**Fe**
**17 Cr**
**7 Ni**
**1 Al**

# 1 General

17-7PH is a semiaustenitic grade of precipitation-hardening stainless steel, which can be readily formed and welded in the annealed condition and subsequently heat treated with minimum distortion to tensile strength levels exceeding 200 ksi. It retains good strength at temperatures up to 900F, but its notched impact resistance is reduced at subzero temperatures. Its corrosion resistance is superior to that of the hardenable martensitic "400-series" stainless steels and in some environments approaches that of the austenitic "300-series" grades. Because of its good combination of strength and corrosion resistance, the alloy has a wide variety of uses ranging from aircraft structural parts to surgical instruments. With excellent spring properties at temperatures up to 600F, hard-drawn 17-7PH is used in many types of springs made of both flat and round wire for aircraft instruments and controls, processing equipment, and automotive and appliance components (Refs. 14, 15, 17, 19).

## 1.1 Commercial Designation

17-7PH.

## 1.2 Alternate Designations

AISI Type 631, UNS S17700.

## 1.3 Specifications

1.3.1 *[Table]* Specifications.

## 1.4 Composition

1.4.1 *[Table]* Composition.

## 1.5 Heat Treatment

1.5.1 General. Type 17-7PH is most often supplied by the producing mills in the solution-treated condition (Condition A), in which it is relatively soft, ductile, and readily fabricated. Following fabrication, it is normally strengthened by one of two alternative precipitation-hardening treatments resulting in Condition RH950 or TH1050 (Refs. 7, 8, 9, 14, 15, 20, 45, 46, 47).

1.5.1.1 Condition A, solution-treated (also annealed): 1900-1950F, cool to room temperature. Specifications recommend 1900F and water quench for bars, shapes, and forgings (Refs. 8, 9). For sheet, plate, strip, and tubing, they generally recommend 1950F and air cool or faster, which presumably implies liquid quench for heavy sections and air cool for thin sections (Refs. 7, 45, 46, 47).

1.5.1.2 Condition RH950, precipitation-hardened: 1750F 10 minutes, air cool to room temperature (results in Condition A1750), cool within 24 hours to -100F, hold 8 hours, warm in air to room temperature (results in Condition R100), age 1 hour at 950F, air cool (results in Condition RH950).

1.5.1.3 Condition TH1050, precipitation-hardened: 1400F 90 minutes, cool to 50-60F within one hour, hold 30 minutes (results in Condition T), age 90 minutes at 1050F, air cool (results in Condition TH1050).

1.5.1.4 For improved ductility and notch toughness but lower strength in wrought products and weldments (see also Section 4.3.1 and Table 4.3.1.2), overaging, that is, higher final aging temperatures, may be employed, for example 1100F, resulting in Condition RH1100 or TH1100.

1.5.1.4.1 *[Figure]* Effect of RH aging temperature (1 hr) on tensile properties of sheet after prior treatment to Condition R100.

1.5.1.4.2 *[Figure]* Effect of RH aging treatment (1 hr) on tensile strength and sharp-notch strength of sheet after prior treatment to Condition R100.

1.5.2 In-process anneals, equivalent to Condition A solution treatment, may be required to restore the ductility of cold-worked material so that it can take additional drawing or forming. In order to develop full strength, severely cold-worked material requires an anneal prior to heat treatment to Condition TH1050; no anneal or cold-worked material is necessary prior to RH-type treatments (Ref. 19).

1.5.2.1 *[Figure]* Effect of cold work introduced in Condition A on tensile properties of sheet subsequently heat treated to Condition TH1050 without an intermediate anneal.

1.5.2.2 *[Figure]* Effect of cold work introduced in Condition A1750 on tensile properties of the alloy after subsequent completion of the RH950 heat treatment.

1.5.3 Strip and wire can be provided by the mills after 60 percent cold reduction, resulting in Condition C. Condition C is usually aged (precipitation hardened) at 900F, 1 hour, and air cooled, resulting in Condition CH900. Springs, for example, are normally fabricated in Condition C, and then aged to Condition CH900 to provide an optimum combination of high strength and elasticity, corrosion resistance, and dimensional stability (Refs. 7, 14, 15, 17).

If somewhat lower strength is acceptable, springs can be treated at 1000 to 1050F to eliminate residual forming stresses while still maintaining good spring properties for room-temperature applications. This treatment results in a constant spring rate (Ref. 17).

1.5.4 When the alloy is heat treated from Condition A to Condition RH950 or TH1050, dimensional changes occur consisting of an expansion of 0.0045 in. per in. during the low-temperature exposure and a contraction of 0.0005 in. per in. during the elevated-temperature aging treatment, resulting in a net expansion of 0.0040 in. per in. When the cold-worked material (Condition C) is aged at 900F to produce Condition CH900, only the 0.0005 in. per in. contraction occurs (Refs. 15, 17, 19).

1.5.5 Air is often a satisfactory furnace atmosphere for heat treating and annealing operations. Controlled reducing atmospheres such as dissociated ammonia or bright-annealing gas introduce the hazards of nitriding and carburizing, which can be detrimental to mechanical properties. For treatments at 1750F and above, essentially scale-free surfaces can be obtained with atmospheres of dry hydrogen, argon, or helium (dew point -75F), but these atmospheres tend to be less effective at lower temperatures because of the extremely low dew point required. For complete freedom from scale or heat discoloration, a vacuum furnace is required. Solution treating (1900F) or austenite conditioning (1750 or 1400F) in molten salts is not recommended because of the danger of carburization or intergranular penetration. Hardening in the 900-1200F range can be done successfully in certain hydride or nitrate salts. The -100F temperature requirement during the RH heat treatment can be achieved with suitable commercial refrigeration equipment or with a saturated bath of dry ice in alcohol or acetone (Refs. 17, 19).

1.5.6 The alloy should be thoroughly cleaned prior to heat treatment to facilitate scale removal and to prevent carburization from organic contamination such as oils and lubricants. Cleaning can be accomplished, first by means of solvents or vapor degreasing, followed by mechanical scrubbing with mild abrasive cleaners to remove insoluble contaminants, and, finally, thorough water rinsing (Ref. 19).

### 1.6 Hardness

1.6.1 *[Table]* Hardness in various heat-treated conditions at room temperature.

1.6.2 *[Figure]* Effects of exposures up to 1000 hours at 600, 800, and 1000F on the room-temperature hardness of sheet in Condition RH950.

### 1.7 Forms and Conditions Available

1.7.1 In Condition A, the alloy is available in the form of sheet, strip, plate, bar, rod, wire, tubing, billets, shapes, and forgings (Refs. 7, 8, 9, 14, 15, 16).

1.7.2 In Condition C, sheet and strip (0.050 in. and thinner) and wire are also available (Refs. 15, 19).

### 1.8 Melting and Casting Practice

1.8.1 The alloy is normally produced in conventional electric-arc furnaces. For optimum quality, vacuum consumable-electrode or electroslag remelt can be employed.

### 1.9 Special Considerations

1.9.1 In heavy sections, the alloy tends to have inferior mechanical properties, particularly ductility and notch strength, in the transverse orientations (see Figures 3.3.7.1.4 and 3.3.7.1.5). For this reason, most applications involve relatively thin sections. In many instances, however, forgings can be successfully applied where the configurations permit directional flow to be developed in the direction of load application (Ref. 41).

1.9.1.1 *[Table]* Effect of section size and orientation on tensile strength and ductility.

1.9.2 Long-time exposures to temperatures in the range 600 to 900F tend to have a strengthening but embrittling effect on the room-temperature properties of 17-7PH as well as on other semiaustenitic and martensitic precipitation-hardening stainless steels (see Figure 3.2.1.4 and Table 3.2.1.5). The embrittlement is reversible by reapplying the precipitation-hardening (final aging) temperature if it is 1025F or higher (Ref. 4). Elevated-temperature strength in the same temperature range is also increased by long exposures at temperature prior to testing (see Figures 3.3.1.13, 3.3.1.14, 3.3.2.6, 3.3.5.3, 3.3.6.1, and 3.3.6.2).

1.9.3 In Conditions RH950 and TH1050, the notched-impact resistance of 17-7PH is generally low at subzero temperatures. The impact values can be improved, while strength properties are decreased, by overaging; that is, by final aging temperatures of 1100F and above (see Figures 3.3.3.1, 3.3.3.2).

1.9.4 Radial cracks running parallel to the wire axis have been observed to form occasionally in spring wire during the cold-drawing process or after a certain incubation period. This phenomenon appears to be an effect of the formation of strain-induced martensite in combination with a high content of aluminum-oxide inclusions. Since martensite formation is essential to the development of the desired spring properties, the cracking tendency should be minimized by the use of clean steel (low content of nonmetallic inclusions). The cracking tendency also appears to decrease with smoother surfaces on the rods from which the wire is drawn (Ref. 44).

## 2 Physical Properties and Environmental Effects

### 2.1 Thermal Properties

2.1.1 Melting Range, 2560 to 2620F (Ref. 23).

2.1.2 Phase Changes.

2.1.2.1 Time-temperature-transformation diagrams.

2.1.2.2 The microstructure of the alloy is mostly austenite, normally with 10 to 15 percent ferrite, in the solution-treated condition (Condition A). Heating to temperatures of 1400 or 1750F destabilizes the austenite by rejecting carbon, greater destabilization occurring at the lower temperature. As a result, austenite conditioned at 1400F and 1750F, respectively, transforms to martensite when cooled to about 55F and -100F. Subsequent heating to temperatures in the range 900 to 1150F causes the precipitation of nickel-aluminum compounds from the martensite (Refs. 10, 14, 15, 21).

2.1.2.3 Cold working of the solution-treated alloy (Condition A) also causes transformation of the austenite to martensite (resulting in Condition C) and subsequent heating at 900F effects precipitation of nickel-aluminum compounds (resulting in Condition CH900) (Refs. 17, 19).

2.1.3 Thermal Conductivity.

2.1.3.1 *[Figure]* Effects of temperatures from 300 to 900F on thermal conductivity.

2.1.4 Thermal Expansion.

2.1.4.1 *[Figure]* Effects of temperatures from 200 to 800F on thermal expansion.

2.1.5 Specific Heat.

2.1.5.1 *[Figure]* Effects of temperatures up to 2000F on specific heat.

2.1.6 Thermal Diffusivity.

### 2.2 Other Physical Properties

2.2.1 Density.

2.2.1.1 *[Table]* Density in various heat-treated conditions at room temperature.

2.2.2 Electrical Properties.

2.2.2.1 *[Table]* Electrical properties in various heat-treated conditions at room temperature.

2.2.3 Magnetic Properties.

2.2.3.1 *[Table]* Magnetic permeability in various heat-treated conditions at room temperature.

2.2.4 Emittance.

2.2.4.1 *[Table]* Total normal emittance at temperatures from 400 to 900F.

2.2.5 Damping Capacity.

### 2.3 Chemical Environments

2.3.1 General Corrosion. The corrosion resistance of 17-7PH in Conditions TH1050 and RH950 in many chemical and atmospheric environments is generally superior to that of the standard hardenable chromium types of stainless steels such as Types 410, 420, and 431, but, overall, not quite as good as chrome-nickel austenitic grades such as Type 304 (Ref. 19).

2.3.1.1 *[Table]* Comparison of typical corrosion rates for 17-7PH and Type 304 stainless steels in seven common chemical reagents.

2.3.2 Stress Corrosion. When immersed in seawater, 17-7PH is susceptible to pitting, tunneling, and crevis types of corrosive attack, and also to stress-corrosion cracking in areas where appreciable applied or residual stresses exist (Ref. 1).

2.3.3 The alloy is resistant to corrosion in liquid oxygen, ammonia, and both liquid and gaseous hydrogen at low temperatures. At high pressures, however, hydrogen tends to cause embrittlement (Refs. 19, 28, 54).

2.3.3.1 *[Table]* Effects of high-pressure hydrogen atmosphere on tensile properties at room temperature.

2.3.4 The alloy is susceptible to stress-corrosion cracking in environments containing hydrogen sulfide (Refs. 17, 19).

2.3.5 Like other high-strength martensitic steels, hardened 17-7PH is susceptible to stress-corrosion cracking when subjected to tensile stresses in moist environments. This tendency is related to the level of tensile stress, the corrosiveness of the environment, and the heat-treated condition of the steel. Tests on 17-7PH sheet in marine environments have indicated that Condition CH900 provides the greatest resistance to stress-corrosion cracking; Condition TH1050, although somewhat less resistant than Condition CH900, appears to be more resistant than Condition RH950 (Ref. 19).

2.3.5.1 *[Table]* Threshold stress intensity factor ($K_{Iscc}$) for stress-corrosion cracking of bar in aerated 3.5 percent aqueous sodium-chloride solution.

### 2.4 Nuclear Environments

## 3 Mechanical Properties

### 3.1 Specified Mechanical Properties

3.1.1 *[Table]* AMS specified mechanical properties for plate, sheet, and strip.

3.1.2 *[Table]* ASTM specified properties for plate, sheet, and strip.

3.1.3 *[Table]* AMS specified mechanical properties for tubing.

3.1.4 *[Table]* AMS specified tensile strength for spring wire.

3.1.5 *[Table]* ASTM specified tensile strength for spring wire.

3.1.6 *[Table]* ASTM specified mechanical properties for longitudinal orientation in bars, shapes, and forgings.

### 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 spring wire at room temperature.

3.2.1.2 *[Figure]* Tensile stress-strain curves for sheet in longitudinal and transverse orientations for Conditions TH1050 and RH950.

3.2.1.3 *[Table]* Tensile properties in various heat-treated conditions at room temperature.

3.2.1.4 *[Figure]* Effects of 500-hour exposures at elevated temperatures up to 900F on tensile properties at room temperature of sheet in Conditions TH1050 and CH900.

3.2.1.5 *[Table]* Effects of 1000-hour exposures to elevated temperatures with load on tensile properties at room temperature of sheet in Conditions TH1050 and RH950.

3.2.2 Compression Stress-strain Diagrams and Compression Properties.

3.2.2.1 *[Figure]* Compression stress-strain curves for sheet in longitudinal and transverse orientations for Conditions TH1050 and RH950 at room temperature.

3.2.2.2 *[Table]* Typical compressive yield strengths at room temperature for various heat-treat conditions.

3.2.3 Impact, see Figures 3.3.3.1 and 3.3.3.2.

3.2.4 Bending.

3.2.5 Torsion and Shear, see Figures 3.3.5.1, 3.3.5.2, 3.3.5.3.

3.2.6 Bearing, see Figures 3.3.6.1 and 3.3.6.2.

3.2.6.1 *[Table]* Bearing properties of sheet at room temperature in Conditions TH1050 and RH950.

3.2.7 Stress Concentration.

3.2.7.1 Notch properties, see Figures 3.3.7.1.1 through 3.3.7.1.5.

3.2.7.1.1 *[Table]* Crack strength of plate at room temperature in Condition RH1050.

3.2.7.2 Fracture toughness, see Table 2.3.5.1.

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]* Tensile stress-strain curves at temperatures from -423F to 1000F for sheet in Condition TH1050.

3.3.1.2 *[Figure]* Tensile stress-strain curves at temperatures from 75F to 1000F for sheet in Condition RH950.

3.3.1.3 *[Figure]* Tensile stress-strain curves for sheet in Condition CH900 at temperatures up to 1200F under conditions of rapid heating, rapid loading, and short time at temperature.

3.3.1.4 *[Figure]* Tensile stress-strain curves at temperatures up to 2000F for sheet in Condition TH1050 loaded at a strain rate of 0.0002 in. per in. per second.

3.3.1.5 *[Figure]* Tensile stress-strain curves at temperatures up to 2000F for sheet in Condition TH1050 loaded at a strain rate of 0.002 in. per in. per second.

3.3.1.6 *[Figure]* Tensile stress-strain curves at temperatures up to 2000F for sheet in Condition TH1050 loaded at a strain rate of 0.02 in. per in. per second.

3.3.1.7 *[Figure]* Tensile stress-strain curves for sheet in Condition TH1050 when simultaneously loaded at a strain rate of 0.0002 in. per in. per second and heated at rates of 2.5 to 19.5F per second.

3.3.1.8 *[Figure]* Tensile stress-strain curves for sheet in Condition TH1050 when simultaneously loaded at a strain rate of 0.002 in. per in. per second and heated at rates of 20 to 220F per second.

3.3.1.9 *[Figure]* Tensile stress-strain curves for sheet in Condition TH1050 when simultaneously loaded at a strain rate of 0.02 in. per in. per second and heated at rates of 400 to 2000F per second.

3.3.1.10 *[Figure]* Effects of temperature up to 1000F on tensile properties of sheet in Conditions TH1050 and RH950.

3.3.1.11 *[Figure]* Effects of low temperatures down to -423F on tensile properties of sheet in Condition TH1050.

3.3.1.12 *[Figure]* Tensile properties of sheet in Condition TH1050 for various rates of loading at temperatures up to 1200F after rapid heating and holding times of 10 seconds and 1/2 hour at temperature.

3.3.1.13 *[Figure]* Tensile properties of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2 and 1000 hours at test temperature.

3.3.1.14 *[Figure]* Effects of test temperatures up to 1000F and of exposure time at temperature on tensile properties of sheet in Condition CH900.

3.3.2 Compression Stress-strain Diagrams and Compression Properties.

3.3.2.1 *[Figure]* Compressive stress-strain curves for sheet in Condition TH1050 at temperatures up to 1200F.

3.3.2.2 *[Figure]* Compressive stress-strain curves for sheet in Condition RH950 at temperatures up to 1000F.

3.3.2.3 *[Figure]* Compressive stress-strain curves for sheet in Condition TH1050 at 800 and 900F after two different exposure times at temperature.

3.3.2.4 *[Figure]* Effects of temperatures up to 1200F on the compressive yield strength of sheet in both the TH1050 and annealed (solution-treated) conditions.

3.3.2.5 *[Figure]* Effects of elevated temperatures and of exposure time at temperature on the compressive yield strength of sheet in Conditions TH1050 and RH950.

3.3.2.6 *[Figure]* Compressive yield strength of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2, 100, and 1000 hours at temperature.

3.3.3 Impact.

3.3.3.1 *[Figure]* Effects of low temperatures on impact resistance in Conditions TH1050 and TH1150.

3.3.3.2 *[Figure]* Impact resistance over a wide range of temperature of bar in various conditions.

3.3.4 Bending.

3.3.5 Torsion and Shear.

3.3.5.1 *[Figure]* Ultimate shear strength of sheet in Conditions TH1050 and RH950 at temperatures up to 1000F.

3.3.5.2 *[Figure]* Ultimate shear strength of plate in Condition RH950 at temperatures up to 1000F after holding times of 1/2, 100, and 1000 hours at test temperature.

3.3.5.3 *[Figure]* Ultimate shear strength of sheet in Condition TH1050 at temperatures up to 900F after holding times of 1/2, 100, and 1000 hours at test temperature.

3.3.6 Bearing.

3.3.6.1 *[Figure]* Bearing properties (e/D = 1.5) of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2 and 1000 hours at test temperature.

3.3.6.2 *[Figure]* Bearing properties (e/D = 2.0) of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2 and 1000 hours at test temperature.

3.3.7 Stress Concentration.

3.3.7.1 Notch properties.

3.3.7.1.1 *[Figure]* Notch strength and tensile strength of sheet in Condition TH1050 at temperatures down to -423F.

3.3.7.1.2 *[Figure]* Comparison of tensile and notch tensile properties at temperatures up to 800F for sheet in Condition RH950.

3.3.7.1.3 *[Figure]* Comparison of tensile and notch tensile properties at temperatures up to 800F for sheet in Condition TH1050.

3.3.7.1.4 *[Figure]* Comparison of tensile and notch tensile properties at temperatures up to 800F for forging in Condition RH950.

3.3.7.1.5 *[Figure]* Comparison of tensile and notch tensile properties at temperatures up to 800F for forging in Condition TH1050.

3.3.7.2 Fracture toughness.

3.3.7.2.1 *[Figure]* Fracture toughness, tensile strength, and yield strength of plate in Condition TH1050 at various temperatures.

3.3.8 Combined Properties.

### 3.4 Creep and Creep Rupture Properties

3.4.1 *[Figure]* Creep properties of sheet in Condition TH1050 at temperatures from 600 to 900F.

3.4.2 *[Figure]* Effect of temperature on tensile stress required to cause creep rupture in 100 and 1000 hours for sheet in various heat-treated conditions.

3.4.3 *[Figure]* Effect of temperature on tensile stress required to cause 0.1 and 0.2 percent creep deformation in 1000 hours for sheet in two heat-treated conditions.

3.4.4 *[Figure]* Isochronous stress-strain curves at 600 to 900F for sheet in Condition RH950.

3.4.5 *[Figure]* Isochronous stress-strain curves at 600 to 900F for sheet in Condition TH1050.

3.4.6 *[Figure]* Short-time creep and rupture properties of sheet in Condition TH1050 at temperatures from 800 to 1200F.

3.4.7 *[Figure]* Short-time creep and rupture properties of sheet in Condition CH900 at temperatures from 800 to 1200F.

3.4.8 *[Figure]* Short-time total strain curves at 600 to 900F for sheet in Condition TH1050.

3.4.9 *[Figure]* Creep-rupture curves at 600 to 900F for smooth and notched sheet in Condition TH1050.

3.4.10 *[Figure]* Loss of load due to stress relaxation of helical compression springs held at constant length and at temperatures from 450 to 750F for 96 hours.

3.4.11 *[Table]* Effects of wire diameter, preset stress, and initial stress on stress relaxation of helical extension springs held at constant extension at room temperature for 100 hours.

### 3.5 Fatigue Properties

3.5.1 *[Figure]* Flexural fatigue properties at room and low temperatures for sheet in Condition TH1050.

3.5.2 *[Figure]* Flexural fatigue properties at room and low temperatures for notched sheet ($K_t$=3.0) in Condition RH950.

3.5.3 *[Figure]* Flexural strain-cycling fatigue curves at room and low temperatures for sheet in Condition RH950.

3.5.4 *[Figure]* Constant-life fatigue curves at room temperature for smooth and notched sheet in Condition RH950.

3.5.5 *[Figure]* Constant-life fatigue curves at 600F for smooth and notched sheet in Condition RH950.

3.5.6 *[Figure]* Constant-life fatigue curves at 800F for smooth and notched sheet in Condition RH950.

3.5.7 *[Figure]* Constant-life fatigue curves at room temperature for smooth and notched sheet in Condition TH1050.

3.5.8 *[Figure]* Constant-life fatigue curves at 600F for smooth and notched sheet in Condition TH1050.

