

- 1 **GENERAL**
Alloy 2124 is one of a series of premium aluminum alloys which were developed as a result of studies into the micromechanisms of fracture in high strength aluminum compositions (34)(35). It is essentially 2024 with close controls on the content of Fe and Si. These elements were shown to form second phase particles which contributed to void formation at low average matrix strains but did not contribute significantly to the strength. Composition control coupled with special processing minimizes the deleterious influence of these phases by reducing their size and controlling their distribution with a resulting increase in fracture toughness and uniformity of fracture properties particularly in the short transverse direction. These improvements have been accomplished with no loss in other properties. The alloy is normally produced in plate form in the T851 condition in a thickness range up to 6 inch. The T351 condition is also available but no minimum mechanical properties have been published for this temper. It would be expected to have a lower strength than T851 but a higher toughness.
- 1.01 **Commercial Designation**
2124 aluminum alloy, 2124-T851.
- 1.02 **Alternate Designations**
UNS A92124.
- 1.03 **Specifications**
Federal specification: QQ-A-250/29, AMS 4101, and ASTM-B209.
- 1.04 **Composition**
Chemical composition, Table 1.04.
- 1.05 **Heat Treatment**
See also 2024-T851 plate.
- 1.051 General. The solution treatment and artificial aging practices applicable to 2124 plate are the same as those specified in MIL-H-6088 F for 2024 plate (4).
- 1.052 Anneal.
- 1.0521 Anneal heat treated material to 0 condition, 745 to 770 F, 2 hr, furnace cool 50 F per hour maximum to 500 F, maximum. The rate of subsequent cooling is not critical (4).
- 1.053 Solution treat.
- 1.0531 Heat 910 to 930 F, 20 min. to 4-1/2 hr depending on thickness. Quench by total immersion in sufficient cold water so as not to raise water temperature above 100 F (4).
- 1.0532 Recommended soaking times required for solution treating plate, Table 1.0532.
- 1.054 Stretch to T351 condition, subsequent to solution treat (4).
- 1.0541 Plate. Stretch 1-1/2 to 3 percent. No straightening is permitted after stretching.
- 1.055 Artificial age 2124 in T351 condition to T851 condition.
- 1.0551 Plate. Heat 365 to 385 F, 12 hr. The time at temperature depends on the time required for

the load to reach temperature. Time shown (see Table 1.0532) is based on rapid heating with soaking time measured from the time the load reaches within 10 F of the applicable temperature (4).

- 1.06 **Hardness**
See Section 1.092.

- 1.07 **Forms and Conditions Available**
1.071 Alloy is available in the form of plate in the T851 or T351 condition up to 6 inch in thickness.

- 1.08 **Melting and Casting Practice**
The alloy is not a casting alloy.

- 1.09 **Special Considerations**
1.091 Hydrogen embrittlement. The naturally aged tempers T-4 and T-3 and the incompletely aged conditions can be embrittled by severe hydrogen charging conditions. This embrittlement was reported as associated with homogeneous coherent precipitates within the matrix which tend to produce planar slip. The observed effects of hydrogen in this alloy are considerably less than in 7075 (24)(27). While the effects of hydrogen on aluminum alloys are of no direct practical importance they may be related to the stress corrosion mechanism.
- 1.0911 Effect of hydrogen charging on the tensile ductility of 2124 in several aged conditions, Table 1.0911.

- 1.092 Slack quenching. To achieve full hardness and strength, very rapid cooling from the solution treated condition is necessary. Plate is normally spray quenched on both top and bottom surfaces as it leaves the solution treating furnace. If the spray quench process is in some way defective, the cooling rate will be insufficient and soft spots will be produced in the plate. These will not normally be detected by samples taken from the plate ends since water run-off adequately cools these regions. The soft areas may show as a dark discoloration after anodizing and will exhibit higher than normal electrical conductivity. The effects of deficiencies in the spray quench system will be most pronounced in the heavier plate gages (> 2 inch thickness). Normally quenched heavy plate exhibits a relatively mild tensile strength, hardness, and electrical conductivity gradient through its thickness (Figure 1.0921) which can be drastically altered by deficient spray quenching (Figure 1.0922).

MIL-H-6088 F (4) provides specifications for qualification of the spray quenching process used for aluminum alloys. Essentially the qualification process is based on sampling the transverse tensile properties from a single run of a 2000 or a 7000 (preferably 7075) alloy of maximum thickness to be run on the line. Tensile samples are required from each end of the plate as well as from the center third of the quenched length. These samples

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

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1.5 Mg
0.6 Mn
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where possible should be selected to represent both center thickness and near-surface properties. For specific details reference should be made to MIL-H-6088 F.

The following discussion will refer to the top and the bottom of a 5-1/2-inch plate which had deficient spray cooling on its bottom surface which caused specimens taken from sections near the bottom of the plate to be softer than those taken from sections near the top. As might be expected, compression and bearing strength (Tables 1.0923 and 1.0924) values show that the softer portions of the plate have considerably reduced strength properties. Stress corrosion tests on these bottom specimens (75 percent F_{ty} alternate immersion 10 min. in 3.5 percent NaCl + 50 min. in air for 600 hr) indicated no stress corrosion problem was associated with the slack quenching of this plate (29). Precracked LT specimens from the top and bottom of the plate did not fail in 2000 hr when subjected to an initial $K_I = 22 \text{ ksi}\sqrt{\text{in.}}$ (29). Crack growth resistance curves revealed a somewhat higher resistance for the bottom specimens (29) as might be expected from their lower yield strength. Constant amplitude fatigue crack-growth rates (Figure 1.0925) and spectrum-growth rates (Figure 1.0926) appeared to be somewhat higher for the softer specimens.

Fatigue specimens containing a small hole (notched specimens) were cut from various positions in relation to the plate thickness and subjected to either constant amplitude fatigue or to a selected spectrum. The results (Figures 1.0927 and 1.0928) show increasing fatigue strength with increasing hardness and decreasing electrical conductivity. Constant amplitude tests on smooth specimens revealed no definite effect on hardness (29).

Both hardness and electrical conductivity are sensitive to slack quenching (Figures 1.0929 and 1.09210). However, electrical conductivity is also sensitive to changes in composition which may result in different relations between tensile strength and conductivity for different lots of the alloy. While hardness measurements appear to be a more reliable index of tensile strength, it is not possible to explore the surfaces of large plates with standard Rockwell or Brinell testers; miniature units requiring special calibrations must be used. Considering these facts, the U.S. Air Force (ASD) has recommended (29) that an indication of proper quenching requires that all conductivity readings on one side of a plate not vary by more than 2 percent IACS. MIL-H-6088 F specifies 2.5 percent IACS variation. While these specifications provide a reasonable and relatively easy method of quality control, the presently available information is not sufficient to establish whether this variation of conductivity will always represent the same

- variation in tensile strength from lot to lot of the same nominal alloy composition.
- 1.0921 Variation of hardness, tensile strength, and electrical conductivity through the thickness of normally quenched 2124-T851 plate, Figure 1.0921.
- 1.0922 Variation of hardness, tensile strength, and electrical conductivity through the thickness of slack quenched 2124-T851 plate, Figure 1.0922.
- 1.0923 Hardness, electrical conductivity, and compression strength of specimens taken from a slack quenched 2124-T851 plate, Table 1.0923.
- 1.0924 Hardness, electrical conductivity, and bearing strength of slack quenched 2124-T851 plate, Table 1.0924.
- 1.0925 Fatigue crack propagation rate for specimens cut from near the top and near the bottom of a slack quenched 2124-T851 plate, Figure 1.0925.
- 1.0926 Fatigue crack growth as a function of $K_{I\text{max}}$ in a fighter spectrum loading for specimens taken from a normal hardness region and a soft region in a 5-1/2-inch slack quenched 2124-T851 plate, Figure 1.0926.
- 1.0927 Notched fatigue life for specimens cut from 2124-T851 slack quenched plate as a function of hardness and electrical conductivity, Figure 1.0927.
- 1.0928 Flights to failure under the Falstaff fatigue spectrum as a function of hardness and electrical conductivity for notched specimens cut from slack quenched 2124-T851 plate, Figure 1.0928.
- 1.0929 Tensile strength properties as a function of hardness for slack quenched and normal quenched 2124-T851 plates, Figure 1.0929.
- 1.09210 Tensile strength properties as a function of electrical conductivity for slack quenched and normal quenched 2124-T851 5-1/2-inch plates, Figure 1.09210.
- 1.093 Directionality. The mechanical anisotropy in this and other high-strength aluminum alloys results in stress corrosion resistance which is substantially poorer for stressing in the short transverse direction than in the longitudinal and long transverse directions (e.g., Table 2.0321). An anisotropy of plane strain fracture toughness is also observed with the K_{IC} values, on the average, being highest for the LT direction, lower for the TL direction, and lowest for the SL direction (e.g., Table 3.02721). Considerable scatter characterizes the fatigue crack-growth data (see Section 3.052) which could define a directionality effect. On balance there appears to be no practical difference between the LT and TL directions. The SL and ST directions appear to have slightly higher growth rates than the LT and TL directions, particularly in a 3.5 percent salt solution. As might be expected the TS and LS exhibit rapidly decreasing rates as the crack deepens (see Figures 3.05219 and 3.052110).
- 1.094 Effects of reheat treatment. The corrosion resistance of this alloy can be reduced by reheat

treatments which involve solution temperatures and/or aging temperatures below those recommended. If such a reheat treatment has occurred, the alloy should be resolution treated using a longer than average soaking time and a temperature within 5 F of the maximum range. Solution treatment above the maximum may produce eutectic melting and possible blistering. Such overheated material will have inferior properties which may not be recoverable (4).

are also observed in slow strain rate tests in 3.5 percent NaCl (Figure 2.0325). Both alternate immersion tests (23) and slow strain rate tests (Figures 2.0326 and 2.0327) show that the underaged conditions are considerably more susceptible to SCC in chloride solutions than the fully aged temper.

Al
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2124 Al

2 PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range, 935 to 1180 F (approximately), based on typical composition (3).

2.012 Phase changes. Alloy is subject to precipitation hardening below 775 F.

2.0121 Time-temperature-transformation diagrams.

2.013 Thermal conductivity:
87.5 Btu ft per (hr ft² F) at 77 F (3)
87.12 Btu ft per (hr ft² F) at 100 F (1)
91.9 Btu ft per (hr ft² F) at 300 F (1).

2.014 Thermal expansion, Figure 2.014.

2.015 Specific heat, Figure 2.015.

2.016 Thermal diffusivity.

2.02 Other Physical Properties

2.021 Density:
0.100 lb per in.³, 2.77 gr per cm³ at 68 F
0.099 lb per in.³, 2.74 gr per cm³ at 300 F
0.098 lb per in.³, 2.72 gr per cm³ at 500 F
0.097 lb per in.³, 2.70 gr per cm³ at 700 F.

2.022 Electrical properties.

2.0221 Electrical conductivity, T851 condition typically 39.3 percent IACS (see also Section 1.092) (7).

2.023 Magnetic properties, alloy is nonmagnetic.

2.024 Emissivity.

2.025 Damping capacity.

2.03 Chemical Environments

2.031 General corrosion. The resistance to atmospheric corrosion including exfoliation is essentially equal to that of 2024 in comparable tempers. Tests conducted in the seacoast atmosphere at Point Judith, Rhode Island, have not produced exfoliation in a period of 8 years (1).

2.032 Stress corrosion. Resistance to stress corrosion has been determined using alternate immersion in 3.5 percent NaCl and by slow strain rate testing. A statistical summary of the results of SCC tests by alternate immersion in 3.5 percent NaCl (Table 2.0321) shows that the threshold for the L and LT direction of 2124-T851 plate is $\geq 0.75 F_{ty}$ and for the ST direction is $\geq 0.50 F_{ty}$. The results for both bend and tension tests of 2124-T851 plate subject to alternate immersion in 3.5 percent NaCl (Table 2.0322) are in agreement with these threshold values. The SCC resistance determined by alternate immersion (Figure 2.0323) or by seacoast exposure (Table 2.0324) shows the SCC resistance in the ST direction decreases with decreasing plate thickness. Similar effects of thickness

2.0321 Smooth bar stress corrosion thresholds for 2124-T851 plate by alternate immersion in 3.5 percent NaCl solution (ASTM G-47), Table 2.0321.

2.0322 Results of alternate immersion tests in 3.5 percent NaCl on 2124-T851 plate stressed in bending or tension at various percentages of the yield strength, Table 2.0322.

2.0323 Effect of exposure of plate of various thicknesses to 3.5 percent NaCl solution, Figure 2.0323.

2.0324 Results of exposure to seacoast atmosphere on 2124-T851 specimens from three lots with different thicknesses, Table 2.0324.

2.0325 Effect of strain rate on tensile properties in air and in 3.5 percent NaCl for two thickness 2124-T851 plates from different lots, Figure 2.0325.

2.0326 Effect of age time on several measures of relative performance for 2124-T351 plate tested at a slow strain rate in corrosion cell containing oxygen saturated 1M AlCl₃ pH-2, Figure 2.0326.

2.0327 Effect of strain rate on the reduction in tensile strength of 2124-T851 and 2124-T351 plate tested in corrosion cell containing oxygen saturated 3.5 percent NaCl or 1M AlCl₃, Figure 2.0327.

2.033 K_{Isc} testing. Various specimen types have been used to investigate the resistance to crack growth in fatigue precracked specimens subjected to a steady load in 3.5 percent NaCl solution. Tests on a 2-inch plate using bolt loaded specimens and compact tension specimens (Table 2.0331) did not reveal any crack growth in LT, TL, SL, and ST specimens after 30 days alternate immersion in 3.5 percent NaCl. Various K_{Ii}/K_{Ic} levels were used. The highest were as follows: LT and TL 0.9, SL 0.87, and ST 0.82. However, the same investigator employing the same alternate immersion conditions reported crack growth in SL surface flawed specimens for K_{Ii}/K_{Ic} = 0.65 but no crack growth in center cracked specimens for K_{Ii}/K_{Ic} = 0.95 (Table 2.0332). This discrepancy may be associated with the presence of bending in these very short (2 inch) SL specimens. A K_{Isc} of about 14 ksi√in. was reported for alternate immersion in 3.5 percent NaCl for SL specimens from 1-inch plate (Figure 2.0333). A K_{Isc} value of about 23 ksi√in. in the SL direction and about 27 ksi√in. in the LT direction was reported for a 3-inch plate tested in fuel tank sump water (Table 2.0334).

