Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

1. GENERAL
The alloy was developed in 1954 to provide for applications at temperatures up to 600F. In the solution heat treated and aged condition this alloy exhibits typical mechanical properties in the 500-600F temperature range superior to those of any other commercially available aluminum alloy. The weldability of the alloy is excellent. Mechanical properties of welded and unwelded 2219 at temperatures down to -423F are also excellent. It is available in all wrought products, sheet, strip, plate and clad with 7072. Due to its low directionality tendencies it is well suited for forgings, (9).

1.01 Commercial Designations
2219, Clad 2219, (X2219 and Clad X2219, obsolete)

1.02 Alternate Designation
None.

1.03 Specifications
Table 1.03.

TABLE 1.03

AMS	FORM	CONDITION	MILITARY	ASTM
4031	Sheet and Plate	O	MIL-A-8920A	B209-64
	Sheet and Plate	F, T31, T351	MIL-A-8920A	B209-64
	Sheet and Plate	T37, T62, T81	MIL-A-8920A	B209-64
	Sheet and Plate	T851, T87	MIL-A-8920A	B209-64
4143	Forgings	T6	QQ-A-367F	B247-64
	Forgings	T852, T87	QQ-A-367F	—
—	Bar, rod, shapes	O, T62	—	B221-64
—	(tube extruded)	T8510, T8511	—	B221-64

1.04 Composition
1.041 Core material, Table 1.041.

TABLE 1.041

Source	AMS (8)	
	Percent	
	Min	Max
Copper	5.8	6.8
Iron	-	0.30
Magnesium	-	0.02
Manganese	0.20	0.40
Silicon	-	0.20
Titanium	0.02	0.10
Vanadium	0.05	0.15
Zinc	-	0.10
Zirconium	0.10	0.25
Others - Each	-	0.05
- Total	-	0.15
Aluminum	Balance	

1.042 Cladding, Table 1.042.

TABLE 1.042

Source	(11)	
Clad Alloy	7072 Alum. (a)	
	Percent	
	Min	Max
Zinc	0.8	1.3
Silicon + Iron	-	0.7
Manganese	-	0.1
Copper	-	0.1
Magnesium	-	0.1
Others		
Each	-	0.05
Total	-	0.15
Aluminum	Balance	

(a) The nominal cladding thickness per side is 10 percent of the total thickness of the composite if the latter is below 0.040 inch and 5 percent for a total thickness of composite products of 0.040 inch to 0.099 inch. For a total thickness of 0.100 inch or more the nominal cladding thickness on each side is 2.5 percent, (Ref. 3.3)

1.05 Heat Treatment
1.051 Anneal
1.0511 Heat treated conditions to O Condition. 750 to 775F, 2 to 3 hours, cool at 50F per hour down to 500F, (9).
1.0512 Intermediate anneal during repeated cold working O Condition. 650F, 30 minutes maximum. The same annealing treatment can be applied to heat treated material if only moderate forming is to be performed, (2).
1.052 Solution treat. 990 to 1010F, 20 minutes to 4 1/2 hours, depending on thickness and equipment, followed by an immediate cold water quench, (9). Maximum allowable quench delay times, Table 1.052.

TABLE 1.052

Source	(23)
Data	Max allowable quench delay times
Nominal thickness, inch	Max time, seconds
≤ 0.016	5
0.017 to 0.031	7
0.032 to 0.090	10
≥ 0.091	15

1.0521 If solution treatment is performed by supplier it is designated T4.
1.0522 If solution treatment is performed by user it is designated T42.
1.053 Modification of T4 by cold working, (9).
1.0531 T4 and stretch for sheet and drawn tube to T31.
1.0532 T4 and stretch 1.5 to 3% for plate to T351.
1.0533 T4 and stretch 1 to 3% for rod and bar to T351.
1.0534 T4 and cold work 2.5% for forgings to T352.
1.0535 T4 and stretch 1% for extrusions to T3511, T3510.
1.0536 T4 and cold work approximate 8% for sheet, plate and forgings to T37.
1.054 Modification of T4 by aging, (9).
1.0541 T4 and age 375F, 26 hours for forgings to T6.
1.0542 T4 and age 375F, 36 hours (18 hours for clad 2219) for sheet, plate, extrusions, drawn tube, rod and bar, to T62.
1.055 Modification of T3 by aging, (9).
1.0551 T31 and age 350F, 18 hours for sheet to T81.
1.0552 T31 and age 375F, 18 hours for drawn tube to T81.
1.0553 T351 and age 350F, 18 hours for plate to T851.
1.0554 T351 and age 375F, 18 hours for rod and bar to T851.
1.0555 T351 and age 350F, 18 hours for forgings to T832.
1.0556 T351 and age 357F, 18 hours for extrusions to T8511, T8510.
1.0557 T37 and age 325F, 24 hours for sheet, plate and hand forgings to T87.
1.056 Natural aging from T4.
1.0561 Effect of natural aging time on tensile properties of alloy in T4 Condition, Fig. 1.0561.

1.06 Hardness
1.061 Typical hardness values for various tempers sheet and plate, Table 1.061.

TABLE 1.061

Source	(9)				
Alloy	2219				
Form	Bare Sheet and Plate				
Condition	T31, T351	T37	T62	T81, T851	T87
BHN, typ 500 Kg load 10mm ball	96	110	113	123	128

1.07 Forms and Conditions Available
1.071 The alloy can be supplied in form of bar and clad sheet, strip and plate, bar, wire, forgings, tubing and extrusions in the full range of commercial sizes, (6).

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

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1.072 Conditions available. Table 1.072.

TABLE 1.072

Source	(10)
Alloy	2219, Clad 2219
Form	Conditions Available
Sheet, plate-bare	O, T31, T351, T37, T62, T81, T851, T87
Sheet, plate-clad	O, T31, T351, T37, T62, T81, T851, T87
Wire, rod and bar	T851
Extruded rod, bar, shapes and tubes	O, T31, T3510, T3511, T62, T81, T8510, T8511
Hand forgings, die	T6
Rolled ring	T6

1.073 Components of clad plate and sheet. Table 1.073.

TABLE 1.073

Source	(10)		
Alloy	Clad 2219		
Cladding	7072		
Thickness - in	≥0.039	0.040 to 0.099	<0.100
Cladding thickness per side-%			
Nominal	10	5	2 1/2
Min-avg	8	4	2

1.08 Melting and Casting Practice

1.081 The impure ore (bauxite) is converted into pure aluminum oxide (alumina) by a series of chemical processes. Oxygen is removed from the alumina by smelting in carbon-lined electric furnaces (reduction pots). Pure molten aluminum is deposited at the bottom of the pot and is siphoned off periodically to form "pigs" and "sows". A separate furnace operation is used to form "alloy pig" from the pure aluminum by the addition of the desired alloying elements. This alloy metal is cast into ingots for further processing.

1.09 Special Considerations

1.091 Solution treating temperature should be closely controlled as higher temperatures may cause solid solution grain boundary melting or eutectic melting which cannot be repaired by subsequent heat treatment. Lower temperatures may result in a loss in hardening potential.

1.092 Rapid quenching after solution treatment is important because of possible precipitation which results in reduced corrosion resistance on slow cooling from the solution treat temperature.

1.093 Reheat treatment of clad material should be done carefully because copper tends to diffuse through the cladding to the surface, thereby decreasing corrosion resistance.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range. 1010 to 1190F, (1).

2.012 Phase changes. Alloy is subject to precipitation hardening.

2.0121 Time-temperature-transformation diagrams.

2.013 Thermal conductivity at room temperature.
99 Btu ft per (hr sq ft F), O Condition
65 Btu ft per (hr sq ft F), T31, T37, T42 Conditions.
72 Btu ft per (hr sq ft F), T6, T62, T81, T87 Conditions, (9).

2.014 Thermal expansion, Fig. 2.014.

2.015 Specific heat at 212F, 0.23 Btu per (lb F), (9).

2.016 Thermal diffusivity

2.02 Other Physical Properties

2.021 Density, Fig. 2.021.

2.022 Electrical resistivity at room temperature. O Condition, 1.54 microhm-in; T31, T37, T42 Condition, 2.42 microhm-in, (9). Varies with chemical composition.

2.023 Magnetic properties. Alloy is nonmagnetic.

2.024 Emissivity

2.025 Damping capacity

2.026 Crystal structure. fcc.

2.03 Chemical Properties

2.031 Corrosion resistance. The alloy has about the same degree of resistance to atmospheric corrosion as other Al-Cu alloys, (see 2014 and 2024). When aged to T81 or T87 temper, the resistance to corrosion or stress corrosion cracking is similar to that of 2024-T6 and is considerably superior to 2014-T6. Corrosion characteristics of naturally aged tempers, T31 and T37 are similar to those of 2024-T3. For sheet thicknesses of 0.064 inch and greater, the corrosion resistance of the artificially aged tempers is superior to that of naturally aged tempers, (12).

2.0311 Effect of salt spray corrosion on tensile properties of sheet in various tempers, Fig. 2.0311.

2.04 Nuclear Properties

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.011 AMS specified mechanical properties for sheet and plate, Table 3.011.

TABLE 3.011

Source		(8)			
Alloy		2219			
Form		Sheet and Plate			
Condition		O		Solution and precipitation heat treatment	
Thickness - in		0.040 to 0.499	0.499 to 2.00	0.040 to 1.000	1.000 to 2.000
F_{tu},	-min-ksi*	30	30	54	56
F_{ty},	-min-ksi*	16	-	36	36
e(2 in)	-min-%	12		6	6

* Maximum for O Condition

3.012 AMS specified mechanical properties for forgings, Table 3.012.

TABLE 3.012

Source	(8)						
Alloy	2219						
Form	Die forgings		Hand forgings			Rolled rings	
Condition	T6						
Thickness - in	≤ 4.00		≤4.00		2.375 to 4.00*	≤2.5	
Direction	L	T	L	T	ST	Tang.	Axial
F_{tu}, -min*-ksi	58	53	58	55	53	56	55
F_{ty}, -min*-ksi	38	35	40	37	35	40	37
e(2 in) -min -%	7	3	6	4	2	6	4

* Applicable only for thickness range shown.

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

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3.013 Aluminum Association mechanical property limits for sheet and plate, Table 3.013.

