1. GENERAL

Tantalum has moderate room temperature strength, which decreases comparatively slowly with increasing temperature It has a very low ductile-to-brittle transition temperature, excellent fabricability, high melting point and good resistance to chemical corrosion. Oxidation resistance at elevated temperatures is poor, (2, p. 1)(11, p. 431).

1.01 Commercial Designation. Tantalum, comm. pure.

1.02 Alternate Designation

1.03 Specifications. Table 1.03.

TABLE 1.03

ASTM	Form
B 365-61T	Rod and wire
B 364-61T	Ingots and flat mill products

1.04 Composition. Table 1.04.

TABLE 1.04

Source	ASTM B364-61T, B365-61T (15)(16)	
	Percent	
	Min	Max
Carbon	-	0.03
Columbium	-	0.10
Iron	-	0.02
Nickel	-	0.02
Silicon	-	0.02
Titanium	-	0.01
Tungsten	-	0.03
Hydrogen	-	0.01
Nitrogen	-	0.015
Oxygen	-	0.03
Tantalum	99.8	-

1.05 Heat Treatment

1.051 Annealing. 2372 to 2552 F, 1 hr, in vacuum or inert atmosphere of argon or helium. Heat in a high vacuum below 10^{-5} mm Hg or 10^{-3}mm Hg, if part to be annealed is protected by wrapping in tantalum foil, (11, p. 318). Recrystallization temperature 1832 to 2552 F depending upon degree of cold work, (2, p. 245).

1.06 Hardenability

See Table 3.021.

1.07 Forms and Conditons Available

Rod, sheet, tube, wire and foil, Table 1.07. Also available as hex bar, threaded rod, seamless tubing, tubes, hex nuts, studs, rivets and cups, (17).

TABLE 1.07

Source	(12, p. 2, 18)(17)(18)		
Metal	Tantalum, comm. pure		
Size	Thickness - in	Width-in	Dia or length in
Rod	-	-	1½
Wire	-	-	0.003*
Foil	0.00055 - 0.004	10	coil
Strip	0.005 - 0.007	12	-
	0.010 - 0.059	5	-
	0.060 - 0.125	6	-
Sheet	0.01 - 0.02	12	84
	0.020 - 0.040	24	120
	0.050 - 0.100	24	96
	0.125	24	72
	0.187	24	36
	0.250	24	36
Plate	0.750	18	36

* minimum (other values are maximum)

1.08 Melting and Casting Practice

1.081 Powder metallurgy process of consolidation is used, followed by sintering, cold working and a second sintering, (11, p. 249). Sintered and/or cold worked Tantalum can be melted by arc melting or electron beam refining techniques, (5, p. 37).

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting point, 5425 F, (12, p. 3).

2.012 Phase changes, None.

2.013 Thermal conductivity, Fig. 2.013.

2.014 Thermal expansion, 3.7×10^{-6} in per in per F for temperature range 32 to 212 F, (12, p. 3). For high temperatures see Fig. 2.014.

2.015 Specific heat, Fig. 2.015.

2.016 Emissivity, Fig. 2.016.

2.02 Other Physical Properties

2.021 Density. 0.60 lb per cu in. 16.6 gr per cu cm, (7, p. 2).

2.022 Electrical resistivity, Fig. 2.022.

2.03 Chemical Properties

2.031 Corrosion resistance. Table 2.031.

TABLE 2.031

Source	(12, p. 6)
Excellent resistance	Poor resistance
Air (to 480 F)	Air (above 480 F)
Bromine, dry (to 570 F)	Alkalis
Bromine, wet	Fluorine
Chlorine, dry(to 392 F)	Hydrofluoric acid
Chlorine, wet	Oleum
Chromic acid	Potassium hydroxide (concentrated
Hydrochloric acid	Sodium hydroxide(concentrated)
Inorganic chlorides	Sulfur trioxide
Nitric acid	
Phosphoric acid	
Sodium hydroxide(to 5 percent)	
Sulphuric acid	

2.032 Oxidation resistance.

2.0321 A stable oxide film is formed below 572 F, (11, p. 486). A protective coating is necessary for elevated temperature service in air above 1800 F, (6, p. 8).

