3003 Aluminum: Mechanical properties

Temper	Tensile strength MPa	Tensile strength ksi	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, %	Hardness HB(a)	Hardness HR	Shear strength MPa	Shear strength ksi	Fatigue strength(b) MPa	Fatigue strength(b) ksi
Typical properties													
O	110	16	...	...	42	6	30-40	28	45-65	76	11	48	7
H12	130	19	...	...	125	18	10-20	35	55-75	83	12	55	8
H14	150	22	...	...	145	21	8-16	40	70-90	97	14	62	9
H16	175	25	...	...	175	25	5-14	47	75-92	105	15	69	10
H18	200	29	...	...	185	27	4-10	55	84-95	110	16	69	10
Property limits	Minimum		Maximum		Minimum				Minimum				
O (0.006-3.000 in. thick)	97	14	130	19	34	5	14-25	...	...	...	...	...	...
H12 (0.017-2.000 in. thick)	115	17	160	23	83	12	3-10	...	...	...	...	...	...
H14 (0.009-1.000 in. thick)	140	20	180	26	115	17	1-10	...	...	...	...	...	...
H16 (0.006-0.162 in. thick)	165	24	205	30	145	21	1-4	...	...	...	...	...	...
H18 (0.006-0.128 in. thick)	185	27	...	...	165	24	1-4	...	...	...	...	...	...
H112													
(0.250-0.499 in. thick)	115	17	...	...	69	10	8	...	...	...	...	...	...
(0.500-2.000 in. thick)	105	15	...	...	41	6	12	...	...	...	...	...	...
(2.000-3.000 in. thick)	100	14.5	...	...	41	6	18	...	...	...	...	...	...
Property limits, Alclad 3003 (c)													
O (0.006-0.499 in. thick)	90	13	125	18	31	4.5	14-25	...	...	...	...	...	...
(0.500-3.000 in. thick)	97	14	130	19	34	5.0	23	...	...	...	...	...	...
H12													
(0.017-0.499 in. thick)	110	16	150	22	77	11	4-9	...	...	...	...	...	...
(0.500-2.000 in. thick)	115	17	160	23	83	12	10	...	...	...	...	...	...
H14													
(0.009-0.499 in. thick)	130	19	170	25	110	16	1-8	...	...	...	...	...	...
(0.500-2.000 in. thick)	140	20	180	26	115	17	10	...	...	...	...	...	...
H16 (0.006-0.162 in. thick)	160	23	200	29	140	20	1-4	...	...	...	...	...	...
H18 (0.006-0.128 in. thick)	180	26	...	...	...	...	1-4	...	...	...	...	...	...
H112													
(0.250-0.499 in. thick)	110	16	...	...	62	9	8	...	...	...	...	...	...
(0.500-2.000 in. thick)	105	15	...	...	41	6	12	...	...	...	...	...	...
(2.000-3.000 in. thick)	100	14.5	...	...	41	6	18	...	...	...	...	...	...

(a) 500 kg load, 10 mm ball, 30 s duration of loading. (b) At 5×10^8 cycles. R.R. Moore type test. (c) Mechanical properties of 3003 clad with 7072 are practically the same as for bare material, except that hardness and fatigue resistance tend to be slightly lower for the clad product

3003 Aluminum: Standard specifications

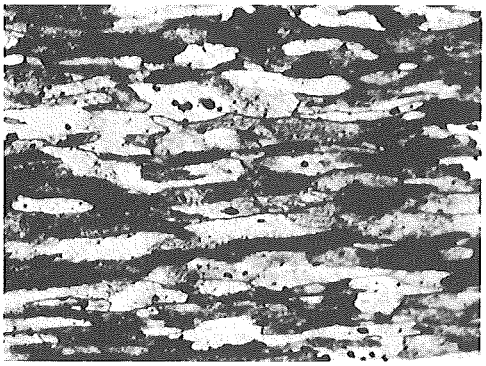
Mill form and condition	Specification number AMS	ASME	ASTM	Government
Bare 3003				
Sheet and plate	4006	SB209	B 209	QQ-A-250/2
	4008	...	...	...
Wire, rod, and bar (rolled or cold finished)	...	...	B 211	QQ-A-225/2
Wire, rod, bar, shapes, and tube (extruded)	...	SB221	B 221	QQ-A-200/1
Tube				
Extruded, seamless	...	SB241	B 241	...
Extruded, coiled	...	...	B 491	...
Drawn	...	...	B 483	...
Drawn, seamless	4065	SB210	B210	WW-T-700/2
	4067	...	...	...
Condenser	...	SB234	B 234	...
Condenser with integral fins	...	...	B 404	...
Welded	...	...	B 313	...
	...	...	B 547	...
Pipe: seamless	...	...	B 241	MIL-P-25995
Gas and oil transmission	...	...	B 345	...
Rivet wire and rod	...	...	B 316	QQ-A-430
Forgings	...	SB247	B 247	...
Foil	4010	...	...	MIL-A-81596
Alclad 3003				
Sheet and plate	...	...	B 209	
Tube				
Drawn, seamless			B 210	
Extruded			B 221	
Extruded, seamless			B 241	
Condenser			B 234	
Condenser with integral fins			B 404	
Welded			B 547	
Pipe (gas and oil transmission)			B 345	

