AUTHOR: W. F. BROWN, Jr.

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

1 GENERAL

Age-hardenable aluminum alloy 7050 has a good combination of strength, fracture toughness, and corrosion resistance in both thick and thin wrought sections. In relatively thick forgings, extrusions, and plate, it provides a combination of strength, stress-corrosion resistance, and toughness superior to that of 7075. In sheet and relatively thin extrusions, 7050 in the T76 type temper provides strength comparable to that of 7075-T6 with superior exfoliation resistance and fracture toughness. Its chemical composition differs from that of other Al-Zn-Mg-Cu alloys in two significant respects: one, it contains zirconium in place of chromium as a recrystallization and grain-control addition, and two, it has a copper-magnesium ratio greater than 0.8. The absence of chromium contributes to low quench sensitivity, and the relatively high copper content results in additional strengthening during second-step aging.

Alloy 7050 has close controls on its iron and silicon contents and is one of the newer high purity aluminum alloys which combine high strength with good fracture toughness.

7050 is generally available in three tempers: (a) T73 which provides the highest resistance to stress-corrosion cracking and the highest fracture toughness along with the lowest tensile strength; (b) T76 which provides the highest strength but stress corrosion resistance and fracture toughness inferior to that in the T73 temper; and (c) T74 (previously T736) which provides properties intermediate between the T73 and T76 tempers.

7050 should be considered for any aerospace applications requiring strength levels in the range provided by 7075-T6 and 7079-T6 alloys along with high resistance to stress corrosion and exfoliation and good toughness (4,8,11).

1.01 Commercial Designation

7050, ALCOA MA15.

1.02 Alternate Designation

SAE-ASTM UNS A97050.

1.03 Specifications

ASTM B 247.

1.031 AMS Specifications, Table 1.031.

1.04 Composition

1.041 AMS specified alloy composition, Table 1.041.

1.042 Producer's composition of cladding alloys for 7050, Table 1.042.

1.05 Heat Treatment

1.051 Solution treatment. Generally from 880 to 900 F followed by water quenching. Details concerning the temperature of the quench bath and soaking times are given in Tables 1.056 and 1.057. Plate is generally spray quenched and particular attention should be given to the proper operation of the spray equipment to avoid soft areas in the product. (See Code 3221, Section 1.09.)

Forgings are sometimes quenched in a mixture of water and polyalkylene glycol which exhibits inverse solubility in water. It is soluble at room temperature but when the temperature is raised above about 165 F a precipitate separates from the solution in the form of an organic polymer which will be deposited on the surface of a quenched part. Under these circumstances, cooling is somewhat slower than with a water quench but more uniform. Consequently, residual stresses and distortions are significantly reduced. For 7050 the following recommendations are given concerning glycol quenching (40): (a) maximum thickness of 3-inch, (b) mechanical agitation of the part or quench medium, (c) quench time of 2 min./in., (d) maximum glycol concentration of 12 percent, and (e) maximum quench temperature of 90 F.

1.052 Stress relief. Relief of quenching stresses for all products except die forgings, wire, rod, and rivets is accomplished by plastic deformation of 1 to 5 percent depending on the product form as shown in Table 1.056.

1.053 Aging. Some specifications (e.g., AMS 2770D) call for aging to be delayed several days at room temperature following quenching. However, for 7050, the magnitude of the delay time has an insignificant effect on the aged properties. For all products a double aging is employed. The aging conditions for all products except sheet are given in Tables 1.056 and 1.057 for the AMS and MIL specifications, respectively.

Producer's recommendations for aging are shown in Table 1.058. Note that there are variations between the producer's recommended aging treatments and those given by the AMS (compare Tables 1.056 and 1.058), with longer aging times being specified for some products by the AMS. While these differences are not large, longer aging will result in reduced tensile strength properties but increased resistance to stress corrosion. Stress relief by plastic deformation preceding aging will introduce a strength anisotropy and reduce peak strengths (37).

Sheet would normally be furnished in the T76 condition. AMS 2770D (39) gives the following aging treatment for this condition: 250 F, 6 to 8 hr + 350 F 3.5 to 4.5 hr. Attempts to change the temper condition (e.g., T6 to T7) by reaging require carefully controlled specially designed treatments for which no general rules have been established.

1.054 Annealing. The type of annealing treatment depends on the thermal and mechanical history of the material. Reannealing of the annealed temper 0 may be required following partial forming and can be accomplished by holding at 650 F for sufficient time to achieve uniform temperature. Rapid heating and minimum holding times will avoid grain coarsening. Annealing treatment for other temper conditions is as follows: 760 F, 2 to 3 hr + cooling to 450 F at a rate of 45 to 70 F/hr. For maximum microstructural stability and formability, an additional 2 to 6 hr at 450 F may be employed. When annealing thin gage clad products, time at maximum temperature must be minimized to avoid diffusion from the core to the cladding (37).

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1.055 Special treatments. It is reported that a three- or four-step aging practice can be more "beneficial" than the two-step process for certain complex parts (37).

1.056 AMS specified heat treatments, Table 1.056.

1.057 Heat treatments for plate, extrusions, wire, rod, and rivets specified in MIL 6088F, Table 1.057.

1.058 Producer's recommended heat treatments, Table 1.058.

1.059 Cooling rate effects after solution treatment on the fully aged yield strength for 7000 series alloys, Figure 1.059.

1.0510 Dimensional stability of as-solution treated and quenched 7050, Figure 1.0510.

1.06 Hardness

AMS 4108A and AMS 4107A specify that hardness of forgings should be greater than 135 HRB (10-mm ball/500-kg load). However, this is not a requirement for acceptance if other properties are met.

1.07 Forms and Conditions Available

Forgings, plate, sheet, wire, rod, and rivets as shown in Tables 1.056 and 1.057.

1.08 Melting and Casting Practice

This alloy can be melted and alloyed in oil-fired, gas-fired, or electric furnaces and cast into ingots of any size for subsequent working.

1.09 Special Considerations

1.091 Type 7050 has relatively low quench sensitivity, which means that it does not need to be quenched as rapidly after solution treatment as other age-hardenable aluminum alloys. Slower quenching minimizes distortion and subsequent straightening operations without seriously affecting strength or corrosion resistance; however, some loss in toughness appears to occur in products quenched slowly (8).

1.0911 A comparison of the effects of the cooling rate after solution treatment of various aluminum alloys on the yield strength attained after aging to maximum strength is shown in Figure 1.059.

1.092 Electrical conductivity measurements are used as an indication of the effectiveness of the T74- and T73-type heat treatments for 7050 alloy. Electrical conductivity values above 40 percent IACS indicate that the proper metallurgical structure has been obtained to provide optimum corrosion resistance and toughness. Lower conductivity is indicative of lower corrosion resistance and toughness, but, possibly, higher strength (1,2,3).

1.093 Fatigue in aggressive environments. The conventional fatigue strength is considerably reduced at cyclic lives greater than about 10^5 cycles in the presence of a 3.5 percent salt fog (e.g., Figures 3.0516, 3.0517, and 3.05118). This effect in the high cycle life range is likely associated with pitting corrosion.

The effects of aggressive environments on fatigue crack-growth are complicated by differences in the applied cyclic load frequencies. While various frequencies have been used in investigations of 7050 products, the following general observations appear justified. Exposure to 3.5 percent salt fog moderately increases the crack-growth rates of T7452 hand forgings as compared with the rates obtained in dry air (Figure 3.0521). A more substantial deleterious effect is noted for salt fog in tests on 7050-T7651 extrusions (Figure 3.05210); larger effects are noted for -T6 sheet (Figure 3.05222). The same figures also show that moist air has an accelerating effect but to a smaller degree than salt fog. Tests on 7108-clad 7050-T6 sheet (Figures 3.05223 and 3.05224) yield essentially the same results for the effects of moist air and salt fog as that observed for the bare form. Tests on extrusions in the T7651 condition at 6 Hz show substantial increases in crack-growth rates in a 3.5 percent NaCl solution as compared with the growth rates in dry air (Figures 3.0512 and 3.0513) which appear to fade out at low K values. Sump water appears to have a more aggressive effect than moist air in tests on 7050-T7351 plate (Figure 3.0526). In the case of 7050-T7351 extrusions, the difference between the growth rates in moist air and in dry air is lost in the scatter (Figures 3.05217 to 3.05219).

Information on 7050-T7351 extrusions tested in dry air and in moist air at very low crack-growth rates (Figures 3.05214, 3.05216, and 3.05218) indicate that the threshold ΔK value at $R = 0.5$ is less than 2 ksi $\sqrt{in.}$ and less than 5 ksi $\sqrt{in.}$ for $R = 0.33$. These low growth rate tests corresponded to cyclic frequencies of 15 to 30 Hz. The value of about 4 ksi $\sqrt{in.}$ obtained for a 7050-T7351 extrusion (Figure 3.05216) agrees fairly well with the trend of the curves toward about this value for 7050-T7651 extrusions tested in dry air and in 3.5 percent NaCl solution (Figures 3.05212 and 3.05213). While none of this information can establish a K_{th} value, it is valuable in defining the lower limits of crack propagation in 7050 alloy.

1.094 Fatigue crack-growth in spectrum loading. It has been pointed out that microstructures producing high plane strain fracture toughness values do not always correspond to those which will provide the longest lives under certain types of spectrum (variable load amplitude) loading (42). The results obtained to date illustrate important aspects of the problem but are not yet sufficiently complete to permit design of a microstructure for any given spectrum.

The preliminary conclusions (42,43) may be summarized as follows:

(a) Overaging to T7 tempers coupled with increased copper content increases crack-growth resistance in constant amplitude loading and spectrum loading with either low level overloads, infrequently spaced high level overloads, or low nominal ΔK values.

(b) High purity (reduced intermetallic constituents) favors improved fatigue crack-growth resistance at high ΔK levels. However, for spectra with high overloads superimposed frequently on a base with a relatively low ΔK,

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0.12	Zr

7050 Al

increasing the volume fraction of coarse intermetallics may be beneficial. The effect results from the formation of incipient cracks at particle locations introduced by the overloads. These cracks then tend to produce a branching of the fatigue crack at the lower ΔK levels. This branching is an energy absorbing process and tends to retard general crack growth in the spectrum.

(c) The effect of overaging on spectra with high overloads is to reduce the growth of the main crack during overloads and to decrease the amount of secondary cracks and, therefore, to reduce their effect on crack retardation at lower ΔK levels in the spectra.

1.095 Effect of high rate deformation in compression (shock hardening) on the tensile properties of 7050-T7451 (-T73651) plate, Table 1.095.

2 PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range, 910 to 1165 F (8).

2.012 Phase changes.

2.0121 Time-temperature-transformation diagram.

2.0122 See 7175, Code 3219, Section 2.0122.

2.013 Thermal conductivity at room temperature (37):
T7651X: 89 Btu/ft/hr/ft^2/F
T7451X (T73651): 91 Btu/ft/hr/ft^2/F
T7351X: 93 Btu/ft/hr/ft^2/F.

2.014 Thermal expansion, Figure 2.014.

2.015 Specific heat.

2.016 Thermal diffusivity.

2.02 Other Physical Properties

2.021 Density, 0.102 lb/in.^{3} (8,11).

2.022 Electrical conductivity.

2.0221 Electrical conductivity of various forms and conditions, Table 2.0221

2.0222 AMS specified values for electrical conductivity of various forms and conditions, Table 2.0222.

2.023 Magnetic properties. Alloy 7050 is nonmagnetic.

2.024 Emittance.

2.025 Damping capacity.

2.03 Chemical Properties
(See also Section 4.04.)

2.031 General corrosion resistance. The higher copper content in 7050 as compared with that in 7075 or 7079 results in a slightly greater degree of general surface attack in aggressive environments. All products would be expected to exhibit pitting and a moderate degree of exfoliation when subjected to ASTM G 34-79 (EXCO Test). Results from this test have been reported by the producer and are shown in Table 3.014 for plate, forgings, and extrusions. The rating <EB places the alloy somewhere between superficial (EA) and moderate (EB) ratings for exfoliation resistance.

2.0311 Corrosion protection by cladding. Two cladding compositions (7072 and 7108) have been developed for 7050 (35,38) and are shown in Table 1.042. The 7108 has somewhat higher strength but is more difficult to produce. Both compositions have essentially the same corrosion resistance and give equal protection to the core. 7108-clad 0.180-inch thick sheet panels were exposed to salt-SO_2 fog for 4, 6, and 8 weeks (41). Conditions were as follows: 5 percent NaCl solution pH 6.5 to 7.2, cabinet temperature 95 F, SO_2 gas injection 1 hr every 5 hr at 25 cc/min. Stepped panels were machined to expose the core at the T/4 and T/2 planes and scribed panels were tested to determine the sacrificial protection afforded to the core by the cladding. After the stepped panels were exposed for 4 weeks, the cladding had been reduced by 50 percent from an original value of about 4.3 mils, and after 8 weeks no cladding remained. These stepped panel tests showed the cladding had corrosion resistance superior to the core. The scribed panels showed no core attack for an 1/8-inch wide scribe and only slight attack in a 1/4-inch wide scribe after 8 weeks of exposure.

2.032 Stress corrosion. The 7050 alloy and tempers offer higher combinations of strength and stress corrosion resistance than other aluminum alloy-temper systems, especially in thick products. The capabilities of 7050 for meeting the requirements of ASTM G 47-79 for determining susceptibility to stress corrosion are shown in Table 3.014 for plate, forgings, and extrusions. ASTM G 47 provides short transverse tests for small specimens stressed in tension and subjected to alternate immersion into a 3.5 percent NaCl solution with a 10-min. immersion period and a 50-min. dry time. The exposure time is 20 days for the 7000 series alloys unless cracking occurs sooner. The stresses shown in Table 3.014 should yield a 20-day minimum life.
Qualitative stress corrosion ratings of 7050 and 7075 based on ASTM G 64-80 are shown in Table 2.034. (This table does not list the T73 temper for 7050 which presumably would be equal to the T73 temper of 7075.)
The producer (37) has conducted a very large number of long duration stress corrosion tests on 7050 plate, forgings, and extrusions in the T76, T74, and T73 (extrusions only) tempers. These include alternate immersion tests in 3.5 percent NaCl solution and marine and industrial exposures. While such tests do not establish lower stress bounds they are valuable for comparative purposes and for risk judgments.
Some examples of these types of tests in the ST direction have been included in this section. The results for 2-inch and 3-inch 7050-T7451 plate specimens subjected to alternate immersion into a 3.5 percent NaCl solution and into ASTM synthetic seawater are shown in Table 2.035. For the 2-inch plate, no failures were observed in 1,140 days for exposure to a stress of about 50 percent F_{ty} in the 3.5 percent NaCl solution. For the 3-inch plate, failures were observed in 54 days at a stress of about 66 percent F_{ty}. Interestingly, a similar exposure to synthetic seawater did not produce failure in 1,140 days at about 85 percent F_{ty} for either plate thickness. Table 2.036 indicates that a 4- to 6-inch 7050-T7351 plate subjected to alternate immersion into a 3.5 percent NaCl solution at 50 percent F_{ty} can

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

survive for at least 84 days. The results of alternate immersion tests on 7050-T7651 and -T7351 extrusions are given in Table 2.0311. They indicate that failures well under 84 days might be expected at 50 to 56 percent F_{ty} with the T7351 temper showing considerably better performance than the T7651 temper. The resistance to stress-corrosion cracking tends to decrease with the electrical conductivity as shown in Figure 2.0314. Data on stress-corrosion cracking in fastner holes machined into 7050-T76 extruded bar are provided in Table 2.0317. The results apply to alternate immersion into a 3.5 percent NaCl solution at a gross stress of 34 percent F_{ty} and illustrate the sensitivity to interference fit with the smallest interference producing no cracks in 60 days of exposure.

Stress corrosion tests in marine environments on 7050-T7451 plate (Tables 2.035 and 2.037) indicate survival times in excess of 3 years when stressed to 50 percent F_{ty}. For 7050-T7651 extrusions, marine environment exposure at about 35 percent F_{ty} (Table 2.0312) produced failures in less than 3 months. Extrusions in the T7351 condition given similar exposures survived 6 months at 56 percent F_{ty}.

Stress corrosion tests in industrial atmospheres show less sensitivity to cracking than that observed in marine environments. This is illustrated by comparing the results obtained for 7050-T7651 extrusions (Table 2.0312) and 7050-T7351 extrusions (Table 2.0313) in these two environments. It will be noted that the T7351 temper is superior to the T7651 temper in the industrial atmospheres as might be expected from the additional aging given this condition.

2.033 Stress-corrosion crack velocity. Tests which permit the determination of crack velocity as a function of the stress intensity factor K provide additional information on stress-corrosion cracking resistance and under ideal circumstances can yield a value of stress intensity (K_{Iscc}) below which a crack would not grow under steady load in an aggressive environment. Under the best of circumstances, K_{Iscc} is difficult to determine and for many aluminum alloys the situation is further complicated by the presence of corrosion products which can wedge open the crack.

Crack velocity data for 7050 has been presented in several different ways. The most complete representation gives the velocity as a function of the instantaneous K (Figure 2.039). Two other forms are used which give less information but have the advantage of requiring less data analysis. Both report average velocities over a specified time period. The more complete of the two gives the initially applied K_I and the K_I at the end of the specified time period (Table 2.038), while the other gives only the initially applied K_I (Table 2.0316). None of the available data are sufficient to unambiguously establish a K_{Iscc} value for any of the forms and tempers of 7050.

The data for 7050-T7451 plate subjected to marine exposure (Figure 2.039) illustrate the scatter encountered in crack velocity measurements and the difficulty of establishing a K_{Iscc} even in the most complete representation. On the basis of these data, the K_{Iscc} of the 3-inch plate could be less than 5 ksi $\sqrt{in.}$ and that for the 1-1/4-inch plate could be less than 12 ksi $\sqrt{in.}$ The plateau velocity of the 1-1/4-inch plate is clearly lower than that of the 3-inch plate. Average crack velocities over 15 days in a 3.5 percent NaCl environment are shown for SL tests on 7050-T7351 plate in Table 2.038 for initially applied K values between 24 and 31 ksi $\sqrt{in.}$ With one exception, these velocities increase with increasing plate thickness. Average velocities over 202 days are shown in Table 2.0310 for 7050-T7451 plate tested in the SL orientation by alternate immersion into a 3.5 percent NaCl solution or by periodic moistening with this solution. There seems to be little difference in the velocities considering the scatter normally encountered in such tests. The table does indicate the substantial residual displacement due to corrosion product wedging.

Average crack velocities in 3.5 percent NaCl solution are given in Table 2.0316 for tests in the SL orientation of 7050-T7651 and -T7351 extrusions. The main conclusion from these data is that the T7351 temper has, as might be expected, lower crack velocities. Additional test results on 7050-T7651 and -T7351 extrusions are shown in Table 2.0315. Crack growth occurred in all specimens but the results indicate the superiority of the T7351 temper condition. While very long failure times characterize a K_i level of about 40 percent K_{Ic} for 7050-T7651 and 75 percent K_{Ic} for 7050-T7351, it is not possible to estimate K_{Iscc} values.

3 MECHANICAL PROPERTIES

3.01 <u>Specified Mechanical Properties</u>

3.011 AMS specified minimum tensile properties for 7050-T73651 (-T7451) die forgings, Table 3.011.

3.012 AMS specified tensile properties for 7050-T7651 plate and 7050-T76511, -T73511, and -T736511 (-T7451) extrusions, Table 3.012.

3.013 AMS specified minimum fracture toughness properties for 7050-T73651 (-T7451) plate, Table 3.013.

3.014 Producer's guaranteed minimum properties and capabilities for 7050 plate, forgings, and extrusions, Table 3.014.

3.015 Producer's proposed design mechanical properties for 7050-T7651 plate, Table 3.015.

3.016 Producer's proposed design mechanical properties for 7050-T7451 plate, Table 3.016.

3.017 Producer's tentative mechanical properties for bare and clad 7050-T76 sheet, Table 3.017.

3.02 <u>Mechanical Properties at Room Temperature</u>

3.021 Tension – stress-strain diagrams – tension properties.

3.0211 Tensile stress-strain curves for 7050-T7451 (-T73651) hand forgings, Figure 3.0211.

3.0212 Tensile stress-strain curves for 7050-T74 (-T736) die forgings, Figure 3.0212.

3.0213 Tensile stress-strain curves for 7050-T7451 (-T73651) plate, Figure 3.0213.

3.0214 Tensile stress-strain curves for 7050-T7351 plate, Figure 3.0214.

3.0215 Tensile stress-strain curves for 7050-T7651 extrusions of several thicknesses, Figure 3.0215.

3.0216 Tensile stress-strain curves for 7050-T7351 extrusions of several thicknesses, Figure 3.0216.

3.0217 Tensile stress-strain curves for 7050-T76 sheet, Figure 3.0217.

3.0218 Tensile properties of 7050-T7451 (-T73651) hand forgings of various sizes, Table 3.0218.

3.0219 Tensile properties of 7050-T74 (-T736) die forgings of various sizes, Table 3.0219.

3.02110 Tensile properties of 7050-T7351 plate of various thicknesses, Table 3.02110.

3.02111 Effects of exposures to elevated temperatures on tensile ultimate and yield strengths of 7050-T7451 (-T73651) plate, Figure 3.02111.

3.02112 Tensile properties of 7050-T7451 (-T73651) plate of various thicknesses, Table 3.02112.

3.02113 Tensile properties of 7050-T7651 extrusions of various thicknesses and cross sections, Table 3.02113.

3.02114 Tensile properties of 7050-T7351 extrusions of various thicknesses and cross sections, Table 3.02114.

3.02115 Effect of section thickness on tensile properties of 7050-T7651 extrusions of various cross sections, Table 3.02115.

3.02116 Tensile properties of various extruded shapes in the T76511 condition, Table 3.02116.

3.02117 Tensile properties of 7050-T76 sheet, Table 3.02117.

3.022 Compression – stress-strain diagrams – compression properties.

3.0221 Compressive stress-strain curves for 7050-T7452 (-T73652) hand forgings, Figure 3.0221.

3.0222 Compressive stress-strain curves for 7050-T74 (-T736) die forgings, Table 3.0222.

3.0223 Compressive stress-strain curves for 7050-T7351 plate, Figure 3.0223.

3.0224 Compressive stress-strain curves for 7050-T7451 (-T73651) plate, Figure 3.0224.

3.0225 Compressive stress-strain curves for 7050-T7651 extrusions of several thicknesses, Figure 3.0225.

3.0226 Compressive stress-strain curves for 7050-T76 sheet, Figure 3.0226.

3.0227 Compressive yield strength of 7050-T7452 (-T73652) hand forgings of various sizes, Table 3.0227.

3.0228 Compressive yield strength of 7050-T74 (-T736) die forgings of various thicknesses, Table 3.0228.

3.0229 Compressive yield strength of 7050-T7351 plate of various thicknesses, Table 3.0229.

3.02210 Compressive yield strength of 7050-T6 sheet and 7050-T7451 (-T73651) plate of various thicknesses, Table 3.02210.