Sustained load (0.6 K_{Ic}) tests in air at 300 F using C(T) specimens from a 2-inch 2124-T851

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- plate showed completely intergranular fracture. Cracks develop initially at large second phase particles (CuMgAl_2) at or near grain boundaries which then crack at triple points. Voids form from the cracked particles and the accompanying slip in the matrix imposes shear stresses on the boundaries which slide resulting in a linking of small voids leading to boundary separation. (11).
- 2.0331. Results of alternate immersion tests in 3.5 percent NaCl on 2124-T851 plate using compact specimens loaded to various K_{Ii}/K_{Ic} levels, Table 2.0331.
- 2.0332. Results of alternate immersion tests in 3.5 percent NaCl on 2124-T851 plate tested using surface flawed and center cracked specimens representing several crack orientations, Table 2.0332.
- 2.0333. Crack propagation rate as a function of applied stress intensity for 2124-T851 plate subjected to alternate immersion in 3.5 percent NaCl solution, Figure 2.0333.
- 2.0334. Stress corrosion crack growth stress intensity threshold of plate from the B-1 program tested in fuel tank sump water, Table 2.0334.
- 2.0335. Composition of fuel tank sump residue water used in certain stress corrosion and fatigue crack propagation tests in the B-1 program, Table 2.0335.
- 2.034. Fatigue crack growth. Limited test data indicate the fatigue crack-growth rates at 5.2 Hz are essentially the same in dry air, humid air, and salt fog (see Figure 3.05212). The lack of humidity effect is supported by results from two investigations which did not test the same plate thickness (compare Figures 3.0526 and 3.0527). Tests in low humidity air (10 percent R.H.) show higher growth rates for a cycle frequency of 1 Hz than one of 6 Hz (see Figure 3.0524) and suggest that humidity effects might be observed at very slow cycle frequencies. However, these results are in contrast with data which show the same growth rates for tests at 1 Hz in fuel tank sump water as observed at 6 Hz in low humidity air (see Figure 3.05211). The available data (see Figures 3.05217 to 3.052112) show a consistently higher growth rate in 3.5 percent NaCl solution than in laboratory air at a cycle rate of 5 Hz.
- 3 **MECHANICAL PROPERTIES**
- 3.01 **Specified Mechanical Properties**
- 3.011 Aluminum Association mechanical properties for plate, Table 3.011.
- 3.012 Design mechanical properties for 2124-T851 plate, Table 3.012.
- 3.013 AMS specified tensile properties for 2124-T851 plate, Table 3.013.
- 3.014 Specified plane strain fracture toughness minima and corresponding acceptance criteria based on a sharp notch to tensile strength ratio, Table 3.014.
- 3.015 AMS specified plane strain fracture toughness for 2124-T851 plate, Table 3.015.
- 3.02 **Mechanical Properties at Room Temperature**
- 3.021 Tension – stress/strain diagrams, – tension properties.
- 3.0211 Typical tensile stress-strain curves for 4-inch thick plate, Figure 3.0211.
- 3.0212 Typical tensile properties of 2124-T851 plate, Table 3.0212.
- 3.0213 Tensile properties as a function of distance from surface of 2124-T851 condition thick plates, Figure 3.0213.
- 3.0214 Typical tensile properties of 2-inch and 3-inch thick 2124-T851 plate from the B-1 program, Table 3.0214.
- 3.0215 Effect of 1000 hr exposure at elevated temperatures on retained room temperature tensile properties of 2124-T851 plate, Figure 3.0215.
- 3.022 Compression.
- 3.0221 Typical compression stress-strain curves for 4-inch thick 2124-T851 plate, Figure 3.0221.
- 3.0222 Typical compression, shear, and bearing properties of 2124-T851 plate, Table 3.0222.
- 3.023 Impact.
- 3.024 Bending.
- 3.025 Torsion and shear (see Tables 3.012 and 3.0222).
- 3.026 Bearing (see Tables 3.012 and 3.0222).
- 3.027 Stress concentration.
- 3.0271 Notch properties.
- 3.0272 Fracture toughness.
- 3.02721 Plane strain fracture toughness results for LT, TL, and SL orientations of plate obtained from many tests made by two producers, Table 3.02721.
- 3.02722 Plane strain fracture toughness of a 2-inch and 3-inch plate from the B-1 program, Table 3.02722.
- 3.02723 Scatterbands for relation between sharp-notch strength to yield strength ratio and plane strain fracture toughness determined using two notch specimen diameters for 2124-T851 plate having thicknesses from 1.57 to 6 inch and tested in the LT, TL, and SL orientations with specimens located at plate center and mid thickness, Figure 3.02723.
- 3.028 Combined properties.
- 3.03 **Mechanical Properties at Various Temperatures**
- 3.031 Tension – stress/strain diagrams – tension properties.
- 3.0312 Effect of test temperature and exposure time on tensile properties of 2124-T851 plate, Figure 3.0312.
- 3.0313 Effect of temperature and testing direction on tensile properties of 2124-T851 plate, Figure 3.0313.
- 3.0314 Effect of temperature on tensile properties of 2124-T851 plate, Figure 3.0314.
- 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 Plane strain fracture toughness of plate at room temperature and 250 F, Table 3.03721.

- 3.03722 Effect of temperature on plane strain fracture toughness of two lots of 2124-T851 plate, Figure 3.03722.
- 3.04 **Creep and Creep-Rupture Properties**
- 3.041 Creep and creep-rupture curves at temperatures from 75 to 600 F for 2124-T851 plate, Figure 3.041.
- 3.05 **Fatigue**
- 3.051 Smooth and notch fatigue.
- 3.0511 Cycles to crack initiation as a function of nominal maximum fatigue stress for specimens with carefully polished notches, Figure 3.0511.
- 3.0512 Axial load fatigue curves for longitudinal smooth and notched ($K_t = 3$) specimens from 2124-T851 plate, Figure 3.0512.
- 3.0513 Axial load fatigue curves for transverse smooth and notched ($K_t = 3$) specimens from 2124-T851 plate, Figure 3.0513.
- 3.0514 Axial load fatigue curve for notched ($K_t = 5$) specimens from 4- to 6-inch 2124-T851 plate, Figure 3.0514.
- 3.0515 Rotating bending fatigue curves for smooth specimens from 4-inch 2124-T851 plate, Figure 3.0515.
- 3.0516 Rotating bending fatigue curves for sharply notched specimens from 2124-T851 4-inch plate, Figure 3.0516.
- 3.0517 Effect of salt fog on axial load fatigue life of smooth and notched ($K_t = 3$) specimens from 2124-T851 plate, Figure 3.0517.
- 3.052 Fatigue crack-growth rates. Fatigue crack-growth rate data are available which illustrate the effects of directionality, cycle frequency, corrosive environments, test temperature, and R ratio. The effects of directionality are discussed in Section 1.093 and cycle frequency effects and corrosive environments are discussed in Section 2.034. As might be expected, the fatigue crack-growth rates increase with increasing testing temperature (see Figures 3.05214 to 3.05216). The effect of R ratio is also as expected, with growth rates increasing particularly at the higher ΔK values as R increases (see Figures 3.0527 to 3.0529). Threshold (ΔK_{th}) values as a function of R ratio for 2124-T851 plate in 95 percent RH air at 30 to 35 Hz (Table 3.052113) show the expected trend of reduced ΔK_{th} with increasing R ratio. The threshold value for T-4 sheet appears to be increased substantially for tests at -320 F (Figure 3.05213) as compared with the estimates from room temperature tests (Figure 3.0522).
- 3.0521 Typical fatigue crack-growth data for 2-inch plate in various environments, Figure 3.0521.
- 3.0522 Fatigue crack-growth rates for 2124 sheet in T4 condition, Figure 3.0522.
- 3.0523 Fatigue crack-growth rates for 2124-T851 plate from the B-1 program at several R ratios in low humidity air, Figure 3.0523.
- 3.0524 Fatigue crack-growth rates for 2124-T851 plate from the B-1 program for two loading frequencies in low humidity air, Figure 3.0524.
- 3.0525 Fatigue crack-growth rates at R = 0.33 for 4.5-inch plate, Figure 3.0525.
- 3.0526 Fatigue crack-growth rates at low ΔK values for 2124-T851 plate tested at two R ratios and thicknesses of 0.375, 0.75, and 1.5 inch, Figure 3.0526.
- 3.0527 Fatigue crack-growth rates for 2124-T851 plate tested in high humidity air at R = 0.1, Figure 3.0527.
- 3.0528 Fatigue crack-growth rates for 2124-T851 plate tested in high humidity air at R = 0.25, Figure 3.0528.
- 3.0529 Fatigue crack-growth rates for 2124-T851 plate tested in high humidity air at R = 0.5, Figure 3.0529.
- 3.05210 Fatigue crack-growth rates for two thicknesses of plate tested in high humidity air, Figure 3.05210.
- 3.05211 Fatigue crack-growth rates for 2124-T851 plate from the B-1 program tested in low humidity air and in sump water, Figure 3.05211.
- 3.05212 Typical fatigue crack-growth rates for 2-inch 2124-T851 plate in various environments, Figure 3.05212.
- 3.05213 Fatigue crack-growth rates approaching zero for 2124 sheet in the T4 condition at -320 F, Figure 3.05213.
- 3.05214 Fatigue crack-growth rates for plate tested in the LT direction at cryogenic and elevated temperature, Figure 3.05214.
- 3.05215 Fatigue crack-growth rates for 2124-T851 plate at room and elevated temperatures, Figure 3.05215.
- 3.05216 Fatigue crack-growth rates for 2124-T851 plate at low temperatures, Figure 3.05216.
- 3.05217 Fatigue crack-growth rates for 2124-T851 plate in air and 3.5 percent NaCl for LT direction, Figure 3.05217.
- 3.05218 Fatigue crack-growth rates for 2124-T851 plate in air and in 3.5 percent NaCl for TL direction, Figure 3.05218.
- 3.05219 Fatigue crack-growth rates for 2124-T851 plate in air and in 3.5 percent NaCl for TS direction, Figure 3.05219.
- 3.052110 Fatigue crack-growth rates for 2124-T851 plate in air and in 3.5 percent NaCl for LS direction, Figure 3.052110.
- 3.052111 Fatigue crack-growth rates for 2124-T851 plate in air and in 3.5 percent NaCl for ST direction, Figure 3.052111.
- 3.052112 Fatigue crack-growth rates for 2124-T851 plate in air and in 3.5 percent NaCl for SL direction, Figure 3.052112.
- 3.052113 Fatigue crack growth threshold for 2124-T851 plate in high humidity air at several R ratios, Table 3.052113.
- 3.06 **Elastic Properties**
- 3.061 Poisson's ratio, 0.33 at room temperature.
- 3.062 Modulus of elasticity.
- 3.0621 Modulus of elasticity at low and elevated temperatures, Figure 3.0621.
- 3.0622 Tensile and compressive modulus of elasticity, Table 3.0622.
- 3.063 Modulus of rigidity.
- 3.064 Tangent modulus.
- 3.0641 Tangent modulus curves for 2124-T851 plate, Figure 3.0641.

Al
4.4 Cu
1.5 Mg
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- 4 **FABRICATION**
- 4.01 **Forming**
(See also 2024.)
- 4.011 Forming of plate is preferably accomplished in the 0 condition with subsequent heat treatment (8).
- 4.02 **Machining and Grinding**
(See also 2024.)
- 4.021 General. The alloy is considered to have good machinability in the 0 condition and good to excellent machinability in the T851 condition.
- 4.03 **Joining**
(See 2024.)
- 4.04 **Surface Treatment**
(See also 2024.)
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Alloy	2124	
	Percent	
Composition	Min	Max
Cu	3.8	4.9
Mg	1.2	1.8
Mn	—	0.9
Fe	—	0.25
Zn	—	0.20
Si	—	0.20
Zr+Ti	—	0.20(a)
Ti	—	0.15
Cr	—	0.10
Other		
Each	—	0.05
Total	—	0.15
Al	Balance	

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

(a) AMS only.

TABLE 1.04. CHEMICAL COMPOSITION (1,3,5,33)

Alloy	2124	
	Minimum Soaking Time, min	
Thickness, inch	Salt Bath	Air Furnace
	0.251 to 0.500	45
0.501 to 1.000	60	90
1.001 to 1.500	90	120
1.501 to 2.000	105	150
2.001 to 2.500	120	180
2.501 to 3.000	150	210
3.001 to 3.500	165	240
3.501 to 4.000	180	270
4.001 to 4.500	195	300

TABLE 1.0532. RECOMMENDED SOAKING TIMES REQUIRED FOR SOLUTION TREATING PLATE (4)

Alloy		2124	
Form		0.21-inch diam x 1-inch Gage Length Plate	
Condition		914 F, 20 min, WQ + Age + Hydrogen Charge(a)	
Age	F _{ty} , ksi(b)	Mean, RA percent	
		No H ₂	H ₂
T3 (2% Strain + RT, 50 hr)	39	33	27
T4 (RT, 50 hr)	47	29	22
T8 (2% Strain + RT, 9 hr)	51	30	25
T3 + 374 F, 3 hr	50	30	30
UT (374 F, 4 hr)	32	24	18
σT (374 F, 24 hr)	46	31	31
T6 (374 F, 9 hr)	51	25	25

- (a) Charging conditions: cathodically charged in pH = 1 HCl solution under potentiostatic control at -1500 mV vs standard calomel electrode while being plastically strained at about 1 x 10⁻⁶ per second.
- (b) No H₂.

TABLE 1.0911. EFFECT OF HYDROGEN CHARGING ON TENSILE DUCTILITY OF 2124 IN SEVERAL AGED CONDITIONS (24)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

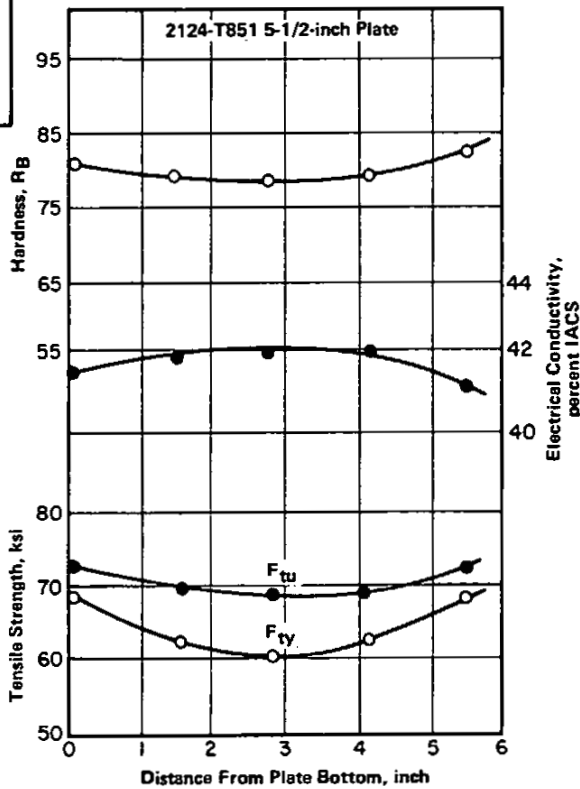


FIGURE 1.0921. VARIATION OF HARDNESS, TENSILE STRENGTH, AND ELECTRICAL CONDUCTIVITY THROUGH THE THICKNESS OF NORMALLY QUENCHED 2124-T851 PLATE (21)

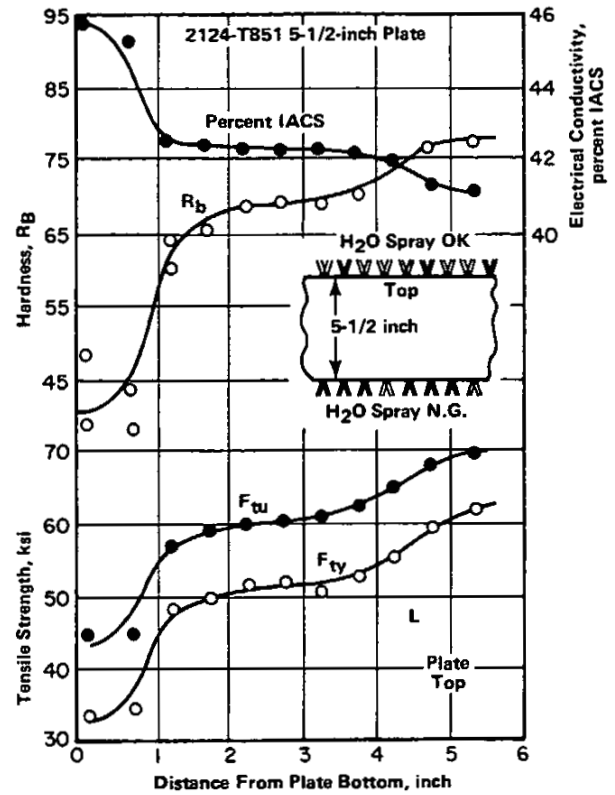


FIGURE 1.0922. VARIATION OF HARDNESS, TENSILE STRENGTH, AND ELECTRICAL CONDUCTIVITY THROUGH THE THICKNESS OF SLACK QUENCHED 2124-T851 PLATE (21)

