Fe
0.30 C
0.55 Ni
0.05 Cr
0.25 Mo

1 General

This low-alloy steel, which is quite similar in properties to Type 4130, is hardenable in sections up to about 2 in. in thickness. In the quenched-and-tempered conditions it has an excellent combination of strength, toughness, and fatigue resistance; good formability and machinability are obtained in the annealed and normalized conditions. The alloy has satisfactory weldability if proper preheat and postheat treatments and low-hydrogen electrodes are used. It is useful for long-time applications at temperatures up to about 700F; at higher temperatures its strength decreases markedly. Like other martensitic or ferritic steels, it undergoes a transition from ductile to brittle behavior at low temperatures, which varies with heat treatment, section size, and degree of stress concentration. For long-time applications in moist environments, protective coatings or cathodic protection is desirable to prevent rusting. Typical applications are pinions, gears, shafting, axles, connecting rods, bolts, and air-frame parts.

1.1 Commercial Designation

8630

1.2 Alternate Designations

AISI 8630, SAE 8630, 8630H.

UNS J13042 (Investment Castings).

UNS J13050 (Sand Castings).

UNS G86300 (Wrought Products).

1.3 Specifications

1.3.1 *[Table]* AMS Specifications.

1.4 Composition

1.4.1 *[Table]* AMS Specified Compositions.

1.5 Heat Treatment

1.5.1 Normalize: 1575-1700F, air cool, for wrought products (Refs. 1, 5, 24); 1650-1750F, air cool, for castings (Refs. 15, 16). Tempering at 800-1200F is sometimes carried out after normalizing to improve strength and toughness.

1.5.2 Anneal: 1550F plus either slow cool from 1350 to 1180F at 20F/hr (8.5 hr total) or cool to 1225F and hold for 6 hours. This treatment produces a spheroidized structure, hardness HB 192 (Ref. 37).

1.5.3 Harden: 1525-1600F, oil quench or water quench. Type 8630 is not sensitive to quench cracking or delayed quench cracking. It should be quenched completely to room temperature to ensure transformation of most of the austenite to martensite and to achieve maximum as-quenched hardness (Ref. 37).

1.5.4 Temper: 400-1300F, 1/2 hour minimum, after hardening (Refs. 1, 5, 24).

1.5.5 Martemper: Type 8630 is commonly martempered to full hardness (Ref. 37).

1.5.6 Stress Relief: 675F for 3 hours but no higher than 50F below the tempering temperature. Stress relief of shot-peened parts should be limited to 400F to avoid relaxing compressive surface stresses (Ref. 28).

1.6 Hardness

1.6.1 *[Figure]* Effect of tempering temperature on hardness of bar.

1.6.2 *[Figure]* Typical hardness of tempered bar.

1.6.3 *[Figure]* Effects of bar diameter on hardness for various heat-treated conditions.

1.6.4 *[Figure]* Effects of bar diameter on as-quenched hardness at various depths in bar.

1.6.5 *[Figure]* Approximate maximum bar diameters hardenable by martempering, oil quenching, and water quenching.

1.6.6 *[Figure]* Effects of cold work on hardness.

1.6.7 *[Figure]* Effects of time at 1000F on room-temperature hardness for various heat treatments.

1.6.8 *[Figure]* End-quench hardenability band.

1.6.9 The end-quench hardenability of Type 8630 can be increased by microalloying with 0.15 percent vanadium (Ref. 29).

1.7 Forms and Conditions Available

1.7.1 The alloy is available in most wrought forms including sheet, strip, plate, bars, rods, tubing, billets, and forgings. Mill products are normally furnished in the hot-rolled, cold-finished, annealed, or normalized condition.

1.7.2 Sand, investment, and centrifugal castings are available in any of the heat-treated conditions.

1.8 Melting and Casting Practice

1.8.1 Type 8630 is generally air melted in basic-electric, basic-open-hearth, or basic-oxygen furnaces. For exceptional quality, it can be induction or consumable-electrode remelted in vacuum.

1.8.2 Ladle desulfurization of acid melted 8630 is recommended as a means of improving tensile elongation and reduction of area and Charpy V-notch properties. Final sulfur levels of 0.010 to 0.014 percent can be consistently achieved by this technique. The reduced sulfur levels also alleviate hot tearing tendencies in complex, thin-walled castings (Ref. 30).

1.9 Special Considerations

1.9.1 Tempering in the range 500-800F is not recommended for Type 8630 (or other low-alloy steels) because it tends to cause embrittlement and increased ductile-to-brittle transition temperature (Ref. 13, see also Figure 3.3.3.4).

1.9.2 See Type 4130, Code 1201, Section 1.9

2 Physical and Environmental Effects

2.1 Thermal Properties

2.1.1 Melting Range 2740F (approximate) (Ref. 5).

2.1.2 Phase Changes.

2.1.2.1 *[Figure]* Time-temperature-transformation diagram.

2.1.2.2 Upon heating under equilibrium conditions, the transformation from pearlite or martensite to austenite starts at 1365F (A_{c1}) and is complete at 1465F (A_{c3}) (Ref. 1).

2.1.2.3 Upon slow cooling under equilibrium conditions, the transformation from austenite to pearlite starts at 1365F (A_{r3}) and is complete at 1205F (A_{r1}) (Ref. 1).

2.1.2.4 Upon rapid quenching from the austenitic condition the transformation to martensite starts at 700F (M_s) and is complete at 540F (M_f) (Ref. 5).

2.1.3 Thermal Conductivity. 21.7 Btu ft per (hr sq ft F) (Ref. 5).

2.1.4 Thermal Expansion.

2.1.4.1 Mean coefficient, in. per in. per F,

0-200F, 6.3×10^{-6}

0-1200F, 8.1×10^{-6}

2.1.4.2 *[Figure]* Thermal expansion at low temperatures (Ref. 5).

2.1.5 Specific heat 0.107 Btu per (lb F) (Ref. 5).

2.1.6 Thermal Diffusivity.

2.2 Other Physical Properties

2.2.1 Density 0.283 lb per cu. in., 7.83 gr per cu. cm. (Ref. 5).

2.2.2 *[Table]* Electrical Properties.

2.2.3 Magnetic Properties. Ferromagnetic.

2.2.4 Emittance.

2.2.5 Damping Capacity.

2.3 Chemical Environment

2.3.1 General Corrosion.

2.3.1.1 Like other ferritic and martensitic steels, Type 8630 rusts in the presence of moisture and oxygen. The rate of rusting increases as the following environmental variables increase: temperature, acidity of the moisture (low pH), and velocity of the water. Contact with a cathodic metal also increases the rate of rusting.

2.3.1.2 See Type 4130, Code 1201, Section 2.3.

2.3.2 Stress Corrosion.

2.4 Nuclear Environment

3 Mechanical Properties

3.1 Specified Mechanical Properties

3.1.1 *[Table]* AMS Specified Mechanical Properties.

3.2 Mechanical Properties at Room Temperature

3.2.1 Tension Stress-strain Diagrams and Tensile Properties.

3.2.1.1 *[Figure]* Tensile stress-strain curves for sheet in various heat-treated conditions.

3.2.1.2 *[Figure]* Tensile stress-strain curves for bar in various heat-treated conditions.

3.2.1.3 *[Figure]* Effects of tempering temperature after both oil quench and water quench on room-temperature tensile properties of 0.530 in. bar.

3.2.1.4 *[Figure]* Effect of tempering temperature on tensile properties of sheet.

3.2.1.5 *[Figure]* Effects of bar diameter on tensile properties for various heat-treated conditions.

3.2.1.6 *[Figure]* Effects of tempering temperature on tensile properties of bar heat treated to two different metallurgical structures.

3.2.1.7 *[Figure]* Effects of cold drawing on tensile properties of normalized bar.

3.2.1.8 *[Table]* Tensile properties of tube in various heat-treated conditions.

3.2.1.9 *[Table]* Tensile properties of extrusions in two heat-treated conditions.

3.2.1.10 *[Table]* Effect of cold extrusion on tensile properties of annealed bar.

3.2.1.11 *[Table]* Tensile properties of castings in two heat-treated conditions.

3.2.2 Compression Stress-strain Diagrams and Compression Properties.

3.2.2.1 *[Figure]* Compressive stress-strain curves for bar in various heat-treated conditions.

3.2.2.2 *[Figure]* Effects of tempering temperature on compressive yield strength of bar heat treated to two different metallurgical structures.

3.2.3 Impact.

3.2.3.1 *[Figure]* Effects of tempering temperature on room-temperature impact strength.

3.2.4 Bending.

3.2.5 Torsion and Shear.

3.2.5.1 *[Table]* Shear strength of bar determined on pin-type double-shear specimens.

3.2.5.2 *[Figure]* Effects of tempering temperature on torsional properties of bar heat treated to two different metallurgical structures.

3.2.6 Bearing.

3.2.6.1 *[Figure]* Effects of tempering temperature on bearing properties.

3.2.7 Stress Concentration.

3.2.7.1 Notch properties.

3.2.7.1.1 *[Figure]* Effect of tempering temperature on notched tensile strength.

3.2.7.2 Fracture toughness.

3.2.8 Combined Properties.

3.3 Mechanical Properties at Various Temperatures

3.3.1 Tension Stress-strain Diagrams and Tensile Properties.

3.3.1.1 *[Figure]* Stress-strain curves from room temperature to 1200F for sheet quenched and tempered to 125 ksi F_{tu}.

3.3.1.2 *[Figure]* Stress-strain curves from room temperature to 1200F for sheet quenched and tempered to 160 ksi F_{tu}.

3.3.1.3 *[Figure]* Monotonic and cyclic stress-strain curves for cast alloy at room temperature and -50F.

3.3.1.4 *[Figure]* Effects of exposures from one-half to 100 hours at test temperature on elevated-temperature tensile properties of sheet quenched and tempered to two different strength levels.

3.3.1.5 *[Figure]* Effects of low temperatures on tensile properties of both normalized and quenched-and-tempered alloy.

3.3.2 Compression Stress-strain Diagrams and Compression Properties.

3.3.2.1 *[Figure]* Stress-strain curves in compression from room temperature to 1000F for sheet quenched and tempered to 120 ksi F_{tu}.

3.3.2.2 *[Figure]* Stress-strain curves in compression from room temperature to 1000F for sheet quenched and tempered to 160 ksi F_{tu}.

3.3.2.3 *[Figure]* Effects of exposures from one-half hour to 100 hours at test temperature on compressive yield strength of sheet quenched and tempered to two F_{tu} levels.

3.3.3 Impact.

3.3.3.1 *[Figure]* Low-temperature impact properties of bar.

3.3.3.2 *[Figure]* Comparison of low-temperature impact properties of hardened-and-tempered and normalized alloy.

3.3.3.3 *[Figure]* Effects of cold work on impact properties at room temperature and -40F.

3.3.3.4 *[Figure]* Effect of tempering temperature on impact (Charpy V) transition temperature.

3.3.3.5 *[Figure]* Effect of temperature on impact energy of cast alloy.

3.3.3.6 *[Figure]* Effect of tempering temperature on impact energy of cast alloy at low temperatures.

3.3.4 Bending.

3.3.5 Torsion and Shear.

3.3.5.1 *[Figure]* Effects of exposures from one-half hour to 100 hours at test temperature on shear strength of sheet quenched and tempered to two F_{tu} levels.

3.3.6 Bearing.

3.3.6.1 *[Figure]* Effects of exposures from one-half hour to 100 hours at test temperature on bearing properties of sheet quenched and tempered to two F_{tu} levels.

