Table 3 (Continued)

Alloy	UNS No.	Temper	Cold workability	Extrudability	Machinability	Brazeability	Weldability			General corrosion resistance	Stress-corrosion resistance
							Gas welding	Arc welding	Spot welding		
		H38	C	B	C	C	A	A	A	A	A
		H39	C	B	C	C	A	A	A	A	A
5052	A95052	O	A	B	D	C	A	A	B	A	A
		H32	B	B	D	C	A	A	A	A	A
		H34	B	B	C	C	A	A	A	A	A
		H36	C	B	C	C	A	A	A	A	A
		H38	C	B	C	C	A	A	A	A	A
5056	A95056	O	A	C	D	D	C	A	B	A(a)	B(a)
		H111	A	C	D	D	C	A	A	A(a)	B(a)
		H12, H32	B	C	D	D	C	A	A	A(a)	B(a)
		H14, H34	B	C	D	D	C	A	A	A(a)	B(a)
		H18, H38	C	C	C	D	C	A	A	A(a)	C(a)
		H192	D	C	C	D	C	A	A	B(a)	D(a)
		H392	D	C	B	D	C	A	A	B(a)	D(a)
5059	A95059	O	B	B	D	D	C	A	B	A(a)	B(a)
		H111	C	B	D	D	C	A	A	A(a)	B(a)
		H116	C	B	D	D	C	A	A	A(a)	B(a)
		H321	C	B	D	D	C	A	A	A(a)	B(a)
5083	A95083	O	B	C	D	D	C	A	B	A(a)	A(a)
		H114	C	C	D	D	C	A	A	A(a)	B(a)
		H116	C	C	D	D	C	A	A	A(a)	B(a)
		H131	C	C	D	D	C	A	A	A(a)	B(a)
		H321	C	C	D	D	C	A	A	A(a)	A(a)
5086	A95086	O	A	B	D	D	C	A	B	A(a)	A(a)
		H32	B	B	D	D	C	A	A	A(a)	A(a)
		H34	B	B	C	D	C	A	A	A(a)	B(a)
		H36	C	B	C	D	C	A	A	A(a)	B(a)
		H39	C	B	C	D	C	A	A	A(a)	B(a)
		H111	B	B	D	D	C	A	A	A(a)	B(a)
		H116	B	B	D	D	C	A	A	A(a)	A(a)
		H321	B	B	D	D	C	A	A	A(a)	A(a)
5154	A95154	O	A	B	D	D	C	A	B	A(a)	A(a)
		H32	B	B	D	D	C	A	A	A(a)	A(a)
		H34	B	B	C	D	C	A	A	A(a)	A(a)
		H36	C	B	C	D	C	A	A	A(a)	A(a)
		H38	C	B	C	D	C	A	A	A(a)	A(a)
5182	A95182	O	A	C	D	D	C	A	B	A(a)	B(a)
		H111	B	C	D	D	C	A	A	A(a)	B(a)
		H39	D	C	C	D	C	A	A	A(a)	B(a)
		H391	D	C	C	D	C	A	A	A(a)	B(a)
		H48	D	C	D	D	C	A	A	A(a)	B(a)
		H481	D	C	D	D	C	A	A	A(a)	B(a)
		H49	D	C	D	D	C	A	A	A(a)	B(a)
5252	A95252	H24	B	B	C	C	A	A	A	A(a)	A(a)
		H25	C	B	C	C	A	A	A	A(a)	A(a)
		H28	C	B	C	C	A	A	A	A(a)	A(a)
5254	A95254	O	A	B	D	D	A	A	B	A(a)	A(a)
		H32	B	B	D	D	A	A	A	A(a)	A(a)
		H34	B	B	C	D	A	A	A	A(a)	A(a)
		H36	C	B	C	D	A	A	A	A(a)	A(a)
		H38	C	B	C	D	A	A	A	A(a)	A(a)
		H112	B	B	C	D	A	A	A	A(a)	A(a)
5383	A95383	O	A	C	D	D	C	A	B	A(a)	A(a)
		H116	C	C	D	D	C	A	A	A(a)	B(a)
		H321	C	C	D	D	C	A	A	A(a)	B(a)
5454	A95454	O	A	B	D	D	C	A	A	A	A
		H32	B	B	D	D	C	A	A	A	A
		H34	B	B	C	D	C	A	A	A	A
		H111	B	B	D	D	C	A	A	A	A
5456	A95456	O	A	C	D	D	C	A	B	A(a)	B(a)
		H116	C	C	D	D	C	A	A	A(a)	B(a)
		H321	C	C	D	D	C	A	A	A(a)	B(a)
5657	A95657	H241	A	B	D	D	A	A	A	A(a)	B(a)
		H25	B	B	D	D	A	A	A	A(a)	B(a)
		H26	B	B	D	D	A	A	A	A(a)	B(a)
		H28, H38	C	B	D	D	A	A	A	A(a)	A(a)
5754	A95754	O	A	B	D	D	A	A	A	A(a)	A(a)
6005	A96005	T5	C	A	C	A	A	A	A	B	B
		T51	C	A	C	A	A	A	A	B	B
6005A	A96005A	T1	C	A	C	A	A	A	A	B	B
		T5	C	A	C	A	A	A	A	B	B
		T61	C	A	C	A	A	A	A	B	B
6009	A96009	T4	B	A	B	A	A	A	A	A	A
		T62	B	A	B	A	A	A	A	A	A
6010	A96010	T4	B	A	B	A	A	A	A	A	A
		T6, T62	B	A	B	A	A	A	A	A	A
6013	A96013	T4	B	A	B	A	A	A	A	B	B
		T6, T651	B	A	B	A	A	A	A	B	B

(continued)

(a) The rating for this material would be lower if used at temperatures at or above 150 °C (300 °F). Source: Ref 1, 4

Table 3 (Continued)

