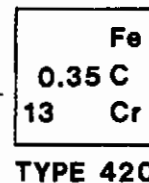
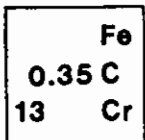


REVISED: SEPTEMBER 1973
AUTHOR: J. R. KATTUS

FERROUS ALLOYS

1. GENERAL
Type 420 is a medium-carbon version of the hardenable (martensitic) family of stainless steels containing about 13 percent chromium. Its carbon content of about 0.35 percent provides heat-treated hardness and strength higher than Type 410 stainless steel. In the hardened condition (quenched and tempered), Type 420 has high strength and wear resistance. It develops its maximum corrosion resistance when hardened and polished. Type 420 has long been used for cutlery, gears, valve and pump parts, surgical instruments, dies, hand tools, and many parts requiring high spring tempers. It can be used up to about 900F in aerospace applications, but its use at elevated temperatures has, to a great extent, been superseded by the modified, more-highly-alloyed Type 422 (Code 1403). Type 420 should not be used for heavily stressed parts that operate at subzero temperatures. It is sometimes welded, but both pre-heat and post-heat are needed for optimum results. Free-machining sulfur-bearing (420F) and selenium-bearing (420F-Se) modifications are produced. They have about 10 percent better machinability than standard Type 420. Aside from somewhat reduced formability and corrosion resistance, the free-machining grades exhibit properties similar to the standard grade. The alloy is also produced in the form of castings for corrosion-resisting applications.
- 1.01 Commercial Designations
Type 420 stainless steel
CA-40 cast stainless steel
Type 420F stainless steel (sulfur-bearing)
Type 420F-Se stainless steel (selenium-bearing)
- 1.02 Alternate Designations
- 1.03 Specifications
Table 1.03.
- 1.04 Composition
Table 1.04.
- 1.05 Heat Treatment
- 1.051 Full anneal: Heat to 1550 - 1650F, soak 1 hour per inch of thickness, furnace cool to 1100F or lower. This treatment results in a hardness of about 185 Brinell, which provides optimum formability and machinability. Extreme care must be taken to maintain a very slow cooling rate of no more than 50F per hour through the critical range in order to avoid rehardening (3)(7)(23)(24).
- 1.052 Process anneal: Heat to 1350 to 1450F, soak 4 hours, air cool. This treatment results in a hardness of about 215 Brinell, which provides limited formability and fair machinability (7)(23)(24).
- 1.053 Hardening: Austenitize at 1800 - 1900F for at least 15 minutes, oil- or air-quench to room temperature. For large parts, complex shapes, or parts already hardened or otherwise stressed, preheating at a temperature in the range 1000 to 1450F is recommended. The austenitizing should be done in inert or endothermic atmosphere if possible to avoid decarburization; if controlled atmosphere is not available, time at temperature should not be unnecessarily prolonged. The alloy is air hardening in sections up to at least 4 inches; larger sections should generally be oil quenched (7)(23)(24).
- 1.054 Tempering: Hold at temperature in the range 300 to 700F or 1050 to 1300F for 1 to 4 hours. The secondary hardening range from about 700 to 1000F should generally be avoided because tempering in that range induces reduced resistance to corrosion and stress corrosion and reduced toughness (7)(23)(24).
- 1.055 Stress relief: Hold at 1300 to 1400F, 6 to 8 hours, and air cool. This treatment, which is quite similar to a process anneal, is recommended after welding and after severe cold forming (7)(19).
- 1.06 Hardness
- 1.061 Effect of tempering temperature on hardness, Figure 1.061.
- 1.062 Effect of temperature on hardness, Figure 1.062.
- 1.063 Effect of exposures at elevated temperatures on room-temperature hardness, Figure 1.063.
- 1.07 Forms and Conditions Available
Table 1.07.
- 1.08 Melting and Casting Practice
- 1.081 For wrought products, Type 420 is generally air melted in electric-arc furnaces. For some applications requiring exceptional quality, it is vacuum remelted by consumable-electrode or induction methods.
- 1.082 For castings, the alloy is usually air melted. Its castability - fluidity, shrinkage, resistance to hot tearing - is rated as good. During melting and casting, clean crucibles, ladles, molds, and other refractories should be used. The metal should be melted rapidly with care to avoid superheat in the molten portion of the charge while solid or cold melting stock is still present. Calcium - manganese - silicon is used for deoxidation. The amount added must be calculated on the basis of silicon and manganese content of the charge, so that the final silicon content is within 10 percent of the maximum limit of the specification. The addition should be mixed into the melt about 30 to 60 seconds before pouring; the deoxidation products should then be skimmed off, the temperature adjusted, and the metal poured. Carbon content must be maintained within the specified limits to obtain proper response to heat treatment. Carbon losses should be established on standard melt cycles and additions made in the form of an iron-carbon alloy. The following precautions are helpful in minimizing pitting and other surface defects:
1. Maintain carbon level near the upper limit.
 2. Maintain chromium level at the mid or lower end of the range.
 3. Use clean furnaces and ladles.
 4. Cool castings through the solidification range as rapidly as possible.
 5. When feasible, introduce an inert atmosphere into the mold before pouring.
- The pouring temperature should normally be 2900 to 2950F; however, it can vary from this level dependent upon complexity of the casting and section size. Pouring of the molds should be done from a minimum height with gates and risers designed to minimize turbulence. For investment castings all traces of wax or plastic pattern material and moisture must be removed from the molds to prevent carbon pickup from the pattern material and gas holes or pin-hole porosity from the moisture (31).
- 1.09 Special Considerations
- 1.091 See Type 422, Code 1403, Sections 1.091 and 1.092.
- 1.092 The strength and toughness of Type 420 can be significantly improved by ausforming at about 1000F (29).
- 1.093 Quenching and tempering induce small dimensional changes which vary with the heat-treating conditions.
- 1.0931 Dimensional changes as a result of hardening and tempering, Figure 1.0931.
2. PHYSICAL AND CHEMICAL PROPERTIES
- 2.01 Thermal Properties
- 2.011 Melting range - 2650 to 2750F (2).
- 2.012 Phase changes.
- 2.0121 Time-temperature-transformation diagrams.
- 2.0122 The exact temperatures for the various phase changes have not been studied as thoroughly as those in Type 422, but the changes and their temperatures closely parallel those of Type 422 (See Code 1403, Sections 2.0122 through 2.0125).
- 2.013 Thermal conductivity, Figure 2.013.
- 2.014 Thermal expansion, Figure 2.014.
- 2.015 Specific heat, Figure 2.015.





