

RELEASED: JUNE 1977
AUTHOR: J. G. SESSLER

NONFERROUS ALLOYS

1. GENERAL
Aluminum alloy 2048 is a recently developed high strength alloy designed to exhibit improved fracture toughness and thermal stability at moderately elevated temperatures with only minor reduction in mechanical properties. Fracture toughness of this alloy is significantly higher than that of 2024 (the alloy from which it was derived) in the T851 Condition. Improved toughness is obtained by reduced copper content and by close control of both composition and thermal processing to reduce the amounts of second-phase particles which then yields a more homogeneous structure, (1)(4).
- Conventional processing of the alloy results in material in the T851 Condition. To date, there appears to be no significant improvement in fatigue resistance nor in resistance to stress corrosion cracking in the T851 Condition as compared to 2024 - T851. However, the 2048 alloy is currently being evaluated to determine the effect of thermomechanical processing (TMP) on fatigue and stress corrosion, (4).
- In this chapter, the information presented is limited to the T851 Condition only.
- 1.01 Commercial Designation
Aluminum alloy 2048, 2048 - T851.
- 1.02 Alternate Designation
None.
- 1.03 Specifications
- 1.04 Composition
Table 1.04.
- 1.05 Heat Treatment.
- 1.051 General. The heat treatment of this alloy is performed by the producer. The T851 Condition is obtained by solution treatment plus stress-relieved by stretching to produce a specified amount of permanent set, followed by artificial aging. Detailed information on heat treating procedure is available from the producer of the alloy.
- 1.06 Hardness.
- 1.07 Forms and Conditions Available.
Conventionally processed material is available as 3 inch plate in the T851 Condition. Data for other gages of sheet and plate are currently being obtained and evaluated, (6).
- 1.08 Melting and Casting Practice.
(See 2024).
- 1.09 Special Considerations.
(See 2024).
2. PHYSICAL AND ENVIRONMENTAL EFFECTS
- 2.01 Thermal Properties.
- 2.011 Melting Range. 935-1180F (approx.).
- 2.012 Phase Changes. Alloy is subject to precipitation hardening.
- 2.0121 Time-temperature-transformation diagrams.
- 2.013 Thermal Conductivity. 91.96 Btu-ft per (hr sq ft F) at RT, (6).
- 2.014 Thermal Expansion. 68-350F 12.9×10^{-6} in/in/F, (2).
70-220F 13.05×10^{-6} in/in/F, (6).
- 2.015 Specific Heat. 0.225 Btu per (16F), (6).
- 2.016 Thermal Diffusivity.
- 2.02 Other Physical Properties.
- 2.021 Density. 0.0994 lb per cu in. 2.748 gr per cu cm, at 68F,(6).
- 2.022 Electrical Properties.
- 2.0221 Electrical Conductivity. 42 percent IACS, (6).
- 2.0222 Electrical Resistivity. 1.586 micro-ohm-in, (6).
- 2.023 Magnetic Properties. Alloy is nonmagnetic.
- 2.024 Emittance.
- 2.025 Damping Capacity.
- 2.03 Chemical Environment
- 2.031 Stress corrosion. Seven specimens were tested for stress corrosion crack resistance in 4 point bend tests by alternate immersion in 3.5 percent sodium chloride solution at room temperature. Stress applied was 80 percent of the tensile yield strength of the material. The stress corrosion bend specimens were 5 inches by 0.5 inches and 0.050 inch thick. No cracks were observed in any of the specimens after 1000 hrs exposure, (2).
- 2.032 Results of stress corrosion tests with double cantilever bend (DCB) specimens taken from plate, Figure 2.032.
- 2.04 Nuclear Environment.
3. MECHANICAL PROPERTIES
- 3.01 Specified Mechanical Properties.
- 3.011 Tentative minimum mechanical properties for plate, Table 3.011.
- 3.02 Mechanical Properties at Room Temperature.
- 3.021 Tension.
- 3.0211 Stress-strain diagrams.
Typical tensile stress-strain curves for plate (longitudinal), Figure 3.02111.
- 3.02112 Typical tensile stress-strain curves for plate (transverse), Figure 3.02112).
- 3.0212 Room temperature mechanical properties of plate, Table 3.0212.
- 3.0213 Effect of 1000 hour exposure at 400F on room temperature properties of plate, Table 3.0213.
- 3.022 Compression.
- 3.0221 Stress-strain diagrams.
Typical compressive stress-strain curves for plate (longitudinal), Figure 3.02211.
- 3.02212 Typical compressive stress-strain curves for plate (transverse), Figure 3.02212.
- 3.0222 Room temperature compressive yield strength of plate, see Table 3.0212.
- 3.023 Impact.
- 3.0231 V-notch Charpy. L 7.6 ft-lb. T 4.5 ft-lb, (1).
- 3.024 Bending.
- 3.025 Torsion and Shear.
- 3.0251 Room temperature shear strength of plate, see Table 3.0212.
- 3.026 Bearing.
- 3.027 Stress Concentration.
- 3.0271 Notch Properties.
- 3.0272 Fracture toughness. (See Appendix C).
- 3.02721 Results of slow bend fracture toughness tests on plate, Table 3.02721.
- 3.02722 Tentative minimum fracture toughness values for plate, see Table 3.011.
- 3.02723 Room temperature fracture toughness of plate, Table 3.02723.
- 3.028 Combined properties.
- 3.03 Mechanical Properties at Various Temperatures.
- 3.031 Tension.
- 3.0311 Stress-strain diagrams, see Figures 3.02111 and 3.02112
- 3.0312 Tensile properties of plate at room and elevated temperatures, Figure 3.0312.
- 3.0313 Tensile properties of plate at room and elevated temperatures, Figure 3.0313.
- 3.032 Compression.
- 3.0321 Stress-strain diagrams, see Figures 3.02211 and 3.02212.
- 3.0322 Compressive properties of plate at room and elevated temperatures, 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. (See Appendix C).
- 3.03721 Fracture toughness of plate at 200 and 400F, Table 3.03721
- 3.038 Combined Properties.