Alloy	UNS No.	Temper	Cold workability	Extrudability	Machinability	Brazeability	Weldability: Gas welding	Weldability: Arc welding	Weldability: Spot welding	General corrosion resistance	Stress-corrosion resistance
		T8	B	A	B	A	A	A	A	B	B
6020	A96020	T651*x*	B	A	B	A	A	A	A	B	B
		T8	B	A	B	A	A	A	A	B	B
6022	A96022	T4	B	A	B	A	A	A	A	B	B
		T62	B	A	B	A	A	A	A	B	B
6041	A96041	T6-type	B	A	B	A	A	A	A	B	B
6042	A96042	T5, T551*x*	B	A	B	A	A	A	A	B	B
6053	A96053	T6	B	A	C	B	A	A	A	A	B
6056	A96056	T4, T451*x*	B	A	C	B	A	A	A	B	C
		T6	B	A	C	B	A	A	A	B	C
		T72	B	A	C	B	A	A	A	B	C
6060	A96060	T51	B	A	C	B	A	A	A	B	C
		T61	B	A	C	B	A	A	A	B	C
6061	A96061	O	A	B	D	A	A	A	B	B	A
		T1	B	B	C	A	A	A	A	B	A
		T4, T451	B	B	C	A	A	A	A	B	B
		T51	B	B	C	A	A	A	A	C	C
		T6, T651	B	A	C	A	A	A	A	B	A
6062	A96062	T5	B	A	C	A	A	A	A	C	C
		T6	B	A	C	A	A	A	A	C	C
6063	A96063	O	A	A	D	A	A	A	B	A	A
		T4	B	A	D	A	A	A	A	A	A
		T5	B	A	C	A	A	A	A	A	A
		T6	B	A	C	A	A	A	A	A	A
		T65	B	A	C	A	A	A	A	A	A
		T83	B	A	C	A	A	A	A	A	A
		T837	B	A	C	A	A	A	A	A	A
6066	A96066	O	B	B	D	D	D	B	B	C	A
		T4, T451	C	B	C	D	D	B	B	C	B
		T6, T651	C	B	B	D	D	B	B	C	B
6070	A96070	T4	C	B	C	D	D	B	B	B	B
		T6	C	B	B	D	D	B	B	B	B
6082	A96082	T5	B	B	C	A	A	A	A	B	B
		T6, T651*x*	B	B	C	A	A	A	A	B	B
6101	A96101	H111	C	A	C	A	A	A	A	A	A
		T6	B	A	D	A	A	A	A	A	A
6105	A96105	T5	C	A	C	A	A	A	A	A	A
6111	A96111	T4	C	A	C	A	A	A	A	A	A
		T41	C	A	C	A	A	A	A	A	A
		T62	C	A	C	A	A	A	A	A	A
6151	A96151	T6	C	A	C	A	A	A	A	A	A
6162	A96162	T5, T551*x*	C	A	C	A	A	A	A	A	A
		T6, T651*x*	C	A	C	A	A	A	A	A	A
6201	A96201	T81	B	A	C	A	A	A	A	A	A
6205	A96205	T1	C	A	C	A	A	A	A	B	B
		T5	C	A	C	A	A	A	A	B	B
		T54	C	A	C	A	A	A	A	B	B
6262	A96262	T9	C	A	C	A	A	A	A	B	A
6351	A96351	T4	C	A	C	C	B	A	B	A	A
		T5	C	A	C	C	B	A	A	A	A
		T6	C	A	C	C	B	A	A	A	A
6360	A96360	T5	C	A	C	A	A	A	A	B	B
		T6	C	A	C	A	A	A	A	B	B
6463	A96463	T1	B	A	D	A	A	A	A	A	A
		T5	B	A	C	A	A	A	A	A	A
		T6, T62	C	A	C	A	A	A	A	A	A
6560	A96560	T5	C	A	C	A	A	A	A	B	B
		T6	C	A	C	A	A	A	A	B	B
6951	A96951	T42, T62	C	A	C	A	A	A	A	B	B
7004	A97004	T5	D	B	B	B	C	A	A	C	C
7005	A97005	T53	D	B	B	D	D	D	B	C	C
7010	A97010	T7451	D	B	B	D	D	D	B	C	B
		T7651	D	B	B	D	D	D	B	C	B
7019	A97019	T651	D	B	B	D	D	D	B	C	C
7021	A97021	O	C	B	D	D	D	D	B	C	B
		T6-type	D	B	B	D	D	D	B	C	C
7029	A97029	T5	D	C	B	D	D	D	B	C	C
7033	A97033	T6	D	C	B	D	D	D	B	C	C
7039	A97039	T64	D	C	B	D	D	D	B	C	C
7040	A97040	T74511	D	C	B	D	D	D	B	C	B
7049	A97049	T73	D	C	B	D	D	D	B	C	B
		T7352	D	C	B	D	D	D	B	C	B
7050	A97050	T7351*x*	D	C	B	D	D	D	B	C	B
		T7451	D	C	B	D	D	D	B	C	B
		T7651	D	C	B	D	D	D	B	C	B
7055	A97055	T7451	D	C	B	D	D	D	B	C	B
		T7651	D	C	B	D	D	D	B	C	B
7068	A97068	T651*x*	D	C	B	D	D	D	B	C	C
7075	A97075	O	C	C	D	D	D	D	B	C	B
		T6, T651	D	C	B	D	D	D	B	C	C

(continued)

(a) The rating for this material would be lower if used at temperatures at or above 150 °C (300 °F). Source: Ref 1, 4

Table 3 (Continued)

Alloy	UNS No.	Temper	Cold workability	Extrudability	Machinability	Brazeability	Weldability: Gas welding	Weldability: Arc welding	Weldability: Spot welding	General corrosion resistance	Stress-corrosion resistance
		T73, T735*x*	D	C	B	D	D	D	B	C	B
7079	A97079	T6, T65*x*	D	C	B	D	D	D	B	C	C
7085	A97085	T735*x*, T765*x*	D	C	B	D	D	D	B	C	B
7116	A97116	T5	D	C	B	D	D	C	B	C	B
7129	A97129	T5	D	C	B	D	D	C	B	C	B
7136	A97136	T7651*x*	D	C	B	D	D	C	B	C	B
7140	A97140	T7451	D	C	B	D	D	C	B	C	B
		T7651	D	C	B	D	D	C	B	C	B
7149	A97149	T73, T7351	D	C	B	D	D	C	B	C	B
7150	A97150	T6151	D	C	B	D	D	C	B	C	B
		T7751	D	C	B	D	D	C	B	C	B
7175	A97175	T74	D	C	B	D	D	C	B	C	B
7178	A97178	O	C	C	B	D	D	D	B	C	C
		T6, T651	D	C	B	D	D	D	B	C	C
		T76, T7651	D	C	B	D	D	D	B	C	B
7249	A97249	T7452	D	C	B	D	D	D	B	C	B
7250	A97250	T7451	D	C	B	D	D	D	B	C	B
7349	A97349	T651*x*	D	C	B	D	D	D	B	C	C
7449	A97449	T7651	D	C	B	D	D	D	B	C	B
		T7951, T7951*x*	D	C	B	D	D	D	B	C	C
7475	A97475	T61	D	C	B	D	D	B	B	C	C
		T651	D	C	B	D	D	B	B	C	C
		T7351	D	C	B	D	D	D	B	C	B
		T761	D	C	B	D	D	D	B	C	B
		T7651	D	C	B	D	D	D	B	C	B
8017	A98017	H212	A	A	D	A	A	A	A	A	A
8030	A98030	H221	A	A	E	A	A	A	A	A	A
8176	A98176	H24	A	A	D	A	A	A	A	A	A

