	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

1 **GENERAL**

This heat-treatable low-alloy steel has relatively low hardenability; nevertheless, it is one of the most popular alloy steels because of its good formability and weldability along with an excellent combination of mechanical properties. Its optimum combination of properties is developed in limited section thicknesses by quench-and-temper heat treatment, but sufficient strength and toughness for many applications can be obtained by normalizing. It is recommended for use at temperatures up to a maximum of 700 F because its strength decreases markedly with increasing temperatures above that level. At sub-zero temperatures it undergoes a transition from ductile to brittle behavior in a Charpy V impact test, when it has poor impact properties. The transition temperature varies with the heat treatment.

This steel is not subject to temper embrittlement, and can be nitrided. It is usually forged at 2000 F to 2200 F and the finishing temperature should never fall below 1800 F. For applications in moist, marine, and other corrosive environments, paint, electroplate, or other protective coatings should be applied to inhibit rusting and other corrosion. It is used in both cast and wrought form for many applications requiring high strength and toughness.

4130 steel is available as billet, bar, rod, forgings, sheet, plate, tubing, and castings. It is used to make automotive connecting rods, engine mounting lugs, shafts, fittings, bushings, gears, bolts, axles, gas cylinders, airframe components, hydraulic lines, and nitrided machinery parts. (30,74)

1.01 **Commercial Designation**
4130.

1.02 **Alternate Designations**
AISI 4130, SAE 4130, 4130H, UNS G41300, UNS H41300.

1.03 **Specifications**
Table 1.03.

1.04 **Composition**
Table 1.04.

1.05 **Heat Treatment**

1.051 Normalize: Heat to 1600 to 1700 F, air cool (tempering at 900 F or above is often carried out after normalizing to raise the relatively low as-normalized yield strength) (30).

1.052 Anneal: Heat to 1525 to 1575 F, furnace cool (30).

1.053 Harden: Heat to 1500 to 1600 F, water quench, or heat to 1575 to 1625 F, oil quench. Inert or endothermic atmosphere is desirable to prevent decarburization (30).

1.054 Temper: Heat to 400 to 1300 F, hold 1/2 hour minimum, air cool or water quench (the alloy is not susceptible to temper embrittlement) (30).

1.055 Spheroidize: Heat to 1400 to 1425 F, hold at temperature for 6 to 12 hours, cool slowly (30).

1.06 **Hardness**

1.061 Effect of tempering temperature on hardness of bar, Figure 1.061.

1.062 Effect of tempering temperature on hardness of oil-quenched and water-quenched bar, Figure 1.062.

1.063 Effect of exposures at elevated temperatures on room-temperature hardness of sheet after three different tempering treatments, Figure 1.063.

1.064 Hardness of bar, plate, sheet, and extrusion in various heat-treated conditions, Table 1.064.

1.065 Effect of diameter on surface hardness of quenched-and-tempered bars, Figure 1.065.

1.066 End-quench hardenability, Figure 1.066.

1.067 Hardness profile through nitrided case, Figure 1.067.

1.068 Effect of repress (forging) pressure and temperature on hardness of powder metallurgy forging, Figure 1.068.

1.069 Effect of fabrication process on hardness properties of powder metallurgy forging, Table 1.069.

1.07 **Forms and Conditions Available**

1.071 Wrought products are available in the full range of sizes and forms including billets, bars, rods, forgings, sheets, plates, strip, and tubing. The products are furnished in the annealed, normalized and tempered, or hardened and tempered conditions (30).

1.072 Sand, centrifugal, and investment castings are available in any desired heat-treated condition (30).

1.08 **Melting and Casting Practice**

1.081 The alloy is generally air melted in basic-electric, basic-open-hearth, or basic-oxygen furnaces. For some applications requiring exceptional quality, it is induction or consumable-electrode remelted in vacuum.

1.09 **Special Considerations**

1.091 Because of the limited hardenability of Type 4130, optimum and uniform mechanical properties can be obtained only in section thicknesses that are small enough to through-harden when quenched from the austenitizing temperature. For critical applications requiring high strength and toughness, therefore, use should be made of precise hardenability calculations to determine the suitability of specific heat compositions.

1.092 Type 4130 is susceptible to hydrogen embrittlement in chrome-, nickel-, and cadmium-plating solutions and in hydrochloric-acid pickling. It is generally not susceptible in alkaline cleaners or anodic acid cleaners. Baking at 375 F for times up to 24 hours, depending upon the severity of the embrittlement, is effective in relieving the embrittlement (19,20).

1.093 Effect of hydrogen gas pressure on embrittlement (see Figure 3.02726).

2 **PHYSICAL AND CHEMICAL PROPERTIES**

2.01 **Thermal Properties**

2.011 Melting range – about 2795 F.

2.012 Phase changes.

2.0121 Time-temperature-transformation diagram, Figure 2.0121.

2.0122 Upon heating under equilibrium conditions, the transformation from pearlite or martensite to austenite starts at 1395 F (AC_1) and is complete at 1490 F (AC3) (35).

2.0123 Upon slow cooling under equilibrium conditions, the transformation from austenite to pearlite starts at 1390 F (Ar_3) and is complete at 1380 F (Ar_1) (35).

2.0124 Upon rapid quenching from the austenitic condition the transformation to martensite starts at 700 F (M_s) and is complete at 550 F (M_f) (30).

2.013 Thermal conductivity, Figure 2.013.

2.014 Thermal expansion, Figure 2.014.

2.015 Specific heat, Figure 2.015.

2.016 Thermal diffusivity.

2.02 **Other Physical Properties**

2.021 Density, 0.2834 lb/in.^{3}, 7.845 gr/cm^3 (30).

2.0211 Effect of initial compacting pressure on density of powder metallurgy forging, Figure 2.0211.

2.0212 Effect of repress (forging) pressure and temperature on density of powder metallurgy forging, Figure 2.0212.

2.022 Electrical properties.

2.0221 Electrical resistivity as a function ot temperature, Figure 2.0221.

2.023 Magnetic properties, ferromagnetic.

2.024 Emittance.

2.025 Damping capacity.

2.0251 Effect of number of cycles in reversed bending and maximum cyclic tensile strain (Em) on damping capacity, Figure 2.0251.

2.03 **Chemical Properties**

2.031 Type 4130 is susceptible to general corrosion – rusting and pitting – and to stress corrosion, particularly in industrial and marine environments. For most applications it should be protected by suitable electroplating, paint, or a combination of both (21). Corrosion rate in seawater decreases at least by 50 percent with exposure from 1 year to 3-1/2 years, and the rate at a depth of 5500 feet is less than half that in surface waters (67).

2.032 Stress corrosion of cadmium-plated bar and sheet subjected to alternate immersions (10 minutes in and 50 minutes out) in 3-1/2 percent solution of sodium chloride having pH of 6.8 to 7.2, Table 2.032.

2.033 Type 4130 is resistant to corrosion by pure fluorinated hydrocarbons, such as Propellants 113 and 114B2 (Freon-113 and Freon-114B2), which are used as solvents and refrigerants as well as propellants. In the presence of small amounts of moisture, however, these types of hydrocarbons significantly attack the alloy (37).

2.034 Effect of temperature and chloride concentration on "break point" of sheet in two-point bend test, Table 2.034.

2.035 Effect of sulfur hexafluoride (SF_6) on tensile properties (see Section 3.02121).

2.036 Effect of yield strength and flaw depth on threshold stress intensity (K_{Iscc}) (see Figure 3.02725).

3 **MECHANICAL PROPERTIES**

3.01 **Specified Mechanical Properties**
Table 3.01.

3.02 **Mechanical Properties at Room Temperature**

3.021 Tension – stress-strain diagrams – tension properties.

3.0211 Stress-strain curves (see Figure 3.0311).

3.0212 Tensile properties of round bar in various heat-treated conditions, Table 3.0212.

3.0213 Tensile properties of plate in various heat-treated conditions, Table 3.0213.

3.0214 Tensile properties of 3/8 inch plate heat treated to various hardnesses, Table 3.0214.

3.0215 Tensile properties of extruded round bar in various heat-treated conditions, Table 3.0215.

3.0216 Tensile properties of extruded flat bar in various heat-treated conditions, Table 3.0216.

3.0217 Tensile properties of castings in various heat-treated conditions, Table 3.0217.

3.0218 Effect of tempering temperature on room-temperature tensile properties of 0.530 inch bar, Figure 3.0218.

3.0219 Effect of tempering temperature on tensile properties of oil-quenched and water-quenched 1 inch bar, Figure 3.0219.

3.02110 Effect of sheet thickness and tempering temperature on tensile properties, Table 3.02110.

3.02111 Effect of austenitizing temperature and quench medium on tensile properties of as-quenched material, Table 3.02111.

3.02112 Effect of quench medium and tempering temperature on tensile properties of rolled bar, Table 3.02112.

3.02113 Effect of quench medium on tensile properties of sheet, Table 3.02113.

3.02114 Effect of bar diameter on tensile properties in various heat-treated conditions, Figure 3.02114.

3.02115 Tensile properties of quenched and tempered round bar, Figure 3.02115.

3.02116 Effect of explosive forming on tensile properties of plate, Table 3.02116.

3.02117 Effect of fabrication process on tensile properties of powder metallurgy forging, Table 3.02117.

3.02118 Effect of repress (forging) pressure and temperature on ultimate tensile strength of powder metallurgy forging, Figure 3.02118.

3.02119 Effect of Mn plating and elevated temperature exposure on tensile properties of sheet, Table 3.02119.

3.02120 Temperature limits for prolonged unstressed exposure which prevent degradation of tensile strength, Table 3.02120.

3.02121 Exposure to sulfur hexafluoride (SF_6) at a temperature of 440 F and a pressure of 525 psi for up to 24 hours does not degrade the tensile ultimate (F_{tu}) and yield (F_{ty}) strengths of 0.094-inch-thick sheet (64).

3.022 Compression – stress-strain diagrams – compression properties.

3.0221 Stress-strain curves (see Figure 3.0321).

3.0222 Compressive yield strength (see Figure 3.0322).

3.023 Impact.

3.0231 Impact properties of extruded bar, Table 3.0231.

3.0232 Effect of tempering temperature on room-temperature impact strength, Figure 3.0232.

Fe	
0.3	C
0.95	Cr
0.2	Mo

4130

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

3.03713 Effect of temperature and loading rate on crack strength (net fracture stress) and fracture appearance of fatigue cracked sheet specimens quenched and tempered at 400 F, Figure 3.03713.

3.03714 Effect of temperature on crack strength (net fracture stress) and fracture appearance of both fatigue-cracked and shear-cracked sheet specimens quenched and tempered at 825 F, Figure 3.03714.

3.0372 Fracture toughness.

3.038 Combined properties.

3.04 **Creep and Creep Rupture Properties**

3.041 Creep-rupture curves from 700 to 1100 F, Figure 3.041.

3.042 Creep-rupture and minimum-creep-rate characteristics of normalized sheet at 1000 and 1200 F, Figure 3.042.

3.05 **Fatigue Properties**

3.051 Fatigue life as a function of cyclic strain for Type 4130 tempered at 1200 F, Figure 3.051.

3.052 Fatigue life as a function of cyclic strain for Type 4130 tempered at 750 F, Figure 3.052.

3.053 Effect of maximum cyclic tensile strain on fatigue life in reversed bending, Figure 3.053.

3.054 Fatigue-crack growth rate as a function of maximum cyclic stress intensity factor (K) for center cracked specimens, Figure 3.054.

3.055 Fatigue-crack-growth rate in air and vacuum as a function of stress intensity amplitude (ΔK) for compact tension specimen, Figure 3.055.

3.056 Effect of prestressing and removal of surface-layer stress by thermal relaxation on fatigue crack growth rate of plate, Figure 3.056.

3.057 Effect of prestressing and chem-milling on fatigue crack growth rate of sheet, Figure 3.057.

3.058 S-N curve at room temperature in rotating bending, Figure 3.058.

3.059 Comparison of axial-loading and rotating-beam-bending fatigue data, Figure 3.059.

3.0510 Axial-stress S-N curves for edge-notched specimens, Figure 3.0510.

3.0511 Effect of temper treatment (measured by Rockwell hardness) on repeated-bending fatigue properties, Figure 3.0511.

3.0512 Effect of temper treatment (measured by Rockwell hardness) on rotating-beam fatigue properties, Figure 3.0512.

3.0513 Effect of chromium coating on axial-stress fatigue properties of sheet, Figure 3.0513.

3.06 **Elastic Properties**

3.061 Poisson's ratio, 0.25 to 0.29 (22,36).

3.062 Modulus of elasticity.

3.0621 Effect of temperature on modulus of elasticity in tension and compression of sheet after three different tempering treatments, Figure 3.0621.

3.0622 Compressive tangent modulus curves for sheet after three different tempering treatments, Figure 3.0622.

3.063 Modulus of rigidity.

4 **FABRICATION**

4.01 **Formability**

4.011 In the annealed condition, Type 4130 has good cold formability for a heat-treatable alloy steel; but its cold formability, of course, does not approach that of a low-carbon steel.

4.012 Its hot formability is excellent. All forging should be done within the temperature range 2250 to 1800 F; the optimum forging range is 2200 to 2000 F. Parts should be slow cooled in air or other appropriate environment after hot forming (30,35).

4.013 Effect of temperature on formability of sheet, Figure 4.013.

4.02 **Machining and Grinding**

4.021 Type 4130 can be readily machined in the annealed, normalized, and cold-drawn conditions. In the cold-drawn condition, which provides optimum machinability for this alloy, machinability is 60 to 70 percent of that of AISI B1112 screw stock.

4.03 **Welding**

4.031 Type 4130 has good weldability by oxyacetylene techniques and by any of the automatic or manual electric-arc processes. In oxyacetylene welding, the filler metal should be the same alloy as the base metal. In arc-welding, low-hydrogen low-alloy electrodes should be used. Although good welded properties can be obtained without thermal treatment, preheating to about 400 F and post-weld tempering are recommended when possible for improved weld properties. If complete quench and temper heat treatment can be carried out after welding, joint efficiencies approaching 100 percent can be obtained.

4.032 Tensile properties of parent metal and of 0.5 inch thick plate with butt weld as the center of the specimen gage length, Table 4.032.

4.033 Charpy V-notch impact properties at -65 F of butt-welded 0.50-inch-thick plate, Table 4.033.

4.034 Tensile properties of sheet butt welded by various arc processes, Table 4.034.

4.035 Tensile properties of butt-welded sheet, Table 4.035.

4.036 Effect of electrode alloy and sheet or plate thickness on tensile ultimate strength of bead-off butt welds, Table 4.036.

4.037 Effect of electrode alloy and sheet or plate thickness on shear ultimate strength of longitudinal-weld lap joints, Table 4.037.

4.038 Tensile and shear ultimate-strength design curves for sheet and plate welds heat treated to either 150 or 175 ksi, Figure 4.038.

4.039 Constant-life diagram for an axial-loaded tube splice – stresses calculated in the large tube, Figure 4.039.

4.0310 Constant-life diagram for an axial-loaded tube splice – stresses calculated in the small tube, Figure 4.0310.

4.04 **Surface Treatments**

4.041 With proper surface preparation, protective coatings of paint and electroplating can be applied with excellent results.

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

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Fe
0.3 C
0.95 Cr
0.2 Mo

4130

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Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130				
Forms					
Sheet, Strip, Plate	Bars, Billets, Forgings	Pipe, Tube	Castings	Welding Wire	General
AMS 6350F	AMS 6348	AMS 6360G	AMS 5336D	AMS 6457	QQ-M-105b
AMS 6351C	AMS 6370J	AMS 6361B	MIL-S-22141		SAE 4130
AMS 6350C	QQ-S-621b	AMS 6362C	ASTM A487		SAE 4130H
QQ-S-626a	MIL-S-6758A	AMS 6371F			AISI 4130
QQ-S-627b	MIL-S-16974B	AMS 6373B			AISI 4130H
MIL-S-18729C	MIL-S-81242	AMS 6374			AISI TS4130
ASTM A505	ASTM A274	QQ-T-00825			AISI TS4130H
ASTM A507	ASTM A304	MIL-T-6736B			
ASTM A410	ASTM A322	ASTM A519			
	ASTM A372	ASTM A513			
	ASTM A322				
	ASTM A331				
	ASTM A274				
	ASTM A372				

TABLE 1.03. SPECIFICATIONS (1–13,28,29)

Alloy	4130							
Form	Wrought		Investment Castings (1)		Castings (29)		Welding Wire	
	Min	Max	Min	Max	Min	Max	Min	Max
Carbon	0.28[(a)]	0.33[(a)]	0.05	0.35	–	0.33	0.28	0.33
Manganese	0.40	0.60	0.40	0.80	0.60	1.00	0.40	0.60
Silicon	0.15[(b)]	0.35	–	1.00	–	0.80	0.15	0.35
Phosphorus	–	0.025	–	0.04	–	0.04	–	0.008[(c)]
Sulphur	–	0.025	–	0.04	–	0.045	–	0.008[(c)]
Chromium	0.80	1.10	0.80	1.10	0.75	1.10	0.80	1.10
Molybdenum	0.15	0.25	0.15	0.25	0.15	0.30	0.15	0.25
Nickel	–	0.25	–	0.25	–	0.50	–	0.25
Copper	–	0.35	–	0.25	–	–	–	0.10
Vanadium	–	–	–	–	–	–	–	0.06
Oxygen	–	–	–	–	–	–	–	0.0025
Nitrogen	–	–	–	–	–	–	–	0.005
Hydrogen	–	–	–	–	–	–	–	0.0010
Iron	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance

(a) AMS 6336C gives 0.30 min and 0.35 max.
(b) AMS 6360G gives 0.20.
(c) Phosphorus + sulphur 0.012.

TABLE 1.04. COMPOSITION (1–13,29)

Fe	
0.3	C
0.95	Cr
0.2	Mo

4130

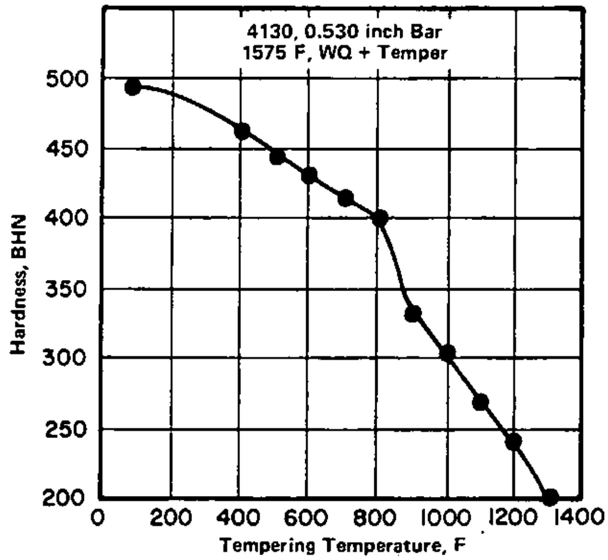


FIGURE 1.061. EFFECT OF TEMPERING TEMPERATURE ON HARDNESS OF BAR (16)

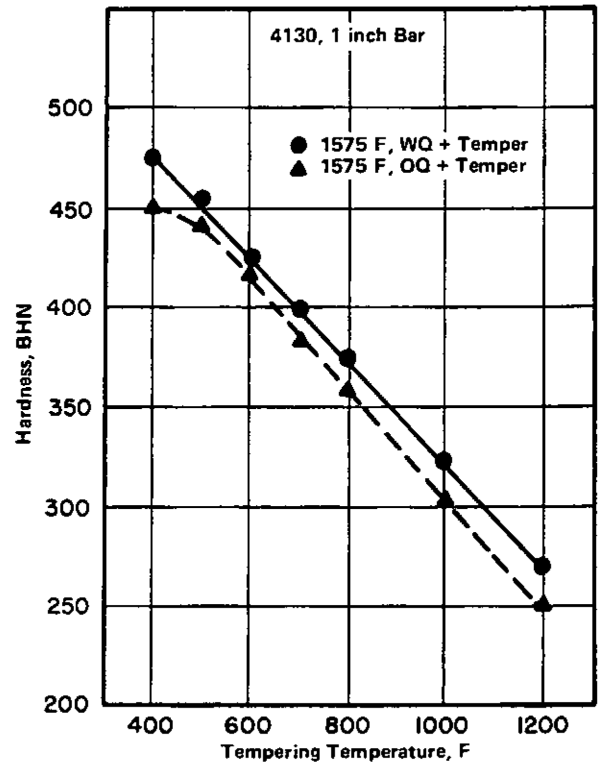


FIGURE 1.062. EFFECT OF TEMPERING TEMPERATURE ON HARDNESS OF OIL-QUENCHED AND WATER-QUENCHED BAR (30)

