

3.012 Producers guaranteed mechanical properties for annealed material, Table 3.012.

TABLE 3.012

Source	(52)(53)		
Alloy	Ti-6Al-4V		
Form	Sheet, plate and bar		
Condition	Ann		
Grade	Normal	ELI (a)	
F _{tu} , -min-ksi	130	130	
F _{ty} , -min-ksi	120	120	
e(2in), -min-percent	10 (b)	10 (c)	
RA, -min-percent	20	-	
Impact charpy V min, ft-lb RT	12	-	
-80F (d)	10	15	

- (a) Specifications apply to plate < 1 inch thick and bar < 2 inch dia.
- (b) Applies to section > 0.025 inch thick.
- (c) 0.012 through 0.020, 8 percent; plate 10 percent.
- (d) Applies to plate ≤ 1 1/2 inch

3.013 Producers guaranteed tensile properties for bar and forgings solution treated and aged in full section size, Table 3.013.

TABLE 3.013

Source	(9, p. 1)									
Alloy	Ti-6Al-4V									
Form	Bar and forgings									
Condition	1650 to 1750F, 15 to 30 min, WQ + 900 to 1000F, 4 to 8 hr									
Thickness, as received - in	≤ 1	1 to 2		2 to 3		3 to 5				
Thickness, as heat treated - in	≤ 1	≤ 1	> 1 to 2	≤ 1	> 1 to 2	> 2 to 3	≤ 1	> 1 to 2	> 2 to 5	
F _{tu} , -min-ksi	160	155	150	155	145	140	150	140	130	
F _{ty} , -min-ksi	150	145	140	145	135	130	140	130	120	
e(4D), -min-percent L	10	10	8	8	8	8	6	6	6	
T	8	8	6	6	6	6	4	4	4	
RA, -min-percent L	25	25	20	20	20	20	15	15	15	
T	20	20	15	15	15	15	10	10	10	

3.014 Producers specified mechanical properties for heat treated bar and forgings, Table 3.014.

TABLE 3.014

Source	(50)									
Alloy	Ti-6Al-4V									
Form	Bar and forgings									
Condition	HT in full section size 1750F, 2 hr, WQ + 1000F, 4 hr, AC									
Width - in	up to 1/2					up to 4				
Thickness - in (a)	up to 1/2	> 1/2 to 1	> 1 to 1 1/2	> 1 1/2 to 2	> 2 to 3	up to 1/2	> 1/2 to 1	> 1 to 1 1/2	> 1 1/2 to 2	> 2 to 3
F _{tu} , -min-ksi	160	155	150	145	135	160	150	145	140	135
F _{ty} , -min-ksi	150	145	140	135	125	150	140	135	130	125

(a) Thickness > 3 inch, annealed properties apply (F_{tu} = 130 ksi, F_{ty} = 120 ksi)

3.02 Mechanical Properties at Room Temperature
See also 3.03.

3.021 Tension

3.0211 Stress-strain diagrams. See 3.0311.

3.0212 Effect of annealing temperature on the tensile properties of ELI plate, Fig. 3.0212.

3.0213 Effect of aging temperature on the tensile properties of sheet and forgings, Fig. 3.0213

3.0214 Effect of stretching after solution treating on tensile properties of aged sheet, Fig. 3.0214.

3.0215 Effect of stretching on compressive and tensile yield strengths of annealed and aged sheet (Bauschinger effect), Fig. 3.0215.

3.0216 Effect of exposure to elevated temperatures with and without load on tensile properties of annealed sheet, Fig. 3.0216.

3.0217 Effect of exposure to elevated temperatures with load on tensile properties of annealed bar, Fig. 3.0217.

3.0218 Effect of short time exposure to elevated temperatures on tensile properties of aged sheet, Fig. 3.0218.

3.0219 Effect of strain rate on tensile properties of annealed and aged bar, Fig. 3.0219.

3.022 Compression (see Fig. 3.0214 and 3.032).

3.0221 Stress-strain diagrams (see 3.0321).

3.023 Impact (see 3.033)

3.024 Bending

3.025 Torsion and shear

3.0251 Effect of thickness on shear strength of annealed sheet, Fig. 3.0251.

3.026 Bearing

3.027 Stress concentration

3.0271 Notch properties

3.02711 Effect of stress concentration on notch strength of aged sheet, Fig. 3.02711.

3.02712 Effect of notch geometry on notch strength ratio of aged sheet and plate at room temperature, Fig. 3.02712

3.02713 Effect of aging temperature on the sharp notch strength of sheet, Fig. 3.02713.

3.0272 Fracture toughness (see also 3.0372).

3.02721 Sharp notch strength and plane strain fracture toughness of surface cracked specimens cut from solution treated forgings and aged at various temperatures, Fig. 3.02721.

3.02722 Effect of surface crack length on sharp notch properties of solution treated and aged specimens cut from forgings, Fig. 3.02722.

3.028 Combined properties

3.03 Mechanical Properties at Various Temperatures

3.031 Tension

3.0311 Stress-strain diagrams

3.03111 Stress-strain curves at various temperatures for annealed sheet, Fig. 3.03111.

3.03112 Stress-strain curves at room and elevated temperatures for annealed bar, Fig. 3.03112.

3.03113 Longitudinal tension stress-strain curves at elevated temperatures for aged sheet, Fig. 3.03113.

3.03114 Transverse tension stress-strain curves at elevated temperature for aged sheet, Fig. 3.03114.

3.03115 Stress-strain curves at low temperatures for aged sheet, Fig. 3.03115.

3.0312 Spread of tensile test data at room and elevated temperatures for annealed sheet and bar, Fig. 3.0312.

3.0313 Effect of low test temperature on tensile properties of annealed sheet, Fig. 3.0313.

3.0314 Effect of low test temperature on tensile properties of annealed sheet and bar, Fig. 3.0314.

3.0315 Tensile data for aged sheet.

3.03151 Spread of tensile data at room and elevated temperatures for eight heats of aged sheet, Fig. 3.03151.

3.03152 Effect of test temperature and testing direction on tensile properties of aged sheet, Fig. 3.03152.

3.03153 Effect of low and elevated temperatures on the tensile properties of aged sheet, Fig. 3.03153.

3.03154 Effect of exposure and test temperature on tensile properties of aged sheet, Fig. 3.03154.

3.03155 Effect of elevated temperature exposure on room and elevated temperature tensile properties of aged sheet, Fig. 3.03155.

Ti
6 Al
4 V

Ti-6Al-4V

Ti
6 Al
4 V

Ti-6Al-4V

- 3.03156 Effect of test temperature on tensile properties of aged bar, Fig. 3.03156.
- 3.03157 Effect of test temperature on tensile properties of solution treated and aged specimens cut from forging, Fig. 3.03157.
- 3.032 Compression
- 3.0321 Stress-strain diagrams
- 3.03211 Stress-strain curves in compression at room and elevated temperatures for annealed sheet, Fig. 3.03211.
- 3.03212 Longitudinal compression stress-strain curves at elevated temperature for aged sheet, Fig. 3.03212.
- 3.03213 Transverse compression stress-strain curves at elevated temperature for aged sheet, Fig. 3.03213.
- 3.03214 Stress-strain curves in compression at room and elevated temperatures for annealed bar, Fig. 3.03214.
- 3.0322 Compressive yield strength
- 3.03221 Spread of compressive yield strength at room and elevated temperatures for eight heats of aged sheet, Fig. 3.03221.
- 3.03222 Directionality of compressive yield strength at room temperature and 800F for annealed and for aged sheet, Table 3.03222.

TABLE 3.03222

Source		(32)											
Alloy		Ti-6Al-4V											
Form		0.051 in sheet											
Condition		Ann, 1550F, 5 hr, FC						1700F, 20 min, WQ + 1000F, 4 hr, AC					
Temp-F		RT		800		RT		800		RT		800	
Direction		L	45	T	L	45	T	L	45	T	L	45	T
F _{cy} -ksi		142	136	184	63	63	113	165	168	227	106	83	133

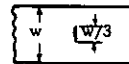
- 3.03223 Effect of exposure and test temperature on compressive yield strength of annealed and aged sheet and bar, Fig. 3.03223.
- 3.033 Impact (see also Fig. 4.034).
- 3.0331 Effect of test temperature on impact strength of annealed and aged plate and bar, Fig. 3.0331.
- 3.034 Bending
- 3.035 Torsion and shear
- 3.0351 Spread of shear strength at room and elevated temperature for eight heats of aged sheet, Fig. 3.0351.
- 3.0352 Effect of test temperature on shear strength of annealed and aged sheet and bar, Fig. 3.0352.
- 3.036 Bearing
- 3.0361 Spread of bearing strength at room and elevated temperature for eight heats of aged sheet, Fig. 3.0361.
- 3.0362 Effect of test temperature on bearing properties of annealed sheet and bar, Fig. 3.0362.
- 3.0363 Effect of exposure and test temperature on bearing properties of aged sheet, Fig. 3.0363.
- 3.037 Stress concentration
- 3.0371 Notch properties
- 3.03711 Notch strength ratio as a function of stress-concentration factor for annealed sheet tested at room temperature and -320F, Fig. 3.03711.
- 3.03712 Notch strength ratio as a function of stress-concentration factor for aged sheet tested at room temperature and -320F, Fig. 3.03712.
- 3.03713 Effect of test temperature and stress-concentration factor on notch strength of aged sheet, Fig. 3.03713.
- 3.03714 Effect of low test temperatures on the mild and sharp notch properties of annealed ELI sheet, Fig. 3.03714.
- 3.03715 Effect of crack length on sharp notch properties of annealed sheet, tested at several temperatures, Fig. 3.03715.
- 3.03716 Effect of test temperature on sharp notch properties of several heats of mill annealed sheet, Fig. 3.03716.
- 3.03717 Effect of test temperature on sharp notch strength of annealed sheet before and after elevated temperature exposure, Fig. 3.03717.
- 3.03718 Effect of test temperature on sharp notch strength of aged sheet before and after elevated temperature exposure, Fig. 3.03718.

- 3.03719 Effect of test temperature on the sharp notch properties of solution treated and aged specimens of various thicknesses cut from forging, Fig. 3.03719.
- 3.0372 Fracture toughness
- 3.03721 Effect of test temperature and specimen thickness on the fracture toughness of solution treated and aged specimen cut from forging, Table 3.03721.

TABLE 3.03721

Source		(26)							
Alloy		Ti-6Al-4V							
Form		3 x 9 in forging							
Condition		1650F, 1hr, WQ, + 1100F, 4 hr, AC ^d							
Thickness - in		3/16		3/8		1.0		9	
Width - in		3							
Temp - F		-110		RT		-110		RT	
Direction		L	T	L	T	L	T	L	T
F _{ty} - ksi		176	174	147	152	176	147	176	147
K _{IC} - ksi-√in		111	75	150	110	117	156	76	96

* Applied to specimens



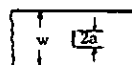
Center fatigue crack specimen heat treat before cracking; slow crack extension by motion pictures

- 3.03722 Plane strain fracture toughness of annealed plate at low temperatures, Fig. 3.03722.
- 3.03723 Effect of test temperature on sharp notch strength ratio and plane strain fracture toughness of solution treated and aged round bars cut from forging, Fig. 3.03723.
- 3.03724 Low temperature sharp notch strength and plane strain fracture toughness of annealed plate and solution treated and aged specimens cut from extrusion, Table 3.03724.

TABLE 3.03724

Source		(30)(31)	
Alloy		Ti-6Al-4V	
Form		Extrusion	
		OD = 44 in ID = 4.34 in	
Condition*		1300F, 1 hr, FC	
		1500F, 10 min, WQ + 1000F, 7 hr, AC	
Direction		Circumferential	
-320F property			
F _{ty} - ksi		212	213
Notch strength-ksi		152	86
K _{IC} - ksi-√in		69	41

* Specimen blanks cut and then heat treated



	w	r	2a	b
Plate	6	1/4	~1/2	~0.07
Extrusion	2	0.3	0.33	~0.1

Surface crack specimens heat treated before cracking

- 3.03725 Sharp notch strength ratio and plane strain fracture toughness of solution treated and aged specimens cut from forging, Table 3.03725.

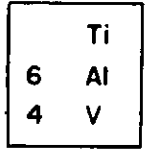
TABLE 3.03725

Source		(26)							
Alloy		Ti-6Al-4V							
Form		3 x 9 in forging							
Condition		1650F, 1hr, WQ + 1100F, 4 hr, AC(b)							
Exposure (c)		25ksi, 650F, 1000hr				None			
Temp - F		-110		RT		-110		RT	
		400	650	400	650	400	650	400	650
F _{ty} - ksi		178	153	111	94	175	152	112	98
Sharp notch-yield strength ratio		0.33	0.48	1.24	1.37	0.45	0.56	1.47	1.63
K _{IC} - ksi-√in(a)		25	32	-	-	35	37	-	-

(a) For specimen details see Fig. 3.03723 (D = 1 1/8 inch, Dir. - T)

(b) Applies to specimens

(c) Exposed before specimen preparation



Ti-6Al-4V

- 3.038 Combined properties
- 3.04 Creep and Creep Rupture Properties
- 3.041 Average creep and rupture curves at several temperatures for aged sheet from three heats, Fig. 3.041.
- 3.042 Creep and creep ruptures curves at 750 and 850F for annealed bar, Fig. 3.042.
- 3.043 Creep and creep rupture curves at 650 to 850F for aged bar, Fig. 3.043.
- 3.05 Fatigue Properties
- 3.051 Axial fatigue properties for aged sheet at room and elevated temperatures, Table 3.051.
- 3.054 Stress range diagram at 10^7 cycles for smooth and notched specimens of mill annealed sheet, Fig. 3.054.
- 3.055 Stress range diagram at 10^7 cycles for smooth and notched specimens of aged sheet, Fig. 3.055.
- 3.06 Elastic Properties
- 3.061 Effect of test temperature on Poisson's ratio, Fig. 3.061.
- 3.062 Modulus of elasticity
- 3.0621 Spread of elastic modulus at room and elevated temperatures for eight heats of aged sheet, Fig. 3.0621.
- 3.0622 Modulus of elasticity at low and elevated temperature for annealed sheet, Fig. 3.0622.

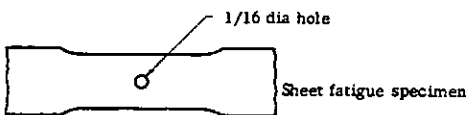
TABLE 3.051

Source		(41)														
Alloy		Ti-6Al-4V														
Form		0.063 and 0.125 in sheet, L														
Condition		1700F, 3 to 20 min, WQ + 900 to 950F, 4 hr														
Method		Direct stress $K_t = 1$														
Stress ratio		A = ∞ R = 1					A = 1 R = 0					A = 0.3 R = 0.5				
Cycles		10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷
Fatigue strength, ksi at temp																
RT		152	120	70	55	54	180	150	100	85	78	180	178	135	107	105
400F		115	90	58	40	35	155	40	77	65	60	150	148	120	100	100
600F		105	82	50	37	35	-	120	76	62	60	140	138	115	100	98
800F		100	80	45	33	28	125	110	73	60	55	135	132	93	83	78
900F		93	65	40	32	25	120	97	70	60	50	112	110	85	65	55

- 3.052 Axial fatigue properties at $K_t = 2.82$ for 0.063 inch aged sheet at room and elevated temperatures, Table 3.052.
- 3.0623 Dynamic modulus of elasticity for annealed bar at elevated temperatures, Fig. 3.0623.

TABLE 3.052

Source		(41)														
Alloy		Ti-6Al-4V														
Form		0.063 in sheet														
Condition		1700F, 3 min to 20 min, WQ + 900 to 950F, 4 hr, AC														
Method		Direct stress $K_t = 2.82^*$														
Stress ratio		A = ∞ R = 1					A = 1 R = 0					A = 0.3 R = 0.5				
Cycles		10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷
Fatigue strength, ksi at temp																
RT		100	60	40	25	22	150	95	50	40	40	180	140	80	60	57
400F		120	60	35	24	21	123	85	47	38	37	160	130	70	60	60
600F		85	55	30	20	19	120	80	40	37	37	145	120	70	60	58
800F		80	50	25	18	17	120	70	40	37	37	130	115	60	50	40
900F		70	45	24	18	17	118	70	40	35	35	115	95	60	50	40



- 3.053 Axial fatigue properties at $K_t = 2.82$ for 0.125 inch aged sheet at room and elevated temperatures, Table 3.053.
- 3.0624 Spread of elastic compressive modulus at room and elevated temperature for eight heats of aged sheet, Fig. 3.0624.
- 3.063 Modulus of rigidity
- 3.064 Tangent modulus
- 3.0641 Tangent modulus curves in compression at room and elevated temperatures for annealed sheet, Fig. 3.0641.
- 3.0642 Longitudinal tensile tangent modulus curves at elevated temperatures for aged sheet, Fig. 3.0642.
- 3.0643 Transverse tensile tangent modulus curves at elevated temperatures for aged sheet, Fig. 3.0643.

TABLE 3.053

Source		(41)														
Alloy		Ti-6Al-4V														
Form		0.125 in sheet														
Condition		1700F, 3 min to 20 min, WQ + 900 to 950F, 4 hr, AC														
Method		Direct stress $K_t = 2.82^*$														
Stress ratio		A = ∞ R = 1					A = 1 R = 1					A = 0.3 R = 0.5				
Cycles		10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷
Fatigue strength, ksi at temp																
RT		100	60	40	35	34	140	100	60	40	40	170	135	80	60	50
400F		88	60	40	30	25	120	80	45	38	38	145	120	70	58	50
600F		90	60	35	22	20	120	78	45	35	30	130	115	70	55	50
800F		75	55	30	20	18	115	70	42	32	27	123	110	70	55	50
900F		62	40	27	20	18	105	65	40	30	26	110	100	70	55	50

* For specimen See Table 3.052.