3003 Aluminum: Typical mechanical properties at various temperatures

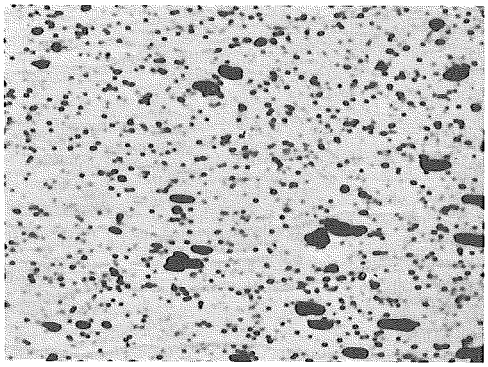
Temperature °C	Temperature °F	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(a) MPa	Yield strength(a) ksi	Elongation, %
O temper						
–200	–328	230	33	60	8.6	46
–100	–148	150	22	52	7.5	43
–30	–22	115	17	45	6.5	41
25	77	110	16	41	6	40
100	212	90	13	38	5.5	43
200	392	60	8.6	30	4.3	60
300	572	29	4.2	17	2.5	70
400	752	18	2.6	12	1.7	75
H14 temper						
–200	–328	250	36	170	25	30
–100	–148	175	25	155	22.5	19
–30	–22	150	22	145	21	16
25	77	150	22	145	21	16
100	212	145	21	130	19	16
200	392	96	14	62	9	20
300	572	29	4.2	17	2.5	70
400	752	18	2.6	12	1.7	75
H18 temper						
–200	–328	290	42	230	33	23
–100	–148	230	33	210	30	12
–30	–22	210	30	190	38	10
25	77	200	29	185	27	10
100	212	180	26	145	21	10
200	392	96	14	62	9	18
300	572	29	4.2	17	2.5	70
400	752	18	2.6	12	1.7	75

(a) Lowest strengths for exposures up to 10 000 h at temperature, no load; test load applied at 35 MPa/min (5 ksi/min) to yield strength and then at strain rate of 5%/min to fracture

3003 Aluminum: Microstructures. (a) 3003-O sheet, annealed. Longitudinal section shows recrystallized grains. Grain elongation indicates rolling direction, but not the crystallographic orientation within each grain. Polarized light. Barker's reagent. 100×. (b) 3003-O sheet, annealed. Same as adjoining microstructure, but shown at a higher magnification. Dispersion of insoluble particles of $(Fe,Mn)Al_6$ (large) and aluminum-manganese-silicon (both large and small) was not changed by annealing. 0.5% HF. 750×



(a)



(b)

3003 Aluminum: Microstructures. 3003-F sheet, hot rolled. Longitudinal section shows stringer of oxide from an inclusion in the cast ingot and particles of phases that contain manganese, both primary (large, angular) and eutectic (small). As-polished. 500×

3004, Alclad 3004

Chemical Composition. Composition Limits (3004). 0.25 Cu max, 0.30 Si max, 0.70 Fe max, 1.00 to 1.50 Mn, 0.80 to 1.30 Mg, 0.25 Zn max, 0.05 others max (each), 0.15 others max (total), bal Al

Composition Limits (Alclad 3004). 7072 cladding—0.10 Cu max, 0.10 Mg max, 0.10 Mn max, 0.7 Fe max + Si, 0.80 to 1.30 Zn, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). ASTM. 3004: sheet and plate, B 209; extruded tubing, B 221; welded tubing, B 313, B 547. Alclad 3004: sheet and plate, B 209; welded tubing, B 313; culvert pipe, B 547; SAE. J 454; UNS. A93004; Government: culvert pipe. WW-P-402; (Australia) A 3004; (France) NFA-M1G; (Germany) DIN AlMn1Mg1

Available Product Forms. Sheet, plate, drawn tubing. Alclad: sheet and plate

Characteristics

Major alloying elements: 1.2Mn-1.0Mg. Provides combination of good formability and higher strength than alloy 3003.

Typical Uses. Drawn and ironed rigid containers (cans). Chemical-handling and storage equipment, sheet metal work, builders' hardware, incandescent and fluorescent lamp bases. Alclad: siding, culvert pipe, industrial roofing.

For more information on resistance to corrosion, cold workability, machining, brazeability, and weldability, see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Annealing. Product is treated at 415 °C (775 °F)

3004 Aluminum: Mechanical properties

Temper	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, %	Hardness, HB(a)	Shear strength MPa	Shear strength ksi	Fatigue strength(b) MPa	Fatigue strength(b) ksi
Typical properties										
O	180	26	...	...	69	10	20-25	45	110	16	97	14
H32	215	31	...	...	170	25	10-17	52	115	17	105	15
H34	240	35	...	...	200	29	9-12	63	125	18	105	15
H36	260	38	...	...	230	33	5-9	70	140	20	110	16
H38	285	41	...	...	250	36	4-6	77	145	21	110	16
Property limits	Minimum		Maximum		Minimum							
O (0.006-3.000 in. thick)	150	22	200	29	59	8.5	10-18	...	...	...	...	...
H32 (0.017-2.000 in. thick)	195	28	240	35	145	21	1-6	...	...	...	...	...
H34 (0.009-1.000 in. thick)	220	32	260	38	170	25	1-5	...	...	...	...	...
H36 (0.006-0.162 in. thick)	240	35	285	41	195	28	1-4	...	...	...	...	...
H38 (0.006-0.128 in. thick)	260	38	...	...	215	31	1-4	...	...	...	...	...
H112 (0.250-3.000 in. thick)	160	23	...	...	62	9	7	...	...	...	...	...
Property limits, Alclad 3004(c)												
O												
(0.006-0.499 in. thick)	145	21	195	28	55	8	10-18	...	...	...	...	...
(0.500-3.000 in. thick)	150	22	200	29	59	8.5	16	...	...	...	...	...
H32												
(0.017-0.499 in. thick)	185	27	235	34	140	20	1-6	...	...	...	...	...
(0.500-2.000 in. thick)	195	28	240	35	145	21	6	...	...	...	...	...
H34												
(0.009-0.499 in. thick)	215	31	255	37	165	24	1-5	...	...	...	...	...
(0.500-1.000 in. thick)	220	32	260	38	170	25	5	...	...	...	...	...
H36 (0.006-0.162 in. thick)	235	34	275	40	185	27	1-4	...	...	...	...	...
H38 (0.006-0.128 in. thick)	255	37	...	...	...	...	1-4	...	...	...	...	...
H112												
(0.250-0.499 in. thick)	150	22	...	...	59	8.5	7	...	...	...	...	...
(0.500-3.000 in. thick)	160	23	...	...	62	9	7	...	...	...	...	...