3.02211 Compressive yield strength of 7050-T7651 extrusions of various thicknesses and cross sections, Table 3.02211.

3.02212 Compressive yield strength of 7050-T7351 extrusions of various thicknesses and cross sections, Table 3.02212.

3.023 Impact.

3.024 Bending.

3.025 Torsion and shear.

3.0251 Shear strength of 7050-T7452 (-T73652) hand forgings, Table 3.0251.

3.0252 Shear strength of 7050-T74 (-T736) die forgings, Table 3.0252.

3.0253 Shear strength of 7050-T6 sheet and 7050-T7451 (-T73651) plate, Table 3.0253.

3.0254 Shear strength of 7050-T7351 plate, Table 3.0254.

3.0255 Shear strength of 7050-T7651 extrusions, Table 3.0255.

3.0256 Shear strength of 7050-T7351 extrusions, Table 3.0256.

3.026 Bearing.

3.0261 Bearing properties of 7050-T7452 (-T73652) hand forgings, Table 3.0261.

3.0262 Bearing properties of 7050-T74 (-T736) die forgings, Table 3.0262.

3.0263 Bearing properties of 7050-T76 sheet and 7050-T7451 (-T73651) plate, Table 3.0263.

3.0264 Bearing properties of 7050-T651 extrusions, Table 3.0264.

3.0265 Bearing strength of 7050-T7651 extrusions, Table 3.0265.

3.0266 Bearing properties of 7050-T7351 extrusions, Table 3.0266.

3.027 Stress concentration.

3.0271 Notch properties.

3.0272 Fracture toughness.

3.02721 General. Static fracture in high strength aluminum alloys occurs primarily by a process of void nucleation and growth. Under these circumstances the fracture toughness is affected by the size and distribution of impurity particles. These particles are formed during ingot solidification by a combination of iron and silicon, and sometimes manganese, with aluminum and solute atoms. These particles do not contribute to the strength of the alloy and have been shown to fracture at very low average matrix strains resulting in void formation (39). The 7050 alloy is produced with close controls on iron and silicon and offers a considerable advantage in fracture toughness over 7075 with negligible sacrifice in strength. Fracture toughness of 7050 like other high strength aluminum alloys decreases with product thickness and is anisotropic being lower in the SL or ST directions (e.g., Table 3.02722, Figure 3.02724, and Table 3.02725). Special ingot processing techniques (intermediate thermal mechanical treatments) have been applied (30) in an attempt to improve the properties of 7050. These treatments (Table 3.02727) increased the yield strength but reduced the fracture toughness in comparison to the commercially produced product.

3.02722 Plane strain fracture toughness of plate, hand forgings, and die forgings, Table 3.02722.

3.02723 Plane strain fracture toughness values for crack initiation and arrest in 7050-T7451 (-T73651) plate for SL orientation, Table 3.02723.

3.02724 Effect of extrusion section thickness on plane strain fracture toughness, Figure 3.02724.

3.02725 Plane strain fracture toughness of various extruded shapes, Table 3.02725.

3.02726 Extrusion cross sections used for fracture toughness and crack-growth rate tests, Figure 3.02726.

	Al
6.2	Zn
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7050 Al

3.02727 Plane strain fracture toughness of specially processed very high purity 7050 plate, Table 3.02727.
3.02728 Special processing schedules provided to 7050 very high purity plate, Table 3.02728.
3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures
3.031 Tension – stress-strain diagrams – tension properties.
3.0311 Tensile stress-strain curves for 7050-T7452 (-T73652) plate at room and elevated temperatures, Figure 3.0311.
3.0312 Tensile properties of 7050-T7451 (-T73651) plate in the temperature range -65 to 350 F, Figure 3.0312.
3.0313 Tensile properties of 7050-T7451 (-T73651) plate in the temperature range of 70 to 500 F, Figure 3.0313.
3.0314 Effects of elevated temperatures on tensile ultimate and yield strengths of 7050-T7451 (-T73651) plate after various exposure times at test temperature, Figure 3.0314.
3.0315 True stress as a function of strain rate for tests on a sheet at 900 F, Figure 3.0315.
3.032 Compression – stress-strain diagrams – compression properties.
3.0321 Compressive stress-strain curves for 7050-T7451 (-T73651) plate at room and elevated temperatures, Figure 3.0321.
3.0322 Effects of temperature on compressive yield strength of 7050-T7451 (-T73651) plate, Figure 3.0322.
3.033 Impact.
3.034 Bending.
3.035 Torsion and shear.
3.036 Bearing.
3.037 Stress concentration.
3.0371 Notch properties.
3.0372 Fracture toughness.
3.03721 Effects of low and elevated temperatures on plane-strain fracture toughness of 7050-T7451 (-T73651) plate, Figure 3.03721.
3.038 Combined properties.

3.04 Creep and Creep-Rupture Properties
3.041 Creep and creep-rupture curves for 7050-T7451 (-T73651) plate, Figure 3.041.

3.05 Fatigue Properties
3.051 Conventional fatigue properties.
3.0511 Low cycle fatigue results for 7050 plate subjected to different aging treatments, Figure 3.0511.
3.0512 Low cycle fatigue results for two processing treatments of very high purity 7050 plate, Figure 3.0512.
3.0513 Modified Goodman diagrams for longitudinal smooth and notch fatigue properties of 7050-T7452 (-T73652) hand forgings, Table 3.0513.
3.0514 Modified Goodman diagrams for long transverse smooth and notch fatigue properties of 7050-T7452 (-T73652) hand forgings, Figure 3.0514.
3.0515 Modified Goodman diagrams for short transverse smooth and notch fatigue properties of 7050-T7452 (-T73652) hand forgings, Figure 3.0515.
3.0516 S-N curves at R = 0 for smooth specimens from 7050-T7452 (-T73652) hand forgings tested in air and in salt fog, Figure 3.0516.
3.0517 S-N curves at R = 0 for smooth specimens from 7050-T7451 (-T73651) plate tested in air and in salt fog, Figure 3.0517.
3.0518 S-N bands at R = 0 for smooth, L, LT, and ST specimens from 7050-T7351 plate of various thicknesses, Figure 3.0518.
3.0519 S-N band at R = 0 for notched specimens from 7050-T7351 plate of various thicknesses, Figure 3.0519.
3.05110 Fatigue life at various temperatures of smooth and notched 7050-T7451 (-T73651) plate, Figure 3.05110.
3.05111 Modified Goodman diagrams for fatigue properties of smooth and notched 7050-T7451 (-T73651) plate, Figure 3.05111.
3.05112 S-N band at R = +0.1 for smooth specimens from 7050-T7651 and -T7351 extrusions of various thicknesses and cross sections, Figure 3.05112.
3.05113 S-N band at R = -1.0 for smooth specimens from 7050-T7651 and -T7351 extrusions of various thicknesses and cross sections, Figure 3.05113.
3.05114 S-N band at R = +0.1 for notched specimens from 7050-T7651 and -T7351 extrusions of various thicknesses and cross sections, Figure 3.05114.
3.05115 S-N band at R = -1.0 for notched specimens from 7050-T7651 and -T7351 extrusions of various thicknesses and cross sections, Figure 3.05115.
3.05116 Modified Goodman diagrams for smooth and notch fatigue properties of 7050-T76511 extrusions, Figure 3.05116.
3.05117 S-N band at R = +0.1 for smooth specimens from 7050-T7651 extrusions subjected to salt fog, Figure 3.05117.
3.05118 S-N curves at R = 0 for smooth specimens from 7050 extrusions in the T76511 condition tested in air and in salt fog, Figure 3.05118.
3.05119 S-N band at R = 0.1 for smooth and notched specimens of 7050-T7351 extrusions subjected to salt fog, Figure 3.05119.
3.05120 Modified Goodman diagrams for smooth and notch fatigue properties of 7050-T6 sheet, Figure 3.05120.
3.05121 S-N bands at several R ratios for smooth L and LT specimens from 7050-T6 clad sheet, Figure 3.05121.
3.05122 S-N bands at several R ratios for L and LT notched specimens from 7050-T6 clad sheet, Figure 3.05122.
3.052 Fatigue crack-growth rates.
3.0521 Fatigue crack-growth rates of 7050-T7452 (-T73652) hand forgings in TL and SL orientations in dry air, humid air, and salt fog, Figure 3.0521.
3.0522 Fatigue crack-growth rates of 7050-T7451 (-T73651) plate and 7050-T74 (-T736) die forgings in dry air and in 3.5 percent NaCl solution, Figure 3.0522.
3.0523 Fatigue crack-growth rates for 1-inch and 6-inch 7050-T7451 (-T73651) plate in TL and SL orientations in dry air and in salt fog, Figure 3.0523.
3.0524 Crack growth in 7050-T7451 (-T73651) plate subjected to a truncated transport flight spectrum, Table 3.0524.

3.0525 Fatigue crack-growth rates in dry air and in sump water for 2-inch and 4-inch 7050-T7351 plate tested in LT orientation, Figure 3.0525.

3.0526 Fatigue crack-growth rates in dry air, moist air, and in sump water for 2-inch 7050-T7351 plate tested in TL orientation, Figure 3.0526.

3.0527 Fatigue crack-growth rates in sump water for 4-inch 7050-T7351 plate tested in TL orientation, Figure 3.0527.

3.0528 Fatigue crack-growth rates in dry air, moist air, and in sump water for 4-inch 7050-T7351 plate tested in SL orientation, Figure 3.0528.

3.0529 Composition of synthetic sump tank water, Table 3.0529.

3.05210 Fatigue crack-growth rates in dry air, humid air, and in salt fog for 7050-T7651 extrusions tested in TL and SL orientations, Figure 3.05210.

3.05211 Fatigue crack-growth rates in dry air and in moist air for 7050-T7651 extrusion tested in LT and TL orientations, Figure 3.05211.

3.05212 Fatigue crack-growth rates for various extruded shapes of 7050-T76511 tested in TL orientation in dry air and in salt water, Figure 3.05212.

3.05213 Fatigue crack-growth rates for various extruded shapes of 7050-T76511 tested in LT orientation in dry air and in salt water, Figure 3.05213.

3.05214 Near threshold fatigue crack-growth rates at R = 0.5 in dry air and in moist air for TL specimens from 7050-T7351 C5A wing plank extrusion, Figure 3.05214.

3.05215 Fatigue crack-growth rates in dry air and in moist air for LT specimens from 7050-T7351 C5A wing plank extrusion, Figure 3.05215.

3.05216 Fatigue crack-growth rates in dry air and in moist air for 7050-T7351 extrusion tested in TL orientation, Figure 3.05216.

3.05217 Fatigue crack-growth rates in dry air and in moist air for 7050-T7351 extrusion tested in LT and TL orientations, Figure 3.05217.

3.05218 Near threshold fatigue crack-growth rates at R = 0.5 in dry air and in moist air for LT specimens from 7050-T7351 C5A wing plank extrusion, Figure 3.05218.

3.05219 Fatigue crack-growth rates in dry air and in moist air for TL specimens from 7050-T7351 C5A wing plank extrusion, Figure 3.05219.

3.05220 Fatigue crack-growth rates at R = 0.05 and R = 0.275 in dry argon for 7050-T6 sheet tested in LT orientation, Figure 3.05220.

3.05221 Fatigue crack-growth rates at R = 0.5 and R = 0.7 in dry argon for 7050-T6 sheet tested in LT orientation, Figure 3.05221.

3.05222 Fatigue crack-growth rates in dry air, humid air, and salt fog for 7050-T6 sheet tested in TL and LT orientations, Figure 3.05222.

3.05223 Fatigue crack-growth rates in dry air, moist air, and in 3.5 percent salt fog for clad 7050-T76 sheet tested in LT orientation, Figure 3.05223.

3.05224 Fatigue crack-growth rates in dry air, moist air, and in 3.5 percent salt fog for clad 7050-T76 sheet tested in TL orientation, Figure 3.05224.

3.06 <u>Elastic Properties</u>

3.061 Poisson's ratio, 0.33.

3.062 Modulus of elasticity.

3.0621 Static modulus of elasticity in tension and compression for various forms, Figure 3.0621.

3.0622 Effect of temperature on the static modulus of elasticity in tension and compression for 7050-T7451 (-T73651) plate, Figure 3.0622.

3.0623 Mean ($\bar{X}$) and standard deviation(s) of the tension and compression modulus for 7050-T7651 and -T7351 extrusions and 7050-T7351 plate, Table 3.0623.

3.063 Modulus of rigidity, 3.9×10^3 ksi.

3.064 Tangent modulus.

3.0641 Tensile tangent modulus for 7050-T7651 extrusions of several thicknesses, Figure 3.0641.

3.0642 Tensile tangent modulus for 7050-T7351 extrusions of various thicknesses, Figure 3.0642.

3.0643 Compressive tangent modulus for 7050-T7451 (-T73651) plate at various temperatures, Figure 3.0643.

3.0644 Compressive tangent modulus for 7050-T7351 plate, Figure 3.0644.

4 FABRICATION

4.01 <u>Forming</u>

The recommended minimum bend radii for 7050 are equal to or less than those required for 7075, depending on the material thickness and temper (e.g., the suggested minima for 0.5-inch 7050-0 and -T7451 plate are 3t and 6t, respectively) (37).

4.02 <u>Machining and Grinding</u>

Machinability is excellent in all forms and tempers. Chemical milling of 7050-T7451 is slightly slower than that for 7075-T651 with a slightly more uniform surface than that obtained in the 7075 alloy.

4.03 <u>Joining</u>

4.031 Welding. Weldability of 7050 is not good. Butt welds of 7050 plate have been made using standard (5356, 4043) and experimental filler alloys and the GMA and GTA processes. Most of the resulting welds contained cracks and porosity. Tensile tests across the welds showed approximately 50 percent joint efficiency and very low elongation of about 1.0 percent (8).

4.032 Brazing as a practical joining technique for the 7050 alloy is precluded by wetting problems and its relatively low melting range (8).

4.033 Fastening. 7050-T73 (E) rivets are an excellent replacement for 2024-T4 (DD) "ice box" rivets. They are slightly stronger and can be driven in the T73 condition. Design allowables for 7050-T73 style rivets in rivets joints have been developed. Threaded fasteners have been produced successfully and appear to be at least 15 percent stronger than 7075-T73. Additionally, they have superior toughness to 2024-T4 threaded fasteners as measured by resistance to twist-off.

4.04 <u>Surface Treating</u>

Procedures for cleaning, anodizing, conversion coating, and painting are similar to those used for 7075. However, it has been reported that deoxidizing and etching treatments used prior to anodizing or dye penetrant inspection resulted in

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

more intergranular attack in 7050-T7 tempers than in 7075-T7 tempers. The producer has developed procedures to avoid these problems should they arise (37).

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Alloy	7050						
Form	Hand Forgings	Die Forgings	Plate		Extrusions		
Condition	Sol Treat + Age	Sol Treat + SR(a) + Age	Sol Treat + Age	Sol Treat + SR + Age	Sol Treat + SR + Age		
Temper	T736	T73652	T73651(b)	T7651	T73511	T76511	T736511(c)
AMS	4108A	4107A	4050A	4201	4341	4340A	4342
Source	3	2	1	21	22	23	24

(a) SR – stress relieved by plastic deformation (see Section 1.05).
(b) Alcoa T7451.
(c) Alcoa T74511.

TABLE 1.031. AMS SPECIFICATIONS (1-3, 21-24)

Alloy	7050	
	Percent	
Composition	Min	Max
Zn	5.7	6.7
Cu	2.0	2.6
Mg	1.9	2.6
Zr	0.08	0.15
Fe	–	0.15
Si	–	0.12
Mn	–	0.10
Ti	–	0.06
Cr	–	0.04
Other, Each	–	0.05
Other, Total	–	0.15
Al	Balance	

TABLE 1.041. AMS SPECIFIED ALLOY COMPOSITION (1-3, 21-24)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050			
Form	Cladding Alloys			
Designation	7072		7108	
	Percent			
Composition	Min	Max	Min	Max
Zn	0.8	1.3	4.5	5.5
Cu	–	0.10	–	0.05
Mg	–	0.10	0.7	1.4
Zn	–	–	0.12	0.25
Fe	–	(a)	–	0.10
Si	–	(a)	–	0.10
Mn	–	0.10	–	0.05
Ti	–	–	–	0.05
All Others(b)	–	0.15	–	0.10

(a) Composition of Fe and Si was 0.7 percent (maximum).
(b) Composition of any of "all other" elements was 0.05 percent (maximum).

TABLE 1.042. PRODUCER'S COMPOSITION OF CLADDING ALLOYS FOR 7050 (38)

Alloy	7050						
Form	Hand Forgings	Die Forgings	Plate		Extrusions		
Condition	T73652(a)	T736(b)	T73651(c)	T7651	T73511	T76511	T736511(d)
Solution Treat	880 to 900 F, 1 hr, Min WQ (140 to 160 F) +	880 to 900 F, 1 hr, Min WQ (140 to 160 F) +	(e)	(e)	880 to 890 F, 1/4 hr, Min WQ (<100 F) +	880 to 890 F, WQ (<100 F) +	880 to 890 F, WQ (<100 F) +
Stress(f) Relief	1 to 5 percent Compression +	0 +	1.5 to 3 percent Stretch	1.5 to 3 percent Stretch	1 to 3 percent Stretch +	1 to 3 percent Stretch +	1 to 3 percent Stretch +
Age	240 to 260 F, 24 hr + 340 to 360 F, 8 hr, AC	240 to 260 F, 24 hr + 340 to 360 F, 12 hr, AC	(e)	(e)	240 to 260 F, 1 to 24 hr + 340 to 360 F, 12 hr, AC	240 to 260 F, 3 to 24 hr + 340 to 360 F, 8 hr, AC	240 to 260 F, 1 to 24 hr + 340 to 360 F, 10 hr, AC
Source	3	2	1	21	23	22	24

(a) Alcoa T7452.
(b) Alcoa T74.
(c) Alcoa T7451.
(d) Alcoa T74511.
(e) See Table 1.057.
(f) Plastic strain.

TABLE 1.056. AMS SPECIFIED HEAT TREATMENTS (1-3, 21-24)

Alloy	7050				
Form	Plate		Extrusions		Wire, Rod, and Rivets
Condition	T7651	T7451(a)	T76510	T76511(b)	T73
Solution(c) Treat	880 to 900 F, WQ	880 to 900 F, WQ	880 to 900 F, WQ	880 to 900 F, WQ	880 to 900 F, WQ
Age(a)	+ 240 to 260 F, 3 to 6 hr, AC + 315 to 335 F, 12 to 15 hr, AC	+ 240 to 260 F, 3 to 6 hr, AC + 315 to 335 F, 24 to 30 hr	+ 240 to 260 F, 3 to 8 hr, AC + 315 to 335 F, 15 to 18 hr, AC	+ 240 to 260 F, 3 to 6 hr, AC + 315 to 335 F, 15 to 18 hr, AC	+ 245 to 255 F, 4 min., AC + 350 to 360 F, 8 hr

(a) Preceeding aging stress relief is applied by stretching to all products except wire, rod, and rivets.
(b) This temper designation indicates minor straightening follows stress relief.
(c) Soaking time at solution temperature depends on the method of heating and the thickness. (See MIL H6088F, Table 4.) Quench delay time depends on thickness. (See MIL H6088F, Table 6.)

TABLE 1.057. HEAT TREATMENTS FOR PLATE, EXTRUSIONS, WIRE, ROD, AND RIVETS SPECIFIED IN MIL 6088F (36)

Alloy	7050						
Solution Treatment	890 F, WQ, All Forms						
First Step Aging	To T7 Temper 250, 3 to 8 hr, All Forms						
Second Step[a] Aging at 350 F	Hand Forgings	Die Forgings	Plate[b]			Extrusions	Rivets
Temper	T7452	T74	T7651	T7451	T7351	T7651X	T73
Time, hr	6 to 8	6 to 12	3.4 to 7.3	6.8 to 8.6	(b)	4.3 to 5.1	(8 Min)

(a) Equivalent time of second step aging within the limits 300 to 360 F:

$t_T = t_{350} \exp\left(\frac{31390}{T + 460} - 39.42\right)$ where t_{350} is given in above Table and t_T is the time at another temperature.

(b) 330 F, 36 hr.

Note: Essentially equivalent to MIL 6088F.

TABLE 1.058. PRODUCER'S RECOMMENDED HEAT TREATMENTS (37)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

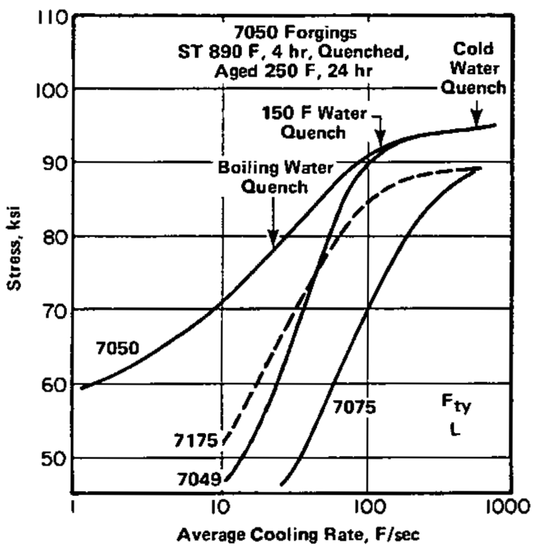

FIGURE 1.059. COOLING RATE EFFECTS AFTER SOLUTION TREATMENT ON FULLY AGED YIELD STRENGTH FOR 7000 SERIES ALLOYS (8,13)

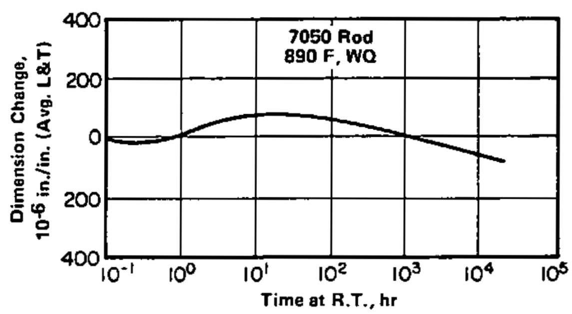

FIGURE 1.0510. DIMENSIONAL STABILITY OF AS-SOLUTION TREATED AND QUENCHED 7050 (32)

Alloy	7050							
Form	1/2-inch Plate							
Condition	7050-T7451							
Treatment	As Received		As Received + 250 F, 4 hr		250 F, 4 hr + Shock Hardened (Shock Velocity 5730 m/sec, 2 μsec Pulse, 9 percent Transient Strain)			
					As Shocked		Shocked + 250 F, 4 hr	
Direction	L	T	L	T	L	T	L	T
F_{tu}, ksi	75	75	76	75	73	69	74	76
F_{ty}, ksi	65	65	66	65	72	70	69	68
e (inch), percent	16	12	15	12	10	5	9	13
RA, percent	42	38	44	37	17	9.7	10	38

TABLE 1.095. EFFECT OF HIGH RATE DEFORMATION IN COMPRESSION (SHOCK HARDENING) ON THE TENSILE PROPERTIES OF 7050-T7451 (-T73651) (25)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

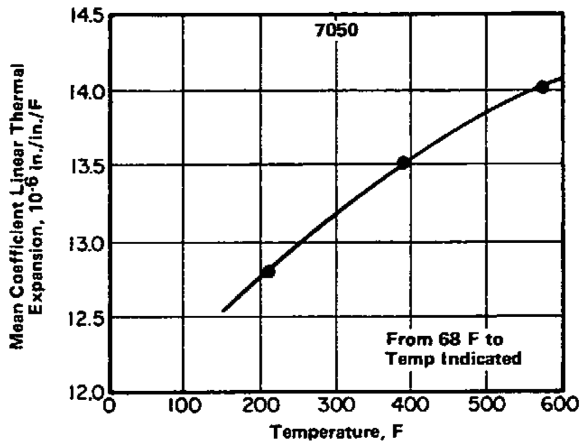

FIGURE 2.014. THERMAL EXPANSION (37)

Alloy	7050			
		Electrical Conductivity,		Electrical Resistivity, microhm-in.
Form	Condition	percent IACS	megohms/ in.^{3}	
Sheet	T76	38.3	0.563	1.78
Plate	T7451	41.4	0.607	1.65
Die Forgings	T736	41.4	0.607	1.65
Hand Forgings	T7452	42.2	0.621	1.61
Extrusions	T76511	39.4	0.580	1.73

TABLE 2.0221. ELECTRICAL CONDUCTIVITY OF VARIOUS FORMS AND CONDITIONS (4, 37)

Alloy	7050						
Form	Hand Forgings	Die Forgings	Plate		Extrusions		
AMS	4108	4107A	4050A	4201	4341	4340A	4342
Condition	T736	T73652(a)	T73651(b)	T7651	T73511	T76511	T736511
Electrical Conductivity, percent IACS	>40	>40	>40	>39	>40(c)	≥39(d)	>40

(a) Alcoa T7452.
(b) Alcoa T7451.
(c) 40 = IACS <41, F_{ty} (L) <69 ksi, IACS >41, and F_{ty} is not limited.
(d) AMS gives an unclear qualification to this value.