TYPE 420

2.016	Thermal diffusivity, Figure 2.016.	3.03111	Tensile stress-strain curves for sheet at room and elevated temperatures, Figure 3.03111.
2.02	<u>Other Physical Properties</u>	3.0312	Effect of temperature on tensile properties of bar, Figure 3.0312.
2.021	Density. 0.28 lb per in ³ ; 7.75 gr per cm ³ (10)(12)(23) (24).	3.0313	Effect of temperature on tensile properties of sheet of different thicknesses, Figure 3.0313.
2.022	Electrical properties, Table 2.022.	3.0314	Effect of exposure time at test temperature on the tensile properties of sheet, Figure 3.0314.
2.023	Magnetic properties. Ferromagnetic in all conditions (24).	3.032	Compression.
2.024	Emissance.	3.0321	Stress-strain diagrams.
2.025	Damping capacity.	3.03211	Compressive stress-strain curves for sheet at room and elevated temperatures, Figure 3.03211.
2.03	<u>Chemical Properties</u>	3.0322	Effect of temperature on compressive yield strength after two different exposure times at test temperature, Figure 3.0322.
2.031	Type 420 attains its optimum resistance to both general and stress corrosion when quenched and tempered except that tempering in the secondary-hardening range - about 700 to 1000F - results in a marked deterioration in corrosion resistance. See Table 2.0311 and Figures 2.0312 and 2.0313. Inferior corrosion resistance is also exhibited by annealed material and by material with scale and other surface contaminants (7)(10).	3.033	Impact.
2.0311	Effect of tempering temperature on susceptibility to stress corrosion in salt spray, Table 2.0311.	3.0331	Effect of temperature on impact properties, Figure 3.0331.
2.0312	Effect of tempering temperature on susceptibility to stress corrosion of bar totally immersed in 3 percent sodium-chloride solution, Figure 2.0312.	3.034	Bending.
2.0313	Effect of tempering temperature on general corrosion resistance of bar totally submerged in 3 percent sodium-chloride solution, Figure 2.0313.	3.035	Torsion and shear.
2.032	Hardened and cleaned Type 420 resists corrosion from the atmosphere, water, steam, carbonic acid, crude oil, gasoline, blood, perspiration, alcohol, ammonia, mercury, sterilizing solutions, soaps and oxidizing solutions such as nitric acid and nitrates. Deaerated or reducing solutions tend to attack the alloy (10)(30).	3.0351	Effect of temperature on shear strength after two different exposure times at test temperature, Figure 3.0351.
2.033	Resists excessive oxidation in continuous service at temperatures up to 1200F.	3.036	Bearing.
2.04	<u>Nuclear Properties</u>	3.0361	Effect of temperature on bearing properties after two different exposure times at test temperature, Figure 3.0361.
3.	<u>MECHANICAL PROPERTIES</u>	3.037	Stress concentration.
3.01	<u>Specified Mechanical Properties</u> Table 3.01.	3.0371	Notch properties.
3.02	<u>Mechanical Properties at Room Temperature</u>	3.0372	Fracture toughness.
3.021	Tension.	3.038	Combined properties.
3.0211	Stress-strain diagrams (see Figure 3.03111).	3.04	<u>Creep and Creep-Rupture Properties</u>
3.0212	Effect of tempering temperature on tensile properties of bar, Figure 3.0212.	3.041	Creep-rupture curves at 800 to 1100F, Figure 3.041.
3.0213	Effect of tempering temperature in tensile properties of castings, Figure 3.0213.	3.042	Stresses to cause various amounts of creep deformation in 1000 hours at 700, 800, and 900F, Figure 3.042.
3.0214	Effect of ausforming on tensile properties of sheet, Table 3.0214.	3.043	Stress to cause 1 percent creep deformation in 10,000 hours at 1000 to 1300F, Figure 3.043.
3.0215	Tensile properties of non-hardened material, Table 3.0215.	3.05	<u>Fatigue Properties</u>
3.022	Compression.	3.06	<u>Elastic Properties</u>
3.0221	Stress-strain diagrams (see Figure 3.03211).	3.061	Poisson's ratio.
3.0222	Compressive yield strength (see Figure 3.0322).	3.062	Modulus of elasticity.
3.023	Impact.	3.0621	Effect of temperature on modulus of elasticity in tension and compression, Figure 3.0621.
3.0231	Effect of tempering temperature on impact properties of bar at room temperature, Figure 3.0231.	3.0622	Tangent modulus curves in compression for sheet at room and elevated temperatures, Figure 3.0622.
3.0232	Effect of tempering temperature on impact properties of castings at room temperature, Figure 3.0232.	3.063	Modulus of rigidity - 11.7×10^3 ksi (2)(24).
3.024	Bending.	4.	<u>FABRICATION</u>
3.025	Torsion and shear.	4.01	<u>Formability</u>
3.0251	Shear strength (see Figure 3.0351).	4.011	Hot working. The alloy can be readily hot worked by starting at 2000 to 2200F and finishing above 1650F. If necessary, it should be reheated to maintain the hot working temperature above 1650F. Material to be hot worked should be preheated at 1400 to 1500F and then heated to the working temperature. Cooling cracks should be prevented by slow cooling after hot work. This can be accomplished by charging the hot worked material into a furnace at 1550F and furnace cooling or by burying the material in an insulating material such as dry lime or ashes (7)(10).
3.026	Bearing.	4.012	Cold working. Type 420 can be cold formed moderately in the fully annealed condition and only to a very limited extent in the process-annealed condition. A full anneal or stress-relief anneal is recommended after severe cold forming (7)(10).
3.0261	Bearing ultimate and yield strengths (see Figure 3.0361).	4.02	<u>Machining and Grinding</u>
3.027	Stress concentration.	4.021	Type 420 is usually machined in the fully annealed condition at speeds about 50 percent of those used for free-machining AISI B1112 steel. For the free-machining grades machining speeds are about 10 percent higher. Machinability in the process-annealed condition is somewhat less. Machining of the quenched-and-tempered
3.0271	Notch properties.		
3.0272	Fracture toughness.		
3.028	Combined properties.		
3.03	<u>Mechanical Properties at Various Temperatures.</u>		
3.031	Tension.		
3.0311	Stress-strain diagrams.		

