ALLOY 400

Alloy 400 (UNS N04400/ W.Nr. 2.4360 and 2.4361) is a solid-solution alloy that can be hardened only by cold working. It has high strength and toughness over a wide temperature range and excellent resistance to many corrosive environments. Composition is shown in Table 1. Alloy 400 is widely used in many fields, especially marine and chemical processing. Typical applications are valves and pumps; pump and propeller shafts; marine fixtures and fasteners; electrical and electronic components; springs; chemical processing equipment; gasoline and fresh water tanks; crude petroleum stills, process vessels and piping; boiler feedwater heaters and other heat exchangers; and deaerating heaters.

PHYSICAL CONSTANTS AN THERMAL PROPERTIES

The physical constants and thermal properties of Alloy 400 are shown in Tables 2 and 3. The effect of temperature on modulus of elasticity in tension is in Figure 1. It will be noted in Table 2 that the Curie temperature lies within the ambient range. It is affected by variations in chemical composition. The values shown represent the range which can be expected from normal production; therefore, some heats will be magnetic at room temperature and others not. If there is a strong requirement for nonmagnetic characteristics, other alloys should be considered.

MECHANICAL PROPERTIES

Tensile Properties and Hardness

The nominal room-temperature tensile properties of Alloy 400 are shown in Table 4. Additional data on hardness of various tempers of sheet and strip are in Table 5. Figures 2 and 3 are based on typical data that show relationships between properties of rods and forgings and sheet and strip. Short-time high-temperature properties of hot-rolled annealed material are shown in Figure 4. Alloy 400 has excellent mechanical properties at subzero temperatures. Strength and hardness increase with only slight impairment of ductility or impact resistance. The alloy does not undergo a ductile-to-brittle transition even when cooled to the temperature of liquid hydrogen. This is in marked contrast to many ferrous materials which are brittle at low temperatures despite their increased strength. Table 6 shows mechanical properties of the alloy at low temperatures.

Torsional Strength

Some torsional properties of alloy 400 are shown in Table 7.

Compressive Strength

Compressive properties, determined in triplicate on single typical melts, are shown in Table 8 along with the corresponding tensile properties and hardness. The modulus of elasticity in compression is the same as that in tension.

Shear Strength

Room-temperature shear strength of Alloy 400 sheet is shown in Table 9. The values are the averages of several tests. The shear strength of rivet wire at various temperatures is given in Table 10. Shear properties were determined on 1/8-in. diameter wire in double shear. In U.S. Navy tear tests at temperatures down to -320°F, the material showed excellent ductility and tough fracture characteristics over this temperature range with the maximum load increasing considerably with decrease in temperature. The data appear in Table 11.

Bearing Strength
It is possible, in riveted joints, for failure to occur by tearing out a segment of sheet instead of by shearing the rivet. The resistance of sheet metal to this deformation is known as bearing strength. It can be evaluated by using a hard pin or rivet to enlarge or tear a hole in a sample of sheet metal. The data shown in Table 12 were determined with samples 0.062 X 1.25 X 2.5 in. in size having a 3/16-in. hole located so that its center was 3/8-in. from the edge. A snugly fitted pin was placed in the hole. The maximum load for tearing out the hole and the load required for a permanent enlargement of the hole diameter by 2% were determined and calculated as ultimate and yield strengths, respectively, in bearing.

Impact Strength
Alloy 400 is notable for its toughness, which is maintained over a considerable range of temperatures. Table 13 shows room-temperature Charpy and Izod impact strength values as determined on typical material from production melts. Tension and torsion impact data appear in Tables 14 and 15. Complete fractures occurred in the tension impact test specimens whereas the torsion specimens remained intact. Attempts to produce fractures in the torsion specimens by reducing the minimum area by 75% were not successful because of the toughness of the material. The effect of decrease of temperature on impact strength appears in Table 16. Impact tests conducted on hot-finished plate at liquid-hydrogen and liquid-helium temperatures are summarized in Table 17. Tests were conducted on samples representing both longitudinal and transverse orientation in the plate, and on welded samples. No evidence of brittle fractures was shown. The welded specimens all fractured in the weld. No significant amount of anisotropy was evidenced.

Fatigue Strength
Fatigue strength of various tempers of Alloy 400 is given in Table 18. Values for sheet and strip are in Table 19, cold drawn wire in Figure 5, and annealed rod in Figure 6.

Creep and Rupture Properties
Alloy 400 is useful at temperatures up to and including 1000°F in oxidizing atmospheres. Higher temperatures may be employed if the alloy is in a reducing environment. Creep and rupture properties are shown in Figures 7-11.

MICROSTRUCTURE

Alloy 400 is a solid-solution binary alloy. As nickel and copper are mutually soluble in all proportions, it is a single-phase alloy. It has a face-centered cubic lattice structure with a lattice parameter of 3.534 A. Figure 12 shows the typical microstructure of the material.
In the unetched condition, a polished specimen of Alloy 400 will exhibit only randomly dispersed non-metallic inclusions. These consist of metal sulfides or silicates. Under some conditions, graphite particles may also be present.

CORROSION RESISTANCE

Alloy 400 exhibits resistance to corrosion by many reducing media. It is also generally more resistant to attack by oxidizing media than higher copper alloys. This versatility makes Alloy 400 suitable for service in a variety of environments. Alloy 400 is widely used in marine applications. While Alloy 400 products exhibit very low corrosion rates in flowing seawater, stagnant conditions have been shown to induce crevice and pitting corrosion. Alloy 400 is also resistant to stress corrosion cracking and pitting in most fresh and industrial waters.
Alloy 400 offers exceptional resistance to hydrofluoric acid in all concentrations up to the boiling point. It is perhaps the most resistant of all commonly used engineering alloys.
It is also resistant to many forms of sulfuric and hydrochloric acids under reducing conditions.

WORKING INSTRUCTIONS

Alloy 400 can be readily joined and fabricated. By proper control of the amount of hot or cold work and by the selection of appropriate thermal treatments, finished fabrications can be produced to a rather wide range of mechanical properties.