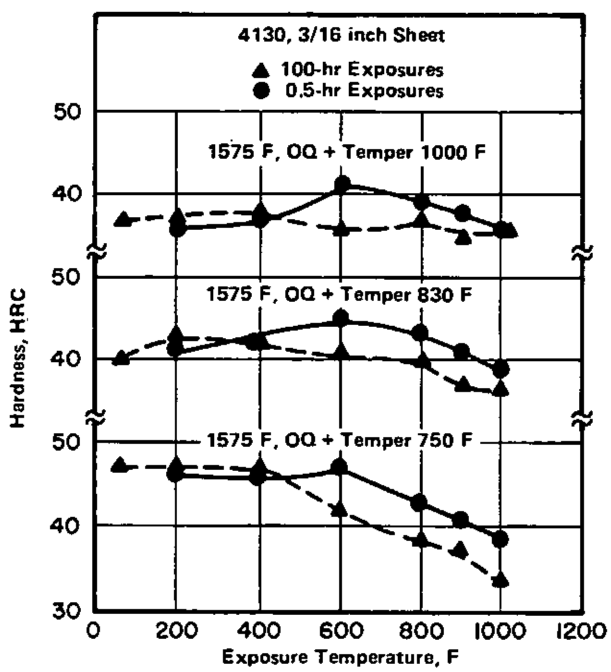


FIGURE 1.063. EFFECT OF EXPOSURES AT ELEVATED TEMPERATURES ON ROOM-TEMPERATURE HARDNESS OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS (14)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy Form	4130 Condition	Hardness BHN	HRB	HRC
5/8 in. Diam Bar	Normalized 1550 F, WQ, tempered 800 F, 1 hr	–	–	40
1 in. Bar	Hot rolled:			
	As hot rolled	229	–	–
	Normalized 1600 F	207	–	–
	Annealed 1550 F	179	–	–
	Cold drawn:			
	As cold drawn	248	–	–
	Annealed 1550 F	201	–	–
0.50 in. Plate	Normalized 1600 F	–	–	14
	Normalized + tempered 1100 F	–	–	12
	Oil quenched + tempered 1000 F	–	–	34
	Oil quenched + tempered 1200 F	–	–	22
1 in. Diam Extruded Bar, Allegheny Ludlum Steel	Annealed 1550 F, 1 hr + slow cool	–	80	–
	Normalized 1575 F, 1 hr, OQ and			
	Temper 850 F, 2 hr	–	–	32
	Temper 1200 F, 2 hr	–	88	–
3/4 x 3-1/8 in. Extruded Flat Allegheny Ludlum Steel	Normalized 1650 F, 1 hr	–	92	–
	Annealed 1550 F, 1 hr	–	76	–
	Normalized 1575 F, 1 hr, OQ +			
	Tempered 850 F, 2 hr	–	–	29
	Tempered 1200 F, 2 hr	–	93	–
0.063 in. Sheet	Austenitized 1575 F, 1 hr, WQ + temper 700 F, 1/2 hr, air cool	–	–	41
	Austenitized 1575 F, 1/2 hr, WQ + temper 500 F, 1/2 hr, air cool	–	–	46

TABLE 1.064. HARDNESS OF BAR, PLATE, SHEET AND EXTRUSION IN VARIOUS HEAT-TREATED CONDITIONS (11,26,30,44,45)

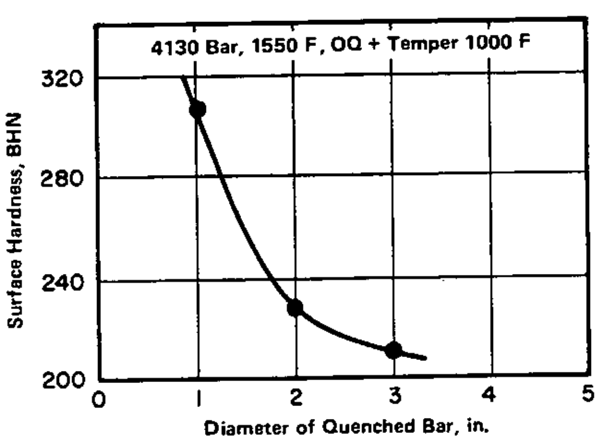


FIGURE 1.065. EFFECT OF DIAMETER ON SURFACE HARDNESS OF QUENCHED-AND-TEMPERED BARS (30)

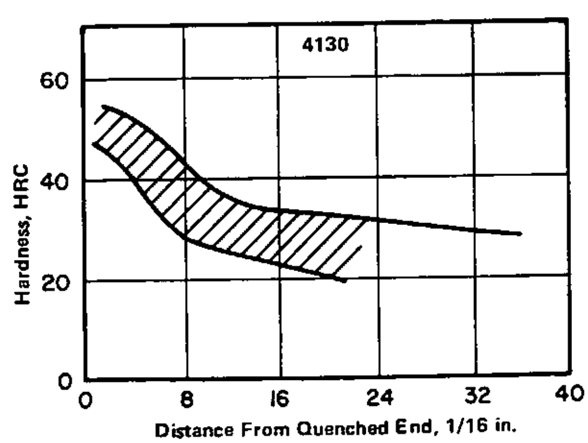


FIGURE 1.066. END-QUENCH HARDENABILITY (33)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

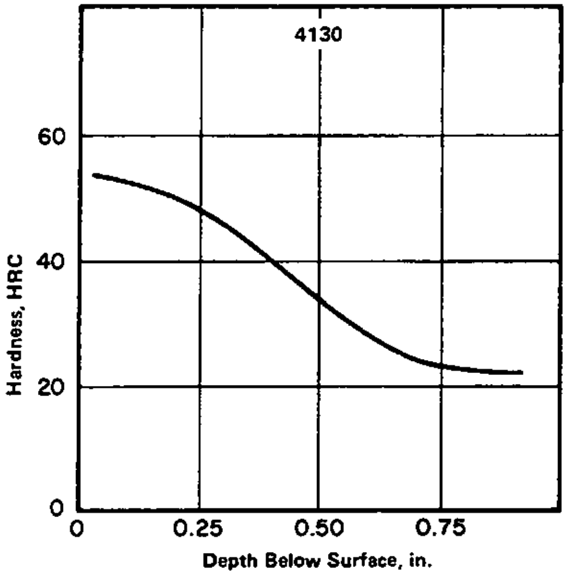


FIGURE 1.067. HARDNESS PROFILE THROUGH NITRIDED CASE (74)

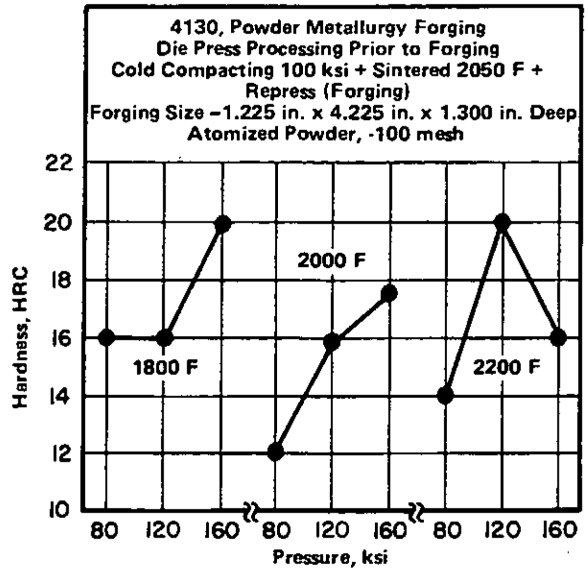


FIGURE 1.068. EFFECT OF REPRESS (FORGING) PRESSURE AND TEMPERATURE ON HARDNESS OF POWDER METALLURGY FORGING (46)

Alloy	4130					
Form	Powder Metallurgy Forgings, Die Press Process – 1.125 x 4.225 x 3.000 inch Deep, Isostatic Press Process – 0.565 x 4.000 x 1.300 inch Deep, High Energy Rate Forming (HERF), 2.5 inch Diameter x 5.5 inch Long Water Atomized Powder, -100 Mesh					
Condition	Austenitized 1575 F, RT Water Quench, Tempered 800 F, 1 hr					
	Compacting		Sinter	Repress (Forging)		
Process	Temperature, F	Pressure, ksi	Temperature, F(a)	Temperature, F	Pressure, ksi	Hardness, HRC
Die Press	RT	100	2050	2200	150	31
Isostatic	RT	50	1650	2200	150	39
HERF	–	–	–	2200	275	35

(a) For 1 hour.

TABLE 1.069. EFFECT OF FABRICATION PROCESS ON HARDNESS PROPERTIES OF POWDER METALLURGY FORGING (46)

Fe	
0.3	C
0.95	Cr
0.2	Mo

4130

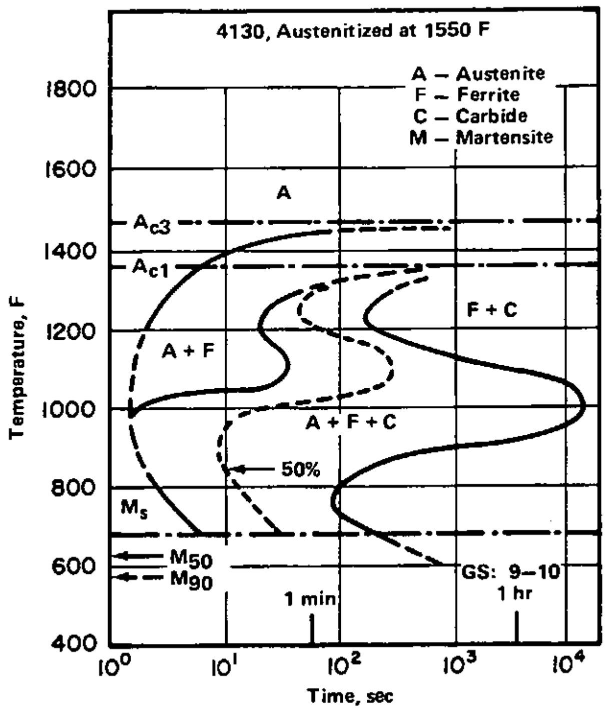


FIGURE 2.0121. TIME-TEMPERATURE-TRANSFORMATION DIAGRAM (34)

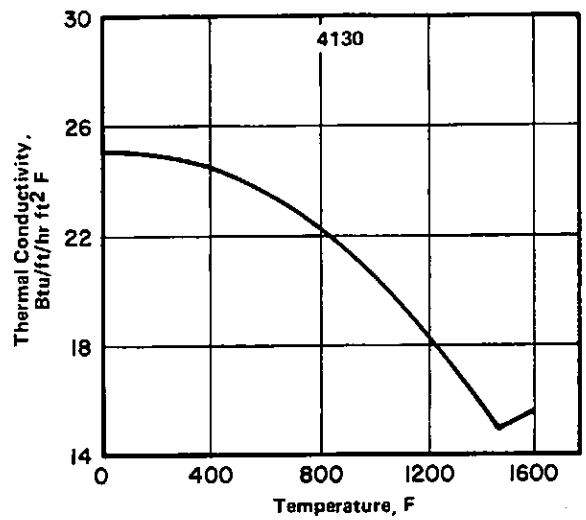


FIGURE 2.013. THERMAL CONDUCTIVITY (36)

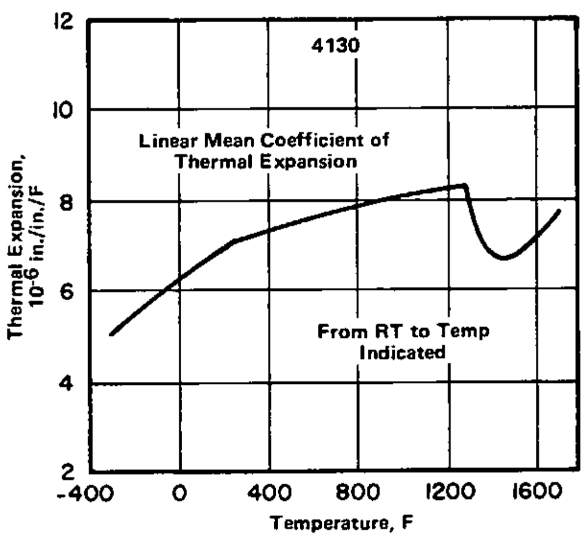


FIGURE 2.014. THERMAL EXPANSION (36)

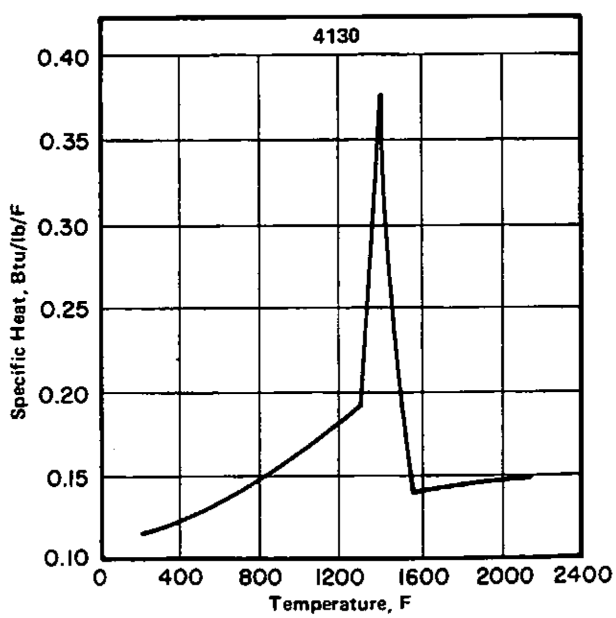


FIGURE 2.015. SPECIFIC HEAT (36)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

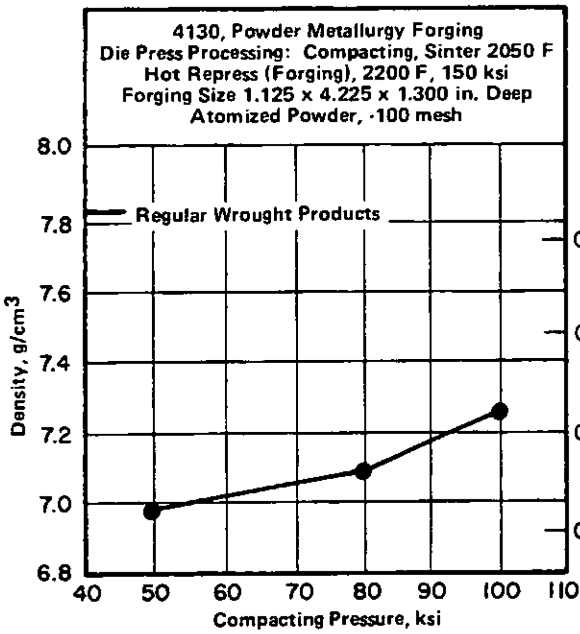


FIGURE 2.0211. EFFECT OF INITIAL COMPACTING PRESSURE ON DENSITY OF POWDER METALLURGY FORGING (46)

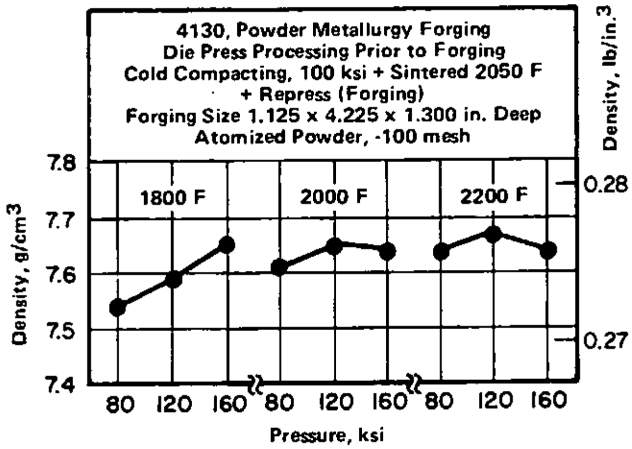


FIGURE 2.0212. EFFECT OF REPRESS (FORGING) PRESSURE AND TEMPERATURE ON DENSITY OF POWDER METALLURGY FORGING (46)

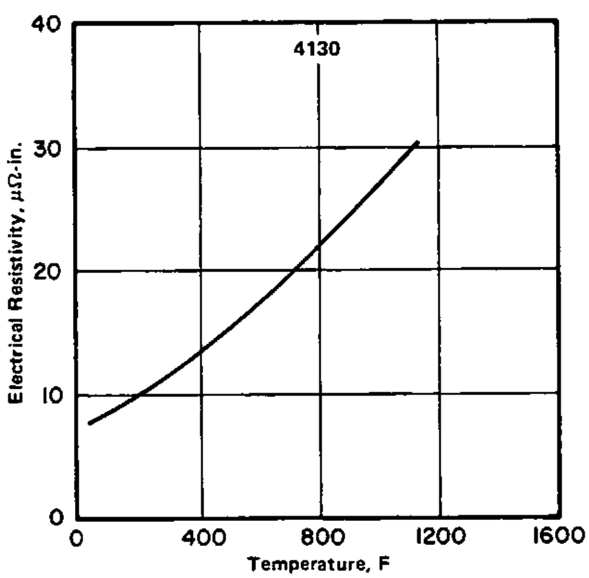


FIGURE 2.0221. ELECTRICAL RESISTIVITY AS A FUNCTION OF TEMPERATURE (36)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

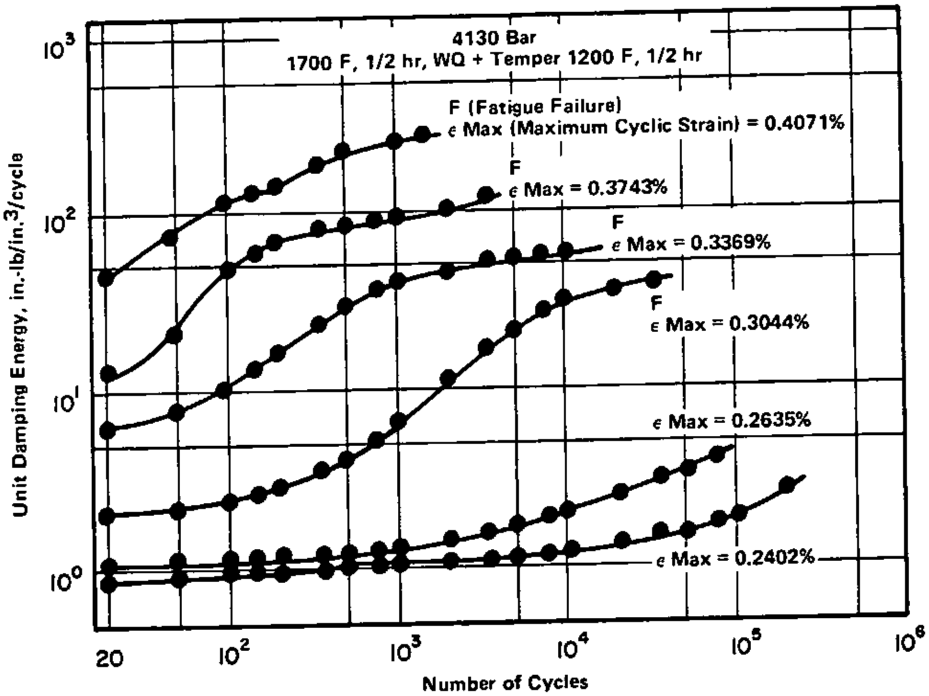


FIGURE 2.0251. EFFECT OF NUMBER OF CYCLES IN REVERSED BENDING AND MAXIMUM CYCLIC TENSILE STRAIN (ε MAX) ON DAMPING CAPACITY (24)

Alloy	4130					
Form	Condition	Orientation	F_{ty}, ksi	Applied Stress, ksi	No. Specimens	Days to Failure
2-1/2 inch Diam Bar	A(a)	T	155	116	3	–(c)
			155	155	3	–
		L	154	116	3	–
			154	154	3	–
	B(b)	T	161	121	3	–
			161	161	3	–
		L	148	111	3	–
			148	148	3	–
0.060 inch Sheet	A	T	142	107	3	–
			142	142	3	–
		L	147	110	3	–
			147	147	3	–
	B	T	171	124	3	–
			171	171	3	109,134, 144
		L	171	128	3	–
			171	171	3	28,56

(a) 1575 F, WQ + temper 900 F.
(b) 1575 F, WQ + temper 800 F.
(c) No cracking in maximum exposure time of 180 days.

TABLE 2.032. STRESS CORROSION OF CADMIUM-PLATED BAR AND SHEET SUBJECTED TO ALTERNATE IMMERSIONS (10 MINUTES IN AND 50 MINUTES OUT) IN 3.5 PERCENT SOLUTION OF SODIUM CHLORIDE HAVING pH OF 6.8 TO 7.2 (21)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130	
Form	0.035 inch Sheet	
Condition	Normalized and Tempered to Various Yield Strengths	
Specimen Orientation	L	
Temperature, F	Chloride Concentration[a], percent	Yield Strength Break Point[b], ksi
78	0	113
	1	110
	5	110
	20	118
215	5	140
	20	142
425	5	140
	20	138

(a) Modified NACE Solution, which is deaerated aqueous solution of 5% NaCl, 0.5% acetic acid, saturated with a continuous flow of H_2S.

(b) "Break Point" is the highest value of RT yield strength which survived the environment when loaded to approximately its yield strength in a two-point bend test (ASTM G39-73). The yield strengths were varied in the range 100 to 150 ksi by using different tempering times and temperatures.