- material is difficult but possible with carbide cutting tools (7)(10).
- 4.03 **Welding**
 4.031 The alloy can be arc welded by any of the common manual and automatic techniques. Because of its air-hardening characteristic and resulting tendency toward weld embrittlement, it should be preheated to 450F and immediately after welding should be stress relieved (see Section 1.055). Type 420 may be used as filler metal. Higher weld ductility but lower strength is provided by an austenitic stainless filler, such as Type 309 or 310 (7)(10).
- 4.04 **Surface Treatment**
 See Type 422, Code 1403, Sections 4.041 and 4.042.

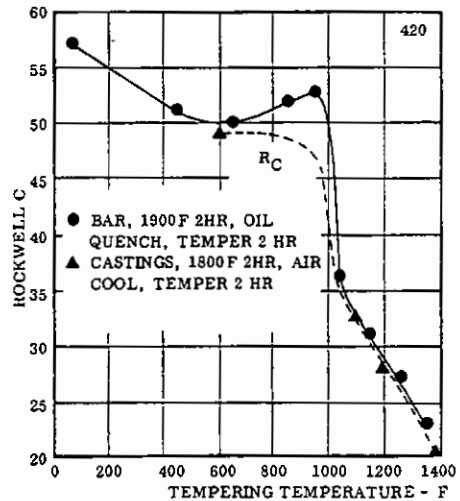
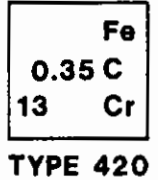


FIG. 1.061 EFFECT OF TEMPERING TEMPERATURE ON HARDNESS (7)(19)

Alloy	420
Source	(4)(5)(6)(8)(9)(18)
Specification	Forms
AMS 5621	Bars, forgings, forging stock
AMS 5620B	Free-machining bars, forgings, forging stock
AMS 5506A	Sheet, strip, plate
QQ-S-763C (1) Cl. 420	Bars, forgings
QQ-S-766C (5) Cl. 420	Plates, sheet, strip
QQ-W-423A	
ASTM A276	Bars
ASTM A314	Billets and bars for reforging
ASTM A473	Forgings
ASTM A296	Castings
MIL-S-862B, Cl. 420	Bars
MIL-S-22216	Castings
MIL-S-8142	
MIL-W-17481A	
SAE 51420	Martensitic stainless steel
SAE 60420	Corrosion-resistant castings
AJISI 420	Stainless steel
AWS A5.9-69 ER420	Electrode and rod
ACI CA40	Castings

TABLE 1.03 SPECIFICATIONS

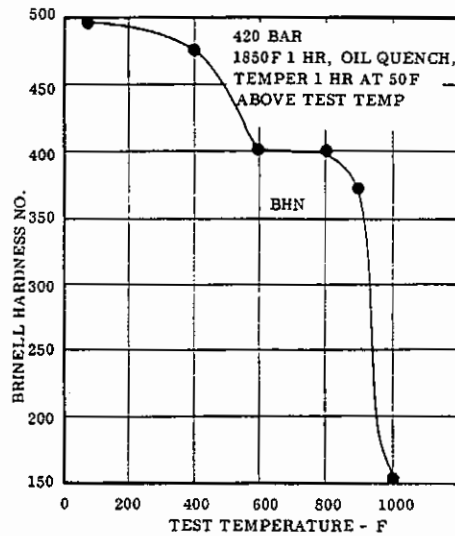


FIG. 1.062 EFFECT OF TEMPERATURE ON HARDNESS (10)

Alloy	420		420F		420F-Se		420		420 (CA-40)	
	min	max	min	max	min	max	min	max	min	max
Source	AMS 5621 (4) AMS 5506 (5)		AMS 5620B (6)		AMS 5620B (6)		ASTM A276(15) ASTM A314(16) ASTM A473(17)		ASTM A296 (18) SAE 60420	
Form	Wrought		Wrought		Wrought		Wrought		Cast	
Carbon	0.30	0.40	0.30	0.40	0.30	0.40	0.15	-	0.20	0.40
Manganese	-	1.00	-	1.25	-	1.25	-	1.00	-	1.00
Silicon	-	1.00	-	1.00	-	1.00	-	1.00	-	1.50
Phosphorus	-	0.040	-	0.040	-	0.040	-	0.040	-	0.04
Sulfur	-	0.030	0.15	0.35	-	0.030	-	0.030	-	0.04
Chromium	12.00	14.00	12.00	14.00	12.00	14.00	12.00	14.00	11.5	14.0
Nickel	-	0.50	-	0.50	-	0.50	-	-	-	1.00
Mo or Zr	-	0.50	-	0.60	-	0.60*	-	-	-	0.50
Selenium	-	-	-	-	0.18	0.35	-	-	-	-
Iron	Balance		Balance		Balance		Balance		Balance	