3.5.9 *[Figure]* Constant-life fatigue curves at 800F for smooth and notched sheet in Condition TH1050.

3.5.10 *[Figure]* Constant-life fatigue curves at room temperature for smooth and notched forging in Condition RH950.

3.5.11 *[Figure]* Constant-life fatigue curves at 600F for smooth and notched forging in Condition RH950.

3.5.12 *[Figure]* Constant-life fatigue curves at 800F for smooth and notched forging in Condition RH950.

3.5.13 *[Figure]* Constant-life fatigue curves at room temperature for smooth and notched forging in Condition TH1050.

3.5.14 *[Figure]* Constant-life fatigue curves at 600F for smooth and notched forging in Condition TH1050.

3.5.15 *[Figure]* Constant-life fatigue curves at 800F for smooth and notched forging in Condition TH1050.

3.5.16 *[Table]* Effects of wire diameter and surface condition on the fatigue endurance limit of helical compression springs at room temperature.

3.5.17 *[Table]* Effect of surface protection with dodecyl alcohol on fatigue crack initiation and propagation of notched bar.

### 3.6 Elastic Properties

3.6.1 Poisson's Ratio.

3.6.2 Modulus of Elasticity.

3.6.2.1 *[Figure]* Modulus of elasticity at various temperatures.

3.6.2.2 *[Figure]* Effects of temperatures up to 1200F on the modulus of elasticity in compression of sheet.

3.6.3 Modulus of Rigidity.

3.6.3.1 *[Figure]* Modulus of rigidity at room and elevated temperatures.

3.6.3.2 *[Figure]* Effects of temperatures from -105 to 750F on modulus of rigidity of spring wire.

3.6.4 Tangent Modulus.

3.6.4.1 *[Figure]* Tangent-modulus curves in tension at room temperature for sheet in Conditions TH1050 and RH950.

3.6.4.2 *[Figure]* Tangent-modulus curves in compression for sheet in Condition TH1050 at temperature up to 1200F.

3.6.4.3 *[Figure]* Tangent-modulus curves in compression for sheet in Condition RH950 at room temperature and 600F, showing effects of prior exposure at 600F.

3.6.4.4 *[Figure]* Tangent-modulus curves in compression for sheet in Condition RH950 at 800 and 1000F, showing effects of prior exposure to test temperature.

3.6.5 Secant Modulus.

## 4 Fabrication

### 4.1 Forming

4.1.1 Cold Forming.

4.1.1.1 Type 17-7PH in Condition A has cold-forming characteristics similar to those of Type 301 austenitic stainless steel (Code 1301). Because of its high rate of work hardening, which leads to large spring back, intermediate annealing (Condition A) may be required in deep drawing or forming intricate parts. When Condition TH1050 is desired in the final product, severely cold-worked material should be fully heat treated starting with the Condition A anneal; but when Condition RH950 is desired, the 1750F conditioning treatment serves the purpose of an anneal (Ref. 19, see also Sections 1.5.1.1, 1.5.1.2, 1.5.1.3 and Figures 1.5.2.1, 1.5.2.2, and 4.1.1.6.2).

4.1.1.2 *[Figure]* Effect of cold work on tensile properties of sheet given less cold reduction than required for Condition C (see Section 1.5.3).

4.1.1.3 *[Figure]* Effect of cold work on tensile properties of sheet given less cold reduction than required for Conditions C and CH900 and then aged for one hour at 900F (see Section 1.5.3).

4.1.1.4 *[Figure]* Effect of cold work on hardness of sheet given less cold reduction than required for Conditions C and CH900 (see Section 1.5.3).

4.1.1.5 Parts that are to be used in the hardened condition but are fabricated in Condition A should be made undersize by the proper amount to compensate for the dimensional changes that occur during heat treatment (see Section 1.5.4).

4.1.1.6 Shear forming (Ref. 26).

4.1.1.6.1 *[Figure]* Effect of percent reduction by shear forming on tensile properties.

4.1.1.6.2 *[Figure]* Effects of shear forming and subsequent heat treatment on hardness (see Sections 1.5.2 and 4.1.1.1).

4.1.2 Hot Forming.

4.1.2.1 Forging practices are similar to those used for austenitic stainless steels such as Type 302. Forging temperature should not exceed 2250F, but scale loss will be lessened with lower forging temperatures of 2150F or less. There is no critical temperature range in which the alloy may not be worked. The alloy may be charged into either a hot or cold furnace, and air cooling or oil or water quenching may be employed (Ref. 17).

## 4.2 Machining and Grinding

4.2.1 The alloy is normally machined in Condition A, T, or R100 (see Sections 1.5.1.1, 1.5.1.2, and 1.5.1.3) with characteristics somewhat similar to those of Type 302 austenitic stainless steel (Code 1301), requiring maximum feed at low speeds. Machining in Condition T or R100 results in minimum dimensional changes during subsequent precipitation-hardening treatment. One comparative classification rates the machinability of Type 17-7PH and Type 302 as 33 percent and 50 percent respectively, based on 100 percent for AISI B1112 using high-speed steel cutting tools (Refs. 15, 17, 25).

## 4.3 Joining

4.3.1 Whereas 17-7PH can be welded by most of the arc and resistance processes used for stainless steel, the gas-tungsten-arc (GTA) process is the preferred method. The heat of welding effectively solution treats the zone immediately adjacent to the weld. Therefore, regardless of the condition of the base metal prior to welding, the as-deposited welds and heat-affected zones are normally relatively soft with strength comparable to that of the alloy in Condition A. The steel, therefore, may be welded in any condition of heat treatment without preheat and without critical control of interpass temperature or postweld cooling rate. When matching filler metal is used, which responds to heat treatment similarly to the base metal, improved weld strength can be obtained by full postweld RH or TH type heat treatment. Because they enhance weld ductility, either TH1100 or RH1100 is frequently the preferred postweld treatment, although TH1050 and RH950 provide higher strength. Conditions C and CH900, which require cold work, are not normally obtainable in welds. Filler metals consisting of standard grades of austenitic stainless steels, such as Type 308L, can be employed, but they do not respond to precipitation-hardening heat treatment; consequently the joints are relatively tough and ductile, but strength levels are less than those obtainable with the matching precipitation-hardenable grade. To achieve best ductility, welders should use helium shielding, stringer-bead practice, slow weld travel speeds, and low current (Refs. 6, 21).

4.3.1.1 Fusion weld deposits of 17-7PH tend to form more ferrite in their microstructures than is normally present in wrought products. Excessive amounts of ferrite in the deposits can result in hot cracking or embrittlement. Susceptibility to these weld deficiencies is governed, largely, by the composition balance of the deposit and the amount of ferrite that the composition retains in the weld microstructure. In addition, susceptibility tends to become more pronounced with thicker weld beads, higher welding current, and faster welding speed. Fusion welds in light-gage sheet up to 0.037 in. made single pass with square-butt edges generally have low ferrite contents resulting in reasonably good toughness over a range of heat-treated strengths. Welds in intermediate-gage sheets (0.037-0.093 in.) are best used in an overaged condition, that is, TH1100 or RH1100. For weldments in heavy material where single-pass weld deposits may have excessive ferrite contents, multipass weld practice should be considered (Ref. 21).

4.3.1.2 *[Table]* Tensile properties determined on sheet with butt welds across the gage length of the test specimens.

4.3.1.3 *[Table]* Comparison of tensile properties at both room and elevated temperatures of sheets in Condition TH1075 with the same sheets containing butt welds (as-welded) across the gage length of the test specimens.

4.3.2 Resistance spot and seam welding can be performed on 17-7PH with good results that satisfy the requirements of NIL-W-6858B. Normally, best results are obtained by welding just before or after the final hardening treatment, which leaves the nugget in a tough, but relatively soft, austenitic condition (Ref. 21).

4.3.2.1 *[Table]* Shear strength of spot-welded joints.

4.3.3 Type 17-7PH can be brazed with either torch- or furnace-brazing methods. In torch brazing and in furnace brazing in an air atmosphere, fluxes are necessary. However, by using a controlled atmosphere, for which argon or helium is preferred, bright furnace brazing can be done without flux. Atmospheres containing either carbonaceous materials or dissociated ammonia should not be used since carburizing and nitriding impair mechanical properties. Typical brazing alloys that are suitable for high-temperature brazing (above 1500F) are the silver-base alloys containing manganese or copper, sometimes with additions of lithium, which provides a fluxing action. A typical alloy for low-temperature brazing (below 1500F) is one containing about 50 percent silver with additions of copper, zinc, nickel, and cadmium. Other common brazing alloys such as copper, nickel-base alloys, and alloys containing silicon or boron have a high penetration rate into the base metal, which can cause embrittlement.

Type 17-7PH is usually brazed in Condition A and then transformed and aged (see Sections 1.5.1.2 and 1.5.1.3); brazing after transformation is not recommended. If an entire RH or TH type transformation-and-age cycle is to be carried out after brazing, the melting point of the brazing alloy must be high enough to hold the joints together during the 1750 or 1400F stage of the cycle. On the other hand, it is often possible to combine the brazing and heat-treat cycles producing base-metal mechanical properties similar to those of the standard heat treatments. For example, if the brazing can be carried out at about 1750F (high-temperature) or 1400F (low-temperature) the brazing operation can also be the first step in a standard RH or TH cycle, with subsequent steps to be carried out as given in Sections 1.5.1.2 or 1.5.1.3. If the brazing temperature must differ from the recommended austenite-conditioning temperatures, properly modified heat-treat procedures are capable of providing base-metal mechanical properties approaching those of the standard TH1050 and RH950 heat treatments (Ref. 21).

## 4.4 Surface Treating

4.4.1 Wet grit blasting is the preferred method of scale removal because it avoids the hazard of intergranular attack from acid pickling, and it provides possible advantages of better fatigue resistance and corrosion resistance. For parts that have been thoroughly cleaned prior to heat treatment (see Section 1.5.5), acid pickling with 10 percent nitric acid plus 2 percent hydrofluoric acid, if properly controlled, can be effective particularly for the removal of light discoloration or heat tint produced by final hardening treatment at 900-1200F. An alternative descaling method, particularly effective for heavy scales and poorly cleaned parts, is the use of one of the commercially available salt-bath conditioning treatments followed by the nitric-plus-hydrofluoric acid pickle. However, fused-salt conditioning should not be used on material in Condition A1750 since it will inhibit maximum transformation upon subsequent refrigeration. In such instances a boiling aqueous solution of 10 percent sodium hydroxide plus 3 percent potassium permanganate may be substituted for the fused salt. If the effective operating temperature range for the conditioning salt bath, as recommended by the manufacturer, is compatible with the final precipitation-hardening temperature, the two operations may be combined (Refs. 17, 19).

4.4.2 Certain military applications require dark, nonreflective finishes. One study showed the following effects of various blackening processes on the corrosion resistance of 17-7PH and other precipitation-hardening stainless steels: (1) black chromium plating improves corrosion resistance; (2) zinc phosphate coatings improve corrosion resistance but form a gray-colored surface; (3) alkaline-oxidizing treatments slightly reduce corrosion resistance; and (4) molten dichromate coatings significantly reduce corrosion resistance (Ref. 43).

Table 1.3.1 Specifications (Refs. 17, 19, 27, 45-49)

| Alloy: 17-7PH | |
|---|---|
| Specification | Form |
| AMS 5528E | Sheet, strip, and plate, solution treated |
| AMS 5529D | Sheet and strip, cold rolled |
| AMS 5568C | Welded tubing |
| AMS 5644 | Bars and forgings (non-current) |
| AMS 5678B | Wire, spring temper |
| AMS 5824B | Welding wire |
| ASTM A 313 | Spring wire, Type 631 |
| ASTM A 564 | Bars and shapes, Type 631 |
| ASTM A 579 | Forgings, Grade 62 |
| ASTM A 693 | Plate, sheet, and strip, Type 631 |
| ASTM A 705 | Forgings, Type 631 |
| MIL-S-25043 | Plate, sheet, strip |
| QQ-S-766 | Plate, sheet, strip |

Table 1.4.1 Composition (Refs. 45-49)

| Alloy: 17-7PH | | | | | | |
|---|---|---|---|---|---|---|
| **Specification** | **AMS (45, 46, 47)** | | **AMS (48)** | | **AMS (49)** | |
| **Form** | **Sheet, Strip, Plate, Tubing** | | **Wire, Spring Temper** | | **Welding Wire** | |
| **Element** | **Percent** | | **Percent** | | **Percent** | |
| | **Min** | **Max** | **Min** | **Max** | **Min** | **Max** |
| Carbon | - | 0.09 | - | 0.09 | - | 0.09 |
| Manganese | - | 1.00 | - | 1.00 | - | 1.00 |
| Silicon | - | 1.00 | - | 1.00 | - | 0.50 |
| Phosphorus | - | 0.040 | - | 0.040 | - | 0.025 |
| Sulfur | - | 0.030 | - | 0.030 | - | 0.025 |
| Chromium | 16.00 | 18.00 | 16.00 | 18.00 | 16.00 | 18.00 |
| Nickel | 6.50 | 7.75 | 6.50 | 7.75 | 6.50 | 7.75 |
| Aluminum | 0.75 | 1.50 | 0.75 | 1.50 | 0.75 | 1.25 |
| Molybdenum | - | - | - | 0.75 | - | - |
| Copper | - | - | - | 0.50 | - | - |

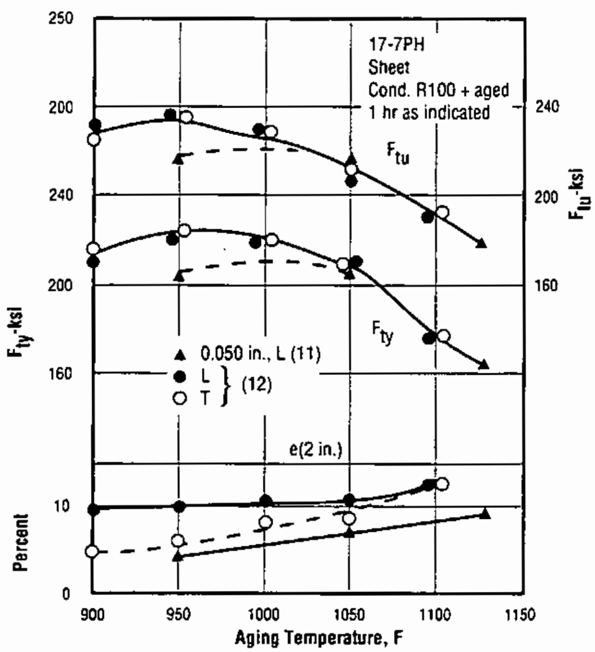



Fig. 1.5.1.4.1 Effect of RH aging temperatures (1 hr) on tensile properties of sheet after prior treatment to Condition R100 (Refs. 11, 12)

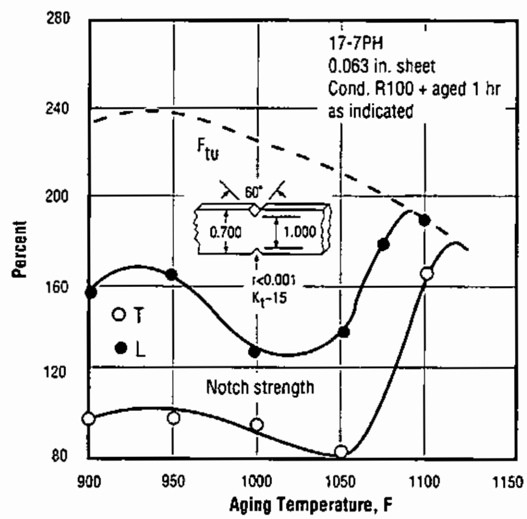



Fig. 1.5.1.4.2 Effect of RH aging temperatures (1 hr) on tensile strength and sharp-notch strength of sheet after prior treatment to Condition R100 (Ref. 12)

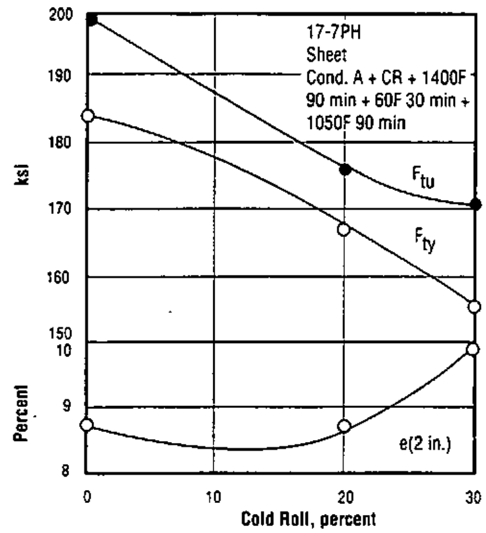



Fig. 1.5.2.1 Effect of cold work introduced in Condition A on tensile properties of sheet subsequently heat treated to Condition TH1050 without an intermediate anneal (Ref. 13)

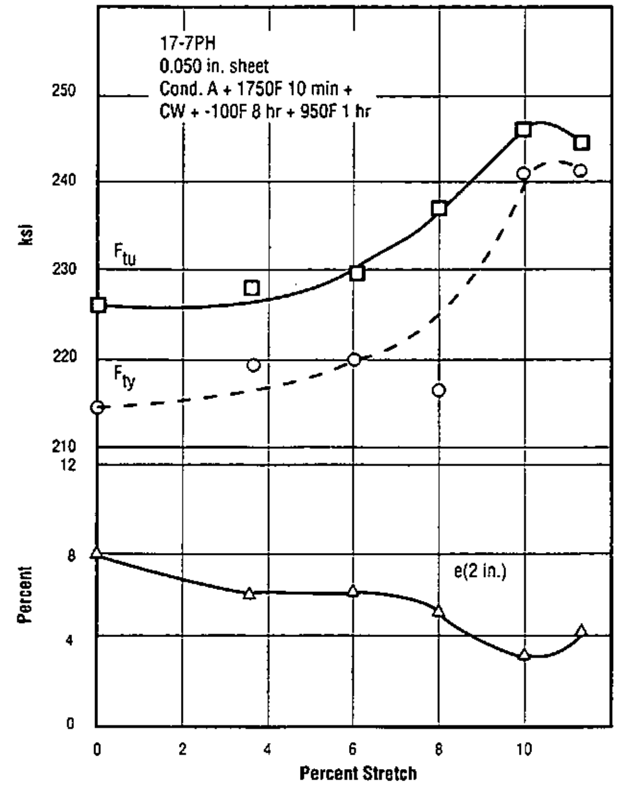



Fig. 1.5.2.2 Effect of cold work introduced in Condition A1750 on tensile properties of the alloy after subsequent completion of the RH950 heat treatment (Ref. 13)

Table 1.6.1 Hardness in various heat-treated conditions at room temperature (Refs. 17, 19)

| Alloy: 17-7PH | | |
|---|---|---|
| **Condition** | **Hardness, Rockwell** | |
| | **Sheet & Strip** | **Bar, Rod, Wire** |
| A | B 85 | B 90 |
| T | C 31 | C 32 |
| TH1050 | C 43 | C 42 |
| A1750 | B 85 | - |
| R100 | C 36.5 | C 34 |
| RH950 | C 48 | C 44 |
| C | C 43 | C 44 min |
| CH900 | C 49 | C 48 min |

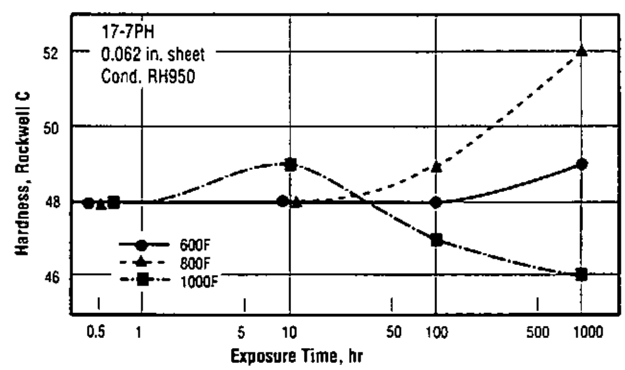



Fig. 1.6.2 Effects of exposures up to 1000 hours at 600, 800, and 1000F on the room-temperature hardness of sheet in Condition RH950 (Ref. 35)

Table 1.9.1.1 Effect of section size and orientation on tensile strength and ductility (Ref. 41)

| Alloy: 17-7PH | | | | | | |
|---|---|---|---|---|---|---|
| **Condition** | **Form, in.** | **Melting** | **Orientation** | **$F_{tu}$, ksi** | **e(2 in.) percent** | **RA percent** |
| TH1050 | 6 x 6 forging | arc air | L | 169 | 2.0 | 2.0 |
| | | | T | 140 | 0 | 0 |
| TH1050 | 6 x 6 forging | vac. melt | L | 179 | 8.0 | 14.0 |
| | | | T | 150 | 1.0 | 0 |
| RH950 | 3 5/8 dia. forg. | arc air | L | 205 | 3.0 | 6.0 |
| | | | T | 185 | 1.0 | 0 |
| RH950 | 3 5/8 dia. forg. | vac. melt | L | 216 | 7.0 | 11.0 |
| | | | T | 188 | 3.0 | 2.0 |
| TH1050 | 4 plate | arc air | L | 195 | 10.0 | 25.0 |
| | | | T | 186 | 1.0 | 0.5 |
| | | | ST | 112 | 0 | 0 |
| TH1050 | 2 1/4 plate | arc air | L | 179 | 12.0 | 1.0 |
| | | | T | 178 | 10.0 | 26.0 |
| | | | ST | 113 | 0 | 0 |
| TH1050 | 0.050 sheet | arc air | L | 193 | 182 | 10.0 |
| | | | T | 193 | 182 | 10.0 |

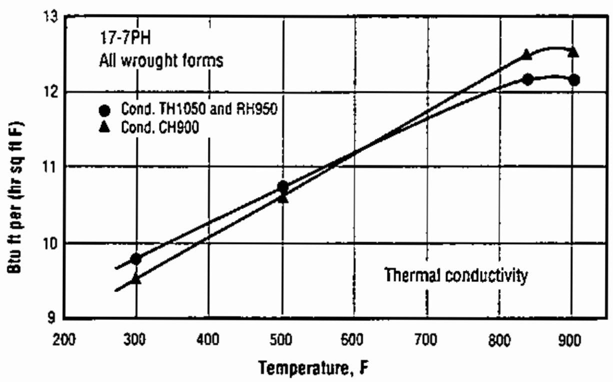



Fig. 2.1.3.1 Effects of temperatures from 300 of 900F on thermal conductivity (Refs. 17, 19)

