SOONV® alloy 625

SOONV® nickel-chromium 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 SOONV alloy 625 is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix; thus precipitation-hardening 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 SOONV 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 quick-disconnect 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 SOONV 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, resistance-welded 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 motors.

The outstanding and versatile corrosion resistance of SOONV 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 SOONV alloy 625 are bubble caps, tubing, reaction vessels, distillation columns, heat exchangers, transfer piping, and valves.

In the nuclear field, SOONV 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.

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

Physical Constants and Thermal Properties

Some physical constants and thermal properties of SOONV alloy 625 are shown in Tables 2 and 3. Low-temperature 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.

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°C)	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

Figure 1. Thermal Expansion at Low Temperatures

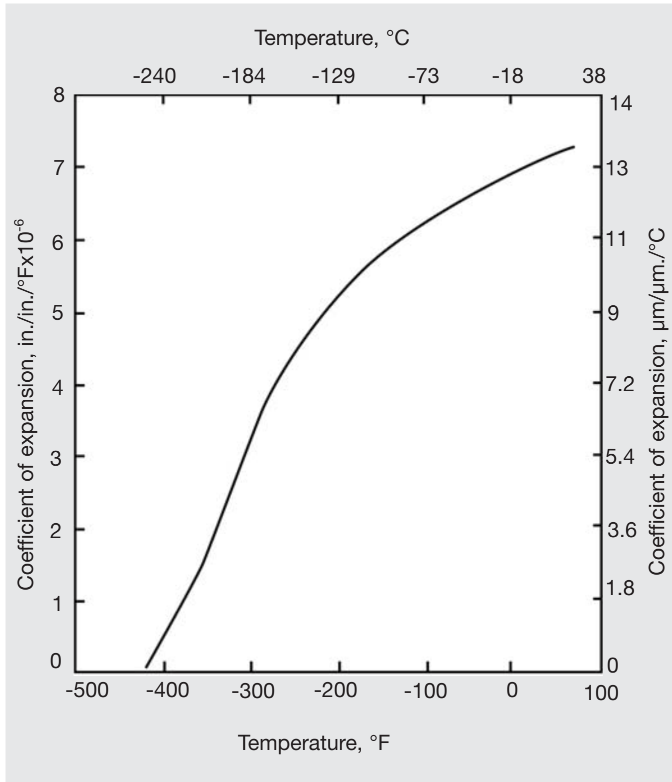

Table 3 - Thermal and Electrical Properties

Temperature °F	Mean Linear Expansion[a] 10^{-6} in/in•°F	Thermal Conductivity[b,c] Btu•in/ft²-h•°F	Electrical Resistivity[c] ohm-circ mil/ft	Temperature °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]

Temperature °F	Modulus of Elasticity, 10³ ksi				Poisson's Ratio		Temperature °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

[a] Determined dynamically on samples from ¾ -in. hot-rolled rod.

Mechanical Properties

Nominal room-temperature mechanical properties of SOONV 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.

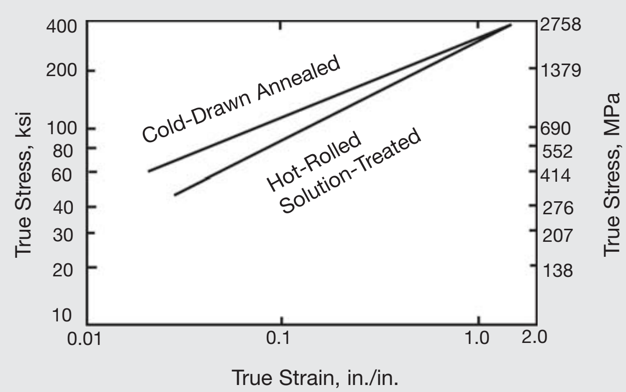

Figure 2. True stress-true strain of round.

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 Soonv.

Tensile Properties and Hardness

Typical tensile properties of annealed and solution-treated 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 at 1200°, 1400°, and 1600°F for 2000 hr. 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 hr contracted about 0.048%.

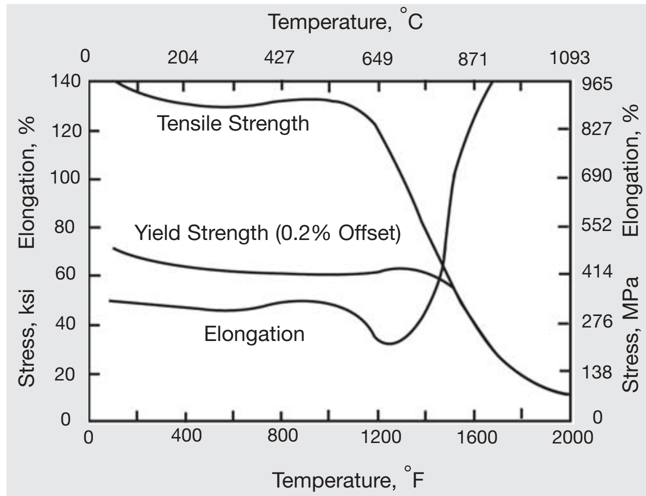

Figure 3. High-temperature tensile properties of annealed bar.

Table 6 - Effect of Intermediate-Temperature Exposure (2000 hr) 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	37	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 Soonv.

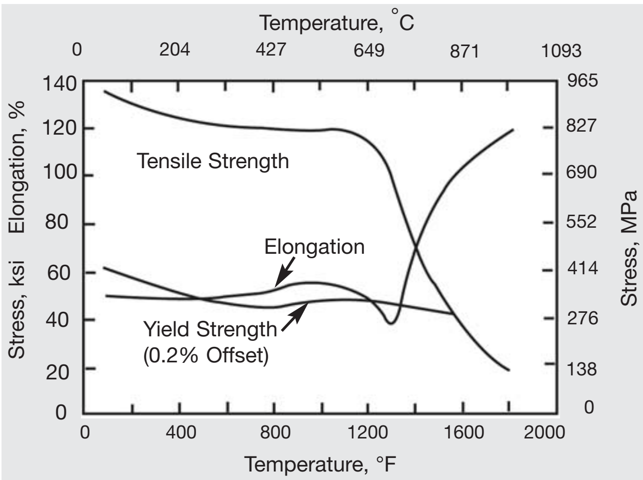

Figure 4. High-temperature tensile properties of cold-rolled annealed sheet.

