ALLOY 625

Alloy 625 (UNS N06625/W.Nr. 2.4856) is used for its high strength, excellent fabricability (including joining), and outstanding corrosion resistance. Service temperatures range from cryogenic to 1800°F (982°C). Composition is shown in Table 1.

Strength of Alloy 625 is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix; thus precipitationhardening treatments are not required. This combination of elements also is responsible for superior resistance to a wide range of corrosive environments of unusual severity as well as to high-temperature effects such as oxidation and carburization.

The properties of Alloy 625 that make it an excellent choice for sea-water applications are freedom from local attack (pitting and crevice corrosion), high corrosion-fatigue strength, high tensile strength, and resistance to chloride-ion stress-corrosion cracking. It is used as wire rope for mooring cables, propeller blades for motor patrol gunboats, submarine auxiliary propulsion motors, submarine quickdisconnect fittings, exhaust ducts for Navy utility boats, sheathing for undersea communication cables, submarine transducer controls, and steam-line bellows. Potential applications are springs, seals, bellows for submerged controls, electrical cable connectors, fasteners, flexure devices, and oceanographic instrument components.

High tensile, creep, and rupture strength; outstanding fatigue and thermal-fatigue strength; oxidation resistance; and excellent weldability and brazeability are the properties of Alloy 625 that make it interesting to the aerospace field. It is being used in such applications as aircraft ducting systems, engine exhaust systems, thrust-reverser systems, resistancewelded honeycomb structures for housing engine controls, fuel and hydraulic line tubing, spray bars, bellows, turbine shroud rings, and heat-exchanger tubing in environmental control systems. It is also suitable for combustion system transition liners, turbine seals, compressor vanes, and thrust-chamber tubing for rocket The outstanding and versatile corrosion resistance of Alloy 625 under a wide range of temperatures and pressures is a primary reason for its wide acceptance in the chemical processing field. Because of its ease of fabrication, it is made into a variety of components for plant equipment. Its high strength enables it to be used, for example, in thinner-walled vessels or tubing than possible with other materials, thus improving heat transfer and saving weight. Some applications requiring the combination of strength and corrosion resistance offered by Alloy 625 are bubble caps, tubing, reaction vessels, distillation columns, heat exchangers, transfer piping, and valves. In the nuclear field, Alloy 625 may be used for reactor-core and control-rod components in nuclear water reactors. The material can be selected because of its high strength, excellent uniform corrosion resistance, resistance to stress cracking and excellent pitting resistance in 500°-600°F (260-316°C) water. Alloy 625 is also being considered in advanced reactor concepts because of its high allowable design strength at elevated temperatures, especially between 1200°-1400°F (649-760°C).

The properties given in this bulletin, results of extensive testing, are typical of the alloy but should not be used for specification purposes.

Applicable specifications appear in the last section of this publication.

Physical Constants and Thermal Properties

Some physical constants and thermal properties of Alloy 625 are shown in Tables 2 and 3. Lowtemperature thermal expansion, based on measurements made by the National Bureau of Standards, is shown in Figure 1. Elevated-temperature modulus of elasticity data are given in Table 4.

Mechanical Properties
Nominal room-temperature mechanical properties of Alloy 625 are shown in Table 5.
For service at 1200°F and below, hot-finished, cold-finished, and annealed conditions (depending on requirements involved) are recommended.
For service above 1200°F, either annealed or solution-treated material will give best service. The solution-treated condition is recommended for components that require optimum resistance to creep or rupture. Fine-grained (annealed) material may be advantageous at temperatures up to 1500°F with respect to fatigue strength, hardness, and tensile and yield strength.
MacGregor's two-load was used for determination of the true stress-strain curve for Alloy 625 at room temperature. The two-load test requires no strain measurement during the test, and only the maximum and fracture loads are recorded. Data for both annealed and solution-treated material are shown in Figure 2.

Tensile Properties and Hardness
Typical tensile properties of annealed and solutiontreated material from room to elevated temperature are shown in Figures 3, 4, and 5. The approximate relationship between the hardness and tensile and yield strength of strip is shown in Figure 6.
Increased tensile properties for service at moderate temperature can be achieved by cold work. See the section, "Working Instructions" for some specific data.
Upon exposure to intermediate temperatures, some hardening takes place in Alloy 625. To demonstrate this reaction, samples of annealed rod were exposed to 1200°, 1400°, and 1600°F for 2000 hours. The effect of exposure on properties both at room temperature and at exposure temperature is shown in Table 6. Measurements were made to determine dimensional stability; the samples exposed at 1200° to 1400°F for 2000 hours contracted about 0.048%.

Fatigue Strength
Room-temperature fatigue strength of hot-rolled round in the as-rolled and annealed conditions is shown in Figure 7. Elevated-temperature fatigue strengths of solution-treated and annealed bar can be compared in Figures 8 and 9.
The endurance limit (10^8 cycles) at room temperature of cold-rolled annealed sheet tested in completely reversed bending was found to be 90,000 psi for smooth bar and 35,000 psi (notched specimen K+3.3).

Ductility and Toughness
Alloy 625 retains its excellent ductility and toughness at low temperature. Impact and tensile data t0 -320F are shown in table 7 and Figure 10.

Creep and Rupture Strength
Typical creep and rupture strength of solution-treated material is given in Figures 11 and 12. For comparison purposes, creep and rupture properties of annealed material are shown in Figures 13 and 14. Annealed material, when selected for some other consideration, will exhibit adequate creeprupture properties for many applications, although the values are not as high as those shown for solution treated material.

ASME Boiler and Pressure Vessel Code
Alloy 625 is an approved material of construction under the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers (ASME). Allowable design stresses for Grade 1 material for Section VIII, Division 1 construction up to 1200°F, for Section III, Class 2 and 3 construction up to 800 °F, and for Grade 2 material for Section VIII, Division 1 construction up to 1600°F are reported in Table 1B of ASME Section II, Part D. Design stress intensity values for Section III, Class 1 construction for Grade 1 material are found in Table 2B of ASME Section II, Part D. Allowable stresses and rules for Section 1 construction with Grade 1 material up to 1100°F are found in ASME Code Case 1935.

Microstructure
Alloy 625 is a solid-solution matrixstiffened face-centered-cubic alloy. The alloy may contain carbides, which are inherent in this type of alloy. Carbides that can be found are MC and M6C (rich in nickel, niobium, molybdenum, and carbon). In addition M23C6, a chromium-rich carbide, appears in solution-treated material exposed at lower temperatures.
The hardening effect that takes place in the material on exposure in the range centered around 1200°F (See Mechanical Properties section) is due to sluggish precipitation of a nickel-niobium-rich phase, gamma prime. This phase gradually transforms to orthorhombic Ni3Nb when the alloy is heated for long times in the intermediate temperature range. Extensive investigation of the stability of Alloy 625 following exposure for extended periods in the 1000° to 1800°F temperature range has shown complete absence of embrittling intermetallic phases such as sigma.

Corrosion Resistance
Aqueous Corrosion
The high alloy content of Alloy 625 enables it to withstand a wide variety of severe corrosive environments. In mild environments such as the atmosphere, fresh and sea water, neutral salts, and alkaline media there is almost no attack. In more severe corrosive environments the combination of nickel and chromium provides resistance to oxidizing chemicals, whereas the high nickel and molybdenum contents supply resistance to non-oxidizing environments. The high molybdenum content also makes this alloy very resistant to pitting and crevice corrosion, and niobium acts to stabilize the alloy against sensitization during welding, thereby preventing subsequent intergranular cracking. Also, the high nickel content provides freedom from chloride ion stresscorrosion cracking.
This combination of characteristics makes Alloy 625 useful over a broad spectrum of corrosive conditions. For instance, it has been recommended as a material of construction for a storage tank to handle chemical wastes, including hydrochloric and nitric acids – chemicals which represent directly opposite types of corrosion problems. Materials which resist either one of these acids are normally severely attacked by the other.