TABLE 3.013

Source	(10)							
Alloy	2219							
Form	Sheet and plate							
Condition	O	T31	T31, T351	T37	T62	T81	T81, T851	T87
Width - in	All							
Thickness - in	0.020-2.000	0.020-0.249	0.250-6.000	0.020-5.000	0.020-2.000	0.020-0.249	0.250-6.000	0.020-5.000
F_{tu}, -min*-ksi	32.0	46.0	46.0-39.0	49.0-43.0	54	59.0-61.0	61.0-54.0	63.0-57.0
F_{ty}, -min*-ksi	16.0	29.0-28.0	28.0-25.0	38.0-34.0	36	44.0	44.0-41.0	50.0-47.0
e(2 in), -min -%	12	8-10	10-8	6-4	6	6	6-4	5-3

* Maximum for O Condition

3.014 Aluminum Association mechanical property limits for clad sheet and plate, Table 3.014.

TABLE 3.014

Source	(10)							
Alloy	Clad 2219							
Form	Clad sheet and plate							
Condition	O	T31	T31, T351	T37	T62	T81	T81, T851	T87
Width-in	All							
Thickness-in	0.040-2.000	0.040-0.249	0.250-0.499	0.040-0.499	0.040-0.499	0.040-0.249	0.250-0.499	0.040-0.499
F_{tu}, -min*-ksi	32.0	42.0-44.0	44	45.0-47.0	47.0-51.0	55.0-58.0	58.0	57.0-59.0
F_{ty}, -min*-ksi	16.0	25.0-26.0	26	34.0-35.0	32.0-34.0	40.0-42.0	42.0	46.0-48.0
e(2 in), -min- %	12	10	10	6	6	6	6	5

* Maximum for O Condition

3.015 Aluminum Association mechanical property limits for rolled or cold finished wire, rod and bar and extruded rod, bar, shapes and tubes, Table 3.015.

TABLE 3.015

Source	(10)							
Alloy	2219							
Form	Rolled or CF wire, rod and bar		Extruded rod, bar, shapes and tube					
Condition	T851		O	T31, T3510, T3511		T62		T81, T8510, T8511
Area - sq in	-		All	≤ 25		≤ 25	≤ 32	≤ 25
Thickness or Dia - in	0.500 - 2.000	2.001 - 4.000	All	≤ 0.499	0.500-2.999	≤0.999	≥ 1.000	≤ 2.999
F_{tu}, -min*-ksi	58	57	32	42	45	54		58
F_{ty}, -min*-ksi	40	39	18	26	27	36		42
e(in) -min -%	4	4	12	14	14	6		6

* Maximum for O Condition

3.016 Aluminum Association mechanical property limits for die forgings, hand forgings and rolled rings, Table 3.016.

TABLE 3.016

Source	(10)										
Alloy	2219										
Form	Die forgings		Hand forgings						Rolled rings		
Condition	T6		T6			T852			T6		
Thickness - in	≤4.00		≤ 4.00						≤ 2.500		
Direction	L	T	L	LT	ST	L	LT	ST	Tang.	Axial	Radial
F_{tu}, -min-ksi	58	56	58	55	53	62	62	60	56	55	53
F_{ty}, -min-ksi	38	36	40	37	35	50	49	46	40	37	35
e(2 in) -min-%	10	4	6	4	2	6	4	3	6	4	2

3.02 Mechanical Properties at Room Temperature

3.021 Tension

3.0211 Stress-strain diagrams. (See 3.0311).

3.0212 Typical tensile properties, Table 3.0212.

TABLE 3.0212

Source	(9)											
Alloy	2219											
Form	Sheet and plate											
Condition	O	T42	T31, T351		T37		T62		T81, T851		T87	
Direction	T	T	L	T	L	T	L	T	L	T	L	T
F_{tu}, typ -ksi	25	50	52	52	56	56	58	58	66	66	68	68
F_{ty}, typ -ksi	11	25	36	34	45	44	40	40	50	50	56	56
e(2 in), typ -%	18	20	20	16	12	10	10	10	10	10	10	10

	Al
6.3	Cu
0.3	Mn
0.18	Zr
0.10	V
0.06	Ti

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3.0213 Effect of exposure to elevated temperatures on tensile properties of forged rod in T6 Condition, Fig. 3.0213.
3.0214 Effect of exposure to elevated temperatures on tensile properties of plate in T6 Condition, Fig. 3.0214.
3.0215 Effect of exposure on tensile properties of plate in T62 Condition, Fig. 3.0215.
3.0216 Effect of exposure on tensile properties of sheet and plate in T81 and T851 Condition, Fig. 3.0216.
3.0217 Effect of exposure on tensile properties of plate in T87 Condition, Fig. 3.0217.
3.022 Compression
3.0221 Stress-strain diagrams
3.0222 Typical compressive yield strength, Table 3.0222.

TABLE 3.0222

Source	(9)					
Alloy	2219					
Form	Sheet and plate					
Condition	T62		T81, T851		T87	
Direction	L	T	L	T	L	T
F_{cy}, typ - ksi	44	44	53	54	57	60

3.023 Impact. See 3.033.
3.024 Bending
3.025 Torsion and shear
3.0251 Typical ultimate shear strength, Table 3.0251.

TABLE 3.0251

Source	(9)		
Alloy	2219		
Form	Sheet and plate		
Condition	T62	T81, T851	T87
F_{su}, typ. - ksi	36	38	40

3.026 Bearing
3.0261 Typical bearing properties, Table 3.0261.

TABLE 3.0261

Source	(9)					
Alloy	2219					
Form	Sheet and plate					
Condition	T62		T81, T851		T87	
e/D	1.5	2.0	1.5	2.0	1.5	2.0
F_{bru}, typ. - ksi	90	120	96	125	100	131
F_{bry}, typ. - ksi	67	80	76	87	80	90

3.027 Stress concentration. See 3.037.
3.0271 Notch properties
3.0272 Fracture toughness
3.028 Combined properties

3.03 Mechanical Properties at Various Temperatures
3.031 Tension
3.0311 Stress-strain diagrams
3.03111 Stress-strain curves for alloy in T6 Condition at room and elevated temperatures, Fig. 3.03111.
3.03112 Stress-strain curves for T62 sheet at low temperatures, Fig. 3.03112.
3.03113 Stress-strain curves for T81 sheet at low temperatures, Fig. 3.03113.
3.03114 Stress-strain curves for T87 sheet at low temperatures, Fig. 3.03114.
3.0312 Exposure time effect on tensile properties
3.03121 Effect of exposure and test temperature on tensile properties of alloy in T6 Condition, Fig. 3.03121.
3.03122 Effect of test temperature and exposure time on tensile properties of plate in T6 Condition, Fig. 3.03122.
3.03123 Effect of test temperature and exposure time on tensile properties of sheet and plate in T81 and T851 Condition, Fig. 3.03123.
3.03124 Effect of test temperature and exposure time on tensile properties of plate in T87 Condition, Fig. 3.03124.
3.03125 Effect of test temperature and exposure time on tensile properties of forgings in T6 Condition, Fig. 3.03125.
3.0313 Effect of test temperature on minimum tensile properties of alloy in T62 and T81 Conditions, Fig. 3.0313.
3.0314 Effect of test temperature on tensile properties of alloy in T6 and T62 Conditions, Fig. 3.0314.
3.0315 Effect of low temperature on tensile properties of sheet in T62 Condition, Fig. 3.0315.
3.0316 Effect of low temperature on tensile properties of sheet in T81 Condition, Fig. 3.0316.
3.0317 Effect of low temperature on tensile properties of sheet and plate in T87 Condition, Fig. 3.0317.
3.0318 Effect of elevated temperature on the tensile properties of sheet in T81 Condition, Fig. 3.0318.
3.0319 Effect of test temperature on tensile properties of extrusion in T6 Condition, Fig. 3.0319.
3.032 Compression
3.0321 Stress-strain diagrams
3.0322 Effect of test temperature on compressive yield stress of sheet and plate in the T62 Condition, Fig. 3.0322.
3.033 Impact
3.0331 Effect of low temperature on impact strength of plate in T87 Condition, Fig. 3.0331.
3.034 Bending
3.035 Torsion and shear
3.0351 Effect of test temperature on shear strength of sheet and plate in T62 Condition, Fig. 3.0351.
3.0352 Effect of low temperature on shear strength of sheet in various conditions, Fig. 3.0352.
3.036 Bearing
3.0361 Effect of test temperature on bearing properties of sheet in T31 and T81 Conditions, Fig. 3.0361.
3.037 Stress concentration
3.0371 Notch properties
3.03711 Effect of low temperature on tensile and notch properties of alloy in T87 Condition, Fig. 3.03711.
3.03712 Effect of stress concentration factor on low temperature notch strength of sheet and plate, Fig. 3.03712.
3.0372 Fracture toughness
3.03721 Effect of test temperature on net fracture strength of T81 sheet, Fig. 3.03721.
3.038 Combined properties

3.04 Creep and Creep Rupture Properties
3.041 Creep rupture curves for extrusion in T6 Condition at 400 and 600F, Fig. 3.041.
3.042 Creep and creep rupture curves for plate and forging in T6, T87 and T851 Conditions at room temperature, Fig. 3.042.
3.043 Creep and creep rupture curves for plate and forgings in T6, T62, T87 and T851 Conditions at 300F, Fig. 3.043.
3.044 Creep and creep rupture curves for forgings in T6 Condition from 400F to 700F, Fig. 3.044.
3.045 Creep and creep rupture curves for plate in T62, T851, and T87 Conditions from 400F to 700F, Fig. 3.045.
3.046 Creep and creep rupture curves for sheet in T81 Condition from 300F to 600F, Fig. 3.046.
3.047 Creep curves for clad sheet in T6 Condition at 400F, Fig. 3.047.
3.048 Creep curves for clad sheet in T6 Condition at 500F, Fig. 3.048.
3.049 Creep curves for clad sheet in T6 Condition at 600F, Fig. 3.049.

3.05 Fatigue Properties
3.051 Fatigue strength of alloy in T6 Condition at room and elevated temperatures, Table 3.051.

TABLE 3.051

Source	(3)							
Alloy	2219							
Form	Forged rod							
Condition	T6							
Temp - F	Method	Stress Ratio		Fatigue Strength - ksi at Cycles				
		A	R	10^5	10^6	10^7	10^8	5×10^8
RT	Rot Beam	∞	-1	30	25	21	18.5	17.5
300				27	22	17.5	14.5	13.5
400				25	20	15	12	11
500				22	17	12	9	8
600				18	13	9	7	6.5

3.052 Fatigue strength of extrusion in T6 Condition at 400 and 600F, Table 3.052.

TABLE 3.052

Source	(5)						
Alloy	2219						
Form	Extrusion						
Condition	T6						
Thickness-in	Temp-F	Method	Stress Ratio		Fatigue Strength-ksi at Cycles		
			A	B	10^5	10^6	10^7
1 1/2	400	Direct stress	+1	0	36	28	22
	600				25	20	14
1/8	600				25	20	16

3.053 Fatigue limit in rotating beam tests at 5×10^8 cycles, Table 3.053.

TABLE 3.053

Source	(9)	
Alloy	2219	
Form	Sheet and plate	
Condition	T62, T81, T851, T87	
Temp - F	Method	Fatigue limit-5×10^8 cycles
RT	Rot beam	15 ksi

3.054 S-N curves for smooth and notched specimens of plate in T81 Condition, Fig. 3.054.

3.055 S-N curves for forgings in T6 Condition at 400 and 600F, Fig. 3.055.

3.056 S-N curves for sheet in T87 Condition at room temperature and low temperatures, Fig. 3.056.

3.06 Elastic Properties

3.061 Poisson's ratio

3.062 Modulus of elasticity

3.0621 Modulus of elasticity for all Conditions at room temperature, $E = 10.6 \times 10^3$ ksi, (9).

3.0623 Modulus of elasticity at various temperatures for forgings in T6 Condition, Fig. 3.0623.

3.0624 Modulus of elasticity at various temperatures for sheet and plate in various Conditions, Fig. 3.0624.

3.0625 Modulus of elasticty at low temperature of sheet in T81 Condition, Fig. 3.0625.

3.063 Modulus of rigidity

3.0631 Design value of modulus of rigidity at room temperature for sheet and plate, $G = 4.0 \times 10^3$ ksi, (9).

4. FABRICATION

4.01 Formability

4.011 General. The alloy exhibits equal or superior formability characteristics to 2024 and 7075 for comparable tempers, (22).