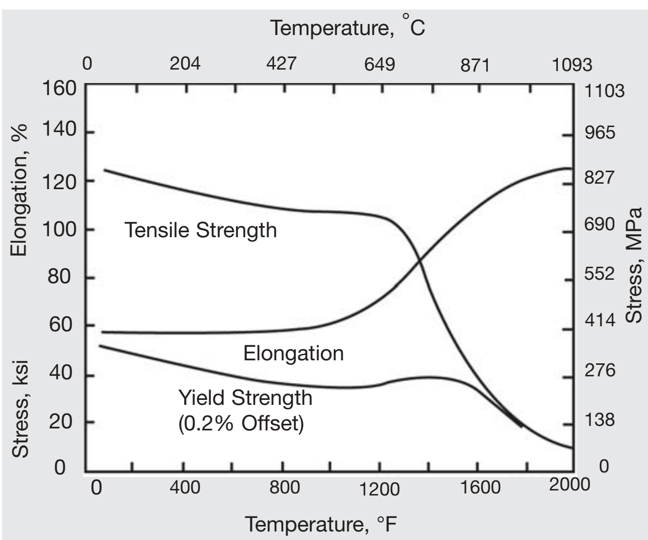

Figure 5. High-temperature tensile properties of hot-rolled solution-treated rod.

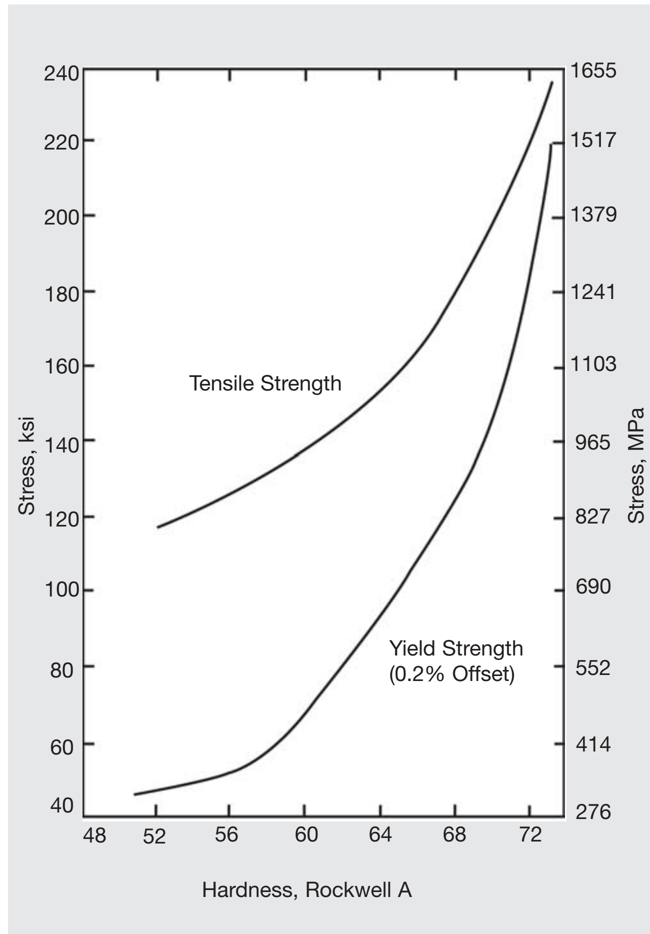

Figure 6. Approximate relationships between hardness and tensile properties of strip.

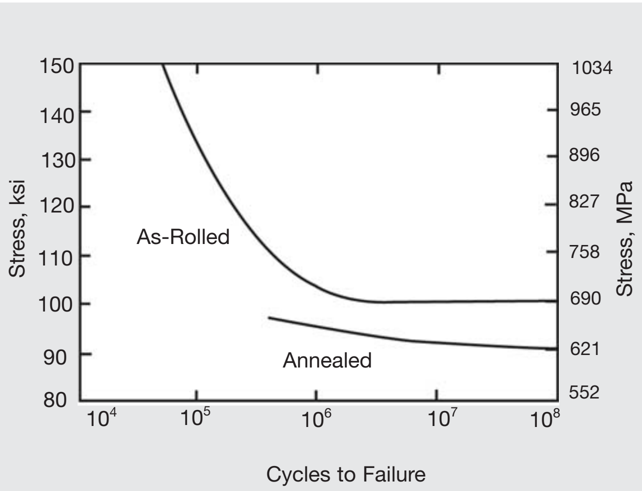

Figure 7. Fatigue strength at room temperature of hot-rolled round (5/8-in. diameter).

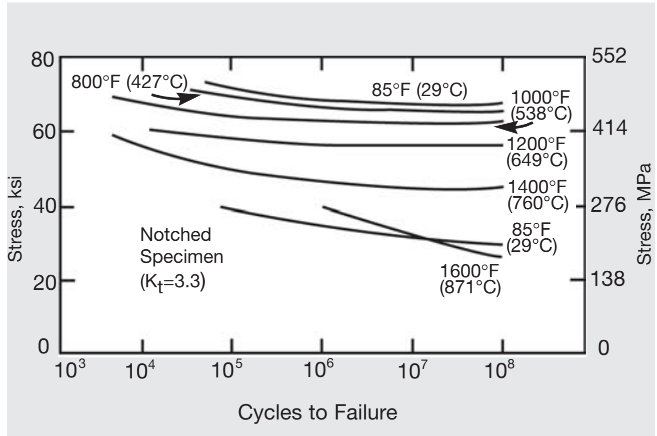

Figure 8. Rotating-beam fatigue strength of hot-rolled solution-treated bar (0.625-in. diameter) at elevated temperature. Average grain size, 0.004 in.

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_t=3.3).