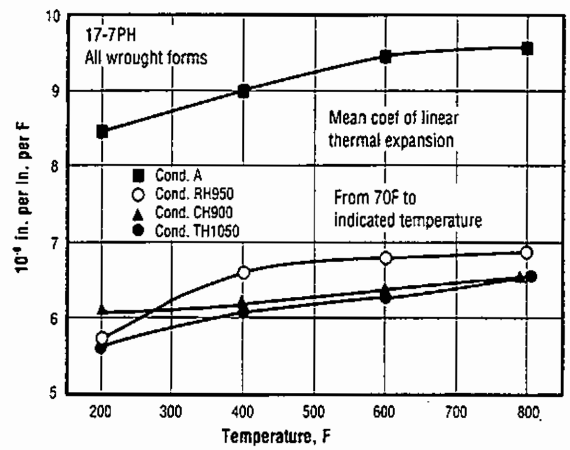



Fig. 2.1.4.1 Effects of temperatures from 200 to 800F on thermal expansion (Refs. 17, 19)

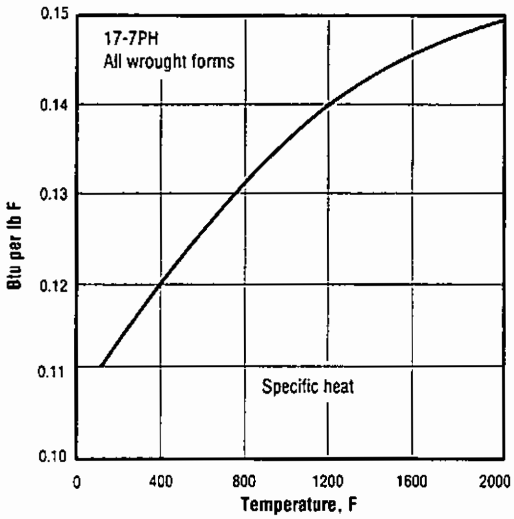



Fig. 2.1.5.1 Effect of temperatures up to 2000F on specific heat (Refs. 22, 60)

Table 2.2.1.1 Density in various heat-treated conditions at room temperature (Refs. 17, 19)

| Alloy: 17-7PH | | | | |
|---|---|---|---|---|
| **Condition** | **A** | **TH1050** | **RH950** | **CH900** |
| lb per cu in. | 0.282 | 0.276 | 0.276 | 0.277 |
| gr per cu cm | 7.81 | 7.65 | 7.65 | 7.67 |

Table 2.2.2.1 Electrical properties in various heat-treated conditions at room temperature (Refs. 17, 19)

| Alloy: 17-7PH | | | | |
|---|---|---|---|---|
| **Condition** | **A** | **TH1050** | **RH950** | **CH900** |
| Electrical Resistivity, microohm - in. | 31.5 | 32.3 | 32.7 | 33.0 |
| Electrical Conductivity, megmhos per in. | .0317 | .0310 | .0306 | .0303 |
| Electrical Conductivity, % IACS | 2.16 | 2.11 | 2.08 | 2.06 |

Table 2.2.3.1 Magnetic permeability in various heat-treated conditions at room temperature (Refs. 17, 19)

| Alloy: 17-7PH | | | | |
|---|---|---|---|---|
| **Condition** | **A** | **TH1050** | **RH950** | **CH900** |
| 25 oersteds | 1.4 - 3.4 | 132 - 194 | 82 - 88 | - |
| 50 oersteds | 1.4 - 3.6 | 120 - 167 | 113 - 130 | - |
| 100 oersteds | 1.4 - 3.5 | 80 - 99 | 75 - 87 | 70 |
| 200 oersteds | 1.4 - 3.2 | 46 - 55 | 44 - 52 | 43.5 |
| maximum | 1.4 - 3.6 | 134 - 208 | 119 - 135 | 125 |

Table 2.2.4.1 Total normal emittance at temperatures from 400 to 900F (Ref. 2)

| Alloy: 17-7PH | |
|---|---|
| **Condition** | **TH1050, Pickled** |
| **Temperature, F** | **Total Normal Emittance** |
| 400 | 0.54 |
| 500 | 0.72 |
| 600 | 0.63 |
| 700 | 0.61 |
| 750 | 0.62 |
| 800 | 0.63 |
| 900 | 0.60 |

Table 2.3.1.1 Comparison of typical corrosion rates for 17-7PH and Type 304 stainless steels in seven common reagents (Refs. 17, 19)

| Alloy: 17-7PH | | | | | Type 304 |
|---|---|---|---|---|---|
| **Form** | | | **Sheet** | | **Sheet** |
| **Condition** | | | **TH1050** | **RH950** | **Annealed** |
| **Medium** | **Concentration percent** | **Temp. F** | **Corrosion Rate mils per year (a)** | | |
| Sulfuric Acid | 1 | 95 | 0.5 | 0.2 | 0.4 |
| | 2 | 95 | 0.9 | 0.7 | 1.3 |
| | 5 | 95 | 124 | 132 | 7.7 |
| Sulfuric Acid | 1 | 176 | 50 | 297 | 22.2 |
| | 2 | 176 | 374 | 884 | 65 |
| Hydrochloric Acid | 0.5 | 95 | 65 | 4 | 7.1 |
| | 1 | 95 | 695 | 447 | 17.3 |
| Nitric Acid | 25 | Boiling | 19 | 20.4 | 1.2 |
| | 50 | Boiling | 70 | 81 | 3.0 |
| | 65 | Boiling | 128 | 136 | 7.2 |
| Formic Acid | 5 | 176 | 2.7 | 4.3 | 4.1 |
| | 10 | 176 | 5.5 | 5.7 | 18.0 |
| Acetic Acid | 33 | Boiling | 3.1 | 5.6 | 2.6 |
| | 60 | Boiling | 12.3 | 3.0 | 10.9 |
| Phosphoric Acid | 20 | Boiling | 7.0 | 18 | 1.6 |
| | 50 | Boiling | 24 | 46 | 8.5 |
| | 70 | Boiling | 104 | 315 | 39 |
| Sodium Hydroxide | 30 | 76 | 13.1 | 3.7 | 0.9 |
| | 30 | Boiling | 67 | 58 | 17.5 |

(a) Rates determined after total immersion, in most instances for five 48-hour periods. Chemically pure laboratory reagents were used. The data should be used only as guide to comparative performance.

Table 2.3.3.1 Effects of high-pressure hydrogen atmosphere on tensile properties at room temperature (Ref. 54)

| Alloy: 17-7PH | | |
|---|---|---|
| **Form** | **Bar** | |
| **Condition** | **TH1050** | |
| **Environment** | **Air zero psig** | **Hydrogen 10,000 psig** |
| $F_{tu}$, ksi | 174 | 151 |
| $F_{ty}$, ksi | 163 | 148 |
| e(1.25 in.) percent | 17.0 | 1.7 |
| RA, percent | 45.0 | 2.5 |

Table 2.3.5.1 Threshold stress intensity factor (Klscc) for stress-corrosion cracking of bar in aerated 3.5 percent aqueous sodium-chloride solution (Ref. 5)

| Alloy: 17-7PH | | | | | |
|---|---|---|---|---|---|
| **Form** | **1 3/4-in. Square Bar** | | | | |
| **Condition** | **$F_{ty}$, ksi** | **$F_{tu}$, ksi** | **e(2 in.)** | **$K_{Ic}$, ksi $\sqrt{in.}$** | **$K_{Iscc}$, ksi $\sqrt{in.}$** |
| RH950 | 171.3 | 186.5 | 11 | 32.3 | <19.0 |
| TH1050 | - | 197.2 | 9 | 38.7 | 15.8 |

Notes
1. $K_{Ic}$ specimens: SE (B)(L-T), 1/2 in. thick
2. $K_{Iscc}$ specimens: SE (B Cantilever)(L-T), 1/2 in. thick

Table 3.1.1 AMS specified mechanical properties for plate, sheet, and strip (Refs. 45, 46)

| Alloy: 17-7PH | | | | | |
|---|---|---|---|---|---|
| Form | | Plate, Sheet, Strip | | | |
| Condition | Thickness, in. | $F_{ty}$, ksi min | $F_{tu}$, ksi | e(2 in.) percent min | Hardness, Rockwell |
| A | 0.005 to 0.010 | 65 | 150 min | 20 | B 92 max |
| A | >0.010 | 55 | 150 min | 20 | B 92 max |
| TH1050 | 0.005 to 0.010 | 150 | 180 - 210 | 4 | C 38 - 46 |
| TH1050 | >0.010 to 0.019 | 150 | 180 - 210 | 5 | C 38 - 46 |
| TH1050 | >0.019 to 1.000 | 150 | 180 - 210 | 6 | C 38 - 46 |
| C | 0.0015 to 0.050 | 175 | 200 min | 1 | C 41 min |
| CH900 | 0.0015 to 0.050 | 230 | 240 min | 1 | C 46 min |

Table 3.1.2 ASTM specified mechanical properties for plate, sheet, and strip (Ref. 7)

| Alloy: 17-7PH | | | | | | |
|---|---|---|---|---|---|---|
| Form | | Plate, Sheet, Strip | | | | |
| Condition | Thickness, in. | $F_{ty}$, ksi min | $F_{tu}$, ksi min | e(2 in.) (T) percent min | RA (T) percent min | Hardness, Rockwell |
| A | 0.010 in. and under | 65 | 150 | - | - | - |
| A | >0.010 in. to 4.0 in. | 55 | 150 | 20 | - | B 92 max |
| TH1050 | 0.0015 to 0.0049 | 150 | 180 | 3 | - | C 38 min |
| TH1050 | 0.0050 to 0.0099 | 150 | 180 | 4 | - | C 38 min |
| TH1050 | 0.010 to 0.0199 | 150 | 180 | 5 | - | C 38 min |
| TH1050 | 0.020 to 0.1874 | 150 | 180 | 6 | - | C 38 min |
| TH1050 | 0.1875 to 0.625 | 140 | 170 | 7 | 20 | C 38 min |
| RH950 | 0.0015 to 0.0049 | 190 | 210 | 1 | - | C 44 min |
| RH950 | 0.0050 to 0.0099 | 190 | 210 | 2 | - | C 44 min |
| RH950 | 0.010 to 0.0199 | 190 | 210 | 3 | - | C 44 min |
| RH950 | 0.020 to 0.1874 | 190 | 210 | 4 | - | C 44 min |
| RH950 | 0.1875 to 0.625 | 180 | 200 | 6 | 20 | C 43 min |
| C | 0.0015 to 0.050 | 175 | 200 | 1 | - | C 41 min |
| CH900 | 0.0015 to 0.050 | 230 | 240 | 1 | - | C 46 min |

Table 3.1.3 AMS specified mechanical properties for tubing (Ref. 47)

| Alloy: 17-7PH | | | | |
|---|---|---|---|---|
| Form | Tubing | | | |
| Condition | $F_{ty}$, ksi | $F_{tu}$, ksi | e(2 in.) percent | Hardness, Rockwell |
| A | 55 max | 150 max | 20 min | C 92 max |
| TH1050 | 150 min | 180 min | 6 min | C 38 min |

Table 3.1.4 AMS specified tensile strength for spring wire (Ref. 48)

| Alloy: 17-7PH | | | | |
|---|---|---|---|---|
| **Form** | **Wire, Spring Temper** | | | |
| **Condition** | **C** | | **CH900** | |
| **Diameter, in.** | **$F_{tu}$, ksi** | | **$F_{tu}$, ksi** | |
| | **min** | **max** | **min** | **max** |
| 0.016 to 0.020 | 248 | 305 | 335 | 365 |
| over 0.020 to 0.025 | 243 | 300 | 330 | 360 |
| over 0.025 to 0.029 | 239 | 295 | 325 | 355 |
| over 0.029 to 0.041 | 234 | 290 | 320 | 350 |
| over 0.041 to 0.051 | 230 | 285 | 310 | 340 |
| over 0.051 to 0.061 | 225 | 280 | 305 | 335 |
| over 0.061 to 0.071 | 218 | 272 | 297 | 327 |
| over 0.071 to 0.086 | 216 | 270 | 292 | 322 |
| over 0.086 to 0.090 | 207 | 260 | 282 | 312 |
| over 0.090 to 0.100 | 204 | 257 | 279 | 309 |
| over 0.100 to 0.106 | 201 | 253 | 274 | 304 |
| over 0.106 to 0.130 | 199 | 251 | 272 | 302 |
| over 0.130 to 0.138 | 194 | 245 | 260 | 290 |
| over 0.138 to 0.146 | 192 | 243 | 258 | 288 |
| over 0.146 to 0.162 | 190 | 241 | 256 | 286 |
| over 0.162 to 0.180 | 188 | 239 | 254 | 284 |
| over 0.180 to 0.207 | 186 | 237 | 252 | 282 |
| over 0.207 to 0.225 | 183 | 233 | 248 | 278 |
| over 0.225 to 0.306 | 178 | 228 | 242 | 272 |
| over 0.306 to 0.440 | 173 | 222 | 235 | 265 |

Note: Armco specifies minimum hardness of RC 44 for Condition C and RC 48 for Condition CH900 regardless of diameter (17).

Table 3.1.5 ASTM specified tensile strength for spring wire (Ref. 18)

| Alloy: 17-7PH | | | |
|---|---|---|---|
| **Form** | **Spring Wire** | | |
| **Condition** | **C** | **CH900** | |
| **Diameter, in.** | **$F_{tu}$, ksi** | **$F_{tu}$, ksi** | |
| | **nominal** | **min** | **max** |
| 0.010 to 0.015 | 295 | 335 | 365 |
| over 0.015 to 0.020 | 290 | 330 | 360 |
| over 0.020 to 0.029 | 285 | 325 | 355 |
| over 0.029 to 0.041 | 275 | 320 | 350 |
| over 0.041 to 0.051 | 270 | 310 | 340 |
| over 0.051 to 0.061 | 265 | 305 | 335 |
| over 0.061 to 0.071 | 257 | 297 | 327 |
| over 0.071 to 0.086 | 255 | 292 | 322 |
| over 0.086 to 0.090 | 245 | 282 | 312 |
| over 0.090 to 0.100 | 242 | 279 | 309 |
| over 0.100 to 0.106 | 238 | 274 | 304 |
| over 0.106 to 0.130 | 236 | 272 | 302 |
| over 0.130 to 0.138 | 230 | 260 | 290 |
| over 0.138 to 0.146 | 228 | 258 | 288 |
| over 0.146 to 0.162 | 226 | 256 | 286 |
| over 0.162 to 0.180 | 224 | 254 | 284 |
| over 0.180 to 0.207 | 222 | 252 | 282 |
| over 0.207 to 0.225 | 218 | 248 | 278 |
| over 0.225 to 0.306 | 213 | 242 | 272 |
| over 3.306 to 0.440 | 207 | 235 | 265 |
| over 0.440 to 0.625 | 203 | 230 | 260 |

Notes:

1. When wire is specified in straightened and cut lengths minimum tensile strength ($F_{tu}$) shall be 90 percent of the values listed in the table.
2. For hardness, Armco specifies a minimum of Rockwell C 44 for Condition C and C 48 for Condition CH900 regardless of diameter (17).

Table 3.1.6 ASTM specified mechanical properties for longitudinal specimens from bars, shapes, and forgings (Refs. 8, 9)

| Alloy: 17-7PH | | | | | | |
|---|---|---|---|---|---|---|
| **Form** | | **Bars, Shapes, and Forgings** | | | | |
| **Condition** | **Thickness, or Diameter, in.** | **$F_{ty}$, ksi min** | **$F_{tu}$, ksi min** | **e(2 in.) min** | **RA, percent min** | **Hardness, Rockwell** |
| A | - | - | - | - | - | (a) |
| TH1050 | up to 6 in. | 140 | 170 | 6 | 25 | C 38 min |
| RH950 | up to 4 in. | 150 | 185 | 6 | 10 | C 41 min |

(a) Rockwell B 98 max for bars and shapes (8) and B 89 max for forgings (9).

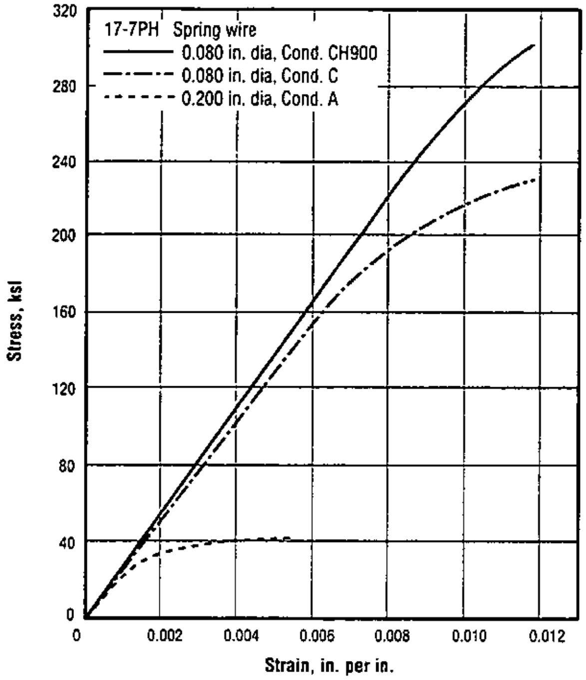



Fig. 3.2.1.1 Tensile stress-strain curves for spring wire at room temperature (Ref. 17)

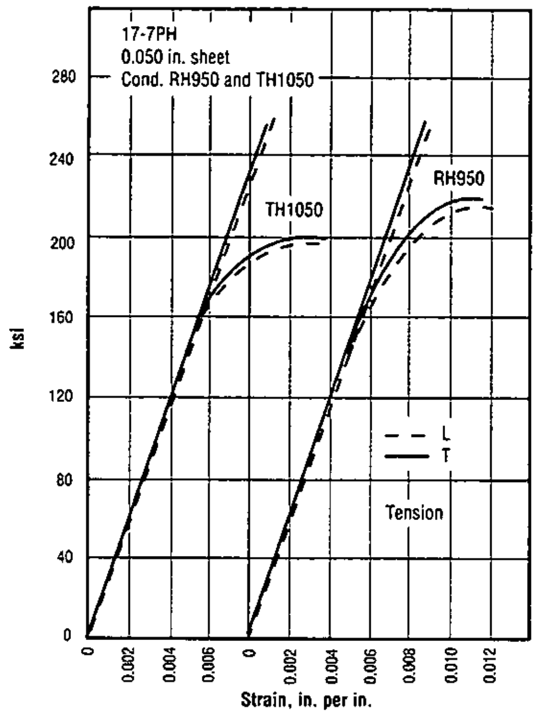



Fig. 3.2.1.2 Tensile stress-strain curves for sheet in longitudinal and transverse orientations for Conditions TH1050 and RH950 (Ref. 13)

Table 3.2.1.3 Tensile properties in various heat-treated conditions at room temperature (Refs. 17, 19)

| Alloy: 17-7PH | | | | | |
|---|---|---|---|---|---|
| Form | Condition | Tensile Properties | | | |
| | | $F_{ty}$, ksi | $F_{tu}$, ksi | e(2 in.) percent | RA percent |
| (1) | A | 40 | 130 | 35 | - |
| (1) | T | 100 | 145 | 9 | - |
| (1) | TH1050 | 185 | 200 | 9 | - |
| (2) | TH1050 | 155 | 175 | 12 | 34 |
| (1) | A1750 | 42 | 133 | 19 | - |
| (1) | R100 | 115 | 175 | 9 | - |
| (1) | RH950 | 220 | 235 | 5 | - |
| (2) | RH950 | 175 | 200 | 10 | 30 |
| (1) | C | 190 | 220 | 5 | - |
| (1) | CH900 | 260 | 265 | 2 | - |

(1) Sheet and strip, (2) Bar, rod, and wire

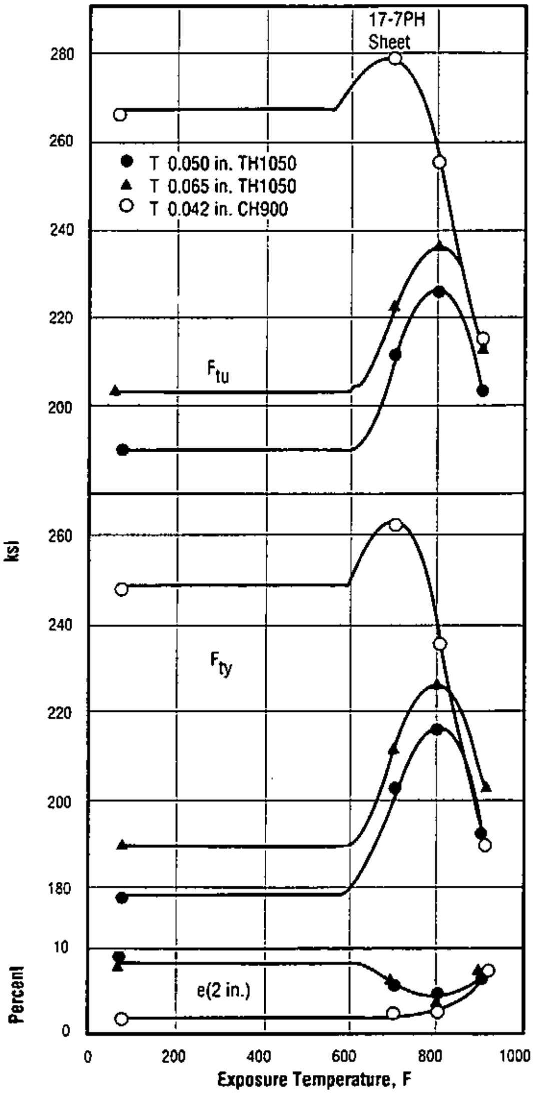



Fig. 3.2.1.4 Effects of 500-hour exposures at elevated temperatures up to 900F on tensile properties at room temperature of sheet in Conditions TH1050 and CH900 (Ref. 29)