TABLE 1.04 COMPOSITION

Fe
0.35 C
13 Cr
TYPE 420

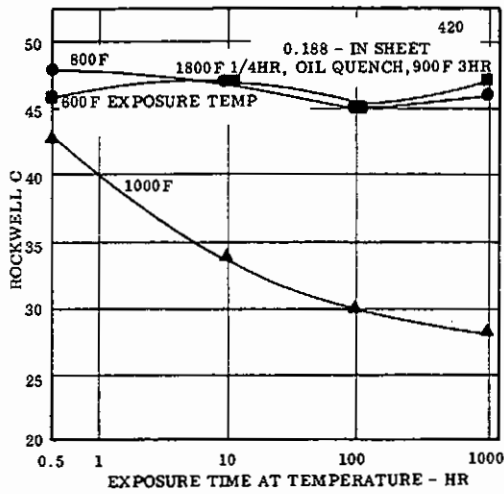


FIG. 1.063 EFFECT OF EXPOSURES AT ELEVATED TEMPERATURES ON ROOM - TEMPERATURE HARDNESS (11)

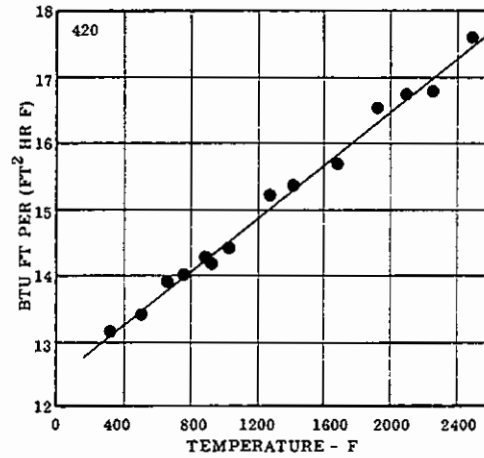


FIG. 2.012 THERMAL CONDUCTIVITY (1)

Alloy	420
Source	(9)(10)(12)(19)(26)(27)(28)
Form	Condition
Forging billets and bars	Annealed
Bars	Hot rolled or cold finished
Tubular products	Annealed
Wire	Annealed or cold finished
Wire rods	Annealed or cold finished
Sheet and strip	Annealed or cold rolled
Plate	Annealed or hot rolled
Forgings	Annealed or hardened
Castings	Annealed or hardened

TABLE 1.07 FORMS AND CONDITIONS AVAILABLE

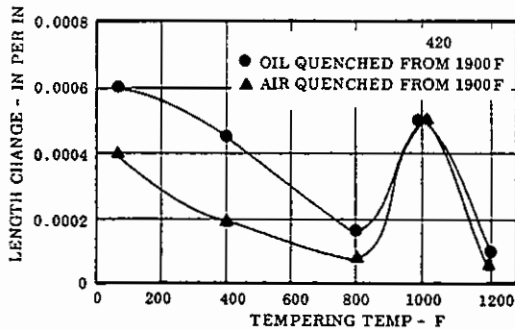


FIG. 1.0931 DIMENSIONAL CHANGES AS A RESULT OF HARDENING AND TEMPERING (10)

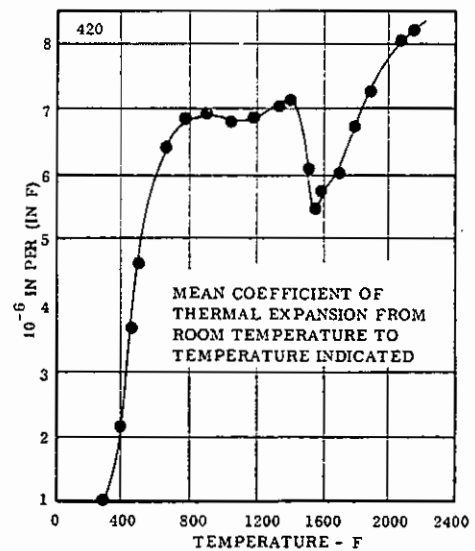


FIG. 2.014 THERMAL EXPANSION (1)

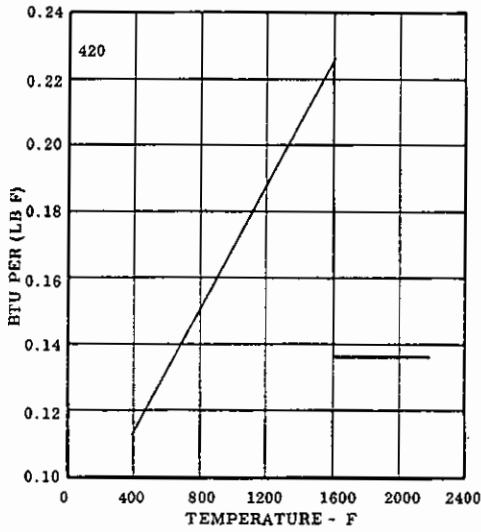


FIG. 2.015 SPECIFIC HEAT (1)

Alloy	420
Form	Forgings
Condition	1850F oil quench, tempered 2 hr.
Source	(20)
Tempering Temp. (F)	Stress corrosion,* days to failure
300	no failure
400	no failure
500	no failure
600	no failure
700	no failure
800	4
900	1/2
1000	6
1100	no failure

*Exposed 75 days to 5 percent salt spray under 100 ksi stress.