High-Temperature Oxidation
Alloy 625 has good resistance to oxidation and scaling at high temperature. Its performance in an extremely sever test is shown in comparison with that of other materials in Figure 15. In this test, periodic weight-loss determinations indicate the ability of the alloy to retain a protective oxide coating under drastic cyclic conditions. 1800°F is a temperature at which scaling resistance becomes a significant factor in service.

Working Instructions

Heating

Hot- or cold-formed parts are usually annealed at 1700°-1900°F for times commensurate with thickness; higher temperatures may be used to soften material for additional cold work.
Alloy 625 is solution-treated at 2000°-2200°F. These temperatures are metal temperatures based on batch operations and may not apply to continuous annealing, which normally consists of short exposure in the hot zone of a furnace set at higher temperatures. The rate of cooling after heating has no significant effect on Alloy 625.
Tables 8 and 9 can be used as a guide for determining the preferred temperature for reducing the stress level of the alloy. Heating cold-drawn material at 1100° to 1400°F reduces residual stress. Stress relief is virtually complete when the material is heated to 1600°F.

Pickling

When heated, Alloy 625, like other nickel-chromium and nickel-chromium-iron alloys, forms a tightly adherent oxide or scale unless it has been bright-annealed in very dry hydrogen or in a vacuum. To remove the oxide which results from heating, treatment in a fused-salt bath prior to pickling is usually recommended.

Hot and cold forming

Because Alloy 625 was especially developed to retain high strength at elevated temperature, it resists deformation at hot-working temperatures. It is readily fabricated by hot forming, however, provided adequately powerful equipment is used.
When Alloy 625 is hot-formed, it should be heated in a furnace whose temperature is held at (but not above) 2150°F. The work should be brought up to as close to 2150°F as conditions permit. Heavy forging can be carried out from 2150°F down to 1850°F. Lighter reductions can be taken down to 1700°F. To guard against duplex grain structure, the work should be given uniform reductions. Final minimum reductions of 15 to 20% for open-die work are recommended.
Alloy 625 can be cold-formed by standard processes. The force required to shear the alloy in the annealed condition is shown in Figure 17.
More indications of its resistance to deformation can be derived from the true stress-true strain curves (see the "Mechanical Properties" section of this bulletin) and the effect of cold work on hardness (Figure 18).
Increased tensile properties can be achieved by cold work for moderate-temperature applications. Tensile strengths of more than 300,000 psi accompanied by good ductility have been developed in 0.010-0.020-in.diameter wire after 75-90% cold reduction (See Table 10). Effects of cold work on plate are shown in Table 11.

Welding

Alloy 625 is readily joined by conventional welding processes and procedures. Like Alloy 625, deposited weld metals are highly resistant to corrosion and oxidation and have high strength and toughness from the cryogenic range to 1800°F. They require no postweld heat treatments to maintain their high strength and ductility. When used to weld Alloy 625 to dissimilar metals, both products tolerate a high degree of dilution yet maintain characteristic properties.

All-Weld-Metal Properties

High-temperature properties of weld metals are shown in Figures 19, 20, and 21. These welds were made by the gas-tungsten-arc process and the shielded-metal-arc process. Low-temperature toughness of weld metals is shown by the impact-strength data in Table 14.

Room-temperature fatigue strength (106 cycles; rotating-beam tests at 10,000 rpm) of polished all-weld-metal specimens was found to be 68,000 psi (Filler Metal 625) and 58,000 psi (Electrode 112).
The results of stress-rupture tests performed on all-weld-metal specimens of Electrode 112 are reported in Figure 22.

Transverse Properties
Properties of Alloy 625 welds made with the recommended welding products are shown in Figures 19 and 21.
As another example of weld quality, the gas-tungsten-arc process with 1/8-in. Filler Metal 625 was used to join 1/2-in. annealed plate. Transverse bends with a radius equal to two thicknesses (2T) had no fissuring or cracking.
Rupture strength of Alloy 625 welds made by the gas-tungsten-arc process and Filler Metal 625 is shown in Figure 23.
Both Filler Metal 625 and Welding Electrode 112 have been used to join Alloy 625 to a variety of dissimilar metals. The results of tests made on welds of Alloy 625 joined to a nickel-iron-chromium-molybdenum alloy (Alloy X), a precipitation-hardenable nickel-chromium alloy (Alloy 718), a cast chromium-nickel-iron-tungsten alloy and Types 304 and 410 stainless steel are shown in Table 15. All the joints passed dye-penetrant and radiographic inspection and guided-bend tests

Table 1 – Limiting Chemical Composition, %

Nickel	58.0 min.
Chromium	20.0-23.0
Iron	5.0 max.
Molybdenum	8.0-10.0
Niobium (plus Tantalum)	3.15-4.15
Carbon	0.10 max.
Manganese	0.50 max.
Silicon	0.50 max.
Phosphorus	0.015 max.
Sulfur	0.015 max.
Aluminum	0.40 max.
Titanium	0.40 max.
Cobalt[a]	1.0 max.

[a]If determined

Table 2 – Physical Constants

Density, lb/cu in	0.305
gram/cc	8.44
Melting Range, °F	2350-2460
°C	1290-1350
Specific Heat[a], Btu/lb°F (J/kg°C)	
0°F (-18°C)	0.096 (402)
70°F (21°)	0.098 (410)
200°F (93°C)	0.102 (427)
400°F (204°C)	0.109 (456)
600°F (316°C)	0.115 (481)
800°F (427°C)	0.122 (511)
1000°F (538°C)	0.128 (536)
1200°F (649°C)	0.135 (565)
1400°F (760°C)	0.141 (590)
1600°F (871°C)	0.148 (620)
1800°F (982°C)	0.154 (645)
2000°F (1093°C)	0.160 (670)
Permeability at 200 Oersted (15.9 kA/m)	1.0006
Curie Temperature, °F	<-320
°C	-196

[a]Calculated

Table 3 – Thermal and Electrical Properties

Temp. °F	Meal Linear Expansion[a] 10^{-6}in/in•°F	Thermal Conductivity[b,c] Btu•in/ft^2-h•°F	Electrical Resistivity[c] ohm-circ mil/ft	Temp °C	Mean Linear Expansion[a] µm/ µm•°C	Thermal Conductivity [b,c] W/m•°C	Electrical Resistivity[c] µΩ-cm
-250	-	50	-	-157	-	7.2	-
-200	-	52	-	-129	-	7.5	-
-100	-	58	-	-73	-	8.4	-
0	-	64	-	-18	-	9.2	-
70	-	68	776	21	-	9.8	129
100	-	70	780	38	-	10.1	130
200	7.1	75	794	93	12.8	10.8	132
400	7.3	87	806	204	13.1	12.5	134
600	7.4	98	812	316	13.3	14.1	135
800	7.6	109	818	427	13.7	15.7	136
1000	7.8	121	830	538	14.0	17.5	138
1200	8.2	132	830	649	14.8	19.0	138
1400	8.5	144	824	760	15.3	20.8	137
1600	8.8	158	818	871	15.8	22.8	136
1700	9.0	-	-	927	16.2	-	-
1800	-	175	812	982	-	25.2	135
2000	-	-	806	1093	-	-	134

[a]From 70°F to temperature shown [b]Measurements made at Battelle Memorial Institute [c]Material annealed 2100°F/1 hr

Table 4 – Modulus at Elevated Temperatures[a]

Temp. °F	Modulus of Elasticity, 10^3 ksi				Poisson's Ratio		Temp. °C	Modulus of Elasticity, GPa			
	Tension		Shear					Tension		Shear	
	Annealed	Solution-Treated	Annealed	Solution-Treated	Annealed	Solution-Treated		Annealed	Solution-Treated	Annealed	Solution-Treated
70	30.1	29.7	11.8	11.3	0.278	0.312	21	207.5	204.8	81.4	78.0
200	29.6	29.1	11.6	11.1	0.280	0.311	93	204.1	200.6	80.0	76.5
400	28.7	28.1	11.1	10.8	0.286	0.303	204	197.9	193.7	76.5	74.5
600	27.8	27.2	10.8	10.4	0.290	0.300	316	191.7	187.5	74.5	71.7
800	26.9	26.2	10.4	10.0	0.295	0.302	427	185.5	180.6	71.7	68.9
1000	25.9	25.1	9.9	9.6	0.305	0.312	538	178.6	173.1	68.3	66.2
1200	24.7	24.0	9.4	9.2	0.321	0.314	649	170.3	165.5	64.8	63.4
1400	23.3	22.8	8.7	8.8	0.340	0.305	760	160.6	157.2	60.0	60.7
1600	21.4	21.5	8.0	8.3	0.336	0.289	871	147.5	148.2	55.2	57.2