Table 3.2.1.5 Effects of 1000-hour exposure to elevated temperatures with load on tensile properties at room temperature of sheet in Conditions TH1050 and RH950 (Ref. 29)

| Alloy: 17-7PH | | | | | |
|---|---|---|---|---|---|
| **Form** | | **0.050-in. Sheet, T** | | | |
| **Condition** | | **TH1050** | | | |
| **1000-hr Exposure at** | | **Tensile Properties after Exposure** | | | |
| | | **$F_{tu}$, ksi** | | **e(2 in.) Percent** | |
| **Temp, F** | **Load, ksi** | **Heat A** | **Heat B** | **Heat A** | **Heat B** |
| RT | - | 201.5 | 188.8 | 8.0 | 11.0 |
| 600 | 80.0 | 206.2 | 190.0 | 7.5 | 10.0 |
| | 120.0 | 209.8 | 192.6 | 7.0 | 7.5 |
| 700 | 50.0 | 221.0 | 207.0 | 6.0 | 7.5 |
| | 90.0 | 228.4 | 210.0 | 4.5 | 7.0 |
| 800 | 50.0 | 235.7 | 220.0 | 4.5 | 3.5 |
| | 80.0 | 245.0 | 227.0 | 4.0 | 3.5 |
| 900 | 15.0 | 208.0 | 190.6 | 5.5 | 5.5 |
| | 35.0 | 210.0 | 192.8 | 5.0 | 5.0 |
| **Condition** | | **RH950** | | | |
| **1000-hr Exposure at** | | **Tensile Properties after Exposure** | | | |
| **Temp, F** | **Load, ksi** | **$F_{tu}$, ksi** | | **e(2 in.) Percent** | |
| RT | - | 232.6 | | 7.5 | |
| 600 | 40.0 | 236.0 | | 7.5 | |
| | 170.0 | 270.1 | | 2.3 | |
| 700 | 40.0 | 253.0 | | 5.5 | |
| | 115.0 | 263.2 | | 3.0 | |
| 800 | 30.0 | 255.7 | | 2.0 | |
| | 70.0 | 263.0 | | 1.0 | |
| 900 | 10.0 | 224.5 | | 5.5 | |
| | 30.0 | 227.0 | | 4.5 | |

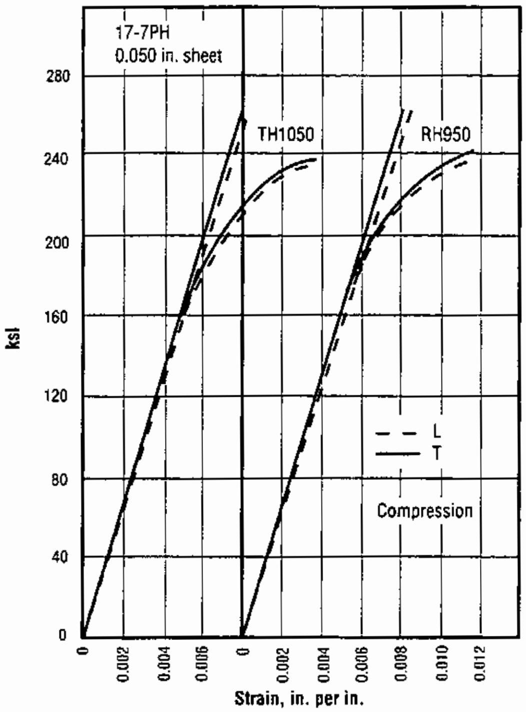



Fig. 3.2.2.1 Compression stress-strain curves for sheet in longitudinal and transverse orientations for Conditions TH1050 and RH950 at room temperature (Ref. 13)

Table 3.2.2.2 Typical compressive yield strengths at room temperature for various heat-treat conditions (Ref. 19)

| Alloy: 17-7PH | |
|---|---|
| **Form** | **Sheet** |
| **Condition** | **$F_{cy}$, ksi** |
| TH1050 | 203 |
| RH950 | 240 |
| C | 218 |
| CH900 | 300 |

Table 3.2.6.1 Bearing properties of sheet at room temperature in Conditions TH1050 and RH950 (Refs. 56, 57, 58)

| Alloy: 17-7PH | | | | | |
|---|---|---|---|---|---|
| **Form** | **0.048 to 0.065 in. Sheet** | | | | |
| **Condition** | **TH1050** | | **RH950** | | |
| **Orientation** | - | - | T | L | T |
| (e/D = 1.5) | | | | | |
| $F_{bru}$, ksi | - | - | - | 358 | 358 |
| $F_{bry}$, ksi | - | - | - | 300 | 296 |
| $F_{bru}/F_{tu}$ | - | - | - | 1.62 | 1.63 |
| $F_{bry}/F_{tu}$ | - | - | - | 1.47 | 1.45 |
| (e/D = 2.0) | | | | | |
| $F_{bru}$, ksi | 313 | 365 | 463 | - | - |
| $F_{bry}$, ksi | 273 | 270 | 379 | - | - |
| $F_{bru}/F_{tu}$ | 1.60 | 1.93 | - | - | - |
| $F_{bry}/F_{tu}$ | 1.42 | 1.47 | - | - | - |

Table 3.2.7.1.1 Crack strength of plate at room temperature in Condition RH1050 (Ref. 55)

| Alloy: 17-7PH | | |
|---|---|---|
| **Form** | **0.36-in. Plate** | |
| **Specimen** | **Full plate thickness by 3.0 in. wide with 1.0 in. fatigue crack** | |
| **Condition** | **RH1050** | |
| | **Longitudinal** | **Transverse** |
| $F_{ty}$, ksi | 186.6 | 185.4 |
| Crack strength, ksi | 149.2 | 122.8 |
| Ratio, crack strength/$F_{ty}$ | 0.80 | 0.66 |
| Percent shear fracture | 85 - 90 | 30 - 40 |

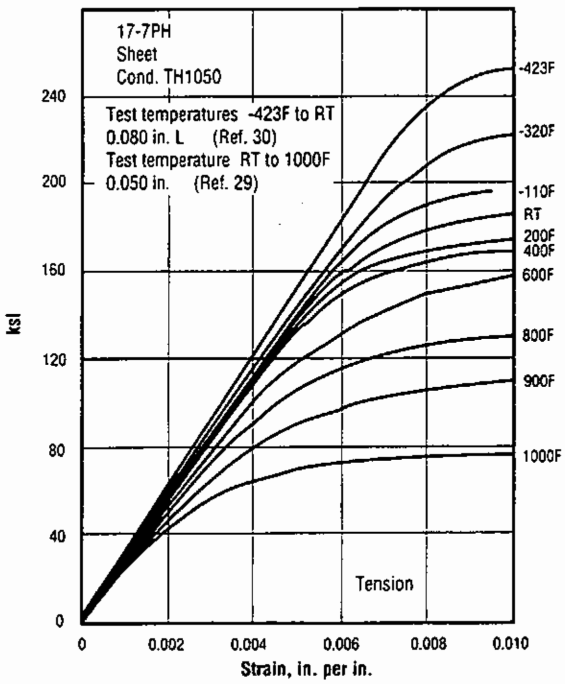



Fig. 3.3.1.1 Tensile stress-strain curves at temperatures from -423F to 1000F for sheet in Condition TH1050 (Refs. 29, 30)

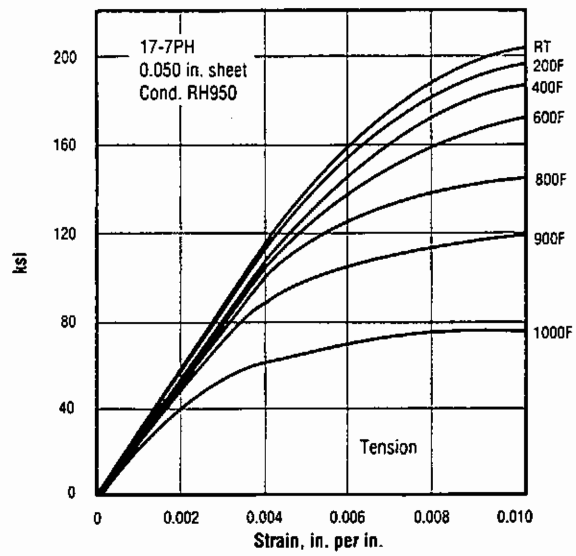



Fig. 3.3.1.2 Tensile stress-strain curves at temperatures from 75F to 1000F for sheet in Condition RH950 (Ref. 29)

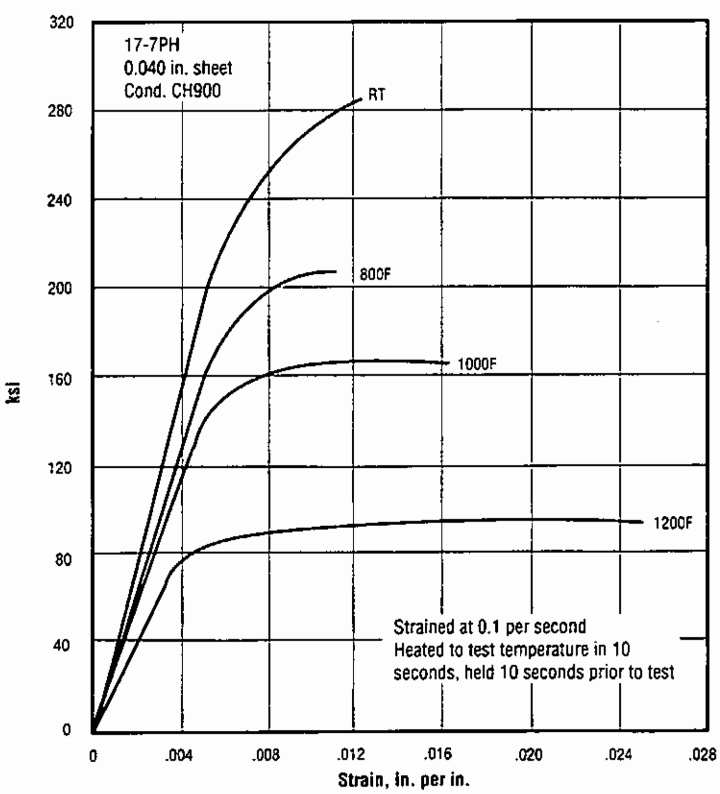



Fig. 3.3.1.3 Tensile stress-strain curves for sheet in Condition CH900 at temperatures up to 1200F under conditions of rapid heating, rapid loading, and short time at temperature (Ref. 31)

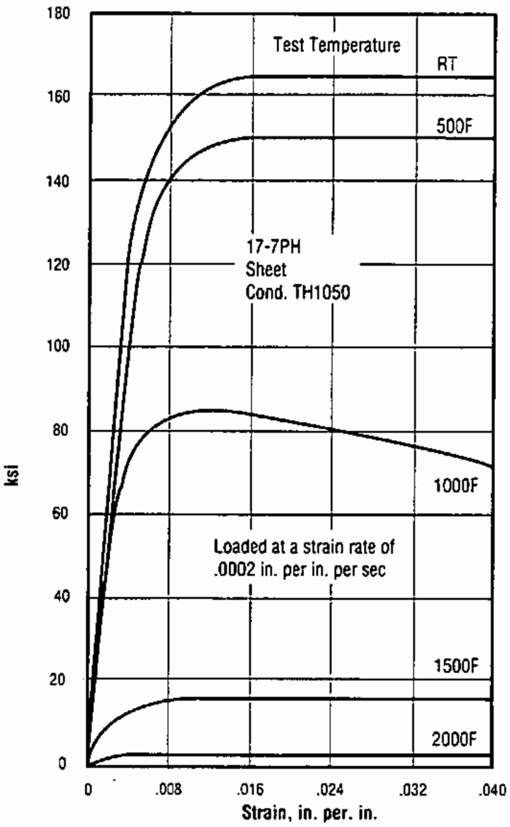



Fig. 3.3.1.4 Tensile stress-strain curves at temperatures up to 2000F for sheet in Condition TH1050 loaded at a strain rate of 0.0002 in. per in. per second (Ref. 32)

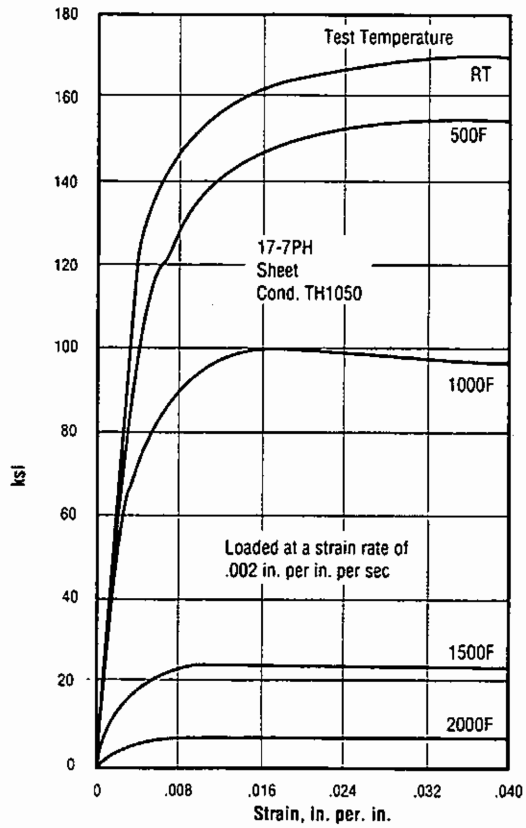



Fig. 3.3.1.5 Tensile stress-strain curves at temperatures up to 2000F for sheet in Condition TH1050 loaded at a strain rate of 0.002 in. per in. per second (Ref. 32)

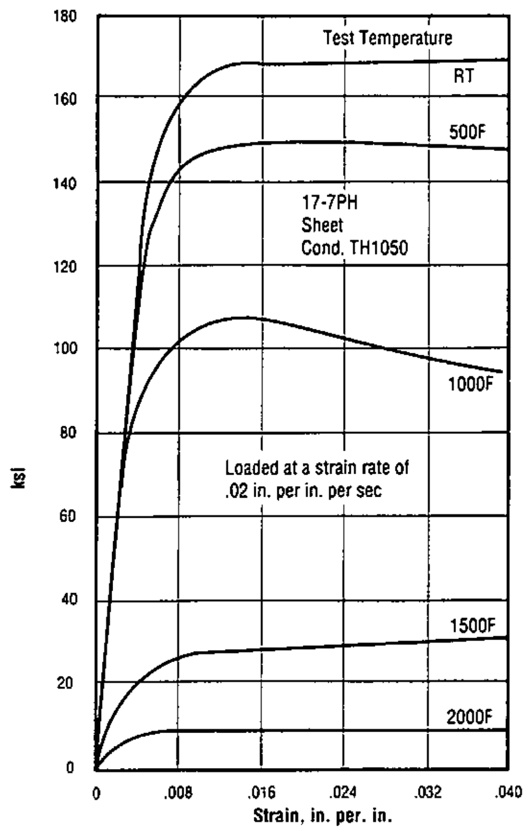



Fig. 3.3.1.6 Tensile stress-strain curves at temperatures up to 2000F for sheet in Condition TH1050 loaded at a strain rate of 0.02 in. per in. per second (Ref. 32)

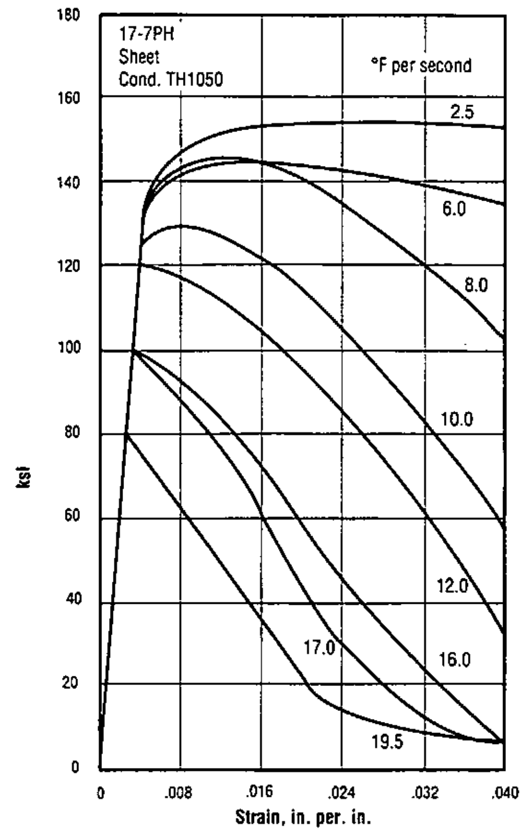



Fig. 3.3.1.7 Tensile stress-strain curves for sheet in Condition TH1050 when simultaneously loaded at a strain rate of 0.0002 in. per in. per second and heated at rates of 2.5 to 19.5F per second (Ref. 32)

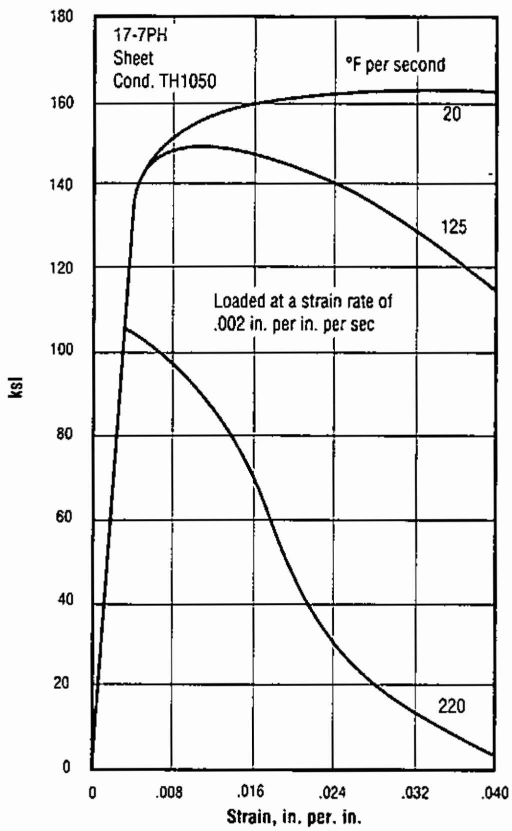



Fig. 3.3.1.8 Tensile stress-strain curves for sheet in Condition TH1050 when simultaneously loaded at a strain rate of 0.002 in. per in. per second and heated at rates of 20 to 220F per second (Ref. 32)

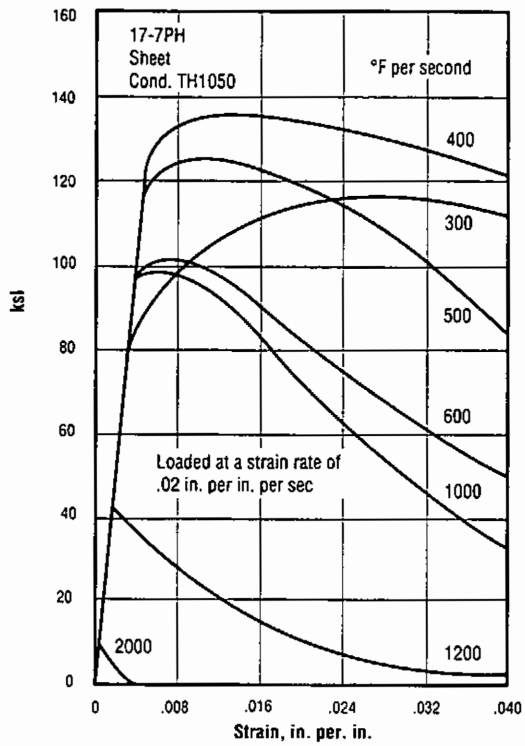



Fig. 3.3.1.9 Tensile stress-strain curves for sheet in Condition TH1050 when simultaneously loaded at a strain rate of 0.02 in. per in. per second and heated at rates of 400 to 2000F per second (Ref. 32)

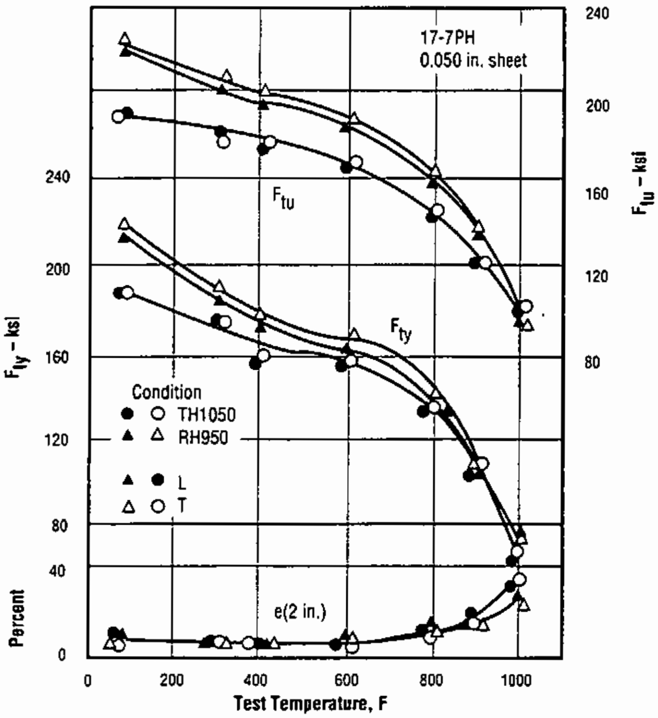



Fig. 3.3.1.10 Effects of temperatures up to 1000F on tensile properties of sheet in Conditions TH1050 and RH950 (Ref. 29)

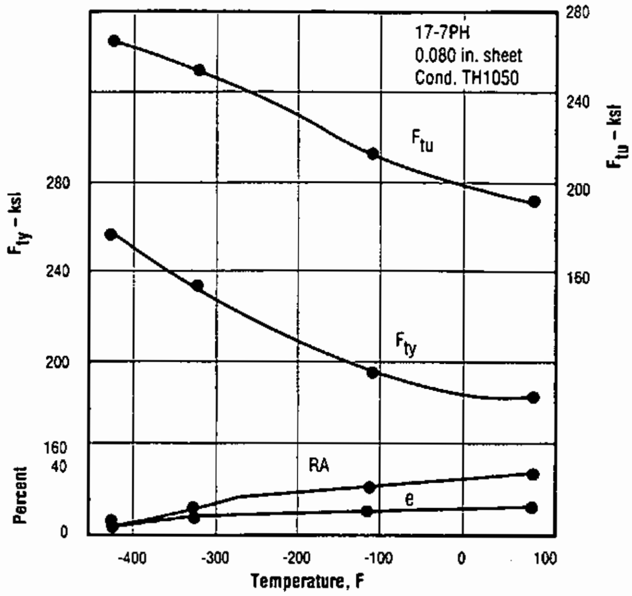



Fig. 3.3.1.11 Effects of low temperatures down to -423F on tensile properties of sheet in Condition TH1050 (Ref. 30)