HEATING AND PICKLING

Thermal treatments

The material will remain bright and free from discoloration when heated and cooled in a reducing atmosphere or quenched in an alcohol-water solution. Rate of cooling will have no significant effect. Alloy 400 will form an adherent oxide film if allowed to cool in air after heating. Both cold-worked and hot-worked Alloy 400 requires thermal treatment to develop the optimum combination of strength and ductility and to minimize distortion during subsequent machining. How thermal treatment affects properties is shown in Figure 13. Stress equalizing of cold-worked material causes an increase in the yield strength at 0.00% offset without marked effects on other properties (see Figure 13). Stress equalizing is done by holding for about 3 hr at a temperature of 575°F. Stress relieving will reduce stresses without producing a recrystallized grain structure. This treatment is recommended to obtain minimum “walking” or distortion after metal removal. Heating for 1 to 2 hr at 1000° to 1050°F will relieve strains in either hot or cold-worked products. Stress relief (1000°-1200°F/1 hr, followed by slow cooling) is strongly recommended as a precaution against stress-corrosion cracking in certain environments. As shown in Figure 13, stress relieving slightly decreases tensile strength, yield strength, and hardness and slightly increases elongation. Annealing can completely soften work-hardened material. Time and temperature required depend on the amount of previous cold work. In general, Alloy 400 is annealed by the open heating method by holding at 1600° to 1800°F for 2-10 min, whereas box annealing is done most satisfactory at 1400° to 1500°F for 1-3 hr at temperature. The effects of heating on properties of cold-drawn and hot-rolled material are compared in Figures 13 and 14. In these tests, the cold-drawn rod developed an annealed temper after 3 hr at temperature at 1300°F, and the hot-rolled plate, after 3 hr at about 1470°F. More data on time-temperature-hardnesss relationships are shown in Figure 15. They may be used as guides for establishing procedures for specific applications. Grain growth occurs when material is heated in the upper portion of the annealing temperature range. Figure 16 indicates grain sizes which may be expected from open annealing of cold-rolled strip.

Pickling

Pickling can produce bright, clean surfaces on Alloy 400.

FABRICATING

Alloy 400 is readily fabricated by standard processes.

Hot Forming
With respect to its resistance to hot deformation, Alloy 400 is softer than many steels. It can, therefore, be hot-formed into almost any shape. The use of proper temperature during hot forming is important. The range of hot-forming temperatures is 1200°F to 2150°F. For heavy reductions, recommended metal temperature is 1700° to 2150°F. Light reductions may be taken down to 1200°F. Working at the lower temperatures produces higher mechanical properties and smaller grain size. Prolonged soaking at hot-working temperatures is detrimental. If a delay occurs during processing, the furnace should be cut back to 1900°F and not brought to temperature until operations are resumed. In no case should the alloy be heated above 2150°F; permanent damage may result. Heavy forging should not be carried out so rapidly that the metal becomes overheated from working. The use of an optical pyrometer is recommended. In hot-bending operations the metal should be worked as soon as possible after removal from the furnace. Preheating tools and dies to about 500°F is helpful to prevent chilling the material while working. A controlled forging procedure is necessary to meet the requirements of some specifications for forged, hot-finished parts. Both the amount of reduction and the finishing temperature must be controlled in order to develop the desired properties. One procedure for producing forgings to such specifications consists of taking 30-35% reduction following the final reheat.
This is accomplished as follows:

1. Reheat,
2. Forge to a section having about 5% larger area than the final shape (take at least 25% reduction),
3. Cool to 1300°F,
4. Finish to size (5% reduction).

High-tensile forgings, as described in certain military specifications, also require a minimum of 30-35% reduction following the last reheat.
This is taken in the following manner:

1. Reheat,
2. Forge to a section having an area about 25% larger than the final shape (take about 5% reduction),
3. Cool to 1300°F,
4. Finish to size (25% reduction).

Grain refinement is achieved by using a temperature of 2000°F for the final reheat and by increasing the amount of reduction taken after the last reheat.

Cold Forming
Alloy 400 is adaptable to virtually all methods of cold fabrication. The forces required and the rate of work hardening are intermediate between those of mild steel and Type 304 stainless steel (see Figure 17).

Machining
Alloy 400 can be machined at satisfactory rates with machine tools generally employed by industry. In general, cold-drawn or cold-drawn, stress-relieved material is recommended for best machinability and smoothest finish.

Joining
Alloy 400 is readily joined by conventional processes and procedures. Most of the conventional welding processes may be used to join Alloy 400 to itself or dissimilar alloys. The choice of welding product is dependent upon the materials being joined and the environment to which they will be exposed.

Table 1 - Limiting Chemical Composition, % Alloy 400

Nickel (plus Cobalt)	63.0 min.
Carbon	0.3 max.
Manganese	2.0 max.
Iron	2.5 max.
Sulfur	0.024 max.
Silicon	0.5 max.
Copper	28.0 - 34.0

Table 2 - Physical Constants Alloy 400

Density, g/cm³	8.80
lb/in.³	0.318
Melting Range, °F	2370-2460
°C	1300-1350
Modulus of Elasticity, 10^3 ksi	
Tension	26.0
Compression	26.0
Torsion	9.5
Poisson's Ratio	0.32
Curie Temperature, °F	70-120
°C	21-49

Table 3 - Thermal Properties

Temperature		Mean Linear Expansion[b]		Thermal Conductivity		Specific Heat		Electrical Resistivity [c]	
°F	°C	in/in/°F x 10^{-6}	µm/m•°C	Btu-in/h/ft²/°F	W/m•°C	Btu/lb/°F	J/kg•°C	ohm-circ mil/ft	µΩ•m
-320	-200	-	-	-	-	-	-	205	.360
-300	-180	6.1	11.1	113	16.5	0.050	223	-	-
-200	-130	6.4	11.4	130	18.2	0.078	320	-	-
-100	-70	6.7	12.1	139	19.8	0.088	378	-	-
70	21	-	-	151	22.0	0.102	427	307	0.511
200	100	7.7	14.2	167	24.0	0.105	445	322	0.537
400	200	8.6	15.2	193	26.9	0.110	459	337	0.559
600	300	8.8	15.7	215	30.1	0.114	470	346	0.574
800	400	8.9	16.1	238	33.4	-	-	355	0.587
1000	500	9.1	16.3	264	36.5	-	-	367	0.603
1200	600	9.3	16.6	287	39.4	-	-	379	0.620
1400	700	9.6	17.0	311	42.4	-	-	391	0.639
1600	800	9.8	17.4	335[d]	45.5[d]	-	-	403	0.658
1800	900	10.0[d]	17.7	360[d]	48.8[d]	-	-	415	0.675
2000	1000	10.3[d]	18.1[d]	-	-	-	-	427	0.692

[b]Annealed material. Between 70°F (21°C) and temperature shown.
[c]Annealed material.
[d]Extrapolated.