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.011 ASTM specified mechanical properties, Table 3.011.

TABLE 3.011

Source	ASTM (15, p. 627)						ASTM (16, p. 630)	
Metal	Tantalum, comm. pure							
Form	Ingots and flat mill						Rod, Wire	
Condition	CW		Stress relief		Full ann		CW	Ann
Size - in	<.021	≥.021	<.021	≥.021	≤.021	>.021	-	-
F_{tu}, min-ksi	75	75	55	55	35	35	70	40
e, (2in), min-percent	2	2	10	7.5	30	25	-	-
(10in)min-percent	-	-	-	-	-	-	1	10

3.02 Mechanical Properties at Room Temperature

3.021 Typical mechanical properties at room temperature, Table 3.021.

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TABLE 3.021

Source	(2, p. 197)				(12, p. 41)			
Metal	Tantalum, comm. pure							
Form	Sheet		Wire		Sheet		Wire	
Condition	Ann	CW	Ann	As drawn	Ann, 2250 F	As CR	Ann, 2250 F	As CD
Size - in	0.010		0.002 dia					
F_{tu}, typ-ksi	50	110	100	180	55 - 75	110 - 150	60 - 80	120 - 135
F_{ty}, typ-ksi	-	-	-	-	35 - 55	-	-	-
e, typ - percent	40	1	11	2	25 - 35	0 - 1	10 - 30	10 - 30
Hardness, Rockwell	-	-	-	-	B 60 - 70	C 30	-	-

3.03 Mechanical Properties at Various Temperatures

3.031 Short time tension properties

3.0311 Effect of room and elevated temperatures on tensile properties of wrought, recrystallized and cold rolled Tantalum sheet, Fig. 3.0311.

3.0312 Effect of low and elevated temperatures on tensile properties of recrystallized powder metallurgy sheet, Fig. 3.0312.

3.0313 Effect of low and elevated temperatures on tensile properties of recrystallized rod, Fig. 3.0313.

3.0314 Effect of high test temperature on tensile properties of arc melted and powder metallurgy produced sheet, Fig. 3.0314.

3.0315 Stress strain curves at various temperatures for stress relieved and recrystallized wrought bar, Fig. 3.0315.

3.032 Short time properties other than tension

3.033 Static stress concentration effects

3.0331 Effect of low and room temperatures on tensile strength of notched and unnotched recrystallized bar, Fig. 3.0331.

3.0332 Effect of low and room temperatures on tensile strength of notched and unnotched stress relieved wrought bar, Fig. 3.0332.

3.04 Creep and Creep Rupture Properties

3.041 Creep and creep rupture curves for sheet at 1380 to 2550 F, Fig. 3.041.

3.042 Creep and creep rupture curves for annealed sheet at 3000 to 5000 F, Fig. 3.042.

3.043 Rupture properties of high purity Tantalum, Fig. 3.043.

3.05 Fatigue Properties

3.051 Fatigue curves for annealed sheet at room and sub-zero temperatures, Fig. 3.051.

3.052 Fatigue curves for annealed wire at room and sub-zero temperatures, Fig. 3.052.

3.06 Elastic Properties

3.061 Modulus of elasticity at room and elevated temperatures, Fig. 3.061.

3.0611 Modulus of elasticity at temperatures above 3000 F for arc melted sheet, Fig. 3.0611.

3.062 Poisson's ratio, 0.35, (11, p. 398).

4. FABRICATION

4.01 Forming and Casting

4.011 General. Cold forming is preferred because of poor oxidation resistance. It is readily drawn, formed, stamped, forged, cut and blanked by conventional methods. Annealed Tantalum has a tendency to seize, tear or gall, (12, p. 11).