4.012 Forging. Forgings are made using either the open die or closed die methods and by impact or pressure. Small runs are made using the hand forging open die techniques. Hand forgings over a ton in weight can be made.

4.013 Cold forming. The formability of the alloy in sheet and plate is directly related to the temper strength and ductility. Suggested minimum bend radii of sheet and plate in various tempers, Table 4.013.

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

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4.02 Machining and Grinding

4.021 The alloy has good machining qualities in the annealed state. Since most of the machining is done in the heat treated conditions, lathe tools should be ground to 10-20° side rake and 8-10° clearance. Parting tools should have a 15-20° top rake with a 4-5° side rake. Planer and shaper tools for roughing cuts should have a 12-15° top rake, 32-38° side rake and a 8-10° front and side clearance. Finishing tools should have a 45-50° top rake, 50-60° side rake, 8-10° front clearance and little or no side clearance. Twist drills should have larger spiral angles than standard, highly polished deep flutes, narrow bands, and up to 18° lip clearance. Threading taps should have highly polished flutes and should be under cut. Spiral fluted taps are usually better than straight fluted. The rake angles should be increased to 12-18°. Soluble oil emulsions, kerosene, and kerosene-lard oil mixtures are recommended for most machining operations, but high viscosity lubricants are recommended for tapping operations, (22).

4.03 Welding

4.031 General. The alloy can be satisfactory welded by fusion and resistance welding techniques. Brazing, gas welding and soldering are not considered suitable techniques for joining the alloy, (9).

4.032 Fusion welding. Fusion welding of the alloy using 2319 alloy filler and the inert gas metal arc welding process has been found to be superior to any other heat treatable alloy of similar strength. The alloy is very similar to 6061 using 4043 filler with respect to ease of welding. Direct fusion welds are entirely practicable without the use of filler metal, (9).

TABLE 4.013

Source	(9)									
Alloy	2219									
Form	Sheet and plate									
Thickness - in Condition	Minimum bend radii for 90° cold bends									
	1/64	1/32	1/16	1/8	3/16	1/4	3/8	1/2	3/4	1
0	0		1/2 - 1 1/2t			1-2t		2-3t		3-4t
T42	0-1t		1-2t		1 1/2-2 1/2t		2-3t	2 1/2-3 1/2t	3-4t	3 1/2-4 1/2t
T31	1/2 - 1 1/2t	1 - 2t	1 1/2-2 1/2t	1 1/2 - 3t	2-4t		2 1/2-4t	3-5t		
T37	1/2 - 1 1/2t	1 - 2t	1 1/2-3t	2 1/2 - 4t	3 - 4 1/2t	3 1/2-5t	4-6t	5-7t		
T62, T81	2 - 3 1/2t	2 1/2 - 4t	3-5t	4-6t		5-7t		6-9t		
T87	2 1/2 - 4t	3- 5t	4-6t	5-7t	5 1/2-8t	6-9t	7-10t	8-11t		

4.0321 Welds in the alloy have high tensile efficiency and good ductility following a post weld heat treatment. Typical mechanical properties of butt welds, Table 4.0321.

TABLE 4.0321

Source	(9)			
Alloy	2219			
Form	Butt welded sheet and plate			
Condition	T81, T87	T31	-	-
After welding	As welded	Aged to T81 or T87	Reheat and Aged to T62	Reheat, shot peened and aged to T81
F_{tu}, typ-ksi	41	45	57	63
F_{ty}, typ-ksi	30	39	39	49
e(2in) type-%	3	2	8	8

Al	
6.3	Cu
0.3	Mn
0.18	Zr
0.10	V
0.06	Ti

2219
CLAD 2219

4.033 Resistance welding. The alloy can be successfully spot and seam welded using machine schedules similar to those established for 2014 and 2024 alloys. Conventional pre-cleaning practices are used. Shear strength of resistance welds is in the same range as obtained with 2014 and 2024 alloys. (9).

4.04 Heat Treatment

4.05 Surface Treatment

4.051 The same techniques used for anodizing, hard coating, and producing conversion coatings on 2024 and 2014 can be used on this alloy. (9).

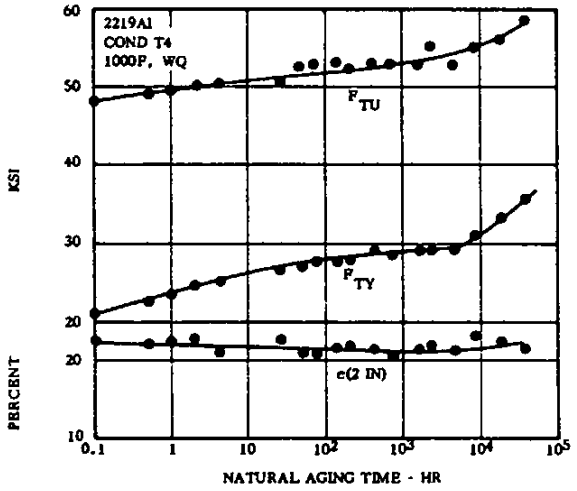


FIG. 1.0561 EFFECT ON NATURAL AGING TIME ON TENSILE PROPERTIES OF ALLOY IN T4 CONDITION (9, p. 26)

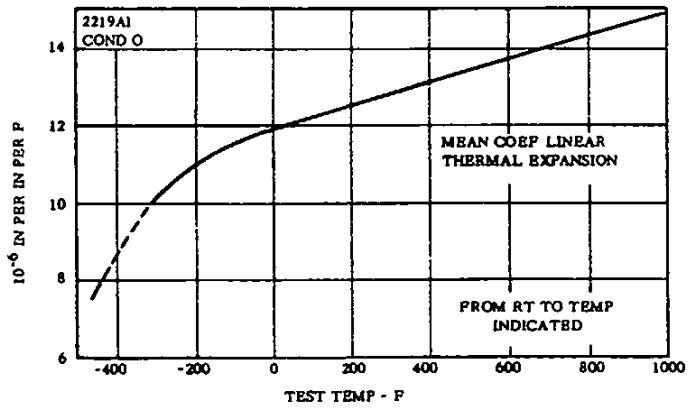


FIG. 2.014 THERMAL EXPANSION (11)

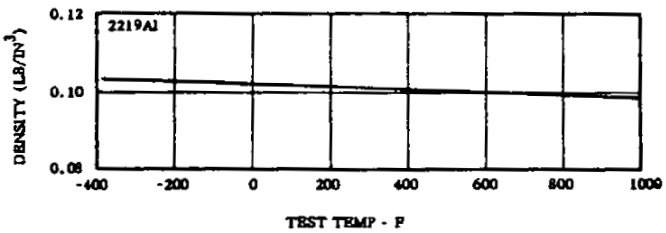


FIG. 2.021 DENSITY (11)

	Al
6.3	Cu
0.3	Mn
0.18	Zr
0.10	V
0.06	Ti

2219
CLAD 2219

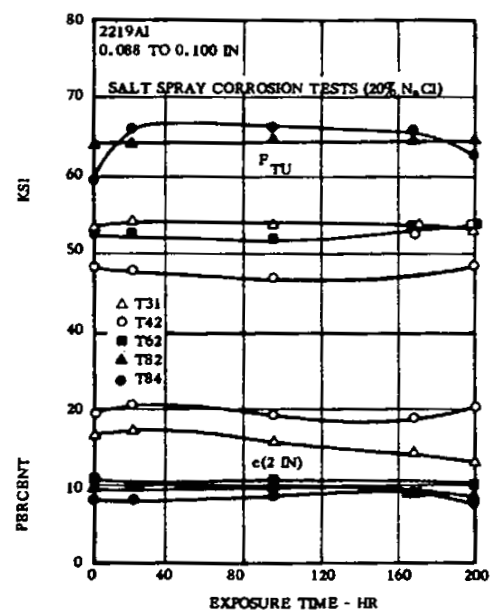


FIG. 2.0311 EFFECT OF SALT SPRAY CORROSION ON TENSILE PROPERTIES OF SHEET IN VARIOUS TEMPERS

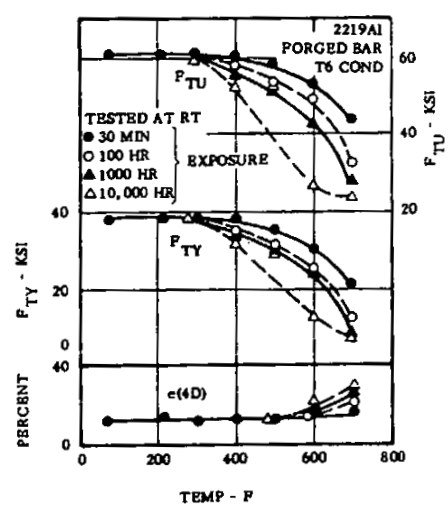


FIG. 3.0213 EFFECT OF EXPOSURE TO ELEVATED TEMPERATURES ON TENSILE PROPERTIES OF FORGED ROD IN T6 CONDITION (3)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

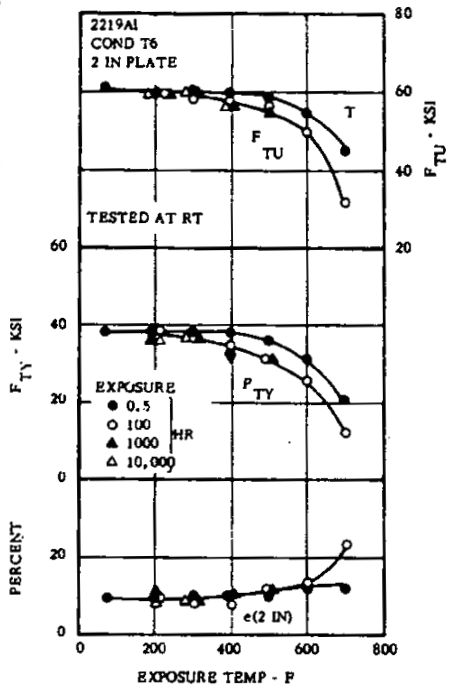


FIG. 3.0214 EFFECT OF EXPOSURE ON TENSILE PROPERTIES OF PLATE IN T6 CONDITION (13)