Table 5 – Nominal Room-Temperature Mechanical Properties[a]

Form And Condition	Tensile Strength		Yield Strength (0.2% Offset)		Elongation	Reduction Of Area	Hardness, Brinell
	ksi	MPa	ksi	MPa	%	%	
ROD, BAR, PLATE							
As-Rolled	120-160	827-1103	60-110	414-758	60-30	60-40	175-240
Annealed	120-150	827-1034	60-95	414-655	60-30	60-40	145-220
Solution-Treated	105-130	724-896	42-60	290-414	65-40	90-60	116-194
SHEET and STRIP							
Annealed	120-150	827-1034	60-90	414-621	55-30	-	145-240
TUBE and PIPE, COLD-DRAWN							
Annealed	120-140	827-965	60-75	414-517	55-30	-	-
Solution-Treated	100-120	689-827	40-60	276-414	60-40	-	-

[a]Values shown are composites for various product sizes up to 4 in. They are not suitable for specification purposes. For properties of larger-sized products, consult Special Metals Corporation.

Table 6 – Effect of Intermediate-Temperature Exposure (2000 hrs) on Properties of Hot-Rolled Annealed Bar

Exposure Temperature, °F (°C)	Properties at Room Temperature					Properties at Exposure Temperature				
	Tensile Strength		Yield Strength (0.2% offset)		Elongation, %	Tensile Strength		Yield Strength (0.2% offset)		Elongation, %
	ksi	MPa	ksi	MPa		ksi	MPa	ksi	MPa	
No Exposure	140.0	965.3	69.5	479.2	54	-	-	-	-	-
1200 (649)	176.0	1213.5	126.5	872.2	30	146.5	1010.1	106.5	734.3	54
1400 (760)	163.0	1123.8	107.0	737.7	26	84.8	584.7	79.0	544.7	62
1600 (871)	144.0	992.8	76.7	528.8	34	41.2	284.1	40.0	275.8	80

[a]Values shown are composites for various product sizes up to 4 in. They are not suitable for specification purposes. For properties of larger-sized products, consult Special Metals Corporation.

Table 7 – Low-Temperature Impact Strength[a] of Hot-Rolled, As-Rolled Plate (1/2-in. thickness)

Test Temperature,		Orientation	Impact Strength,	
°F	°C		ft•lb	J
85	29	Longitudinal	48, 49, 50	65, 66, 68
		Transverse	46, 49, 51.5	62, 66, 70
-110	-79	Longitudinal	39, 44, 49	53, 57, 60
		Transverse	39, 42, 44	53, 57, 60
-320	-196	Longitudinal	35, 35, 35.5	47, 47, 48
		Transverse	31, 32, 36	42, 43, 49

[a]Charpy keyhole specimens in triplicate.

Table 10 – Room-Temperature Tensile Properties of As-Drawn Wire[a]

Wire Diameter,		Cold Reduc-tion, %	Tensile Strength		Yield Strength (0.2% offset)[b],		Elonga-tion In 10 Inches, %
In.	Mm		ksi	MPa	ksi	MPa	
0.0397[c]	1.008[c]	0	138	952	61.5	424	52.3
0.036	0.914	19	174.5	1203	153.3	1057	17.5
0.0318[d]	0.808[d]	37	220	1517	205	1413	2.0
0.0285[d]	0.724[d]	49	246	1696	218	1503	2.0
0.0253[d]	0.643[d]	60	269	1855	253	1744	2.4
0.0226[d]	0.574[d]	68	283	1951	242	1669	2.2
0.020[d]	0.508[d]	75	293	2020	251	1731	2.0
0.0179	0.455	80	295.3	2036	220	1517	3.8
0.0159	0.404	84	303	2089	250	1727	3.4
0.0142	0.361	87	306	2110	252.8	1743	3.0
0.0126	0.320	90	316	2181	269	1855	2.6
0.0111	0.282	92	316	2179	264	1820	2.3
0.0099	0.251	94	322.3	2222	274.5	1893	3.0

[a]Average of 2 tests unless otherwise shown.
[b]Crosshead speed, 0.1 in./min.
[c]Strand-annealed at 2150°F, 29 ft/min, in 10-ft furnace with 6-7 ft hot zone
[d]One test.

Table 8 – Effect of Annealing (1 hour) on Room-Temperature Properties of Hot-Rolled Rod

Annealing Temper-ature, °F	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elonga-tion, %	Reduction Of Area, %	Hardness, Rb
As-Rolled	147.5	92.0	46.0	55.3	98
1400	145.5	90.8	43.0	49.5	101
1500	143.5	85.0	42.0	45.7	101
1600	145.5	87.2	39.0	41.5	101
1700	147.0	86.0	40.0	48.0	103
1800	143.5	83.6	44.0	48.0	101
1850	142.5	78.6	46.0	53.0	99
1900	142.5	66.3	49.0	51.5	95
2000	124.0	52.5	64.0	62.5	93
2100	116.0	50.0	62.0	61.0	89
2200	116.5	48.0	72.0	61.3	88
Annealing Temper-ature, °C	**Tensile Strength, MPa**	**Yield Strength (0.2% Offset), MPa**	**Elonga-tion, %**	**Reduction Of Area, %**	**Hardness, Rb**
As-Rolled	1017.0	634.3	46.0	55.3	98
760	1003.2	626.0	43.0	49.5	101
816	989.4	586.1	42.0	45.7	101
871	1003.2	601.2	39.0	41.5	101
927	1013.5	593.0	40.0	48.0	103
982	989.4	576.4	44.0	48.0	101
1010	982.5	542.0	46.0	53.0	99
1038	982.5	457.1	49.0	51.5	95
1093	855.0	362.0	64.0	62.5	93
1149	799.8	344.7	62.0	61.0	89
1204	803.2	331.0	72.0	61.3	88

Table 9 – Effect of Annealing (1 Hour) on Room-Temperature Properties of Cold-Drawn Rod

Annealing Temperature,		Tensile Strength,		Yield Strength (0.2% Offset),		Elongation %	Reduction Of Area, %	Hardness, Rb	Impact Strength (Charpy V)		Grain Size,	
°F	°C	ksi	MPa	ksi	MPa				ft•lb	J	in.	mm
As-Drawn	As-Drawn	163.0	1123.8	145.5	1003.2	21.0	50.5	106	64.5	87.5	0.003	.076
1100	593	160.5	1106.6	134.3	926.0	28.0	48.3	106	75.0	101.7	0.0035	.089
1200	649	159.5	1099.7	133.5	920.5	28.5	47.2	106	71.5	97.0	0.0045	.114
1300	704	164.0	1130.7	135.0	930.8	26.0	38.8	106	57.0	77.3	0.005	.127
1400	760	162.5	1120.4	135.5	934.2	27.0	39.0	106	53.0	71.9	0.005	.127
1500	816	152.0	1048.0	120.0	827.4	29.0	41.5	105	55.0	74.6	0.0035	.089
1600	871	146.5	1010.1	102.5	706.7	35.0	45.2	103	62.0	84.1	70% 0.005	.127
											30% 0.009	.229
1700	927	133.5	920.5	62.3	429.5	48.5	44.0	97	82.5	111.9	0.0008	.203
1800	982	127.5	879.1	62.3	429.5	52.0	55.3	95	84.5	114.6	0.0009	.229
1900	1038	130.5	899.8	60.8	419.2	53.0	55.7	95	91.0	123.4	0.0008	.203
2000	1093	126.5	872.2	56.5	389.6	57.0	61.0	93	115.5	156.6	0.0019	.048
2100	1149	118.0	813.6	48.3	333.0	63.0	60.4	89	138.0	187.1	0.0032	.081
2200	1204	113.0	779.1	44.6	307.5	62.3	58.4	86	141.0	191.2	0.006	.152