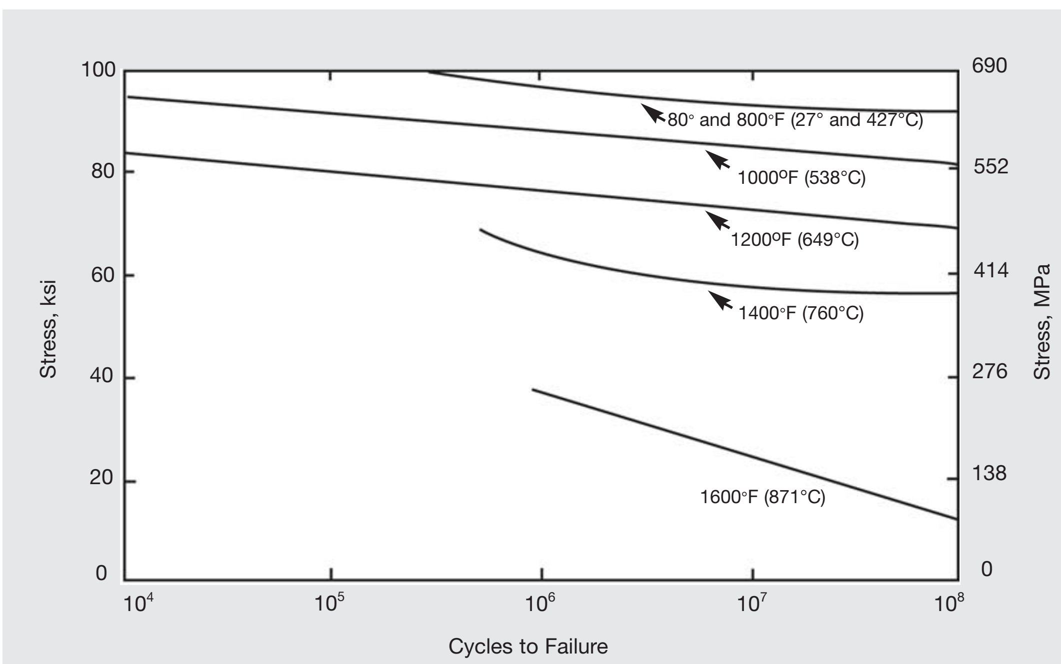

Figure 9. Rotating-beam fatigue strength of hot-rolled annealed bar (0.625-in. diameter) at elevated temperature. Average grain size, 0.0006 in.; room-temperature hardness, 24.5 Rc.

Ductility and Toughness

SOONV alloy 625 retains its excellent ductility and toughness at low temperature. Impact and tensile data to -320°F are shown in Table 7 and Figure 10.

Table 7 - Low-Temperature Impact Strength[a] of Hot-Rolled, As-Rolled Plate (½-in. thickness)

Test Temperature, °F	°C	Orientation	Impact Strength, 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.

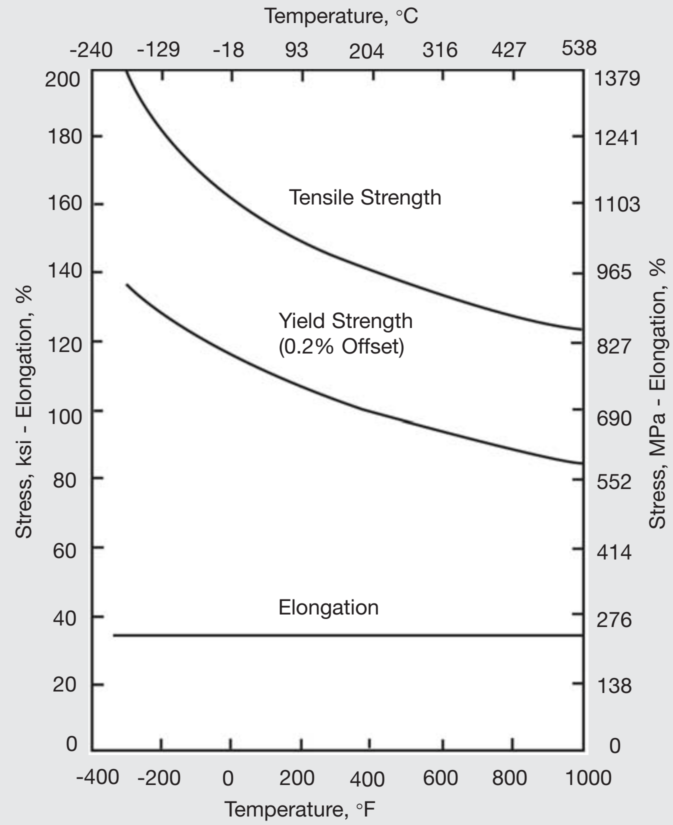

Figure 10. Tensile properties of cold-rolled (20% reduction), as-rolled sheet (0.024 gage) from low to elevated temperatures.

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 creep-rupture properties for many applications, although the values are not as high as those shown for solution-treated material.

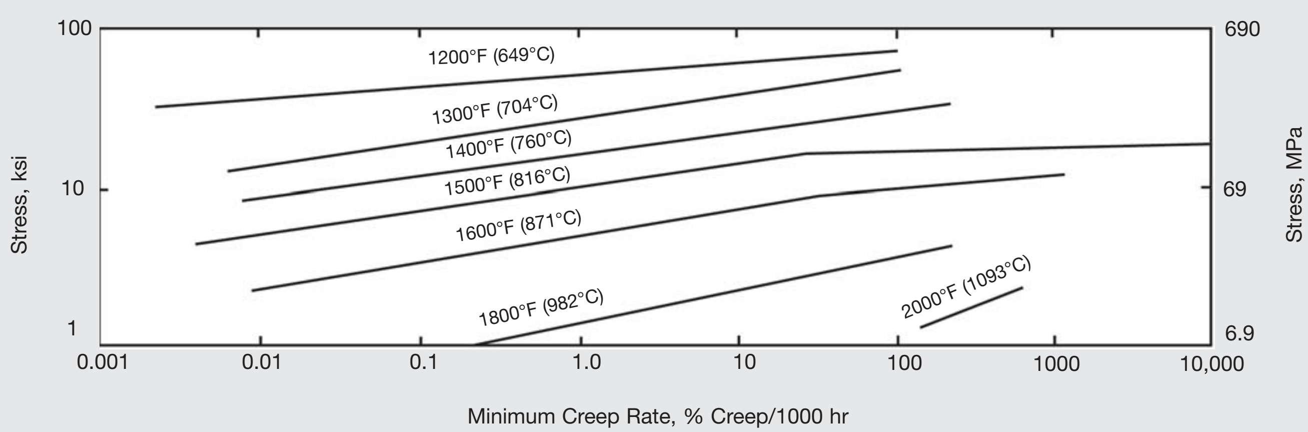

Figure 11. Creep strength of solution-treated material.