Al
3.3 Cu
1.5 Mg
0.4 Mn

2048 Al

CODE 3223

PAGE 1

Al
3.3 Cu
1.5 Mg
0.4 Mn

2048 Al

- 3.04 Creep and Creep-Rupture Properties.
- 3.041 Stress-rupture and plastic deformation curves for plate, Figure 3.041.
- 3.05 Fatigue Properties.
- 3.051 Scatterband of fatigue data for smooth specimens at room and elevated temperatures, Figure 3.051.
- 3.052 Scatterband of fatigue data for notched specimens at room and elevated temperatures, Figure 3.052.
- 3.06 Elastic Properties.
- 3.061 Poisson's ratio.
- 3.062 Modulus of elasticity.
- 3.0621 Tensile modulus of elasticity at room and elevated temperatures, Figure 3.0621.
- 3.0622 Compressive modulus of elasticity at room and elevated temperatures, Figure 3.0622.
- 3.063 Modulus of rigidity.
- 3.064 Tangent modulus.
- 3.0641 Typical tangent modulus curves for plate (longitudinal), Figure 3.0641.
- 3.0642 Typical tangent modulus curves for plate (transverse), Figure 3.0642.

4. FABRICATION

- 4.01 Forming. (See also 2024).
- 4.011 Forming operations on plate is best accomplished in the O Condition with subsequent heat treatment.
- 4.02 Machining and Grinding. (See also 2024).
- 4.021 General. This alloy is rated as having good machinability in the annealed condition and very good to excellent machinability in heat treated conditions.
- 4.03 Joining. (See also 2024).
- 4.031 General. Heat treatable aluminum alloys, such as 2048, generally exhibit poor weldability. Fusion welding, although not usually recommended, can be accomplished using inert gas methods. Resistance welding of the alloy in heat treated conditions is possible, using special techniques. Brazing and soldering are not recommended.
- 4.04 Surface Treating. (See also 2024 and 2124).
- 4.041 The medium or atmosphere for solution treating may be molten salt, air or controlled atmospheres. Solution treat temperature should be controlled within $\pm 10F$.
- 4.042 Anodizing of the surfaces will improve the corrosion resistance of this alloy. Pretreatments include chemical or mechanical cleaning. Anodizing should be followed by sealing.
- 4.043 Scratching of surfaces should be avoided during handling of this alloy.