TABLE 2.0222. AMS SPECIFIED VALUES FOR ELECTRICAL CONDUCTIVITY OF VARIOUS FORMS AND CONDITIONS (1-3, 21-24)

Alloy and Temper	Test Direction	Rolled Plate	Rod and Bar	Extruded Shapes	Forgings
7050-T76	L	A	A	A	(1)
	LT	A	B	A	(1)
	ST	C	B	C	(1)
7050-T74	L	A	(1)	A	A
	LT	A	(1)	A	A
	ST	B	(1)	B	B
7075-T6	L	A	A	A	A
	LT	B(2)	D	B(2)	B(2)
	ST	D	D	D	D
7075-T76	L	A	(1)	A	(1)
	LT	A	(1)	A	(1)
	ST	C	(1)	C	(1)
7075-T73	L	A	A	A	A
	LT	A	A	A	A
	ST	A	A	A	A

Rating	Interpretation
A	Very high. No record of service problems and SCC not anticipated in general applications.
B	High. No record of service problems and SCC not anticipated at stresses of the magnitude caused by solution heat treatment. Precautions must be taken to avoid high sustained tensile stress exceeding 50 percent of the minimum specified yield strength produced by any combination of sources including heat treatment straightening, forming, fit-up, and sustained service loads.
C	Intermediate. SCC not anticipated if the total sustained tensile stress is less than 25 percent of the minimum specified yield strength. This rating is designed for the short transverse direction in improved products used primarily for high resistance to exfoliation corrosion in relatively thin structures where appreciable short transverse stresses are unlikely.
D	Low. SCC failures have occurred in service or would be anticipated if there is any sustained tensile stress in the designated test direction. This rating currently is designated only for the short transverse direction in certain materials.

Note: The stress levels mentioned above are not to be interpreted as "threshold" stresses, and are not recommended for design. Other documents, such as MIL-HDBK-5, MIL-STD-1568, NASC-SD-24, and MSFC-SPEC-522A should be consulted for design recommendations.

(1) Rating is not established because the product is not offered commercially.
(2) Rating is one class lower for thicker sections: extrusions, 1-inch (25 mm) and over; plate and forgings, 1.5-inch (40 mm) and over.

TABLE 2.034. ASTM G 64 CLASSIFICATION OF RESISTANCE TO STRESS-CORROSION CRACKING OF 7050 AND 7075 (37)

Alloy	7050-T7451 (ST Direction)																
Form	Plate																
Thickness	2-inch (F_{ty} = 61 ksi) 0.07 Fe, 0.06 Si									3-inch (F_{ty} = 59 ksi) 0.11 Fe, 0.06 Si							
Exposure(a)	Sea Coast(b)			AI(c) 3.5 percent NaCl			AI(d) Seawater			Sea Coast(b)			AI(c) 3.5 percent NaCl		AI(d) Seawater	
Stress, ksi	31	46	61	31	46	51	31	46	51	26	39	50	39	50	39	50
Number Exposed	8	8	8	3	3	3	3	3	3	8	8	8	3	3	3	3
Number Failed	0	0	2	0	2	3	0	0	0	0	1	0	2	3	0	0
Failure Time Range, days	–	–	840 to 1020	–	87	87	–	–	–	–	810	–	54 to 63	54 to 78	–	–

(a) Test discontinued after 1,140 days.
(b) 120 to 130 ft from MCAN high tide at Kennedy Space Center.
(c) Alternate immersion (AI) – Method 823 (Fed. Std. 1516) is essentially the same as ASTM G44.
(d) Alternate immersion in ASTM 0114-52 synthetic seawater using Method 823.

TABLE 2.035. RESULTS OF STRESS CORROSION TESTS FOR THE ST DIRECTION OF 7050-T7451 (-T73651) PLATE IN SEVERAL ENVIRONMENTS (31)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050-T7351 (0.06 to 0.08 Fe, 0.03 to 0.06 Si)					
Form	Plate					
Exposure	Alternate Immersion 3.5 percent NaCl (ASTM G44-75)					
	ST Direction					
Thickness	4-inch (F_{ty} = 60 ksi)		5-inch (F_{ty} = 59 ksi)		6-inch (F_{ty} = 57 ksi)	
Stress, ksi	30 to 31	46	29 to 30	43 to 44	29	43
Number Exposed	6	6	6	6	6	6
Number Failed	0	0	0	1	0	1
Failure Time Range, days	–	–	–	84	–	64
Survival[a] Time, days	84	84	84	84	84	84

(a) Test discontinued at 84 days.

TABLE 2.036. RESULTS OF ALTERNATE IMMERSION TESTS IN 3.5 PERCENT NaCl SOLUTION ON SHORT TRANSVERSE SPECIMENS OF 7050-T7351 PLATE (20)

Alloy	7050-T7451							
Thickness	1.25-inch Plate				3-inch Plate			
Tensile Strengths	LT F_{tu} = 78 ksi, F_{ty} = 69 ksi				LT F_{tu} = 73 ksi, F_{ty} = 62 ksi			
Fracture Toughness	LT K_{Ic} = 29 ksi $\sqrt{in.}$, SL K_{Ic} = 24.3 ksi $\sqrt{in.}$				LT K_{Ic} = 24.8 ksi $\sqrt{in.}$, SL K_{Ic} = 25.4 ksi $\sqrt{in.}$			
Applied Stress, ksi ST Direction	25	35	45	55	25	35	45	55
Max Exposure[a] 54 months (1,620 days)	3/0	3/0	3/3 All in 9 months	3/3 3.4 months 5 months 11 months	3/0	3/0	3/0	3/1 19 months

(a) Number exposed/number failed in months indicated; specimens were 0.125-inch in diameter.

TABLE 2.037. STRESS CORROSION RESULTS FOR 7050-T7451 (-T73651) PLATE EXPOSED TO A MARINE ENVIRONMENT AT DAYTONA BEACH (17)

Alloy	7050-T7351			
Form	Plate SL Direction			
Thickness	2-inch	4-inch	6-inch (Lot 1)	6-inch (Lot 2)
Average Crack Velocity Over 15 days, 10^{-4} in./hr	1.19	2.4	0.29	4.5
K_I at 15 day, ksi $\sqrt{in.}$	28	25.5	25	20

Note: Bolt loaded double cantilever beam: B = 1-inch, 2H = 1-inch, W = 5-inch, 24 < K_{Ii} < 31 ksi $\sqrt{in.}$, 3.5 percent NaCl solution drops in notch, three times per day (Monday through Friday) once per day on Saturday and Sunday.

TABLE 2.038. AVERAGE CRACK VELOCITIES FOR VARIOUS THICKNESSES OF 7050-T7351 PLATE EXPOSED TO 3.5 PERCENT NaCl SOLUTION WITH CRACKS IN SL DIRECTION (20)

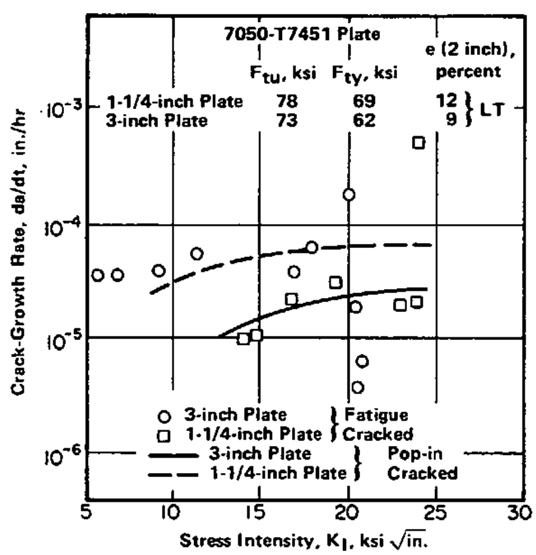

FIGURE 2.039. CRACK-GROWTH RATES IN SL ORIENTATION AS A FUNCTION OF STRESS INTENSITY FOR 7050-T7451 (-T73651) PLATE EXPOSED TO A MARINE ATMOSPHERE AT DAYTONA BEACH (17)

Al
6.2 Zn
2.25 Mg
2.3 Cu
0.12 Zr

7050 Al

Alloy	7050-T7451 (L and T F_{tu} = 75.4 ksi, F_{ty} = 66.8 ksi)					
Test Type[(a)]	Alternate Immersion[(b)] 3.5 percent NaCl (pH ~6) 1 hr in Solution + 11 hr Out (RT)			Periodic Moistening[(b)] Twice per Day with 3.5 percent NaCl (pH ~6) (RT)		
Location of Specimen	Surface	Center	Surface	Surface	Center	Surface
Crack Growth, inch	0.067	0.055	0.11	0.051	0.051	0.094
Mean da/dt[(c)], in./hr x 10^{-4}	0.14	0.12	0.23	0.10	0.10	0.19
Percent Residual Displacement[(d)]	24	24	27	25	23	27

(a) SL, DB (My) specimen, bolt loaded: 2H = 0.67-inch, W = 3.5-inch, A_o ~ 1.46-inch, fatigue cracked to K_i ~ 24 ksi $\sqrt{in.}$

(b) Total exposure 202 days.

(c) More than 202 days.

(d) Displacement after unloading due to corrosion product wedging.

TABLE 2.0310. CRACK GROWTH RESULTS FOR 7050-T7451 (-T73651) PLATE IN 3.5 PERCENT NaCl SOLUTION (15)

Alloy	7050					
Form	Extrusions (See Table 3.02113)					
Exposure	Alternate Immersion in 3.5 percent NaCl (ASTM G44-75)					
Condition	ST Direction					
	T7351 (XST F_{ty} = 62.8 ksi, S = 1.74 ksi)			T7651 (XST F_{ty} = 68.9 ksi, S = 1.84 ksi)		
Stress, ksi	52	45	35	35	25	15
Number Exposed	15	39	24	15	32	12
Number Failed	15	35	23	11	18	1
Failure Time Range, days	7 to 84	19 to 84	28 to 84	3 to 7	10 to 84	69
Survival Time, days[(a)]	–	84	84	84	84	84

(a) Test discontinued at 84 days.

TABLE 2.0311. RESULTS OF ALTERNATE IMMERSION TESTS IN 3.5 PERCENT NaCl SOLUTION ON SHORT TRANSVERSE SPECIMENS OF 7050-T7651 AND -T7351 EXTRUSIONS (19)

Alloy	7050			
Form	Extrusions (See Table 3.02113)			
Condition	T7651 (XST F_{ty} = 68.9 ksi, S = 1.84 ksi)[(a)]			
Exposure[(b)]	Sea Coast Atmosphere		Industrial Atmosphere	
Stress, ksi[(c)]	35	25	35	25
Number Exposed	15	23	15	24
Number Failed	13	5	2	1
Failure Time Range, days	75 to 401	75 to 231	1097	1140
Survival Time Range, days	681 to 1304	385 to 1304	705 to 1335	432 to 1335

(a) Based on F_{ty} of all shapes.

(b) Sea coast – Point Judith, R.I., and industrial – Alcoa Center, Pa.

(c) Tensile bars, 0.125-inch, stressed in constant strain fixtures in ST direction.

TABLE 2.0312. RESULTS OF STRESS CORROSION TESTS ON SHORT TRANSVERSE SPECIMENS OF 7050-T7651 EXTRUSIONS (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050					
Form	Extrusions (See Table 3.02113)					
Condition	T7351 ($\bar{X}$ST F_{ty} = 62.8 ksi, S = 1.74 ksi)(a)					
Exposure(b)	Sea Coast Atmosphere			Industrial Atmosphere		
Stress, ksi(c)	52	45	35	52	45	35
Number Exposed	18	33	24	18	30	27
Number Failed	9	7	1	2	0	0
Failure Time, Range, days	102 to 527	71 to 276	198	426 to 431	–	–
Survival Time Range, days	385 to 681	283 to 681	283 to 385	432 to 694	362 to 694	362 to 432

(a) Based on F_{ty} of all shapes.
(b) Sea coast – Point Judith, R.I., and industrial – Alcoa Center, Pa.
(c) Tensile bars, 0.125-inch, stressed in constant strain fixtures in ST direction.

TABLE 2.0313. RESULTS OF STRESS CORROSION TESTS ON SHORT TRANSVERSE SPECIMENS OF 7050-T7351 EXTRUSIONS (19)

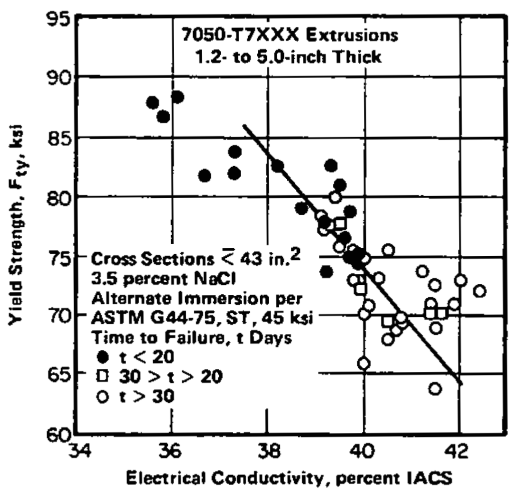

FIGURE 2.0314. STRESS CORROSION PERFORMANCE AS A FUNCTION OF ELECTRICAL CONDUCTIVITY FOR 7050 EXTRUSIONS STRESSED TO 45 PERCENT F_{ty} IN THE ST DIRECTION (19)

Alloy	7050								
Form	Extrusions								
Condition	T7651 ($\bar{X}$ST F_{ty} = 68.9 ksi, S = 1.84)						T7351 ($\bar{X}$ST F_{ty} = 62.8 ksi, S = 1.74)		
Section Size, inch	3 x 18		5 x 6-1/4				3 x 18		
K_{Ic}, ksi $\sqrt{in.}$	19		18				20		
K_i, percent K_{Ic}(a)	65	40	80	70	60	50	90	80	75
Test Time, hr(b)	566	>2304	120	540	822	2820	198	>2172	>3082
Crack Growth,(c) 10^{-4}-inch	1250	1160	770	2500	3030	3710	1370	670	1420
K_{If}, ksi $\sqrt{in.}$(c)	19	10	17	19	22	20	23	18	20

(a) Ring loaded C(T) specimens, SL orientation: B = 1-inch, W/B ~3; K_i based on load and crack mouth displacement.
(b) Time to failure on 0.3 M NaCl, pH = 4.
(c) Based on load and crack mouth displacement, monitored every 8 hr.

TABLE 2.0315. FAILURE TIMES OF C(T) SL SPECIMENS FROM 7050-T7651 AND -T7351 EXTRUSIONS SUBJECTED TO VARIOUS INITIAL STRESS INTENSITY (K_i) LEVELS IN A SALT-DICHROMATE SOLUTION (19)

Al
6.2 Zn
2.25 Mg
2.3 Cu
0.12 Zr

7050 Al

Alloy	7050(a)			
Form	Extrusions SL Direction			
Condition	T7651		T7351	
Extrusion(b) Cross Section, in.^{2}	<43	61 to 66	<43	61 to 66
Initial K_i, ksi $\sqrt{in.}$	18 to 24	19 to 26	24 to 25	22 to 28
Average Crack Velocity, 10^{-4} in./hr				
in 15 days	6.6	6.6	4.4	3.4
in 30 days	4.7	5.5	2.56	2.4

(a) See note under Table 2.038 for specimen and exposure conditions.
(b) Various extruded shapes, 1.8- to 5-inch thickness.

TABLE 2.0316. AVERAGE CRACK VELOCITIES IN 3.5 PERCENT NaCl SOLUTION FOR VARIOUS EXTRUDED SHAPES OF 7050-T7651 AND -T7351 TESTED IN SL DIRECTION (19)

Alloy	7050-T76		
Form	Extruded Bar		
Condition	3/16-inch Holes in ST Direction Without and With Interference Fit Fastners of Al and Ti		
Exposure	Alternate Immersion 3.5 percent NaCl, 10 min. Immersion + 50 min. Air at 34 percent F_{ty}		
Interference, inch	0.033 to 0.005	0.002	0.0005
Evidence for SCC in 60 Days	Cracks	Incipient Cracks	No Cracks

TABLE 2.0317. EFFECT OF INTERFERENCE FIT ON STRESS-CORROSION CRACKING OF FASTNER HOLES IN 7050-T76 EXTRUSION (26)

Alloy	7050-T73651 (-T7451)						
Form	Die Forgings						
Direction	L				T		
	Axis of Specimen <15° from Forging Flow Lines				Axis of Specimen >15° from Forging Flow Lines		
Thickness, t, inch	t ≤ 2	2 < t ≤ 4	4 < t ≤ 5	5 < t ≤ 6	t ≤ 2	2 < t ≤ 4	4 < t ≤ 6
F_{tu}, ksi	72	71	70	70	68	67	66
F_{ty}, ksi	62	61	60	59	56	55	54
e (2-inch or 4D), percent	7	7	7	7	5	4	3

TABLE 3.011. AMS SPECIFIED MINIMUM TENSILE PROPERTIES FOR 7050-T73651 (-T7451) DIE FORGINGS (2)

Alloy	7050				
Form	Plate		Extrusions		
Condition	T7651		T76511	T73511	T736511 (T7451)
Thickness, inch	0.25 to 2.500		N/A	N/A	N/A
Direction	L	LT	L	L	L
F_{tu}, ksi	76	76	79	70	73
F_{ty}, ksi	66	66	69	60	63
e (2-inch or 4D), percent	8	6	7	8	7

TABLE 3.012. AMS SPECIFIED TENSILE PROPERTIES FOR 7050-T7651 PLATE (21) AND 7050-T76511, -T73511, AND T736511 (-T7451) EXTRUSIONS (22-24)

Alloy	7050-T73651 (-T7451)		
Form	2- to 6-inch Thick Plate		
Direction	LT	TL	SL
K_{Ic}, ksi $\sqrt{in.}$	24	22	20

TABLE 3.013. AMS SPECIFIED MINIMUM FRACTURE TOUGHNESS PROPERTIES FOR 7050-T73651 (-T7451) PLATE (1)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050													
Form	Condition	Thickness, inch	Direction	F_{tu} (Min), ksi	F_{ty}, ksi Min	F_{ty}, ksi Max	e (Min), percent	SCC[a] Stress, % F_{ty}	SCC[a] Stress, ksi	Exfoliation[b] Corrosion, EXCO	Exfoliation[b] Corrosion, Plane	K_{Ic} (Min), ksi$\sqrt{in.}$[c] L-T	T-L	S-L
Plate	T7651	0.250 to 1.000	LT	76.0	66.0	–	8	–	20	<EB	t/10	26	24	–
		1.001 to 1.500	LT	77.0	67.0	–	8	–	20	<EB	t/10	26	24	20
		1.501 to 2.000	LT	76.0	66.0	–	8	–	20	<EB	t/10	26	24	20
		2.001 to 3.000	LT	76.0	66.0	–	7	–	20	<EB	t/10	24	23	20
	T7451	0.250 to 2.000	LT	74.0	64.0	–	9	50	–	<EB	Any	29	25	–
		2.001 to 3.000	LT	73.0	63.0	–	8	50	–	<EB	Any	27	24	21
		3.001 to 4.000	LT	72.0	62.0	–	6	–	35	<EB	Any	26	23	21
		4.001 to 5.000	LT	71.0	61.0	–	5	–	35	<EB	Any	25	22	21
		5.001 to 6.000	LT	70.0	60.0	–	4	–	35	<EB	Any	24	22	21
Die Forgings	T74	Up to 2.000	(d)	72.0	62.0	72.0	7	50	–	–	–	–	–	–
		2.001 to 4.000	(d)	71.0	61.0	72.0	7	50	–	–	–	–	–	–
		4.001 to 5.000	(d)	70.0	60.0	72.0	7	50	–	–	–	–	–	–
		5.001 to 6.000	(d)	70.0	59.0	72.0	7	50	–	–	–	–	–	–
		0.700 to 0.350	–	–	–	–	–	–	–	–	–	27	19	19
		3.501 to 7.000	–	–	–	–	–	–	–	–	–	25	19	19
Hand Forgings	T7452	Up to 2.000	L	72.0	63.0	–	9	50	–	–	–	–	–	–
		2.001 to 3.000	L	72.0	62.0	–	9	50	–	–	–	–	–	–
		3.001 to 4.000	L	71.0	61.0	–	9	–	35	–	–	–	–	–
		4.001 to 5.000	L	70.0	60.0	–	9	–	35	–	–	–	–	–
		5.001 to 6.000	L	69.0	59.0	–	9	–	35	–	–	–	–	–
		6.001 to 7.000	L	68.0	58.0	–	9	–	35	–	–	–	–	–
		7.001 to 8.000	L	67.0	57.0	–	9	–	35	–	–	–	–	–
		0.700 to 0.350	–	–	–	–	–	–	–	–	–	27	17	16
		3.501 to 7.000	–	–	–	–	–	–	–	–	–	25	17	16
Extrusions	T7651X	0.250 to 5.000	L	79.0	69.0	–	7	25	–	<EB	t/1	–	–	–
	T7451X	0.250 to 3.000	L	73.0	63.0	–	7	50	–	<EB	Any	–	–	–
		3.001 to 5.000	L	73.0	63.0	–	7	–	35	<EB	Any	–	–	–
	T7351X	0.250 to 5.000	L	70.0	60.0	–	8	75	–	–	–	–	–	–
		0.250 to 5.000	L	70.0	60.0	69.0	8	75	–	–	–	–	–	–

(a) ASTM G47-79, 20-day survival.
(b) ASTM G34-79.
(c) ASTM E399 and B645. Lower thickness limit for a valid K_{Ic} is 0.5-inch (12.7 mm); S-L specimens require thickness of at least 1.2-inch (30.5 mm).
(d) Parallel to direction of grain flow.

