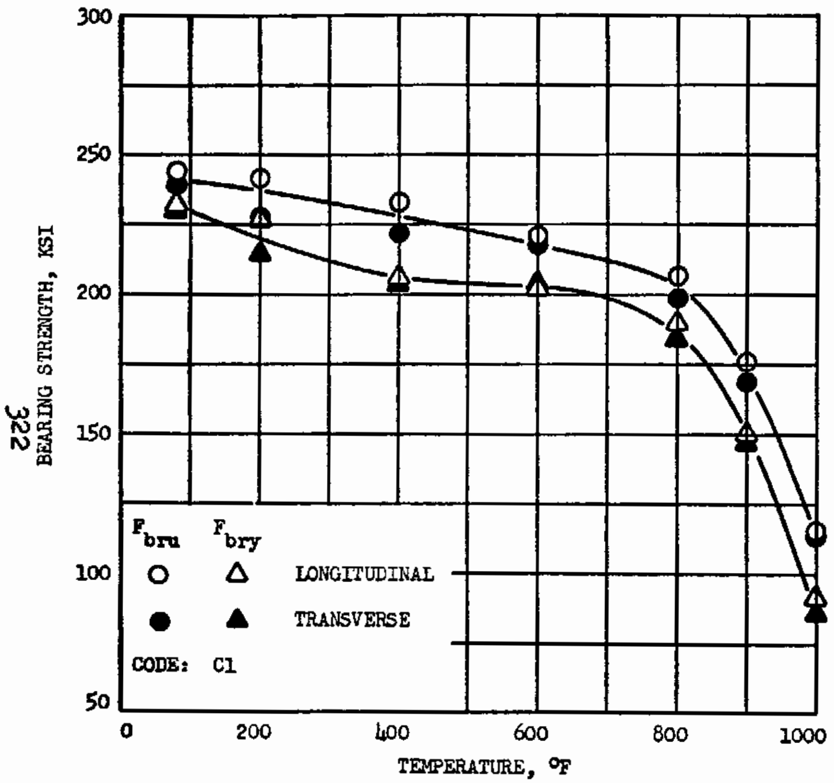


FIGURE 236 – AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 22093)

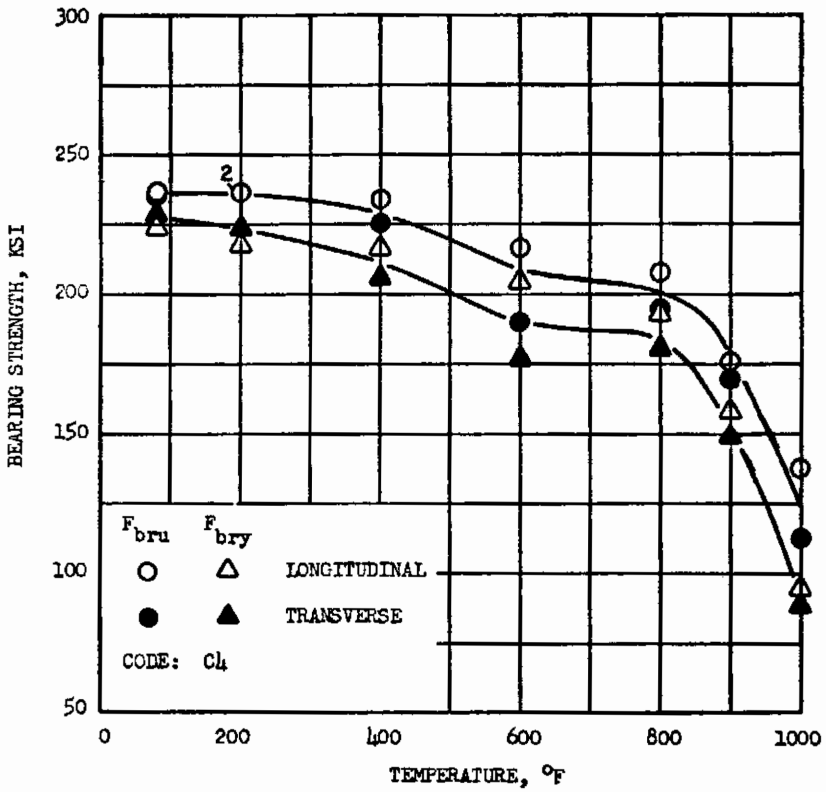


FIGURE 237 – AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 24990)

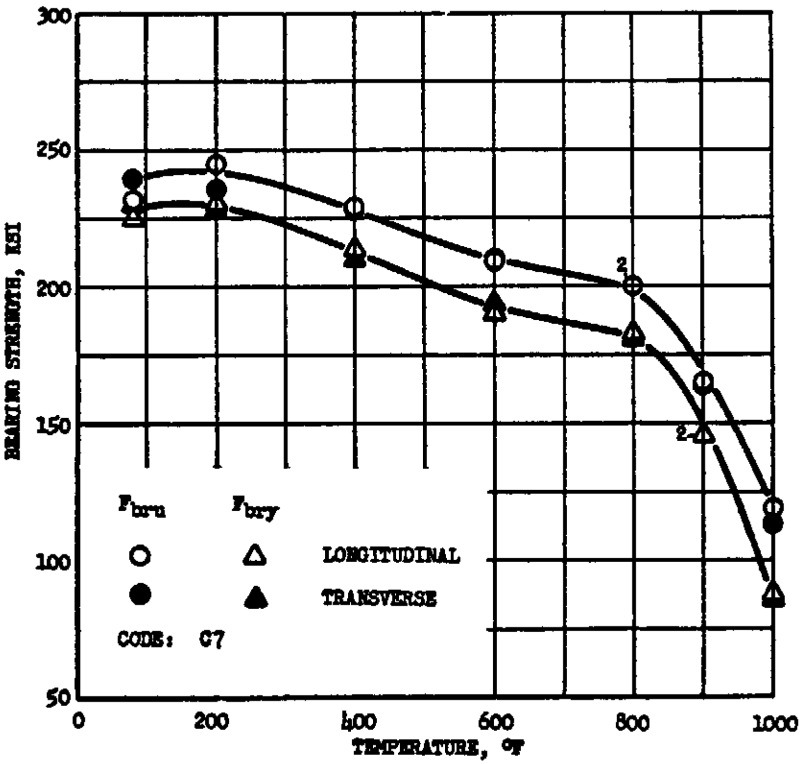


FIGURE 238 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 24814)

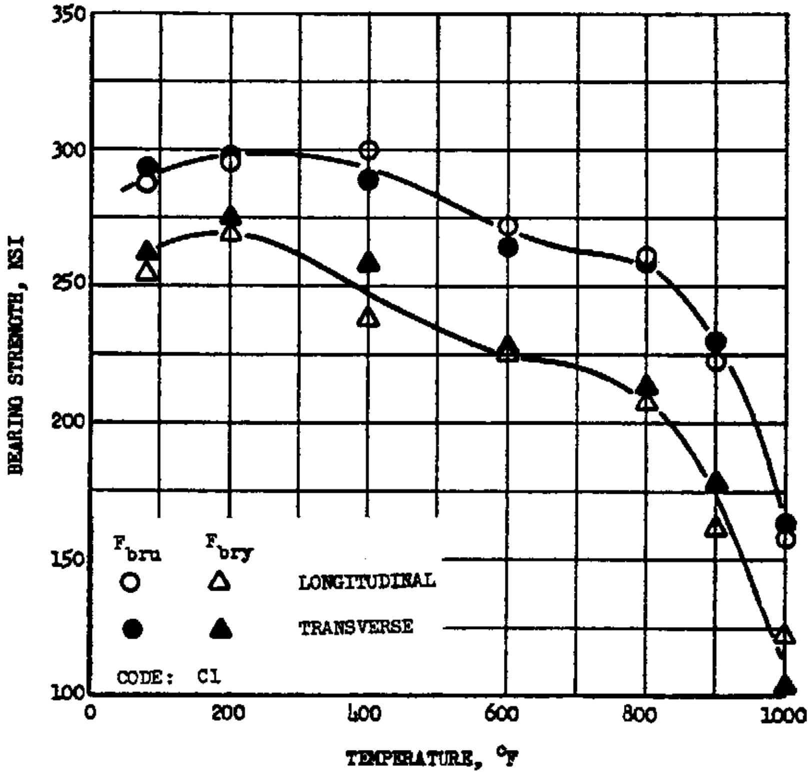


FIGURE 239 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 22093)

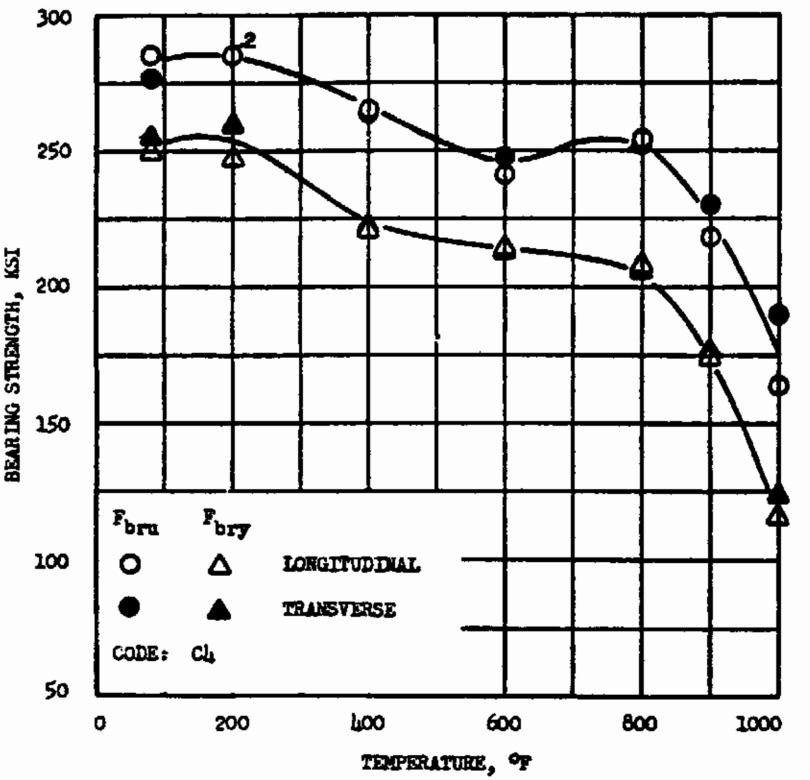


FIGURE 240 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (REACTIVE METALS HEAT NO. 24990)

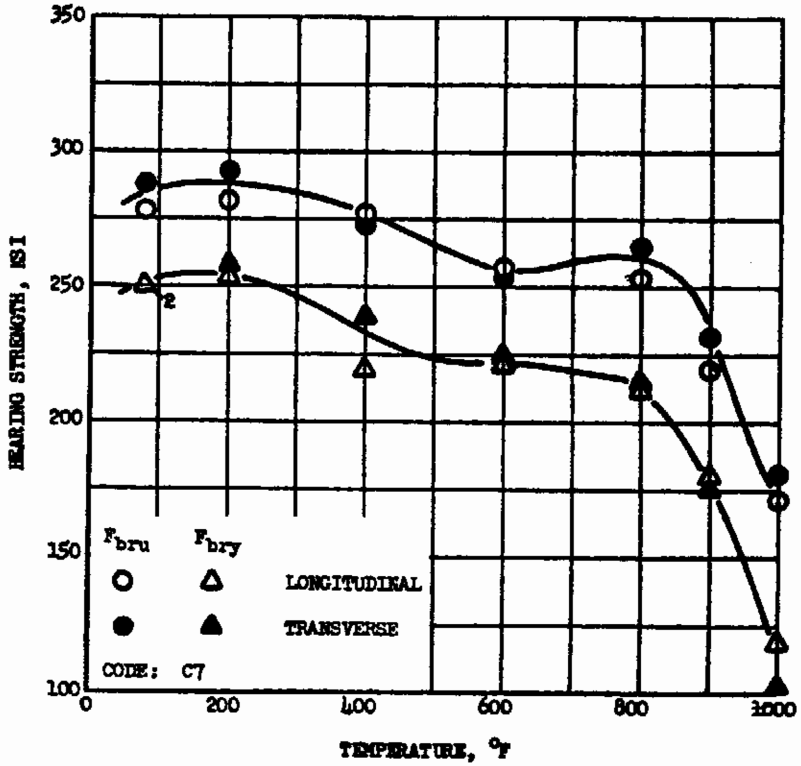


FIGURE 241 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING DIAMETER = 0.1875 INCH (REACTIVE METALS NO. 24814)

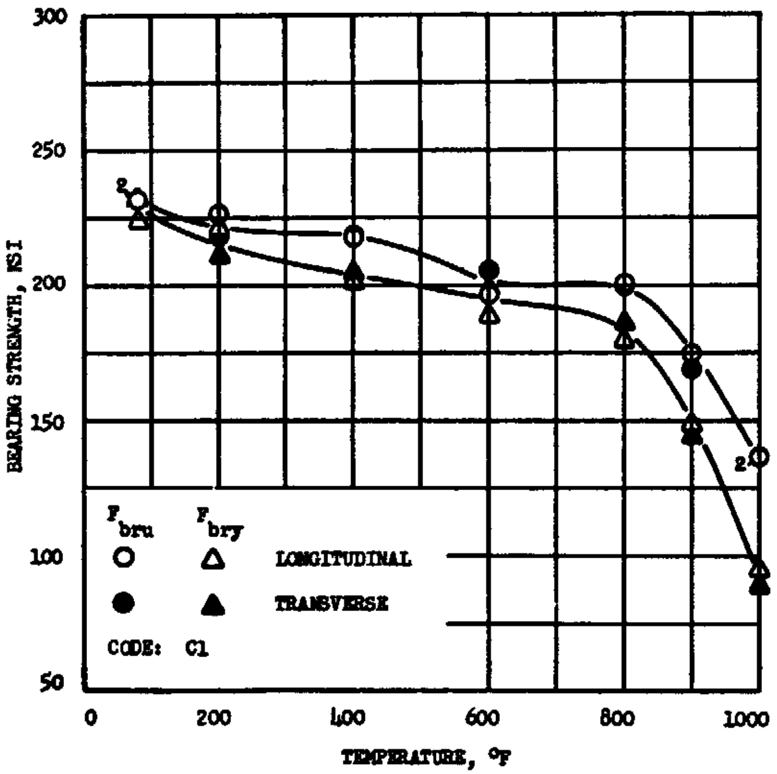


FIGURE 242 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 22093)

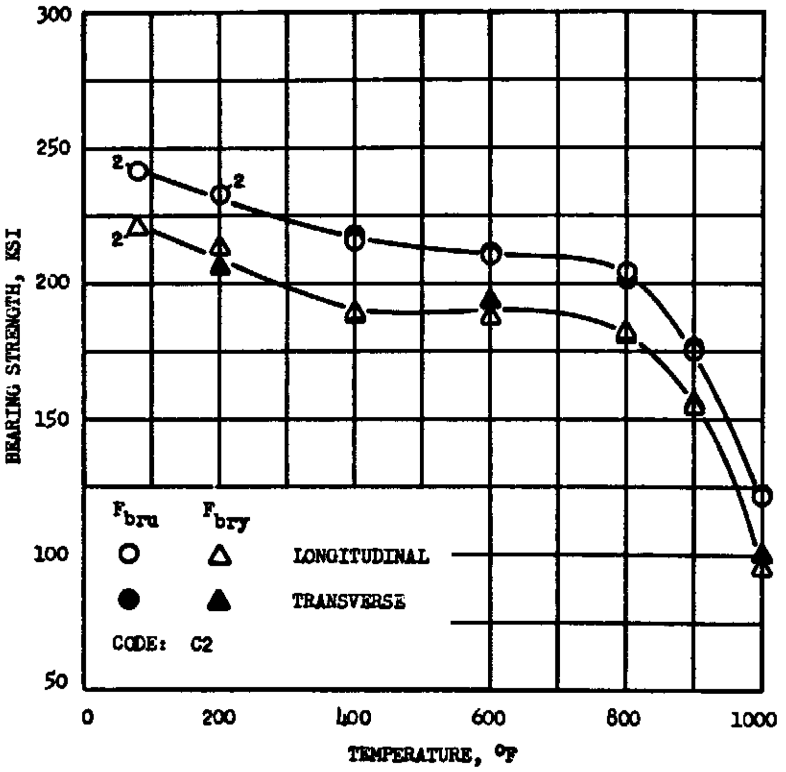


FIGURE 243 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 22154)

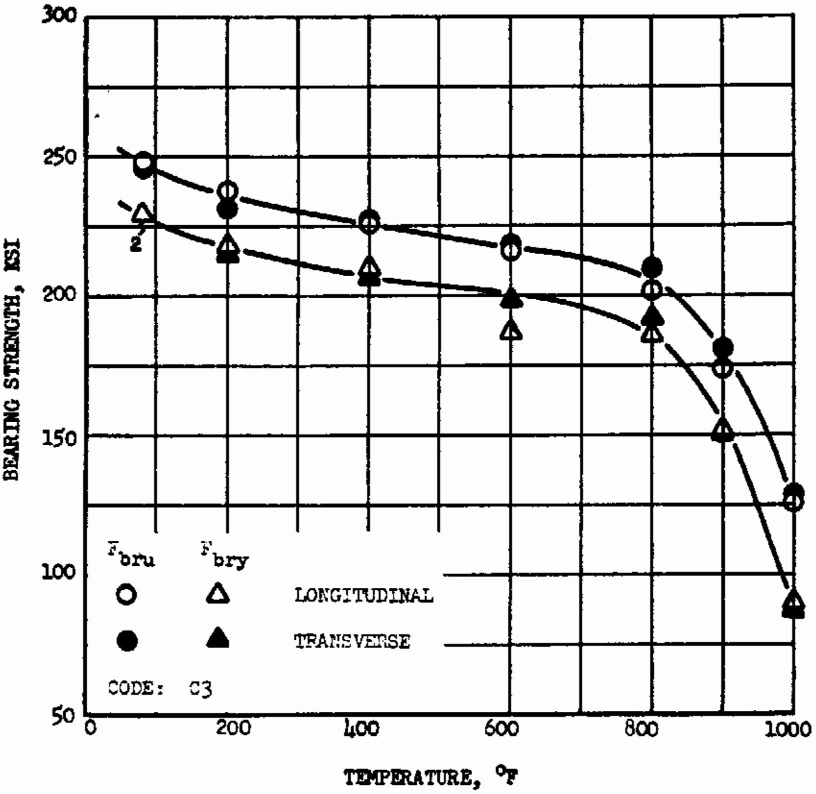


FIGURE 244 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (MALLORY-SHARON HEAT NO. 23354)

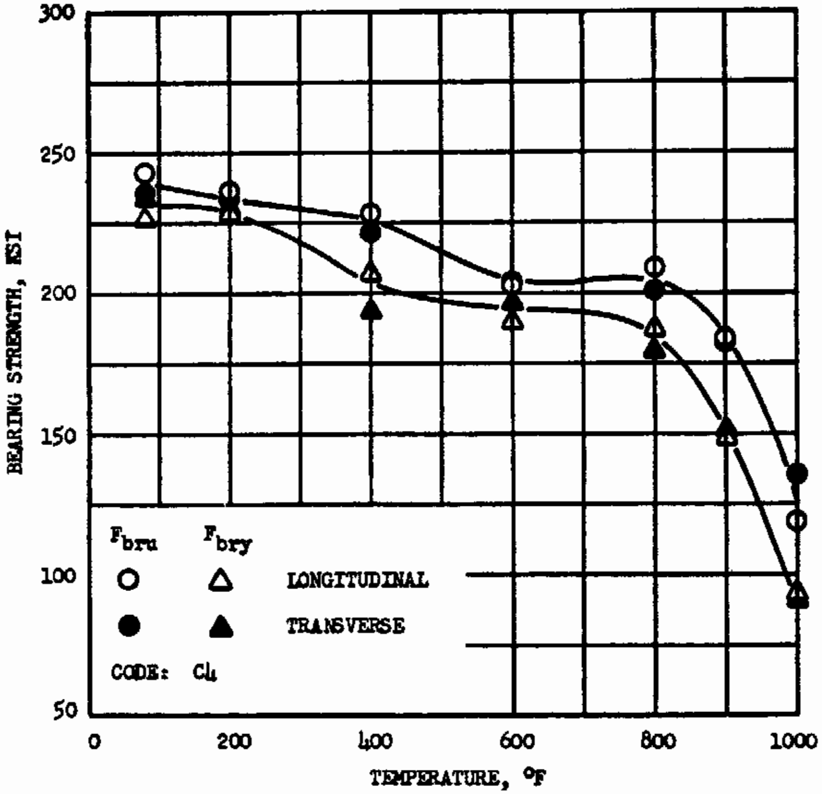


FIGURE 245 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24990)

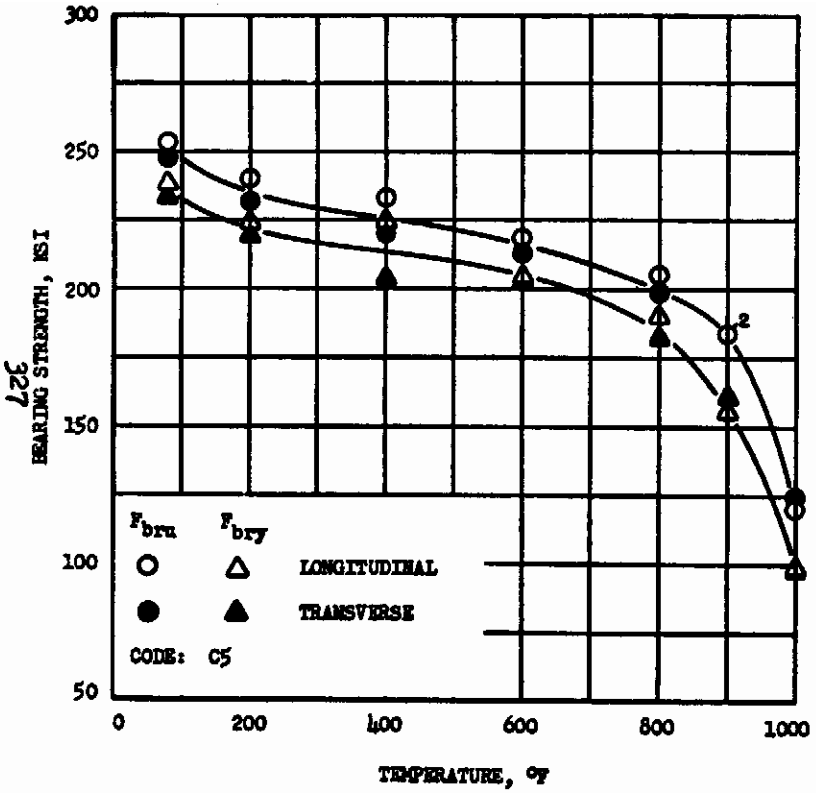


FIGURE 246 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24806)

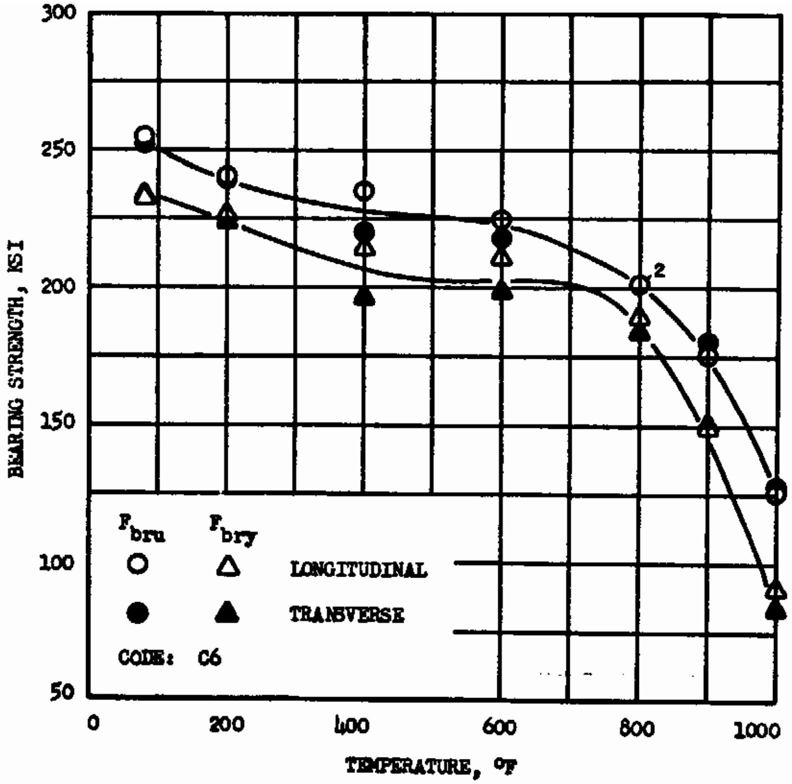


FIGURE 247 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 23372)

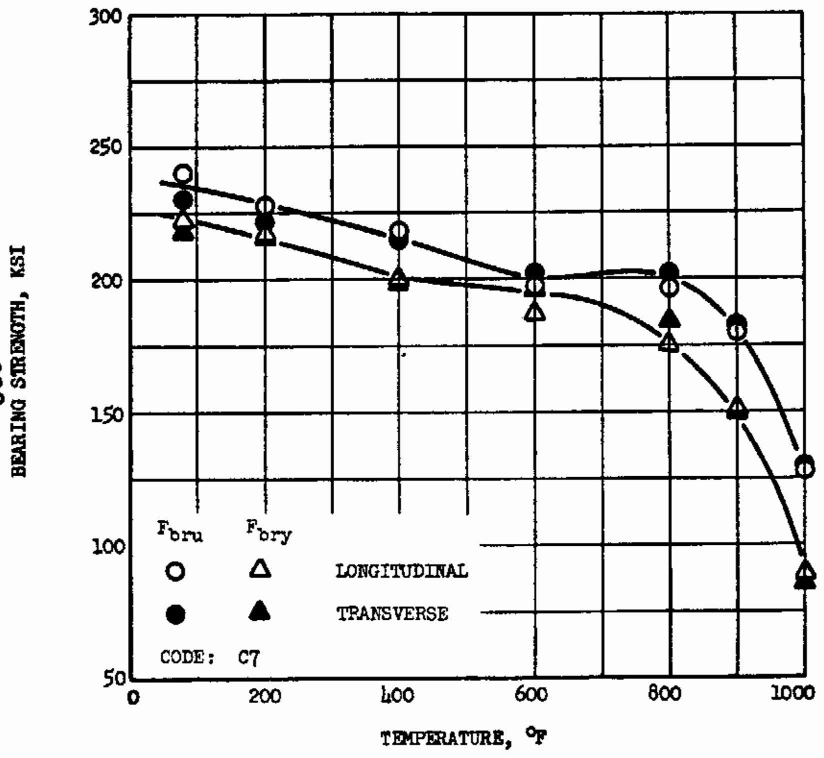


FIGURE 248 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24814)

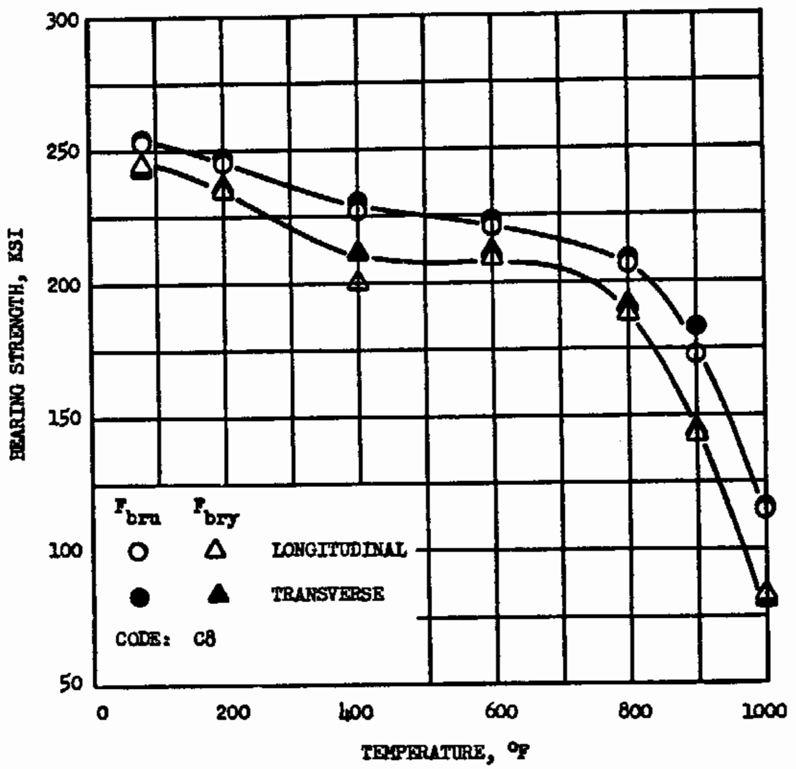


FIGURE 249 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24814)

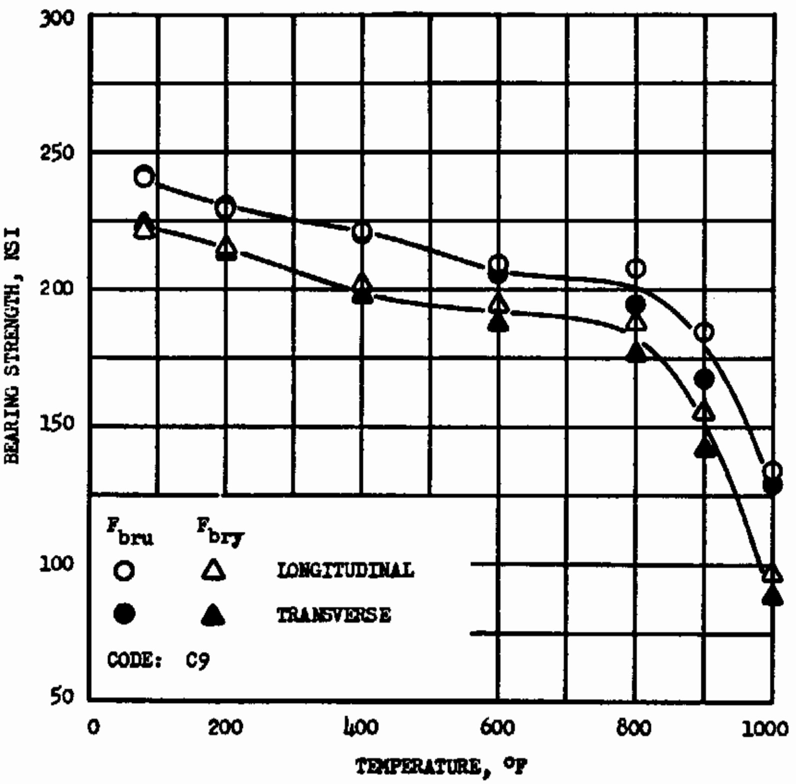


FIGURE 250 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 23345)

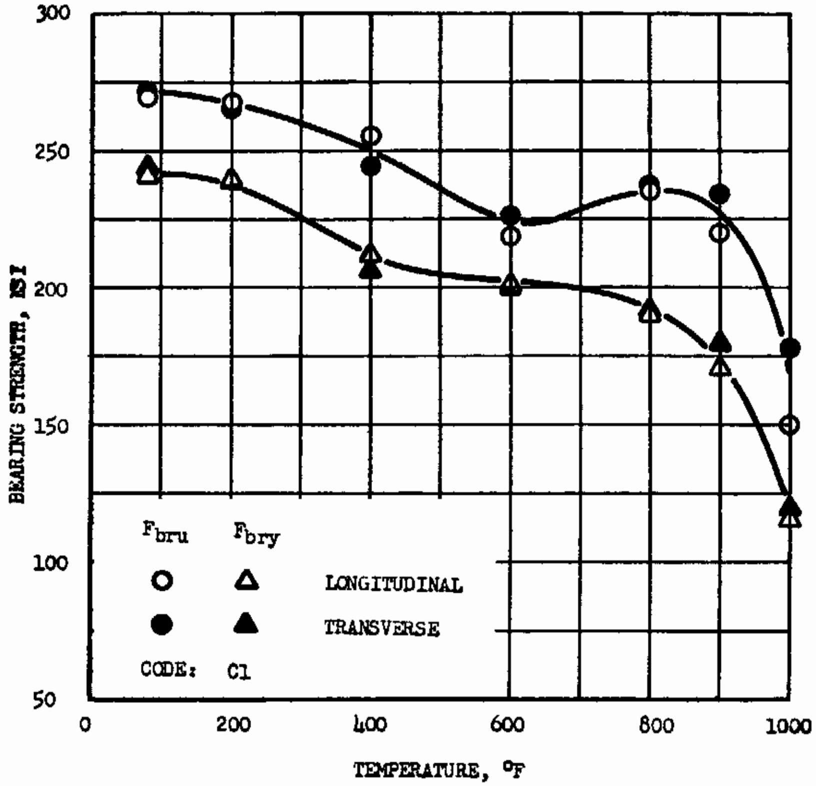


FIGURE 251 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 22093)

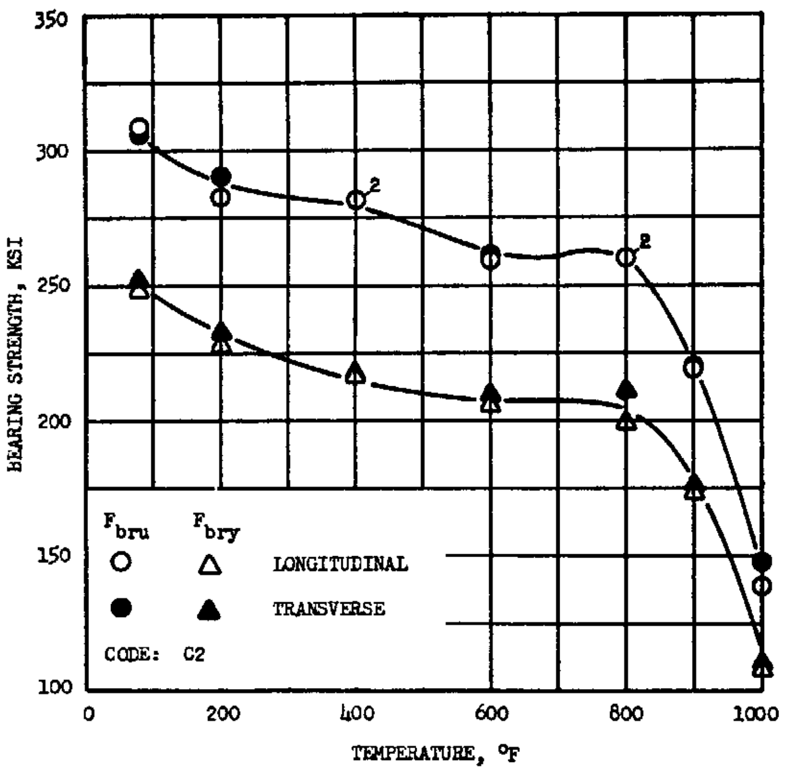


FIGURE 252 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 22154)

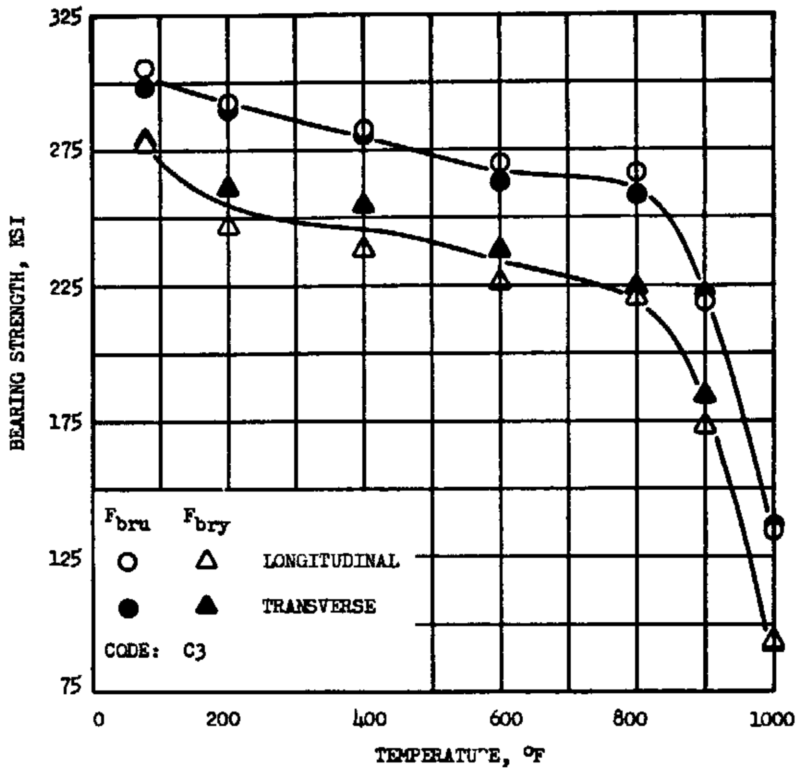


FIGURE 253 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 23354)

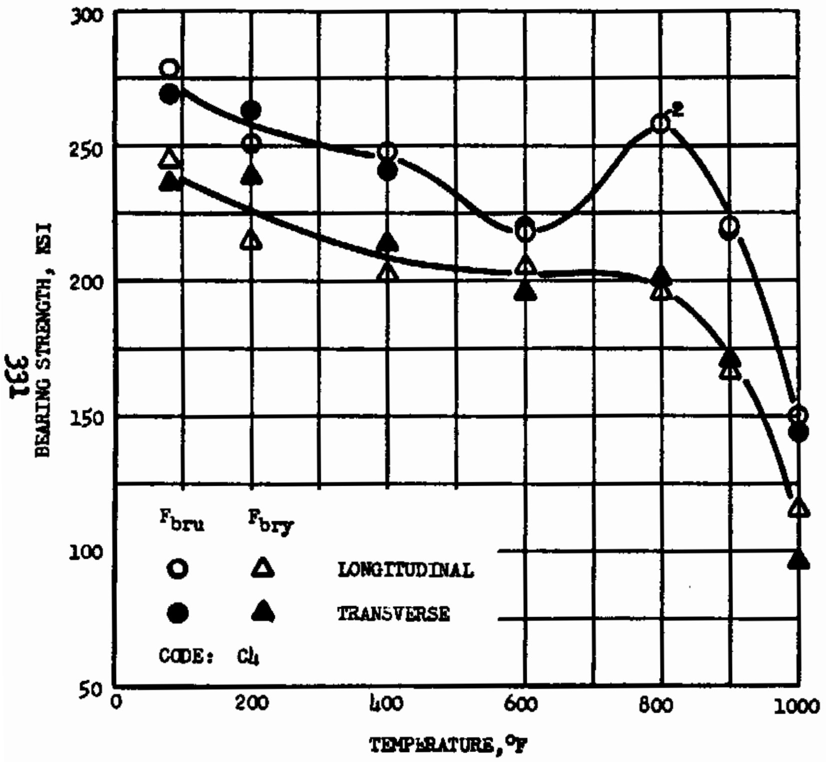


FIGURE 254 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24990)

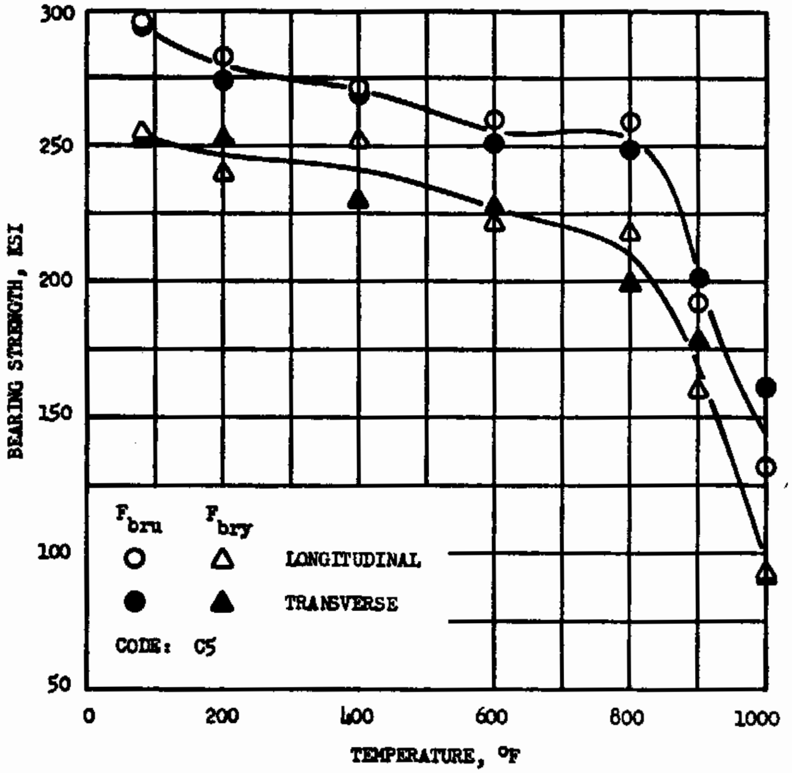


FIGURE 255 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24806)

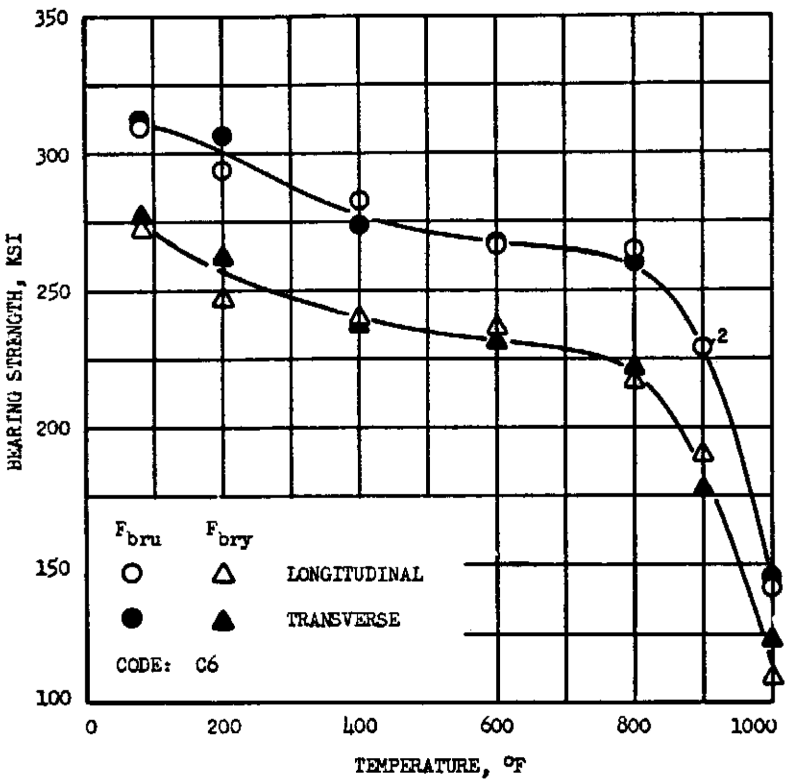


FIGURE 256 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 23372)

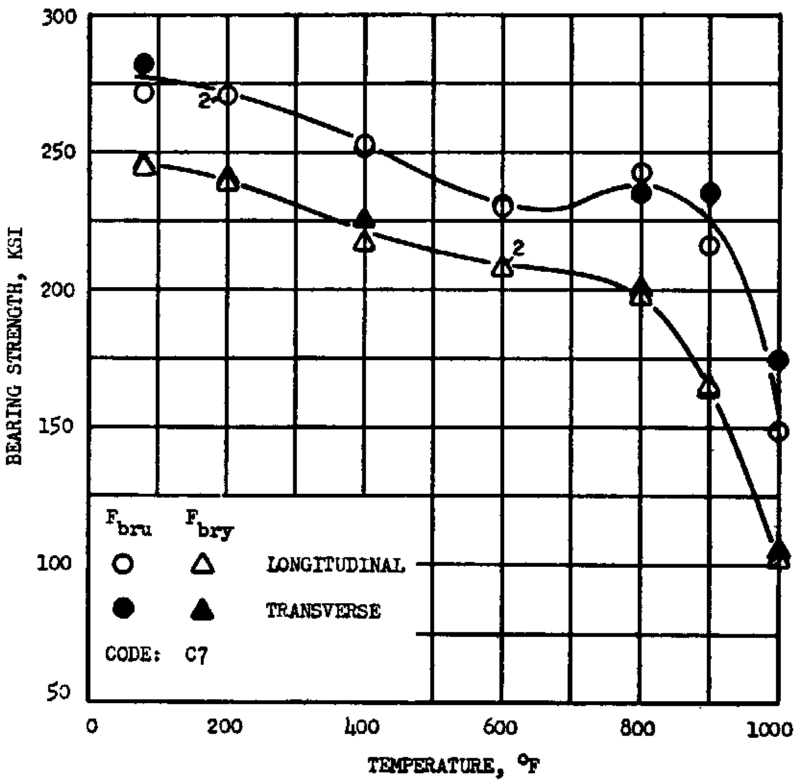


FIGURE 257 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24814)

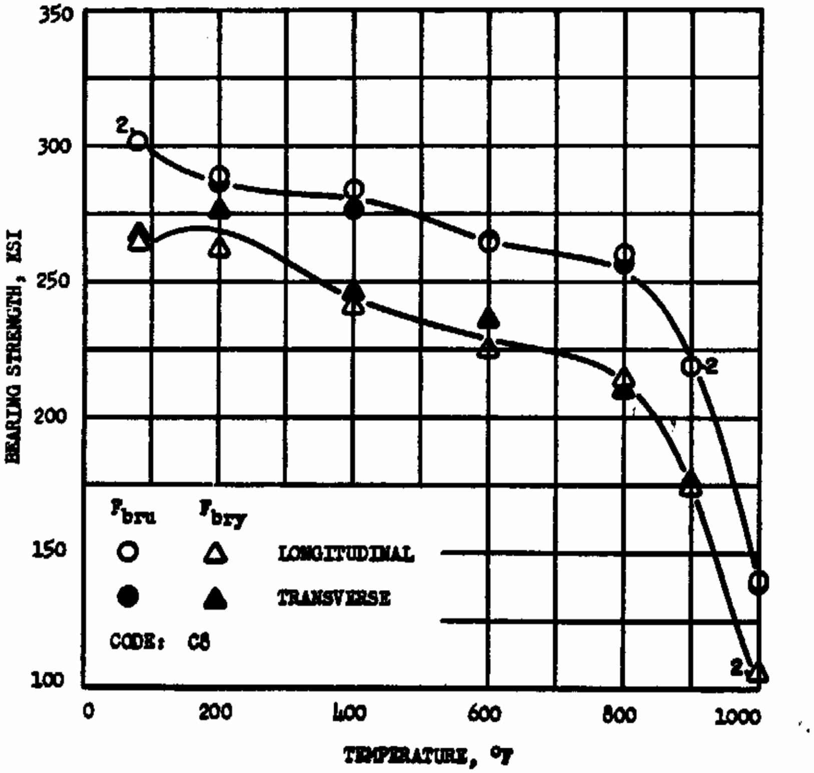


FIGURE 258 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 24814)

