

72/Aluminum

Temperature range		Average coefficient	
°C	°F	$\mu\text{m}/\text{m}\cdot\text{K}$	$\mu\text{in.}/\text{in.}\cdot\text{°F}$
-50- +20	-58- +68	20.8	11.5
20- 100	68- 212	22.5	12.5
20- 200	68- 392	23.4	13.0
20- 300	68- 572	24.4	13.6

Volumetric: $65.1 \times 10^{-6} \text{ m}^3/\text{m}^3\cdot\text{K}$
($3.62 \times 10^{-5} \text{ in.}^3/\text{in.}^3\cdot\text{°F}$)

Btu/lb·°F at 20 °C (68 °F)

Thermal conductivity. At 20 °C (68 °F): O temper, 192 W/m·K (111 Btu/ft·h·°F); T3, T4, T451 tempers, 134 W/m·K (77.4 Btu/ft·h·°F); T6, T651, T652 tempers, 155 W/m·K (89.5 Btu/ft·h·°F)

Electrical Properties

Electrical conductivity. At 20 °C (68 °F): O temper, 50% IACS; T3, T4, T451 tempers, 34% IACS; T6, T651, T652 tempers, 40% IACS

Electrical resistivity. At 20 °C (68 °F): O temper, 34 nΩ·m; T3, T4, T451 tempers, 51 nΩ·m; T6, T651, T652 tempers, 43 nΩ·m. Temperature coefficient: O, T3, T4, T451, T6, T651, T652 tempers, 0.1 nΩ·m per K at 20 °C (68 °F)

Electrolytic solution potential. At 25 °C (77 °F): -0.68 V (T3, T4, T451 tempers) or -0.78 V (T6, T651, T652 tempers) vs 0.1N calomel electrode in an aqueous solution containing 53 g NaCl plus 3 g H₂O₂ per litre

Fabrication Characteristics

Annealing temperature. 413 °C (775 °F)

Solution temperature. 502 °C (935 °F)

Aging temperature. T6 temper. Sheet, plate, wire, rod, bar, shapes and tube: 160 °C (320 °F) for 18 h at temperature. Forgings: 171 °C (340 °F) for 10 h at temperature

2024, Alclad 2024 4.4Cu-1.5Mg-0.6Mn

Specifications

AMS. See Table 20.

ASME. Rolled or drawn wire, rod and bar: SB211. Extrusions: SB221

ASTM. See Table 20.

SAE. J454

Table 18 Typical tensile properties of alloy 2014-T6 or -T651 at various temperatures (a)

Temperature		Tensile strength		Yield strength (b)		Elongation, %
°C	°F	MPa	ksi	MPa	ksi	
-196	-320	579	84	496	72	14
-80	-112	510	74	448	65	13
-28	-18	496	72	427	62	13
24	75	483	70	414	60	13
100	212	439	63	393	57	15
149	300	276	40	241	35	20
204	400	110	16	90	13	38
260	500	66	9.5	52	7.5	52
316	600	45	6.5	34	5	65
371	700	30	4.3	24	3.5	72

(a) Lowest strength for exposures up to 10 000 h at temperature under no load; test loading applied at 5 000 psi/min to yield strength and then at strain rate of 5%/min to fracture. (b) 0.2% offset.