	Ti	3.0644	Longitudinal compression tangent modulus curves at elevated temperatures for aged sheet, Fig. 3.0644.
6	Al	3.0645	Transverse compression tangent modulus curves at elevated temperatures for aged sheet, Fig. 3.0645.
4	V	3.065	Secant modulus
		3.0651	Longitudinal compression secant modulus curves at elevated temperatures for aged sheet, Fig. 3.0651.
		3.0652	Transverse compression secant modulus curves at elevated temperatures for aged sheet, Fig. 3.0652.

Ti-6Al-4V

4. FABRICATION

4.01 Formability

4.011 General. Annealed Ti-6Al-4V is one of the most difficult to form among annealed titanium alloys. Heating to 1200F can be used for severe forming operations.

4.012 Parts to be aged are preferably formed in the solution treated Condition, either cold or hot, depending upon the severity of the operation, and finish formed by one of several methods developed for heat treated titanium alloys and specifically for this alloy. One of the most promising methods is finish forming combined with aging in dies heated to 950 to 1000F and held at temperature for 6 to 10 hours. In the aged Condition this alloy can be bent at room temperature to moderate radii and subjected to somewhat more severe operations at temperatures below the aging temperature.

4.013 Bending

4.0131 TMCA specified bend factors for sheet at room temperature ≤ 0.070 in $R/t = 4.5$ and > 0.070 in, $R/t = 5.0$.

4.0132 Effect of test temperature on bend factor for annealed sheet, Fig. 4.0132.

4.014 Forging. Starting temperature, 1850F maximum, finishing temperature, 1450F minimum. To obtain optimum properties, reductions equivalent to 25 to 40 percent should be performed in the alpha + beta range in the final forging operation. Subsequent reheating, such as required for sizing operations, should not exceed, generally, a temperature of about 200F below the beta to alpha + beta transformation temperature.

4.02 Machining and Grinding

See Ti Commercially Pure.

4.03 Welding

4.031 General. Extreme cleanliness is necessary in order to avoid porosity and weld cracking. However, proper procedures are now well developed and the alloy may be welded successfully.

4.032 Fusion welding is accomplished by using complete inert gas shielding. Both tungsten arc and consumable electrode processes have given good results. Ti-6Al-4V, Ti-3Al alloy or Commercially Pure Titanium filler rod is used.

4.033 Resistance welding requires techniques similar to those used for austenitic stainless steels.

4.034 Effect of test temperature on the impact properties of plate welded with various fillers, Fig. 4.034.

4.04 Heat Treatment

See Ti, Commercially Pure. Only complementary or different information is listed below.

4.041 Solution treatment of sheet or other thin section requires supporting and restraining fixtures to prevent sagging during heating and severe distortion on quenching in water or oil. To insure maximum response to aging, quenching delay must be minimized.

4.042 To maintain formed tolerances during aging, parts should be supported or jugged.

4.05 Surface Treating

See Ti, Commercially Pure.

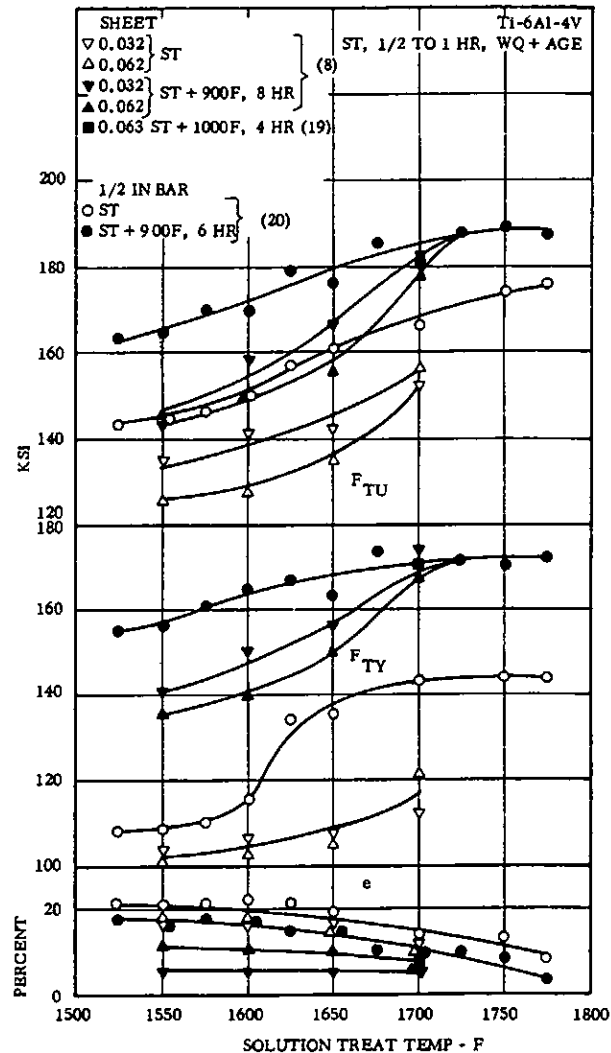


FIG. 1.0544 EFFECT OF SOLUTION TREAT TEMPERATURE ON TENSILE PROPERTIES OF SHEET AND BAR (8, p. G-14, 15)(19)(20)

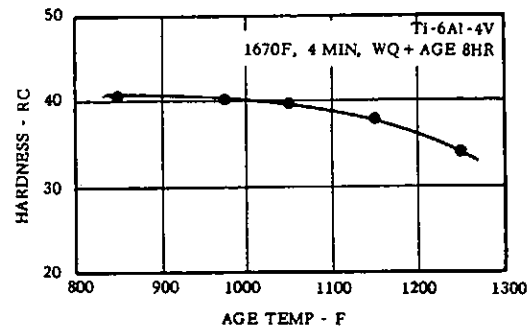


FIG. 1.061 EFFECT OF AGING TEMPERATURE ON HARDNESS OF SOLUTION TREATED SHEET (49)

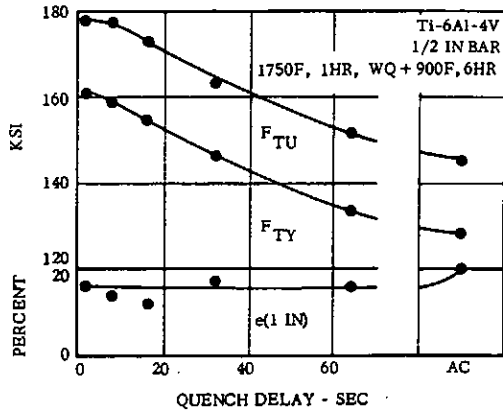


FIG. 1.062 EFFECT OF QUENCH DELAY ON TENSILE PROPERTIES OF AGED BAR (21)

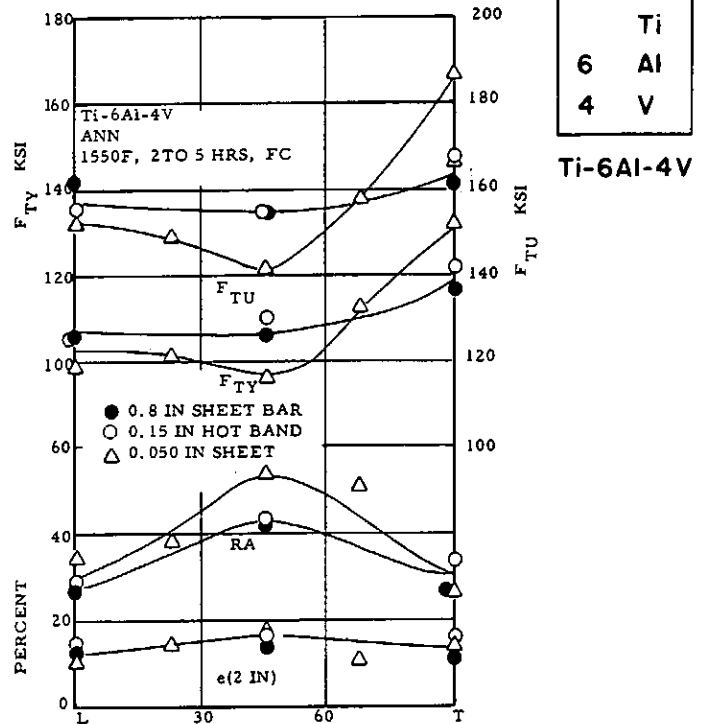


FIG. 1.0911 DIRECTIONALITY OF TENSILE PROPERTIES FOR STRIP PRODUCT IN ANNEALED CONDITION (32, Tables 31, 30, 35)

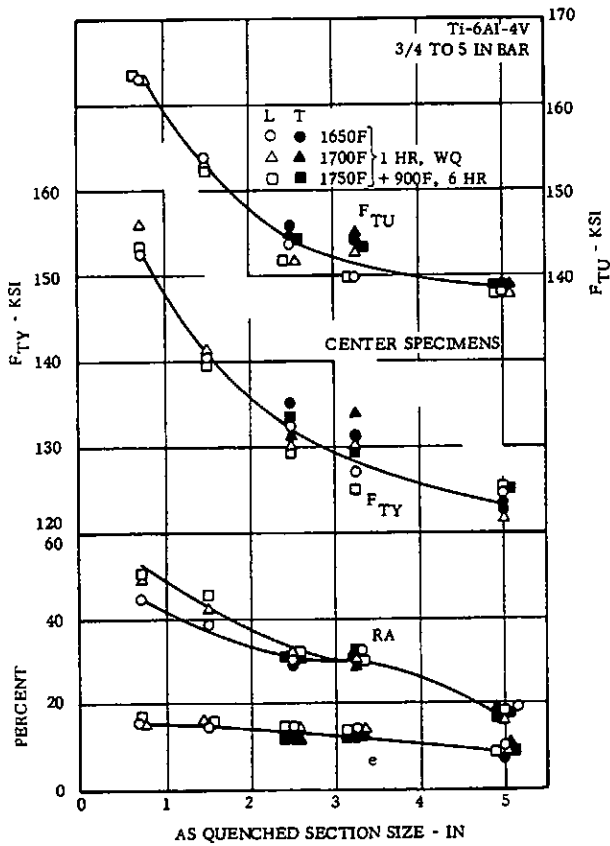
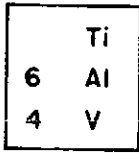


FIG. 1.063 EFFECT OF AS QUENCHED SECTION SIZE ON TENSILE PROPERTIES OF AGED BAR (13, p. 21-26)



Ti-6Al-4V

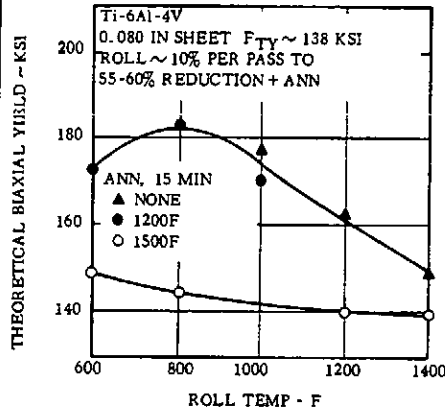


FIG. 1.0912 EFFECT OF ROLLING TEMPERATURE AND ANNEALING TREATMENT ON THE THEORETICAL YIELD STRENGTH IN 2:1 BIAxIAL STRESS FIELD (45, p. 11)

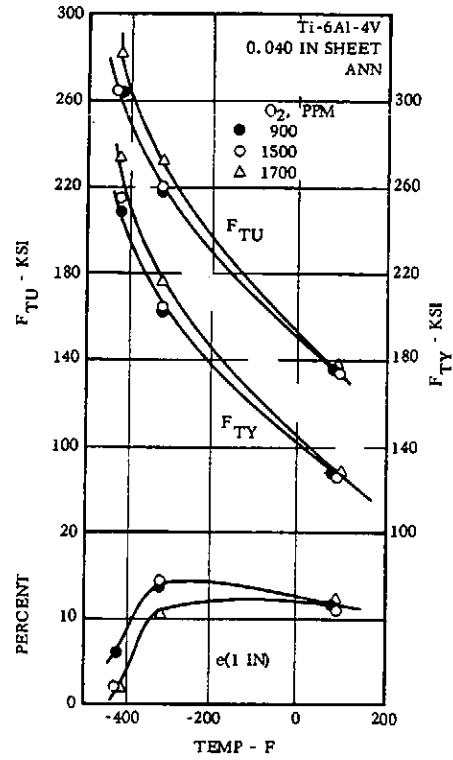


FIG. 1.0921 EFFECT OF OXYGEN CONTENT ON LOW TEMPERATURE TENSILE PROPERTIES OF ANNEALED SHEET (29, Table 3)

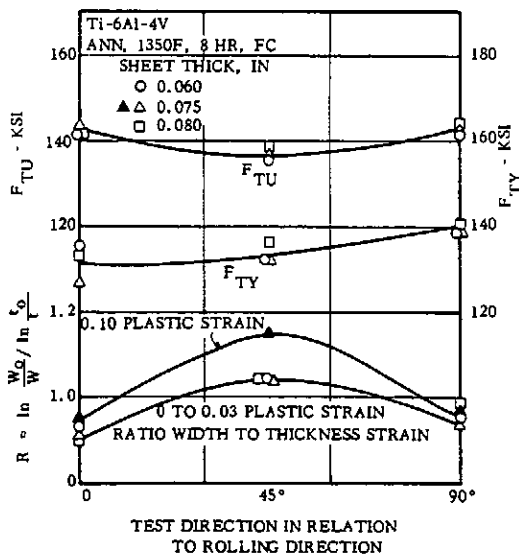


FIG. 1.0913 DIRECTIONALITY OF STRENGTH AND STRAIN FOR TENSILE TESTS ON THREE HEATS OF ANNEALED SHEET (33, Table 5)

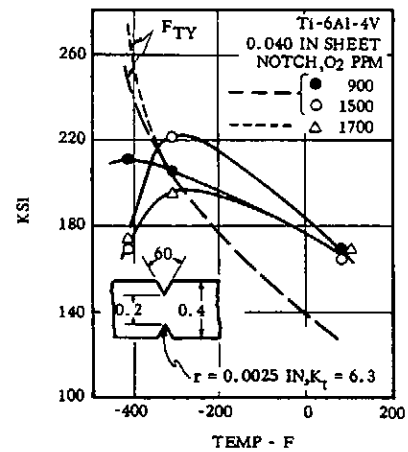


FIG. 1.0922 EFFECT OF OXYGEN CONTENT ON LOW TEMPERATURE MILD NOTCH PROPERTIES OF ANNEALED SHEET (29)

CORRECTED DECEMBER 1984

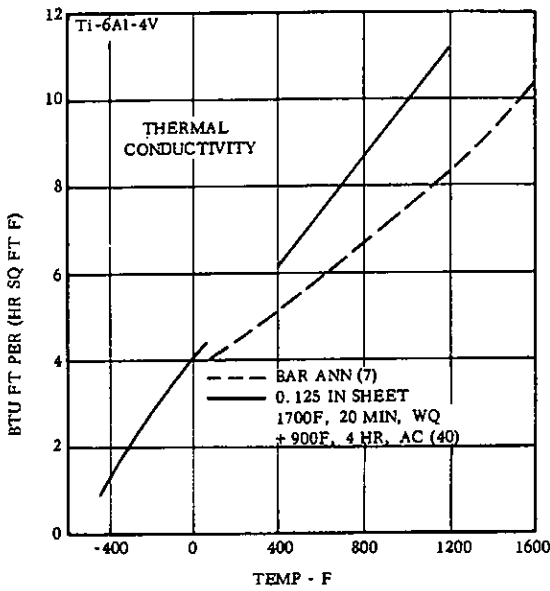


FIG. 2.013 THERMAL CONDUCTIVITY (7)(40, p. 286)

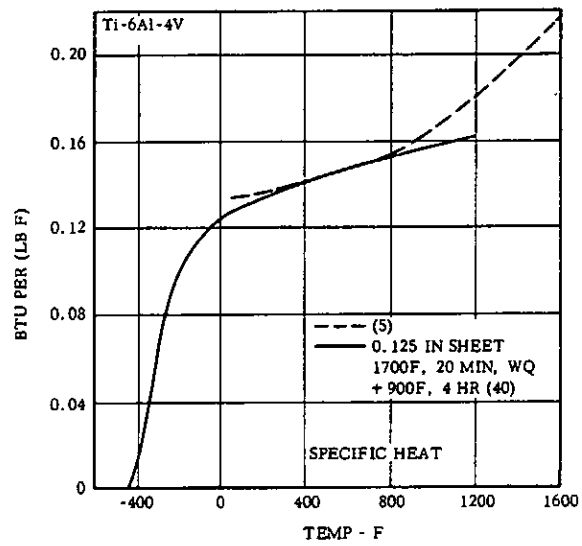


FIG. 2.015 SPECIFIC HEAT (5)(40, p. 287)

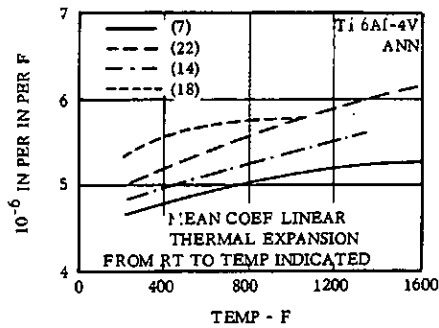
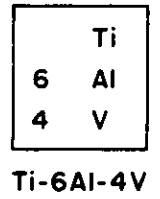


FIG. 2.0141 THERMAL EXPANSION FOR ANNEALED ALLOY (7, p.3)(14, p.2)(18, p.50)(22)

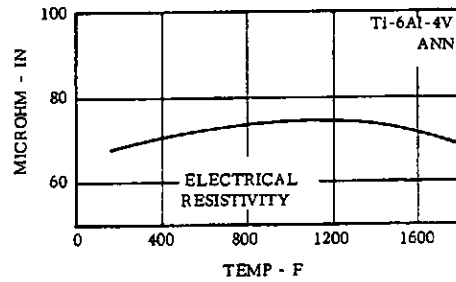


FIG. 2.022 ELECTRICAL RESISTIVITY (5, p. W-3, 4)