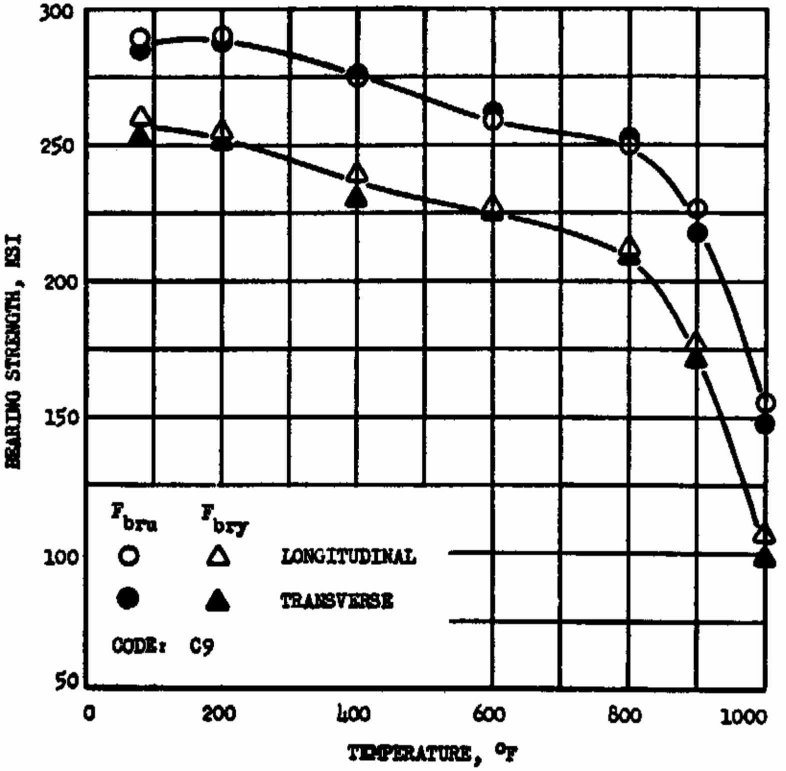


FIGURE 259 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (REACTIVE METALS HEAT NO. 23345)

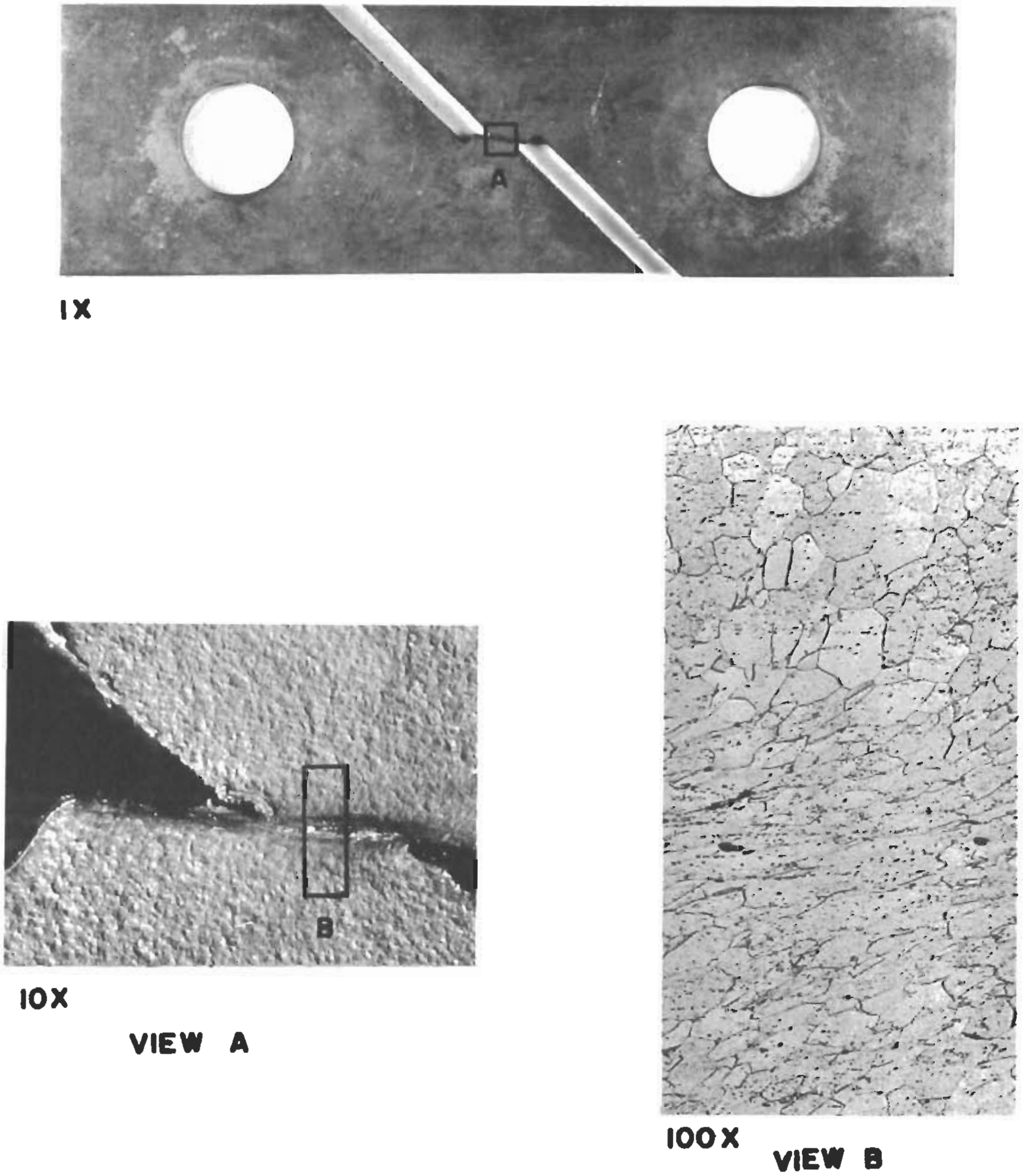


FIGURE 260 - Ti-2.5Al-16V SHEAR SPECIMEN TESTED AT 1000°F AND UNLOADED PRIOR TO FAILURE

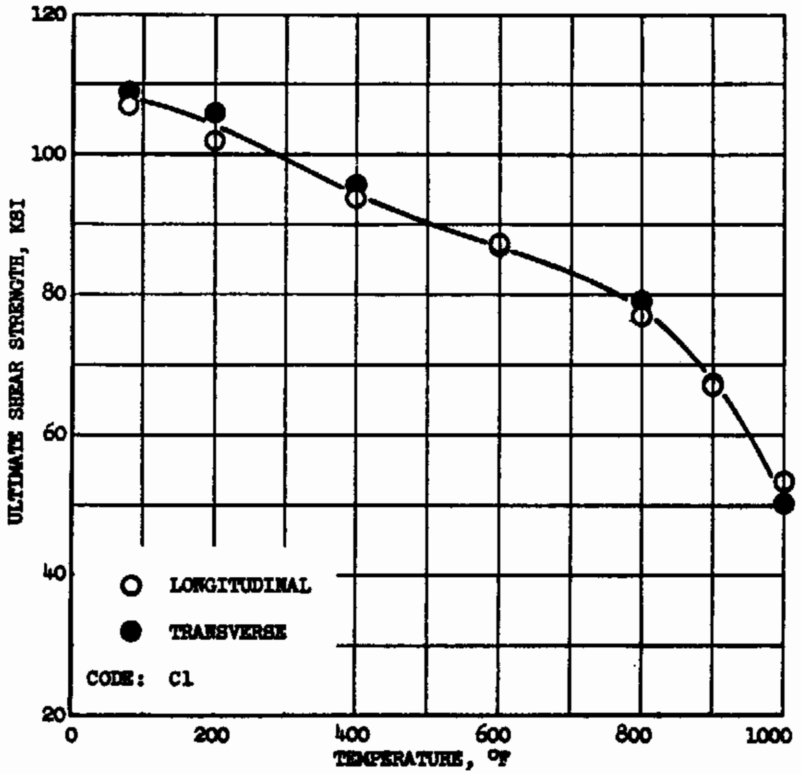


FIGURE 261 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO. 22093)

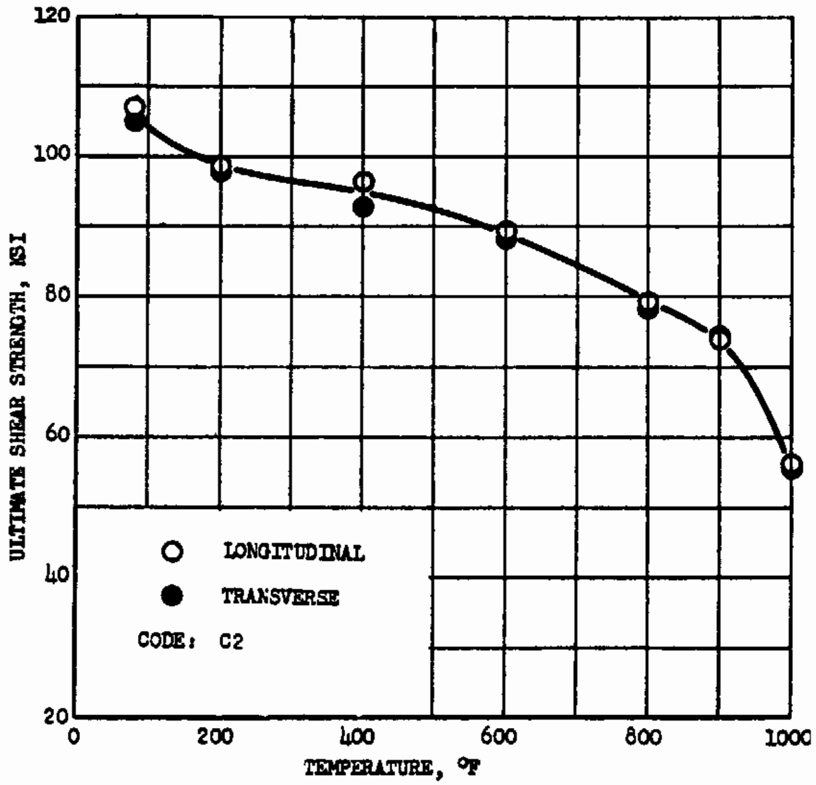


FIGURE 262 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 22154)

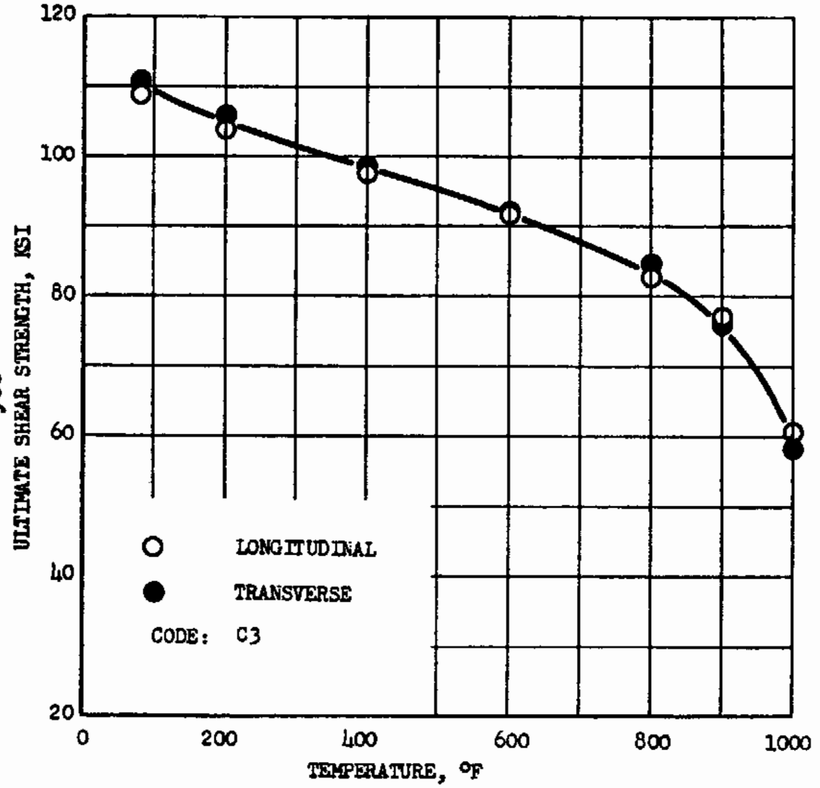


FIGURE 263 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23354)

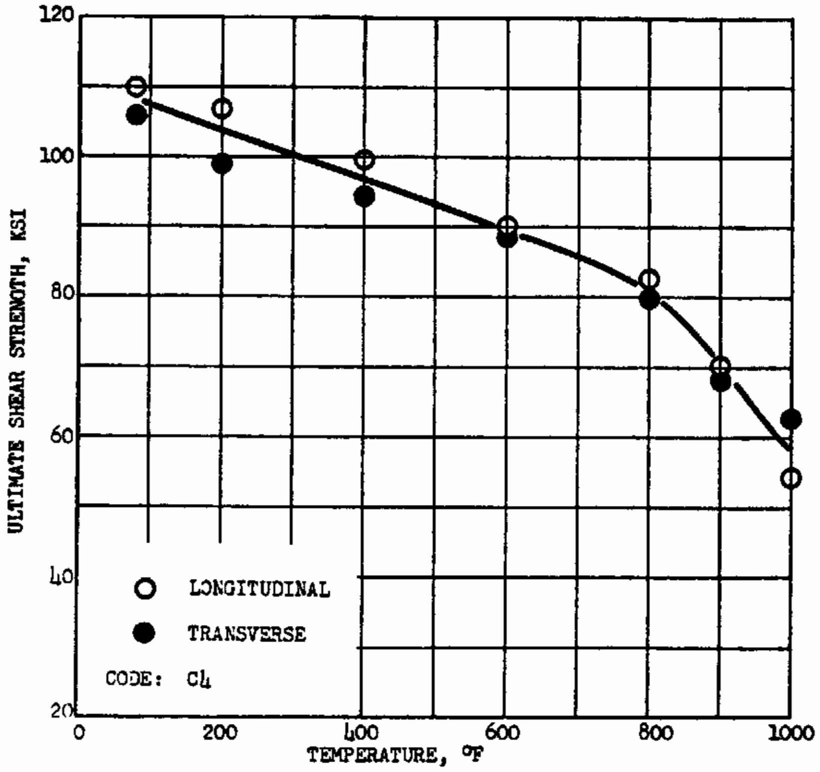


FIGURE 264 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO. 24990)

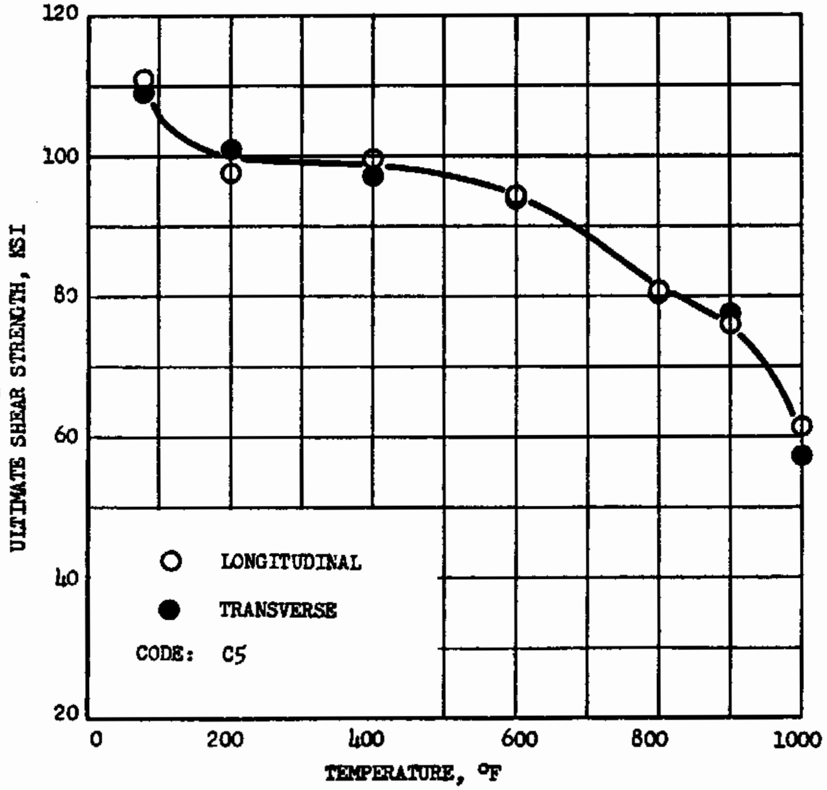


FIGURE 265 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24806)

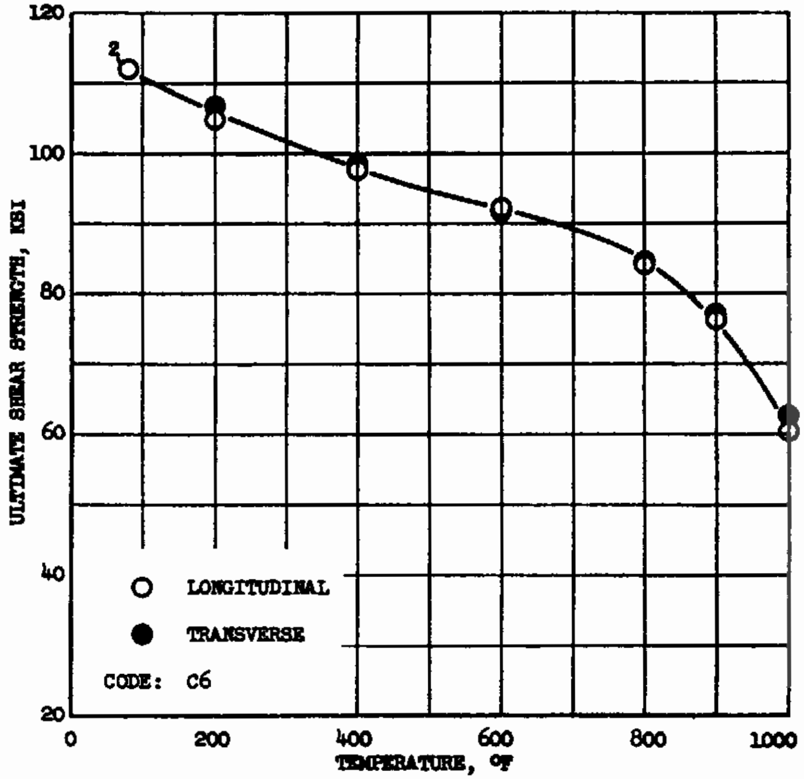


FIGURE 266 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23372)

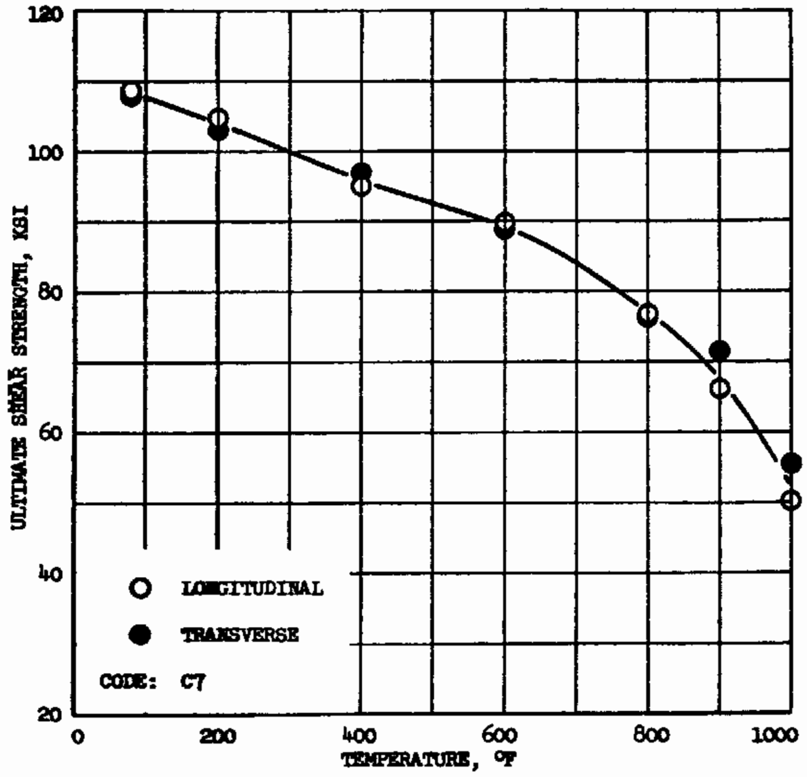


FIGURE 267 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.020 INCH THICK (REACTIVE METALS HEAT NO. 24814)

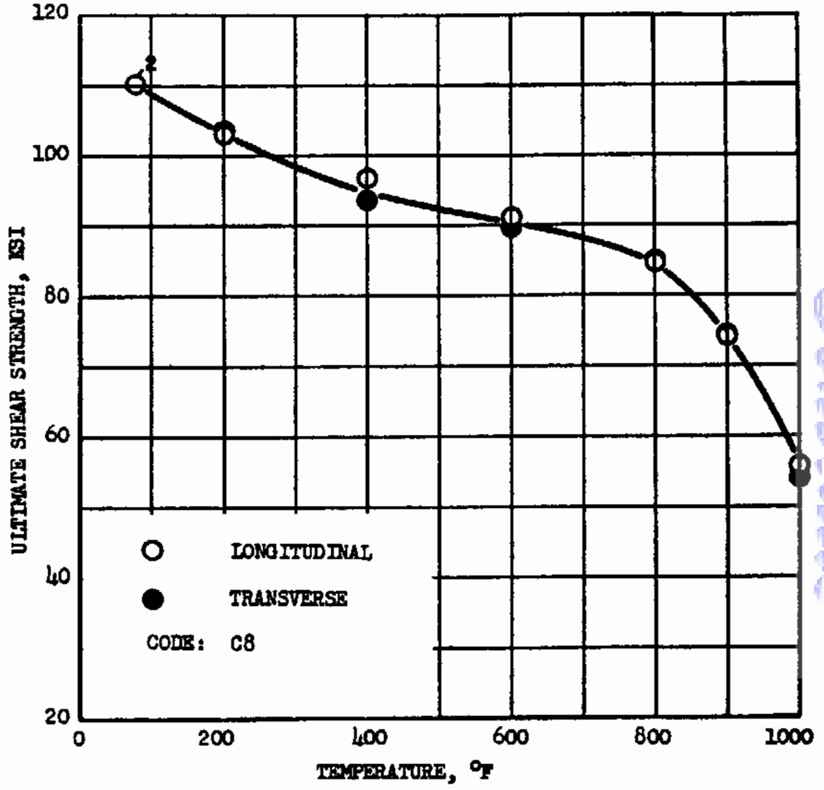


FIGURE 268 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 24814)

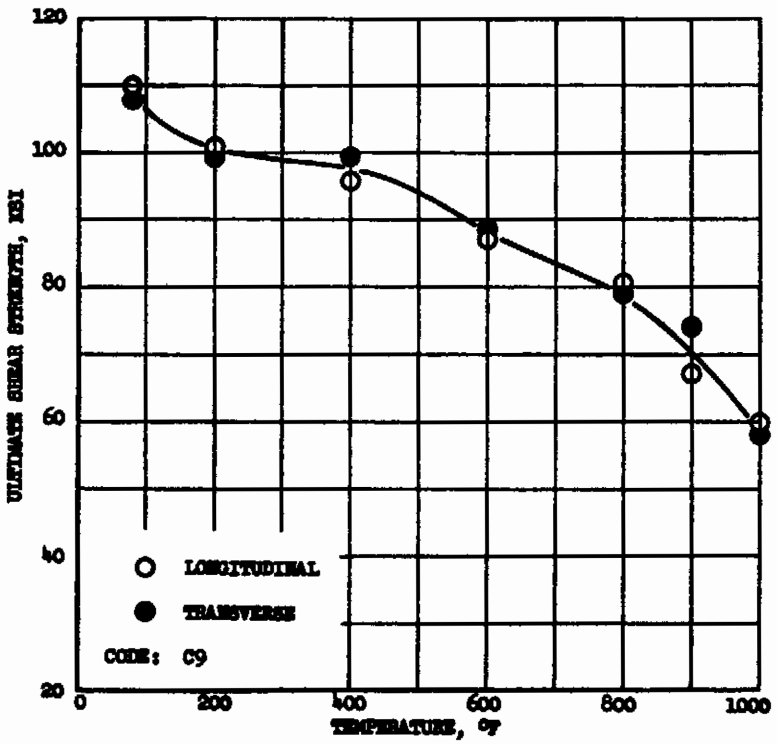


FIGURE 269 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23345)

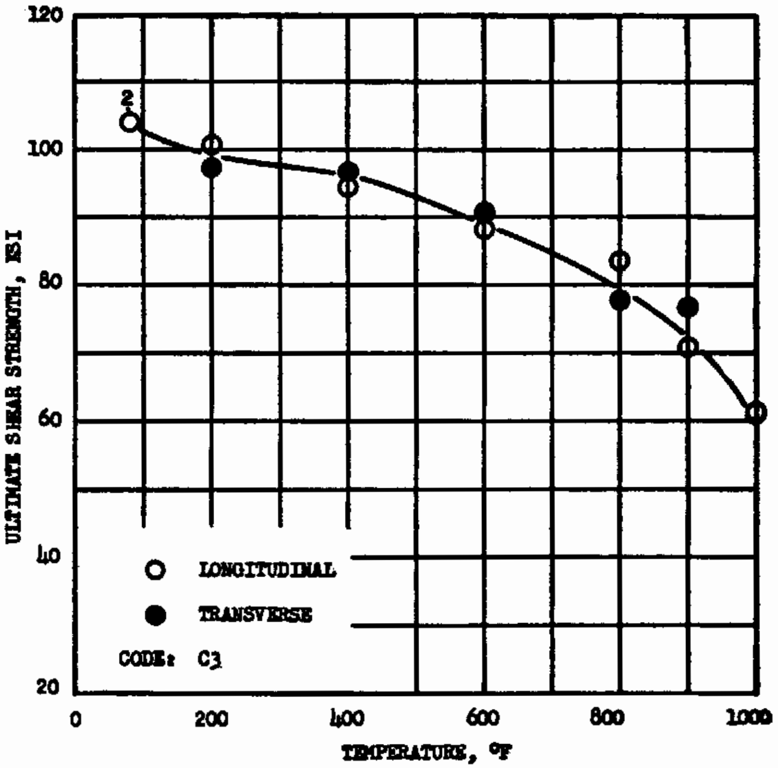


FIGURE 270 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23354)

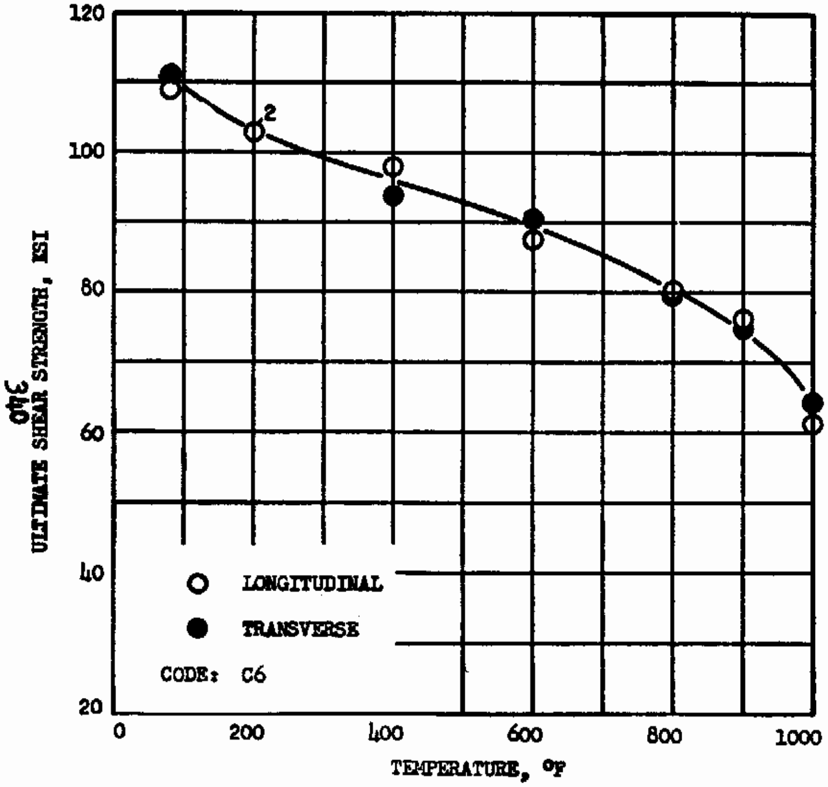


FIGURE 271 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23372)

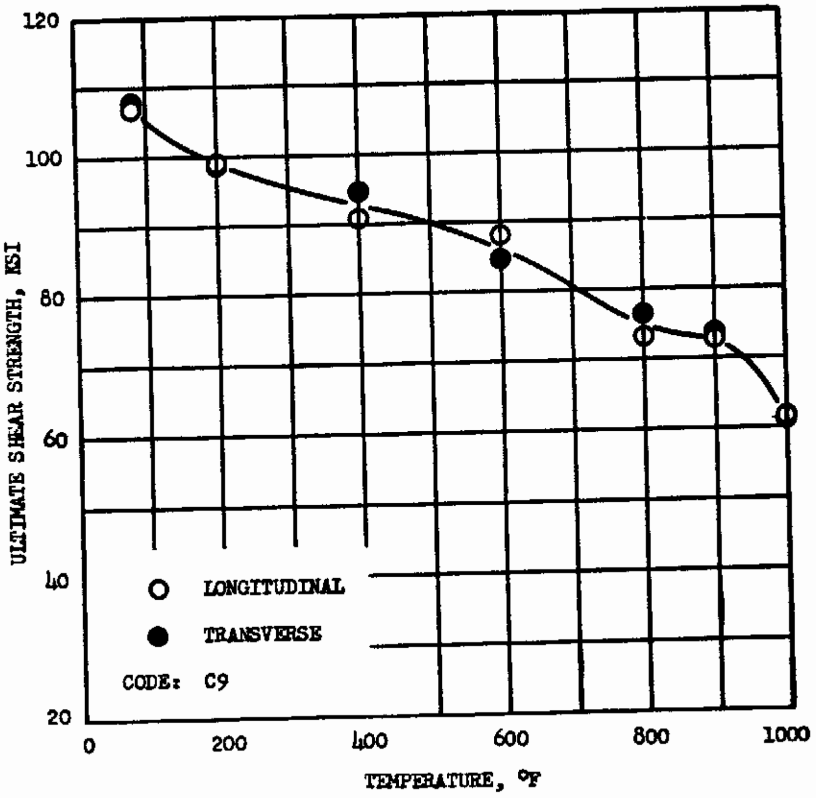


FIGURE 272 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.125 INCH THICK (REACTIVE METALS HEAT NO. 23345)

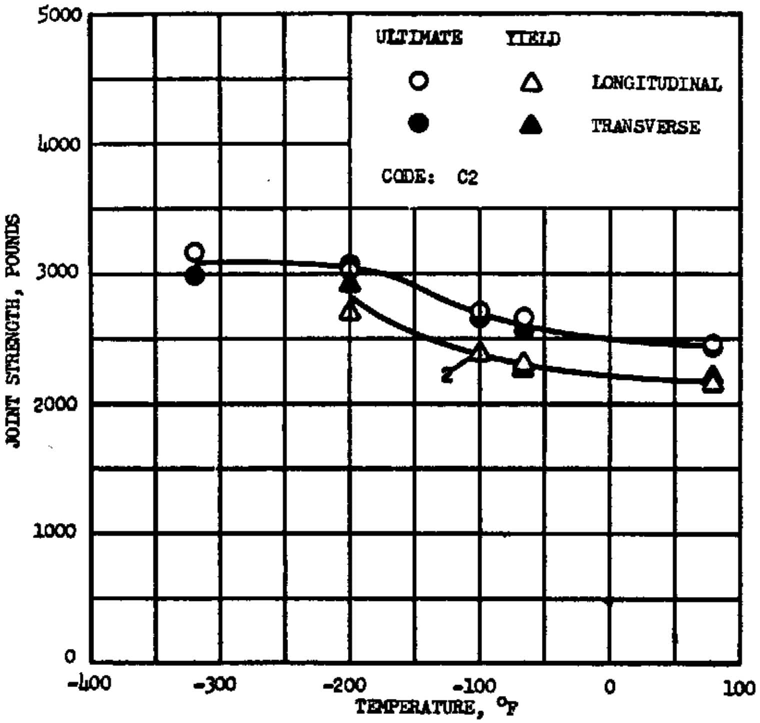


FIGURE 273 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER NAS2506-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 22154)

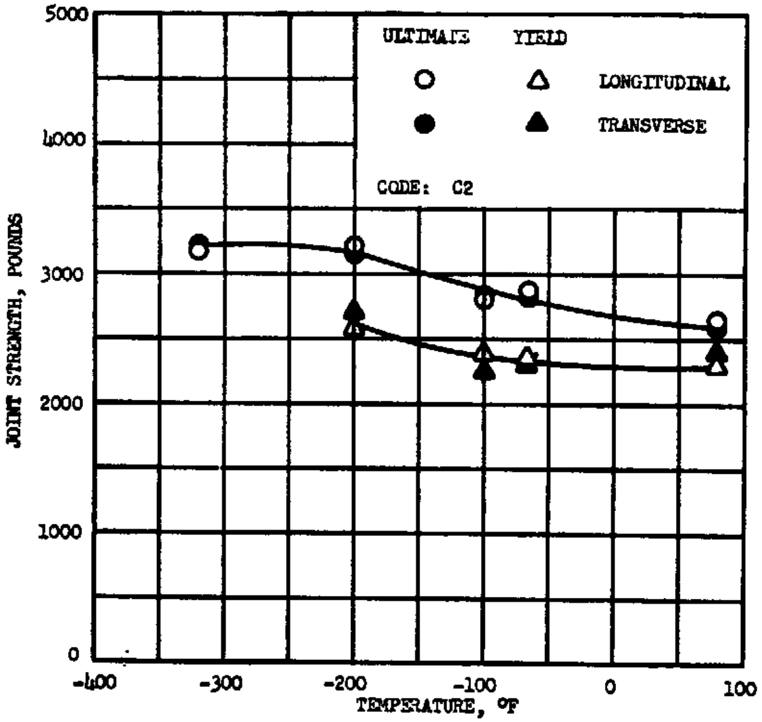


FIGURE 274 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER H111V-6-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 22154)

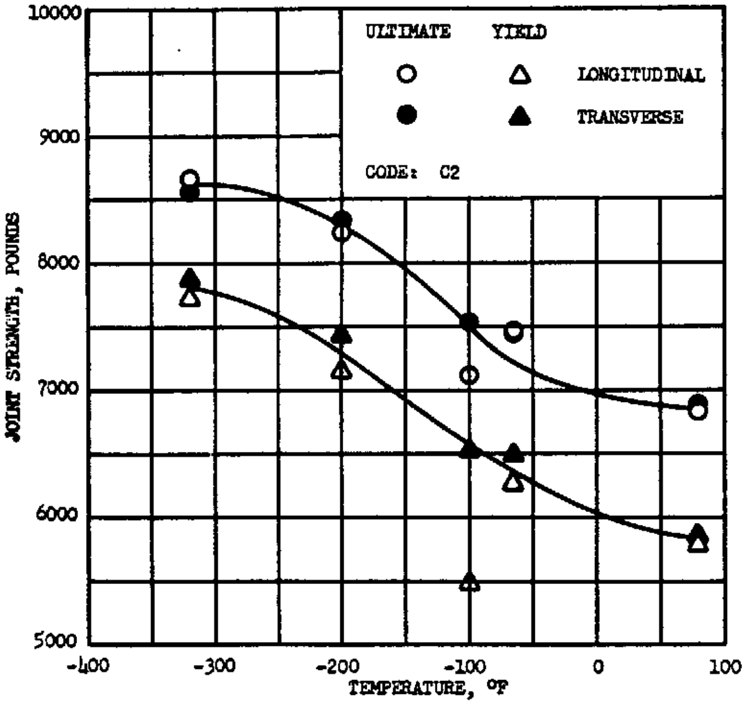


FIGURE 275 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS2010-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 22154)

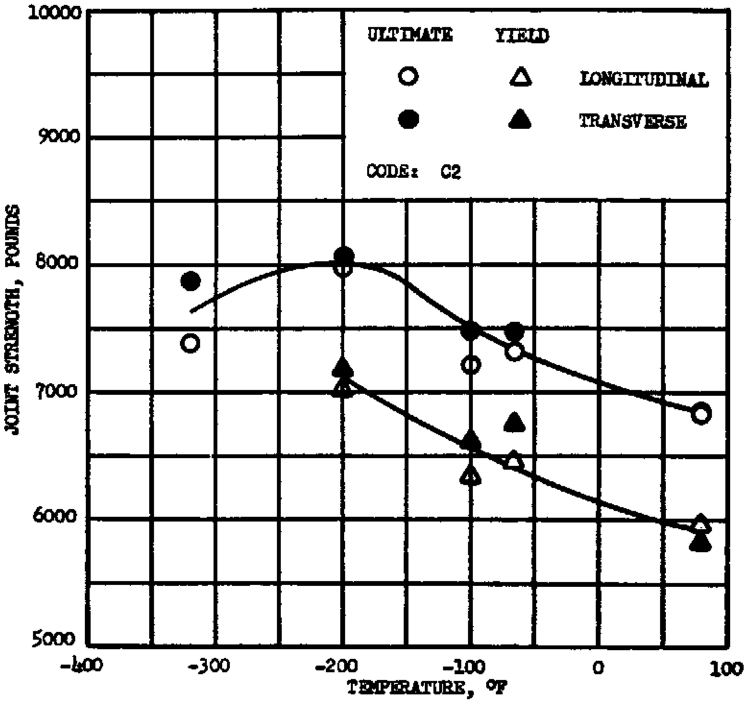


FIGURE 276 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS675-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (REACTIVE METALS HEAT NO. 22154)

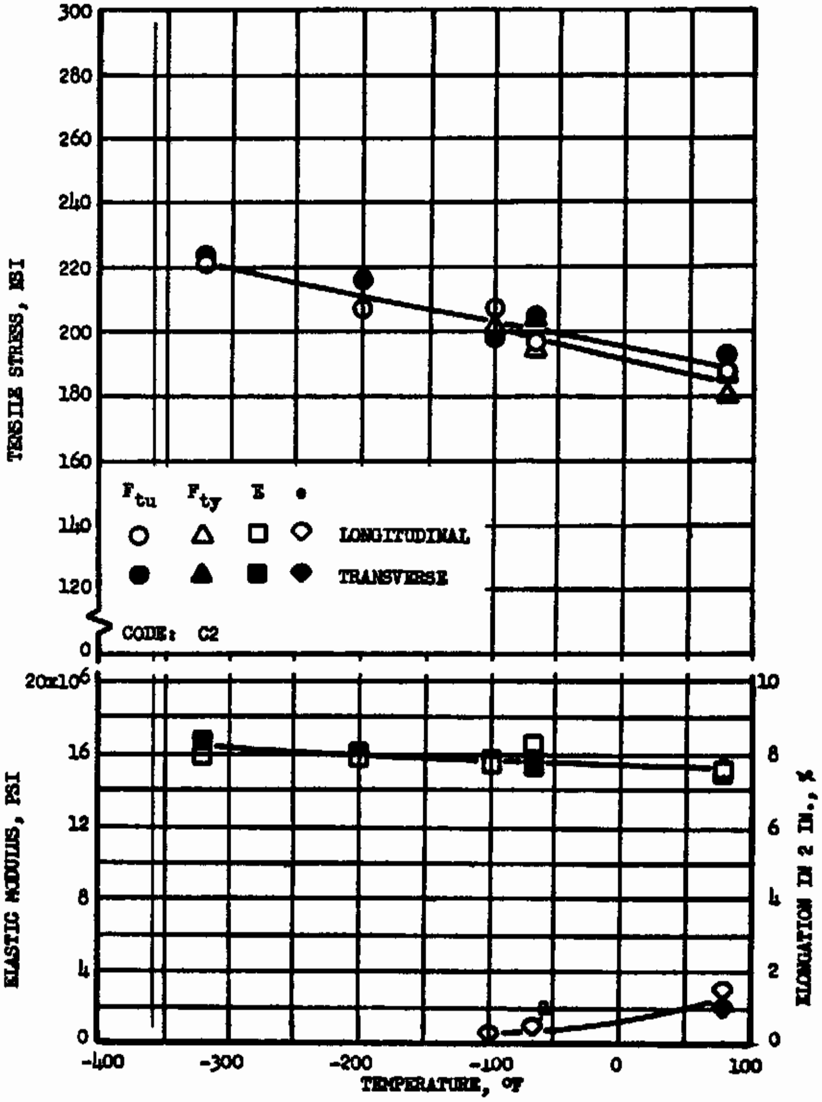


FIGURE 277 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK 2.5Al-16V TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED PRIOR TO AGING (REACTIVE METALS HEAT NO. 22154)

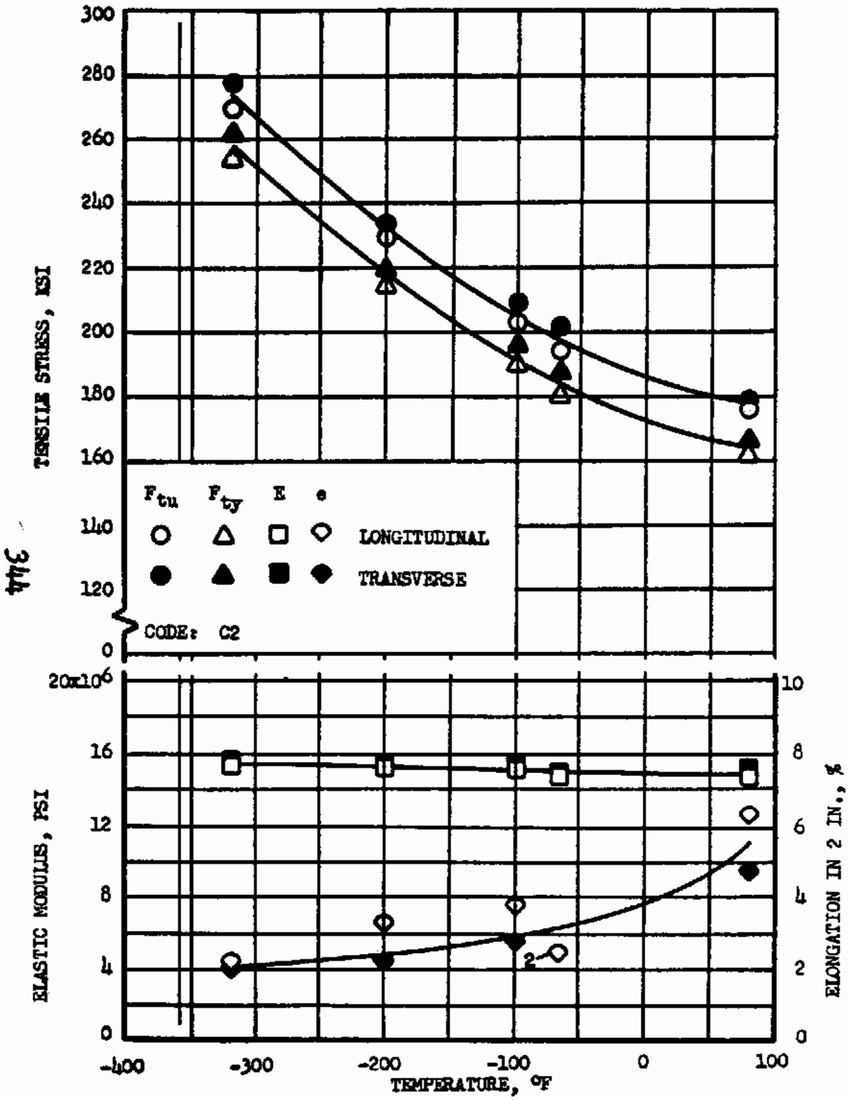


FIGURE 278 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 22154)

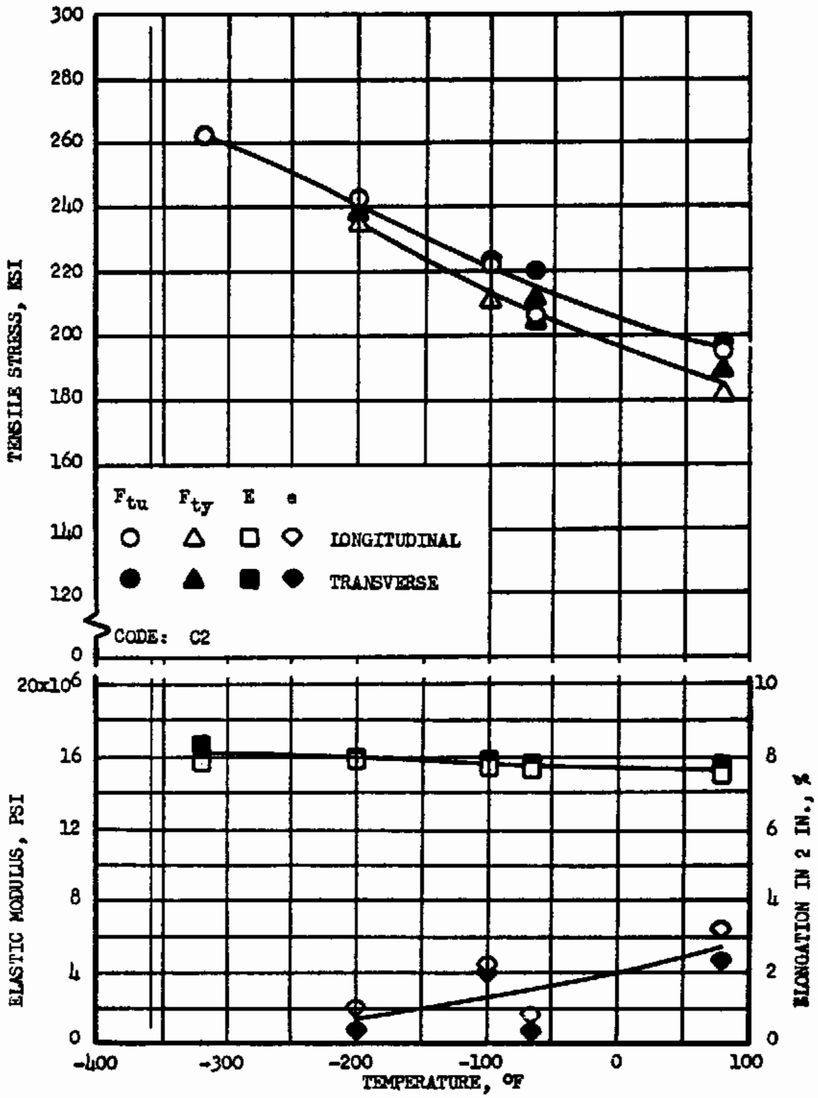


FIGURE 279 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK, AGED BY LOCKHEED (REACTIVE METALS HEAT NO. 22154)