Table 11 – Effect of Cold Work on Mechanical Properties of Strips Cut From Hot-Rolled Plate (0.372-in.), Solution-Treated 2150°F/1 hr and Cold Worked

Cold Reduction, %	Tensile Strength		Yield Strength (0.2% offset)[b]		Elongation %	Reduction Of Area, %	Hardness	
	ksi	MPa	ksi	MPa			Rockwell C	Vickers
0	115.5	796.3	49.5	341.3	67.0	60.4	88 Rb	179
5	121.0	834.3	77.5	534.3	58.0	58.1	94 Rb	209
10	130.0	896.3	102.5	706.7	47.5	54.6	25	257
15	137.0	944.6	112.5	775.7	39.0	51.9	32	309
20	143.0	986.0	125.0	861.8	31.5	50.0	34	326
30	165.0	1137.6	152.0	1048.0	17.0	49.3	36	344
40	179.5	1237.6	167.0	1151.4	12.5	41.9	39	372
50	189.5	1306.6	177.0	1220.4	8.5	38.0	40	382
60	205.0	1413.4	180.5	1244.5	6.5	32.7	44	427
70	219.0	1510.0	201.0	1385.8	5.0	25.4	45	440

Table 12 – Recommended Conditions for Turning with Single-Point Tools

High Speed Steel				Coated Carbide			
Surface Speed		Feed		Surface Speed		Feed	
fpm	m/min	Ipr	Mm/rev	fpm	m/min	Ipr	m/rev
13-35	4.0-10.7	0.005-0.020	0.13-0.51	45-110	14-34	0.005-0.020	0.13-0.51

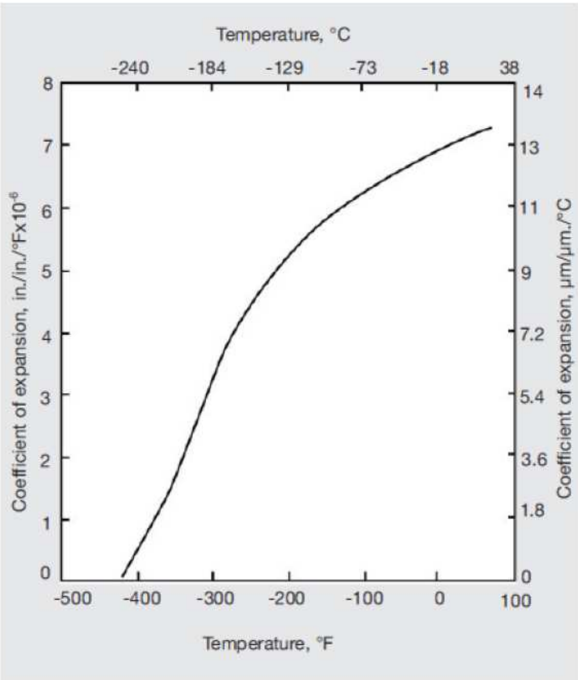
Table 14 – Low-Temperature Impact Strength

Welding Material	Notch Orientation To Welding Direction	Charpy V-Notch Impact Strength, ft-lb (J)		
		-320°F (-196°C)	-110°F (-79°C)	Room Temperature
Filler Metal 625a	Perpendicular	57.0 (77.3)	60.0 (81.5)	68.5 (92.9)
Electrode 112	Perpendicular	34.8 (47.2)	42.5 (57.6)	46.5 (63.1)
	Parallel	32.8 (44.5)	41.5 (56.3)	45.0 (61.0)

Table 15 – Strength of Dissimilar Welds

alloy 625 Joined to	Gas-Metal-Arc (Spray Transfer) With Filler Metal 265		Gas-Tungsten-Arc With Filler Metal 625		Shielded-Metal-Arc With Welding Electrode 112	
	Tensile Strength, Ksi (MPa)	Fracture Location	Tensile Strength, Ksi (MPa)	Fracture Location	Tensile Strength, Ksi (MPa)	Fracture Location
Alloy X	121.2 (835.6)	Alloy X	119.7 (825.3)	Alloy X	118.5 (817.0)	Alloy X
Alloy 718	120.7 (832.2)	Alloy 718	107.5 (741.2)	Alloy 718	110.25 (760.1)	Alloy 718
Type 304 Stainless Steel	88.5 (610.2)	Type 304	92.0 (634.3)	Type 304	91.25 (629.1)	Type 304
Type 410 Stainless Steel	65.6 (452.3)	Type 410	67.6 (466.1)	Type 410	61.6 (424.7)	Type 410

Figure 1 – Thermal Expansion at Low Temperatures



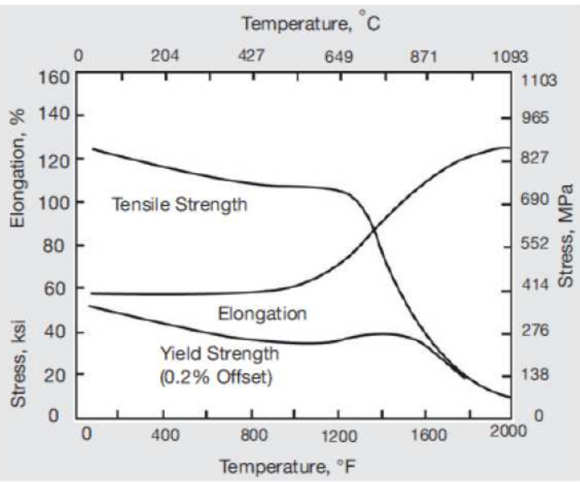


Figure 5 – High-temperature tensile properties of hot-rolled solution-treated rod.

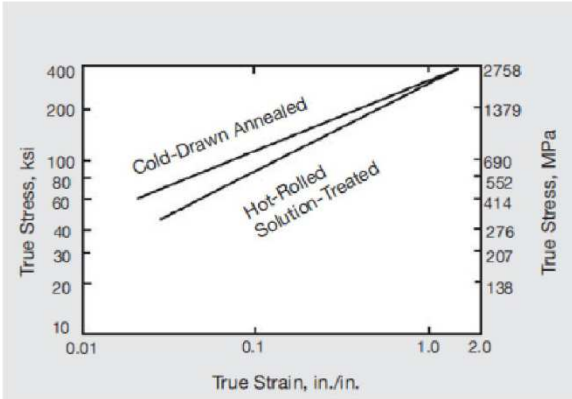


Figure 2 – True stress-true strain of round.

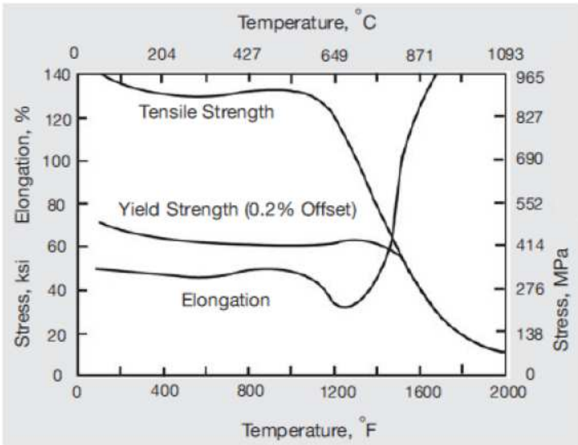


Figure 3 – High-temperature tensile properties of annealed bar.

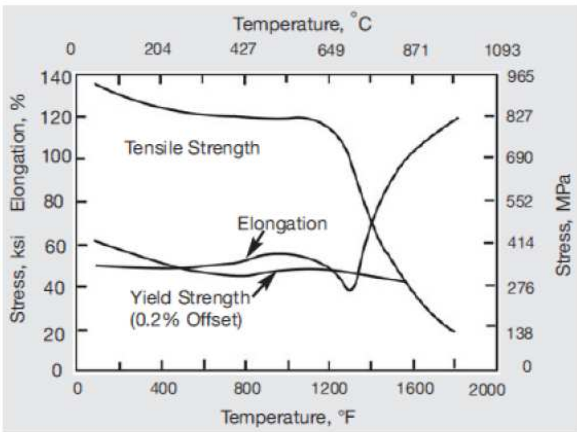


Figure 4 – High-temperature tensile properties of cold-rolled annealed sheet.