4.012 Forging. The metal work hardens slowly to a maximum of ~RC 30 and may be cold forged under a hammer or press. Water cooling before reductions is necessary to avoid heating. No intermediate anneal is required, (12, p. 13).

4.013 Heavy sections can be heated for forgings to about 800 F, (13, p. 1).

4.014 Blanking and punching. There are no difficulties in blanking and punching. Scoring of the die can be prevented by carbon tetrachloride or trichloroethane as a substitute. Steel dies are used, (13, p. 1).

4.0141 Form stamping. The techniques are similar to those of mild steel. Where there is a slipping of the metal, aluminum bronze or beryllium copper dies should be used. Annealed Tantalum does not spring back from the dies, (13, p. 2).

4.015 Drawing. In order to prevent galling and welding in the dies special lubricants are required for drawing of large bars. Flooded dies with chlorinated hydrocarbon oils containing titanium oxide pigment or carbon tetrachloride and beeswax is sufficient. The surface of fine wire can be oxidized by heating or anodizing which prevents metal pickup on the die. The oxides have to be removed before annealing in order to prevent oxygen diffusion and hardening, (12, p. 12).

4.0151 Deep drawing. For this operation only annealed Tantalum sheet should be used. The work-hardening which is not as rapid as in most metals appears at the die entrance. The permissible reduction increases with thicker material. Sulphonated tallow is recommended as a lubricant. In multiple drawings the depth of the first draw should not exceed 50 percent of the diameter. Anneal between draws is recommended, (13, p. 2).

4.016 Spinning. Conventional techniques are used, (13, p. 2).

4.02 Machining

4.021 General. The machining of Tantalum is similar to that of stainless steels in respect to gall or seize.

4.022 Hard metal tools have a tendency to weld to the metal and should be avoided, (11, p. 326). The metal can be milled, drilled, threaded and tapped. High speed tools with maximum rake, clearance and good cutting edge strength in connection with high speeds, 100 sfpm minimum, are recommended for best results. Carbon tetrachloride, trichloro- or tetrachloroethane are satisfactory as cutting fluids, (13, p. 4, 5).

4.023 Turning. The same general procedure as in 4.022 is used for turning. Satisfactory results are obtained with sharp tools and light feeds and finishing the work in one operation, (13, p. 4).

4.024 Grinding. Grinding of annealed Tantalum is impractical. Hardened Tantalum can be ground with silicon carbide wheels, flooded with soluble oil and dressed frequently, (11, p. 327).

4.03 Welding

4.031 General. The metal may be welded to itself and certain other metals by inert gas arc and resistance welding, (13, p. 3).

4.032 Resistance welding. Resistance welding can be done with conventional equipment, and methods are not substantially different from those used in welding other materials. Welding time should be kept as short as possible and work should be flooded with cooling water where possible. Too much welding force causes too little interface resistance, (13, p. 4).

4.033 Inert gas arc welding. The inert gas arc welding technique is preferred for welding Tantalum sheet material greater than 0.020 in, but is unsatisfactory for material less than 0.020 in. The alloy can be joined by this method using highly purified gas. Strong ductile welds can be achieved through the Tungsten inert gas method. Extreme care must be taken to cover with inert gas all surfaces which are raised above 600 F by welding heat. Homogeneous and high ductility can be achieved by use of welding chamber, (11, p. 335) (13, p. 4).

4.034 Other welding methods. Carbon arc and electron welding have been successfully used, (11, p. 339). Tantalum cannot be gas torch welded, (13, p. 3).

4.04 Heating and Heat Treating

4.041 Sintering. Bars produced by vacuum sintering are reduced 20 to 50 percent by rolling, forging and swaging. Sintered a second time at 4712 F, 1 to 2 hr.

4.042 Anneal at 2250 F, furnace cool, to obtain material for deep drawing and subsequent working, (12, p. 17).

4.05 Surface Treatment

4.051 Cleaning. Conventional cleaning methods and materials may be used safely, although hot caustics must be avoided, (13, p. 2).