3.3.7 Stress Concentration.

3.3.7.1 Notch properties.

3.3.7.2 Fracture toughness.

3.3.7.2.1 The J_{Ic} fracture toughness was determined using the ASTM E 813 Standard Test for cast, heat-treated (as in Figure 3.5.5) 8630 alloy as 456 in-lb/in^2 at room temperature. Based on this determination, a conservative value for the plane strain fracture toughness, K_{Ic}, was estimated as 123 ksi(in)$^{1/2}$. At -50F, the cleavage fracture toughness, J_{c1}, was measured as 175 in-lb/in^2, from which K_{c1} was estimated as 77 ksi(in)$^{1/2}$ (Ref. 31).

3.4 Creep and Creep Rupture Properties

3.4.1 *[Figure]* Short-time creep properties of sheet heat treated to an F_{tu} level of 125 ksi.

3.4.2 *[Figure]* Short-time creep properties of sheet heat treated to an F_{tu} level of 180 ksi.

3.4.3 *[Figure]* Long-time creep properties of sheet in the annealed and quenched-and-tempered conditions.

3.5 Fatigue Properties

3.5.1 *[Figure]* Fatigue properties of bar at several strength levels and under various loading conditions.

3.5.2 *[Figure]* Low-temperature fatigue properties of notched bar.

3.5.3 *[Figure]* Fatigue properties of castings in the normalized-and-tempered and quenched-and-tempered conditions.

3.5.4 *[Figure]* Effects of cold work on fatigue endurance limit at 10^7 cycles.

3.5.5 *[Figure]* Fatigue behavior of cast alloy at room temperature.

3.5.6 *[Figure]* Fatigue behavior of cast alloy at -50F.

3.5.7 *[Figure]* Fatigue crack-growth rate for cast alloy at R = 0.5.

3.5.8 *[Figure]* Fatigue crack-growth rate for cast alloy at R = 0.

3.5.9 *[Figure]* Threshold and near-threshold fatigue crack-growth rates for cast alloy at room temperature and -50F.

3.6 Elastic Properties

3.6.1 Poisson's Ratio. 0.32 (Ref. 12).

3.6.2 Modulus of Elasticity. 30 x 10^3 ksi (Ref. 12).

3.6.2.1 *[Figure]* Effects of temperature on modulus of elasticity in tension for sheet quenched and tempered to two F_{tu} levels.

3.6.2.2 *[Figure]* Effects of temperature on modulus of elasticity in compression for sheet quenched and tempered to two F_{tu} levels.

3.6.3 Modulus of Rigidity. 11.3 x 10^3 ksi (Ref. 12).

3.6.4 Tangent Modulus.

3.6.4.1 *[Figure]* Tangent modulus curves in compression at room and elevated temperatures for sheet quenched and tempered to 120 ksi F_{tu}.

3.6.4.2 *[Figure]* Tangent modulus curves in compression at room and elevated temperatures for sheet quenched and tempered to 160 ksi F_{tu}.

3.6.5 Secant Modulus.4 Fabrication

4 Fabrication

4.1 Forming

4.1.1 The forming characteristics, both cold and hot, of Type 8630 are similar to those of Type 4130. (See Chapter Code 1201, Sections 4.1.1 and 4.1.2.)

4.2 Machining and Grinding

4.2.1 Type 8630 has good machinability in the annealed, normalized, and cold-drawn conditions. Optimum machinability is obtained when the alloy is annealed and then cold drawn, which provides a machinability rating of 63 percent or more of that of AISI B1112 steel (Ref. 5).

4.3 Joining

4.3.1 The weldability of this alloy is similar to that of Type 4130 steel. (See Chapter code 1201, Section 4.3.1.)

4.3.2 Type 8630 steel is subject to underbead cracking after fusion welding. This cracking can be reduced or eliminated by weld pre-heating and by post-weld holding at an elevated temperature. Cast alloy has superior resistance to underbead cracking than wrought alloy because the globular inclusions in the cast material are much less favorable sites for crack initiation than the elongated, almost needle-shaped inclusions in wrought alloy (Ref. 32).

4.4 Surface Treatment

4.4.1 With proper surface preparation, this alloy can be painted or electroplated for both protective and decorative purposes.

4.4.2 Type 8630 heat treated up to 180 ksi can be cleaned by pickling, but higher strength material should be cleaned with alkaline scale conditioner or alkaline electrocleaner or mechanically cleaned by sand blasting (Ref. 28).

Table 1.3.1 AMS specifications (Refs. 15-19)

Alloy: 8630	
AMS Specification	**Product Form**
6280H	Bars, rods, forgings
6355L (a)	Sheet, strip, and plate
6281G	Mechanical tubing
5334D	Investment castings
5335D	Sand castings

(a) Superseded as of December 1990. The requirements of this specification are embodied in the latest issue of AMS 6350H (SAE 4130).

Table 1.4.1 AMS specified compositions

Alloy: 8630						
Form	**All Wrought Forms**		**Sand Cast**		**Investment Cast**	
Reference	**17, 18**		**16**		**15**	
Composition (percent)	**min**	**max**	**min**	**max**	**min**	**max**
Carbon	0.28	0.33	0.25	0.33	0.25	0.35
Manganese	0.70	0.90	0.60	0.95	0.60	0.95
Silicon	0.15	0.35	0.50	0.90	-	1.00
Phosphorus	-	0.025	-	0.025	-	0.04
Sulfur	-	0.025	-	0.025	-	0.04
Chromium	0.40	0.60	0.40	0.90	0.35	0.65
Nickel	0.40	0.70	0.40	1.10	0.35	0.75
Molybdenum	0.15	0.25	0.15	0.25	0.15	0.30
Copper	-	0.35	-	0.35	-	0.35

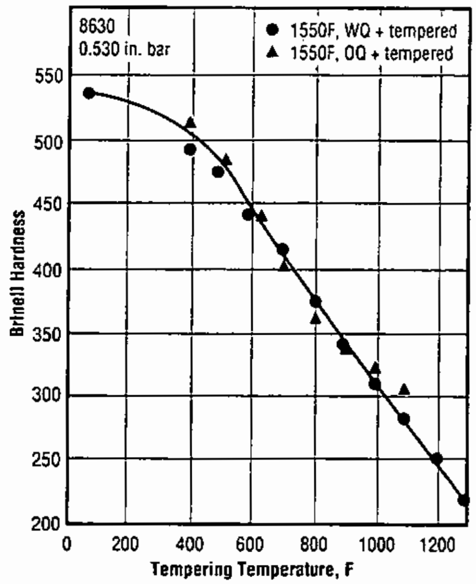

Fig. 1.6.1 Effect of tempering temperature on hardness of bar (Refs. 1, 5)

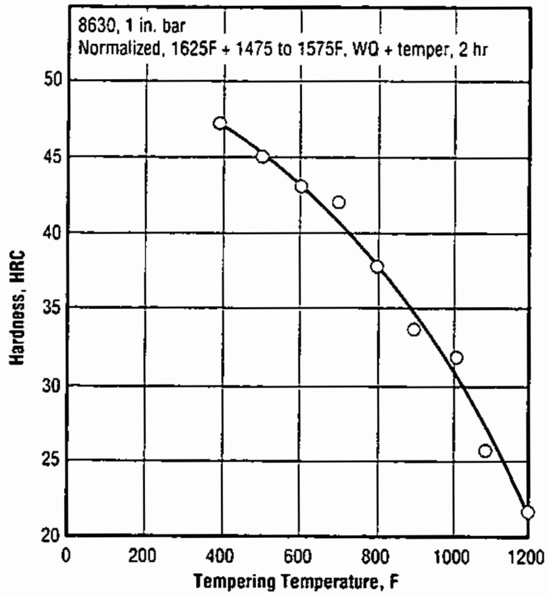

Fig. 1.6.2 Typical hardness of tempered bar (Ref. 37)

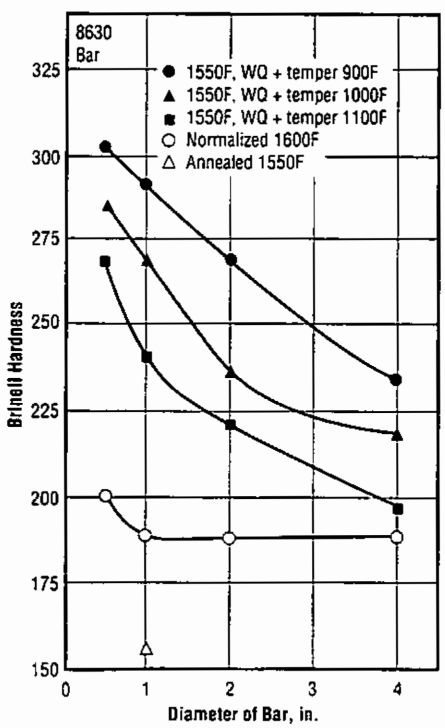

Fig. 1.6.3 Effects of bar diameter on hardness for various heat-treated conditions (Ref. 1)

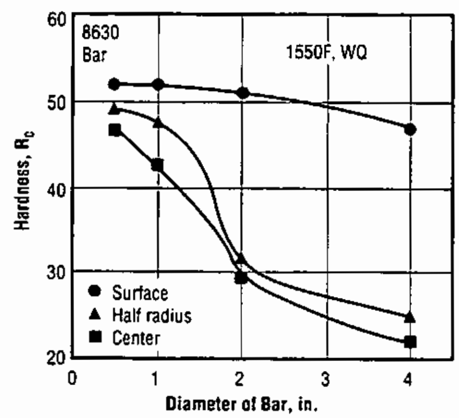

Fig. 1.6.4 Effects of bar diameter on as-quenched hardness at various depths on bar (Ref. 1)

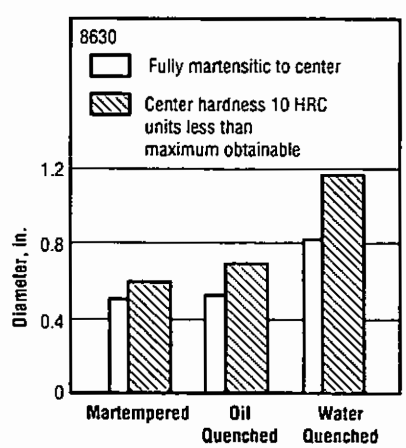

Fig. 1.6.5 Approximate maximum bar diameters hardenable by martempering, oil quenching, and water quenching (Ref. 37)

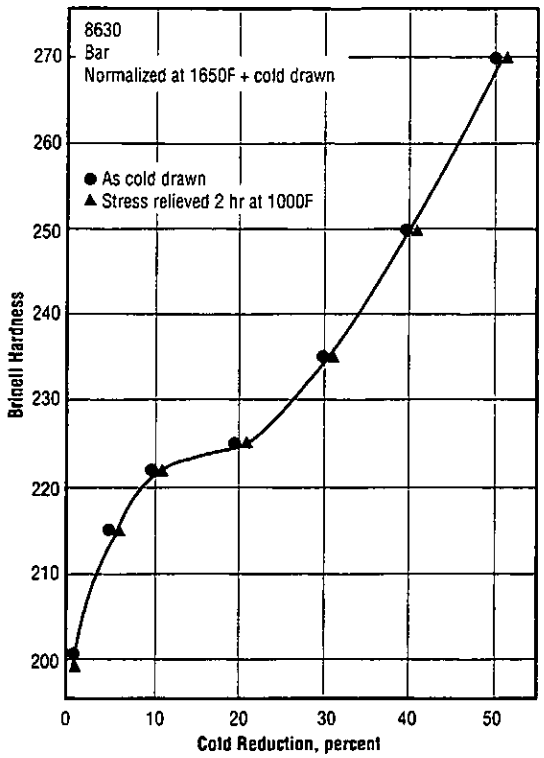

Fig. 1.6.6 Effects of cold work on hardness (Ref. 14)