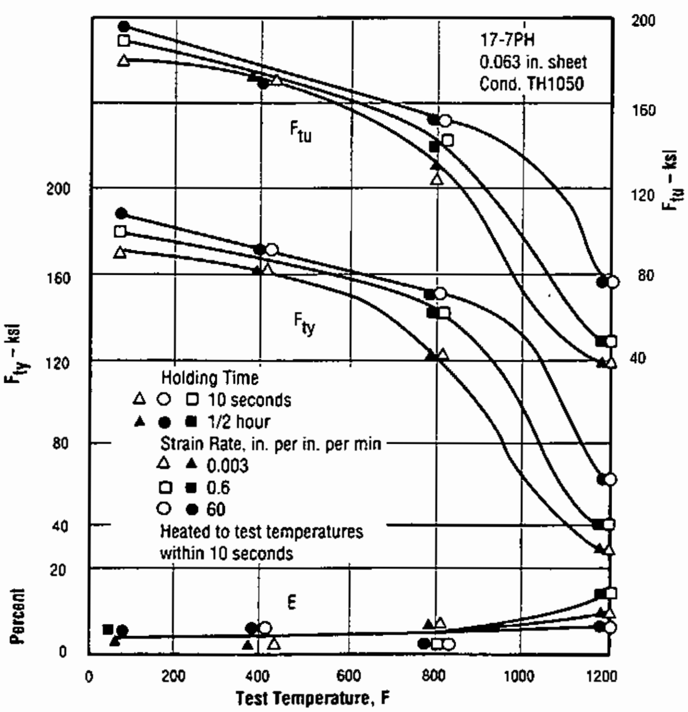



Fig. 3.3.1.12 Tensile properties of sheet in Condition TH1050 for various rates of loading at temperatures up to 1200F after rapid heating and holding times of 10 seconds and 1/2 hour at temperature (Ref. 33)

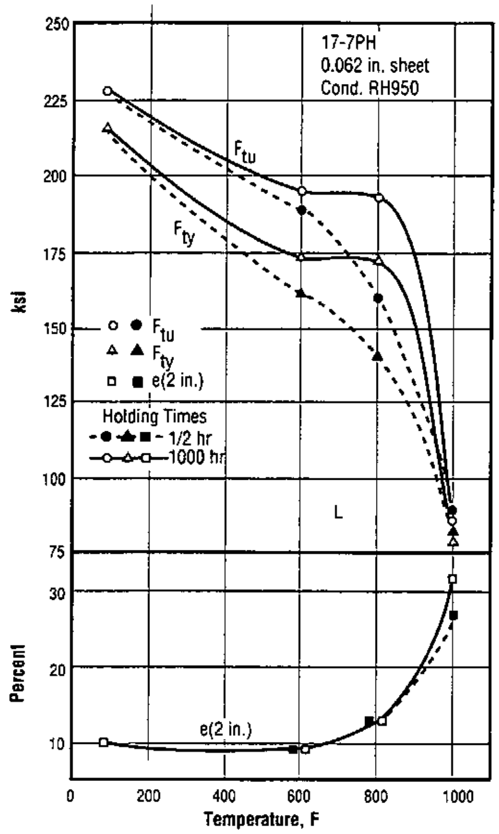



Fig. 3.3.1.13 Tensile properties of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2 and 1000 hours at test temperatures (Ref. 35)

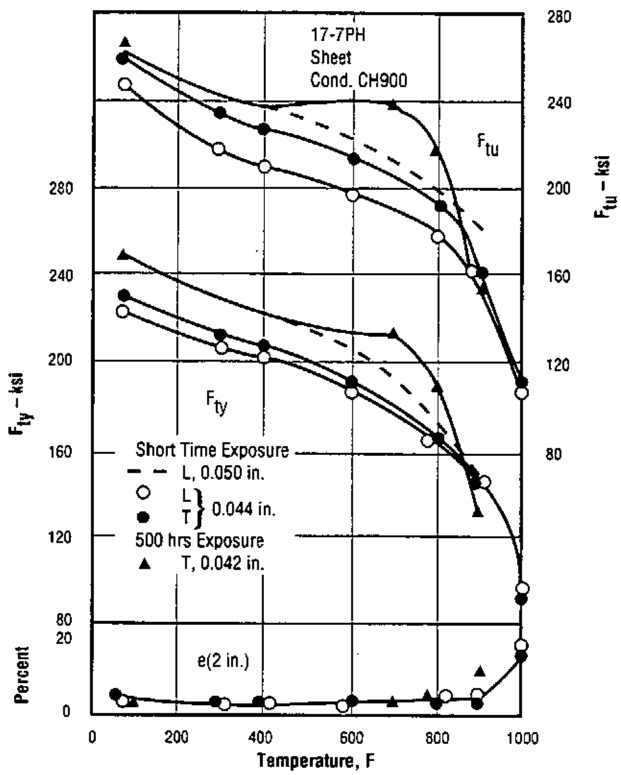



Fig. 3.3.1.14 Effects of test temperatures up to 1000F and of exposure time at temperature on tensile properties of sheet in Condition CH900 (Ref. 29)

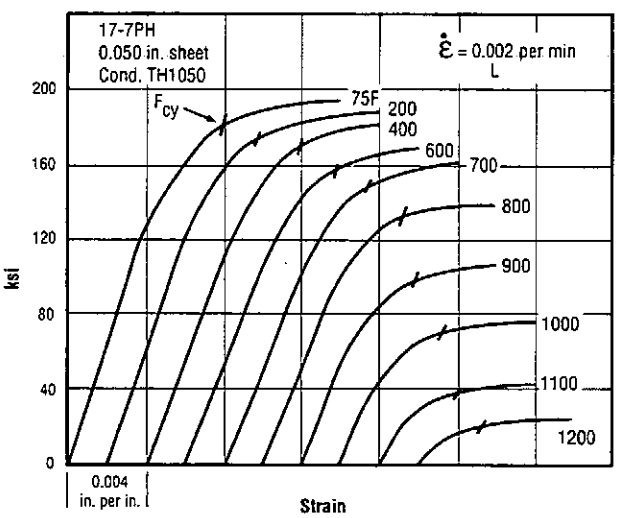



Fig. 3.3.2.1 Compressive stress-strain curves for sheet in Condition TH1050 at temperatures up to 1200F (Ref. 3)

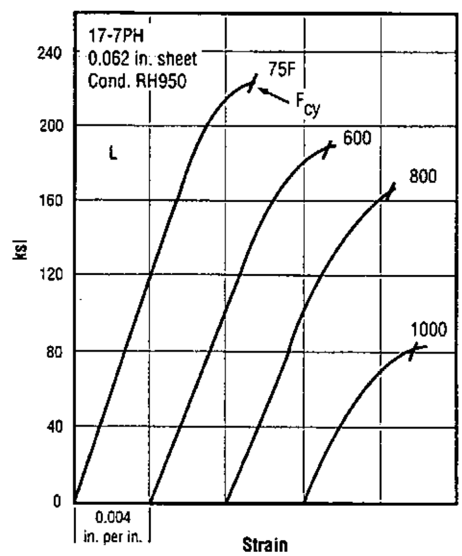



Fig. 3.3.2.2 Compressive stress-strain curves for sheet in Condition RH950 at temperatures up to 1000F (Ref. 35)

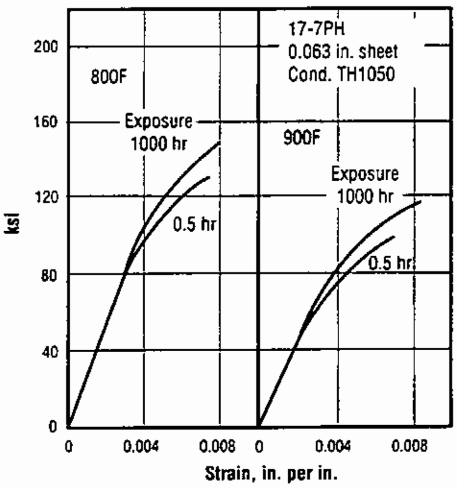



Fig. 3.3.2.3 Compressive stress-strain curves for sheet in Condition TH1050 at 800 and 900F after two different exposure times at temperature (Ref. 34)

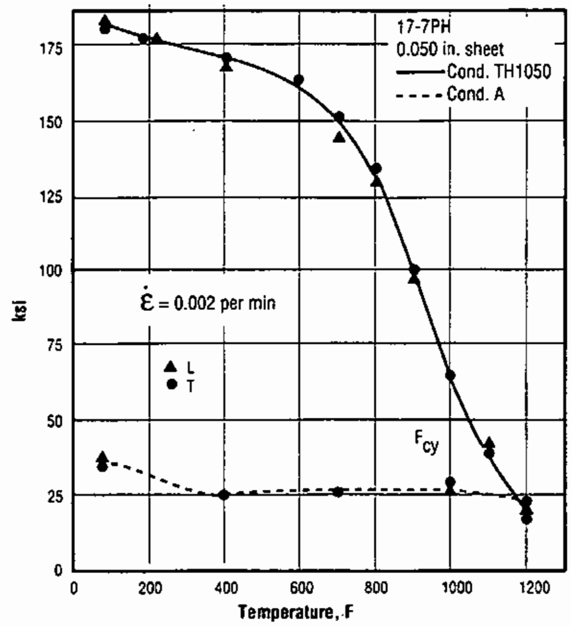



Fig. 3.3.2.4 Effects of temperatures up to 1200F on the compressive yield strength of sheet in both the TH1050 and annealed (solution-treated) conditions (Ref. 3)

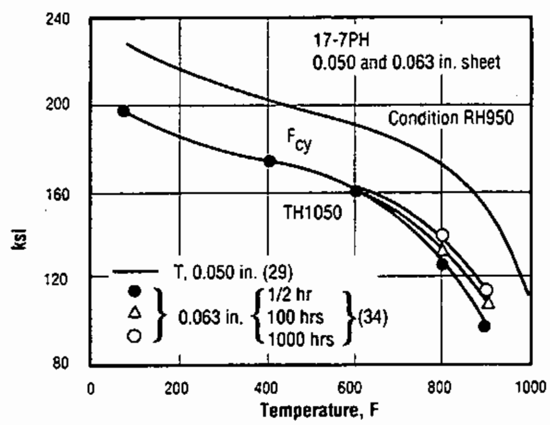



Fig. 3.3.2.5 Effects of elevated temperatures and of exposure time at temperature on the compressive yield strength of sheet in Conditions TH1050 and RH950 (Refs. 29, 34)

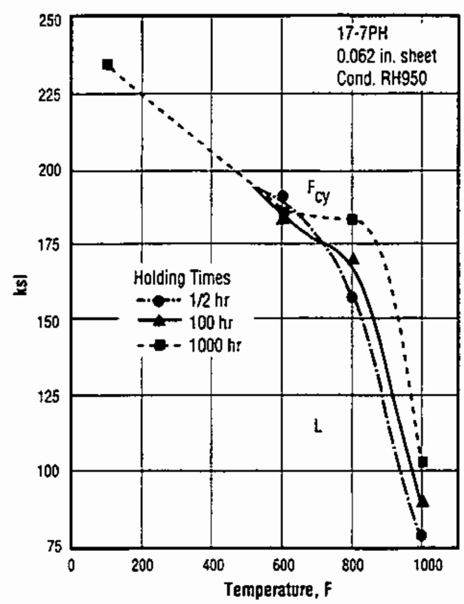



Fig. 3.3.2.6 Compressive yield strength of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2, 100, and 1000 hours at temperature (Ref. 35)

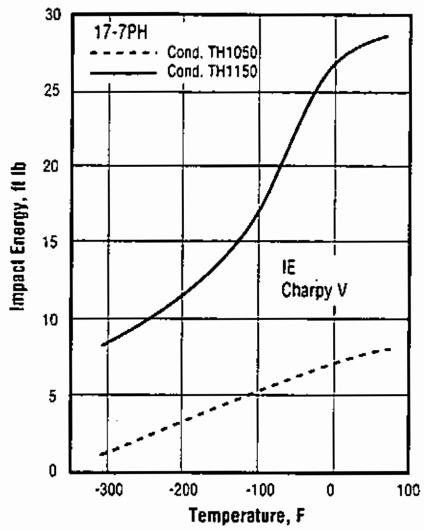



Fig. 3.3.3.1 Effects of low temperatures on impact resistance in Conditions TH1050 and TH1150 (Ref. 10)

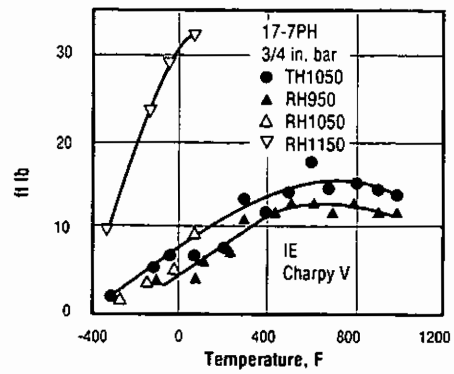



Fig. 3.3.3.2 Impact resistance over a wide range of temperature of bar in various conditions (Ref. 53)

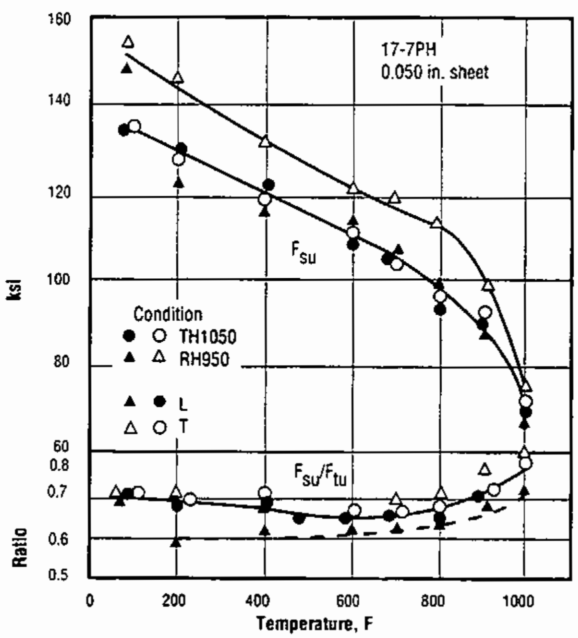



Fig. 3.3.5.1 Ultimate shear strength of sheet in Conditions TH1050 and RH950 at temperatures up to 1000F (Ref. 29)

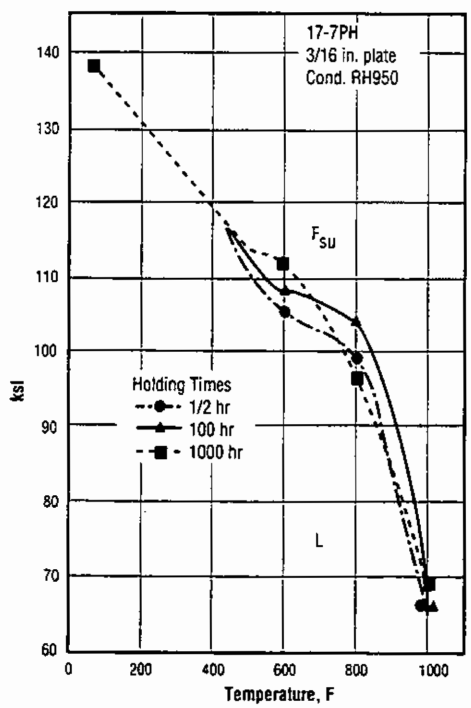



Fig. 3.3.5.2 Ultimate sheer strength of plate in Condition RH950 at temperatures up to 1000F after holding times of 1/2, 100, and 1000 hours at test temperature (Ref. 35)

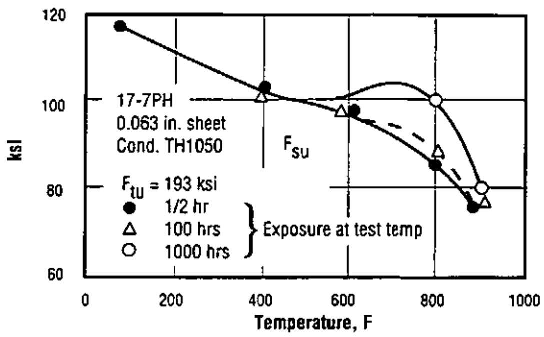



Fig. 3.3.5.3 Ultimate shear strength of sheet in Condition TH1050 at temperatures up to 900F after holding times of 1/2, 100, and 1000 hours at test temperatures (Ref. 34)

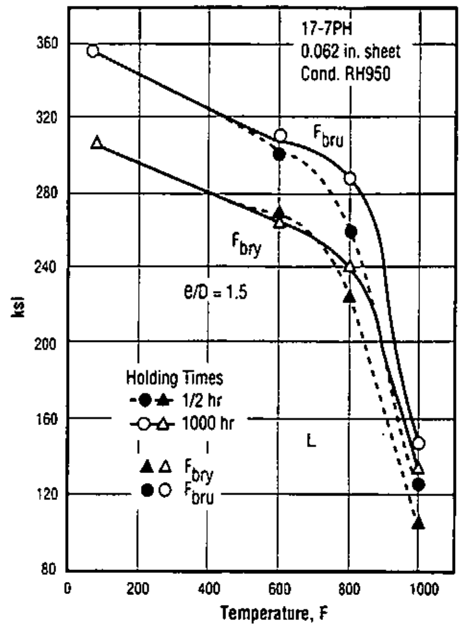



Fig. 3.3.6.1 Bearing properties (e/D = 1.5) of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2 and 1000 hours at test temperature (Ref. 35)

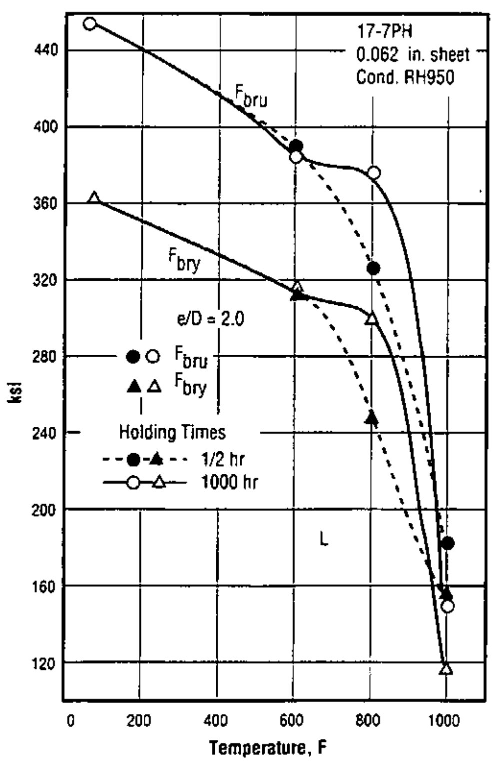



Fig. 3.3.6.2 Bearing properties (e/D = 2.0) of sheet in Condition RH950 at temperatures up to 1000F after holding times of 1/2 and 1000 hours at test temperature (Ref. 35)

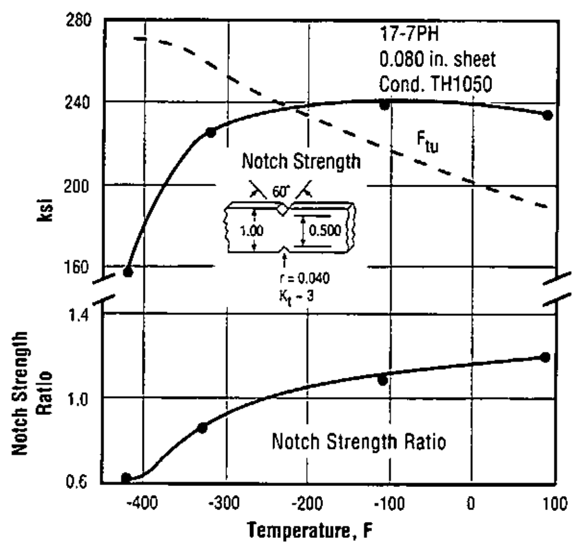



Fig. 3.3.7.1.1 Notch strength and tensile strength of sheet in Condition TH1050 at temperatures down to -423F (Ref. 30)

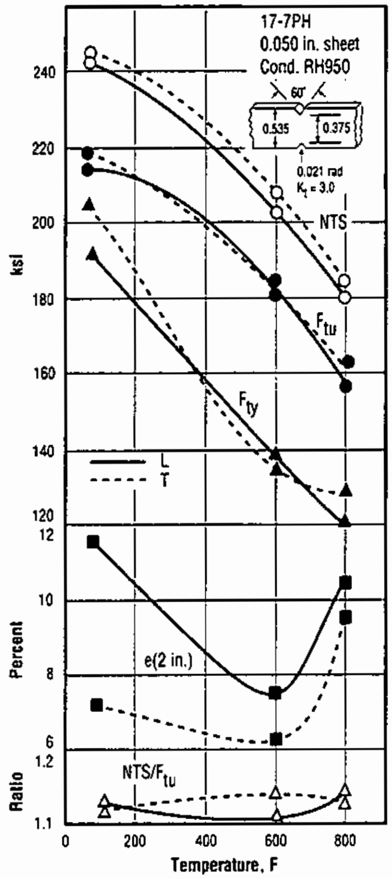



Fig. 3.3.7.1.2 Comparison of tensile and notch tensile properties at temperatures up to 800F for sheet in Condition RH950 (Ref. 39)

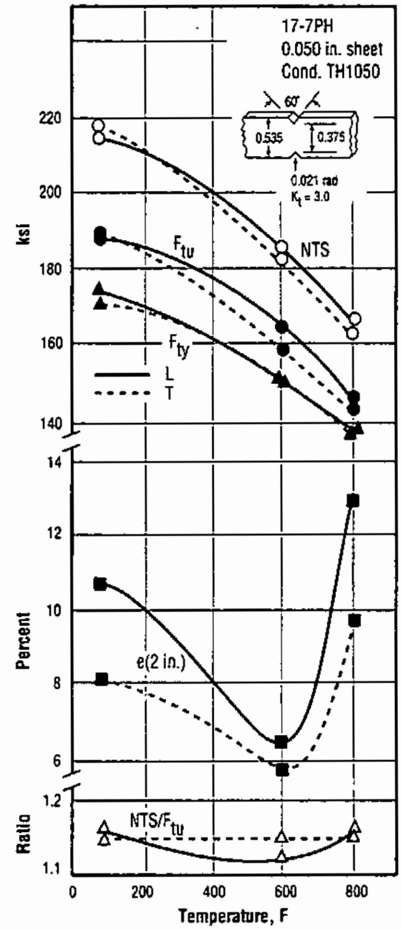



Fig. 3.3.7.1.3 Comparison of tensile and notch tensile properties at temperatures up to 800F for sheet in Condition TH1050 (Ref. 38)