Alloy	2124-T851	
Form	5-1/2-inch Plate	
Condition	Slack Quenched	
Specimen Location	Near Plate Top	Near Plate Bottom
Hardness, R_b	80.3	50.9
Electrical Conductivity, percent IACS	40.6	45
Compressive Yield Strength (F_{cy}), ksi	62.4	27.6

TABLE 1.0923. HARDNESS, ELECTRICAL CONDUCTIVITY, AND COMPRESSION STRENGTH OF SPECIMENS TAKEN FROM A SLACK QUENCHED 2124-T851 PLATE (29)

Alloy	2124-T851	
Form	5-1/2-inch Plate	
Condition	Slack Quenched	
Specimen Location	Near Plate Top	Near Plate Bottom
Hardness, R_b	77	56.8
Electrical Conductivity, percent IACS	40.7	43.9
Bearing Yield Strength (F_{by}), ksi	98.4	68.3
Bearing Ultimate Strength (F_{bru}), ksi	130.7	101.0

TABLE 1.0924. HARDNESS, ELECTRICAL CONDUCTIVITY, AND BEARING STRENGTH OF SLACK QUENCHED 2124-T851 PLATE (29)

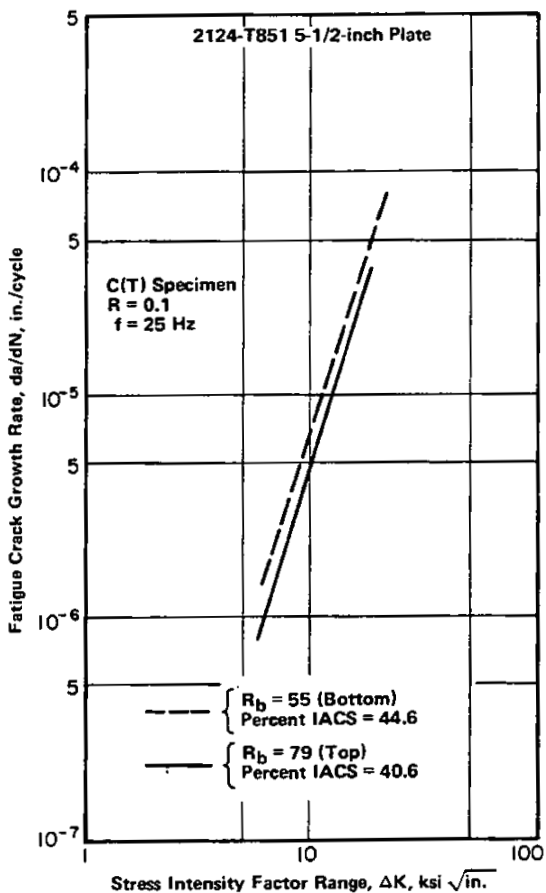


FIGURE 1.0925. FATIGUE CRACK PROPAGATION RATE FOR SPECIMENS CUT FROM NEAR THE TOP AND NEAR THE BOTTOM OF A SLACK QUENCHED 2124-T851 PLATE (21)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

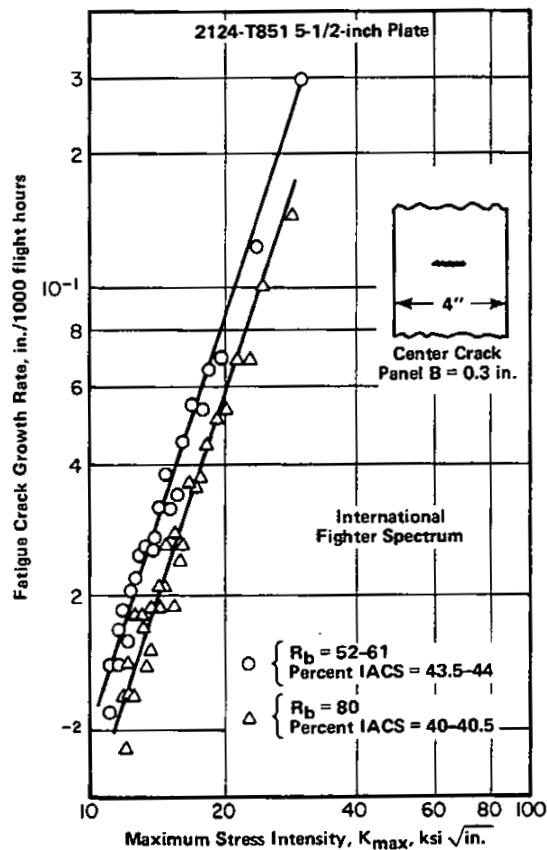


FIGURE 1.0926. FATIGUE CRACK GROWTH AS FUNCTION OF KMAX IN A FIGHTER SPECTRUM LOADING FOR SPECIMENS TAKEN FROM A NORMAL HARDNESS REGION AND A SOFT REGION IN A 5-1/2-INCH SLACK QUENCHED 2124-T851 PLATE (29, 30)

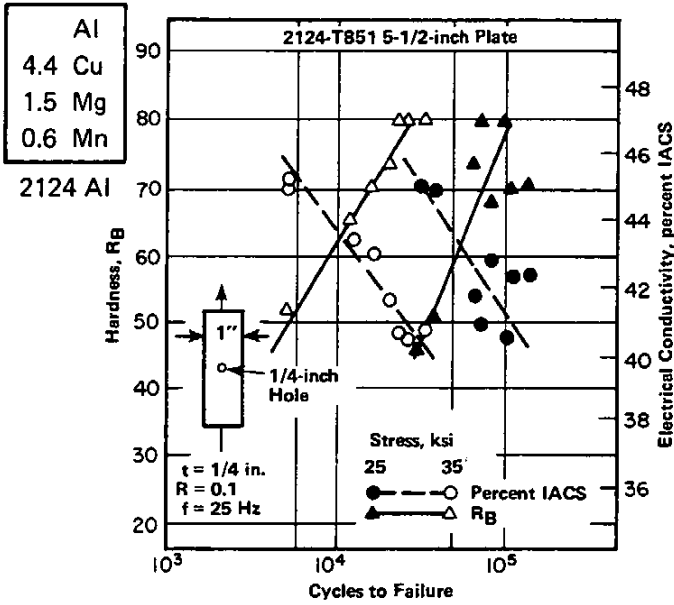


FIGURE 1.0927. NOTCHED FATIGUE LIFE FOR SPECIMENS CUT FROM 2124-T851 SLACK QUENCHED PLATE AS A FUNCTION OF HARDNESS AND ELECTRICAL CONDUCTIVITY (21)

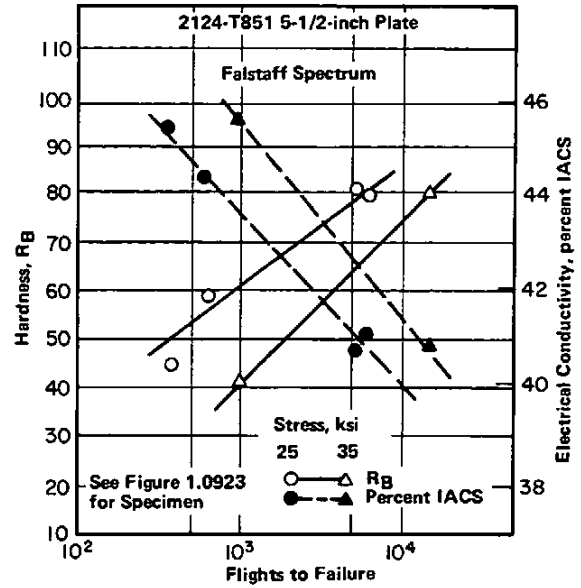


FIGURE 1.0928. FLIGHTS TO FAILURE UNDER THE FALSTAFF FATIGUE SPECTRUM AS A FUNCTION OF HARDNESS AND ELECTRICAL CONDUCTIVITY FOR NOTCHED SPECIMENS CUT FROM SLACK QUENCHED 2124-T851 PLATE (30)

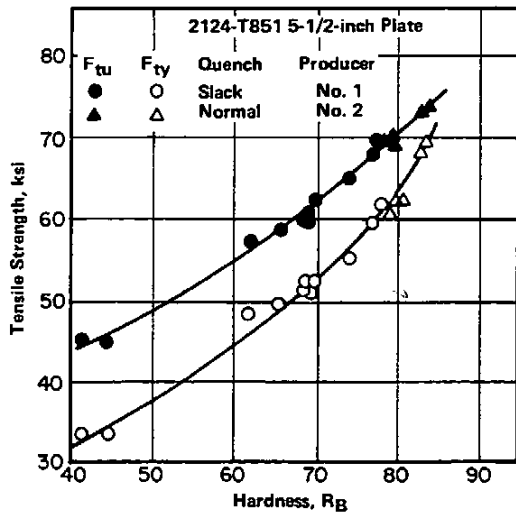


FIGURE 1.0929. TENSILE STRENGTH PROPERTIES AS A FUNCTION OF HARDNESS FOR SLACK QUENCHED AND NORMAL QUENCHED 2124-T851 PLATES (29)

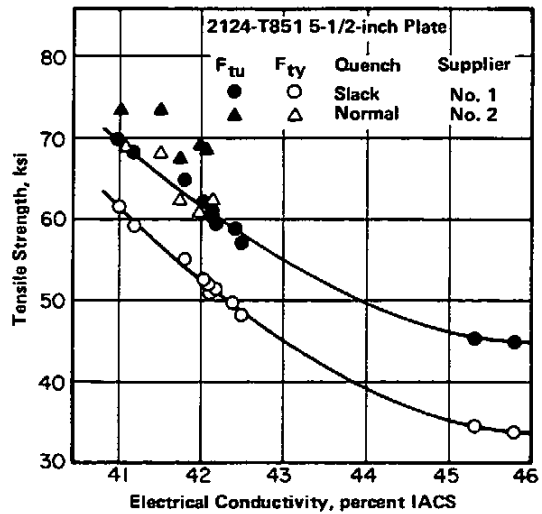


FIGURE 1.09210. TENSILE STRENGTH PROPERTIES AS A FUNCTION OF ELECTRICAL CONDUCTIVITY FOR SLACK QUENCHED AND NORMAL QUENCHED 2124-T851 5-1/2-INCH PLATES (29)

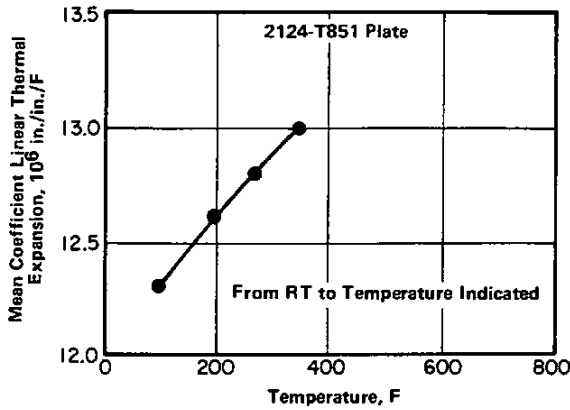


FIGURE 2.014. THERMAL EXPANSION (1)

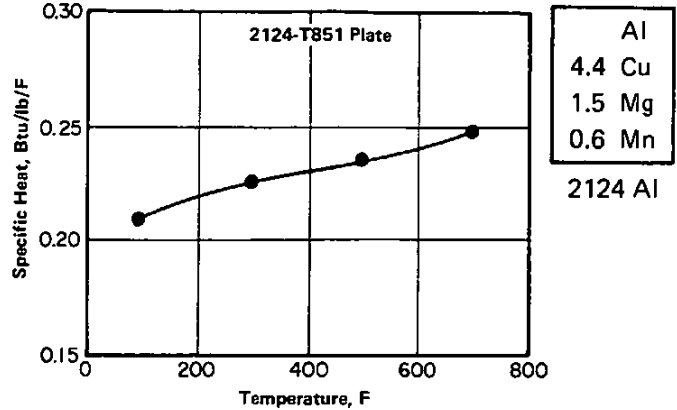


FIGURE 2.015. SPECIFIC HEAT (1)

Alloy	2124-T851		
Form	Rolled Plate		
Direction	L	LT	ST
Threshold(a)	≥0.75 F _{ty}	≥0.75 F _{ty}	≤0.50 F _{ty}

(a) Thresholds established by tests on a minimum of 10 random lots with results representing 90 percent probability with 95 percent confidence.

TABLE 2.0321. SMOOTH BAR STRESS CORROSION THRESHOLDS FOR 2124-T851 PLATE BY ALTERNATE IMMERSION IN 3.5 PERCENT NaCl SOLUTION (ASTM G-47) (20)

Alloy	2124-T851					
Form	2-inch Plate					
Direction and Specimen Type ^(f)	L and T ^(a) Bend ^(c)	ST ^(b) Bend ^(c)	ST Bend	ST Bend	ST Tension ^(d)	ST Tension
Environment	3.5 percent NaCl 50 min in Solution + 10 min in Air					
F _{ty} , percent	46 to 92	49	66	82 to 98	35 to 65	70 to 78
Time, days	30	30	30	10 to 30	30	9
Result ^(e)	SP, GC No SCC	SP, GC No SCC	SP, GC IGC	SP, GC IGC	SP, GC No SCC	Failure
			0.020 inch	~1/16 inch		

- (a) F_{TU} = 72 ksi (L & T), F_{TY} = 66 ksi (L & T), RA = 20 percent (L), RA = 16 percent T.
- (b) F_{TU} = 67 ksi (ST), F_{TY} = 61 ksi (ST), RA = 1.0 percent (ST).
- (c) L and T bends: L = 5 inch, W = 3/4 inch, t = 1/8 inch and ST beam: L = 2 inch, W = 3/8 inch, t = 1/16 inch.
- (d) ST tensiles gage section: L = 1/2 inch, W = 3/4 inch, t = 1/8 inch.
- (e) SP = surface pits; GC = general corrosion; and IGC = intergranular cracks (SCC).
- (f) Bend specimens were four point loaded and tension specimens were pin loaded.

TABLE 2.0322. RESULTS OF ALTERNATE IMMERSION TESTS IN 3.5 PERCENT NaCl ON 2124-T851 PLATE STRESSED IN BENDING OR TENSION AT VARIOUS PERCENTAGES OF THE YIELD STRENGTH (16)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

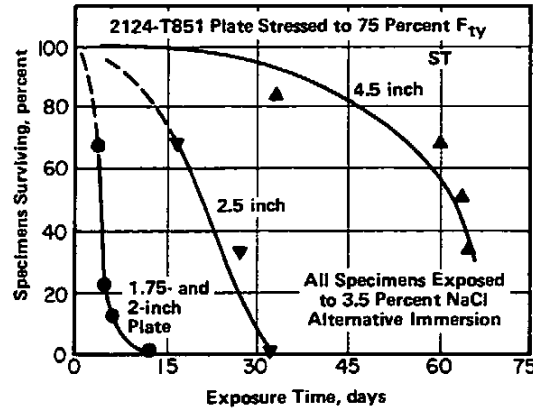


FIGURE 2.0323. EFFECT OF EXPOSURE OF PLATE OF VARIOUS THICKNESSES TO 3.5 PERCENT NaCl SOLUTION (6)

Alloy	2124-T851								
Form	Plate								
Exposure	Stressed (ST) Tensile Specimens 120 to 130 ft From Mean High Tide at KSC(a), Max Time = 38 Months								
Thickness, inch	2(b)			2.5(c)			3.9(d)		
Applied Stress									
F _{ty} , percent	0	50	75	0	50	75	0	50	75
Failures(e)	0/2	0/5	1/5(5)	0/2	0/4	4/5 (4.5,5,12)	0/2	0/5	0/5
Loss in F _{tu} (Avg), percent	16	33	42	5	22	-	14	29	44

- (a) KSC refers to Kennedy Space Center.
- (b) Lot 1: F_{tu} = 67 ksi and F_{ty} = 61 ksi.
- (c) Lot 2: F_{tu} = 62 ksi and F_{ty} = 59 ksi.
- (d) Lot 3: F_{tu} = 61 ksi and F_{ty} = 57 ksi.
- (e) No. failed/no. exposed (failure times, months).