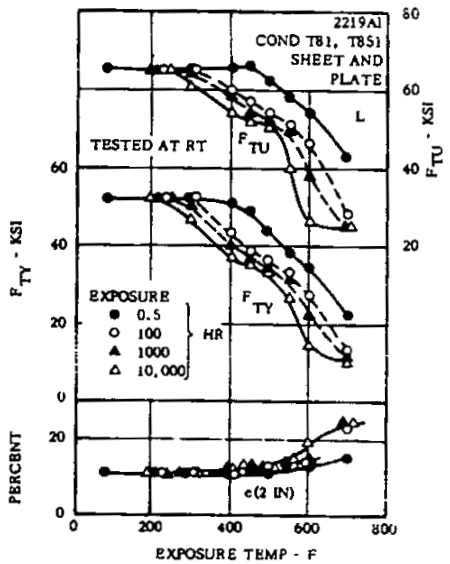


FIG. 3.0216 EFFECT OF EXPOSURE ON TENSILE PROPERTIES OF SHEET AND PLATE IN T81 AND T851 CONDITION (9, p. 15)

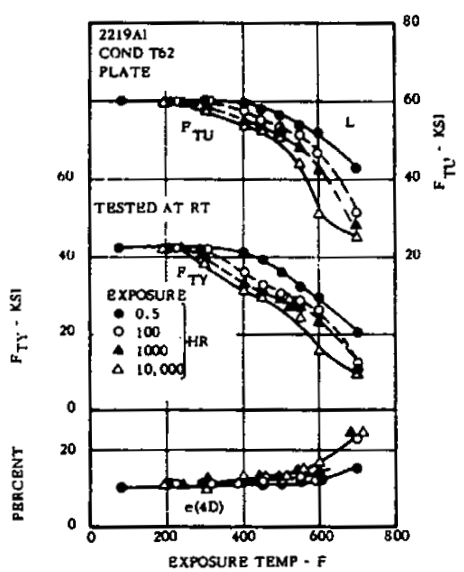


FIG. 3.0215 EFFECT OF EXPOSURE ON TENSILE PROPERTIES OF PLATE IN T62 CONDITION (9, p. 14)

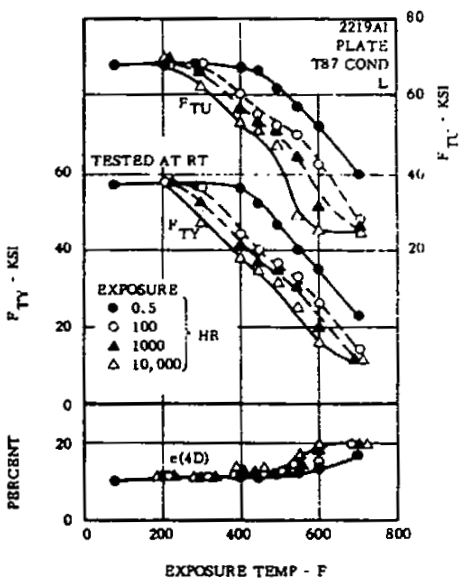


FIG. 3.0217 EFFECT OF EXPOSURE ON TENSILE PROPERTIES OF PLATE IN T87 CONDITION (9, p. 17)

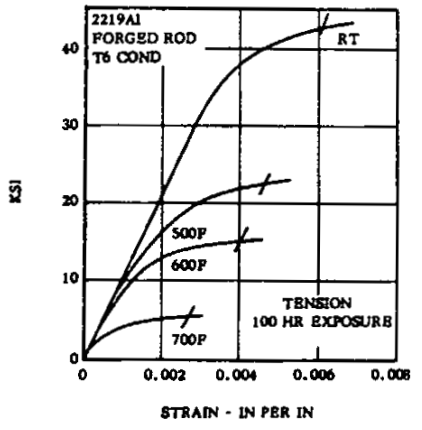
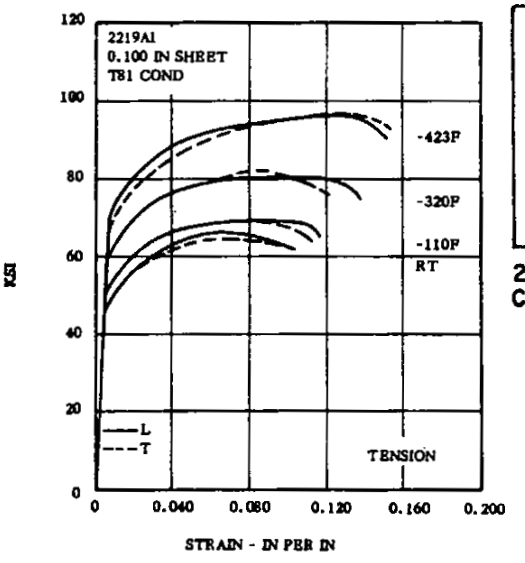


FIG. 3.03111 STRESS-STRAIN CURVES FOR ALLOY IN T6 CONDITION AT ROOM AND ELEVATED TEMPERATURES (4, p. 144)



Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

FIG. 3.03113 STRESS-STRAIN CURVES FOR T81 SHEET AT LOW TEMPERATURES (14, p. A.5.h-2, A-5.h-3)

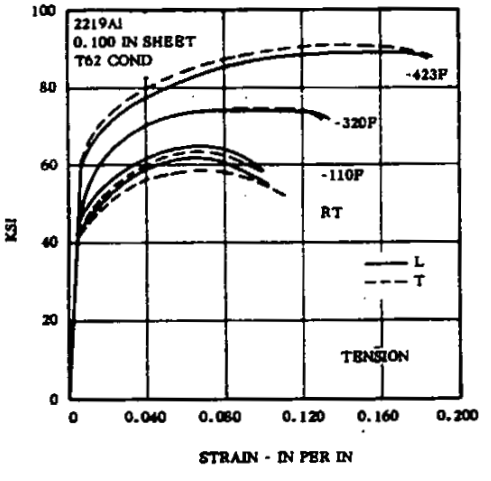


FIG. 3.03112 STRESS-STRAIN CURVES FOR T62 SHEET AT LOW TEMPERATURES (14, p. A.5.h, A.5.h-1)

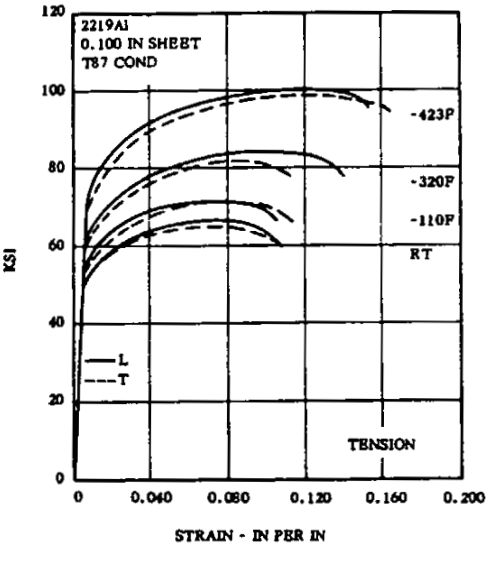


FIG. 3.03114 STRESS-STRAIN CURVES FOR T87 SHEET AT LOW TEMPERATURES (14, p. A.5.h-4, A.5.h-5)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

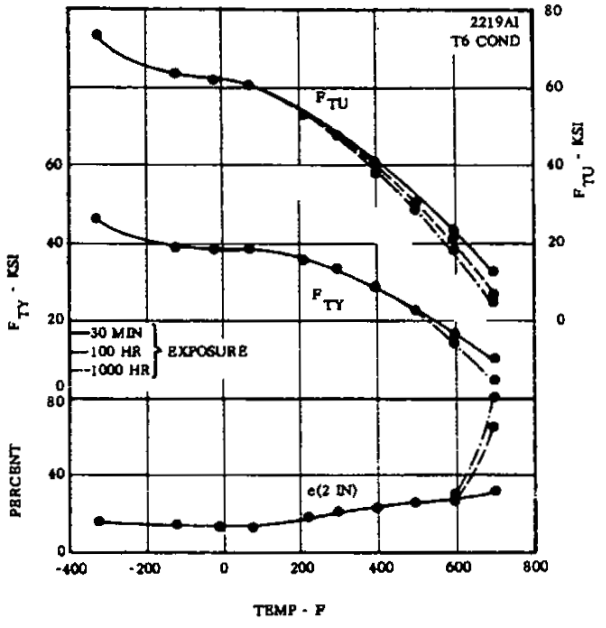


FIG. 3.03121 EFFECT OF EXPOSURE AND TEST TEMPERATURE ON TENSILE PROPERTIES OF ALLOY IN T6 CONDITION (3)

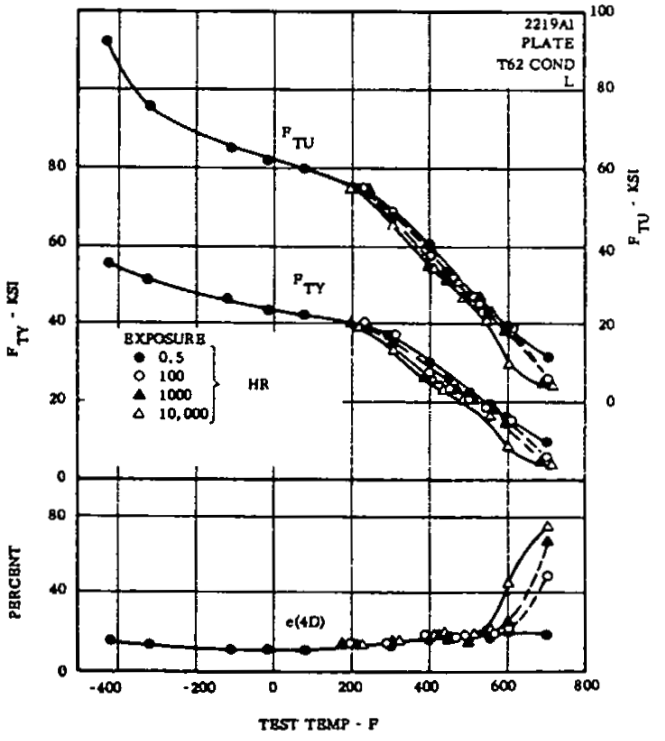


FIG. 3.03122 EFFECT OF TEST TEMPERATURE AND EXPOSURE TIME ON TENSILE PROPERTIES OF PLATE IN T6 CONDITION (9, p. 14)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