For chemical surface cleanliness, hot sulphuric acid solution of chromic oxide is recommended, (12, p. 17).

4.052 Pickling. Where surface contamination occurs, pickling in a 40 percent nitric 60 percent hydrofluoric acid solution at room temperature is necessary. Rinse with clean or distilled water and dry in a blast of air, (12, p. 17).

4.053 Polishing. Tantalum can be polished but not to a mirrorlike finish, (13, p. 5).

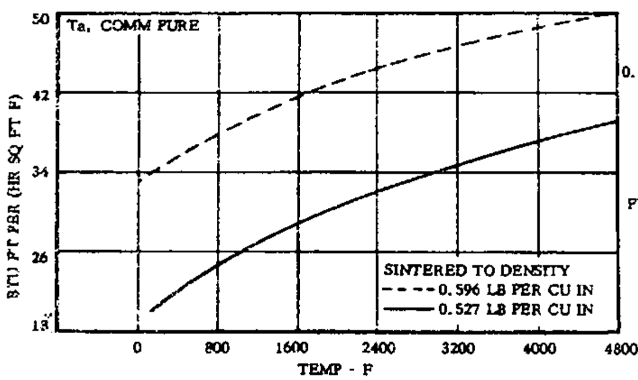

FIG. 2.013 THERMAL CONDUCTIVITY (9, p. I-R)

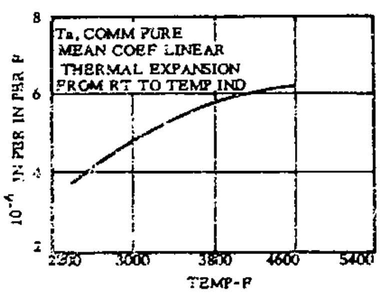

FIG. 2.014 THERMAL EXPANSION (8, p. 4)

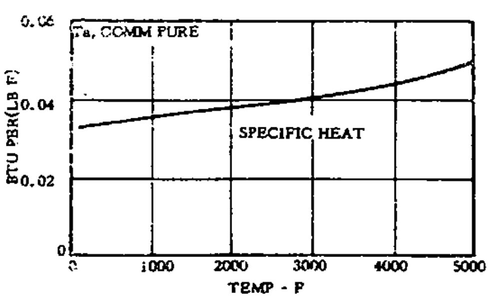

FIG. 2.015 SPECIFIC HEAT (8, p. 2)

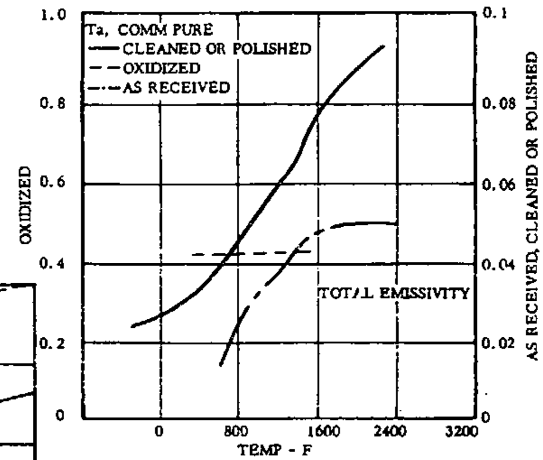

FIG. 2.016 EMISSIVITY (2, p. 34)

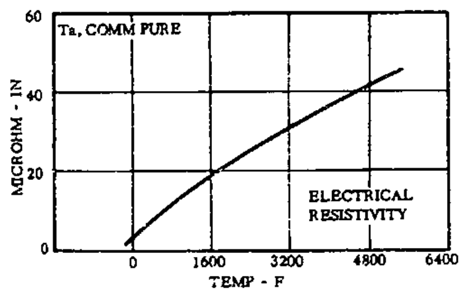

FIG. 2.022 ELECTRICAL RESISTIVITY (2, p. 24, 25)