Source	(1)	
	Element	Percent
		Min Max
Copper	2.8	3.8
Magnesium	1.2	1.8
Manganese	0.20	0.60
Zinc	-	0.25
Iron	-	0.20
Silicon	-	0.15
Titanium	-	0.10
Other (Total)	-	0.15
Aluminum		Balance

TABLE 1.04 CHEMICAL COMPOSITION

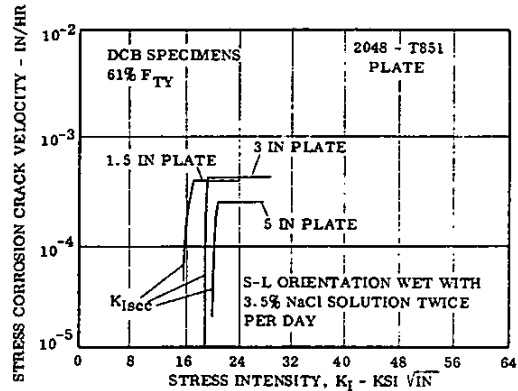


FIG. 2.032 RESULTS OF STRESS CORROSION TESTS WITH DOUBLE CANTILEVER BEND (DCB) SPECIMENS TAKEN FROM PLATE. (6)

Source	(6)		
Alloy	2048		
Form	Plate - 3 in thick		
Condition	T851		
Orientation	L	T	ST
Ftu, min - ksi	62	62	60
Fty, min - ksi	56	56	54
e(ln 4D) - percent	6	5	2.5
K _{1C} - ksi sqrt(in)	33	30	24

TABLE 3.011 TENTATIVE MINIMUM MECHANICAL PROPERTIES FOR PLATE.

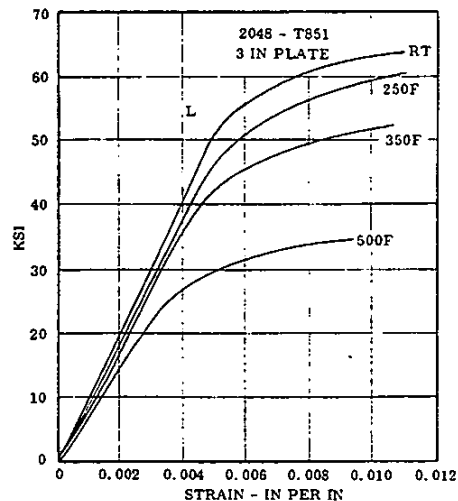


FIG. 3.02111 TYPICAL TENSILE STRESS-STRAIN CURVES FOR PLATE (LONGITUDINAL). (2)

NONFERROUS ALLOYS

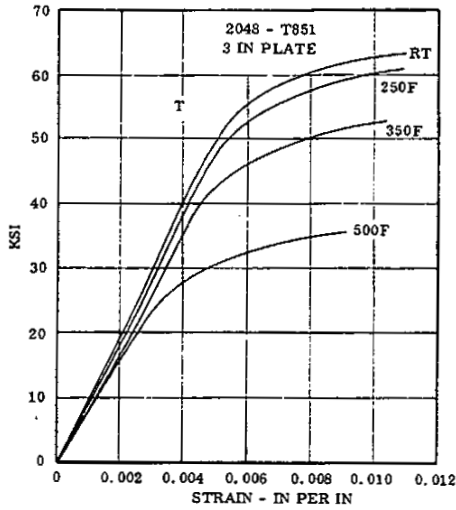


FIG. 3.02112 TYPICAL TENSILE STRESS-STRAIN CURVES FOR PLATE (TRANSVERSE). (2)

Source	(5)					
Alloy	2048					
Form	3 inch Plate					
Condition	T851					
Exposure	Tested at Room Temp (a) (No prior E. T. Exposure)			Tested at Room Temp (a) (After 1000 HR at 400F)		
Orientation	L	T	ST	L	T	ST
F _{tu} , ksi	68.0	68.4	65.5	47.9	48.0	44.7
F _{ty} , ksi	62.3	62.1	59.1	33.4	33.8	31.7
e - percent	7.0	6.1	4.7	7.6	6.6	4.7
RA, (1 inch) - percent	15.7	11.1	10.9	13.7	10.6	4.3

(a) Average of 3 tests.