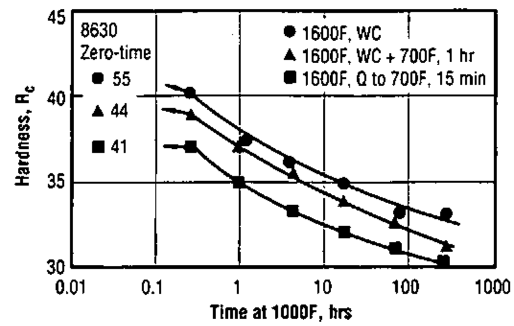

Fig. 1.6.7 Effects of time at 1000F on room-temperature hardness for various heat treatments (Ref. 25)

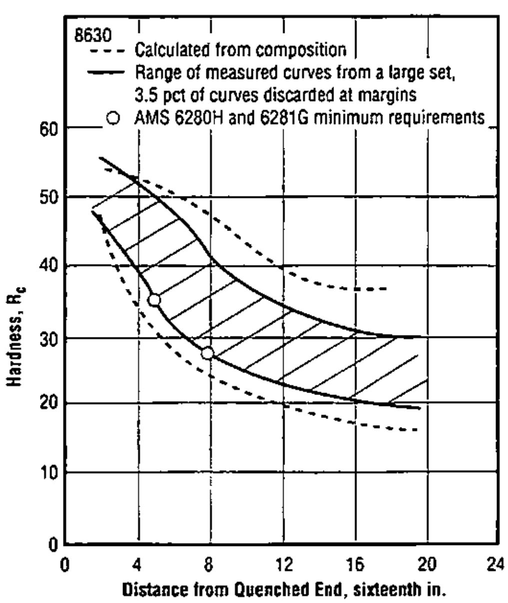

Fig. 1.6.8 End-quench hardenability band (Ref. 33)

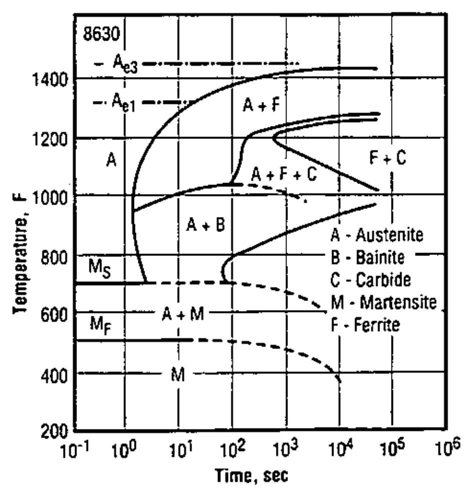

Fig. 2.1.2.1 Time-temperature-transformation diagram (Refs. 2, 37)

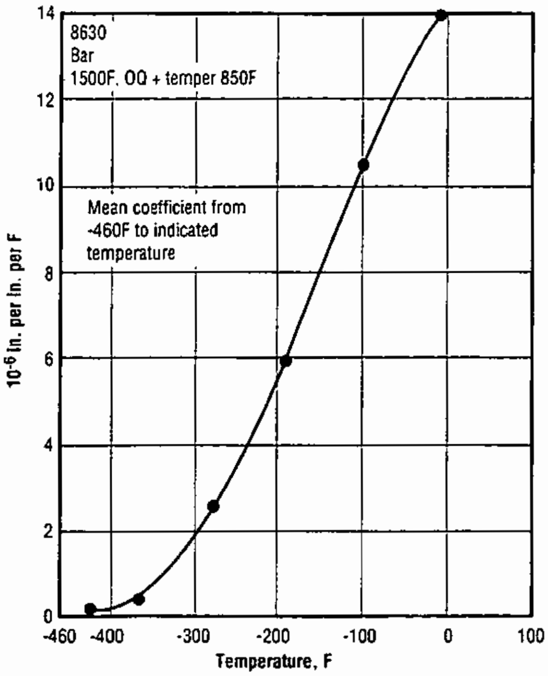

Fig. 2.1.4.2 Thermal expansion at low temperatures (Ref. 9)

Table 2.2.2 Electrical properties (Ref. 5)

Alloy: 8630			
Temperature (F)	Electrical Conductivity		Electrical Resistivity (microhm-in.)
	percent IACS	megohms per in.	
120	5.8	0.085	11.8
570	3.6	0.053	18.9

Table 3.1.1 AMS Specified mechanical properties (Refs. 15-18)

Alloy: 8630									
AMS Specification	Form	Condition	Tensile Properties				Hardness	
			F_{ty} (ksi, min)	F_{tu} (ksi, min)	e (pct, min)	RA (pct, min)	min	max
6281G	Mechanical tubing	Cold finished	-	-	-	-	-	25 R_c
		Hot finished	-	-	-	-	-	99 R_b
6280H	Bars							
	0.500 in. and under	Cold finished	-	125 max	-	-	-	27 R_c
	Over 0.500 in.	Hot finished	-	-	-	-	-	229 BHN
		Cold finished	-	-	-	-	-	248 BHN
5335D	Sand castings	Normalized and tempered	-	-	-	-	183 BHN	229 BHN
		1600F, OQ + temper 800F	150	165	8	-	331 BHN	-
5334D	Investment castings	Normalized and tempered	-	-	-	-	-	99 R_b
		1600F, OQ + temper 825F	125	150	5	10	32 R_c	38 R_c

Note: The original AMS documents should be consulted for complete specification details.

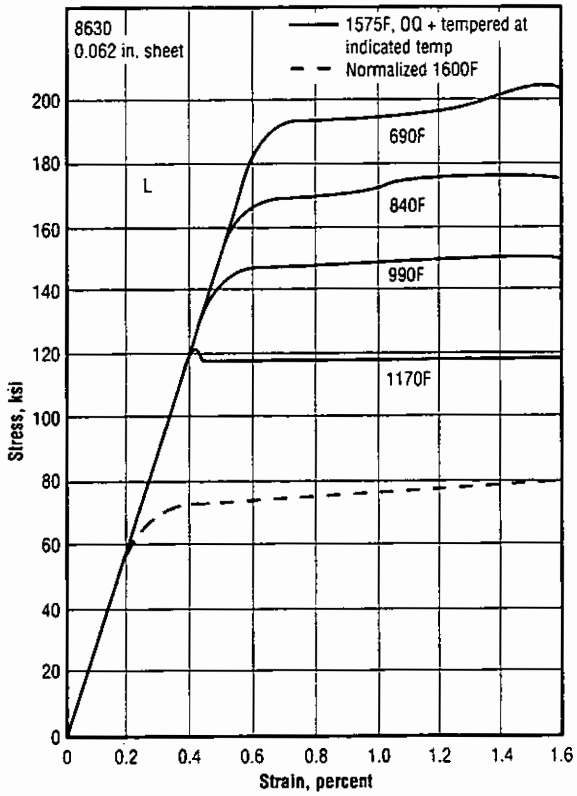

Fig. 3.2.1.1 Tensile stress-strain curves for sheet in various heat treated conditions (Ref. 12)

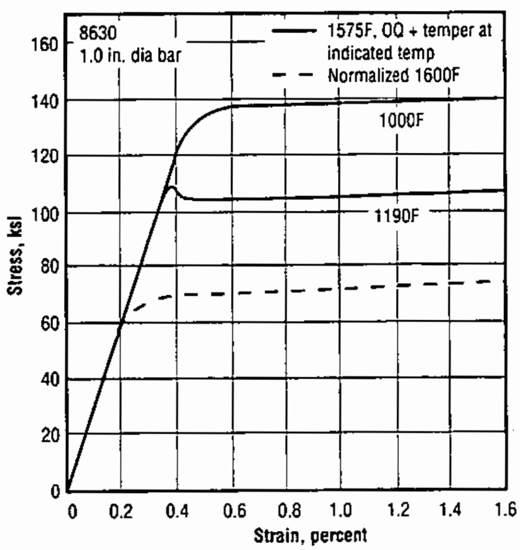

Fig. 3.2.1.2 Tensile stress-strain curves for bar in various heat treated conditions (Ref. 12)

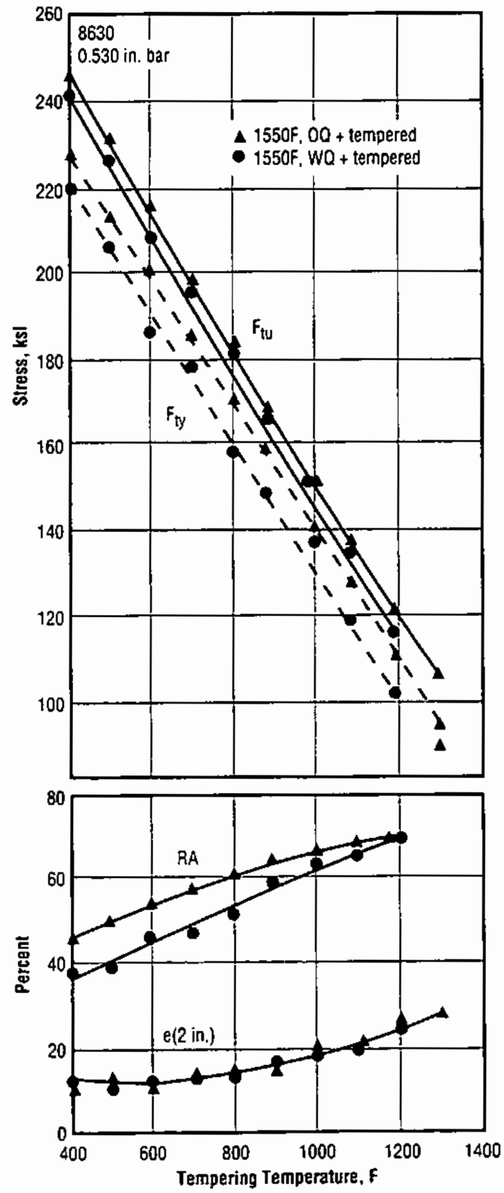

Fig. 3.2.1.3 Effects of tempering temperature after both oil quench and water quench on room temperature tensile properties of 0.530 in bar (Refs. 1, 5)

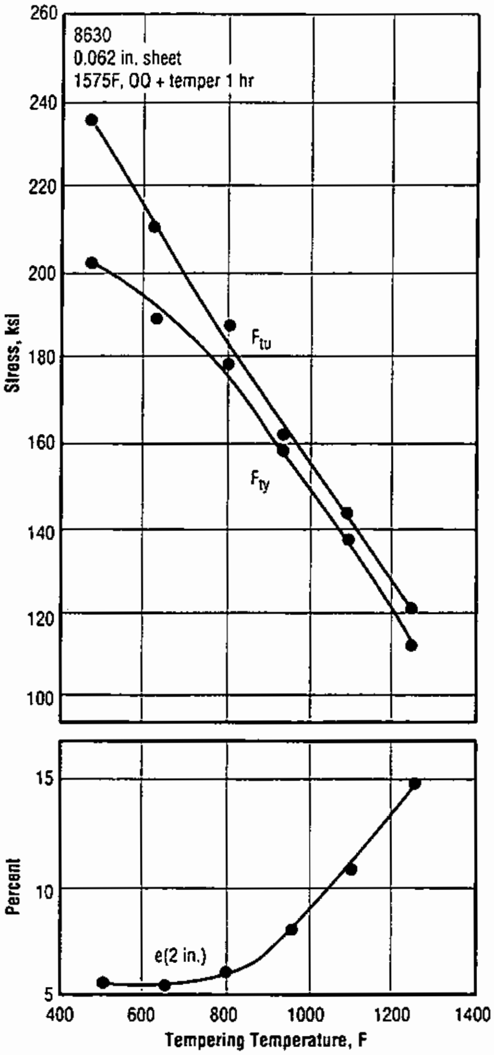

Fig. 3.2.1.4 Effect of tempering temperature on tensile properties of sheet (Ref. 8)

