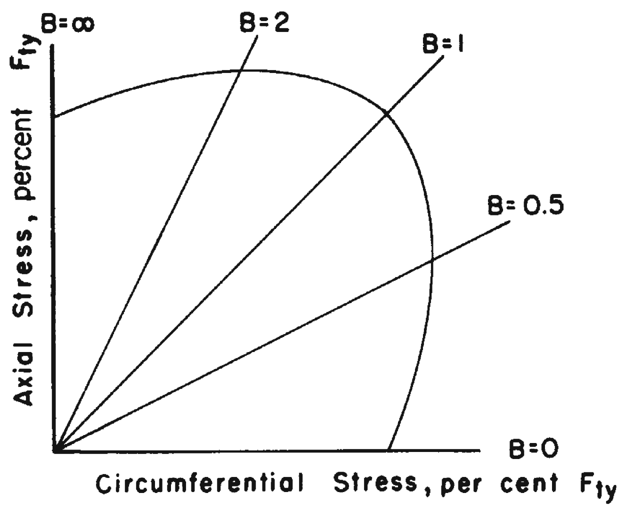

Figure 1.4.11.2. Typical biaxial yield stress envelope.

1.4.11.3 ***Biaxial Ultimate Stress*** — Biaxial ultimate stress is defined as the highest nominal principal stress attained in specimens of a given configuration, tested at a given biaxial stress ratio. This property is highly dependent upon geometric configuration of the test parts. Therefore, such data should be limited in use to the same design configurations.

The method of presenting biaxial ultimate strength data is similar to that described in the preceding section for biaxial yield strength. Both biaxial ultimate strength and corresponding uniform elongation data are reported, when available, as a function of biaxial stress ratio test conditions.

1.4.12 FRACTURE TOUGHNESS — The occurrence of flaws in a structural component is an unavoidable circumstance of material processing, fabrication, or service. Flaws may appear as cracks, voids, metallurgical inclusions, weld defects, design discontinuities, or some combination thereof. The fracture toughness of a part containing a flaw is dependent upon flaw size, component geometry, and a material property defined as fracture toughness. The fracture toughness of a material is literally a measure of its resistance to fracture. As with other mechanical properties, fracture toughness is dependent upon alloy type, processing variables, product form, geometry, temperature, loading rate, and other environmental factors.

This discussion is limited to brittle fracture, which is characteristic of high strength materials under conditions of loading resulting in plane-strain through the cross section. Very thin materials are described as being under the condition of plane-stress. The following descriptions of fracture toughness properties applies to the currently recognized practice of testing specimens under slowly increasing loads. Attendant and interacting conditions of cyclic loading, prolonged static loadings, environmental influences other than temperature, and high strain rate loading are not considered.

2.3.0.3 ***Environmental Considerations*** — Alloy steels containing chromium or high percentages of silicon have somewhat better oxidation resistance than the carbon or other alloy steels. Elevated-temperature strength for the alloy steels is also higher than that of corresponding carbon steels. The mechanical properties of all alloy steels in the heat-treated condition are affected by extended exposure to temperatures near or above the temperature at which they were tempered. The limiting temperatures to which each alloy may be exposed for no longer than approximately 1 hour per inch of thickness or approximately one-half hour for thicknesses under one-half inch without a reduction in strength occurring are listed in Table 2.3.0.3. These values are approximately 100°F below typical tempering temperatures used to achieve the designated strength levels.

Table 2.3.0.3. Temperature Exposure Limits for Low-Alloy Steels

	Exposure Limit, °F						
F_{tu}, ksi	125	150	180	200	220	260	270 & 280
Alloy:							
AISI 4130 and 8630	925	775	575	. . .	. . .	. . .	. . .
AISI 4140 and 8740	1025	875	725	625	. . .	. . .	. . .
AISI 4340	1100	950	800	700	. . .	350	. . .
AISI 4135 and 8735	975	825	675	. . .	. . .	. . .	. . .
D6AC	1150	1075	1000	950	900	500	. . .
Hy-Tuf	875	750	650	550	450	. . .	. . .
4330V	925	850	775	700	500	. . .	. . .
4335V	975	875	775	700	500	. . .	. . .
300M	. . .	. . .	. . .	. . .	. . .	. . .	475

a Quenched and tempered to F_{tu} indicated. If the material is exposed to temperatures exceeding those listed, a reduction in strength is likely to occur.