(a) 500 kg load, 10 mm ball, 30 s duration of loading. (b) At 5×10^8 cycles, R.R. Moore type test. (c) Mechanical properties of 3004 clad with 7072 are practically the same as for bare material, except that hardness and fatigue resistance tend to be slightly lower for the clad product

3004 Aluminum: Typical mechanical properties at various temperatures

Temperature °C	Temperature °F	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(a) MPa	Yield strength(a) ksi	Elongation, %
O temper						
–200	–328	290	42.5	90	13.2	38
–100	–148	200	29	80	11.5	31
–30	–22	180	26	69	10	26
25	77	180	26	69	10	25
100	212	180	26	69	10	25
200	392	96	14	65	9.5	55
300	572	50	7.2	34	4.9	80
400	752	30	4.4	9	2.8	90
H34 temper						
–200	–328	360	52	235	34	26
–100	–148	270	39	212	31	17
–30	–22	245	36	200	29	13
25	77	240	35	200	29	12
100	212	240	35	200	29	12
200	392	145	21	105	15	35
300	572	50	7.2	34	4.9	80
400	752	30	4.4	19	2.8	90
H38 temper						
–200	–328	400	58	295	43	20
–100	–148	310	45	267	39	10
–30	–22	290	42	245	36	7
25	77	280	41	245	36	6
100	212	275	40	245	36	7
200	392	150	22	105	15	30
300	572	50	7.2	34	4.9	80
400	752	30	4.4	19	2.8	90

(a) Lowest strengths for exposures up to 10 000 h at temperature, no load; test loading applied at 35 MPa/min (5 ksi/min) to yield strength and then at strain rate of 5%/min to fracture

3105

Chemical Composition. Composition Limits. 0.60 Si max, 0.70 Fe max, 0.30 Cu max, 0.20 to 0.80 Mn, 0.20 to 0.80 Mg, 0.20 Cr max, 0.40 Zn max, 0.10 Ti max, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). ASTM. B 209; SAE. J 454

Available Product Forms. Sheet, in O, H12, H14, H16, H18, and H25 tempers

Characteristics

Major alloying elements: 0.55Mn-0.50Mg

Typical Uses. Residential siding, mobile home sheet, gutters and downspouts, sheet metal work, bottle caps, and closures.

For information on resistance to corrosion, machinability, brazeability, and weldability see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Annealing. Treatment temperature is 345 °C (650 °F)

3105 Aluminum: Mechanical properties of 3105 sheet

Temper	Tensile strength MPa	Tensile strength ksi	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, %	Shear strength MPa	Shear strength ksi
Typical properties									
O	115	17	...	...	55	8	24	83	12
H12	150	22	...	...	130	19	7	97	14
H14	170	25	...	...	150	22	5	105	15
H16	195	28	...	...	170	25	4	110	16
H18	215	31	...	...	195	28	3	115	17
H25	180	26	...	...	160	23	8	105	15
Property limits	Minimum		Maximum		Minimum				
O (0.013-0.080 in. thick)	97	14	145	21	34	5	16-20	...	...
H12 (0.017-0.080 in. thick)	130	19	180	26	105	15	1-3	...	...
H14 (0.013-0.080 in. thick)	150	22	200	29	125	18	1-2	...	...
H16 (0.013-0.080 in. thick)	170	25	220	32	145	21	1-2	...	...
H18 (0.013-0.080 in. thick)	195	28	...	...	165	24	1-2	...	...
H25 (0.013-0.080 in. thick)	160	23	...	...	130	19	2-6	...	...

4032

Chemical Composition. Composition Limits. 11.00 to 13.50 Si, 1.00 Fe max, 0.50 to 1.30 Cu, 0.80 to 1.30 Mg, 0.10 Cr max, 0.50 to 1.30 Ni, 0.25 Zn max, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). AMS. Forgings and forging stock: 4145; ASTM. Forgings: B247; SAE. J454; Government. Forgings: QQ-A-367; Foreign. (Canada) CSA SG121; (France) NF A-S12UN; (Italy) UNI P-AlSi12MgCuNi

Available Product Forms. Forgings and forging stock

Characteristics

An Al-Cu-Mg-Si alloy for high temperature service

Typical Uses. Pistons and other parts that see high temperatures. For information on resistance to corrosion, machinability, brazeability, and weldability, see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Solution Heat Treating. Heat to 500 to 515 °C (930 to 960 °F), hold for 4 min at temperature, then quench in cold water. Quench heavy or complicated forgings in water at 65 to 100 °C (150 to 212 °F)

Precipitation Heat Treating (Artificial Aging). Die forgings are heated to 170 to 175 °C (340 to 345 °F), and held 8 to 12 h at temperature

Annealing. Metal is heated to 415 °C (775 °F); held for 2 to 3 h at temperature, then furnace cooled to 260 °C (500 °F) at 25 °C (50 °F) per hour max