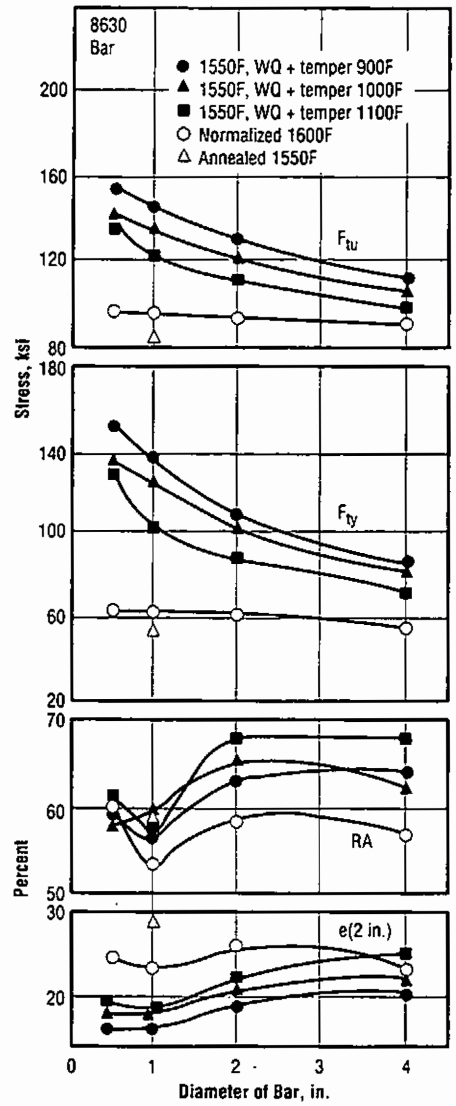

Fig. 3.2.1.5 Effects of bar diameter on tensile properties for various heat treated conditions (Ref. 1)

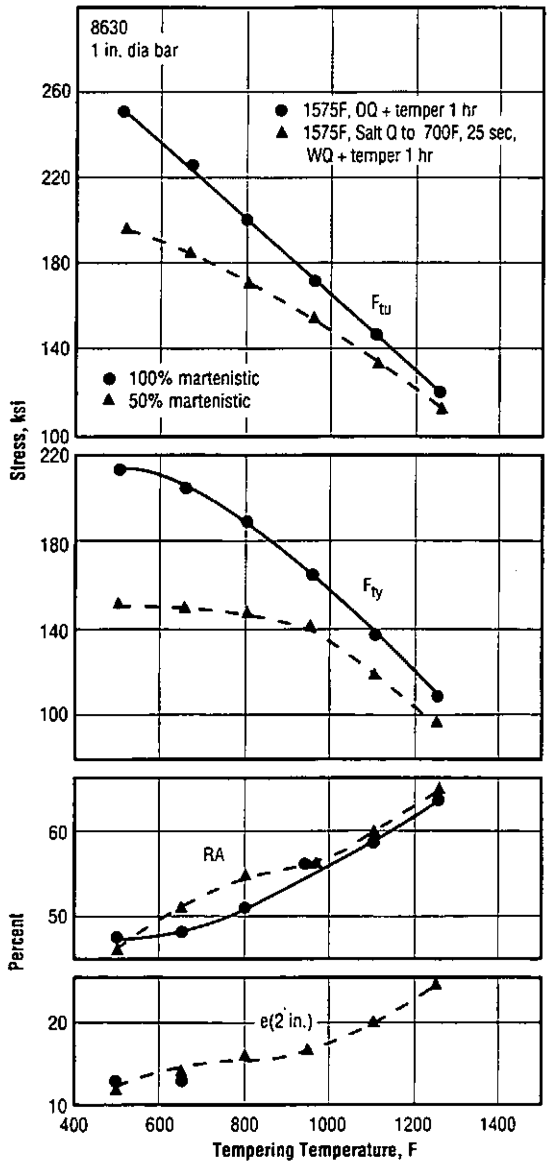

Fig. 3.2.1.6 Effect of tempering temperature on tensile properties of bar heat treated to two different metallurgical structures (Ref. 8)

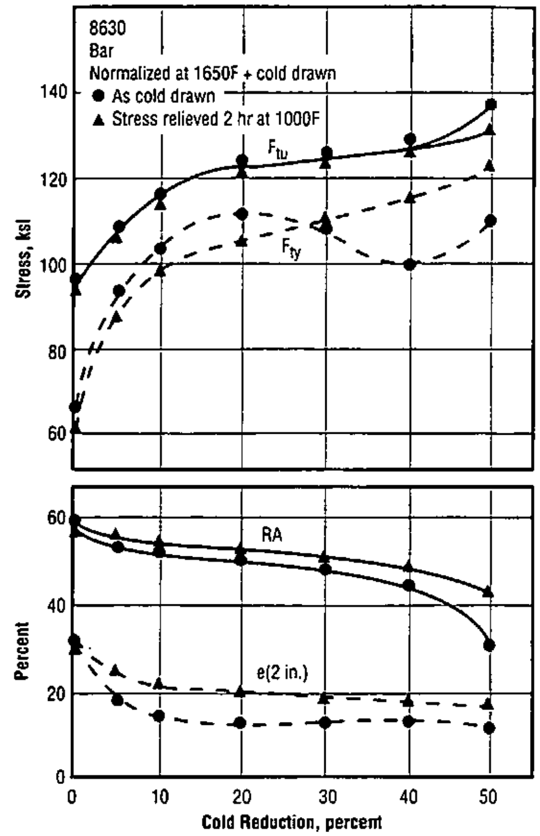

Fig. 3.2.1.7 Effects of cold drawing on tensile properties of normalized bar (Ref. 14)

Table 3.2.1.8 Tensile properties of tube in various heat-treated conditions (Ref. 5)

Alloy: 8630			
Form	Tube, 1.0 in. OD x 0.062 in. Wall		
Condition	F_{ty} (ksi)	F_{tu} (ksi)	e, 2 in. (percent)
Normalized 1650F	61.5	114.1	23.8
Normalized 1700F	63.4	118.5	22.2
1550F, OQ + temper 700F	184.2	196.4	8.7
1550F, OQ + temper 900F	160.2	163.4	16.5
1550F, OQ + temper 1100F	126.4	133.2	17.0

Table 3.2.1.9 Tensile properties of extrusions in two heat-treated conditions (Ref. 4)

Alloy: 8630				
Form	Extruded T, 3/4 x 1 3/4 in.			
Condition	F_{ty} (ksi)	F_{tu} (ksi)	e, 2 in. (a) (percent)	RC
1550F, OQ + 800F	193.5	200.0	8.5	43
1550F, OQ + 1100F	127.5	137.9	15.7	31

(a) Flat specimen

Table 3.2.1.10 Effect of cold extrusion on tensile properties of annealed bar (Ref. 6)

Alloy: 8630				
Form	Bar			
Condition	F_{ty} (ksi)	F_{tu} (ksi)	e, 2 in. (percent)	RA (percent)
Annealed	54.0	81.8	29	59
Cold extruded to 60 percent cold reduction	171	166	12	46

Table 3.2.1.11 Tensile properties of castings in two heat-treated conditions (Ref. 7)

Alloy: 8630					
Form	1.0 in. Dia Cast Bars				
Condition	F_{ty} (ksi)	F_{tu} (ksi)	e,4D (percent)	RA (percent)	BHN
Normalized 1650F + tempered 1200F	85.6	110.5	19.0	53.7	223
1550F, WQ + tempered 1200F	125.8	137.5	14.8	34.5	286

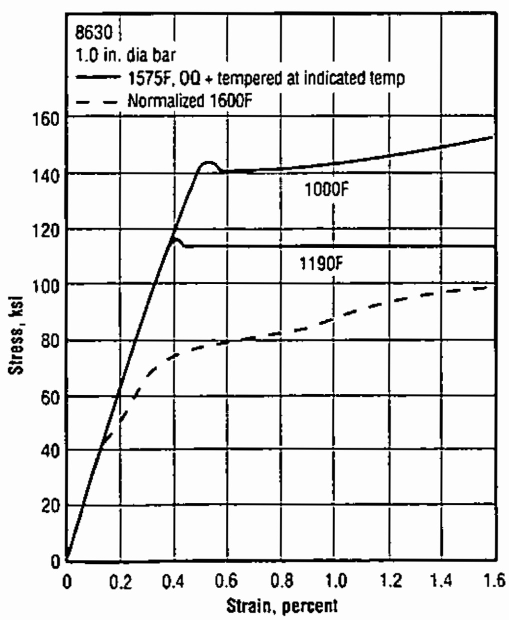

Fig. 3.2.2.1 Compressive stress-strain curves for bar in various heat-treated conditions (Ref. 12)

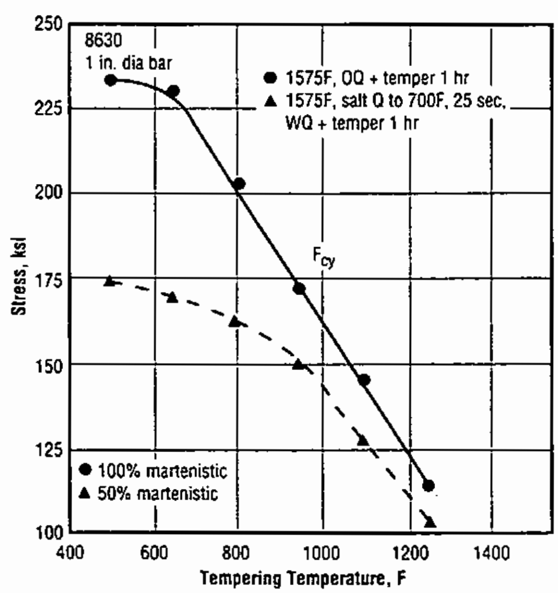

Fig. 3.2.2.2 Effects of tempering temperature on compressive yield strength of bar heat treated to two different metallurgical structures (Ref. 8)

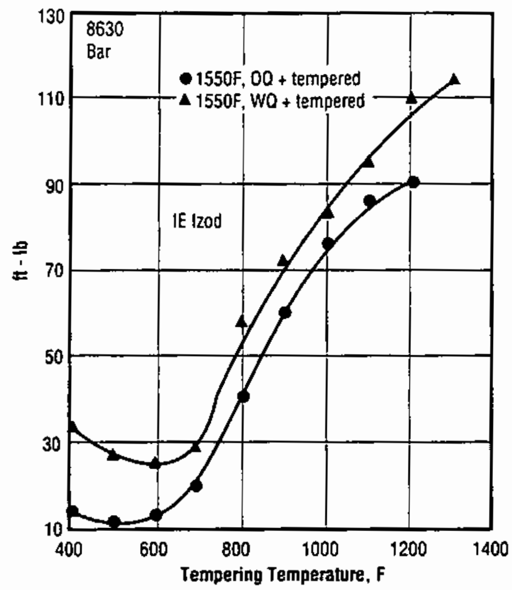

Fig. 3.2.3.1 Effects of tempering temperature on room-temperature impact strength (Ref. 5)

Table 3.2.5.1 Shear strength of bar determined on pin-type double-shear specimens (Ref. 12)