TABLE 2.0324. RESULTS OF EXPOSURE TO SEACOAST ATMOSPHERE ON 2124-T851 SPECIMENS FROM THREE LOTS WITH DIFFERENT THICKNESSES (14)

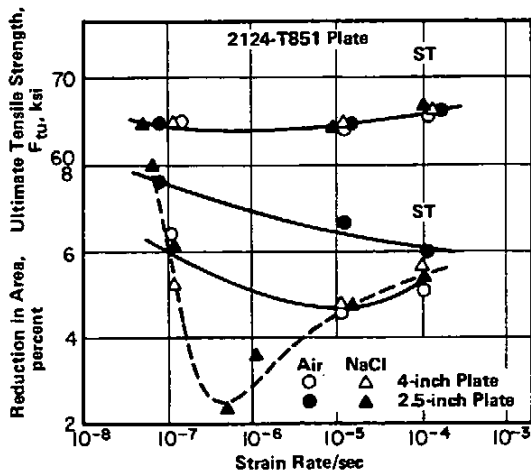


FIGURE 2.0325. EFFECT OF STRAIN RATE ON TENSILE PROPERTIES IN AIR AND IN 3.5 PERCENT NaCl FOR TWO THICKNESS 2124-T851 PLATES FROM DIFFERENT LOTS (18)

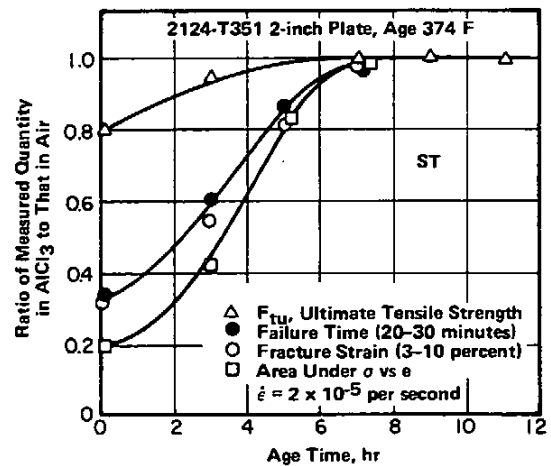
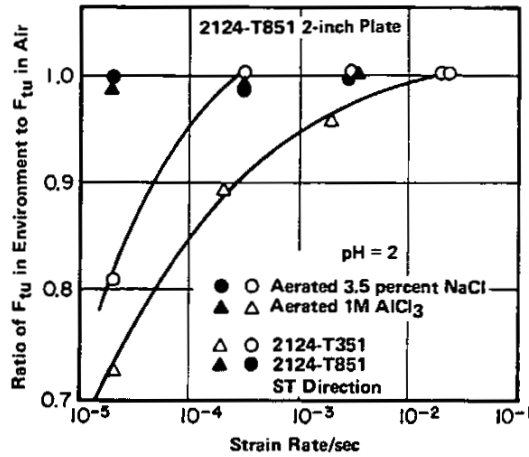


FIGURE 2.0326. EFFECT OF AGE TIME ON SEVERAL MEASURES OF RELATIVE PERFORMANCE FOR 2124-T351 PLATE TESTED AT A SLOW STRAIN RATE IN CORROSION CELL CONTAINING OXYGEN SATURATED 1M AlCl₃, pH-2 (23)



Al
 4.4 Cu
 1.5 Mg
 0.6 Mn
 2124 Al

FIGURE 2.0327. EFFECT OF STRAIN RATE ON REDUCTION IN TENSILE STRENGTH OF 2124-T851 AND 2124-T351 PLATE TESTED IN CORROSION CELL CONTAINING OXYGEN SATURATED 3.5 PERCENT NaCl OR 1M AlCl₃ (23)

Alloy	2124-T851					
Form	2-inch Plate					
Environment	30-Day Alternate Immersion in 3.5 percent NaCl 50 min in Solution + 10 min in Air					
Specimen	MCW _b (a)			C(T)(b)		
Direction	LT	TL	SL	ST	SL	ST
K _{Ij} /K _{Ic}	0.6 to 0.9	0.6 to 0.9	0.41 to 0.70	0.36 to 0.73	0.65 to 0.87	0.75 to 0.82
K _{Ic} , ksi√in.(c)	28	26	23	23	23	23
Results	No Failures After 30 Days and No Compliance Change on any Specimen. No Evidence of SCC on Fractured Surfaces.					

- (a) Bolt loaded compact specimens: W = 1.6 inch, α/W = 0.4, B = 0.5 inch.
- (b) Specimens dead weight loaded.
- (c) E 399-81 C(T) specimen: W/B = 3.2, B = 0.5 inch.

TABLE 2.0331. RESULTS OF ALTERNATE IMMERSION TESTS IN 3.5 PERCENT NaCl ON 2124-T851 PLATE USING COMPACT SPECIMENS LOADED TO VARIOUS K_{Ij}/K_{Ic} LEVELS (16)

Alloy	2124-T851						
Form	2-inch Plate(e)						
Environment	30-Day Alternate Exposure in 3.5 percent NaCl, 50 min in Solution + 10 min in Air						
Direction	LS and TS		LT	SL		SL	
Specimen Type	PS(a)		PS	PS		MT(b)	
Flaw Size(a), inch	0.165 <a< 0.330		0.116 <a< 0.169	0.286	0.306	0.72	1.03 1.10
Q	1.36 <Q< 1.59		1.22 <Q< 1.39	1.59	1.66	-	- -
Stress, ksi	33		39	13	18	11	14 13
K _{Ij} /K _{Ic} (f)	-		0.61	0.48	0.65	0.93	0.95 >1
Result	No SCC		No SCC	No SCC	SCC(e)	No SCC	No SCC SCC(d)

- (a) Surface flaw specimen: W = 3 inch and B = 1/2 inch.
- (b) Center crack specimen: W = 3.5 inch and B = 1/2 inch.
- (c) Δa = 0.04 inch.
- (d) Δa = 0.1 inch.
- (e) For tensile properties see Table 2.0322.
- (f) For K_{Ic} see Table 2.0331.

TABLE 2.0332. RESULTS OF ALTERNATE IMMERSION TESTS IN 3.5 PERCENT NaCl ON 2124-T851 PLATE TESTED USING SURFACE FLAWED AND CENTER CRACKED SPECIMENS REPRESENTING SEVERAL CRACK ORIENTATIONS (16)

Al
4.4 Cu
1.5 Mg
0.6 Mn

2124 Al

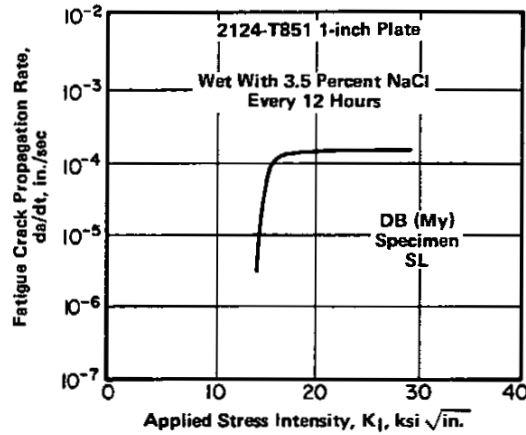


FIGURE 2.0333. CRACK PROPAGATION RATE AS A FUNCTION OF APPLIED STRESS INTENSITY FOR 2124-T851 PLATE SUBJECTED TO ALTERNATE IMMERSION IN 3.5 PERCENT NaCl SOLUTION (22)

Alloy		2124-T851				
Form		3-inch Plate				
Environment		Fuel Tank Sump Residue Water ^(a)				
Direction		LT		SL		
	Total Test Time, hr	Total Crack Growth, inch	K _{Isc.} , ksi√in.	Total Test Time, hr	Total Crack Growth, inch	K _{Isc.} , ksi√in.
	1,172	0.02	28	2,177	0.17	26
	1,172	0.015	27	906	0.19	21
	906	0.01	25	906	0.06	21

(a) See Table 2.0335 for composition.

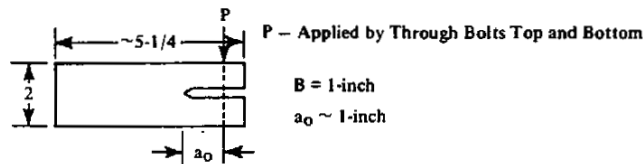


TABLE 2.0334. STRESS CORROSION CRACK GROWTH STRESS INTENSITY THRESHOLD OF PLATE FROM THE B-1 PROGRAM TESTED IN FUEL TANK SUMP WATER (25)

Sump Tank Water Composition, ppm	
CaCl ₂	50
CdCl ₂	1,000
MgCl ₂	50
NaCl	100
ZnCl	10
PbCl	1
CrCl ₃ · H ₂ O	1
CuCl ₃ · 2H ₂ O	1
FeCl ₃	5
MnCl ₂ · 4H ₂ O	5
NiCl ₂ · 6H ₂ O	1
Distilled Water	Remainder

TABLE 2.0335. COMPOSITION OF FUEL TANK SUMP RESIDUE WATER USED IN CERTAIN STRESS CORROSION AND FATIGUE CRACK PROPAGATION TESTS IN THE B-1 PROGRAM (16)

Al
4.4 Cu
1.5 Mg
0.6 Mn

2124 Al

Alloy		2124-T851(a)(b)				
Form		Plate				
Thickness, inch		1.500 to 2.000	2.001 to 3.000	3.001 to 4.000	4.001 to 5.000	5.001 to 6.000
F _{tu} (Min), ksi	L	66.0	65.0	65.0	64.0	63.0
	T	66.0	65.0	65.0	64.0	63.0
	ST	64.0	63.0	62.0	61.0	58.0
F _{ty} (Min), ksi	L	57.0	57.0	56.0	55.0	54.0
	T	57.0	57.0	56.0	55.0	54.0
	ST	55.0	55.0	54.0	53.0	51.0
e (2 inch or 4D), percent (Min)	L	6	6	5	5	5
	T	5	4	4	4	4
	ST	1.5	1.5	1.5	1.5	1.5

- (a) For stress relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
- (b) Type of specimen used depends on thickness of material.

TABLE 3.011. ALUMINUM ASSOCIATION MECHANICAL PROPERTIES FOR PLATE (3)

Alloy		2124-T851										
Form		Plate										
Thickness, inch		1.000 to 1.500	1.501 to 2.000		2.001 to 3.000		3.001 to 4.000		4.001 to 5.000		5.001 to 6.000	
Basis		S(c)	A	B	A	B	A	B	A	B	A	B
F _{tu} , ksi	L	66	66	68	65	68	65	67	64	66	63	65
	LT	66	66	68	65	68	65	67	64	66	63	65
	ST	64(a)	64	66	63	64	62	63	61	62	58	59
F _{ty} , ksi	L	57	57	61	57	61	56	60	55	58	54	56
	LT	57	57	61	57	61	56	60	55	58	54	56
	ST	55(a)	55	59	55	59	54	57	53	55	51	53
F _{cy} , ksi	L	57	57	61	56	60	55	59	53	56	52	54
	LT	57	57	61	57	61	56	60	55	58	54	56
	ST	-	57	61	58	62	57	61	57	60	56	58
F _{su} , ksi	L	-	38	39	38	39	38	39	37	38	37	38
	LT	-	38	39	38	39	38	39	37	38	37	38
	ST	-	36	37	36	37	36	37	35	36	35	36
F _{bru} , ksi (e/D = 1.5)	-	-	97	100	96	100	96	99	94	97	93	96
	-	-	126	130	125	130	125	128	123	126	121	125
F _{bry} , ksi (e/D = 1.5)	-	-	79	84	80	85	80	85	79	84	79	82
	-	-	91	98	92	99	92	99	92	97	91	95
e, percent	L	6	6	-	6	-	5	-	5	-	5	-
	LT	5(b)	5	-	4	-	4	-	4	-	4	-
	ST	1.5(a)	1.5	-	1.5	-	1.5	-	1.5	-	1.5	-

- (a) Short transverse values applicable to 1.500 inch (38.1 mm) thickness only.
- (b) The above table is in agreement with MIL-HDBK-5 Table 3.2.5.0(b), except for the LT elongation shown for the 1.000 to 1.500 inch (25.4-38.1 mm) thickness range. The 5 percent value is accepted by federal and industry specifications such as QQ-A-250/29 and ASTM B209.
- (c) Specification values.

TABLE 3.012. DESIGN MECHANICAL PROPERTIES FOR 2124-T851 PLATE (1)

Alloy		2124-T851														
Form		Plate														
Thickness, inch		1-1/2 to 2			>2 to 3			>3 to 4			>4 to 5			>5 to 6		
Direction		L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST	L	LT	ST
F _{tu} , ksi		66	66	64	65	65	63	65	65	64	64	64	61	63	63	58
F _{ty} , ksi		57	57	55	57	57	55	56	56	52	55	55	53	54	54	51
e (2 inch or 4D), percent		6	5	1.5	6	4	1.5	5	4	1.5	5	4	1.5	5	4	1.5

TABLE 3.013. AMS SPECIFIED TENSILE PROPERTIES FOR 2124-T851 PLATE (33)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

Alloy	2124-T851		
Form	Plate		
Thickness (t), inch	1.5 ≤ t < 5.0		
Direction	LT	TL	SL
K _{Ic} , ksi√in. (Min)	24	20	18
Notch/F _{ty} (a) Ratio	1.01	0.83	0.69

(a) Based on 1-1/16-inch diameter sharp notch specimen (see Figure 3.02723).