Table 4 - Nominal Room-Temperature Tensile Properties

Form and Condition	Tensile Strength		Yield Strength (0.2% Offset)		Elongation, %	Hardness	
	ksi	MPa	ksi	MPa		Brinell (3000-kg)	Rockwell B
Rod and Bar							
Annealed	75-90	517-620	25-50	172-345	60-35	110-149	60-80
Hot-Finished (except Hexagons over 2 1/8 inches and Angles)	80-110	552-758	40-100	276-690	60-30	140-241	75-100
Hot-Finished Hexagons over 2 1/8 inches and Angles	75-100	517-690	30-55	207-379	50-30	130-184	72-90
Cold-Drawn, Stress-Relieved	84-120	579-827	55-100	379-690	40-22	160-225	85-20C
Plate							
Hot-Rolled, As-Rolled	75-95	517-655	40-75	276-517	45-30	125-215	70-96
Hot-Rolled, Annealed	70-85	482-586	28-50	193-345	50-35	110-140	60-76
Sheet							
Annealed	70-85	482-586	30-45	207-310	45-35	-	65-80
Cold-Rolled, Hard	100-120	690-827	90-110	621-758	15-2	-	93 min.[a]
Strip, Cold-Rolled							
Annealed	70-85	482-586	25-45	172-310	55-35	-	68 max.[a]
Spring Temper	100-140	690-965	90-130	621-896	15-2	-	98 min.[a]
Tube and Pipe, Seamless							
Cold-Drawn, Annealed	70-85	482-586	25-45	172-310	50-35	-	75 max.[a]
Cold-Drawn, Stress-Relieved	85-120	586-827	55-100	379-690	35-15	-	85-100[a]
Heat-Exchanger, Annealed	70-85	482-586	28-45	193-310	50-35	-	75 max.[a]
Heat-Exchanger, Stress-Relieved	85-105	586-724	55-90	379-621	35-15	-	85-97[a]
Hot-Extruded	-[b]	-[b]	-[b]	-[b]	-[b]	-	-[b]
No. 1 Temper (Annealed)	85 max.	586 max.	30-45	207-310	45-30	-	73 max.[a]
No. 2 Temper (Half-Hard)	85-105	586-724	55-80	379-552	30-10	-	75-97[a]
No. 3 Temper (Full-Hard)	110-130	758-896	90-110	621-758	10-3	-	95-27C
Wire, Cold Drawn[c]							
Annealed	70-95	482-655	30-55	207-379	45-25	-	-
No. 1 Temper	85-100	586-690	50-75	345-517	30-20	-	-
Quarter-Hard	95-120	655-827	65-95	448-655	25-15	-	-
Half-Hard	110-135	758-931	85-120	586-827	15-8	-	-
Three-Quarter-Hard	125-150	862-1034	100-135	690-931	8-5	-	-
Full-Hard--Spring Temper	145-180	1000-1241	125-170	862-1172	5-2	-	-

[a]The ranges shown are composites for various product sizes and therefore are not suitable for specification purposes. Hardness values are suitable for specification purposes providing tensile properties are not also specified.
[b]Properties on request.
[c]Properties shown are for sizes from 0.032 to 0.250-in. diameter. Properties for other sizes may vary from these.

Table 5 - Hardness of Cold-Rolled Alloy 400 Sheet and Strip

Temper	Rockwell B Hardness	
	Sheet	Strip
Deep-Drawing and Spinning Quality	76 max.	76 max.
Annealed[a]	73 max.	68 max.
Skin-Hard	-	68-73
Quarter-Hard	73-83	73-83
Half-Hard	82-90	82-90
Three-Quarter-Hard	-	89-94
Hard	93 min.	93-98
Spring	-	98 min.

[a]Hardness for information only where tensile requirements apply.

Table 6 - Tensile Properties of Alloy 400 at Low Temperatures

Temper	Temperature, °F	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elongation, %	Reduction of Area, %
Cold-Drawn	Room	103.80	93.70	19.0	71.0
	-110	117.45	100.85	21.8	70.2
	Room[a]	103.40	93.30	17.3	72.5
Forged	70	92.00	67.00	31.0	72.7
	-297	128.25	91.50	44.5	71.8
	-423	142.00	96.40	38.5	61.0
Annealed	70	78.65	31.30	51.5	75.0
	-297	115.25	49.50	49.5	73.9

[a]Held at -110°F for several hours prior to testing at room temperature.

Table 7 - Torsional Properties

Form and Condition	Dia., in.	Tensile Properties		Torsional Properties		Ratio		
		Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Breaking Strength, ksi	Proportional Limit, ksi	Breaking Strength Torsional/Tensile Strength	Tortional Propertional Limit/Tensile Strength	Torsional Proportional Limit/Torsional Breaking Strength
Wire								
Cold-Drawn, 75%	0.148	157	-	110	68	0.700	0.433	0.618
Cold-Drawn, 75% Stress-Relieved	0.148	160	-	105	65	0.656	0.404	0.619
Rod								
Hot-Rolled	1	86	38	66	23	0.768	0.267	0.349
Cold-Drawn, 20%	1	115	107	72	47	0.626	0.408	0.653
	1.5	113	102	71	45	0.628	0.398	0.634

Table 8 - Compressive Properties

Temper	Compression		Tension			
	Yield Strength (0.01% Offset), ksi	Yield Strength (0.2% Offset), ksi	Tensile Strength, ksi	Yield Strength (0.01% Offset), ksi	Yield Strength (0.2% Offset), ksi	Elongation, %
Hot-Rolled	33	38	84	37	41	39.5
Cold-Drawn[a]	58	81	97	75	87	27.0
Annealed[b]	19	28	78	28	33	44.0

[a]Stress-equalized at 525°F after cold drawing.
[b]Cold-drawn +1450°F/3 hr, F.C.

Table 9 - Shear Strength of Alloy 400 Sheet[a]

Temper	Thickness, in.	Shear Strength, ksi	Tensile Strength, ksi	Hardness, Rb	Ratio Shear Strength/ Tensile Strength
Hot-Rolled, Annealed	0.042	48.75	73.0	65	0.67
Cold-Rolled, Annealed	0.029	49.50	76.8	60	0.65

[a]Double-shear tests at room temperature.

Table 10 - Shear Strength of Alloy 400 Rivet Wire

Property	Condition	
	Annealed	B & S No. 1[a]
Shear Strength, ksi		
Room	48.5	54.5
600[b]	45.0	52.0
800[b]	37.0	47.5
1000[b]	29.0	38.0
800[c]	38.5	49.5
1000[c]	30.5	38.5
Tensile Strength, ksi	78.5	88.0
Yield Strength (0.2% Offset), ksi	46.0	75.5
Elongation, %	41	18

[a]Corresponds to the approximate strength of the shank of a headed rivet.
[b]30 min at temperature before testing.
[c]24 hr at temperature before testing.