(a) The rating for this material would be lower if used at temperatures at or above 150 °C (300 °F). Source: Ref 1, 4

Wrought Non-Heat-Treatable Alloys

The wrought non-heat-treatable alloys include the commercially pure aluminum alloys (1*xxx*), the aluminum-manganese alloys (3*xxx*), the aluminum-silicon alloys (4*xxx*), and the aluminum-magnesium alloys (5*xxx*). These alloys cannot be hardened by heat treatment and are therefore hardened by a combination of solid-solution strengthening (Fig. 1) and cold working (Fig. 2). The 5*xxx* alloys have the highest strengths of the non-heat-treatable alloys (Table 4), with tensile strengths ranging from 125 to 435 MPa (18 to 63 ksi). The 5*xxx* series provide excellent combinations of strength and corrosion resistance by solid-solution strengthening and work hardening. The 3*xxx* series have moderate strength (ultimate tensile strengths of 110 to 297 MPa, or 16 to 43 ksi) and are used when good ductility, excellent corrosion resistance, and higher strength than 1*xxx* are required.

1xxx Alloys

Aluminum of 99.00% or higher purity has many applications, especially in the electrical and chemical fields. These grades of aluminum are characterized by excellent corrosion resistance, high thermal and electrical conductivities, low mechanical properties, and excellent workability. They are readily joined by welding, brazing, and soldering. Typical ultimate tensile strength ranges from 69 to 186 MPa (10 to 27 ksi). Moderate increases in strength may be obtained by strain hardening. Iron and silicon are the major impurities. The more prevalent commercially pure grades (99.0 wt% minimum aluminum) are available in most product forms and are used for applications such as electrical conductors, chemical processing equipment, aluminum foil, cooking utensils, architectural products, and decorative trim. The most popular 1*xxx* alloy is alloy 1100; it has a tensile strength of 90 MPa (13 ksi), which can be increased to 165 MPa (24 ksi) by work hardening. The 1*xxx* series are also used for electrical applications, primarily alloy 1350, which has relatively tight controls on impurities that would adversely affect electrical conductivity.

3xxx Aluminum-Manganese Alloys

The aluminum-manganese system is the basis for the oldest aluminum alloys, and the 3*xxx* alloys are widely used because of their excellent formability and resistance to corrosion. These alloys generally are non-heat-treatable but have approximately 20% more strength than 1*xxx*-series alloys. Because only a limited percentage of manganese (up to approximately 1.5%) can be effectively added to aluminum, manganese is used as a major element in only a few alloys. However, three of them—3003, 3*x*04, and 3105—are widely used as general-purpose alloys for moderate-strength applications requiring good workability. These applications include beverage cans, cooking utensils, heat exchangers, storage tanks, awnings, furniture, highway signs, roofing, siding, and other architectural applications.

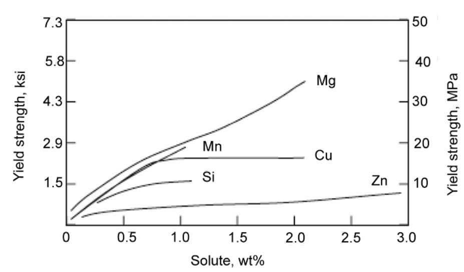

Fig. 1 Solid-solution strengthening of annealed high-purity aluminum with magnesium, manganese, copper, silicon, and zinc additions

4xxx Aluminum-Silicon Alloys

The major alloying element in 4*xxx*-series alloys is silicon, which can be added in sufficient quantities (up to 12%) to cause substantial lowering of the melting range without producing brittleness. For this reason, aluminum-silicon alloys are used in welding wire and as brazing alloys for joining aluminum, where a lower melting range than that of the base metal is required. These alloys have medium strength, with typical ultimate tensile strength ranging from 172 to 379 MPa (25 to 55 ksi). Most alloys in this series are non-heat-treatable, but when used in welding heat treatable alloys, they will pick up some of the alloying constituents of the latter and thus respond to heat treatment to a limited extent. The alloys containing appreciable amounts of silicon become dark gray to charcoal when anodic oxide finishes are applied and thus are in demand for architectural applications. Alloy 4032 has a low coefficient of thermal expansion and high wear resistance and thus is well suited to production of forged engine pistons.

5xxx Aluminum-Magnesium Alloys

The major alloying element in 5*xxx*-series alloys is magnesium. Uses include architectural, ornamental, and decorative trim; cans and can ends; household appliances; streetlight standards; boats and ships; cryogenic tanks; crane parts; and automotive structures.

Magnesium is considerably more effective than manganese as a hardener, approximately 0.8% Mg being equal to 1.25% Mn, and it can be added in considerably higher quantities. Aluminum and magnesium also form solid solutions over a wide range of compositions. Alloys containing magnesium in amounts from 0.8 to approximately 5 wt% are widely used. When it is used as a major alloying element or with manganese, the result is a moderate-to-high-strength work-hardenable alloy (Table 4) with relatively high ductility, usually in excess of 25%.

The 5*xxx* alloys have very high toughness, even at cryogenic temperatures to near absolute zero (Fig. 3), and are readily weldable by a variety of techniques at thicknesses up to 20 cm (8 in.). Corrosion resistance is very good even in saltwater, but certain limitations should be placed on the amount of cold work and the safe operating temperatures permissible for the higher-magnesium alloys (over approximately 3.5% for operating temperatures above approximately 65 °C, or 150 °F) to avoid susceptibility to stress-corrosion cracking.

8xxx Alloys (Aluminum with Other Elements)

Common alloying elements include iron, nickel, and lithium. These alloys are heat treatable and have high conductivity, strength, and hardness. Typical ultimate tensile strength ranges from 117 to 414 MPa (17 to 60 ksi). Common applications for 8*xxx*-series alloys include specialty foil products, electrical products, and high-modulus aircraft components.