4032 Aluminum: Fatigue strength of 4032-T6 at various temperatures

Temperature °C	Temperature °F	No. of cycles	Stress(a) MPa	Stress(a) ksi
24	75	10^4	359	52
		10^5	262	38
		10^6	207	30
		10^7	165	24
		10^8	124	18
		5×10^8	114	16.5
150	300	10^5	207	30
		10^6	165	24
		10^8	90	13
		5×10^8	79	11.5
205	400	10^5	186	27
		10^6	138	20
		10^7	90	13
		10^8	55	8
		5×10^8	48	7
260	500	10^5	131	19
		10^6	83	12
		10^7	55	8
		10^8	34	5
		5×10^8	34	5

(a) Based on rotating beam tests at room temperature and cantilever beam tests at elevated temperatures

4032 Aluminum: Creep-rupture properties

Temperature °C	Temperature °F	Time under stress, h	Rupture stress MPa	Rupture stress ksi	Stress for creep of: 1.0% MPa	1.0% ksi	0.5% MPa	0.5% ksi	0.2% MPa	0.2% ksi
100	212	0.1	331	48	283	41	269	39	...	...
		1	317	46	283	41	262	38	...	...
		10	303	44	283	41	262	38	...	...
		100	296	43	276	40	262	38	...	...
		1000	296	43	276	40	255	37	...	...
150	300	0.1	290	42	276	40	248	36	...	...
		1	276	40	269	39	241	35	...	...
		10	269	39	255	37	234	34	...	...
		100	248	36	241	35	221	32	...	...
		1000	207	30	200	29	186	27	...	...
205	400	0.1	234	34	228	33	221	32	138	20
		1	214	31	207	30	200	29	131	19
		10	186	27	179	26	165	24	103	15
		100	138	20	131	19	124	18	59	8.5
		1000	83	12	76	11	69	10	...	...

4032 Aluminum: Typical mechanical properties of 4032-T6 at various temperatures

Temperature °C	Temperature °F	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, %
–200	–328	460	67	337	49	11
–100	–148	415	60	325	47	10
–30	–22	385	56	315	46	9
25	77	380	55	315	46	9
100	212	345	50	300	44	9
200	392	90	13	62	9	30
300	572	38	5.5	24	3.5	70
400	752	21	3.1	12	1.8	90

4043

Chemical Composition. Composition Limits. 4.50 to 6.00 Si, 0.80 Fe max, 0.30 Cu max, 0.05 Mn max, 0.05 Mg max, 0.10 Zn max, 0.20 Ti max, 0.05 others max (each), 0.15 others max (total), 0.0008 Be max (welding electrode only), bal Al

Specifications (U.S. and/or Foreign). AMS. Bare welding rod and electrodes: 4190; SAE. J454; Government. Bare welding rod and electrodes: QQ-R-566, MIL-E-16053; spray gun wire: MIL-W-6712; (Australia) B 4043; (Canada) CSA S5; (France) NF A-S5; (United Kingdom) BS N21; (Germany) DIN AlSi5, Werstoff-Nr. 3.2245

Available Product Forms. Welding rod and electrodes

Characteristics

Major alloying element: 5.2 Si

Typical Uses. General purpose weld filler alloy (rod or wire) for welding all wrought and foundry alloys (except those rich in magnesium)

Recommended Heat Treating Practice

Annealing. Product is annealed at 350 °C (660 °F)

5005

Chemical Composition. Composition Limits. 0.30 Si max, 0.70 Fe max, 0.20 Cu max, 0.20 Mn max, 0.50 to 1.10 Mg, 0.10 Cr max, 0.25 Zn max, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). ASTM. Sheet and plate: B 209. Wire, H19 temper; B 396. Stranded conductor: B 397. Rivet wire and rod: B 316. Rolled rod: B 531. Drawn tubing: B 483; SAE. J 454; UNS. A95005; Government. Rivet wire and rod: QQ-A-430; (France) NFA-G0.6; (United Kingdom) B5 N41; (Germany) DIN AlMg1. ISO: AlMg1

Available Product Forms. Sheet, plate, wire and rod, conductor, tubing. Tempers include O, H12, H14, H16, H18, H32, H34, H36, H38

Characteristics

Major alloying element: 0.8 Mg. Medium strength and good resistance to corrosion are properties similar to those of Alloy 3003. Anodized 5005 is clearer and lighter than anodized 3003, and color match with 6063 architectural extrusions is better

Typical Uses. Electrical conductor wire, cooking utensils, appliances, and architectural uses.

For more information on resistance to corrosion, cold workability, machinability, brazeability, and weldability see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Annealing. Product is treated at 345 °C (650 °F); holding at temperature is not required

Hot Working Temperature. Range is 260 to 510 °C (500 to 950 °F)

5005 Aluminum: Mechanical property limits for sheet and plate

Temper	Tensile strength, Minimum MPa	Tensile strength, Minimum ksi	Tensile strength, Maximum MPa	Tensile strength, Maximum ksi	Yield strength (min) MPa	Yield strength (min) ksi	Elongation (min)(a), %
O	105	15	145	21	35	5	12-22
H12	125	18	165	24	95	14	2-9
H14	145	21	185	27	115	17	1-8
H16	165	24	205	30	135	18	1-3
H18	185	27	...	...	...	...	1-3
H32	120	17	160	23	85	12	3-10
H34	140	20	180	26	105	15	2-8
H36	160	23	200	29	125	18	1-4
H38	180	26	...	...	...	...	1-4
H112							
0.250-0.492 in. thick	115	17	...	...	...	...	8
0.492-1.60 in. thick	105	15	...	...	...	...	10
1.60-3.20 in. thick	100	15	...	...	...	...	16