TABLE 3.0213 EFFECT OF 1000 HOURS EXPOSURE AT 400F ON ROOM TEMPERATURE TENSILE PROPERTIES OF PLATE.

Al
3.3 Cu
1.5 Mg
0.4 Mn
2048 Al

Source	(1)		
Alloy	2048		
Form	Plate - 3 in thick (a)		
Condition	T851		
Orientation	L	T	ST
F _{tu} , ksi	66.3	67.4	67.1
F _{ty} , ksi	60.4	60.9	58.9
e, percent (in 2 inch)	8.3	7.2	6.3
RA, percent	15.7	11.7	9.4
F _{cy} , ksi	60.9	60.6	-
F _{su} , ksi (b)	39.3	39.2	-

(a) Values are averages of triplicate tests except as otherwise indicated.
(b) Double-shear pin-type specimens; average of 4 tests in each direction.

TABLE 3.0212 ROOM TEMPERATURE MECHANICAL PROPERTIES OF PLATE.

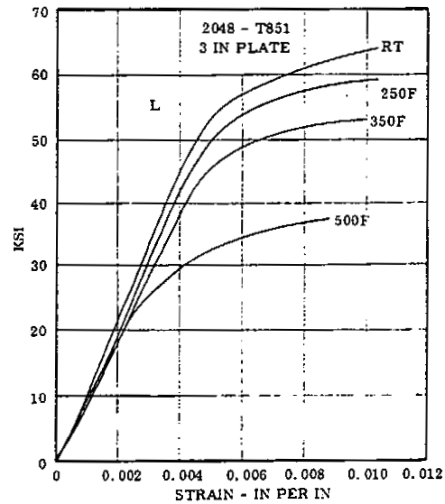


FIG. 3.02211 TYPICAL COMPRESSIVE STRESS-STRAIN CURVES FOR PLATE (LONGITUDINAL). (2)

Al
3.3 Cu
1.5 Mg
0.4 Mn
2048 Al

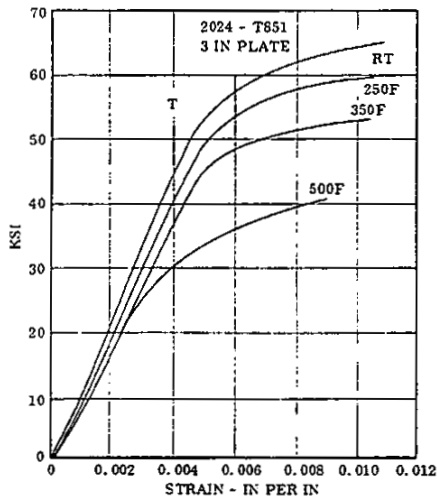


FIG. 3.02212 TYPICAL COMPRESSIVE STRESS-STRAIN CURVES FOR PLATE (TRANSVERSE). (2)

Source (2)				
Alloy	2048-T851 (a)(b)			
Form	3 in Plate			
Orientation	a (in)	P (lbs)	f (a/w)	K _{IC} (ksi√in)(c)
T-L	0.903	4500	2.294	29.20
T-L	0.936	4100	2.410	27.95
T-L	0.946	4350	2.448	30.12
T-L	0.942	4300	2.433	29.59
T-L	0.911	4350	2.321	28.56
T-L	0.916	4425	2.339	29.27
				Average 29.12
L-T	0.876	4925	2.205	30.72
L-T	0.903	4950	2.294	32.12
L-T	0.918	4900	2.346	32.52
L-T	0.947	5075	2.452	35.19
L-T	0.880	4880	2.218	30.61
L-T	0.920	4950	2.353	32.94
				Average 32.35

(a) All tests were chevron-notched slow bend fracture toughness tests. ASTM Method E-399-72. Specimens were precracked and tested under 3 point bend loading.
 (b) W = 2.00 inches
 T = 1.00 inches
 Span = 8.0 inches
 (c) These values meet ASTM E-399-72 criteria.

TABLE 3.02721 RESULTS OF SLOW BEND FRACTURE TOUGHNESS TESTS ON PLATE.