Alloy: 8630		
Form	**1.0 in. dia bar**	
Condition	**F_{tu} (ksi)**	**F_{su} (ksi)**
Normalized 1675F	116.0	81.0
1575F, OQ + temper 1190F	120.5	88.4
1575F, OQ + temper 1000F	147.5	109.0

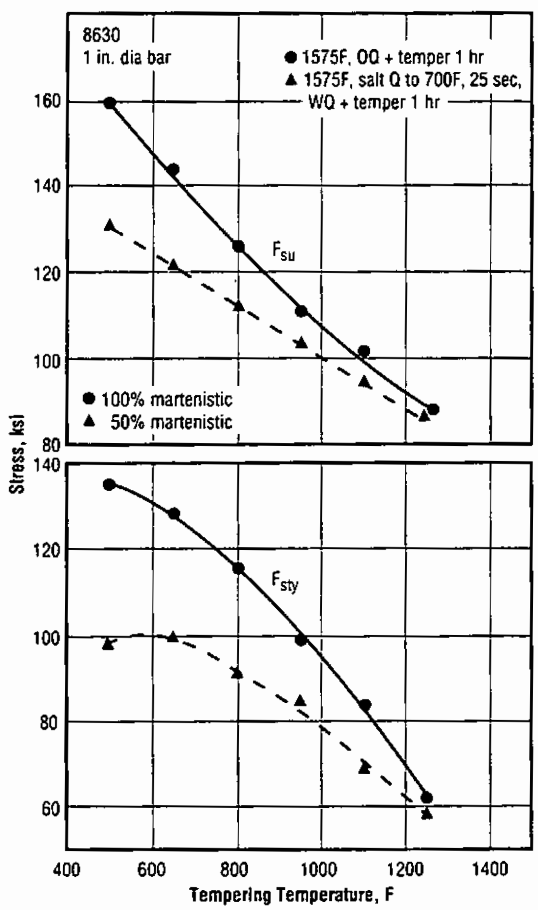

Fig. 3.2.5.2 Effects of tempering temperature on torsional properties of bar heat treated to two different metallurgical structures (Ref. 8)

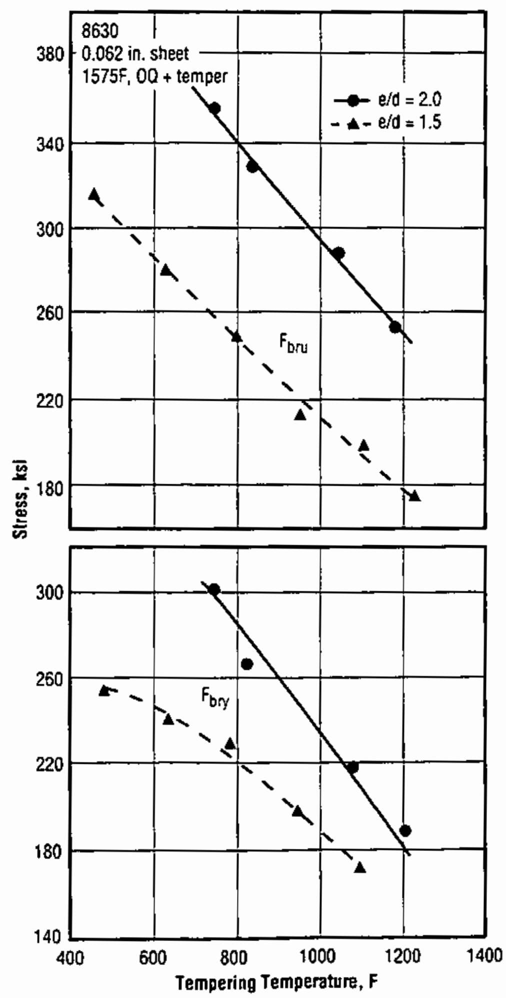

Fig. 3.2.6.1 Effects of tempering temperature on bearing properties (Refs. 8, 12)

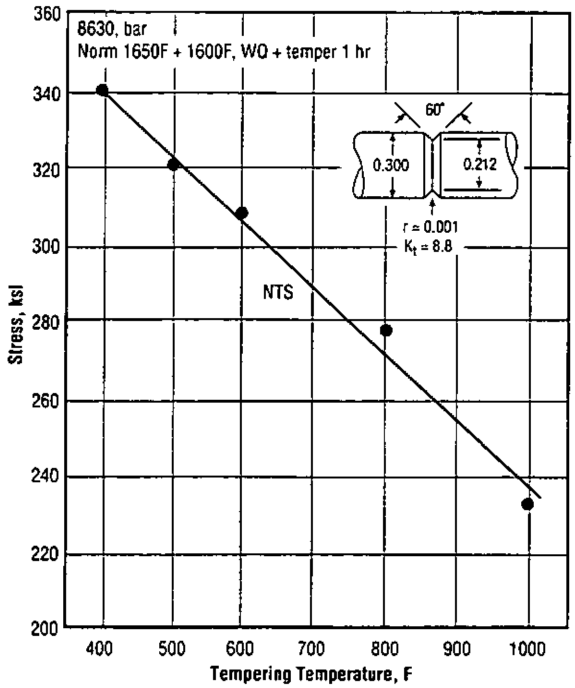

Fig. 3.2.7.1.1 Effect of tempering temperature on notched tensile strength (Ref. 26)

Note: See Fig. 3.2.1.3 for tensile properties of bar in approximately equivalent heat-treated conditions.

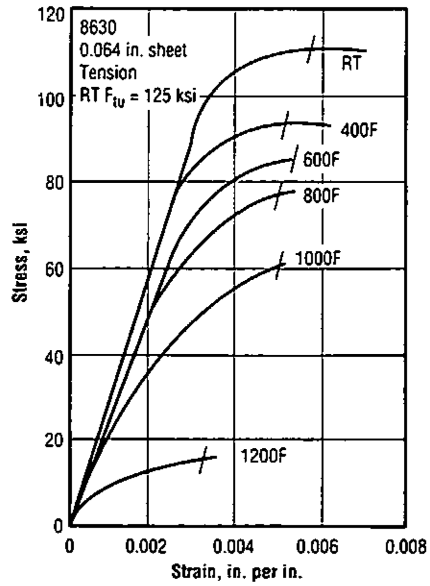

Fig. 3.3.1.1 Stress-strain curves from room temperature to 1200F for sheet quenched and tempered to 125 ksi F_{tu} (Ref. 27)

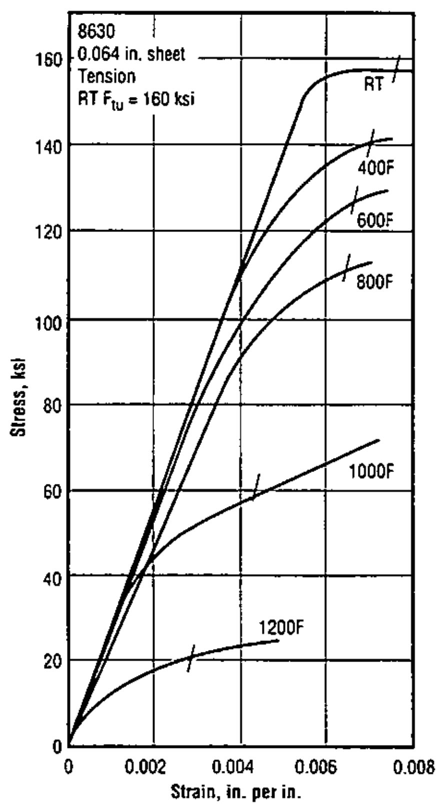

Fig. 3.3.1.2 Stress-strain curves from room temperature to 1200F for sheet quenched and tempered to 160 ksi F_{tu} (Ref. 27)

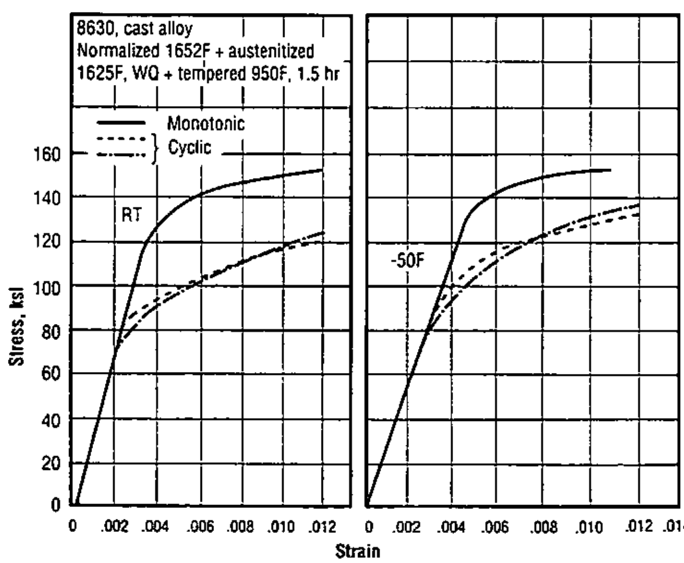

Fig. 3.3.1.3 Monotonic and cyclic stress-strain curves for cast alloy at room temperature and -50F (Ref. 34)

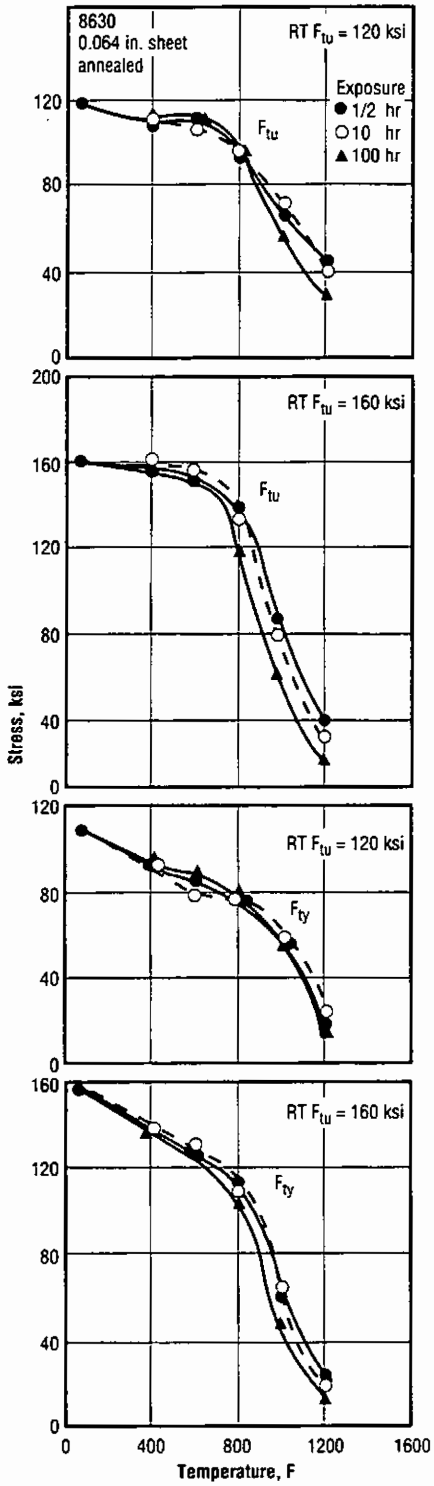

Fig. 3.3.1.4 Effects of exposures from one-half hour to 100 hours at test temperature on elevated-temperature tensile properties of sheet quenched and tempered to two different strength levels (Ref. 27)