Table 11 - U. S. Navy Tear Tests on Alloy 400 Hot-Rolled Plate[a]

Temperature, °F	Maximum Load, lb	Corrected Energy Values, ft-lb			Reduction of Thickness, %
		Initiation	Propagation	Total	
Room	32,340	715	2008	2723	57.0
-184	39,000	649	2402	3051	50.0
-238	42,000	795	2408	3203	51.0
-320	47,800	899	2802	3701	46.0
-320[b]	41,300	676	2138	2814	45.0

[a]In all cases, appearance of fracture was double-cup shear.
[b]Tested with jeweler's-saw notch

Table 12 - Bearing Strength of Alloy 400 Sheet

Temper	Tensile Properties			Bearing Strength		Ratio, Bearing Strength/	
	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elongation, %	Yield Strength[a], ksi	Ultimate Strength[b], ksi	Yield Strength	Ultimate Strength
Annealed	70.0	27.2	42.5	58.0	145.0	2.13	2.07
Half-Hard	75.8	56.2	32.0	98.1	166.0	1.75	2.19
Full-Hard	117.8	110.0	5.0	162.0	211.5	1.47	1.79

[a]2% enlargement of hole diameter in sheet.
[b]Tearing out of sheet.

Table 13 - Impact Strength of Alloy 400[a]

Temper	Impact Strength, ft•lb	
	Izod	Charpy U Notch
Hot-Rolled	100-120+	220
Forged	75-115	-
Cold-Drawn	75-115	150
Annealed	90-120+	215

[a]Tested at room temperature. None of the specimens was completely fractured.

Table 16 - Impact Strength Alloy 400 (Charpy V-Notch)

Temper	Impact Strength, ft•lb			
	75°F	-20°F	-112°F	-310°F
Hot-Rolled	219	-	213	196
Cold-Drawn, Annealed	216	212	219	212
Weld, As-Welded	78	-	-	73

Table 14 - Tension Impact Strength of Alloy 400 Rod

Temper	Tensile Impact			Tensile Properties				
	Impact Strength, ft•lb	Elongation in 3.54 in., %	Reduction of Area, %	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elongation in 2 in., %	Reduction of Area, %	Hardness, Brinell (3000-kg)
Cold Drawn 24% Stress Relieved	96[a]	15.0	63.7	97.25	86.65	27.0	66.4	199
Annealed 1450°F/ 3 hr	129[a]	29.5	68.0	78.35	33.35	44.0	65.9	123

[a]Specimen completely broken.

Table 15 - Charpy Torsion Impact Strength of Alloy 400 Rod

Temper	Impact Strength		Angle of Twist[a], Degree	Hardness, Brinell (3000-kg)
	ft•lb	ft•lb/in^2		
Hot-Rolled	34	694	101.5	145
Cold-Drawn 24%, Stress-Relieved	39	788	98.0	199
Annealed 1450°F/3 hr	30	599	102.0	123

[a]Gage length about 3/16 in.

Table 17 - Charpy Impact Strength of Hot-Finished Alloy 400 Plate

Temperature, °F	Notch	Orientation	Impact Strength, ft•lb
-423[a]	V	Long.	141-219
-423[a]	V	Trans.	121-216
-423[a]	Keyhole	Long.	81-87
-423[a]	Keyhole	Trans.	72-75
-440[b]	V	Long.	Unbroken
-440[b]	V	Trans.	171-193
-440[b]	Keyhole	Long.	123-146
-440[b]	Keyhole	Trans.	91-116

[a]Range for 5 tests liquid-hydrogen temperature.
[b]Range for 4 tests at liquid-helium temperature.

Table 18 - Fatigue Strength[a] of Alloy 400 Rod

Temper	Fatigue Strength (10^8 cycles), ksi	Tensile Strength, ksi	Ratio, Fatigue Strength/ Tensile Strength
Annealed	33.5	82.0	0.41
Hot-Rolled	42.0	88.0	0.48
Cold-Drawn, As-Drawn	40.5	105.0	0.39
Cold-Drawn, Stress-Equalized[b]	44.0	104.0	0.42
Cold-Drawn, Stress-Relieved[c]	37.0	96.5	0.38

[a]Rotating-beam tests of polished specimens in air at room temperature and 10,000 rpm.
[b]525°F/3 hr.
[c]1000°F/3 hr.

Table 19 - Fatigue Strength of Alloy 400 Sheet and Strip[a]

Temper	Fatigue Strength (10^8 cycles), ksi	Tensile Strength, ksi	Ratio, Fatigue Strength/ Tensile Strength
Annealed	21.0	74.7	0.28
Quarter-Hard	24.5	76.5	0.32
Half-Hard	28.5	84.2	0.34
Full-Hard	39.0	126.0	0.31
Full-Hard, Stress-Equalized (525°F/21 hr)	41.0	133.0	0.31

[a]As-rolled surface. Tested in air at room temperature. Specimen length parallel to direction of rolling. Completely reversed stress.

Table 20 - High-Temperature Tensile Properties

Temperature, °F	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elongation, %	Reduction of Area, %
		All-Weld Metal		
Room	74.35	46.65	41.0	66.4
200	42.25	46.05	39.0	56.5
400	68.60	43.10	33.5	64.2
600	69.25	43.15	34.0	59.9
800	66.10	43.00	32.5	47.4
1000	55.95	38.70	22.0	24.5
		Transverse Across Weld[b]		
Room	76.2	48.50	24.0	48.0
400	69.6	45.00	24.0	58.3
600	68.5	45.80	21.0	56.5
800	69.0	41.00	28.0	44.2

[a]Butt joints--1/2-in.
[b]All breaks occurred in weld.

Table 21 - Room-Temperature Properties of Butt Joint Weld of 1 1/4-in. Alloy 400 and Steel

Property	As-Welded		Heat-Treated 1150°F/10 hr, A.C.	
	All-Weld Metal	Transverse Across Weld[a]	All-Weld Metal	Transverse Across Weld[a]
Tensile Strength, ksi	71.0	78.0	70.5	76.4
Yield Strength, ksi	48.3	51.5	45.3	36.7
Elongation, %	38	21	38	31
Reduction of Area, %	63.3	60.5	63.3	59.3

[a]Break occurred in weld.

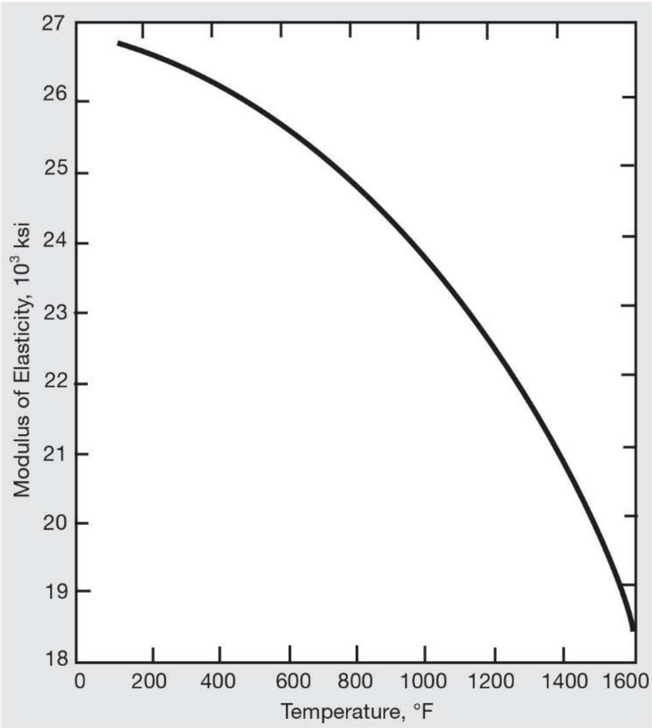

Figure 1. Effect of temperature on modulus of elasticity in tension (determined by dynamic method).