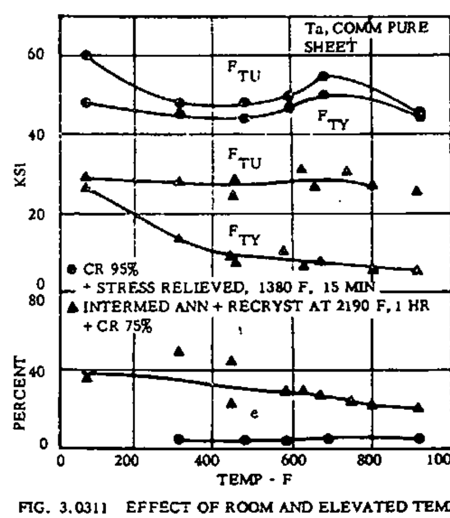

FIG. 3.0311 EFFECT OF ROOM AND ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF WROUGHT, RECRYSTALLIZED AND COLD ROLLED TANTALUM SHEET (2, p. 207)

Ta, COMM PURE

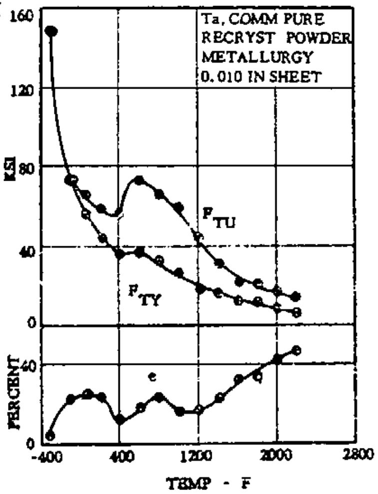

FIG. 3.0312 EFFECT OF LOW AND ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF RECRYSTALLIZED POWDER METALLURGY SHEET (8, p. 9)

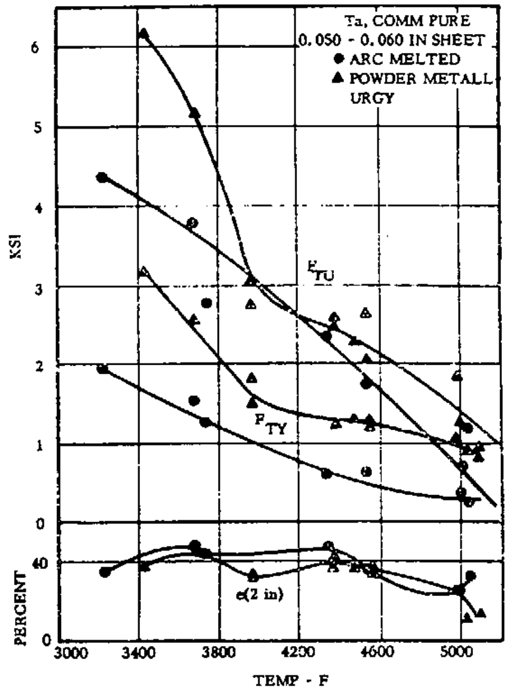

FIG. 3.0314 EFFECT OF HIGH TEST TEMPERATURE ON TENSILE PROPERTIES OF ARC MELTED AND POWDER METALLURGY PRODUCED SHEET (2, p. 211, 212)

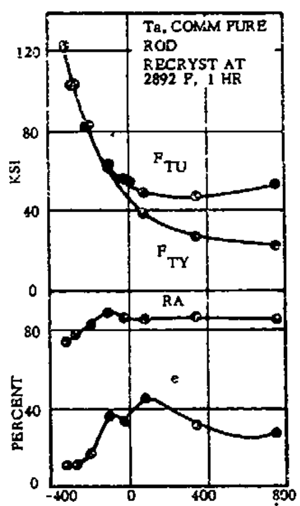

FIG. 3.0313 EFFECT OF LOW AND ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF RECRYSTALLIZED ROD (8, p. 9)