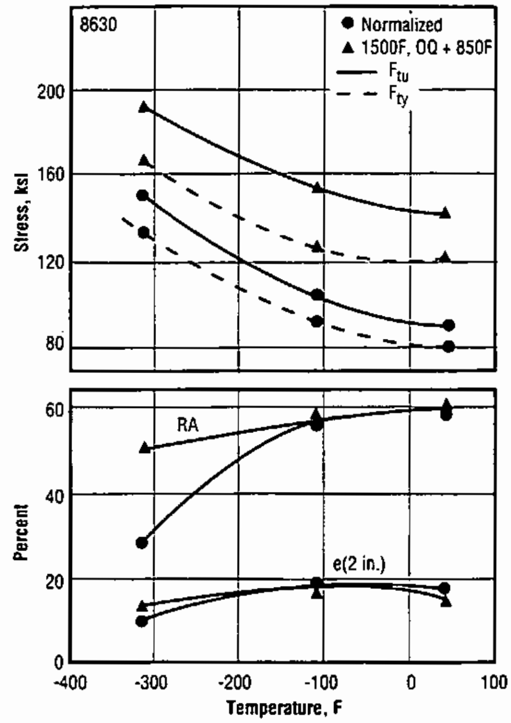

Fig. 3.3.1.5 Effects of low temperature on tensile properties of both normalized and quench-and-tempered alloy (Ref. 27)

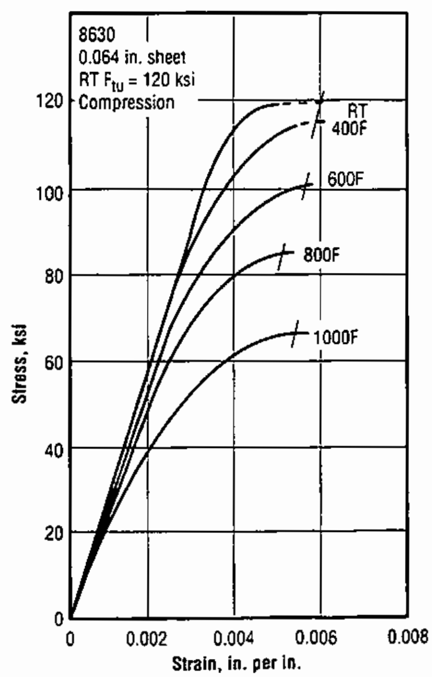

Fig. 3.3.2.1 Stress-strain curves in compression from room temperature to 1000F for sheet quenched and tempered to 120 ksi F_{tu} (Ref. 27)

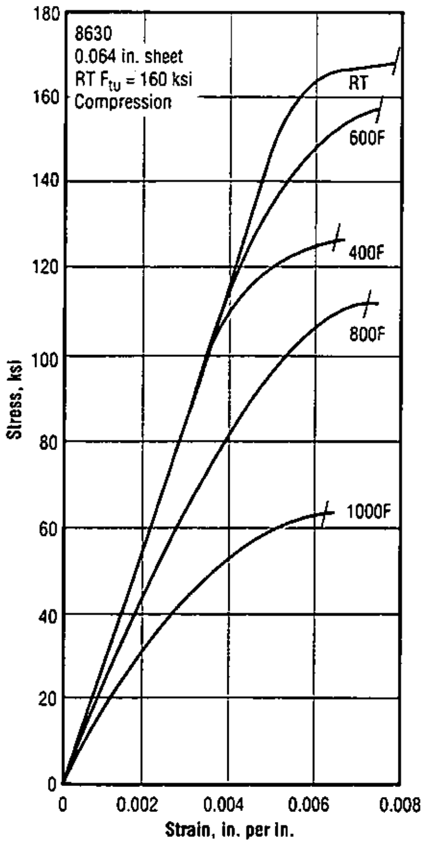

Fig. 3.3.2.2 Stress-strain curves in compression from room temperature to 1000F for sheet quenched and tempered to 160 ksi F_{tu} (Ref. 27)

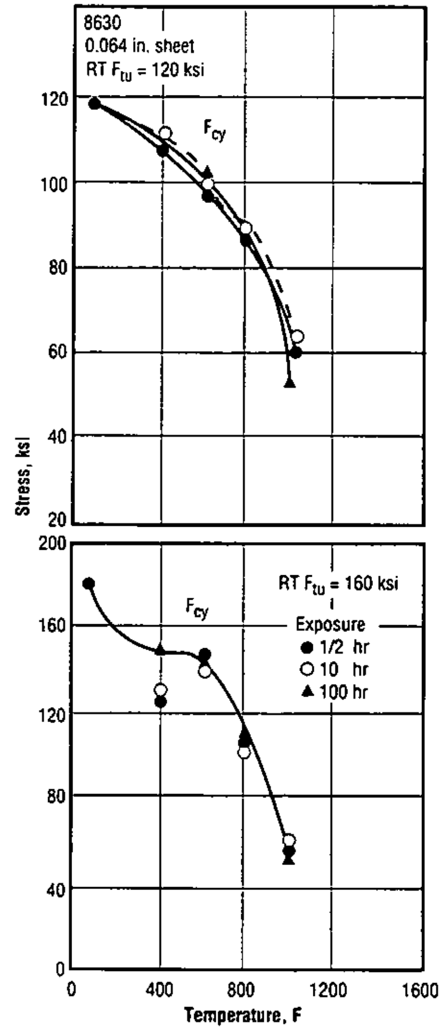

Fig. 3.3.2.3 Effects of exposures from one-half hour to 100 hours at test temperature on compressive yield strength of sheet quenched and tempered to two F_{tu} levels (Ref. 27)

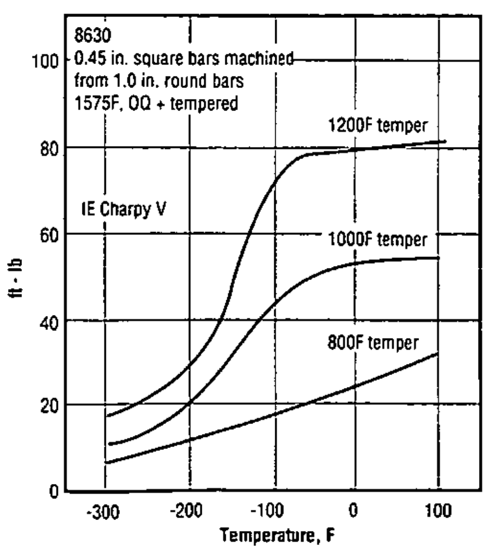

Fig. 3.3.3.1 Low-temperature impact properties of bar (Ref. 3)

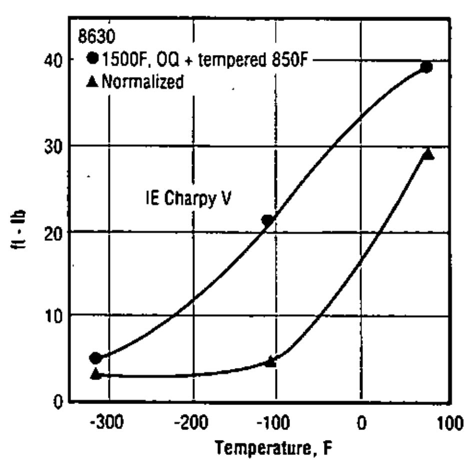

Fig. 3.3.3.2 Comparison of low-temperature impact properties of hardened-and-tempered and normalized alloy (Ref. 5)

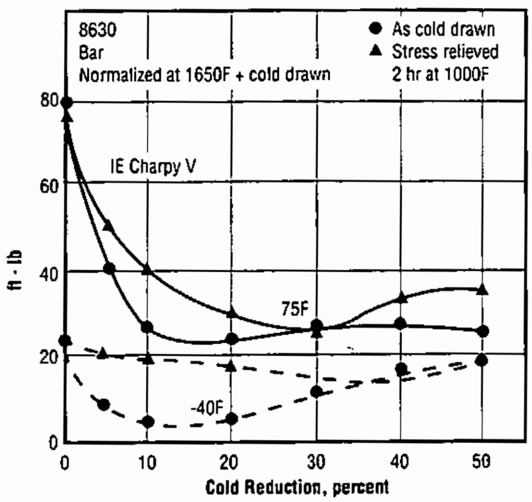

Fig. 3.3.3.3 Effects of cold work on impact properties at room temperature and -40F

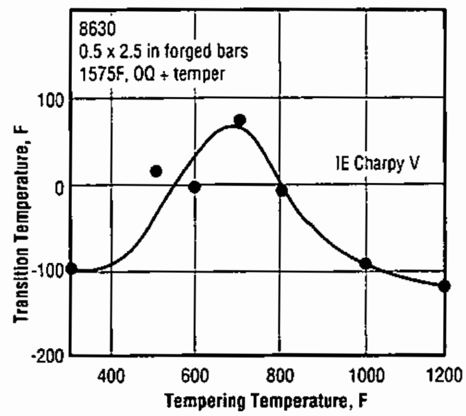

Fig. 3.3.3.4 Effect of tempering temperature on impact (Charpy V) transition temperature. Impact transition temperature in this instance is defined as the temperature at which impact energy absorption is 80 percent of the shelf energy. (Ref. 13)

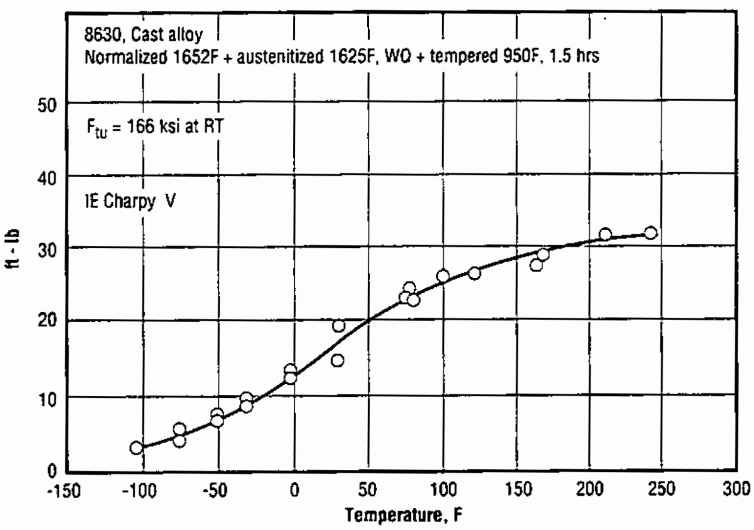

Fig. 3.3.3.5 Effect of temperature on impact energy of cast alloy (Ref. 34)

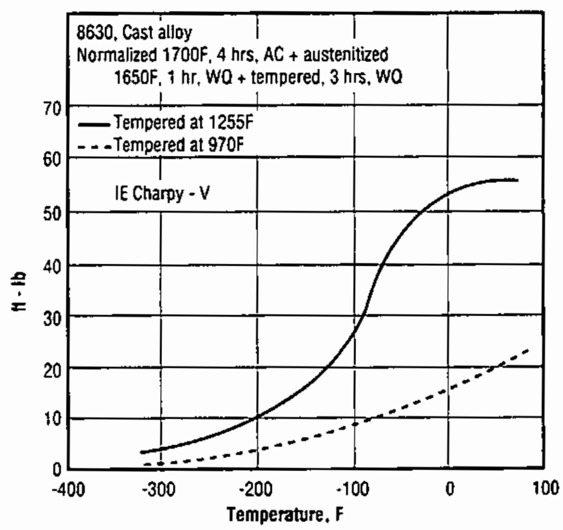

Fig. 3.3.3.6 Effect of tempering temperature on impact energy of cast alloy at low temperatures (Ref. 35)