TABLE 2.034. EFFECT OF TEMPERATURE AND CHLORIDE CONCENTRATION ON "BREAK POINT" OF SHEET IN TWO-POINT BEND TEST (47)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130							
Source	Form	Condition	F_{ty}, ksi (Min)	F_{tu}, ksi (Min)	e (2 in.), percent (Min)	RA, percent (Min)	Hardness Min	Hardness Max
AMS 5336D (1)	Casting, investment	Normalized or normalized and tempered	–	–	–	–	30 HRC	–
		Plus: 1600 F $\geq$ 30 min, OQ, temper at 825 F $\geq$ 1 hr, air cool, 2nd temper 825 F $\geq$ 1 hr, air cool	125(a)	150(a)	5(a)	10(a)	32 HRC(b)	38 HRC(b)
AMS 6350F (3)	Sheet, strip	Annealed	–	–	–	–	–	98 HRB
	Plate	Hot rolled or annealed	–	–	–	–	–	25 HRC
	<0.250 in. sheet, strip, plate	1600 F, OQ + 900 F, 30 min	–	125	–	–	26 HRC	–
AMS 6351C (4)	Sheet, strip, plate	Spheroidized	–	–	–	–	–	85 HRB
	<0.250 in. sheet, strip, plate	1600 F, OQ + 900 F, 30 min	–	125	–	–	26 HRC	–
AMS 6356C (5)	Sheet and strip	Cold finished and annealed or hot rolled and annealed	–	–	–	–	–	95 HRB
	Plate	Hot rolled, annealed if necessary	–	–	–	–	–	95 HRB
AMS 6360G (6)	Tube:	Cold drawn and stress relieved or normalized						
	Up to 0.500 in. OD							
	<0.1881 in. wall		75	95	10	–	–	–
	>0.188 in. wall		70	90	10	–	–	–
	0.500 in. and over OD							
	<0.1881 in. wall		75	95	12(c)	–	–	–
	>0.188 in. wall		70	90	15(c)	–	–	–
AMS 6361B (7)	Tube	1550 F, Q + temper	100	125	12(c)	–	–	–
AMS 6362C (8)	Tube	1550 F, Q + temper	135	150	10(c)	–	–	–
AMS 6770J (9)	Bars							
	0.500 in. diam and under	Cold finished	130 (Max)	–	–	–	–	–
	Over 0.500 in. diam	Hot finished	–	–	–	–	–	229 BHN
	Over 0.500 in. diam	Cold finished	–	–	–	–	–	241 BHN
AMS 6371F (10)	Tube	Cold finished	–	–	–	–	–	25 HRC
		Hot finished	–	–	–	–	–	99 HRB
ASTM A487 (29)	Castings	Normalized + tempered	60	90	20	35	–	–
		Quenched + tempered	85	105	16	35	–	–

(a) From separately cast specimens. For properties from casting, see AMS 2360.
(b) From casting or (a).
(c) Elongation values pertain to full tube; strip samples 5 percent lower.

TABLE 3.01. SPECIFIED MECHANICAL PROPERTIES

Alloy	4130				
Form	Bar				
Bar Diameter	Condition	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent	RA, percent
1 inch	Hot Rolled:				
	As hot rolled	70	116	22	53
	Normalized 1600 F	65	108	27	57
	Annealed 1550 F	60	88	30	65
	Cold Drawn:				
	As cold drawn	105	122	16	45
	Annealed 1550 F	82	98	20	53
5/8 inch	Cold Drawn:				
	Normalized 1550 F, water quenched, tempered 800 F, 1 hr	164.8(a)	186.1	11.8	59.3

(a) Proportional limit.

TABLE 3.0212. TENSILE PROPERTIES OF ROUND BAR IN VARIOUS HEAT-TREATED CONDITIONS (30,44)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

Alloy	4130				
Form	Plate				
Thickness, in.	Condition	Specimen Orientation	F_{ty}, ksi	F_{tu}, ksi	Elongation (in 2 In.), percent
0.50	Normalized 1600 F	L	65.2	94.8	30.8
		T	64.4	94.4	26.2
	Normalized + temper	L	64.4	94.0	31.8
	1100 F	T	63.2	93.8	26.2
	Oil quench + temper	L	113.8	130.8	18.8
	1000 F	T	128.4	143.2	13.8
	Oil quench + temper	L	97.4	113.2	24.8
	1200 F	T	94.4	110.0	20.2
>1.00	Normalized 1600 F, 2 hr, oil quench, temper 1175 F, 2 hr, air cool	T	92	119	21

TABLE 3.0213. TENSILE PROPERTIES OF PLATE IN VARIOUS HEAT-TREATED CONDITIONS (26,69)

Alloy	4130		
Form	3/8 inch Plate		
Specimen Orientation	Longitudinal		
Condition	F_{ty}, ksi	F_{tu}, ksi	Elongation (in 0.5 In.), percent
Normalized 1625 F, then			
Tempered to Rc 26	118	129	17.0
Tempered to Rc 34	143	150	14.5
Tempered to Rc 44	194	206	10.0

TABLE 3.0214. TENSILE PROPERTIES OF 3/8 INCH PLATE HEAT TREATED TO VARIOUS HARDNESSES (49)

Alloy	4130			
Form	1-inch Diameter Extruded Bar			
Composition	C-0.31, Mn-0.58, Si-0.23, P-0.009, S-0.014, Cr-0.99, Ni-0.95, Mo-0.21			
Condition	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent	RA, percent
1550 F, 1 hr + Slow Cool	46.5	85.2	27.0	56.3
1575 F, 1 hr + OQ +				
Tempered 850 F, 2 hr	145.5	167.0	14.0	55.0
Tempered 1200 F, 2 hr	64.5	82.5	31.0	72.6
Composition	C-0.30, Mn-0.55, Si-0.35, P-0.005, S-0.005, Cr-0.98, Ni-0.11, Mo-0.20			
1550 F, 1 hr + Slow Cool	48.0	83.5	27.5	52.6
1575 F, 1 hr + OQ +				
Tempered 850 F, 2 hr	160.5	174.0	14.0	51.1
Tempered 1200 F, 2 hr	90.0	110.8	23.5	70.2

TABLE 3.0215. TENSILE PROPERTIES OF EXTRUDED ROUND BAR IN VARIOUS HEAT-TREATED CONDITIONS (45)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130				
Form	3/4 inch x 3-1/8 inch Extruded Flat				
Composition	C-0.30, Mn-0.50, Si-0.27, P-0.016, S-0.016, Ni-0.11, Cr-0.99, Mo-0.18				
Condition	Specimen Orient.	F_{ty}, ksi	F_{tu}, ksi	e (1 in.), percent	RA, percent
1650 F, 1 hr + Air Cool	L	84.2	115.8	23.5	56.4
	T	81.8	111.0	21.2	54.2
1575 F, 1 hr + OQ + Tempered 850 F, 2 hr	L	157.6	164.9	16.5	57.8
	T	154.0	159.2	11.5	49.6
Tempered 1200 F, 2 hr	L	86.1	103.2	23.5	73.0
	T	84.3	100.2	23.5	56.4
Composition	C-0.31, Mn-0.58, Si-0.23, P-0.009, S-0.014, Cr-0.99, Ni-0.95, Mo-0.21				
1550 F, 1 hr + Slow Cool	L	41.3	76.0	30.0	55.9
	T	40.6	73.6	25.5	52.4
1575 F, 1 hr + OQ + Tempered 850 F, 2 hr	L	155.5	165.5	15.5	58.8
	T	153.0	162.0	12.0	42.8
Tempered 1200 F, 2 hr	L	53.6	77.3	36.5	73.2
	T	58.7	74.8	29.5	61.4
Composition	C-0.30, Mn-0.55, Si-0.35, P-0.005, S-0.005, Cr-0.98, Ni-0.11, Mo-0.20				
1550 F, 1 hr + Slow Cool	L	42.6	77.3	30.0	55.1
	T	41.0	75.4	28.0	43.8
1575 F, 1 hr + OQ + Tempered 850 F, 2 hr	L	160.0	167.5	16.0	59.4
	T	153.6	163.0	14.5	41.0
Tempered 1200 F, 2 hr	L	86.6	104.0	25.0	71.6
	T	84.4	101.8	20.0	59.0

TABLE 3.0216. TENSILE PROPERTIES OF EXTRUDED FLAT BAR IN VARIOUS HEAT-TREATED CONDITIONS (45)

Alloy	4130			
Form	Castings			
Condition	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent	RA, percent
Normalized 1650 F and				
Tempered 1100 F	95.0	115.0	16.0	35.0
Tempered 1200 F	61.5	93.5	23.0	37.3
Tempered 1250 F	56.5	88.0	22.0	38.0
1575 F, WQ and				
Tempered 950 F	148.0	176.5	10.0	24.6
Tempered 1100 F	120.0	140.0	17.0	38.5
Tempered 1175 F	95.0	115.0	19.5	42.0

TABLE 3.0217. TENSILE PROPERTIES OF CASTINGS IN VARIOUS HEAT-TREATED CONDITIONS (30)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

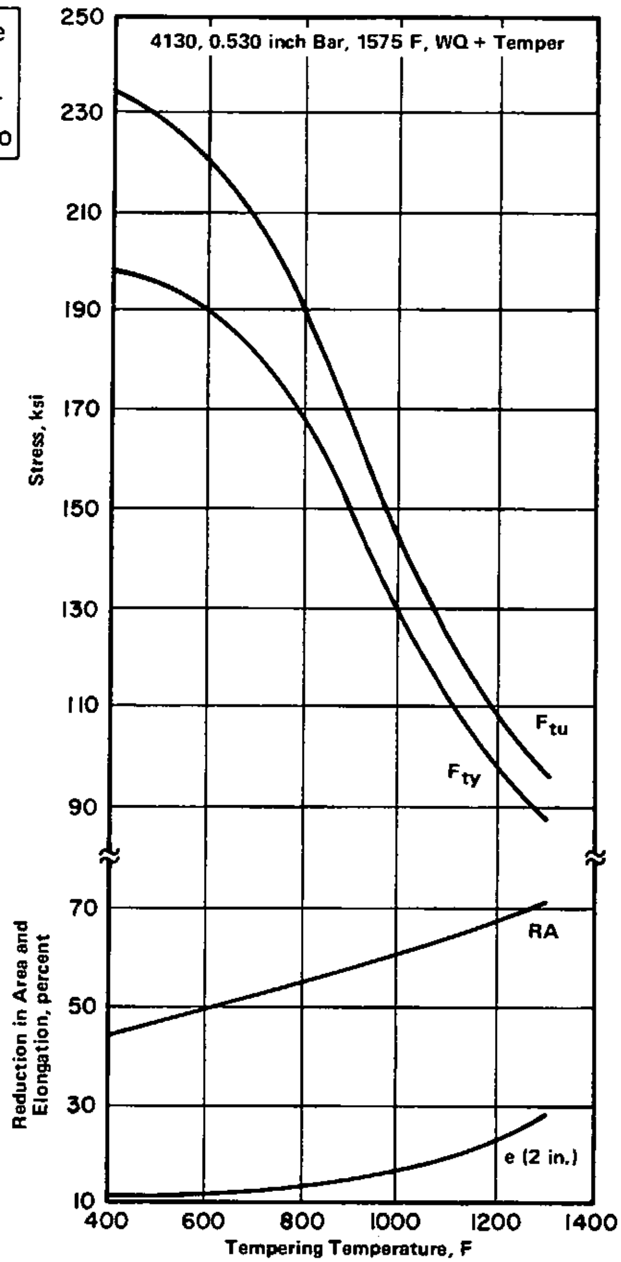


FIGURE 3.0218. EFFECT OF TEMPERING TEMPERATURE ON ROOM TEMPERATURE TENSILE PROPERTIES OF 0.530 INCH BAR (16)

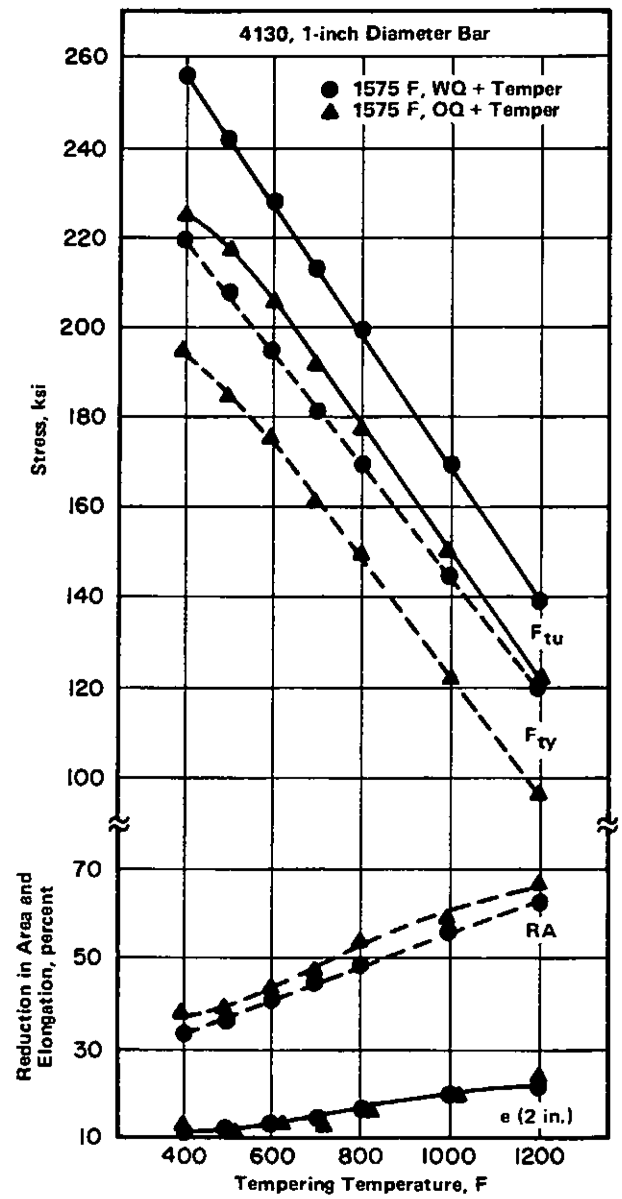


FIGURE 3.0219. EFFECT OF TEMPERING TEMPERATURE ON TENSILE PROPERTIES OF OIL-QUENCHED AND WATER-QUENCHED 1 INCH BAR (30)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130					
Form	Sheet					
Condition	Specimen Orient.	Thickness, in.	F_{ty}, ksi	F_{tu}, ksi	e (1 in.), percent	RA, percent
Austenitized 1575 F, 1 hr, WQ, Tempered 700 F, 30 min, Air Cool	T	0.030	167.8	183.4	–	7.1
		0.050	171.6	197.6	3.5	7.5
		0.063	169.5	193.0	3.8	11.2
		0.087	183.4	205.2	3.0	6.5
		0.125	176.4	197.9	4.5	16.5
		0.250	173.7	195.3	7.5	36.8
Austenitized 1575 F, 1/2 hr, WQ, Tempered 500 F, 30 min, Air Cool	T	0.030	185.2	221.4	2.5	7.1
		0.050	184.6	219.8	3.0	10.7
		0.063	178.4	226.0	5.2	27.8
		0.087	200.3	233.2	3.5	20.1
		0.125	191.2	228.1	6.0	23.2
		0.250	185.4	221.5	–	36.9
Austenitized 1650 F, 1 hr, OQ, Tempered 800 F, 1 hr	L	0.125	175(a)	–	–	–

(a) Proportional limit = 163 ksi.

TABLE 3.02110. EFFECT OF SHEET THICKNESS AND TEMPERING TEMPERATURE ON TENSILE PROPERTIES (59,68)

Alloy	4130			
Form	5/8 inch Thick Flat Bar			
Austenitizing Temperature, F, and Quench Medium	F_{ty}, ksi	F_{tu}, ksi	e (4D), percent	RA, percent
1600, Oil	201	284	11.4	32.9
2200, Oil	205	276	5.6	9.9
2200, Ice-Brine	215	249	1.6	6.6

TABLE 3.02111. EFFECT OF AUSTENITIZING TEMPERATURE AND QUENCH MEDIUM ON TENSILE PROPERTIES OF AS-QUENCHED MATERIAL (50)

Alloy	4130					
Form	3/8-inch Thick Rolled Flat Bar					
Specimen Orient.	Longitudinal					
Austenitizing Temperature, Time	Quench Medium	Temper Temperature, F	F_{ty}, ksi	F_{tu}, ksi	e (1.4 in.), percent	RA, percent
2200 F, 1 hr	IBLN(a)	As quenched	167	245	–(b)	–
		392	186	257	–(b)	–
		536	184	225	7.6	21.0
		662	180	209	9.8	37.0
2200 F, 1 hr	Water	As quenched	167	278	5.2	14.0
		392	210	258	9.7	–
		536	182	228	10.3	38.7
		662	180	210	9.8	25.2
2200 F, 1 hr	Oil	As quenched	161	276	5.6	9.8
		392	176	262	7.5	18.1
		536	194	246	8.0	25.5
		662	182	222	7.7	30.6
2200 F, 1 hr, Cooled to 1600 F, 1/2 hr	IBLN	As quenched	170	279	6.6	12.0
		392	195	261	–(b)	–
		536	184	230	7.8	25.9
		662	200	210	9.3	32.4

(a) Ice-brine followed by liquid nitrogen storage.
(b) Quench cracks visible.

TABLE 3.02112. EFFECT OF QUENCH MEDIUM AND TEMPERING TEMPERATURE ON TENSILE PROPERTIES OF ROLLED BAR (51)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

Alloy	4130		
Form	0.125 inch Sheet		
Condition	Austenitized 1575 F, 15 min, Quenched, Tempered 1050 F, 1 hr		
Quench Medium	F_{ty}, ksi	F_{tu}, ksi	Elongation, percent
Oil	146.0	156.4	14.0
Nitrogen Gas	147.0	162.0	13.0

TABLE 3.02113. EFFECT OF QUENCH MEDIUM ON TENSILE PROPERTIES OF SHEET (52)

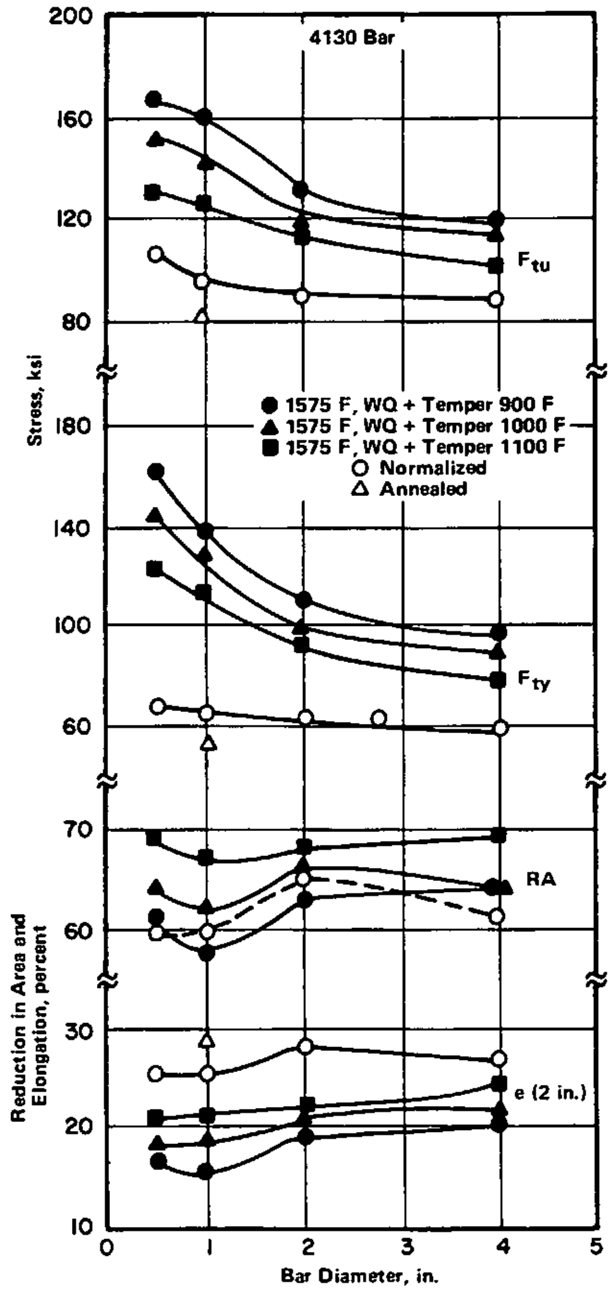


FIGURE 3.02114. EFFECT OF BAR DIAMETER ON TENSILE PROPERTIES IN VARIOUS HEAT-TREATED CONDITIONS (16)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

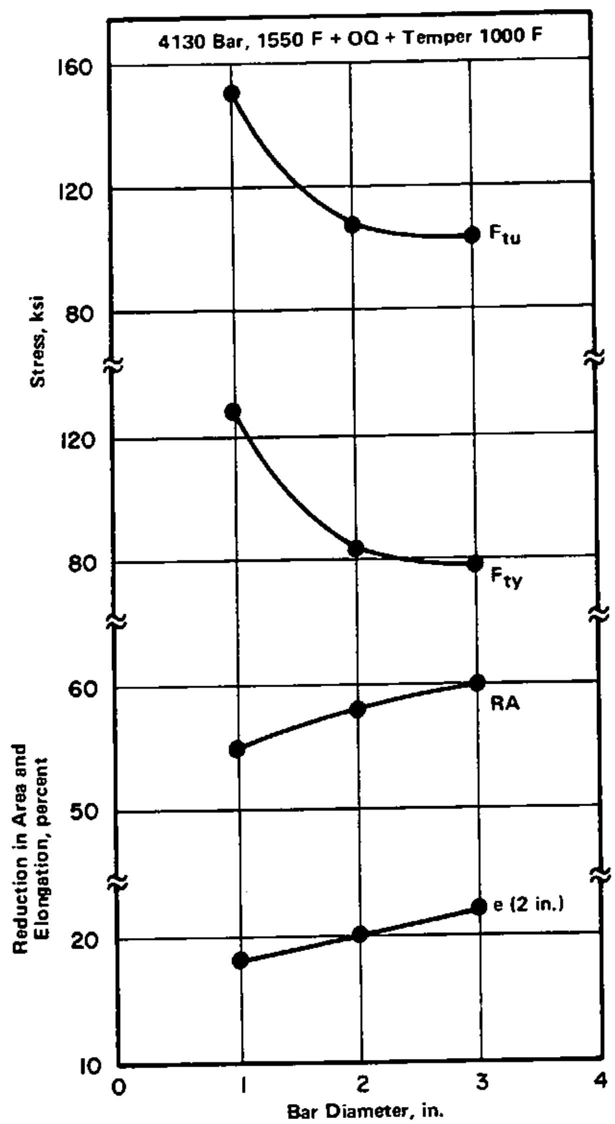


FIGURE 3.02115. TENSILE PROPERTIES OF QUENCHED AND TEMPERED ROUND BAR (74)

Alloy	4130					
Form	1/4 inch Plate					
Orientation	Longitudinal					
Condition	Treatment	Effective Strain	F_{ty}, ksi	F_{tu}, ksi	e (1 in.), percent	RA, percent
Annealed	None	0	66.5	97.1	29.5	60.2
	Explosively formed	0.068	90.7	98	26.5	43.2
	Cold rolled	0.066	68.1	96.7	26.0	43.3
Heat Treated(a)	None	0	149	155	10.5	39.1
	Explosively formed	0.068	148	155	12.3	41.3
	Cold rolled	0.066	140	149	12.5	35.7

(a) Austenitized 1600 F, 40 min, oil quenched, tempered 1000 F, 55 min.