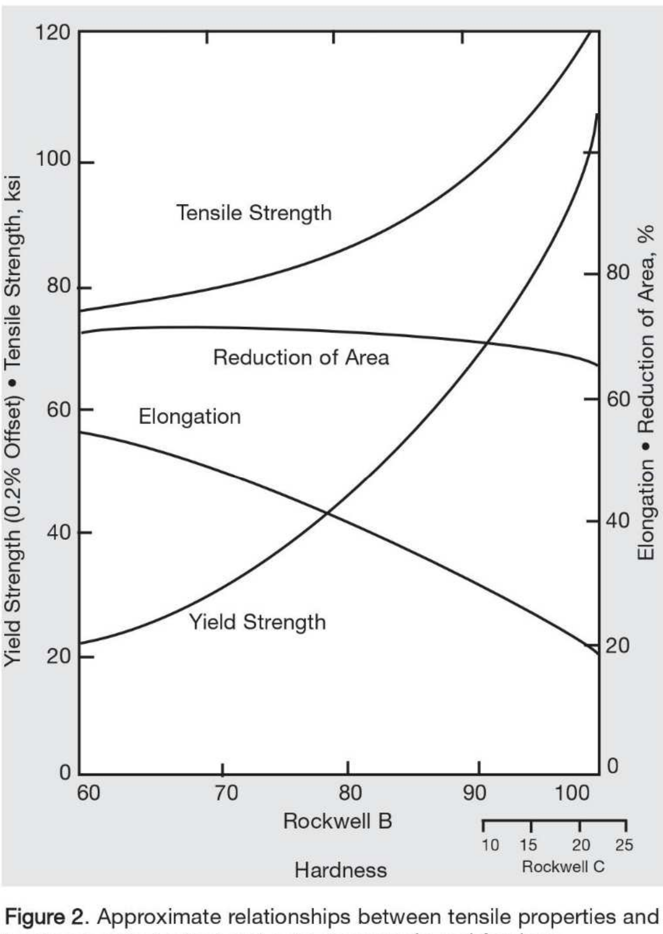

Figure 2. Approximate relationships between tensile properties and hardness of hot-rolled and cold-drawn rods and forgings.

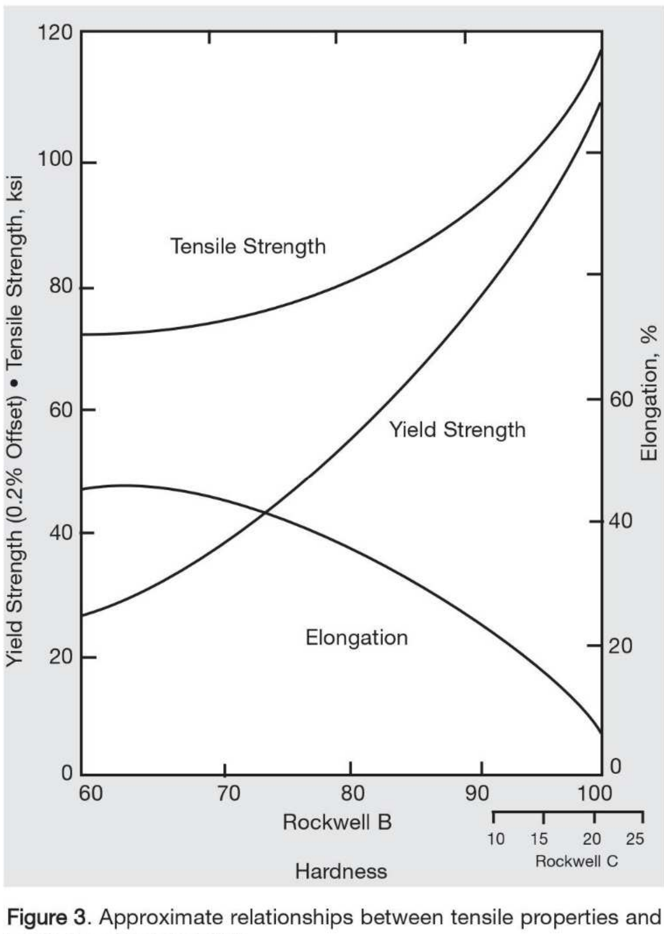

Figure 3. Approximate relationships between tensile properties and hardness sheet and strip.