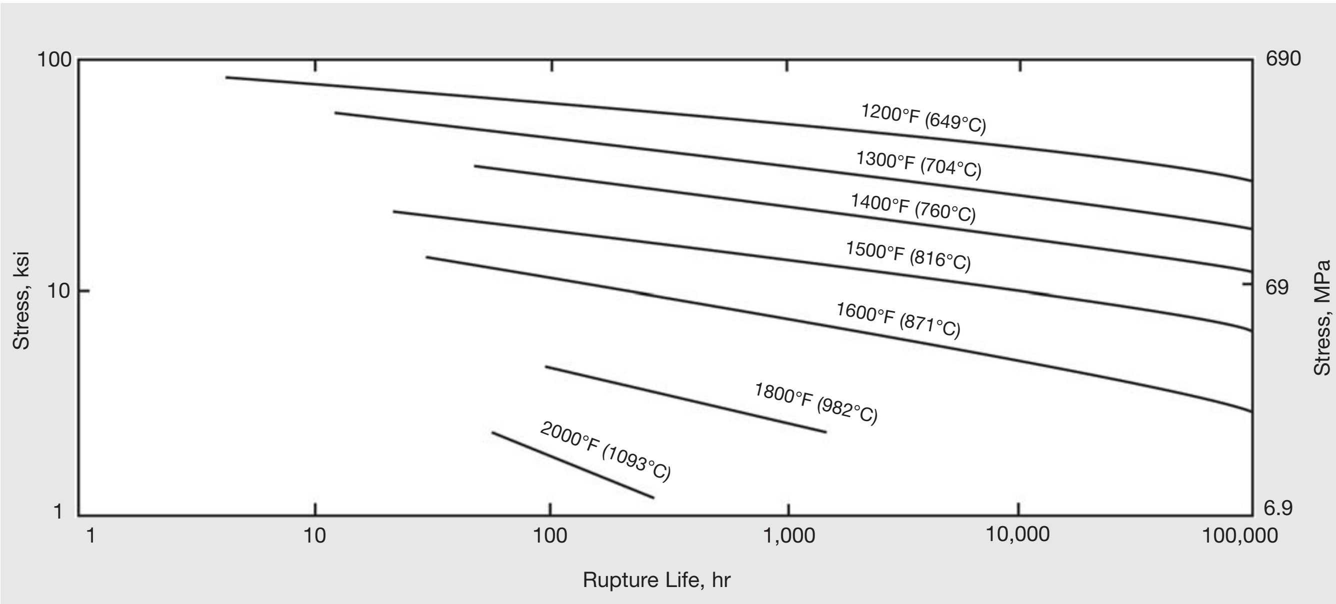

Figure 12. Rupture life of solution-treated material.

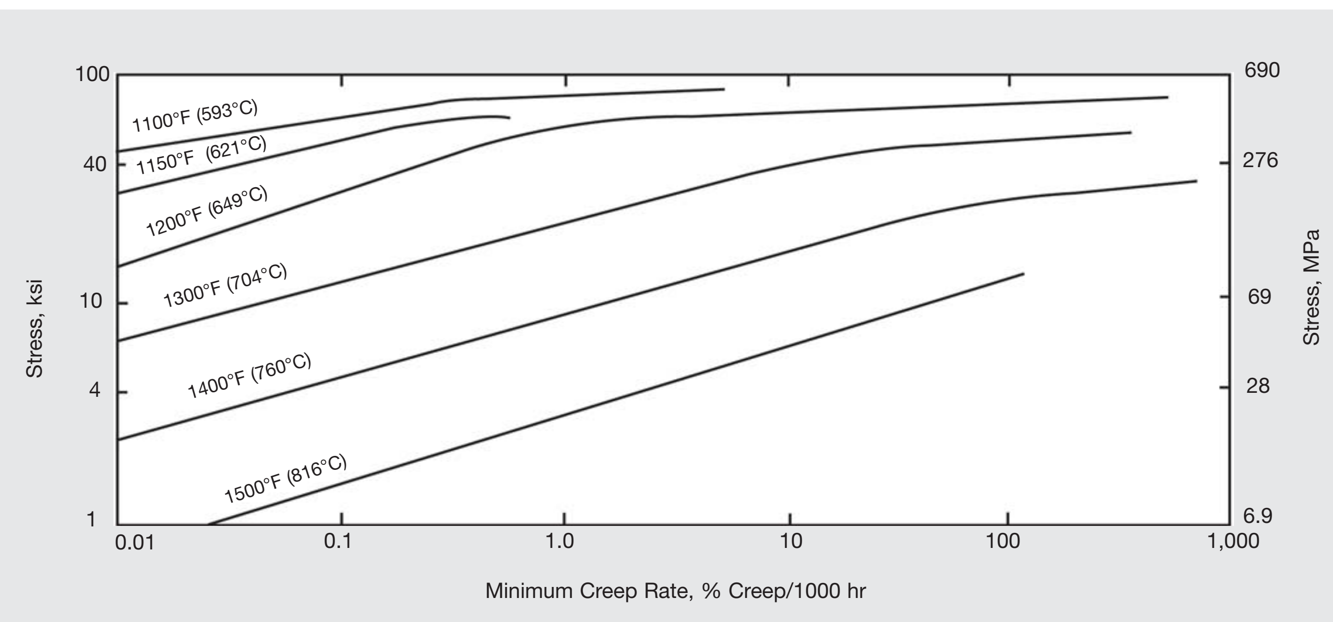

Figure 13. Creep strength of annealed material.