Table 19 Tensile-property limits for alloy 2014

Temper	Tensile strength		Yield strength		Elongation (a), %	
	Minimum MPa	Maximum ksi	Minimum MPa	ksi		
Flat Products, Bare						
Sheet and plate, O						
0.020-0.499 in. thick	...	220	32	110(max)	16(max)	16
0.500-1.000 in. thick	...	220	32	...	...	10
Flat sheet, T3						
0.020-0.039 in. thick	405	59	...	240	35	14
0.040-0.249 in. thick	405	59	...	250	36	14
Coiled sheet, T4						
0.020-0.249 in. thick	405	59	...	240	35	14
Plate, T451 (b)						
0.250-2.000 in. thick	400	58	...	250	36	14-12
2.001-3.000 in. thick	395	57	...	250	36	8
Sheet and plate, T42						
0.020-1.000 in. thick	400	58	...	235	34	14
Sheet, T6, T62						
0.020-0.039 in. thick	440	64	...	395	57	6
0.040-0.249 in. thick	455	66	...	400	58	7
Plate, T62, T651						
0.250-2.000 in. thick	460	67	...	405	59	7-4
2.001-2.500 in. thick	450	65	...	400	58	2
2.501-3.000 in. thick	435	63	...	395	57	2
3.001-4.000 in. thick	405	59	...	380	55	1
Flat Products, Alclad						
Sheet and plate, O						
0.020-0.499 in. thick	...	205	30	95(max)	14(max)	16
0.500-1.000 in. thick	...	220	32	...	...	10
Flat sheet, T3						
0.020-0.024 in. thick	370	54	...	230	33	14
0.025-0.039 in. thick	380	55	...	235	34	14
0.040-0.249 in. thick	395	57	...	240	35	15
Coiled sheet, T4						
0.020-0.024 in. thick	370	54	...	215	31	14
0.025-0.039 in. thick	380	55	...	220	32	14
0.040-0.249 in. thick	395	57	...	235	34	15
Plate, T451 (b)						
0.500-2.000 in. thick	400	58	...	250	36	12-14
0.250-0.499 in. thick	395	57	...	250	36	15
0.500-2.000 in. thick	400	58	...	250	36	12-14
2.001-3.000 in. thick	395	57	...	200	36	8
Sheet and plate, T4						
0.020-0.024 in. thick	370	54	...	215	31	14
0.025-0.039 in. thick	380	55	...	220	32	14
0.040-0.499 in. thick	395	57	...	235	34	15
0.500-1.000 in. thick	400	58	...	235	34	14
Sheet, T6						
0.020-0.024 in. thick	425	62	...	370	54	7
0.025-0.039 in. thick	435	63	...	380	55	7
0.040-0.249 in. thick	440	64	...	395	57	8

(continued)

Properties of Wrought Aluminum/73

Table 19 (continued)

Temper	Tensile strength		Yield strength		Elongation (a), %
	Minimum MPa	Maximum ksi	Minimum MPa	Maximum ksi	
Plate, T62, T651					
0.250 - 0.499 in. thick	440	64	395	57	8
0.500 - 2.000 in. thick	460	67	405	59	6
2.001 - 2.500 in. thick	450	65	400	58	2
2.501 - 3.000 in. thick	435	63	395	57	2
3.001 - 4.000 in. thick	405	59	380	55	1
Rolled or Cold Finished Wire, Rod and Bar					
T4, T42, T451(b)	380	55	220	32	16
T6, T62, T651	450	65	380	55	8
Extruded Wire, Rod, Bar and Shapes					
O		205	30	125(max)	12(max)
T4, T4510, T4511	345	50		240	35
T42	345	50		200	29
T6, T6510, T6511					
Up thru 0.499 in. thick	415	60	365	53	7
0.500 - 0.749 in. thick	440	64	400	58	7
0.750 in. thick and over	470	68	415	60	7
T62	415	60	365	53	7(c)
Extruded Tube					
O		205	30	125(max)	18(max)
T4, T4510, and T4511	345	50		240	35
T42	345	50		200	29
T6, T6510, T6511					
Up thru 0.499 in. thick	415	60	365	53	7
0.500 - 0.749 in. thick	440	64	400	58	7
0.750 in. thick and over	470	68	415(d)	60(d)	7(d)
T62	415	60	365	53	7(c)
Drawn Tube					
O, 0.18 - 0.500 in. thick		220	32	110(max)	16(max)
T4, T42					
0.018 - 0.500 in. thick	370	54	205	30	10 - 16
Die forgings: Axis Parallel to Direction of Grain Flow					
T4, Up thru 4 in. thick	380	55	205	30	11(e)(f)
T6					
Up thru 2 in. thick	450	65	385	56	6(e)(g)
Over 2 thru 3 in. thick	450	65	380	55	6(e)(g)
Over 3 thru 4 in. thick	435	63	380	55	6(e)(g)
Die Forgings: Axis Not Parallel to Direction of Grain Flow					
T6, Up thru 2 in. thick	440	64	380	55	3(e)(h)
Over 2 thru 4 in. thick	435	63	370	54	2(e)
Hand Forgings					
T6					
Up thru 2.000 in. thick longitudinal,					
long transverse	450	65	385	56	3 - 8
2.001 - 3.000 in. thick					
Longitudinal	440	64	385	56	8
Long transverse	440	64	380	55	3
Short transverse	425	62	380	55	2
3.001 - 4.000 in. thick					
Longitudinal,					
long transverse	435	63	380	55	3 - 8
Short transverse	420	61	370	54	2
4.001 - 5.000 in. thick					
Longitudinal,					
long transverse	425	62	370	54	2 - 7
Short transverse	415	60	365	53	1
5.001 - 6.000 in. thick					
Longitudinal,					
long transverse	420	61	365	53	2 - 7
Short transverse	405	59	365	53	1