TABLE 3.014. SPECIFIED PLANE STRAIN FRACTURE TOUGHNESS MINIMA AND CORRESPONDING ACCEPTANCE CRITERIA BASED ON A SHARP NOTCH TO TENSILE STRENGTH RATIO (1)

Alloy	2124-T851		
Form	Plate		
Thickness, inch	1-1/2 to 6 inch		
Direction	LT	TL	SL
K _{Ic} , ksi√in. (Min)	24	20	18

TABLE 3.015. AMS SPECIFIED PLANE STRAIN FRACTURE TOUGHNESS FOR 2124-T851 PLATE (21)

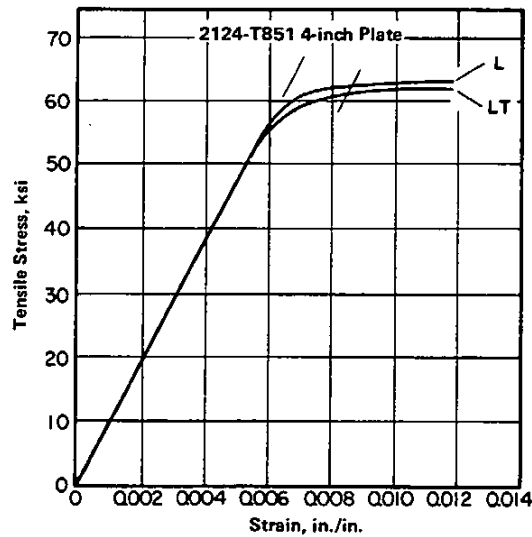


FIGURE 3.0211. TYPICAL TENSILE STRESS-STRAIN CURVES FOR 4-INCH THICK PLATE (1)

Alloy	2124-T851									
Form	Plate									
Producer(a)	A	B	C	A	A	B	A	C	A	C
Thickness, inch	1.75	2.04	2.00	2.5	3.5	4.00	4.5	4.5	5.5	6.00
F _{tu} , ksi	L 72.0	70.8	71.5	71.5	70.3	70.2	70.2	67.8	68.2	65.2
	T 71.5	70.9	71.1	70.7	69.9	69.7	69.4	67.5	67.5	64.6
	ST 70.4	68.2	68.2	69.2	68.5	65.9	65.6	64.1	63.6	60.6
F _{ty} , ksi	L 67.0	65.4	66.2	65.4	63.9	65.5	63.4	59.8	61.1	57.1
	T 65.7	65.2	65.4	64.2	62.7	64.2	61.4	58.5	59.3	55.0
	ST 65.3	62.7	64.9	63.5	61.4	60.2	59.8	57.3	57.5	54.8
e (2 inch or 4D), percent	L 10.0	8.5	9.5	9.0	9.0	6.5	8.0	8.0	8.0	8.0
	T 8.0	7.0	8.0	7.0	7.0	5.5	6.0	8.0	7.0	7.0
	ST 3.1	4.7	3.1	3.0	4.0	4.0	3.0	2.5	2.5	3.5
RA, percent	L 25	22	25	22	21	10	19	13	16	18
	T 18	26	15	14	13	11	11	11	10	9
	ST 8	8	9	6	6	6	3	5	4	2

(a) Producer: A - Alcoa; B - Kaiser; C - Reynolds.

TABLE 3.0212. TYPICAL TENSILE PROPERTIES OF 2124-T851 PLATE (6)

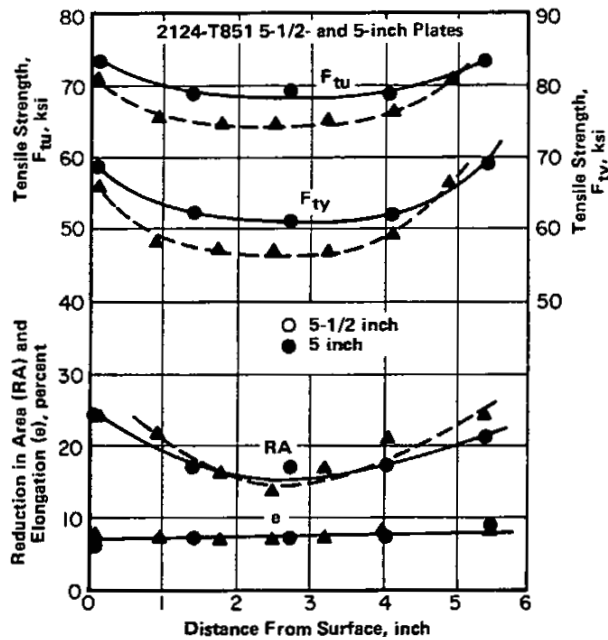


FIGURE 3.0213. TENSILE PROPERTIES AS A FUNCTION OF DISTANCE FROM SURFACE OF 2124-T851 CONDITION THICK PLATES (29)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

Alloy	2124-T851				
	Plate				
Thickness	2 inch		3 inch		
Supplier	A		B		
Test Direction	L	T	L	T	ST
F _{tu} , ksi	71	71	72	73	69
F _{ty} , ksi	65	66	65	67	63
e, percent	8	7	8	8	4
RA, percent	-	-	16	19	9

TABLE 3.0214. TYPICAL TENSILE PROPERTIES OF 2-INCH AND 3-INCH THICK 2124-T851 PLATE FROM THE B-1 PROGRAM (26)

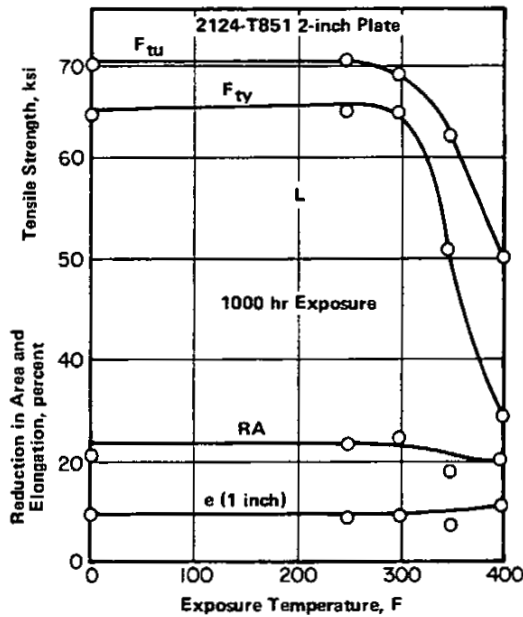


FIGURE 3.0215. EFFECT OF 1000 HR EXPOSURE AT ELEVATED TEMPERATURES ON RETAINED ROOM TEMPERATURE TENSILE PROPERTIES OF 2124-T851 PLATE (12)

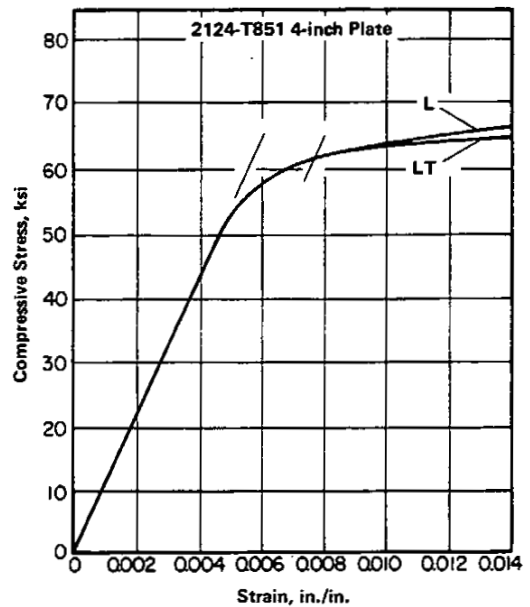


FIGURE 3.0221. TYPICAL COMPRESSION STRESS-STRAIN CURVES FOR 4-INCH THICK 2124-T851 PLATE (1)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

Alloy		2124-T851									
Form		Plate									
Producer(a)		A	C	B	A	A	B	A	C	A	C
Thickness, inch		0.75	2.00	2.04	2.5	3.5	4.00	4.5	4.5	5.5	6.00
F _{cy} , ksi	L	66.7	65.2	63.4	63.9	62.9	63.1	61.1	57.3	58.3	52.1
	T	67.0	66.7	65.7	66.0	63.7	64.2	62.9	58.1	60.1	56.0
	ST	68.0	68.0	66.2	66.7	64.9	65.7	64.2	62.4	61.6	58.5
F _{su} , ksi	L	41.9	41.2	41.2	40.9	40.7	40.7	40.5	39.1	40.0	38.2
	T	42.1	41.2	41.2	41.0	40.7	40.7	40.5	39.3	40.0	38.0
	ST	39.8	39.1	39.6	39.6	39.1	38.7	38.9	36.8	38.4	36.4
F _{bru} , ksi (e/D = 1.5)(b)	L	107.5	108.1	105.7	106.4	104.9	103.7	103.8	100.9	101.7	96.5
	T	107.2	107.4	105.4	106.6	105.5	103.4	105.4	100.9	102.5	97.4
	ST	-	-	-	-	-	-	-	-	-	-
F _{bru} , ksi (e/D = 2.0)(b)	L	139.5	139.1	138.3	138.3	136.2	133.8	135.0	131.2	131.5	125.3
	T	139.1	138.1	136.3	137.0	135.4	135.6	135.7	130.4	132.0	126.5
	ST	-	-	-	-	-	-	-	-	-	-
F _{bry} , ksi (e/D = 1.5)(b)	L	94.8	96.5	92.0	93.0	91.3	94.3	93.3	85.2	90.3	83.8
	T	94.1	95.5	92.8	92.1	92.0	91.8	93.0	86.4	88.6	84.1
	ST	-	-	-	-	-	-	-	-	-	-
F _{bry} , ksi (e/D = 2.0)(b)	L	109.8	107.2	105.8	108.7	107.1	106.3	107.1	98.4	103.7	97.0
	T	108.8	109.0	106.4	105.1	104.6	106.3	105.8	97.8	105.1	94.1
	ST	-	-	-	-	-	-	-	-	-	-

(a) Producer: A - Alcoa; B - Kaiser; C - Reynolds.
(b) Specimens and fixtures cleaned ultrasonically.

TABLE 3.0222. TYPICAL COMPRESSION, SHEAR, AND BEARING PROPERTIES OF 2124-T851 PLATE (6)

Alloy	2124-T851		
Form	1.5- to 6-inch Plate(a)		
Crack Orientation	LT	TL	SL
Number of Tests	138	145	135
Average K _{Ic} , ksi√in.	30	25.3	21.4
Standard Deviation, ksi√in.	2.7	2.2	2.0
Skewness Coefficient	+0.4	+0.5	-0.2
Min Value, ksi√in.	24	21.1	17
A - Value(b), ksi√in.	22.9 to 23.9	19.4 to 20.4	16.2 to 15.9
B - Value, ksi√in.	26.0 to 26.2	21.9 to 22.1	18.4 to 18.4

(a) Data from two producers November 1975 to August 1978.
(b) Lower limit based on normal distribution and upper limit based on Pearson type III function using skewness.

TABLE 3.02721. PLANE STRAIN FRACTURE TOUGHNESS RESULTS FOR LT, TL, AND SL ORIENTATIONS OF PLATE OBTAINED FROM MANY TESTS MADE BY TWO PRODUCERS (28)

Alloy	2124-T851				
Form	Plate				
Thickness, inch	2(a)		3(b)		
Supplier	A		B		
Crack Orientation	LT	TL	LT	TL	ST
K _{Ic} , ksi√in.	24	23	29	24	24
K _{Ic} ² /σ _{ys} ² , inch(c)	0.14	0.12	0.20	0.13	0.15

(a) Compact specimen: B = 0.75 and W/B = 2.7.
(b) Compact specimens: 0.62 < B < 0.75 and 3.23 < W/B < 3.33.
(c) See Table 3.0214 for tensile properties.

TABLE 3.02722. PLANE STRAIN FRACTURE TOUGHNESS OF A 2-INCH AND 3-INCH PLATE FROM THE B-1 PROGRAM (26)

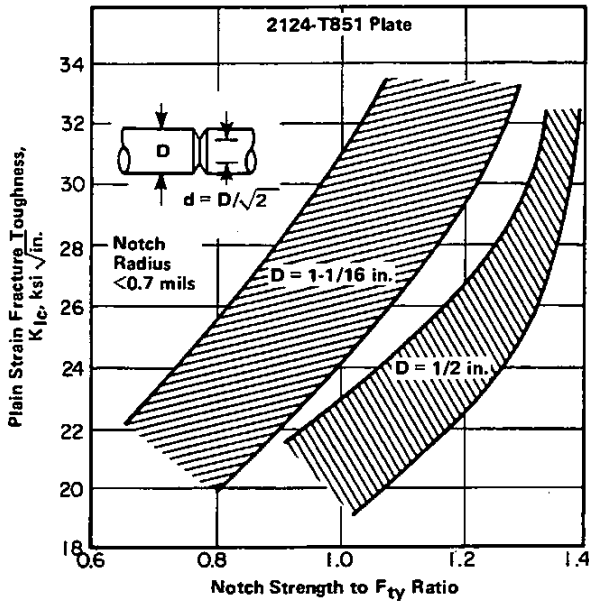


FIGURE 3.02723. SCATTERBANDS FOR RELATION BETWEEN SHARP-NOTCH STRENGTH TO YIELD STRENGTH RATIO AND PLANE STRAIN FRACTURE TOUGHNESS DETERMINED USING TWO NOTCH SPECIMEN DIAMETERS FOR 2124-T851 PLATE HAVING THICKNESS FROM 1.57 TO 6 INCH AND TESTED IN LT, TL, AND SL ORIENTATIONS WITH SPECIMENS LOCATED AT PLATE CENTER AND MID THICKNESS (15)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

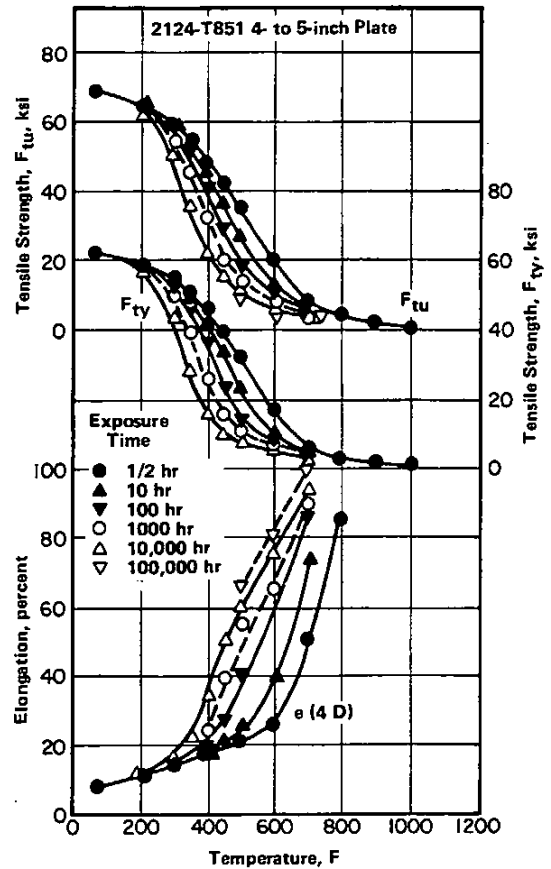


FIGURE 3.0312. EFFECT OF TEST TEMPERATURE AND EXPOSURE TIME ON TENSILE PROPERTIES OF 2124-T851 PLATE (1)

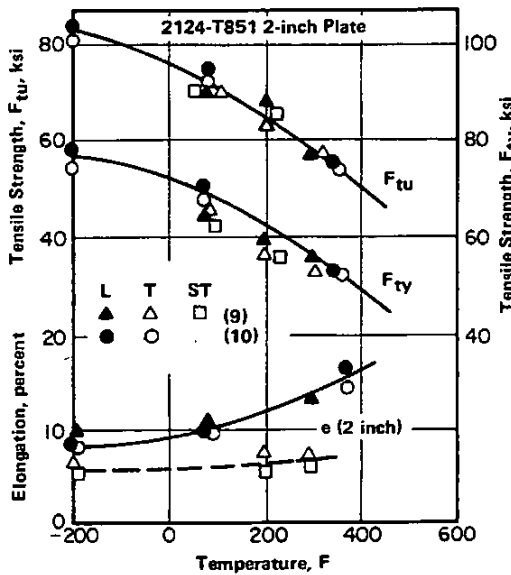


FIGURE 3.0313. EFFECT OF TEMPERATURE AND TESTING DIRECTION ON TENSILE PROPERTIES OF 2124-T851 PLATE (9, 10)