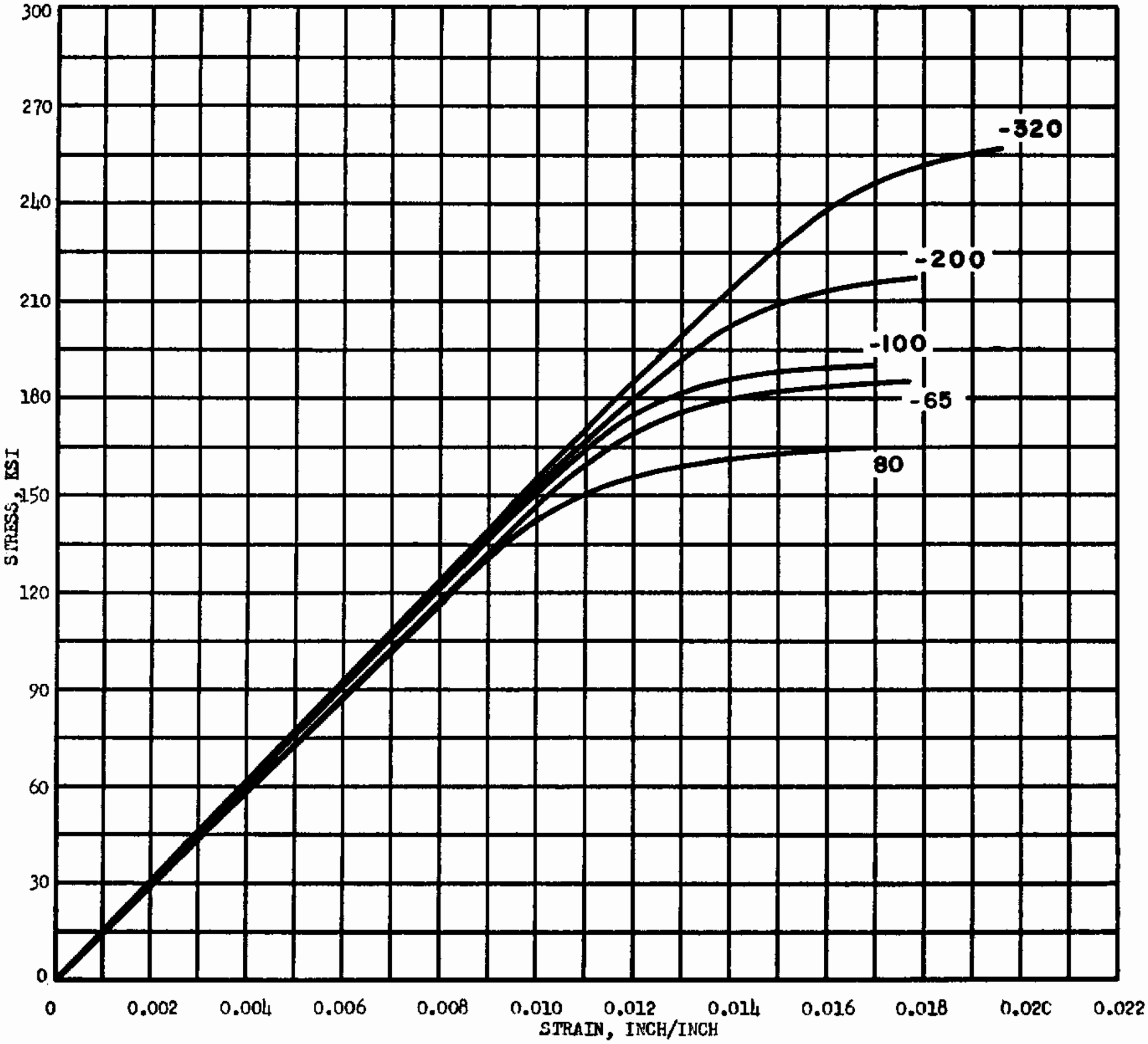


FIGURE 280 - TYPICAL LONGITUDINAL TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET, 0.063 INCH THICK (REACTIVE METALS HEAT NO. 22154)

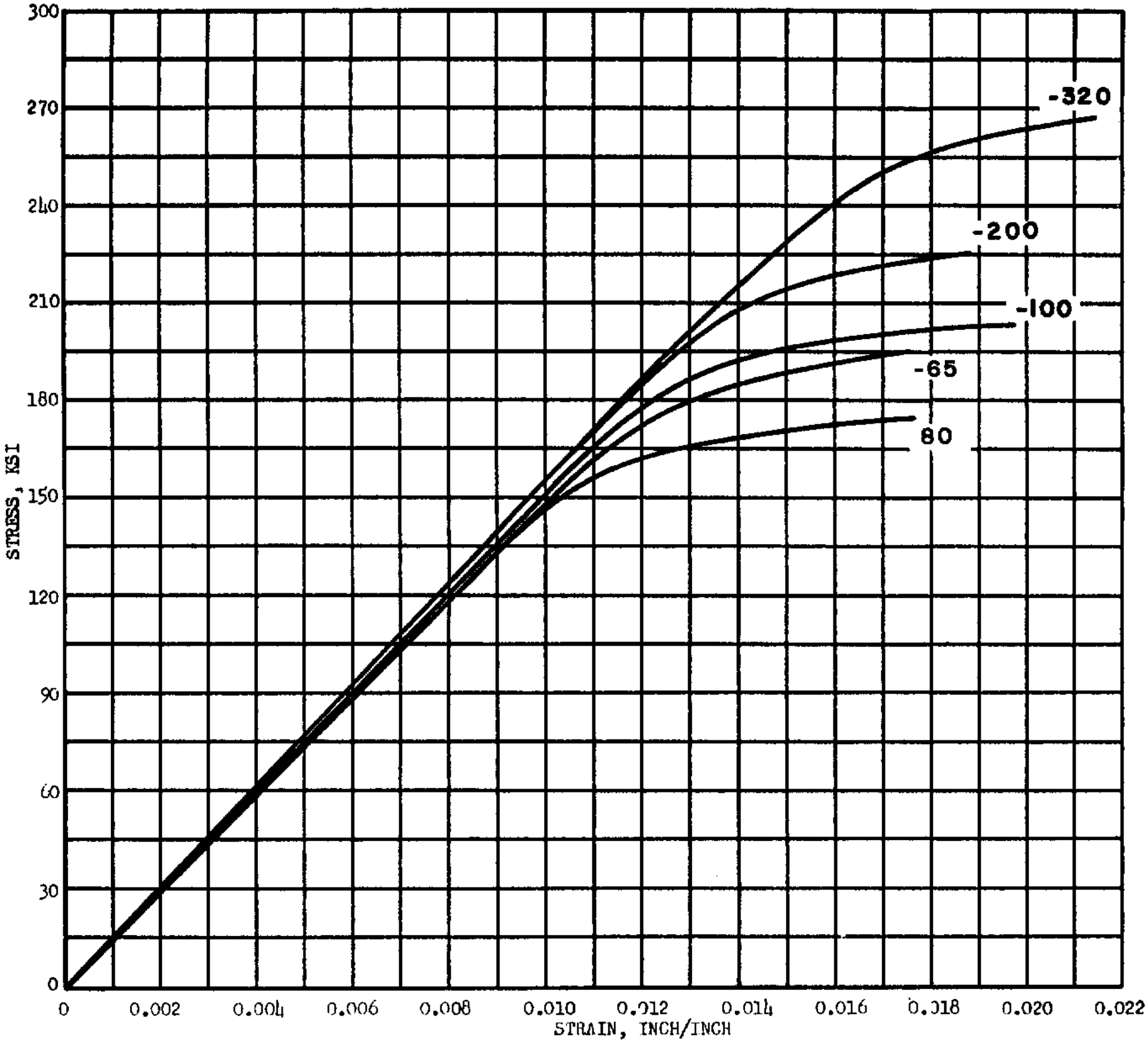
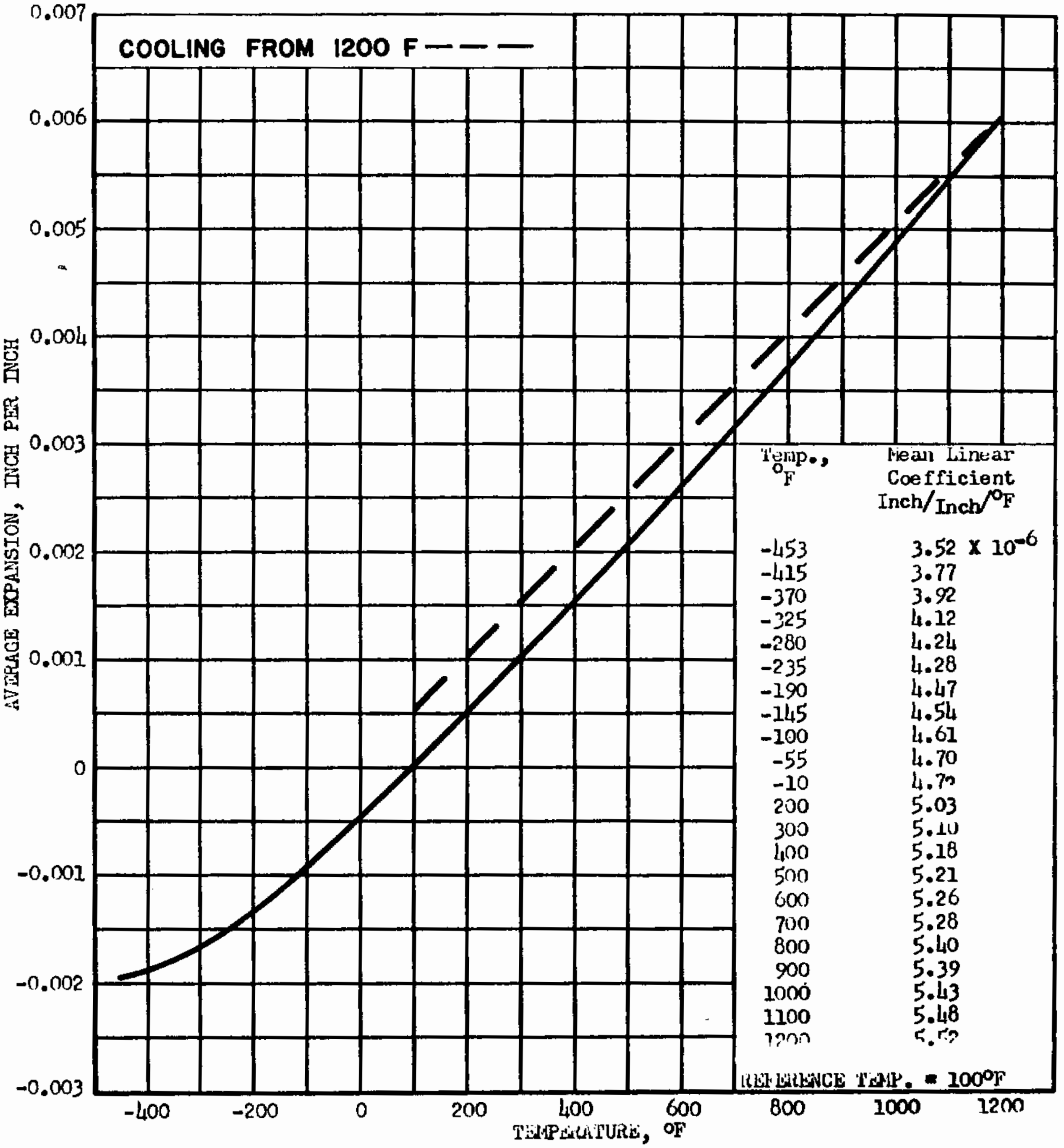


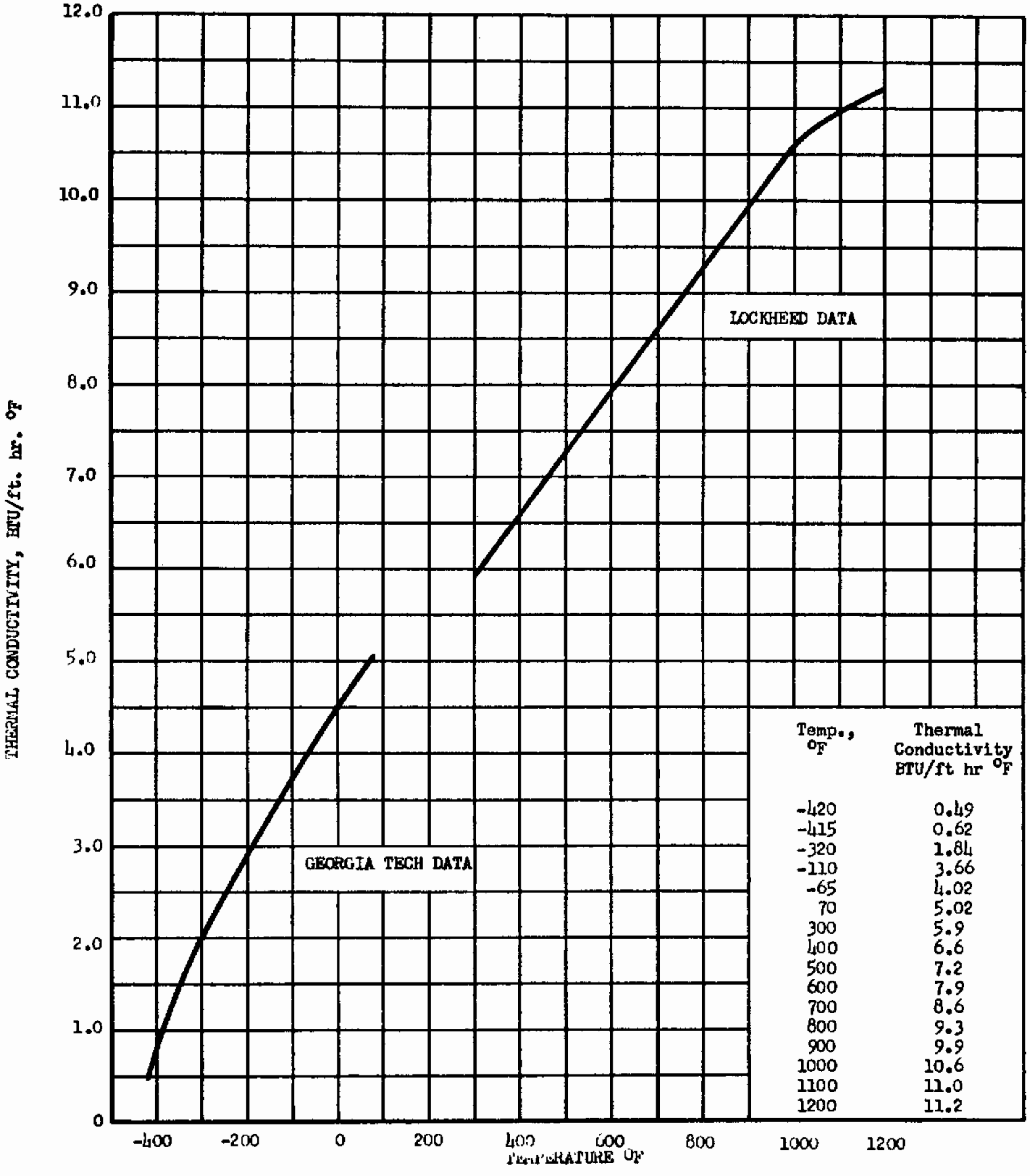
FIGURE 281 - TYPICAL TRANSVERSE TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET 0.063 INCH THICK (REACTIVE METALS HEAT NO. 22154)



Temp., °F	Mean Linear Coefficient Inch/Inch/°F
-453	3.52×10^{-6}
-415	3.77
-370	3.92
-325	4.12
-280	4.24
-235	4.28
-190	4.47
-145	4.54
-100	4.61
-55	4.70
-10	4.79
200	5.03
300	5.10
400	5.18
500	5.21
600	5.26
700	5.28
800	5.40
900	5.39
1000	5.43
1100	5.48
1200	5.52

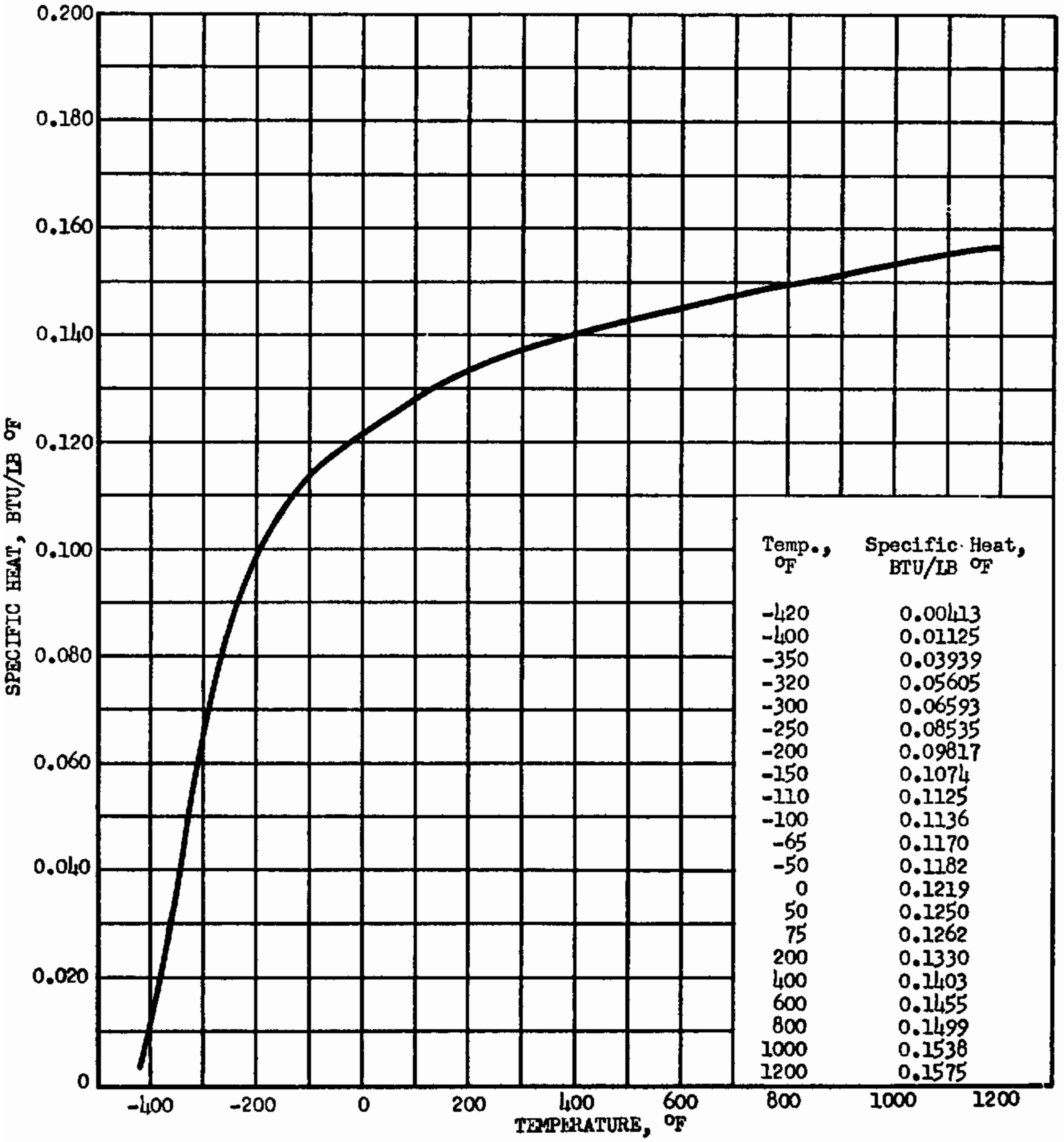
REFERENCE TEMP. = 100°F

FIGURE 282 - AVERAGE EXPANSION VERSUS TEMPERATURE FOR 0.125 INCH THICK 2.5Al-16V TITANIUM ALLOY SHEET (REACTIVE METALS HEAT NO. 23345, SHEET NO. 1149-3)



Temp., °F	Thermal Conductivity BTU/ft hr °F
-420	0.49
-415	0.62
-320	1.84
-110	3.66
-65	4.02
70	5.02
300	5.9
400	6.6
500	7.2
600	7.9
700	8.6
800	9.3
900	9.9
1000	10.6
1100	11.0
1200	11.2

FIGURE 283 - THERMAL CONDUCTIVITY VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET (REACTIVE METALS HEAT NO. 23345, SHEET NO. 1149-3)



Temp., °F	Specific Heat, BTU/LB °F
-420	0.00413
-400	0.01125
-350	0.03939
-320	0.05605
-300	0.06593
-250	0.08535
-200	0.09817
-150	0.1074
-110	0.1125
-100	0.1136
-65	0.1170
-50	0.1182
0	0.1219
50	0.1250
75	0.1262
200	0.1330
400	0.1403
600	0.1455
800	0.1499
1000	0.1538
1200	0.1575

FIGURE 284 - SPECIFIC HEAT VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED 2.5Al-16V TITANIUM ALLOY SHEET (REACTIVE METALS HEAT NO. 23345, SHEET NO. 1149-3)

VII - RESULTS FOR 4Al-3Mo-1V TITANIUM ALLOY

Tensile Test Results - Ti-4Al-3Mo-1V

Longitudinal and transverse tensile data for Ti-4Al-3Mo-1V are summarized in Figures 285 through 293 by curves which show average variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature. These curves represent approximately 500 tests from seven heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch for the 80°F to 1000°F temperature range. Tabulations of the summarized data and percent elongation in 1/8 and 1/4 inch are in Tables CCXXVI through CCXXXIV, pages 234 through 242 of Volume 3.

A complete room-temperature stress-strain curve is shown in Figure 294 and typical families of longitudinal and transverse stress-strain curves and stress versus tangent modulus curves for each thickness are in Volume 1. Volume 1 also contains statistically determined "B" design values for each thickness at room temperature as well as design curves for elevated temperature.

Figures 295 through 298 show the variation of Poisson's ratio with tensile strain for longitudinal and transverse grain directions for one heat of 0.063 inch thick sheet. Additional elastic values of Poisson's ratio for two heats are in Table LXXIV.

Tables LXXV through LXXXIII contain results for longitudinal and transverse tensile specimens from seven heats and three thicknesses after being temperature exposed and temperature-stress exposed. Exposure temperatures of 600°F and 900°F for 500 hours and ten hours, respectively, and exposure stresses equal to 1/3 the tensile ultimate at the exposure temperatures are represented. These data are summarized in a manner more usable for design purposes in Volume 1.

Compressive Test Results - Ti-4Al-3Mo-1V

Average compressive yield stress and elastic modulus versus temperature summarizing data for six heats and thicknesses of 0.063 inch and 0.125 inch are in Figures 299 through 304. These curves represent approximately 350 tests for the 80°F to 1000°F temperature range. The summarized data along with the Ramberg-Osgood shape factor and secant stresses at 0.85 E and 0.70 E are in Tables CCXXXV through CCXL, pages 243 through 248 of Volume 3.

Families of typical longitudinal and transverse compressive stress-strain curves, stress versus tangent modulus curves and stress versus secant modulus curves for the two thicknesses are in Volume 1. Statistically determined "B" design values at room temperature, as well as design curves for elevated temperature, are also in Volume 1.

Bearing Test Results - Ti-4Al-3Mo-1V

Data for approximately 1700 bearing tests for e/D ratios of 1.5 and 2.0 and bearing hole diameters of 1/8 inch, 3/16 inch and 5/16 inch are summarized in Figures 305 through 334. These curves show longitudinal and transverse bearing ultimate and yield stresses versus temperature for the 80°F to 1000°F range, and represent seven heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch. Data tabulations are in Tables CCXLI through CCLXX, pages 249 through 278, Volume 3.

Design curves for elevated temperature and statistically determined "B" design values [illegible] room temperature for both e/D ratios with a 5/16 inch bearing hole diameter are in Volume

Single Shear Test Results - Ti-4Al-3Mo-1V

Longitudinal and transverse single shear data are summarized by Figures 335 through 343 which show ultimate shear strength variation with temperature for the 80°F to 1000°F range. Approximately 500 tests representing seven heats for sheet thicknesses of 0.020 inch, 0.063 inch and 0.125 inch are summarized by these plots. Tabulations of the data are in Tables CCLXXI through CCLXXIII, pages 279 through 281 of Volume 3.

Statistically determined "B" design values for room temperature and design curves for elevated temperatures for each thickness are in Volume 1.

Double Shear Test Results - Ti-4Al-3Mo-1V

Curves showing variation of longitudinal and transverse double shear strength with temperature for four heats of 0.125 inch thick sheet are in Figures 344, 345 and 346. These data, representing approximately 175 tests for the 80°F to 1000°F temperature range, are in Table CCLXXIV, page 282, Volume 3.

Crippling Test Results - Ti-4Al-3Mo-1V

Longitudinal and transverse crippling data obtained for two specimen sizes over the 80°F to 1000°F temperature range are in Tables LXXXIV through LXXXVII. The data are for specimens formed from one heat of 0.063 inch thick solution treated Ti-4Al-3Mo-1V which was aged subsequent to forming. Compressive properties, including Ramberg-Osgood parameters, for specimens from the same solution treated sheets as the crippling specimens and aged at the same time are in Table LXXXVIII.

Fastener Joint Test Results - Ti-4Al-3Mo-1V

Figures 347 through 350 summarize longitudinal and transverse single fastener lap joint data obtained for one heat of 0.063 inch thick sheet over the -320°F to 80°F temperature range. Screw type and lock bolt type Ti-6Al-4V fasteners of 3/16 inch and 5/16 inch nominal diameters are represented by these data. The data are for specimens having an e/D ratio of two and a W/D ratio of five. Tabular data are in Tables CCCVIII through CCCXI, pages 316 through 319, Volume 3.

Tensile data obtained for the same heat and temperature range are summarized under Low-Temperature Tensile Test Results.

Weld Joint Test Results - Ti-4Al-3Mo-1V

Data obtained for longitudinal and transverse specimens from a 0.063 inch thick sheet which was fusion welded in the solution treated and aged condition are summarized in Figure 351 A similar plot is shown in Figure 352 for tests from a sheet of a different heat, welded in the solution treated condition and subsequently aged. These curves show variations of ultimate tensile stress, tensile yield stress, elastic modulus and percent elongation in two inches with temperature for the -320°F to 80°F range. Tabulations of these test values along with joint efficiencies and percent elongation in 1/8 inch and 1/4 inch are in Tables CCCXII and CCCXIII, pages 320 and 321, Volume 3.

Tensile data obtained for the same heats and temperature range and used as a basis for computing joint efficiency are summarized under Low-Temperature Tensile Test Results.

Low-Temperature Tensile Test Results - Ti-4Al-3Mo-1V

Summary plots for longitudinal and transverse tensile data showing average variations of ultimate tensile strength, tensile yield strength, elastic modulus and percent elongation in two inches with temperature for the -320°F to 80°F range are presented in Figures 353 and 354. Two heats of 0.063 inch thick sheet are included in these plots and are the same as those used for fastener and weld joints. Typical families of longitudinal and transverse stress-strain curves are shown in Figures 355 and 356 for the heat which was aged by the producer. Tabulations of the data obtained are in Tables CCCXIV and CCCXV, pages 322 and 323 of Volume 3.

Thermal Expansion Measurement Results - Ti-4Al-3Mo-1V

Figure 357 summarizes thermal expansion data obtained for longitudinal specimens from one 0.125 inch thick sheet. Mean linear thermal expansion coefficients for several temperatures in the -453°F to 1200°F range are also in this figure. These data represent measurements made for six specimens, three each for the low and elevated temperature ranges. Measurement results for each specimen are in Tables CCCXVI and CCCXVII, pages 324 and 325. The curve in Figure 357 was obtained from these measurements by adjusting the low-temperature data to a reference of 100°F.

Thermal Conductivity Measurement Results - Ti-4Al-3Mo-1V

Figure 358 summarizes thermal conductivity data obtained for specimens from one 0.125 inch thick sheet. Tabulated conductivity values at several temperatures for the -420°F to 1200°F range are also included in the figure. The elevated-temperature curve represents the average of measurements made by Lockheed for three specimens. Results of the individual measurements are in Table CCCXVIII, page 326, Volume 3.

Measurements for the low-temperature curve were made by Georgia Tech, and the method employed measured the combined conductivity of three specimens. Additional data are in Georgia Tech's report, Reference 13.

Specific Heat Measurement Results - Ti-4Al-3Mo-1V

Measurements of specific heat made by Georgia Tech for one 0.125 inch thick sheet are summarized in Figure 359. Also in this figure are values of specific heat at several temperatures in the -420°F to 1200°F range. These data give typical values for the sheet since a specimen for measurement consisted of several samples for different locations within the sheet. Additional data are in Georgia Tech's report, Reference 27.

TABLE LXXIV

ELASTIC POISSON'S RATIO DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK

Grain Direction	Tensile Specimen Number	Test Temp., °F	Poisson's Ratio
Longitudinal	D2LA1-1	80	.309
	D2LA1-4	80	.311
	D2LA1-13	80	.314
	D2LA1-16	80	.326
	D2LA1-22	80	.326
	D2LA1-25	80	.296
	D5LA1P-1 *	80	.325
	D5LA1P-2 *	80	.363
	D2LA2-13	200	.320
	D2LA2-18	200	.306
	D2LA2-19	200	.366
	D5LA2P-6 *	200	.338
	D5LA3P-1 *	400	.350
	D2LA4-9	600	.320
	D2LA4-12	600	.333
	D5LA4P-2 *	600	.388
	D5LA6P-7 *	800	.370
	D2LA7-20	900	.355
	D5LA7P-4 *	900	.350
	D5LA8P-5 *	1000	.306
Transverse	D2TA1-1	80	.325
	D2TA1-4	80	.319
	D2TA1-7	80	.327
	D2TA1-10	80	.315
	D2TA1-13	80	.352
	D2TA1-16	80	.335
	D2TA1-19	80	.324
	D2TA1-22	80	.322
	D2TA1-25	80	.351
	D2TA1-28	80	.322
	D5TA1P-1 *	80	.345
	D5TA1P-2 *	80	.350
	D2TA2-8	200	.348
	D2TA2-16	200	.378
	D2TA2-18	200	.313
	D5TA2P-6 *	200	.336
	D2TA3-6	400	.386
	D2TA3-13	400	.360
	D2TA3-15	400	.376
	D5TA3P-1 *	400	.329
	D2TA4-1	600	.359
	D2TA4-9	600	.367
	D2TA4-12	600	.336
	D5TA4P-2 *	600	.355
	D2TA6-10	800	.381
	D2TA6-14	800	.372
	D2TA6-17	800	.387
	D5TA6P-3 *	800	.367
	D2TA7-2	900	.364
	D2TA7-5	900	.325
	D5TA7P-4 *	900	.361
	D5TA8P-5 *	1000	.383

* Curves are plotted for indicated specimens

TABLE LXXV - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.**— CRUCIBLE R4815 **SHEET THICKNESS**— 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D1LA1B-1	195,000	193,000	17.5	-	-	-
					-2	212,000	187,000	17.4	3.5	10	12
					-3	210,000	188,000	17.2	4.0	14	24
					Average	206,000	189,000	17.4	3.8	12	18
				T	D1TA1B-1	203,000	182,000	18.3	4.5	16	24
					-2	201,000	181,000	18.2	4.5	-	-
					-3	205,000	182,000	18.0	4.5	-	-
					Average	203,000	182,000	18.2	4.5		
			600	L	D1LA4B-1	162,000	126,000	15.3	3.0	8	20
					-2	163,000	125,000	15.0	3.5	12	-
					-3	161,000	119,000	13.7	4.0	12	-
					Average	162,000	123,000	14.7	3.5	11	
				T	D1TA4B-1	155,000	124,000	14.5	2.0	10	12
					-2	160,000	122,000	15.1	4.0	8	20
					-3	160,000	121,000	14.8	4.0	10	20
					Average	158,000	122,000	14.8	3.3	9.3	17
		52,000	80	L	D1LA1A-1	206,000	186,000	16.8	-	-	-(1)
					-2	206,000	186,000	16.8	3.5	10	12
					-3	209,000	187,000	16.6	4.0	14	24
					Average	207,000	186,000	16.7	3.8	12	18
		52,000		T	D1TA1A-1	210,000	191,000	17.1	4.0	16	28
					-2	208,000	189,000	17.4	5.0	14	20
					-3	208,000	185,000	17.2	3.5	12	20
					Average	209,000	188,000	17.2	4.2	14	23
		52,000	600	L	D1LA4A-1	155,000	120,000	14.4	3.0	8	12
					-2	158,000	120,000	13.9	3.0	10	16
					-3	157,000	120,000	14.6	3.0	10	16
					Average	157,000	120,000	14.3	3.0	9	15
		52,000		T	D1TA4A-1	155,000	125,000	13.2	2.5	8	12
					-2	160,000	127,000	14.5	2.5	8	12
					-3	154,000	117,000	15.2	3.0	10	16
					Average	156,000	123,000	14.3	2.7	9	13
900	10	ZERO	80	L	D1LA1C-1	210,000	188,000	17.0	4.0	16	28
					-2	211,000	189,000	16.8	3.5	14	16
					-3	210,000	184,000	16.5	4.0	14	-
					Average	210,000	187,000	16.8	3.8	15	22
				T	D1TA1C-1	208,000	188,000	17.2	4.5	16	28
					-2	208,000	186,000	17.0	3.5	8	12
					-3	205,000	183,000	16.6	4.5	18	24
					Average	207,000	186,000	16.9	4.2	14	21
			900	L	D1LA7C-1	137,000	99,000	11.4	4.5	14	-
					-2	132,000	88,000	12.0	5.5	18	-
					-3	134,000	92,600	11.2	4.5	16	28
					Average	134,000	93,200	11.5	4.8	16	
				T	D1TA7C-1	135,000	94,400	11.8	6.5	18	32
					-2	135,000	90,800	11.6	5.0	14	24
					-3	134,000	93,400	12.9	7.0	18	28
					Average	135,000	92,900	12.1	6.2	17	28
		42,000	80	L	D1LA1D-1	209,000	187,000	17.0	4.0	16	16
					-2	212,000	188,000	17.1	4.0	16	-
					-3	208,000	182,000	16.7	4.5	16	20
					Average	210,000	186,000	16.9	4.2	16	18
		43,000		T	D1TA1D-1	199,000	182,000	17.3	3.5	16	28
					-2	199,000	180,000	17.5	3.5	16	-
					-3	203,000	183,000	17.8	2.5	16	-
					Average	200,000	182,000	17.5	3.2	16	
		42,000	900	L	D1LA7D-1	135,000	97,800	11.0	8.0	22	36
					-2	130,000	86,300	11.8	9.5	28	44
					-3	138,000	91,400	12.8	9.0	22	32
					Average	134,000	91,800	11.9	8.8	24	37
		43,000		T	D1TA7D-1	128,000	93,400	10.7	7.5	14	20
					-2	133,000	94,200	10.2	4.5	16	28
					-3	136,000	92,500	11.9	6.5	32	52
					Average	132,000	93,400	10.9	6.0	21	33

(1) Failed outside gage marks.

TABLE LXXVI-EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.**— CRUCIBLE P7653 **SHEET THICKNESS**— 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in 2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D2LA1B-1	195,000	164,000	16.4	4.0	16	-
					-2	196,000	165,000	16.4	5.5	24	36
					-3	192,000	156,000	16.3	5.5	16	28
					Average	194,000	162,000	16.4	5.0	19	32
				T	D2TA1B-1	192,000	168,000	17.7	-	-	-
					-2	192,000	172,000	18.0	5.5	24	36
					-3	195,000	168,000	17.6	6.0	16	28
					Average	193,000	169,000	17.8	5.8	20	32
			600	L	D2LA4B-1	152,000	116,000	13.7	5.0	22	40
					-2	146,000	-	-	5.0	22	32(1)
					-3	150,000	105,000	13.3	6.0	22	40
					Average	149,000	110,000	13.5	5.3	22	37
				T	D2TA4B-1	151,000	121,000	14.3	4.0	18	32
					-2	150,000	122,000	14.6	4.5	22	40
					-3	151,000	116,000	13.6	4.5	-	-
					Average	151,000	120,000	14.2	4.3	20	36
		49,000	80	L	D2LA1A-1	193,000	159,000	16:4	4.5	26	44
					-2	194,000	156,000	16.0	7.0	26	40
					-3	172,000	144,000	15.5	4.5	16	20
					Average	186,000	153,000	16.0	5.3	23	35
		49,000		T	D2TA1A-1	198,000	179,000	16.9	3.5	18	20
					-2	198,000	178,000	16.8	4.0	26	44
					-3	185,000	164,000	16.8	5.5	30	44
					Average	194,000	174,000	16.8	4.3	25	35
		49,000	600	L	D2LA4A-1	146,000	107,000	13.3	6.3	24	44
					-2	124,000	90,600	12.6	7.3	32	52
					-3	124,000	88,800	12.4	7.0	30	48
					Average	131,000	95,500	12.8	6.9	29	48
		49,000		T	D2TA4A-1	152,000	122,000	14.5	4.0	20	36
					-2	142,000	110,000	14.1	5.5	26	32
					-3	142,000	111,000	14.8	5.5	24	40
					Average	145,000	114,000	14.5	5.0	23	36
900	10	ZERO	80	L	D2LA1C-1	197,000	168,000	16.3	5.0	14	20
					-2	196,000	165,000	16.9	4.0	16	-
					-3	191,000	158,000	16.0	5.0	-	-
					Average	195,000	164,000	16.4	4.7	15	
				T	D2TA1C-1	196,000	174,000	17.5	5.0	24	32
					-2	195,000	172,000	17.1	5.0	24	-
					-3	184,000	162,000	17.0	7.0	-	-
					Average	192,000	169,000	17.2	5.7	24	
			900	L	D2LA7C-1	127,000	92,900	10.9	5.0	16	-(2)
					-2	118,000	87,100	11.1	7.0	44	68
					-3	123,000	90,700	11.2	11.0	34	52
					Average	123,000	90,200	11.1	7.7	31	60
				T	D2TA7C-1	132,000	91,000	12.2	5.5	22	32
					-2	119,000	91,100	11.0	9.5	28	52
					-3	119,000	92,400	11.6	9.0	32	44
					Average	123,000	91,500	11.6	8.0	27	43
		42,000	80	L	D2LA1D-1	195,000	163,000	16.2	5.5	28	40
					-2	195,000	164,000	16.5	5.5	26	44
					-3	192,000	161,000	15.9	7.0	22	-
					Average	194,000	163,000	16.2	6.0	25	42
		42,700		T	D2TA1D-1	191,000	169,000	17.7	6.5	26	52
					-2	192,000	170,000	18.8	7.0	30	-
					-3	191,000	166,000	17.1	6.5	24	44
					Average	191,000	168,000	17.9	6.7	27	48
		42,000	900	L	D2LA7D-1	127,000	82,300	12.6	8.0	28	36
					-2	123,000	76,300	12.4	11.0	36	56
					-3	126,000	87,800	10.7	10.7	38	60
					Average	125,000	82,100	11.9	9.7	34	51
		42,700		T	D2TA7D-1	129,000	86,400	12.7	8.0	32	52
					-2	127,000	87,400	12.6	-	28	48
					-3	126,000	91,000	11.1	8.0	24	36
					Average	127,000	88,300	12.1	8.0	28	45

(1) Unusable load-deformation curve.
(2) Failed at knife edge.

TABLE LXVII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE R6736 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D3LA1B-1	193,000	163,000	15.9	5.0	20	-
					-2	194,000	164,000	16.4	-	-	-(1)
					-3	189,000	160,000	16.3	5.5	20	-
					Average	192,000	162,000	16.2	5.2	20	
				T	D3TA1B-1	196,000	174,000	17.2	7.5	28	40
					-2	195,000	175,000	17.3	5.0	14	24
					-3	193,000	174,000	16.5	5.5	16	20
					Average	195,000	174,000	17.0	6.0	19	28
			600	L	D3LA4B-1	145,000	106,000	12.7	6.5	20	40
					-2	143,000	107,000	13.5	7.0	28	44
					-3	144,000	107,000	13.1	7.5	40	64
					Average	144,000	107,000	13.1	7.0	29	49
				T	D3TA4B-1	151,000	118,000	14.6	8.0	36	60
					-2	152,000	121,000	15.7	7.0	40	68
					-3	151,000	121,000	14.3	6.8	36	60
					Average	151,000	120,000	14.9	7.3	37	63
		48,300	80	L	D3LA1A-1	195,000	163,000	17.5	5.0	18	30
					-2	195,000	165,000	16.7	5.5	18	32
					-3	191,000	159,000	17.2	5.5	18	32
					Average	194,000	162,000	17.1	5.3	18	31
		50,700		T	D3TA1A-1	193,000	166,000	17.1	9.0	28	-
					-2	192,000	171,000	17.9	6.0	28	40
					-3	196,000	-	17.8	6.5	32	52(2)
					Average	194,000	168,000	17.6	7.2	29	46
		48,300	600	L	D3LA4A-1	144,000	102,000	13.0	7.0	22	36
					-2	149,000	107,000	13.9	5.5	24	36
					-3	143,000	105,000	12.7	6.5	28	44
					Average	145,000	105,000	13.2	6.3	25	39
		50,700		T	D3TA4A-1	150,000	116,000	15.2	7.0	40	76
					-2	153,000	123,000	13.8	6.5	36	60
					-3	154,000	123,000	15.3	6.0	36	64
					Average	152,000	121,000	14.8	6.5	37	67
900	10	ZERO	80	L	D3LA1C-1	182,000	171,000	16.2	4.5	20	32
					-2	188,000	157,000	16.1	5.0	16	16
					-3	188,000	160,000	16.1	5.5	20	20
					Average	186,000	163,000	16.1	5.0	19	23
				T	D3TA1C-1	190,000	172,000	17.5	9.0	28	32
					-2	191,000	172,000	17.8	7.0	24	28
					-3	195,000	176,000	17.6	7.0	26	36
					Average	192,000	173,000	17.6	7.7	26	32
			900	L	D3LA7C-1	118,000	79,800	13.0	12.0	34	92
					-2	123,000	83,400	11.8	8.0	28	40
					-3	117,000	80,700	11.1	9.0	26	32
					Average	119,000	81,300	12.0	9.6	29	55
				T	D3TA7C-1	126,000	87,300	15.7	10.0	38	68
					-2	129,000	89,400	13.7	11.0	46	76
					-3	124,000	89,300	11.3	9.0	40	64
					Average	126,000	88,700	13.6	10.0	41	69
		39,700	80	L	D3LA1D-1	190,000	153,000	15.8	5.5	20	24
					-2	191,000	152,000	16.3	5.0	16	28
					-3	189,000	156,000	16.0	5.0	22	24
					Average	190,000	154,000	16.0	5.2	19	25
		42,700		T	D3TA1D-1	197,000	175,000	17.8	4.5	28	28
					-2	198,000	174,000	18.0	7.0	24	36
					-3	192,000	172,000	17.2	6.0	24	36
					Average	196,000	174,000	17.7	5.8	25	33
		39,700	900	L	D3LA7D-1	118,000	77,500	11.0	9.5	28	40
					-2	119,000	78,400	10.9	10.0	36	40
					-3	119,000	80,600	10.5	9.0	32	40
					Average	119,000	78,800	10.8	9.5	32	40
		42,700		T	D3TA7D-1	130,000	93,400	13.7	14.0	44	44
					-2	128,000	90,000	12.5	9.5	44	72
					-3	126,000	89,400	14.9	10.0	46	72
					Average	128,000	90,900	13.7	11.2	45	63

(1) Failed outside gage marks.
(2) Unusable load-deformation curve beyond elastic portion.

TABLE LXXVIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE R4765 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D4LA1B-1	208,000	182,000	17.6	3.0	8	12
					-2	209,000	182,000	17.6	3.5	10	16
					-3	199,000	172,000	17.0	3.5	12	16
					Average	205,000	179,000	17.4	3.3	10	15
				T	D4TA1B-1	204,000	178,000	18.0	3.0	12	16
					-2	206,000	182,000	17.3	3.0	14	20
					-3	206,000	180,000	17.7	4.0	16	28
					Average	205,000	180,000	17.7	3.3	14	21
			600	L	D4LA4B-1	155,000	117,000	13.7	3.5	14	-
					-2	147,000	110,000	13.1	3.5	12	-
					-3	152,000	108,000	12.5	4.0	14	-
					Average	151,000	112,000	13.1	3.7	13	
				T	D4TA4B-1	156,000	118,000	14.7	3.0	12	-
					-2	156,000	-	-	3.0	14	-(1)
					-3	159,000	122,000	14.7	3.5	12	-
					Average	157,000	120,000	14.7	3.2	13	
		50,400	80	L	D4LA1A-1	198,000	168,000	16.1	3.0	10	20
					-2	207,000	183,000	16.5	3.5	8	16
					-3	208,000	182,000	16.9	3.5	10	20
					Average	204,000	178,000	16.5	3.3	9	19
		50,700		T	D4TA1A-1	197,000	174,000	17.0	5.0	20	28
					-2	201,000	180,000	17.8	5.0	20	24
					-3	204,000	180,000	17.5	5.0	-	-
					Average	201,000	178,000	17.4	5.0	20	26
		50,400	600	L	D4LA4A-1	153,000	118,000	14.3	3.5	8	12
					-2	152,000	-	-	3.5	10	16(1)
					-3	154,000	113,000	13.7	3.0	8	16
					Average	153,000	116,000	14.0	3.3	9	15
		50,700		T	D4TA4A-1	143,000	111,000	13.4	3.0	12	20
					-2	151,000	116,000	14.4	3.5	14	20
					-3	151,000	114,000	14.8	4.0	12	24
					Average	148,000	114,000	14.2	3.5	13	21
900	10	ZERO	80	L	D4LA1C-1	202,000	178,000	17.1	5.0	16	24
					-2	205,000	178,000	16.8	3.0	10	12
					-3	202,000	176,000	16.4	3.5	16	20
					Average	203,000	177,000	16.8	3.8	14	19
				T	D4TA1C-1	186,000	168,000	17.0	5.0	16	28
					-2	191,000	170,000	16.8	5.0	18	32
					-3	204,000	178,000	17.2	5.5	22	32
					Average	194,000	172,000	17.0	5.2	19	31
			900	L	D4LA7C-1	132,000	92,400	12.8	5.0	16	28
					-2	131,000	88,300	11.4	4.0	12	28
					-3	134,000	93,600	10.9	3.0	16	32
					Average	132,000	91,400	11.7	4.0	15	29
				T	D4TA7C-1	123,000	89,500	11.1	2.0	8	12
					-2	136,000	96,800	12.9	4.0	16	32
					-3	135,000	91,600	13.1	3.0	16	28
					Average	131,000	92,600	12.4	3.0	13	24
		42,000	80	L	D4LA1D-1	203,000	179,000	17.4	3.0	8	-
					-2	204,000	180,000	17.4	2.5	12	-
					-3	201,000	176,000	17.0	4.5	16	20
					Average	203,000	178,000	17.3	3.3	12	
		42,000		T	D4TA1D-1	201,000	178,000	17.4	4.0	-	-
					-2	177,000	-	17.3	1.0	8	12(2)
					-3	202,000	177,000	17.2	4.5	18	24
					Average	193,000	178,000	17.3	3.2	13	18
		42,000	900	L	D4LA7D-1	127,000	88,500	12.1	4.0	16	24
					-2	127,000	84,200	11.5	3.5	16	28
					-3	126,000	88,300	10.1	4.5	16	36
					Average	127,000	87,000	11.2	4.0	16	29
		42,000		T	D4TA7D-1	130,000	89,900	12.7	3.0	14	28
					-2	132,000	98,700	10.7	6.0	18	24
					-3	131,000	91,100	10.4	7.0	20	28
					Average	131,000	93,200	11.3	5.3	17	27

(1) Unusable load-deformation curve.
(2) Specimen failed prior to attaining yield deformation.