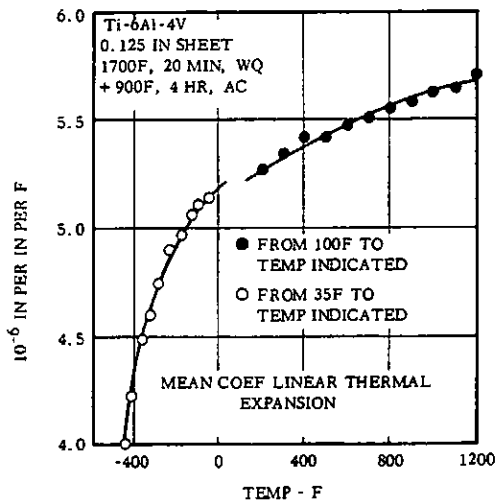


FIG. 2.0142 THERMAL EXPANSION FOR AGED SHEET (39, p. 137-138)

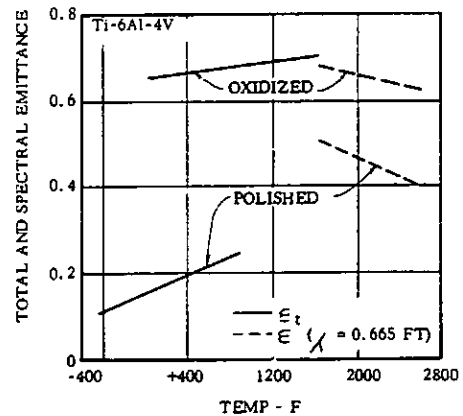
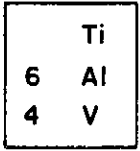


FIG. 2.0241 TOTAL AND SPECTRAL NORMAL EMITTANCE FOR OXIDIZED AND POLISHED SURFACES (37, p. 46, 47)



Ti-6Al-4V

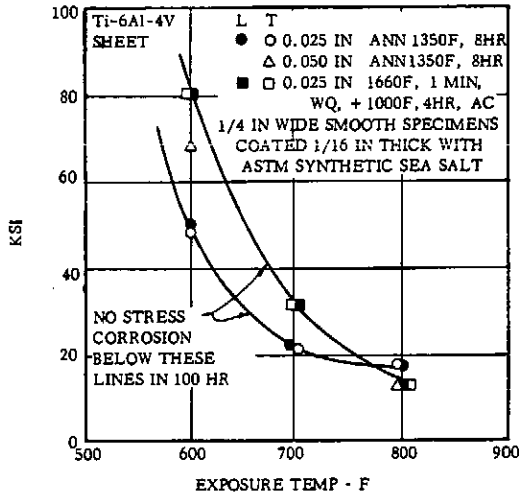


FIG. 2.0341 EFFECT OF STRESS AND TEMPERATURE ON 100 HOUR STRESS CORROSION OF ANNEALED AND AGED SHEET (46, Tables 96, 97, 98)

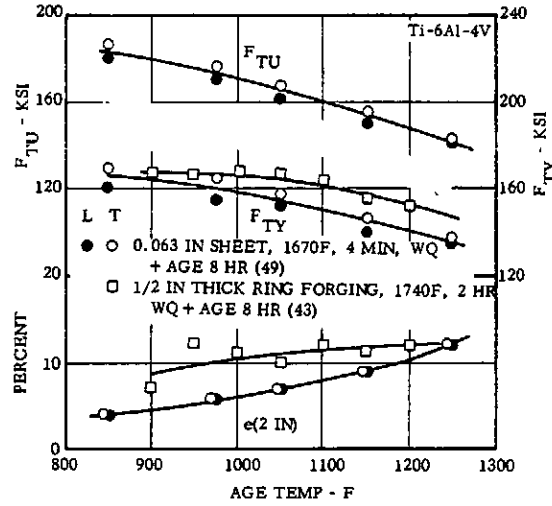


FIG. 3.0213 EFFECT OF AGING TEMPERATURE ON THE TENSILE PROPERTIES OF SHEET AND FORGINGS (43)(49)

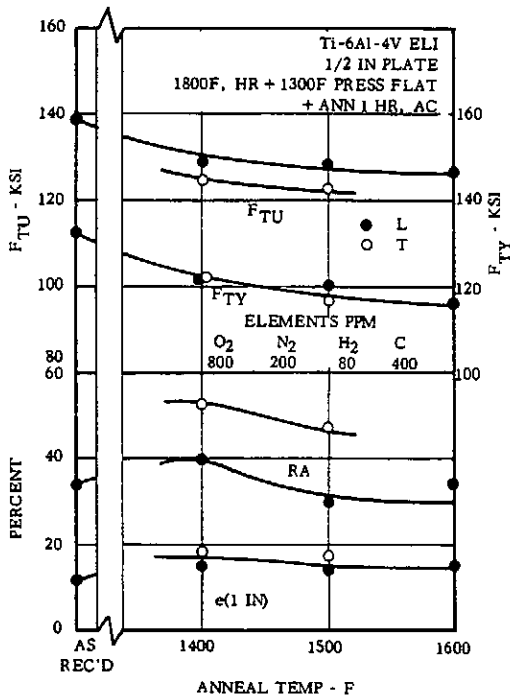


FIG. 3.0212 EFFECT OF ANNEALING TEMPERATURE ON THE TENSILE PROPERTIES OF ELI PLATE (53)

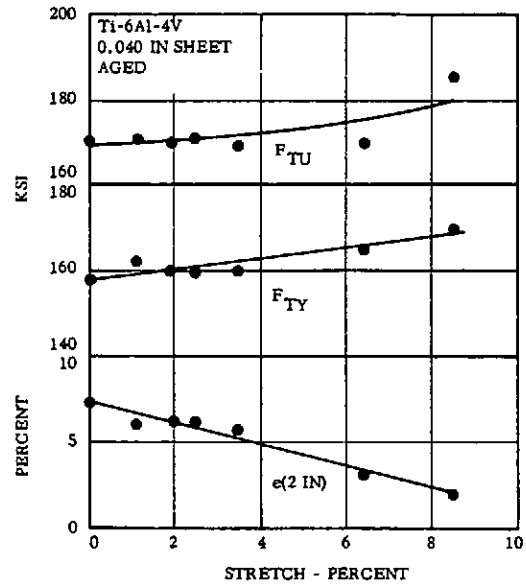


FIG. 3.0214 EFFECT OF STRETCHING AFTER SOLUTION TREATING ON TENSILE PROPERTIES OF AGED SHEET (19)

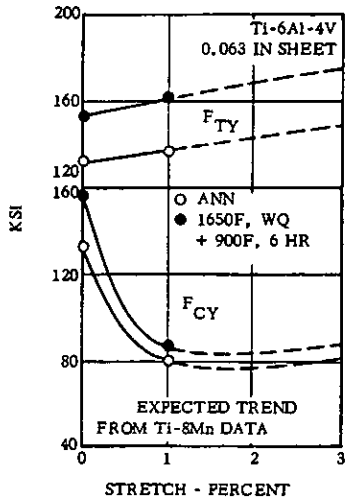
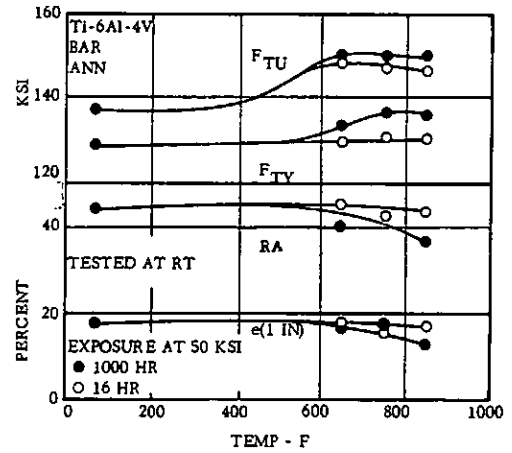


FIG. 3.0215 EFFECT OF STRETCHING ON COMPRESSIVE AND TENSILE YIELD STRENGTHS OF ANNEALED AND AGED SHEET (BAUSCHINGER EFFECT) (17)



Ti
6 Al
4 V

Ti-6Al-4V

FIG. 3.0217 EFFECT OF EXPOSURE TO ELEVATED TEMPERATURES WITH LOAD ON TENSILE PROPERTIES OF ANNEALED BAR (18, p. 33-36)

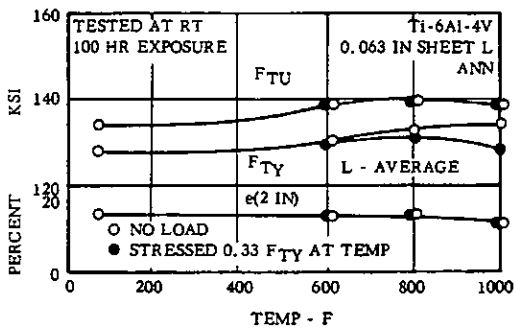


FIG. 3.0216 EFFECT OF EXPOSURE TO ELEVATED TEMPERATURES WITH AND WITHOUT LOAD ON TENSILE PROPERTIES OF ANNEALED SHEET (3, p. 93-96)

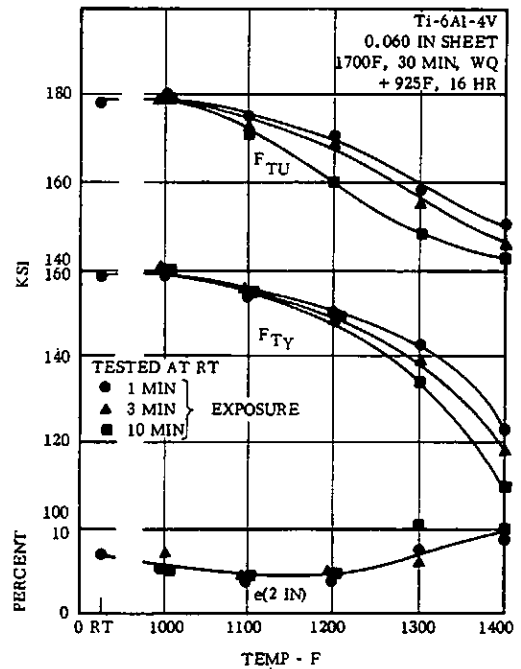
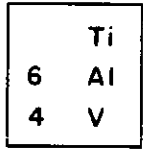


FIG. 3.0218 EFFECT OF SHORT TIME EXPOSURE TO ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF AGED SHEET (23)



Ti-6Al-4V

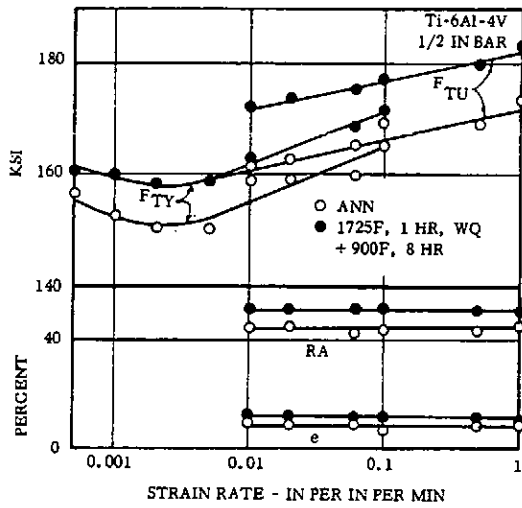


FIG. 3.0219 EFFECT OF STRAIN RATE ON TENSILE PROPERTIES OF ANNEALED AND AGED BAR (13, p. 9)

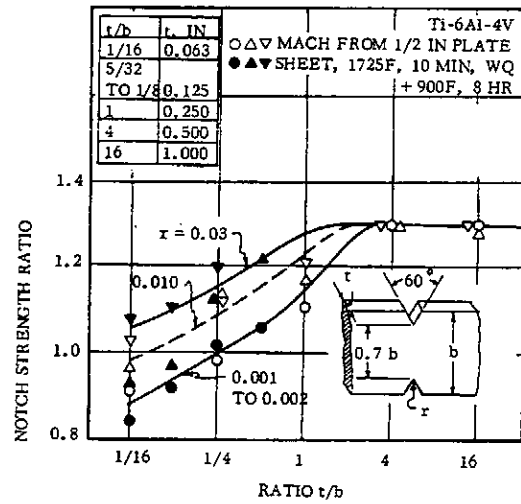


FIG. 3.02712 EFFECT OF NOTCH GEOMETRY ON NOTCH STRENGTH RATIO OF AGED SHEET AND PLATE AT ROOM TEMPERATURE (11, p. 7)

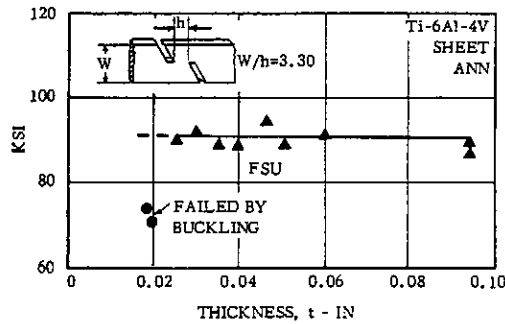


FIG. 3.0251 EFFECT OF THICKNESS ON SHEAR STRENGTH OF ANNEALED SHEET (16, p. A-13,14)

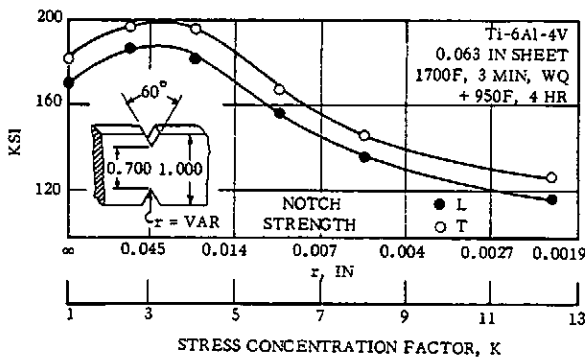


FIG. 3.02711 EFFECT OF STRESS CONCENTRATION ON NOTCH STRENGTH OF AGED SHEET (10, p. 19)

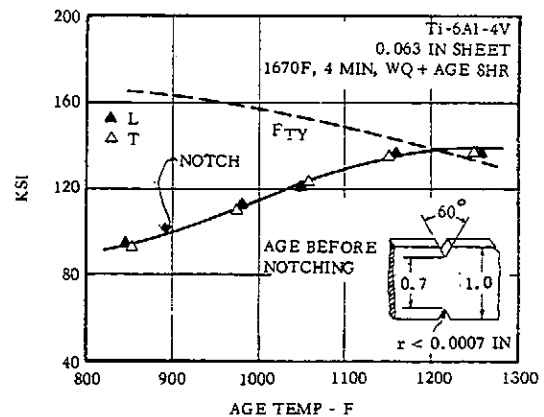


FIG. 3.02713 EFFECT OF AGING TEMPERATURE ON THE SHARP NOTCH STRENGTH OF SHEET (49)

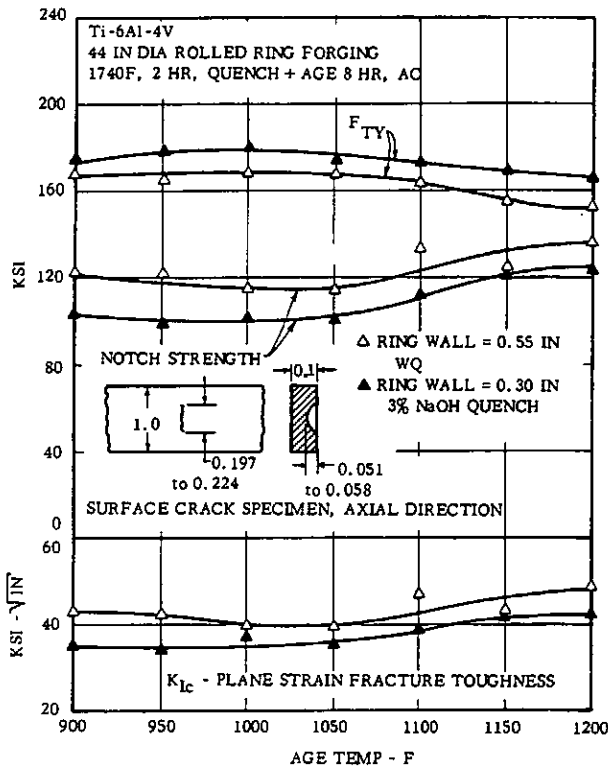


FIG. 3.02721 SHARP NOTCH STRENGTH AND PLANE STRAIN FRACTURE TOUGHNESS OF SURFACE CRACKED SPECIMENS CUT FROM SOLUTION TREATED FORGINGS AND AGED AT VARIOUS TEMPERATURES (43)

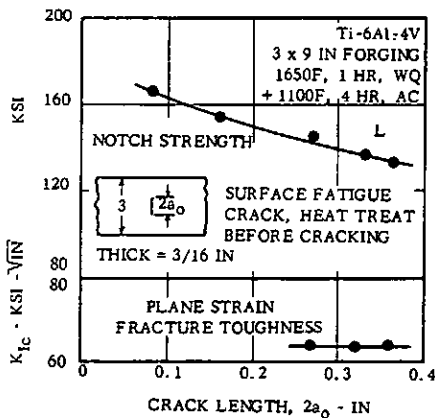


FIG. 3.02722 EFFECT OF SURFACE CRACK LENGTH ON SHARP NOTCH PROPERTIES OF SOLUTION TREATED AND AGED SPECIMENS CUT FROM FORGING (26, Table 32)