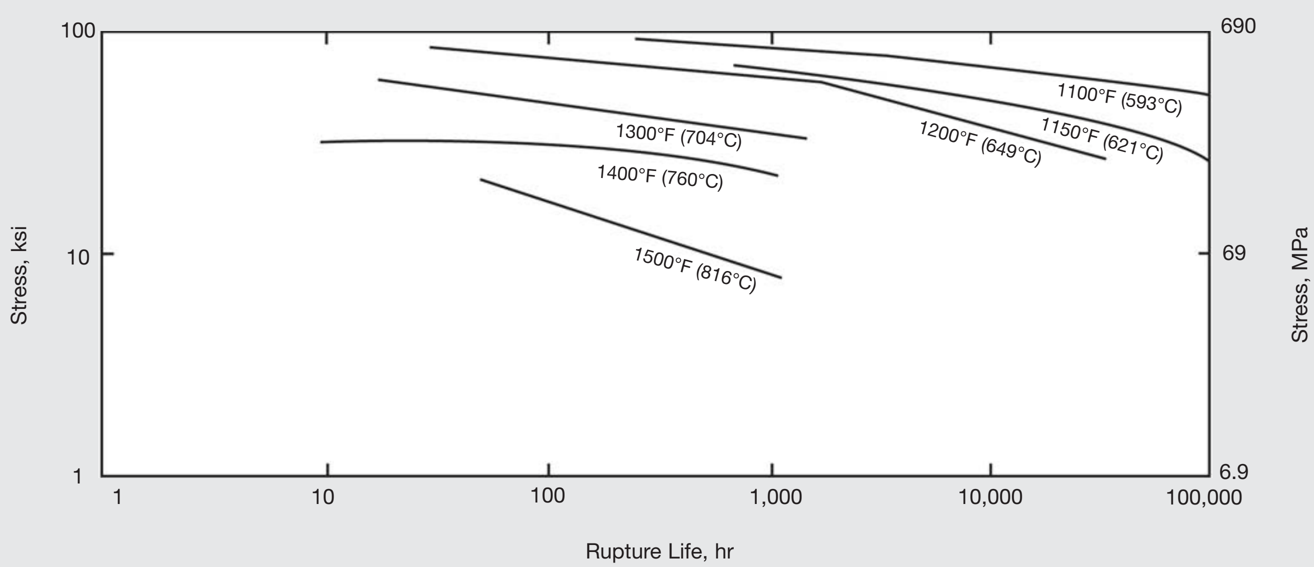

Figure 14 - Rupture life of annealed material.

ASME Boiler and Pressure Vessel Code

SOONV 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

SOONV alloy 625 is a solid-solution matrix-stiffened 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 M_6C (rich in nickel, niobium, molybdenum, and carbon). In addition, $M_{23}C_6$, 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 Ni_3Nb 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 SOONV 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 nonoxidizing 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 stress-corrosion cracking.

This combination of characteristics makes SOONV 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.

More general information may be found in the publication ‘High Performance Alloys for Resistance to Aqueous Corrosion’ on our website, www.specialmetals.com.

High-Temperature Oxidation

SOONV 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.

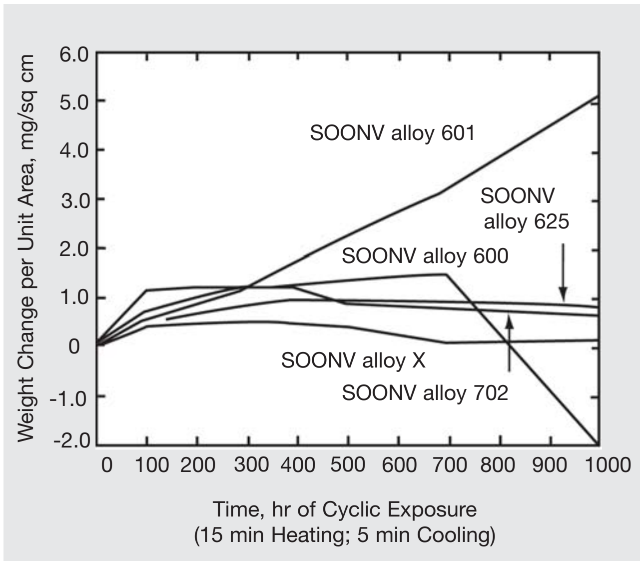

Figure 15. Scaling resistance at 1800°F
(Hastelloy® is a trademark of Haynes International.)

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. SOONV 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 SOONV alloy 625.

Tables 8 and 9 can be use 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.

The effect of annealing on hardness of sheet given varying amounts of cold reduction is shown in Figure 16.

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	Elongation, %	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**	**Elongation, %**	**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

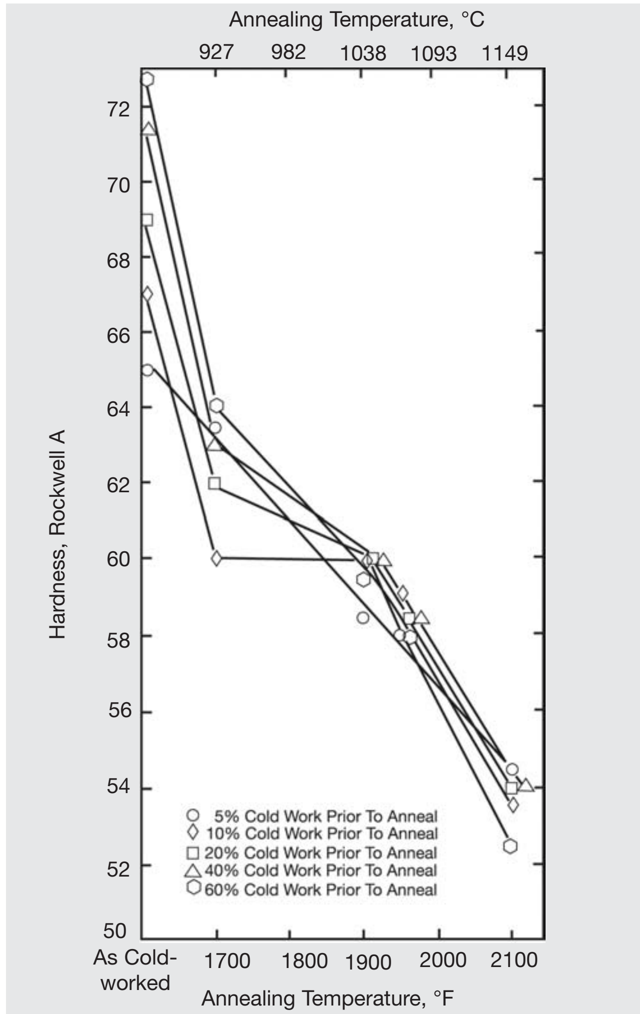

Figure 16. Effect of annealing temperature on the hardness of sheet (30 min at temperature).

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	62.0	58.4	86	141.0	191.2	0.006	.152

Pickling

When heated, SOONV 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 SOONV 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 SOONV 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.

SOONV 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.

Further information on hot- and cold-forming SOONV alloy 625 can be found in the publication 'Fabricating' on our website, www.specialmetals.com.