TABLE LXXIX - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE R4765 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^6 PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D5LA1B-1	204,000	173,000	15.6	5.5	20	-
					-2	201,000	173,000	15.7	5.5	20	-
					-3	204,000	175,000	15.8	6.5	22	36
					Average	203,000	174,000	15.7	5.8	21	
				T	D5TA1B-1	204,000	174,000	16.0	5.0	16	-
					-2	197,000	178,000	16.5	-	-	-(1)
					-3	202,000	175,000	16.3	6.5	20	-
					Average	201,000	176,000	16.2	5.8	18	
			600	L	D5LA4B-1	153,000	111,000	13.4	3.5	16	28
					-2	153,000	113,000	13.5	5.0	24	32
					-3	156,000	113,000	13.6	6.0	20	32
					Average	154,000	112,000	13.5	4.8	20	31
				T	D5TA4B-1	158,000	122,000	13.7	4.5	26	-(2)
					-2	154,000	118,000	13.8	6.5	26	-
					-3	154,000	116,000	13.2	5.5	24	-
					Average	155,000	119,000	13.6	5.5	25	
		50,100	80	L	D5LA1A-1	203,000	172,000	15.9	3.5	12	20
					-2	205,000	175,000	16.1	4.0	20	-
					-3	207,000	177,000	15.9	5.0	18	28
					Average	205,000	175,000	16.0	4.2	17	24
		50,000		T	D5TA1A-1	204,000	175,000	16.2	5.0	-	-
					-2	205,000	176,000	16.1	4.0	14	-
					-3	204,000	175,000	16.2	6.5	22	-
					Average	204,000	175,000	16.2	5.2	18	
		50,100	600	L	D5LA4A-1	156,000	110,000	12.9	6.5	30	-
					-2	151,000	111,000	12.7	5.5	24	-
					-3	154,000	115,000	12.6	6.0	26	40
					Average	154,000	112,000	12.7	6.0	27	
		50,000		T	D5TA4A-1	160,000	123,000	13.5	6.5	22	44
					-2	153,000	117,000	14.6	5.5	26	44
					-3	152,000	112,000	13.7	6.0	32	36
					Average	155,000	117,000	13.9	6.0	27	41
900	10	ZERO	80	L	D5LA1C-1	203,000	176,000	16.7	8.0	16	-
					-2	205,000	179,000	16.6	5.5	-	-
					-3	204,000	180,000	16.3	4.5	20	32
					Average	204,000	178,000	16.5	6.0	18	
				T	D5TA1C-1	204,000	179,000	16.8	5.0	-	-
					-2	206,000	180,000	17.1	-	-	-(1)
					-3	201,000	177,000	17.1	5.5	20	28
					Average	204,000	179,000	17.0	5.2		
			900	L	D5LA7C-1	124,000	90,600	11.5	13.0	44	60
					-2	119,000	90,400	10.1	11.0	40	52
					-3	124,000	92,900	10.8	10.0	40	68
					Average	122,000	91,300	10.8	11.0	41	60
				T	D5TA7C-1	123,000	99,400	11.4	11.0	40	52
					-2	128,000	87,000	11.5	8.5	36	60
					-3	128,000	94,600	10.7	9.5	28	36
					Average	126,000	93,700	11.2	9.7	35	49
		42,700	80	L	D5LA1D-1	204,000	174,000	16.8	5.5	32	-
					-2	205,000	174,000	16.6	5.5	14	-
					-3	205,000	173,000	16.5	5.5	26	-
					Average	205,000	174,000	16.6	5.5	24	
		45,000		T	D5TA1D-1	204,000	175,000	17.3	5.5	-	-
					-2	203,000	174,000	17.0	9.5	-	-
					-3	203,000	180,000	17.2	5.5	20	24
					Average	203,000	176,000	17.2	6.5		
		42,700	900	L	D5LA7D-1	126,000	83,300	10.2	12.0	36	56
					-2	123,000	81,900	11.2	13.0	38	60
					-3	129,000	82,000	10.0	11.0	34	48
					Average	126,000	82,400	10.5	12.0	36	55
		45,000		T	D5TA7D-1	127,000	93,800	11.7	14.0	42	72
					-2	122,000	90,700	10.2	11.0	26	40
					-3	123,000	94,000	10.2	13.0	40	60
					Average	124,000	92,800	10.7	13.0	36	57

(1) Test section shattered into several pieces.
(2) Failed at knife edge.

TABLE LXXX - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE R6741 **SHEET THICKNESS—** 0.125 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, $X10^{-6}$, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D6LA1B-1	194,000	168,000	16.3	5.0	20	28
					-2	194,000	165,000	17.4	5.0	20	28
					-3	195,000	170,000	16.8	6.0	24	32
					Average	194,000	168,000	16.8	5.3	21	29
				T	D6TA1B-1	198,000	179,000	17.8	5.0	16	44
					-2	198,000	179,000	17.2	5.0	20	28
					-3	196,000	179,000	17.2	6.0	28	48
					Average	197,000	179,000	17.4	5.3	21	40
			600	L	D6LA4B-1	153,000	104,000	13.1	6.0	30	40
					-2	146,000	106,000	13.2	7.0	24	44
					-3	146,000	107,000	13.6	7.0	28	48
					Average	148,000	106,000	13.3	6.7	27	44
				T	D6TA4B-1	151,000	117,000	13.6	8.0	40	-
					-2	153,000	119,000	13.9	7.0	40	64
					-3	151,000	117,00C	14.7	8.0	44	-
					Average	152,000	118,000	14.1	7.7	41	
		48,400	80	L	D6LA1A-1	195,000	153,000	15.7	5.5	16	24
					-2	195,000	159,000	15.4	6.0	20	28
					-3	195,000	164,000	16.5	5.0	14	20
					Average	195,000	159,000	15.9	5.5	17	24
		49,000		T	D6TA1A-1	196,000	171,000	17.3	7.5	30	48
					-2	196,000	171,000	16.9	5.0	16	28
					-3	199,000	182,000	17.9	7.3	34	44
					Average	197,000	175,000	17.4	6.6	27	40
		48,400	600	L	D6LA4A-1	146,000	105,000	13.2	6.8	24	44
					-2	146,000	108,000	13.9	7.0	30	48
					-3	148,000	110,000	12.8	8.0	36	44
					Average	147,000	108,000	13.3	7.3	30	45
		49,000		T	D6TA4A-1	147,000	110,000	14.8	8.0	44	76
					-2	152,000	118,000	13.8	7.0	44	76
					-3	152,000	116,000	14.0	7.0	30	52
					Average	150,000	115,000	14.2	7.3	39	68
900	10	ZERO	80	L	D6LA1C-1	188,000	158,000	15.9	6.0	14	20
					-2	189,000	158,000	16.0	5.0	20	24
					-3	191,000	162,000	15.9	5.5	20	24
					Average	189,000	159,000	15.9	5.5	18	23
				T	D6TA1C-1	192,000	170,000	17.5	7.0	22	-
					-2	192,000	170,000	17.1	7.0	12	20
					-3	195,000	175,000	17.6	8.0	28	44
					Average	193,000	172,000	17.4	7.3	21	32
			900	L	D6LA7C-1	118,000	81,400	11.5	10.0	46	-
					-2	123,000	81,400	11.3	9.0	40	68
					-3	124,000	87,400	10.8	12.0	52	108
					Average	122,000	83,400	11.2	10.0	46	88
				T	D6TA7C-1	124,000	87,300	12.9	11.0	52	84
					-2	130,000	92,400	13.5	10.0	44	80
					-3	132,000	94,800	14.2	9.5	42	68
					Average	129,000	91,500	13.5	10.0	46	77
		40,300	80	L	D6LA1D-1	191,000	152,000	15.7	5.0	16	-
					-2	190,000	151,000	16.0	5.0	18	-
					-3	193,000	158,000	16.1	5.0	20	32
					Average	191,000	154,000	15.9	5.0	18	
		42,700		T	D6TA1D-1	197,000	172,000	17.3	6.0	22	24
					-2	197,000	173,000	17.1	4.5	8	20
					-3	197,000	174,000	17.2	7.0	28	32
					Average	197,000	173,000	17.2	5.8	19	25
		40,300	900	L	D6LA7D-1	116,000	77,000	10.4	13.0	44	60
					-2	120,000	79,300	11.2	12.0	48	84
					-3	122,000	81,400	10.4	13.0	38	68
					Average	119,000	79,200	10.7	13.0	43	71
		42,700		T	D6TA7D-1	128,000	88,300	12.1	12.0	52	92
					-2	127,000	90,300	11.3	14.0	50	72
					-3	128,000	83,800	12.5	14.0	52	92
					Average	128,000	87,500	12.0	13.0	51	85

TABLE LXXXI - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE R4805 **SHEET THICKNESS—** 0.020 in.

EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D7LA1B-1	216,000	195,000	18.2	3.5	10	-
					-2	218,000	200,000	17.9	4.0	14	20
					-3	207,000	186,000	17.9	4.5	16	20
					Average	214,000	194,000	18.0	4.0	13	20
				T	D7TA1B-1	212,000	196,000	18.2	3.5	10	24
					-2	206,000	189,000	17.8	2.5	8	16
					-3	207,000	188,000	17.2	5.0	20	28
					Average	208,000	191,000	17.7	3.7	13	23
			600	L	D7LA4B-1	163,000	123,000	15.3	3.5	-	-
					-2	156,000	115,000	15.6	4.5	-	-
					-3	156,000	114,000	15.4	4.5	-	-
					Average	158,000	117,000	15.4	4.2		
				T	D7TA4B-1	157,000	117,000	14.0	3.5	-	-
					-2	150,000	117,000	14.0	3.5	-	-
					-3	159,000	127,000	14.1	4.5	-	-
						155,000	120,000	14.0	3.8		
		52,000	80	L	D7LA1A-1	216,000	193,000	18.3	3.0	12	20
					-2	218,000	205,000	17.6	3.5	12	20(1)
					-3	205,000	183,000	17.9	3.5	14	-
					Average	213,000	194,000	17.9	3.3	13	20
		52,000		T	D7TA1A-1	208,000	184,000	18.0	3.5	12	16
					-2	208,000	192,000	18.5	-	12	16
					-3	203,000	184,000	17.2	-	-	-
					Average	206,000	187,000	17.9		12	16
		52,000	600	L	D7LA4A-1	161,000	122,000	15.1	3.0	10	12
					-2	153,000	114,000	14.8	3.5	14	20
					-3	147,000	116,000	12.8	2.0	14	16
					Average	154,000	117,000	14.2	2.8	13	16
		52,000		T	D7TA4A-1	155,000	122,000	14.0	2.0	10	20
					-2	149,000	117,000	15.1	3.0	12	16
					-3	149,000	121,000	13.6	3.5	10	16
					Average	151,000	120,000	14.2	2.8	11	17
900	10	ZERO	80	L	D7LA1C-1	207,000	183,000	16.8	4.5	16	20
					-2	209,000	185,000	17.0	5.0	16	20
					-3	206,000	184,000	17.0	5.0	18	-
					Average	207,000	184,000	16.9	4.8	17	20
				T	D7TA1C-1	206,000	183,000	17.1	3.5	16	20
					-2	204,000	182,000	16.8	3.0	16	20
					-3	201,000	185,000	16.8	4.0	18	28
					Average	204,000	183,000	16.9	3.5	17	23
			900	L	D7LA7C-1	130,000	93,500	12.2	4.0	14	20
					-2	132,000	90,100	12.3	2.0	8	12
					-3	127,000	92,900	12.2	2.0	14	28
					Average	130,000	92,200	12.2	2.7	12	20
				T	D7TA7C-1	126,000	91,100	12.9	5.5	14	16
					-2	122,000	105,000	14.4	4.5	16	28
					-3	129,000	92,100	13.0	6.0	14	28
					Average	126,000	96,100	13.4	5.3	15	24
		43,000	80	L	D7LA1D-1	209,000	183,000	17.4	5.0	18	-
					-2	210,000	183,000	17.7	4.5	18	-
					-3	205,000	182,000	17.5	4.5	16	36
					Average	208,000	183,000	17.5	4.7	17	
		43,000		T	D7TA1D-1	207,000	189,000	17.4	3.5	16	-
					-2	205,000	184,000	17.2	2.5	16	20
					-3	203,000	181,000	16.9	3.5	18	28
					Average	205,000	185,000	17.2	3.2	17	24
		43,000	900	L	D7LA7D-1	134,000	91,200	12.2	5.0	16	28
					-2	130,000	88,300	11.1	6.5	22	36
					-3	126,000	91,600	10.8	7.0	22	32
					Average	130,000	90,400	11.4	6.2	20	32
		43,000		T	D7TA7D-1	132,000	96,300	12.1	-	-	-(2)
					-2	130,000	95,700	12.3	6.0	16	32
					-3	130,000	89,300	11.4	7.5	22	40
					Average	131,000	93,800	11.9	6.8	19	36

(1) Failed within 1/4 inch of fillet.
(2) Failed outside gage marks.

TABLE LXXXII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE R4815 **SHEET THICKNESS—** 0.063 in.

EXPOSURE CONDITIONS			TEST TEMP. °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP., °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D8LA1B-1	207,000	-	16.1	5.0	16	28(1)
					-2	208,000	176,000	15.5	5.0	22	32
					-3	207,000	178,000	15.5	7.5	28	-
					Average	207,000	177,000	15.7	5.8	22	30
				T	D8TA1B-1	205,000	181,000	16.5	5.0	14	-
					-2	204,000	180,000	16.1	6.5	24	-
					-3	203,000	178,000	16.0	7.0	-	-
					Average	204,000	180,000	16.2	6.2	19	
			600	L	D8LA4B-1	160,000	118,000	14.0	6.0	28	-
					-2	156,000	115,000	13.8	6.5	26	-
					-3	156,000	115,000	14.1	6.5	26	-
					Average	157,000	116,000	14.0	6.3	27	
				T	D8TA4B-1	155,000	121,000	14.2	5.0	28	-
					-2	151,000	115,000	14.8	6.5	-	-
					-3	152,000	115,000	14.3	6.5	28	-
					Average	153,000	117,000	14.4	6.0	28	
		50,000	80	L	D8LA1A-1	209,000	178,000	15.3	5.5	24	44
					-2	209,000	181,000	15.8	6.5	22	-
					-3	210,000	180,000	16.1	6.0	-	-
					Average	209,000	180,000	15.7	6.0	23	
		50,000		T	D8TA1A-1	206,000	180,000	16.3	5.5	28	44
					-2	207,000	182,000	16.7	5.0	-	-
					-3	204,000	177,000	16.2	7.5	-	-
					Average	206,000	180,000	16.4	6.0		
		50,000	600	L	D8LA4A-1	160,000	113,000	12.5	6.5	24	44
					-2	157,000	115,000	13.7	7.0	26	36
					-3	157,000	114,000	13.1	7.0	30	48
					Average	158,000	114,000	13.1	6.8	27	43
		50,000		T	D8TA4A-1	156,000	120,000	13.7	6.0	26	48
					-2	153,000	114,000	12.7	7.0	32	-
					-3	153,000	116,000	13.0	6.0	32	56
					Average	154,000	117,000	13.1	6.3	30	52
900	10	ZERO	80	L	D8LA1C-1	207,000	181,000	16.5	5.0	12	20
					-2	208,000	184,000	16.4	5.0	14	16
					-3	207,000	181,000	16.2	6.5	24	28
					Average	207,000	182,000	16.4	5.5	17	21
				T	D8TA1C-1	204,000	184,000	16.7	6.0	20	-
					-2	204,000	182,000	17.2	4.5	20	28
					-3	209,000	190,000	17.6	6.5	20	-
					Average	206,000	185,000	17.2	5.7	20	
			900	L	D8LA7C-1	126,000	93,100	10.4	10.0	36	60
					-2	125,000	89,000	11.8	14.0	56	92
					-3	129,000	92,600	11.0	9.0	30	44
					Average	127,000	91,600	11.1	11.0	41	65
				T	D8TA7C-1	130,000	97,600	11.7	8.5	28	48
					-2	127,000	93,400	10.9	9.5	26	48
					-3	125,000	90,900	10.7	11.0	34	52
					Average	127,000	94,000	11.1	9.7	29	49
		42,000	80	L	D8LA1D-1	205,000	172,000	17.4	6.0	24	32
					-2	204,000	176,000	16.5	5.0	22	32
					-3	203,000	176,000	16.3	5.5	22	32
					Average	204,000	175,000	16.7	5.5	23	32
		42,700		T	D8TA1D-1	194,000	168,000	16.6	7.0	28	32
					-2	201,000	176,000	16.6	7.5	26	32
					-3	201,000	176,000	16.3	-	-	-
					Average	199,000	173,000	16.5	7.2	27	32
		42,000	900	L	D8LA7D-1	128,000	83,400	11.5	12.0	30	68
					-2	124,000	90,300	10.1	-	-	-
					-3	125,000	88,800	11.2	13.0	52	80
					Average	126,000	87,500	10.9	12.0	41	74
		42,700		T	D8TA7D-1	127,000	90,900	12.1	12.0	52	92
					-2	124,000	83,000	12.2	13.0	60	96
					-3	126,000	86,000	11.6	13.0	46	92
						126,000	86,600	12.0	13.0	53	93

(1) Unusable load-deformation curve beyond elastic portion.

TABLE LXXXIII - EFFECT OF TEMPERATURE EXPOSURE ON THE TENSILE PROPERTIES OF AGED TITANIUM ALLOYS

ALLOY— Ti-4Al-3Mo-1V **HEAT NO.—** CRUCIBLE P7647 **SHEET THICKNESS—** 0.125 in.

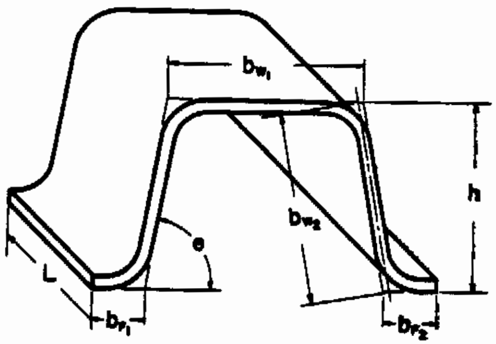
EXPOSURE CONDITIONS			TEST TEMP, °F	GRAIN DIR.	SPECIMEN NUMBER	TENSILE PROPERTIES					
TEMP, °F	TIME, HRS.	STRESS, PSI				TENSILE ULTIMATE, PSI	TENSILE YIELD, PSI	ELASTIC MODULUS, X10^{-6}, PSI	ELONGATION, % in		
									2 IN.	.25 IN.	.125 IN.
600	500	ZERO	80	L	D9LA1B-1	193,000	160,000	15.9	5.5	16	20
					-2	194,000	164,000	16.2	5.5	16	28
					-3	191,000	159,000	16.7	5.0	20	28
					Average	193,000	161,000	16.3	5.3	17	25
				T	D9TA1B-1	196,000	173,000	18.2	7.5	30	48
					-2	195,000	168,000	17.3	7.0	30	40
					-3	189,000	168,000	17.0	7.5	36	36
					Average	193,000	172,000	17.5	7.3	32	41
			600	L	D9LA4B-1	145,000	101,000	14.5	-	-	-
					-2	144,000	102,000	13.4	6.0	24	52
					-3	144,000	100,000	14.0	6.0	28	36
					Average	144,000	101,000	14.0	6.0	26	44
				T	D9TA4B-1	151,000	113,000	15.1	7.5	44	-
					-2	149,000	111,000	15.9	6.5	38	68
					-3	148,000	112,000	15.5	6.5	38	60
					Average	149,000	112,000	15.5	6.8	40	64
		47,600	80	L	D9LA1A-1	192,000	159,000	15.4	5.0	14	24
					-2	191,000	156,000	15.2	5.0	16	20
					-3	193,000	160,000	16.6	5.0	16	28
					Average	192,000	158,000	15.7	5.0	15	24
		48,300		T	D9TA1A-1	194,000	166,000	17.1	8.0	24	40
					-2	195,000	169,000	18.0	9.5	34	40
					-3	198,000	173,000	17.8	9.0	32	48
					Average	196,000	169,000	17.6	8.8	30	43
		47,600	600	L	D9LA4A-1	144,000	101,000	13.5	8.0	32	48
					-2	142,000	96,400	13.6	6.0	28	44
					-3	141,000	98,300	13.7	6.0	20	32
					Average	142,000	98,600	13.6	6.7	27	41
		48,300		T	D9TA4A-1	145,000	111,000	15.6	8.0	40	68
					-2	151,000	116,000	13.9	7.5	36	68
					-3	150,000	116,000	15.6	8.3	44	80
					Average	149,000	114,000	15.0	7.9	40	72
900	10	ZERO	80	L	D9LA1C-1	188,000	152,000	16.1	5.0	16	20
					-2	187,000	153,000	16.1	5.0	14	20
					-3	192,000	160,000	16.2	5.0	8	12
					Average	189,000	155,000	16.1	5.0	13	17
				T	D9TA1C-1	191,000	168,000	17.4	8.0	28	44
					-2	191,000	165,000	17.3	8.0	32	44
					-3	193,000	171,000	17.1	8.0	32	32
					Average	192,000	168,000	17.3	8.0	31	40
			900	L	D9LA7C-1	118,000	79,200	12.7	15.0	40	68
					-2	122,000	72,800	12.8	10.0	34	36
					-3	119,000	81,100	9.42	10.0	38	48
					Average	120,000	77,700	11.6	12.0	37	51
				T	D9TA7C-1	123,000	87,300	13.3	10.0	38	56
					-2	125,000	87,400	13.2	12.0	40	76
					-3	124,000	87,800	13.7	10.0	38	68
					Average	124,000	87,500	13.4	11.0	39	67
		38,000	80	L	D9LA1D-1	190,000	146,000	16.0	4.5	8	16
					-2	189,000	146,000	15.6	6.5	18	20
					-3	191,000	150,000	15.7	-	-	-(1)
					Average	190,000	147,000	15.8	5.5	13	18
		41,700		T	D9TA1D-1	193,000	162,000	17.0	9.5	32	52
					-2	193,000	169,000	17.4	9.5	36	52
					-3	194,000	162,000	16.7	9.5	38	52
					Average	193,000	164,000	17.0	9.5	35	52
		38,000	900	L	D9LA7D-1	116,000	73,700	11.8	14.0	44	68
					-2	118,000	77,100	10.5	13.0	34	48
					-3	117,000	77,600	10.2	12.0	36	36
					Average	117,000	76,100	10.8	13.0	38	51
		41,700		T	D9TA7D-1	125,000	83,000	12.9	11.0	50	84
					-2	123,000	84,600	11.2	11.0	52	68
					-3	125,000	83,800	11.8	10.0	40	60
					Average	124,000	83,800	12.0	11.0	47	71

(1) Failed outside gage marks.

TABLE LXXXIV - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-4Al-3Mo-1V
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE P7653

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	D2LC1FL-1	0.61	0.60	78.2	2.02	1.95	1.92	.0614	.3864	35250	91.2
	-2	0.59	0.63	80.0	2.03	1.92	1.90	.0615	.3869	37750	97.6
	-8	0.59	0.57	77.8	2.03	1.95	1.92	.0648	.4065	42050	103
	-10	0.62	0.59	79.0	2.04	1.95	1.92	.0637	.4024	40400	100
	-11	0.60	0.60	80.0	2.07	1.95	1.94	.0603	.3800	35300	92.9
	-19	0.61	0.61	79.5	2.02	1.96	1.95	.0634	.3986	39800	99.8
	-20	0.59	0.59	78.0	2.03	1.95	1.93	.0599	.3765	35000	93.0
	-22	0.60	0.60	79.0	2.04	1.95	1.93	.0597	.3751	35100	93.6
	-23	0.58	0.60	79.2	2.08	1.93	1.94	.0594	.3727	34350	92.2
	-26	0.59	0.60	79.2	2.04	1.96	1.94	.0586	.3679	33550	91.2
	Average										95.4
200	D2LC2FL-6	0.58	0.63	77.5	2.02	1.98	1.93	.0644	.4061	40250	99.1
	-12	0.59	0.59	79.6	2.02	1.96	1.94	.0642	.4056	40600	100
	-16	0.61	0.61	80.0	2.07	1.98	1.95	.0638	.4033	39350	97.6
	Average										98.9
400	D2LC3FL-7	0.61	0.61	78.5	2.01	1.96	1.93	.0628	.3945	33600	85.2
	-18	0.60	0.60	78.0	2.03	1.95	1.92	.0598	.3765	29775	79.1
	-21	0.60	0.59	79.0	2.06	1.95	1.94	.0593	.3738	30850	82.5
	Average										82.3
600	D2LC4FL-4	0.61	0.61	78.0	2.04	1.97	1.94	.0630	.3958	33000	83.4
	-14	0.62	0.61	79.0	2.06	1.96	1.93	.0617	.3878	30700	79.2
	-24	0.63	0.63	76.2	1.97	1.94	1.89	.0595	.3735	29650	79.4
	Average										80.7
800	D2LC6FL-5	0.60	0.61	78.2	2.02	1.96	1.93	.0630	.3946	29450	74.6
	-15	0.59	0.60	79.2	2.05	1.98	1.94	.0603	.3812	26750	70.2
	-27	0.60	0.60	79.0	2.06	1.97	1.93	.0590	.3714	26500	71.4
	Average										72.1
900	D2LC7FL-9	0.64	0.63	78.5	2.02	1.97	1.92	.0589	.4082	28600	70.1
	-17	0.61	0.61	78.2	2.06	1.95	1.93	.0608	.3829	25850	67.5
	-28	0.59	0.58	79.0	2.07	1.96	1.94	.0586	.3690	23175	62.8
	Average										66.8
1000	D2LC8FL-3	0.60	0.60	78.8	2.03	1.96	1.93	.0645	.4014	24450	63.4
	-25	0.60	0.60	78.0	2.03	1.95	1.91	.0620	.3913	22900	58.5
	-29	0.62	0.61	80.0	2.03	1.97	1.95	.0636	.3712	20800	56.0
	Average										59.3

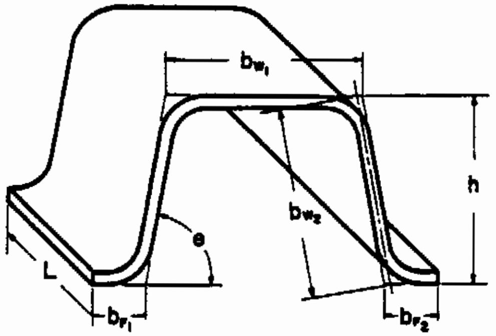


CONFIGURATION 2, LENGTH = 6.89"

TABLE LXXXV - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-4Al-3Mo-1V
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE P7653

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS								CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
		bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}		
80	D2TC1FL-1	0.59	0.58	78.5	2.02	1.98	1.94	.0606	.3815	36550	95.8
	-2	0.62	0.60	79.1	2.02	1.94	1.92	.0604	.3800	36550	96.2
	-6	0.62	0.61	78.0	2.01	1.96	1.92	.0624	.3926	39250	100
	-7	0.62	0.61	79.0	2.02	1.95	1.93	.0638	.4017	41500	103
	-12	0.59	0.58	77.5	2.08	1.96	1.93	.0589	.3722	33550	90.1
	-16	0.62	0.61	78.4	2.04	1.96	1.94	.0650	.4100	43200	105
	-19	0.60	0.60	78.0	2.05	1.96	1.93	.0610	.3833	38200	99.7
	-22	0.61	0.61	79.5	2.08	1.97	1.95	.0598	.3762	36350	96.6
	-23	0.61	0.61	78.0	1.96	2.00	1.96	.0597	.3755	34950	93.1
	-26	0.61	0.59	79.5	2.05	1.98	1.96	.0590	.3700	34200	92.4
	Average										97.2
200	D2TC2FL-10	0.62	0.62	79.0	2.02	1.96	1.93	.0634	.3997	39250	98.2
	-11	0.59	0.60	79.5	2.07	1.96	1.94	.0631	.3987	39750	99.7
	-20	0.60	0.58	78.0	2.04	1.96	1.93	.0602	.3787	34400	90.8
	Average										96.2
400	D2TC3FL-5	0.60	0.60	78.0	2.00	1.95	1.91	.0617	.3888	33350	85.8
	-13	0.60	0.60	78.8	2.02	1.96	1.93	.0638	.4018	34500	85.9
	-21	0.59	0.59	78.0	2.02	1.96	1.92	.0603	.3794	31850	83.9
	Average										85.2
600	D2TC4FL-3	0.61	0.61	79.0	2.05	1.97	1.92	.0612	.3856	30150	78.2
	-14	0.62	0.63	81.5	2.06	1.96	1.94	.0624	.3619	31075	81.4
	-24	0.60	0.59	78.3	2.03	1.96	1.94	.0596	.3755	28050	74.7
	Average										78.1
800	D2TC6FL-4	0.60	0.60	79.2	2.01	1.98	1.95	.0622	.3912	28650	73.2
	-15	0.61	0.61	77.5	2.01	1.98	1.92	.0646	.4096	31850	77.8
	-27	0.59	0.59	78.0	2.05	1.97	1.93	.0589	.3709	26100	70.4
	Average										73.8
900	D2TC7FL-8	0.60	0.60	78.0	2.02	1.98	1.93	.0643	.4062	29600	72.9
	-17	0.60	0.61	78.0	2.03	1.97	1.92	.0640	.4031	27050	67.1
	-28	0.60	0.60	79.5	2.06	1.96	1.93	.0591	.3717	25100	67.5
	Average										69.2
1000	D2TC8FL-13	0.60	0.62	78.8	2.04	1.97	1.94	.0649	.4081	25400	62.2
	-18	0.60	0.60	78.0	2.04	1.97	1.93	.0616	.3884	22450	57.8
	-25	0.59	0.58	79.2	2.06	1.99	1.95	.0590	.3703	20550	55.5
	Average										58.5

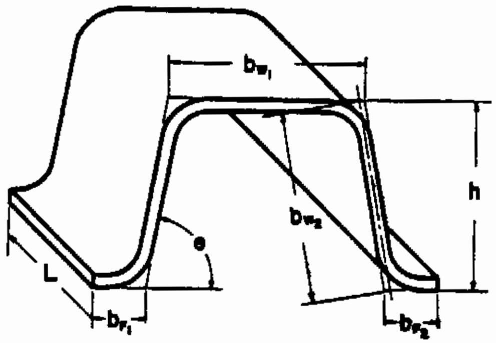


CONFIGURATION 2, LENGTH = 6.89"

TABLE LXXXVI - LONGITUDINAL CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-4Al-3Mo-1V
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE P7653

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}	CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
80	D2LC1EL-1	0.42	0.39	80.5	1.22	1.00	1.01	.0612	.1982	22450	118
	-6	0.41	0.41	81.1	1.18	1.01	1.01	.0605	.1938	21600	111
	-10	0.41	0.40	80.0	1.23	1.03	1.02	.0617	.2009	24450	122
	-11	0.42	0.40	80.0	1.19	1.00	0.99	.0623	.2006	26900	134
	-14	0.41	0.42	77.0	1.20	1.01	0.99	.0626	.2016	27200	135
	-15	0.44	0.42	79.0	1.26	1.01	1.00	.0634	.2069	27950	135
	-18	0.42	0.40	80.8	1.22	1.02	1.02	.0617	.1984	28625	144
	-19	0.42	0.41	81.0	1.24	1.02	1.02	.0644	.2084	28050	134
	-21	0.40	0.40	76.6	1.20	1.00	0.97	.0586	.1879	23900	127
	-26	0.39	0.39	77.3	1.23	1.02	1.00	.0591	.1914	23800	124
	Average										128
200	D2LC2EL-2	0.41	0.41	78.0	1.22	0.99	0.98	.0608	.1960	23000	117
	-12	0.41	0.40	79.6	1.21	1.00	0.99	.0625	.2004	26000	130
	-22	0.42	0.41	82.0	1.22	1.00	0.99	.0582	.1868	22550	121
	Average										123
400	D2LC3EL-3	0.42	0.42	79.0	1.22	1.00	0.99	.0610	.1970	20650	105
	-13	0.42	0.41	79.0	1.19	1.00	0.98	.0621	.2004	22350	112
	-23	0.41	0.41	79.0	1.21	1.00	0.99	.0609	.1876	19500	104
	Average										107
600	D2LC4EL-4	0.39	0.40	80.0	1.21	0.99	0.98	.0613	.1974	17700	89.7
	-16	0.41	0.41	80.0	1.22	0.99	0.98	.0640	.2074	20350	98.1
	-24	0.36	0.36	79.5	1.25	1.00	0.98	.0586	.1881	18100	96.2
	Average										94.7
800	D2LC6EL-17	0.39	0.40	80.5	1.22	1.03	1.01	.0642	.1881	20700	110
	-25	0.40	0.38	81.1	1.24	1.02	1.02	.0593	.1942	16300	83.9
	-28	0.40	0.40	78.5	1.25	1.01	0.99	.0592	.1923	17150	89.2
	Average										94.4
900	D2LC7EL-5	0.39	0.41	78.5	1.20	0.99	0.98	.0616	.1998	16825	84.2
	-8	0.40	0.40	78.0	1.18	1.00	0.99	.0610	.1962	16800	85.6
	-18	0.40	0.40	80.8	1.22	1.02	1.01	.0616	.2081	18650	89.6
	Average										86.5
1000	D2LC8EL-9	0.41	0.41	78.2	1.19	1.01	0.99	.0613	.1973	13500	68.4
	-20	0.40	0.39	78.0	1.21	1.00	0.98	.0589	.1896	12300	64.9
	-27	0.40	0.41	79.2	1.20	1.00	0.98	.0595	.1914	12750	66.6
	Average										66.6

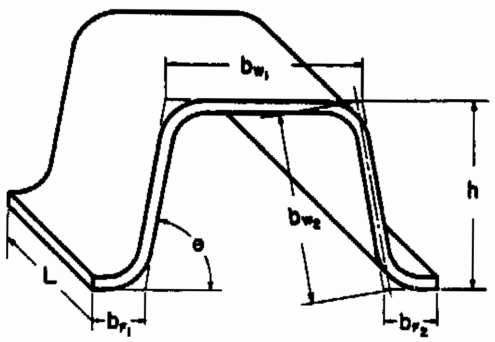


CONFIGURATION 1, LENGTH = 4.13"

TABLE LXXXVII - TRANSVERSE CRIPPLING PROPERTIES FOR SOLUTION TREATED AND AGED TITANIUM ALLOY SHEET

ALLOY - Ti-4Al-3Mo-1V
THICKNESS - 0.063 INCH
HEAT NUMBER - CRUCIBLE P7653

TEST TEMP., °F	SPECIMEN NUMBER	SPECIMEN DIMENSIONS bf_1, in.	bf_2, in.	θ, degree	bw_1, in.	bw_2, in.	h, in.	t, in.	AREA, in.^{2}	CRITICAL CRIPPLING LOAD, lbs.	CRITICAL CRIPPLING STRESS, KSI
80	D2TC1EL-1	0.41	0.41	80.0	1.21	0.98	0.97	.0583	.1871	24800	132
	-5	0.42	0.42	81.2	1.22	0.98	0.97	.0590	.1893	26500	140
	-6	0.43	0.43	83.0	1.24	0.98	0.98	.0630	.2039	29350	144
	-10	0.41	0.42	80.0	1.24	0.99	0.98	.0638	.2055	31000	151
	-11	0.40	0.41	79.0	1.22	1.00	0.99	.0626	.2042	31400	154
	-14	0.40	0.41	78.0	1.24	1.00	0.98	.0638	.2071	30550	148
	-15	0.40	0.40	78.0	1.19	1.00	0.98	.0582	.1883	26150	139
	-21	0.40	0.40	79.0	1.22	1.00	0.99	.0589	.1920	26350	137
	-28	.041	0.40	79.5	1.23	1.00	1.00	.0592	.1928	28450	148
	-31	0.39	0.40	77.0	1.19	1.02	0.99	.0600	.1923	26350	137
	Average										143
200	D2TC2EL-2	0.40	0.40	76.5	1.18	0.99	0.97	.0586	.1870	23350	125
	-12	0.40	0.40	80.0	1.22	1.00	0.99	.0636	.2053	29950	146
	-22	0.40	0.40	79.5	1.23	0.99	0.98	.0590	.1908	24000	126
	Average										132
400	D2TC3EL-3	0.40	0.41	78.5	1.24	0.99	0.96	.0583	.1887	19850	105
	-13	0.40	0.41	78.0	1.21	0.99	0.97	.0635	.2044	26200	128
	-23	0.39	0.40	60.5	1.29	1.00	0.99	.0587	.1917	22150	116
	Average										116
600	D2TC4EL-4	0.42	0.42	80.0	1.23	0.99	0.97	.0590	.1885	18650	98.9
	-16	0.42	0.41	78.5	1.18	1.00	0.98	.0602	.1938	19500	101
	-24	0.41	0.41	79.0	1.22	1.01	1.00	.0580	.1878	19900	106
	Average										102
800	D2TC6EL-7	0.40	0.40	76.5	1.18	0.99	0.97	.0599	.1932	16200	83.8
	-9	0.42	0.41	82.0	1.25	0.99	0.99	.0636	.2057	21000	102
	-17	0.41	0.40	79.0	1.20	1.00	0.99	.0617	.1989	19775	99.4
	Average										95.1
900	D2TC7EL-8	0.41	0.42	79.0	1.23	1.00	0.99	.0637	.2044	19800	96.9
	-26	0.42	0.41	80.0	1.23	1.00	0.99	.0586	.1916	18200	94.9
	-32	0.43	0.42	81.0	1.17	1.00	0.99	.0629	.2043	17400	85.2
	Average										92.3
1000	D2TC8EL-19	0.42	0.41	81.5	1.24	1.00	1.00	.0633	.2053	14950	72.8
	-20	0.40	0.39	79.0	1.20	1.01	1.00	.0587	.1896	13100	69.1
	-27	0.41	0.42	80.0	1.23	1.00	0.99	.0592	.1917	14000	73.0
	Average										71.6



CONFIGURATION 1, LENGTH = 4.13"

TABLE LXXXVIII

LONGITUDINAL COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. P7653)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
D2LB1L-2	80	156,000	16.6	154,000	164,000	14.2
-5	80	155,000	16.3	154,000	164,000	14.2
-8	80	162,000	17.1	160,000	172,000	13.3
-11	80	165,000	14.3	165,000	181,000	10.7
-14	80	168,000	16.3	167,000	181,000	12.2
-17	80	165,000	16.7	163,000	176,000	12.6
-20	80	165,000	17.0	163,000	174,000	14.2
-23	80	154,000	17.2	151,000	162,000	13.7
-26	80	161,000	16.6	158,000	173,000	11.0
-29	80	163,000	16.6	161,000	174,000	12.4
Average		161,000	16.5	160,000	172,000	12.8
D2LB2L-7	200	144,000	14.1	143,000	154,000	12.9
-19	200	148,000	13.4	148,000	160,000	12.4
-22	200	135,000	14.2	134,000	142,000	10.2
Average		142,000	13.9	142,000	152,000	13.8
D2LB3L-13	400	122,000	10.8	121,000	128,000	16.7
-24	400	112,000	13.2	110,000	117,000	15.3
-27	400	111,000	13.0	108,000	113,000	20.7
Average		115,000	12.3	113,000	119,000	17.6
D2LB4L-15	600	108,000	13.6	106,000	113,000	14.1
-18	600	108,000	9.96	107,000	-	-
-25	600	100,000	14.1	98,600	102,000	24.4
Average		105,000	12.6	104,000	108,000	19.2
D2LB6L-4	800	91,000	11.1	89,300	94,600	16.4
-10	800	95,200	13.2	91,200	99,100	11.8
-12	800	96,100	13.3	91,900	97,300	16.5
Average		94,100	12.5	90,800	97,000	14.9
D2LB7L-3	900	81,700	11.9	77,200	85,400	9.7
-16	900	86,500	12.5	79,800	92,500	7.0
-28	900	79,000	10.1	74,900	85,600	7.6
Average		82,400	11.5	77,300	87,800	8.1
D2LB8L-1	1000	68,200	11.3	61,400	70,900	7.2
-9	1000	72,800	10.3	68,600	76,800	8.8
-21	1000	70,600	10.2	65,500	74,500	7.9
Average		70,500	10.6	65,200	74,100	8.0

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

TRANSVERSE COMPRESSIVE PROPERTIES FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. P7653)

Specimen Number	Test Temp., °F	F_{cy}, PSI	E, PSI X 10^{-6}	F_c at 0.85 E, PSI	F_c at 0.70 E, PSI	Shape Parameter n
D2TB1L-2	80	176,000	17.3	174,000	195,000	8.9
-5	80	181,000	17.8	179,000	201,000	8.7
-8	80	188,000	15.4	190,000	215,000	8.1
-11	80	186,000	17.9	184,000	208,000	8.4
-14	80	187,000	17.4	188,000	211,000	8.4
-17	80	181,000	18.1	179,000	205,000	7.6
-20	80	177,000	17.1	176,000	193,000	10.4
-23	80	172,000	17.8	169,000	189,000	8.8
-29	80	186,000	17.4	165,000	211,000	7.8
Average		182,000	17.4	180,000	203,000	8.6
D2TB2L-7	200	161,000	17.2	158,000	171,000	12.1
-19	200	162,000	14.2	162,000	185,000	7.7
-22	200	144,000	12.1	144,000	-	-
Average		156,000	14.5	155,000	178,000	9.9
D2TB3L-13	400	136,000	15.7	131,000	149,000	7.9
-24	400	135,000	14.3	132,000	156,000	6.3
-27	400	129,000	15.7	125,000	138,000	10.3
Average		133,000	15.2	129,000	148,000	8.2
D2TB4L-15	600	122,000	16.1	118,000	129,000	10.6
-18	600	115,000	15.7	111,000	128,000	7.2
-25	600	116,000	12.8	113,000	129,000	7.7
Average		118,000	14.9	114,000	129,000	8.5
D2TB6L-4	800	108,000	13.9	102,000	120,000	6.6
-10	800	102,000	11.2	98,300	120,000	5.5
-12	800	113,000	13.8	107,000	127,000	6.1
Average		108,000	13.0	102,000	122,000	6.1
D2TB7L-3	900	94,300	13.4	86,200	102,000	6.3
-16	900	95,600	13.2	90,400	101,000	8.8
-28	900	96,400	12.6	90,100	106,000	6.3
Average		95,400	13.1	88,900	103,000	7.1
D2TB8L-1	1000	76,000	10.9	73,300	80,500	10.5
-9	1000	73,000	8.73	68,300	81,600	6.0
-21	1000	69,200	7.43	67,100	77,700	7.0
Average		72,700	9.02	69,600	79,900	7.8

NOTE: These specimens came from sheets used for crippling tests and were aged by Lockheed.