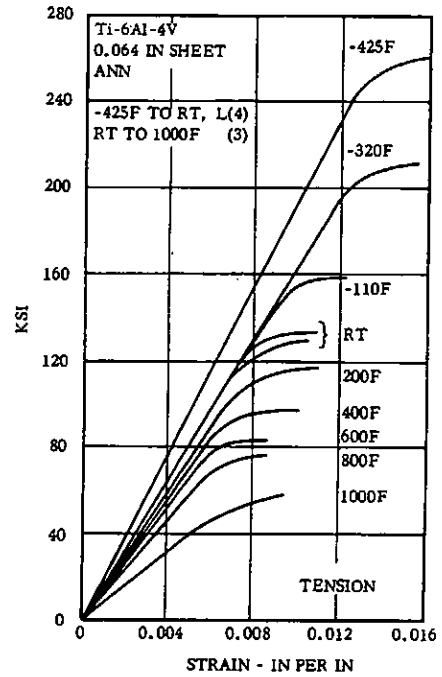


FIG. 3.03111 STRESS-STRAIN CURVES AT VARIOUS TEMPERATURES FOR ANNEALED SHEET (3)(4, p. 44)

Ti
6 Al
4 V

Ti-6Al-4V

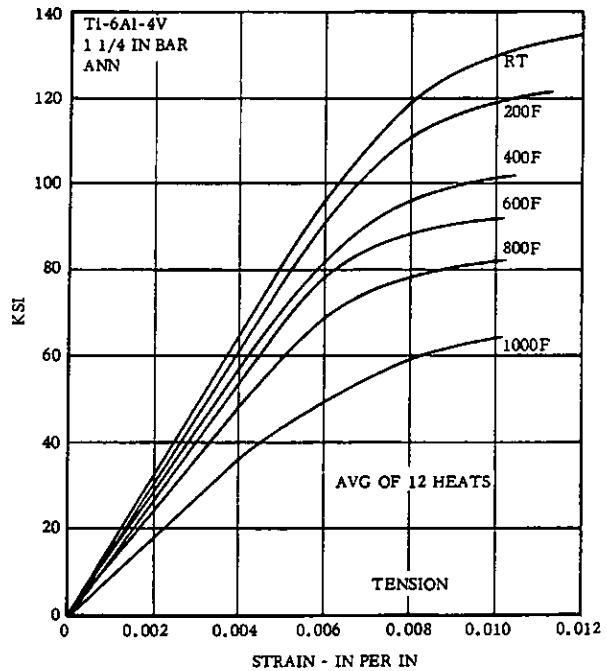


FIG. 3.03112 STRESS-STRAIN CURVES AT ROOM AND ELEVATED TEMPERATURES FOR ANNEALED BAR (3)

	Ti
6	Al
4	V

Ti-6Al-4V

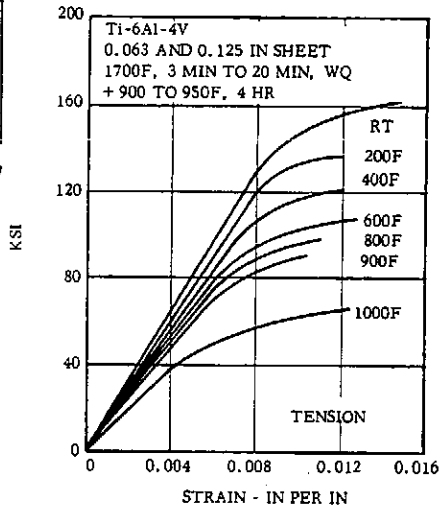


FIG. 3.03113 LONGITUDINAL TENSION STRESS-STRAIN CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 27, 28)

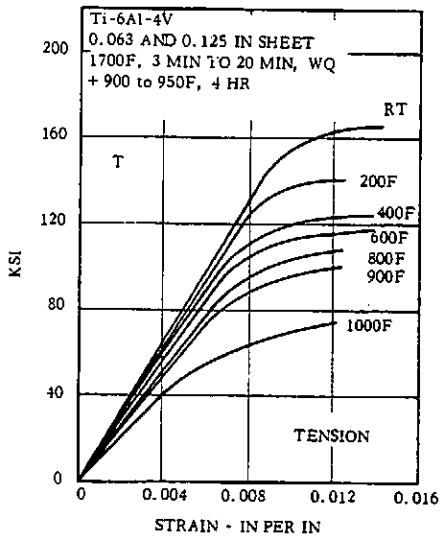


FIG. 3.03114 TRANSVERSE TENSION STRESS-STRAIN CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 27, 28)

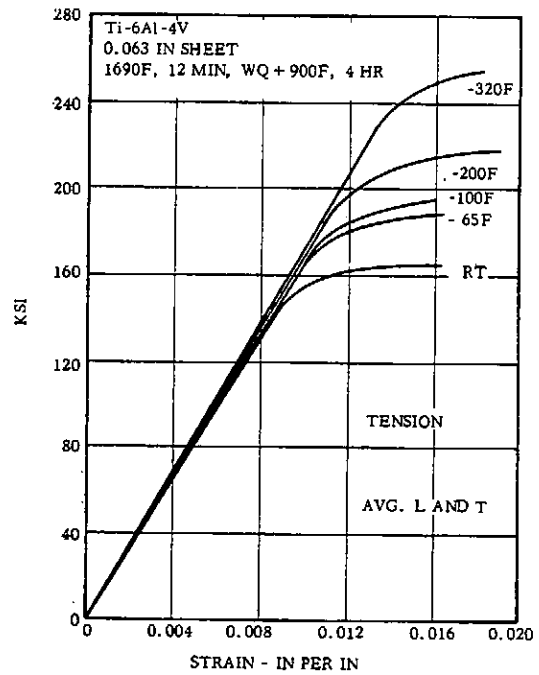


FIG. 3.03115 STRESS-STRAIN CURVES AT LOW TEMPERATURES FOR AGED SHEET

(40, p. 283, 284)

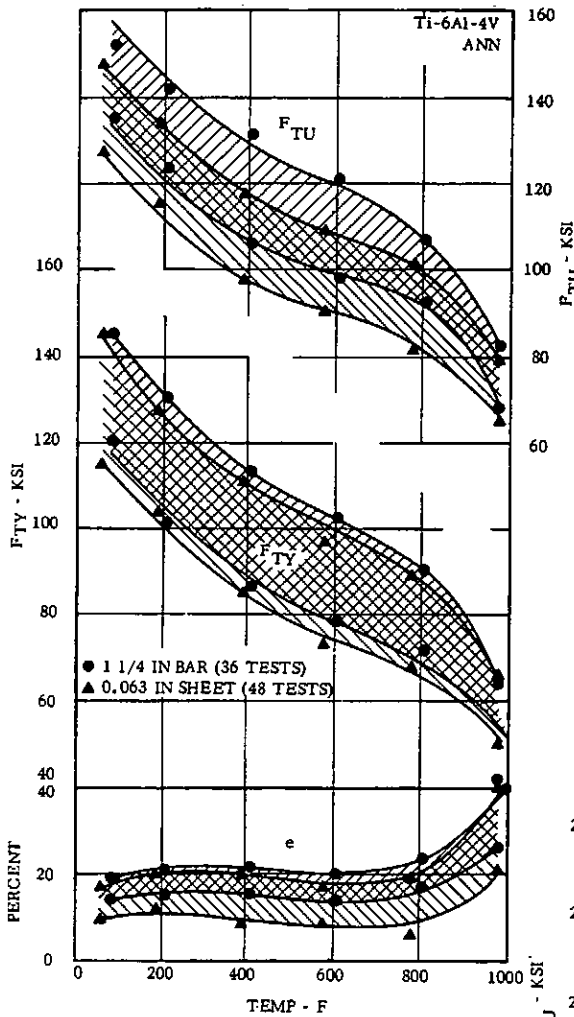


FIG. 3.0312 SPREAD OF TENSILE TEST DATA AT ROOM AND ELEVATED TEMPERATURES FOR ANNEALED SHEET AND BAR (3)

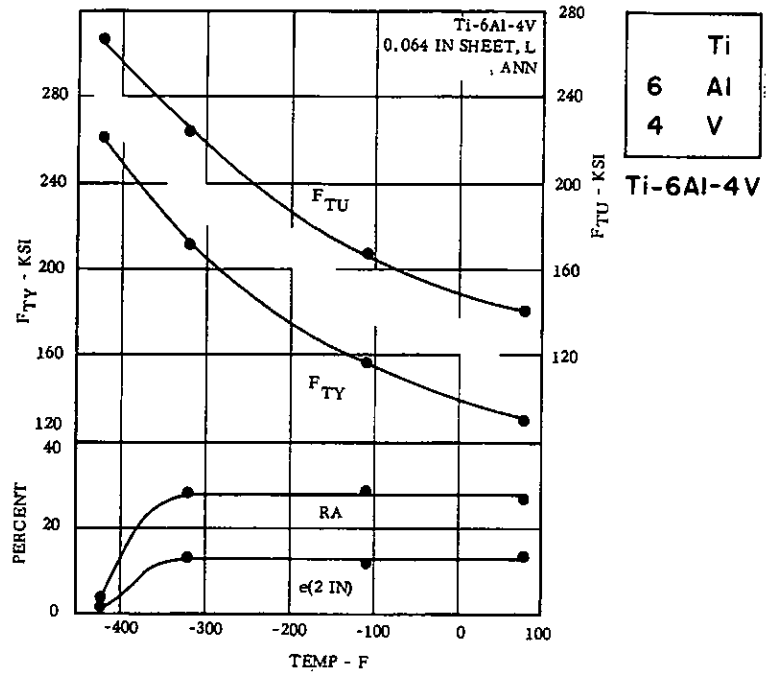


FIG. 3.0313 EFFECT OF LOW TEST TEMPERATURE ON TENSILE PROPERTIES OF ANNEALED SHEET (4, p. 37)

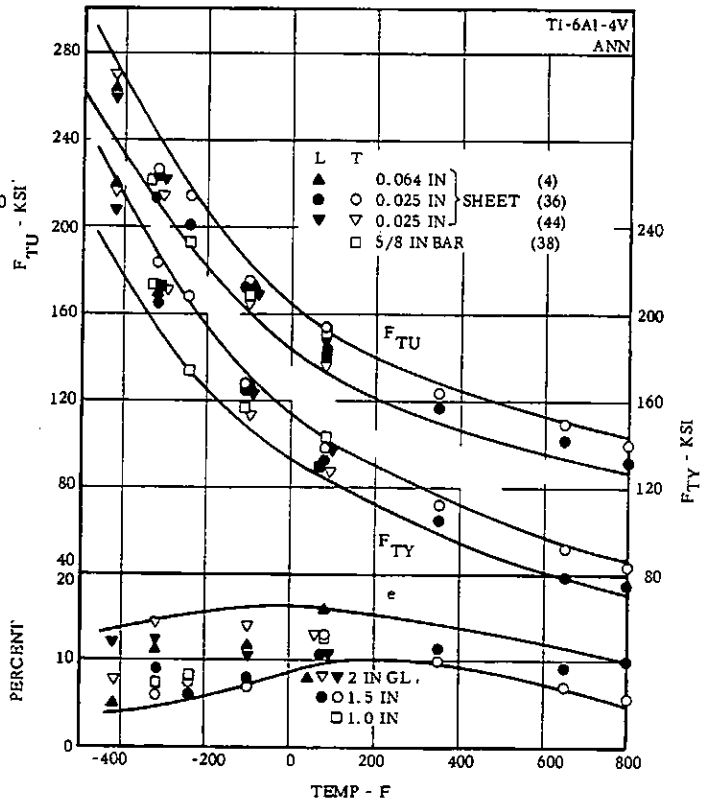


FIG. 3.0314 EFFECT OF LOW TEST TEMPERATURE ON TENSILE PROPERTIES OF ANNEALED SHEET AND BAR (4, p. 37)(36, p. 48)(38, Table 3)(44, p. 114)

	Ti
6	Al
4	V

Ti-6Al-4V

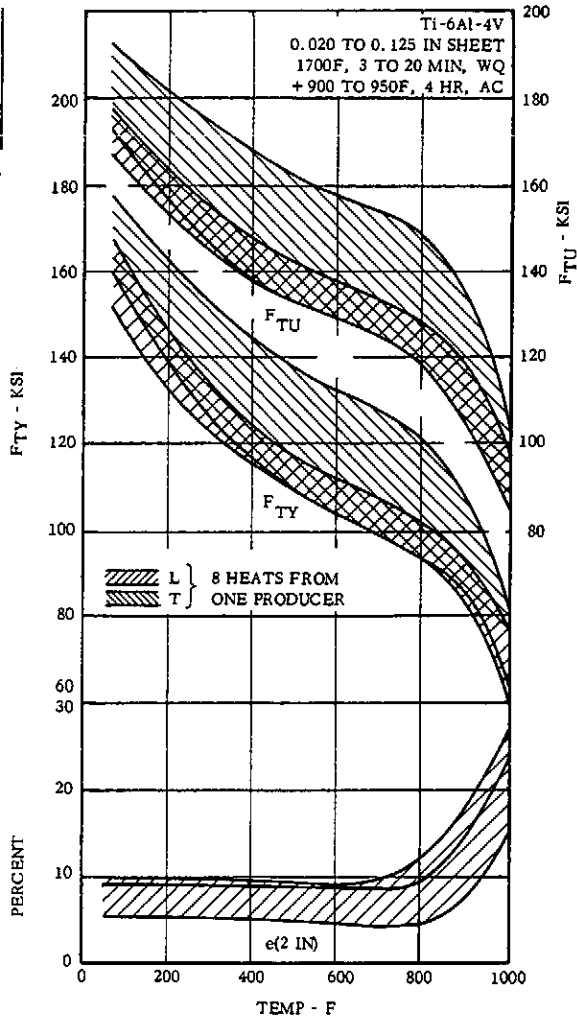


FIG. 3.03151 SPREAD OF TENSILE DATA AT ROOM AND ELEVATED TEMPERATURES FOR EIGHT HEATS OF AGED SHEET (39, p. 68-73)

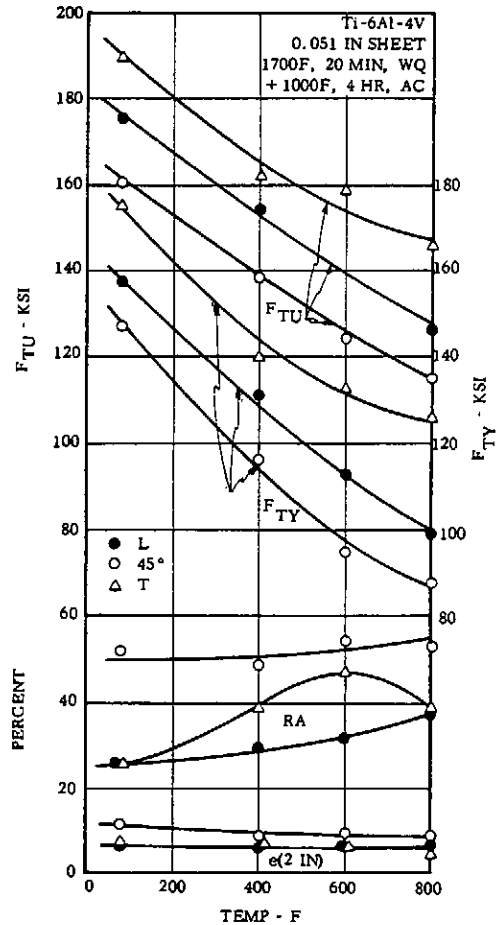


FIG. 3.03152 EFFECT OF TEST TEMPERATURE AND TESTING DIRECTION ON TENSILE PROPERTIES OF AGED SHEET

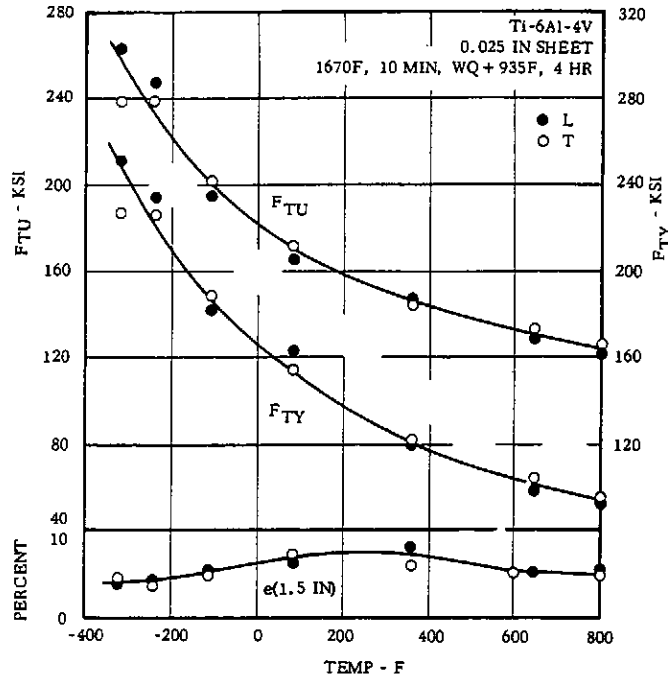


FIG. 3.03153 EFFECT OF LOW AND ELEVATED TEMPERATURES ON THE TENSILE PROPERTIES OF AGED SHEET (36, p. 51)

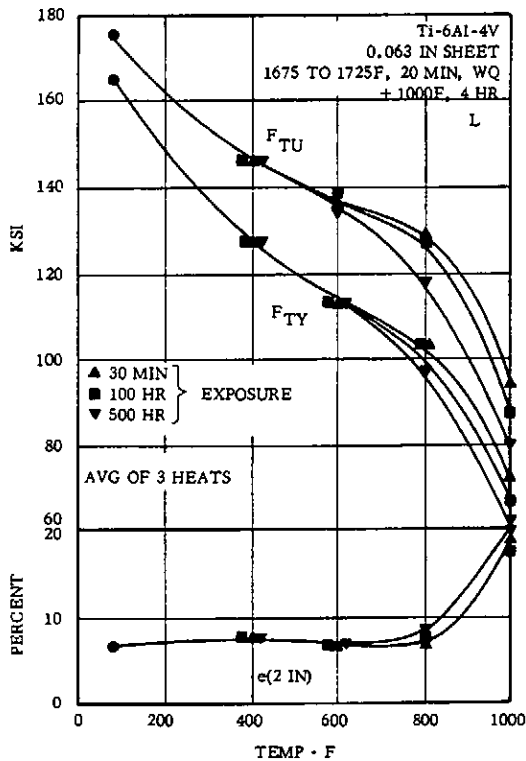
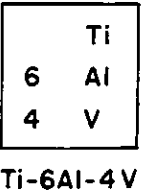