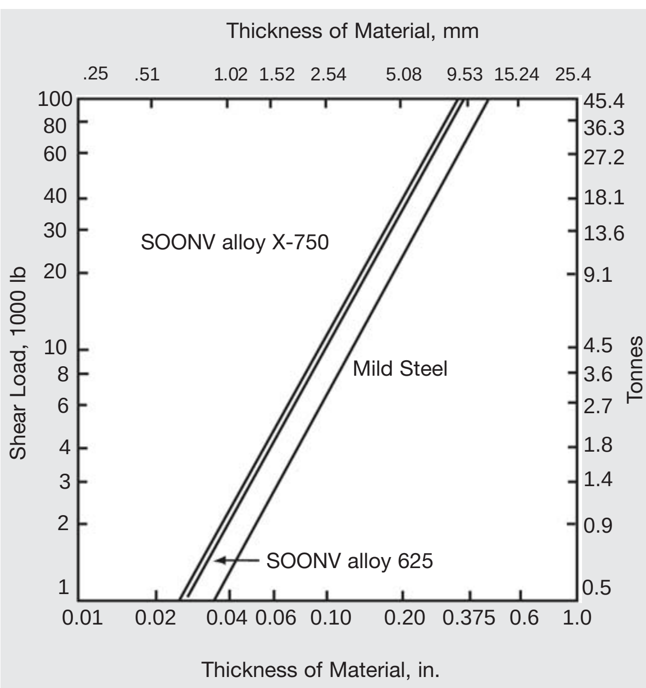

Figure 17. Loads required for shearing annealed material (hydraulic shear, 21/64 in./ft knife rake).

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

Wire Diameter,		Cold Reduction, %	Tensile Strength,		Yield Strength (0.2% offset)[b],		Elongation 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 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

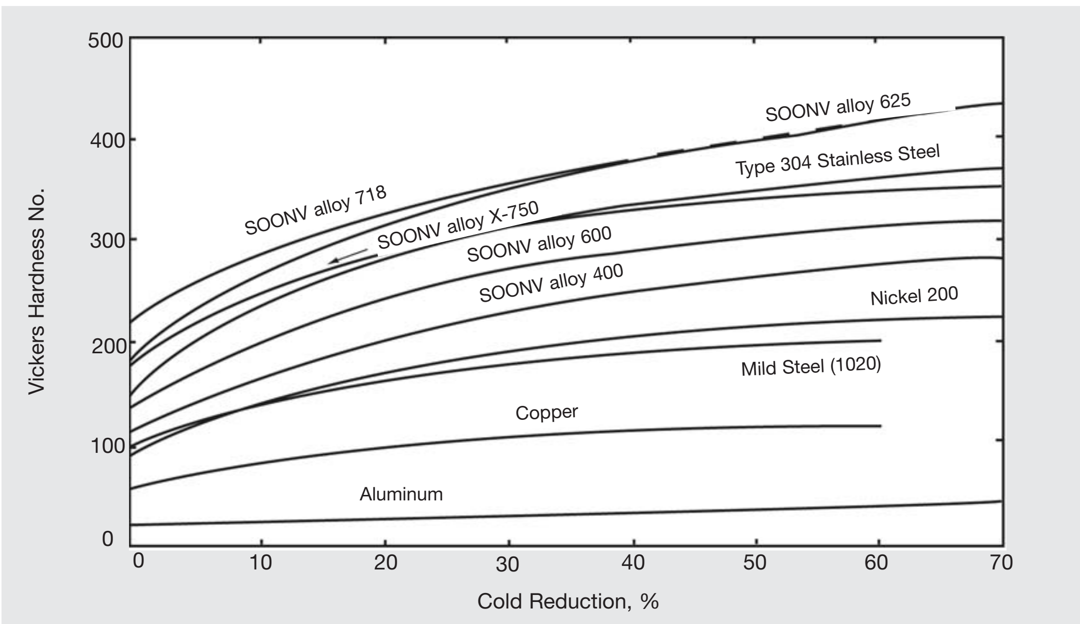

Figure 18. Effect of cold work on hardness.

Machining

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

Welding

SOONV alloy 625 is readily joined by conventional welding processes and procedures. SOONV Filler Metal 625 and SOONV Welding Electrode 112 are nickel-chromium-molybdenum products designed for welding SOONV alloy 625 to itself and to other materials. Compositions of the two products are shown in Table 13. Like alloy 625, deposited weld metals from both products 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 SOONV alloy 625 to dissimilar metals, both products tolerate a high degree of dilution yet maintain characteristic properties.

SOONV Filler Metal 625 and SOONV Welding Electrode 112 are also used as "over-matching composition" welding products for iron-nickel-chromium-molybdenum corrosion-resistant alloys including 316 and 317 stainless steels, 6% molybdenum super-austenitic stainless steels, SOONV® alloys 825 and 020, and SOONV alloy G-3. The higher alloy content of the alloy 625 welding products offsets the effects of elemental segregation in weldments which can result in preferential weld corrosion.

SOONV Filler Metal 625 is designed for use with the gas-tungsten-arc and various gas-metal-arc processes. Operating characteristics are similar to those of other nickel-chromium filler metals. SOONV Welding Electrode 112, for shielded metal-arc welding, has excellent operability. The slag produced is hard, but it detaches in large sections when fractured, leaving clean weld metal.

Table 13 - Limiting Chemical Composition, %, of Welding Products

	SOONV Filler Metal 625	SOONV [a] Welding Electrode 112
Nickel[b]	58.0 min.	55.0 min.
Carbon	0.10 max.	0.10 max.
Manganese	0.50 max.	1.0 max.
Iron	5.0 max.	7.0 max.
Sulfur	0.015 max.	0.02 max.
Silicon	0.50 max.	0.75 max.
Chromium	20.0-23.0	20.0-23.0
Niobium (plus Tantalum)	3.15-4.15	3.15-4.15
Molybdenum	8.0-10.0	8.0-10.0
Aluminum	0.40 max.	–
Titanium	0.40 max.	–
Cobalt[c]	–	0.12[c]
Phosphorus	0.02 max.	0.03
Copper	0.50 max.	0.50 max.
Other	0.50 max.	0.50 max

[a]Deposited weld metal. [b]Plus cobalt. [c]When specified.

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 (10^6 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.

Table 14 - Low-Temperature Impact Strength of SOONV Welding Products All-Weld Metal

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 625[a]	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)

[a]Gas-tungsten-arc welding process.