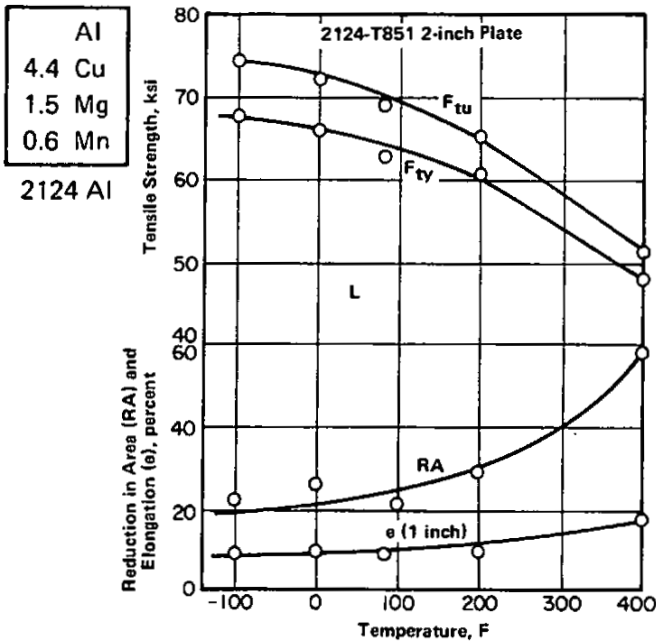


FIGURE 3.0314. EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF 2124-T851 PLATE (12)

Alloy	2124-T851					
Form	2-1/2 inch Plate					
Orientation	TL		LT		ST	
Temp. F	RT	250	RT	250	RT	250
K _{Ic} , ksi√in.	27	27	32	33	25	25

TABLE 3.03721. PLANE STRAIN FRACTURE TOUGHNESS OF PLATE AT ROOM TEMPERATURE AND 250 F (9)

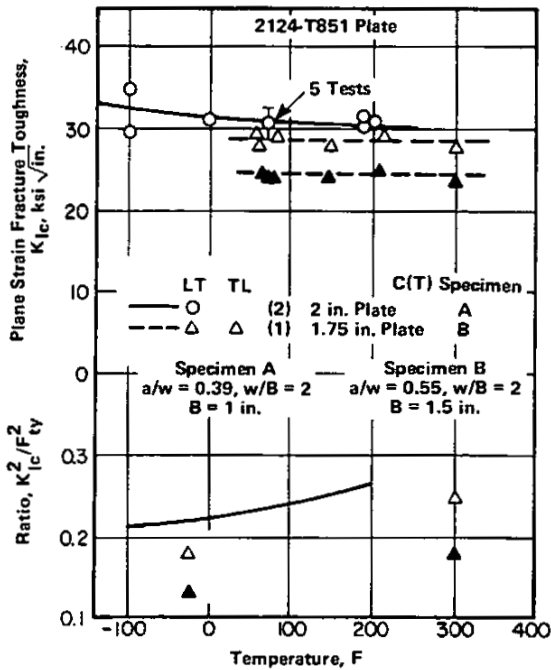


FIGURE 3.03722. EFFECT OF TEMPERATURE ON PLANE STRAIN FRACTURE TOUGHNESS OF TWO LOTS OF 2124-T851 PLATE (12)

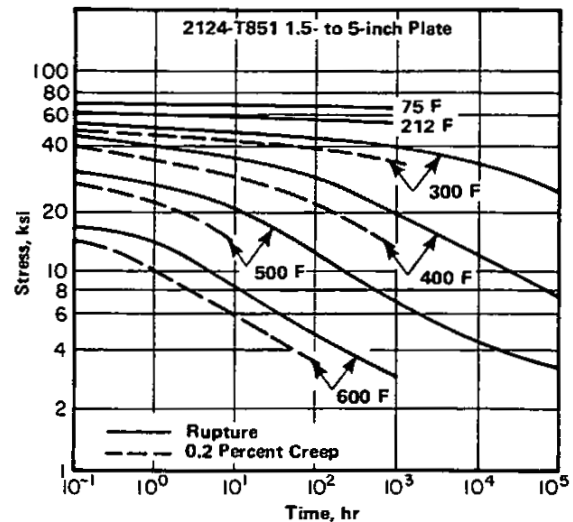


FIGURE 3.041. CREEP AND CREEP-RUPTURE CURVES AT TEMPERATURES FROM 75 TO 600 F FOR 2124-T851 PLATE (1)

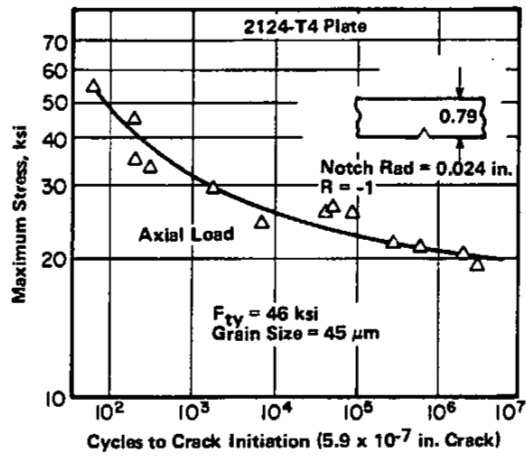


FIGURE 3.0511. CYCLES TO CRACK INITIATION AS A FUNCTION OF NOMINAL MAXIMUM FATIGUE STRESS FOR SPECIMENS WITH CAREFULLY POLISHED NOTCHES (19)

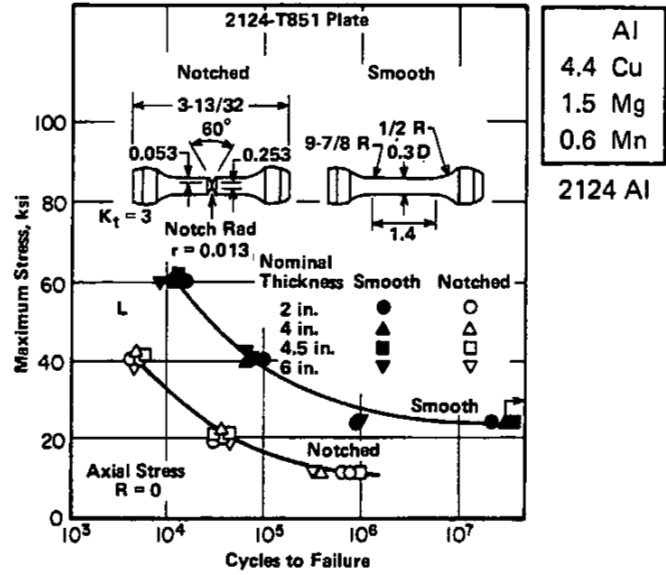


FIGURE 3.0512. AXIAL-LOAD FATIGUE CURVES FOR LONGITUDINAL SMOOTH AND NOTCHED ($K_t = 3$) SPECIMENS FROM 2124-T851 PLATE (6)

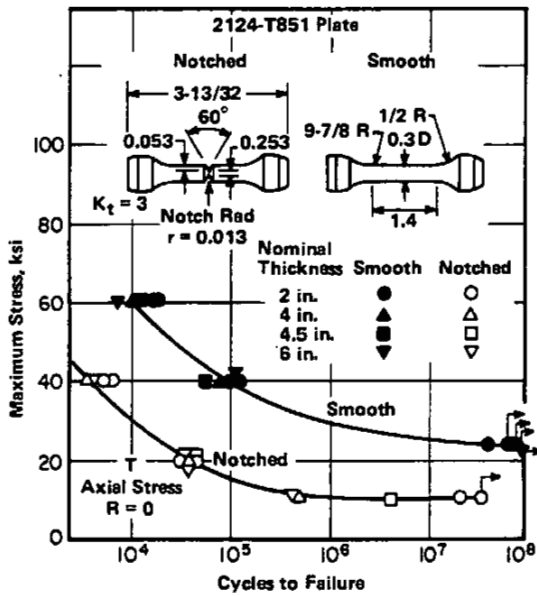


FIGURE 3.0513. AXIAL-LOAD FATIGUE CURVES FOR TRANSVERSE SMOOTH AND NOTCHED ($K_t = 3$) SPECIMENS FROM 2124-T851 PLATE (6)

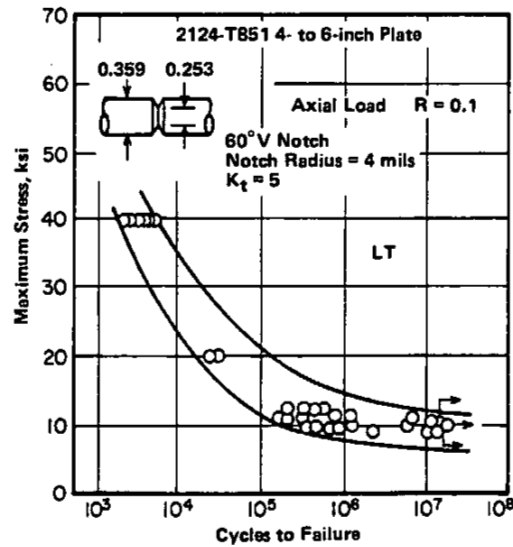


FIGURE 3.0514. AXIAL-LOAD FATIGUE CURVE FOR NOTCHED ($K_t = 5$) SPECIMENS FROM 4- TO 6-INCH 2124-T851 PLATE (1)

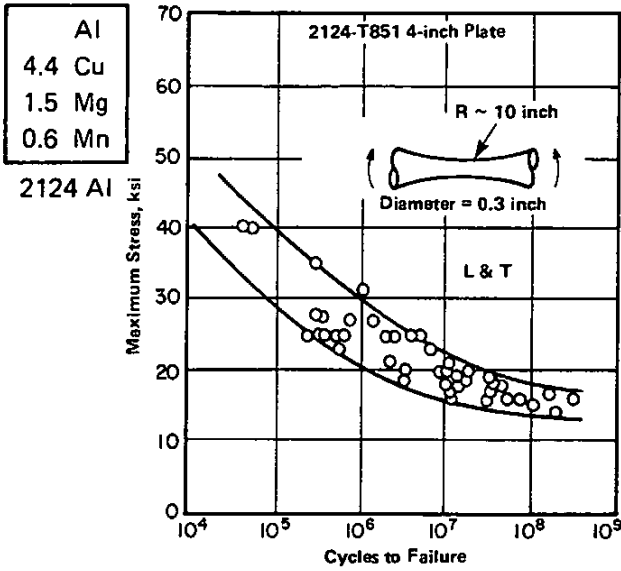


FIGURE 3.0515. ROTATING BENDING FATIGUE CURVES FOR SMOOTH SPECIMENS FROM 4-INCH 2124-T851 PLATE (1)

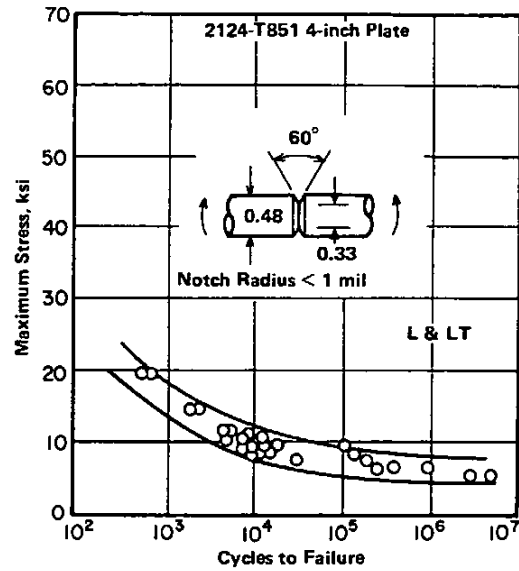


FIGURE 3.0516. ROTATING BENDING FATIGUE CURVES FOR SHARPLY NOTCHED SPECIMENS FROM 2124-T851 4-INCH PLATE (1)

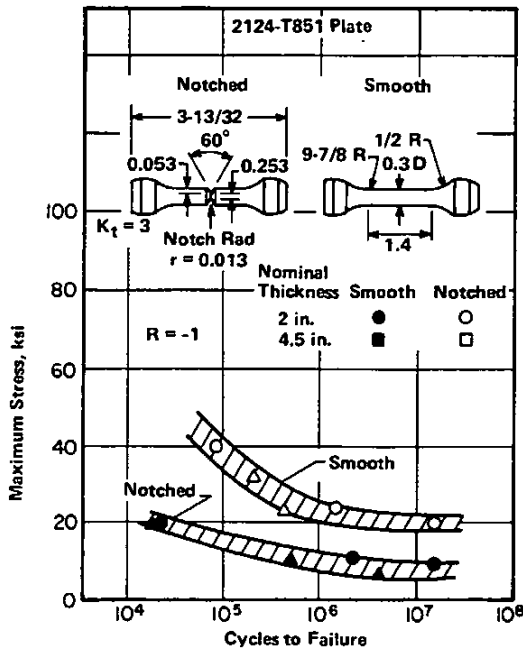


FIGURE 3.0517. EFFECT OF SALT FOG ON AXIAL LOAD FATIGUE LIFE OF SMOOTH AND NOTCHED ($K_t = 3$) SPECIMENS FROM 2124-T851 PLATE (6)

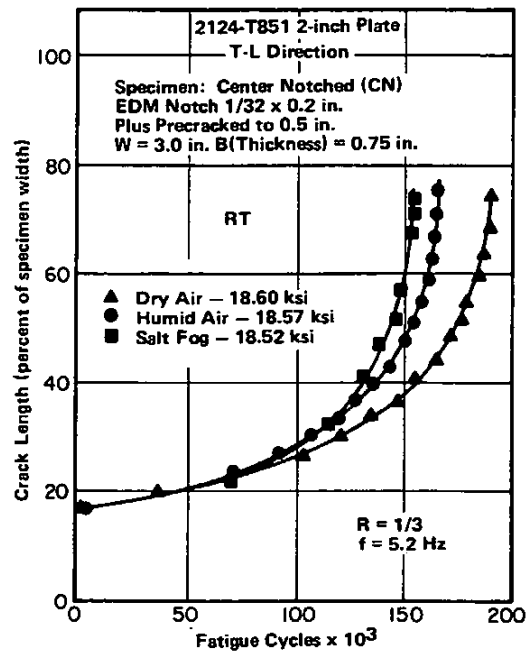


FIGURE 3.0521. TYPICAL FATIGUE CRACK-GROWTH DATA FOR 2-INCH PLATE IN VARIOUS ENVIRONMENTS (6)

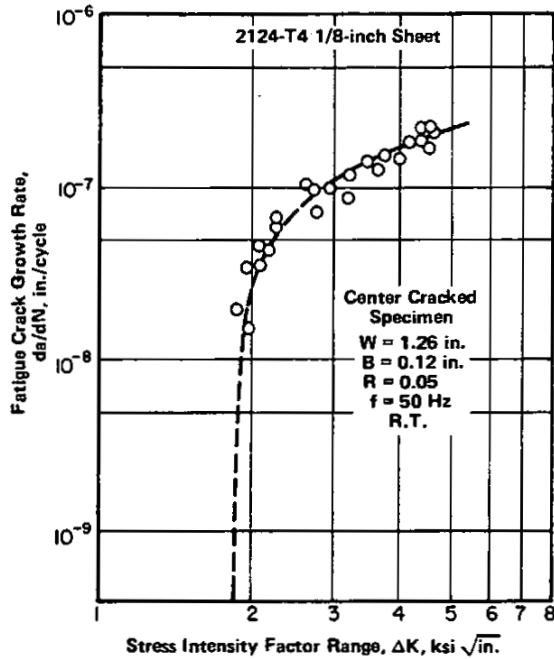


FIGURE 3.0522. FATIGUE CRACK-GROWTH RATES FOR 2124-SHEET IN T4 CONDITION (31)