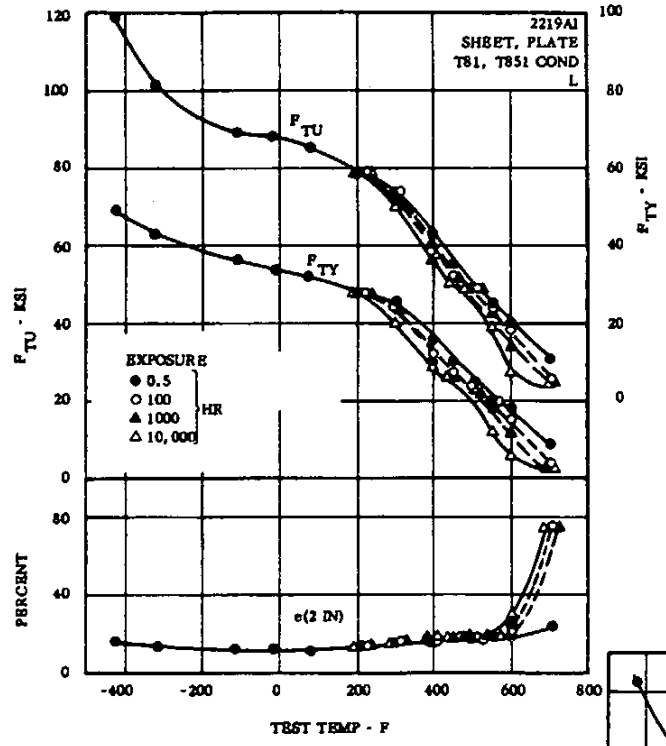


FIG. 3.03123 EFFECT OF TEST TEMPERATURE AND EXPOSURE TIME ON TENSILE PROPERTIES OF SHEET AND PLATE IN T81 AND T851 CONDITION (9, p.15)

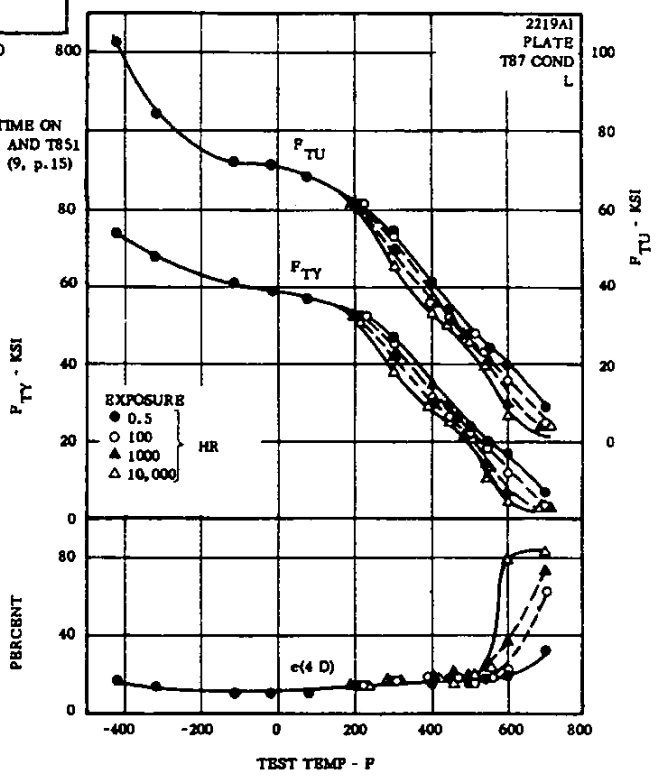


FIG. 3.03124 EFFECT OF TEST TEMPERATURE AND EXPOSURE TIME ON TENSILE PROPERTIES OF PLATE IN T87 CONDITION (9, p.17)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

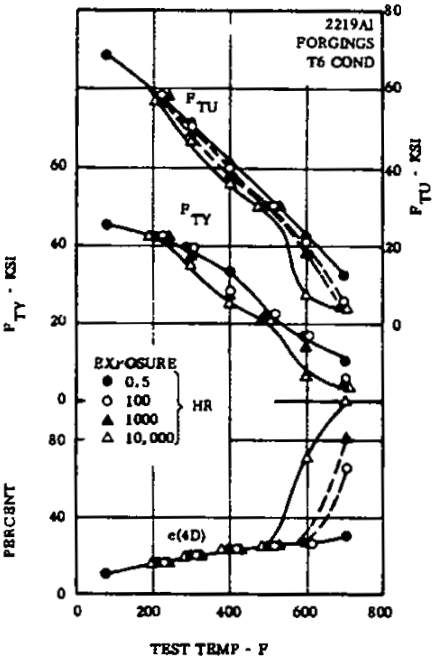


FIG. 3.0312S EFFECT OF TEST TEMPERATURE AND EXPOSURE TIME ON TENSILE PROPERTIES OF FORGINGS IN T6 CONDITION (9,p.18)

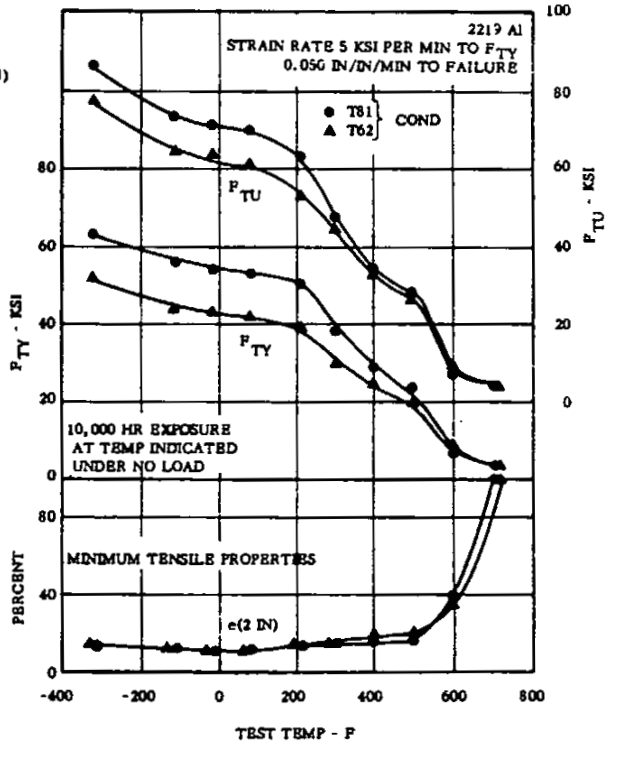


FIG. 3.0313 EFFECT OF TEST TEMPERATURE ON MINIMUM TENSILE PROPERTIES OF ALLOY IN T62 AND T81 CONDITIONS (11, p. 30)

	Al
6.3	Cu
0.3	Mn
0.18	Zr
0.10	V
0.06	Ti

2219
CLAD 2219

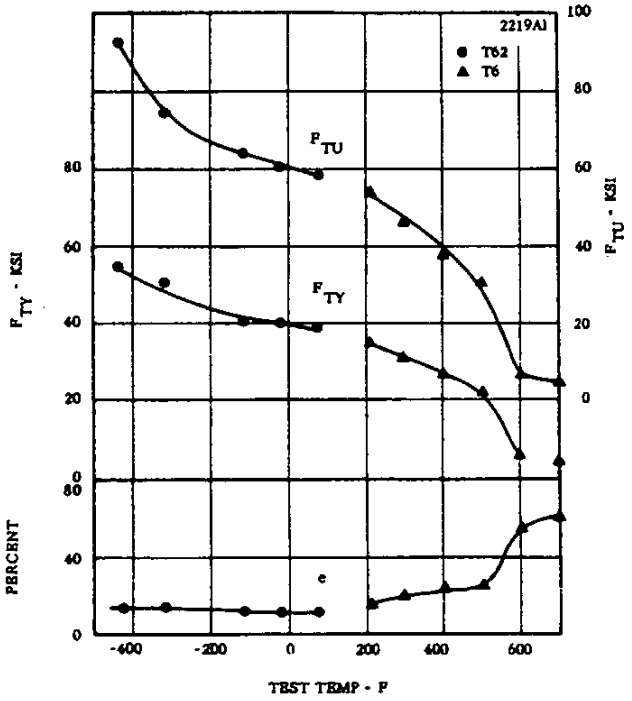


FIG. 3.0314 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF ALLOY IN T6 AND T62 CONDITION (15, p. 45, 49)

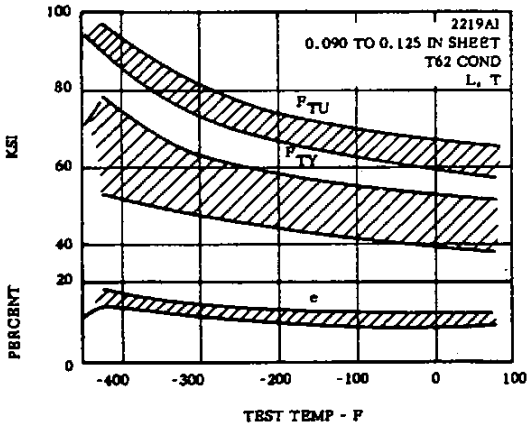


FIG. 3.0315 EFFECT OF LOW TEMPERATURE ON TENSILE PROPERTIES OF SHEET IN T62 CONDITION (14, p. A. 5. A, A. 5. b, A. 5c, A. 5c-1)

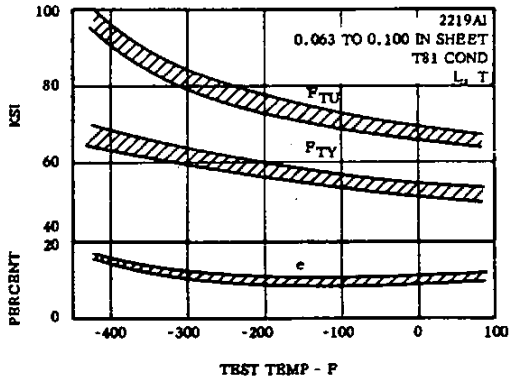


FIG. 3.0316 EFFECT OF LOW TEMPERATURE ON TENSILE PROPERTIES OF SHEET IN T81 CONDITION (14, p. A. 5a-1, A. 5. b-1, A. 5b-2, A. 5c-2, A. 5c-3)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

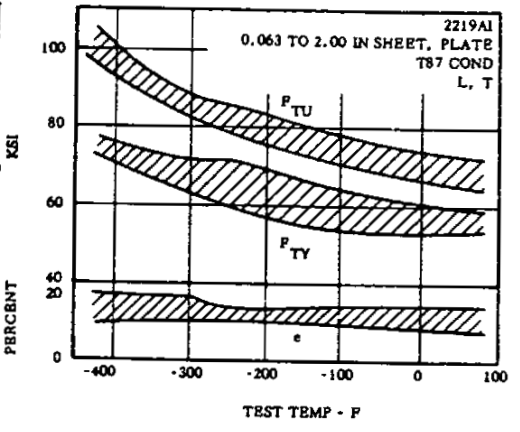


FIG. 3.0317 EFFECT OF LOW TEMPERATURE ON TENSILE PROPERTIES OF SHEET AND PLATE IN T87 CONDITION (14, p. A.5a-2, A.5b-3, A.5c-4)