(continued)

Table 20 Standard specifications for alloy 2024

Mill form and condition	Specification number		
	AMS	ASTM	Government
Sheet and plate			
.....	4033	B209	QQ-A-250/4
	4035	...	...
	4037	...	...
	4097	...	...
	4098	...	...
	4099	...	...
	4103	...	...
	4104	...	...
	4105	...	...
	4106	...	...
	4192	...	...
	4193	...	...
Wire, rod and bar (rolled or cold finished)			
.....	4112	B211	QQ-A-225/6
	4119	...	...
	4120	...	...
Wire, rod, bar, shapes and tube (extruded)			
..	4152	B221	QQ-A-200/3
	4164	...	...
	4165	...	...
Tube (extruded, seamless)			
...		B241	...
Tube (drawn, seamless)			
...	4087	B210	WW-T-700/3
	4088	...	MIL-T-50777
Tube (hydraulic)			
..	4086	...	...
Rivet wire and rod			
.....		B316	QQ-A-430
Foil			
.....	4007	...	MIL-A-81596
Alclad 2024			
Sheet and plate			
.....	4034	B209	QQ-A-250/5
	4040	...	...
	4041	...	...
	4042	...	...
	4060	...	...
	4061	...	...
	4072	...	...
	4073	...	...
	4074	...	...
	4075	...	...
	4194	...	...
	4195	...	...

UNS number. A92024

Government. See Table 20.

Foreign. Austria: Onorm AlCuMg2.

Canada: CSA CG42. France: NF A-

U4G1. Italy: UNI P-AlCu4.5MgMn;

Alclad 2024, P-AlCu4.5MgMn plac.

Spain: UNE L-314. Germany: DIN

AlCuMg2

Chemical Composition

Composition limits. 0.05 max Si;

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Table 19 (continued)

Temper	Tensile strength				Yield strength		Elongation (a), %
	Minimum MPa	ksi	Maximum MPa	ksi	Minimum MPa	ksi	
6.001 - 7.000 in. thick							
Longitudinal,							
long transverse	415	60	...	...	360	52	2-7
Short transverse	400	58	...	...	360	52	1
7.001 - 8.000 in. thick							
Longitudinal,							
long transverse	405	59	...	...	350	51	2-7
Short transverse	395	57	...	...	350	51	1
T652							
Up thru 2.000 in. thick							
Longitudinal,							
long transverse	450	65	...	...	385	56	3-8
2.001 - 3.000 in. thick							
Longitudinal	440	64	...	...	385	56	8
Long transverse	440	64	...	...	380	55	3
Short transverse	425	62	...	...	360	52	2
3.001 - 4.000 in. thick							
Longitudinal,							
long transverse	435	63	...	...	380	55	3-8
Short transverse	420	61	...	...	350	51	2
4.001 - 5.000 in. thick							
Longitudinal,							
long transverse	425	62	...	...	370	54	2-7
Short transverse	415	60	...	...	345	50	1
5.001 - 6.000 in. thick							
Longitudinal,							
long transverse	420	61	...	...	365	53	2-7
Short transverse	405	59	...	...	345	50	1
6.001 - 7.000 in. thick							
Longitudinal,							
long transverse	415	60	...	...	360	52	2-6
Short transverse	400	58	...	...	340	49	1
7.001 - 8.000 in. thick							
Longitudinal,							
long transverse	405	59	...	...	350	51	2-6
Short transverse	395	57	...	...	331	48	1
Rolled Rings, T6, T652							
Up thru 2.500 in. thick							
Tangential	450	65	...	...	380	55	7
Axial	425	62	...	...	380	55	3
Radial	415	60	...	...	380	52	2
2.501 - 3.000 in. thick							
Tangential	450	65	...	...	380	55	6
Axial	425	62	...	...	360	52	2

(a) In 2 in. or 4d, where d is diameter of reduced section of tensile test specimen. Where a range of values appears in this column, specified minimum elongation varies with thickness of the mill product. (b) Upon artificial aging, T451 temper material develops properties applicable to T651 temper. (c) 6% elongation for products over 0.750 in. in diameter or thickness and over 25 thru 32 in.² in cross-sectional area. (d) Value slightly lower for material over 25 thru 32 in.² in cross-sectional area. (e) Test bar machined from sample forging. (f) 16% for test bar taken from separately forged coupon. (g) 8% for test bar taken from separately forged coupon. (h) 2% for forgings over 1 thru 2 in. thick.