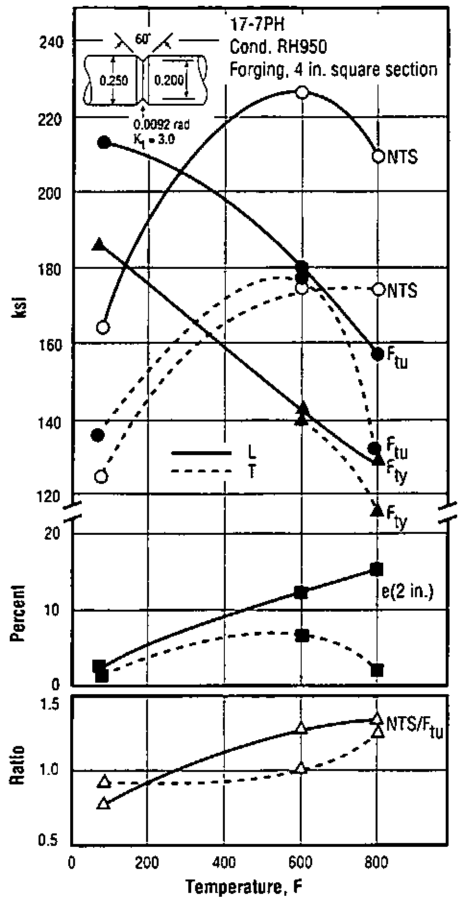



Fig. 3.3.7.1.4 Comparison of tensile and notch tensile properties at temperatures up to 800F for forging in Condition RH950 (Ref. 39)

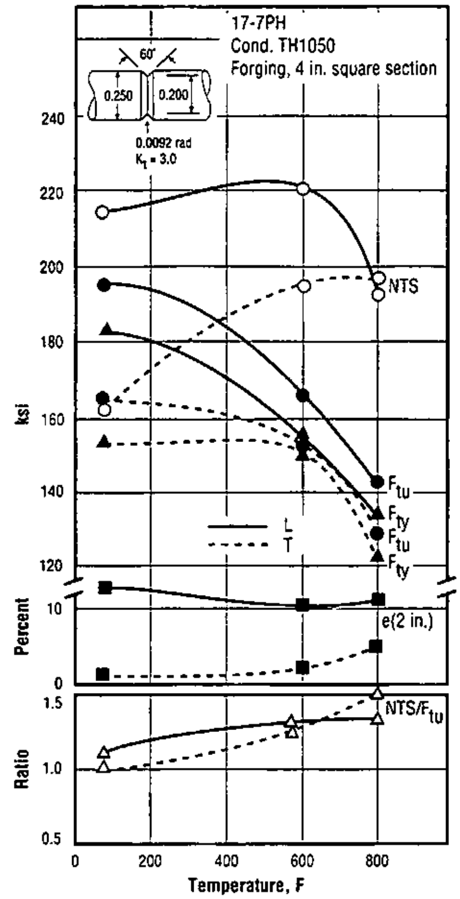



Fig. 3.3.7.1.5 Comparison of tensile and notch tensile properties at temperatures up to 800F for forging in Condition TH1050 (Ref. 39)

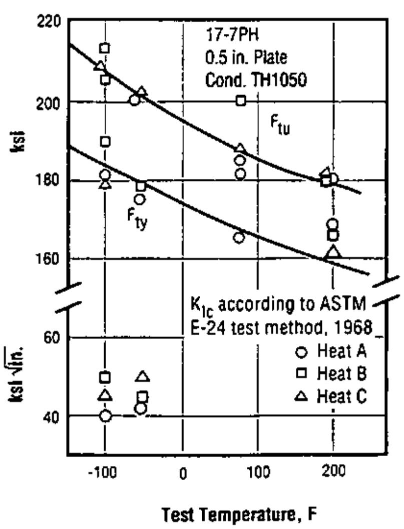



Fig. 3.3.7.2.1 Fracture toughness, tensile strength, and yield strength of plate in Condition TH1050 at various temperatures (Ref. 36)

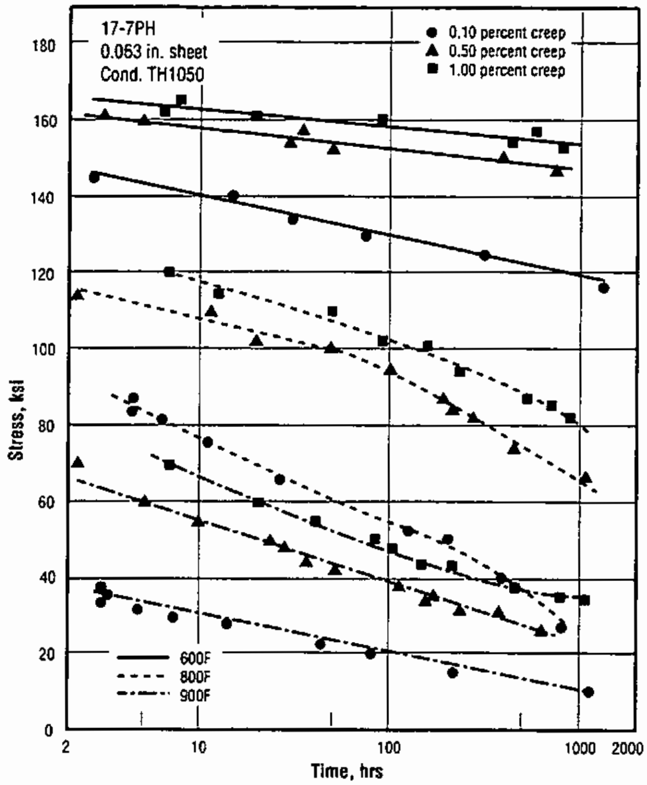



Fig. 3.4.1 Creep properties of sheet in Condition TH1050 at temperatures from 600 to 900F (Ref. 40)

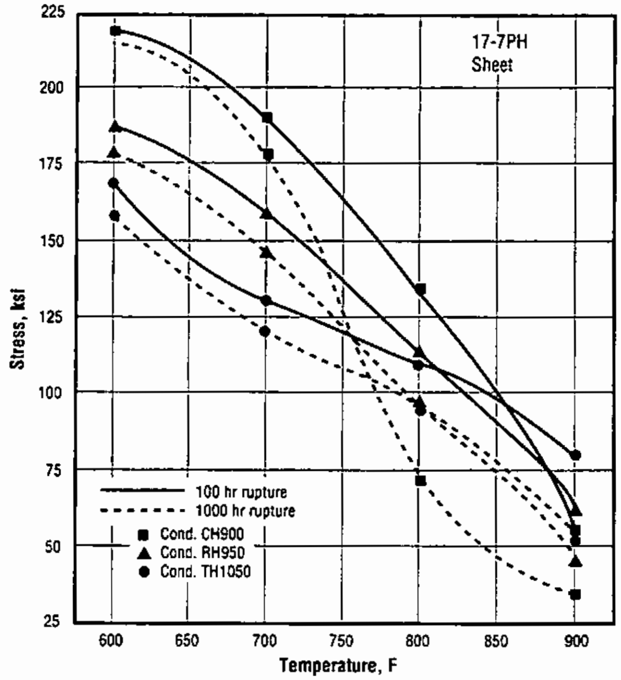



Fig. 3.4.2 Effect of temperature on tensile stress required to cause creep rupture in 100 and 1000 hours for sheet in various heat-treated conditions (Ref. 19)

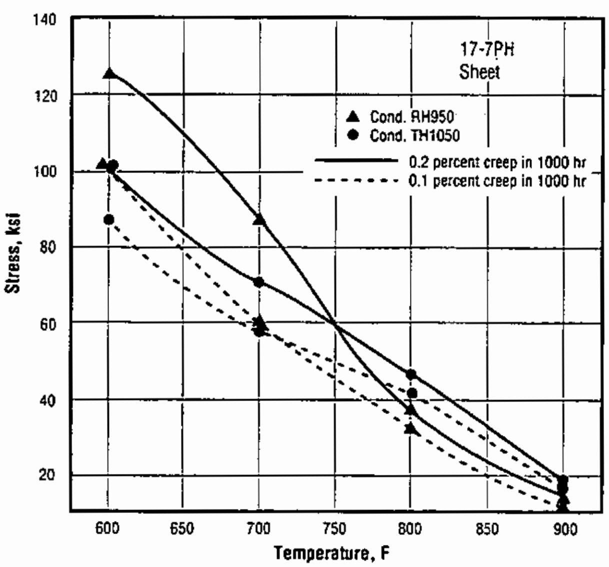



Fig. 3.4.3 Effect of temperature on tensile stress required to cause 0.1 and 0.2 percent creep deformation in 1000 hours for sheet in two heat-treated conditions (Ref. 19)

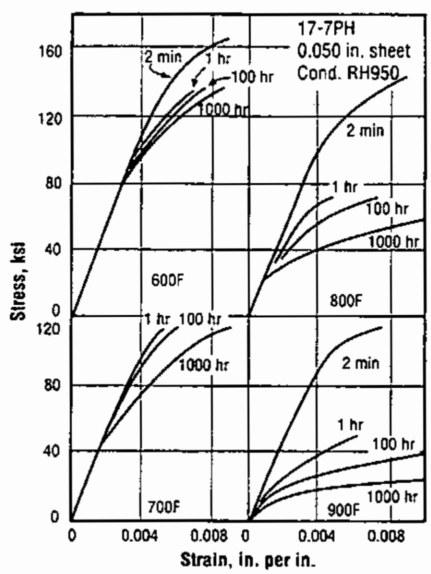



Fig. 3.4.4 Isochronous stress-strain curves at 600 to 900F for sheet in Condition RH950 (Ref. 29)

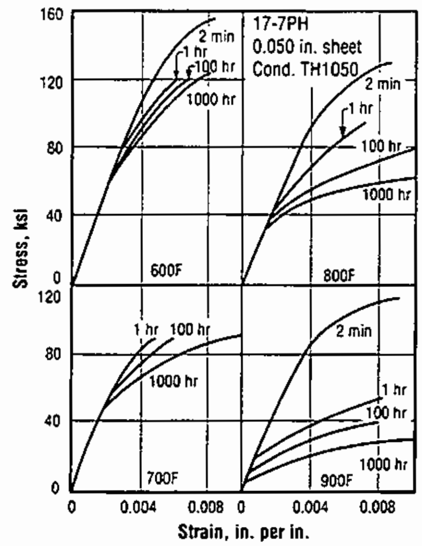



Fig. 3.4.5 Isochronous stress-strain curves at 600 to 900F for sheet in Condition TH1050 (Ref. 29)

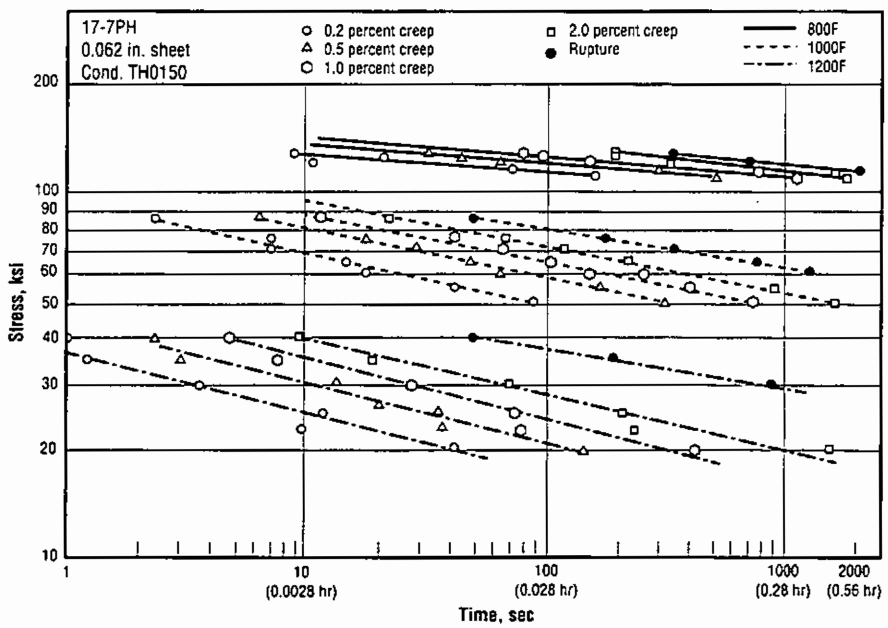



Fig. 3.4.6 Short-time creep and rupture properties of sheet in Condition TH1050 at temperatures from 800 to 1200F (Ref. 31) Note: Specimens were loaded at room temperature, heated rapidly to test temperature, and then creep measurements were started.

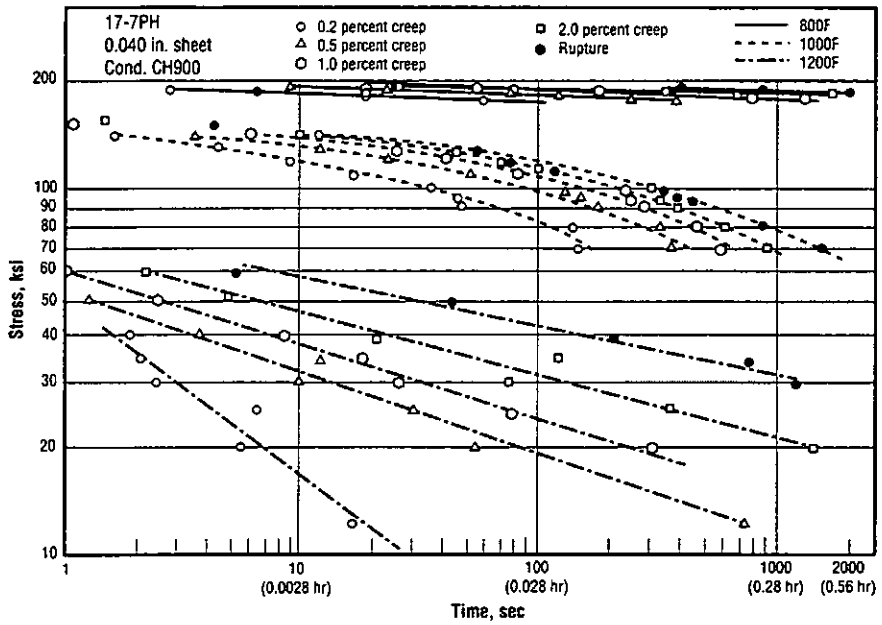



Fig. 3.4.7 Short-time creep and rupture properties of sheet in Condition CH900 at temperatures from 800 to 1200F (Ref. 31) Note: Specimens were loaded at room temperature, heated rapidly to test temperature, and then creep measurements were started.

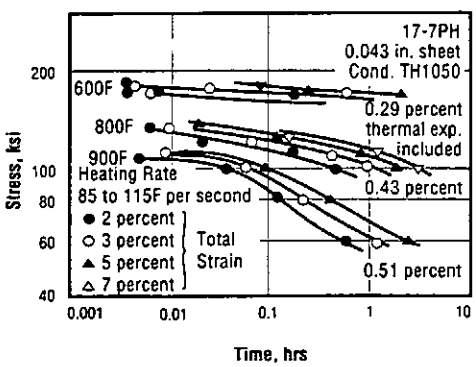



Fig. 3.4.8 Short-time total strain curves at 600 to 900F for sheet in Condition TH1050 (Ref. 37)

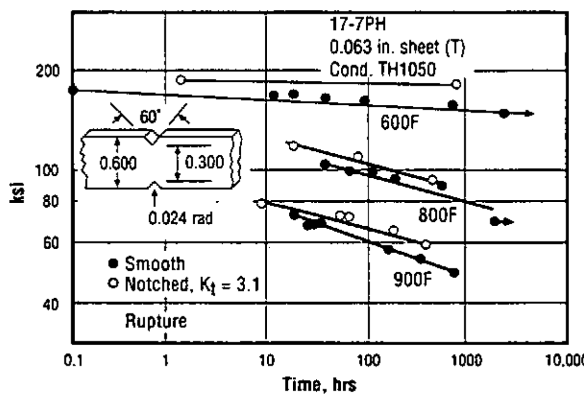



Fig. 3.4.9 Creep-rupture curves at 600 to 900F for smooth and notched sheet in Condition TH1050 (Ref. 50)

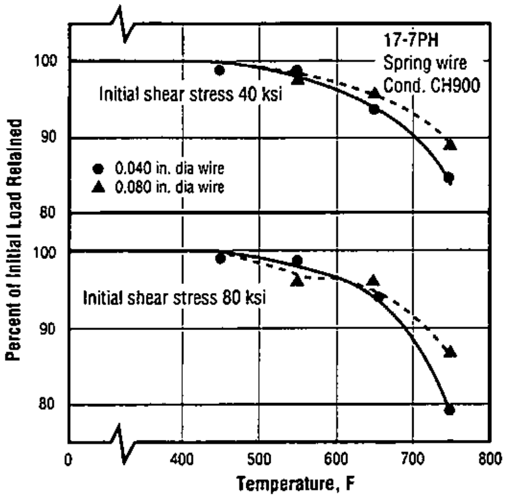



Fig. 3.4.10 Loss of load due to stress relaxation of helical compression springs held at constant length and at temperatures from 450 to 750F for 96 hours (Ref. 17)

Table 3.4.11 Effects of wire diameter, preset stress, and initial stress on stress relaxation of helical extension springs held at constant extension at room temperature for 100 hours (Ref. 42)
Note: The constant extension is the elastic strain associated with the initial shear stress

| Alloy: 17-7PH | | | | | |
|---|---|---|---|---|---|
| **Form** | | **Helical Extension Springs** | | | |
| **Condition** | | **CH900** | | | |
| **Wire Dia, in.** | **$F_{ty}$, ksi** | **$F_{sty}$, ksi** | **Preset (1) ksi** | **Initial Shear Stress, ksi** | **Stress Relaxation in 100 hr., percent (2)** |
| 0.040 | 318 | 223 | 191 | 145 | 1.2 |
| | | | | 174 | 2.2 |
| | | | | 203 | 7.7 |
| 0.040 | 318 | 223 | 223 | 145 | 1.7 |
| | | | | 174 | 3.9 |
| | | | | 203 | 4.3 |
| 0.080 | 293 | 181 | 178 | 145 | 1.4 |
| | | | | 174 | 1.5 |
| 0.080 | 293 | 181 | 181 | 145 | 2.0 |
| | | | | 174 | 2.5 |

Notes:
(1) Preset refers to cycling of the springs to the indicated shear stresses five times prior to the application of the initial stress.
(2) Percentage loss of initial shear stress.

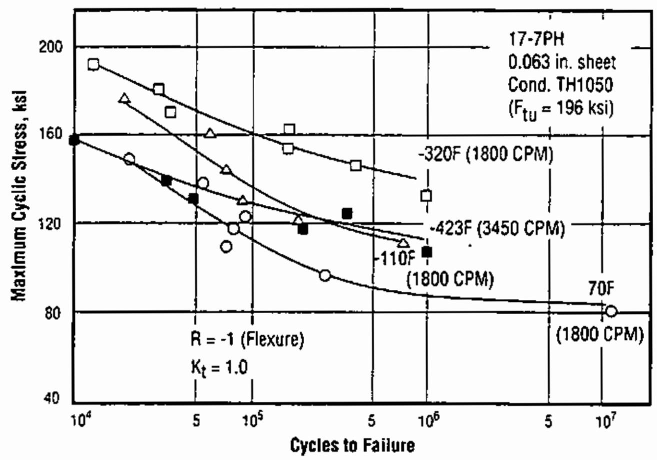



Fig. 3.5.1 Flexural fatigue properties at room and low temperatures for sheet in Condition TH1050 (Ref. 51)

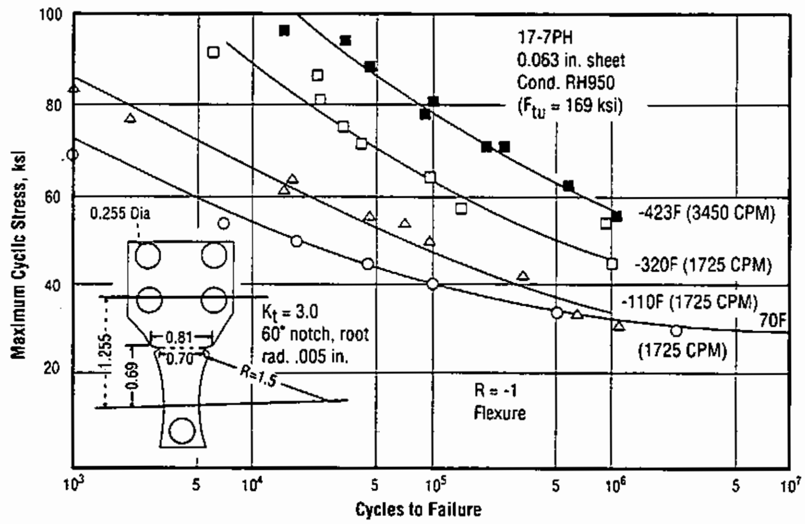



Fig. 3.5.2 Flexural fatigue properties at room and low temperatures for notched sheet ($K_t$ = 3.0) in Condition RH950 (Ref. 51)

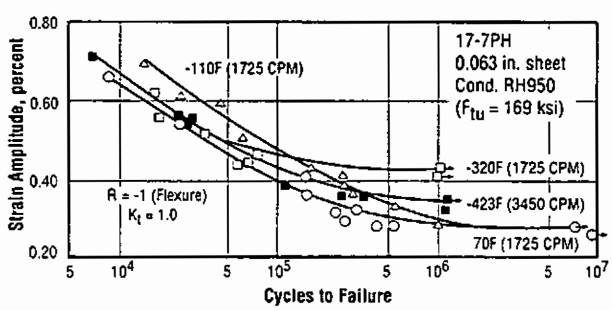



Fig. 3.5.3 Flexural strain-cycling fatigue curves at room and low temperatures for sheet in Condition RH950 (Ref. 51)

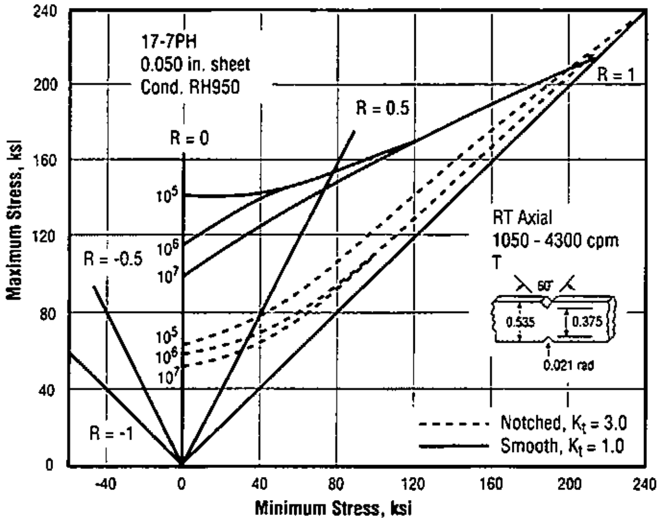



Fig. 3.5.4 Constant-life fatigue curves at room temperature for smooth and notched sheet in Condition RH950 (Ref. 39)