(a) In 50 mm (2 in.) or $5d$, where d is diameter or reduced section of tensile test specimen. Where a range of values appears in this column, the specified minimum elongation varies with thickness of the mill product

5005 Aluminum: Typical mechanical properties

Temper	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(a) MPa	Yield strength(a) ksi	Elongation(a)(b), %	Hardness(c), HB	Shear strength MPa	Shear strength ksi
O	124	18	41	6	25	28	76	11
H12	138	20	131	19	10	...	97	14
H14	159	23	152	22	6	...	97	14
H16	179	26	172	25	5	...	103	15
H18	200	29	193	28	4	...	110	16
H32	138	20	117	17	11	36	97	14
H34	159	23	138	20	8	41	97	14
H36	179	26	165	24	6	46	103	15
H38	200	29	186	27	5	51	110	16

(a) Strengths and elongations unchanged or improved at low temperatures. (b) 1.6 mm (0.0625 in.) thick specimen. (c) 500 kg load; 10 mm diam ball

5050

Chemical Composition. Composition Limits. 0.40 Si max, 0.70 Fe max, 0.20 Cu max, 0.10 Mn max, 1.10 to 1.80 Mg, 0.10 Cr max, 0.25 Zn max, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). ASTM. Sheet and plate: B 209. Drawn, seamless tubing: B 210. Drawn tubing: B 483. Welded tubing: B 313, B 547; SAE. J454; UNS. A95050; (France) NFA-G1; (Italy) P-AlMg1.5; (Switzerland) Al1.5Mg; (United Kingdom) BS 3L44. ISO: AlMg1.5

Available Product Forms. Sheet, plate, tubing, pipe, rod, bar, wire

Characteristics

Major alloying element: 1.4 Mg

Typical Uses. Builder's hardware, refrigerator trim, coiled tubes, tubing for auto gas and oil lines, welded irrigation pipe.

For information on resistance to corrosion, cold workability, machinability, brazeability, and weldability, see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Annealing. Treatment is at 345 °C (650 °F); holding at temperature is not required

5050 Aluminum: Tensile-property limits

Temper	Tensile strength (min) MPa	Tensile strength (min) ksi	Yield strength (min) MPa	Yield strength (min) ksi	Elongation (min)(a), %
O	125	18	41	6	16-20
H32	150	22	110	16	4-6
H34	170	25	138	20	3-5
H36	185	27	151	22	2-4
H38	200	29	...	...	2-4

(a) Where a range of values appears in this column, specified minimum elongation varies with thickness of the mill product

Hot Working Temperature. Product is heated in range of 260 to 510 °C (500 to 950 °F)

5050 Aluminum: Typical tensile properties

Temperature °C	Temperature °F	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength (0.2% offset)(a) MPa	Yield strength (0.2% offset)(a) ksi
-196	-320	255	37	70	10
-80	-112	150	22	60	8.5
-28	-18	145	21	55	8
24	75	145	21	55	8
100	212	145	21	55	8
150	300	130	19	55	8
205	400	95	14	50	7.5
260	500	60	9	41	6
315	600	41	6	29	4.2
370	700	27	3.9	18	2.6
-196	-320	305	44	205	30
-80	-112	205	30	170	25
-28	-18	195	28	165	24
24	75	195	28	165	24
100	212	195	28	165	24
150	300	170	25	150	22
205	400	95	14	50	7.5
260	500	60	9	41	6
315	600	41	6	29	4.2
370	700	27	3.9	18	2.6
-196	-320	315	46	250	36
-80	-112	235	34	205	30
-28	-18	220	32	200	29
24	75	220	32	200	29
100	212	215	31	200	29
150	300	185	27	170	25
205	400	95	14	50	7.5
260	500	60	9	41	6
315	600	41	6	29	4.2
370	700	27	3.9	18	2.6

(a) Lowest strengths for exposures up to 10 000 h at temperature; no load; test loading applied at 35 MPa/min (5 ksi/min) to yield strength and then at strain rate of 5%/min to fracture

5050 Aluminum: Typical mechanical properties

Temper	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(a) MPa	Yield strength(a) ksi	Elongation(a)(b), %	Hardness(c), HB	Shear strength MPa	Shear strength ksi	Fatigue strength(d) MPa	Fatigue strength(d) ksi
O	145	21	55	8	24	36	105	15	83	12
H32	170	25	145	21	9	46	115	17	90	13
H34	190	28	165	24	8	53	123	18	90	13
H36	205	30	180	26	7	58	130	19	97	14
H38	220	32	200	29	6	63	138	20	97	14

(a) Strengths and elongation generally unchanged or improved at low temperatures. (b) 1.6 mm (0.625 in.) thick sheet specimen. (c) 500 kg load; 10 mm diam ball. (d) At 5×10^8 cycles; R.R. Moore type test

5052

Chemical Composition. Composition Limits. 0.25 Si max, 0.40 Fe max, 0.10 Cu max, 0.10 Mn max, 2.20 to 2.80 Mg, 0.15 to 0.35 Cr, 0.10 Zn max, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). AMS. (See adjoining Table); ASTM. (See adjoining Table); SAE. J454; UNS. A95052; Government. Sheet and plate: QQ-A-250/8. Foil: MIL-A-81596. Rolled or cold finished wire, rod, and bar: QQ-A-225/7. Drawn, seamless tubing: WW-T-700/4. Rivet wire and rod: QQ-A430. Rivets: MIL-R-24243; (Canada) CSA GR20; (France) NF A-G2.5C; (Italy) ON.1 P-AlMg2.5; (Germany) DIN AlMg2.5. ISO: AlMg2.5

Available Product Forms. Sheet; plate; bar and shapes (extruded); wire, rod, and bar (rolled or cold finished); tubing; rivet wire and rod; foil

Characteristics

Major alloying elements: 2.5Mg-0.25Cr. Applied when a combination of good workability, good resistance to corrosion, high fatigue strength, weldability, and moderate static strength is required

Typical Uses. Sheet metal work, hydraulic tubing, appliances, street light standards, rivets, and wire. Tempers include O, H32, H34, H36, and H38.