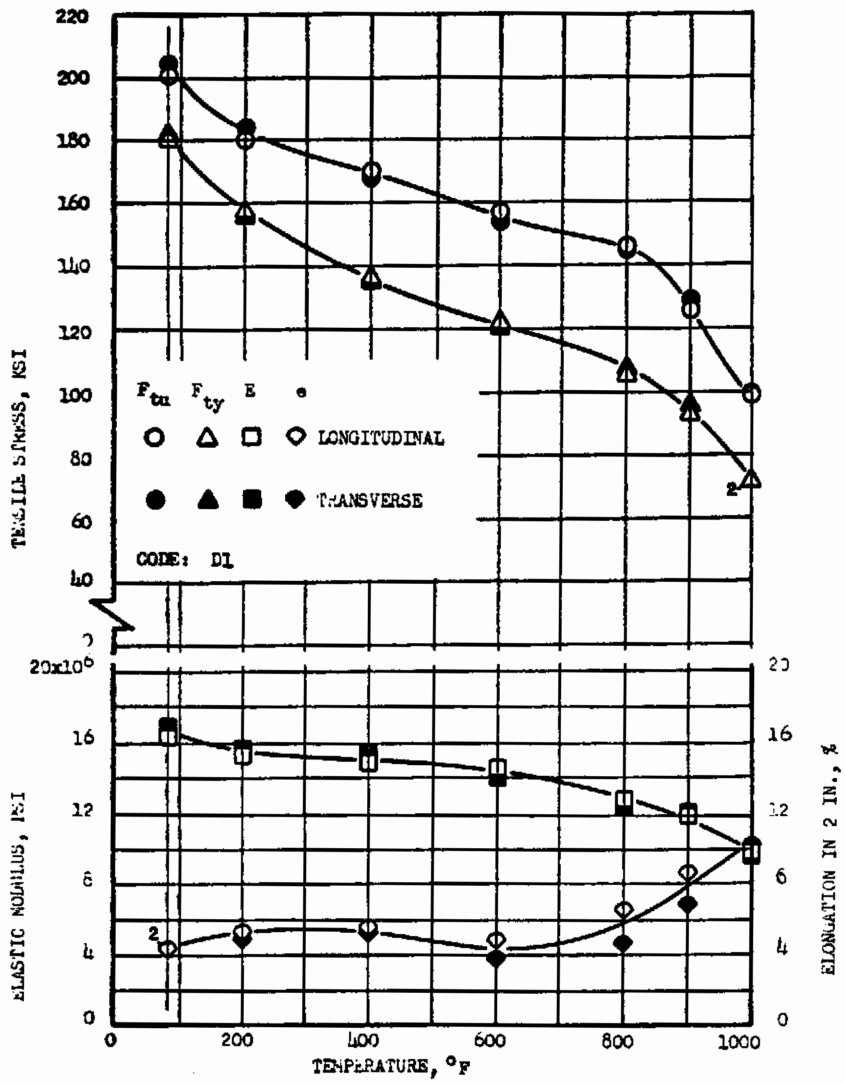


FIGURE 285 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R4815)

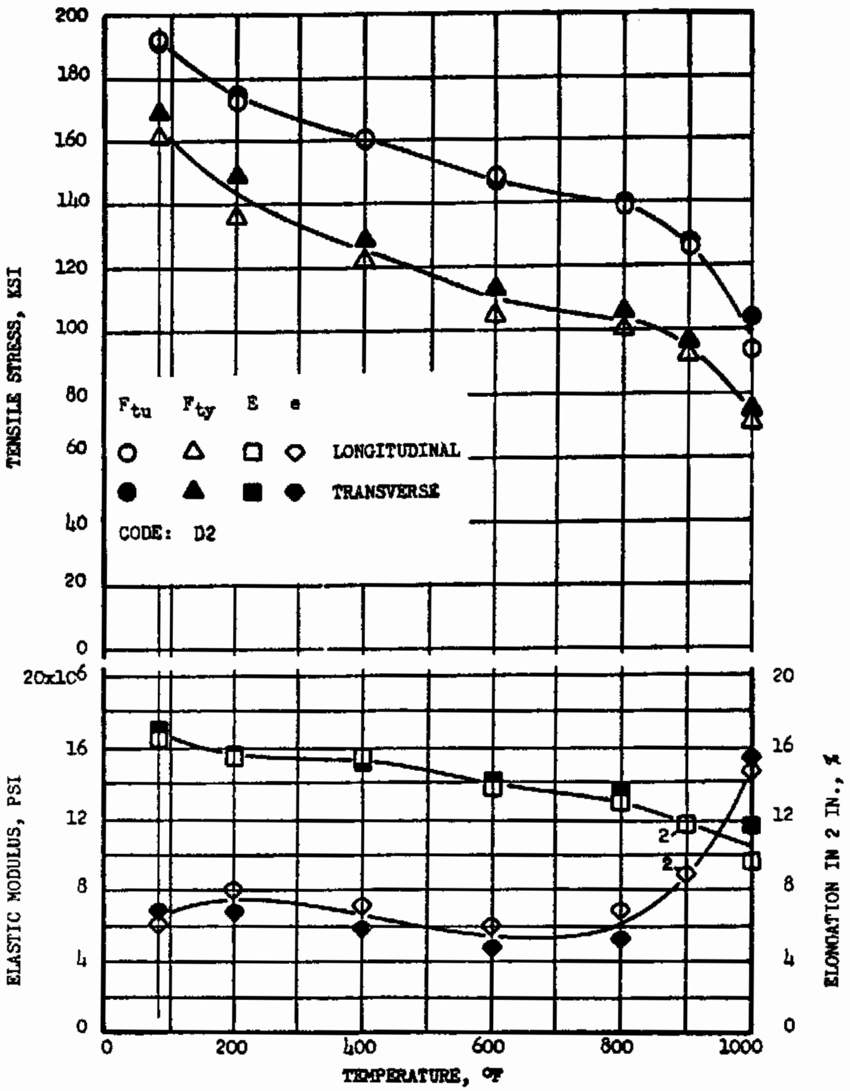


FIGURE 286 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. P7653)

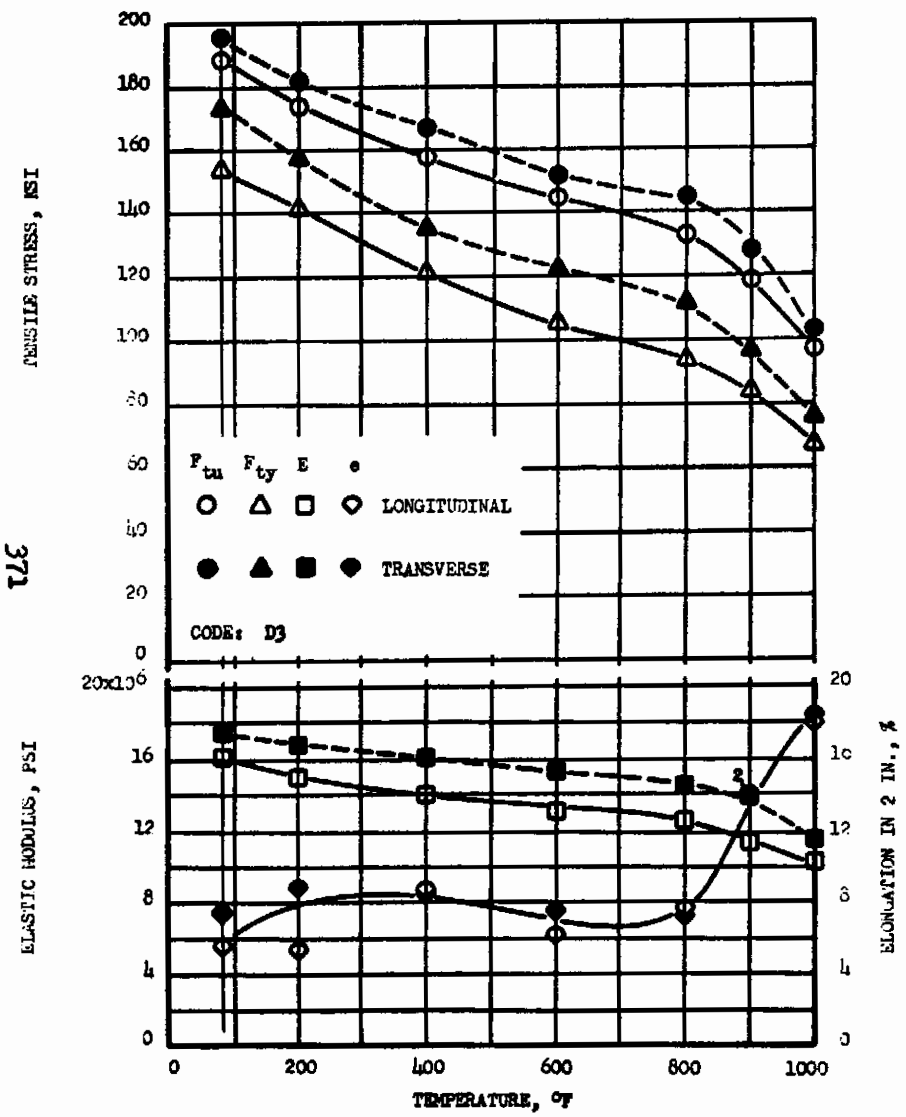


FIGURE 287 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6736)

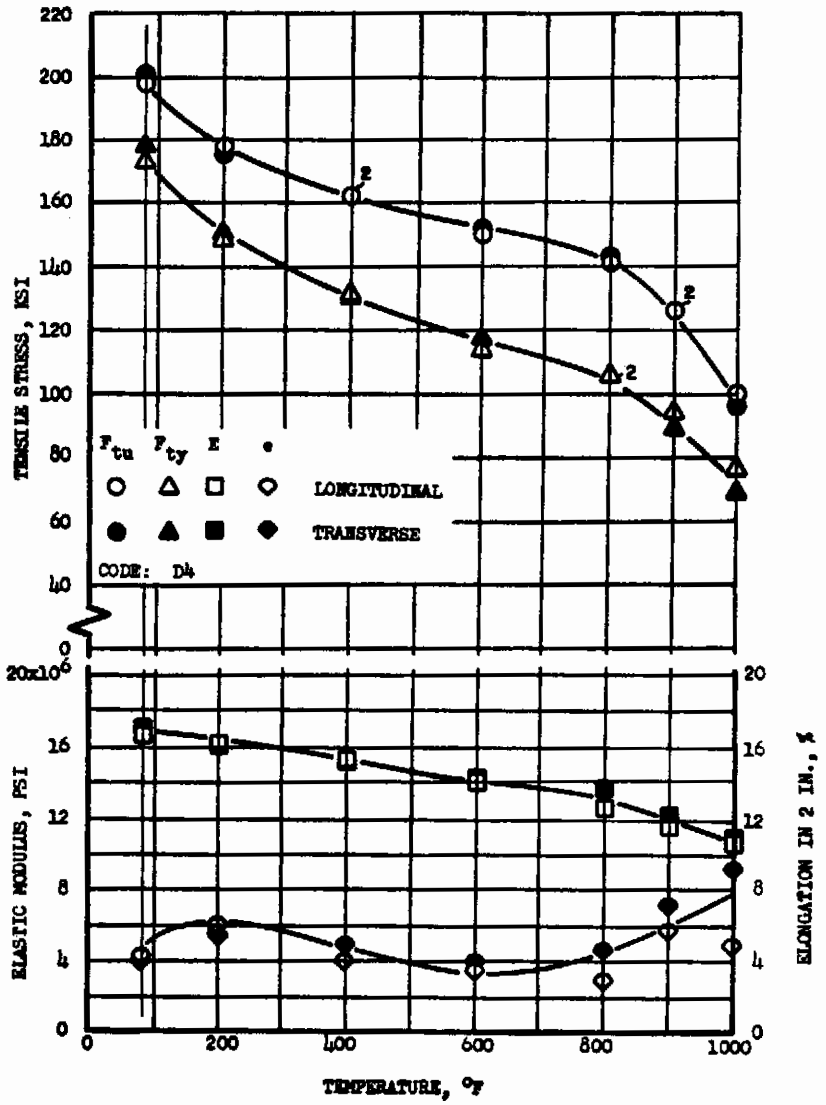


FIGURE 288 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R4765)

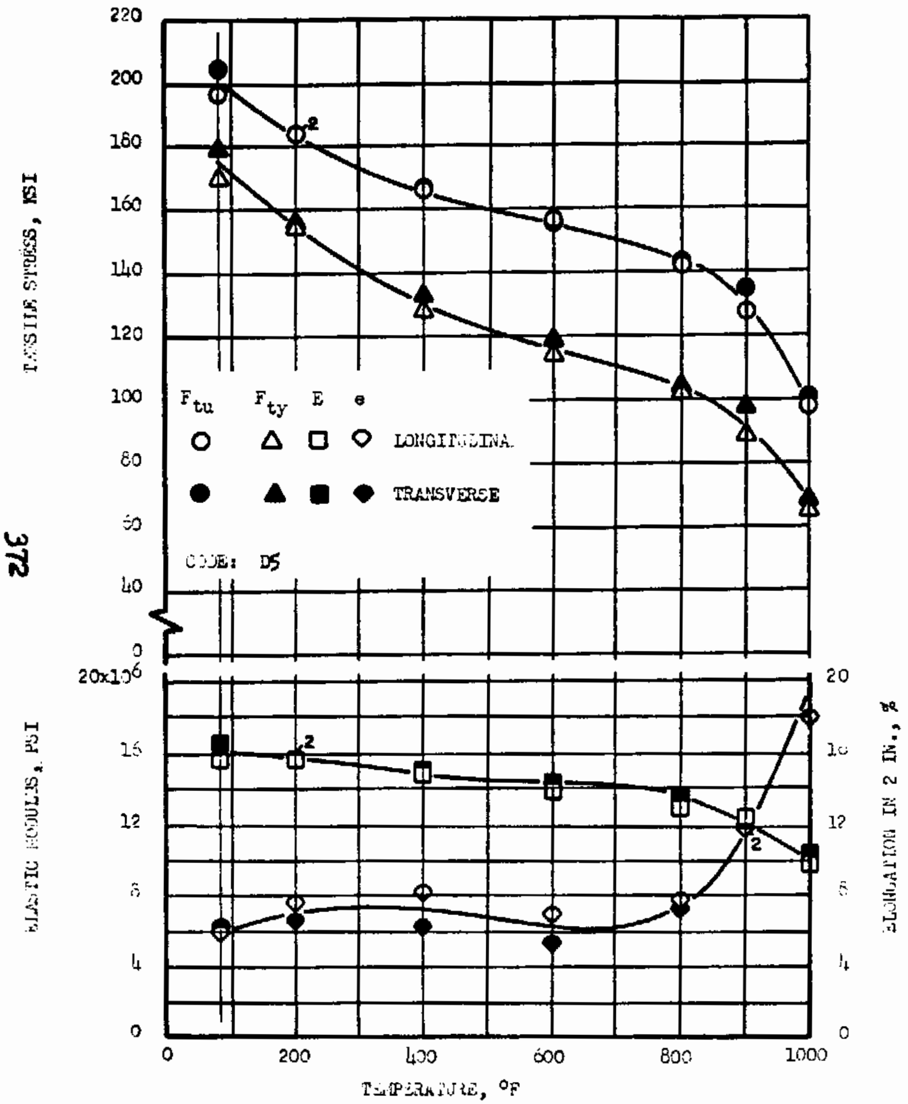


FIGURE 289 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4765)

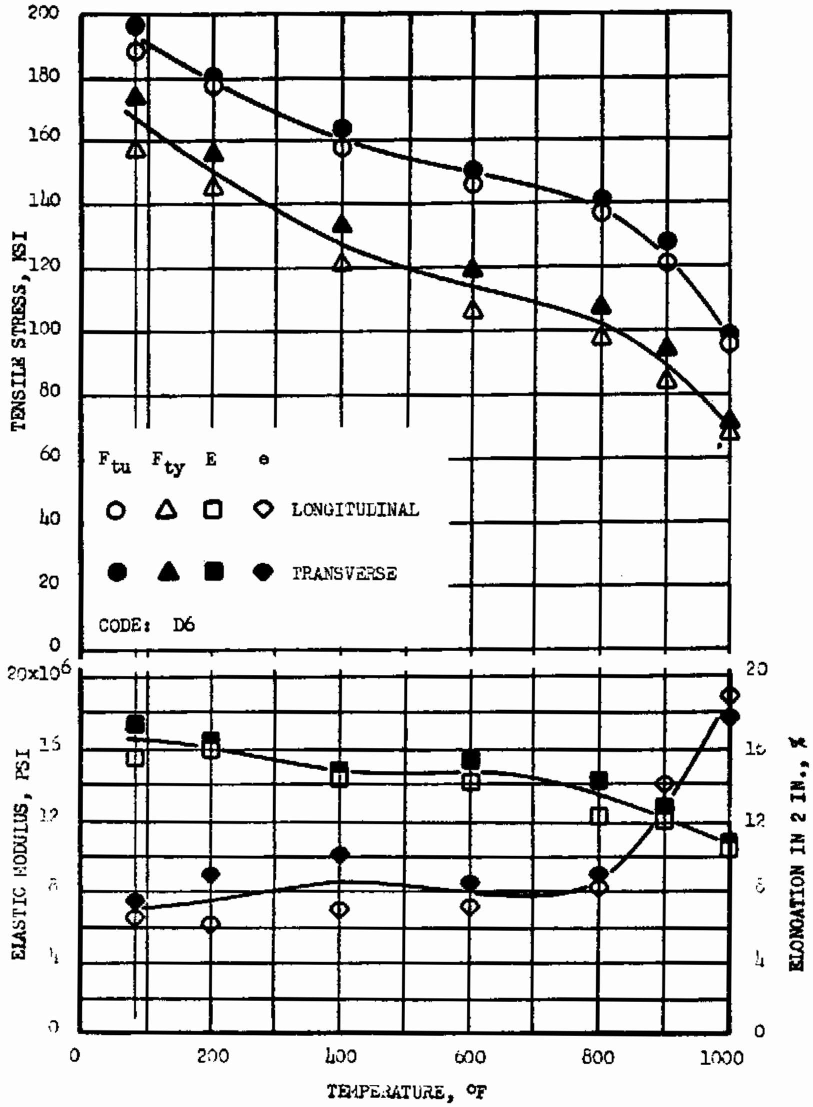


FIGURE 290 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6741)

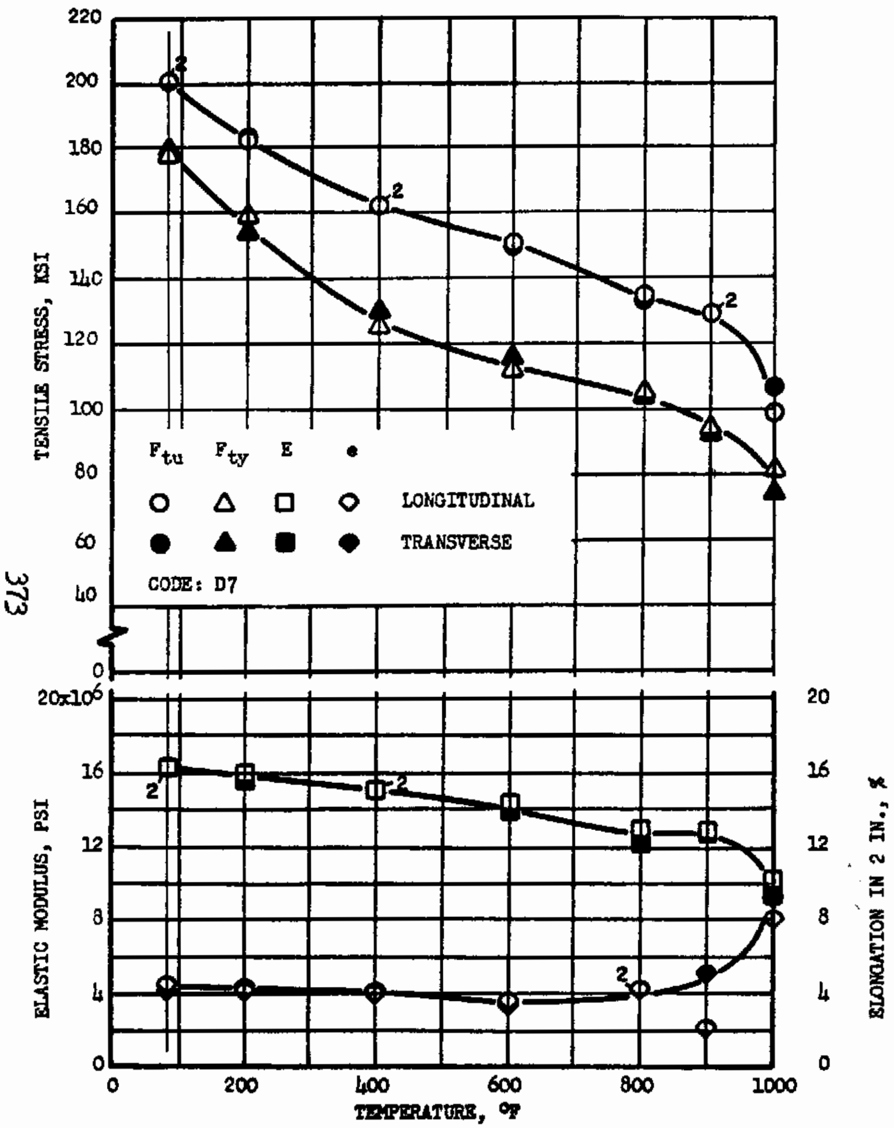


FIGURE 291 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R4805)

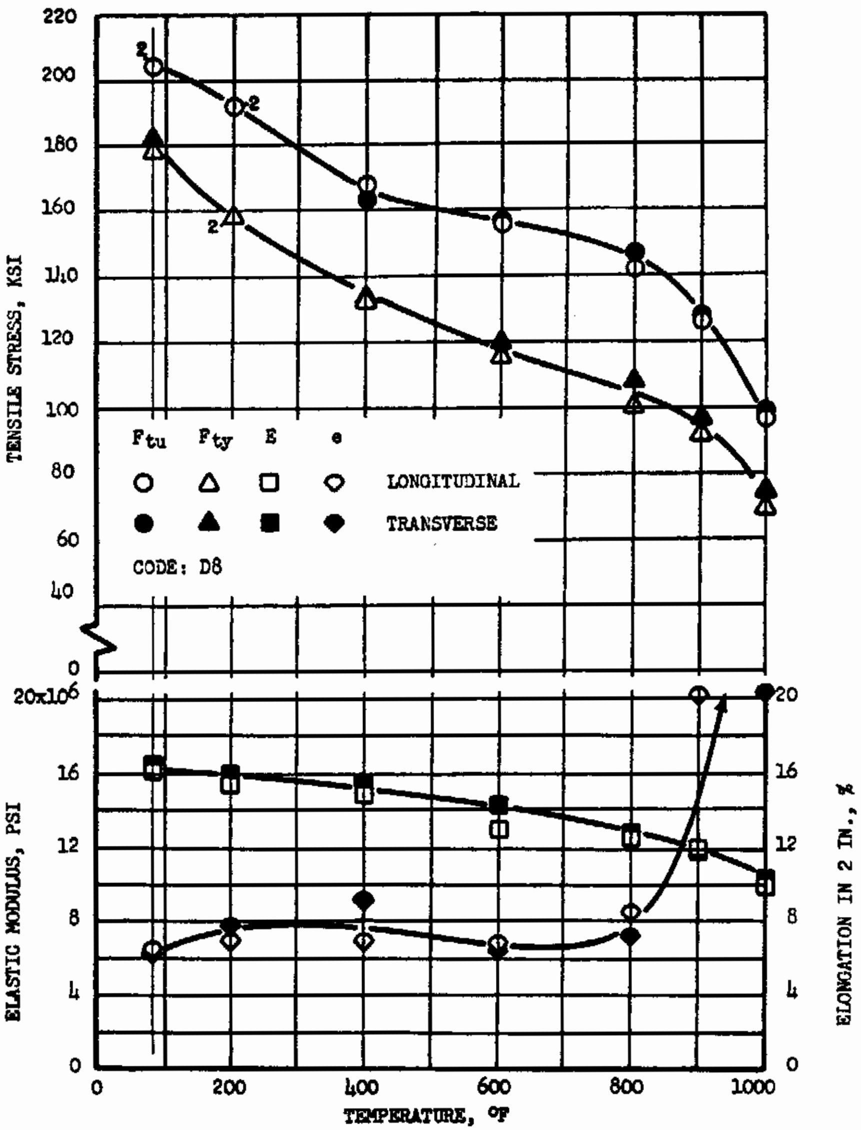


FIGURE 292 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4815)

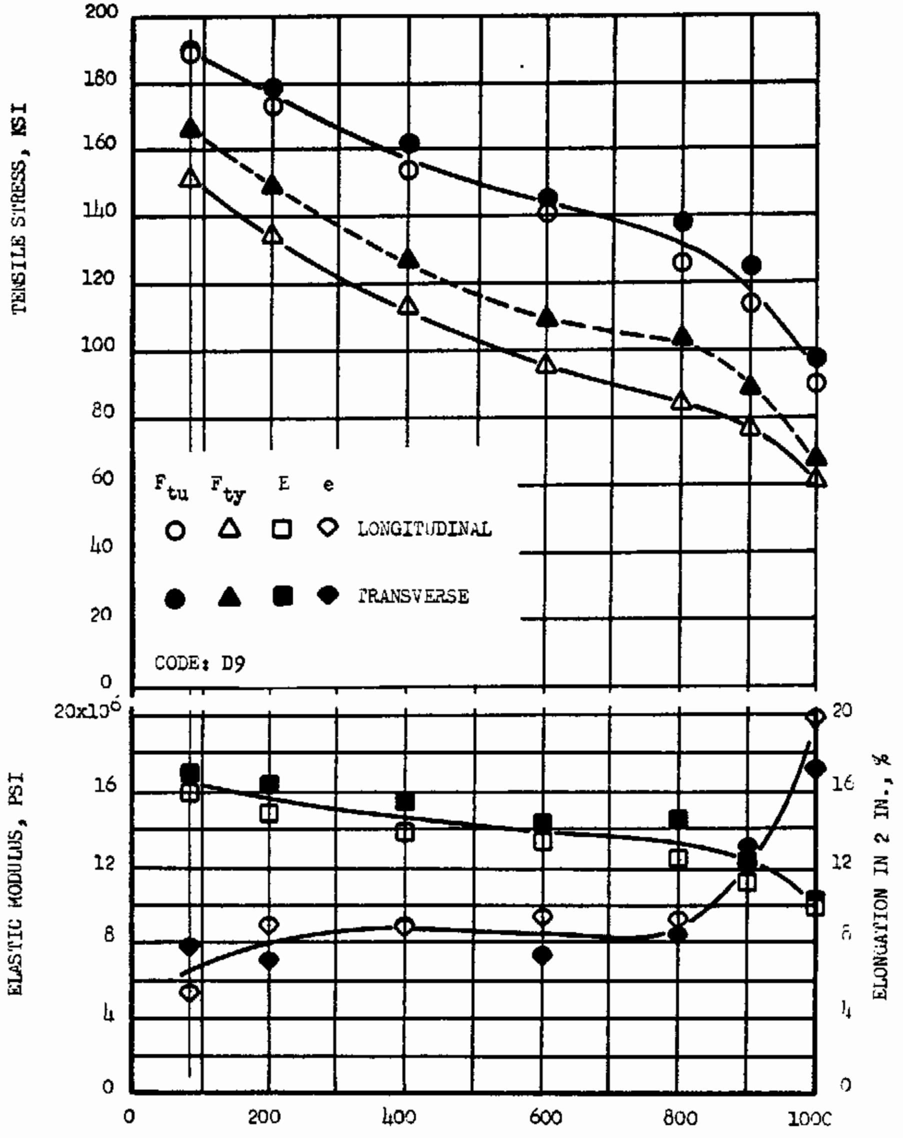


FIGURE 293 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. P7647)

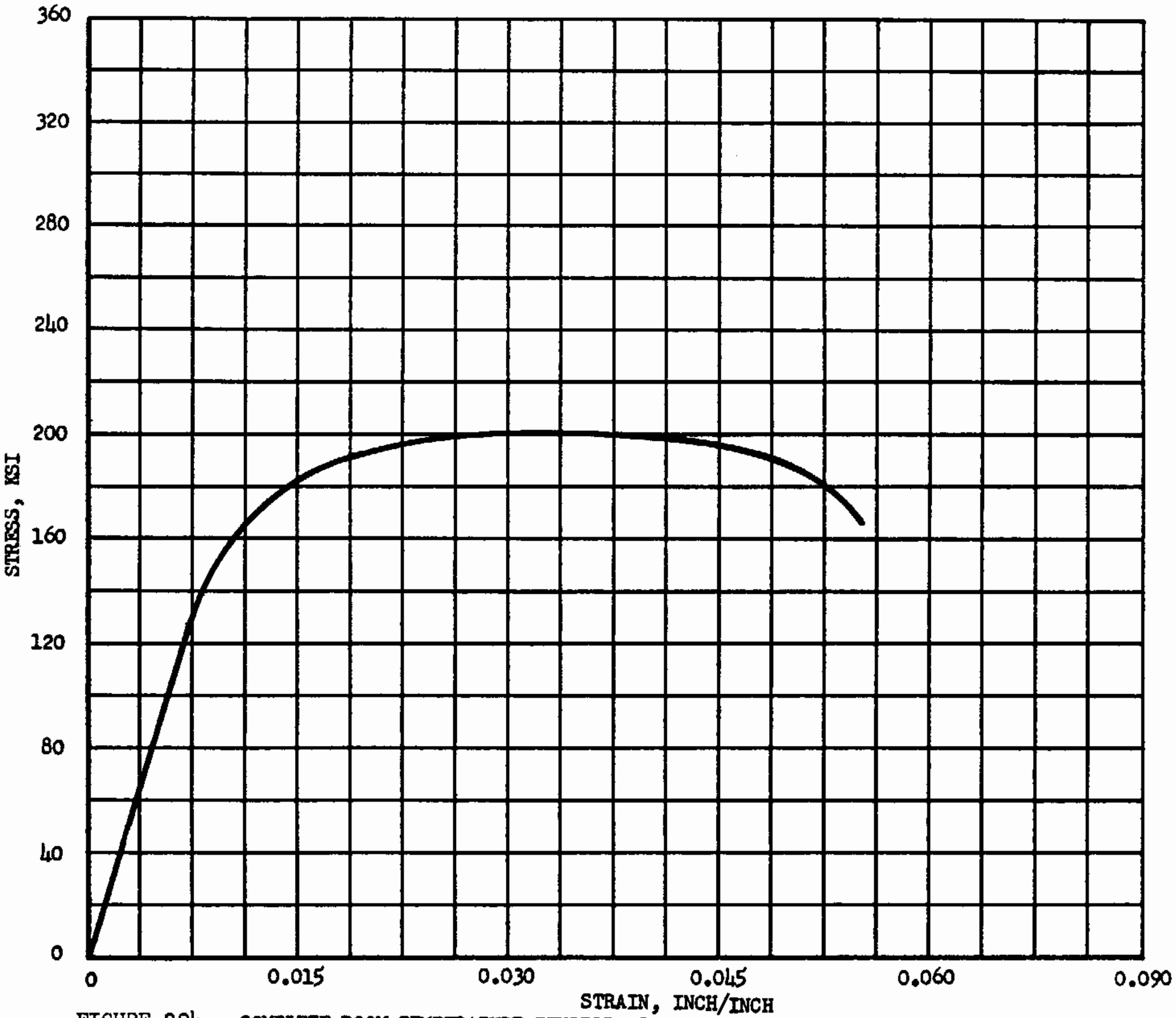


FIGURE 294 - COMPLETE ROOM TEMPERATURE TENSILE STRESS-STRAIN CURVE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (SPECIMEN NO. D2LA1-4)

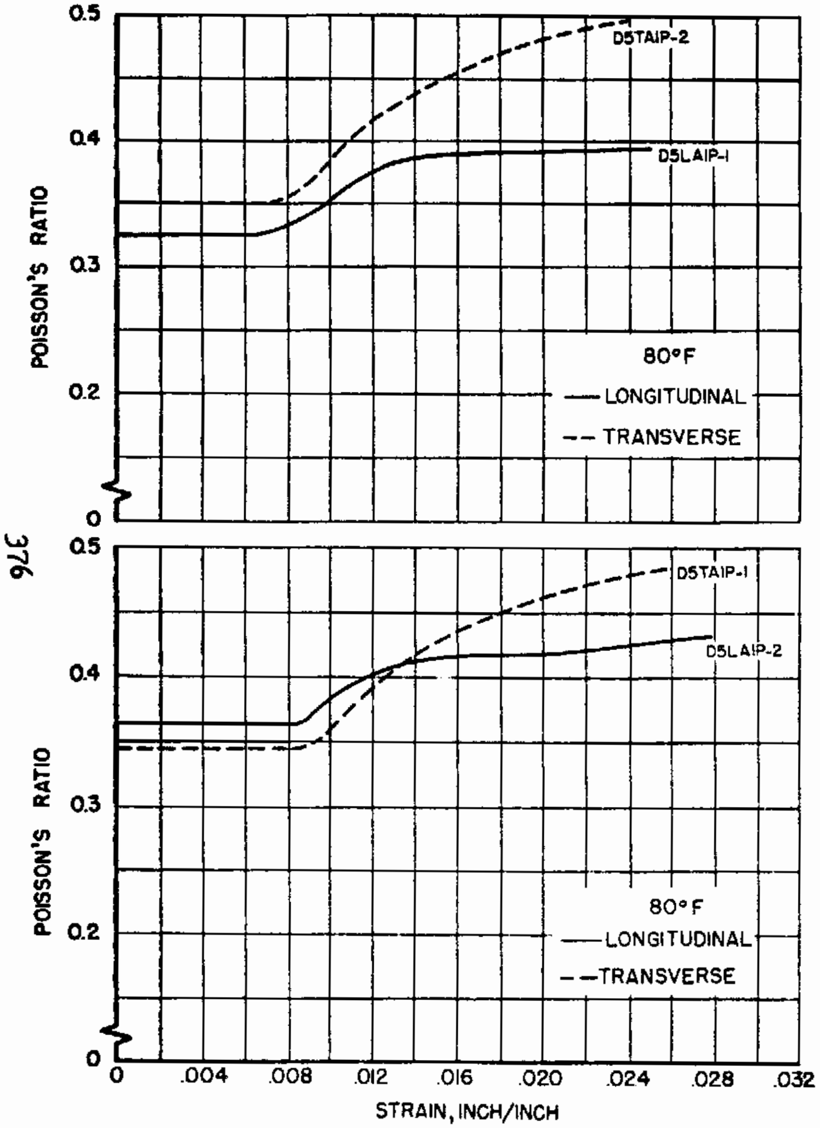


FIGURE 295 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK

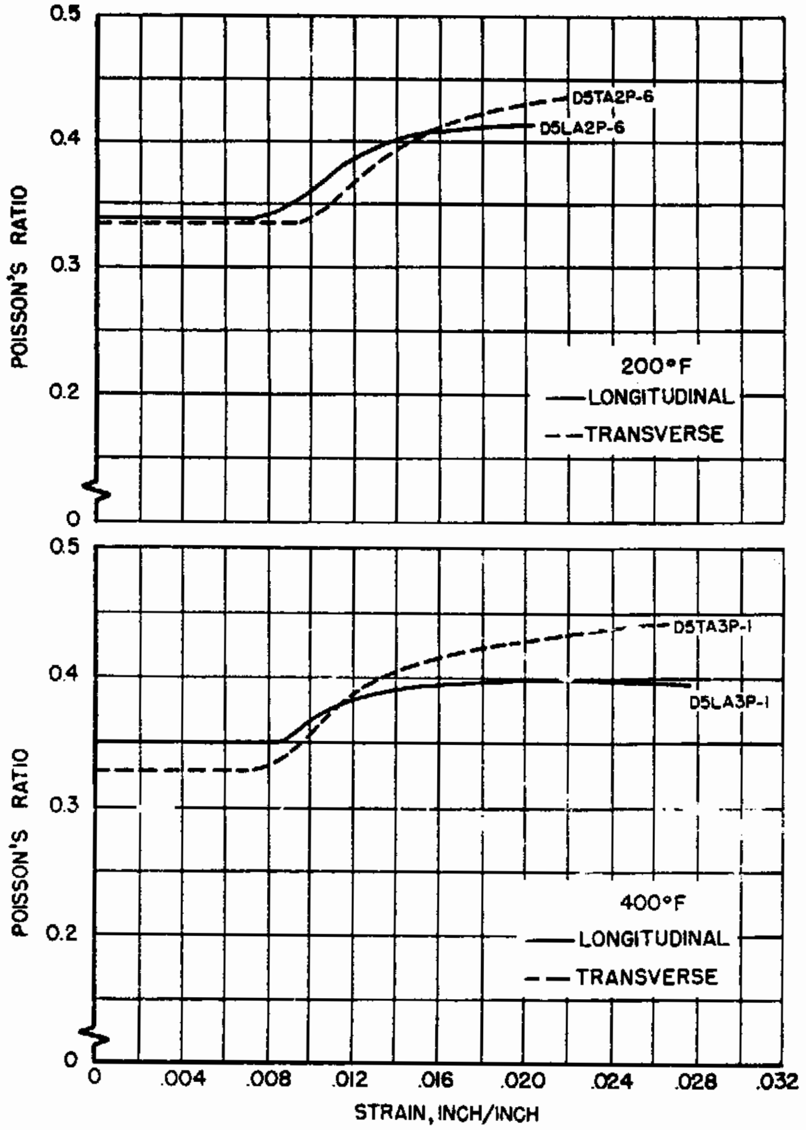


FIGURE 296 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK

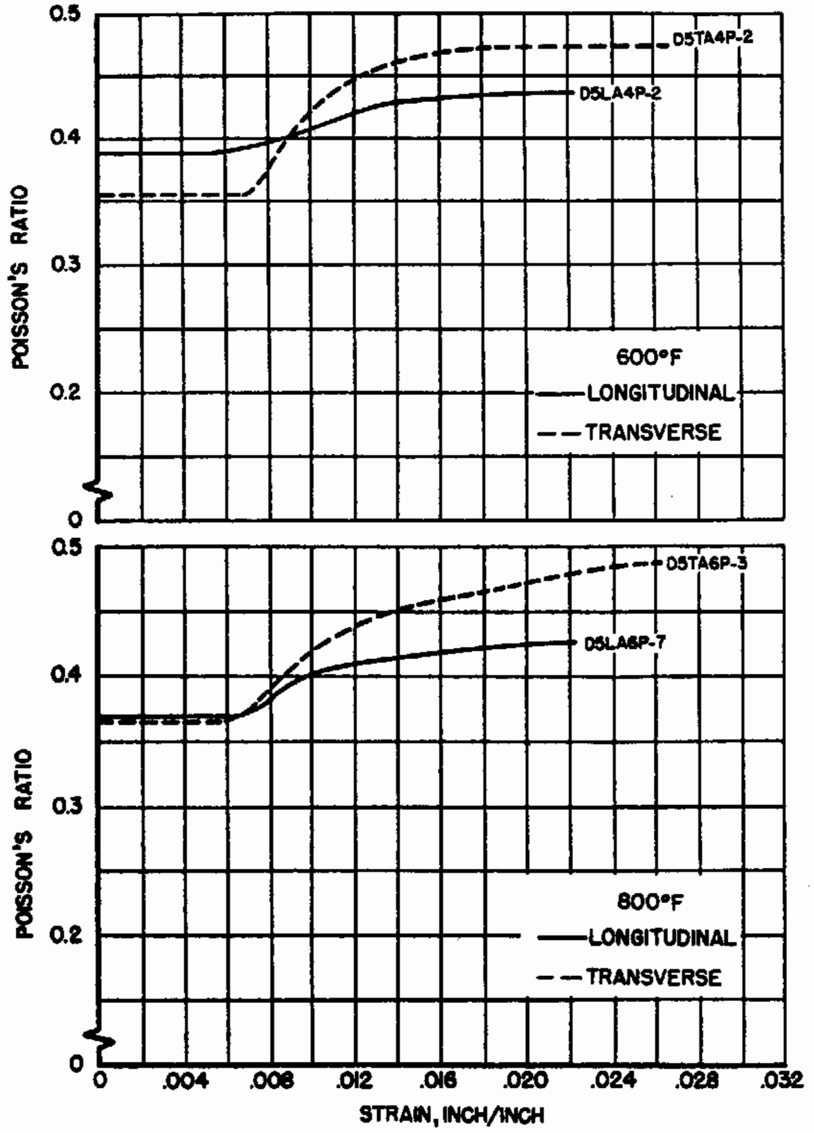


FIGURE 297 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK

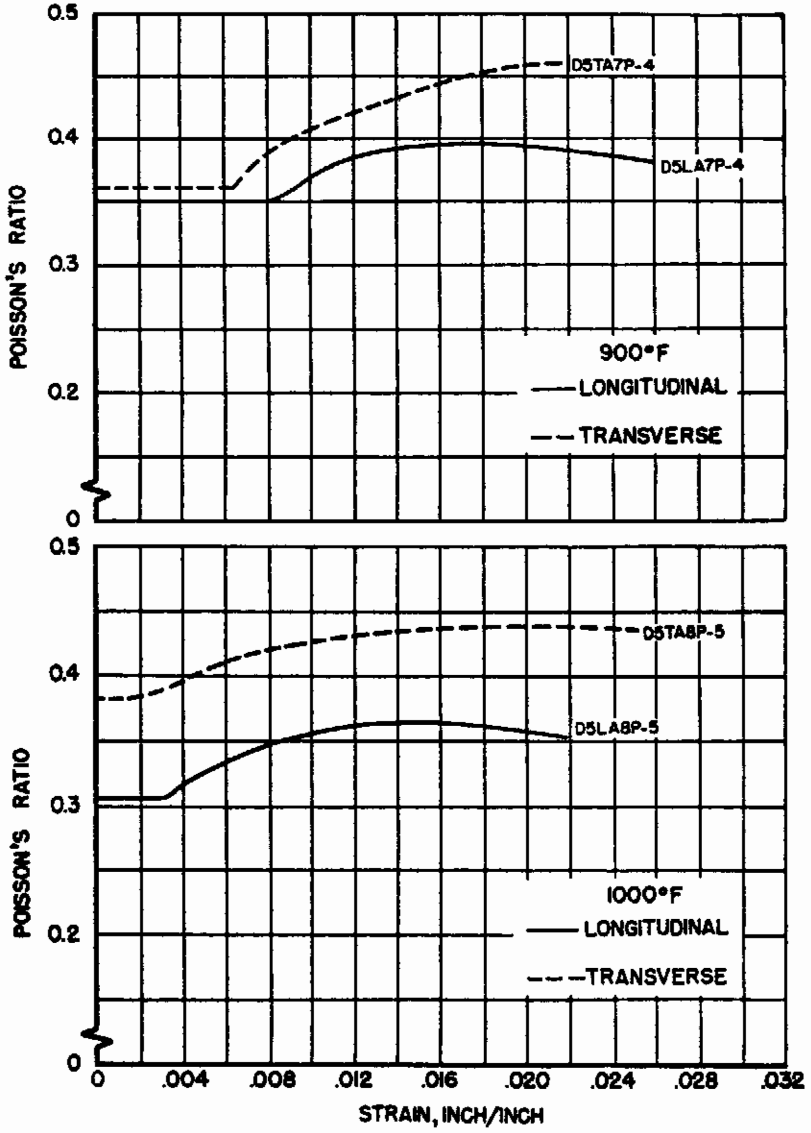


FIGURE 298 - VARIATION OF POISSON'S RATIO IN THE PLANE OF THE SHEET WITH TENSILE STRAIN FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK

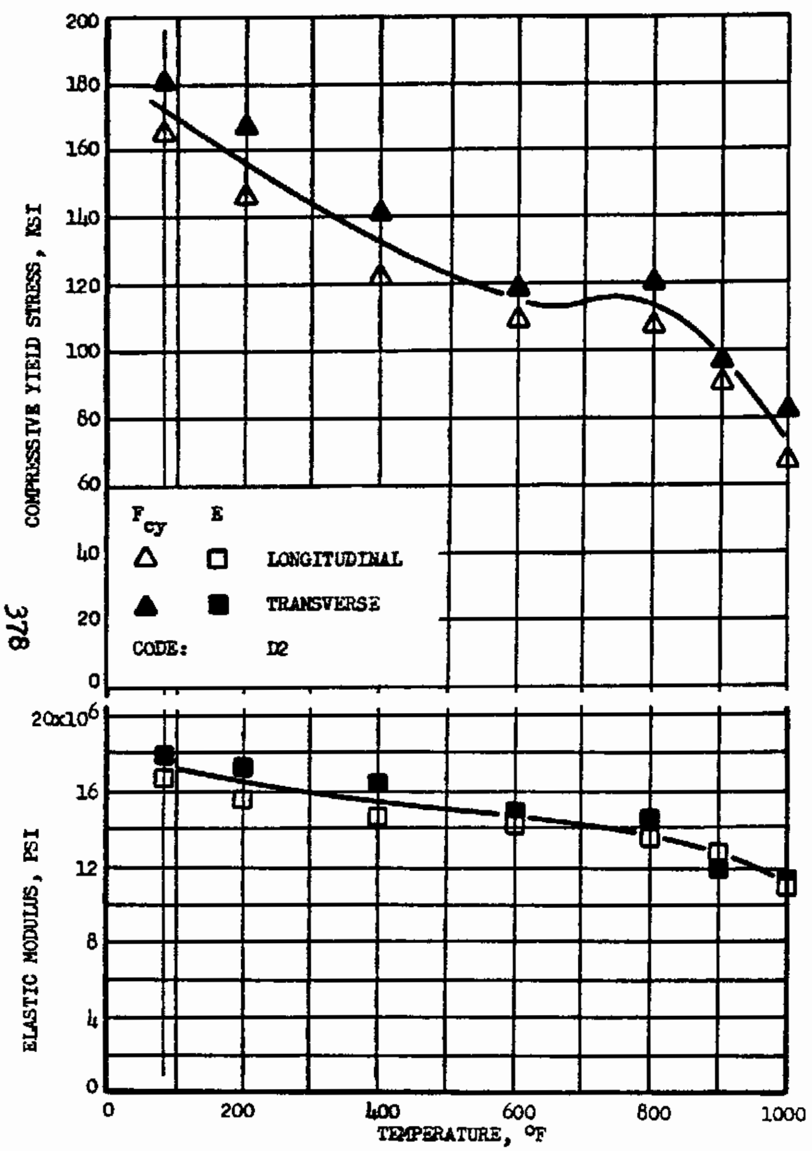


FIGURE 299 – SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. P7653)

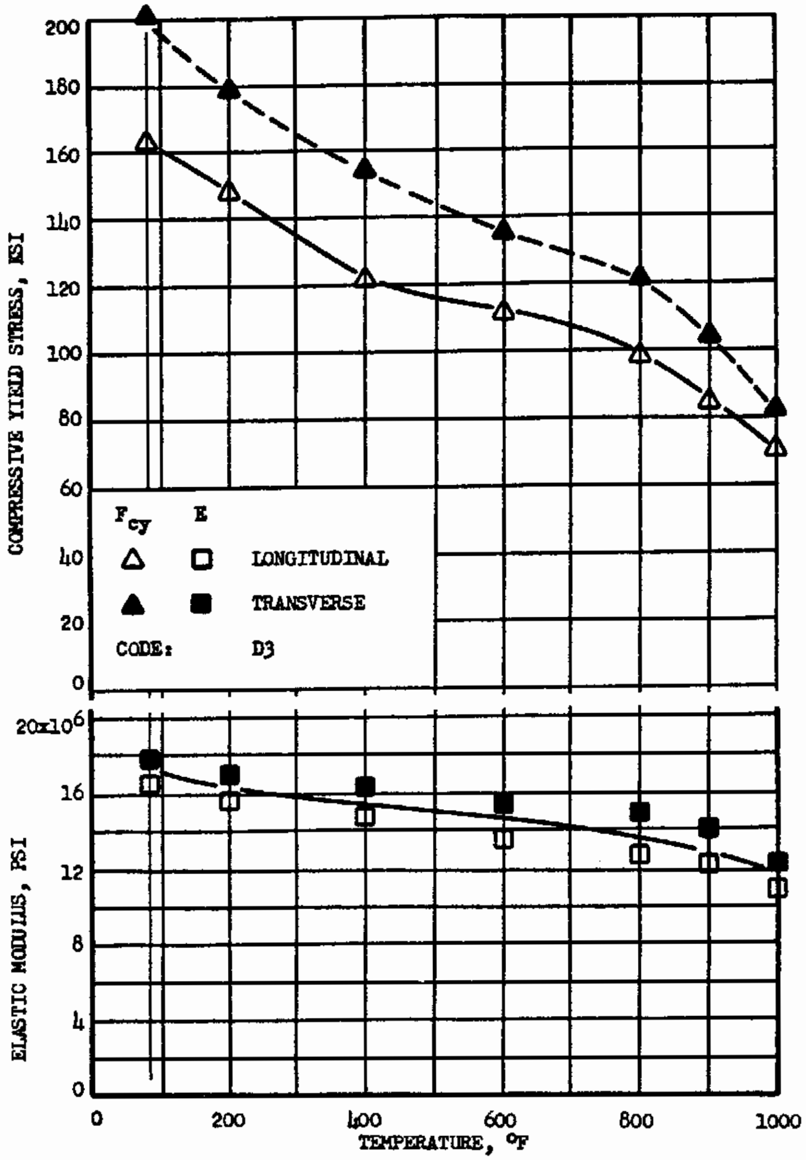


FIGURE 300 – SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6736)

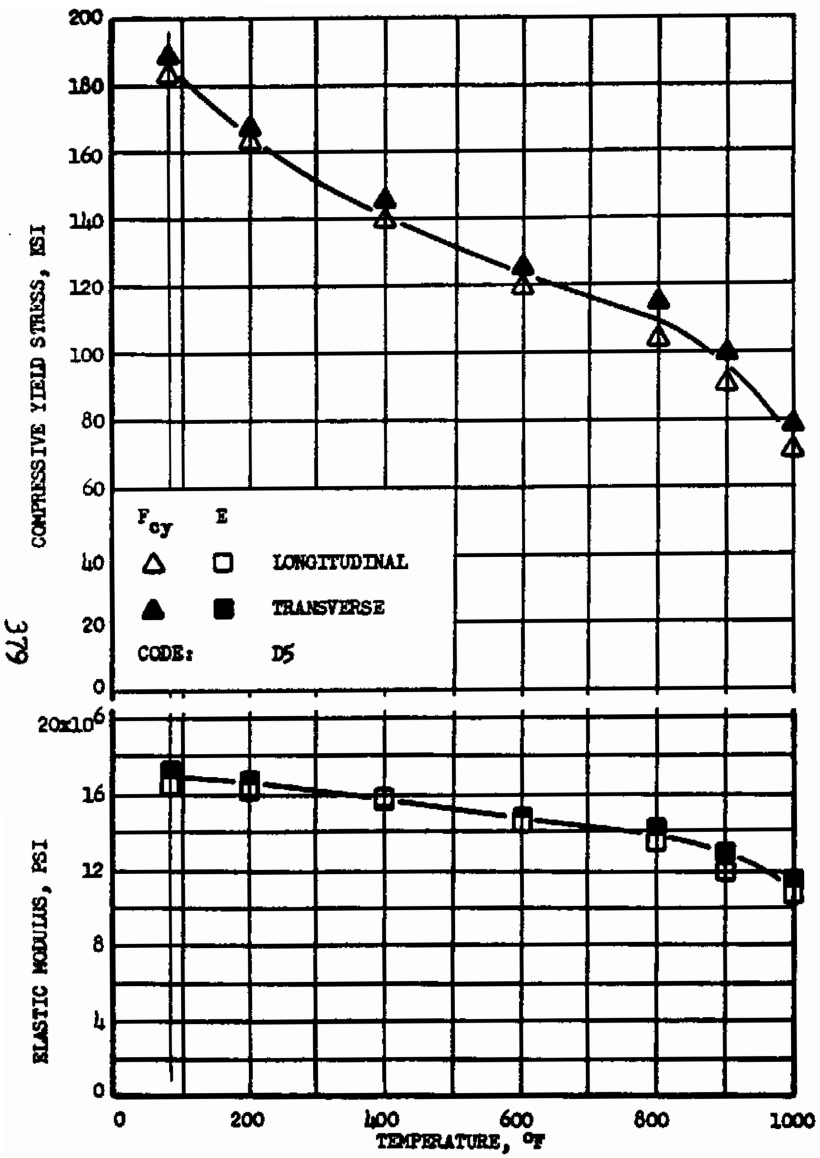


FIGURE 301 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. B4765)