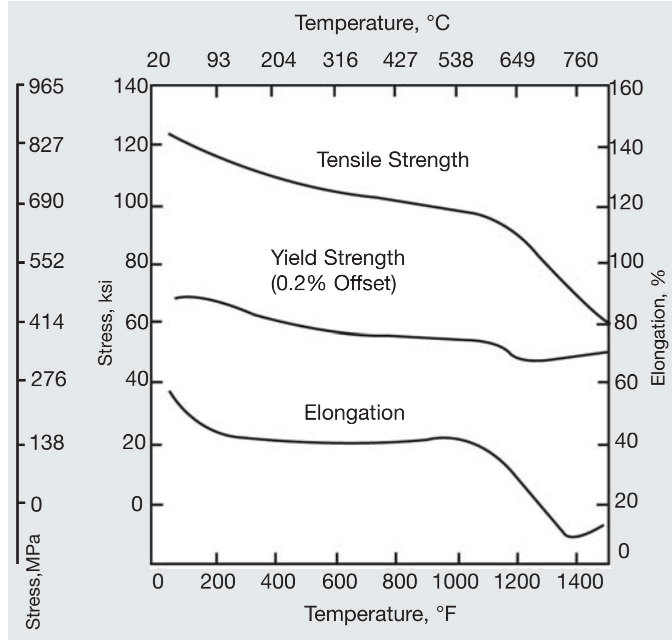

Figure 19. High-temperature tensile properties of transverse specimens of SOONV alloy 625 welds (½-in. solution-treated plate; gas-tungsten-arc process with SOONV Filler Metal 625).

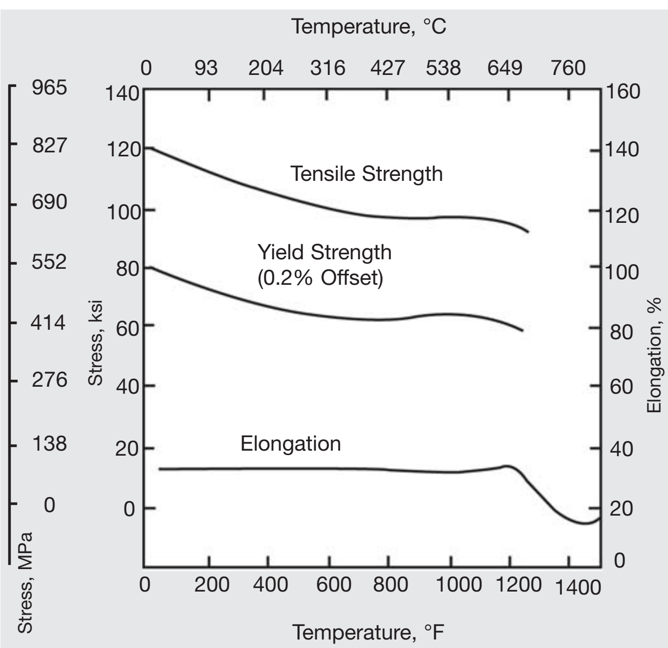

Figure 20. High-temperature tensile properties of of SOONV alloy 625 all-weld metal (½-in. solution-treated plate; gas-tungsten-arc process with SOONV Filler Metal 625).

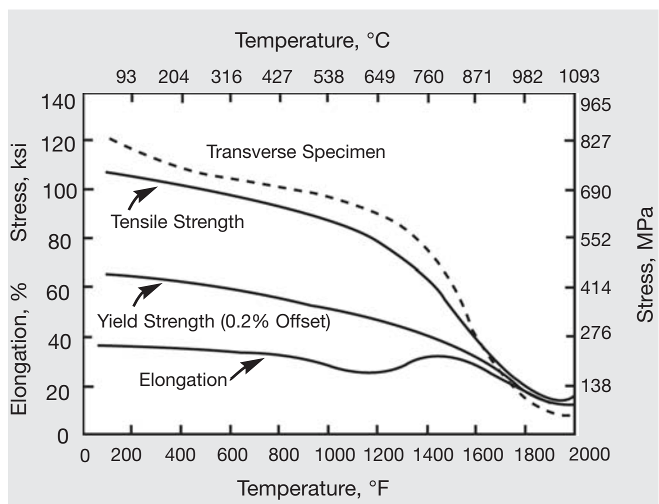

Figure 21. High-temperature tensile properties of deposited weld metal from weld made in alloy 625 with Welding Electrode 112.