TABLE 3.02116. EFFECT OF EXPLOSIVE FORMING ON TENSILE PROPERTIES OF PLATE (54)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130							
Form	Powder Metallurgy Forgings Die Press Process 1.125 x 4.225 x 3.000 inch Isostatic Press Process 0.565 x 4.000 x 1.300 inch High Energy Rate Forming (HERF) 2.5 inch Diam x 5.5 inch Long Water Atomized Powder, -100 mesh							
Condition	Austenitized 1575 F, RT, Water Quench, Tempered 800 F, 1 hr							
	Compacting		Sinter	Repress (Forging)				
Process	Temperature, F	Pressure, ksi	Temperature, F(a)	Temperature, F	Pressure, ksi	F_{ty}, ksi	F_{tu}, ksi	e (1 in.), percent
Die Press	RT	100	2050	2200	150	132	136	1.4
Isostatic Press	RT	50	1650	2200	150	(b)	153	0.5
HERF	–	–	–	2200	275	136	160	1.4

(a) For 1 hour.
(b) Did not have sufficient ductility.

TABLE 3.02117. EFFECT OF FABRICATION PROCESS ON TENSILE PROPERTIES OF POWDER METALLURGY FORGING (46)

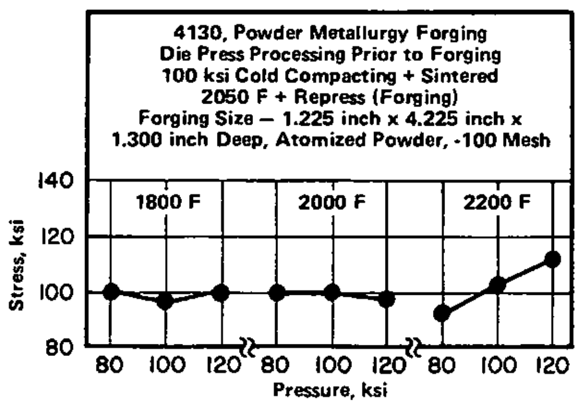


FIGURE 3.02118. EFFECT OF REPRESS (FORGING) PRESSURE AND TEMPERATURE ON ULTIMATE TENSILE STRENGTH OF POWDER METALLURGY FORGING (46)

Alloy	4130				
Form	0.030 inch Sheet				
Condition	F_{ty}, ksi	F_{tu}, ksi	e (1 in.), percent	RA, percent	Prop. Limit, ksi
As received	80.5	106.2	13.2	47	69.9
HT 1800 F, 1 hr	34.8	66.2	23.8	57	29.0
Mn plated	81.5	106.3	12.8	39	77.6
HT 1800 F, 1 hr	37.2	75.3	20.2	34	33.4

TABLE 3.02119. EFFECT OF Mn PLATING AND ELEVATED TEMPERATURE EXPOSURE ON TENSILE PROPERTIES OF SHEET (48)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130	
Condition	Quenched and Tempered	
F_{tu}, ksi(a)		
125	150	180
925 F	775 F	575 F

(a) If the material is exposed for more than 10 hours to temperatures exceeding those listed (unstressed), a permanent reduction in strength is likely to occur. The temperatures are approximately 125 F below the tempering temperature used to achieve the various strength levels.

TABLE 3.02120. TEMPERATURE LIMITS FOR PROLONGED UNSTRESSED EXPOSURE WHICH PREVENT DEGRADATION OF TENSILE STRENGTH (63)

Alloy	4130
Form	3/4 x 3-1/2 inch Extruded Bar
Condition	As Extruded
Specimen Orientation	Keyhole Charpy Impact, ft-lb
L	68
T	36

TABLE 3.0231. IMPACT PROPERTIES OF EXTRUDED BAR (45)

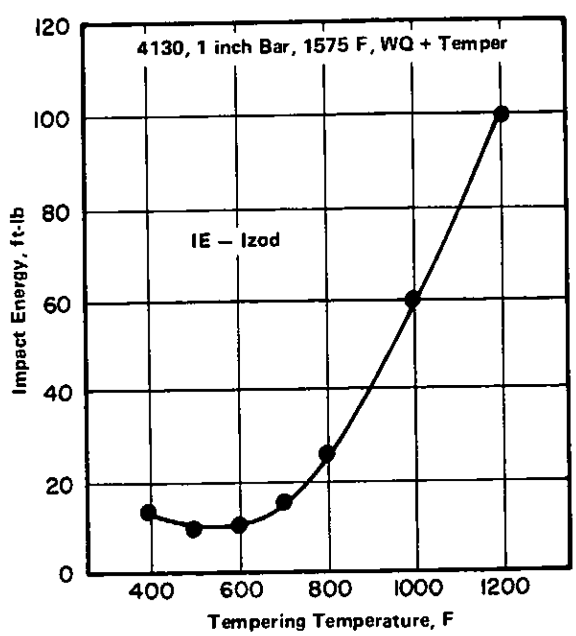


FIGURE 3.0232. EFFECT OF TEMPERING TEMPERATURE ON ROOM TEMPERATURE IMPACT STRENGTH (30)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

Alloy	4130	
Form	Wrought	
Condition	Izod Impact, ft-lb	F_{tu}, ksi
Normalized	63.7	97.0
Annealed	45.5	81.2

TABLE 3.0233. IMPACT RESISTANCE OF NORMALIZED AND ANNEALED MATERIAL (31)

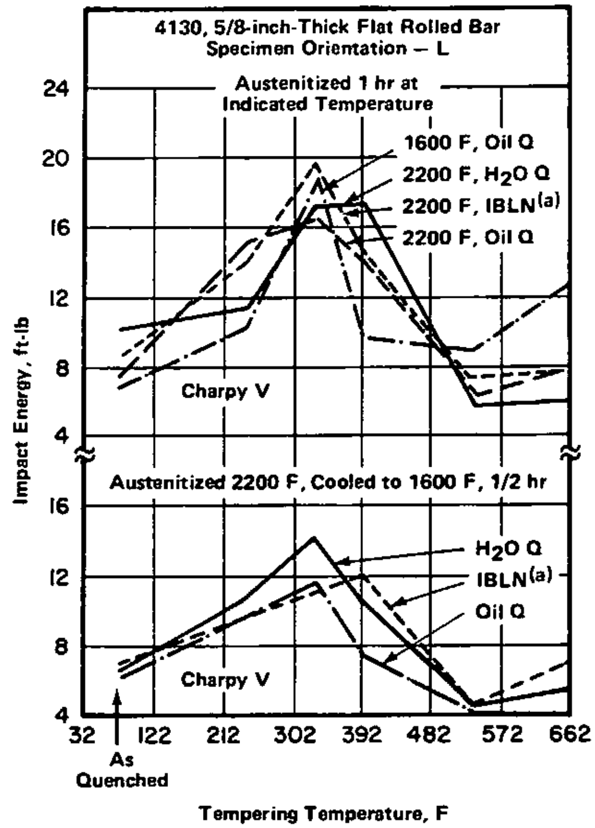


FIGURE 3.0234. EFFECT OF QUENCH MEDIUM AND TEMPERING TEMPERATURE ON IMPACT PROPERTIES OF ROLLED BAR (51)

(a) Ice-brine followed by liquid N_2 storage.

Alloy	4130								
Form	Powder Metallurgy Forgings Die Press Process – 1.125 inch x 4.225 inch x 1.300 inch Deep Isostatic Press Process – 0.565 inch x 4.000 inch x 1.300 inch Deep High Energy Rate Forming (HERF) – 2.5 inch Diameter x 5.5 inch Long Water Atomized Powder – 100 mesh								
Condition	Austenitized 1575 F, RT, H_2O Quench, Tempered 800 F, 1 hr								
	Compacting		Sinter	Repress (Forging)		Charpy-V Notched Impact Energy, ft-lb			
Process	Temperature, F	Pressure, ksi	Temperature, F(a)	Temperature, F	Pressure, ksi	-40 F	77 F	210 F	450 F
Die Press	RT	100	2050	2200	150	4.5	3.2	7.3	5.9
Isostatic Press	RT	50	1650	2200	150	1.0	2.3	2.1	6.2
HERF	–	–	–	2200	275	1.7	1.3	1.2	1.3

(a) For 1 hour.

TABLE 3.0235. EFFECT OF FABRICATION PROCESS AND TEMPERATURE ON IMPACT PROPERTIES OF POWDER METALLURGY FORGING (46)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

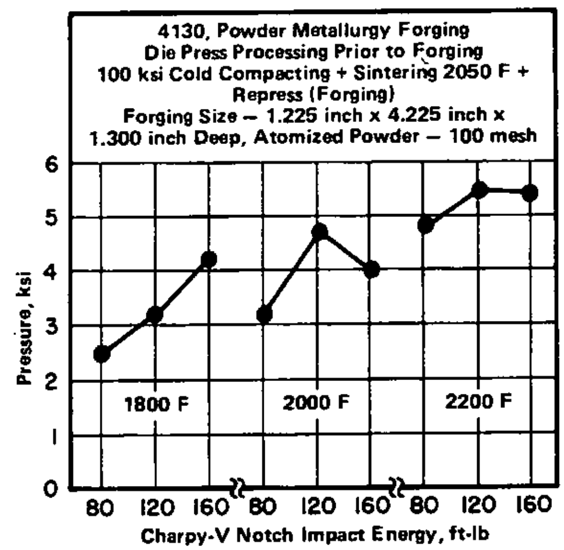


FIGURE 3.0236. EFFECT OF REPRESS (FORGING) PRESSURE AND TEMPERATURE ON IMPACT PROPERTIES OF POWDER METALLURGY FORGING (46)

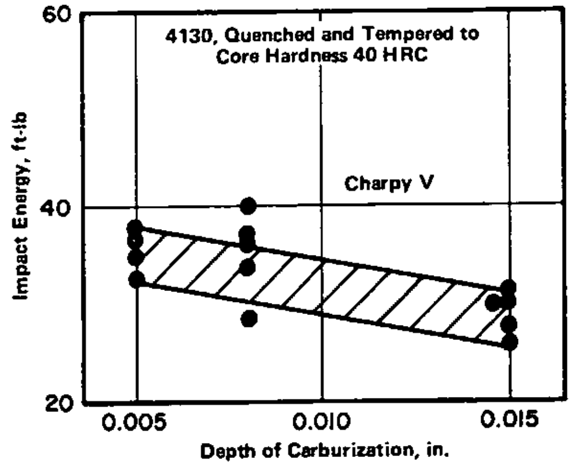


FIGURE 3.0237. EFFECT OF CARBURIZATION ON IMPACT PROPERTIES (74)

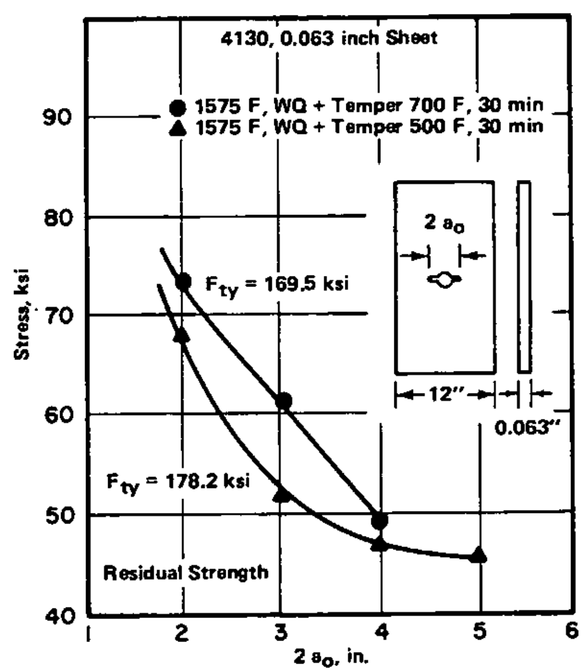


FIGURE 3.02711. EFFECT OF INITIAL CRACK LENGTH (2 a_o) ON RESIDUAL STRENGTH (MAXIMUM LOAD DIVIDED BY GROSS CROSS-SECTIONAL AREA) OF SHEET AFTER TWO DIFFERENT TEMPERING TREATMENTS (17)

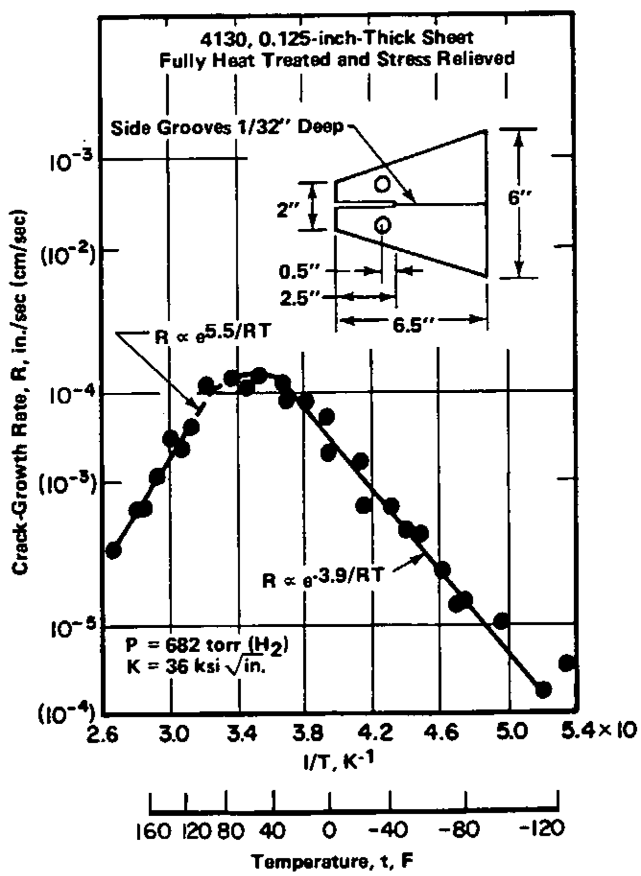


FIGURE 3.02712. EFFECT OF TEMPERATURE ON SLOW-CRACK-GROWTH RATE IN GASEOUS HYDROGEN (66)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

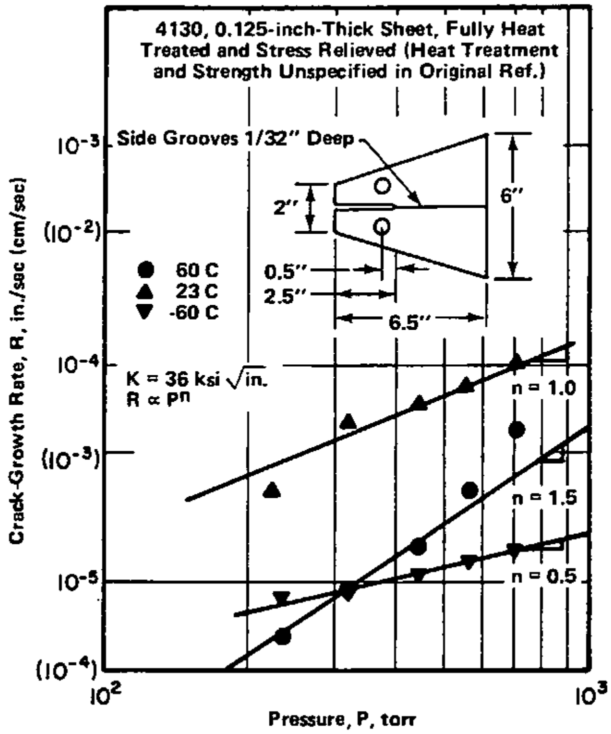


FIGURE 3.02713. EFFECT OF HYDROGEN PRESSURE ON SLOW-CRACK-GROWTH RATE (66)

Alloy	4130		
Form	Sheet		
	Sheet Thickness,	K_c, ksi $\sqrt{in.}$	
Condition	in.	Blunt	Sharp
Austenitized 1575 F, 1 hr, WQ, Temper 700 F, 30 min, Air Cool	0.030	136	148
	0.050	140	173
	0.063	158	182
	0.087	126	134
	0.125	148	153
Austenitized 1575 F, 1/2 hr, WQ, Temper 500 F, 30 min, Air Cool	0.030	–	158
	0.050	149	152
	0.063	141	129
	0.087	122	125
	0.125	165	146
	0.250	124	142

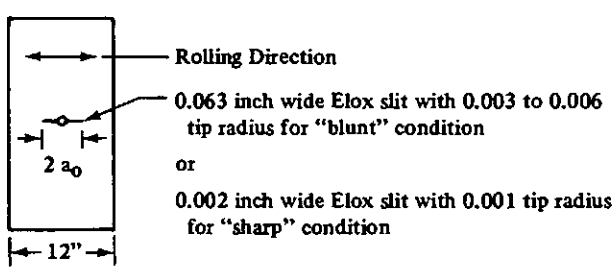


TABLE 3.02722. EFFECT OF SHEET THICKNESS ON FRACTURE-TOUGHNESS PARAMETER K_c (68)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

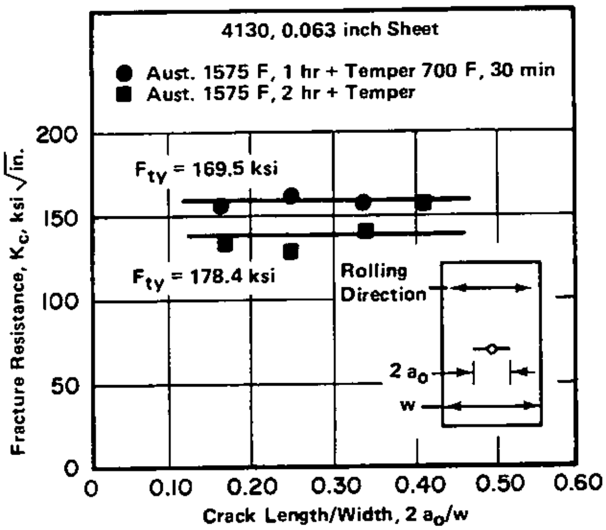


FIGURE 3.02723. EFFECT OF YIELD STRENGTH ON FRACTURE RESISTANCE OF SHEET (71)

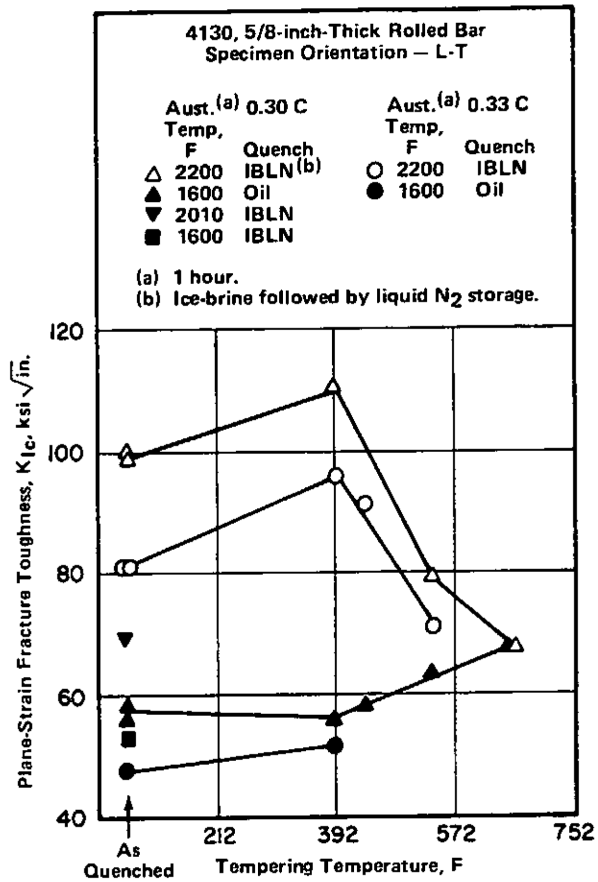


FIGURE 3.02724. EFFECT OF TEMPERING TEMPERATURE, CARBON CONTENT, AND QUENCHING MEDIUM ON PLANE-STRAIN FRACTURE TOUGHNESS OF FLAT ROLLED BAR (51)