Fe
0.35 C
13 Cr
TYPE 420

TABLE 2.0311 EFFECT OF TEMPERING TEMPERATURE ON SUSCEPTIBILITY TO STRESS CORROSION IN SALT SPRAY

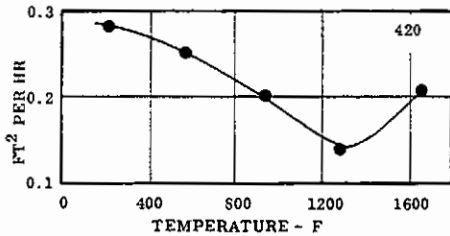


FIG. 2.016 THERMAL DIFFUSIVITY (2)

Alloy	420		
Condition	Annealed		
Source	(2)(3)		
Temperature - F	Electrical Conductivity		Electrical Resistivity, microhm in.
	Percent IACS	megmhos per in ³	
32 - 70	3.15	0.0463	21.6

TABLE 2.022 ELECTRICAL PROPERTIES

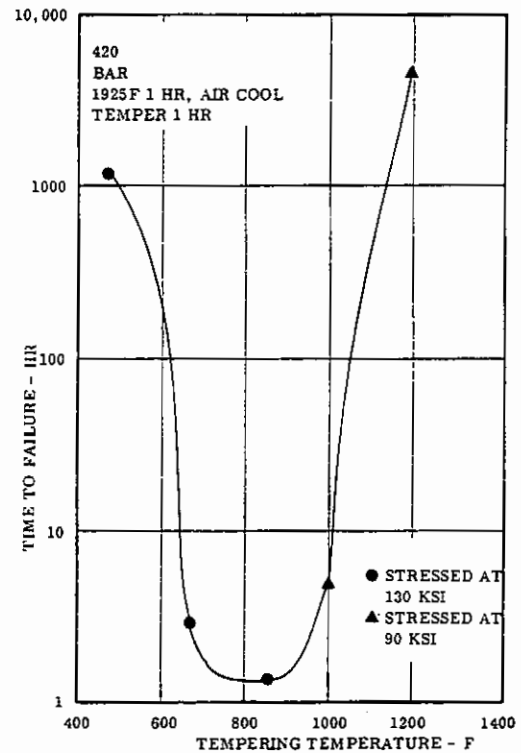


FIG. 2.0312 EFFECT OF TEMPERING TEMPERATURE ON SUSCEPTIBILITY TO STRESS CORROSION OF BAR TOTALLY IMMERSSED IN 3 - PERCENT SODIUM - CHLORIDE SOLUTION (22)

Fe
0.35 C
13 Cr
TYPE 420

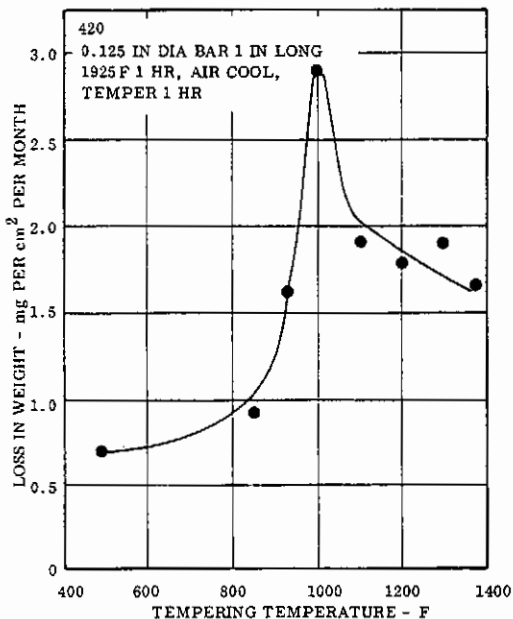


FIG. 2.0313 EFFECT OF TEMPERING TEMPERATURE ON GENERAL CORROSION RESISTANCE OF BAR TOTALLY SUBMERGED IN 3 - PERCENT SODIUM - CHLORIDE SOLUTION (22)

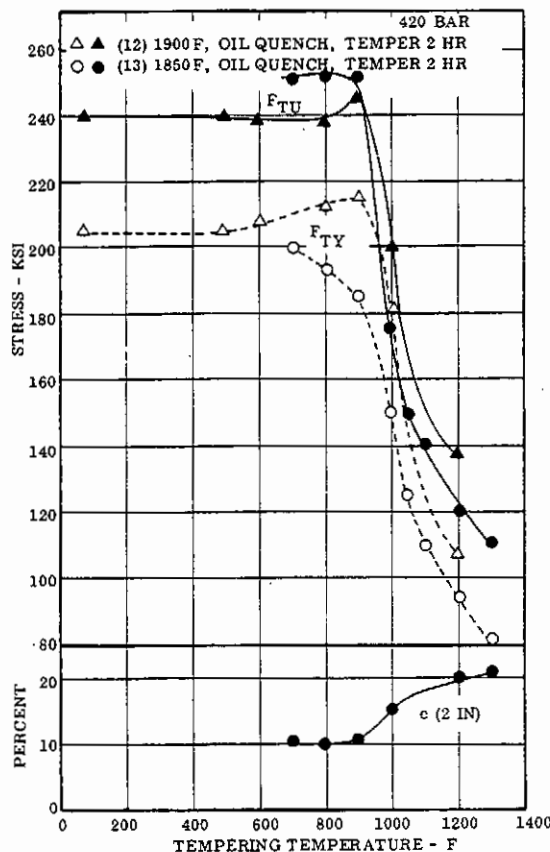


FIG. 3.0212 EFFECT OF TEMPERING TEMPERATURE ON TENSILE PROPERTIES OF BAR (12)(13)

Alloy	420					
	AMS 5506A (5)	AMS 5621 (4) AMS 5620B (6)	ASTM A276 (15)	ASTM A276 (15)	ASTM A473 (17)	ASTM A296 (18)
Form	Sheet, strip	Bars, forging	Bars	Bars	Forgings	Castings
Condition	Annealed	Annealed	Hot finished	Cold finished	Anneal. 1900F OQ	Annealed
F _{TU} , ksi, max.	100	-	-	-	-	-
F _{TU} , ksi, min.	-	-	-	-	-	100
F _{TY} , ksi, min.	-	-	-	-	-	70
e (2 in.), percent, min.	-	-	-	-	-	15
under 0.030 in. thick	12	-	-	-	-	-
0.030 in. and over	15	-	-	-	-	-
RA, percent, min.	-	-	-	-	-	25
BHN, max.	-	241	241	255	223	-
RC, min.	-	-	-	-	50	-