TABLE 3.014. PRODUCER'S GUARANTEED MINIMUM PROPERTIES AND CAPABILITIES FOR 7050 PLATE, FORGINGS AND EXTRUSIONS (37)

Al
6.2 Zn
2.25 Mg
2.3 Cu
0.12 Zr

7050 Al

Alloy		7050-T7651				
Form		Plate				
Thickness, t, inch		0.25 < t ≤ 0.50	0.5 < t ≤ 1.0	1.0 < t ≤ 1.5	1.5 < t ≤ 2.0	2.0 < t ≤ 3.0
Basis(a)		S	S	A	A	S
F_{tu}, ksi	L	76	76	77	76	76
	LT	76	76	77	76	76
	ST	–	–	–	–	70
F_{ty}, ksi	L	66	66	67	66	66
	LT	66	66	67	66	66
	ST	–	–	–	–	60
F_{cy}, ksi	L	64	64	65	64	64
	LT	68	68	69	69	69
	ST	–	–	–	–	68
F_{su}, ksi		44	43	42	46	47
F_{bru}, ksi	e/D = 1.5	112	111	111	115	116
	e/D = 2.0	143	142	141	147	149
F_{bry}, ksi	e/D = 1.5	91	88	87	92	95
	e/D = 2.0	105	103	101	105	109
e, percent	L	9	9	9	9	8
	LT	8	8	8	8	7
	ST	–	–	–	–	1.5
E, 10^3 ksi		10.3				
E_c, 10^3 ksi		10.8				
G, 10^3 ksi		4.0				
Poission's Ratio		0.33				

(a) S = specification properties and A = statistical property values after MIL-HBBK-5.

TABLE 3.015. PRODUCER'S PROPOSED DESIGN MECHANICAL PROPERTIES FOR 7050-T7651 PLATE (37)

Alloy		7050-T7451 (-T73651)					
Form		Plate					
Thickness, t, inch		0.25 ≤ t < 1.5	1.5 < t ≤ 2.0	2.0 < t ≤ 3.0	3.0 < t ≤ 4.0	4.0 < t ≤ 5.0	5.0 < t ≤ 6.0
Basis(a)		A	A	A	A	A	A
F_{tu}, ksi	L	74	74	73	72	71	70
	LT	74	74	73	72	71	70
	ST	–	–	68	68	67	67
F_{ty}, ksi	L	64	64	63	62	61	60
	LT	64	64	63	62	61	60
	ST	–	–	59	58	57	57
F_{cy}, ksi	L	63	62	61	60	58	57
	LT	66	67	66	65	64	63
	ST	–	–	63	63	63	62
F_{su}, ksi		42	44	44	44	43	43
F_{bru}, ksi	e/D = 1.5	105	113	112	110	108	107
	e/D = 2.0	140	145	143	141	139	137
F_{bry}, ksi	e/D = 1.5	86	92	91	91	91	91
	e/D = 2.0	101	103	103	104	105	105
e, percent	L	10	10	9	9	9	8
	LT	9	9	8	6	5	4
	ST	–	–	2	2	2	2
E, 10^3 ksi		10.3					
E_c, 10^3 ksi		10.6					
G, 10^3 ksi		3.9					
Poisson's Ratio		0.33					

(a) A = statistical property values after MIL-HDBK-5.

TABLE 3.016. PRODUCER'S PROPOSED DESIGN MECHANICAL PROPERTIES FOR 7050-T7451 PLATE (25)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy		7050						
Form		Sheet			7108-Clad Sheet		7072-Clad Sheet	
Temper		T76			T76		T76	
Thickness, inch		0.040 to 0.089	0.090 to 0.187	0.188 to 0.249	0.040 to 0.089	0.090 to 0.249	0.040 to 0.089	0.090 to 0.249
F_{tu}, ksi	L	76	76	76	75	74	–	–
	LT	77	77	77	75	75	72	73
F_{ty}, ksi	L	67	67	67	65	65	–	–
	LT	67	67	67	65	65	61	62
F_{cy}, ksi	L	66	67	68	64	64	–	–
	LT	71	71	71	67	67	–	–
F_{su}, ksi		46	45	45	45	45	–	–
F_{bru}, ksi	e/D = 1.5	118	118	118	114	114	–	–
	e/D = 2.0	152	152	152	148	148	–	–
F_{bry}, ksi	e/D = 1.5	93	93	93	92	92	–	–
	e/D = 2.0	106	106	106	106	106	–	–
e, percent	L	–	–	–	–	–	–	–
	LT	7	7	7	7	7	7	7
E, 10^3 ksi		10.2			10.2		–	
E_c, 10^3 ksi		10.6			10.6		–	
G, 10^3 ksi		3.9			3.9		–	
Poisson's Ratio		0.33			0.33		–	

TABLE 3.017. PRODUCER'S TENTATIVE MECHANICAL PROPERTIES FOR BARE AND CLAD 7050-T76 SHEET (37)

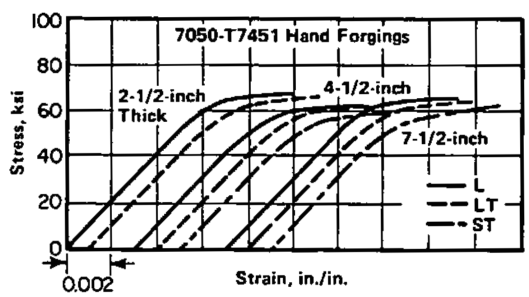

FIGURE 3.0211. TENSILE STRESS-STRAIN CURVES FOR 7050-T7451 (-T73651) HAND FORGINGS (4)

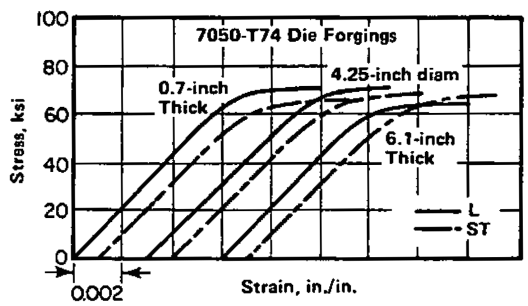

FIGURE 3.0212. TENSILE STRESS-STRAIN CURVES FOR 7050-T74 (-T736) DIE FORGINGS (4)

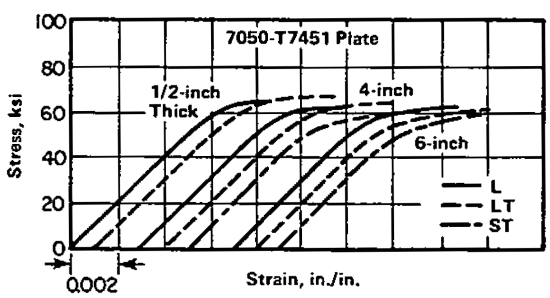

FIGURE 3.0213. TENSILE STRESS-STRAIN CURVES FOR 7050-T7451 (-T73651) PLATE (4)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

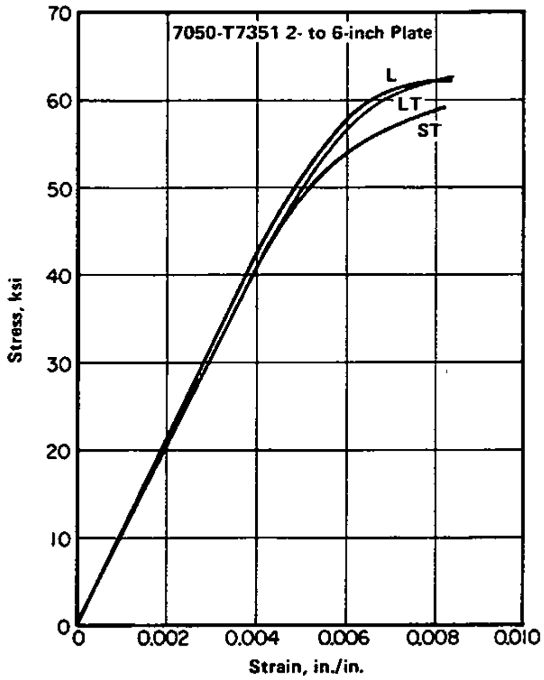

FIGURE 3.0214. TENSILE STRESS-STRAIN CURVES FOR 7050-T7351 PLATE (20)

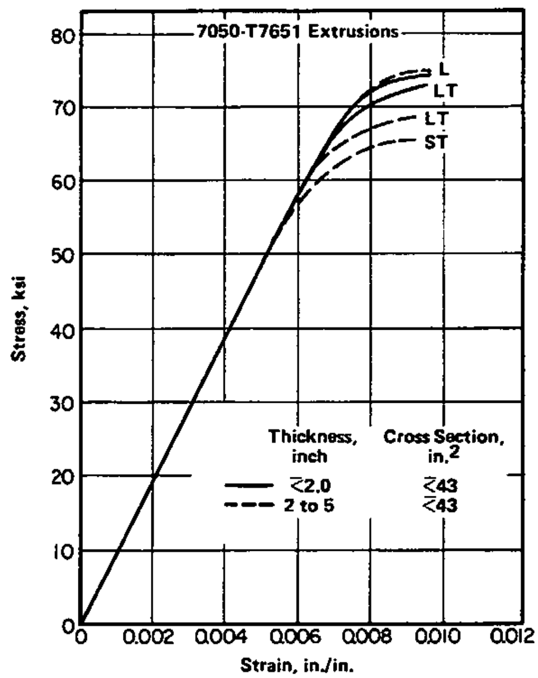

FIGURE 3.0215. TENSILE STRESS-STRAIN CURVES FOR 7050-T7651 EXTRUSIONS OF SEVERAL THICKNESSES (19)

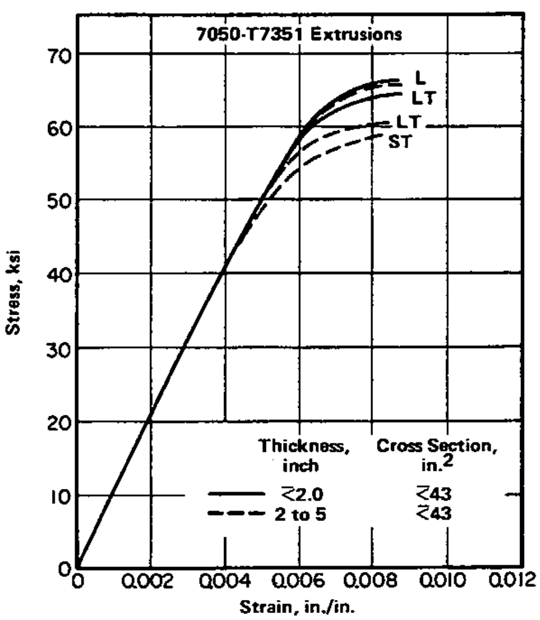

FIGURE 3.0216. TENSILE STRESS-STRAIN CURVES FOR 7050-T7351 EXTRUSIONS OF SEVERAL THICKNESSES (19)

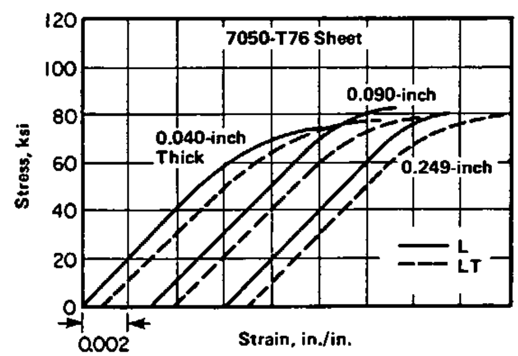

FIGURE 3.0217. TENSILE STRESS-STRAIN CURVES FOR 7050-T76 SHEET (4)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050-T7451			
Form	Hand Forgings			
Size, inch	Direction	F_{tu}, ksi	F_{ty}, ksi	e (2 inch), percent
2 x 8 x 72	L	79.3	72.6	9.5
	LT	78.0	71.3	6.5
	ST	78.7	67.6	4.7
2-1/2 x 22 x 60	L	76.7	67.3	10.5
	LT	75.9	65.5	13.0
	ST	74.3	61.3	10.0
3-1/2 x 14 x 72	L	71.6	61.1	13.5
	LT	70.1	60.2	8.8
	ST	67.9	56.5	4.3
4-1/2 x 22 x 84	L	72.6	62.6	12.5
	LT	70.6	59.8	10.0
	ST	70.6	59.2	7.5
5-1/2 x 22 x 60	L	73.3	64.4	11.5
	LT	71.6	64.4	6.0
	ST	70.4	59.6	4.8
7-1/2 x 22 x 42	L	72.2	61.4	13.2
	LT	71.0	60.8	5.5
	ST	70.2	58.0	5.5

TABLE 3.0218. TENSILE PROPERTIES OF 7050-T7451 (-T73651) HAND FORGINGS OF VARIOUS SIZES

Alloy	7050-T736			
Form	Die Forgings			
Thickness, inch	Direction	F_{tu}, ksi	F_{ty}, ksi	e (2 inch), percent
Up to 2.000	L	77.9	70.4	13.0
	ST	74.5	66.1	7.6
2.001 to 4.000	L	75.6	67.4	13.0
	LT	70.6	63.6	6.0
4.001 to 5.000	L	76.5	69.2	13.0
	ST	73.1	65.2	6.0
5.001 to 6.000	L	74.4	65.8	9.8
	ST	73.5	67.1	5.0

TABLE 3.0219. TENSILE PROPERTIES OF 7050-T74 (-T736) DIE FORGINGS OF VARIOUS SIZES (4)

Alloy	7050-T7351														
Form	Plate														
Thickness(a)	2-inch			3-inch			4-inch			5-inch			6-inch		
Direction	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST
F_{tu}, ksi	71	72	69	73	74	72	73	74	72	72	73	70	70	72	68
F_{ty}, ksi	61	61	55	64	64	61	64	63	59	63	62	59	61	60	57
e (4D), percent	14	12	8	12	11	6.5	11	10	6.8	11	10	6.6	11	10	5.1
RA, percent	34	27	14	29	20	12	27	16	10	23	15	9	20	14	7

(a) Average of single tests on each plate from two lots.

TABLE 3.02110. TENSILE PROPERTIES OF 7050-T7351 PLATE OF VARIOUS THICKNESSES (20)

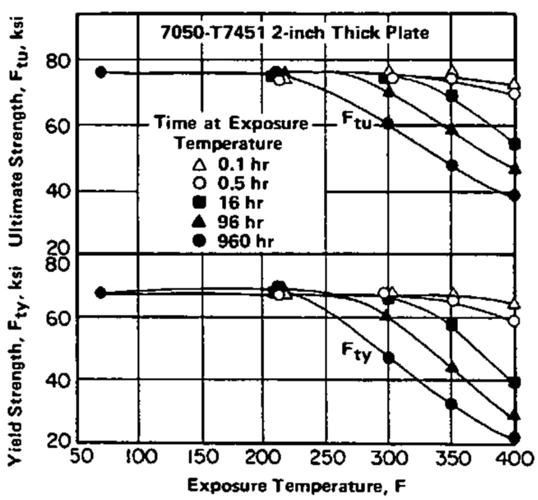

FIGURE 3.02111. EFFECTS OF EXPOSURES TO ELEVATED TEMPERATURES ON TENSILE ULTIMATE AND YIELD STRENGTHS OF 7050-T7451 (-T73651) PLATE (8)

Al
6.2 Zn
2.25 Mg
2.3 Cu
0.12 Zr

7050 Al

Alloy	7050-T7451				
Form	Thickness, inch	Direction	F_{tu}, ksi	F_{ty}, ksi	e (2 inch), percent
Plate	0.250 to 2.000	L	76.3	66.9	13.8
		LT	76.3	66.7	12.8
Plate	4.000	L	73.0	64.4	11.5
		LT	74.5	63.8	10.5
		ST	71.4	60.3	6.8
Plate	6.000	L	71.4	62.6	9.2
		LT	71.8	60.5	6.8
		ST	68.2	58.1	4.2

TABLE 3.02112. TENSILE PROPERTIES OF 7050-T7451 (-T73651) PLATE OF VARIOUS THICKNESSES (4)

Alloy	7050-T7651							
Form	Extrusions							
Thickness, inch	0.187 to 1.2(a)		1.5 to 2.9(b)			3.5 to 5.0(c)		
Direction	L	LT	L	LT	ST	L	LT	ST
F_{tu}, ksi	83	83	82	80	78	86	81	11
F_{ty}, ksi	75	74	75	73	68	78	72	5
e (4D), percent	13	12	13	10	6	77	70	3

(a)-Seven extrusions, 5 to 29 $in.^2$ cross section.
(b)-Five extrusions, 11 to 65 $in.^2$ cross section.
(c)- Three extrusions, 26 to 32 $in.^2$ cross section.

TABLE 3.02113. TENSILE PROPERTIES OF 7050-T7651 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

Alloy	7050-T7351							
Form	Extrusions							
Thickness, inch	0.67 to 1.2(a)		1.5 to 2.9(b)			3.5 to 5.0(c)		
Direction	L	LT	L	LT	ST	L	LT	ST
F_{tu}, ksi	78	77	76	76	74	80	74	75
F_{ty}, ksi	69	68	68	67	63	72	66	64
e (4D), percent	14	11	13	12	6.5	11	8	7.5

(a) Four extrusions, 14 to 29 $in.^2$ cross section.
(b) Nine extrusions, 11 to 65 $in.^2$ cross section.
(c) Two extrusions, 26 and 31 $in.^2$ cross sections.

TABLE 3.02114. TENSILE PROPERTIES OF 7050-T7351 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

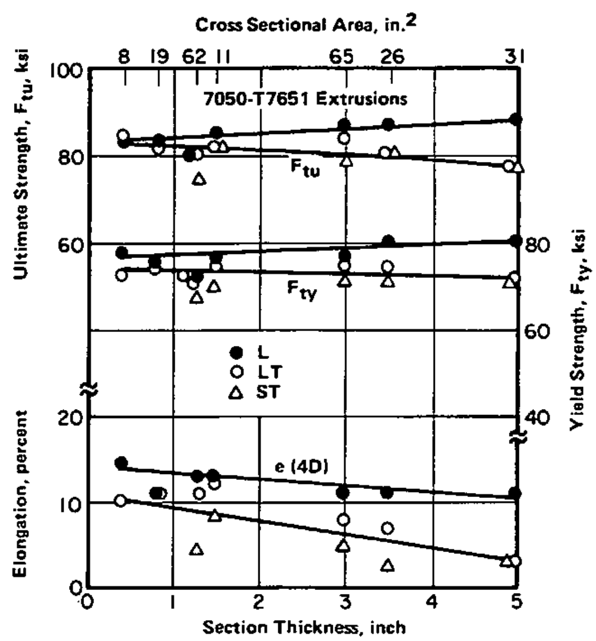

FIGURE 3.02115. EFFECT OF SECTION THICKNESS ON TENSILE PROPERTIES OF 7050-T7651 EXTRUSIONS OF VARIOUS CROSS SECTIONS (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050-T6511											
Form	Extrusions											
Direction	L				T				ST			
Extrusion(a)	W	Y	Z	S	W	Y	Z	S	W	Y	Z	S
F_{tu}, ksi	84	87	88	85	78	82	82	82	78	80	81	82
F_{ty}, ksi	71	79	82	78	76	75	75	75	69	73	71	71
e, percent	11	13	12	14	10	13	9	12	5	9	7	10

(a) See Figure 3.027.

TABLE 3.02116. TENSILE PROPERTIES OF VARIOUS EXTRUDED SHAPES IN THE T6511 CONDITION (18)

Alloy	7050-T76			
Form	Sheet			
Thickness, inch	Direction	F_{tu}, ksi	F_{ty}, ksi	e (2 inch), percent
0.040 to 0.249	L	82.1	76.5	10.7
	LT	82.5	76.3	10.9

TABLE 3.02117. TENSILE PROPERTIES OF 7050-T76 SHEET (4)

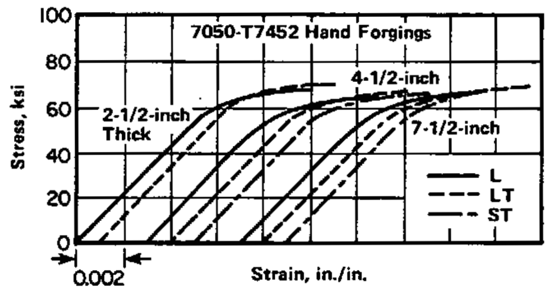

FIGURE 3.0221. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T7452 (-T73652) HAND FORGINGS (4)

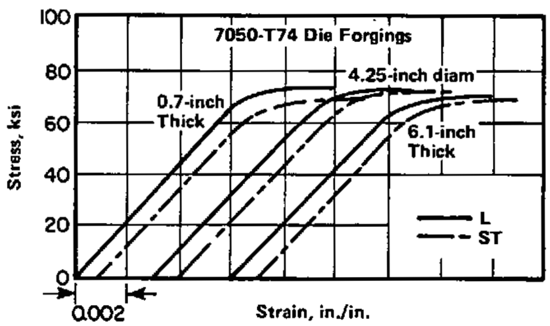

FIGURE 3.0222. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T74 (-T736) DIE FORGINGS (4)

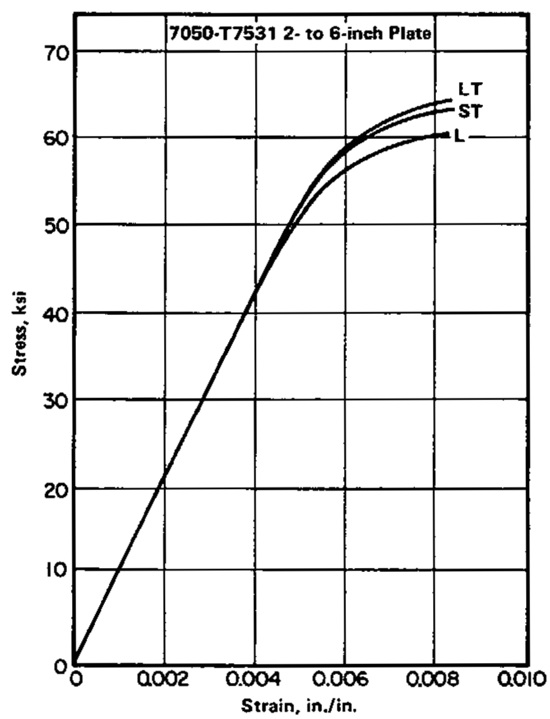

FIGURE 3.0223. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T7351 PLATE (20)

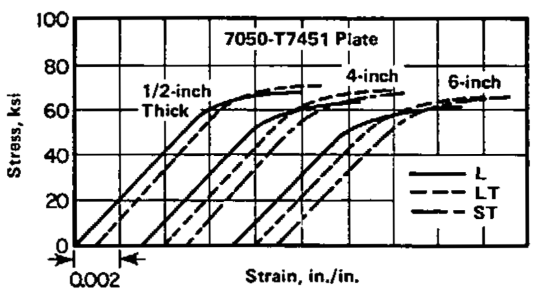

FIGURE 3.0224. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T7451 (-T73651) PLATE (4)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

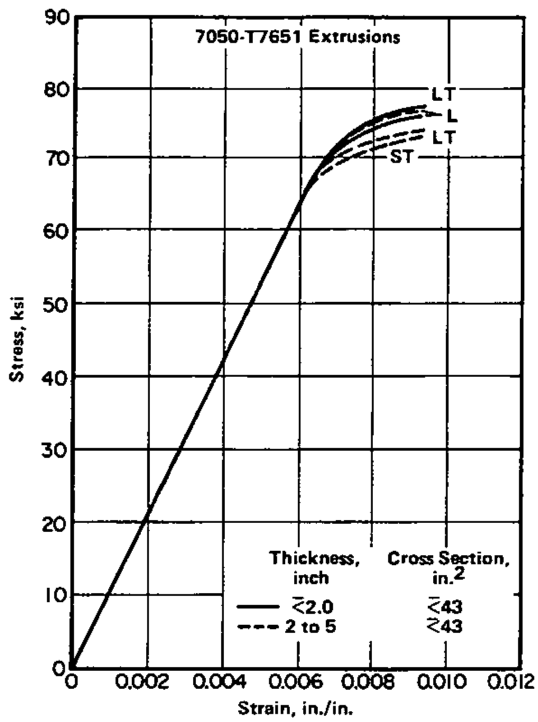

FIGURE 3.0225. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T7651 EXTRUSIONS OF SEVERAL THICKNESSES (19)

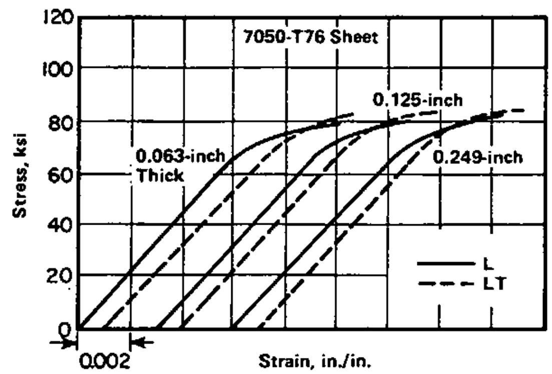

FIGURE 3.0226. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T76 SHEET (4)

Alloy	7050-T7452	
Form	Hand Forgings	
Size, inch	Orientation	F_{cy}, ksi
2 x 8 x 72	L	77.0
	LT	76.4
	ST	79.2
2-1/2 x 22 x 60	L	67.2
	LT	69.0
	ST	68.5
3-1/2 x 14 x 72	L	64.9
	LT	65.1
	ST	63.7
4-1/2 x 22 x 84	L	64.0
	LT	67.2
	ST	63.3
5-1/2 x 22 x 60	L	66.8
	LT	67.0
	ST	66.3
7-1/2 x 22 x 42	L	64.0
	LT	66.0
	ST	65.4

TABLE 3.0227. COMPRESSIVE YIELD STRENGTH OF 7050-T7452 (-T73652) HAND FORGINGS OF VARIOUS SIZES (14)

Alloy	7050-T74	
Form	Die Forgings	
Thickness, inch	Orientation	F_{cy}, ksi
Up to 2.000	L	74.5
	ST	69.8
2.000 to 4.000	L	72.8
	ST	67.8
4.000 to 5.000	L	72.7
	ST	68.1
5.001 to 6.000	L	71.8
	ST	67.9

TABLE 3.0228. COMPRESSIVE YIELD STRENGTH OF 7050-T74 (-T736) DIE FORGINGS OF VARIOUS THICKNESSES (4)

Alloy	7050-T7351														
Form	Plate														
Thickness(a)	2-inch			3-inch			4-inch			5-inch			6-inch		
Direction	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST
F_{cy}, ksi	59	63	62	61	66	65	61	66	64	60	65	63	57	63	61

(a) Average of single tests on each plate from two lots.