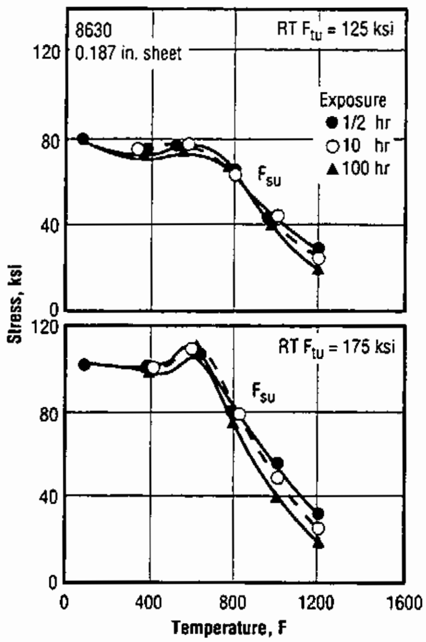

Fig. 3.3.5.1 Effects of exposures from one-half hour to 100 hours at test temperature on shear strength of sheet quenched and tempered to two F_{tu} levels (Ref. 27)

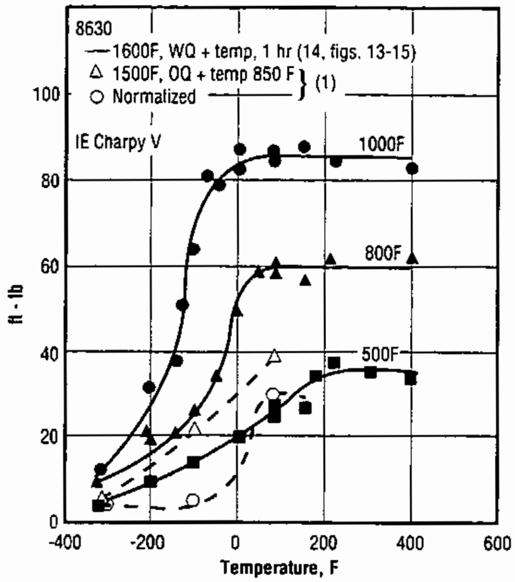

Fig. 3.3.6.1 Effects of exposures from one-half hour to 100 hours at test temperature on bearing properties of sheet quenched and tempered to two F_{tu} levels (Ref. 1, 14)

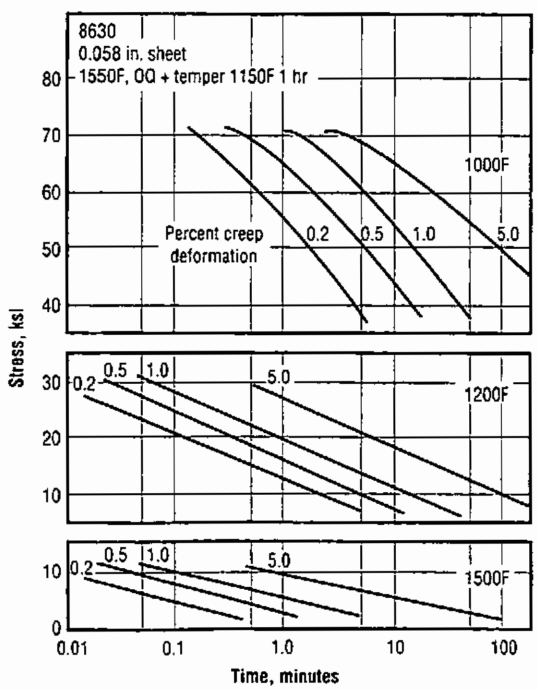

Fig. 3.4.1 Short-time creep properties of sheet heat treated to an F_{tu} level of 125 ksi (Ref. 10)

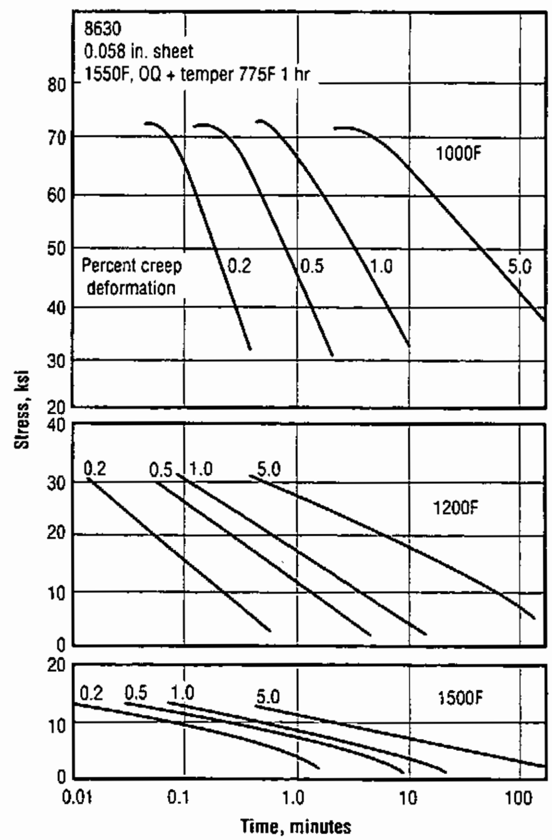

Fig. 3.4.2 Short-time creep properties of sheet heat treated to an F_{tu} level of 180 ksi (Ref. 10)

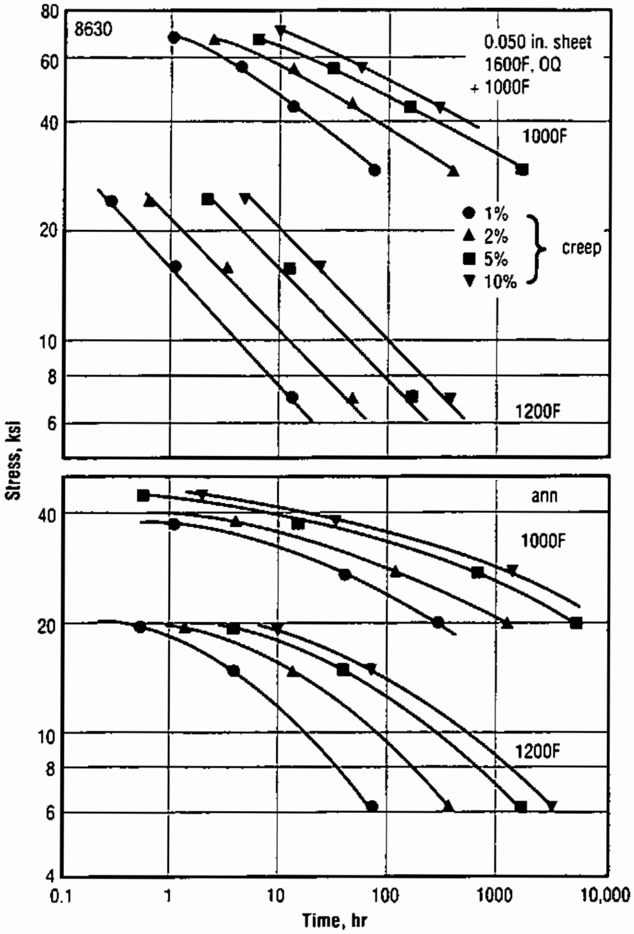

Fig. 3.4.3 Long-time creep properties of sheet in the annealed and quenched-and-tempered conditions (Ref. 25)

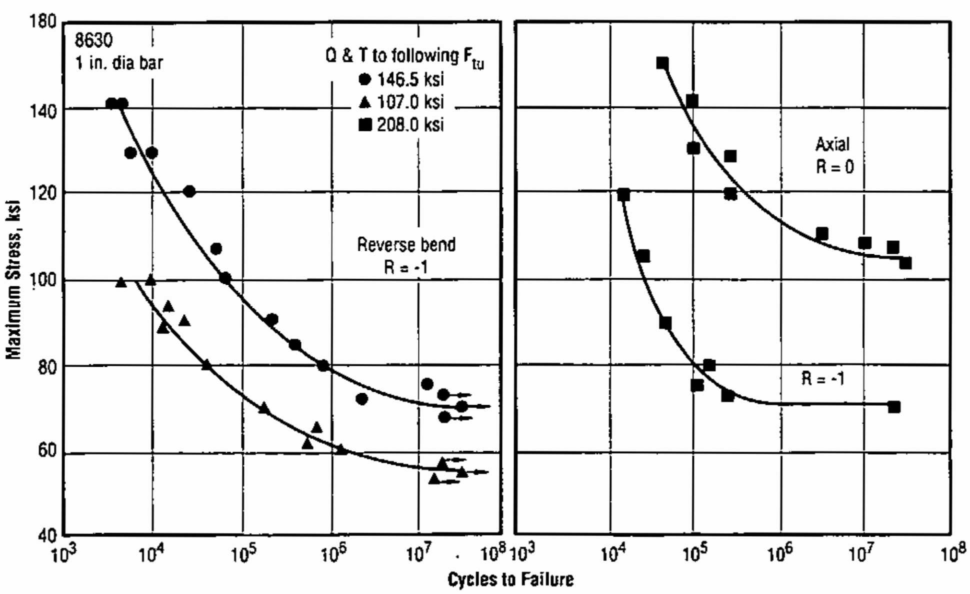

Fig. 3.5.1 Fatigue properties of bar at several strength levels and under various loading conditions (Ref. 11)

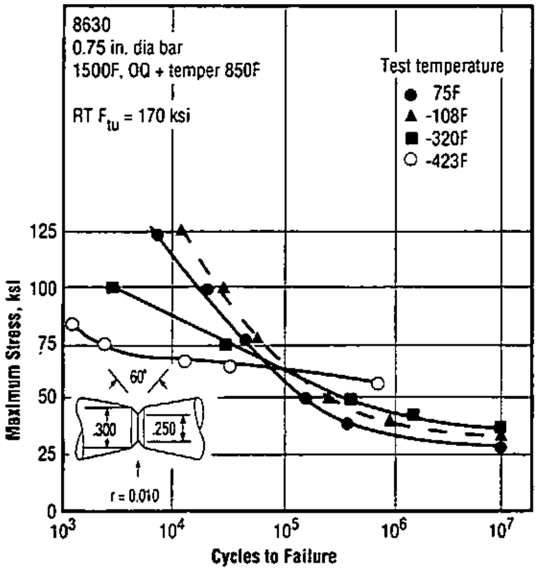

Fig. 3.5.2 Low-temperature fatigue properties of notched bar (Ref. 9)

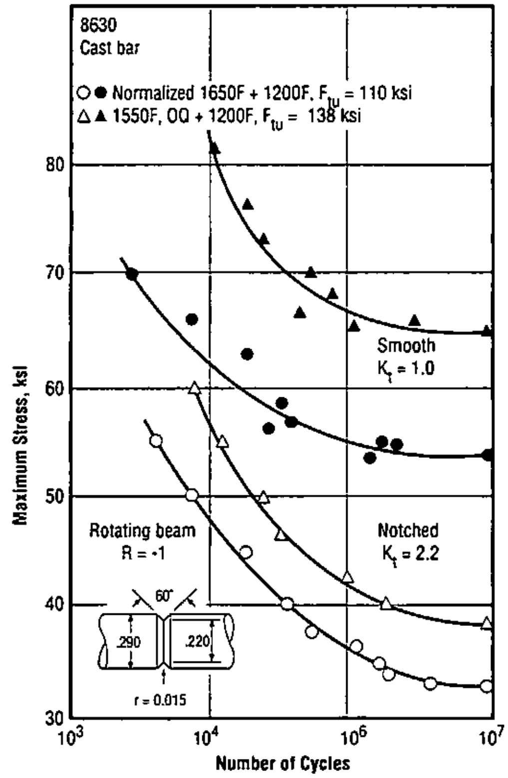

Fig. 3.5.3 Fatigue properties of castings in the normalized-and-tempered and quenched-and-tempered conditions (Ref. 7)