Heat Treatable Wrought Alloys

The wrought heat treatable alloys include the 2*xxx* Al-Cu-(Mg) series, the 6*xxx* Al-Mg-Si series, the 7*xxx* aluminum-zinc series, and various aluminum-lithium alloys. The major precipitation-hardening constituents are:

- Aluminum-copper and Al-Cu-Mg 2*xxx* alloys with hardening from coherent precipitation of Guinier-Preston (GP) zones, subsequent transition precipitates (θ'' and θ'), and ultimately softening with the equilibrium phase $CuAl_2$ (θ)
- Al-Mg-Si 6*xxx* alloys with strengthening from GP zones and transition precipitates of the equilibrium phase Mg_2Si
- Al-Zn-Mg 7*xxx* alloys with strengthening from GP zones and transition precipitates (η') of the equilibrium phase $MgZn_2$ (η)

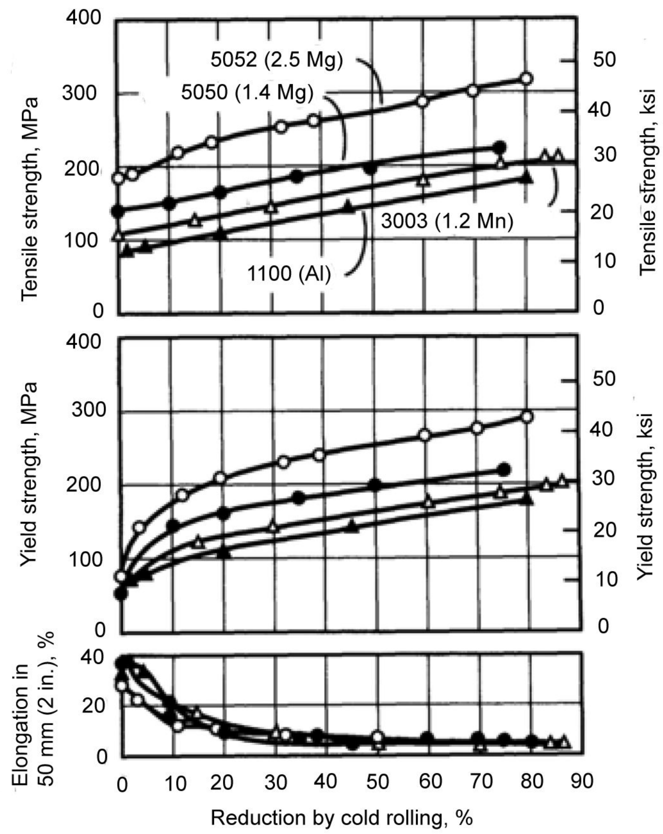

Fig. 2 Strain-hardening curves for aluminum (1100) and for aluminum-manganese (3003) and aluminum-magnesium (5050 and 5052) alloys

Table 4 Typical tensile properties of selected 3*xxx* and 5*xxx* aluminum alloy sheet products

Alloy	Temper	Tensile strength, MPa	Tensile strength, ksi	Yield strength, MPa	Yield strength, ksi	Elongation in 50 mm (2 in.), %
3003	O	100	16	40	6	30
	H14	125	18	115	17	9
	H18	165	24	150	22	5
3004	O	180	26	70	10	20
	H34	240	35	200	29	9
	H38	285	41	250	36	5
	H19	295	43	285	41	2
3005	O	130	19	55	8	25
	H14	180	26	165	24	7
	H18	240	35	225	33	4
3105	O	115	17	55	8	24
	H25	180	26	160	23	8
	H18	215	31	195	28	3
5005	O	125	18	40	6	25
	H34	160	23	140	20	8
	H38	200	29	185	27	5
5050	O	145	21	55	8	24
	H34	190	28	165	24	8
	H38	220	32	200	29	6
5052	O	195	28	90	13	25
	H34	260	38	215	31	10
	H38	290	42	255	37	7
5252	O	180	26	85	12	23
	H25	235	34	170	25	11
	H28	285	41	240	35	5
5154	O	240	35	115	17	27
	H34	290	42	230	33	13
	H38	330	48	270	39	10
	H112	240	35	115	17	25
5454	O	250	36	115	17	22
	H34	305	44	240	35	10
	H111	250	36	125	18	18
	H112	250	36	125	18	18
5056	O	290	42	150	22	35
	H18	435	63	405	59	10
	H38	415	60	345	50	15
5456	O	310	45	160	23	24
	H112	310	45	165	24	22
	H116	350	51	255	37	16
5182	O	275	40	130	19	21

- Aluminum-lithium with age hardening from the continuous precipitation of δ′ (Al_3Li)

Typical tensile properties of some common aluminum heat treatable alloys are in Table 5. The 6*xxx* alloys are heat treatable to moderately high strength levels, have better corrosion resistance than the 2*xxx* and 7*xxx* alloys, are weldable, and offer superior extrudability. Most of the 2*xxx* and 7*xxx* alloys have very limited weldability. The 2*xxx* and 7*xxx* alloys offer very high strength with good fracture toughness. With improvements in impurity control (reduction in iron and silicon), increasing the amount of cold work by stretching after quenching, and the development of improved aging procedures, thicker high-strength plate with good fracture toughness (Fig. 4) has been developed. See also the alloy datasheets in this Volume for more details.

2xxx (Aluminum-Copper) Alloys

Copper is the principal alloying element in 2*xxx*-series alloys, often with magnesium as a secondary addition. Other significant alloying additions include titanium to refine the grain structure during ingot casting, and transition element additions (manganese, chromium, and/or zirconium) that form dispersoid particles ($Al_{20}Cu_2Mn_3$, $Al_{18}Mg_3Cr_2$, and Al_3Zr), which help control the wrought grain structure. Iron and silicon are considered impurities and are held to an absolute minimum, because they form intermetallic compounds (Al_7Cu_2Fe and Mg_2Si) that are detrimental to both fatigue and fracture toughness.

These alloys require solution heat treatment to obtain optimum properties; in the solution heat treated condition, mechanical properties are similar to, and sometimes exceed, those of low-carbon steel. In some instances, precipitation heat treatment (aging) is employed to further increase mechanical properties. This treatment increases yield strength, with attendant loss in elongation; its effect on tensile strength is not as great. Typical ultimate tensile strength ranges from 186 to 428 MPa (27 to 62 ksi).