FIG. 3.03154 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON TENSILE PROPERTIES OF AGED SHEET (15, p. 217-219)

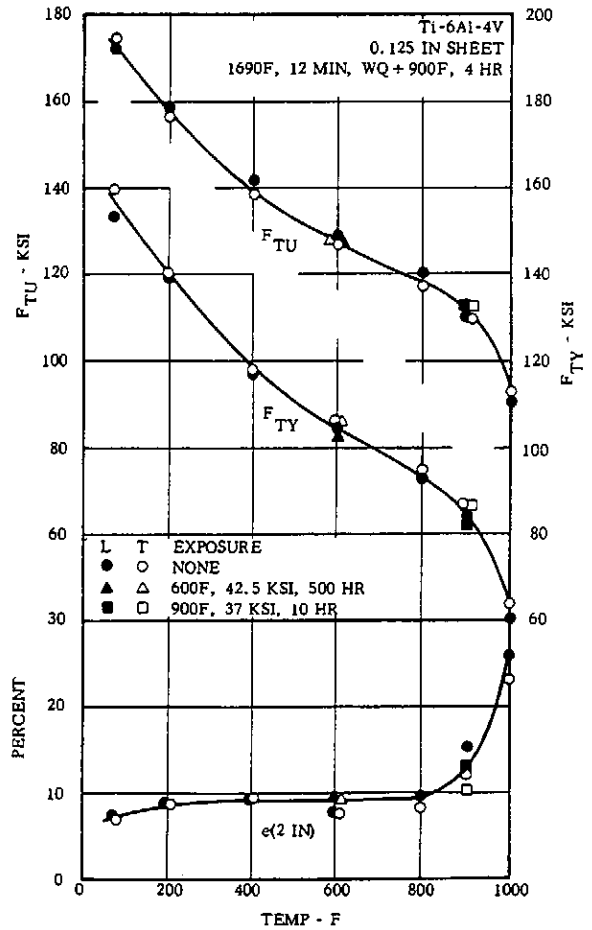
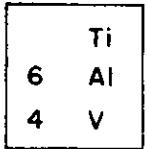


FIG. 3.03155 EFFECT OF ELEVATED TEMPERATURE EXPOSURE ON THE ROOM AND ELEVATED TEMPERATURE TENSILE PROPERTIES OF AGED SHEET (40)



Ti-6Al-4V

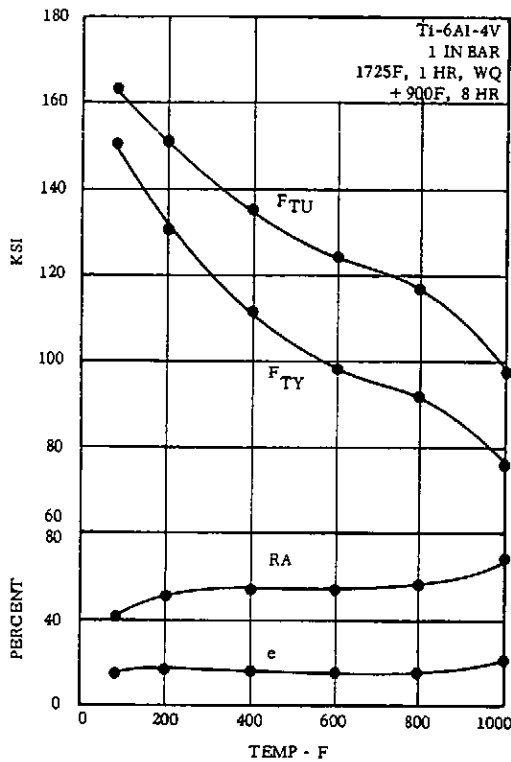


FIG. 3.03156 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF AGED BAR

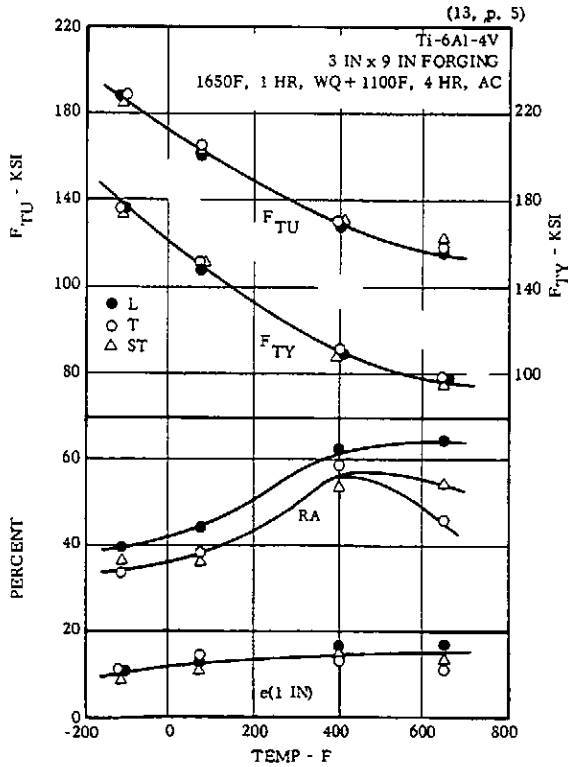


FIG. 3.03157 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF SOLUTION TREATED AND AGED SPECIMENS CUT FROM FORGING (26, Table 7)

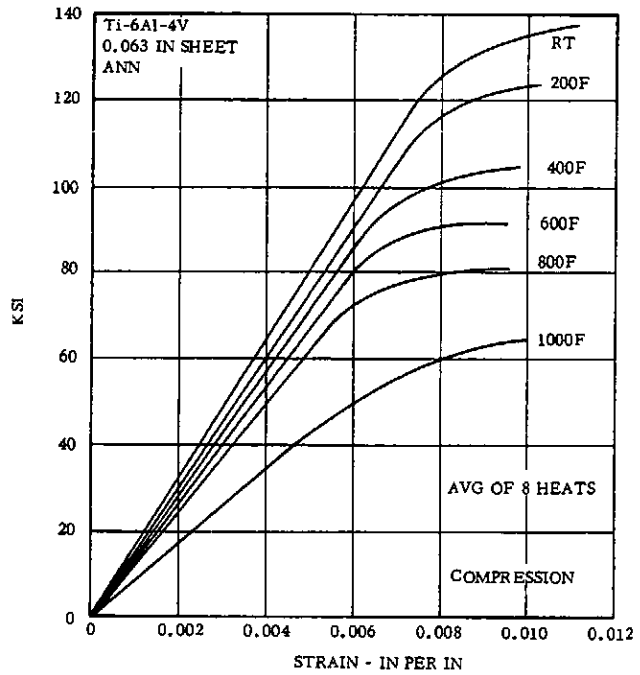


FIG. 3.03211 STRESS-STRAIN CURVES IN COMPRESSION AT ROOM AND ELEVATED TEMPERATURES FOR ANNEALED SHEET (3)

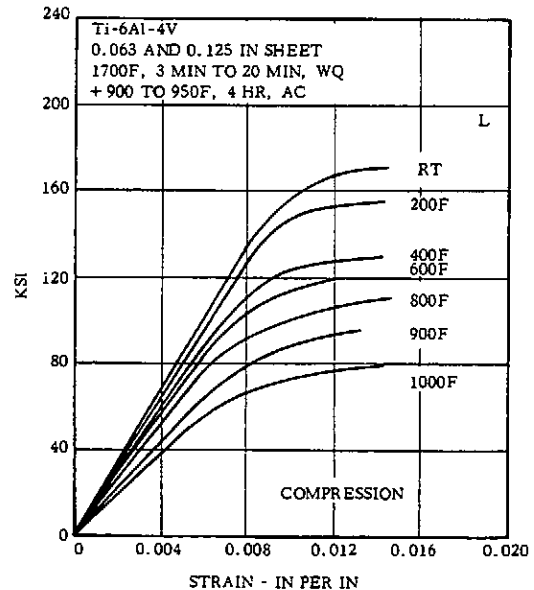


FIG. 3.03212 LONGITUDINAL COMPRESSION STRESS-STRAIN CURVES AT ELEVATED TEMPERATURE FOR AGED SHEET (42, p. 29, 30)

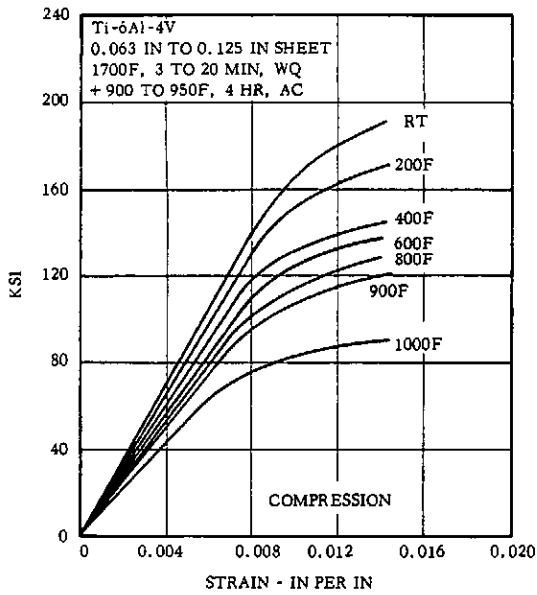


FIG. 3.03213 TRANSVERSE COMPRESSION STRESS - STRAIN CURVE AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 29, 30)

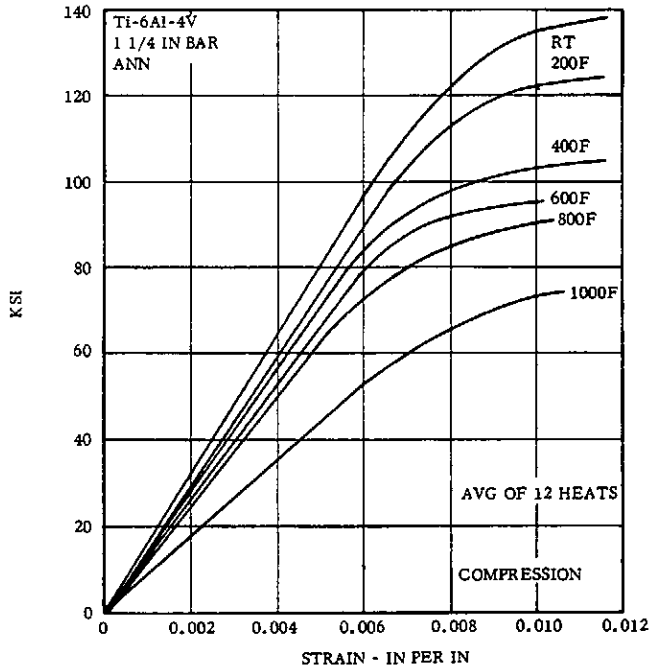
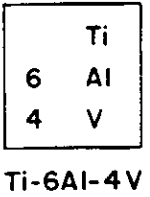


FIG. 3.03214 STRESS-STRAIN CURVES IN COMPRESSION AT ROOM AND ELEVATED TEMPERATURES FOR ANNEALED BAR (3)

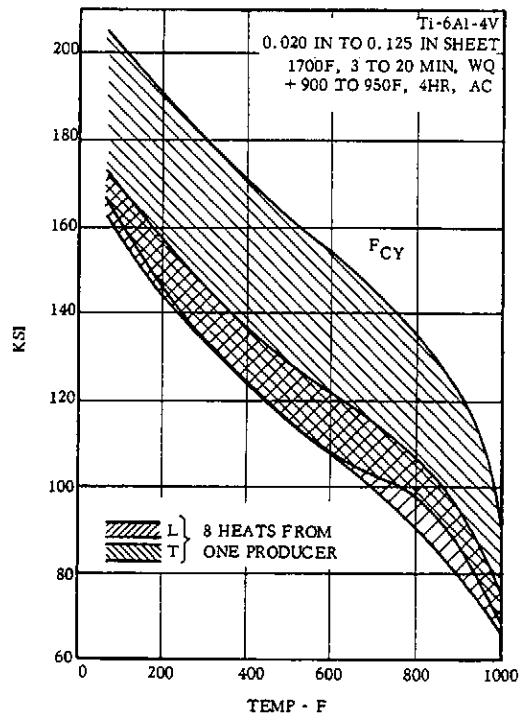


FIG. 3.03221 SPREAD OF COMPRESSIVE YIELD STRENGTH AT ROOM AND ELEVATED TEMPERATURES FOR EIGHT HEATS OF AGED SHEET (39, p. 74-79)

Ti
6 Al
4 V
Ti-6Al-4V

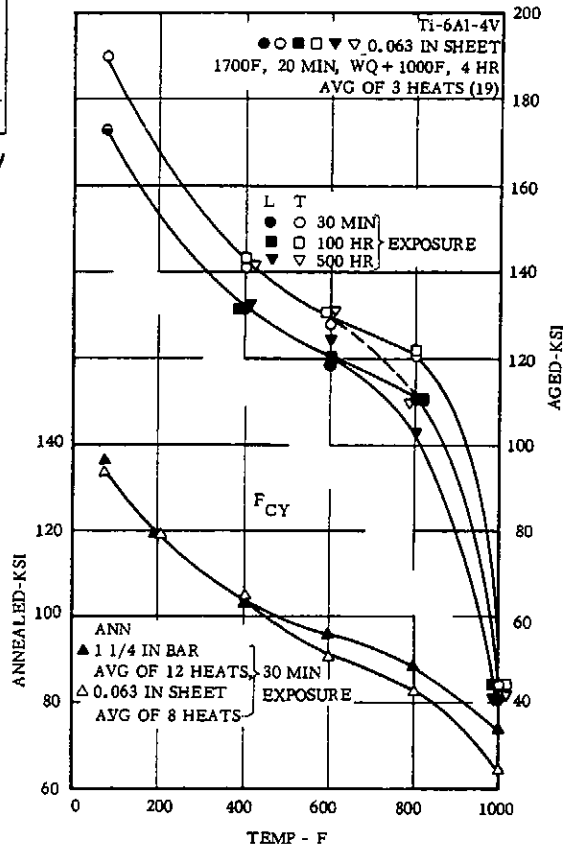


FIG. 3.03223 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON COMPRESSIVE YIELD STRENGTH OF ANNEALED AND AGED SHEET AND BAR (15, p. 229-232)(19)

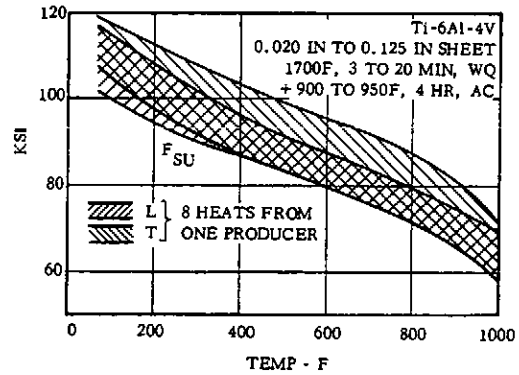


FIG. 3.0351 SPREAD OF SHEAR STRENGTH AT ROOM AND ELEVATED TEMPERATURE FOR EIGHT HEATS OF AGED SHEET (39)

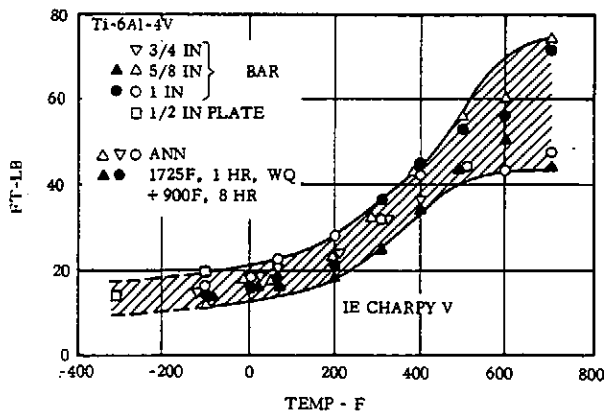


FIG. 3.0331 EFFECT OF TEST TEMPERATURE ON IMPACT STRENGTH OF ANNEALED AND AGED PLATE AND BAR (13, p. 34, 35)

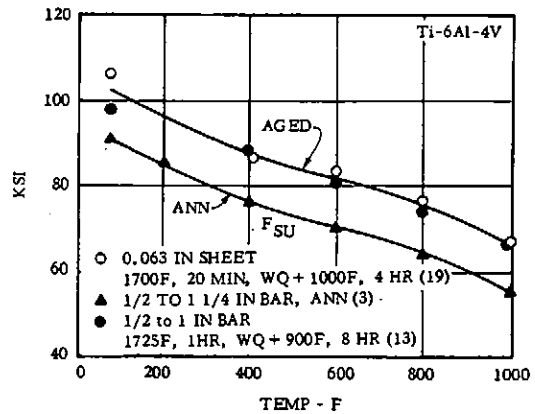


FIG. 3.0352 EFFECT OF TEST TEMPERATURE ON SHEAR STRENGTH OF ANNEALED AND AGED SHEET AND BAR (3)(13, p. 19)(19)