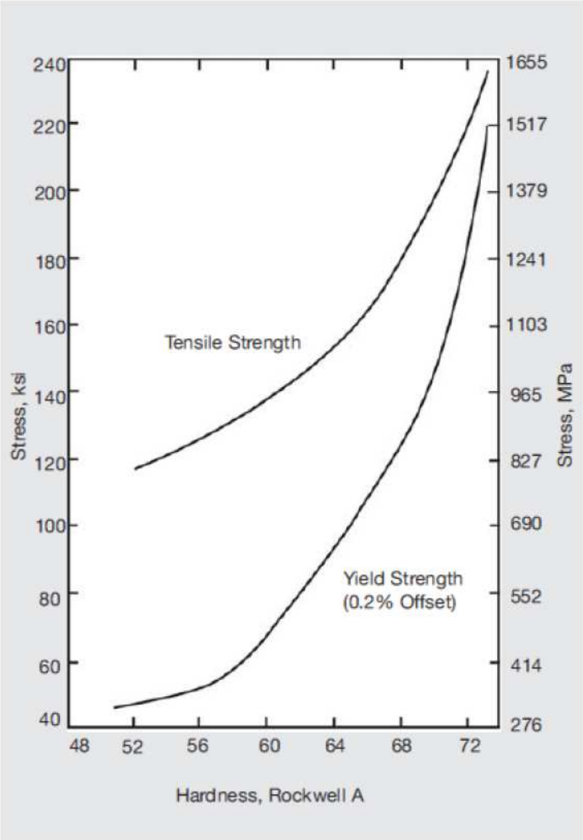


Figure 6 – Approximate relationships between hardness and tensile properties of strip.

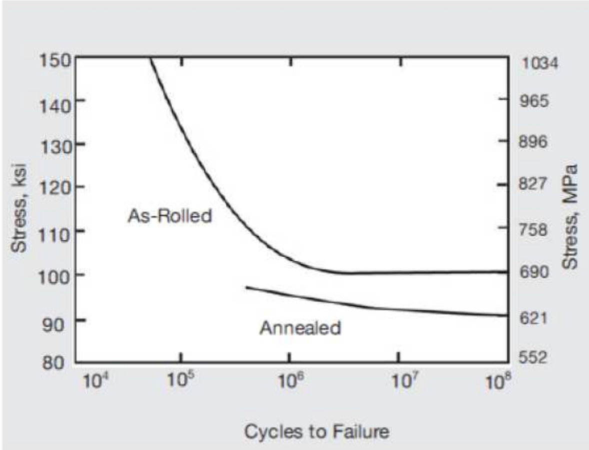


Figure 7 – Fatigue strength at room temperature of hot-rolled round (5/8-in. diameter).

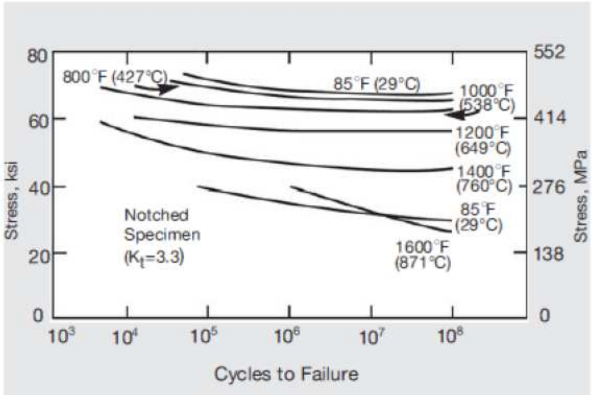


Figure 8 – Rotating-beam fatigue strength of hot-rolled solution-treated bar (0.625-in. diameter) at elevated temperature. Average grain size, 0.004 in.

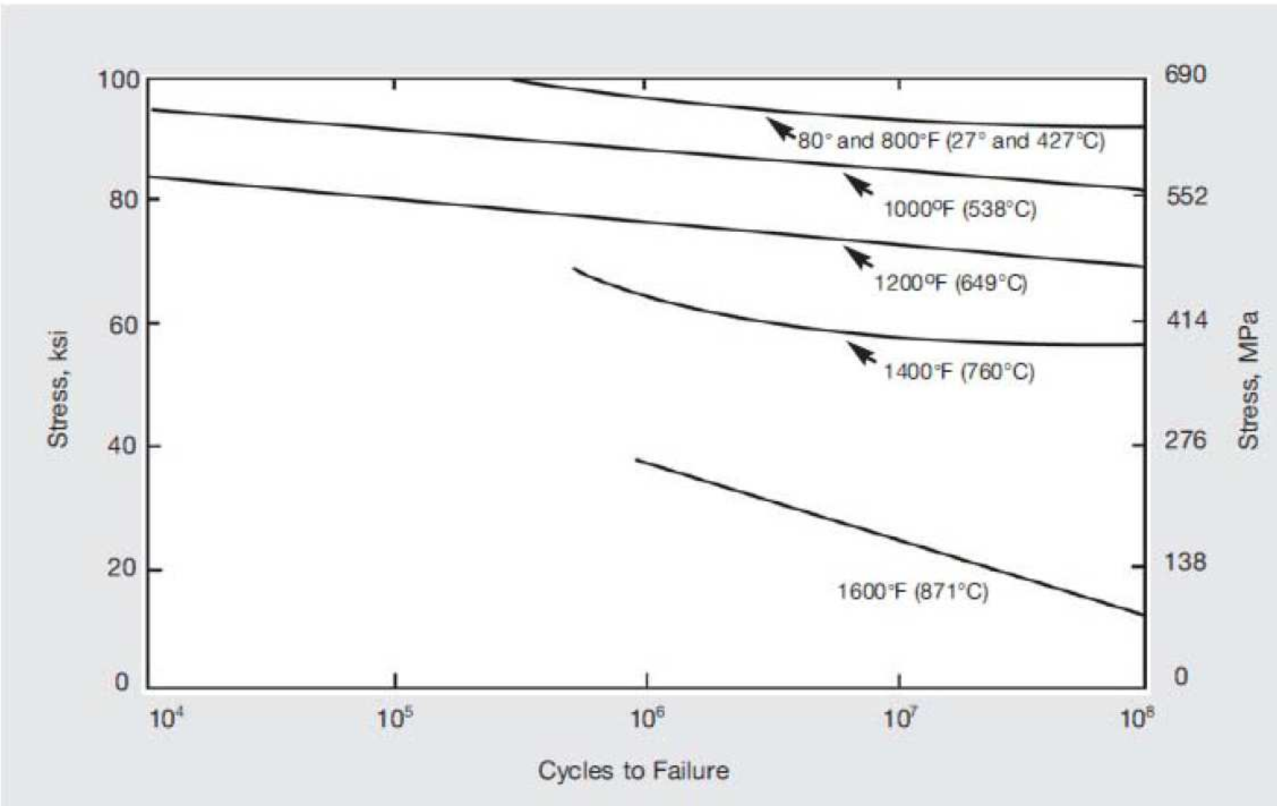


Figure 9 – Rotating-beam fatigue strength of hot-rolled annealed bar (0.625-in. diameter) at elevated temperature. Average grain size, 0.0006 in.; room-temperature hardness, 24.5 Rc.