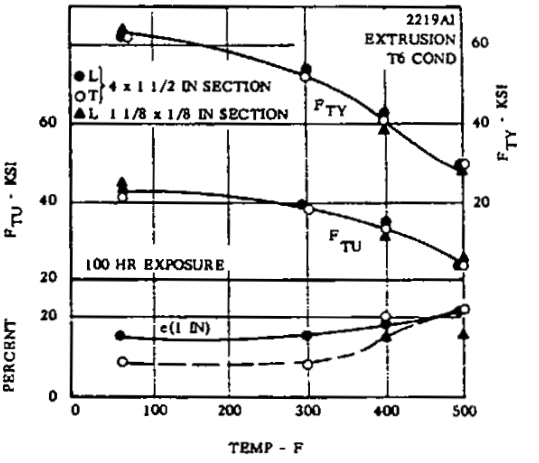


FIG. 3.0319 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF EXTRUSION IN T6 CONDITION (5, p. 8, 9)

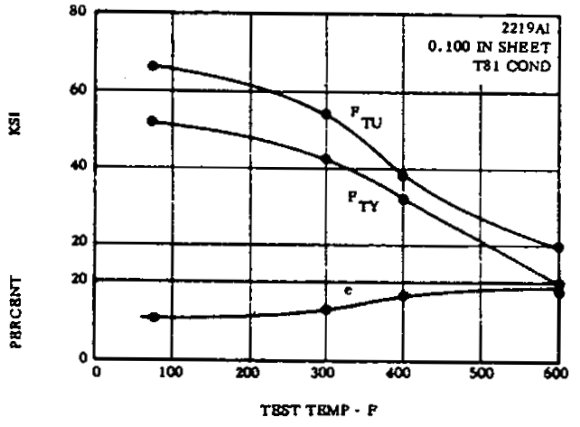


FIG. 3.0318 EFFECT OF ELEVATED TEMPERATURE ON THE TENSILE PROPERTIES OF SHEET IN T81 CONDITION (16)

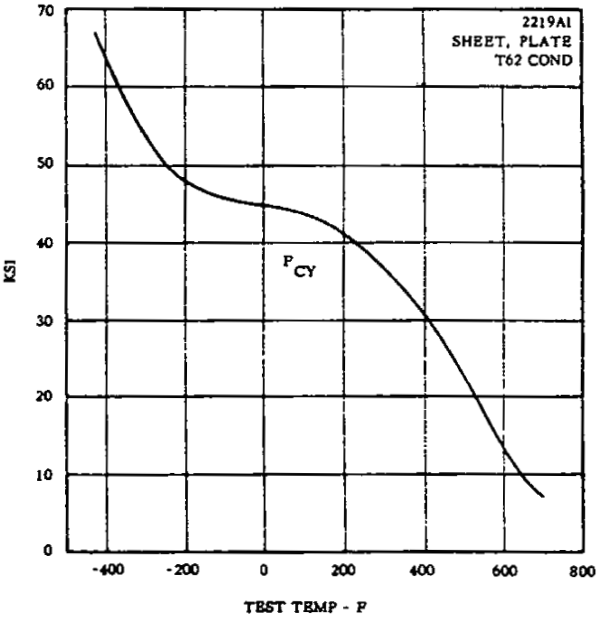


FIG. 3.0322 EFFECT OF TEST TEMPERATURE ON COMPRESSIVE YIELD STRESS OF SHEET AND PLATE IN THE T62 CONDITION (17)

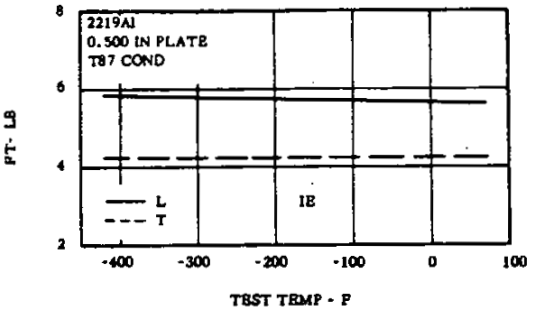
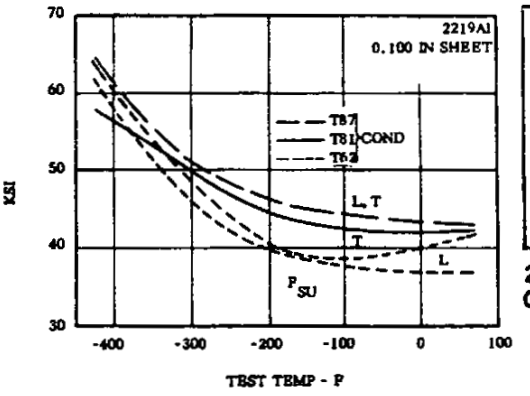


FIG. 3.0331 EFFECT OF LOW TEMPERATURE ON IMPACT STRENGTH OF PLATE IN T87 CONDITION (14, p. A.5.j)



Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

FIG. 3.0352 EFFECT OF LOW TEMPERATURE ON SHEAR STRENGTH OF SHEET IN VARIOUS CONDITIONS (14, p. A.5p, A.5.p)

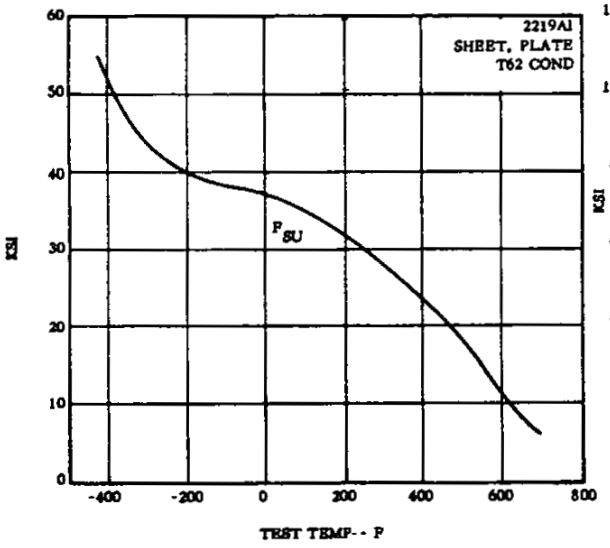


FIG. 3.0351 EFFECT OF TEST TEMPERATURE ON SHEAR STRENGTH OF SHEET AND PLATE IN T62 CONDITION (17)

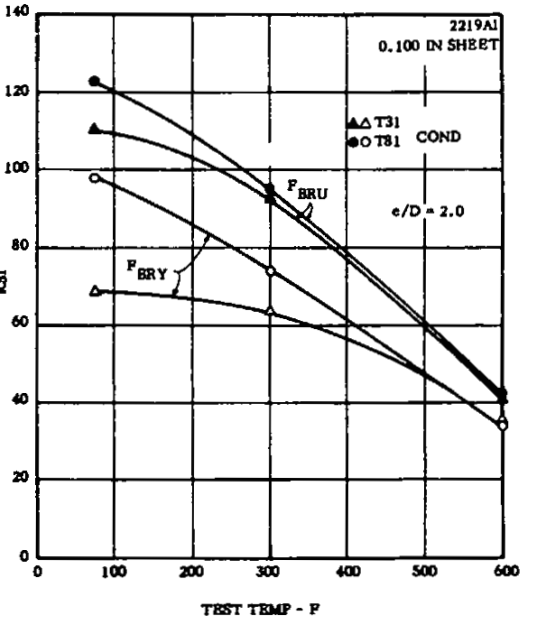


FIG. 3.0361 EFFECT OF TEST TEMPERATURE ON BEARING PROPERTIES OF SHEET IN T31 AND T81 CONDITIONS (16)

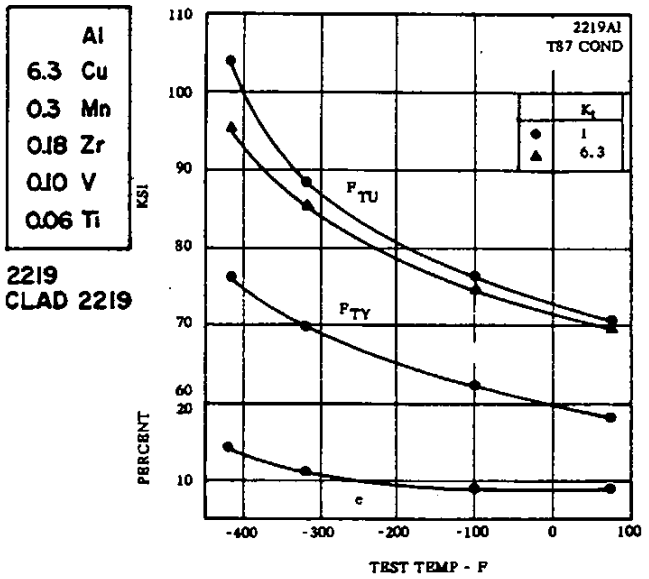


FIG. 3.03711 EFFECT OF LOW TEMPERATURE ON TENSILE AND NOTCH PROPERTIES OF ALLOY IN T87 CONDITION (18)

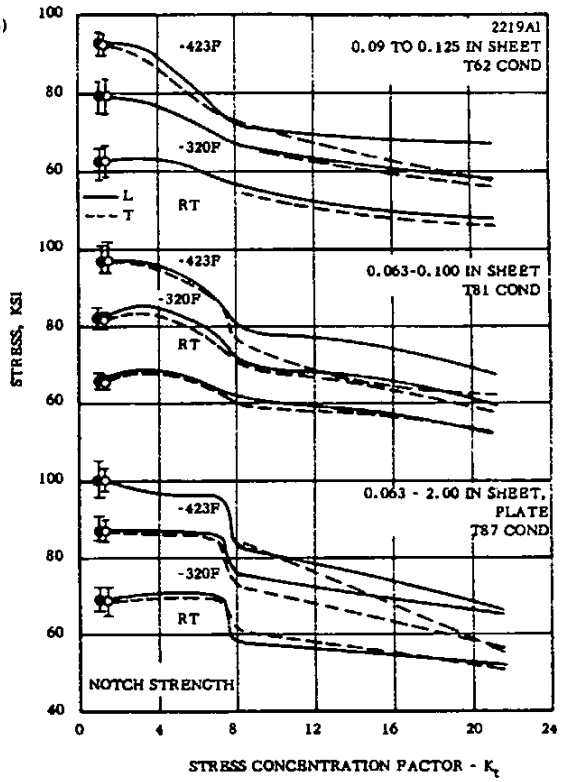


FIG. 3.03712 EFFECT OF STRESS CONCENTRATION FACTOR ON LOW TEMPERATURE NOTCH STRENGTH OF SHEET AND PLATE (14, p. A.5.e)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