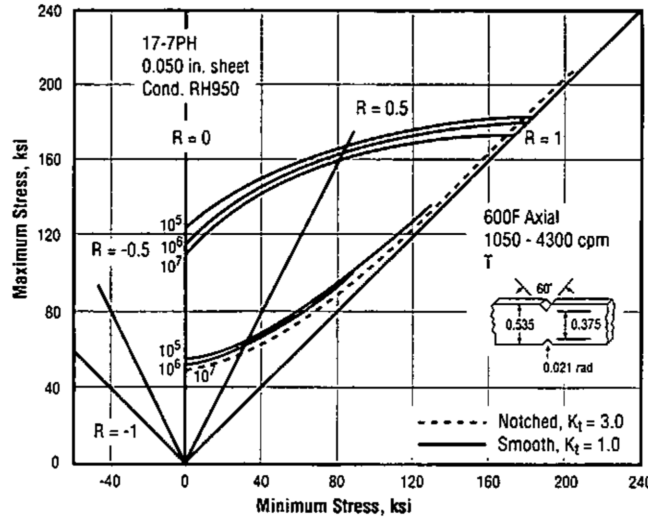



Fig. 3.5.5 Constant-life fatigue curves at 600F for smooth and notched sheet in Condition RH950 (Ref. 39)

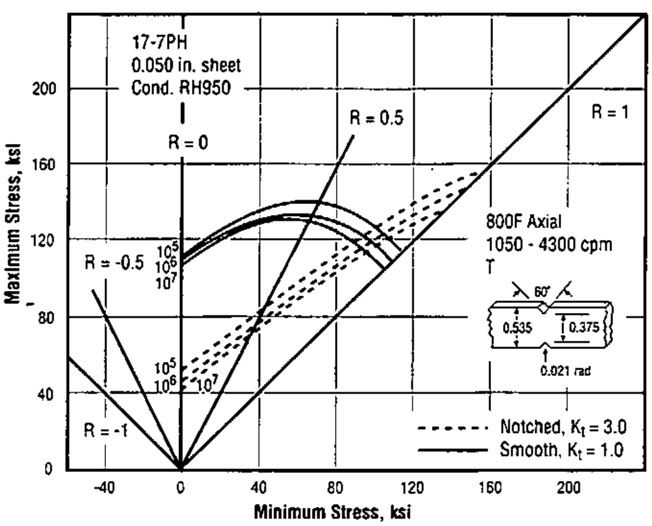



Fig. 3.5.6 Constant-life fatigue curves at 800F for smooth and notched sheet in Condition RH950 (Ref. 39)

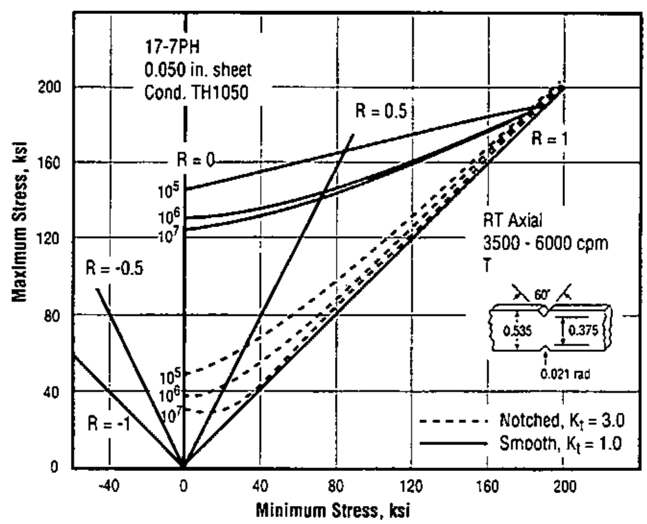



Fig. 3.5.7 Constant-life fatigue curves at room temperature for smooth and notched sheet in Condition TH1050 (Ref. 38)

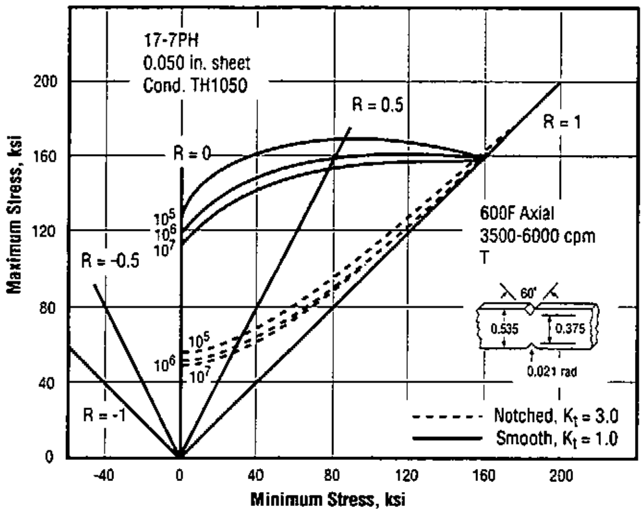



Fig. 3.5.8 Constant-life fatigue curves at 600F for smooth and notched sheet in Condition TH1050 (Ref. 38)

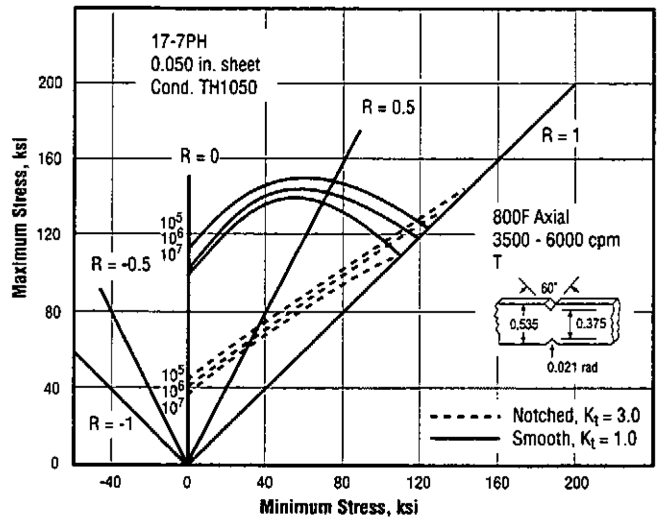



Fig. 3.5.9 Constant-life fatigue curves at 800F for smooth and notched sheet in Condition TH1050 (Ref. 38)

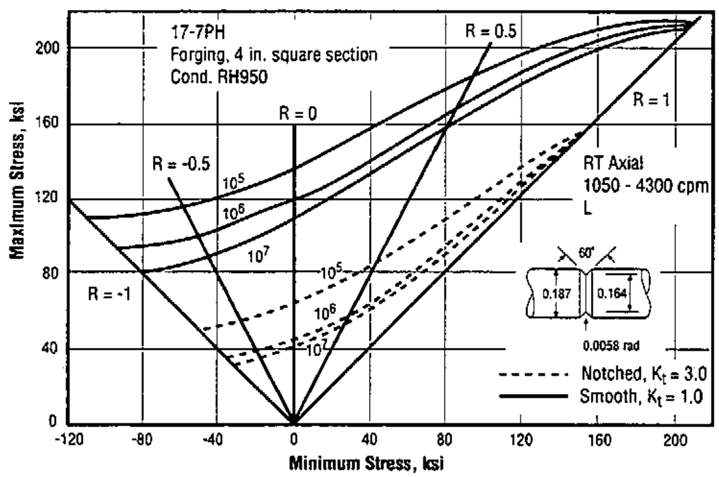



Fig. 3.5.10 Constant-life fatigue curves at room temperature for smooth and notched forging in Condition RH950 (Ref. 39)

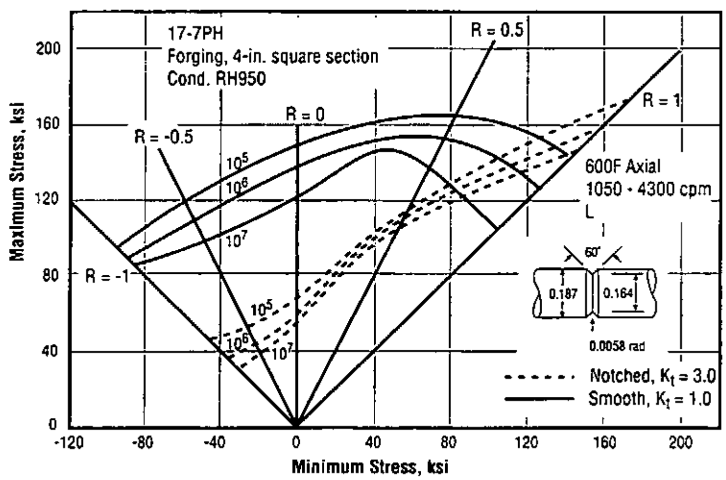



Fig. 3.5.11 Constant-life fatigue curves at 600F for smooth and notched forging in Condition RH950 (Ref. 39)

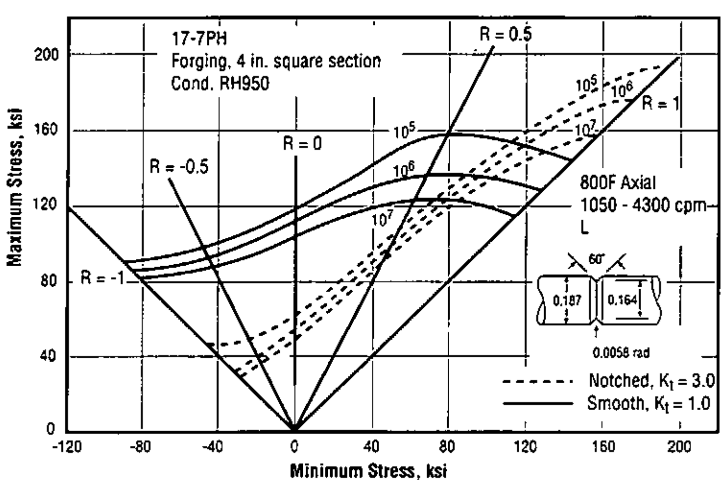



Fig. 3.5.12 Constant-life fatigue curves at 800F for smooth and notched forging in Condition RH950 (Ref. 39)

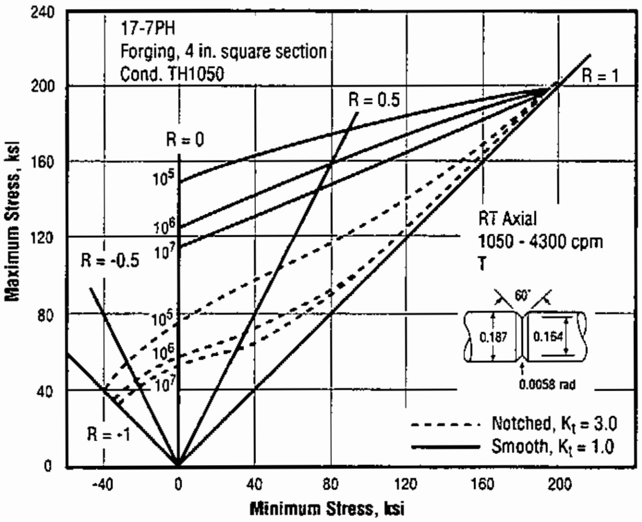



Fig. 3.5.13 Constant-life fatigue curves at room temperature for smooth and notched forging in Condition TH1050 (Ref. 39)

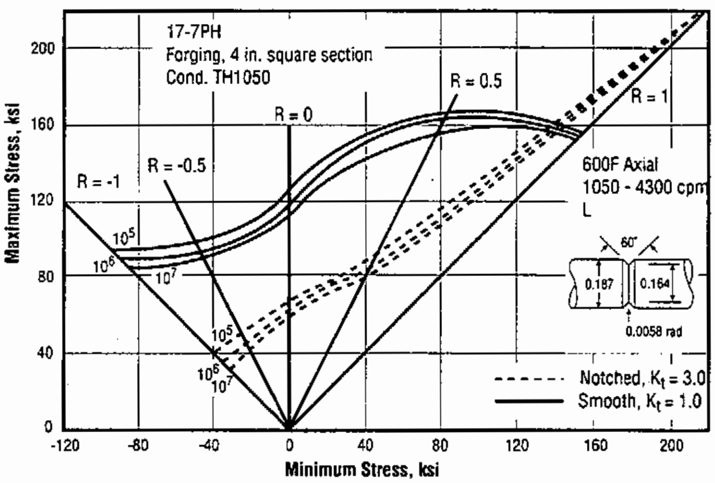



Fig. 3.5.14 Constant-life fatigue curves at 600F for smooth and notched forging in Condition TH1050 (Ref. 39)

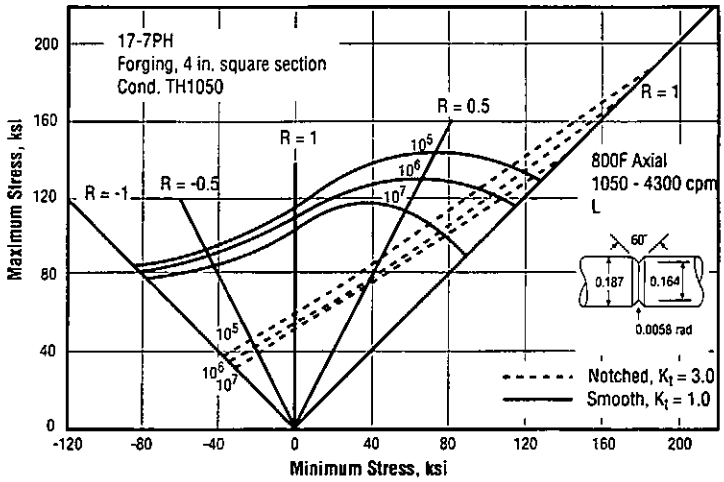



Fig. 3.5.15 Constant-life fatigue curves at 800F for smooth and notched forging in Condition TH1050 (Ref. 39)

Table 3.5.16 Effects of wire diameter and surface condition on the fatigue endurance limit of helical compression springs at room temperature (Ref. 17)

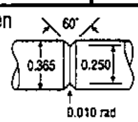
| Alloy: 17-7PH | | | |
|---|---|---|---|
| **Form** | | **Helical Compression Springs** | |
| **Condition** | | **CH900** | |
| **Wire Dia., in.** | **Surface Condition** | **$F_{tu}$, ksi** | **Fatigue Endurance Limit (Shear Stress) at $10^7$ cycles, ksi (a)** |
| 0.067 | Cold Drawn | 297 - 327 | 85 |
| 0.067 | Electropolish | 297 - 327 | 105 |
| 0.085 | Cold Drawn | 292 - 322 | 85 |
| 0.105 | Cold Drawn | 274 - 304 | 85 |
| 0.105 | Shot Peen | 274 - 304 | 120 |
| 0.105 | Electropolish & Shot Peen | 274 - 304 | 130 |
| 0.125 | Cold Drawn | 272 - 302 | 73 |
| 0.125 | Electropolish | 272 - 302 | 85 |

(a) 10 ksi minimum cyclic stress

Table 3.5.17 Effect of surface protection with dodecyl alcohol on fatigue crack initiation and propagation of notched bar (Ref. 59)

| Alloy: 17-7PH | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Form** | **0.365-in. Bar (a)** | | | | | | |
| **Condition** | **TH1050 (45 RC)** | | | | | | |
| **Rotating Beam R = -1 3000 rpm** | **Thousands of cycles of stress (b)** | | | | | | |
| | **Clean Surface** | | | **Surface coated with dodecyl alcohol** | | | |
| **Max Cyclic Stress, ksi** | **$N_c$ (c)** | **$N_p$ (d)** | **$N_f$ (e)** | **$N_c$ (c)** | **$N_p$ (d)** | **$N_f$ (e)** | **R (f)** |
| 42.5 | 40 | 75 | 115 | 40 | 285 | 325 | 3.8 |
| 52.5 | 12 | 20 | 32 | 12 | 27 | 39 | 1.4 |

(a) Notched specimen




(b) Median value, 5-7 specimens
(c) Cycles to cause detectable crack at notch root
(d) Cycles to propagate crack to failure
(e) Total cycles to failure
(f) Ratio of cycles to propagate crack, coated: clean

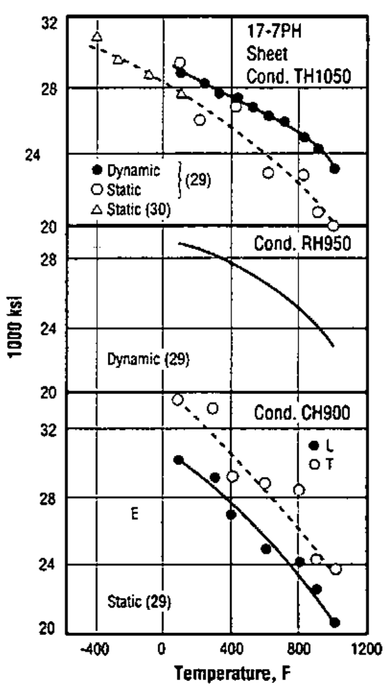



Fig. 3.6.2.1 Modulus of elasticity at various temperatures (Refs. 29, 30)

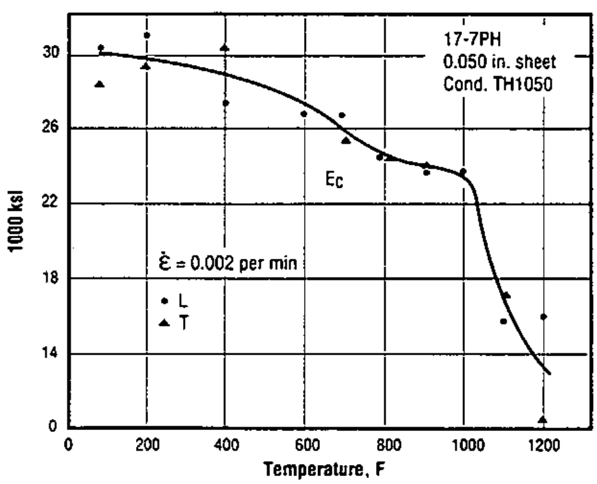



Fig. 3.6.2.2 Effects of temperatures up to 1200F on the modulus of elasticity in compression of sheet (Ref. 3)

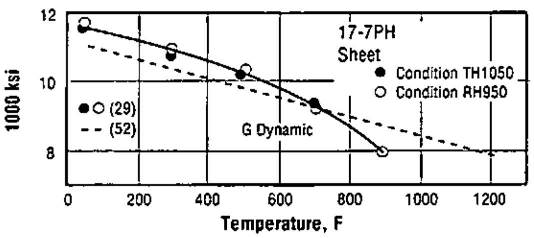



Fig. 3.6.3.1 Modulus of rigidity at room and elevated temperatures (Refs. 29, 52)

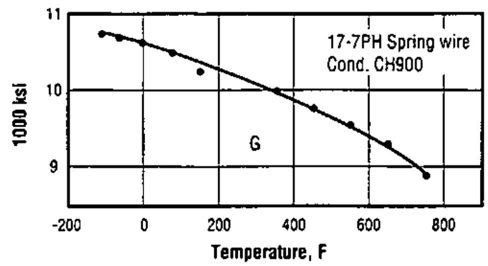



Fig. 3.6.3.2 Effects of temperatures from -105 to 750F on modulus of rigidity of spring wire (Ref. 17)

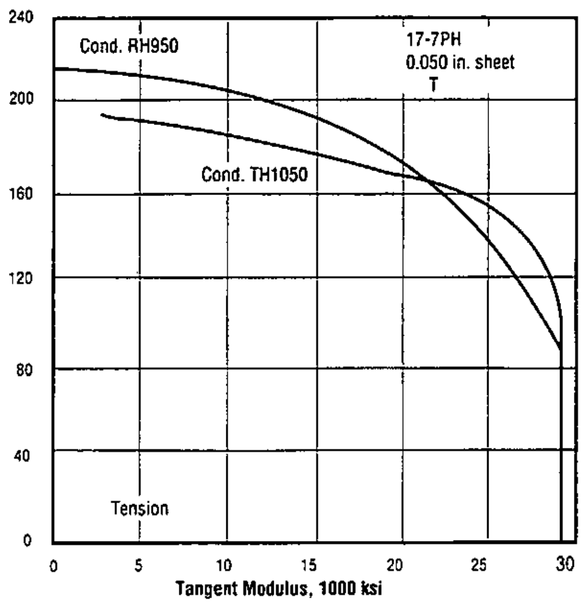



Fig. 3.6.4.1 Tangent-modulus curves in tension at room temperature for sheet in Conditions TH1050 and RH950 (Ref. 29)

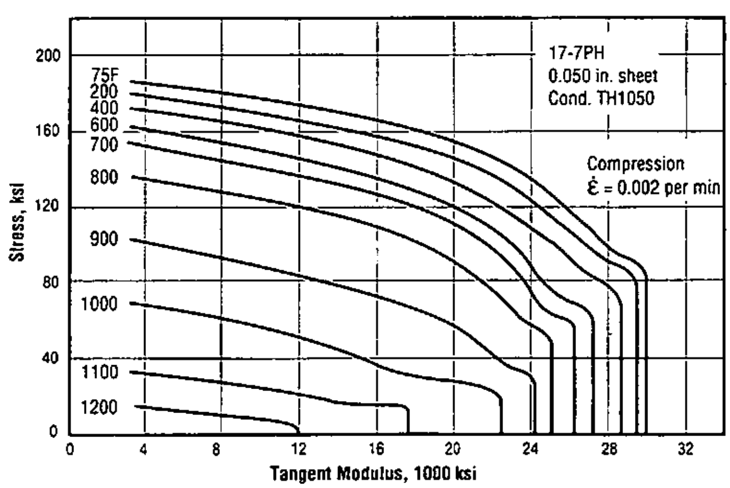



Fig. 3.6.4.2 Tangent-modulus curves in compression for sheet in Condition TH1050 at temperatures up to 1200F (Ref. 3)