Low-alloy steels may undergo a transition from ductile to brittle behavior at low temperatures. This transition temperature varies widely for different alloys. Caution should be exercised in the application of low-alloy steels at temperatures below -100°F. For use at a temperature below -100°F, an alloy with a transition temperature below the service temperature should be selected. For low temperatures, the steel should be heat treated to a tempered martensitic condition for maximum toughness.

Heat-treated alloy steels have better notch toughness than carbon steels at equivalent strength levels. The decrease in notch toughness is less pronounced and occurs at lower temperatures. Heat-treated alloy steels may be useful for subzero applications, depending on their alloy content and heat treatment. Heat treating to strength levels higher than 150 ksi F_{ty} may decrease notch toughness.

The corrosion properties of the AISI alloy steels are comparable to the plain carbon steels.

2.3.1 SPECIFIC ALLOYS

2.3.1.0 *Comments and Properties* — AISI 4130 is a chromium-molybdenum steel that is in general use due to its well-established heat-treating practices and processing techniques. It is available in all sizes of sheet, plate, and tubing. Bar stock of this material is also used for small forgings under one-half inch in thickness. AISI 4135, a slightly higher carbon version of AISI 4130, is available in sheet, plate, and tubing.

AISI 4140 is a chromium-molybdenum steel that can be heat treated in thicker sections and to higher strength levels than AISI 4130. This steel is generally used for structural machined and forged parts one-half inch and over in thickness. It can be welded but it is more difficult to weld than the lower carbon grade AISI 4130.

AISI 4340 is a nickel-chromium-molybdenum steel that can be heat treated in thicker sections and to higher strength levels than AISI 4140.

AISI 8630, 8735, and 8740 are nickel-chromium-molybdenum steels that are considered alternates to AISI 4130, 4135, and 4140, respectively.

There are a number of steels available with compositions that represent modifications to the AISI grades described above. Four of the steels that have been used rather extensively at F_{tu} = 220 ksi are D6AC, Hy-Tuf, 4330V, and 4335V. It should be noted that this strength level is not used for AISI 4340 due to embrittlement encountered during tempering in the range of 500 to 700°F. In addition, AISI 4340 and 300M are utilized at strength levels of F_{tu} = 260 ksi or higher. The alloys, AISI 4340, D6AC, 4330V, 4335V, and 300M, are available in the consumable electrode melted grade. Material specifications for these steels are presented in Tables 2.3.1.0(a) and (b).

The room-temperature mechanical and physical properties for these steels are presented in Tables 2.3.1.0(c) through 2.3.1.0(g). Mechanical properties for heat-treated materials are valid only for steel heat treated to produce a quenched structure containing 90 percent or more martensite at the center. Figure 2.3.1.0 contains elevated temperature curves for the physical properties of AISI 4130 and AISI 4340 steels.

2.3.1.1 *AISI Low-Alloy Steels* — Elevated temperature curves for heat-treated AISI low-alloy steels are presented in Figures 2.3.1.1.1 through 2.3.1.1.4. These curves are considered valid for each of these steels in each heat-treated condition but only up to the maximum temperatures listed in Table 2.3.0.1(b).

2.3.1.2 *AISI 4130 and 8630 Steels* — Typical stress-strain and tangent-modulus curves for AISI 8630 are shown in Figures 2.3.1.2.6(a) through (c). Best-fit S/N curves for AISI 4130 steel are presented in Figures 2.3.1.2.8(a) through (h).

2.3.1.3 *AISI 4340 Steel* — Typical stress-strain and tangent-modulus curves for AISI 4340 are shown in Figures 2.3.1.3.6(a) through (c). Typical biaxial stress-strain curves and yield-stress envelopes for AISI 4340 alloy steel are presented in Figures 2.3.1.3.6(d) through (g). Best-fit S/N curves for AISI 4340 are presented in Figures 2.3.1.3.8(a) through (o).

2.3.1.4 *300M Steel* — Best-fit S/N curves for 300M steel are presented in Figures 2.3.1.4.8(a) through (d). Fatigue-crack-propagation data for 300M are shown in Figure 2.3.1.4.9.

2.3.1.5 D6AC Steel — Fatigue-crack-propagation data for D6AC steel are presented in Figure 2.3.1.5.9.