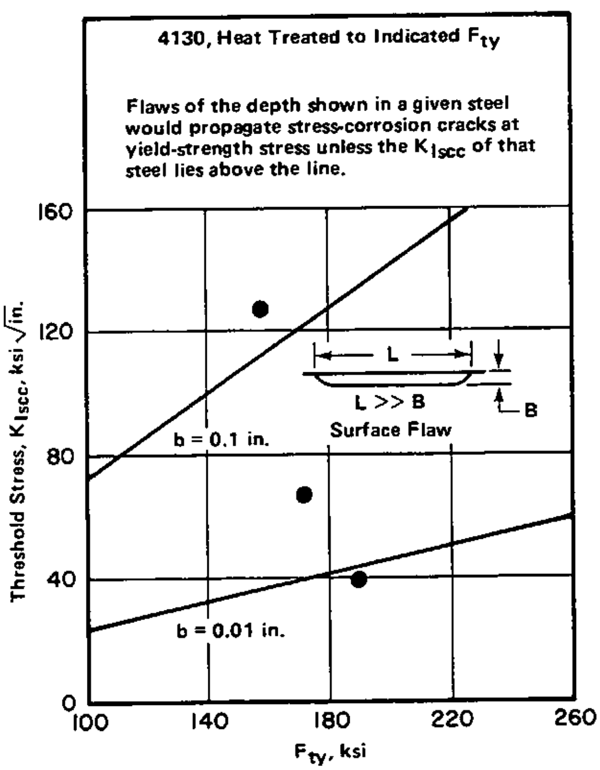


FIGURE 3.02725. EFFECT OF YIELD STRENGTH AND FLAW DEPTH ON THRESHOLD STRESS INTENSITY IN STATIC LOADING (58)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

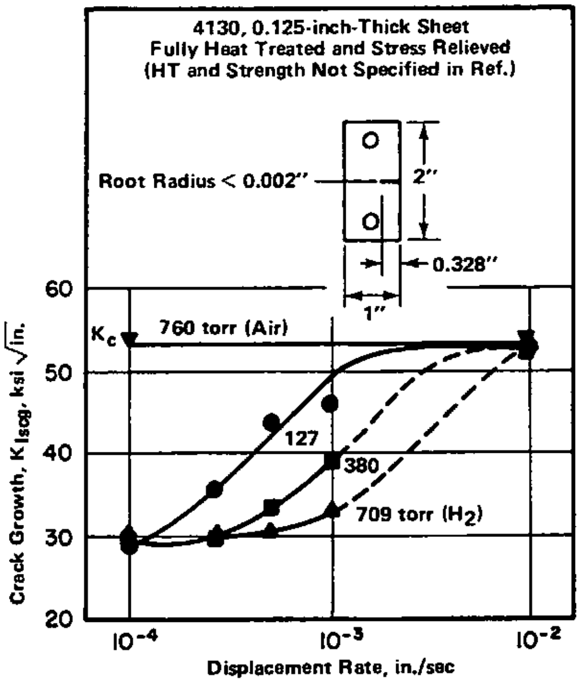


FIGURE 3.02726. EFFECT OF HYDROGEN PRESSURE AND DISPLACEMENT RATE ON INITIATION OF SLOW CRACK GROWTH, K_{Iscg} (EMBRITTLEMENT) (66)

Alloy	4130	
Form	>1 inch Plate	
Condition	1600 F, 2 hr, OQ + 1175 F, 2 hr + AC	
Air, K_Q(a), ksi $\sqrt{in.}$	Hydrogen Pressure(b), psi	Arrest Stress Intensity, ksi $\sqrt{in.}$
114	3,000	80
	6,000	62
	9,000	41
	10,000	29
	14,000	47

(a) 10 percent secent.
(b) Temperature = 55 F.

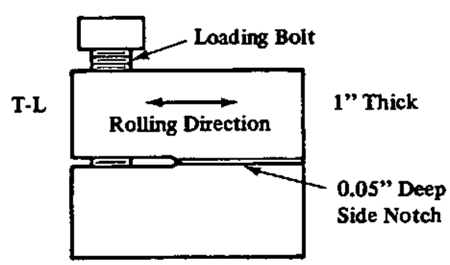


TABLE 3.02727. EFFECT OF HYDROGEN PRESSURE ON THE ARREST OF CRACK PROPAGATION (69)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

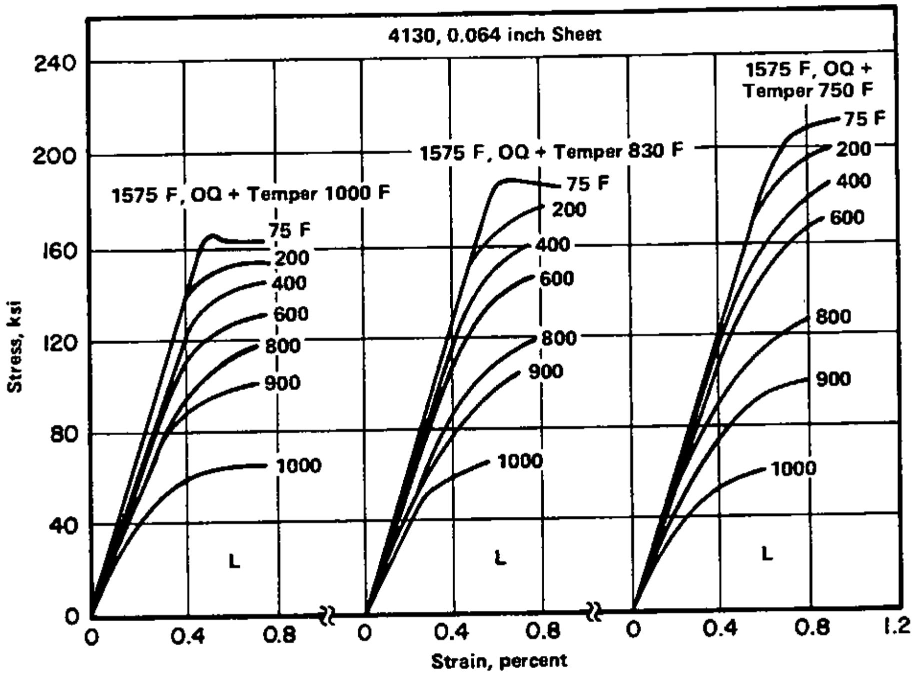


FIGURE 3.0311. TENSILE STRESS-STRAIN CURVES FOR SHEET AT TEMPERATURES UP TO 1000 F AFTER THREE DIFFERENT TEMPERING TREATMENTS: CURVES APPLY TO SPECIMENS HELD FOR 0.5 UP TO 100 HOURS AT TEST TEMPERATURE (14)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

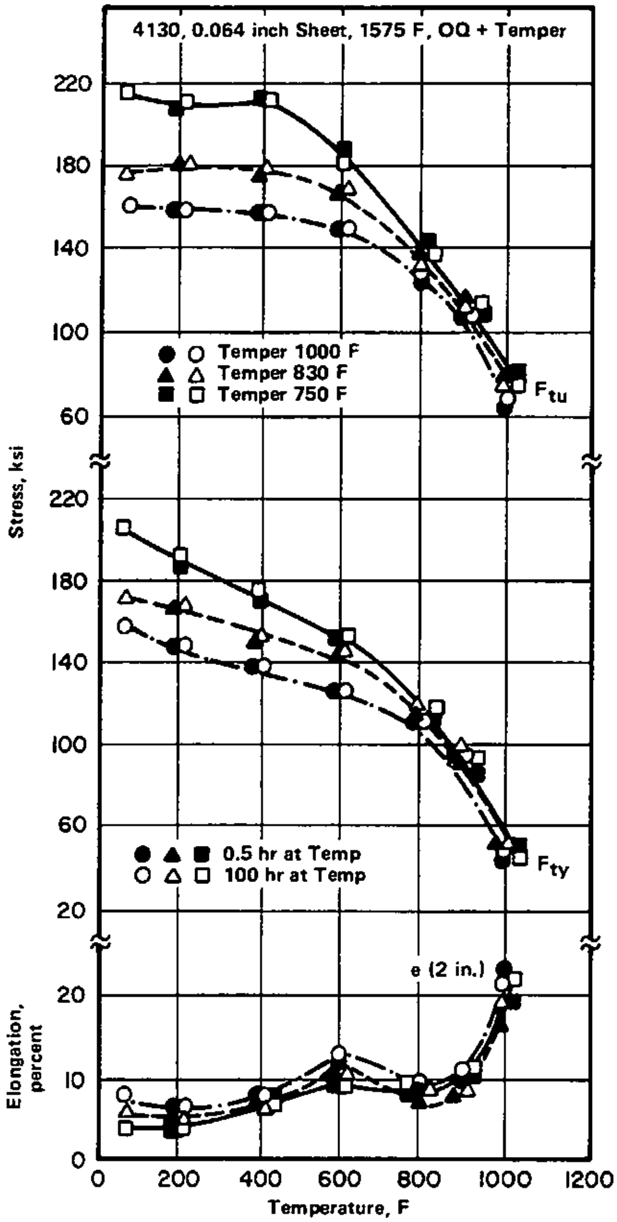


FIGURE 3.0312. EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS AND TWO DIFFERENT EXPOSURE TIMES (14)

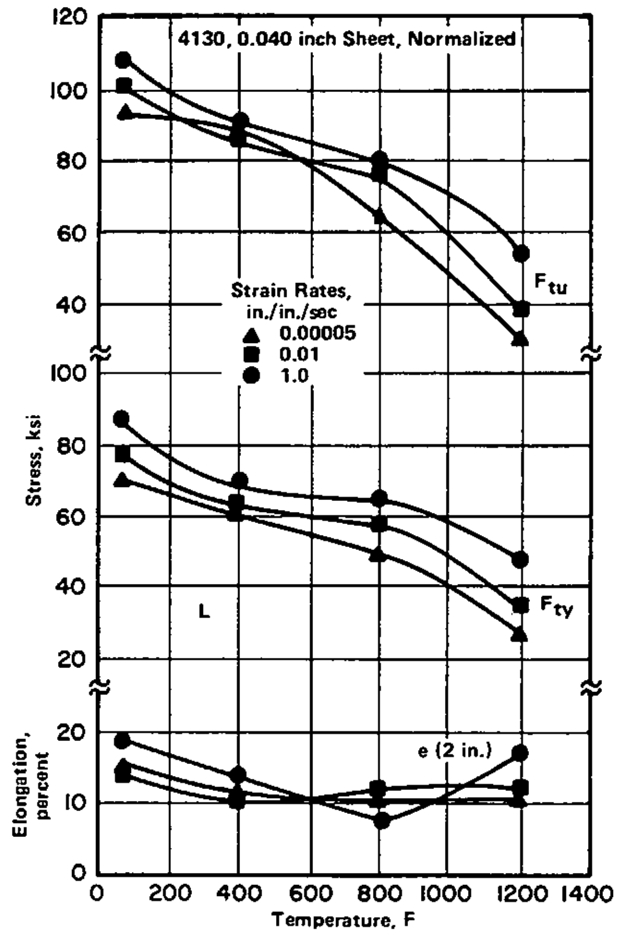


FIGURE 3.0313. EFFECT OF TEMPERATURE AND STRAIN RATE ON TENSILE PROPERTIES OF NORMALIZED SHEET AFTER RAPID HEATING; DATA PERTAIN TO SPECIMENS HELD FOR 10 SECONDS UP TO 1/2 HOUR AT TEST TEMPERATURES (15)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

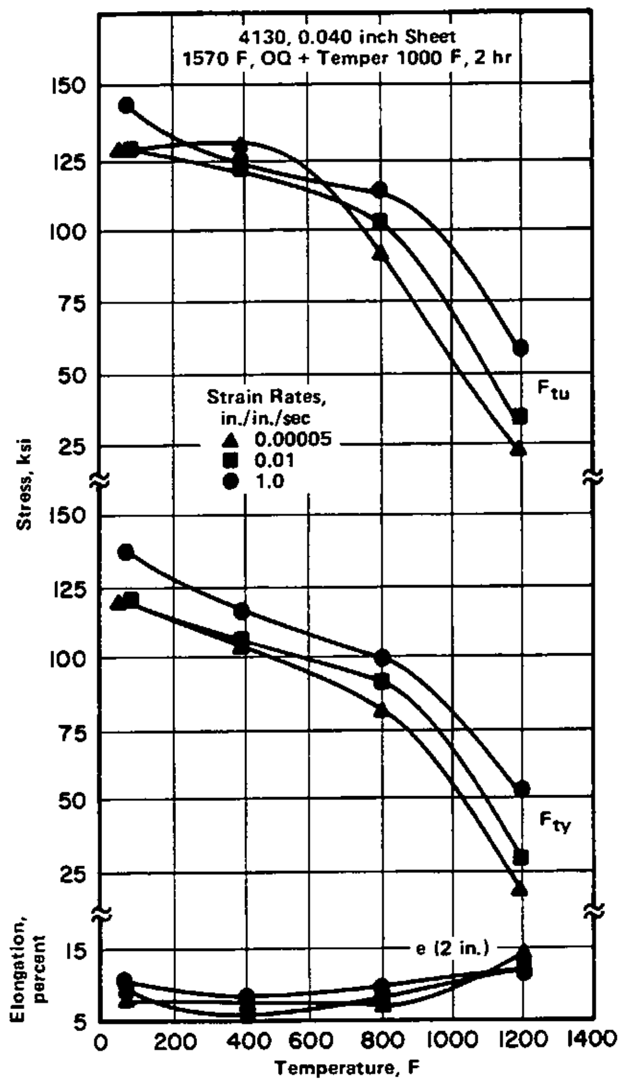


FIGURE 3.0314. EFFECT OF TEMPERATURE AND STRAIN RATE ON TENSILE PROPERTIES OF HEAT TREATED SHEET AFTER RAPID HEATING; DATA PERTAIN TO SPECIMENS HELD FOR 10 SECONDS UP TO 1/2 HOUR AT TEST TEMPERATURE (15)

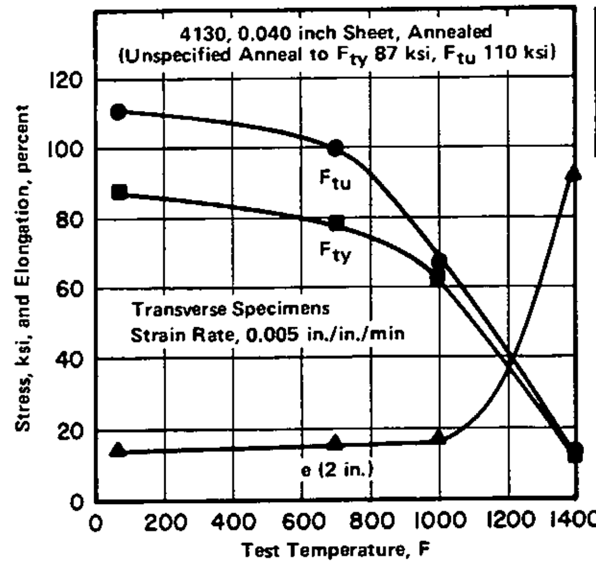


FIGURE 3.0315. EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF SHEET AFTER 5-MINUTE SOAK AT TEMPERATURE (53)

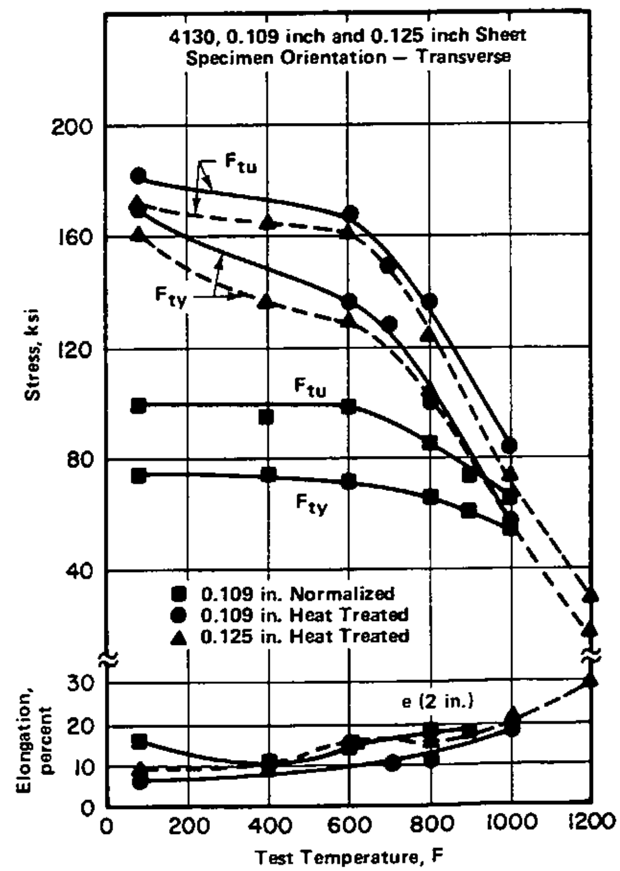


FIGURE 3.0316. EFFECT OF SHORT-TIME EXPOSURE TO ELEVATED TEMPERATURE ON TENSILE PROPERTIES OF SHEET (55)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

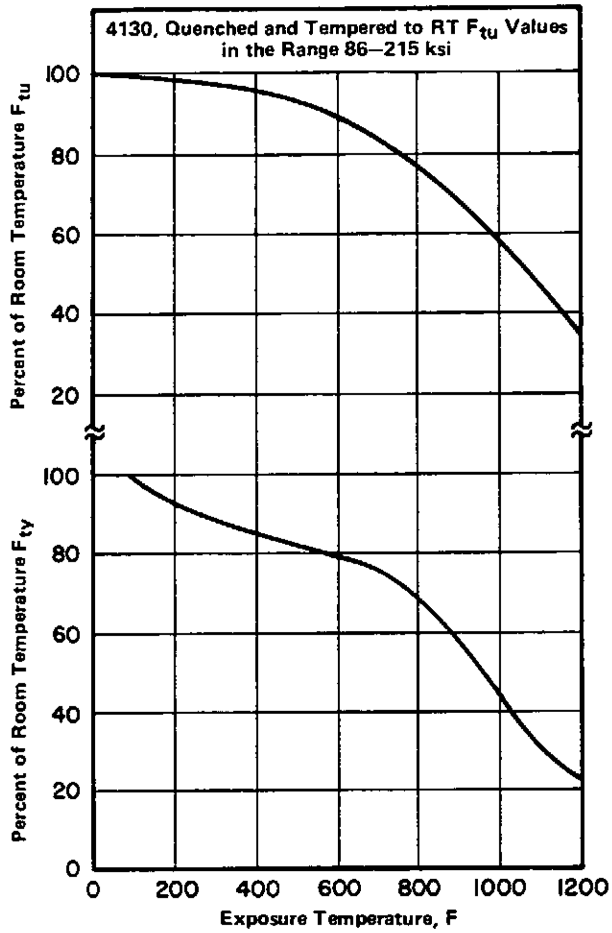


FIGURE 3.0317. EFFECT OF PRIOR EXPOSURE TO TEST TEMPERATURE UP TO 10 HOURS ON TENSILE PROPERTIES (63)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

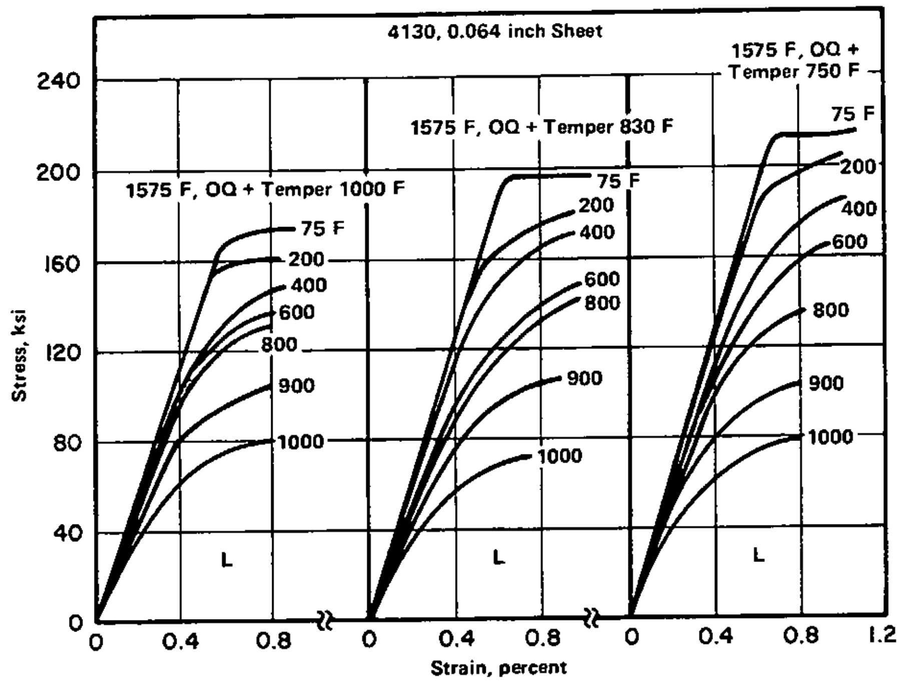


FIGURE 3.0321. COMPRESSIVE STRESS-STRAIN CURVES FOR SHEET AT TEMPERATURES UP TO 1000 F AFTER THREE DIFFERENT TEMPERING TREATMENTS; CURVES APPLY TO SPECIMENS HELD FOR 0.5 UP TO 100 HOURS AT TEST TEMPERATURES (14)