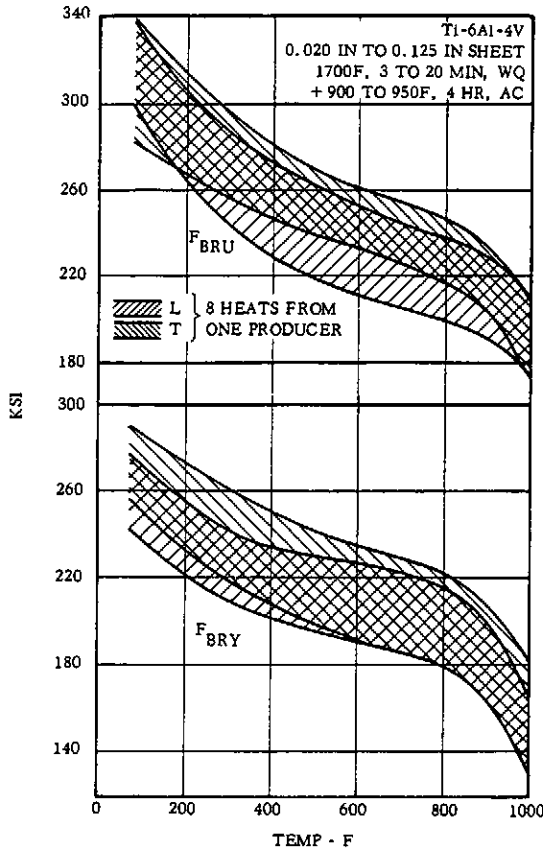


FIG. 3.0361 SPREAD OF BEARING STRENGTH AT ROOM AND ELEVATED TEMPERATURES FOR EIGHT HEATS OF AGED SHEET (39, p. 91-97)

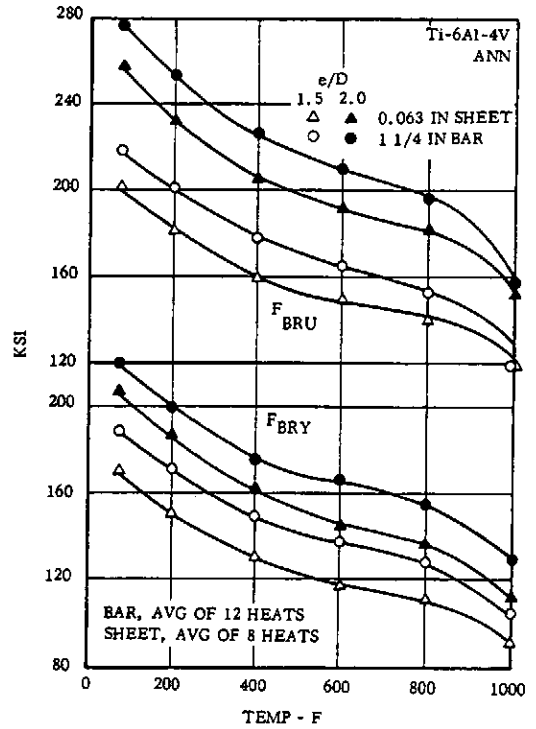


FIG. 3.0362 EFFECT OF TEST TEMPERATURE ON BEARING PROPERTIES OF ANNEALED SHEET AND BAR (3)(7, p. 102)

Ti
6 Al
4 V

Ti-6Al-4V

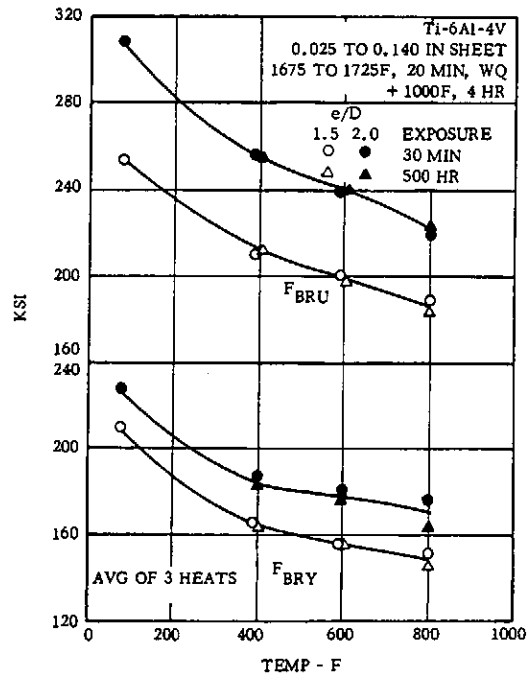


FIG. 3.0363 EFFECT OF EXPOSURE AND TEST TEMPERATURE OF BEARING PROPERTIES OF AGED SHEET (15, p. 234-235)

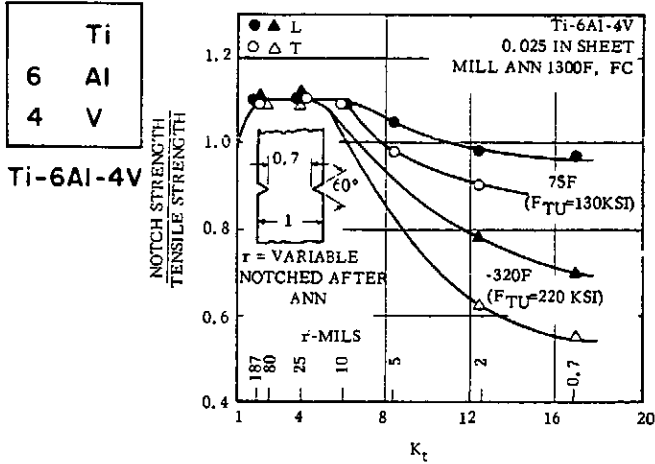


FIG. 3.03711 NOTCH STRENGTH RATIO AS FUNCTION OF STRESS-CONCENTRATION FACTOR FOR ANNEALED SHEET TESTED AT ROOM TEMPERATURE AND -320F (36, p. 114)

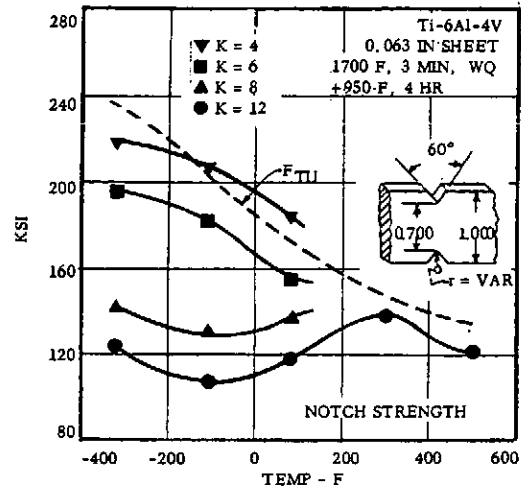


FIG. 3.03713 EFFECT OF TEST TEMPERATURE AND STRESS CONCENTRATION FACTOR ON NOTCH STRENGTH OF AGED SHEET (10, p. 25)

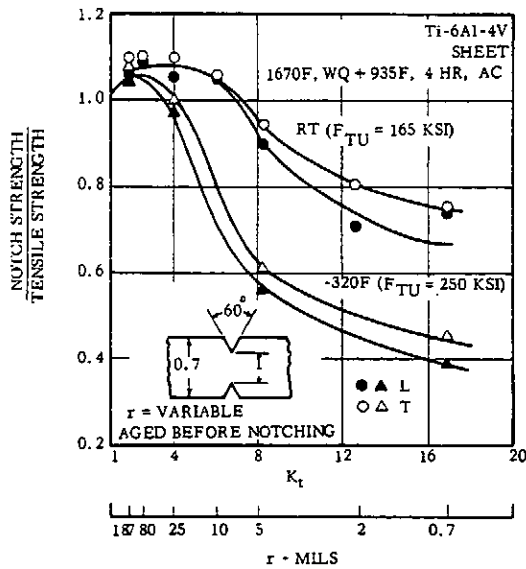


FIG. 3.03712 NOTCH STRENGTH RATIO AS FUNCTION OF STRESS CONCENTRATION FACTOR FOR AGED SHEET TESTED AT ROOM TEMPERATURE AND -320F (26, p. 115)

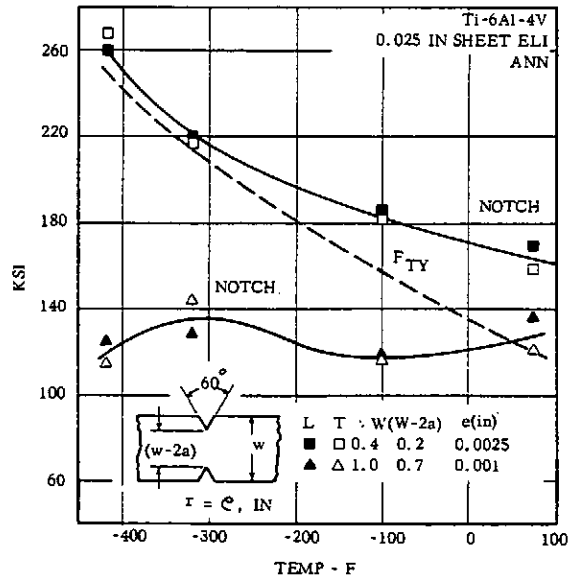


FIG. 3.03714 EFFECT OF LOW TEST TEMPERATURES ON THE MILD AND SHARP NOTCH PROPERTIES OF ANNEALED ELI SHEET (44, p. 414-117)

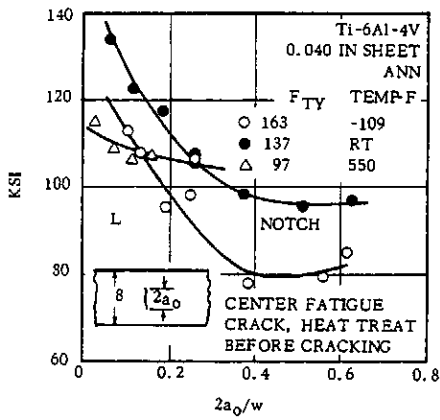


FIG. 3.03715 EFFECT OF CRACK LENGTH ON THE SHARP NOTCH PROPERTIES OF ANNEALED SHEET, TESTED AT SEVERAL TEMPERATURES (35, Table 3)

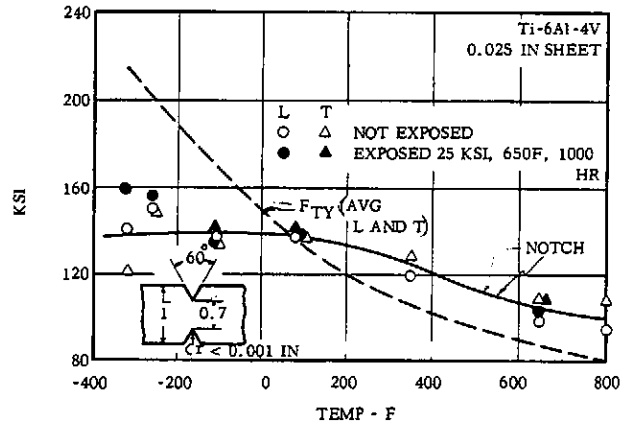


FIG. 3.03717 EFFECT OF TEST TEMPERATURE ON SHARP NOTCH STRENGTH OF ANNEALED SHEET BEFORE AND AFTER ELEVATED TEMPERATURE EXPOSURE (36, p. 49, 50)

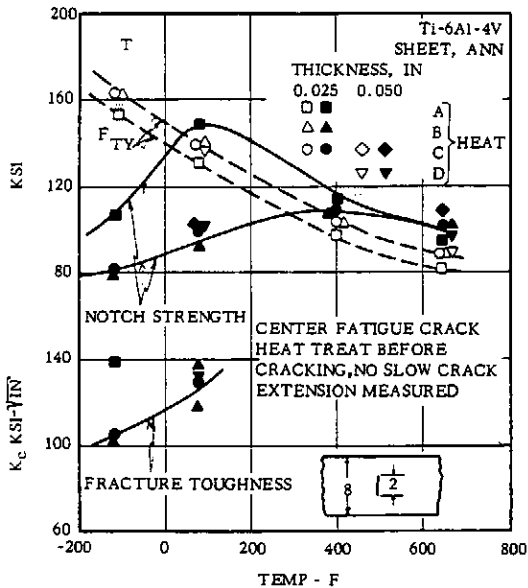
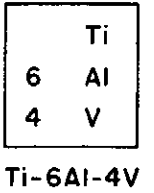


FIG. 3.03716 EFFECT OF TEST TEMPERATURE ON SHARP NOTCH PROPERTIES OF SEVERAL HEATS OF MILL ANNEALED SHEET (34, p. 131, 133)

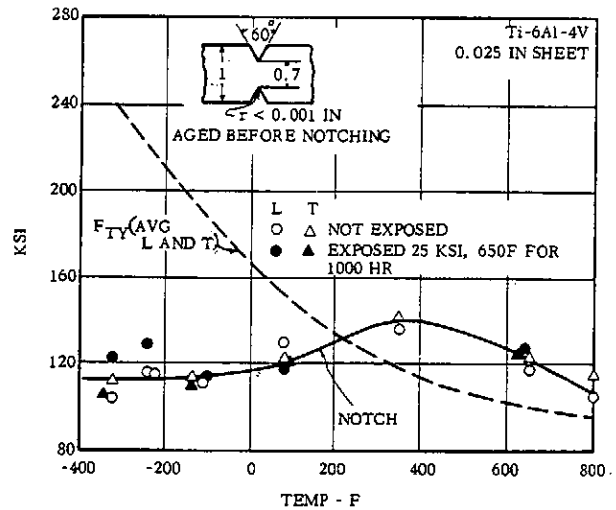
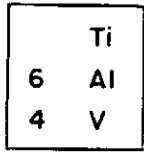


FIG. 3.03718 EFFECT OF TEST TEMPERATURE ON SHARP NOTCH STRENGTH OF AGED SHEET BEFORE AND AFTER ELEVATED TEMPERATURE EXPOSURE (36, p. 52, 53)



Ti-6Al-4V

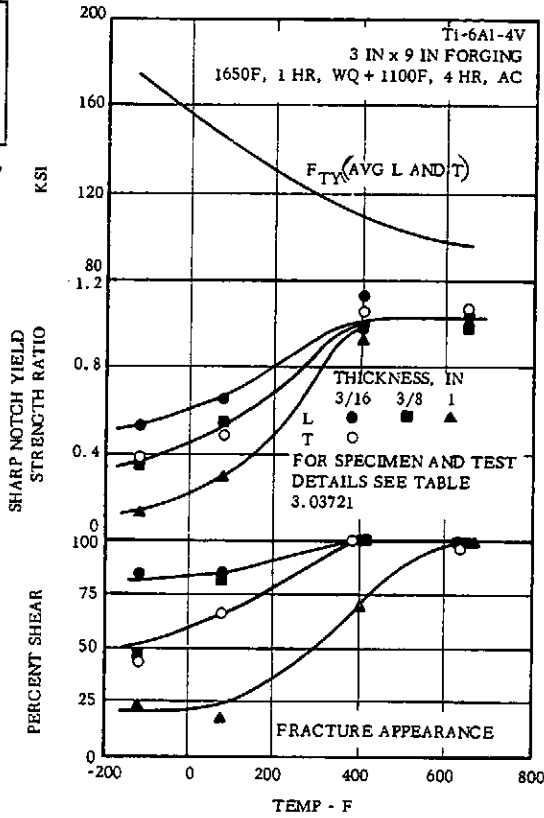


FIG. 3.03719 EFFECT OF TEST TEMPERATURE ON THE SHARP NOTCH PROPERTIES OF SOLUTION TREATED AND AGED SPECIMENS OF VARIOUS THICKNESSES CUT FROM FORGING (26, Table 18)

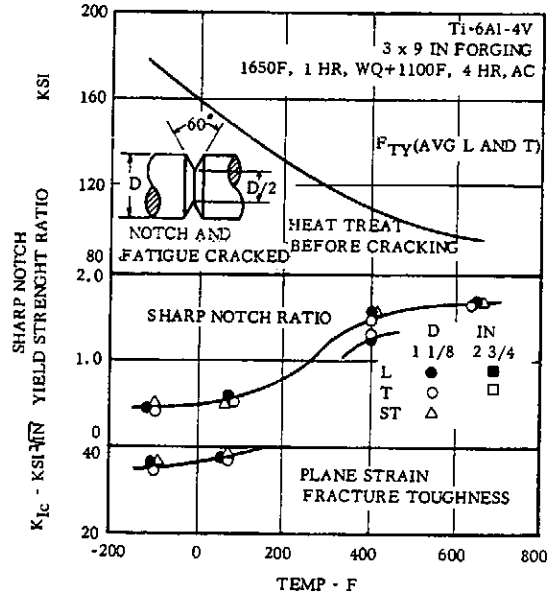


FIG. 3.03723 EFFECT OF TEST TEMPERATURE ON SHARP NOTCH STRENGTH RATIO AND PLANE STRAIN FRACTURE TOUGHNESS AND OF SOLUTION TREATED AND AGED ROUND BARS CUT FROM FORGING (26, Table 27 and 31)

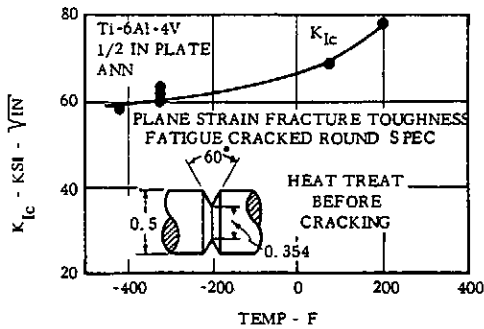


FIG. 3.03722 PLANE STRAIN FRACTURE TOUGHNESS OF ANNEALED PLATE AT LOW TEMPERATURES (30, Fig. 11)