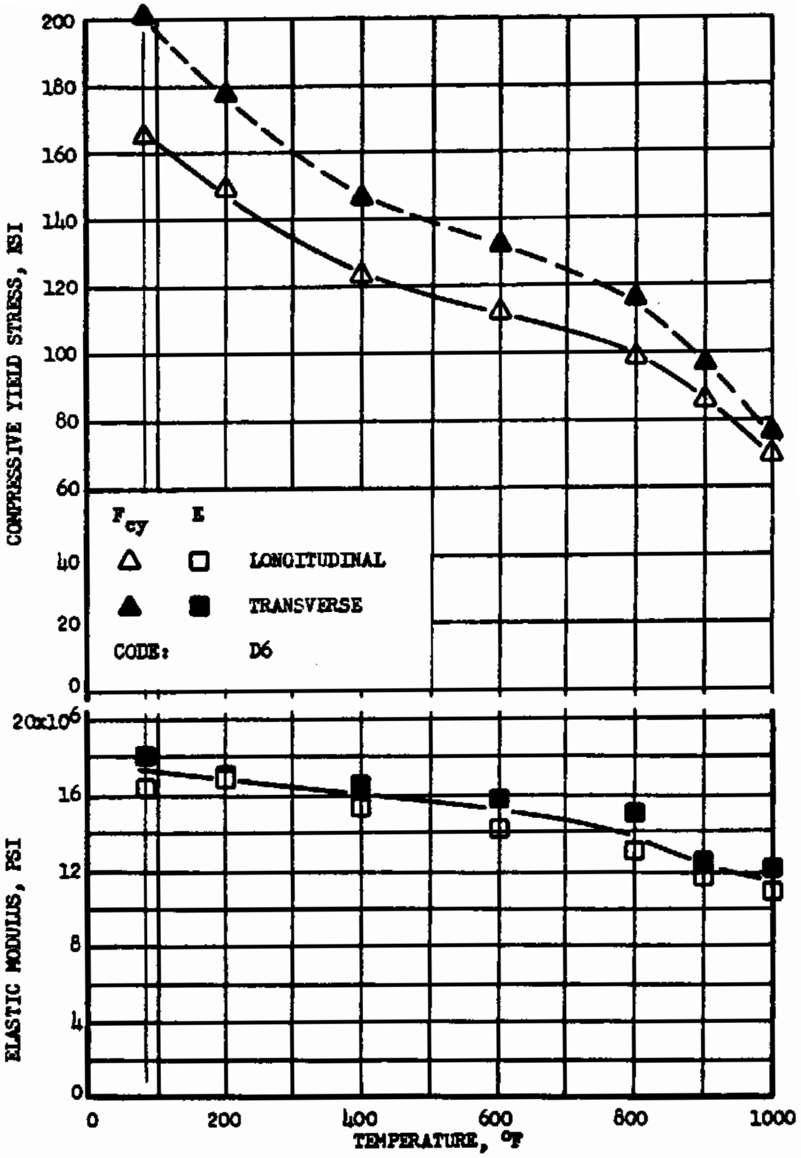


FIGURE 302 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6741)

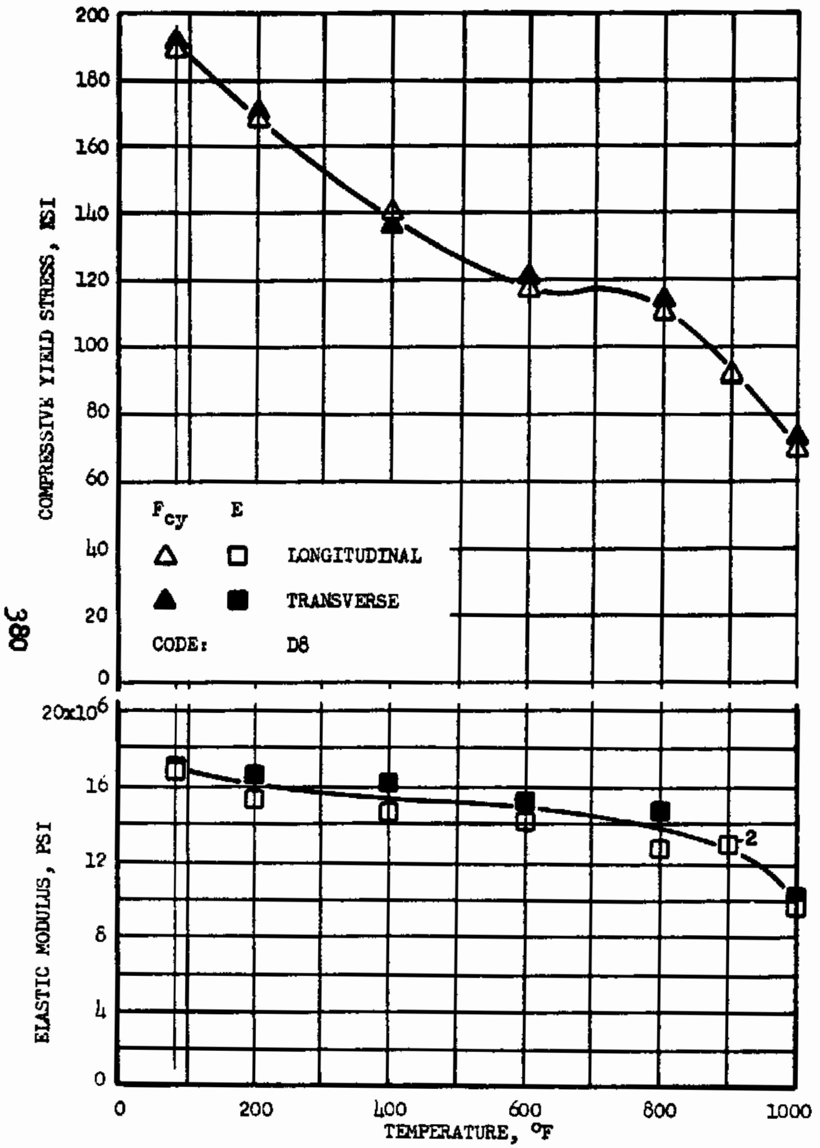


FIGURE 303 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4815)

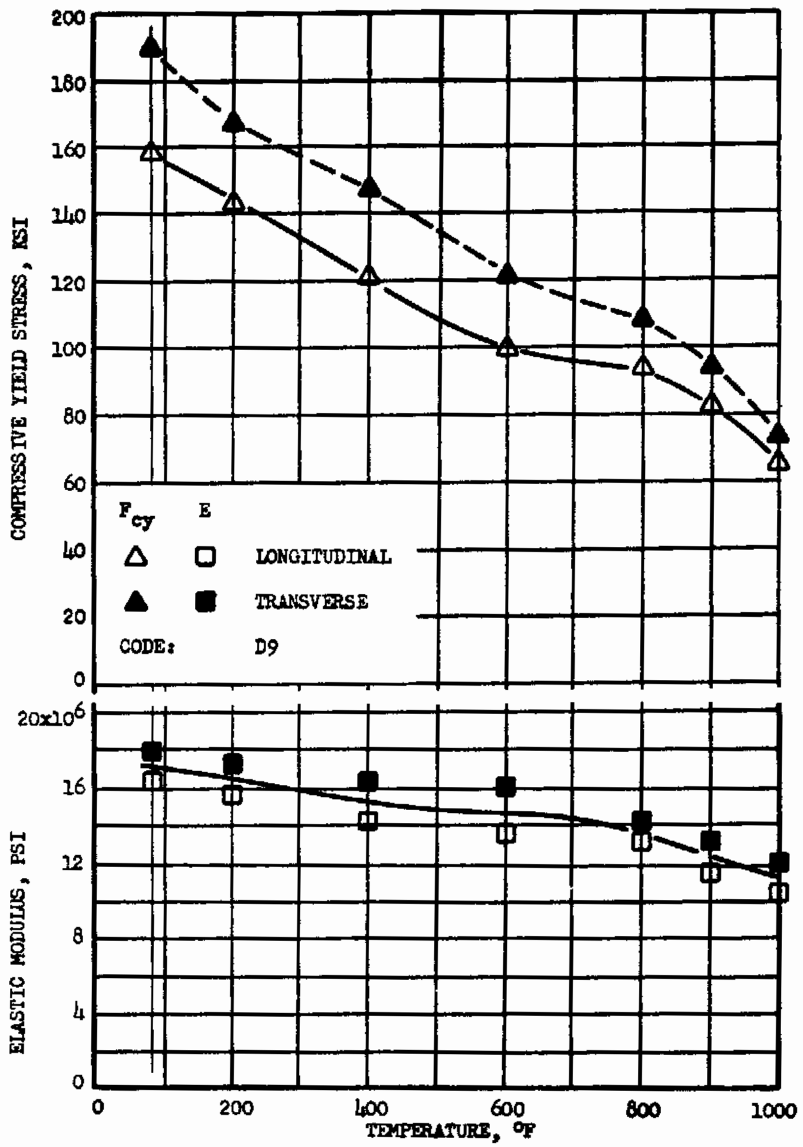


FIGURE 304 - SUMMARY OF COMPRESSIVE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. P7647)

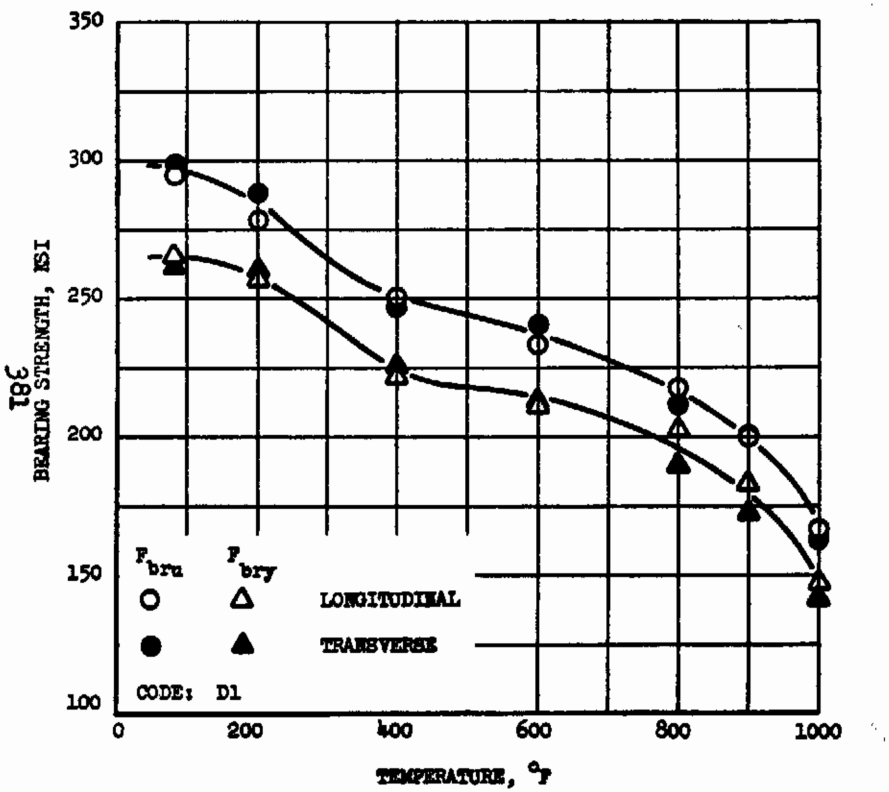


FIGURE 305 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R4815)

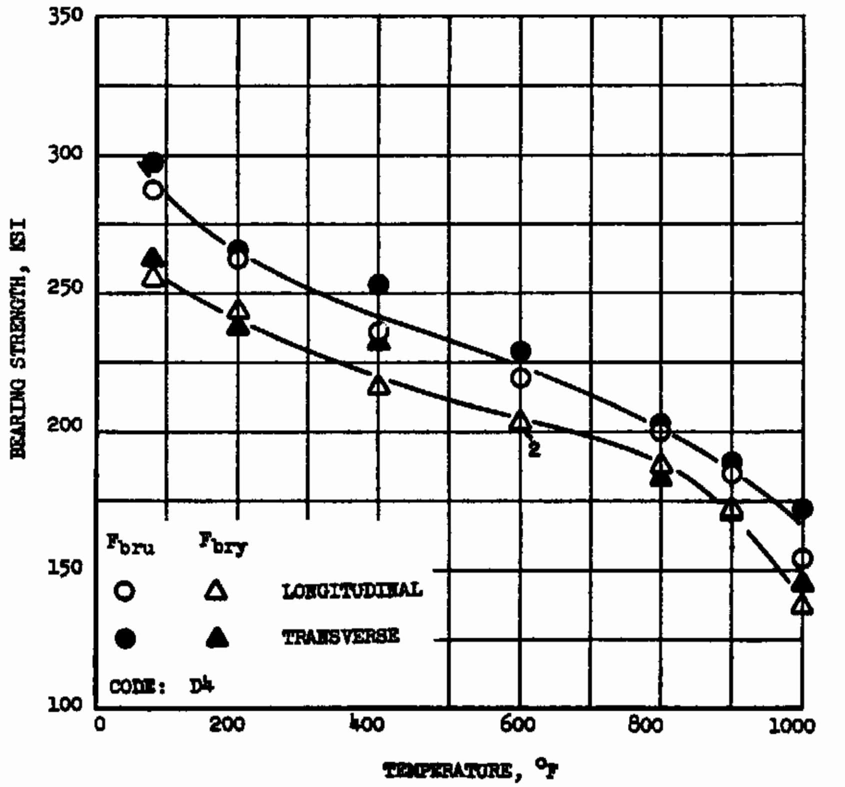


FIGURE 306 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R4765)

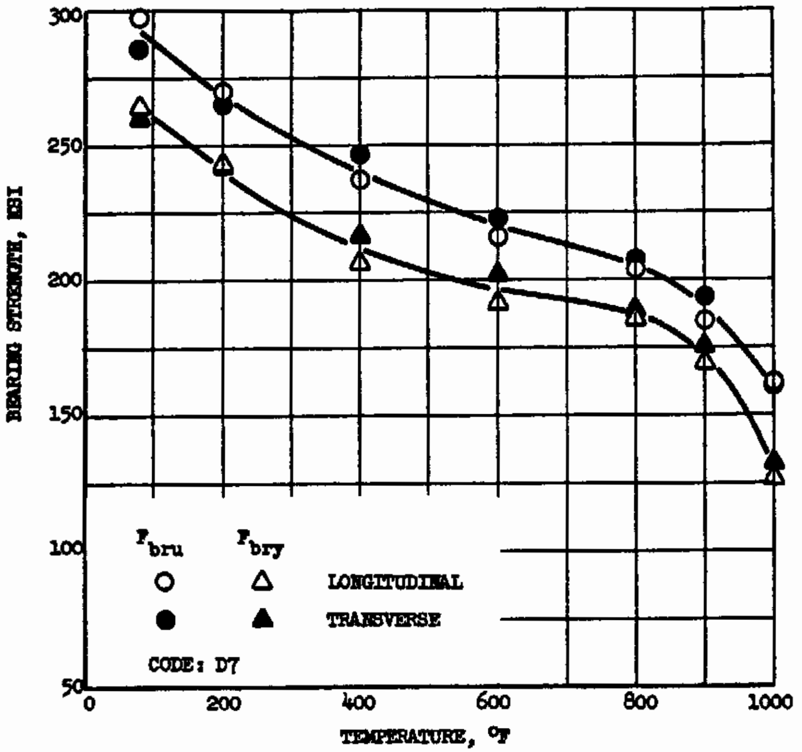


FIGURE 307 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R4805)

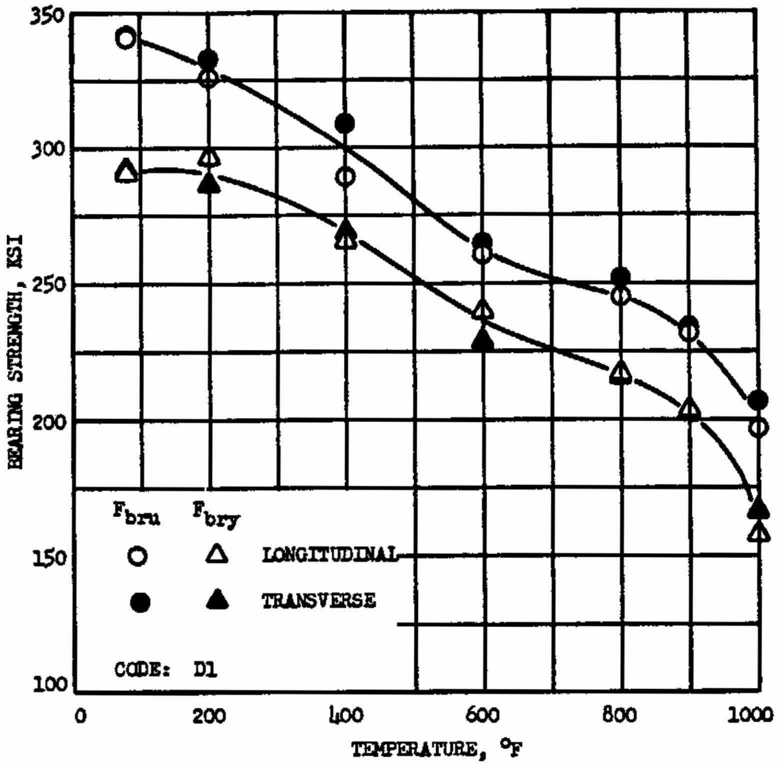


FIGURE 308 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R4815)

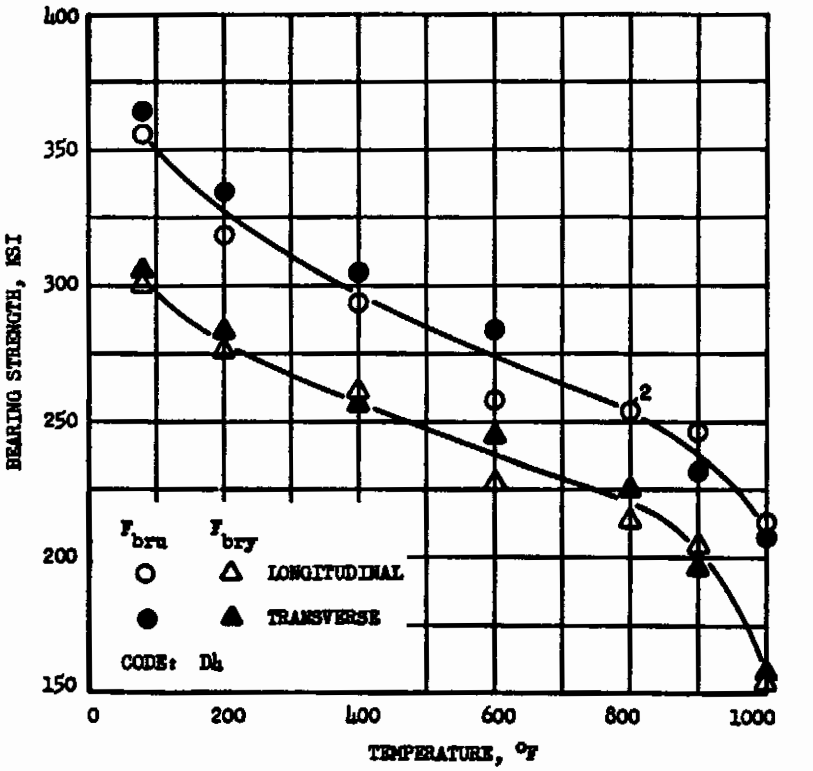


FIGURE 309 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R4765)

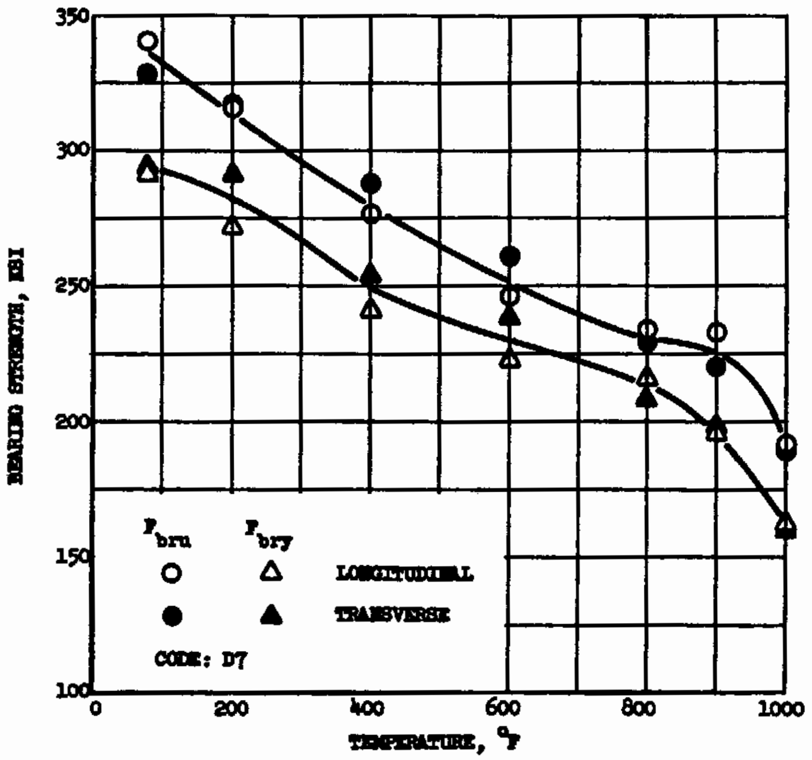


FIGURE 310 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.125 INCH (CRUCIBLE HEAT NO. R4805)

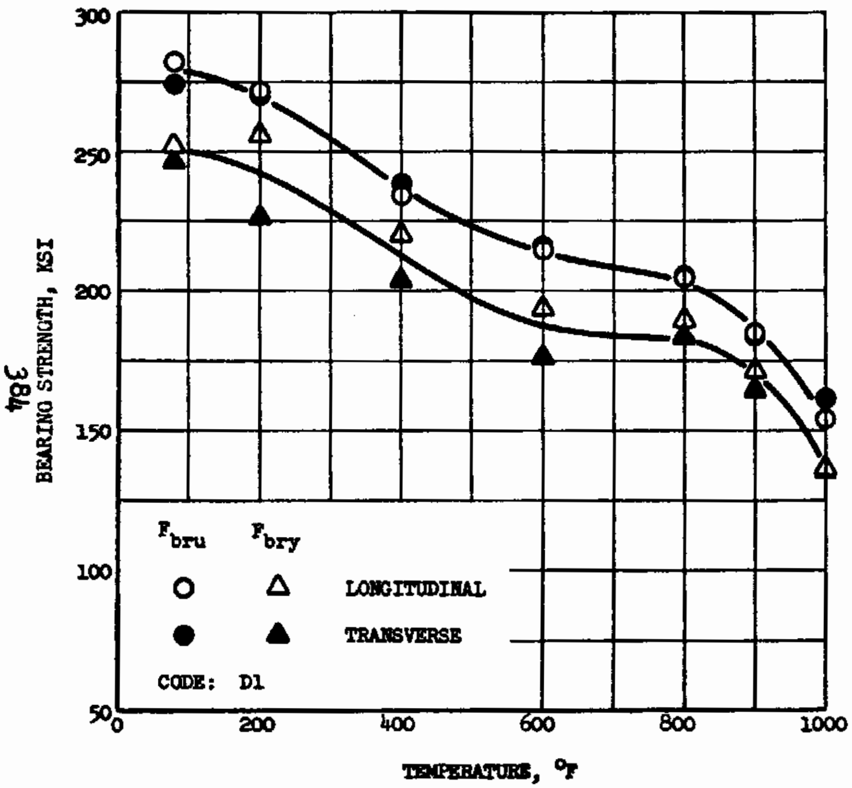


FIGURE 311 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER =0.1875 INCH (CRUCIBLE HEAT NO. R4815)

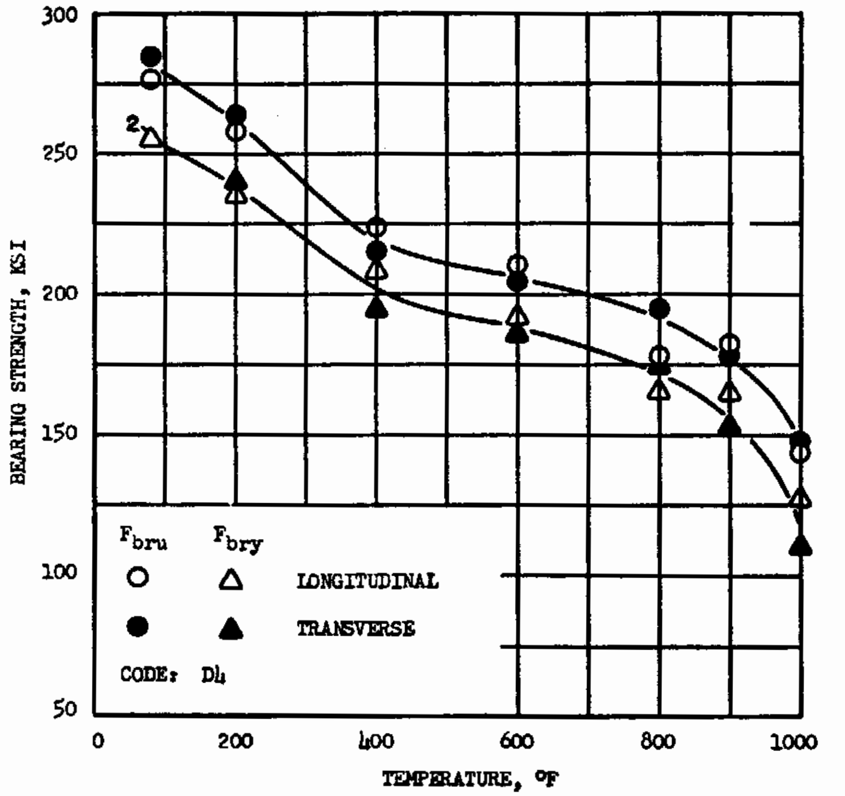


FIGURE 312 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R4765)

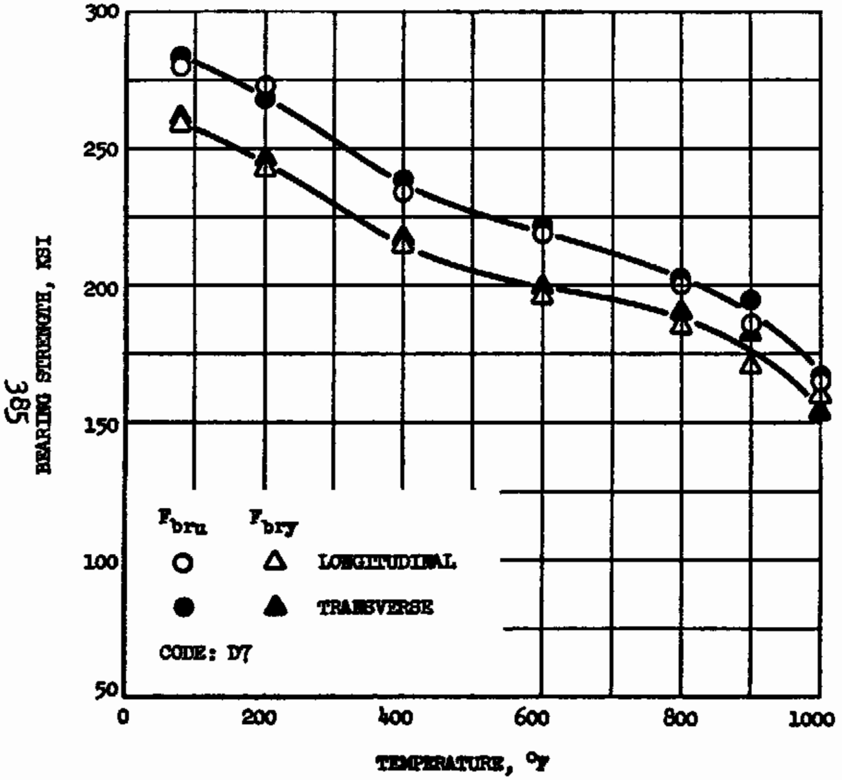


FIGURE 313 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R4805)

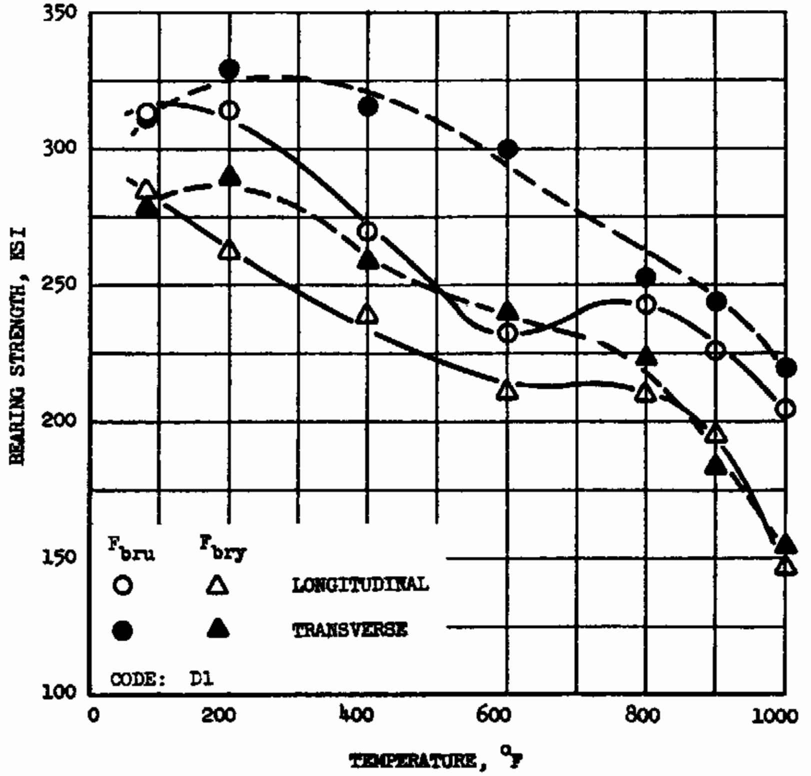


FIGURE 314 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 (CRUCIBLE HEAT NO. R4815)

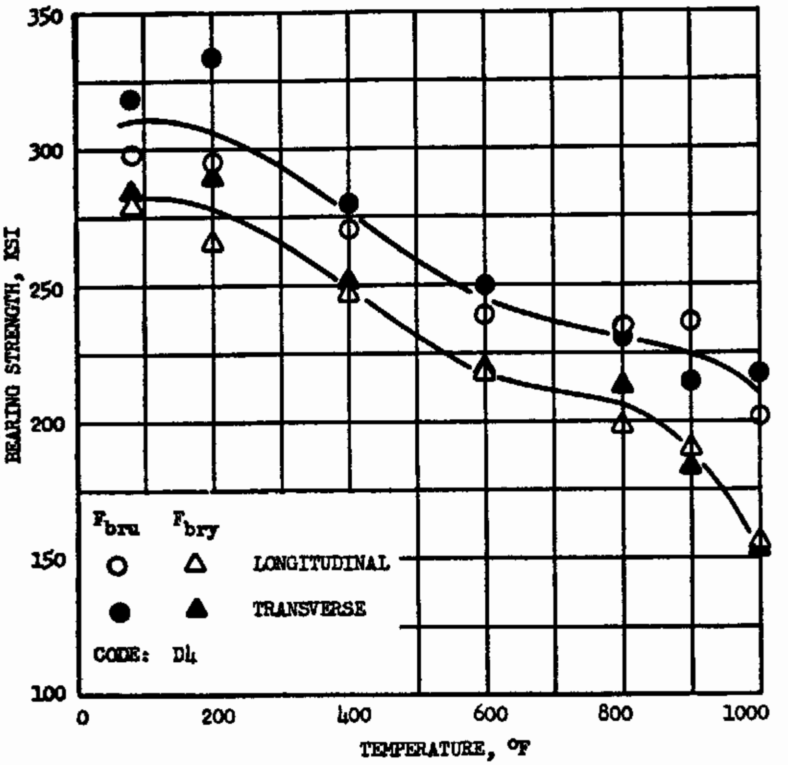


FIGURE 315 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R4765)

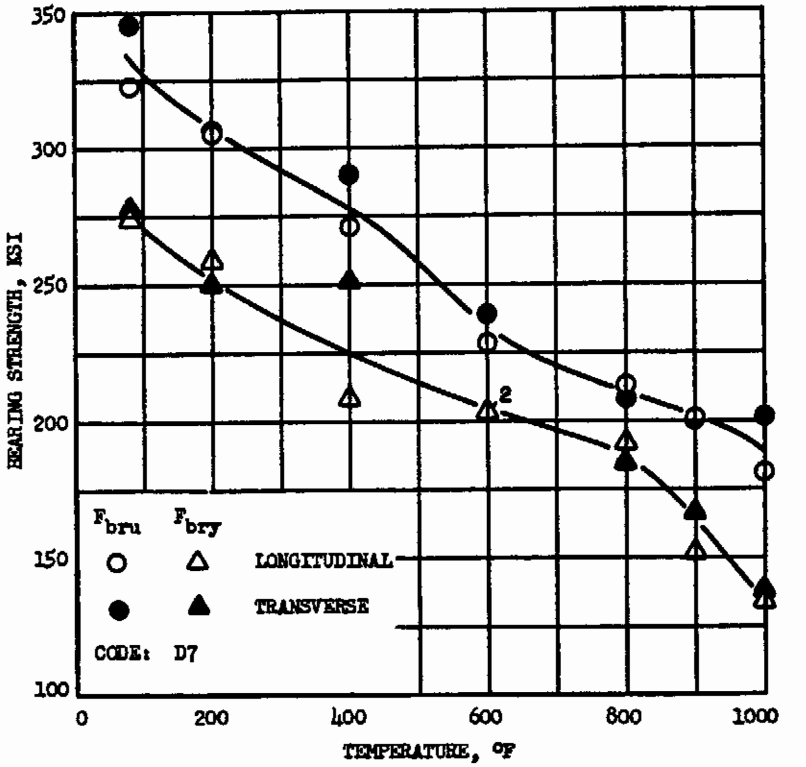


FIGURE 316 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.1875 INCH (CRUCIBLE HEAT NO. R4805)

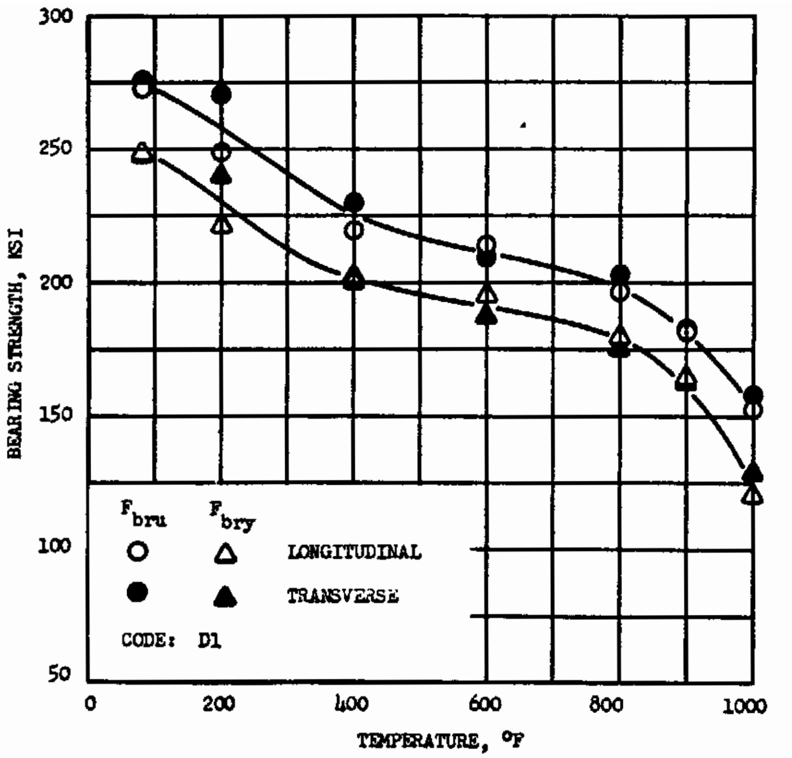


FIGURE 317 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4815)

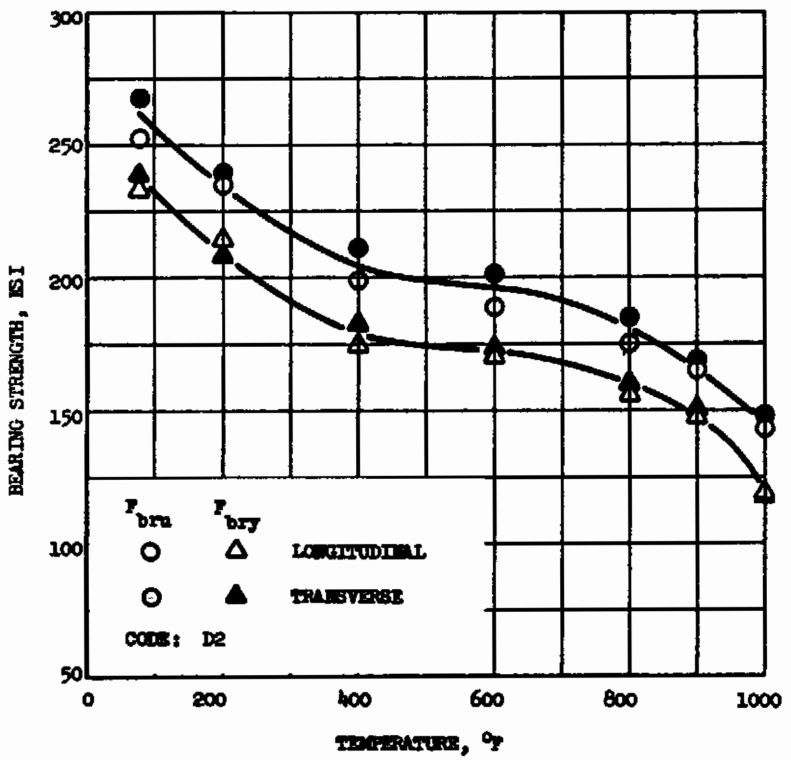


FIGURE 318 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. P7653)

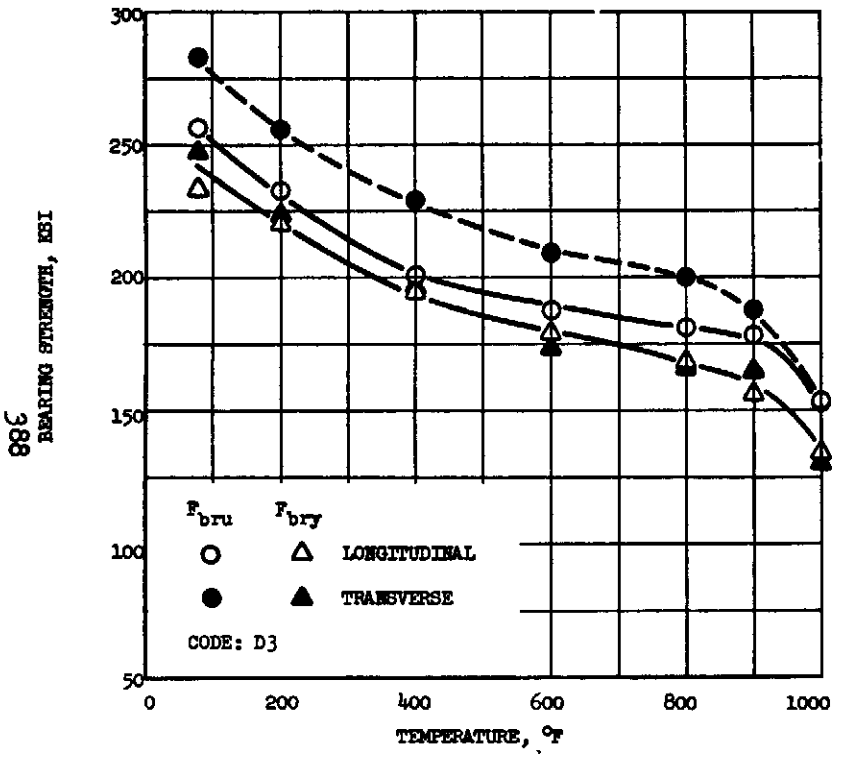


FIGURE 319 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6736)

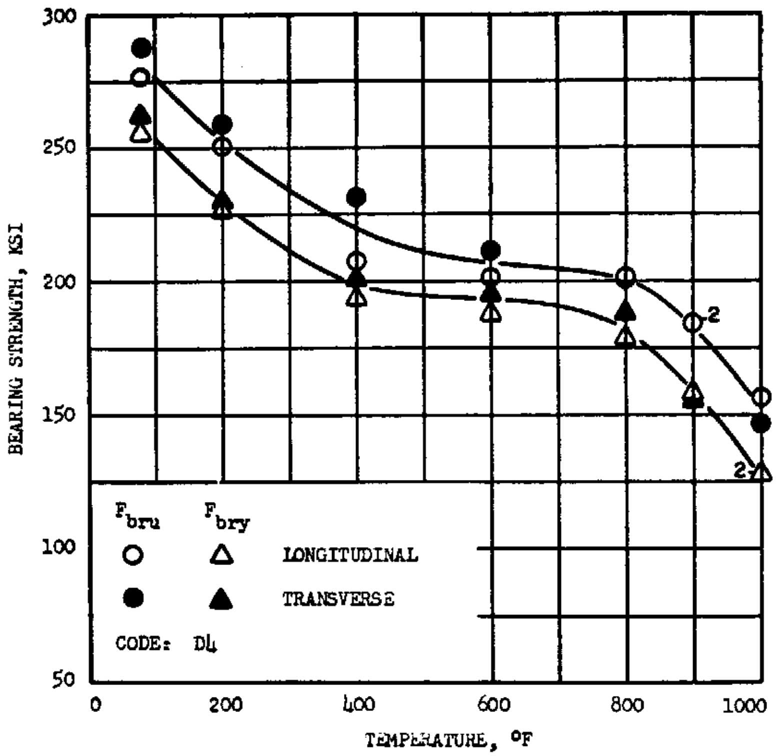


FIGURE 320 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4765)

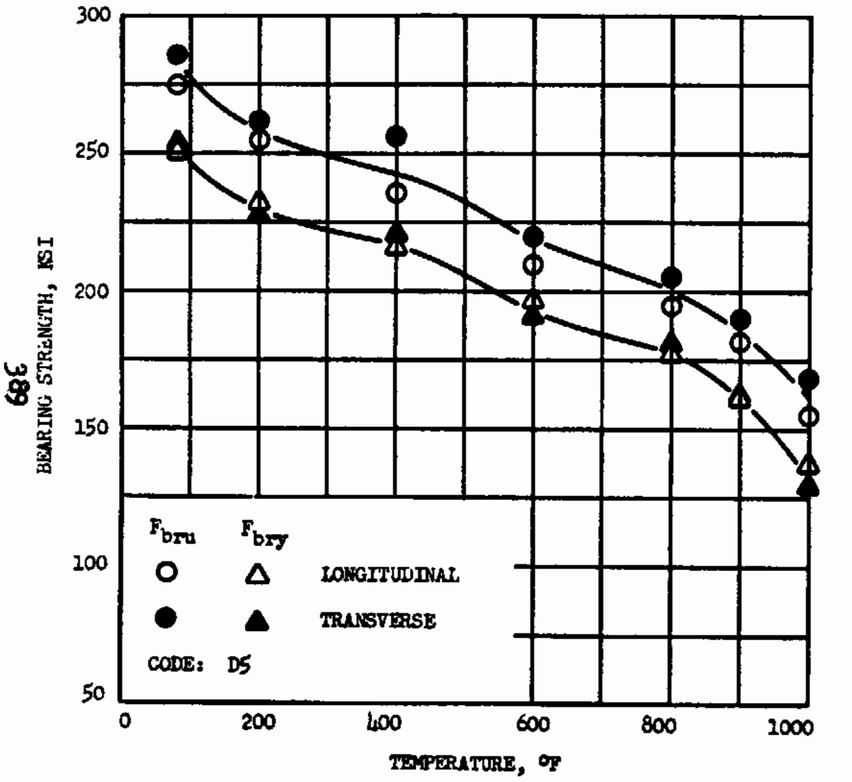


FIGURE 321 – AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. B4765)

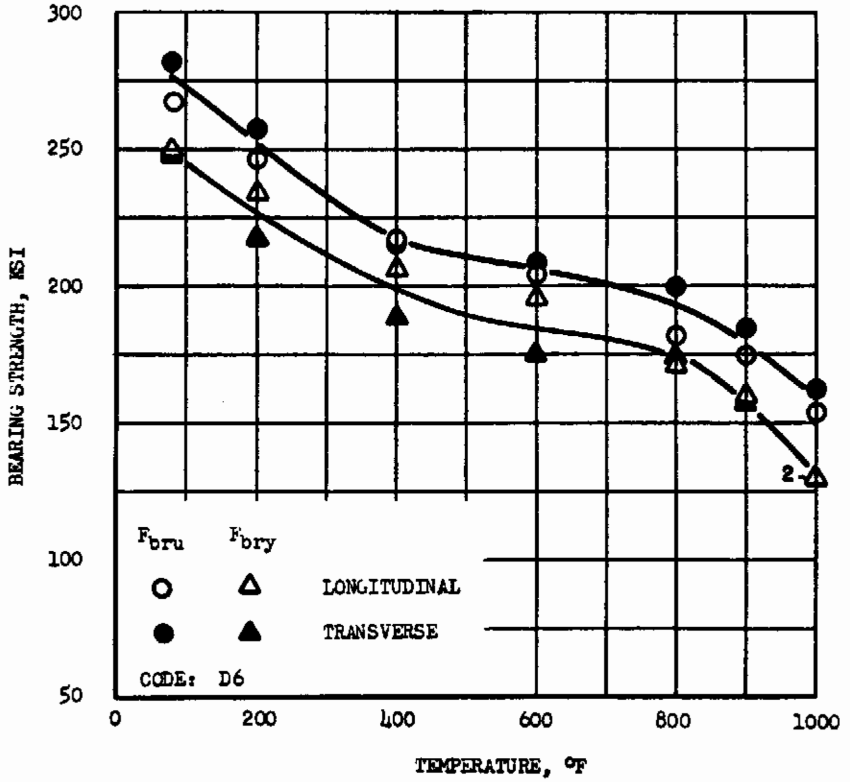


FIGURE 322 – AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6741)

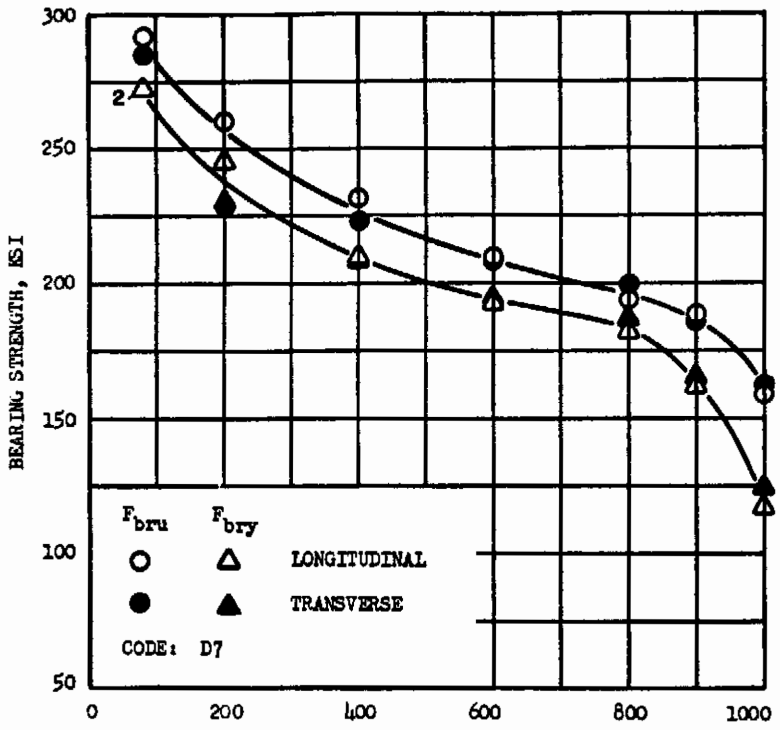


FIGURE 323 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4805)