TABLE 3.0229. COMPRESSIVE YIELD STRENGTH OF 7050-T7351 PLATE OF VARIOUS THICKNESSES (20)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050									
Form	Sheet		Plate							
Condition	T6		T7451							
Thickness, inch	0.040 to 0.25		0.25 to 2.0		4.0			6.0		
Direction	L	LT	L	LT	L	LT	ST	L	LT	ST
F_{cy}, ksi	77	81	66	69	62	68	67	59	65	65

TABLE 3.02210. COMPRESSIVE YIELD STRENGTH OF 7050-T6 SHEET AND 7050-T7451 (-T73651) PLATE OF VARIOUS THICKNESSES (4)

Alloy	7050-T7651							
Form	Extrusions							
Thickness, inch	0.187 to 1.2(a)		1.5 to 2.9(b)			3.5 to 6.0(c)		
Direction	L	LT	L	LT	ST	L	LT	ST
F_{cy}, ksi	77	78	75	77	78	83	78	76

(a) Seven extrusions, 5 to 29 $in.^2$ cross section.
(b) Five extrusions, 11 to 65 $in.^2$ cross section.
(c) Three extrusions, 26 to 32 $in.^2$ cross section.

TABLE 3.02211. COMPRESSIVE YIELD STRENGTH OF 7050-T7651 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

Alloy	7050-T7351							
Form	Extrusions							
Thickness, inch	0.67 to 1.2(a)		1.5 to 2.9(b)			3.5 to 5.0(c)		
Direction	L	LT	L	LT	ST	L	LT	ST
F_{cy}, ksi	69	71	68	70	71	74	69	69

(a) Four extrusions, 14 to 29 $in.^2$ cross section.
(b) Nine extrusions, 11 to 65 $in.^2$ cross section.
(c) Two extrusions, 26 and 31 $in.^2$ cross sections.

TABLE 3.02212. COMPRESSIVE YIELD STRENGTH OF 7050-T7351 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

Alloy	7050-T7452	
Form	Hand Forgings	
Size, inch	Orientation	F_{su}, ksi
2 x 8 x 72	L	48.2
	LT	47.0
	ST	47.5
2-1/2 x 22 x 60	L	43.5
	LT	43.5
	ST	42.4
3-1/2 x 14 x 72	L	42.3
	LT	41.9
	ST	42.1
4-1/2 x 22 x 84	L	42.9
	LT	42.2
	ST	41.5
5-1/2 x 22 x 60	L	43.9
	LT	43.9
	ST	42.0
7-1/2 x 22 x 42	L	43.4
	LT	42.8
	ST	41.5

TABLE 3.0251. SHEAR STRENGTH OF 7050-T7452 (-T73652) HAND FORGINGS (4)

Alloy	7050-T74	
Form	Die Forgings	
Thickness, inch	Orientation	F_{su}, ksi
Up to 2.000	L	47.4
	ST	47.0
2.001 to 4.000	L	44.6
	ST	41.0
4.001 to 5.000	L	46.3
	ST	44.6
5.001 to 6.000	L	47.5
	ST	44.4

TABLE 3.0252. SHEAR STRENGTH OF 7050-T74 (-T736) DIE FORGINGS (4)

Alloy	7050									
Form	Sheet				Plate					
Condition	T6				T7451					
Thickness, inch	0.040 to 0.25		0.25 to 2.0		4.0			6.0		
Direction	L	LT	L	LT	L	LT	ST	L	LT	ST
F_{su}, ksi	50	52	46	46	46	46	43	46	46	42

TABLE 3.0253. SHEAR STRENGTH OF 7050-T6 SHEET AND 7050-T7451 (-T73651) PLATE (4)

Alloy	7050-T7351														
Form	Plate														
Thickness[a]	2-inch			3-inch			4-inch			5-inch			6-inch		
Direction	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST
F_{su}, ksi	44	43	–	45	45	43	46	45	42	45	45	42	44	44	41

(a) Average of single tests on each plate from two lots.

TABLE 3.0254. SHEAR STRENGTH OF 7050-T7351 PLATE (20)

Al
6.2 Zn
2.25 Mg
2.3 Cu
0.12 Zr

7050 Al

Alloy	7050-T7651							
Form	Extrusions							
Thickness, inch	0.187 to 1.2[a]		1.5 to 2.7[b]			3.5 to 5.0[c]		
Direction	L	LT	L	LT	ST	L	LT	ST
F_{su}, ksi	48	47	48	46	41	48	47	42

(a) Seven extrusions, 5 to 29 in.^{2} cross section.
(b) Five extrusions, 11 to 65 in.^{2} cross section.
(c) Three extrusions, 26 to 32 in.^{2} cross section.

TABLE 3.0255. SHEAR STRENGTH OF 7050-T7651 EXTRUSIONS (19)

Alloy	7050-T7351							
Form	Extrusions							
Thickness, inch	0.67 to 1.2[a]		1.5 to 2.9[b]			3.5 to 5.0[c]		
Direction	L	LT	L	LT	ST	L	LT	ST
F_{su}, ksi	45	44	45	44	40	43	43	42

(a) Four extrusions, 14 to 29 in.^{2} cross section.
(b) Nine extrusions, 11 to 65 in.^{2} cross section.
(c) Two extrusions, 26 and 31 in.^{2} cross sections.

TABLE 3.0256. SHEAR STRENGTH OF 7050-T7351 EXTRUSIONS (19)

Alloy	7050-T7452				
Form	Hand Forgings				
		F_{bru}, ksi		F_{bry}, ksi	
Size, inch	Orientation	e/D = 1.5	e/D = 2.0	e/D = 1.5	e/D = 2.0
2 x 8 x 72	L	114.4	154.5	99.1	120.0
	LT	118.5	155.2	102.3	120.1
2-1/2 x 22 x 60	L	105.8	139.0	92.8	111.8
	LT	112.6	145.4	95.3	112.9
3-1/2 x 14 x 72	L	99.7	136.4	91.1	107.7
	LT	102.0	135.0	90.9	108.1
4-1/2 x 22 x 84	L	99.0	133.5	90.4	106.6
	LT	104.2	131.1	88.4	104.0
5-1/2 x 22 x 60	L	104.2	132.9	92.8	108.2
	LT	103.7	136.2	91.8	109.8
7-1/2 x 22 x 42	L	102.2	135.4	87.2	100.8
	LT	102.2	129.4	84.8	99.0

TABLE 3.0261. BEARING PROPERTIES OF 7050-T7452 (-T73652) HAND FORGINGS (4)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050-T74				
Form	Die Forgings				
		F_{bru}, ksi		F_{bry}, ksi	
Thickness, inch	Orientation	e/D = 1.5	e/D = 2.0	e/D = 1.5	e/D = 2.0
Up to 2.000	L	114.0	147.8	97.7	114.6
2.001 to 4.000	L	101.4	137.3	88.4	106.9
4.001 to 5.000	L	109.7	145.1	96.4	110.0
5.001 to 6.000	L	106.1	138.4	95.1	111.0

TABLE 3.0262. BEARING PROPERTIES OF 7050-T74 (-T736) DIE FORGINGS (4)

Alloy	7050						
				F_{bru}, ksi		F_{bry}, ksi	
Form	Condition	Thickness, inch	Orientation	e/D = 1.5	e/D = 2.0	e/D = 1.5	e/D = 2.0
Sheet	T76	0.040 to 0.249	L	129.5	167.9	109.0	121.3
			LT	129.6	167.8	108.6	124.4
Plate	T7451	0.250 to 2.000	L	113.2	148.1	93.2	110.5
			LT	113.4	148.1	93.5	112.9
Plate	T7451	4.000	L	115.8	147.4	96.5	110.0
			LT	114.8	148.0	96.1	112.0
Plate	T7451	6.000	L	110.2	141.8	94.6	110.2
			LT	112.2	144.8	94.8	111.8

TABLE 3.0263. BEARING PROPERTIES OF 7050-T76 SHEET AND 7050-T7451 (-T73651) PLATE (4)

Alloy	7050-T7351									
Form	Plate									
Thickness(a)	2-inch		3-inch		4-inch		5-inch		6-inch	
Direction	L	LT	L	LT	L	LT	L	LT	L	LT
F_{bru}, ksi										
e/D = 1.5	–	110	113	113	112	113	110	111	109	111
e/D = 2.0	–	142	147	147	144	147	142	143	–	140
F_{bry}, ksi										
e/D = 1.5	–	93	93	94	94	94	91	90	89	92
e/D = 2.0	–	109	109	111	111	111	110	109	–	111

(a) Average of single tests on each plate from two lots.

TABLE 3.0264. BEARING PROPERTIES OF 7050-T7351 PLATE (20)

Alloy	7050-T7651											
Form	Extrusions											
e/D	1.5						2.0					
Thickness, inch	0.187 to 1.2(a)		1.5 to 2.9(b)		3.5 to 5.0(c)		0.187 to 1.2		1.5 to 2.0		3.5 to 5.0	
Direction	L	LT	L	LT	L	LT	L	LT	L	LT	L	LT
F_{bru}, ksi	124	125	124	123	123	115	159	160	159	159	157	152
F_{bry}, ksi	106	106	105	104	105	103	123	127	120	121	121	120

(a) Seven extrusions, 5 to 29 in.^{2} cross section.
(b) Five extrusions, 11 to 65 in.^{2} cross section.
(c) Three extrusions, 26 to 32 in.^{2} cross section.

TABLE 3.0265. BEARING STRENGTH OF 7050-T7651 EXTRUSIONS (19)

Alloy	7050-T7351											
Form	Extrusions											
e/D	1.5						2.0					
Thickness, inch	0.67 to 1.6(a)		1.5 to 2.9(b)		3.5 to 5.0(c)		0.67 to 1.6(a)		1.5 to 2.9(b)		3.5 to 5.0(c)	
Direction	L	LT	L	LT	L	LT(d)	L	LT	L	LT	L	LT(c)
F_{bru}, ksi	115	115	116	116	111	112	150	149	150	150	145	145
F_{bry}, ksi	96	96	96	96	97	94	113	114	114	117	115	119

(a) Four extrusions.
(b) Nine extrusions.
(c) Two extrusions.
(d) One extrusion.

TABLE 3.0266. BEARING PROPERTIES OF 7050-T7351 EXTRUSIONS (19)

Al
6.2 Zn
2.25 Mg
2.3 Cu
0.12 Zr

7050 Al

Alloy	7050				
Form	Condition	Thickness, inch	K_{Ic}(a) L-T	T-L	S-L
Plate	T7451	1.000	33.1	28.7	–
		2.000	36.0	29.0	24.5
		4.000	31.8	26.8	24.9
		6.000	27.2	24.8	23.8
Hand Forgings	T7451	2-1/2 x 22 x 60	29.6	26.7	19.2
		3-1/2 x 22 x 84	30.2	22.6	21.2
		4-1/2 x 22 x 84	34.7	20.5	18.4
		5-1/2 x 22 x 60	32.2	20.3	19.4
		7-1/2 x 22 x 42	33.7	–	19.7
Die Forgings	T736	0.7	–	38.2	26.0
		1.25	–	35.4	24.2
		3.5	28.7	–	–
		4.25 diam	38.7	–	–
		5.5	29.5	–	19.7
		6.1	–	–	21.2

(a) Compact tension specimens in accordance with ASTM E399.

TABLE 3.02722. PLANE STRAIN FRACTURE TOUGHNESS OF PLATE, HAND FORGINGS, AND DIE FORGINGS (4)

Alloy	7050
Form	3-inch Plate
Condition	T7451 LT F_{ty} = 65 ksi
Crack Orientation	SL
K_{Ic}, ksi$\sqrt{in.}$	25.4 (Avg of Three Tests)
K_{Ia}, ksi$\sqrt{in.}$ 2H = 1-inch	25.6 (Avg of Seven Measurements)
K_{Ia}, ksi$\sqrt{in.}$ 2H = 3-inch	25.3 (Avg of Six Measurements)

Note:
SL C(T) specimen: B = 1.25-inch, mid-thickness.
SL DB (My) specimen: B = 1-inch and L = 5-inch with 10 percent side grooves.

TABLE 3.02723. PLANE STRAIN FRACTURE TOUGHNESS VALUES FOR CRACK INITIATION AND ARREST IN 7050-T7451 (-T73651) PLATE FOR SL ORIENTATION (16)

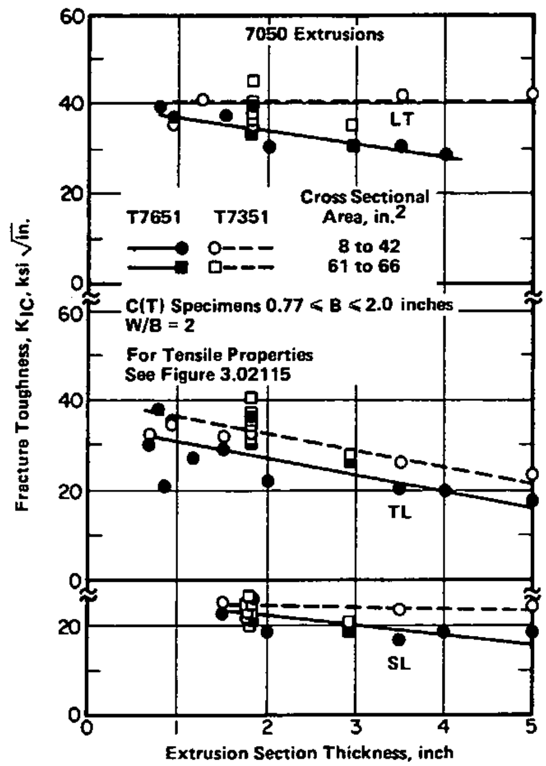

FIGURE 3.02724. EFFECT OF EXTRUSION SECTION THICKNESS ON PLANE STRAIN FRACTURE TOUGHNESS (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

Alloy	7050-T76511												
Form	Extrusions												
Crack Orientation	LT				TL				SL				LS
Extrusion(a)	W	Y	Z	S	W	Y	Z	S	W	Y	Z	S	W
K_{Ic}, ksi $\sqrt{in.}$(b)	33	32	30	39	25	24	19	27	–	27	17	–	50

(a) See Figure 3.02726.
(b) K_{Ic} according to E399-72; C(T) specimens: B = 0.75 inch, W/B = 2.

TABLE 3.02725. PLANE STRAIN FRACTURE TOUGHNESS OF VARIOUS EXTRUDED SHAPES (18)

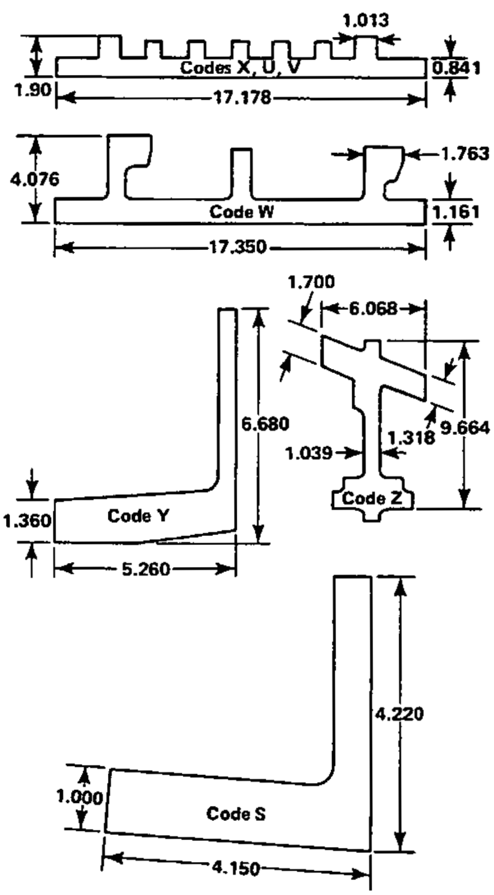

FIGURE 3.02726. EXTRUSION CROSS SECTIONS USED FOR FRACTURE TOUGHNESS AND CRACK-GROWTH RATE TESTS (18)

Alloy	7050 (0.02 Fe, 0.01 Si)		
Form	Plate		
Special Processing (See Table 3.02728)	CP(a)	AR(b)	AR + HR
F_{ty}, ksi	76	84	82
e, percent	11	11	10
K_{Ic}, ksi $\sqrt{in.}$			
LT	24	19	22
TL	26	19	23
Recrystallization, percent	45	94	68

(a) Commercial processing.
(b) As recrystallized.

TABLE 3.02727. PLANE STRAIN FRACTURE TOUGHNESS OF SPECIALLY PROCESSED VERY HIGH PURITY 7050 PLATE (30)

Alloy	7050 (0.02 Fe, 0.01 Si)
Processing Schedule	Procedure
AR(a) (1-inch Plate)	850 F, 48 hr, FC to 775 F, 5 hr, FC to 500 F, 4 hr, WQ + 81 percent HR at 274 F + 850 F, 48 hr, WQ
AR + HR(b)	ITMT + 40 percent HR at 800 F
CP(c) (1.5-inch Plate)	Hot Roll at 775 F, AC
T6X1(d)	ITMT or ITMT + AR or CP 890 F, 3 hr, WQ + 5 days at RT + 250 F, 4 hr + 335 F, 4 hr

(a) As recrystallized.
(b) Hot rolled.
(c) Commercial processing.
(d) Final treatment given to all material.