0.50 max Fe; 3.8 to 4.9 Cu; 0.30 to 0.9 Mn; 1.2 to 1.8 Mg; 0.10 max Cr; 0.25 max Zn; 0.15 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al. Alclad 2024: 1230 cladding—99.30 min Al; 0.7 max Si + Fe; 0.10 max Cu; 0.05 max Mn; 0.05 max Mg; 0.10 max Zn; 0.05 max V; 0.03 max Ti; 0.03 max others (each)

Applications

Typical uses. Aircraft structures, rivets, hardware, truck wheels,

screw machine products and other miscellaneous structural applications

Mechanical Properties

Tensile properties. See Tables 21, 22 and 23.

Shear strength. See Table 22.

Hardness. See Table 22.

Poisson's ratio. 0.33 at 20 °C (68 °F)

Elastic modulus. Tension, 72.4 GPa (10.5 × 10⁶ psi); shear, 28.0 GPa (4.0

× 10⁶ psi); compression, 73.8 GPa (10.7 × 10⁶ psi)

Fatigue strength. See Table 22.

Mass Characteristics

Density. 2.77 Mg/m³ (0.100 lb/in.³) at 20 °C (68 °F)

Thermal Properties

Liquidus temperature. 638 °C (1180 °F)

Solidus temperature. 502 °C (935 °F)

Incipient melting temperature. 502 °C (935 °F)

Coefficient of thermal expansion. Linear:

Temperature range °C	°F	Average coefficient	
		μm/m · K	μin./in. · °F
-50 - +20	-58 - +68	21.1	11.7
20 - 100	68 - 212	22.9	12.7
20 - 200	68 - 392	23.8	13.2
20 - 300	68 - 572	24.7	13.7

Volumetric: 66.0 × 10⁻⁶ m³/m³·K (3.67 in.³/in.³·°F) at 20 °C (68 °F)

Specific heat. 875 J/kg·K (0.209 Btu/lb·°F) at 20 °C (68 °F)

Thermal conductivity:

Temper	Conductivity	
	W/m · K	Btu/ft · h · °F
O	190	110
T3, T36, T351, T361, T4	120	69
T6, T81, T851, T861	151	88

Electrical Properties

Electrical conductivity. Volumetric, at 20 °C (68 °F):

Temper	Conductivity, % IACS
O	50
T3, T36, T351, T361, T4	30
T6, T81, T851, T861	38

Electrical resistivity:

Temper	Resistivity, nΩ · m
O	34
T3, T36, T351, T361, T4	57
T6, T81, T851, T861	45

Temperature coefficient, 0.1 nΩ/m per K at 20 °C (68 °F)

Properties of Wrought Aluminum/75

Table 21 Typical tensile properties of alloy 2024

Temper	Temperature		Tensile strength		Yield strength(a)		Elongation, %
	°C	°F	MPa	ksi	MPa	ksi	
T3 (sheet)	-196	-320	586	85	427	62	18
	-80	-112	503	73	359	52	17
	-28	-18	496	72	352	51	17
	24	75	483	70	345	50	17
	100	212	455	66	331	48	16
	149	300	379	55	310	45	11
	204	400	186	27	138	20	23
	260	500	76	11	62	9	55
	316	600	52	7.5	41	6	75
	371	700	34	5	28	4	100
	T4, T351 (plate)	-196	-320	579	84	421	61	19
-80		-112	490	71	338	49	19
-28		-18	476	69	324	47	19
24		75	469	68	324	47	19
100		212	434	63	310	45	19
149		300	310	45	248	36	17
204		400	179	26	131	19	27
260		500	76	11	62	9	55
316		600	52	7.5	41	6	75
371		700	34	5	28	4	100
T6, T651		-196	-320	579	84	469	68	11
	-80	-112	496	72	407	59	10
	-28	-18	483	70	400	58	10
	24	75	476	69	393	57	10
	100	212	448	65	372	54	10
	149	300	310	45	248	36	17
	204	400	179	26	131	19	27
	260	500	76	11	62	9	55
	316	600	52	7.5	41	6	75
	371	700	34	5	28	4	100
	T81, T851	-196	-320	586	85	538	78
-80		-112	510	74	476	69	7
-28		-18	503	73	469	68	7
24		75	483	70	448	65	7
100		212	455	66	427	62	8
149		300	379	55	338	49	11
204		400	186	27	138	20	23
260		500	76	11	62	9	55
316		600	52	7.5	41	6	75
371		700	34	5	28	4	100
T861		-196	-320	634	92	586	85	5
	-80	-112	558	81	531	77	5
	-28	-18	538	78	510	74	5
	24	75	517	75	490	71	5
	100	212	483	70	462	67	6
	149	300	372	54	331	48	11
	204	400	145	21	117	17	28
	260	500	76	11	62	9	55
	316	600	52	7.5	41	6	75
	371	700	34	5	28	4	100