Source (5)					
Alloy	2048				
Form	3 in Plate				
Condition	T-851				
Orientation	Width (in)	Thickness (in)	a/w	Pmax/Pq	K _{IC} (ksi√in)(a)
L-T	2.8	1.4	0.484	1.06	37.0
L-T	2.8	1.4	0.466	1.07	35.8
L-T	1.75	0.875	0.486	1.06	34.4
L-T	1.75	0.875	0.563	1.05	34.9
L-T	1.75	0.875	0.491	1.06	34.8
T-L	2.5	1.4	0.475	1.01	31.4
T-L	2.5	1.4	0.476	1.01	31.2
T-L	2.8	1.4	0.475	1.02	31.2
T-L	1.75	0.875	0.492	1.00	29.3
T-L	1.75	0.875	0.500	1.02	31.3
T-L	1.75	0.875	0.500	1.05	30.7
T-L	1.5	0.75	0.506	1.07	31.0
T-L	1.5	0.75	0.507	1.02	28.0
T-L	1.5	0.75	0.496	1.02	31.7
S-L	1.75	0.875	0.499	1.03	27.5
S-L	1.75	0.875	0.497	1.05	26.9
S-L	1.75	0.875	0.506	1.05	25.4

(a) ASTM E-399-72 compact tension.

TABLE 3.02723 ROOM TEMPERATURE FRACTURE TOUGHNESS OF PLATE.

NONFERROUS ALLOYS

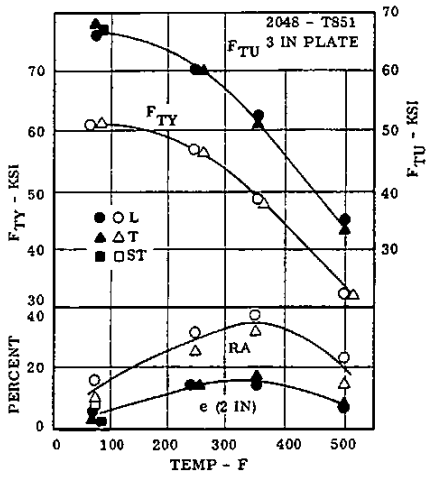


FIG. 3. 0312 TENSILE PROPERTIES OF PLATE AT ROOM AND ELEVATED TEMPERATURES. (1)

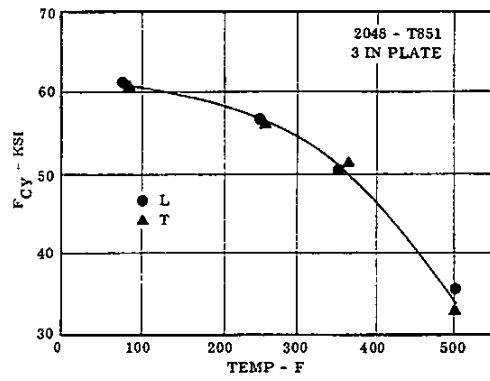


FIG. 3. 0322 COMPRESSIVE PROPERTIES OF PLATE AT ROOM AND ELEVATED TEMPERATURES. (1)

Al
3.3 Cu
1.5 Mg
0.4 Mn
2048 Al

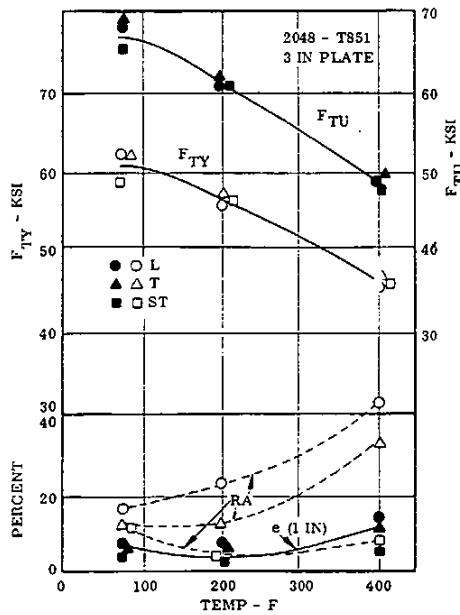


FIG. 3. 0313 TENSILE PROPERTIES OF PLATE AT ROOM AND ELEVATED TEMPERATURES. (5)