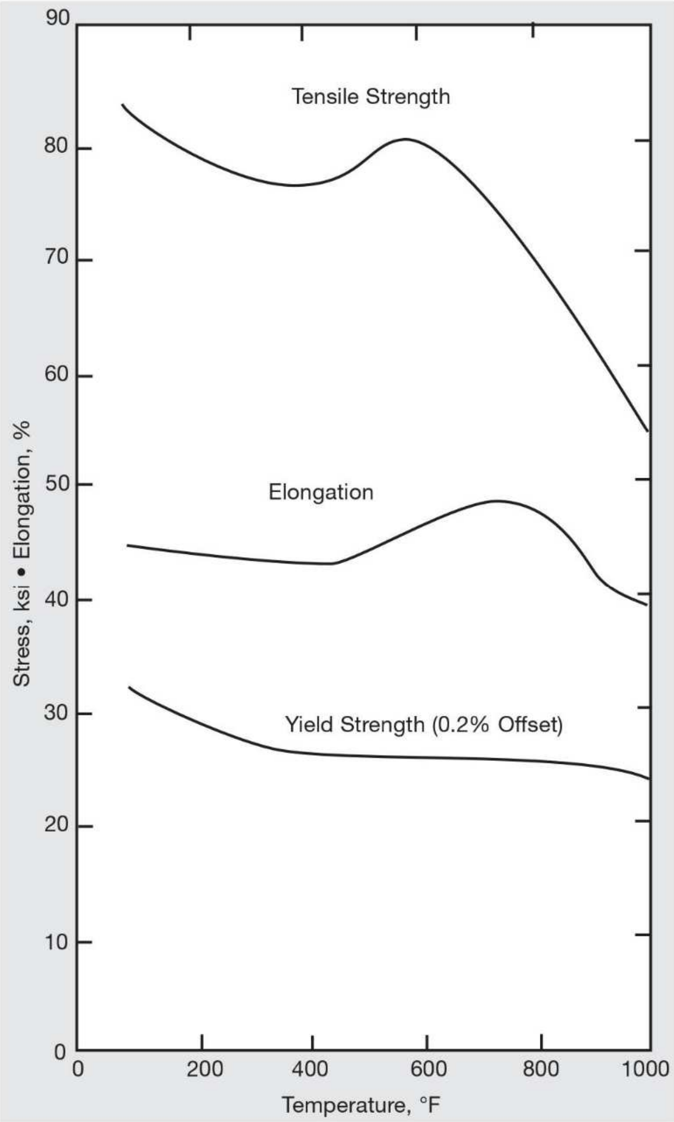

Figure 4. High-temperature properties of annealed

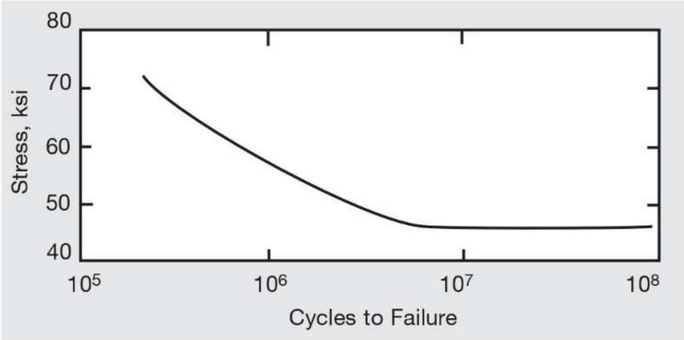

Figure 5. Fatigue strength of commercially produced wire (0.0375-in. diameter, cold-drawn 75% after final anneal). Tested in processed condition. Data determined with a rotating-wire (5000 rpm) arc-fatigue machine.

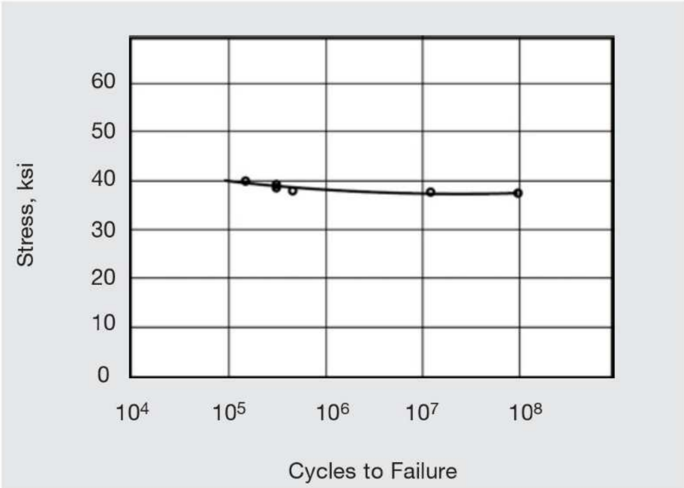

Figure 6. Fatigue strength of commercially produced rod (0.500-in. diameter, cold-drawn, annealed 1500°F/3 hrs). Tested in the processed condition. Data determined by the R.R. Moore rotating beam technique.

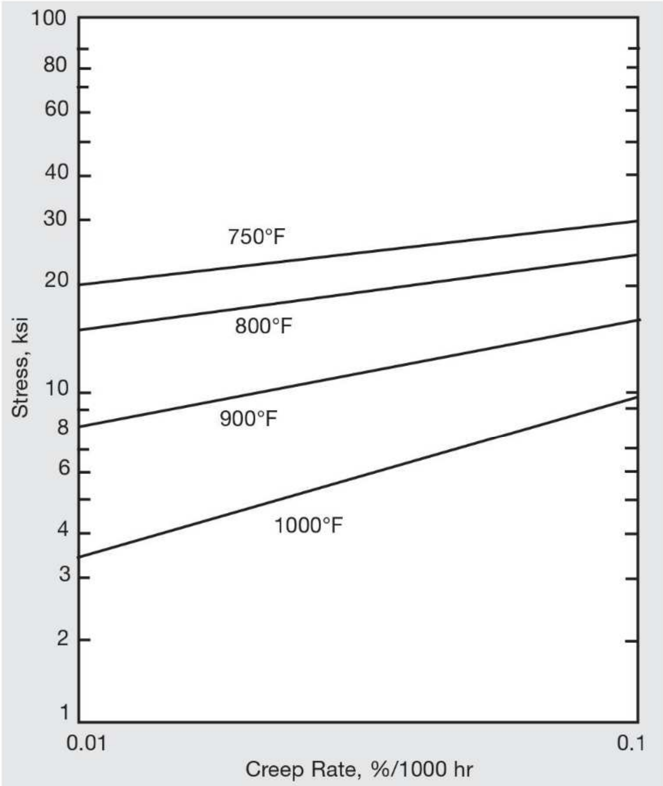

Figure 8. Creep properties of cold-drawn annealed (1500°F/3 hr)