TABLE 3.01 SPECIFIED MECHANICAL PROPERTIES

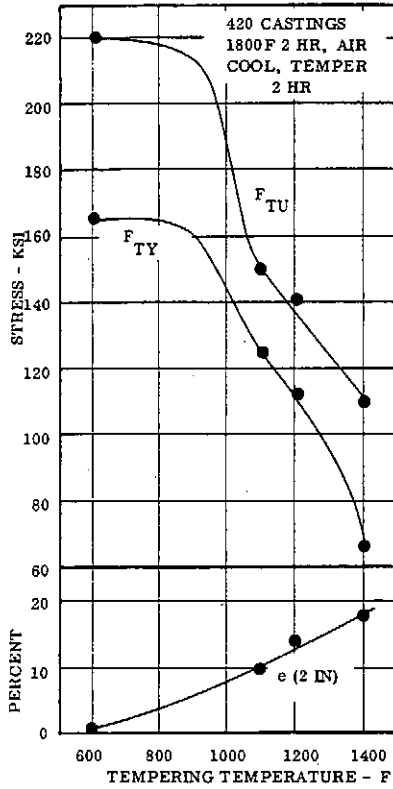


FIG. 3.0213 EFFECT OF TEMPERING TEMPERATURE ON TENSILE PROPERTIES OF CASTINGS (19)

Alloy		420			
Source		(24)			
Form	Condition	F _{ty} ksi	F _{tu} ksi	e (2 in.) percent	RA percent
Strip	Fully annealed	50	95	20	-
Bar	Fully annealed	50	95	25	55
Bar	Annealed & cold drawn	85	105	17	50
Wire	Fully annealed	50	95	20*	65

Fe
0.35 C
13 Cr
TYPE 420

TABLE 3.0215 TENSILE PROPERTIES OF NON-HARDENED MATERIAL

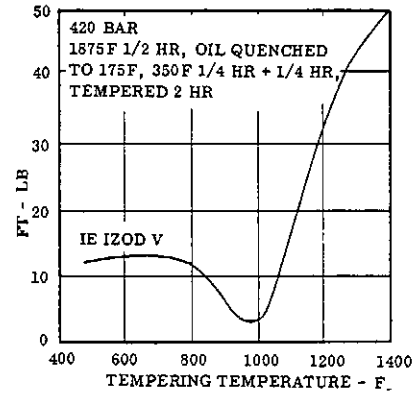


FIG. 3.0231 EFFECT OF TEMPERING TEMPERATURE ON IMPACT PROPERTIES OF BAR AT ROOM TEMPERATURE (14)

Alloy		420	
Form		Sheet	
Source		(29)	
Condition	1900F, OQ, 900F, 2 hr.	1900F, AC to 1000F, Ausformed 85 percent by rolling, OQ, 1000F, 2 hr.	
F _{ty} , ksi	195	220	
F _{tu} , ksi	236	245	
RA, percent	60	40	

TABLE 3.0214 EFFECT OF AUSFORMING ON TENSILE PROPERTIES OF SHEET

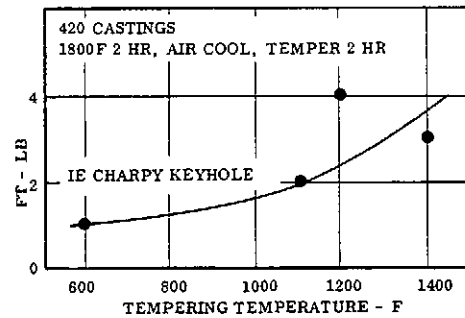


FIG. 3.0232 EFFECT OF TEMPERING TEMPERATURE ON IMPACT PROPERTIES OF CASTINGS AT ROOM TEMPERATURE (19)

Fe
0.35 C
13 Cr
TYPE 420

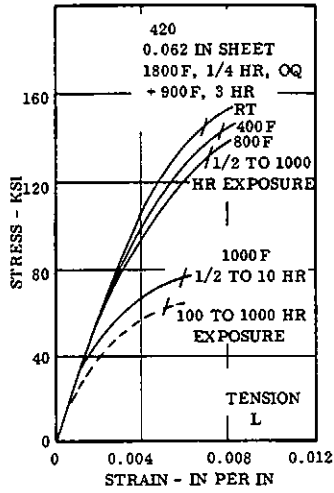


FIG. 3.03111 TENSILE STRESS - STRAIN CURVES FOR SHEET AT ROOM AND ELEVATED TEMPERATURES (11)

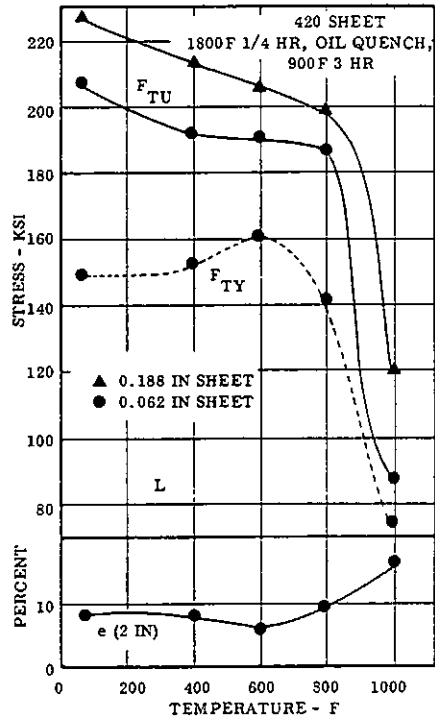


FIG. 3.0313 EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF SHEET OF DIFFERENT THICKNESSES (11)