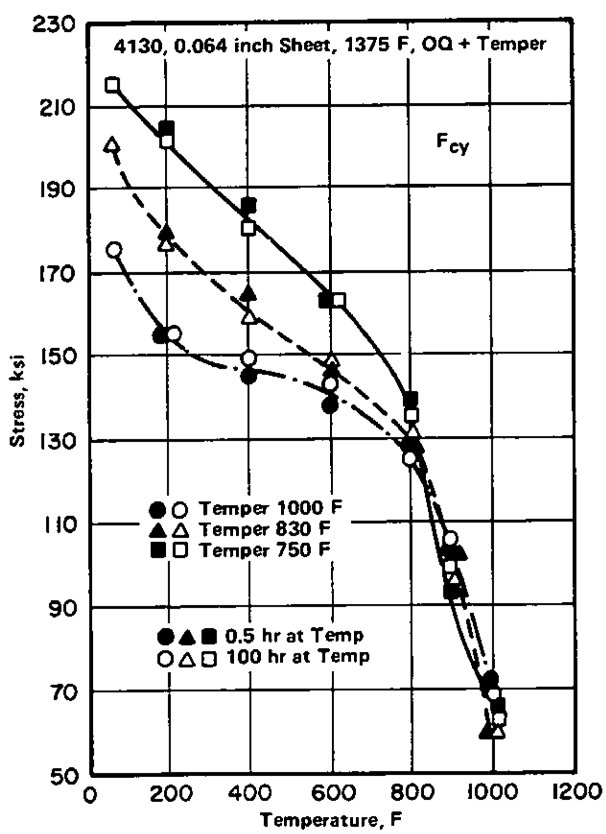


FIGURE 3.0322. EFFECT OF TEMPERATURE ON COMPRESSIVE YIELD STRENGTH OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS AND TWO DIFFERENT EXPOSURE TIMES (14)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

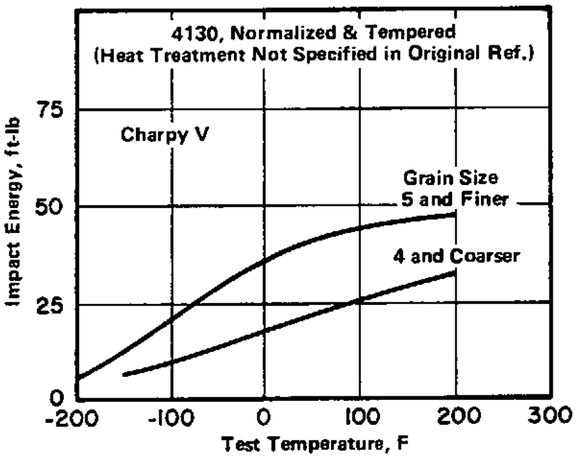


FIGURE 3.0331. EFFECT OF GRAIN SIZE AND TEMPERATURE ON IMPACT PROPERTIES (33)

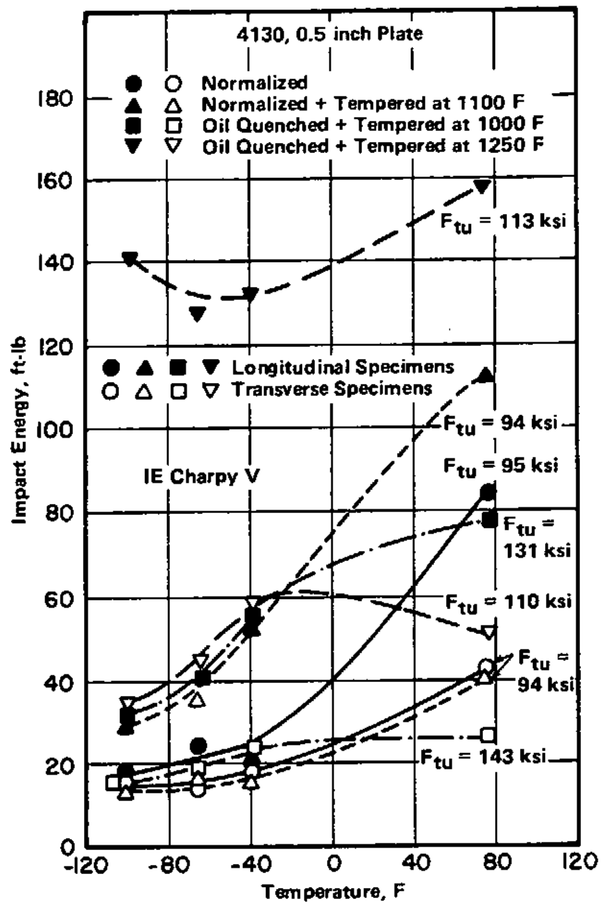


FIGURE 3.0332. EFFECT OF LOW TEMPERATURES ON IMPACT PROPERTIES IN SEVERAL HEAT-TREATED CONDITIONS (26)

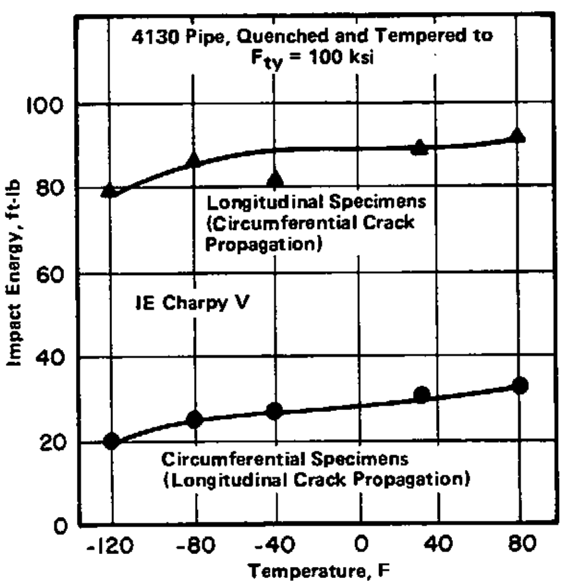


FIGURE 3.0333. EFFECT OF LOW TEMPERATURES ON IMPACT PROPERTIES OF PIPE (42)

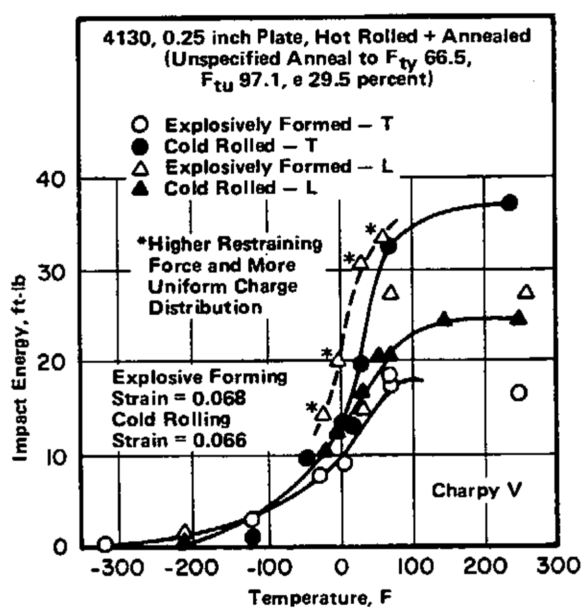


FIGURE 3.0334. EFFECT OF TEMPERATURE ON IMPACT PROPERTIES OF EXPLOSIVELY FORMED AND ROLLED AND ANNEALED PLATE (54)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

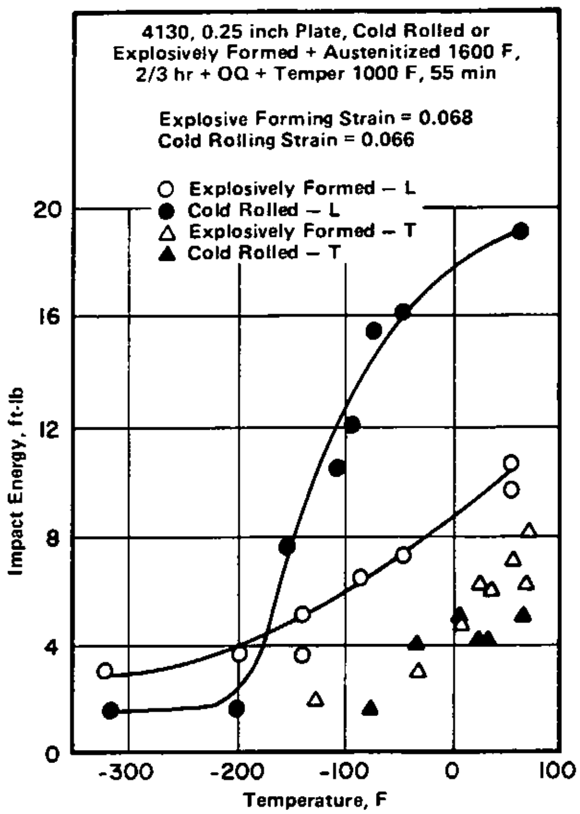


FIGURE 3.0335. EFFECT OF TEMPERATURE ON IMPACT PROPERTIES OF EXPLOSIVELY FORMED AND COLD-ROLLED HEAT-TREATED PLATE (54)

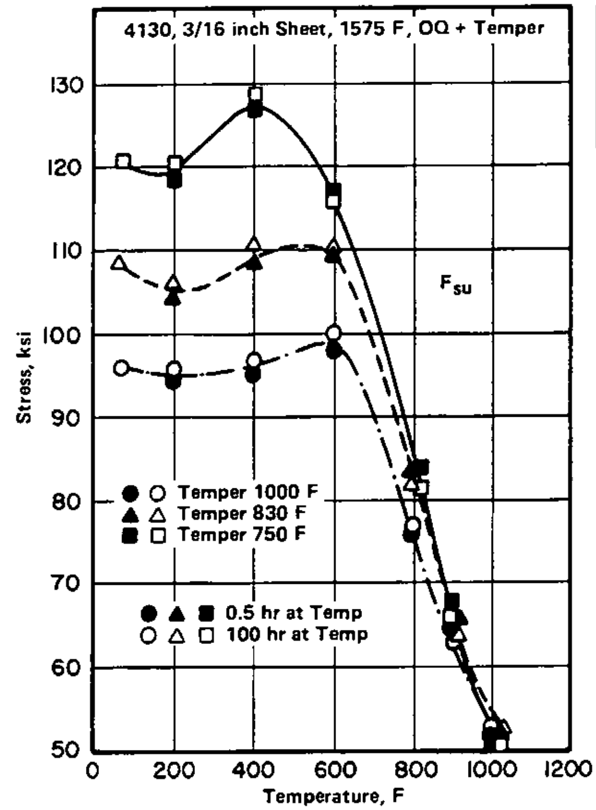


FIGURE 3.0351. EFFECT OF TEMPERATURE ON SHEAR STRENGTH OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS AND TWO DIFFERENT EXPOSURE TIMES (14)

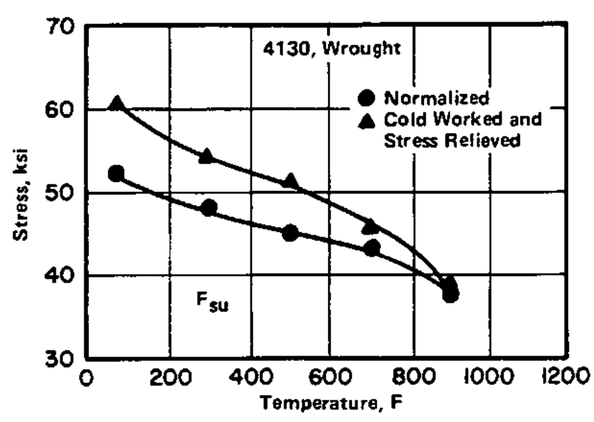


FIGURE 3.0352. EFFECT OF TEMPERATURE ON SHEAR STRENGTH OF NORMALIZED AND OF COLD-WORKED-AND-STRESS-RELIEVED TYPE 4130 (27)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

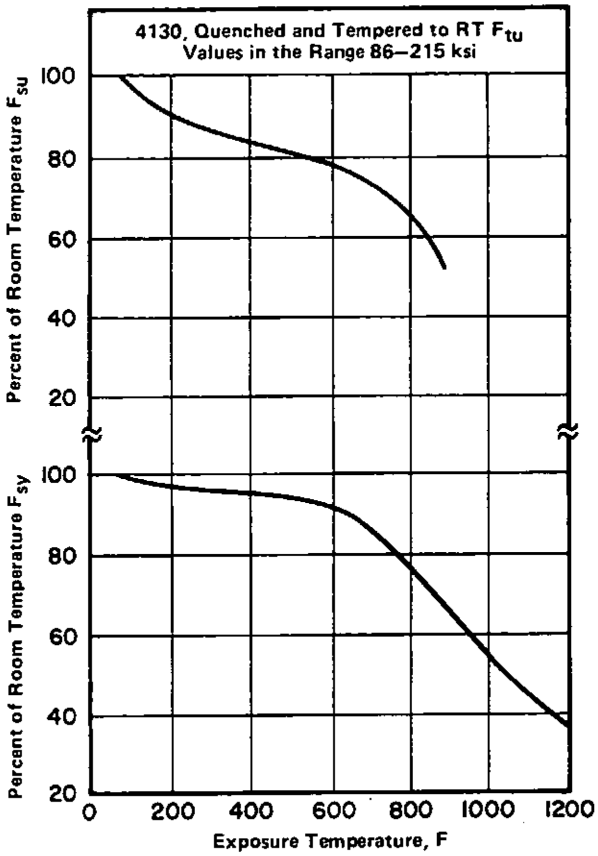


FIGURE 3.0353. EFFECT OF PRIOR TEST TEMPERATURE EXPOSURE UP TO 10 HOURS ON SHEAR PROPERTIES (63)

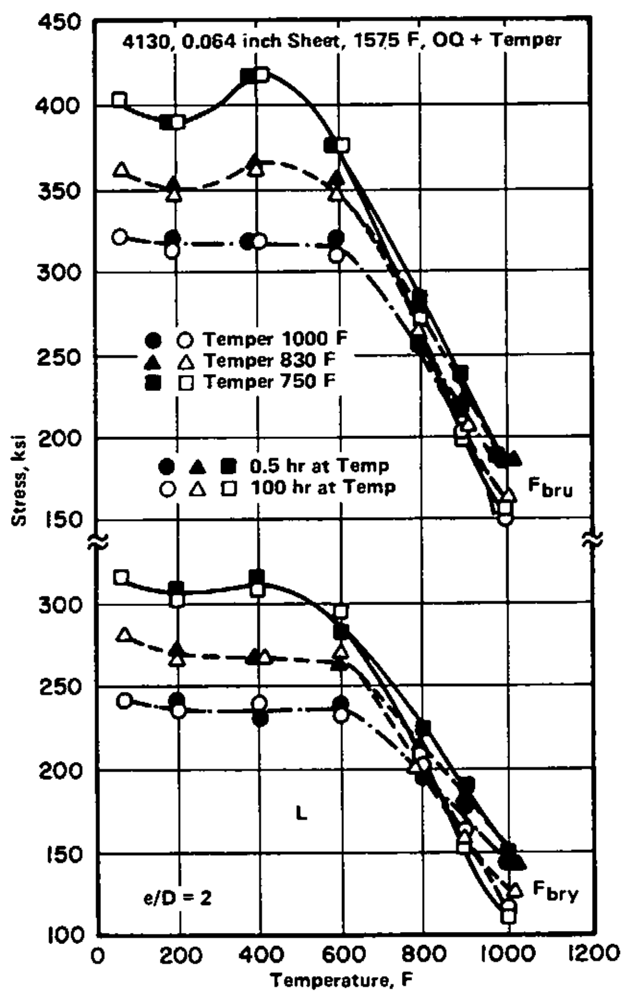


FIGURE 3.0361. EFFECT OF TEMPERATURE ON BEARING STRENGTH (e/D = 2) OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS AND TWO DIFFERENT EXPOSURE TIMES (14)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

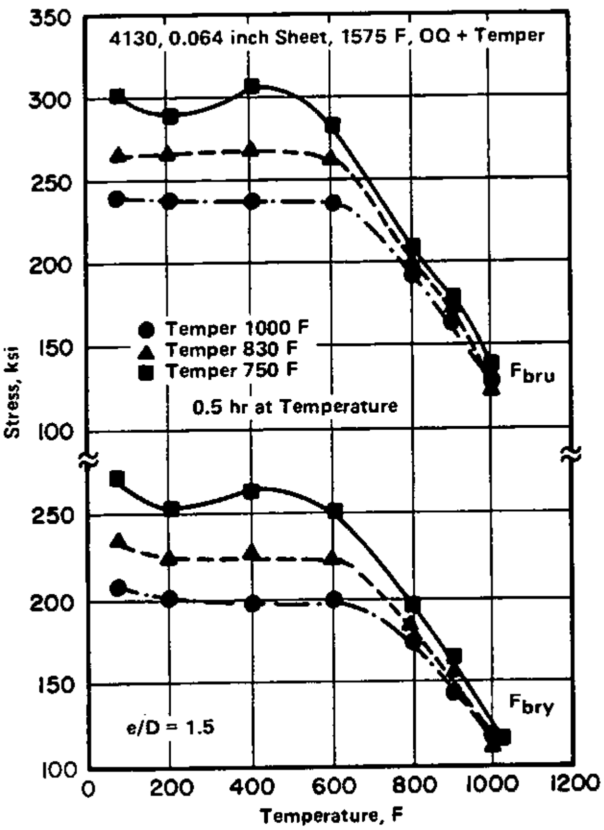


FIGURE 3.0362. EFFECT OF TEMPERATURE ON BEARING STRENGTH (e/D = 1.5) OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS (14)

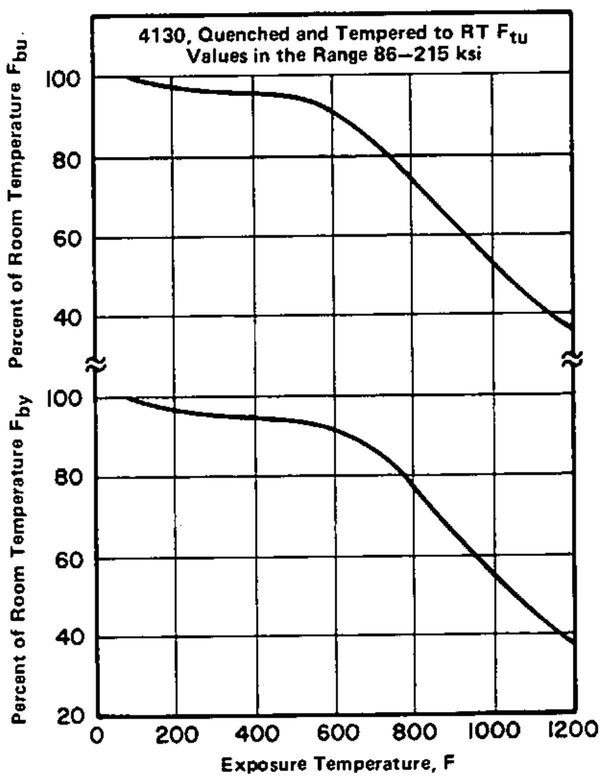


FIGURE 3.0363. EFFECT OF PRIOR TEST TEMPERATURE EXPOSURE UP TO 10 HOURS ON BEARING PROPERTIES (63)

Fe	
0.3	C
0.95	Cr
0.2	Mo

4130

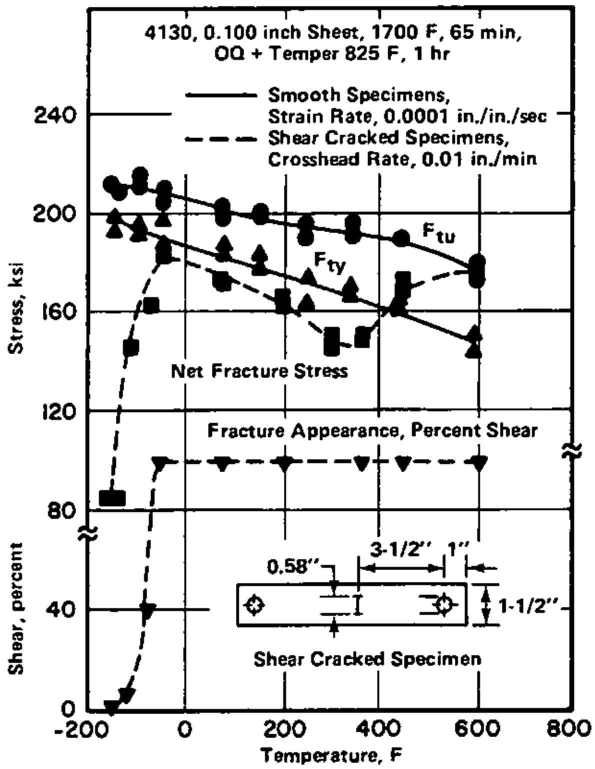


FIGURE 3.03711. COMPARISON OF TENSILE ULTIMATE (F_{tu}) AND YIELD (F_{ty}) STRENGTHS WITH CRACK STRENGTH (NET FRACTURE STRESS) AND FRACTURE APPEARANCE OF SHEAR-CRACKED SHEET SPECIMENS QUENCHED AND TEMPERED AT 825 F (38)