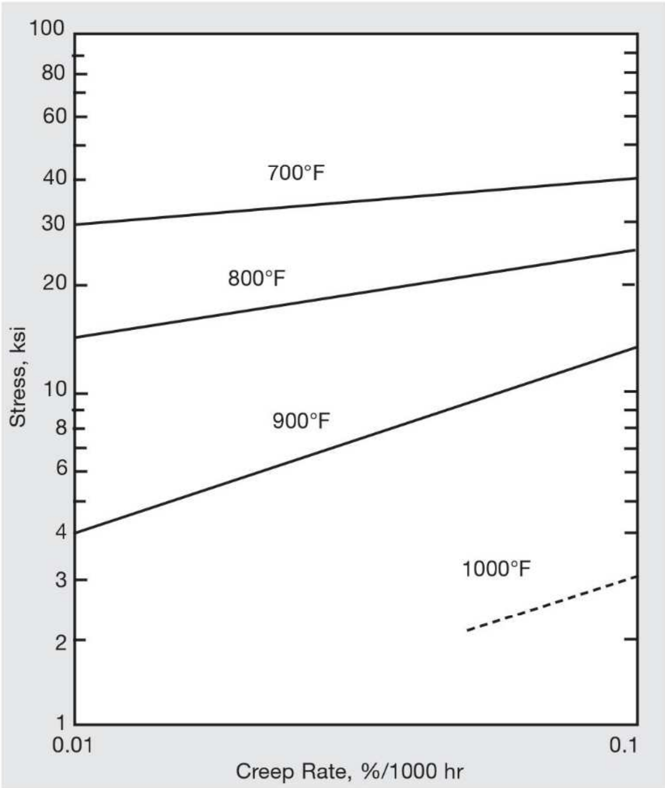

Figure 7. Creep properties of hot-rolled

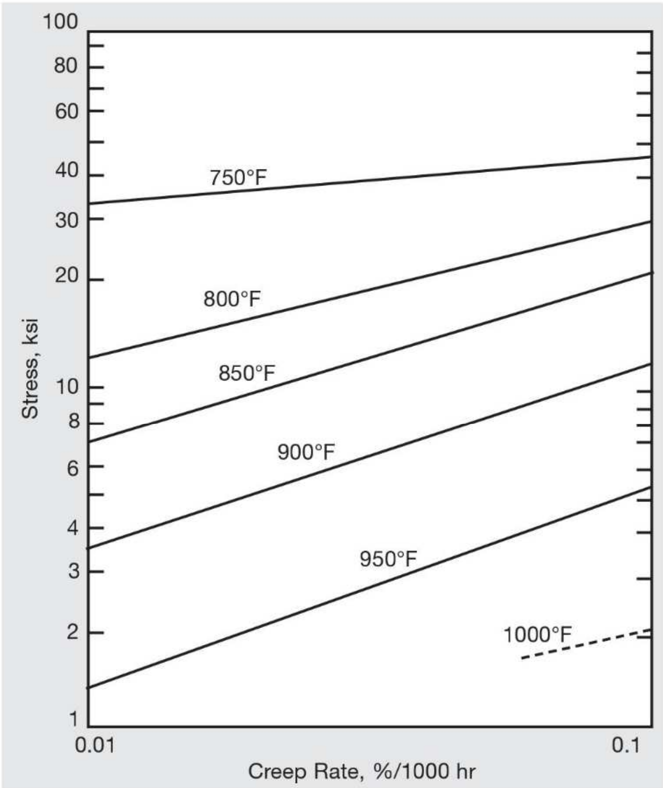

Figure 9. Creep properties of 20% cold-drawn stress-relieved (1000°F/8 hr)

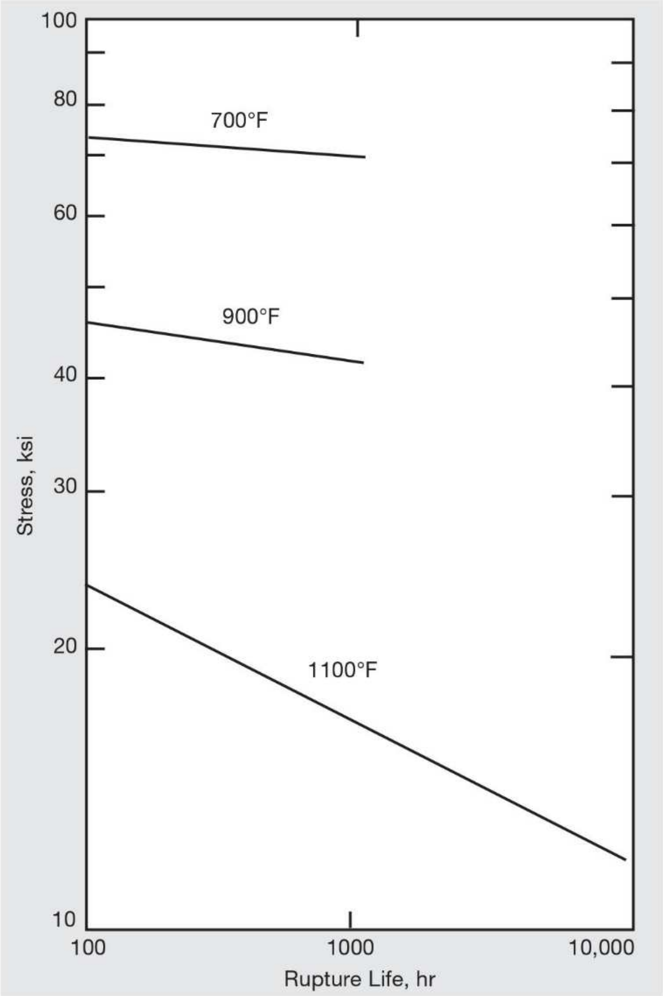

Figure 10. Rupture properties of cold-drawn annealed (1500°F/30 min)

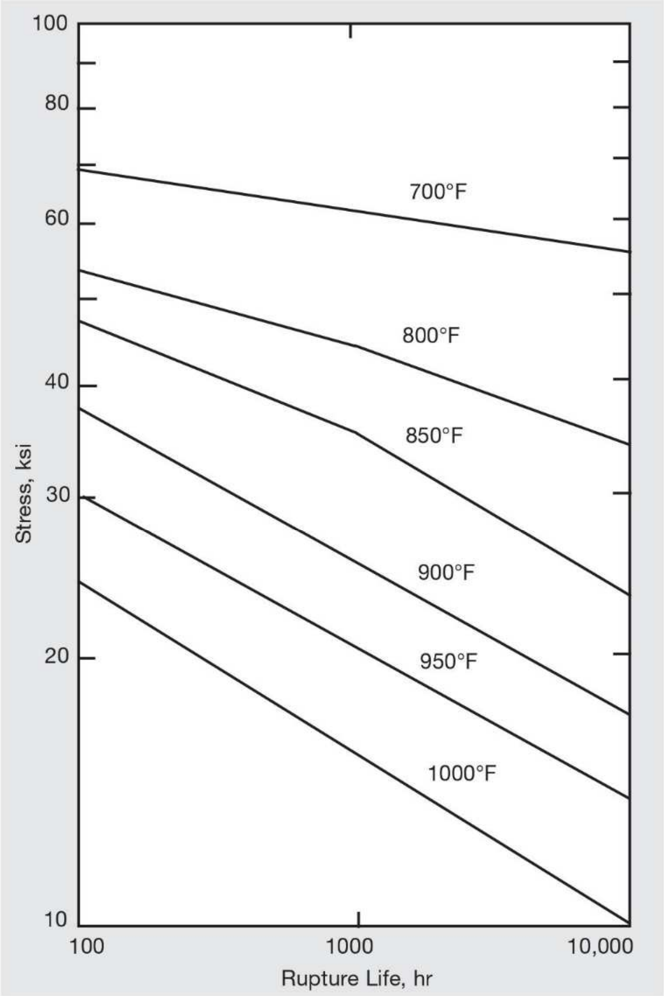

Figure 11. Rupture properties of cold-drawn, stress-relieved (1100°F/8 hr)