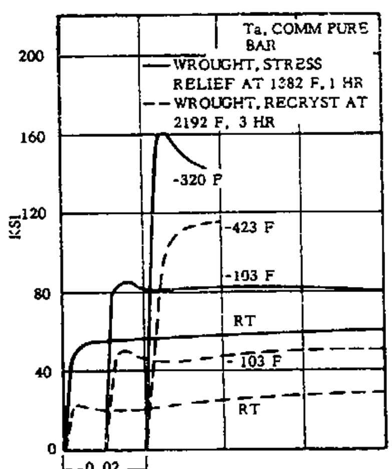

FIG. 3.0315 STRESS-STRAIN CURVES AT VARIOUS TEMPERATURES FOR STRESS RELIEVED AND RECRYSTALLIZED WROUGHT BAR (1, p. 69)

Ta, COMM PURE

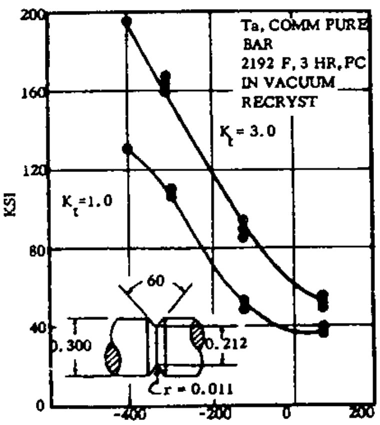

FIG. 3.0331 EFFECT OF LOW AND ROOM TEMPERATURES ON TENSILE STRENGTH OF NOTCHED AND UNNOTCHED RECRYSTALLIZED BAR (1, p.75)

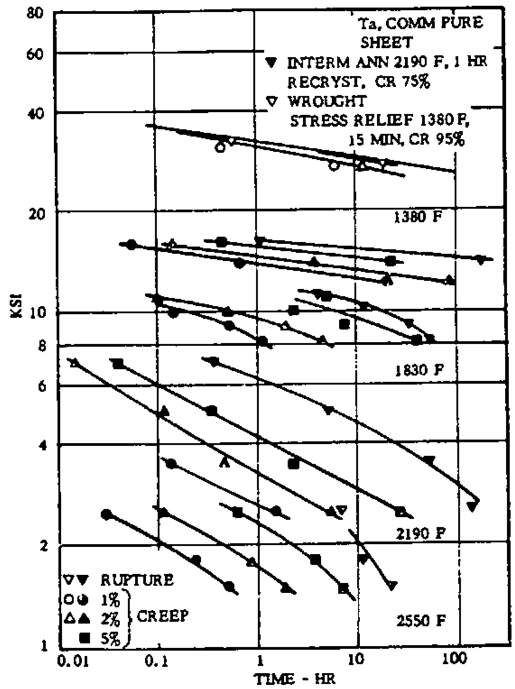

FIG. 3.041 CREEP AND CREEP RUPTURE CURVES FOR SHEET AT 1380 TO 2550 F (2, p.234, 236)

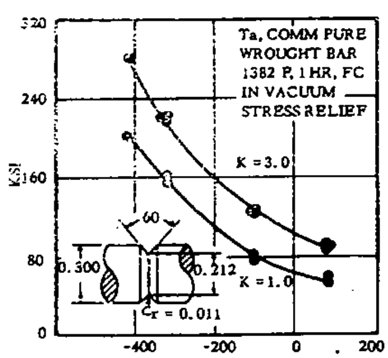

FIG. 3.0332 EFFECT OF LOW AND ROOM TEMPERATURES ON TENSILE STRENGTH OF NOTCHED AND UNNOTCHED STRESS RELIEVED WROUGHT BAR (1, p.72)