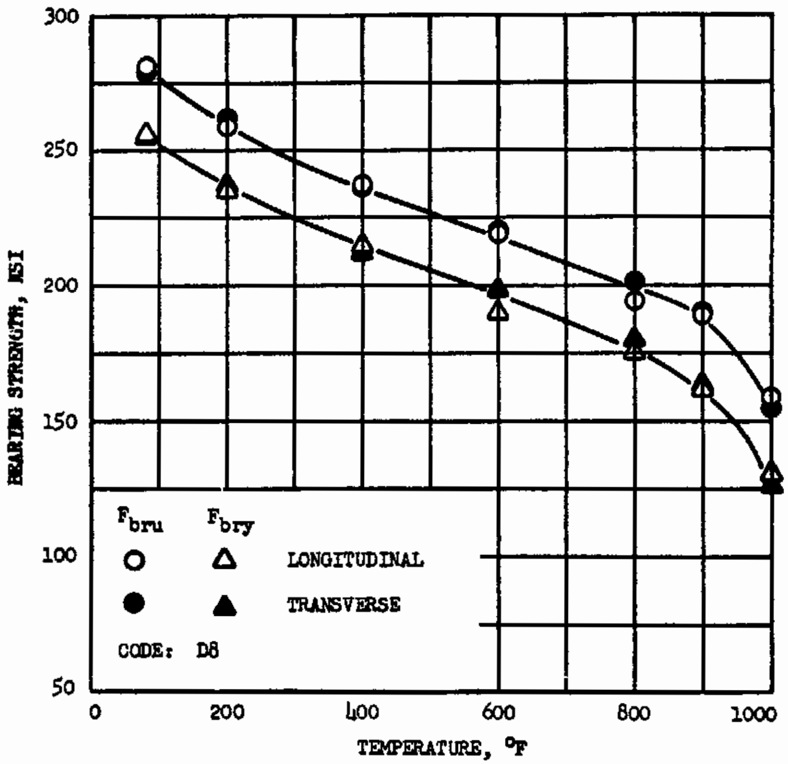


FIGURE 324 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4815)

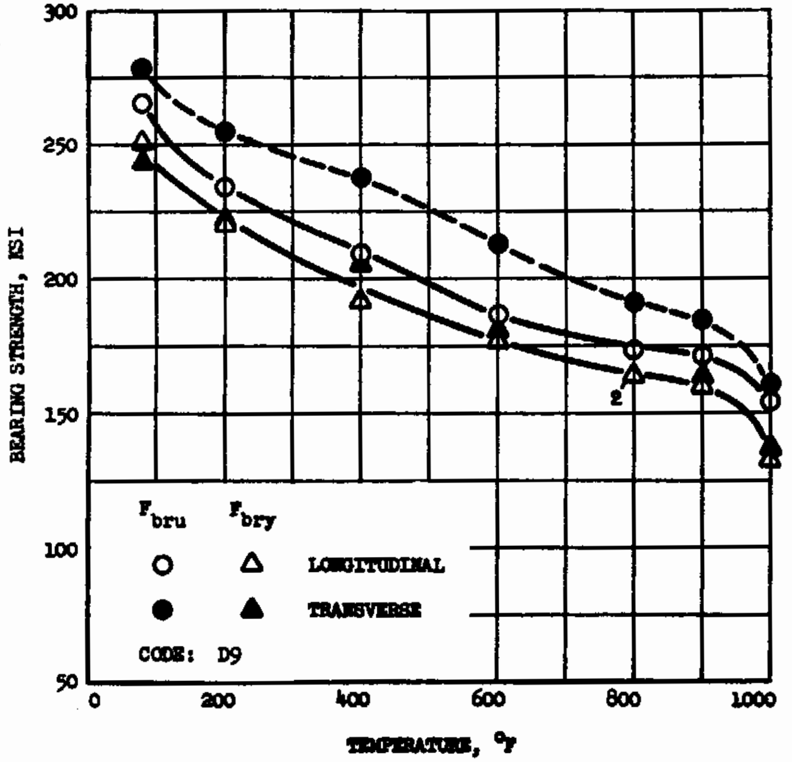


FIGURE 325 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 1.5, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. P7647)

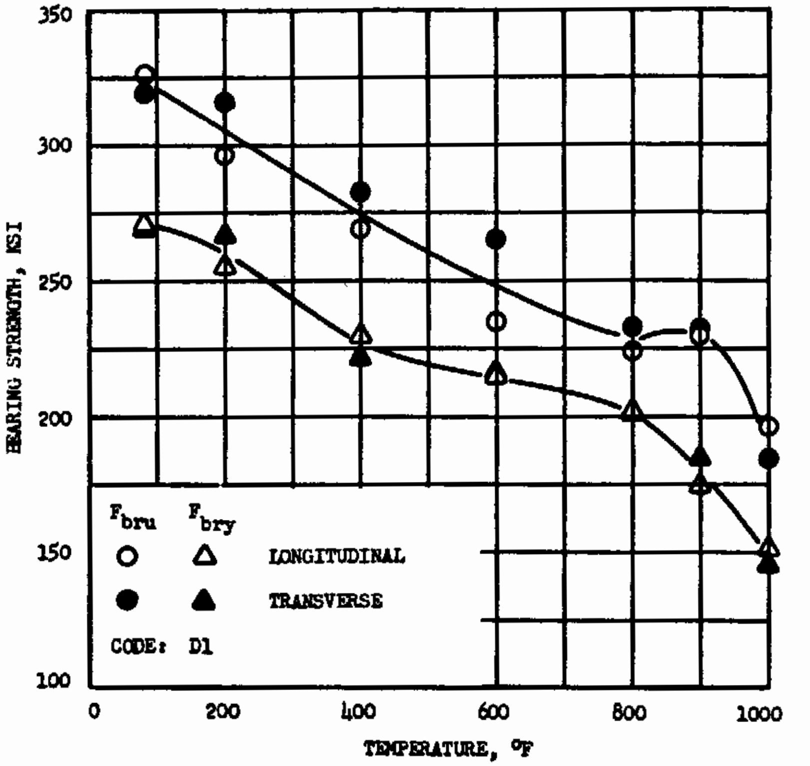


FIGURE 326 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4815)

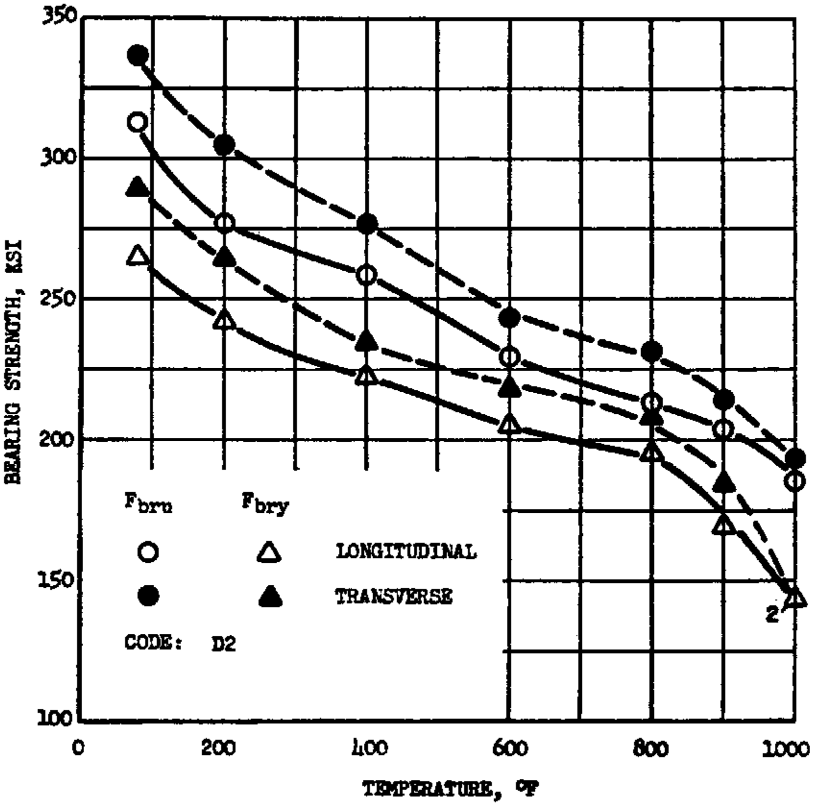


FIGURE 327 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 (CRUCIBLE HEAT NO. P7653)

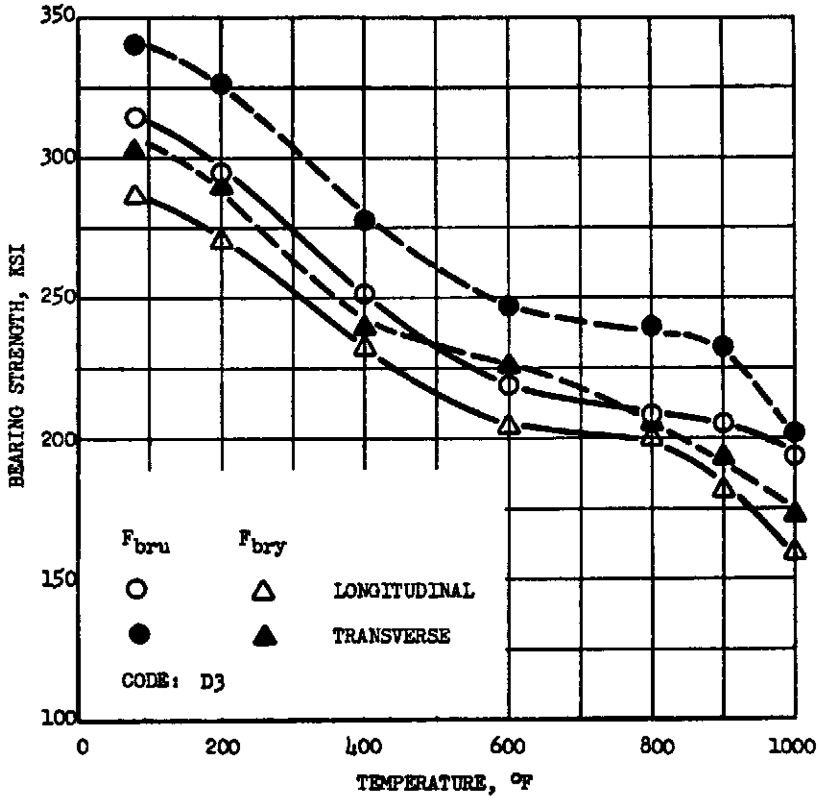


FIGURE 328 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 (CRUCIBLE HEAT NO. R6736)

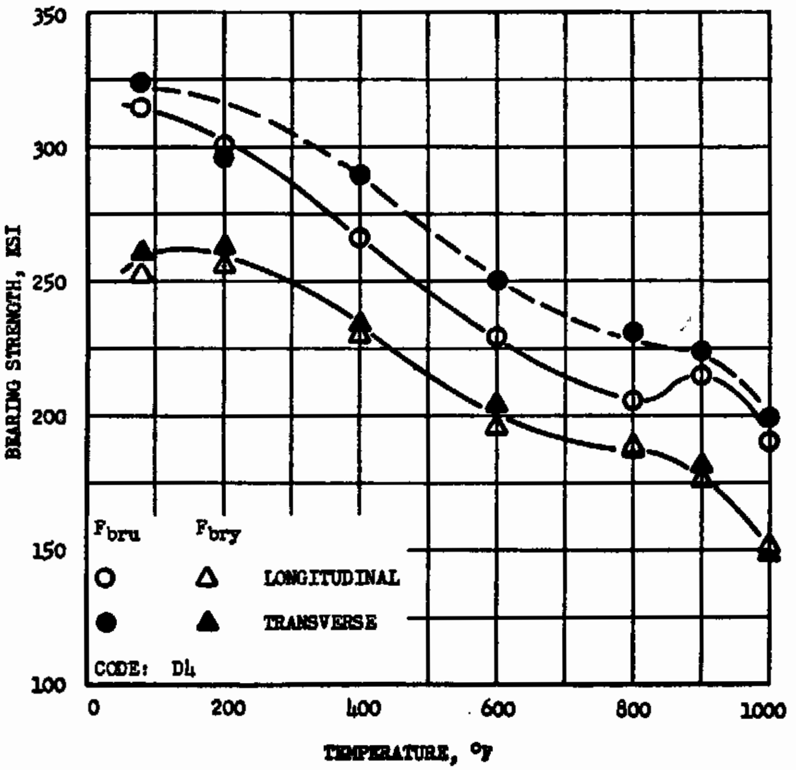


FIGURE 329 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 (CRUCIBLE HEAT NO. R4765)

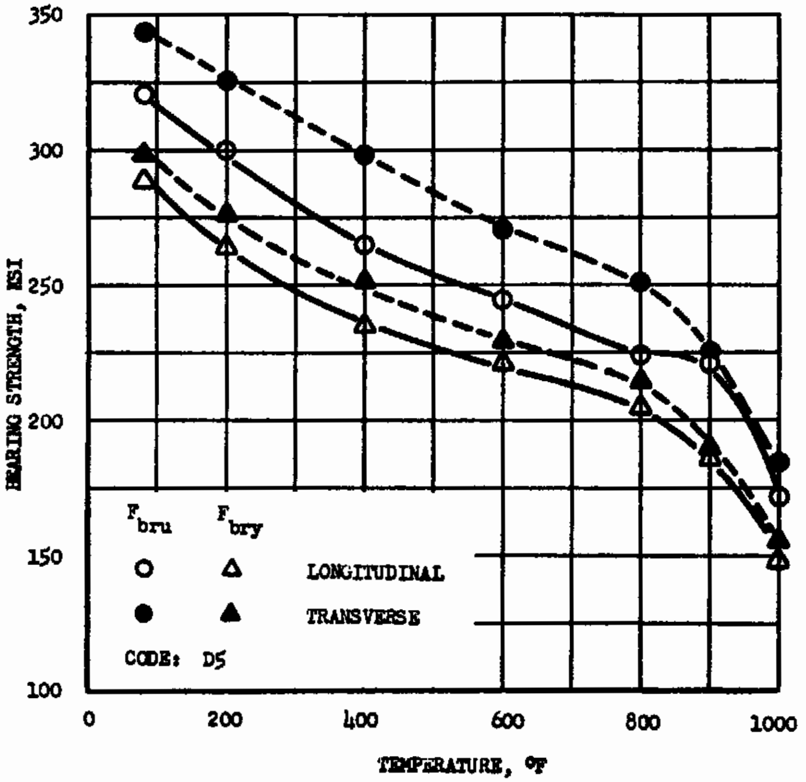


FIGURE 330 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4765)

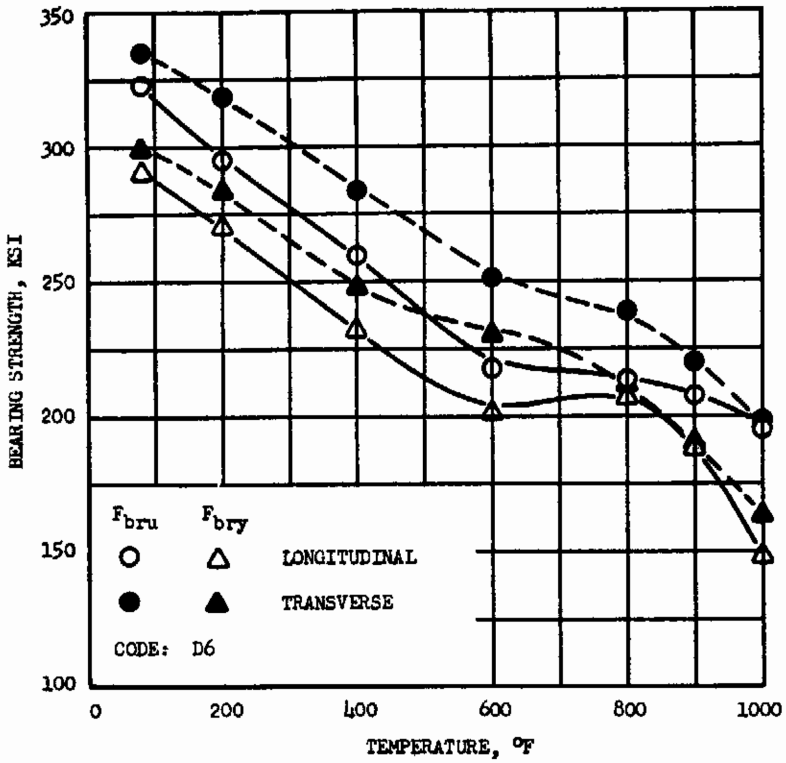


FIGURE 331 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R6741)

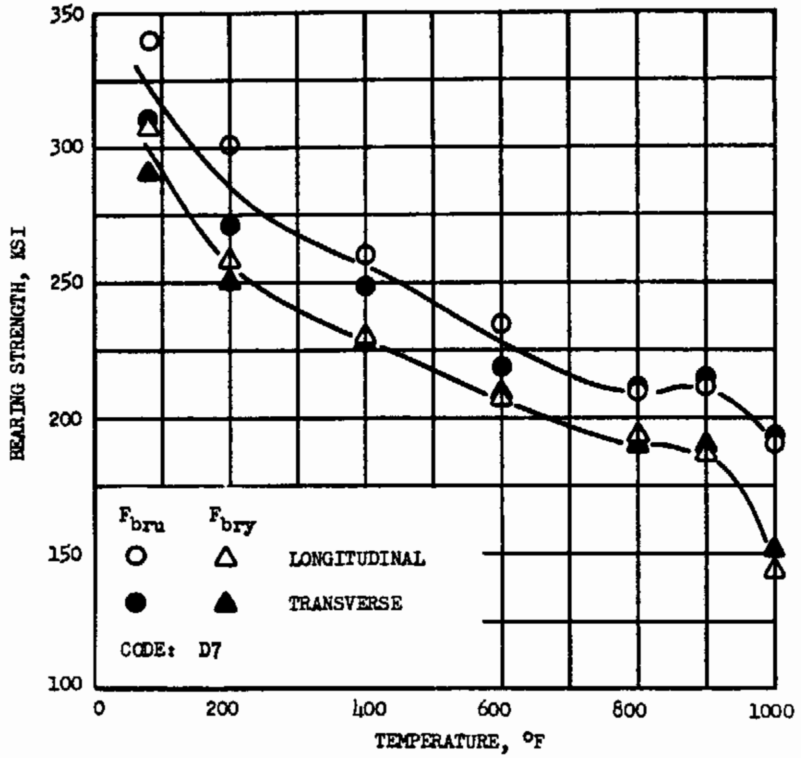


FIGURE 332 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4805)

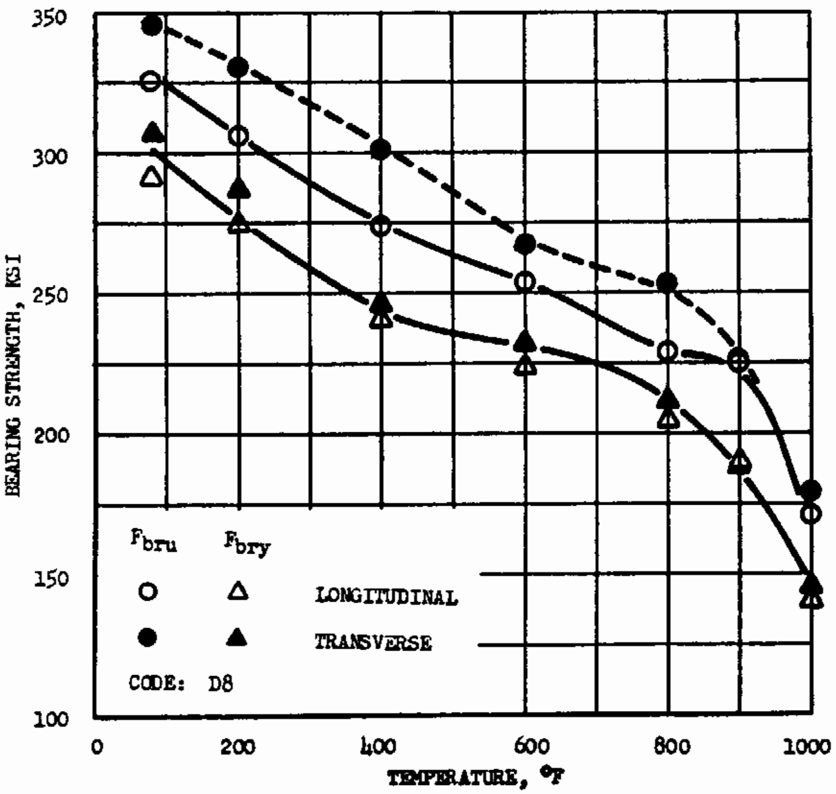


FIGURE 333 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. R4815)

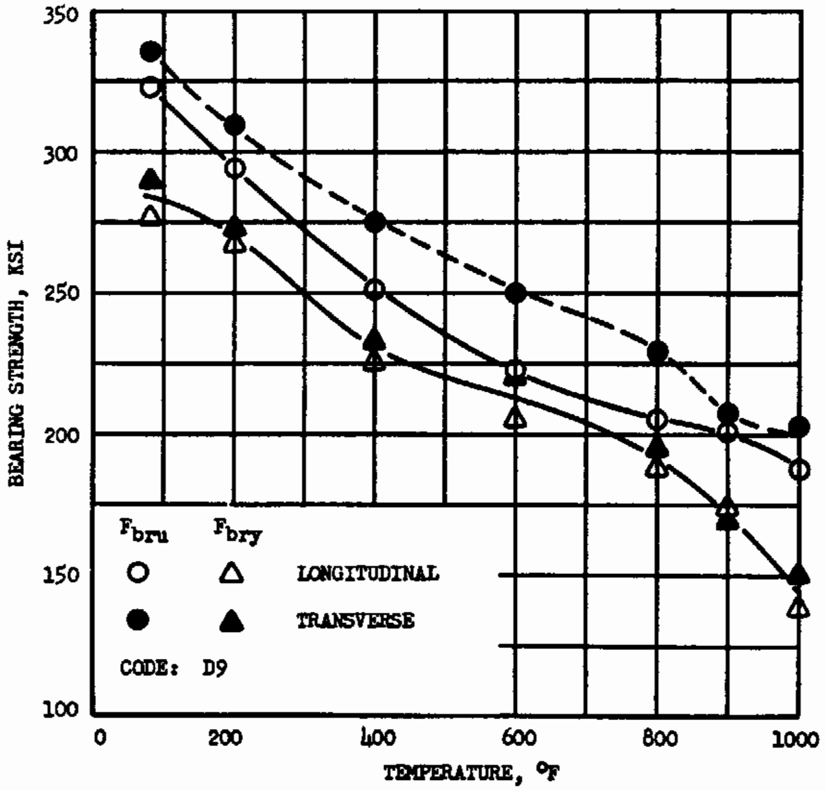


FIGURE 334 - AVERAGE BEARING STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK, e/D = 2.0, BEARING HOLE DIAMETER = 0.3125 INCH (CRUCIBLE HEAT NO. P7647)

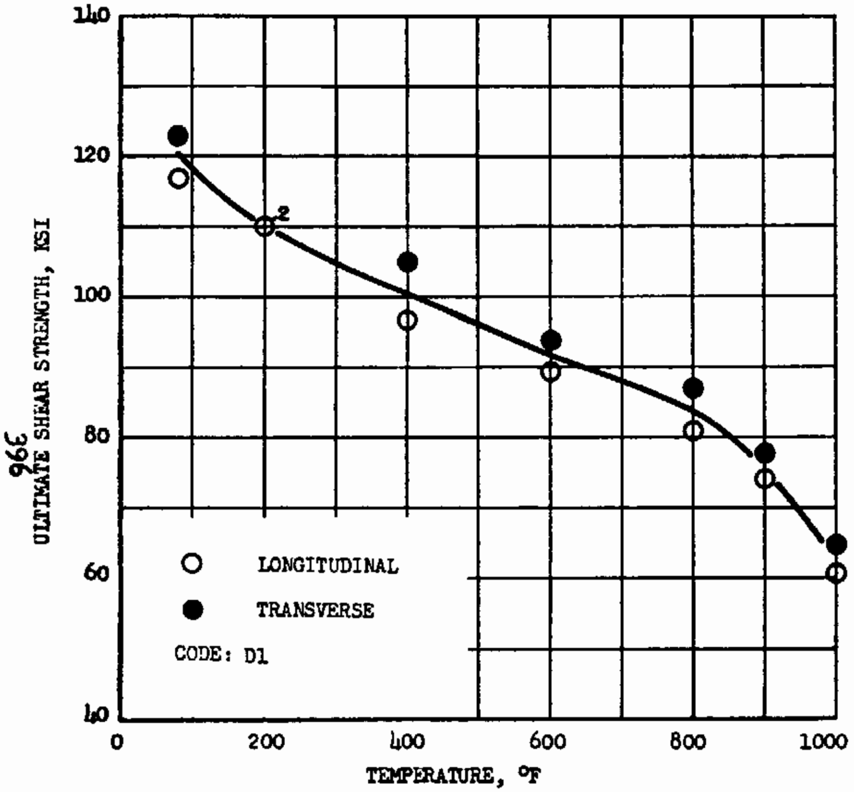


FIGURE 335 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R4815)

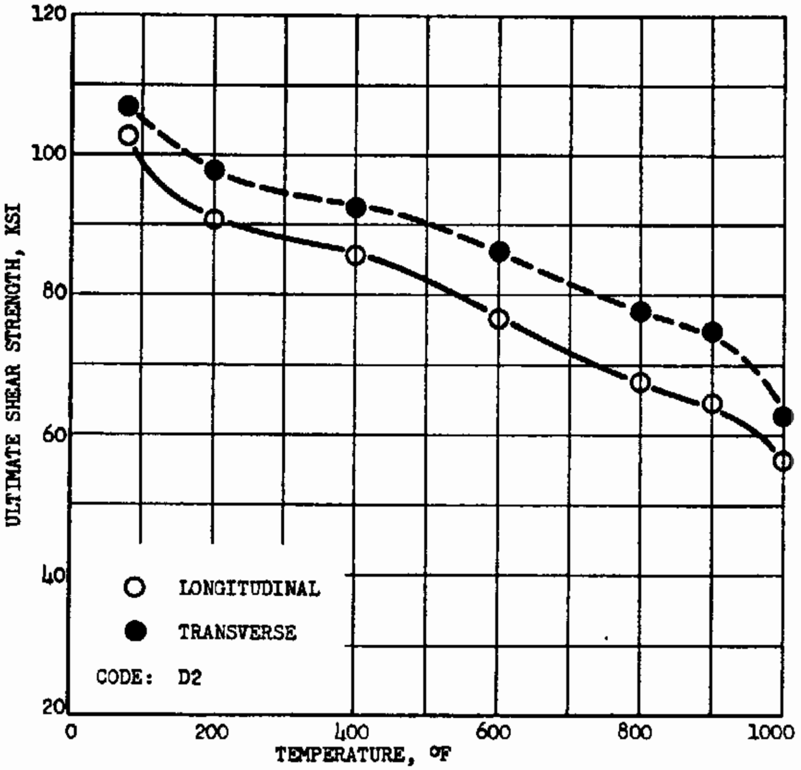


FIGURE 336 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. P7653)

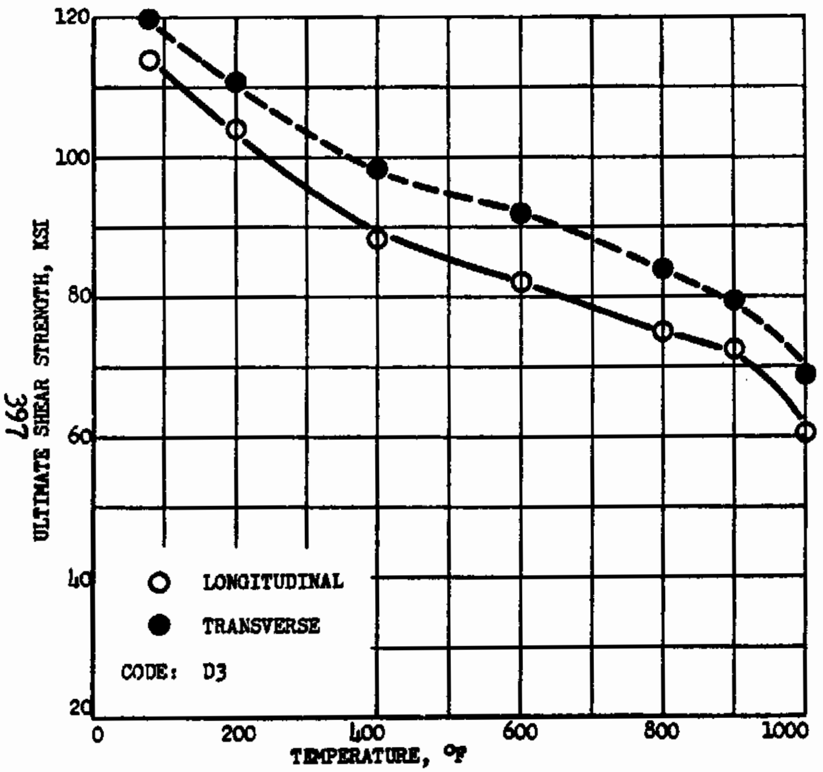


FIGURE 337 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6736)

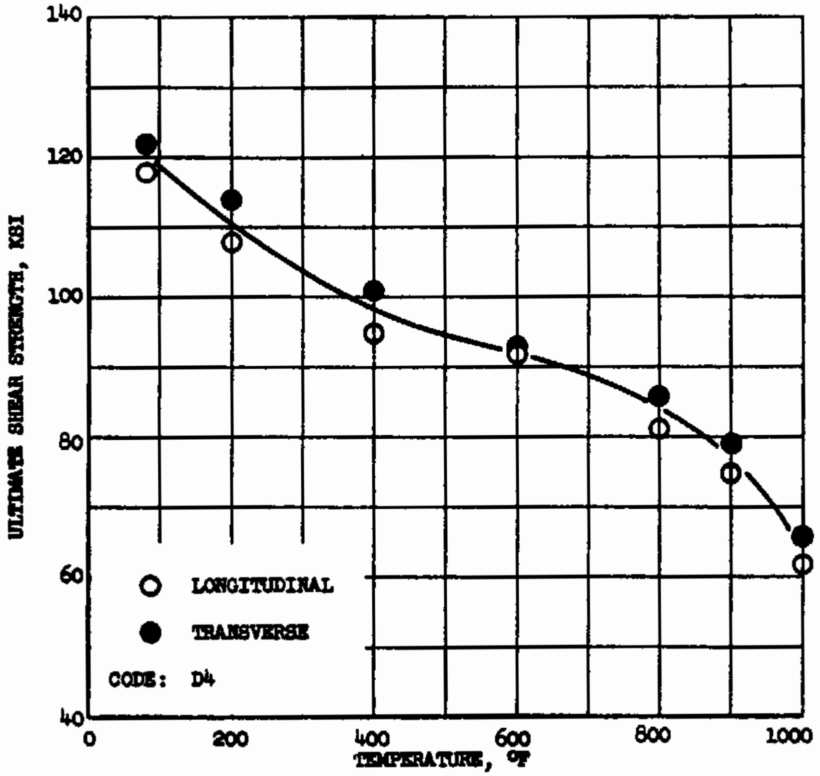


FIGURE 338 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R4765)

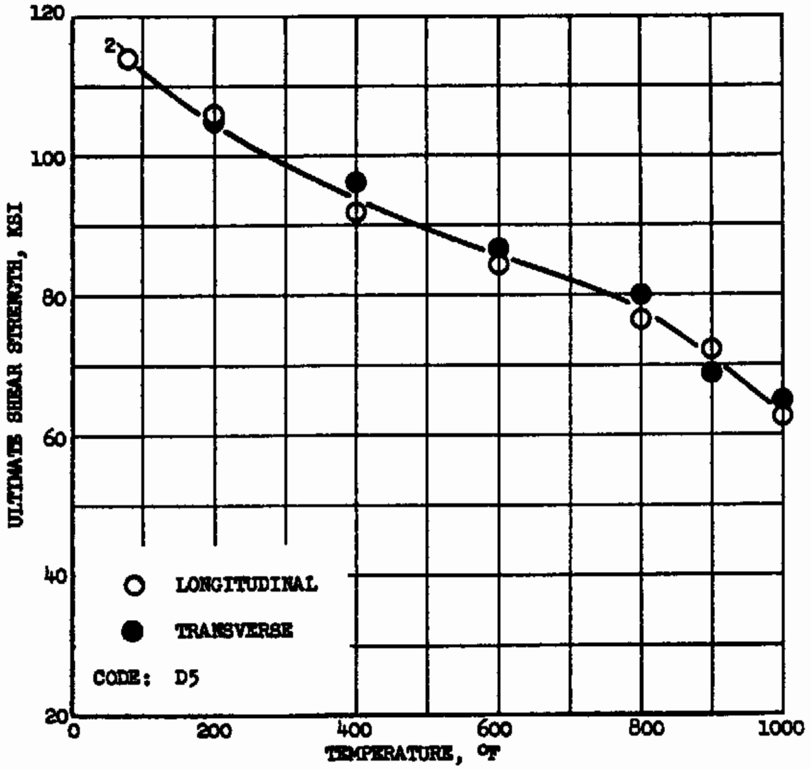


FIGURE 339 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4765)

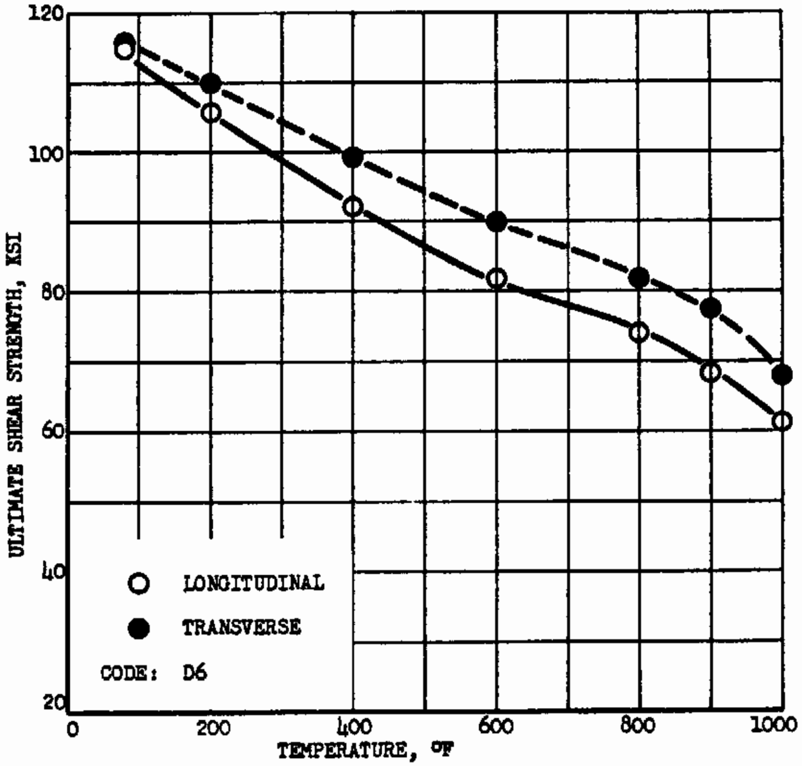


FIGURE 340 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6741)

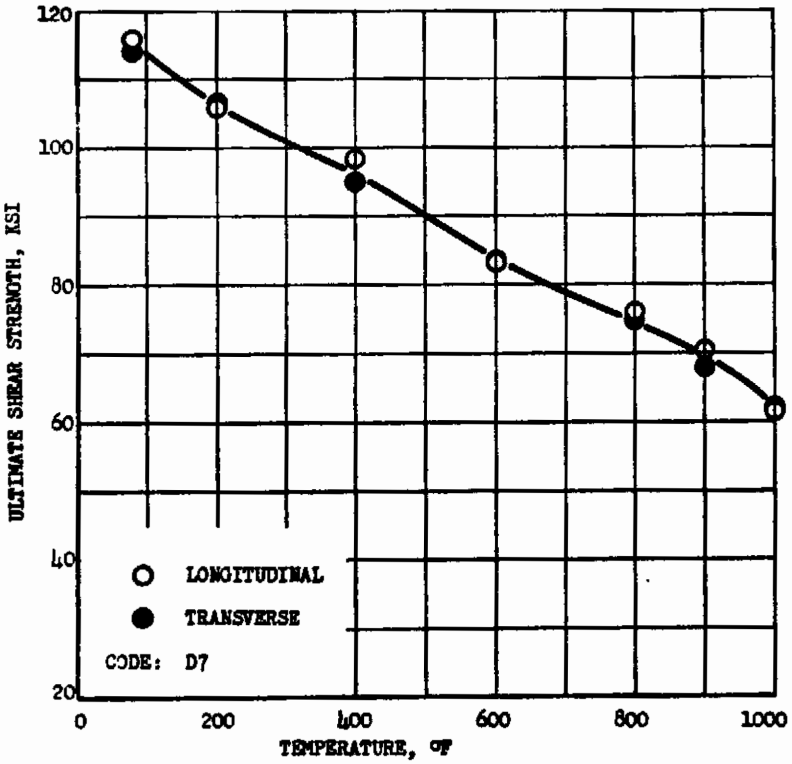


FIGURE 341 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.020 INCH THICK (CRUCIBLE HEAT NO. R4805)

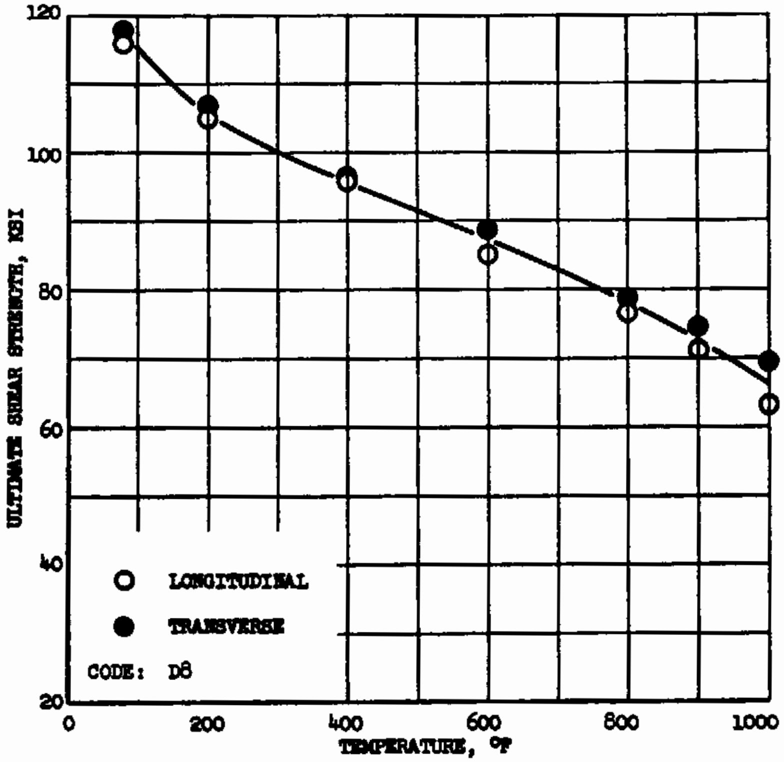


FIGURE 342 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4815)

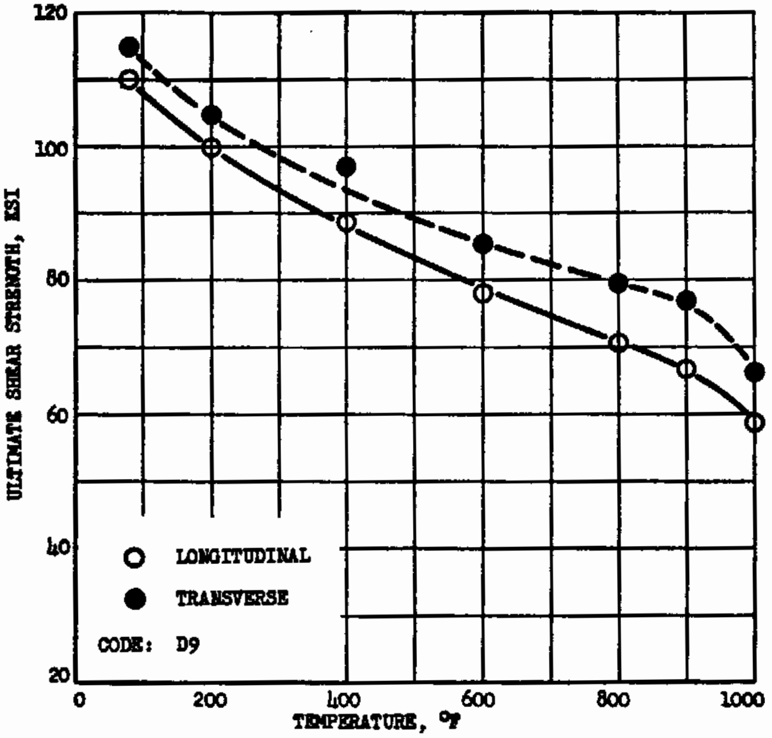


FIGURE 343 - AVERAGE ULTIMATE SINGLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. P7647)

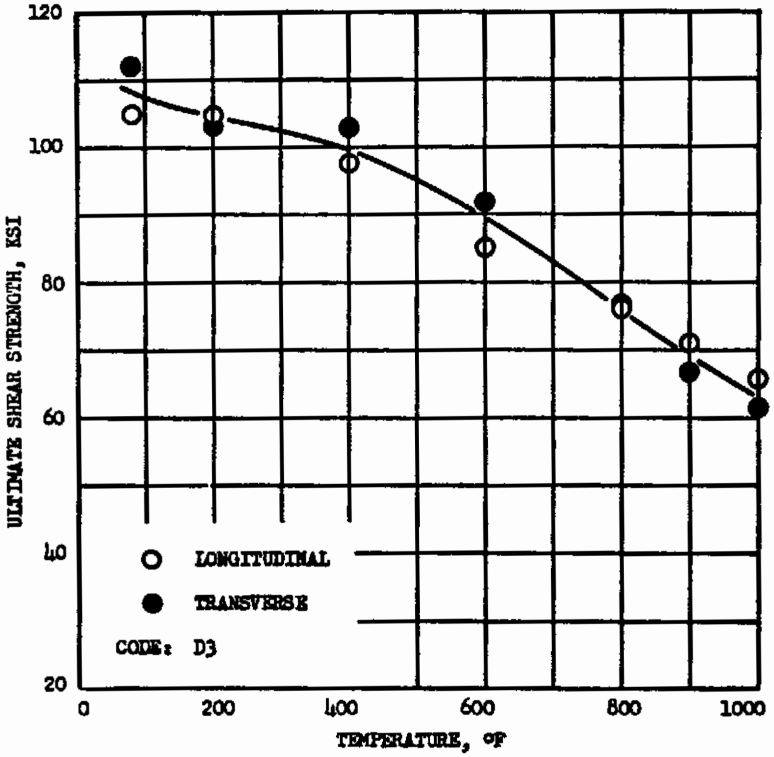


FIGURE 344 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6736)

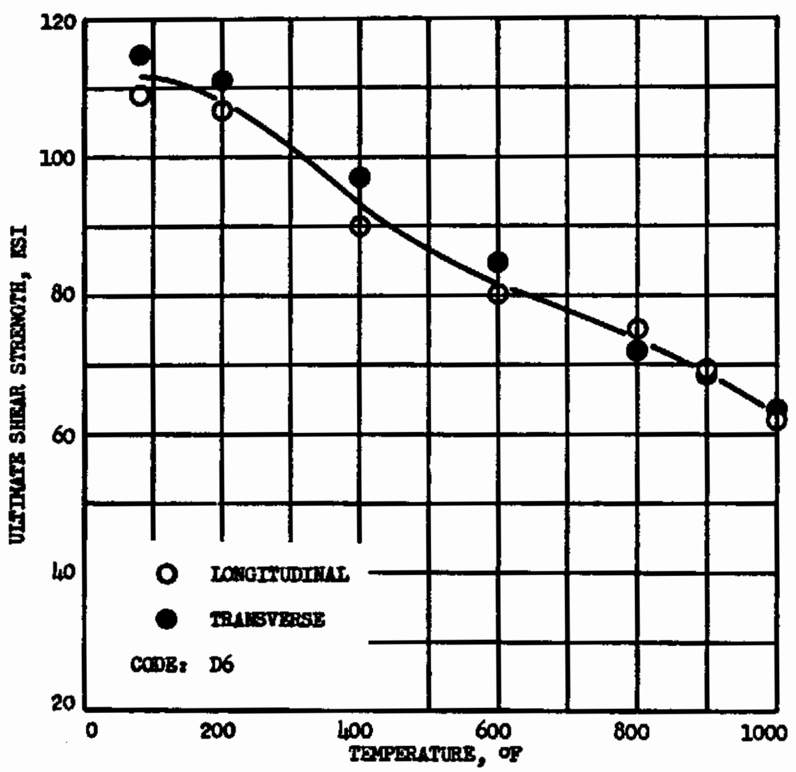


FIGURE 345 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. R6741)

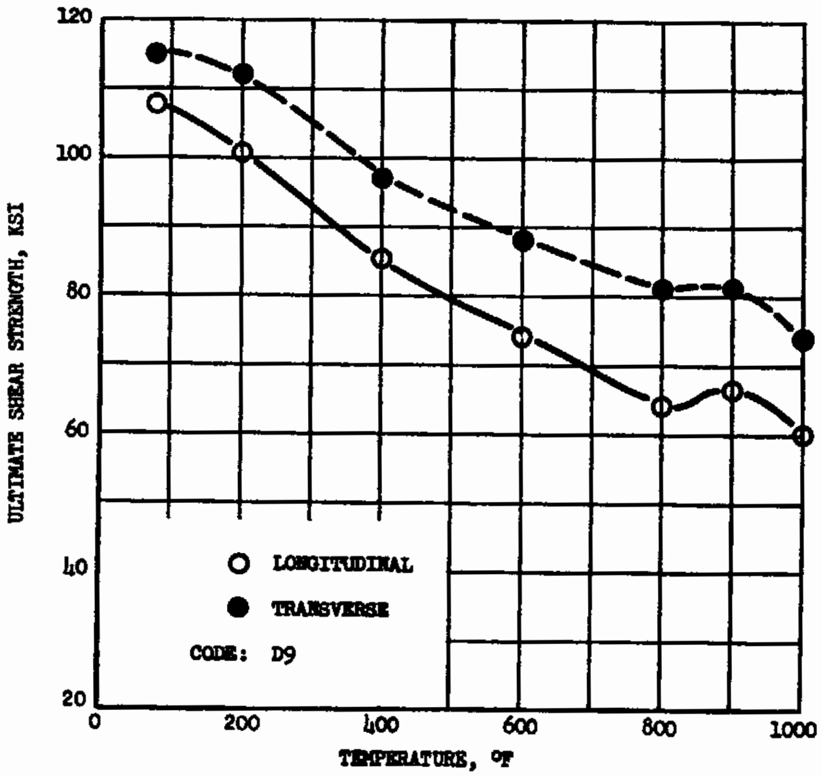


FIGURE 346 - AVERAGE ULTIMATE DOUBLE SHEAR STRENGTH VERSUS TEMPERATURE FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.125 INCH THICK (CRUCIBLE HEAT NO. P7647)