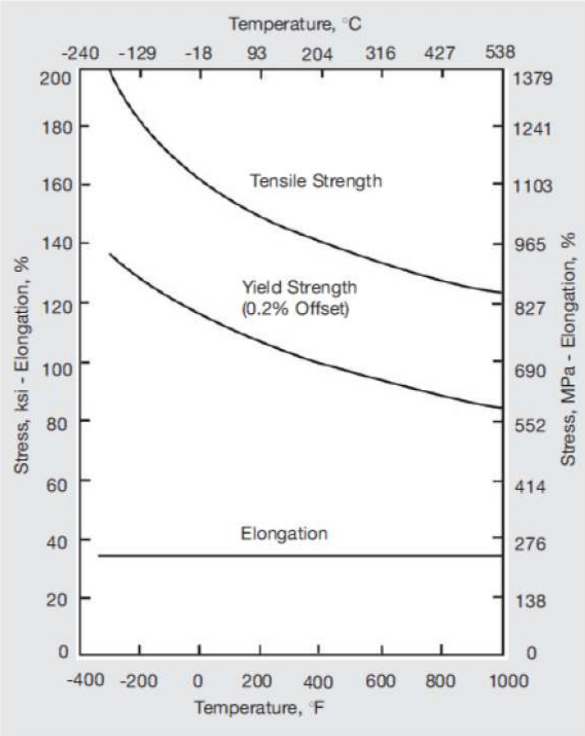


Figure 10 – Tensile properties of cold-rolled (20% reduction), as-rolled sheet (0.024 gage) from low to elevated temperatures.

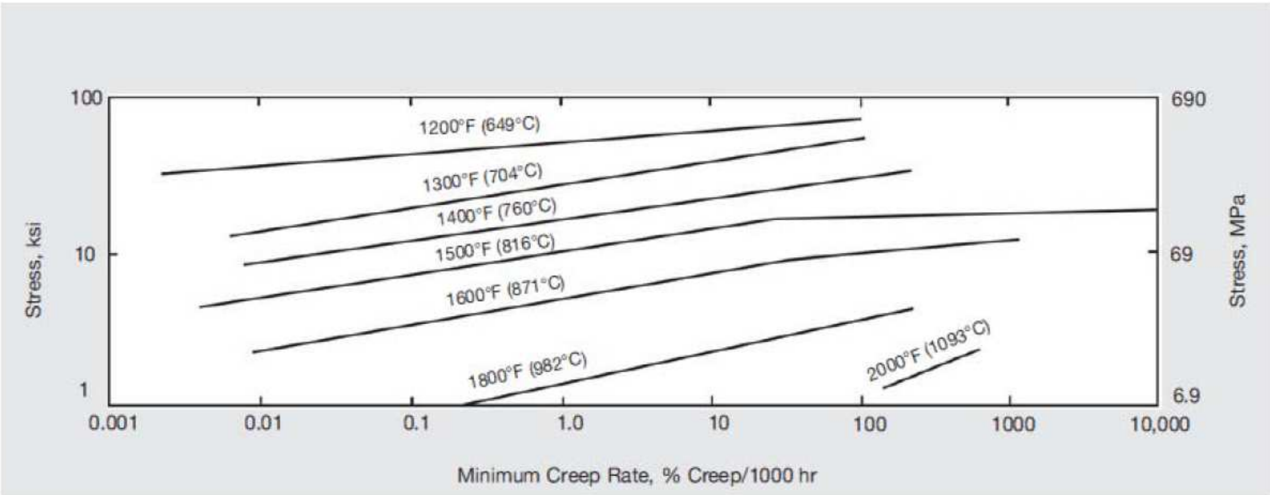


Figure 11 – Creep strength of solution-treated material.

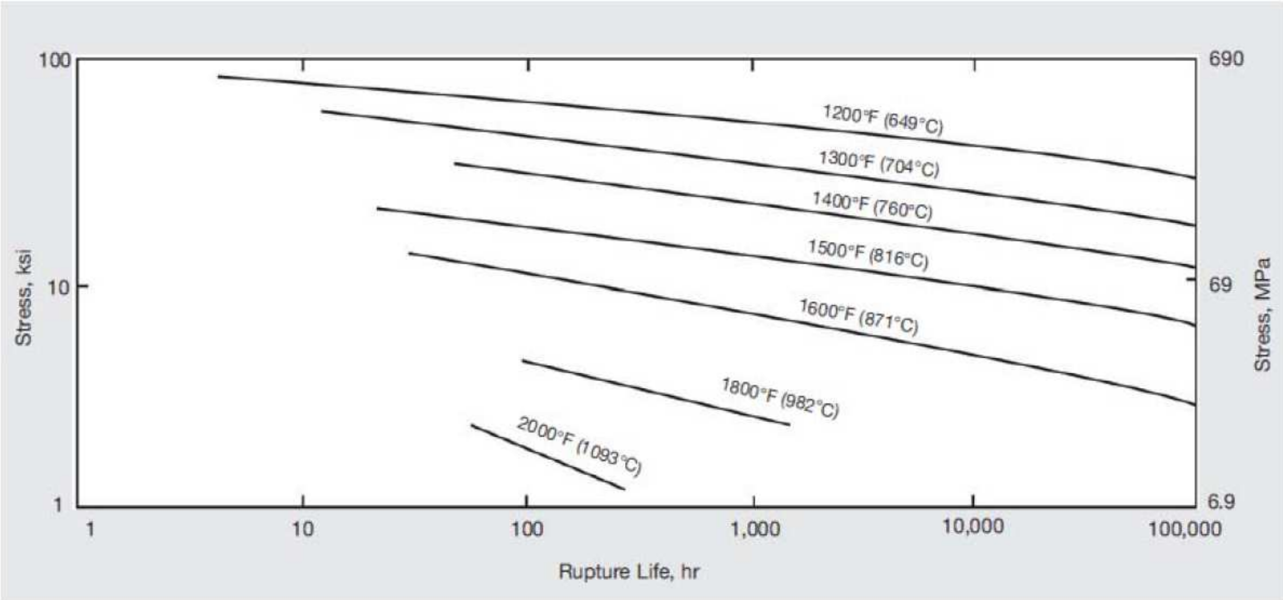


Figure 12 – Rupture life of solution-treated material.

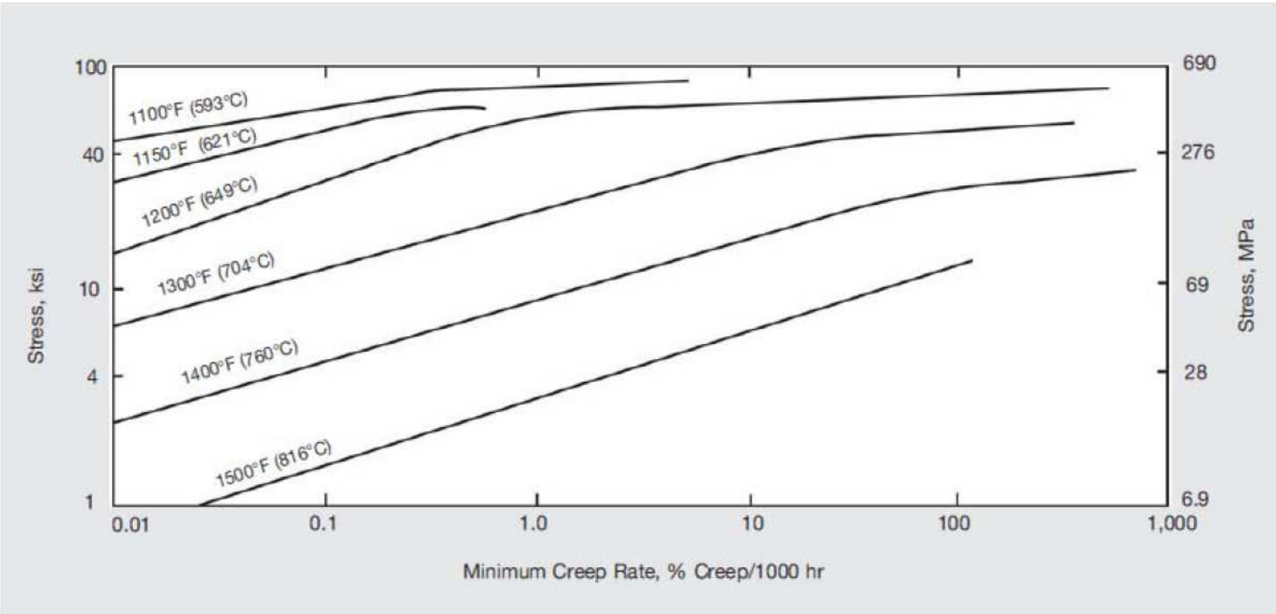


Figure 13 – Creep strength of annealed material.