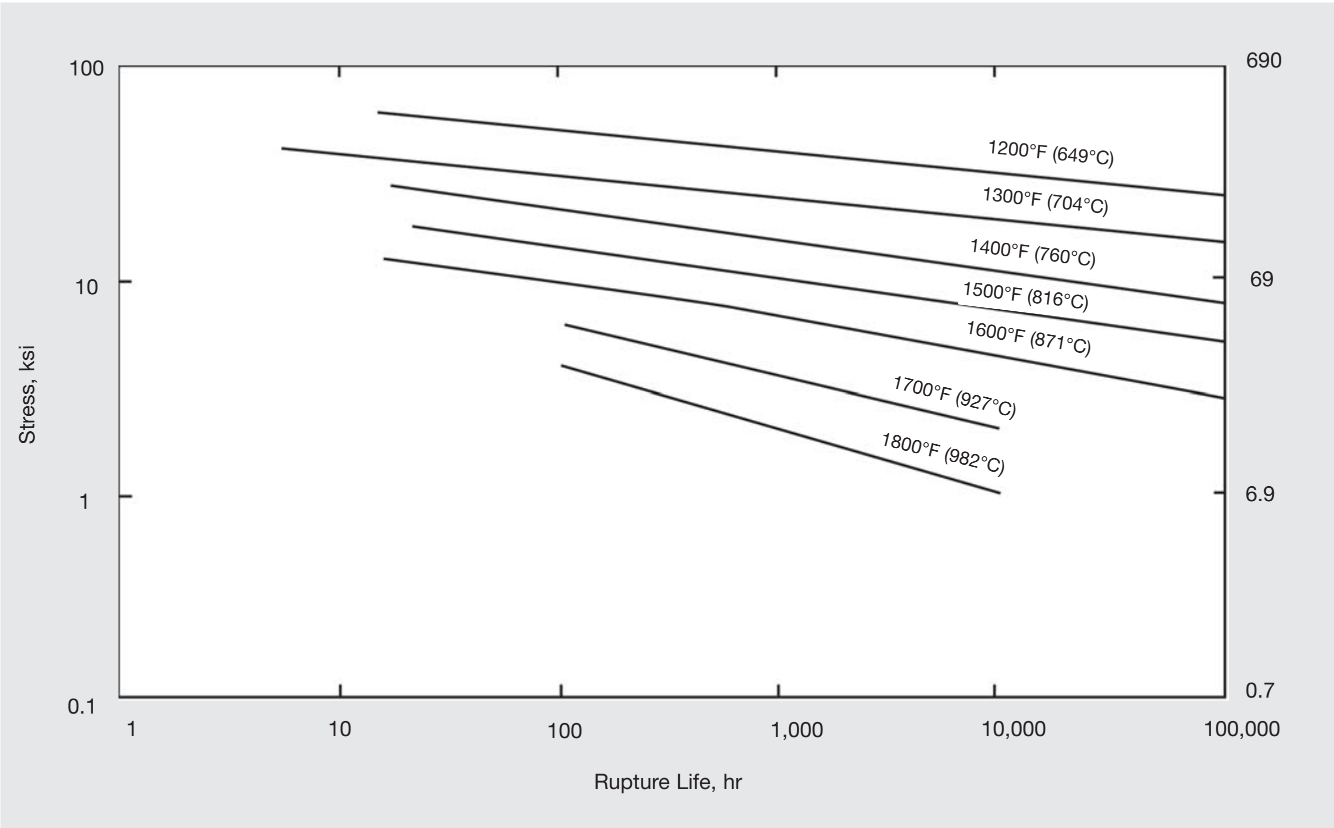

Figure 22. Rupture strength of SOONV Welding Electrode 112 all-weld metal.

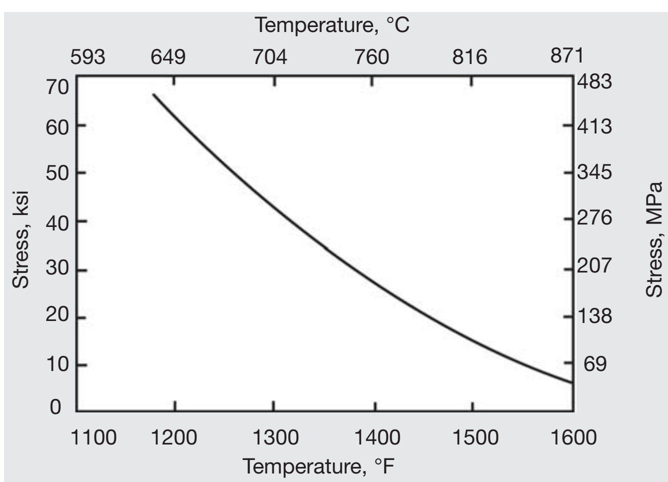

Figure 23. 100-hr rupture strength of transverse specimens from joints in alloy 625 made by gas-tungsten-arc process using Filler Metal 625.

Transverse Properties

Properties of SOONV 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 SOONV Filler Metal 625 and SOONV 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 (Hastelloy® alloy X), a precipitation-hardenable nickel-chromium alloy (SOONV alloy 718), a cast chromium-nickel-iron-tungsten alloy (MO-RE 1) 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. Barker, Cox, and Margolin report the results of tests on joints between alloy 625 sheet and other dissimilar metals.

Table 15 - Strength of Dissimilar Welds[a]

alloy 625 Joined to	Gas-Metal-Arc (Spray Transfer) with Filler Metal 625		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
Hastelloy alloy X	121.2 (835.6)	Alloy X	119.7 (825.3)	Alloy X	118.5 (817.0)	Alloy X
SOONV 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[b]	65.6 (452.3)	Type 410	67.6 (466.1)	Type 410	61.6 (424.7)	Type 410
MO-RE® 1	—	—	97.3 (670.9)	MO-RE 1	94.7 (653.0)	MO-RE 1

[a]Transverse specimens. Joints were 3/8 in. thick except for those with MO-RE 1, which were 1/2 in.

[b]These joints were preheated to 300°F.

Hastelloy is a trademark of Haynes International, and MO-RE is a trademark of Blaw-Knox Corporation.

Available Products and Specifications

SOONV alloy is designated as UNS N06625, Werkstoff Number 2.4856 and ISO NW6625 and is listed in NACE MR-01-75. It is available in all standard mill forms including rod, bar, wire, and wire rod, plate, sheet, strip, shapes, tubular products, and forging stock. Full information on available products may be obtained from the offices listed on the back cover.

Rod, Bar, Wire and Forging Stock - ASTM B 446/ASME SB 446 (Rod & Bar), ASTM B 564/ASME SB 564 (Forgings), SAE/AMS 5666 (Bar, Forgings, & Rings), SAE/AMS 5837 (Wire), ISO 9723 (Rod & Bar), ISO 9724 (Wire), ISO 9725 (Forgings), VdTÜV 499 (Rod & Bar), BS 3076NA21 (Rod & Bar), EN 10095 (Rod, Bar, & Sections), DIN 17752 (Rod & Bar), ASME Code Case 1935 (Rod, Bar, & Forgings), DIN 17754 (forgings), DIN 17753 (Wire).

Plate, Sheet and Strip - ASTM B 443/ASTM SB 443 (Plate, Sheet & Strip), SAE/AMS 5599 & 5869 & MAM 5599 (Plate, Sheet & Strip), ISO 6208 (Plate, Sheet & Strip), VdTÜV 499 (Plate, Sheet & Strip), BS 3072NA21 (Plate & Sheet), EN 10095 (Plate, Sheet & Strip), DIN 17750 (Plate, Sheet & Strip), ASME Code Case 1935.

Pipe & Tube - ASTM B 444/B 829 & ASME SB 444/SB 829 (Seamless Pipe & Tube), ASTM B704/B 751 & ASME SB 704/SB 751 (Welded Tube), ASTM B705/B 775 & ASME SB 705/SB 775 (Welded Pipe), ISO 6207 (Tube), SAE/AMS 5581 (Seamless & Welded Tube), VdTÜV 499 (Tube), BS 3074NA21 (Seamless Pipe & Tube), DIN 17751 (Tube), ASME Code Case 1935.

Other Product Forms - ASTM B 366/ASME SB 366 (Fittings), ISO 4955A (Heat Resisting Steels & Alloys), DIN 17744 (Chemical composition of all product forms).