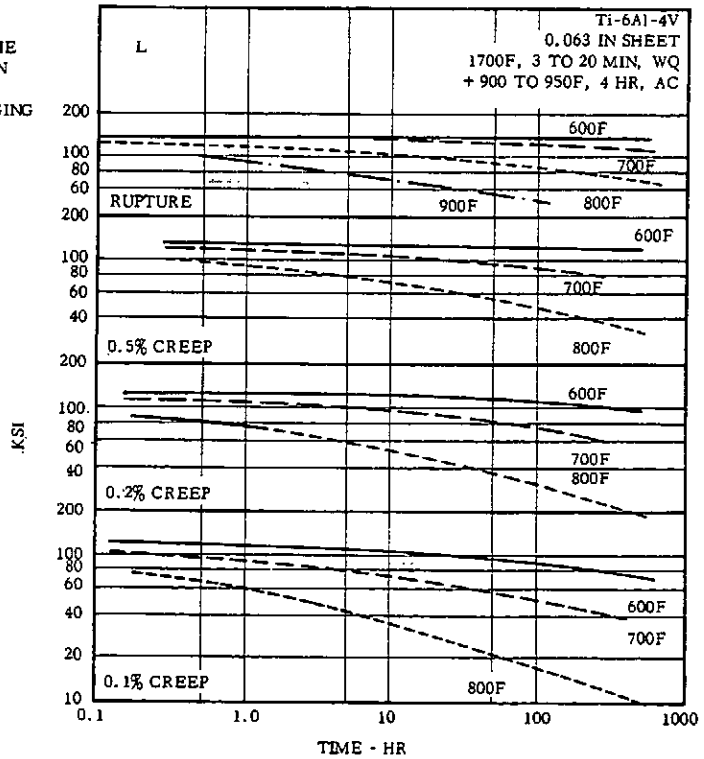


FIG. 3.041 AVERAGE CREEP AND RUPTURE CURVES AT SEVERAL TEMPERATURES FOR AGED SHEET FROM THREE HEATS (41, p. 57-59)

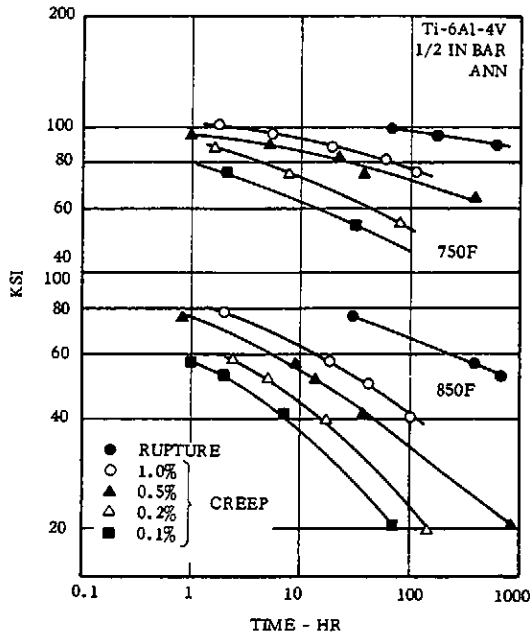


FIG. 3.042 CREEP AND CREEP RUPTURE CURVES AT 750 AND 850F FOR ANNEALED BAR (9, p. 23)

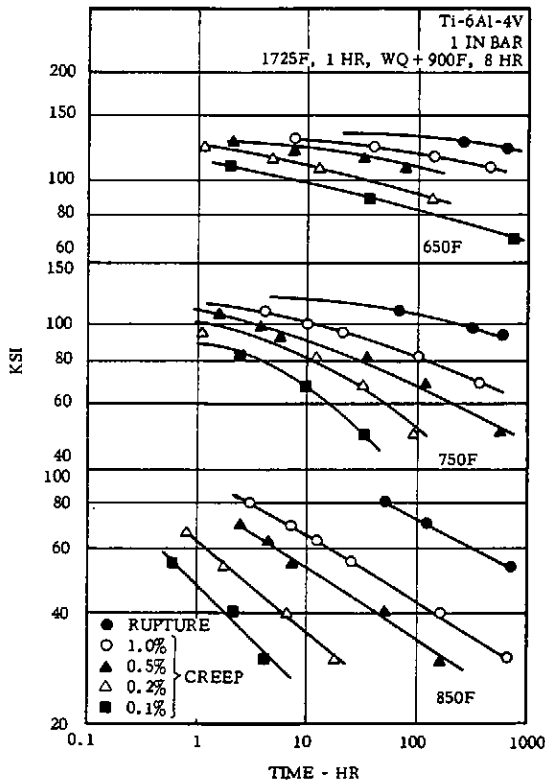


FIG. 3.043 CREEP AND CREEP RUPTURE CURVES AT 650 TO 850F FOR AGED BAR (5, G-16-18)

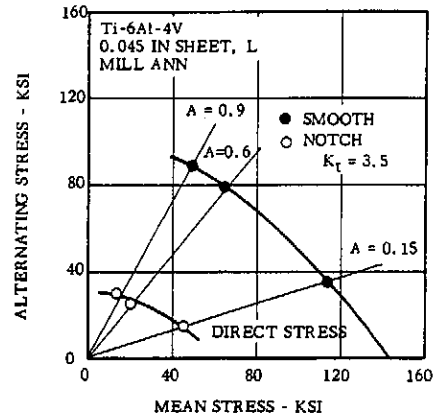


FIG. 3.054 STRESS RANGE DIAGRAM AT 10^7 CYCLES FOR SMOOTH AND NOTCHED SPECIMENS OF MILL ANNEALED SHEET (27, Fig. 11)

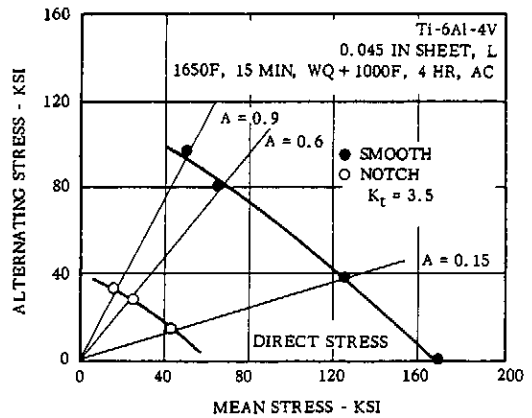


FIG. 3.055 STRESS RANGE DIAGRAM AT 10^7 CYCLES FOR SMOOTH AND NOTCHED SPECIMENS OF AGED SHEET (27, Fig. 12)

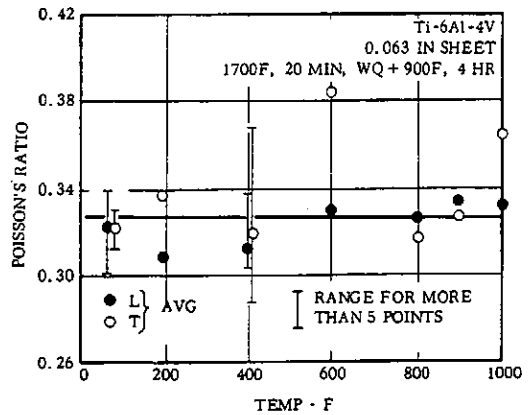
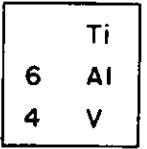
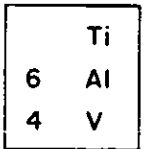


FIG. 3.061 EFFECT OF TEST TEMPERATURE ON POISSON'S RATIO (40, p. 242)



Ti-6Al-4V



Ti-6Al-4V

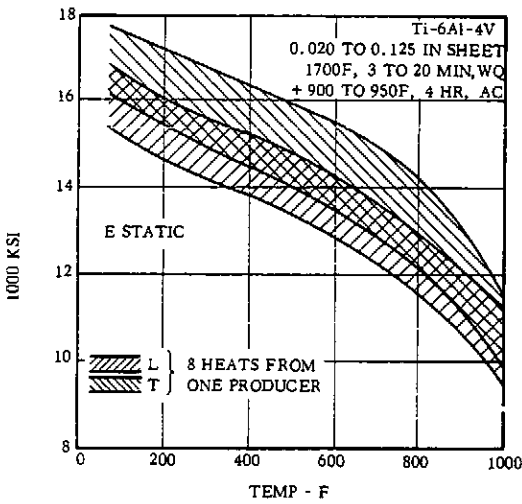


FIG. 3.0621 SPREAD OF ELASTIC MODULUS AT ROOM AND ELEVATED TEMPERATURE FOR EIGHT HEATS OF AGED SHEET (39, p. 68-73)

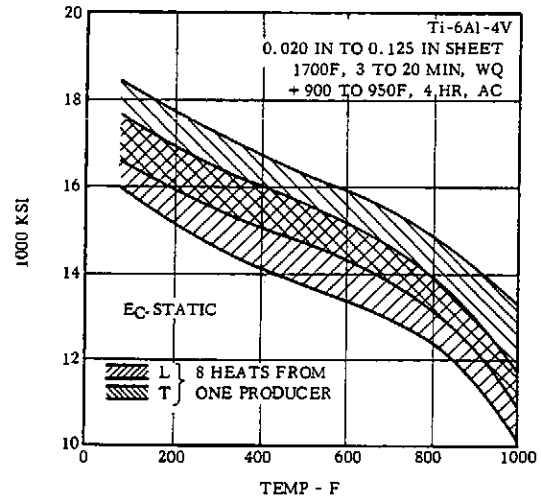


FIG. 3.0624 SPREAD OF ELASTIC COMPRESSIVE MODULUS AT ROOM AND ELEVATED TEMPERATURE FOR EIGHT HEATS OF AGED SHEET (39, p. 74-79)

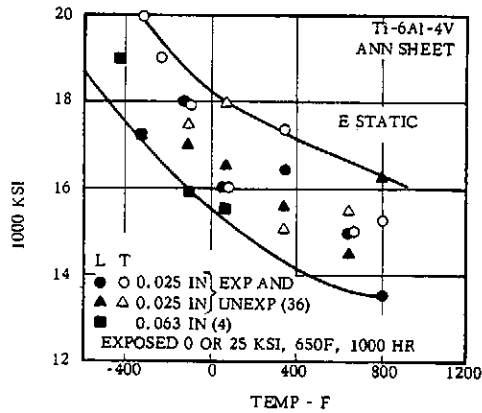


FIG. 3.0622 MODULUS OF ELASTICITY AT LOW AND ELEVATED TEMPERATURES FOR ANNEALED SHEET (4, p. 39)(36, p. 28, 30)

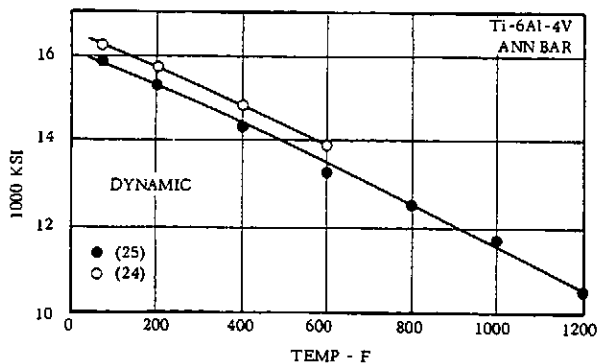


FIG. 3.0623 DYNAMIC MODULUS OF ELASTICITY FOR ANNEALED BAR AT ELEVATED TEMPERATURES (24)(25)

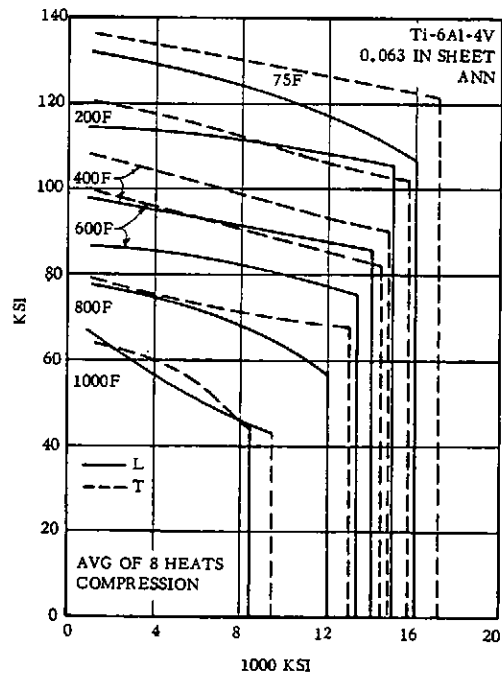


FIG. 3.0641 TANGENT MODULUS CURVES IN COMPRESSION AT ROOM AND ELEVATED TEMPERATURES FOR ANNEALED SHEET (3)

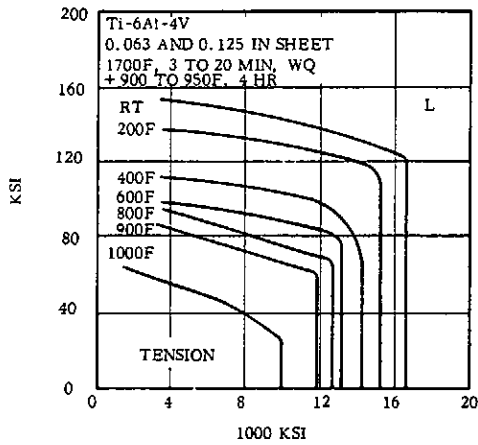


FIG. 3.0642 LONGITUDINAL TENSILE TANGENT MODULUS CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 21, 22)

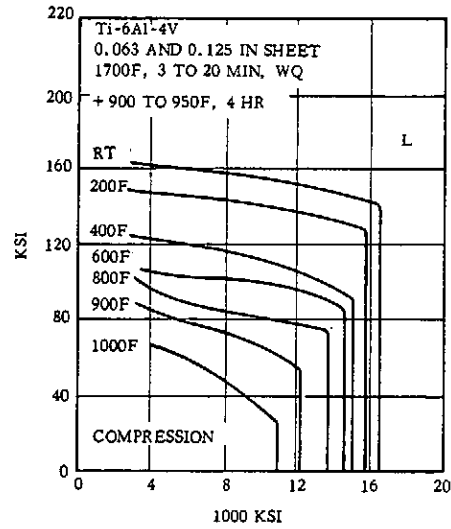
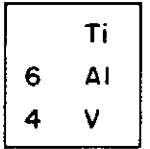


FIG. 3.0644 LONGITUDINAL COMPRESSION TANGENT MODULUS CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 23, 24)



Ti-6Al-4V

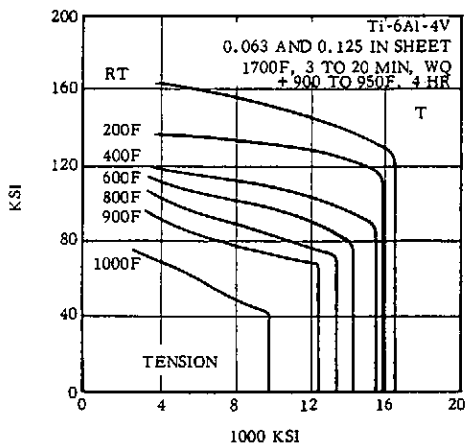


FIG. 3.0643 TRANSVERSE TENSILE TANGENT MODULUS CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 21, 22)

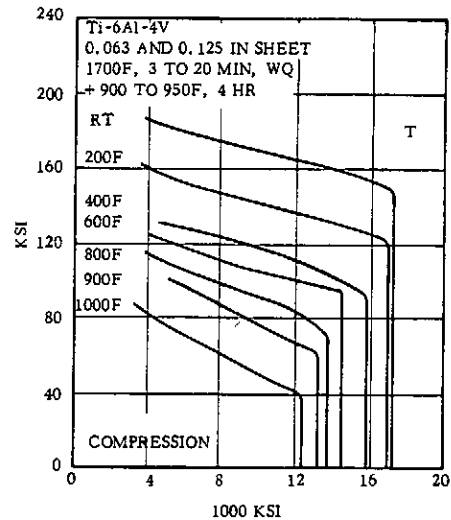
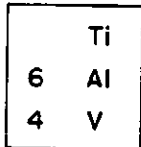


FIG. 3.0645 TRANSVERSE COMPRESSION TANGENT MODULUS CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 23, 24)



Ti-6Al-4V

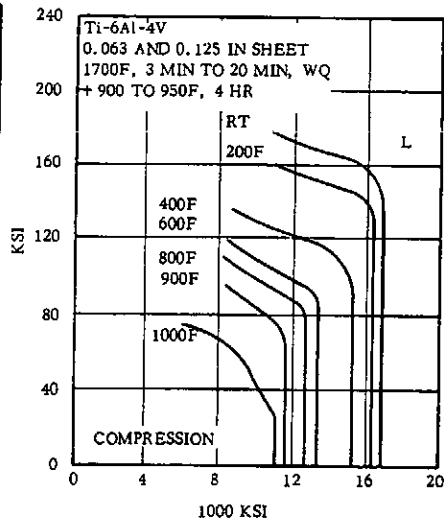


FIG. 3.0651 LONGITUDINAL COMPRESSION SECANT MODULUS CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 25-26)

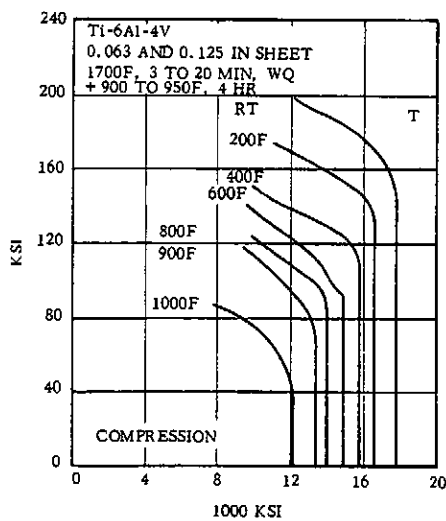


FIG. 3.0652 TRANSVERSE COMPRESSION SECANT MODULUS CURVES AT ELEVATED TEMPERATURES FOR AGED SHEET (42, p. 25, 26)

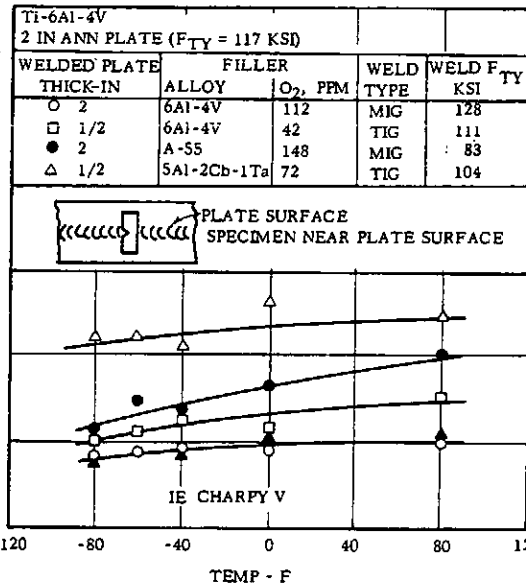


FIG. 4.034 EFFECT OF TEST TEMPERATURE ON THE IMPACT PROPERTIES OF PLATE WELDED WITH VARIOUS FILLERS (28, Figs. 10, 11)

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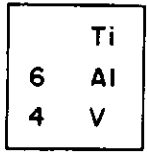
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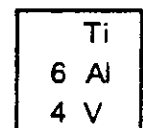
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Ti-6Al-4V



Ti-6Al-4V

A1. GENERAL
 This alloy is the most widely used of all the alpha-beta titanium compositions. It may be heat treated to a range of strength levels and, in its fully aged condition, is successfully used in highly stressed welded structures. However, in the maximum strength conditions, careful attention must be given to the fracture toughness in a design of highly stressed parts. Hardenability is limited and sections over 1 inch thick may not develop full properties. The alloy has good strength and high stability up to 750 F. Very high strength is obtained at cryogenic temperatures, however, the fracture toughness below about -250 F is extremely poor for the fully heat treated conditions. Low temperature applications should employ the extra low interstitial (ELI) grades. The alloy exhibits some susceptibility to environment-assisted cracking in halide containing aqueous environments and in hydrogen. Properties also depend on the texture in rolled products. Improved properties are obtained by using the ELI grades and beta-processing. The alloy can be welded using special techniques. Forming requires special methods and elevated temperatures.