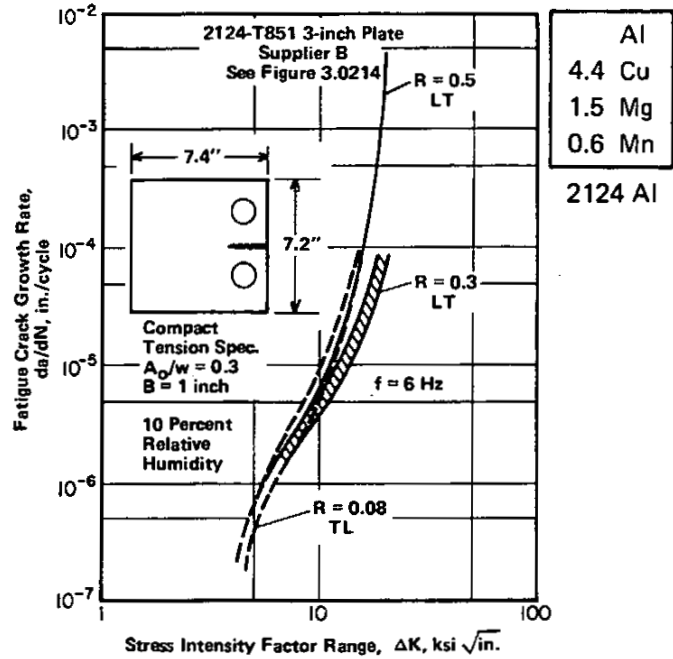


FIGURE 3.0523. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE FROM THE B-1 PROGRAM AT SEVERAL R RATIOS IN LOW HUMIDITY AIR (25)

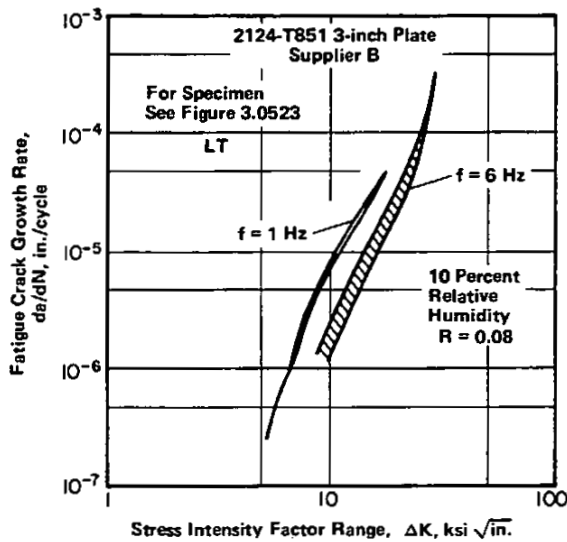


FIGURE 3.0524. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE FROM THE B-1 PROGRAM FOR TWO LOADING FREQUENCIES IN LOW HUMIDITY AIR (25)

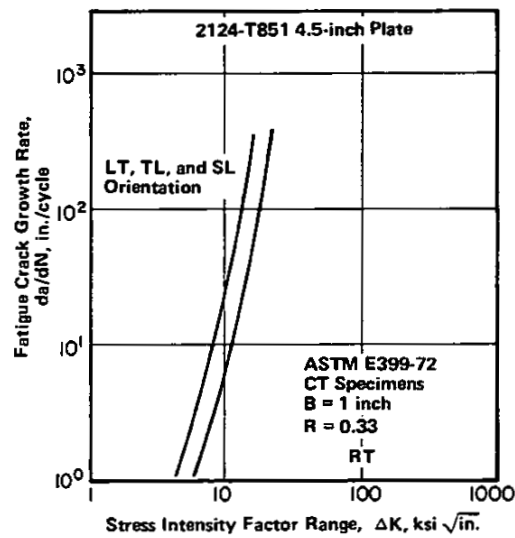


FIGURE 3.0525. FATIGUE CRACK-GROWTH RATES AT R = 0.33 FOR 4.5-INCH PLATE (6)

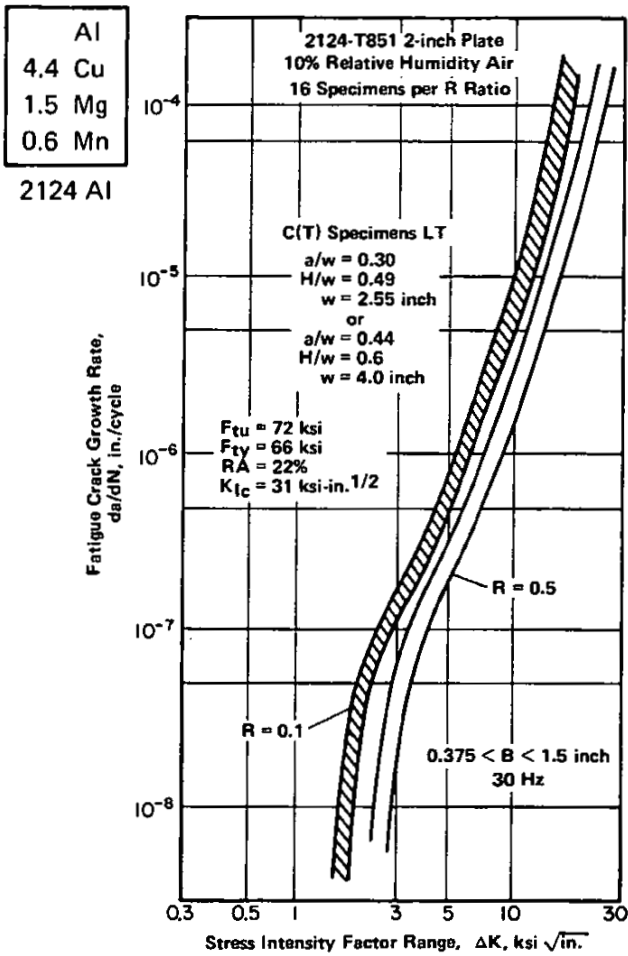


FIGURE 3.0526. FATIGUE CRACK-GROWTH RATES AT LOW ΔK VALUES FOR 2124-T851 PLATE TESTED AT TWO R RATIOS AND THICKNESSES OF 0.375, 0.75, AND 1.5 INCH (13)

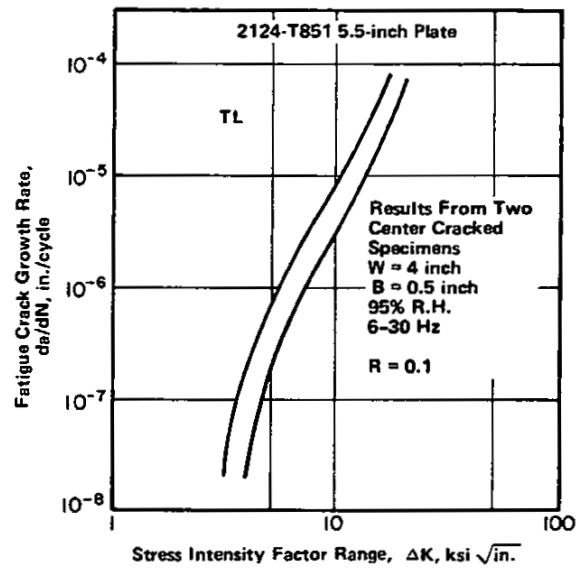


FIGURE 3.0527. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE TESTED IN HIGH HUMIDITY AIR AT R = 0.1 (32)

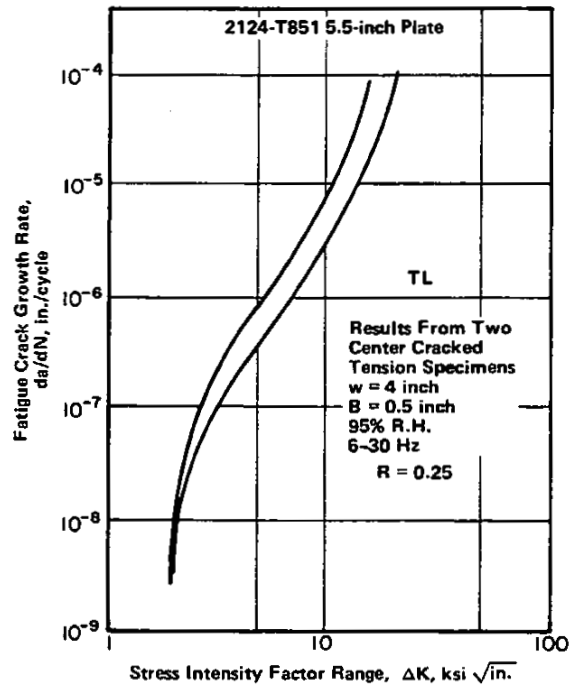


FIGURE 3.0528. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE TESTED IN HIGH HUMIDITY AIR AT R = 0.25 (32)

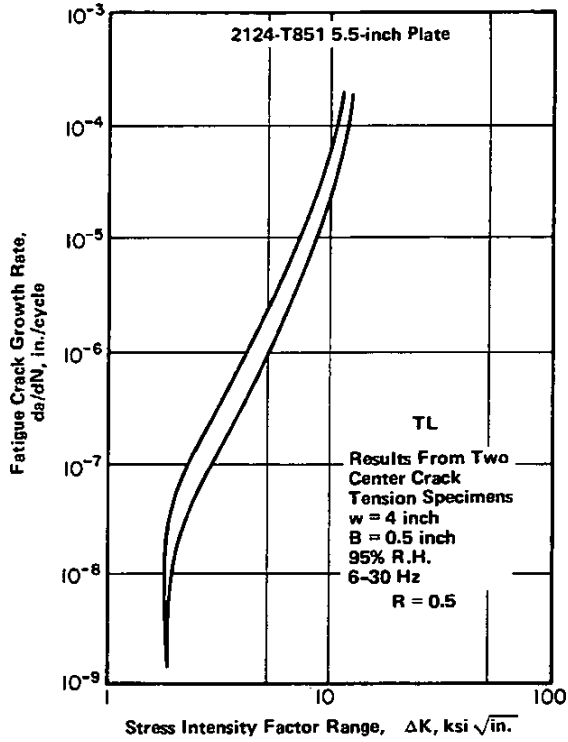


FIGURE 3.0529. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE TESTED IN HIGH HUMIDITY AIR AT R = 0.5 (32)

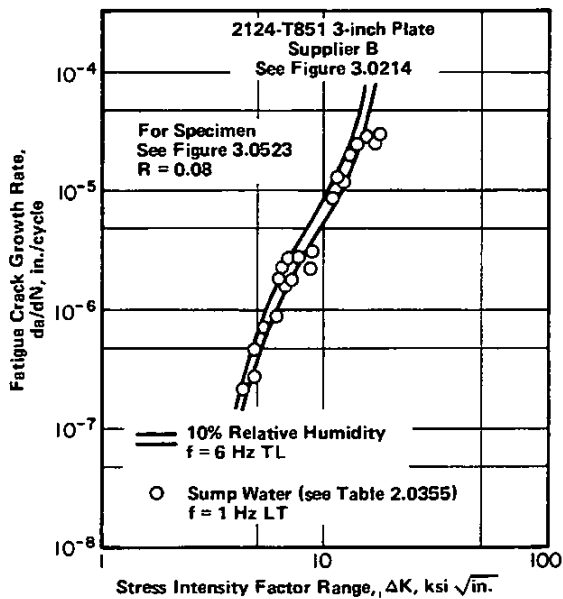


FIGURE 3.05211. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE FROM THE B-1 PROGRAM TESTED IN LOW HUMIDITY AIR AND IN SUMP WATER (25)

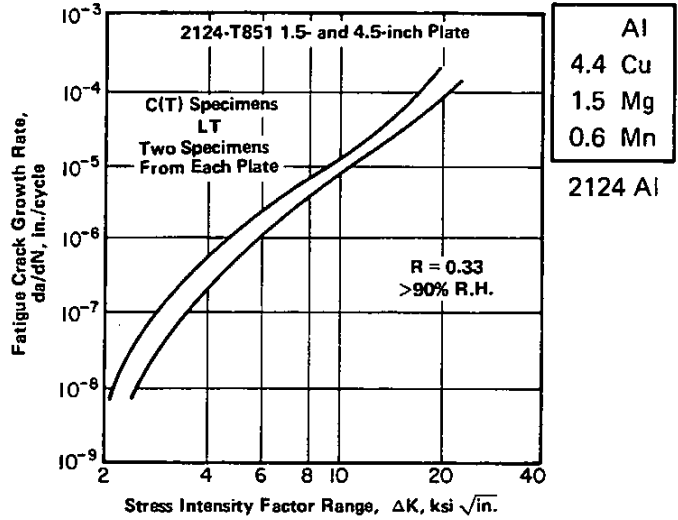


FIGURE 3.05210. FATIGUE CRACK-GROWTH RATES FOR TWO THICKNESSES OF PLATE TESTED IN HIGH HUMIDITY AIR (1)

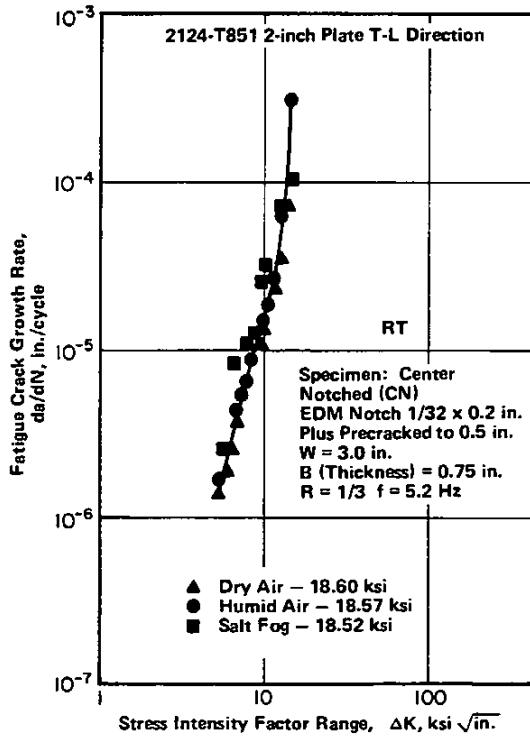


FIGURE 3.05212. TYPICAL FATIGUE CRACK-GROWTH RATES FOR 2-INCH 2124-T851 PLATE IN VARIOUS ENVIRONMENTS (6)

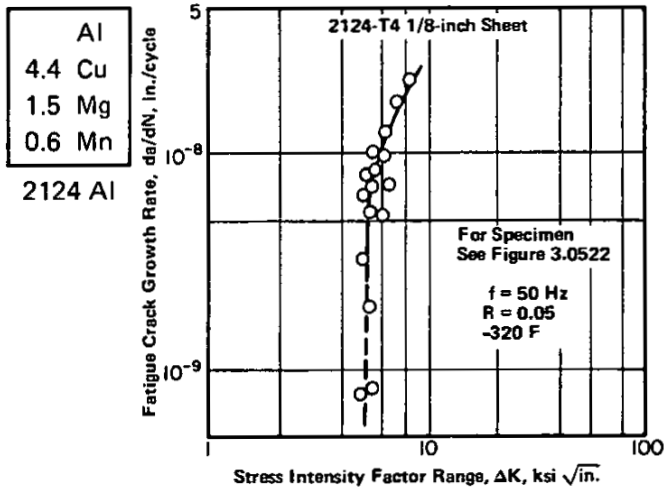


FIGURE 3.05213. FATIGUE CRACK-GROWTH RATES APPROACHING ZERO FOR 2124-SHEET IN THE T4 CONDITION AT -320 F (31)