Table 5 Typical tensile properties of selected 2*xxx*, 6*xxx*, and 7*xxx* aluminum alloy products

			Tensile strength		Yield strength		
Alloy	Temper	Product(a)	MPa	ksi	MPa	ksi	Elongation in 50 mm (2 in.), %
2008	T4	Sheet	250	36	125	18	28
	T6	Sheet	300	44	240	35	13
2014	T6, T651	Plate, forging	485	70	415	60	13
2024	T3, T351	Sheet, plate	450	65	310	45	18
	T361	Sheet, plate	495	72	395	57	13
	T81, T851	Sheet, plate	485	70	450	65	6
	T861	Sheet, plate	515	75	490	71	6
2224	T3511	Extrusion	530	77	400	58	16
2324	T39	Plate	505	73	415	60	12
2524	T3, T351	Sheet, plate	450	65	310	45	21
2036	T4	Sheet	340	49	195	28	24
2219	T81, T851	Sheet, plate	455	66	350	51	10
	T87	Sheet, plate	475	69	395	57	10
2519	T87	Plate	490	71	430	62	10
6009	T4	Sheet	220	32	125	18	25
	T62	Sheet	300	44	260	38	11
6111	T4	Sheet	285	41	165	24	25
	T6	Sheet	350	51	310	45	10
6061	T6, T6511	Sheet, plate, extrusion, forging	310	45	275	40	12
	T9	Extruded rod	405	59	395	57	12
6063	T5	Extrusion	185	27	145	21	12
	T6	Extrusion	240	35	215	31	12
7005	T5	Extrusion	350	51	290	42	13
7049	T73	Forging	540	78	475	69	10
7050	T74, T745*x*	Plate, forging, extrusion	510	74	450	65	13
7150	T651, T6151	Plate	600	87	560	81	11
	T77511	Extrusion	650	94	615	89	12
7055	T7751	Plate	640	93	615	89	10
	T77511	Extrusion	670	97	655	95	11
7075	T6, T651	Sheet, plate	570	83	505	73	11
	T73, T735*x*	Plate, forging	505	73	435	63	13
7475	T7351	Plate	505	73	435	63	15
	T7651	Plate	455	66	390	57	15

(a) Properties of sheet and plate are for the long-transverse direction, and those of extrusions and forgings are for the longitudinal direction.

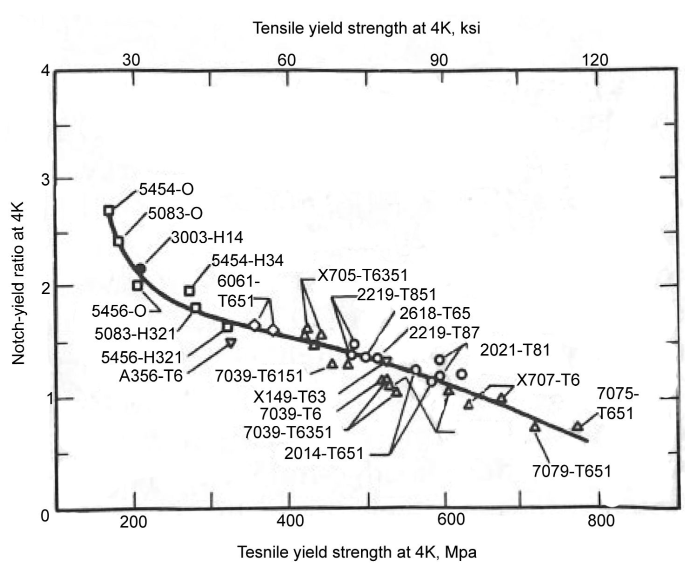

Fig. 3 Notch-yield ratio vs. tensile yield strength for aluminum alloys at 4 K. Source: Ref 5

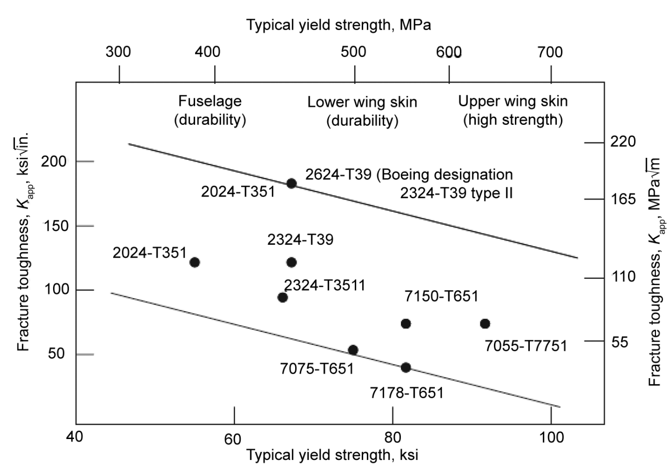

Fig. 4 Fracture toughness vs. yield strength for high-strength aluminum alloys. Source: Ref 6

The alloys in the 2*xxx* series do not have as good corrosion resistance as most other aluminum alloys, and under certain conditions they may be subject to intergranular corrosion. Therefore, these alloys in the form of sheet usually are clad with a high-purity aluminum or with a magnesium-silicon alloy of the 6*xxx* series, which provides galvanic protection of the core material and thus greatly increases resistance to corrosion.

Alloys in the 2*xxx* series are particularly well suited for parts and structures requiring high strength-to-weight ratios and are commonly used to make truck and aircraft wheels, truck suspension parts, aircraft fuselage and wing skins, and structural parts and those parts requiring good strength at temperatures up to 150 °C (300 °F). Except for alloy 2219, these alloys have limited weldability, but some alloys in this series have superior machinability.

6xxx Al-Mg-Si Alloys

Alloys in the 6*xxx* series contain silicon and magnesium approximately in the proportions required for formation of magnesium silicide (Mg_2Si), thus making them heat treatable. Although not as strong as most 2*xxx* and 7*xxx* alloys, 6*xxx*-series alloys have good formability, weldability, extrudability, machinability, and corrosion resistance, with medium strength. Typical ultimate tensile strength ranges from 124 to 400 MPa (18 to 58 ksi). These alloys are readily welded by gas metal arc welding and gas tungsten arc welding methods. Alloys in this heat treatable group may be formed in the T4 temper (solution heat treated but not precipitation heat treated) and strengthened after forming to full T6 properties by precipitation heat treatment. Uses include architectural applications, bicycle frames, transportation equipment, bridge railings, and welded structures.

7xxx Aluminum-Zinc Alloys

Zinc, in amounts of 1 to 8%, is the major alloying element in 7*xxx*-series alloys, and when coupled with a smaller percentage of magnesium results in heat treatable alloys of moderate to very high strength. Usually other elements, such as copper and chromium, are also added in small quantities. The 7*xxx*-series alloys are used in airframe structures, mobile equipment, and other highly stressed parts. Typical ultimate tensile strength ranges from 221 to 607 MPa (32 to 88 ksi).

Higher-strength 7*xxx* alloys exhibit reduced resistance to stress-corrosion cracking and are often used in a slightly overaged temper to provide better combinations of strength, corrosion resistance, and fracture toughness.