- A1.01 Commercial Designation
6Al-4V Titanium Alloy.
- A1.02 Alternate Designations
C 120AV, HA 6510, RS 120A, Ti-6Al-4V, Ti-6Al-4V ELI.
- A1.03 Specifications
Table A1.03.
- A1.04 Composition
- A1.041 AMS specified composition for wrought product and weld wire, Table A1.041.
- A1.042 AMS specified composition for powder and powder metallurgy products, Table A1.042.
- A1.09 Special Considerations
This alloy is somewhat susceptible to environment assisted cracking in halide containing aqueous environments and in hydrogen under sustained loading and in fatigue. The susceptibility depends on heat treatment and mechanical processing (see A2.03).

A2. PHYSICAL AND CHEMICAL PROPERTIES

A2.03 Chemical Properties
 This alloy is somewhat susceptible to environment assisted cracking in halide containing aqueous environments and in hydrogen under sustained load (stress corrosion cracking) and in fatigue (corrosion fatigue). The degree of susceptibility depends on the prior thermal and mechanical treatment, which is reduced by the use of ELI grades and beta-processing (A12, A13). Because recommended practices for obtaining stress-corrosion cracking data are not yet available, such data are not reported here. The reader should consult references (A12, A13) to obtain information on the influences of strength and microstructure on stress-corrosion cracking susceptibility.

A3. MECHANICAL PROPERTIES

- A3.01 Specified Mechanical Properties**
- A3.011 AMS specified mechanical properties.
- A3.0111 AMS specified mechanical properties for sheet, strip, and plate, Table A3.0111.
- A3.0112 AMS specified mechanical properties for bar, forging, and ring, Table A3.0112.
- A3.0113 AMS specified mechanical properties for bar, and forging (rectangle), Table A3.0113.
- A3.0114 AMS specified mechanical properties for extrusions, flash welded rings, and powder-metallurgy products, Table A3.0114.
- A3.05 Fatigue Properties**
- A3.056 Influence of load ratio (R) on fatigue crack growth for mill annealed plate in air at room temperature, Figure A3.056.
- A3.057 Influence of environment on fatigue crack growth for mill annealed plate at room temperature, Figure A3.057.
- A3.058 Fatigue crack growth in dehumidified argon for mill annealed plate at different temperatures and K levels, Figure A3.058.

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- A5. AMS 4967E (January 15, 1977).
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Ti
6 Al
4 V

ADDITIONAL REFERENCES

Ti-6Al-4V

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Alloy	Ti-6Al-4V
AMS	Form
4906	Sheet, strip, and plate
4907C	
4911D	
4928H	Bars and forgings - annealed, 120 ksi yield
4967E	Bars, forgings, and rings - annealed, heat treatable
4934A	Extrusions and flash welded rings - solution heat treated and aged, and annealed
4954C	Welding wire
4956A	
4996	Powder-metallurgy products
4998	Powder

TABLE A1.03. SPECIFICATIONS

Alloy	Ti-6Al-4V			
	Normal		ELI	
	Percent		Percent	
Grade				
Composition	Min	Max	Min	Max
Al	5.50	6.75	5.50	6.50(a)
V	3.50	4.50	3.50	4.50
Fe	-	0.30	-	0.25(a)
O	-	0.20(b)	-	0.13(a)
C	-	0.10(b)(c)	-	0.08(a)
Ni	-	0.05(b)	-	0.05(a)
H	-	(500 ppm)	-	(500 ppm)
Y	-	0.0125(b)(c)	-	0.0125(a)
	-	(125 ppm)	-	(125 ppm)
	-	0.005	-	0.005
	-	(50 ppm)	-	(50 ppm)
Residuals				
Each	-	0.10(d)	-	0.10(a)(d)
Total	-	0.40(d)	-	0.30(a)(d)
Ti	Remainder		Remainder	

- (a) AMS 4956A specifies aluminum - 6.75 Max, iron - 0.15 Max, oxygen - 0.08 Max, carbon - 0.03 Max, nitrogen - 0.012 Max, hydrogen - 0.005 Max, residual elements - 0.03 Max each and 0.10 Max total.
- (b) AMS 4954C specifies oxygen - 0.18 Max, carbon - 0.05 Max, nitrogen - 0.03 Max, hydrogen - 0.015 Max.
- (c) AMS 4906 specifies carbon - 0.08 Max; AMS 4911D specifies carbon - 0.08 Max, hydrogen 0.015 Max.
- (d) Determination not required for routine acceptance.

TABLE A1.041. AMS SPECIFIED COMPOSITION FOR WROUGHT PRODUCT AND WELD WIRE (A1.A2.A3.A4.A5.A6.A7.A8.A9)

Alloy	Ti-6Al-4V			
	Percent		Percent	
	Min	Max	Min	Max
Composition				
Al	5.50	6.75	5.50	6.75
V	3.50	4.50	3.50	4.50
O	0.13	0.19	0.13	0.18
Fe	-	0.30	-	0.30
C	-	0.10	-	0.10
Sn(a)	-	0.10	-	0.10
Mo(a)	-	0.10	-	0.10
Cu(a)	-	0.10	-	0.10
Mn(a)	-	0.10	-	0.10
Zr	-	0.10	-	0.10
Ni	-	0.04	-	0.04
		(400 ppm)		(400 ppm)
H	-	0.0125	-	0.012
		(125 ppm)		(120 ppm)
Y	-	0.001	-	0.001
		(10 ppm)		(10 ppm)
Residuals, total(b)	-	0.20	-	0.20
Ti	Remainder		Remainder	

- (a) Tin plus molybdenum plus copper plus manganese shall not exceed 0.20 Max.
- (b) Determination not required for routine acceptance.

TABLE A1.042. AMS SPECIFIED COMPOSITION FOR POWDER AND POWDER METALLURGY PRODUCTS (A10.A11)

Alloy	Ti-6Al-4V									
	Form	Sheet, Strip, and Plate (Normal Purity)					Sheet, Strip, and Plate(a) (ELI Grade)			
		Annealed					Annealed			
Condition										
Diameter or Thickness, in.	< 0.008	0.008 to 0.025	0.025 to 0.063	0.063 to 0.1875	0.1875 to 4.000	0.008 to 0.015	0.015 to 0.025	0.025 to 1.000	1.000 to 3.000	
F _{TU} , ksi (Min)	134	134	134	134	130	130	130	130	130	
F _{TY} , ksi (Min)	126	126	126	126	120	120	120	120	115	
e _T 2 in. or 4D, percent (Min)	-	6	8	10	10	6	8	10	10	

- (a) Using specified tensile test specimens, product tested at -423 F shall maintain a notch/unnotched tensile ratio of not less than 0.75 (A2).

TABLE A3.0111. AMS SPECIFIED MECHANICAL PROPERTIES FOR SHEET, STRIP, AND PLATE (A2, A3)

CODE 3707

Page 2

Ti
6 Al
4 V

Ti-6Al-4V

Alloy	Ti-6Al-4V							
Form	Bar, Forging, and Ring							
Condition	Annealed							
Diameter or Distance Between Parallel Sides, in.	< 4.000	4.000 to 6.000	0.500	0.500 to 1.000	1.000 to 1.500	1.500 to 2.000	2.000 to 3.000	3.000 to 4.000
F _{TU} , ksi (Min)	130	130	165	160	155	150	135	130
F _{TY} , ksi (Min)	120	120	155	150	145	140	125	120
e(2 in. or 4D), percent (Min)								
Longitudinal	10	10	10	10	10	10	10	10
Transverse	10	10	-	-	-	-	8	6
Short transverse	10	8	-	-	-	-	-	-
RA, percent (Min)								
Longitudinal	25	20	20	20	20	20	20	20
Transverse	20	20	-	-	-	-	-	-
Short transverse	-	15	-	-	-	-	-	-

For AMS 4928H: Using specified notched specimens, product shall have 5-hour minimum rupture life at room temperature when loaded to 170 ksi.

For AMS 4967E: Using specified notched specimens, products up to 1-inch diameter or distance between parallel sides shall have 5-hour minimum rupture life at room temperature when loaded to 185 ksi.

TABLE A3.0112. AMS SPECIFIED MECHANICAL PROPERTIES FOR BAR, FORGING, AND RING (A4, A5)

Alloy	Ti-6Al-4V								
Form	Bar and Forging (Rectangles)								
Condition	Annealed								
Thickness, in.	< 0.500	0.500 to 1.000		1.000 to 1.500		1.500 to 2.000		2.000 to 3.000	3.000 to 4.000
Width, in.	0.500 to 8.000	1.000 to 4.000	4.000 to 8.000	1.500 to 4.000	4.000 to 8.000	2.000 to 4.000	4.000 to 8.000	3.000 to 8.000	4.000 to 8.000
F _{TU} , ksi (Min)	160	155	150	150	145	145	140	135	130
F _{TY} , ksi (Min)	150	145	140	140	135	135	130	125	120
e(2 in. or 4D), percent (Min)									
Longitudinal	10	10	10	10	10	10	10	10	10
Transverse	10	10	10	10	10	10	10	8	6
RA, percent (Min)									
Longitudinal	25	20	20	20	20	20	20	20	20

For AMS 4967E: Using specified notched specimens, products up to 1-inch distance between parallel sides shall have 5-hour minimum rupture life at room temperature when loaded to 185 ksi.

TABLE A3.0113. AMS SPECIFIED MECHANICAL PROPERTIES FOR BAR AND FORGING [RECTANGLES] (A5)

Alloy	Ti-6Al-4V							
Form	Extrusions and Flash Welded Rings						Billets or Preforms	Forged Coupons
Condition	Annealed							
Diameter or Distance Between Parallel Sides, in.	< 0.500	0.500 to 0.750	0.750 to 1.000	1.000 to 2.000	2.000 to 3.000	3.000		
F _{TU} , ksi (Min)	160	155	150	140	130	130	300	300
F _{TY} , ksi (Min)	150	146	140	130	120	120	120	120
e(2 in. or 4D), percent (Min)	6	6	6	6	6	10(L) 8(T)	5	10
RA, percent (Min)	12	12	12	12	12	20(L) 15(T)	10	20

For AMS 4934A: Using specified notched specimens, product shall have 5-hour minimum rupture life at room temperature when loaded to 185 ksi.

For AMS 4935D: Using specified notched specimens, product shall have 5-hour minimum rupture life at room temperature when loaded to 170 ksi.

TABLE A3.0114. AMS SPECIFIED MECHANICAL PROPERTIES FOR EXTRUSIONS, FLASH WELDED RINGS, AND POWDER METALLURGY PRODUCTS (A6, A7, A10)

Ti
6 Al
4 V

Ti-6Al-4V

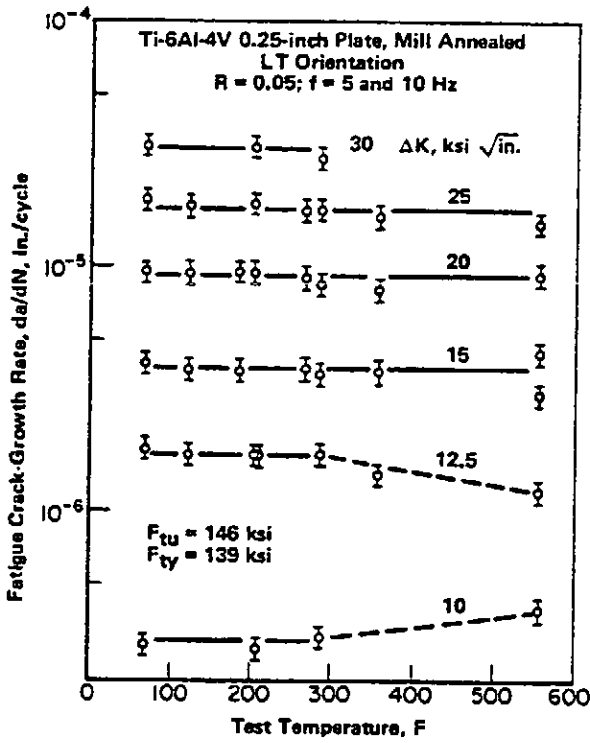


FIGURE A3.058. FATIGUE CRACK GROWTH IN DEHUMIDIFIED ARGON FOR MILL ANNEALED PLATE AT DIFFERENT TEMPERATURES AND K LEVELS (A16)

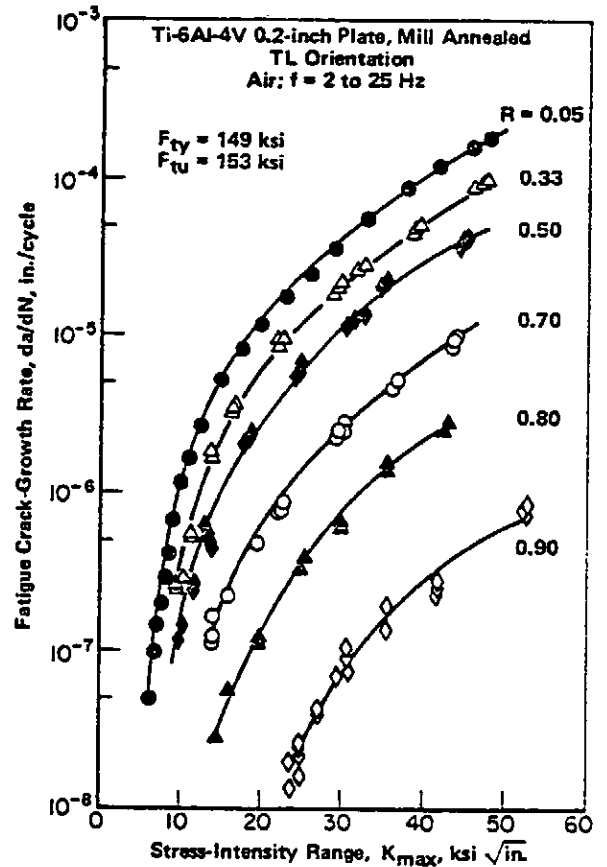


FIGURE A3.056. INFLUENCE OF LOAD RATIO (R) ON FATIGUE CRACK GROWTH FOR MILL ANNEALED PLATE IN AIR AT ROOM TEMPERATURE (A14)

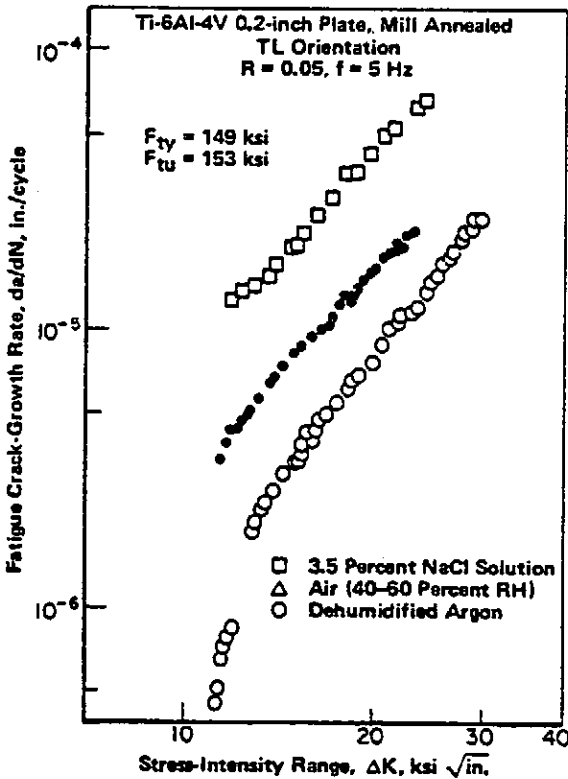


FIGURE A3.057. INFLUENCE OF ENVIRONMENT ON FATIGUE CRACK GROWTH FOR MILL ANNEALED PLATE AT ROOM TEMPERATURE (A15)