(a) 0.2% offset.

Electrolytic solution potential. At 25 °C (77 °F) and vs 0.1N calomel electrode in an aqueous solution containing 53 g NaCl plus 3 g H₂O₂ per litre.

Temper	Volts
T3, T4, T361	-0.68
T6, T81, T861	-0.80
Alclad 2024	-0.83

Fabrication Characteristics

Annealing temperature. 413 °C (775 °F)

Solution temperature. 493 °C (920 °F)

Aging temperature. T6 and T8 tempers: 191 °C (375 °F) for 8 to 16 h at temperature

2036 2.6Cu-0.45Mg-0.25Mn

Specifications

UNS number. A92036

Chemical Composition

Composition limits. 0.50 max Si; 0.50 max Fe; 2.2 max Cu; 0.10 to 0.40 Mn; 0.30 to 0.6 Mg; 0.10 max Cr; 0.25 max Zn; 0.15 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al

Applications

Typical uses. Sheet for auto body panels

Mechanical Properties

Tensile properties. Typical, for 0.64 to 3.18 mm (0.025 to 0.125 in.) flat sheet, T4 temper: tensile strength, 340 MPa (49 ksi); yield strength, 195 MPa (28 ksi); elongation, 24% in 50 mm or 2 in. Minimum, for 0.64 to 3.18 mm flat sheet, T4 temper: tensile strength, 290 MPa (42 ksi); yield strength, 160 MPa (23 ksi); elongation, 20% in 50 mm or 2 in.

Hardness. Typical, T4 temper: 80 HR15T

Strain-hardening exponent. 0.23
Elastic modulus. Tension, 70.3 GPa (10.2 × 10⁶ ksi); compression, 71.7 GPa (10.4 × 10⁶ ksi)

Fatigue strength. Typical, T4 temper: 124 MPa (18 ksi) at 10⁷ cycles for flat sheet tested in reversed flexure

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Mass Characteristics

Density. 2.75 Mg/m³ (0.099 lb/in.³) at 20 °C (68 °F)

Thermal Properties

Liquidus temperature. 649 °C (1200 °F)

Solidus temperature. 554 °C (1030 °F)

Incipient melting temperature. 510 °C (950 °F)

Coefficient of thermal expansion. Linear:

Temperature range		Average coefficient	
°C	°F	μm/m·K	μin/in.·°F
-50- +20	-58- +68	21.6	12.0
20- 100	68- 212	23.4	13.0
20- 200	68- 392	24.3	13.5
20- 300	68- 572	25.2	14.0

Volumetric: 67.5 × 10⁻⁶ m³/m³·K (3.75 × 10⁻⁵ in.³/in.³·°F) at 20 °C (68 °F)

Specific heat. 882 J/kg·K (0.211 Btu/lb·°F) at 20 °C (68 °F)

Thermal conductivity. At 20 °C (68 °F): O temper, 198 W/m·K (114 Btu/ft·h·°F); T4 temper, 159 W/m·K (91.8 Btu/ft·h·°F)

Electrical Properties

Electrical conductivity. Volumetric, at 20 °C (68 °F): O temper, 52% IACS; T4 temper, 41%

Electrical resistivity. At 20 °C (68 °F): O temper, 33.2 nΩ·m; T4 temper, 42.1 nΩ·m. Temperature coefficient. At 20 °C (68 °F): O and T4 tempers, 0.1 nΩ·m per K

Electrolytic solution potential. At 25 °C (77 °F): -0.75 V vs 0.1N calomel electrode in an aqueous solution containing 53 g NaCl plus 3 g H₂O₂ per litre

Fabrication Characteristics

Weldability. Arc welding with inert gas limited due to crack sensitivity, loss of mechanical properties, and/or loss in resistance to corrosion. When used for automotive parts, can be resistance welded with very good results.