Al
3.3 Cu
1.5 Mg
0.4 Mn
2048 Al

Source		(5)				
Alloy		2048				
Form		3 in Plate				
Condition		T851				
Orientation	Width (in)	Thickness (in)	a/w	Test Temp-F	Pmax/Pq	K_{IC} (ksi√in) (a)
L-T	2.8	1.4	0.481	200	1.06	36.9
L-T	2.8	1.4	0.489	200	1.05	37.0
L-T	2.8	1.4	0.482	200	1.05	37.0
T-L	2.8	1.4	0.486	200	1.04	32.1
T-L	2.8	1.4	0.489	200	1.05	31.0
T-L	2.8	1.4	0.477	200	1.04	31.5
S-L	2.5	1.25	0.521	200	1.03	25.6
S-T	2.5	1.25	0.533	200	1.01	28.3
T-L	2.8	1.4	0.475	400	1.05	31.1
S-L	2.5	1.25	0.528	400	1.05	30.7
S-T	2.5	1.25	0.508	400	1.05	32.3

(a) ASTM E-399-72 compact tension.

TABLE 3.03721 FRACTURE TOUGHNESS OF PLATE AT 200 AND 400F.

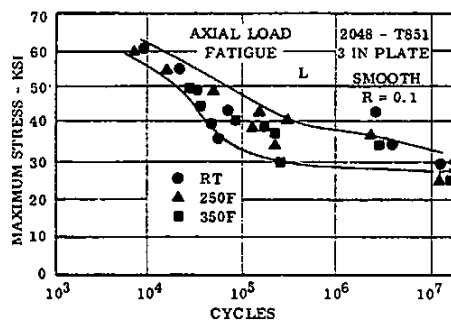


FIG. 3.051 SCATTERBAND OF FATIGUE DATA FOR SMOOTH SPECIMENS AT ROOM AND ELEVATED TEMPERATURES. (2)

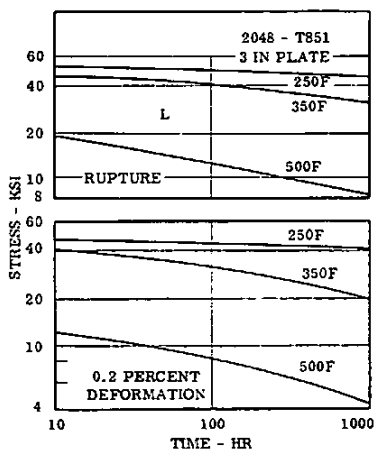


FIG. 3.041 STRESS-RUPTURE AND PLASTIC DEFORMATION CURVES FOR PLATE. (1)

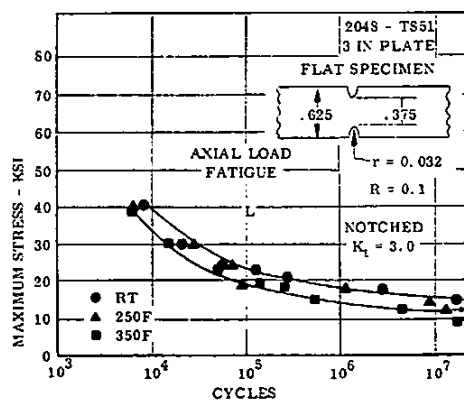


FIG. 3.052 SCATTERBAND OF FATIGUE DATA FOR NOTCHED SPECIMENS AT ROOM AND ELEVATED TEMPERATURES. (2)

NONFERROUS ALLOYS

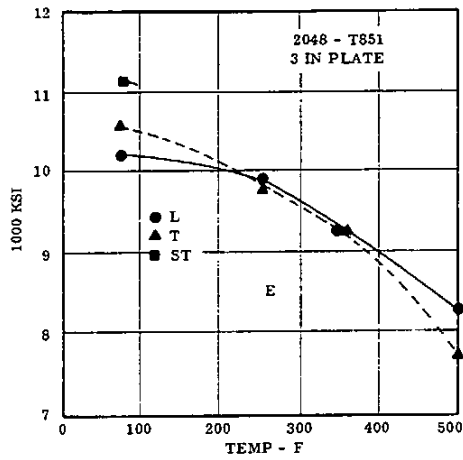


FIG. 3.0621 TENSILE MODULUS OF ELASTICITY AT ROOM AND ELEVATED TEMPERATURES. (1)