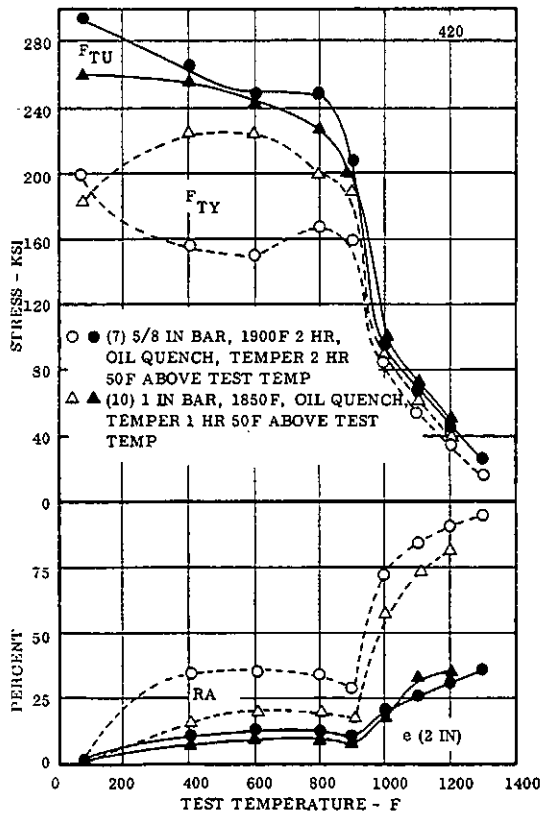


FIG. 3.0312 EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF BAR (7)(10)

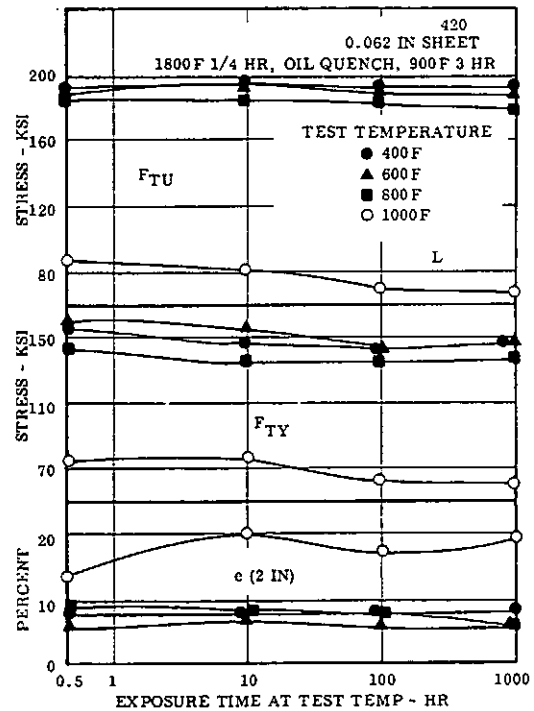


FIG. 3.0314 EFFECT OF EXPOSURE TIME AT TEST TEMPERATURE ON THE TENSILE PROPERTIES OF SHEET (11)

Fe
0.35 C
13 Cr

TYPE 420

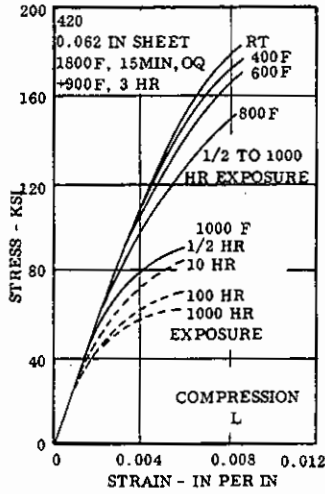


FIG. 3.03211 COMPRESSIVE STRESS - STRAIN CURVES FOR SHEET AT ROOM AND ELEVATED TEMPERATURES (11)

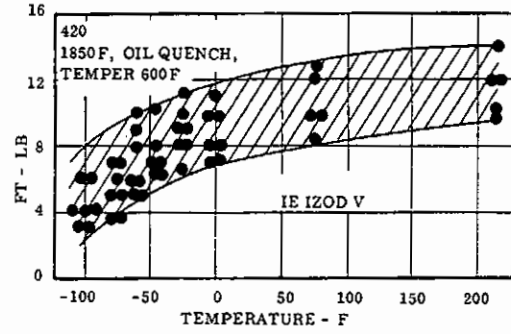


FIG. 3.0331 EFFECT OF TEMPERATURE ON IMPACT PROPERTIES (13)

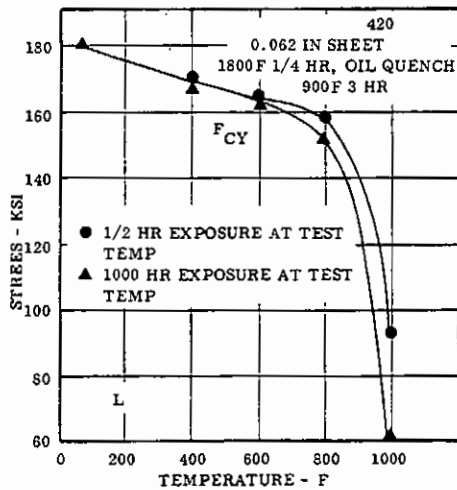


FIG. 3.0322 EFFECT OF TEMPERATURE ON COMPRESSIVE YIELD STRENGTH AFTER TWO DIFFERENT EXPOSURE TIMES AT TEST TEMPERATURE (11)

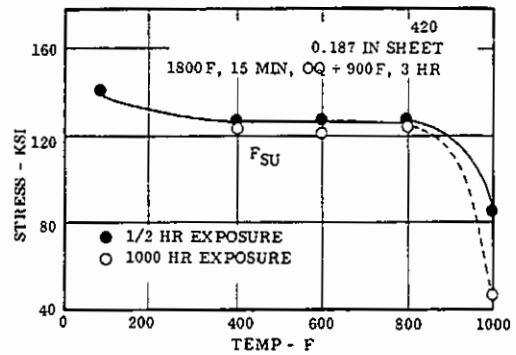


FIG. 3.0351 EFFECT OF TEMPERATURE ON SHEAR STRENGTH AFTER TWO DIFFERENT EXPOSURE TIMES AT TEST TEMPERATURE (11)