Annealing temperature. 385°C (725 °F); hold 2 to 3 h at temperature for sheet

Solution temperature. 499 °C (930 °F)

Table 22 Typical mechanical properties of alloy 2024

Temper	Tensile strength		Yield strength		Elongation (a), %	Hardness (b), HB	Shear strength		Fatigue strength (c)	
	MPa	ksi	MPa	ksi			MPa	ksi	MPa	ksi
O	185	27	75	11	20	47	125	18	90	13
T3	485	70	345	50	18	120	285	41	140	20
T4, T351	470	68	325	47	20	120	285	41	140	20
T361	495	72	395	57	13	130	290	42	125	18
Alclad 2024										
O	180	26	75	11	20	...	125	18	...	...
T3	450	65	310	45	18	...	275	40	...	...
T4, T351	440	64	290	42	19	...	275	40	...	...
T361	460	67	365	53	11	...	285	41	...	...
T81, T851	450	65	415	60	6	...	275	40	...	...
T861	485	70	455	66	6	...	290	42	...	...

(a) 1.6-mm (1/16-in.) thick specimen. (b) 500-kg load; 10-mm ball. (c) At 5 × 10⁸ cycles of completely reversed stress; R. R. Moore type test.

Table 23 Tensile property limits for alloy 2024

Temper	Tensile strength (min)		Yield strength (min)		Elongation (min) (a), %
	MPa	ksi	MPa	ksi	
Sheet and Plate					
O	220 (max)	32 (max)	95 (max)	14 (max)	12
T42					
0.010-0.499 in. thick	425	62	260	38	12-15
0.500-1.000 in. thick	420	61	260	38	8
1.001-2.000 in. thick	415	60	260	38	6-7
2.001-3.000 in. thick	400	58	260	38	4
T62					
0.010-0.499 in. thick	440	64	345	50	5
0.500-3.000 in. thick	435	63	345	50	5
T361					
0.020-0.062 in. thick	460	67	345	50	8
0.063-0.249 in. thick	470	68	350	51	9
0.250-0.500 in. thick	455	66	340	49	9-10
T861					
0.020-0.062 in. thick	485	70	425	62	3
0.063-0.249 in. thick	490	71	455	66	4
0.250-0.499 in. thick	485	70	440	64	4
Alclad O					
0.008-0.062 in. thick	205 (max)	30 (max)	95 (max)	14 (max)	10-12
0.063-1.750 in. thick (b)	220 (max)	32 (max)	95 (max)	14 (max)	12
Alclad T42					
0.008-0.009 in. thick	380	55	235	34	10
0.010-0.062 in. thick	395	57	235	34	12-15
0.063-0.499 in. thick	415	60	250	36	12-15
0.500-1.000 in. thick (b)	420	61	260	38	8
1.001-2.000 in. thick (b)	415	60	260	38	6-7
2.001-3.000 in. thick (b)	400	58	260	38	4
Alclad T62					
0.010-0.062 in. thick	415	60	325	47	5
0.063-0.499 in. thick	425	62	340	49	5
Alclad T361					
0.020-0.062 in. thick	420	61	325	47	8
0.063-0.499 in. thick	440	64	330	48	9
0.500 in. thick (b)	445	66	340	49	10
Alclad T861					
0.020-0.062 in. thick	440	64	400	58	3
0.063-0.249 in. thick	475	69	440	64	4
0.250-0.499 in. thick	470	68	425	62	4
0.500 in. thick (b)	485	70	440	64	4

(continued)

Properties of Wrought Aluminum/77

Table 23 (continued)