For more information on corrosion resistance, cold workability, machinability, brazeability, and weldability, see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

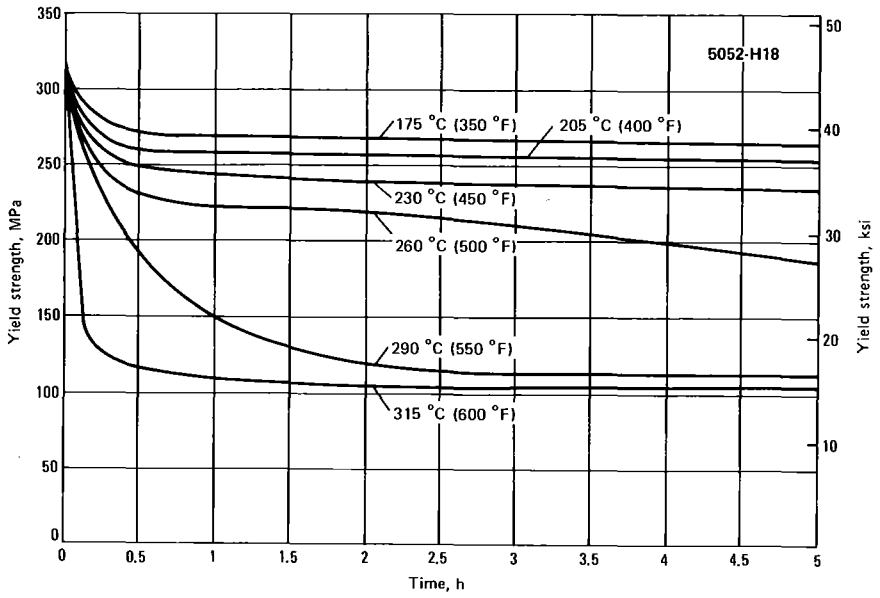
Recommended Heat Treating Practice

Annealing. Treatment is at 345 °C (650 °F); holding at temperature is not required

Hot Working Temperature. Range is 260 to 510 °C (500 to 950 °F)

5052 Aluminum. Representative isothermal annealing curves for 5052-H18

LIVE GRAPH
Click here to view



5052 Aluminum: Typical mechanical properties

Temper	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(a) MPa	Yield strength(a) ksi	Elongation, %(a) 1.6 mm (0.0625 in.) thick	Elongation, %(a) 12.5 mm (0.5 in.) diam	Hardness, HB(b)	Shear strength MPa	Shear strength ksi	Fatigue strength(c) MPa	Fatigue strength(c) ksi
O	195	28	90	13	25	27	47	125	18	110	16
H32	230	33	195	28	12	16	60	140	20	115	17
H34	260	38	215	31	10	12	68	145	21	125	18
H36	275	40	240	35	8	9	73	160	23	130	19
H38	290	42	255	37	7	7	77	165	24	140	20

(a) Strengths and elongations unchanged or improved at low temperatures. (b) 500 kg load; 10 mm diam ball. (c) At 5×10^8 cycles; R.R. Moore type test

5052 Aluminum: Typical tensile properties at various temperatures

Temper	Temperature °C	Temperature °F	Tensile strength MPa	Tensile strength ksi	Yield strength (0.2% offset) MPa	Yield strength (0.2% offset) ksi	Elongation, %
O	–196	–320	303	44	110	16	46
	–80	–112	200	29	90	13	35
	–28	–18	193	28	90	13	32
	24	75	193	28	90	13	30
	100	212	193	28	90	13	36
	150	300	159	23	90	13	50
	205	400	117	17	76	11	60
	260	500	83	12	52	7.5	80
	315	600	52	7.5	38	5.5	110
	370	700	34	5	21	3	130
H34	–196	–320	379	55	248	36	28
	–80	–112	276	40	221	32	21
	–28	–18	262	38	214	31	18
	24	75	262	38	214	31	16
	100	212	262	38	214	31	18
	150	300	207	30	186	27	27
	205	400	165	24	103	15	45
	260	500	83	12	52	7.5	80
	315	600	52	7.5	38	5.5	110
	370	700	34	5	21	3	130
H38	–196	–320	414	60	303	44	25
	–80	–112	303	44	262	38	18
	–28	–18	290	42	255	37	15
	24	75	290	42	255	37	14
	100	212	276	40	248	36	16
	150	300	234	34	193	28	24

5052 Aluminum: Standard specifications

Mill form	Specification No. AMS	Specification No. ASTM
Sheet and plate	4015	B 209
Sheet, plate, bar, and shapes (extruded)	4016, 4017	B 221
Wire, rod, and bar (rolled or cold finished)	4114	B 211
Tube		
Drawn	4069	B 483
Drawn, seamless	4070	B 210
Hydraulic	4071	...
Extruded	...	B 221
Extruded, seamless	...	B 241
Condenser	...	B 234
Condenser with integral fins	...	B 404
Welded	...	B 313, B 547
Rivet wire and rod	...	B 316
Foil	4004	...