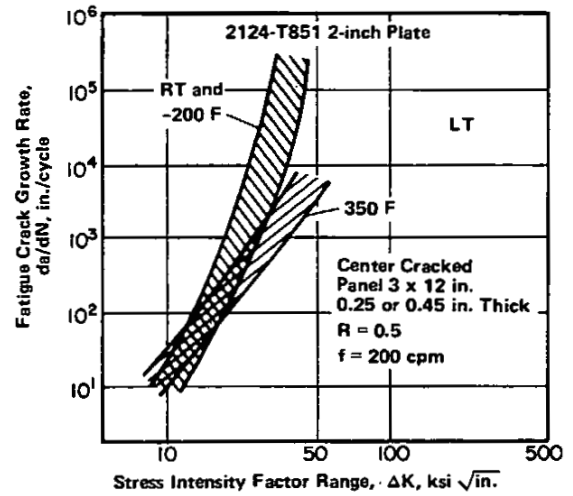


FIGURE 3.05214. FATIGUE CRACK-GROWTH RATES FOR PLATE TESTED IN THE LT DIRECTION AT CRYOGENIC AND ELEVATED TEMPERATURE (10)

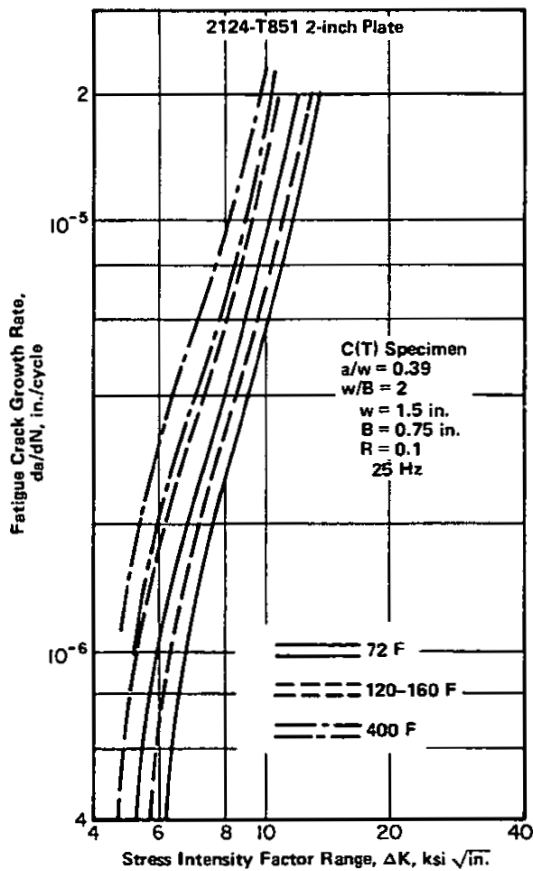


FIGURE 3.05215. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE AT ROOM AND ELEVATED TEMPERATURES (12)

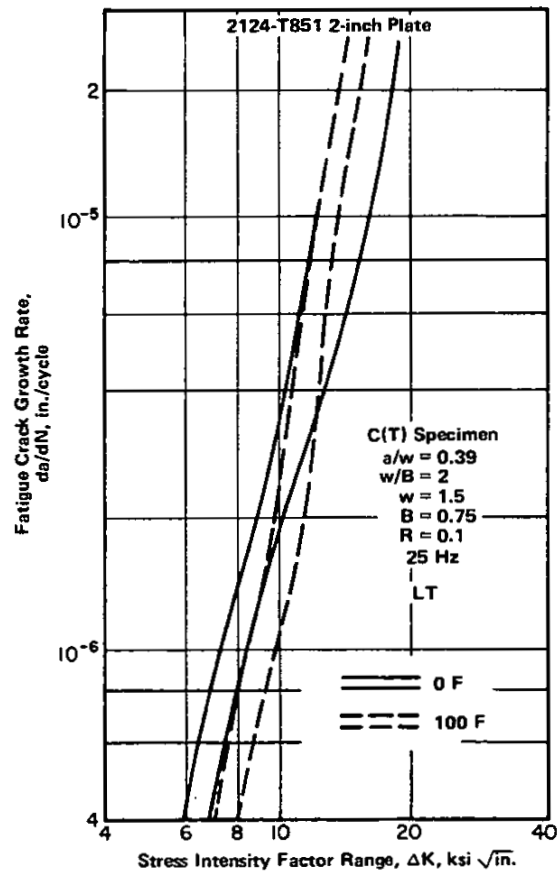


FIGURE 3.05216. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE AT LOW TEMPERATURES (12)

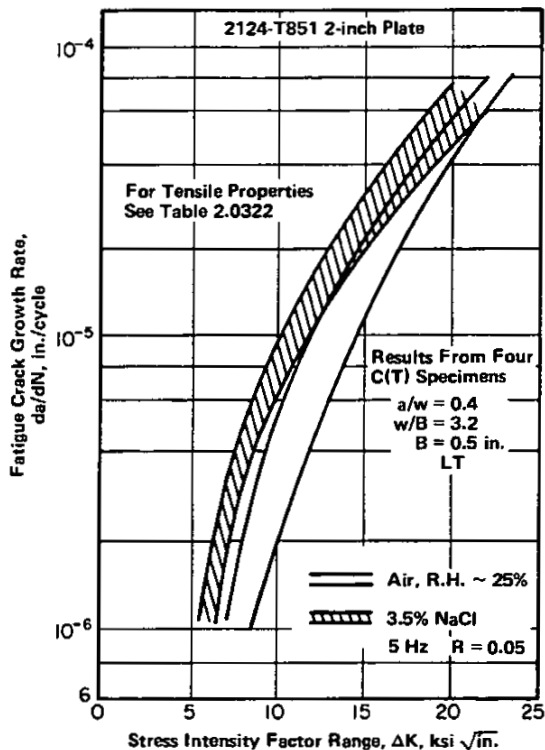


FIGURE 3.05217. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE IN AIR AND 3.5 PERCENT NaCl FOR LT DIRECTION (16)

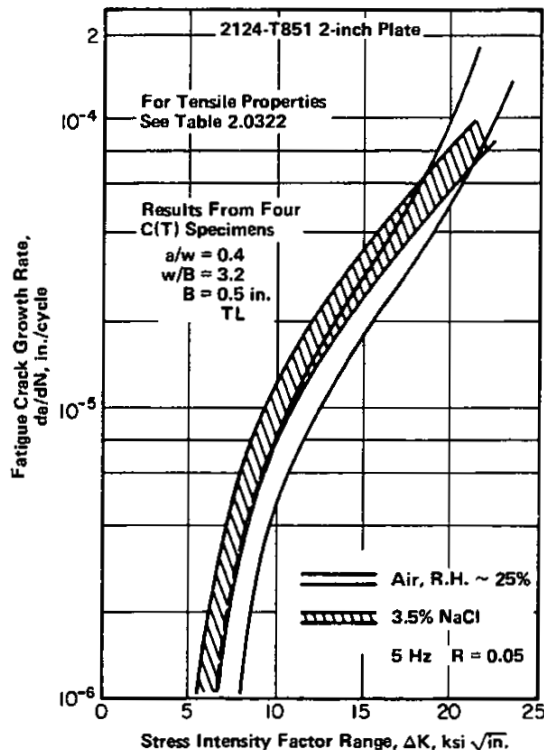


FIGURE 3.05218. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE IN AIR AND IN 3.5 PERCENT NaCl FOR TL DIRECTION (16)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

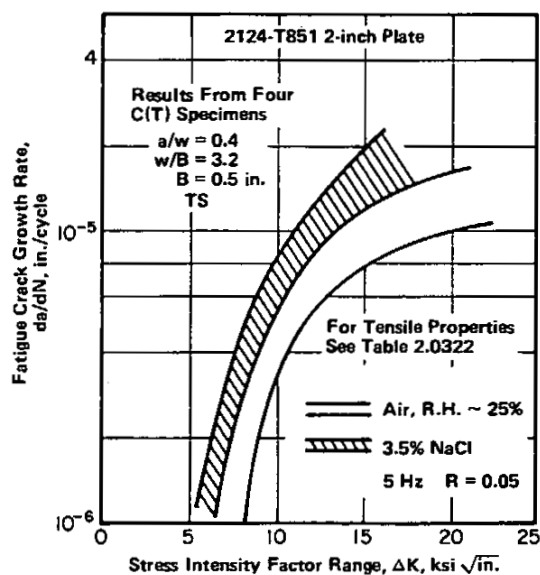


FIGURE 3.05219. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE IN AIR AND IN 3.5 PERCENT NaCl FOR TS DIRECTION (16)

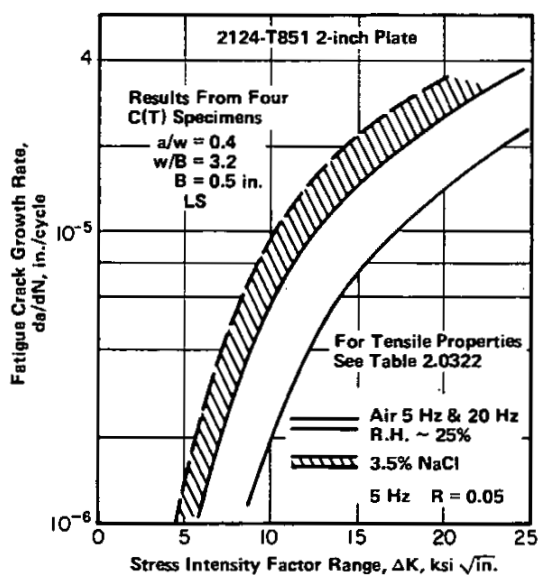


FIGURE 3.052110. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE IN AIR AND IN 3.5 PERCENT NaCl FOR LS DIRECTION (16)

Al
4.4 Cu
1.5 Mg
0.6 Mn
2124 Al

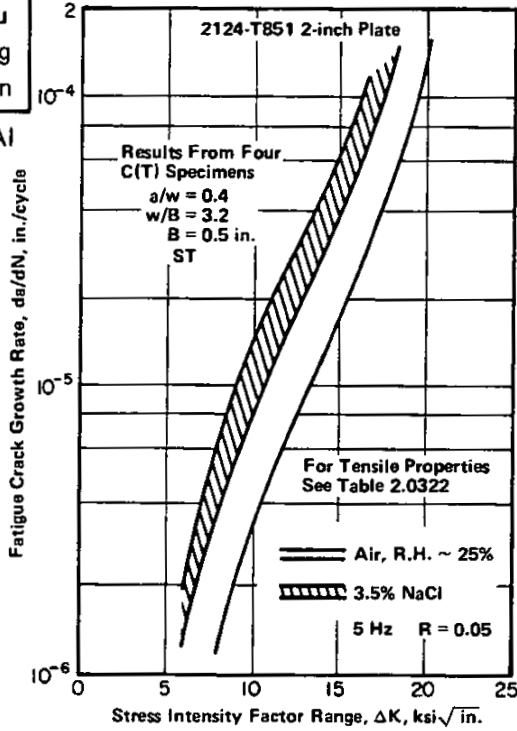


FIGURE 3.052111. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE IN AIR AND IN 3.5 PERCENT NaCl FOR ST DIRECTION (16)

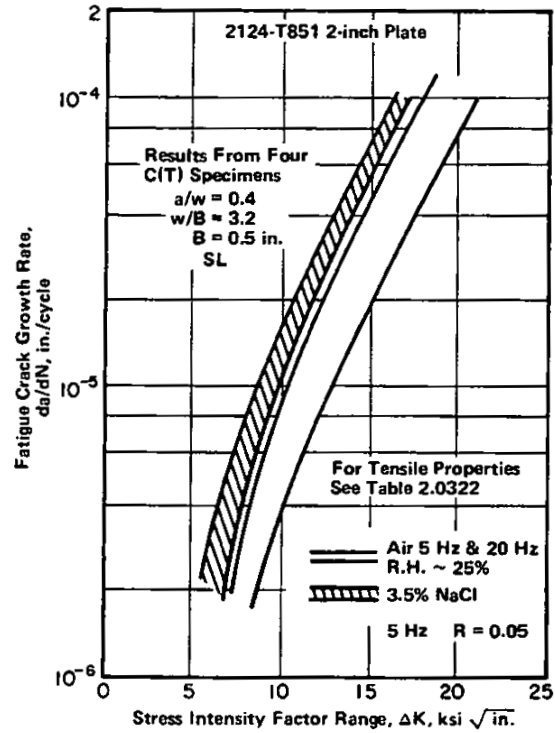


FIGURE 3.052112. FATIGUE CRACK-GROWTH RATES FOR 2124-T851 PLATE IN AIR AND IN 3.5 PERCENT NaCl FOR SL DIRECTION (16)

Alloy	2124-T851		
Form	5.5-inch Plate		
Direction	TL		
Location	Plate Center		
Specimen	Center Crack Tension M(T) W = 4 inch B = 0.5 inch with 4 Cracks Spaced ~8 inch Apart		
Environment	95 percent RH Air		
Frequency	30 to 35 Hz		
R Ratio	0.1	0.25	0.50
ΔK_{th} , ksi√in. (a)	2.8	2.0	1.4

(a) Lowest of observations on all cracks.

TABLE 3.052113. FATIGUE CRACK GROWTH THRESHOLD FOR 2124-T851 PLATE IN HIGH HUMIDITY AIR AT SEVERAL R RATIOS (32)

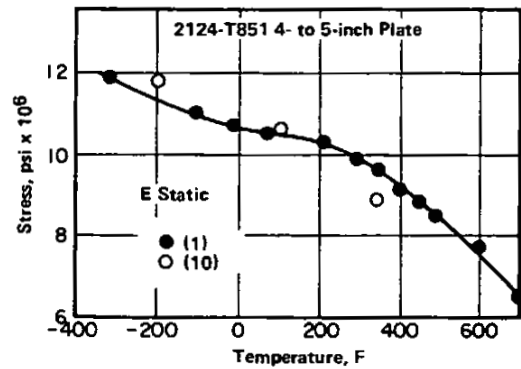


FIGURE 3.0621. MODULUS OF ELASTICITY AT LOW AND ELEVATED TEMPERATURES (1,10)

Al
4.4 Cu
1.5 Mg
0.6 Mn

2124 Al

Alloy	2124-T851					
Form	Plate					
Thickness, inch	Tensile Modulus, 10 ³ ksi			Compressive Modulus, 10 ³ ksi		
	L	T	ST	L	T	ST
1.750	10.49	10.48	10.05	10.90	11.02	10.84
2.500	10.45	10.50	10.35	10.98	10.84	10.81
3.500	10.39	10.38	10.47	10.84	10.94	10.87
4.500	10.37	10.59	10.45	10.77	11.04	10.84
5.500	10.55	10.53	10.47	10.85	10.90	10.86
Average	10.45	10.50	10.36	10.87	10.95	10.84

TABLE 3.0622. TENSILE AND COMPRESSIVE MODULUS OF ELASTICITY (6)

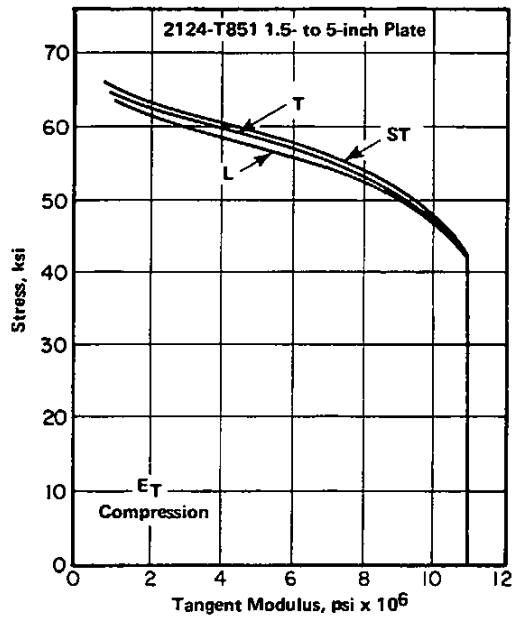


FIGURE 3.0641. TANGENT MODULUS CURVES FOR 2124-T851 PLATE (6)