Temper	Tensile Strength (min)		Yield strength (min)		Elongation (min)(a), %
	MPa	ksi	MPa	ksi	
Flat Sheet					
T3					
0.008-0.128 in. thick	435	63	290	42	10-15
0.129-0.249 in. thick	440	64	290	42	15
T81	460	67	400	58	5
Alclad T3					
0.008-0.009 in. thick	400	58	270	39	10
0.010-0.062 in. thick	405	59	270	39	12-15
0.063-0.128 in. thick	420	61	275	40	15
0.129-0.249 in. thick	425	62	275	40	15
T81					
0.010-0.062 in. thick	425	62	370	54	5
0.063-0.249 in. thick	450	65	385	56	5
Sheet					
T72	415	60	315	46	5
Alclad T72					
0.010-0.062 in. thick	385	56	295	43	5
0.063-0.249 in. thick	400	58	310	45	5
Coiled Sheet					
T4	425	62	275	40	12-15
Alclad T4					
0.010-0.060 in. thick	400	58	250	36	12-15
0.063-0.128 in. thick	420	61	260	38	15
Plate					
T351					
0.250-0.499 in. thick	440	64	290	42	12
0.500-1.000 in. thick	435	63	290	42	8
1.001-2.000 in. thick	425	62	290	42	6-7
2.001-3.000 in. thick	415	60	290	42	4
3.001-4.000 in. thick	395	57	285	41	4
T851					
0.250-0.499 in. thick	460	67	400	58	5
0.500-1.000 in. thick	455	66	400	58	5
1.001-1.499 in. thick	455	66	395	57	5
Alclad T351					
0.250-0.499 in. thick	425	62	275	40	12
0.500-1.000 in. thick(b)	435	63	290	42	8
1.001-2.000 in. thick(b)	425	62	290	42	6-7
2.001-3.000 in. thick(b)	415	60	290	42	4
3.001-4.000 in. thick(b)	395	57	285	41	4
Alclad T851					
0.250-0.499 in. thick	450	65	385	56	5
0.500-1.000 in. thick(b)	455	66	400	58	5
Wire, Rod, and Bar (Rolled or Cold Finished)					
O	240 (max)	35 (max)	...	...	16
T36	475	69	360	52	10
T4					
Up thru 0.499 in. thick or in diam	425	62	310(c)	45(c)	10
0.500-4.500 in. thick or in diam	425	62	290(c)	42(c)	10
4.501-6.500 in. thick or in diam	425	62	275(c)	40(c)	10
6.501-8.00 in. in diam	400	58	260	38	10

(continued)

2048

3.3Cu-1.5Mg-0.40Mn

Specifications

UNS number. A92048

Chemical Composition

Composition limits. 0.15 max Si; 0.20 max Fe; 2.8 to 3.8 Cu; 0.20 to 0.6 Mn; 1.2 to 1.8 Mg; 0.25 max Zn; 0.10 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al

Applications

Typical uses. Sheet and plate in structural components for aerospace application and military equipment

Mechanical Properties

Tensile properties. See Table 24 and Fig. 4.

Shear strength. Longitudinal, 271 MPa (39.3 ksi); transverse, 270 MPa (39.2 ksi)

Compressive properties. See Table 24 and Fig. 5.

Elastic modulus. See Fig. 4 and 5.
Impact strength. Charpy V-notch: longitudinal, 10.3 J (7.6 ft·lb); transverse, 6.1 J (4.5 ft·lb)

Fatigue strength. See Table 24 and Fig. 6 to 9.

Plane-strain fracture toughness. LT crack orientation, 35.2 MPa√m (32.0 ksi√in.); TL crack orientation, 31.9 MPa√m (29.1 ksi√in.)

Creep-rupture characteristics. See Table 24 and Fig. 10.

Mass Characteristics

Density. 2.75 Mg/m³ (0.099 lb/in.³) at 20 °C (68 °F)

Thermal Properties

Coefficient of thermal expansion. Linear, 23.5 μm/m·K (13.0 μin./in.·°F) at 21 to 104 °C (70 to 220 °F)

Specific heat. 926 J/kg·K (0.221 Btu/lb·°F) at 100 °C (212 °F)

Thermal conductivity. T851 temper, 159 W/m·K (92 Btu/ft·h·°F)

Electrical Properties

Electrical conductivity. Volumetric, T851 temper: 42% IACS at 20 °C (68 °F)

Electrical resistivity. T851 temper, 40.3 nΩ·m at 20 °C (68 °F)

78/Aluminum

Table 23 (continued)