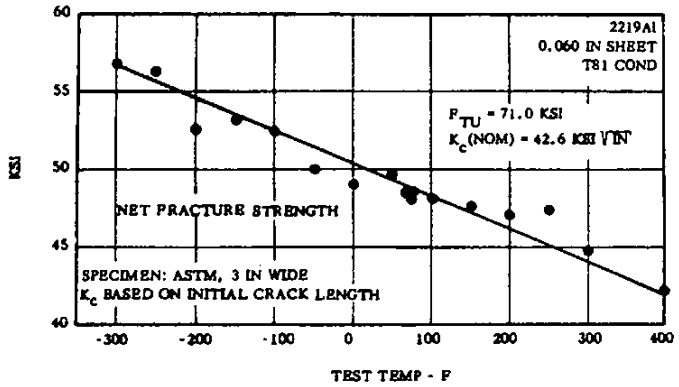


FIG. 3.03721 EFFECT OF TEST TEMPERATURE ON NET FRACTURE STRENGTH OF T81 SHEET

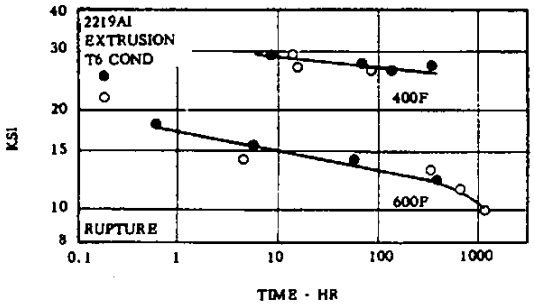


FIG. 3.041 CREEP RUPTURE CURVES FOR EXTRUSION IN T6 CONDITION AT 400 AND 600F (5, p. 13)

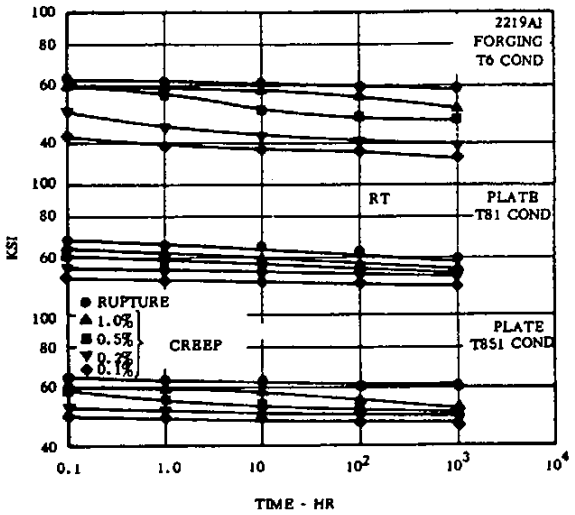


FIG. 3.042 CREEP AND CREEP RUPTURE CURVES FOR PLATE AND FORGING IN T6, T87 AND T851 CONDITIONS AT ROOM TEMPERATURE (9, p. 16, 17, 18)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

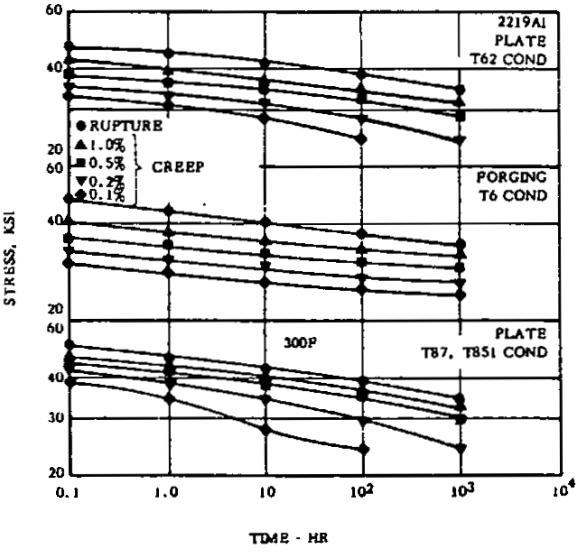


FIG. 3.043 CREEP AND CREEP RUPTURE CURVES FOR PLATE AND FORGING IN T6, T62, T87 AND T851 CONDITIONS AT 300F (9, p. 14, 16, 17, 18)

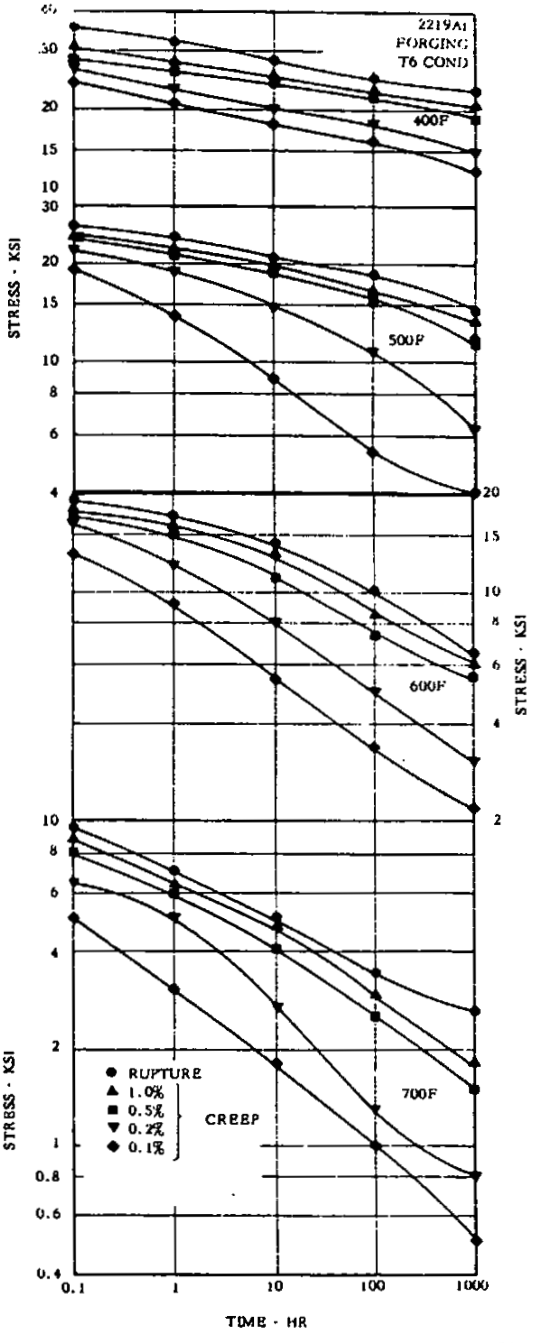


FIG. 3.044 CREEP AND CREEP RUPTURE CURVES FOR FORGINGS IN T6 CONDITION FROM 400F TO 700F (9, p. 18)

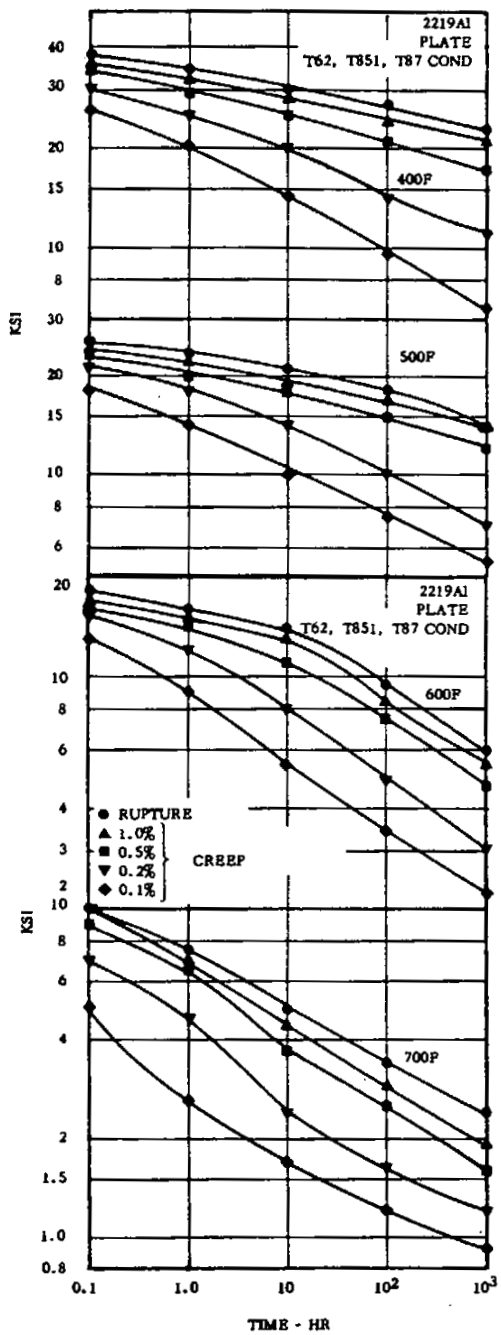
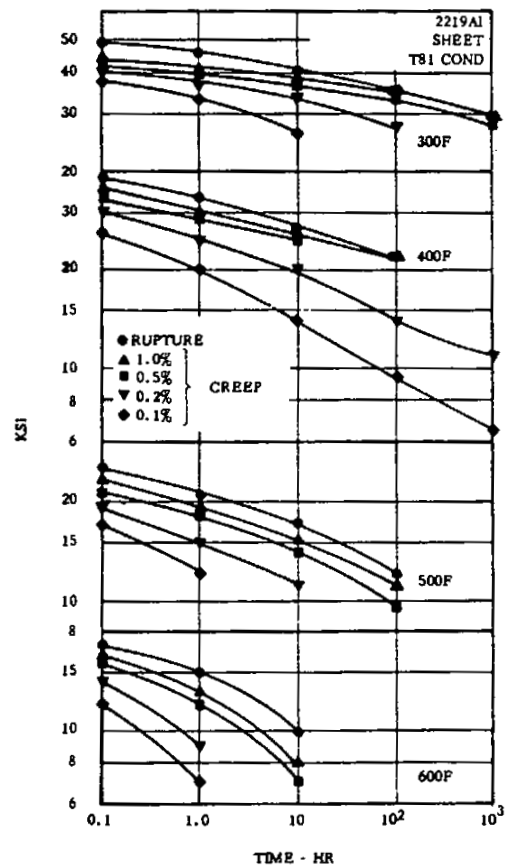


FIG. 3.045 CREEP AND CREEP RUPTURE CURVES FOR PLATE IN T62, T851 AND T87 CONDITIONS FROM 400F TO 700F (9, p. 14, 16, 17)



Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

FIG. 3.046 CREEP AND CREEP RUPTURE CURVES FOR SHEET IN T81 CONDITION FROM 300F TO 600F (9, p. 15)

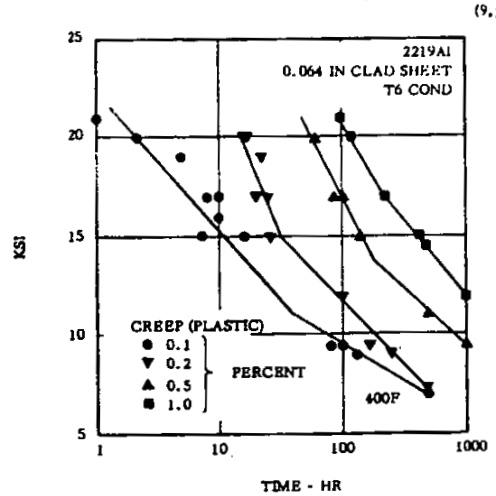


FIG. 3.047 CREEP CURVES FOR CLAD SHEET IN T6 CONDITION AT 400F (19)