TABLE 3.02728. SPECIAL PROCESSING SCHEDULES PROVIDED TO 7050 VERY HIGH PURITY PLATE (30)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

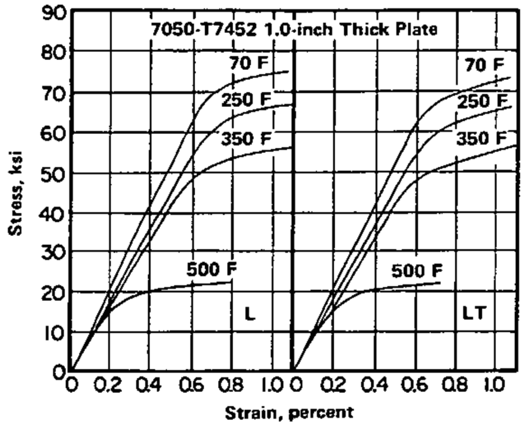

FIGURE 3.0311. TENSILE STRESS-STRAIN CURVES FOR 7050-T7452 (-T73652) PLATE AT ROOM AND ELEVATED TEMPERATURES (11)

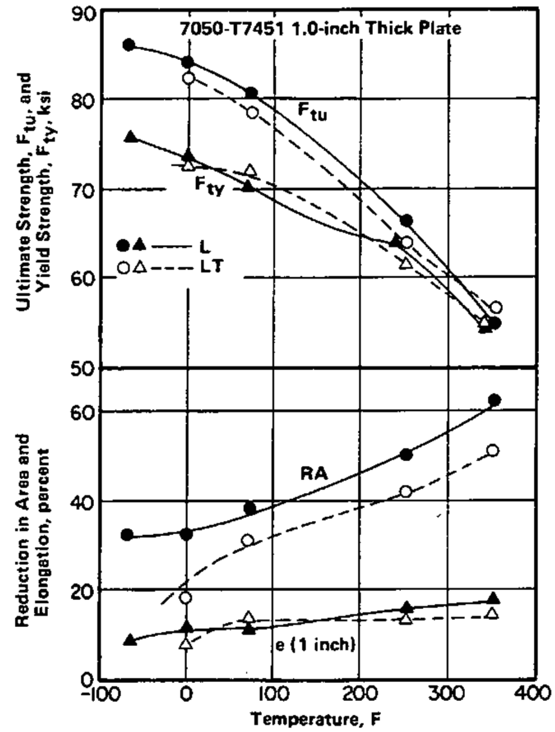

FIGURE 3.0312. TENSILE PROPERTIES OF 7050-T7451 (-T73651) PLATE IN THE TEMPERATURE RANGE -65 TO 350 F (10)

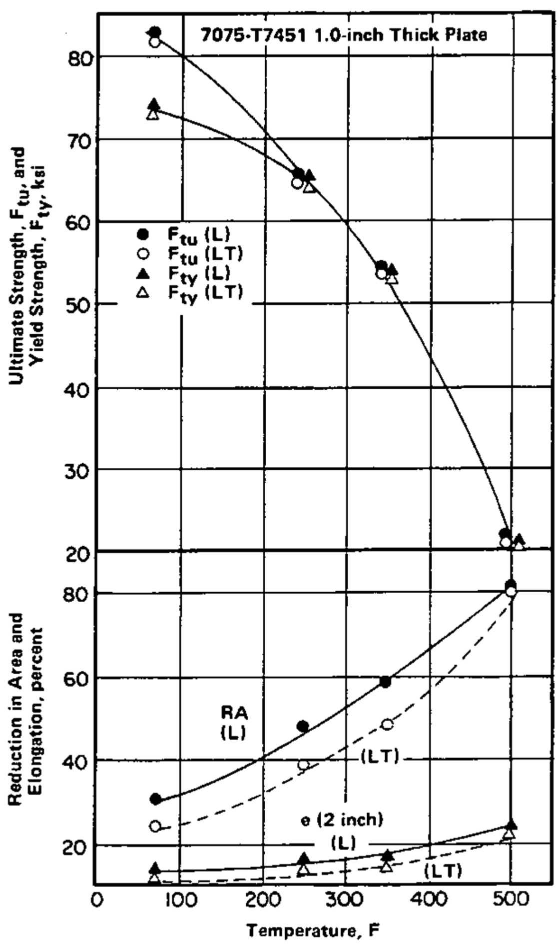

FIGURE 3.0313. TENSILE PROPERTIES OF 7050-T7451 (-T73651) PLATE IN THE TEMPERATURE RANGE OF 70 TO 500 F (11)

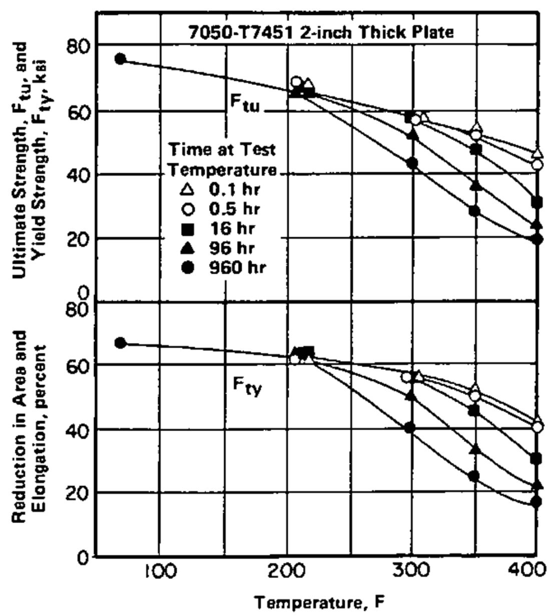

FIGURE 3.0314. EFFECTS OF ELEVATED TEMPERATURES ON TENSILE ULTIMATE AND YIELD STRENGTHS OF 7050-T7451 (-T73651) PLATE AFTER VARIOUS EXPOSURE TIMES AT TEST TEMPERATURE (8)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

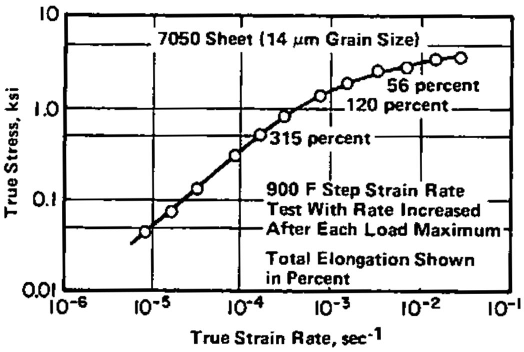

FIGURE 3.0315. TRUE STRESS AS A FUNCTION OF STRAIN RATE FOR TESTS ON A SHEET AT 900 F (28)

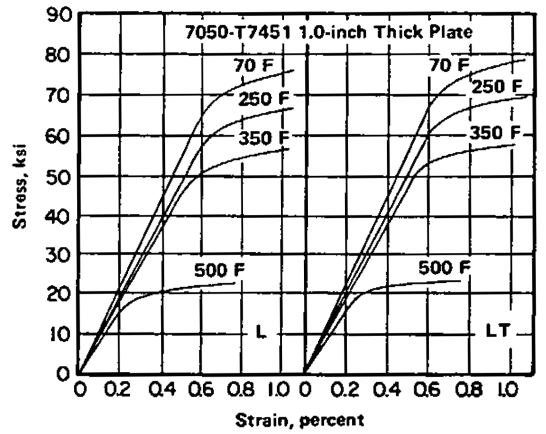

FIGURE 3.0321. COMPRESSIVE STRESS-STRAIN CURVES FOR 7050-T7451 (-T73651) PLATE AT ROOM AND ELEVATED TEMPERATURES (11)

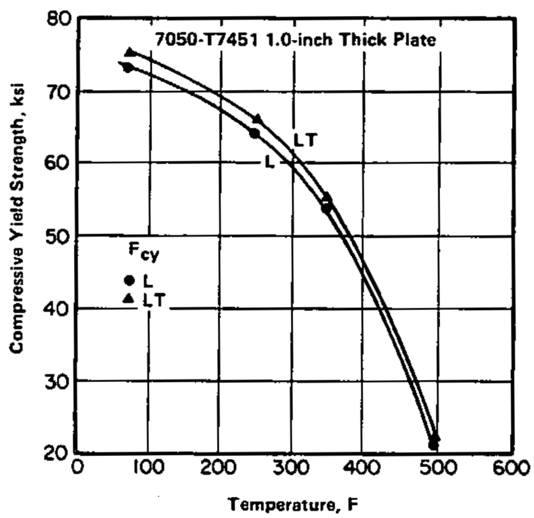

FIGURE 3.0322. EFFECTS OF TEMPERATURE ON COMPRESSIVE YIELD STRENGTH OF 7050-T7451 (-T73651) PLATE (11)

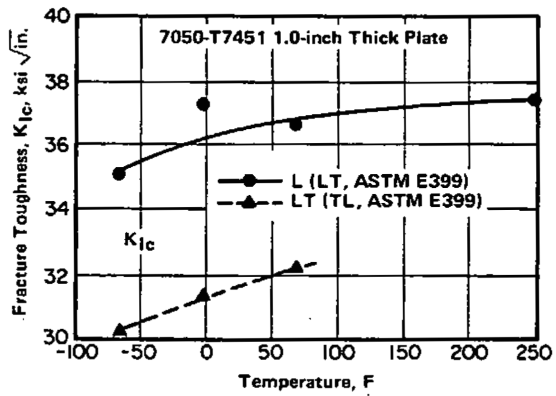

FIGURE 3.03721. EFFECTS OF LOW AND ELEVATED TEMPERATURES ON PLANE-STRAIN FRACTURE TOUGHNESS OF 7050-T7451 (-T73651) PLATE (10)

Note: K_{Ic} values determined with compact tension specimens in accordance with ASTM E399.

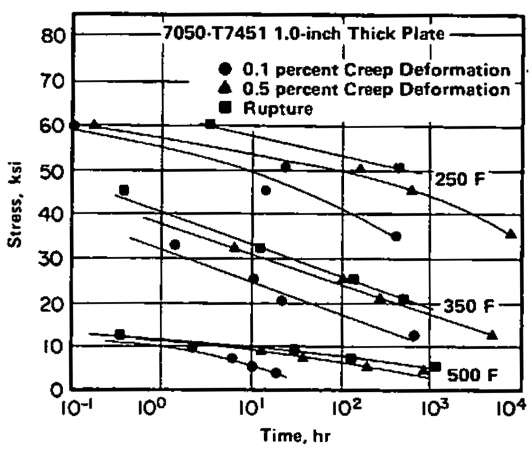

FIGURE 3.041. CREEP AND CREEP-RUPTURE CURVES FOR 7050-T7451 (-T73651) PLATE (11)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

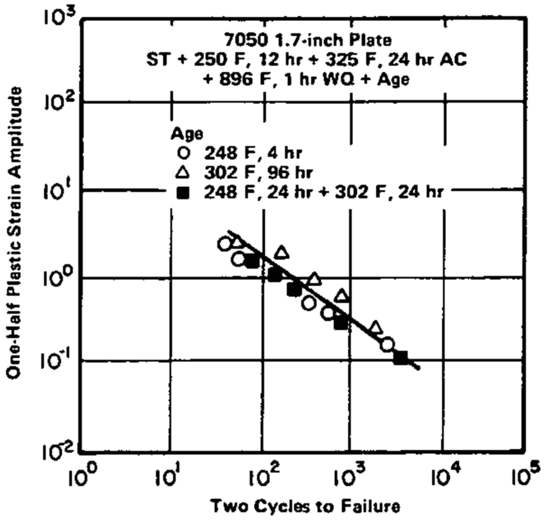

FIGURE 3.0511. LOW CYCLE FATIGUE RESULTS FOR 7050 PLATE SUBJECTED TO DIFFERENT AGING TREATMENTS (33)

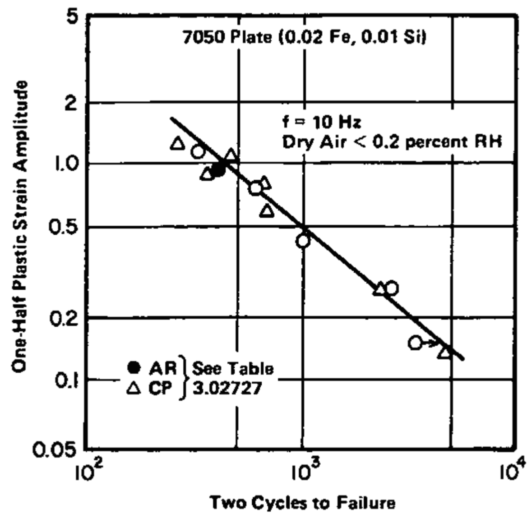

FIGURE 3.0512. LOW CYCLE FATIGUE RESULTS FOR TWO PROCESSING TREATMENTS OF VERY HIGH PURITY 7050 PLATE (30)

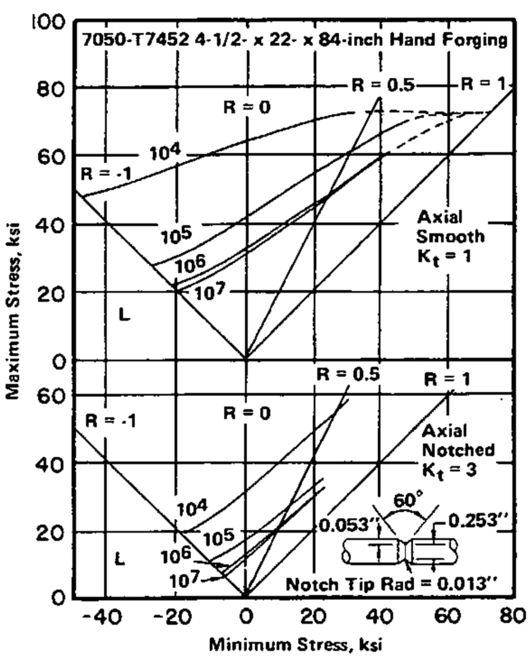

FIGURE 3.0513. MODIFIED GOODMAN DIAGRAMS FOR LONGITUDINAL SMOOTH AND NOTCH FATIGUE PROPERTIES OF 7050-T7452 (-T73652) HAND-FORGINGS (4)

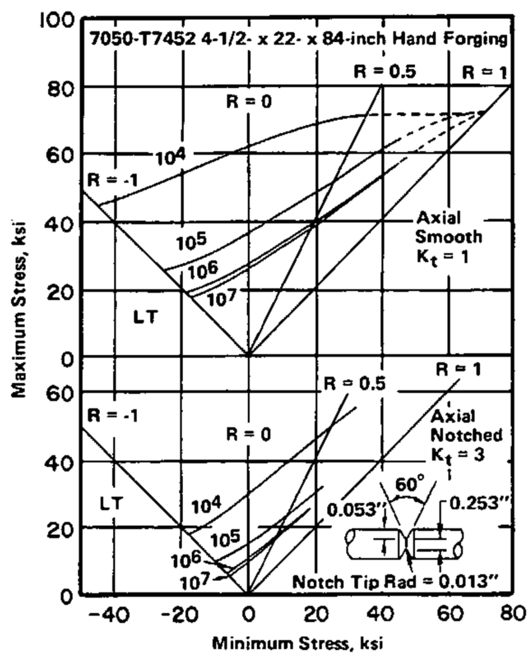

FIGURE 3.0514. MODIFIED GOODMAN DIAGRAMS FOR LONG-TRANSVERSE SMOOTH AND NOTCH FATIGUE PROPERTIES OF 7050-T7452 (-T73652) HAND-FORGINGS (4)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

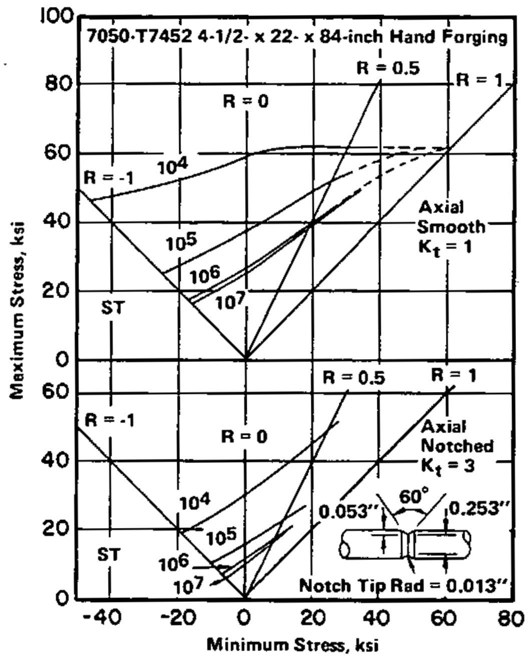

FIGURE 3.0515. MODIFIED GOODMAN DIAGRAMS FOR SHORT-TRANSVERSE SMOOTH AND NOTCH FATIGUE PROPERTIES OF 7050-T7452 (-T73652) HAND-FORGINGS (4)

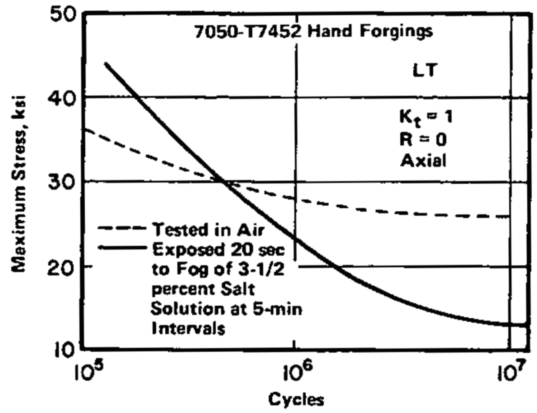

FIGURE 3.0516. S-N CURVES AT R = 0 FOR SMOOTH SPECIMENS FROM 7050-T7452 (-T73652) HAND FORGINGS TESTED IN AIR AND IN SALT FOG (4)

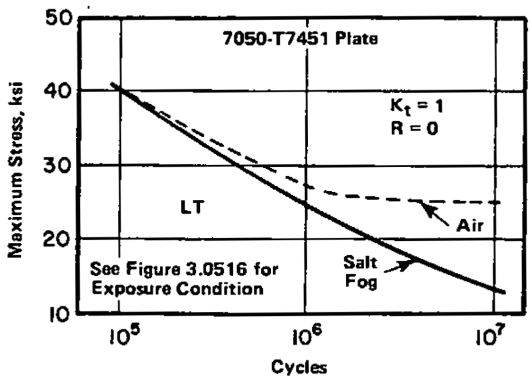

FIGURE 3.0517. S-N CURVES AT R = 0 FOR SMOOTH SPECIMENS FROM 7050-T7451 (-T73651) PLATE TESTED IN AIR AND IN SALT FOG (4)

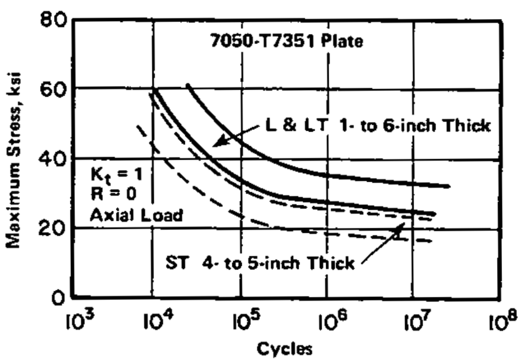

FIGURE 3.0518. S-N BANDS AT R = 0 FOR SMOOTH L, LT, AND ST SPECIMENS FROM 7050-T7351 PLATE OF VARIOUS THICKNESSES (20)

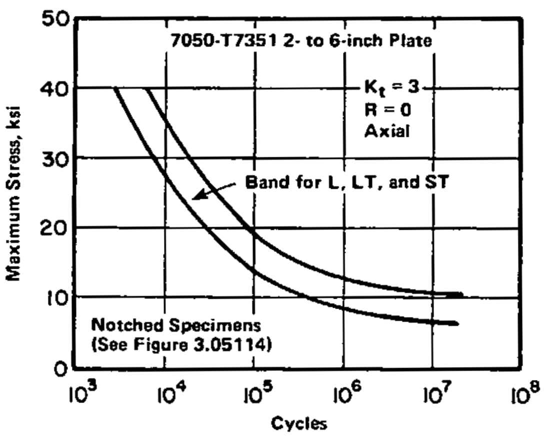

FIGURE 3.0519. S-N BAND AT R = 0 FOR NOTCHED SPECIMENS FROM 7050-T7351 PLATE OF VARIOUS THICKNESSES (20)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

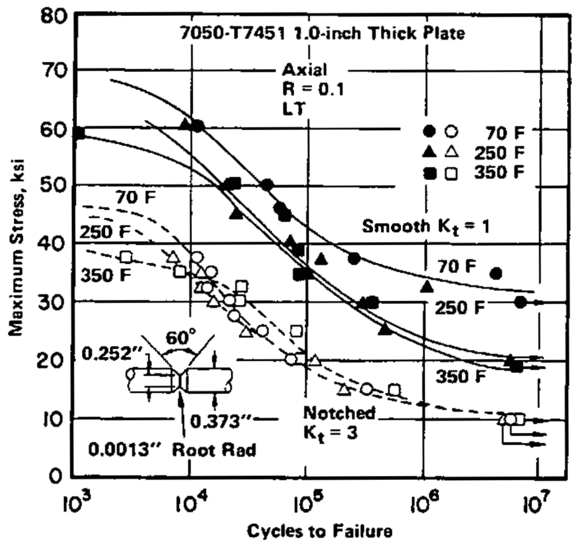

FIGURE 3.05110. FATIGUE LIFE AT VARIOUS TEMPERATURES OF SMOOTH AND NOTCHED 7050-T7451 (-T73651) PLATE (11)

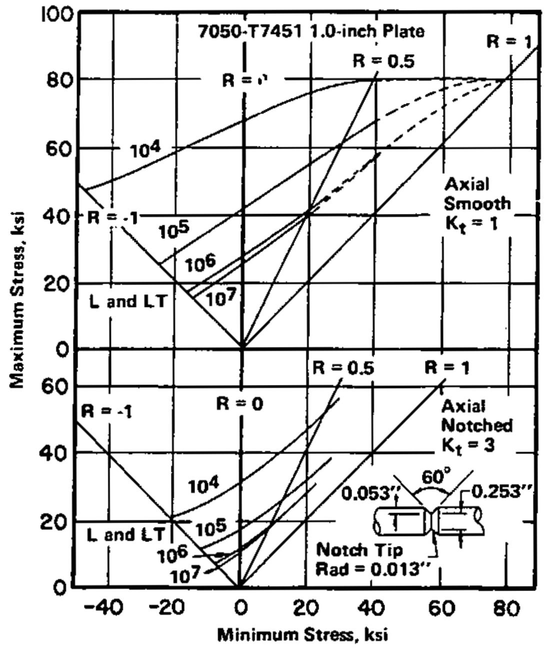

FIGURE 3.05111. MODIFIED GOODMAN DIAGRAMS FOR FATIGUE PROPERTIES OF SMOOTH AND NOTCHED 7050-T7451 (-T73651) PLATE (4)

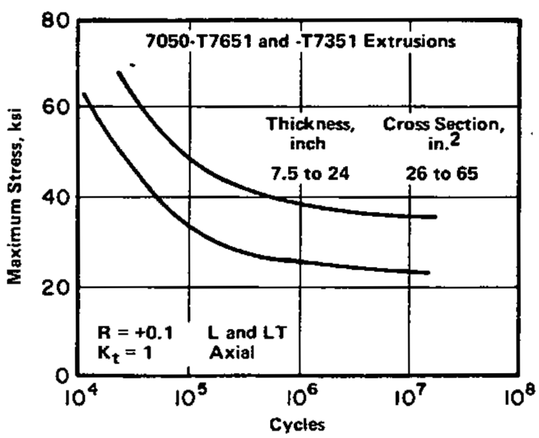

FIGURE 3.05112. S-N BAND AT R = +0.1 FOR SMOOTH SPECIMENS FROM 7050-T7651 AND -T7351 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

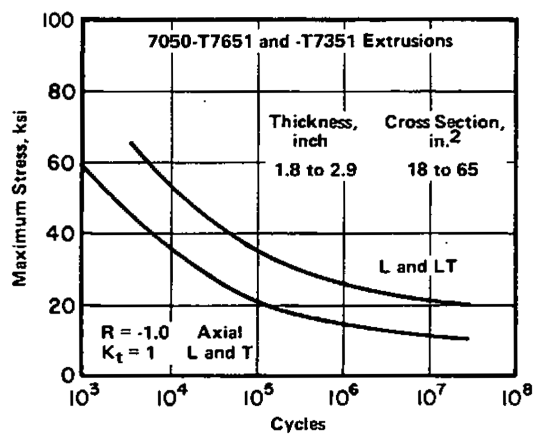

FIGURE 3.05113. S-N BAND AT R = -1.0 FOR SMOOTH SPECIMENS FROM 7050-T7651 AND -T7351 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

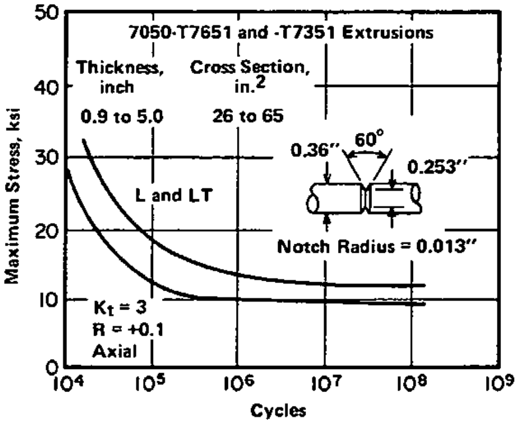

FIGURE 3.05114. S-N BAND AT R = +0.1 FOR NOTCHED SPECIMENS FROM 7050-T7651 AND -T7351 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