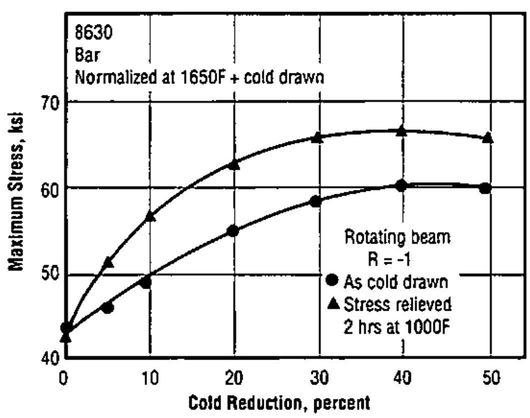

Fig. 3.5.4 Effects of cold work on fatigue endurance limit at 10^7 cycles (Ref. 14)

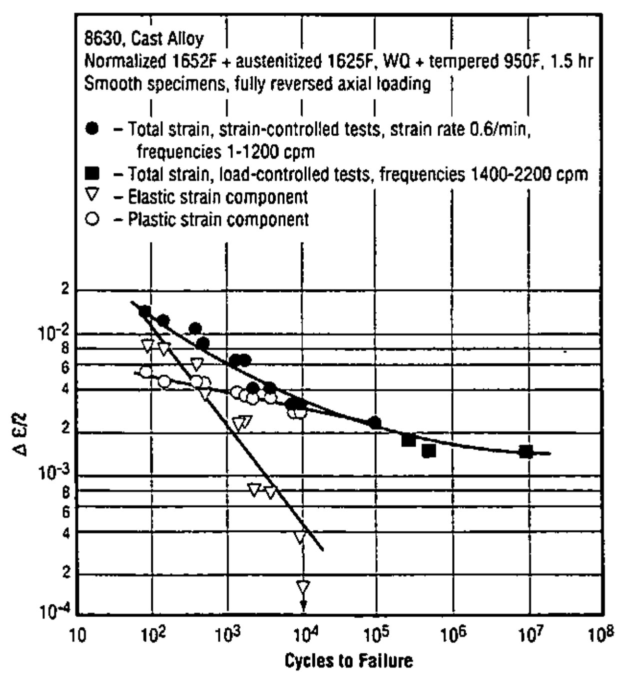

Fig. 3.5.5 Fatigue behavior of cast alloy at room temperature (Ref. 34)

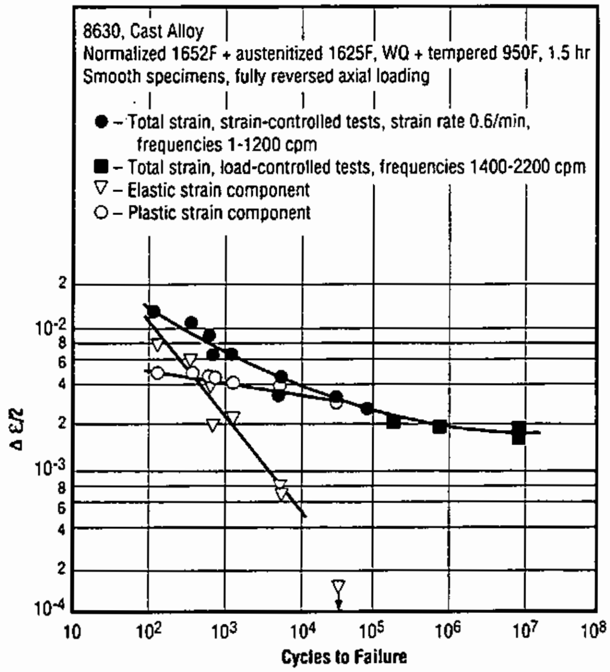

Fig. 3.5.6 Fatigue behavior of cast alloy at -50F (Ref. 34)

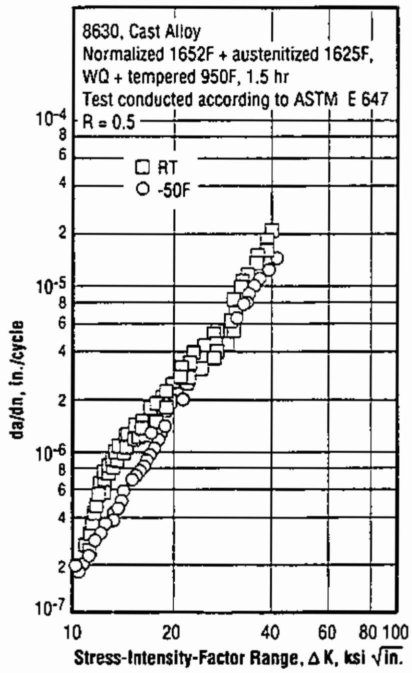

Fig. 3.5.7 Fatigue crack growth rate for cast alloy at R = 0.5 (Ref. 34)

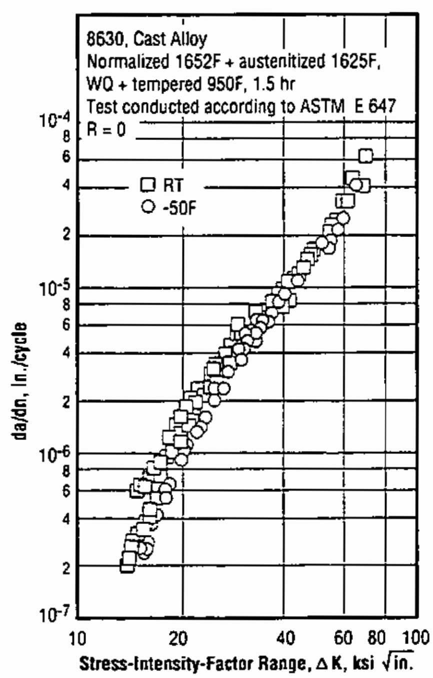

Fig. 3.5.8 Fatigue crack growth rate for cast alloy at R = 0 (Ref. 34)

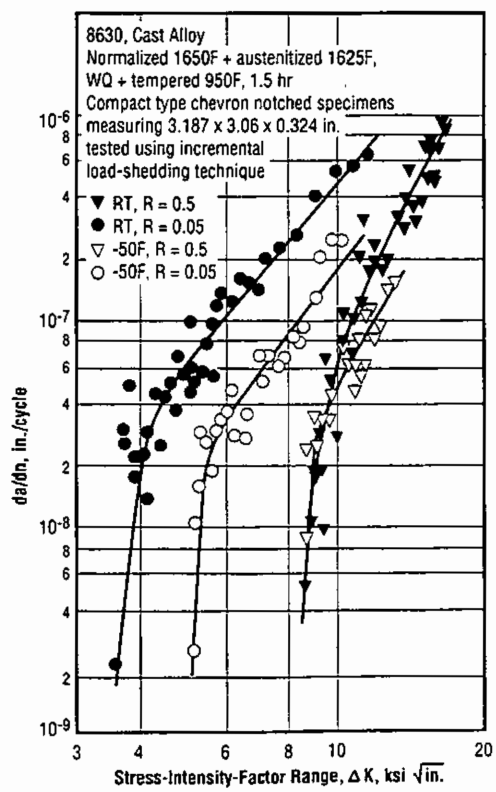

Fig. 3.5.9 Threshold and near-threshold fatigue crack growth rates for cast alloy at room temperature and -50F (Ref. 36)

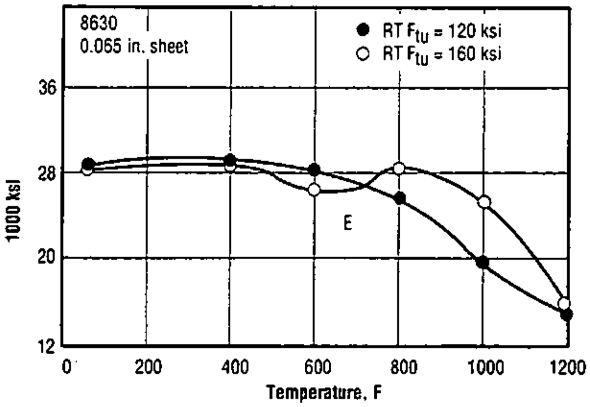

Fig. 3.6.2.1 Effects of temperature on modulus of elasticity in tension for sheet quenched and tempered to two F_{tu} levels (Ref. 27)

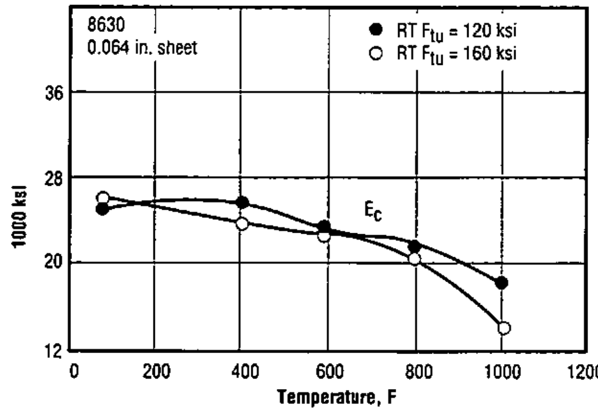

Fig. 3.6.2.2 Effect of temperature on modulus of elasticity in compression for sheet quenched and tempered to two F_{tu} levels (Ref. 27)

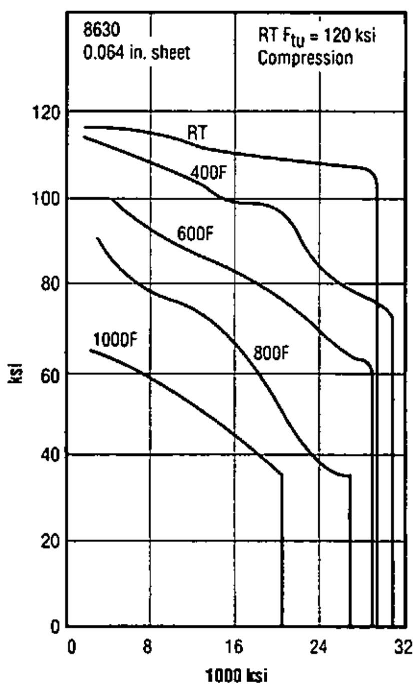

Fig. 3.6.4.1 Tangent modulus curves in compression at room and elevated temperatures for sheet quenched and tempered to 120 ksi F_{tu} (Ref. 27)

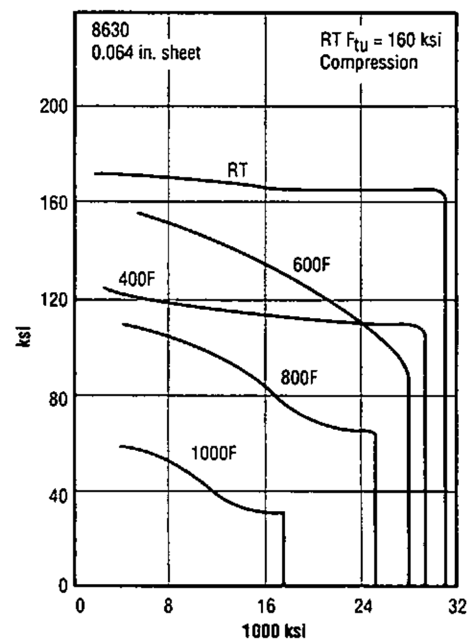

Fig. 3.6.4.2 Tangent modulus curves in compression at room and elevated temperatures for sheet at 160 ksi room temperature F_{tu} (Ref. 15)

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