5056, Alclad 5056

Chemical Composition. Composition Limits (5056). 0.30 Si max, 0.40 Fe max, 0.10 Cu max, 0.05 to 0.20 Mn, 4.50 to 5.60 Mg, 0.20 Cr max, 0.10 Zn max, 0.05 others max (each), 0.15 others max (total), bal Al

Composition Limits (Alclad 5056). 6253 cladding—Si, 45 to 65% of Mg content, 0.50 Fe max, 0.10 Cu max, 1.00 to 1.50 Mg, 0.15 to 0.35 Cr, 1.60 to 2.40 Zn, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). AMS. Rolled or cold finished wire, rod, and bar: 4182. Foil: 4005; ASTM. Rivet wire and rod: B 316. Rolled or cold finished wire, rod, and bar: B 211. Alclad, rolled or cold finished wire, rod, and bar: B 211; SAE. J 454; UNS. A95056; Government. Rivet wire and rod: QQ-A430, foil: MIL-A-81596; (Austria) AlMg5; (Canada) CSA-GM50R; (United Kingdom) BS N6 2L.58; (Germany) DIN AlMg5. ISO: AlMg5

Available Product Forms. Rolled or cold finished wire, rod, and bar; rivet wire and rod

Characteristics

Major alloying elements: 5.0Mg-0.1Mn-0.1Cr

Typical Uses. Rivets for use with magnesium alloy and cable sheathing, zipper stock, and nails. Alclad wire is used exclusively in the fabrication of insect screens and other instances where wire products require good resistance to corrosion.

For more information on resistance to corrosion, cold workability, machinability, brazeability, and weldability, see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Annealing. Treatment is at 415 °C (775 °F); holding at temperature is not required

Hot Working Temperature. Range is 315 to 480 °C (600 to 900 °F)

5056 Aluminum: Typical mechanical properties

Temper	Tensile strength(a) MPa	ksi	Yield strength(a) MPa	ksi	Elongation(a)(b), %	Hardness(c), HB	Shear strength MPa	ksi	Fatigue strength(d) MPa	ksi
O	290	42	152	22	35	65	179	26	138	20
H18	434	63	407	59	10	105	234	34	152	22
H38	414	60	345	50	15	100	221	32	152	22

(a) Strengths and elongation are unchanged or improved at low temperatures. (b) 12.5 mm (0.50 in.) diam; round specimen. (c) 500 kg load; 10 mm diam ball. (d) At 5×10^8 cycles; R.R. Moore type test

5056 Aluminum: Typical tensile properties

Temper	Temperature °C	°F	Tensile strength(a) MPa	ksi	Yield strength(a) MPa	ksi	Elongation, %
O	24	75	290	42	150	22	35
	150	300	214	31	117	17	55
	205	400	152	22	90	13	65
	260	500	110	16	69	10	80
	315	600	76	11	48	7	100
	370	700	41	6	28	4	130
H38	24	75	414	60	345	50	15
	150	300	262	38	214	31	30
	205	400	179	26	124	18	50
	260	500	110	16	69	10	80
	315	600	76	11	48	7	100
	370	700	41	6	28	4	130

(a) Lowest strengths for exposures up to 10 000 h at temperature, no load; test loading applied at 35 MPa/min (5 ksi/min) to yield strength and then at strain rate of 5%/min to fracture

5056 Aluminum: Mechanical-property limits for rolled or cold finished wire, rod, and bar

Temper	Tensile strength (min) MPa	ksi
Bare 5056		
O	315 (max)	46 (max)
H111	305	44
H12	315	46
H32	305	44
H14	360	52
H34	345	50
H18	400	58
H38	380	55
H192	415	60
H392	400	58
Alclad 5056		
H192	360	52
H392	345	50
H393	370(a)	54

(a) Yield strength (min), 325 MPa (47 ksi)

5083

Chemical Composition. Composition Limits. 0.40 Si max, 0.40 Fe max, 0.10 Cu max, 0.40 to 1.00 Mn, 4.00 to 4.90 Mg, 0.05 to 0.25 Cr, 0.25 Zn max, 0.15 Ti max, 0.05 others max (each), 0.15 others max (total), bal Al

Specifications (U.S. and/or Foreign). AMS. Sheet and plate: 4056, 4057, 4058, 4059; ASTM. Sheet and plate: B 209. Extruded wire, bar, rods, shapes, and tubing: B 221. Extruded seamless tubing: B 241. Drawn seamless tubing: B 210. Welded tubing: B 547. Forgings: B 247. Gas and oil transmission pipe: B 245; SAE. J454; Government. Sheet and plate: QQ-A-250/6. Extruded wire, rod, bar, shapes and tubing: QQ-A-200/4. Forgings: QQ-A-367. Armor plate: MIL-A-46027. Extruded armor: MIL-A-46083. Forged armor: MIL-A-45225; (Canada) CSA GM41; (United Kingdom) BS H8; (Germany) DIN AlMg4.5Mn, Werstoff-Nr. 3.3457, ISO: AlMg4.5Mn

Available Product Forms. Sheet; plate; extruded wire, rod, bars, shapes, and tubing; extruded seamless tubing; drawn seamless tubing; welded tubing; forgings; gas and oil transmission pipe

Characteristics

Major alloying elements: 4.4Mg-0.7Mn-0.15Cr. Suitable for applications requiring weldability, moderate high strength, and good resistance to corrosion

Typical Uses. Marine, auto, and aircraft parts; unfired pressure vessels; cryogenics; TV towers; drilling rigs, transportation equipment, missile components, and armor plate. Tempers include H321, H116, H111.