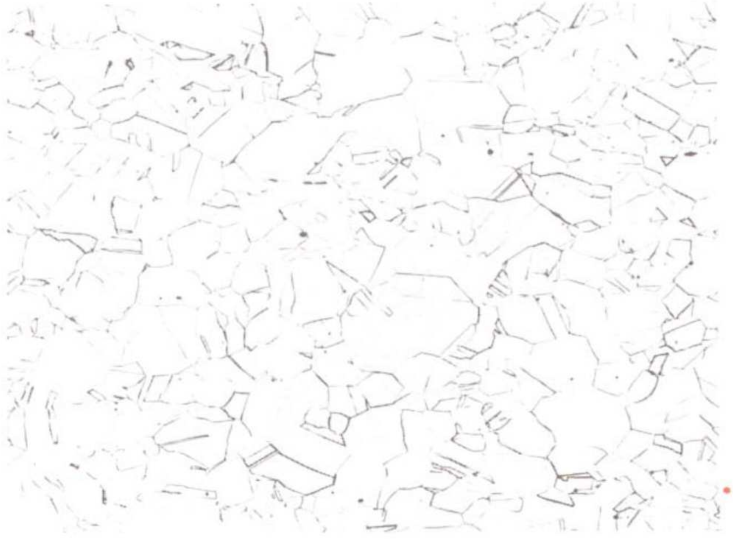

Figure 12. Longitudinal section of cold-drawn rod.
Etchant: Sodium cyanide--ammonium persulfate. 100X.

SALOMON'S METALEN B.V.

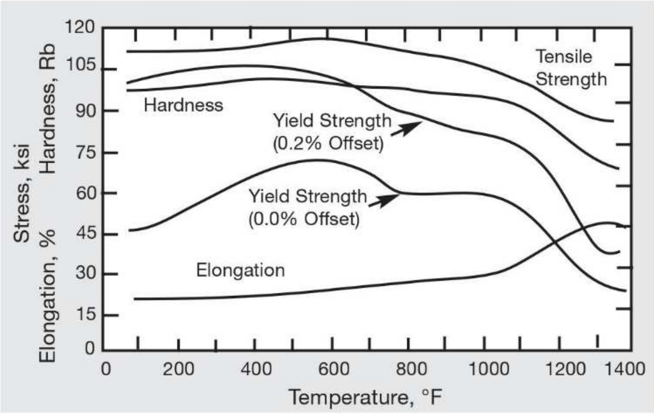

Figure 13. Effect of annealing (3 hr) on room-temperature properties of alloy 400 cold-drawn rod.

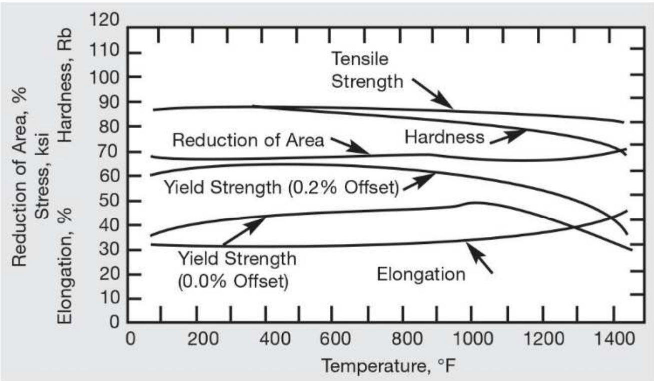

Figure 14. Effect of annealing (3 hr) on room-temperature properties of hot-rolled alloy 400 plate. At 1470°F, material is fully annealed. (Hardness converted from BHN.).

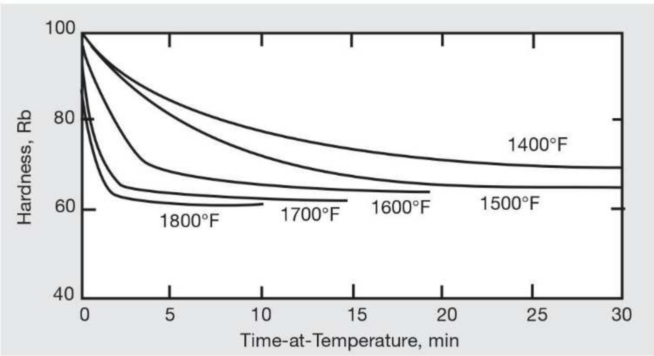

Figure 15. Approximate time required at various temperatures to produce different hardness levels in alloy 400 cold-rolled strip by open annealing.

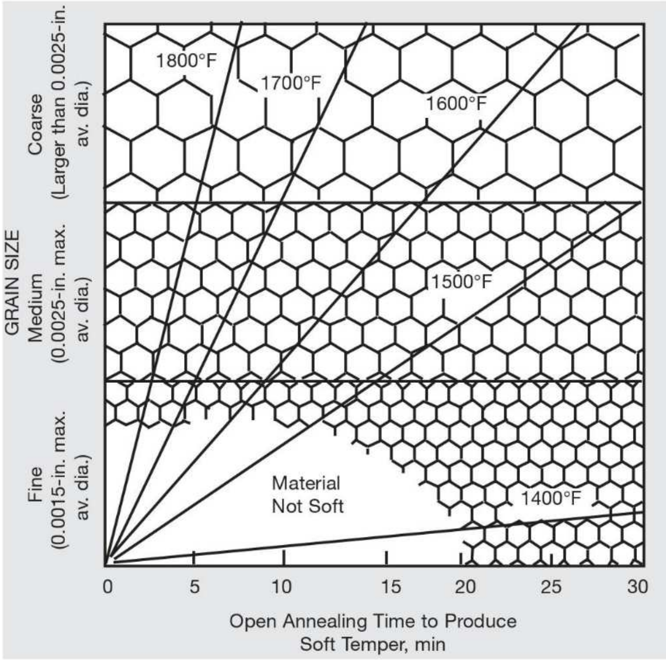

Figure 16. Approximate time required at various temperatures to produce different grain sizes in alloy 400 cold-rolled strip by open annealing.

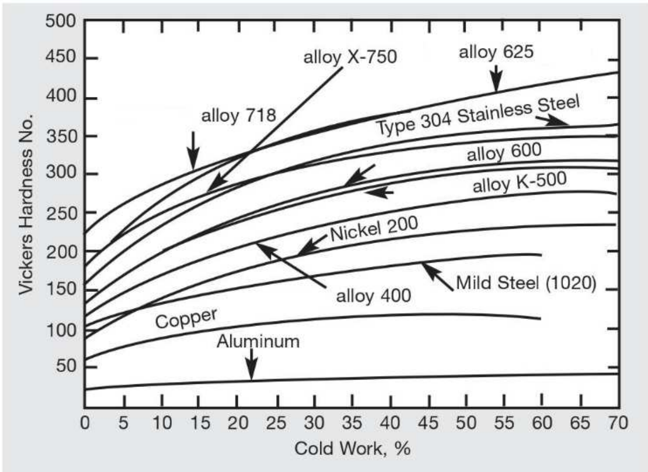

Figure 17. Effect of cold work on hardness.