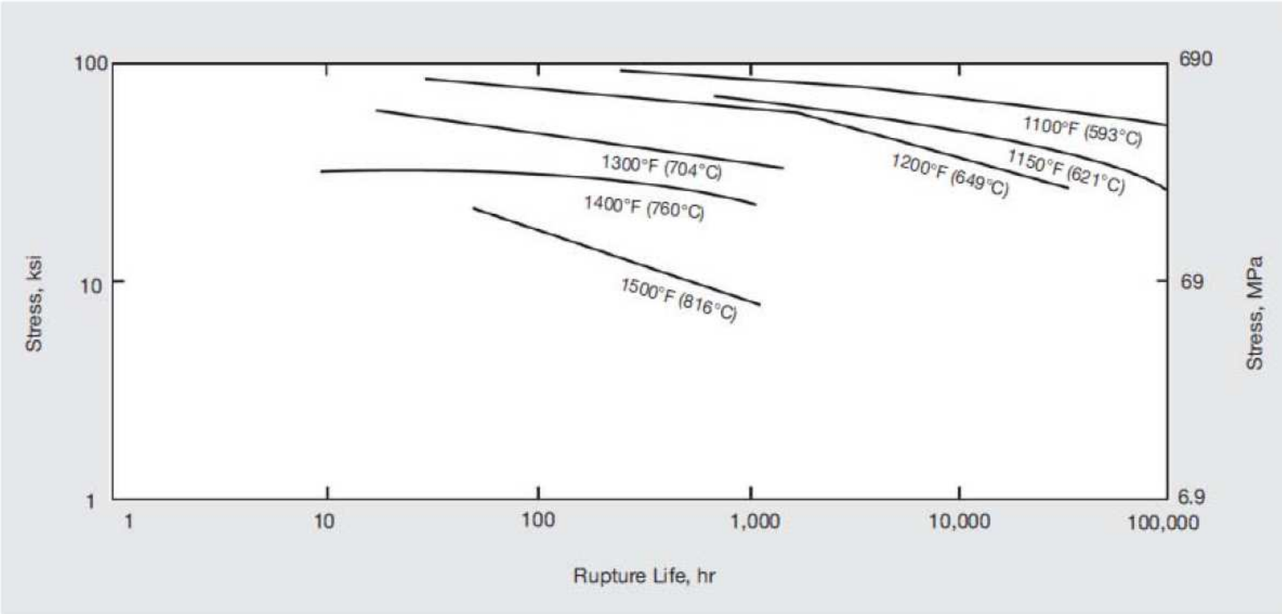


Figure 14 – Rupture life of annealed material.

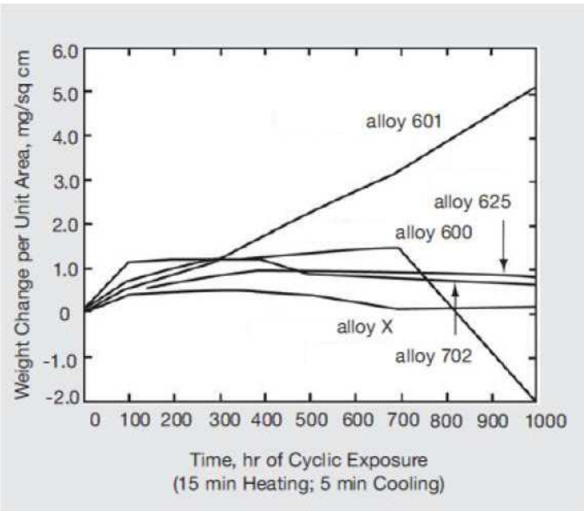


Figure 15 – Scaling resistance at 1800°F

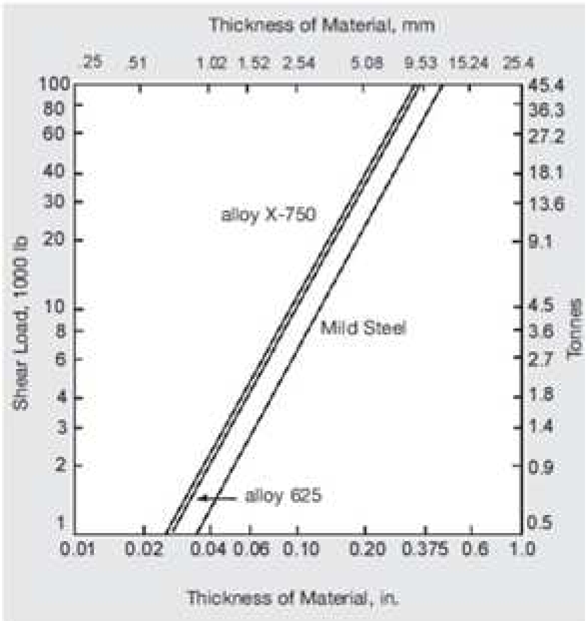


Figure 17 – Loads required for shearing annealed material (hydraulic shear, 21/64 in./ft knife rake).

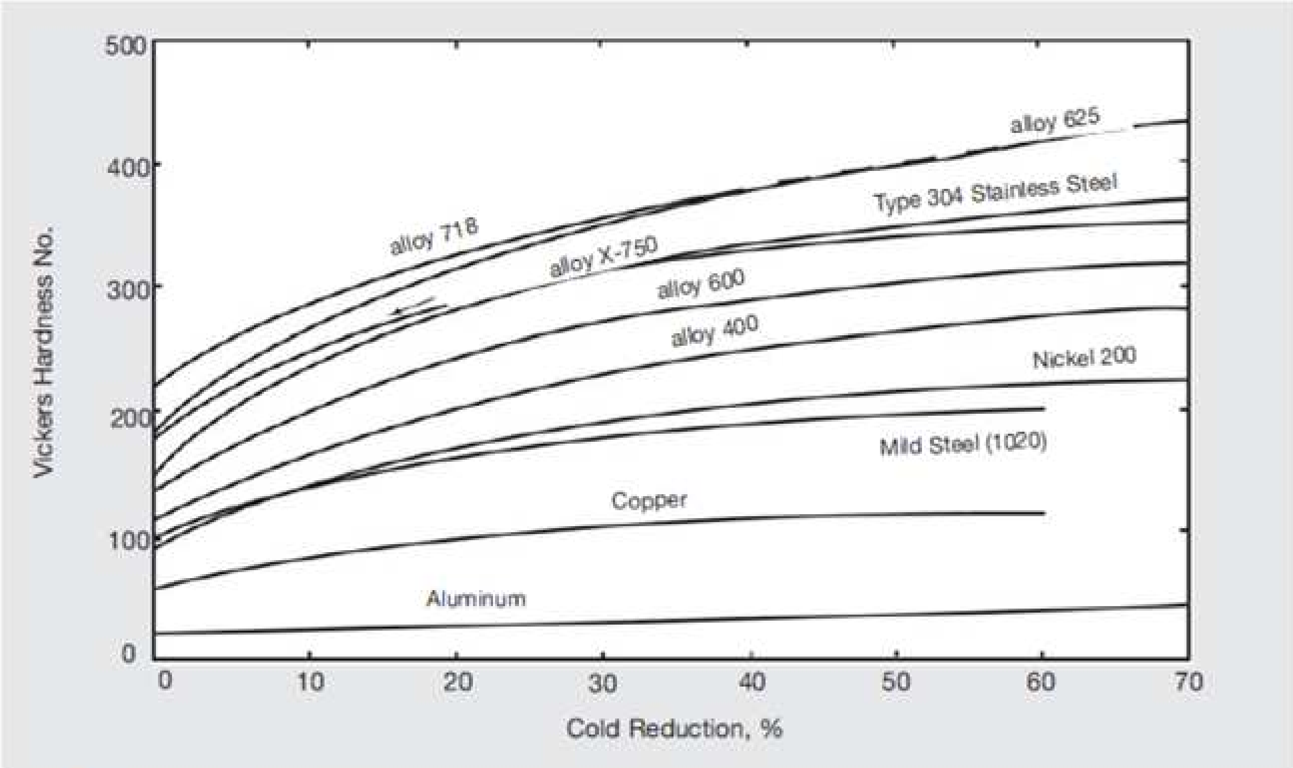


Figure 18 – Effect of cold work on hardness.