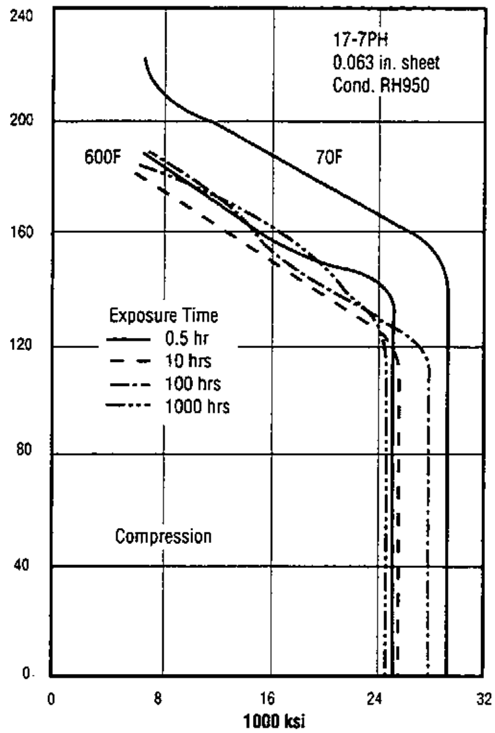



Fig. 3.6.4.3 Tangent-modulus curves in compression for sheet in Condition RH950 at room temperature and 600F, showing effects of prior exposure at 600F (Ref. 35)

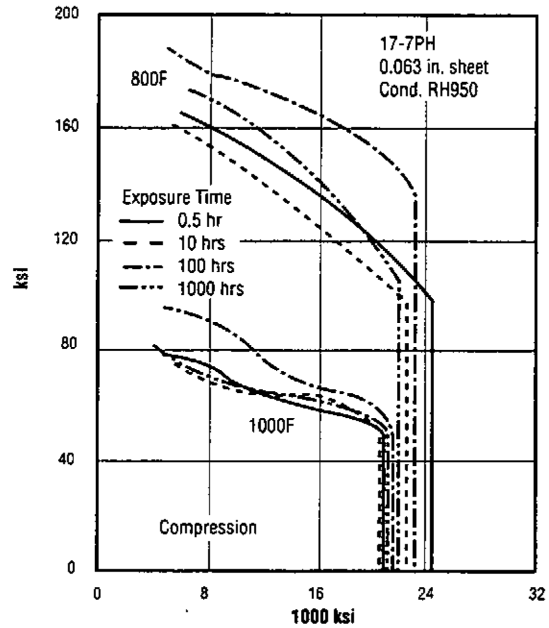



Fig. 3.6.4.4 Tangent-modulus curves in compression for sheet in Condition RH950 at 800 and 1000F, showing effects of prior exposure at test temperature (Ref. 35)

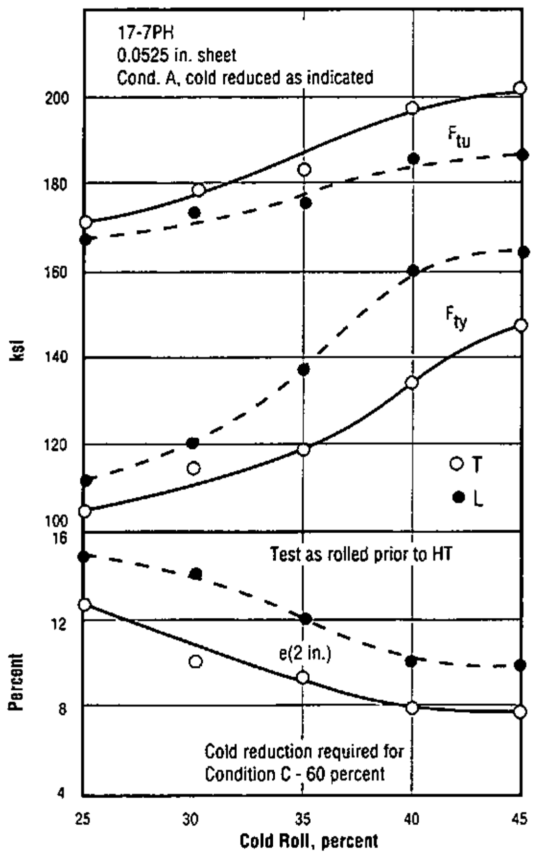



Fig. 4.1.1.2 Effect of cold work on tensile properties of sheet given less cold reduction than required for Condition C (Ref. 13)

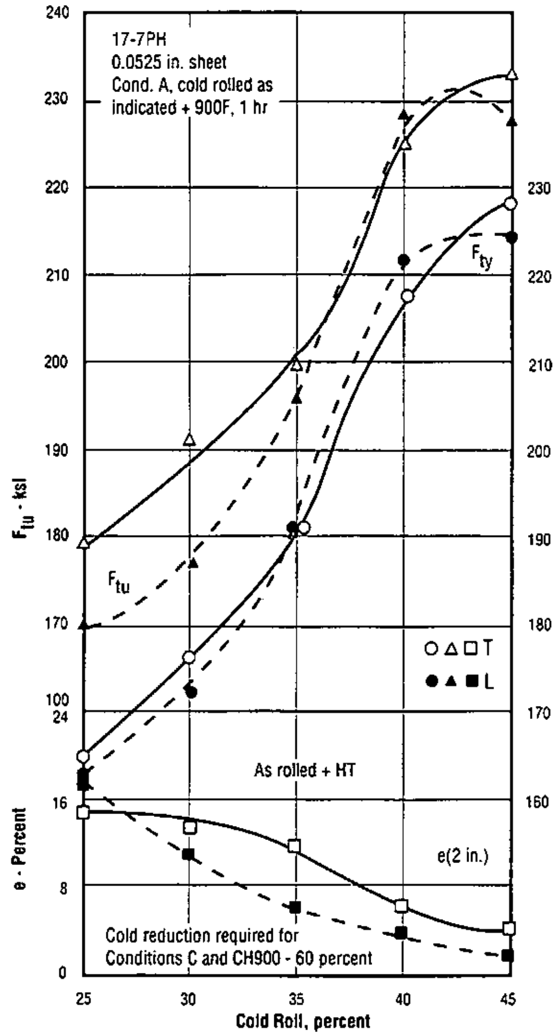



Fig. 4.1.1.3 Effect of cold work on tensile properties of sheet given less cold reduction than required for Conditions C and CH900 and then aged for one hour at 900F (Ref. 13)

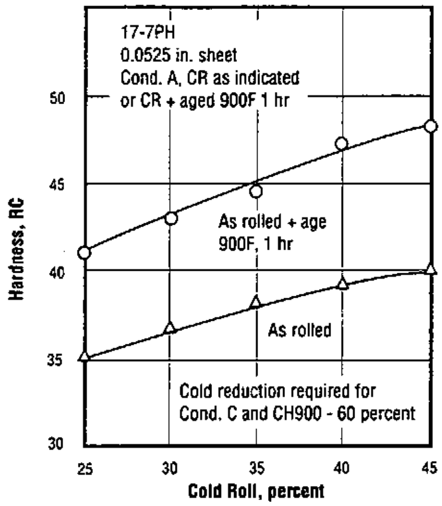



Fig. 4.1.1.4 Effect of cold work on hardness of sheet given less cold reduction than required for Conditions C and CH900 (Ref. 13)

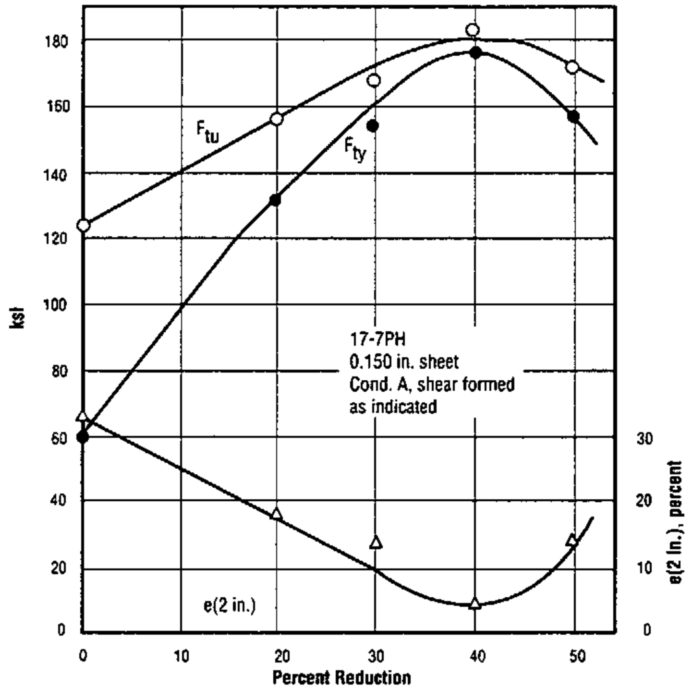



Fig. 4.1.1.6.1 Effect of percent reduction by shear forming on tensile properties at room temperature (Ref. 26)

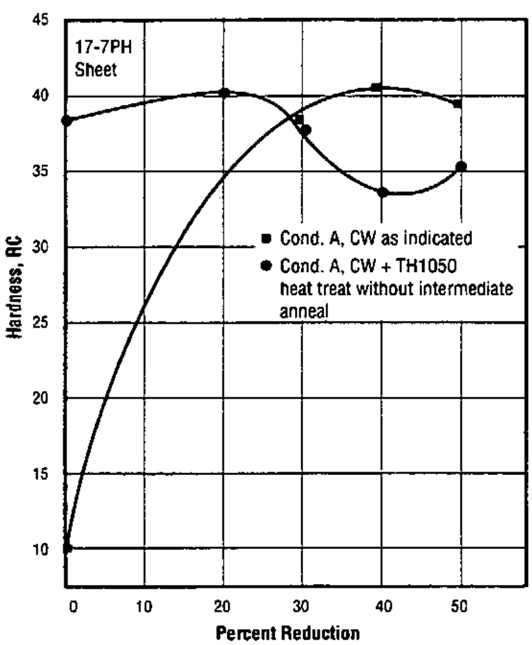



Fig. 4.1.1.6.2 Effects of sheer forming and subsequent heat treatment on hardness (Ref. 26)

Table 4.3.1.2 Tensile properties determined on sheet with butt welds across the gage length of the test specimens (Refs. 6, 10, 21)

| Alloy: 17-7PH | | | |
|---|---|---|---|
| **Form** | **0.062-in. Sheet, Butt Welded (a)** | | |
| **Condition (b)** | **$F_{ty}$, ksi** | **$F_{tu}$, ksi** | **El(2 in.), percent** |
| RH950 | 205 | 220 | 2.0 |
| RH1100 | 132 | 165 | 6.0 |
| TH1050 | 195 | 205 | 1.5 |
| TH1100 | 130 | 160 | 6.0 |
| A, TH1050 | 195 | 208 | 2.5 |
| A, TH1100 | 132 | 160 | 6.0 |

(a) GATW (helium shielding at 60 in. ft. per hr.) at 15 in. per min., d-c s-p, with 1/16-in.-dia. 17-7PH filler added at 28 in. per min.
(b) Sheet was in Condition A when welded and was heat treated to conditions shown after welding. The last two samples were given an intermediate treatment to Condition A after welding but prior to the final treatments.

Table 4.3.1.3 Comparison of tensile properties at both room and elevated temperatures of sheets in Condition TH1075 with the same sheets containing butt welds (as-welded) across the gage length of the test specimens (Ref. 21)

| Alloy: 17-7PH | | | | | | |
|---|---|---|---|---|---|---|
| **Form** | | **Sheet** | | | | |
| **Location** | | | **Base Metal** | | **Weld Joint (a)** | |
| **Condition (b)** | | | **TH1075** | | **As-Welded (c)** | |
| **Sheet Thickness, in.** | **Orientation** | **Temp., F** | **$F_{tu}$, ksi** | **e(2 in.) percent** | **$F_{tu}$, ksi** | **e(2 in.) percent** |
| 0.018 | T | 75 | 182.6 | 10.8 | 143.9 | 2.1 |
| 0.050 | T | 75 | 177.7 | 10.4 | 140.5 | 3.8 |
| 0.080 | T | 75 | 187.5 | 9.0 | 156.7 | 4.7 |
| 0.050 | L | 75 | 184.2 | - | 151.4 | 4.0 |
| 0.078 | L | 75 | 189.0 | - | 145.8 | 5.6 |
| 0.078 | L | 300 | 175.8 | 9.1 | 96.0 | 4.9 |
| 0.050 | L | 500 | 161.3 | 4.7 | 90.1 | 2.8 |
| 0.050 | L | 700 | 152.4 | 6.5 | 92.3 | 3.0 |
| 0.050 | L | 900 | 116.7 | 22.0 | 81.2 | 3.2 |

(a) GTAW with 17-7PH filler wire.
(b) The sheet was in Condition TH1075 prior to welding and no postweld heat treatment was applied.
(c) Specimens fractured in the welds.

Table 4.3.2.1 Shear strength of spot-welded joints (Ref. 21)

| Alloy: 17-7PH | | | |
|---|---|---|---|
| **Form** | **0.050-in. Sheet** | | |
| **Condition in Which Welded (a)** | **Condition in Which Tested** | **Shear Breaking Load lb/weld** | |
| | | **Low Test** | **20 Test Avg.** |
| A | TH1050 (b) | 2720 | 2790 (d) |
| T | TH1050 (b) | 2950 | 2970 (d) |
| TH1050 | TH1050 (c) | 2250 | 2610 (d) |
| A | RH950 (b) | 2300 | 2556 |
| R100 | RH950 (b) | 2582 | 2882 |
| RH950 | RH950 (c) | 2380 | 2660 |
| MIL-W-6858B, minimums | | 2125 | 2620 |

(a) Spot welding conditions: welding pressure 120 lb., current 1500 amps, electrode dome radius 3 in., time 10 cycles, sheet vapor blasted prior to welding.
(b) Postweld heat treatment completed from condition in which welded; no intermediate solution treatment.
(c) No postweld heat treatment.
(d) Average of three tests.

## References

1. Reinhart, F. N., "Corrosion of Materials in Hydrospace—Part VI—Stainless Steels," Naval Civil Engineering Laboratory, Technical Note N-1172 (Sept. 1971).
2. "Emissivity of Metals at Elevated Temperatures," McDonnell Aircraft Corp., Report No. 9096 (Oct. 10, 1962).
3. Stein, B. A., "Compressive Stress-Strain Properties of 17-7 PH and AM 350 Stainless-Steel Sheet at Elevated Temperatures," NACA TN 4074 (Aug. 19, 1957).
4. Clarke, W. C., Jr., "A Study of Embrittlement of a Precipitation Hardening Stainless Steel and Some Related Materials," *Trans. of the Metallurgical Society of AIME*, Vol. 245, pp. 2135-2140 (Oct. 1969).
5. Carter, C. S.; Farwick, D. G.; Ross, A. M.; and Uchida, J. M., "Stress Corrosion Properties of High Strength Precipitation Hardening Stainless Steels, " *Corrosion*, Vol. 27, pp. 190-197 (May 1971).
6. Weymueller, C. R., "The PH Stainlesses—Simple to Weld but Touchy," *Welding Design and Fabrication*, Vol. 53, pp. 68-72 (May 1980).
7. ASTM A 693, *ASTM Annual Book of Standards*, Vol. 1.03.
8. ASTM A 564, *ASTM Annual Book of Standards*, Vol. 1.05.
9. ASTM A 705, *ASTM Annual Book of Standards*, Vol. 1.05.
10. "Precipitation-Hardenable Stainless Steels," The International Nickel Co., Inc., Bulletin D (1963).
11. "Stability of Armco 17-7 PH Steel in the RH Condition on Exposure to Elevated Temperatures," The Martin Co., ER-9582-5 (Oct. 10, 1957).
12. NASA (1959).
13. "Armco 17-7 PH and PH 15-7Mo," Armco Steel Corp. (1966).
14. "Armco Precipitation Hardening Stainless Steels," Armco Stainless Steel Division (Nov. 1983).
15. "Precipitation Hardenable Stainless Steels," Republic Steel Corp. (1975).
16. "Armco Stainless Steels," Armco Specialty Steels Division (Feb. 1985).
17. "Armco 17-7 PH Precipitation-Hardening Stainless Steel, Bar, Rod and Wire," Armco Stainless Steel Division, Bulletin No. S-29e (April 1983).
18. ASTM A 313, *ASTM Annual Book of Standards*, Vol. 1.03.
19. "Armco 17-7 PH Precipitation-Hardening Stainless Steel Sheet and Strip," Armco Product Data Bulletin No. FS-2 (1987).
20. "Heat Treating Armco Stainless Steels," Armco Fabricating Data Bulletin No. SF-56 (1984).
21. "Welding and Brazing Armco 17-7 PH and PH 15-7Mo Precipitation Hardening Stainless Steels," Armco Bulletin SF-5 (1967).
22. "Armco Stainless Steels," Armco Publication LA172 (1972).
23. *Metals Handbook*, Ninth Edition, Vol. 3, ASM International (1980).
24. Campbell, J. E.; Gerberich, W. W.; and Underwood, J. H., "Application of Fracture Mechanics for Selection of Metallic Structural Materials," American Society for Metals (1982).
25. *Metals Handbook*, Tenth Edition, Vol. 1, ASM International (1990).
26. Jacobs, Frank, "Mechanical Properties of Materials Fabricated by Shear Forming," ASD-TDR-62-830 (Feb. 1963).
27. "Stainless Steel, AL 17-7 Precipitation-Hardening Alloy," Allegheny Ludlum Steel Corp., Bulletin B-158-Ed1-3M-186 BPA (1985).
28. Thompson, A. W., "How High-Pressure Hydrogen Affects Stainless Steel," *Metal Progress*, Vol. 110, pp. 30-33 (July 1976).
29. "Armco Precipitation Hardening Stainless Steels Technical Data Manual," Armco Steel Corp. (Nov. 1, 1957).
30. McGee, A. L.; Campbell, J. E.; Carlson, R. L.; and Manning, G. K., "The Mechanical Properties of Certain Aircraft Structural Metals at Very Low Temperatures," WADC TR 58-386 (Nov. 1958).
31. Kattus, J. R., "Tensile and Creep Rupture Properties of Structural Alloys Under Conditions of Rapid Heating, Rapid Loading, and Short Times at Temperature," Southern Research Institute Report 3962-867-2-I to International Nickel Co. (April 10, 1959).
32. Willhelm, A. C., and Kattus, J. R., "Determination of the Mechanical Properties of Aircraft Structural Materials at Very High Temperatures After Rapid Heating"; Part 3, "The Effects of Simultaneous Heating and Loading on the Tensile Properties of Typical Structural Alloys," WADC TR 57-647, Part 3 (Nov. 1960).
33. Morrison, J. D., and Kattus, J. R., "Tensile Properties of Aircraft Structural Metals at Various Rates of Loading After Rapid Heating," WADC TR 55-199, Part 2 (Nov. 1956).
34. Miller, E. D., "Determination of the Physical Properties of Ferrous and Nonferrous Structural Sheet Materials at Elevated Temperatures," AF TR No. 6517, Part 4 (Dec. 1954).

35. Kattus, J. R.; Preston, J. B.; and Lessley, H. L., "Determination of Tensile, Compressive, Bearing, and Shear Properties of Sheet Steels at Elevated Temperatures," WADC Technical Report 58-365 (Nov. 1958).

36. Steigerwald, E. A., "Plane Strain Fracture Toughness for Handbook Presentation," AFML-TR-67-187 (July 1967).

37. AFTR 6731, Part 3 (1955).

38. Bass, C. D., and Harmsworth, C. L., "Fatigue, Tensile, and Creep Properties of 17-7 PH TH1050 and AM 350 SCT Sheet," AFML-TR-69-331 (March 1970).

39. Roach, T. A., "Development of Fatigue Data for Several Alloys for Use in Aerospace Design," AFML-TR-69-175 (June 1969).

40. Fritz, L. J.; Koster, W. P.; and Field, M., "Low-Stress Creep Testing of 17-7 PH Stainless Steel," Metcut Research Associates Report No. 363-1536, Air Material Command Contract No. AF 33(600)-36430 (April 14, 1960).

41. Armco Materials and Processing Update, "The Effect of Composition and Section Size on Transverse Properties of Precipitation Hardening of Stainless Steels" (1981).

42. Idermark, S. U. V., and Johansson, E. R., "Room Temperature Stress Relaxation of High-Strength Strip and Wire Spring Steels—Procedures and Data," *Stress-Relaxation Testing*, ASTM STP 676, pp. 61-77 (1979).

43. Menke, Joseph T., "An Evaluation of Processes for the Blackening of Precipitation-Hardening Stainless Steels," Rock Island Arsenal Technical Report No. EN-79-01 (June 1979).

44. Angel, Stefan, and Solly, Barry, "Factors Controlling the Reliability of 17-7 PH Spring Wire," *Wire Journal International*, Vol. 15, No. 8, pp. 78-81 (Aug. 1982).

45. AMS 5528E, Society of Automotive Engineers (Oct. 1988).

46. AMS 5529D, Society of Automotive Engineers (Oct. 1989).

47. AMS 5568C, Society of Automotive Engineers (Jan. 1988).

48. AMS 5678B, Society of Automotive Engineers (Oct. 1987).

49. AMS 5824B, Society of Automotive Engineers (Jan. 1987).

50. Voorhees, H. R., and Freeman, J. W., "Notch Sensitivity of Aircraft Structural and Engine Alloys," WADC TR 57-58, Part 1 (May 1957).

51. Gideon, D. N.; Favor, R. J.; Koppenhafer, A.; Grover, H. J.; and McClure, G. M., "Investigation of Notch Fatigue Behavior of Certain Alloys in the Temperature Range of Room Temperature to -423F," ASD-TDR-62-351 (Aug. 1962).

52. General Electric Co., "G. E. Spec." (Dec. 17, 1957).

53. AMS 5673C, Society of Automotive Engineers (1974), [Superseded by AMS 5678 (July 1982)].

54. Walter, R. J., and Chandler, W. T., "Effects of High-Pressure Hydrogen," Reports to NASA by Rocketdyne Corp. under Contract NAS8-19, Part I, R-7234-1 (Sept. 1967); Part II, R-7234-2 (March 1968); Part III, R-7234-3 (Sept. 1968).

55. Davis, S. O.; Tupper, N. G.; Lagrone, D. C.; and Niemi, R. M., "Center-Notch Plane-Strain KIc Fracture Toughness Properties of Several High-Strength Steel Alloys," AFML-TR-65-214 (Oct. 1965).

56. Brisbane, A. W., "Mechanical Properties of 17-7 PH and PH 15-7Mo Stainless Steel," WADC TR 58-400 (Jan. 1959).

57. Armco Steel Corp., Private communication (April 9, 1959).

58. WADC TR 6517, Part 4 (1954).

59. Holhauser, W. L., and Utech, H. P., "Effect of Oleophobic Films on Crack Propagation," ASTM *Proceedings*, Vol. 61, pp. 749-54 (1961).

60. Lewis, J. R., "Physical Properties of Stainless Steels," *Handbook of Stainless Steels*, Chapter 19, McGraw-Hill (1977).

This page is blank.