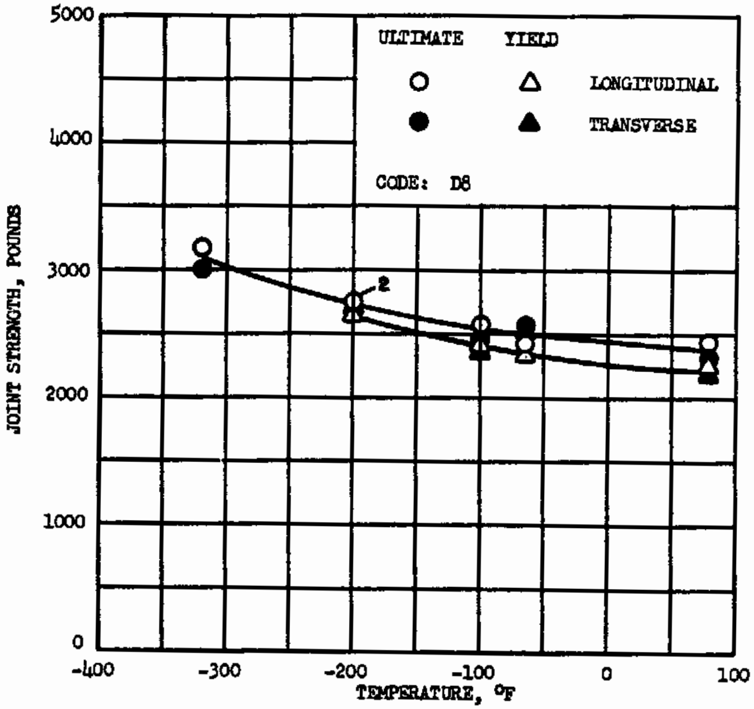


FIGURE 347 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER NAS2506-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R4815)

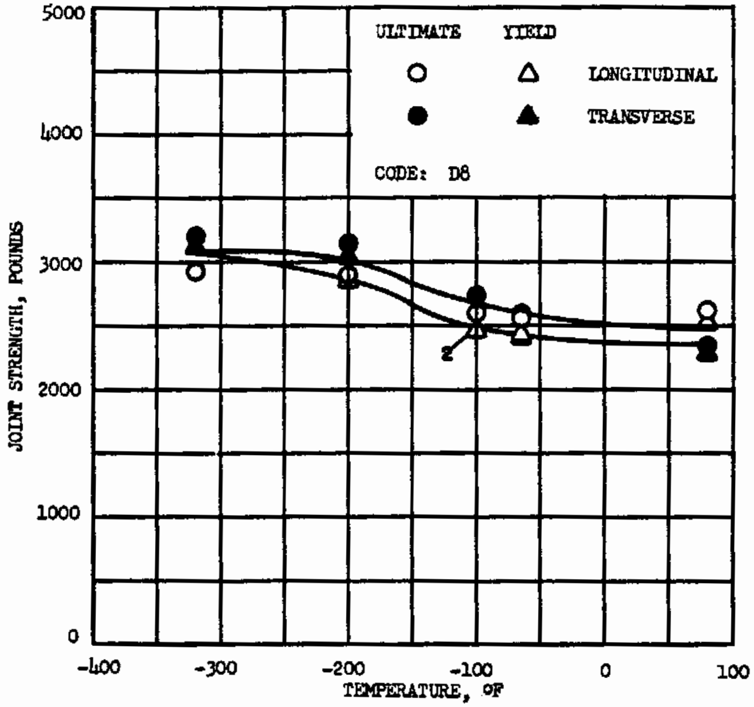


FIGURE 348 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 3/16 INCH DIAMETER HL11V-6-3 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R4815)

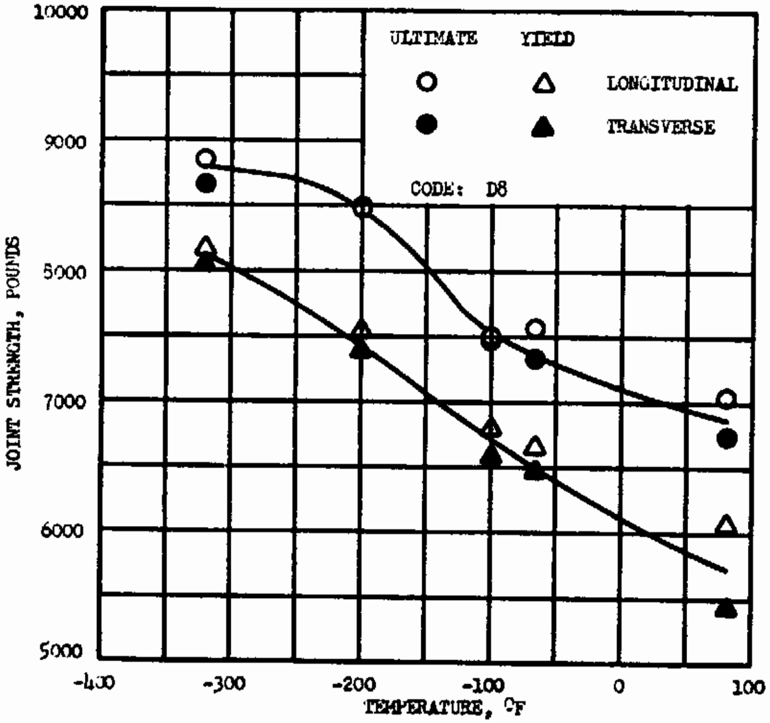


FIGURE 349 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS2010-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R4815)

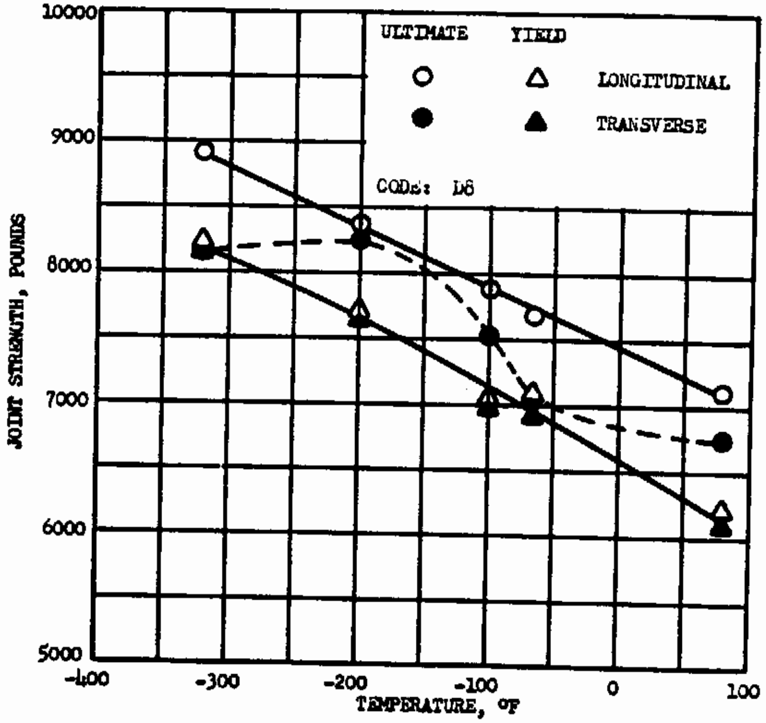


FIGURE 350 - AVERAGE SINGLE FASTENER LAP JOINT STRENGTH FOR 5/16 INCH DIAMETER NAS675-V2 FASTENERS IN 0.063 INCH THICK SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, e/D = 2.0, W/D = 5.0 (CRUCIBLE HEAT NO. R4815)

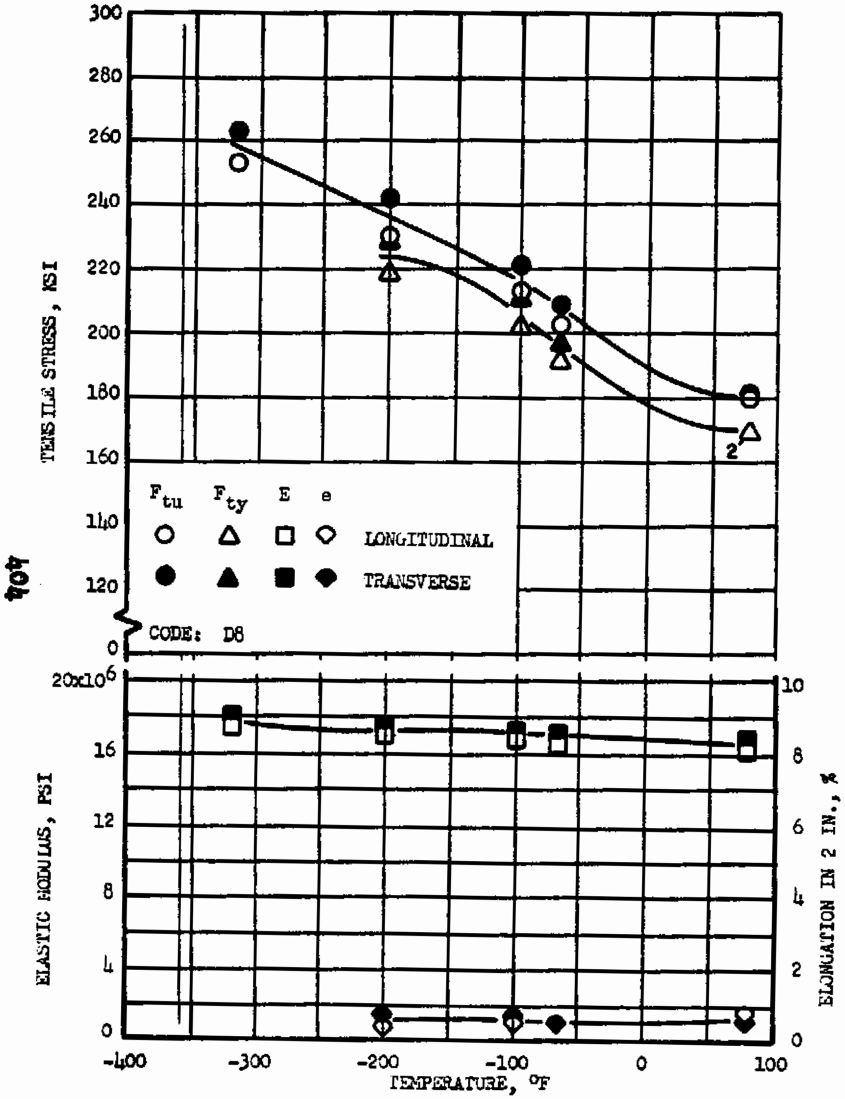


FIGURE 351 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK 4Al-3Mo-1V TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED IN AGED CONDITION (CRUCIBLE HEAT NO. R4815)

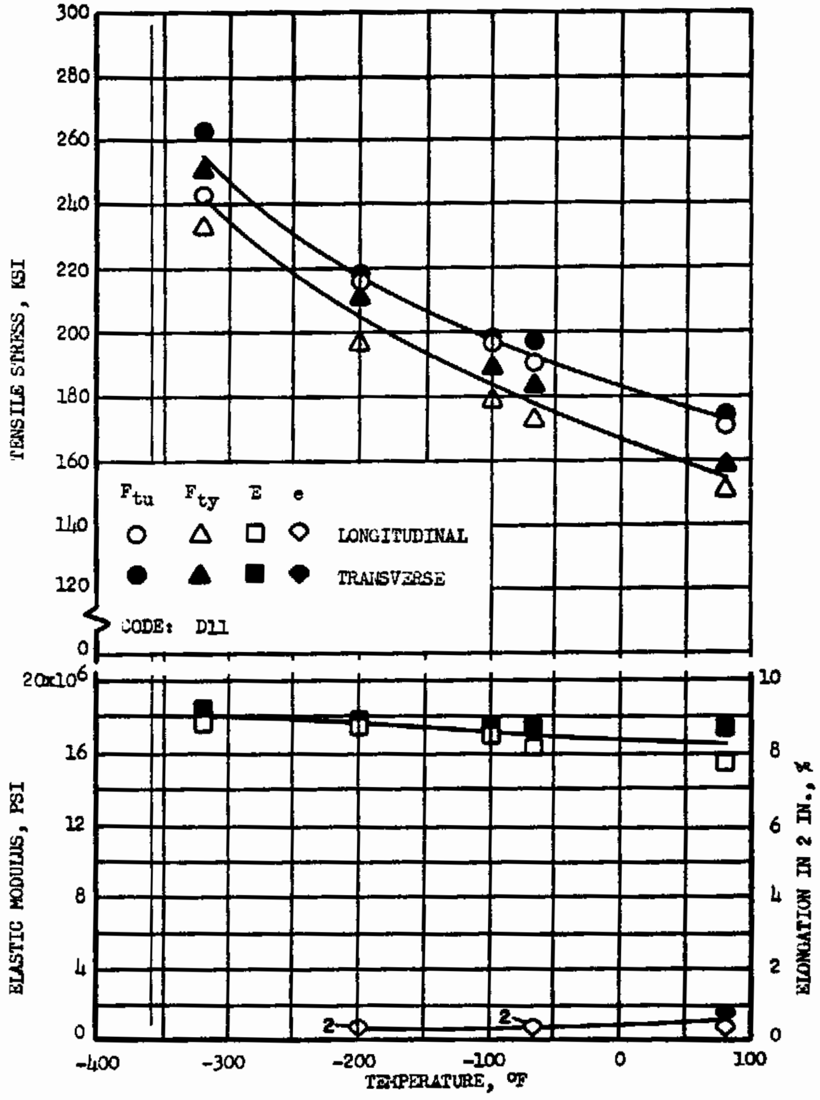


FIGURE 352 - SUMMARY OF TENSILE DATA FOR 0.063 INCH THICK 4Al-3Mo-1V TITANIUM ALLOY SHEET CONTAINING FUSION WELDS, WELDED PRIOR TO AGING (CRUCIBLE HEAT NO. P7647)

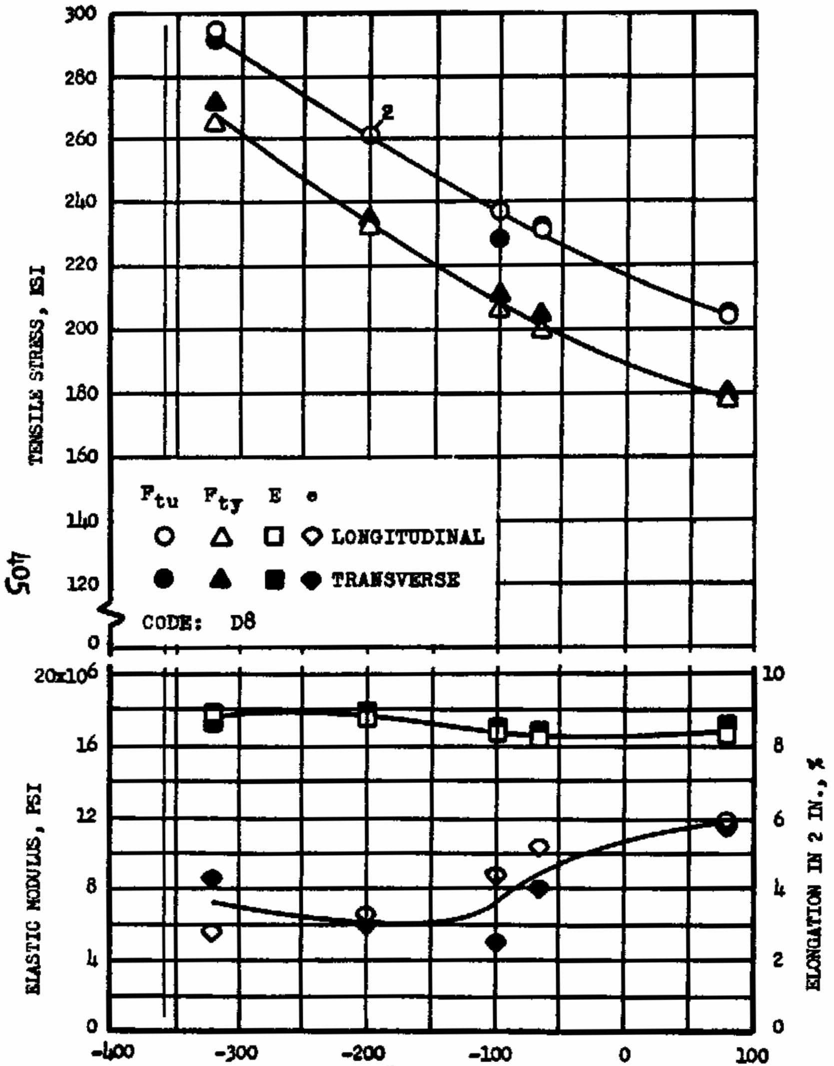


FIGURE 353 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. B4815)

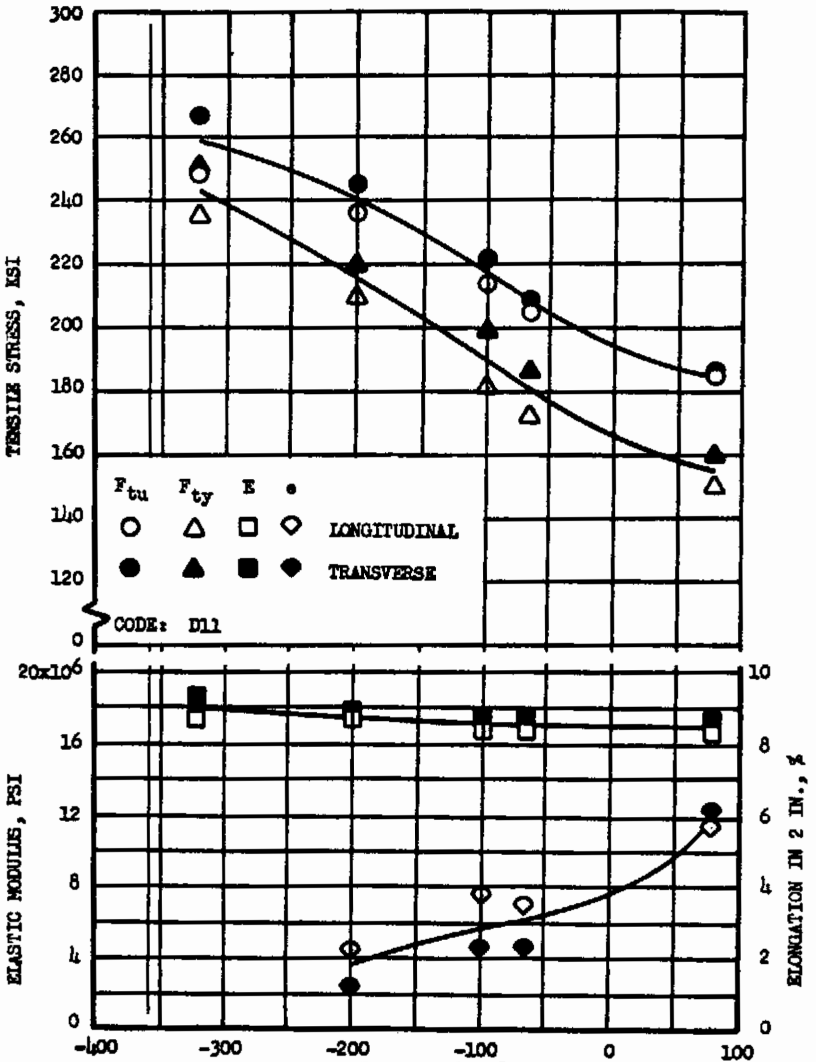


FIGURE 354 - SUMMARY OF TENSILE DATA FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK, AGED BY LOCKHEED (CRUCIBLE HEAT NO. P7647)

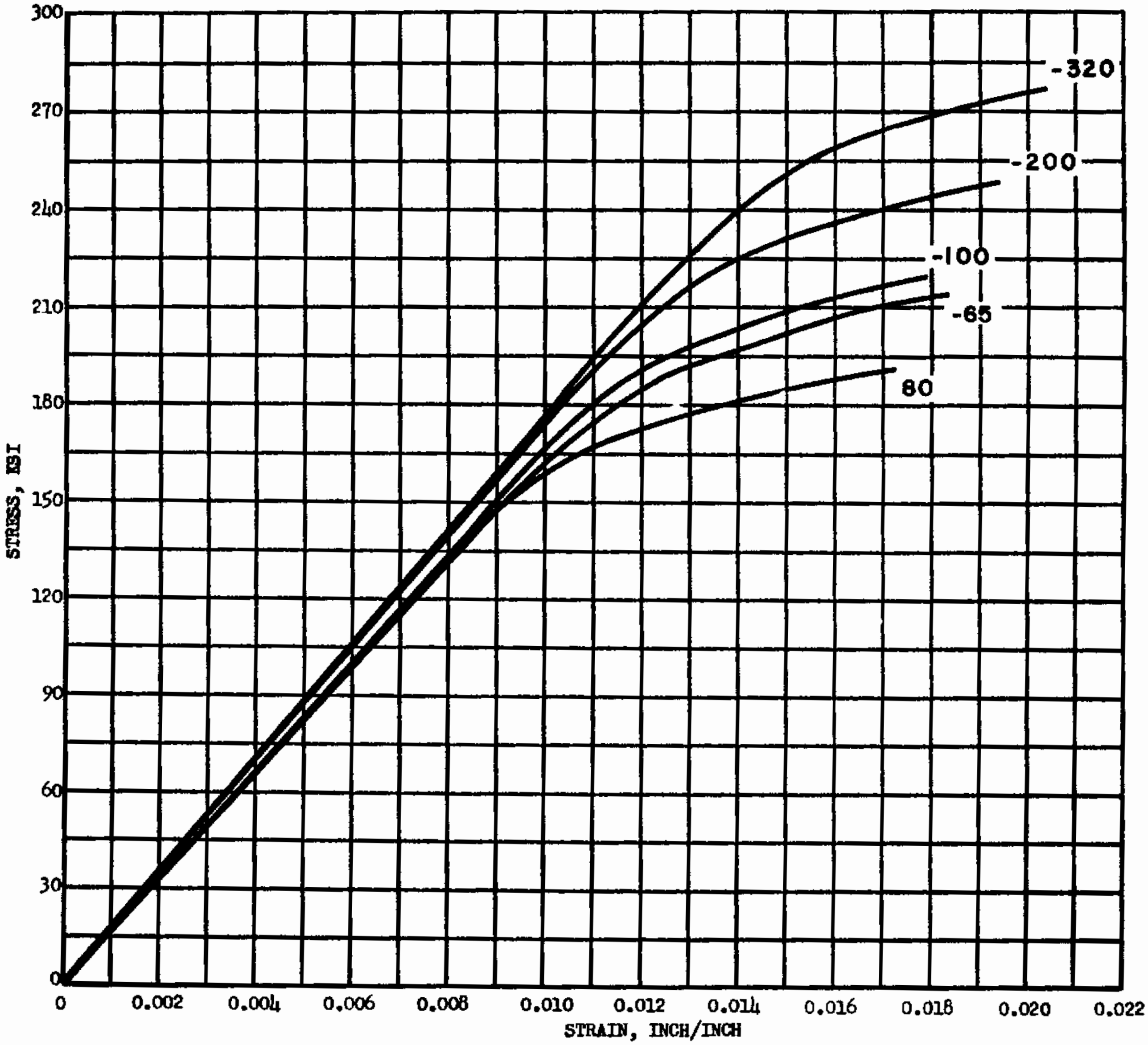


FIGURE 355 - TYPICAL LONGITUDINAL TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4815)

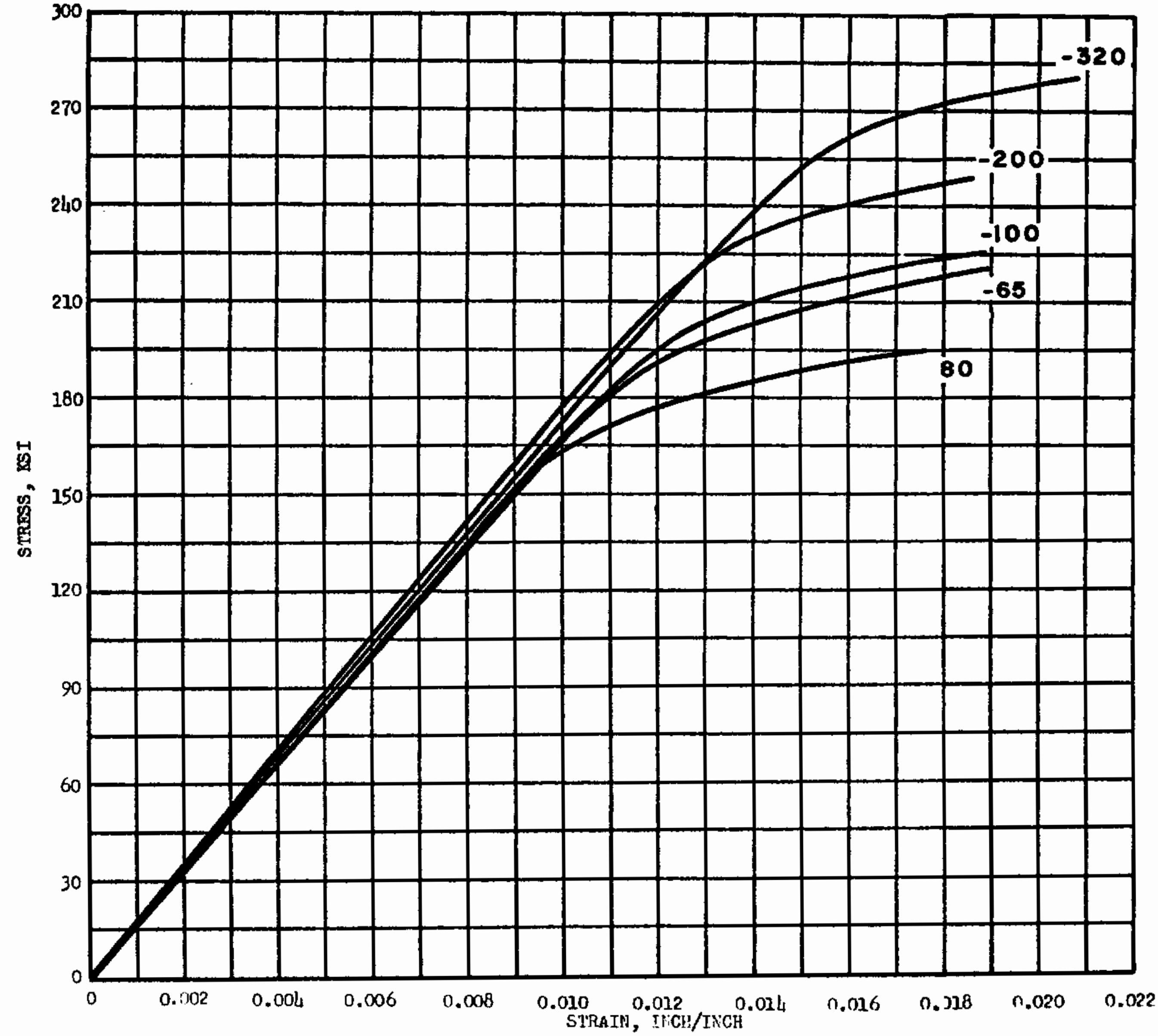
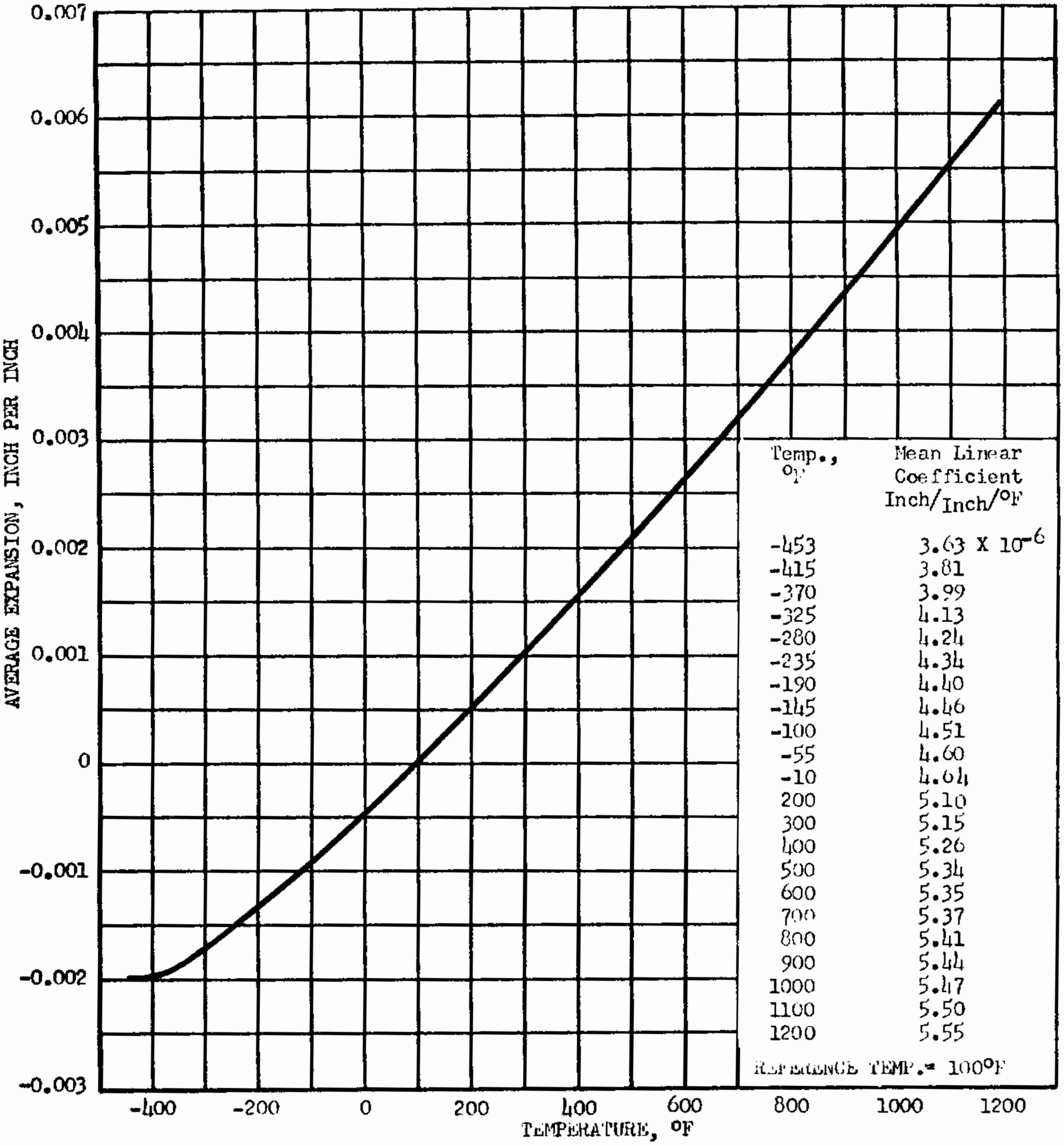


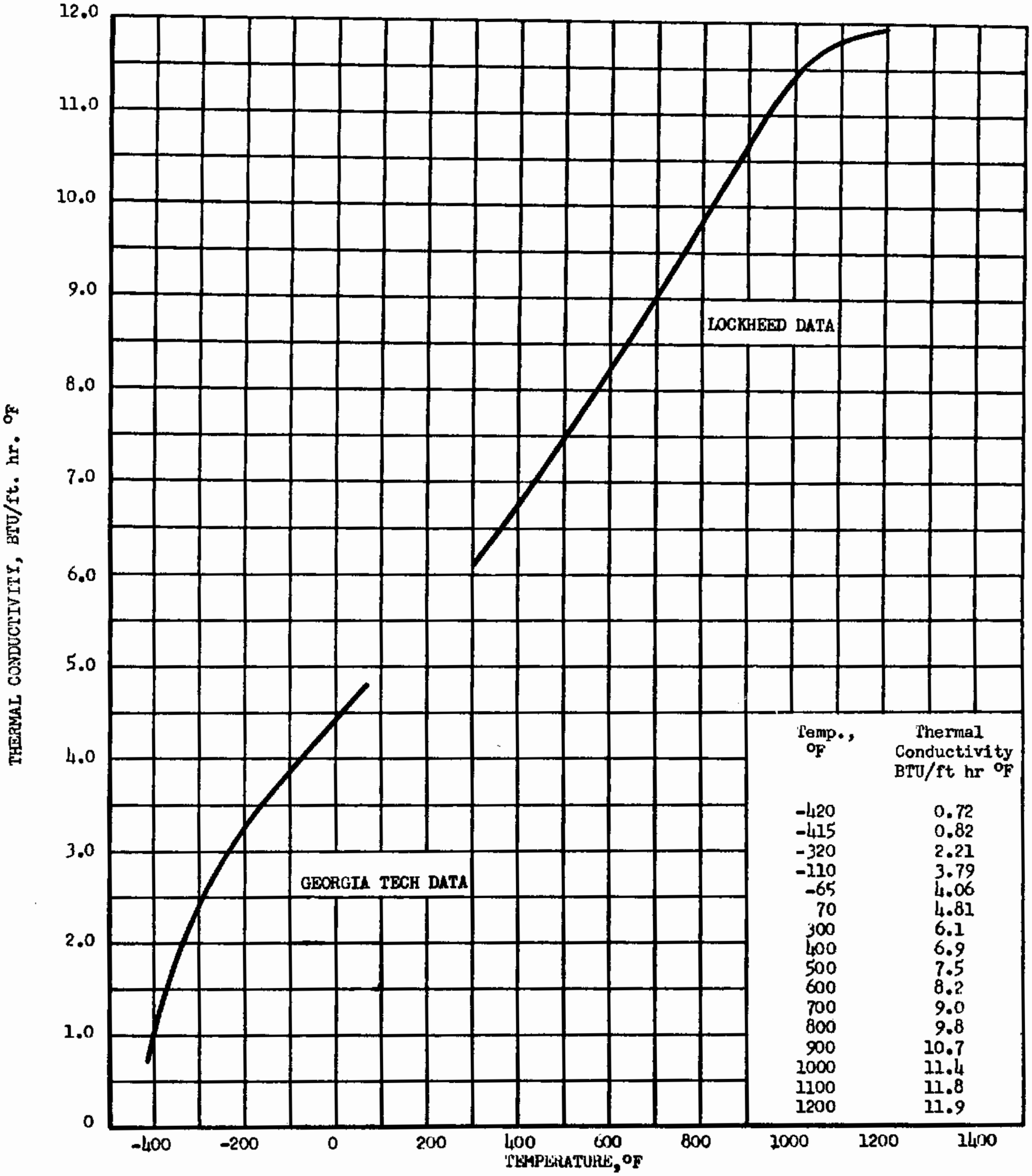
FIGURE 356 - TYPICAL TRANSVERSE TENSILE STRESS-STRAIN CURVES FOR SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET, 0.063 INCH THICK (CRUCIBLE HEAT NO. R4615)



Temp., °F	Mean Linear Coefficient Inch/Inch/°F
-453	3.63×10^{-6}
-415	3.81
-370	3.99
-325	4.13
-280	4.24
-235	4.34
-190	4.40
-145	4.46
-100	4.51
-55	4.60
-10	4.64
200	5.10
300	5.15
400	5.26
500	5.34
600	5.35
700	5.37
800	5.41
900	5.44
1000	5.47
1100	5.50
1200	5.55

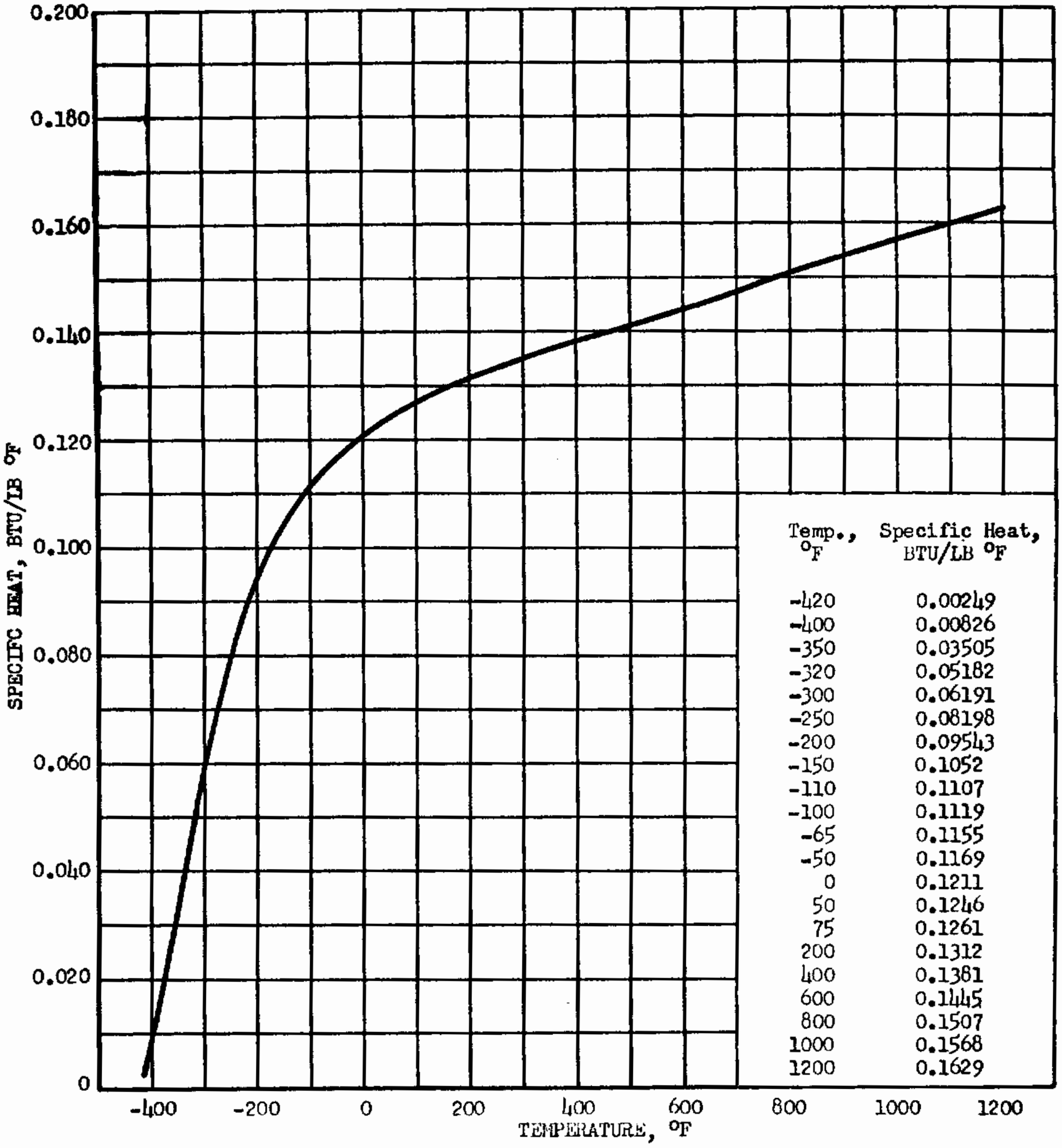
REFERENCE TEMP.= 100°F

FIGURE 357 - AVERAGE EXPANSION VERSUS TEMPERATURE FOR 0.125 INCH THICK 4Al-3Mo-1V TITANIUM ALLOY SHEET (CRUCIBLE HEAT NO. R6736, SHEET NO. B-32)



Temp., °F	Thermal Conductivity BTU/ft hr °F
-420	0.72
-415	0.82
-320	2.21
-110	3.79
-65	4.06
70	4.81
300	6.1
400	6.9
500	7.5
600	8.2
700	9.0
800	9.8
900	10.7
1000	11.4
1100	11.8
1200	11.9

FIGURE 358 - THERMAL CONDUCTIVITY VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET (CRUCIBLE HEAT NO. R6736, SHEET NO. B-32)



Temp., °F	Specific Heat, BTU/LB °F
-420	0.00249
-400	0.00826
-350	0.03505
-320	0.05182
-300	0.06191
-250	0.08198
-200	0.09543
-150	0.1052
-110	0.1107
-100	0.1119
-65	0.1155
-50	0.1169
0	0.1211
50	0.1246
75	0.1261
200	0.1312
400	0.1381
600	0.1445
800	0.1507
1000	0.1568
1200	0.1629

FIGURE 359 - SPECIFIC HEAT VERSUS TEMPERATURE FOR 0.125 INCH THICK SOLUTION TREATED AND AGED 4Al-3Mo-1V TITANIUM ALLOY SHEET (CRUCIBLE HEAT NO. R6736, SHEET NO. B-32)

REFERENCES

1. Subpanel on Uniform Procedures for Structural Design Data Collection, "Uniform Testing Procedures for Sheet Materials", Defense Metals Information Center Report No. 46D, Battelle Memorial Institute, Columbus 1, Ohio, September 12, 1958.

2. H. R. Ogden, "Department of Defense Titanium Sheet-Rolling Program Status Report No. 5", Defense Metals Information Center Report No. 46H, Battelle Memorial Institute, Columbus 1, Ohio, June 1, 1960.

3. "The Manufacture of Heat Treatable Ti-6Al-4V and Ti-2.5Al-16V Titanium Sheets – Navy Bureau of Aeronautics" Bi-Monthly Report XV, Contract NOa(S) 56-994-C, Mallery-Sharon Metals Corporation, Niles, Ohio, January 1959.

4. C. T. Olofson, "Manual on the Machining and Grinding of Titanium and Titanium Alloys", Titanium Metallurgical Laboratory Report No. 80, Battelle Memorial Institute, Columbus 1, Ohio, August 20, 1957.

5. "Tentative Method of Verification and Classification of Extensometers", American Society for Testing Materials Designation E83-52T; ASTM Standards, Part 2, p. 1286, 1952.

6. W. W. Breindel, R. L. Carlson, and G. K. Manning, "Summary Report on the Development of Minimum Design Data on the New Titanium Alloys Being Considered in the Titanium Sheet Rolling Program", Contract NOas 57-148-C, Battelle Memorial Institute, Columbus 1, Ohio, December 20, 1958.

7. Walter Ramberg and William R. Osgood, "Description of Stress-Strain Curves by Three Parameters", NACA TN902, National Advisory Committee for Aeronautics, Washington 25, D.C., July 1943.

8. ASTE Handbook Committee, Tool Engineer's Handbook , McGraw-Hill Book Company, New York, N.Y., 1949.

9. K. Scheel and W. Heuse, "Thermal Expansion of Fused Quartz", Verh. d Deutsch Phys. Ges Vol. 16, p. 1, 1914

10. W. W. Tyler, L. B. Nesbitt, and A. C. Wilson, Jr., "Some Low Temperature Properties of Titanium Alloy RC-130B and Stainless Steel", Journal of Metals, Vol. 5 (No. 9), p. 1104, September 1953.

11. W. W. Tyler and A. C. Wilson, Jr., "Thermal Conductivity and Electrical Resistivity and Thermal Electric Power of Graphite", Physical Review, Vol. 89, p. 870, 1953.

12. W. D. Bradbury, Jr., "A Cryostat for Thermal Conductivity Measurements at Low Temperature", M. S. Thesis, School of Chemical Engineering, Georgia Institute of Technology, Atlanta, Georgia, June 1959.

13. W. T. Ziegler, J. C. Mullins and S. C. P. Hwa, "Cryogenic Phase of DOD Titanium Sheet Rolling Program, Part II – Thermal Conductivity of Titanium Alloys at Low Temperature", Engineering Experiment Station Projects No. A-504 and E-238, Georgia Institute of Technology, Atlanta, Georgia, January 1962.

14. I. Estermann and J. E. Zimmerman, "Heat Conduction in Alloys at Low Temperatures", Journal of Applied Physics, Vol. 23, p. 578, 1952.

15. R. Berman, "LXVII. The Thermal Conductivity of Some Alloys at Low Temperature", Philosophical Magazine, Vol. 42, 7th Series, p. 642, 1951.

16. K. R. Wilkinson and J. Wilks, "Some Measurements of Heat Flow Along Technical Materials in the Region 4° to 20°K", Journal of Scientific Instruments, Vol. 26, p. 19, 1949.

17. J. de Nobel, "Heat Conductivity of Steel and a Few Other Metals at Low Temperatures", Physica, Vol. 17, p. 551, 1951.

18. M. S. R. Chari and J. de Nobel, "Thermal Conductivity of Some Steels at Low Temperatures", Physica, Vol. 25, p. 73, 1959.

19. W. H. Sutton, "Apparatus for Measuring Thermal Conductivity of Ceramic and Metallic Materials to 1200°C", Journal of the American Ceramic Society, Volume 43, No. 2, p. 81F, 1960.

20. R. B. Scott, et al, "Thermodynamics of 1,3-Butadiene in the Solid, Liquid, and Vapor State", Research Paper 1661, Journal of Research National Bureau of Standards, Volume 35, p. 39, 1945.

21. H. A. McGee, Jr., "The Heat Capacity Over the Range 15 – 315°K. Heat of Fusion and Derived Thermodynamic Properties and Alpha-Beta-Pinene", Ph. D Thesis in Chemical Engineering, Georgia Institute of Technology, Atlanta, Georgia, 1955.

22. H. J. Hoge and F. G. Brickwedde, "Establishment of a Temperature Scale for the Calibration of Thermometers Between 14° and 85°K", Research Paper 1188, Journal of Research National Bureau of Standards, Vol. 22, p. 351, 1939.

23. J. C. Southard, "A Modified Calorimeter for High Temperature. The Heat Content of Silica, Wollastonite and Thorium Dioxide Above 25°", Journal of American Chemical Society, Vol. 63, p. 3142, 1941.

24. J. O. Blomeke and W. T. Ziegler, "The Heat Content, Specific Heat and Entropy of La_2O_3, Pr_6O_{11} and Nd_2O_3 Between 30 and 900°K", Journal of American Chemical Society, Vol. 73, p. 5099, 1951.

25. J. O. Blomeke, "The Heat Content, Specific Heat and Entropy of La_2O_3, Pr_6O_{11} and Nd_2O_3 Between 30 and 900°K", Ph. D. Thesis in Chemical Engineering, Georgia Institute of Technology, Atlanta, Georgia, 1950.

26. K. K. Kelly, "Contributions to the Data on Theoretical Metallurgy XIII. High Temperature Heat-Content, Heat-Capacity and Entropy Data for the Elements and Inorganic Compounds", Bureau of Mines Bulletin, p. 584, 1960.

27. W. T. Ziegler and J. C. Mullins, "Cryogenic Phase of DOD Titanium Sheet Rolling Program, Part I - Specific Heat of Titanium Alloys", Engineering Experiment Station Project No. A-504, Georgia Institute of Technology, Atlanta, Georgia, August 1961.

28. D. C. Ginnings and G. T. Furukawa, "Heat-Capacity Standards for the Range 1400° to 1200°K", Journal of American Chemical Society, Vol. 75, p. 522, 1953.

29. L. E. Tanner, "Time-Temperature Transformation Diagrams of the Titanium Sheet-Rolling-Program Alloys", prepared by Armour Research Foundation, Defense Metals Information Center Report No. 46G, Battelle Memorial Institute, Columbus 1, Ohio, October 19, 1959.