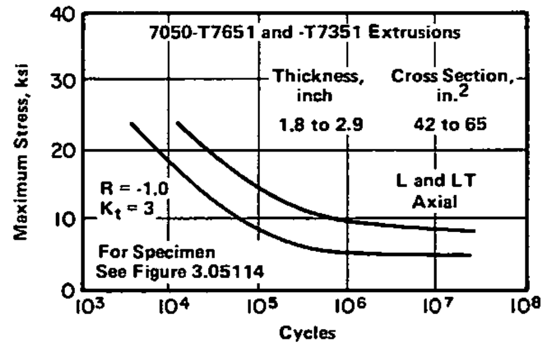

FIGURE 3.05115. S-N BAND AT R = -1.0 FOR NOTCHED SPECIMENS FROM 7050-T7651 AND -T7351 EXTRUSIONS OF VARIOUS THICKNESSES AND CROSS SECTIONS (19)

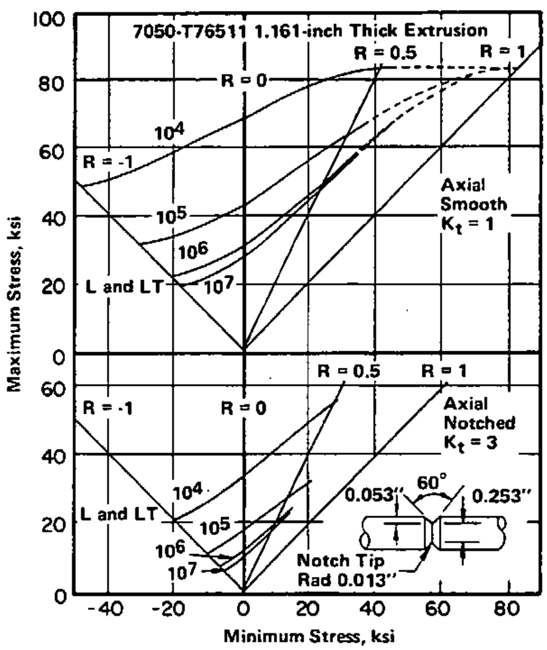

FIGURE 3.05116. MODIFIED GOODMAN DIAGRAMS FOR SMOOTH AND NOTCH FATIGUE PROPERTIES OF 7050-T76511 EXTRUSIONS (4)

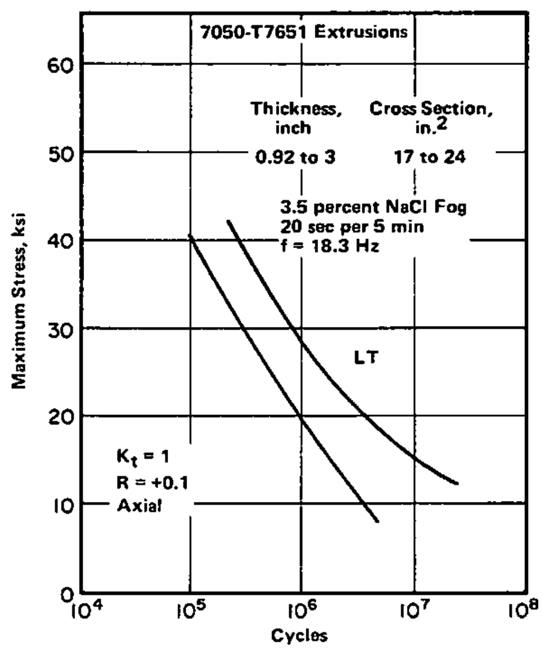

FIGURE 3.05117. S-N BAND AT R = +0.1 FOR SMOOTH SPECIMENS FROM 7050-T7651 EXTRUSIONS SUBJECTED TO SALT FOG (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

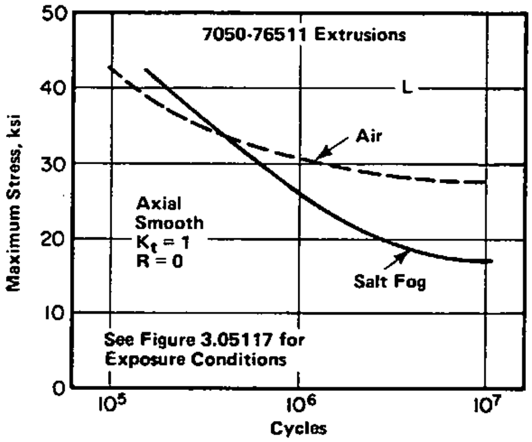

FIGURE 3.05118. S-N CURVES AT R = 0 FOR SMOOTH SPECIMENS FROM 7050 EXTRUSIONS IN T76511 CONDITION TESTED IN AIR AND IN SALT FOG (4)

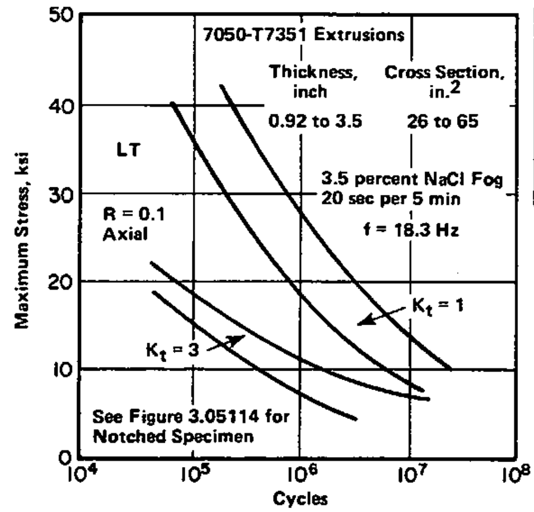

FIGURE 3.05119. S-N BAND AT R = 0.1 FOR SMOOTH AND NOTCHED SPECIMENS OF 7050-T7351 EXTRUSIONS SUBJECTED TO SALT FOG (19)

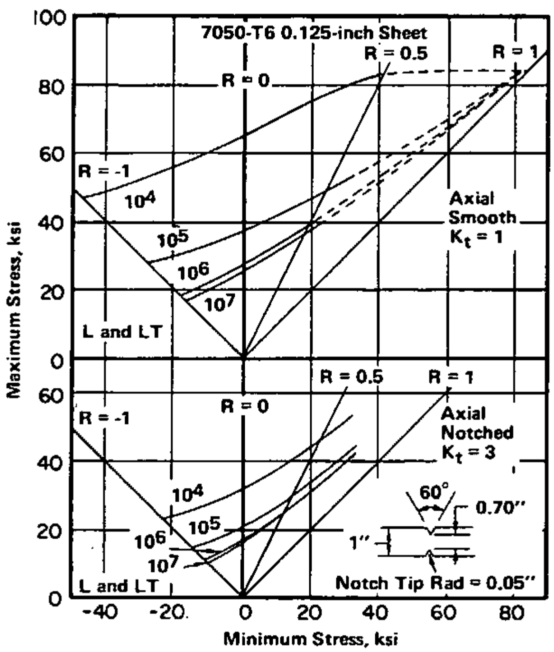

FIGURE 3.05120. MODIFIED GOODMAN DIAGRAMS FOR SMOOTH AND NOTCH FATIGUE PROPERTIES OF 7050-T6 SHEET (4)

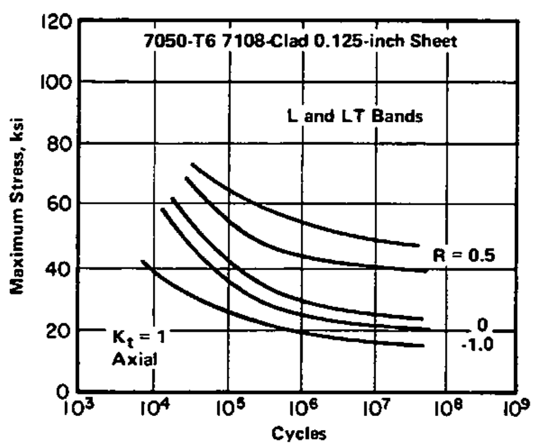

FIGURE 3.05121. S-N BANDS AT SEVERAL R RATIOS FOR SMOOTH L AND LT SPECIMENS FROM 7050-T6 CLAD SHEET (37)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

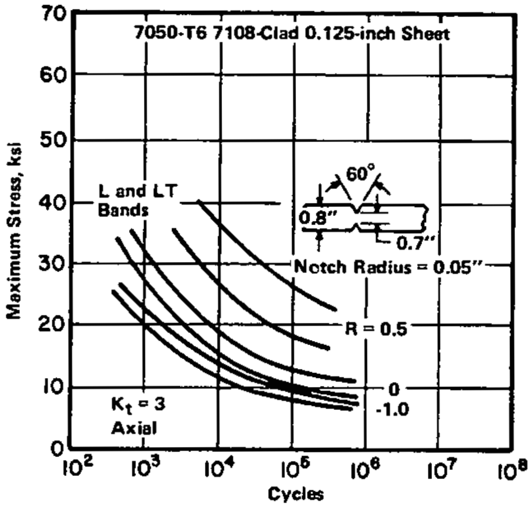

FIGURE 3.05122. S-N BANDS AT SEVERAL R RATIOS FOR L AND LT NOTCHED SPECIMENS FROM 7050-T6 CLAD SHEET (37)

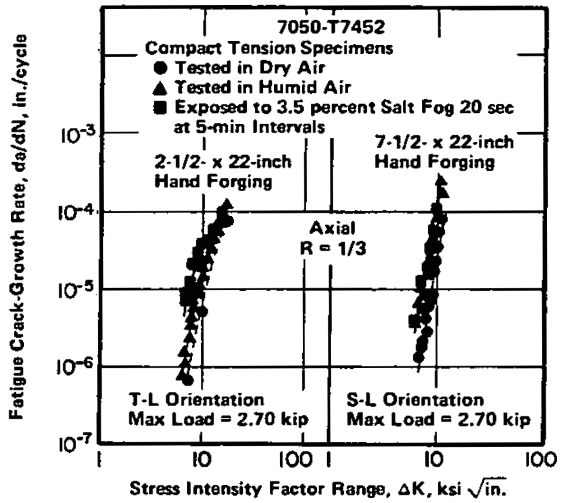

FIGURE 3.0521. FATIGUE CRACK-GROWTH RATES OF 7050-T7452 (-T73652) HAND FORGINGS IN TL AND SL ORIENTATIONS IN DRY AIR, HUMID AIR, AND SALT FOG (4)

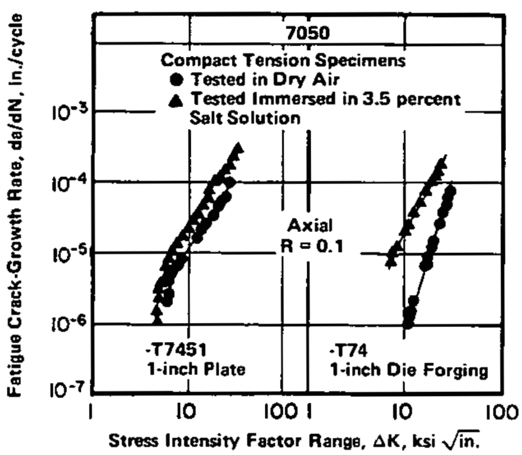

FIGURE 3.0522. FATIGUE CRACK-GROWTH RATES OF 7050-T7451 (-T73651) PLATE AND 7050-T74 (-T36) DIE FORGINGS IN DRY AIR AND IN 3.5 PERCENT NaCl SOLUTION (14)

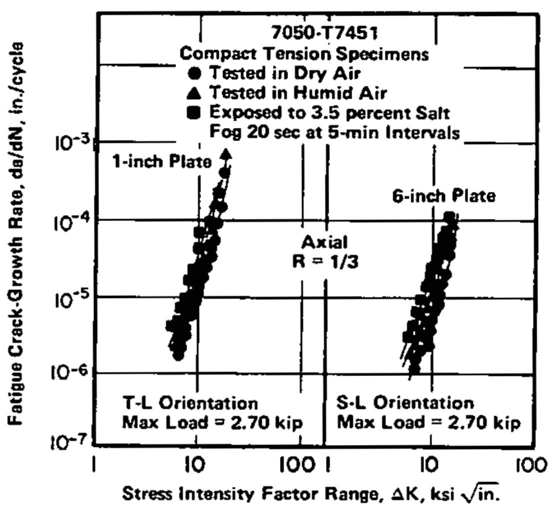

FIGURE 3.0523. FATIGUE CRACK-GROWTH RATES FOR 1-INCH AND 6-INCH 7050-T7451 (-T73651) PLATE IN TL AND SL ORIENTATIONS IN DRY AIR AND IN SALT FOG (4)

Alloy	7050		
Form	3.3-inch Plate		
Condition	T7451 L and T F_{tu} = 75.4 ksi, F_{ty} = 66.8 ksi		
Flights for[a] 0.32 < Δa < 1.18-inch	Surface	Core	Surface
Thickness, inch			
0.079	5272	5405	4890
0.157	4358	3691	4341
0.354	3530	3712	3515
0.551	3275	3143	3385

(a) TWIST spectrum truncated: ± 1.3 σ_{max}/σ_o gust levels occurring eight times per 4000 flights; σ_o = 8 ksi is mean flight stress.

(b) LT, center cracked plate specimens, W = 4.33-inch.

TABLE 3.0524. CRACK GROWTH IN 7050-T7451 (-T73651) PLATE SUBJECTED TO A TRUNCATED TRANSPORT FLIGHT SPECTRUM (15)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

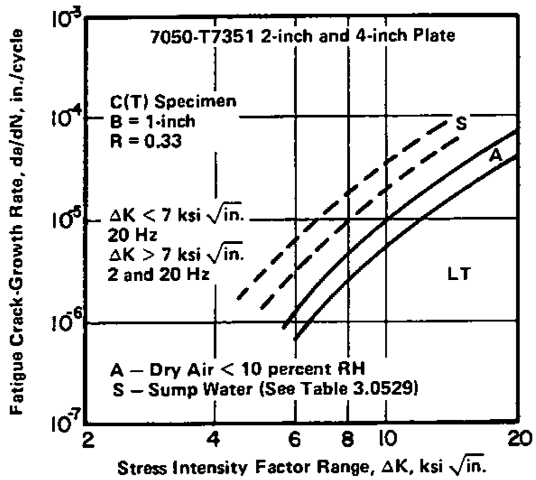

FIGURE 3.0525. FATIGUE CRACK-GROWTH RATES IN DRY AIR AND IN SUMP WATER FOR 2-INCH AND 4-INCH 7050-T7351 PLATE TESTED IN LT ORIENTATION (20)

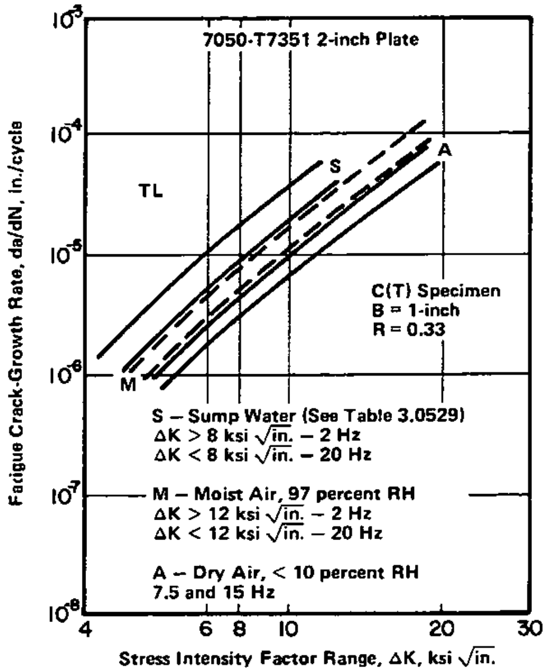

FIGURE 3.0526. FATIGUE CRACK-GROWTH RATES IN DRY AIR, MOIST AIR, AND IN SUMP WATER FOR 2-INCH 7050-T7351 PLATE TESTED IN TL ORIENTATION (20)

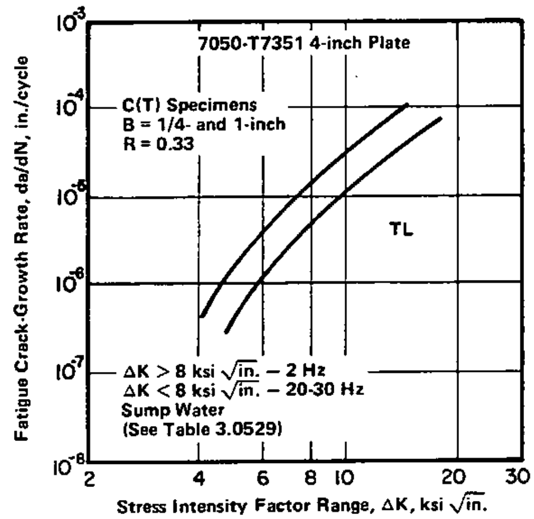

FIGURE 3.0527. FATIGUE CRACK-GROWTH RATES IN SUMP WATER FOR 4-INCH 7050-T7351 PLATE TESTED IN TL ORIENTATION (20)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

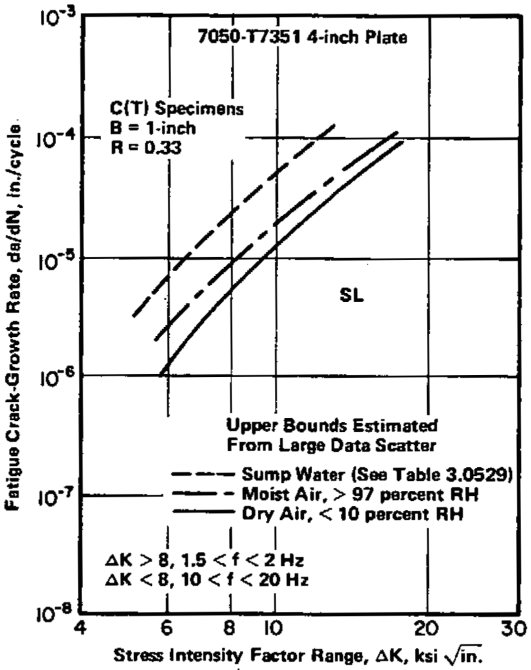

FIGURE 3.0528. FATIGUE CRACK-GROWTH RATES IN DRY AIR, MOIST AIR, AND IN SUMP WATER FOR 4-INCH 7050-T7351 PLATE TESTED IN SL ORIENTATION (20)

Sump Tank Water			
Composition	Salt, ppm	Metal Ion, ppm	Chloride, ppm
$CaCl_2$	15	18	32
$CdCl_2$	1000	490	310
$MgCl_2$	50	6	18
NaCl	100	20	30
$ZnCl_2$	10	4.7	5.2
$CrCl_3 \cdot 6H_2O$	1	0.2	0.3
$CrCl_3 \cdot 2H_2O$	1	0.4	0.4
$FeCl_3$	5	1.7	3.3
$MnCl_2 \cdot 4H_2O$	5	1.4	1.8
$NiCl_2 \cdot 6H_2O$	1	0.2	0.3
$PbCl_2$	1	0.7	0.3

TABLE 3.0529. COMPOSITION OF SYNTHETIC SUMP TANK WATER (20)

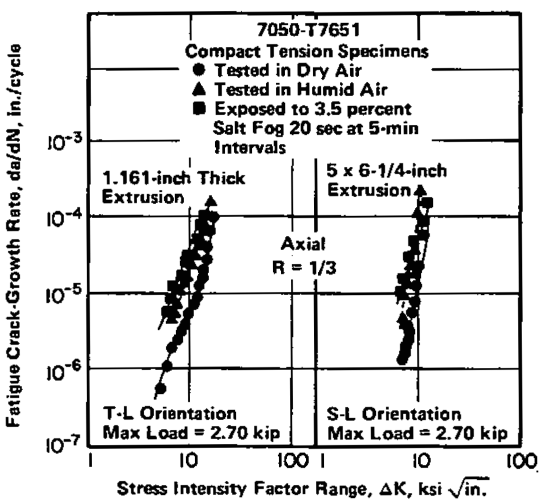

FIGURE 3.05210. FATIGUE CRACK-GROWTH RATES IN DRY AIR, HUMID AIR, AND IN SALT FOG FOR 7050-T7651 EXTRUSIONS TESTED IN TL AND SL ORIENTATIONS (4)

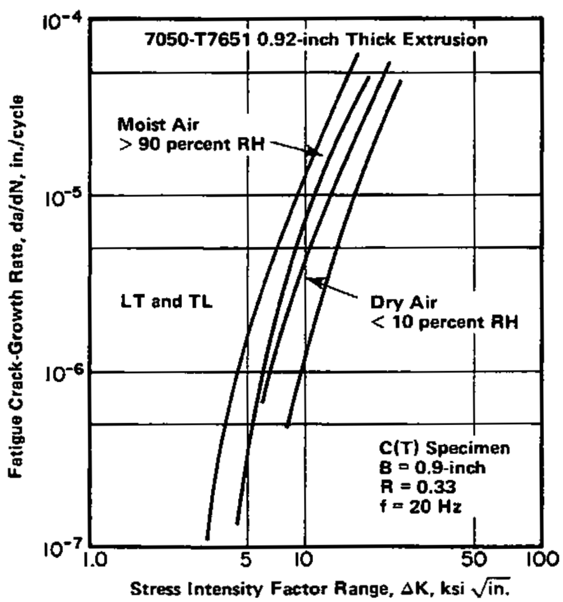

FIGURE 3.05211. FATIGUE CRACK-GROWTH RATES IN DRY AIR AND IN MOIST AIR FOR 7050-T7651 EXTRUSION TESTED IN LT AND TL ORIENTATIONS (19)

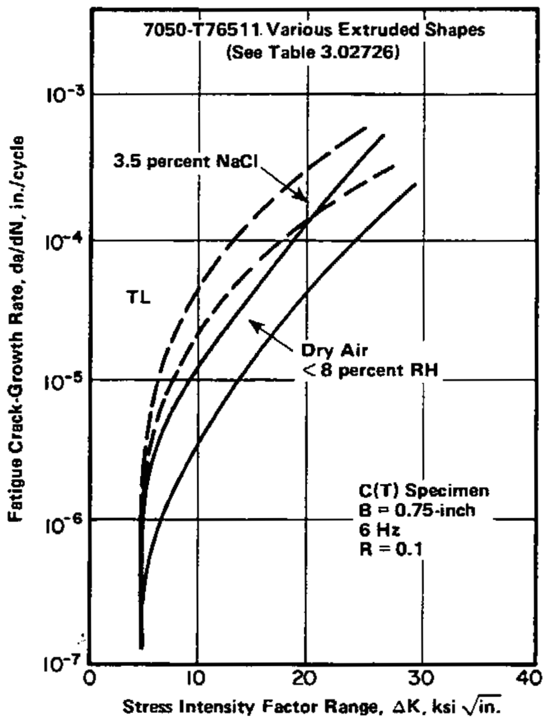

FIGURE 3.05212. FATIGUE CRACK-GROWTH RATES FOR VARIOUS EXTRUDED SHAPES OF 7050-T76511 TESTED IN TL ORIENTATION IN DRY AIR AND IN SALT WATER (18)