Physical Properties

Typical physical properties of wrought aluminum alloys at room temperature are summarized in “Typical Room-Temperature Physical Properties of Wrought Aluminum Alloys” in the appendix of this Volume. The data are distilled from a variety of published industry sources, specifically Ref 4 and 7 to 14. In any cases where there are questions of authority, the most reliable sources for compositions and specification values are always The Aluminum Association’s publications and the ASTM International standards (Ref 1, 7), and for design information, the Metallic Materials Properties Development and Standardization (MMPDS) and the *Aluminum Structural Handbook* (Ref 4, 8). In some instances where no published values were available for individual alloys, they have been calculated by relational analysis (Ref 14, 15) if adequate supporting data were available.

A common designation for electrical conductivity is a percent of the International Annealed Copper Standard (IACS), where the quantity %IACS is the relative conductivity of a material compared to the conductivity of unalloyed, annealed copper at 20 °C (68 °F). Copper, under these conditions, is assigned a conductivity of 100 %IACS. Conductivity (σ) is the reciprocal of electrical resistivity (ρ), which is typically expressed in units of $\mu\Omega \cdot cm$. The conversion is:

$$\sigma(\%IACS) = \frac{172.41}{\rho(\mu\Omega \cdot cm)}$$

The electrical conductivity of 99.99% pure aluminum at 20 °C (68 °F) is in the range of 64 to 65 %IACS. The conductivity of aluminum ranges from roughly 25 to 60 %IACS for conventional aluminum alloys, depending on the alloying and the extent in solid solution. Metallic additions to aluminum reduce its electrical conductivity to a greater extent when in solid solution. Table 6 (Ref 16, 17) is a summary

Table 6 Electrical conductivity of various wrought aluminum alloys

Material	%IACS
1050-O	61.30
1060-O	62.00
1060-H18	61.00
1100-O	59.00
1100-H18	57.00
1145-O	61.00
1145-H18	60.00
1199-O	64.50
1350-O	61.80
1350-H*x*	61.00
2011-T3	36.0–36.50
2011-T3 and T4	39.00
2011-T8	45.00
2014-F and O	48.60–50.70
2014-O	50.00
2014-T3 and T4	32.50–34.80
2014-T3, T4, and T451	34.00
2014-T6	38.00–39.70
2014-T6, T651, and T652	40.00
2017-F	49.30–49.50
2017-O	50.00
2017-T4	34.00
2024-F	46.80–48.50
2024-O	50.00
2024-T3	28.60–36.10
2024-T36	29.10–29.50
2024-T3, T36, T351, T361, and T4	30.00
2024-T4	28.80–31.00
2024-T6, T81, T851, and T861	38.00
2036-O	52.00
2036-T4	41.00
2048-T851	42.00
2124-O	50.00
2124-T851	39.00
2127-T4	42.10–42.40
2218-T61	37.40
2218-T61	38.00
2218-T72	40.00
2219-O	44.00
2219-T31, T37, and T351	28.00
2219-T62, T81, T87, and T851	30.00
2319-O	44.00
2618-T61	37.00
3003-O	44.70–49.80
3003-O	50.00
3003-H14 and H12	37.80–51.50
3003-H12	42.01
3003-H14	41.00
3003-H18	40.00
3003-H24 and H28	37.80–47.50
3004-O	42.00
X3005-O	50.10–50.30
3105-O	45.00
4032-O	40.00
4032-T6	35.30–36.30
4032-T6	36.00
4043-F	52.30–54.30
4043-O	42.00
5005-O and H38	52.00
5050-O and H38	50.00
5052	33.60–37.60
5052-O and H38	35.00
5056	28.10–29.80
5056-O	29.00
5056-H38	27.00
5083	29.00

(continued)

Source: Ref 16, 17

Table 6 (Continued)

Material	%IACS	Material	%IACS	Material	%IACS
5086	31.00	6063-T1	50.00	7005-O	43.00
5154	30.50–32.80	6063-T5	55.00	7005-T53, T5351, T63, and T6351	38.00
5356-O	29.00	6063-T6 and T83	53.00	7005-T6	35.00
5357	42.30–47.00	6066-O	40.00	7039	32–40
5454	34.00	6066-T6	37.00	7050-O	47.00
5456	29.00	6070-T6	44.00	7050-T76 and T7651	39.50
5457	46.00	6101-T6	57.00	7050-T736 and T73651	40.50
5652	35.00	6101-T61	59.00	7072	60.00–60.10
5657	54.00	6101-T63	58.00	7072-O	60.00
6005-T5	49.00	6101-T64	60.00	7075-F	44.50–47.80
6009-O	54.00	6101-T65	58.00	7075-T6	31.40–34.80
6009-T4	44.00	6151-O	53.30–55.00	7075-T6	32.00
6009-T6	47.00	6151-O	54.00	7075-W	27.00–37.00
6010-O	53.00	6151-T4	41.50–43.30	7075-T6, T62, T651, and T652	33.00
6010-T4	39.00	6151-T6	42.00	7075-T76 and T7651	38.50
6010-T6	44.00	6151-T6	43.90–45.00	7075-T73, T7351, and T7352	40.00
6053	39.30–48.00	6151-T6	45.00	7076	35.00
6061-F and O	42.30–48.50	6201-T81	54.00	7175-O	46.00
6061-O	47.00	6205-T1	45.00	7175-T66	36.00
6061-T4	37.60–40.50	6205-T5	49.00	7175-T736 and T73652	40.00
6061-T4	40.00	6262-T9	44.00	7178-O	46.00
6061-T6 and T9	40.00–44.80	6351-T6	46.00	7178-T6 and T651	32.00
6061-T6	43.00	6463-T1	50.00	7178-T76 and T7651	39.00
6062-F	47.00–51.00	6463-T5	55.00	7475-O	46.00
6062-T4	43.50–44.00	6463-T6	53.00	7475-T61 and T651	36.00
6062-T6	44.70–49.50	6951-F	53.00–53.10	7475-T761 and T7651	40.00
6063-O	58.00	6951-O	55.70–56.50	7475-T7351	42.00

Source: Ref 16, 17

of conductivity values for various wrought alloys and tempers. See also the article "Physical Metallurgy of Aluminum Alloys" in *Aluminum Science and Technology*, Volume 2A of *ASM Handbook*, 2018.

The densities and moduli of elasticity of all aluminum alloys are directly dependent on the alloying content and the properties of the alloying elements themselves. The dependence is such that these properties may be estimated for alloys for which they have not been measured directly by summing the percentages of each element multiplied by their own density and/or moduli, respectively (i.e., the rule of averages). Table 7 is a summary of the densities and average moduli of elasticity of aluminum and the more commonly used alloying elements to aid in such estimates (Ref 18). Values calculated in this manner should be considered estimates, and care should be taken to note the exceptions to the rule for modulus, for example, magnesium, for which the effect is greater than would be expected based on its modulus alone.