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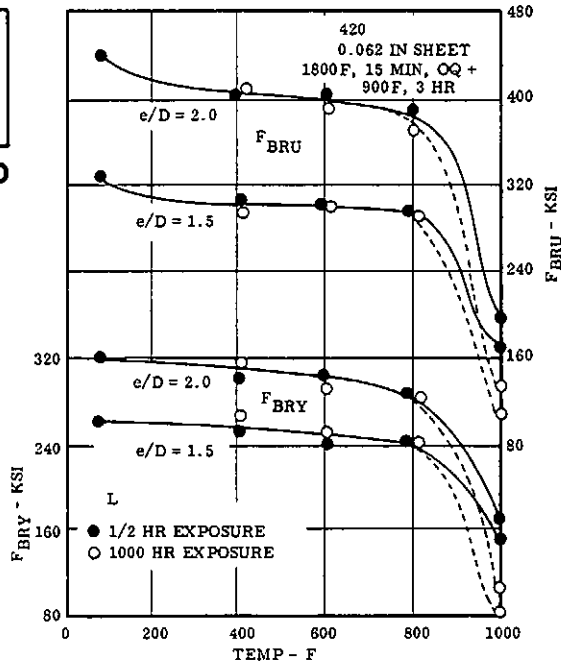


FIG. 3.0361 EFFECT OF TEMPERATURE ON BEARING PROPERTIES AFTER TWO DIFFERENT EXPOSURE TIMES AT TEST TEMPERATURE (11)

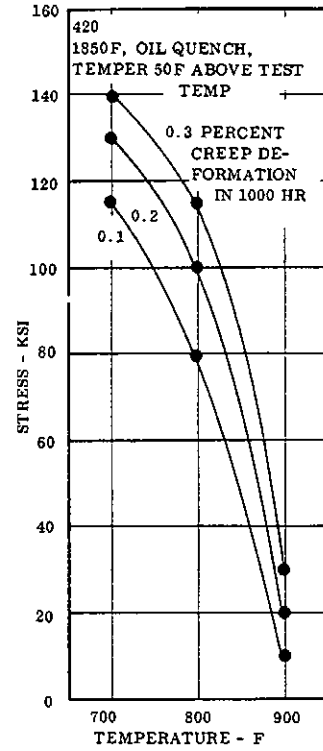


FIG. 3.042 STRESSES TO CAUSE VARIOUS AMOUNTS OF CREEP DEFORMATION IN 1000 HOURS AT 700, 800, AND 900F (25)

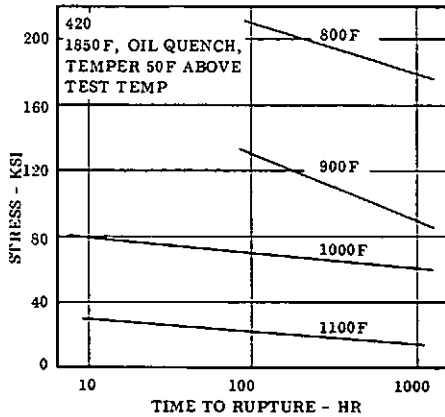


FIG. 3.041 CREEP - RUPTURE CURVES AT 800 TO 1100F (25)

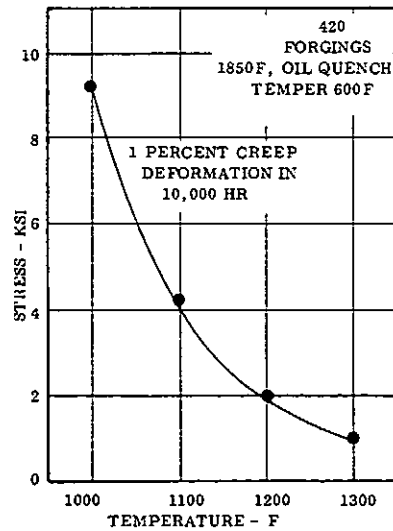


FIG. 3.043 STRESS TO CAUSE 1 PERCENT CREEP DEFORMATION IN 10,000 HOURS AT 1000 TO 1300F (21)

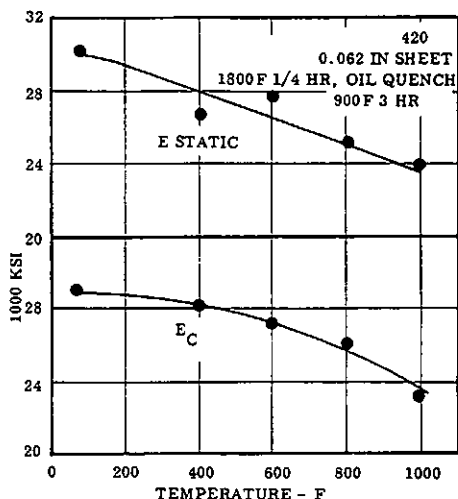


FIG. 3.0621 EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY IN TENSION AND COMPRESSION (11)

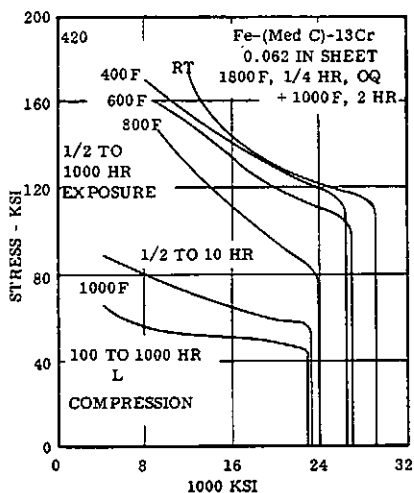


FIG. 3.0622 TANGENT MODULUS CURVES IN COMPRESSION FOR SHEET AT ROOM AND ELEVATED TEMPERATURES (11)

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