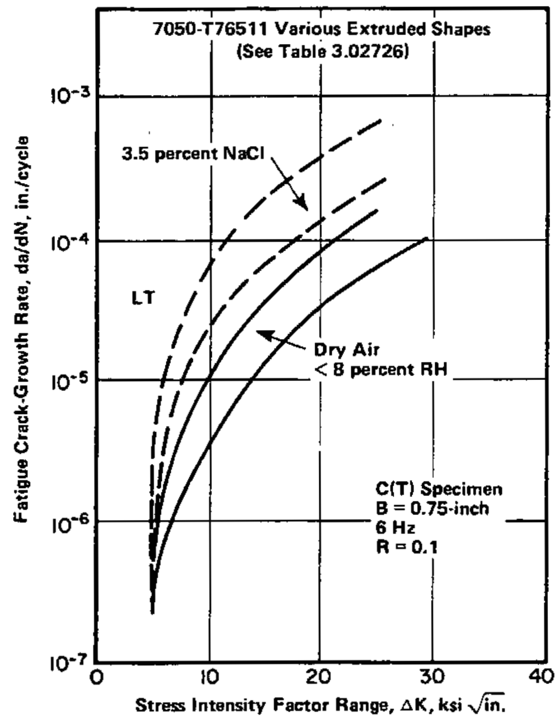

FIGURE 3.05213. FATIGUE CRACK-GROWTH RATES FOR VARIOUS EXTRUDED SHAPES OF 7050-T76511 TESTED IN LT ORIENTATION IN DRY AIR AND IN SALT WATER (18)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

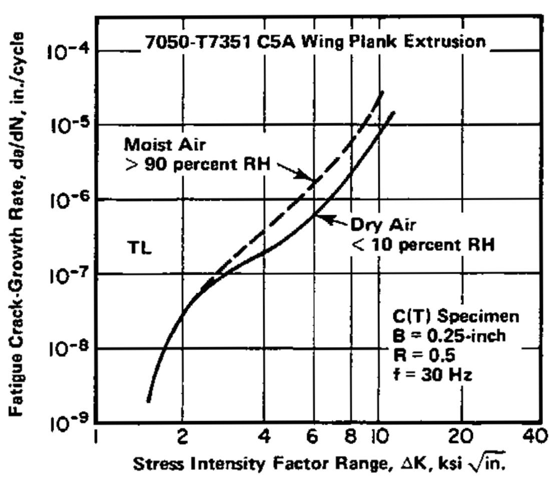

FIGURE 3.05214. NEAR THRESHOLD FATIGUE CRACK-GROWTH RATES AT R = 0.5 IN DRY AIR AND IN MOIST AIR FOR TL SPECIMENS FROM 7050-T7351 C5A WING PLANK EXTRUSION (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

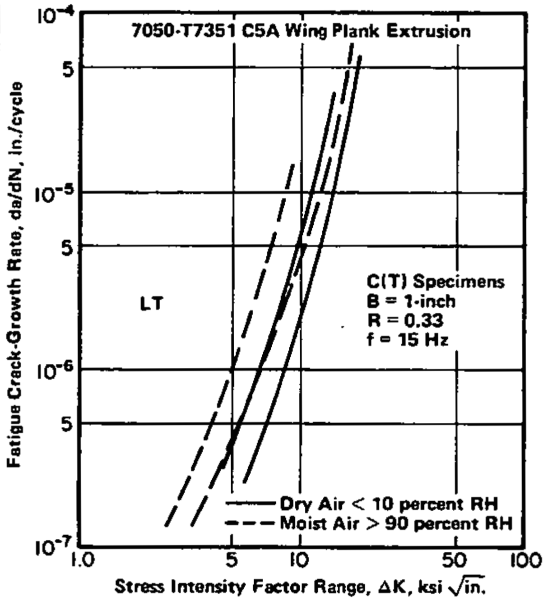

FIGURE 3.05215. FATIGUE CRACK-GROWTH RATES IN DRY AIR AND IN MOIST AIR FOR LT SPECIMENS FROM 7050-T7351 C5A WING PLANK EXTRUSION (19)

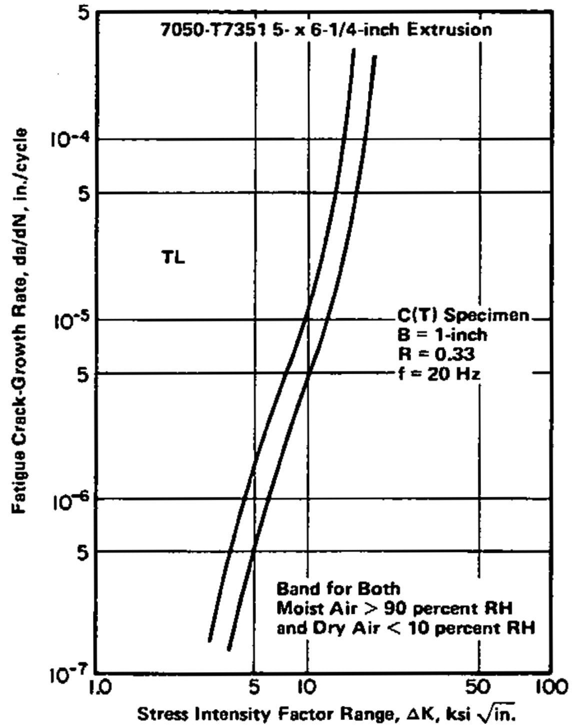

FIGURE 3.05216. FATIGUE CRACK-GROWTH RATES IN DRY AIR AND IN MOIST AIR FOR 7050-T7351 EXTRUSION TESTED IN TL ORIENTATION (19)

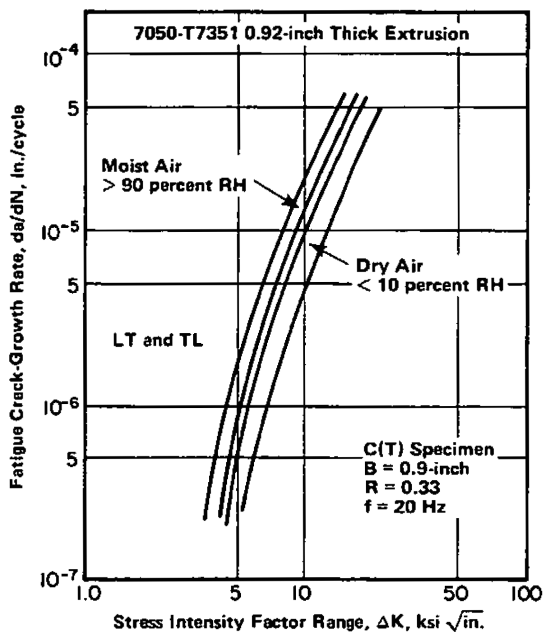

FIGURE 3.05217. FATIGUE CRACK-GROWTH RATES IN DRY AIR AND IN MOIST AIR FOR 7050-T7351 EXTRUSION TESTED IN LT AND TL ORIENTATIONS (19)

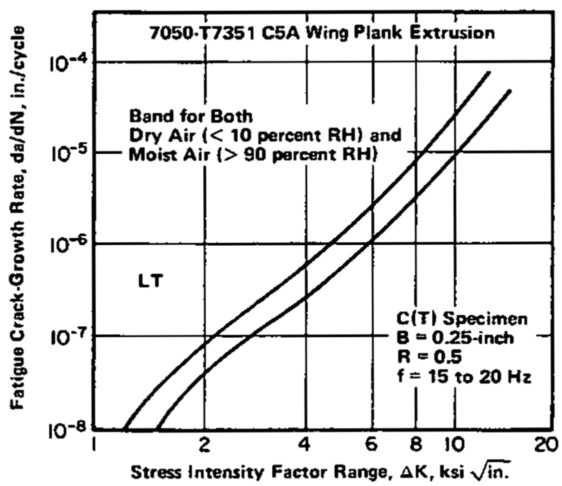

FIGURE 3.05218. NEAR THRESHOLD FATIGUE CRACK-GROWTH RATES AT R = 0.5 IN DRY AIR AND IN MOIST AIR FOR LT SPECIMENS FROM 7050-T7351 C5A WING PLANK EXTRUSION (19)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

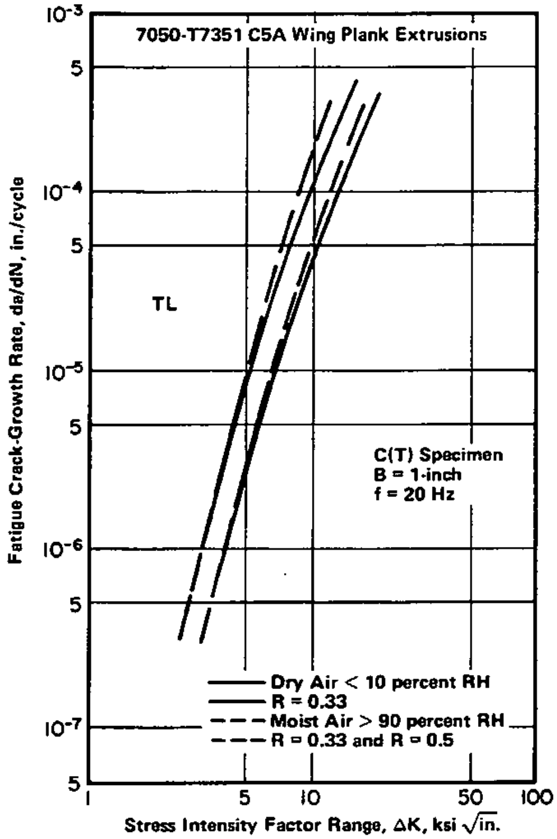

FIGURE 3.05219. FATIGUE CRACK-GROWTH RATES IN DRY AIR AND IN MOIST AIR FOR TL SPECIMENS FROM 7050-T7351 C5A WING PLANK EXTRUSION (19)

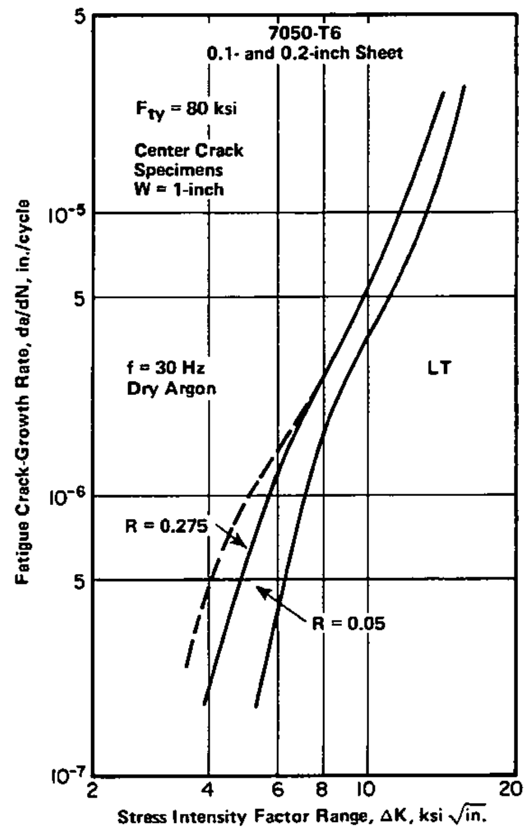

FIGURE 3.05220. FATIGUE CRACK-GROWTH RATES AT R = 0.05 AND R = 0.275 IN DRY ARGON FOR 7050-T6 SHEET TESTED IN LT ORIENTATION (29)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

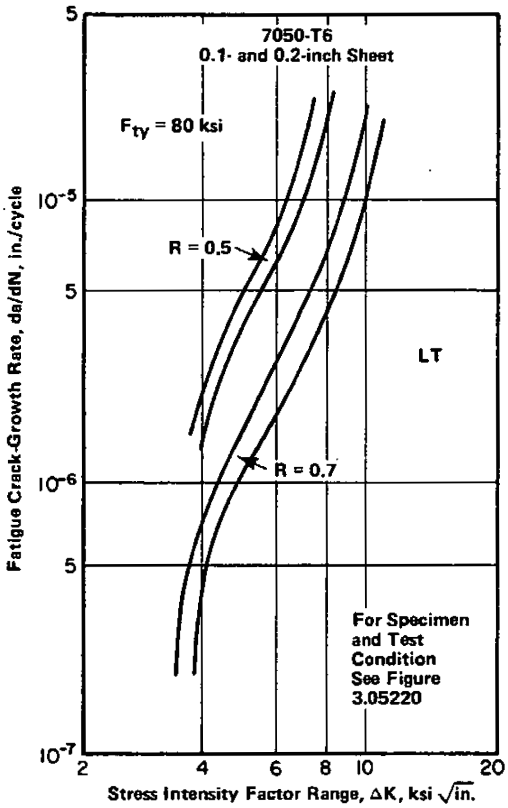

FIGURE 3.05221. FATIGUE CRACK-GROWTH RATES AT R = 0.5 AND R = 0.7 IN DRY ARGON FOR 7050-T6 SHEET TESTED IN LT ORIENTATION (29)

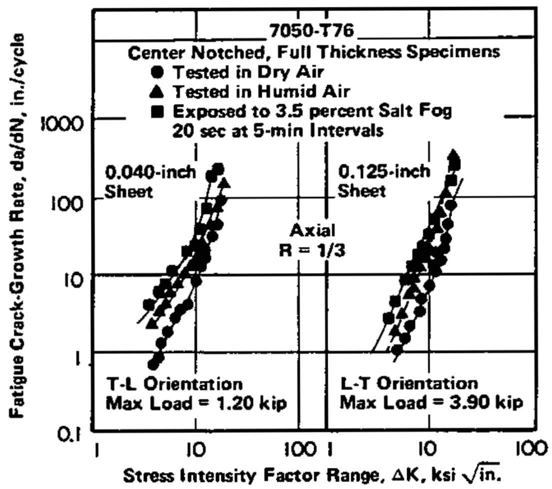

FIGURE 3.05222. FATIGUE CRACK-GROWTH RATES IN DRY AIR, HUMID AIR, AND SALT FOG FOR 7050-T76 SHEET TESTED IN TL AND LT ORIENTATIONS (4)

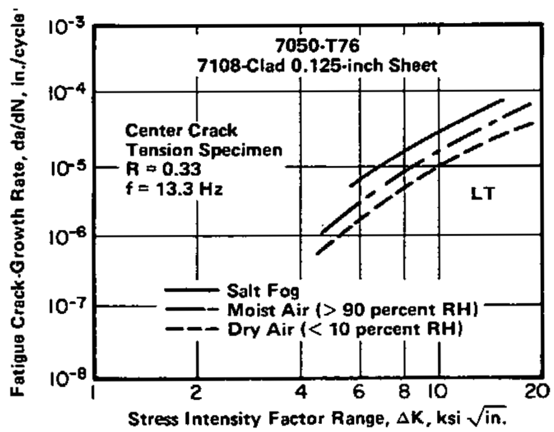

FIGURE 3.05223. FATIGUE CRACK-GROWTH RATES IN DRY AIR, MOIST AIR, AND IN 3.5 PERCENT SALT FOG FOR CLAD 7050-T76 SHEET TESTED IN LT ORIENTATION (37)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

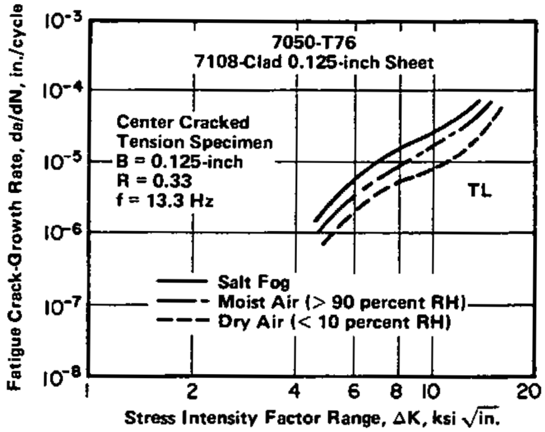

FIGURE 3.05224. FATIGUE CRACK-GROWTH RATES IN DRY AIR, MOIST AIR, AND IN 3.5 PERCENT SALT FOG FOR CLAD 7050-T76 SHEET TESTED IN TL ORIENTATION (37)

Alloy	7050		
Form	Condition	E, 10^3 ksi	E_c, 10^3 ksi
Sheet	T76	10.2	10.5
Plate	T7451	10.3	10.5
Hand Forgings	T7452	10.2	10.5
Die Forgings	T736	10.2	10.5

Note: Variations in specimen orientation (L, LT, and ST) have no significant effects on these values.

TABLE 3.0621. STATIC MODULUS OF ELASTICITY IN TENSION AND COMPRESSION FOR VARIOUS FORMS (4)

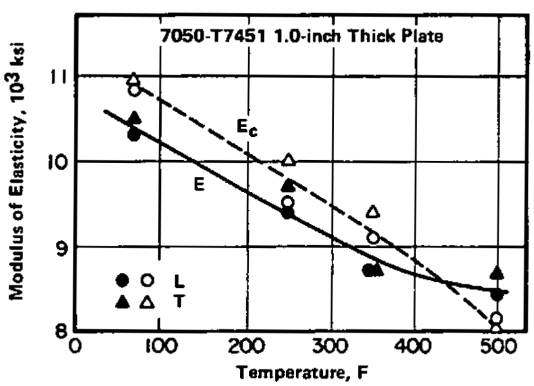

FIGURE 3.0622. EFFECT OF TEMPERATURE ON STATIC MODULUS OF ELASTICITY IN TENSION AND COMPRESSION FOR 7050-T7451 (-T73651) PLATE (11)

Alloy	7050								
Form	Extrusions						Plate		
Condition	T7651X			T7351X			T7351		
Direction	L	LT	ST	L	LT	ST	L	LT	ST
Number of Extrusions or Plates	7	7	3	7	7	2	5 Plates (2- to 6-inch)		
E,									
$\bar{X}$, 10^3 ksi	10.24	10.45	10.15	10.26	10.66	10.23	10.24	10.34	10.19
S, 10^3 ksi	0.155	0.166	–	0.0808	0.0423	–	0.021	0.048	0.04
E_c,									
$\bar{X}$, 10^3 ksi	10.73	11.03	10.83	10.66	11.02	10.66	10.54	–	–
S, 10^3 ksi	0.101	0.0711	–	0.0424	0.134	–	0.042	–	–

TABLE 3.0623. MEAN ($\bar{X}$) AND STANDARD DEVIATION(S) OF THE TENSION AND COMPRESSION MODULES FOR 7050-T7651 AND -T7351 EXTRUSIONS AND 7050-T7351 PLATE (19,20)

	Al
6.2	Zn
2.25	Mg
2.3	Cu
0.12	Zr

7050 Al

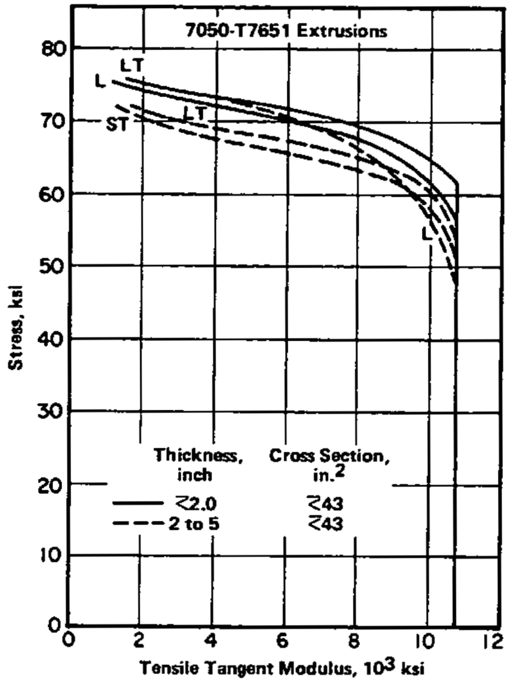

FIGURE 3.0641. TENSILE TANGENT MODULUS FOR 7050-T7651 EXTRUSIONS OF SEVERAL THICKNESSES (18)

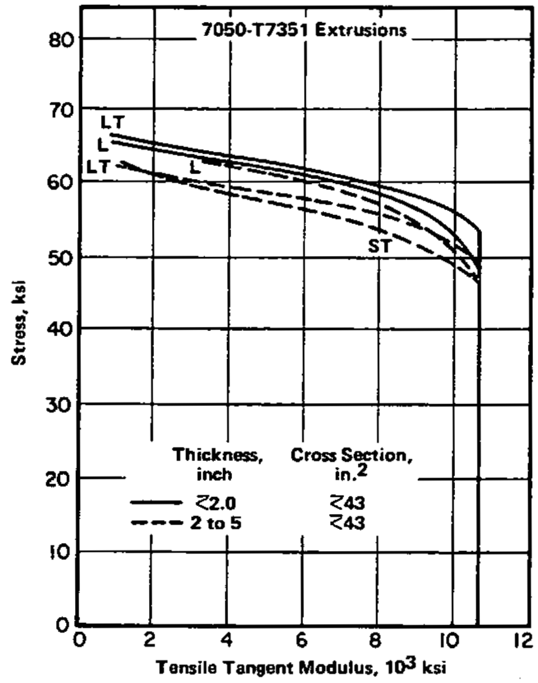

FIGURE 3.0642. TENSILE TANGENT MODULUS FOR 7050-T7351 EXTRUSIONS OF VARIOUS THICKNESSES (18)

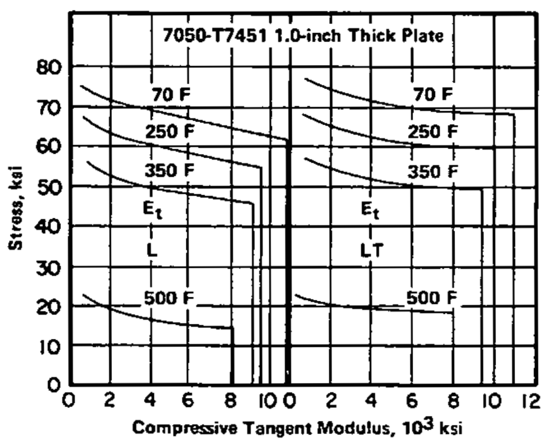

FIGURE 3.0643. COMPRESSIVE TANGENT MODULUS FOR 7050-T7451 (-T73651) PLATE AT VARIOUS TEMPERATURES (11)

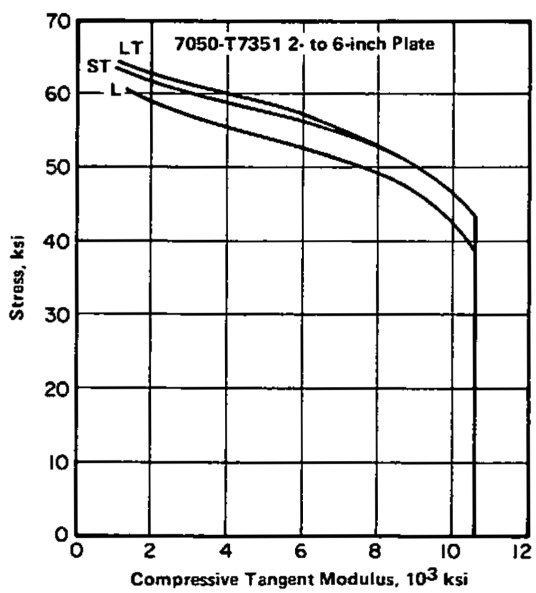

FIGURE 3.0644. COMPRESSIVE TANGENT MODULUS FOR 7050-T7351 PLATE (20)