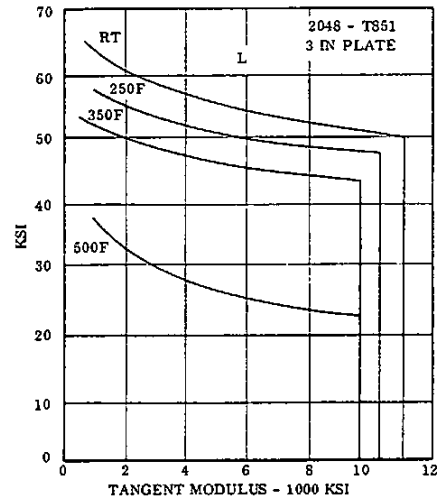


FIG. 3.0641 TYPICAL TANGENT MODULUS CURVES FOR PLATE (LONGITUDINAL).

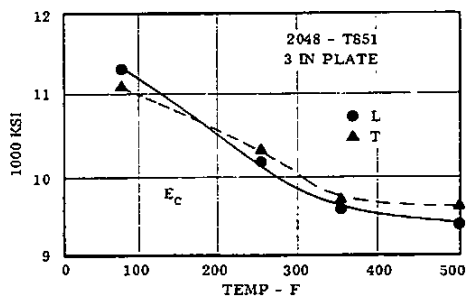


FIG. 3.0622 COMPRESSIVE MODULUS OF ELASTICITY AT ROOM AND ELEVATED TEMPERATURES. (1)

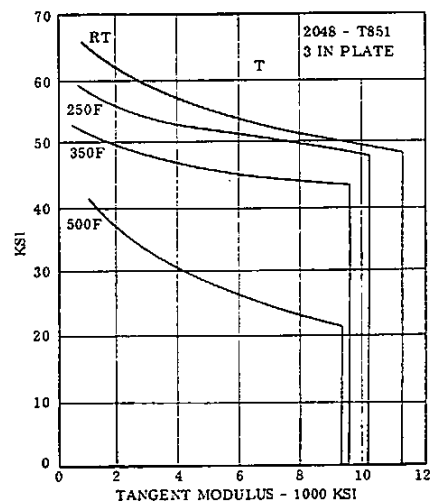


FIG. 3.0642 TYPICAL TANGENT MODULUS CURVES FOR PLATE (TRANSVERSE). (2)

Al
3.3 Cu
1.5 Mg
0.4 Mn

2048 Al

REFERENCES

1. "Mechanical-Property Data X-2048-T851 Aluminum Alloy", Data Sheet F33615-72-1280; Prepared by Battelle Memorial Institute, Columbus, Ohio; Issued by Air Force Materials Laboratory (October 1972).
2. Deel, O. L., Ruff, P. E. and Mindlin, H., "Engineering Data on New Aerospace Structural Materials", Data Sheet F33615-72-C-1280; Battelle Memorial Institute, Columbus, Ohio, Technical Report AFML-TR-73-114 (June 1973).
3. Thompson, D. S., Levy, S. A., Spangler, G. E. and Benson, D. K., "Program to Improve Fracture Toughness and Fatigue Resistance of Aluminum Sheet and Plate for Aircraft Applications", Reynolds Metals Company, AFML-TR-73-247, Vol. I (September 1973).
4. Thompson, D. S. and Zinkham, H. E., "Program to Improve the Fracture Toughness and Fatigue Resistance of Aluminum Sheet and Plate for Aircraft Applications", Reynolds Metals Company, AFML-TR-73-247, Vol. II (September 1974).
5. Petrak, G. J., "Fracture Related Properties of X-2048-T851 Plate Including Specimen Size Effects on K_{IC} ", Dayton University, AFML-TR-74-261 (December 1974).
6. Levy, S. A., Thompson, D. S. and Spangler, G. E., "2048 Update, Conventional and Thermomechanical Aging" Metals Engineering Quarterly (May 1975).