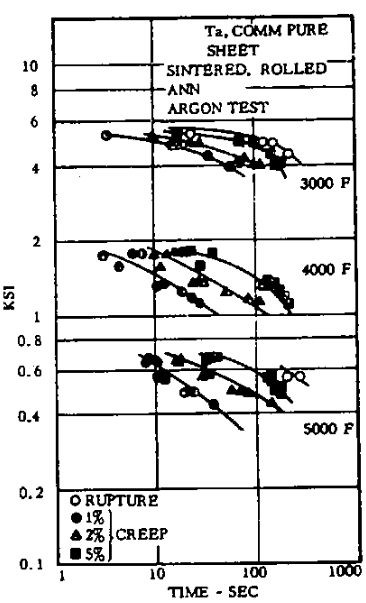

FIG. 3.042 CREEP AND CREEP RUPTURE CURVES FOR ANNEALED SHEET AT 3000 TO 5000 F (8, p.11)

Ta, COMM PURE

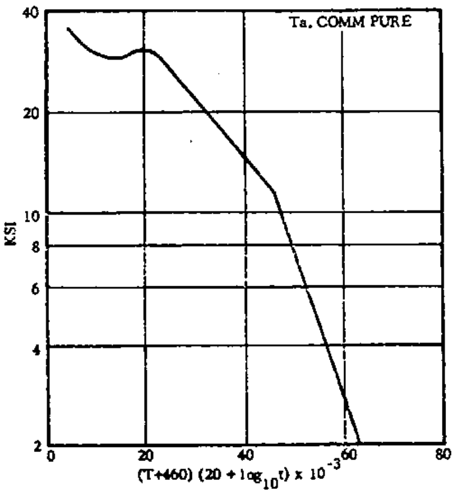

FIG. 3.043 RUPTURE PROPERTIES OF HIGH PURITY TANTALUM (4, p. 18)

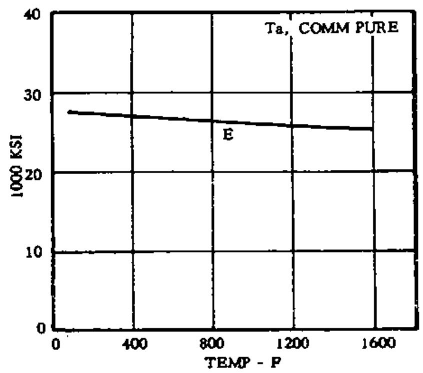

FIG. 3.061 MODULUS OF ELASTICITY AT ROOM AND ELEVATED TEMPERATURES (4, p. 25)

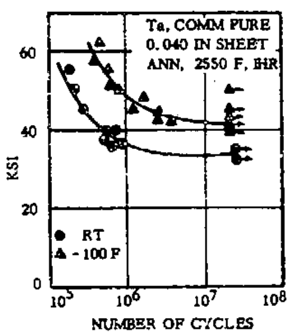

FIG. 3.051 FATIGUE CURVES FOR ANNEALED SHEET AT ROOM AND SUB-ZERO TEMPERATURES (2, p. 226)

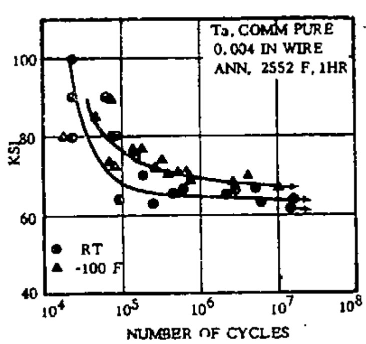

FIG. 3.052 FATIGUE CURVES FOR ANNEALED WIRE AT ROOM AND SUB-ZERO TEMPERATURES (2, p. 228)

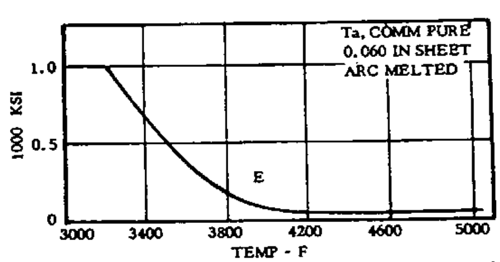

FIG. 3.0611 MODULUS OF ELASTICITY AT TEMPERATURES ABOVE 3000 F FOR ARC MELTED SHEET (8, p. 13)

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