Table 7 Densities and elastic moduli of aluminum and aluminum alloying elements

	Density		Elastic modulus	
Alloying element	g/cm^3	lb/in.^{2}	GPa	10^6 psi
Aluminum	2.699	0.0971	69	10
Chromium	7.19	0.26	248	36
Copper	8.96	0.324	128	16
Iron	7.87	0.284	208	28.5
Magnesium	1.74	0.0628	44(a)	6.5(a)
Manganese	7.43	0.268	159	23
Nickel	8.9	0.322	207	30
Silicon	2.33	0.084	110	16
Tin	7.3	0.264	44	6
Titanium	4.54	0.164	120	16.8
Zinc	7.13	0.258	69(b)	10(b)
Zirconium	6.5	0.23	49	11

(a) Effect of magnesium is equivalent to approximately 75 GPa (11.0 × 10^6 psi). (b) The modulus of zinc is not well defined; these values are lower-limit estimates. Source: Ref 18

A comparison of the damping characteristics of alclad 2024-T3 with the band for data for a variety of bare (not clad) heat treated alloys is shown in Fig. 5. These results are based on the decay of vibrations in cantilever-mounted beam specimens (Ref 19). It is clear that

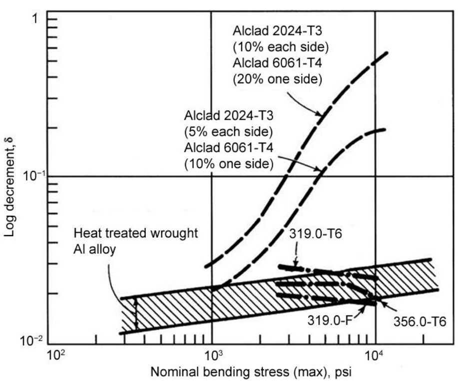

Fig. 5 Damping characteristics of bare and clad aluminum alloys compared with those of bare (unclad) wrought and cast aluminum alloys. Source: Ref 19

cladding of aluminum alloys greatly increases their damping characteristics. As a result, where vibrations may occur from high sonic or mechanical stresses, the advantage of using clad products is indicated.

Typical Minimum Mechanical Properties

Tables 8A and B summarize the typical room-temperature properties of a wide variety of wrought aluminum alloys in engineering and metric units, respectively. The data are distilled from a variety of published industry sources, specifically Ref 4 and 7 to 14. In any cases where there are questions of authority, the most reliable sources for compositions and specification values are always The Aluminum Association's publications and the ASTM International standards (Ref 1, 7), and for design information the MMPDS and the *Aluminum Structural Handbook* (Ref 4, 8). In some instances where no published values were available for individual alloys, they have been calculated by relational analysis (Ref 14, 15), if adequate supporting data were available. Tables 9A and B summarize the estimated minimum or design properties of a wide variety of wrought aluminum alloys at room temperature in engineering and metric units, respectively (Ref 4, 7, 8). Tables 10A and B present, respectively, the estimated

Table 8A Typical mechanical properties of wrought aluminum alloys (engineering units)

Alloy	UNS No.	Temper	Ultimate tensile strength, ksi	Tensile yield strength(a), ksi	Elongation in 4D, %	Elongation in 2 in., %	Brinell hardness number (BHN)	Ultimate shear strength, ksi	Fatigue endurance limit(b), ksi	Modulus of elasticity (E)(c), × 10^3 ksi	Notes
1060	A91060	O	10	4	43	...	19	7	3	10.0	...
		H12	12	11	16	...	23	8	4	10.0	...
		H14	14	13	12	...	26	9	5	10.0	...
		H16	16	15	8	...	30	10	6.5	10.0	...
		H18	19	18	6	...	35	11	6.5	10.0	...
1100	A91100	O	13	5	35	45	23	9	5	10.0	...
		H12	16	15	12	25	28	10	6	10.0	...
		H14	18	17	9	20	32	11	7	10.0	...
		H16	21	20	6	17	38	12	9	10.0	...
		H18	24	22	5	15	44	13	9	10.0	...
1350	A91350	O	12	4	23	...	23	8	5	10.0	...
		H12	14	12	12	...	26	9	6	10.0	...
		H14	16	14	9	...	30	10	7	10.0	...
		H16	18	16	6	...	36	11	9	10.0	...
		H19	27	24	1.5	...	48	15	9	10.0	...
2008	A92008	T4	36	18	28	...	65	21	15	10.2	...
		T62	44	35	13	...	80	26	17	10.2	...
2010	A92010	T4	35	19	25	...	65	21	8	10.2	...
		T41	35	19	25	...	65	21	15	10.2	...
		T62	39	29	15	...	75	23	17	10.2	...
2011	A92011	T3	55	43	...	15	95	32	18	10.2	...
		T8	59	45	...	12	100	35	18	10.2	...
2013	A92013	T6511	63	57	...	10	105	37	19	10.4	(d)
2014	A92014	O	27	14	...	18	45	18	13	10.6	...
		T4, T451	62	42	...	20	105	38	20	10.6	...
		T6, T651	70	60	...	13	135	42	18	10.6	...
Alclad 2014	Alc A92014	O	25	10	21	...	...	18	...	10.5	...
		T3	63	40	20	...	...	37	...	10.5	...
		T4, T351	61	37	22	...	...	37	...	10.5	...
		T6, T651	68	60	10	...	...	41	...	10.5	...
2017	A92017	O	26	10	...	22	45	18	13	10.5	...
		T4, T451	62	40	...	22	105	38	18	10.5	...
2020	A92020	T6, T651	84	74	6	8	138	50	24	11.4	...
2024	A92024	O	27	11	20	22	47	18	13	10.6	...
		T3	70	50	18	...	120	41	20	10.6	...
		T4, T351	68	47	20	19	120	41	20	10.6	...
		T361	72	57	13	...	130	42	18	10.6	...
Alclad 2024	Alc A92024	O	26	11	20	...	...	18	...	10.6	...
		T3	65	45	18	...	...	40	...	10.6	...
		T4, T351	64	42	19	...	...	40	...	10.6	...
		T361	67	63	11	...	...	41	...	10.6	...
		T81, T851	65	60	6	...	...	40	...	10.6	...
		T861	70	66	6	...	...	42	...	10.6	...
2025	A92025	T6	58	37	...	19	110	35	18	10.4	...
2026	A92026	T3511	77	57	...	14	145	45	20	10.4	(d)
2027	A92027	T351	72	55	...	16	130	42	18	10.4	(d)
2036	A92036	T4	49	28	24	...	85	29	18	10.3	...
2038	A92038	T4	44	22	24	...	81	26	14	10.4	(d)
		T6	55	48	10	...	110	32	18	10.4	(d)
2050	A92050	T84	78	74	...	10	145	45	20	10.4	(d)
Alclad 2056	Alc A92056	T3	70	50	18	...	...	41	...	10.3	(d)
2090	A92090	T3	51	34	8	...	90	30	15	11.2	(d)
		T83	68	64	8	8	130	41	18	11.2	...
2097	A92097	T87	68	62	...	6	130	39	17	11.2	(d)
2098	A92098	T8	81	80	...	8	150	47	20	11.2	(d)
2099	A92099	T83	88	80	...	9	155	51	22	11.2	(d)
2117	A92117	T4	43	24	...	27	70	28	14	10.3	...
2124	A92124	T851	70	64	...	8	120	42	20	10.6	...
2195	A92195	T34, T351	57	40	...	16	110	33	18	11.2	...
		T8, T851	85	80	...	8	155	49	21	11.2	...
2196	A92196	T851*x*	83	77	...	9	152	48	23	11.2	(d)
2198	A92198	T8	81	80	...	8	150	47	20	11.2	(d)
2199	A92199	T8	88	80	...	9	155	51	22	11.2	(d)
2218	A92218	T61	61	44	...	9	110	35	16	10.6	(d)
		T72	42	32	...	7	70	24	14	10.6	(d)
2219	A92219	O	25	11	18	...	45	15	...	10.6	...
		T62	60	42	10	...	110	35	15	10.6	...
		T81, T851	66	51	10	...	115	38	15	10.6	...
		T87	69	57	10	...	122	42	15	10.6	...
2224	A92224	T851	70	64	...	8	120	42	20	10.6	(d)
2297	A92297	T87	80	74	8	8	150	46	18	11.4	...
2324	A92324	T39	77	66	...	12	145	45	18	10.6	(d)
2397	A92397	T87	68	63	...	8	120	39	16	11.2	(d)
2424	A92424	T3	69	46	...	17	120	40	16	10.6	(d)