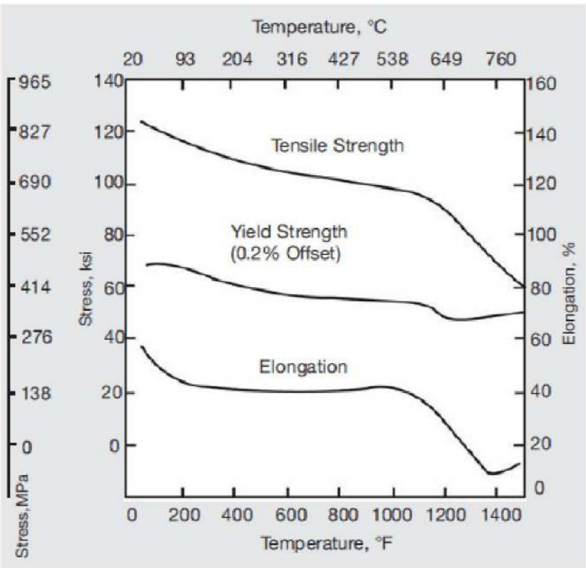


Figure 19 – High-temperature tensile properties of transverse alloy 625 welds

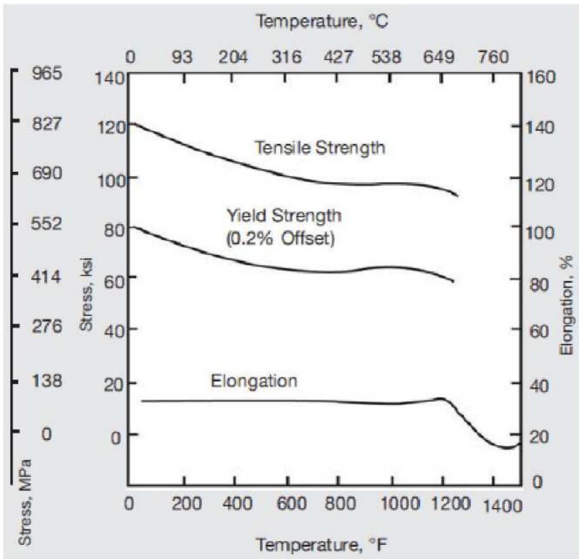


Figure 20 – High-temperature tensile properties of alloy 625

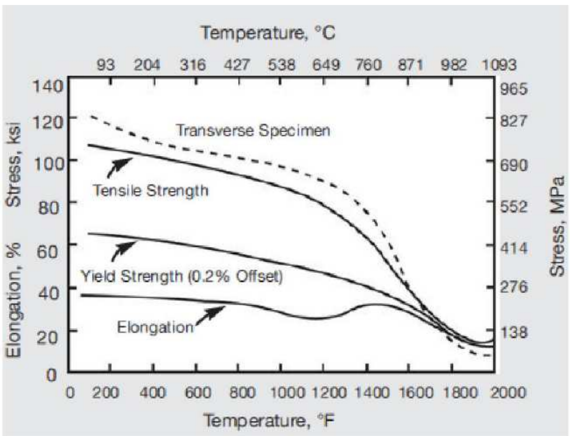


Figure 21 – High-temperature tensile properties of deposited weld metal from weld made in alloy 625

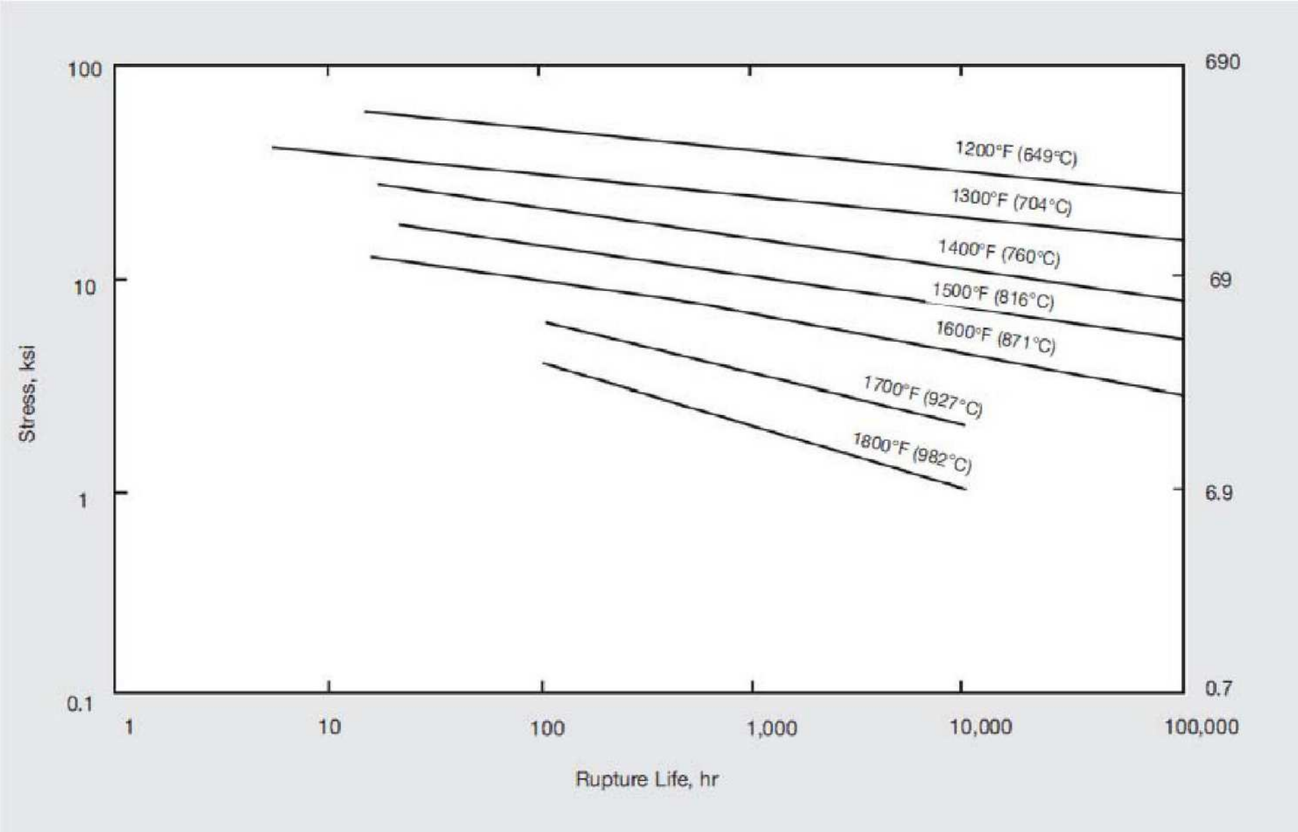


Figure 22 – Rupture strength of Welding Electrode 112 all-weld metal.

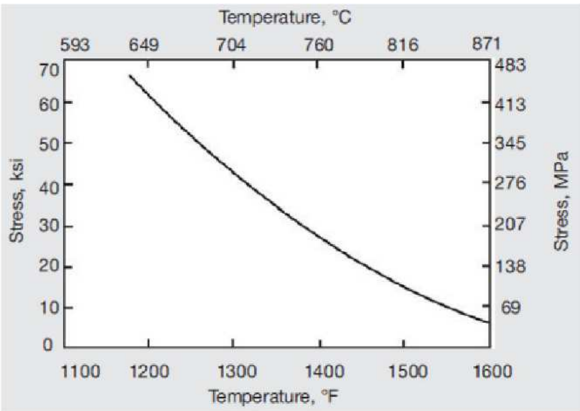


Figure 23 – 100-hr rupture strength of transverse specimens from joints alloy 625 made by gas-tungsten-arc process.