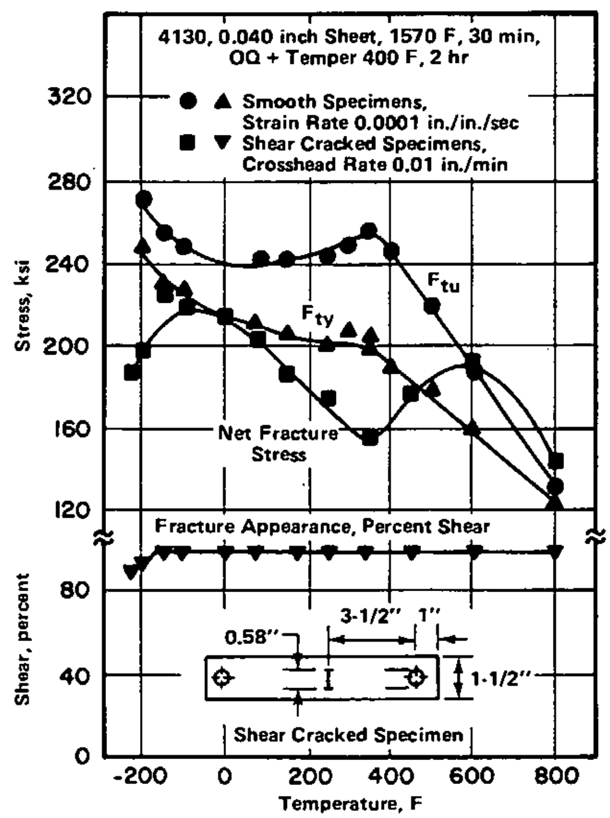


FIGURE 3.03712. COMPARISON OF TENSILE ULTIMATE (F_{tu}) AND YIELD (F_{ty}) STRENGTHS WITH CRACK STRENGTH (NET FRACTURE STRESS) AND FRACTURE APPEARANCE OF SHEAR-CRACKED SHEET SPECIMENS QUENCHED AND TEMPERED AT 400 F (38)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

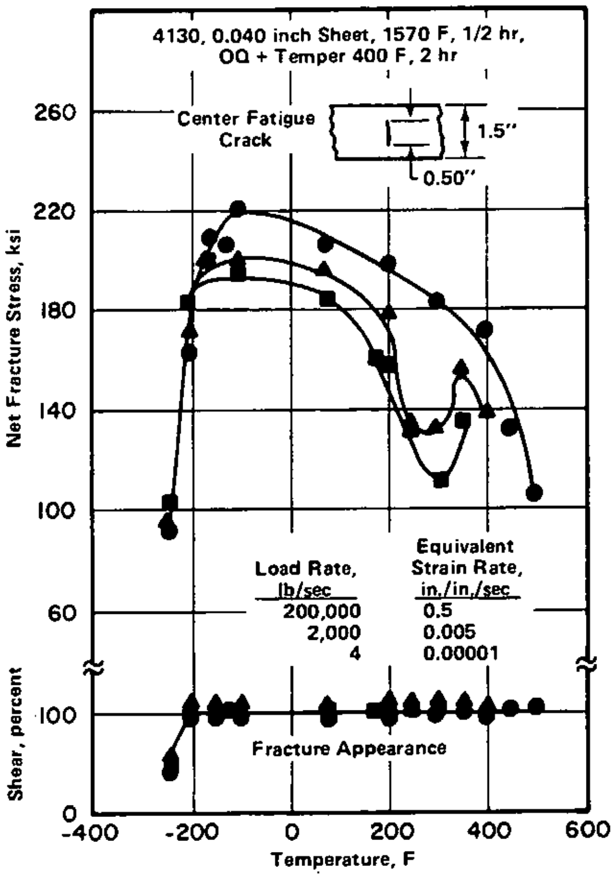


FIGURE 3.03713. EFFECT OF TEMPERATURE AND LOADING RATE ON CRACK STRENGTH (NET FRACTURE STRESS) AND FRACTURE APPEARANCE OF FATIGUE-CRACKED SHEET SPECIMENS QUENCHED AND TEMPERED AT 400 F (39)

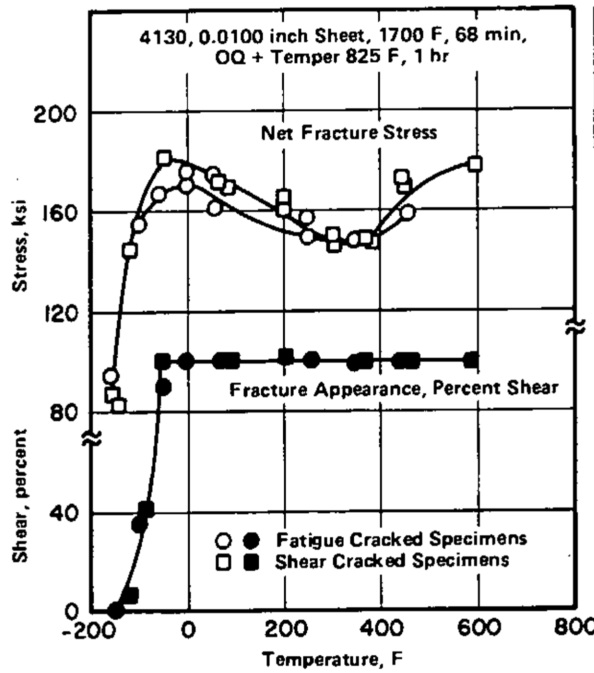


FIGURE 3.03714. EFFECT OF TEMPERATURE ON CRACK STRENGTH (NET FRACTURE STRESS) AND FRACTURE APPEARANCE OF BOTH FATIGUE-CRACKED AND SHEAR-CRACKED SHEET SPECIMENS QUENCHED AND TEMPERED AT 825 F (38)

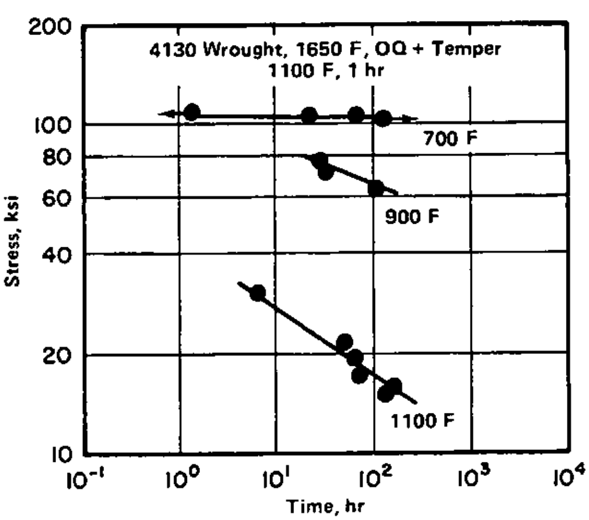


FIGURE 3.041. CREEP-RUPTURE CURVES FROM 700 TO 1100 F (40)

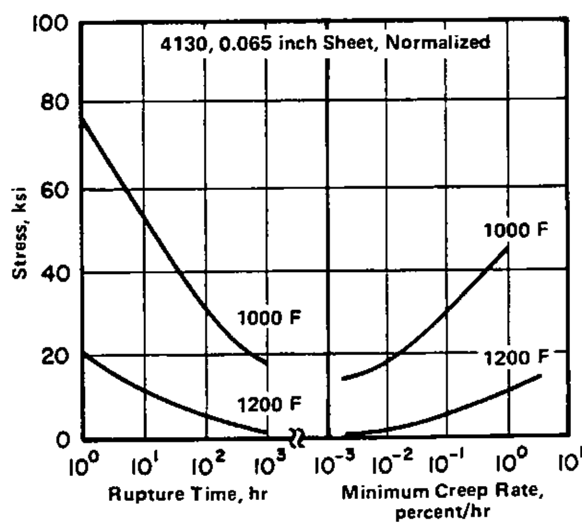


FIGURE 3.042. CREEP-RUPTURE AND MINIMUM-CREEP-RATE CHARACTERISTICS OF NORMALIZED SHEET AT 1000 AND 1200 F (18)

Fe	
0.3	C
0.95	Cr
0.2	Mo

4130

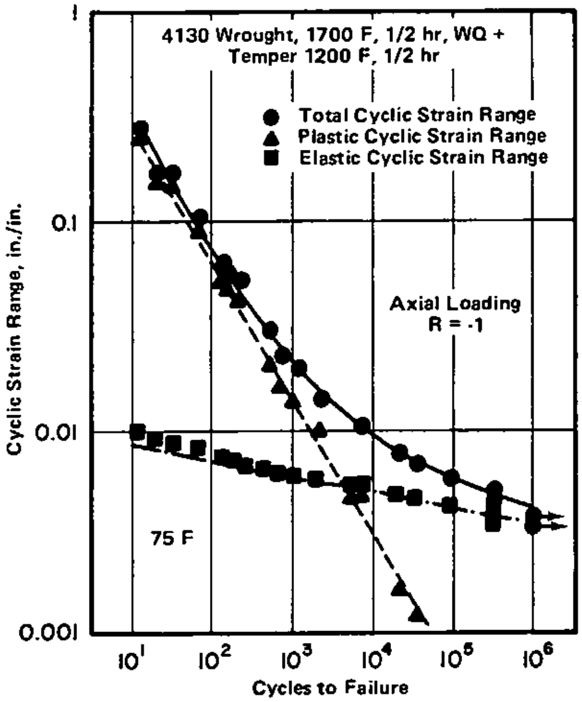


FIGURE 3.051. FATIGUE LIFE AS A FUNCTION OF CYCLIC STRAIN FOR TYPE 4130 TEMPERED AT 1200 F (22)

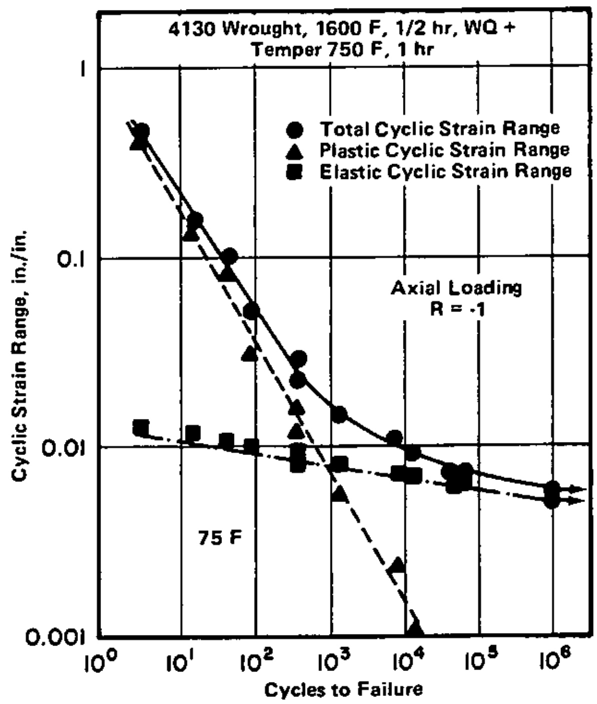


FIGURE 3.052. FATIGUE LIFE AS A FUNCTION OF CYCLIC STRAIN FOR TYPE 4130 TEMPERED AT 750 F (22)

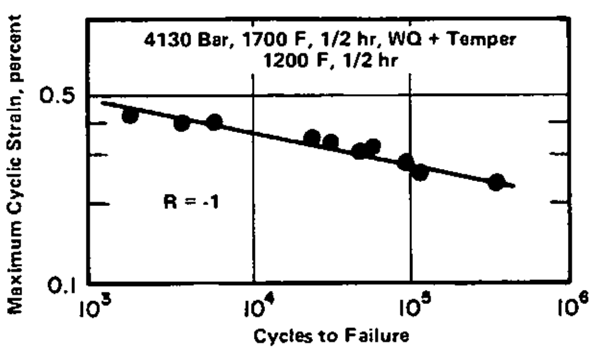


FIGURE 3.053. EFFECT OF MAXIMUM CYCLIC TENSILE STRAIN ON FATIGUE LIFE IN REVERSED BENDING (24)

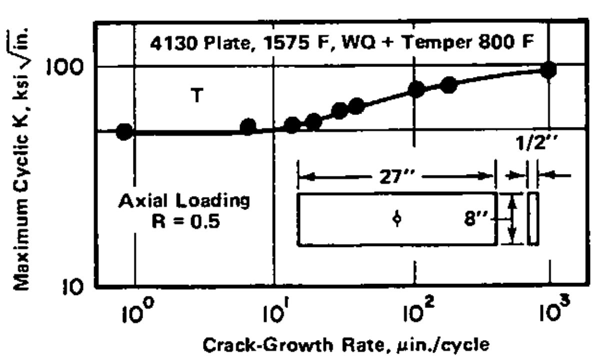


FIGURE 3.054. FATIGUE-CRACK-GROWTH RATE AS A FUNCTION OF MAXIMUM CYCLIC STRESS INTENSITY FACTOR (K) FOR CENTER-CRACKED SPECIMENS (23)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

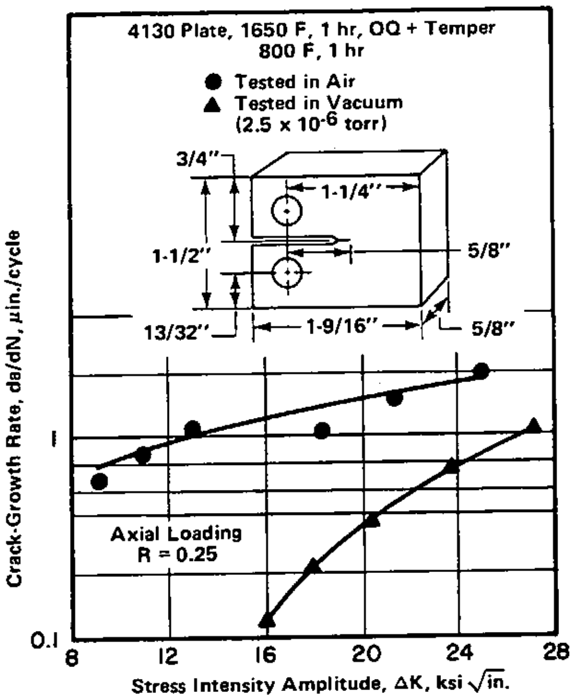


FIGURE 3.055. FATIGUE-CRACK-GROWTH RATE IN AIR AND VACUUM AS A FUNCTION OF STRESS INTENSITY AMPLITUDE (ΔK) FOR COMPACT TENSION SPECIMEN (25)

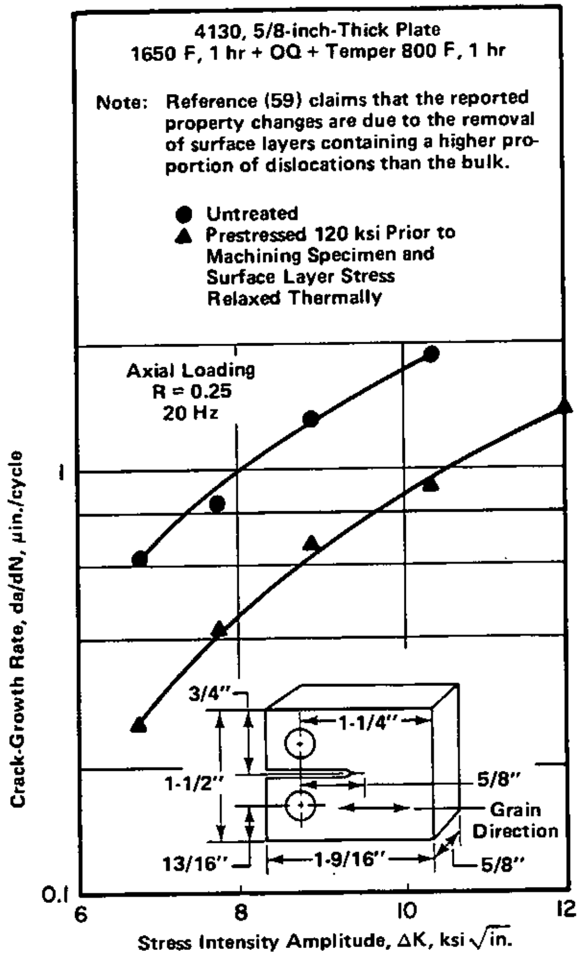


FIGURE 3.056. EFFECT OF PRESTRESSING AND REMOVAL OF SURFACE-LAYER STRESS BY THERMAL RELAXATION ON FATIGUE CRACK GROWTH RATE OF PLATE (59)

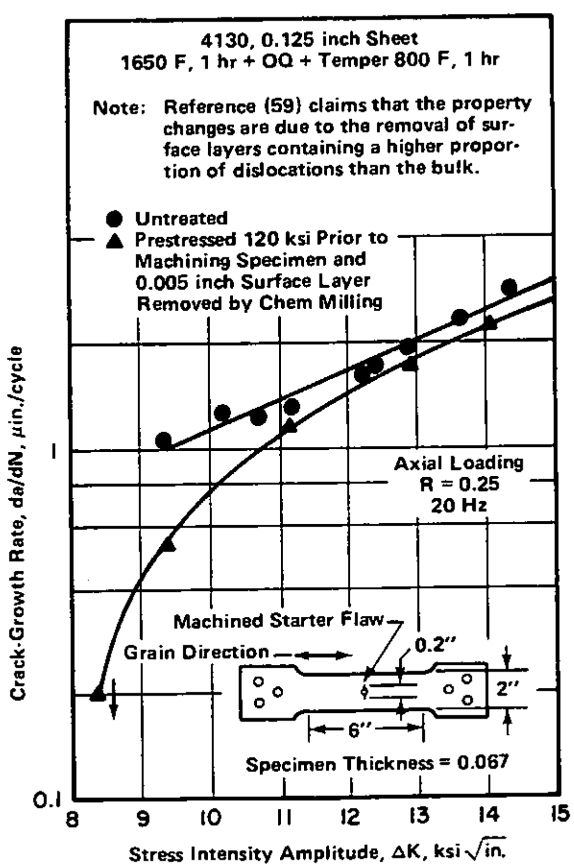


FIGURE 3.057. EFFECT OF PRESTRESSING AND CHEM-MILLING ON FATIGUE CRACK GROWTH RATE OF SHEET (59)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

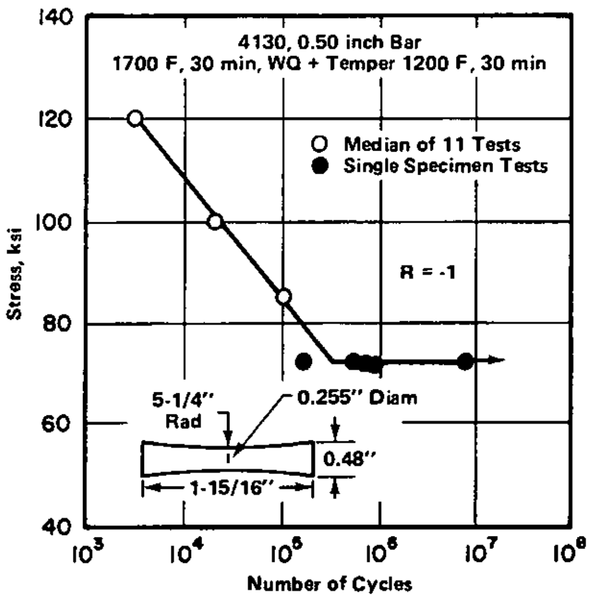


FIGURE 3.058. S-N CURVE AT ROOM TEMPERATURE IN ROTATING BENDING (41)

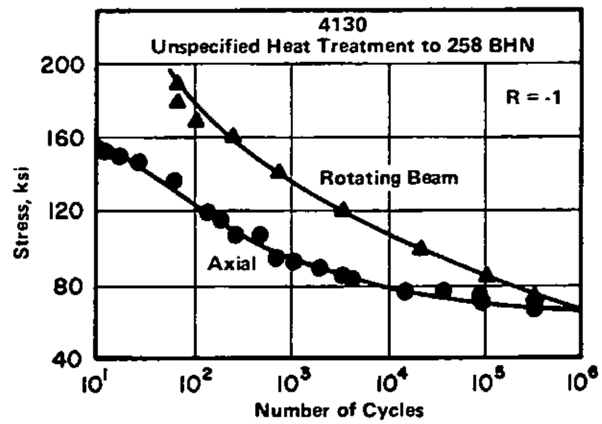


FIGURE 3.059. COMPARISON OF AXIAL-LOADING AND ROTATING-BEAM-BENDING FATIGUE DATA (65)