Temper	Tensile Strength (min)		Yield strength (min)		Elongation (min)(a), %
	MPa	ksi	MPa	ksi	
T42	425	62	275	40	10
T351	425	62	310	45	10
T6	425	62	345	50	5
T62	415	60	315	46	5
T851	455	66	400	58	5
Wire, Rod, Bar and Shapes (Extruded)					
O	240 (max)	35 (max)	130 (max)	19 (max)	12
T3, T3510, T3511:					
Up thru 0.249 in. thick or in diam	395	57	290	42	12
0.250-0.749 in. thick or in diam	415	60	305	44	12
0.750-1.499 in. thick or in diam	450	65	315	46	10
1.5000 and over in. thick or in diam:					
Up thru 25 in. ² area	485	70	360	52	10
Over 25 thru 32 in. ² area	470	68	330	48	8
T42	395	57	260	38	8-12
T81, T851, T8510, T8511					
0.050-0.249 in. thick or in diam	440	64	385	56	4
0.250-1.500 and over in. thick or in diam:					
area up thru 32 in. ²	455	66	400	58	5
Extruded Tube					
O	240 (max)	35 (max)	130 (max)	19 (max)	12
T3, T3510, T3511					
Up thru 0.249 in. thick	395	57	290	42	10
0.250-0.749 in. thick	415	60	305	44	10
0.750-1.499 in. thick	450	65	315	46	10
1.500 and over in. thick:					
Area up thru 25 in. ²	485	70	330	48	10
Area over 25 thru 32 in. ²	470	68	315	46	8
T42	395	57	260	38	12-8
T81, T8510, T8511					
0.050-0.249 in. thick	440	64	385	56	4
0.250-1.500 and over; area up thru 32 in. ²	455	66	400	58	5
Drawn Tube					
O	220 (max)	32 (max)	105 (max)	15 (max)	...
T3	440	64	290	42	10-16(e)
T42	440	64	275	40	10-16(e)
Rivet and Cold-heading Wire and Rod					
O	240 (max)	35 (max)	...	...	...
H13	220	32	...	...	...
	290 (max)	42 (max)	...	...	...
T4	425	62	275	40	10

(a) In 2 in. or 4d, where d is diameter of reduced section of tension-test specimen. Where a range of values appears in this column, the specified minimum elongation varies with thickness of the mill product. (b) For plate 0.500 in. or over in thickness, listed properties apply to core material only. Tensile and yield strengths of composite plate are slightly lower than the listed value, depending on thickness of the cladding. (c) Minimum yield strength of coiled wire and rod, 276 MPa (40 ksi). (d) Applicable to rod only. (e) Full section specimen; min elongation is 10 to 12% for cut-out specimen.

2124

4.4Cu-1.5Mg-0.6Mn

Specifications

AMS. 4101
ASTM. B209
UNS number. A92124
Government. QQ-A-250/29

Chemical Composition

Composition limits. 0.20 max Si; 0.30 max Fe; 3.8 to 4.9 Cu; 0.30 to 0.9 Mn; 1.2 to 1.8 Mg; 0.10 max Cr; 0.25 max Zn; 0.15 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al

Consequence of exceeding impurity limits. Degrades fracture toughness

Applications

Typical uses. Plate in thicknesses of 1.500 through 6.000 in. for aircraft structures

Mechanical Properties

Tensile properties. See Tables 25 and 26.

Poisson's ratio. 0.33 at 20 °C (68 °F)

Elastic modulus. See Table 26.

Plane-strain fracture toughness.

T851 temper, plate: LT, 31.9 MPa \sqrt{m} (29.0 ksi $\sqrt{in.}$); TL, 27.5 MPa \sqrt{m} (25.0 ksi $\sqrt{in.}$); SL, 24.2 MPa \sqrt{m} (22.0 ksi $\sqrt{in.}$)

Creep-rupture characteristics. See Table 27.

Mass Characteristics

Density. 2.77 Mg/m³ (0.100 lb/in.³) at 20 °C (68 °F)

Thermal Properties

Liquidus temperature. 638 °C (1180 °F)

Solidus temperature. 502 °C (935 °F)

Incipient melting temperature. 502 °C (935 °F)

Coefficient of thermal expansion. Linear:

Temperature range		Average coefficient	
°C	°F	$\mu m/m \cdot K$	$\mu in./in. \cdot ^\circ F$
-50 - +20	-58 - +68	21.1	11.7
20 - 100	68 - 212	22.9	12.7
20 - 200	68 - 392	23.8	13.2
20 - 300	68 - 572	24.7	13.7

Volumetric: 66.0 $\times 10^{-6}$ m³/m³·K (3.6 $\times 10^{-5}$ in.³/in.³·°F) at 20 °C (68 °F)