For information on resistance to corrosion, cold workability, machinability, brazeability, and weldability, see Table titled "Comparative Characteristics and Applications" in introduction to this chapter

Recommended Heat Treating Practice

Annealing. Treatment is at 415 °C (775 °F); holding at temperature is not required

Hot Working Temperature. Range is 315 to 480 °C (600 to 900 °F)

5083 Aluminum: Typical tensile properties

Temper	Tensile strength(a) MPa	ksi	Yield strength MPa	ksi	Elongation(a)(b), %
O	290	42	145	21	22
H112	303	44	193	28	16
H116	317	46	228	33	16
H321	317	46	228	33	16
H323, H32	324	47	248	36	10
H343, H34	345	50	283	41	9

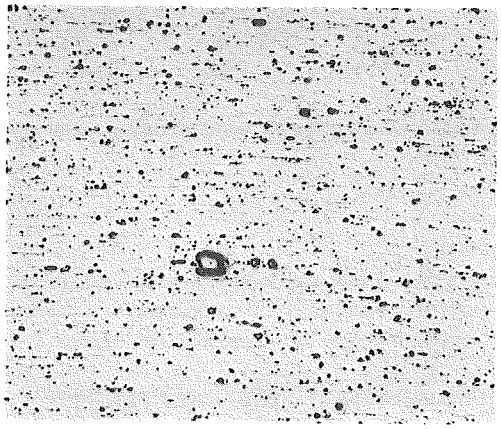
(a) Strengths and elongations are unchanged or improved at low temperatures. (b) 1.6 mm (0.0625 in.) thick specimens

5083 Aluminum: Mechanical-property limits

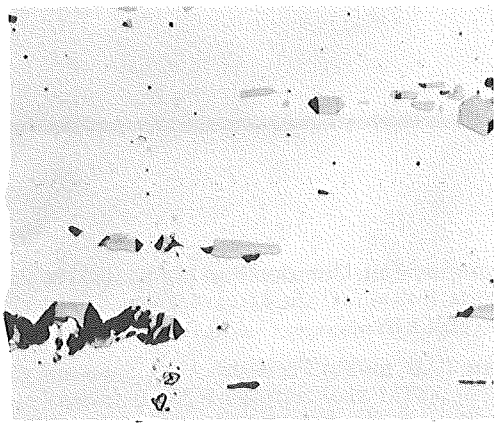
Temper	Tensile strength, Minimum, MPa	Tensile strength, Minimum, ksi	Tensile strength, Maximum, MPa	Tensile strength, Maximum, ksi	Yield strength, Minimum, MPa	Yield strength, Minimum, ksi	Yield strength, Maximum, MPa	Yield strength, Maximum, ksi	Elongation (min)(a), %
O									
0.051-1.5000 in. thick	275	40	350	51	125	18	200	29	16
1.501-3.000 in. thick	270	39	345	50	115	17	200	29	16
3.001-5.000 in. thick	260	38	...	...	110	16	...	...	14-16
5.001-7.000 in. thick	255	37	...	...	105	15	...	...	14
7.001-8.000 in. thick	250	36	...	...	95	14	...	...	12
H112									
0.250-1.500 in. thick	275	40	...	...	125	18	...	...	12
1.501-3.000 in. thick	270	39	...	...	115	17	...	...	12
H116									
0.063-1.500 in. thick	305	44	...	...	215	31	...	...	12
1.501-3.000 in. thick	285	41	...	...	200	29	...	...	12
H321									
0.188-1.500 in. thick	305	44	385	56	215	31	295	43	12
1.501-3.000 in. thick	285	41	385	56	200	29	295	43	12
H323	310	45	370	54	235	34	305	44	8-10
H343	345	50	405	59	270	39	340	49	6-8

(a) In 50 mm (2 in.) or 4*d*, where *d* is diameter of reduced section of tensile test specimen. Where a range of values appears in this column, the specified minimum elongation varies with thickness of the mill product

5083 Aluminum: Microstructures. (a) 5083-H112 plate, cold rolled. Longitudinal section shows particles of primary $MnAl_6$ (gray, outlined). Small, dark areas may be particles of insoluble phases, such as phases that contain magnesium (for example, Mg_2Si) or that contain manganese. Keller's reagent. 50×. (b) 5083 plate, cold rolled. The coarse, gray areas are particles of insoluble $(Fe,Mn)_3SiAl_{12}$; adjacent black areas are voids caused by breakup of the brittle $(Fe,Mn)_3SiAl_{12}$ particles during cold rolling. Separate black areas may be insoluble particles of Mg_2Si. As-polished. 500×



(a)



(b)

5083 Aluminum: Typical tensile properties at various temperatures

Temperature, °C	Temperature, °F	Tensile strength(a), MPa	Tensile strength(a), ksi	Yield strength (0.2% offset)(a), MPa	Yield strength (0.2% offset)(a), ksi	Elongation, %
–195	–315	405	59	165	24	36
–80	–112	295	43	145	21	30
–30	–22	290	42	145	21	27
25	80	290	42	145	21	25
100	212	275	40	145	21	36
150	302	215	31	130	19	50
205	400	150	22	115	17	60
260	500	115	17	75	11	80
315	600	75	11	50	7.5	110
370	698	41	6	29	4.2	130

(a) Lowest strength for exposures up to 10 000 h at temperature, no load; test loading applied at 35 MPa/min (5 ksi/min) to yield strength and then at strain rate of 10%/min to fracture