Al
6.3 Cu
0.3 Mn
0.18 Zr
0.10 V
0.06 Ti

2219
CLAD 2219

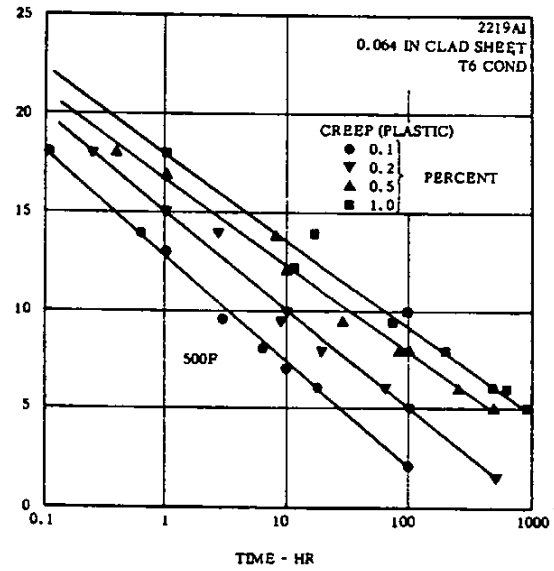


FIG. 3.048 CREEP CURVES FOR CLAD SHEET IN T6 CONDITION AT 500F (19)

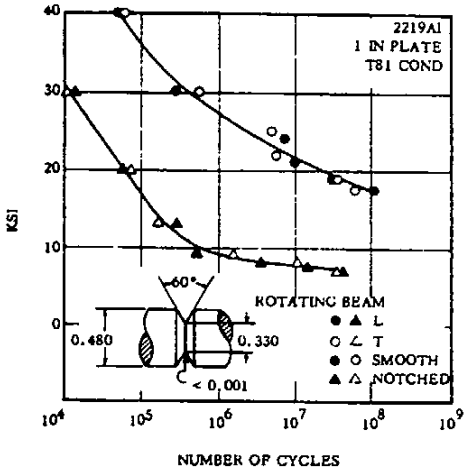


FIG. 3.054 S-N CURVES OF SMOOTH AND NOTCHED SPECIMENS OF PLATE IN T81 CONDITION (9, p. 22)

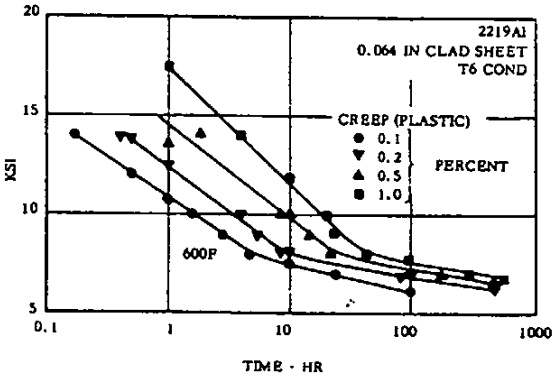


FIG. 3.049 CREEP CURVES FOR CLAD SHEET IN T6 CONDITION AT 600F (19)

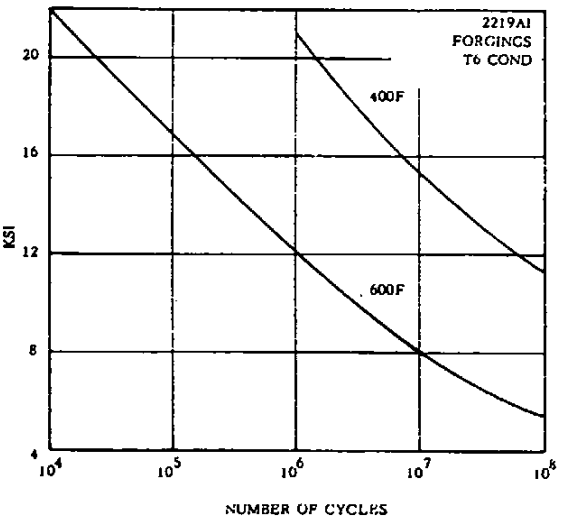


FIG. 3.055 S-N CURVES FOR FORGINGS IN T6 CONDITION AT 400 AND 600F (20)

	Al
6.3	Cu
0.3	Mn
0.18	Zr
0.10	V
0.06	Ti

2219
CLAD 2219

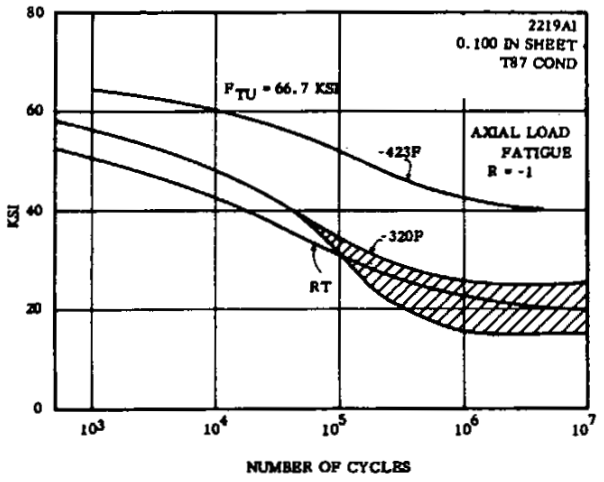


FIG. 3.056 S-N CURVES FOR SHEET IN T87 CONDITION AT ROOM TEMPERATURE AND LOW TEMPERATURES (14, p. A.5.0)

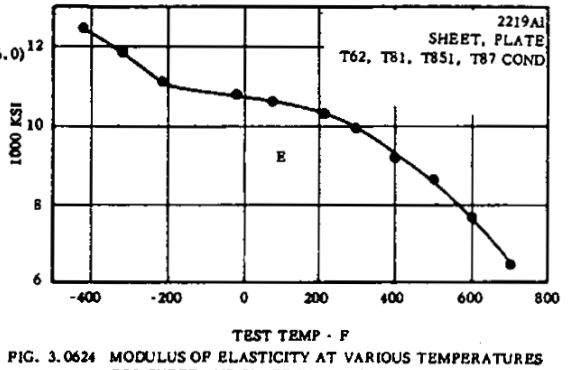


FIG. 3.0624 MODULUS OF ELASTICITY AT VARIOUS TEMPERATURES FOR SHEET AND PLATE IN VARIOUS CONDITIONS (9, p. 14-17)

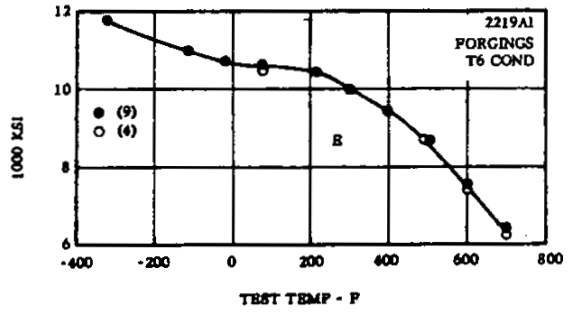


FIG. 3.0623 MODULUS OF ELASTICITY AT VARIOUS TEMPERATURES FOR FORGINGS IN T6 CONDITION (4, p. 144)(9, p. 18)

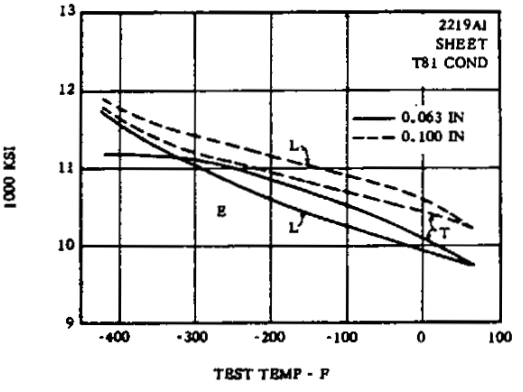


FIG. 3.0625 MODULUS OF ELASTICITY AT LOW TEMPERATURE OF SHEET IN T81 CONDITION (14, p. A.51, A.5.1-1)

	Al
6.3	Cu
0.3	Mn
0.18	Zr
0.10	V
0.06	Ti

2219
CLAD 2219

REFERENCES

1 Aluminum Co. of America, "Aluminum Sheet and Plate General Information, Mechanical and Physical Properties", Product Data, Sec. AC2A, (Dec. 1, 1961)

2 Aluminum Co. of America, "Alcoa Alloy 2219", Development Div., (Mar. 28, 1959)

3 Aluminum Co. of America, Research Laboratories, Data Sheet, (May 24, July 25, 1957)

4 Achbach, W.P., Favor, R.J. and Hyler, W.S., "Material-Property-Design Criteria for Metals", WADC TR 55-150, Part VI, (Oct. 1955)

5 Hendricks, P.L., "Metallurgical Investigation of Aluminum Alloy X-2219-T6", WADC TN 58-57, (June 1958)

6 Guy, D.M., Jr., "Personal Letter", Aluminum Co. of America, (May 28, 1959)

7 Brennecke, M. W., "Welding Characteristics of X-2219 Alloy", Aluminum Co. of America, Research Laboratories, Rep. No. 2-58-11a, (May 15, 1958)

8 AMS 4031, (June 30, 1962)
AMS 4143, (Feb. 15, 1965)

9 Mayer, L.W., "Aluminum Alloy 2219", Alcoa Green Letter, (Nov. 1963)

10 "Standards for Aluminum Mill Products", Aluminum Association, (Sept. 1965)

11 "Alcoa Aluminum Handbook", Aluminum Co. of America, (1962)

12 Nock, J. A. et al, "A New High Strength Aluminum Alloy ", Metal Progress, Vol. 80, No.2, (Sept. 1961)

13 "The Elevated Temperature Properties of Aluminum and Magnesium Alloys", ASTM STP 291, (1960)

14 Schwartzberg, F.R. et al, "Cryogenic Materials Data Handbook", ML-TDR-64-280, August 1964 and Progress Rep. No. 1, (Feb. 1965)

15 "The Aluminum Data Book", Reynolds Metals Co., (1965)

16 "Summary Information Regarding Aluminum Alloy 2219", Martin-Denver Evaluation Report No. 1, MI-64-44, (Nov. 1961)

17 "Materials Properties Data Book", Report No. 2275 to AEC-NASA, Nerva Program, Aerojet-General Corp. (Revised July 1964)

18 Christian, J.L. et al, "Structural Alloys for Cryogenic Service", Metal Progress, Vol. 83, No. 3, (March 1963)

19 Mahorter, R.G., Jr. and Emmons, W.F., "A Study of Creep Resistance, Formability and Heat Treatment of Clad X-2219-T6 Aluminum Alloy", Report No. NAMC-AML-AE 1100, Naval Air Materials Center, (August 1959)

20 Dix, E.H., Jr., "Aluminum Alloys for Elevated Temperature Applications", ASME Paper No. 56-AV-8, (1956)

21 Kaiser Aluminum and Chemical Sales, Inc., "Alloy Technical Data", (March 15, 1964)

22 Alloy Digest, "Aluminum 2219", Filing Code Al-96, (Oct. 1960)

23 Military Specification, "Heat Treatment of Aluminum Alloys", MIL-H-6088C, (October 15, 1962)