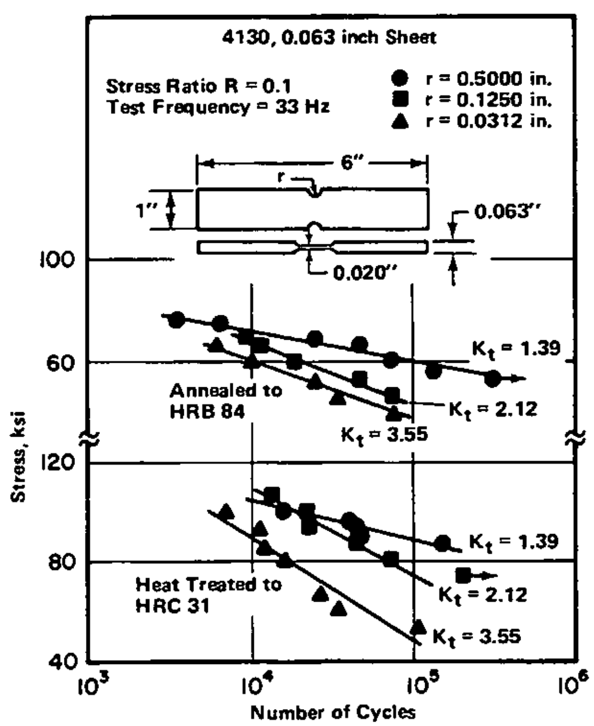


FIGURE 3.0510. AXIAL-STRESS S-N CURVES FOR EDGE-NOTCHED SPECIMENS (65)

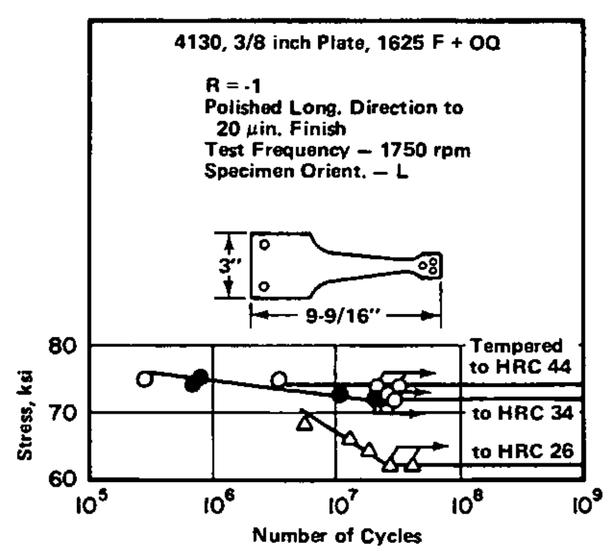


FIGURE 3.0511. EFFECT OF TEMPER TREATMENT (MEASURED BY ROCKWELL HARDNESS) ON REPEATED-BENDING FATIGUE PROPERTIES (49)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

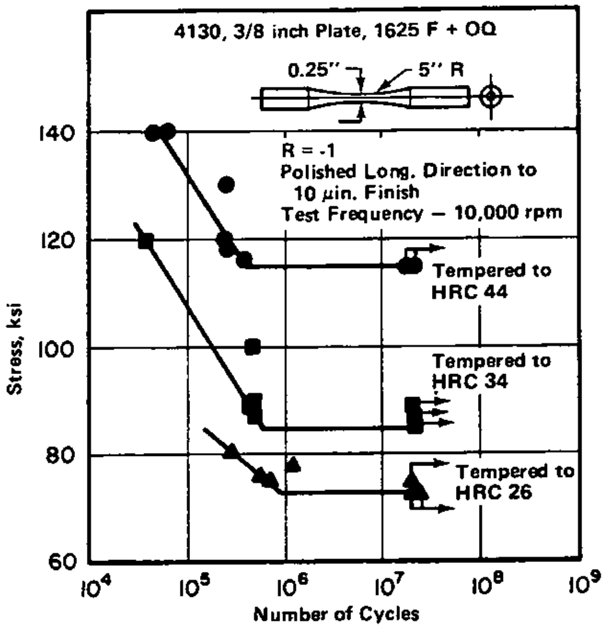


FIGURE 3.0512. EFFECT OF TEMPER TREATMENT (MEASURED BY ROCKWELL HARDNESS) ON ROTATING-BEAM FATIGUE PROPERTIES (49)

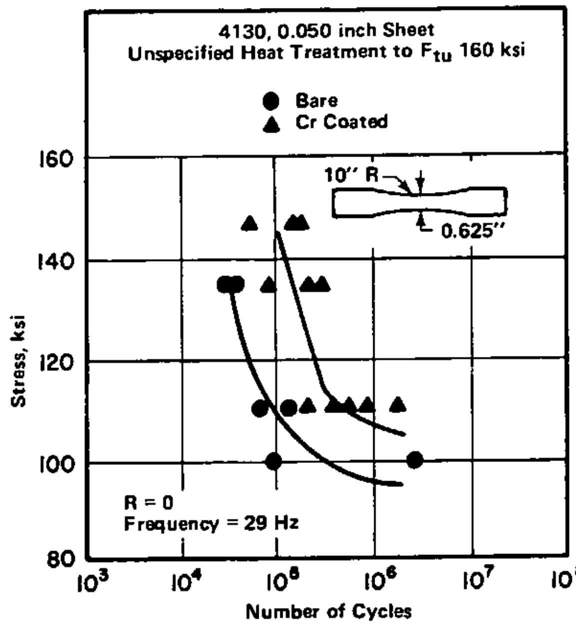


FIGURE 3.0513. EFFECT OF CHROMIUM COATING ON AXIAL-STRESS FATIGUE PROPERTIES OF SHEET (57)

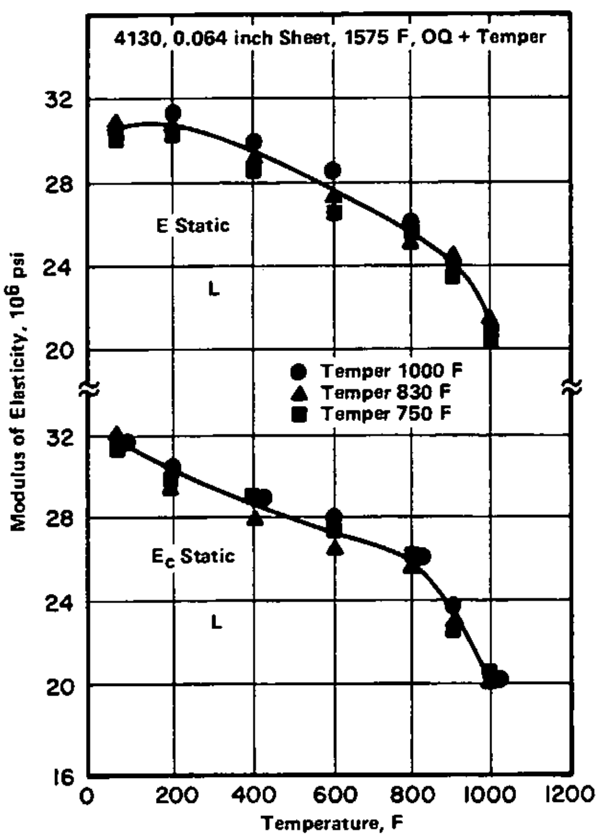


FIGURE 3.0621. EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY IN TENSION AND COMPRESSION OF SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS (14)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

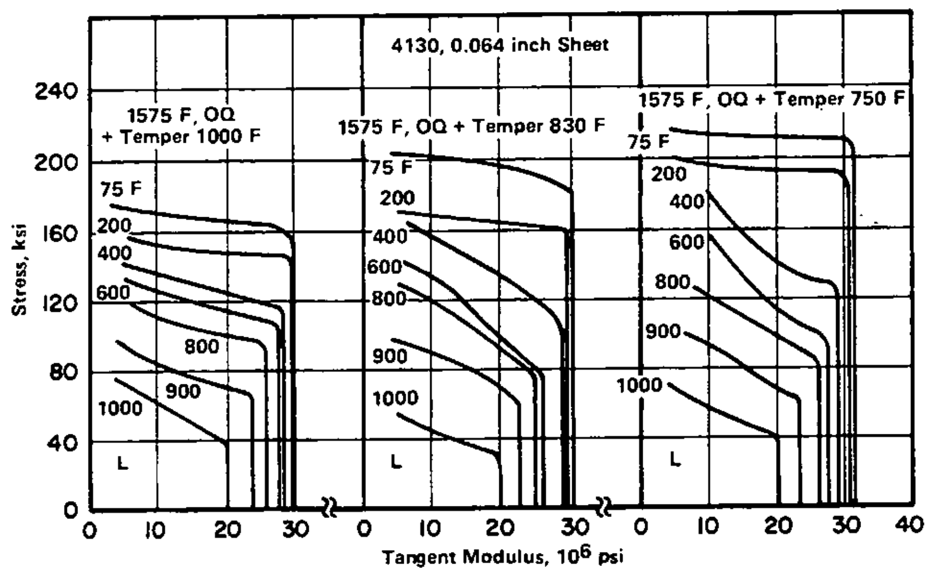


FIGURE 3.0622. COMPRESSIVE TANGENT MODULUS CURVES FOR SHEET AFTER THREE DIFFERENT TEMPERING TREATMENTS (14)

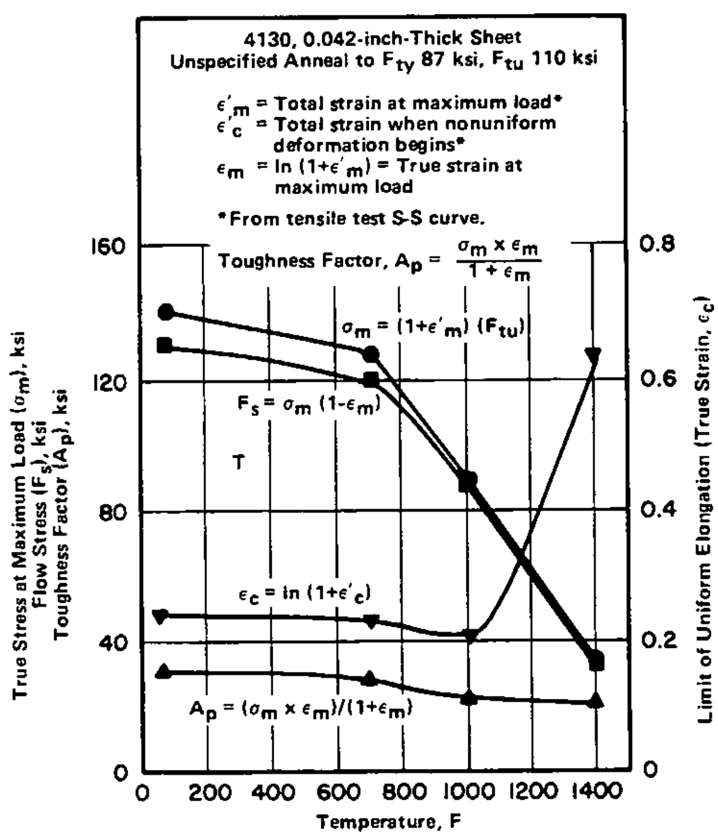


FIGURE 4.013. EFFECT OF TEMPERATURE ON FORMABILITY OF SHEET (53)

Alloy	4130			
Form	0.50-inch-Thick Plate			
Condition	OQ + 1250 F + Weld With 8016N Coated Stick Electrodes (2.5 percent Ni)			
Specimens	Orientation	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent
Parent metal	L	97.5	113	24.8
	T	94.5	110	20.2
As welded	L	79.0	105	20.2
	T	81.0	106	21.2

TABLE 4.032. TENSILE PROPERTIES OF PARENT METAL AND OF 0.5 INCH THICK PLATE WITH BUTT WELD AT THE CENTER OF THE SPECIMEN GAGE LENGTH (26)

Alloy	4130
Form	0.50-inch-Thick Plate
Condition	OQ + 1250 F + Weld With 8016Q Coated Stick Electrodes (2.5 percent Ni)
Test Temp, F	-65
Notch Position	Charpy V, ft-lb
In weld metal	22
In heat-affected zone	34
In outer edge of heat-affected zone	31
In parent metal (longitudinal)	130
In parent metal (transverse)	44

TABLE 4.033. CHARPY-V NOTCH IMPACT PROPERTIES AT -65 F OF BUTT-WELDED 0.50-INCH-THICK PLATE (26)

Alloy	4130					
Form	0.090 inch Sheet					
Condition	Annealed or As Welded			1575 F, 1 hr, OQ + 900 F, 1 hr		
	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent
Base Metal	43.6	68.6	30.4	151.6	167.5	8.9
GTA[(a)]	46.3	67.1	21.8	150.4	163.5	8.6
PGTA[(b)]	17.3	66.5	19.6	153.8	165.7	8.6
GMA[(c)]	45.4	66.4	18.2	151.9	165.5	7.8
PGMA[(d)]	48.1	69.2	16.5	153.9	164.1	7.2

(a) Gas tungsten arc welded.
(b) Pulsed gas tungsten arc welded.
(c) Gas metal arc welded.
(d) Pulsed gas metal arc welded.

TABLE 4.034. TENSILE PROPERTIES OF SHEET BUTT WELDED BY VARIOUS ARC PROCESSES (43)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130		
Form	0.125 inch Sheet		
	F_{ty}, ksi	F_{tu}, ksi	e (2 in.), percent
Annealed	48.9	68.4	30.7
GTA Welded	47.8	67.0	22.9

TABLE 4.035. TENSILE PROPERTIES OF BUTT-WELDED SHEET (60)

Alloy	4130			
Form	Sheet and Plate Butt Welds – Beads Off			
Type Electrode	Weld Heat Treatment (to F_{tu} Listed)	Thickness, in.	Duplicate Tests F_{tu}, ksi	Duplicate Tests Failure Location(a)
Arcaloy 502	150 ksi	0.185	158	H B
		0.236	150	– –
		0.375	161	H W
		0.500	152	H H
	175 ksi	0.078	165	– –
		0.100	177	– –
		0.236	176	W B
		0.245	159	– –
		0.375	178	H H
		0.500	162	W W
P & H21	150 ksi	0.235	156	B B
		0.350	155	B B
		0.492	154	W H
	175 ksi	0.077	176	– –
		0.162	180	– –
		0.235	166	W W
		0.255	164	– –
		0.235	173	W W
		0.492	166	W W
AW-4	175 ksi	0.095	175	– –

(a) H = heat-affected zone, W = weld metal, B = base metal.

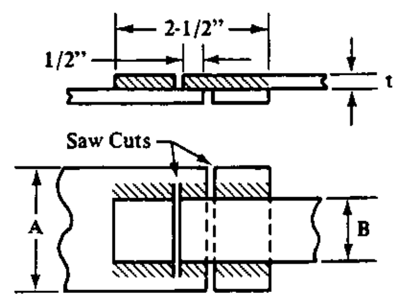
TABLE 4.036. EFFECT OF ELECTRODE ALLOY AND SHEET OR PLATE THICKNESS ON TENSILE ULTIMATE STRENGTH OF BEAD-OFF BUTT WELDS (70)

Fe
0.3 C
0.95 Cr
0.2 Mo

4130

Alloy	4130		
Form	Sheet and Plate Fillet Welds		
Type Electrode	Weld Heat Treatment (to F_{tu} Listed)	Thickness, in.	F_{su}, ksi
Arcaloy	150 ksi	0.076	93.3
		0.190	68.6
		0.248	64.5
		0.258	60.5
		0.385	62.5
		0.496	44.3
	175 ksi	0.076	98.7
		0.190	74.3
		0.250	66.5
		0.260	62.9
		0.388	62.1
		0.496	44.3
P & H21	150 ksi	0.076	98.1
		0.156	78.8
		0.246	77.5
		0.250	65.8
		0.380	55.5
		0.512	50.3
	175 ksi	0.076	93.4
		0.156	83.4
		0.245	74.8
		0.250	57.1
		0.380	54.6
		0.512	52.0
AW-4	150 ksi	0.076	100.8
		0.093	93.8
		0.123	87.0
		0.255	58.8
		0.258	60.8
		0.388	58.8
		0.500	49.2
	175 ksi	0.078	99.1
		0.093	94.3
		0.123	90.1
		0.255	58.6
		0.260	61.6
		0.386	53.5
		0.496	40.8

Shear Specimen



t	A	B
1/4	2	1
3/8	2	1
1/2	3	1-1/2

TABLE 4.037. EFFECT OF ELECTRODE ALLOY AND SHEET OR PLATE THICKNESS ON SHEAR ULTIMATE STRENGTH OF LONGITUDINAL-WELD LAP JOINTS (70)

	Fe
0.3	C
0.95	Cr
0.2	Mo

4130

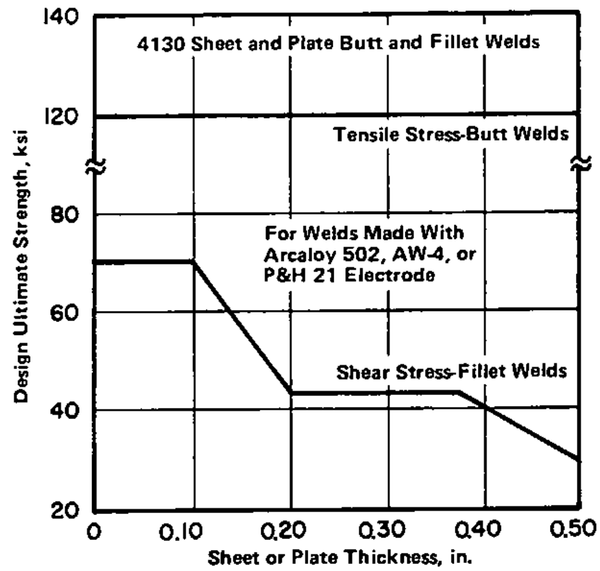


FIGURE 4.038. TENSILE AND SHEAR ULTIMATE-STRENGTH DESIGN CURVES FOR SHEET AND PLATE WELDS HEAT TREATED TO EITHER 150 OR 175 KSI (70)

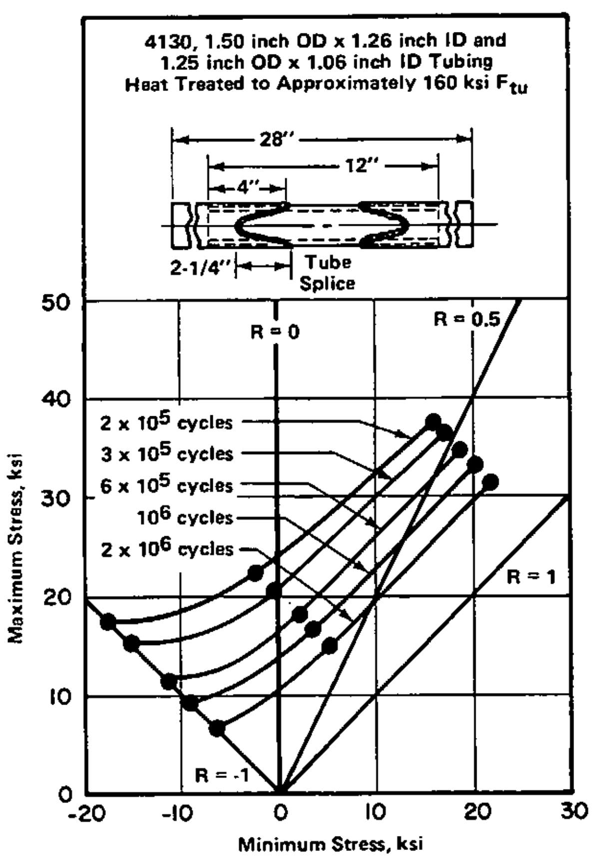


FIGURE 4.039. CONSTANT-LIFE DIAGRAM FOR AN AXIAL-LOADED TUBE SPLICE — STRESSES CALCULATED IN THE LARGE TUBE (61)

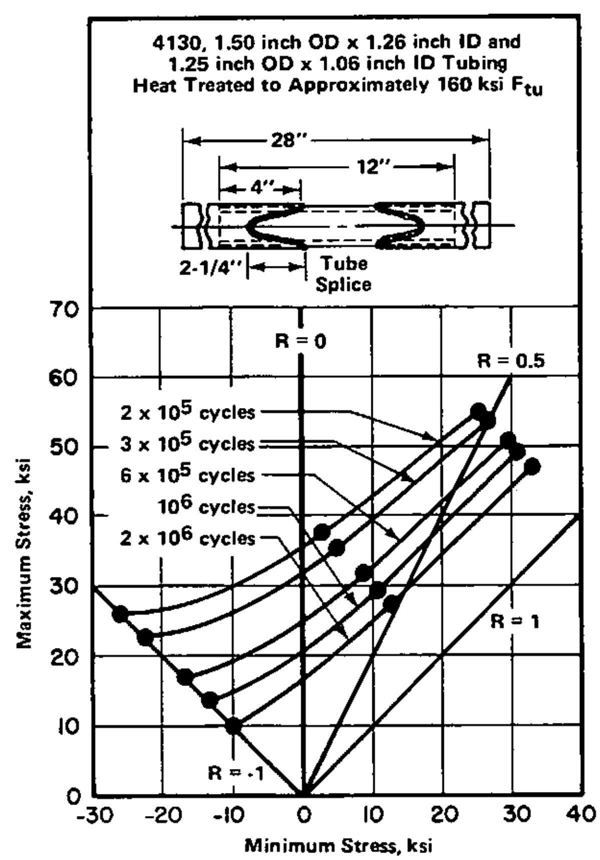


FIGURE 4.0310. CONSTANT-LIFE DIAGRAM FOR AXIAL-LOADED TUBE SPLICES — STRESSES CALCULATED IN SMALL TUBE (61)