(continued)

(a) Offset = 0.2%. (b) At 500,000,000 cycles in R.R. Moore rotating-bending machines. (c) Under tensile loading. (d) No typical properties are published for this alloy and temper; values shown have been derived by relational analysis.

Table 8A (Continued)

Alloy	UNS No.	Temper	Ultimate tensile strength, ksi	Tensile yield strength(a), ksi	Elongation in 4*D*, %	Elongation in 2 in., %	Brinell hardness number (BHN)	Ultimate shear strength, ksi	Fatigue endurance limit(b), ksi	Modulus of elasticity (*E*)(c), $\times 10^3$ ksi	Notes
2519	A92519	T87	75	64	...	9	145	44	17	10.6	(d)
2524	A92524	T851	70	64	...	8	120	42	20	10.6	(d)
2624	A92624	T851	70	64	...	8	120	42	20	10.6	(d)
2618	A92618	T61	64	54	...	10	115	38	18	10.8	...
3002	A93002	O	13	5	22	...	25	8	5	10.0	(d)
3003	A93003	O	16	6	30	40	28	11	7	10.0	...
		H12	19	18	10	20	35	12	8	10.0	...
		H14	22	21	8	16	40	14	9	10.0	...
		H16	26	25	5	14	47	15	10	10.0	...
		H18	29	27	4	10	55	16	10	10.0	...
Alclad 3003	Alc A93003	O	16	6	30	40	...	11	...	10.0	...
		H12	18	18	10	20	...	12	...	10.0	...
		H14	22	21	8	16	...	14	...	10.0	...
		H16	26	25	5	14	...	15	...	10.0	...
		H18	29	27	4	10	...	16	...	10.0	...
3004	A93004	O	26	10	20	25	45	16	14	10.0	...
		H32	31	25	10	17	52	17	15	10.0	...
		H34	35	29	9	12	63	18	15	10.0	...
		H36	38	33	5	9	70	20	16	10.0	...
		H38	41	36	5	6	77	21	16	10.0	...
Alclad 3004	Alc A93004	O	26	10	20	25	...	16	...	10.0	...
		H32	31	25	10	17	...	17	...	10.0	...
		H34	35	29	9	12	...	18	...	10.0	...
		H36	38	33	5	9	...	20	...	10.0	...
		H38	41	36	5	6	...	21	...	10.0	...
3005	A93005	O	19	9	22	33	34	12	7	10.0	(d)
		H12	22	19	7	...	41	13	8	10.0	(d)
		H14	26	23	5	...	46	15	9	10.0	(d)
		H16	31	27	4	...	50	18	10	10.0	(d)
		H18	35	32	3	...	57	20	12	10.0	(d)
		H19	37	34	2	...	60	21	13	10.0	(d)
		H25	29	24	6	...	47	17	9	10.0	(d)
		H26	31	26	6	...	50	18	9	10.0	(d)
		H27	33	29	6	...	53	19	9	10.0	(d)
		H28	34	30	6	...	56	20	10	10.0	(d)
3102	A93102	O	14	6	26	...	25	9	5	10.0	(d)
3105	A93105	O	17	8	24	33	32	12	7	10.0	...
		H12	22	19	7	...	41	14	8	10.0	...
		H14	25	22	5	...	46	15	9	10.0	...
		H16	28	25	4	...	50	16	10	10.0	...
		H18	31	28	3	...	57	17	12	10.0	...
		H24	25	22	10	...	46	15	8	10.0	...
		H25	27	23	9	...	47	15	9	10.0	...
		H26	28	24	9	...	50	16	9	10.0	...
		H28	31	26	8	...	56	17	10	10.0	...
4032	A94032	T6	55	46	...	9	120	38	11	11.4	...
		T72	39	28	...	7	70	23	10	11.4	(d)
5005	A95005	O	18	6	25	...	28	11	7	10.0	...
		H32	20	17	11	...	36	14	8	10.0	...
		H34	23	20	8	...	41	14	9	10.0	...
		H36	26	24	6	...	46	15	9	10.0	...
		H38	29	27	6	...	51	16	10	10.0	......
5010	A95010	O	17	7	5	...	32	10	7	10.0	(d)
		H22	19	16	4	...	35	11	8	10.0	(d)
		H24	22	19	3	...	40	13	9	10.0	(d)
		H26	25	23	3	...	47	15	9	10.0	(d)
		H28	29	24	3	...	55	17	10	10.0	(d)
5042	A95042	O	33	12	12		62	19	11	10.0	(d)
		H48	48	43	6	...	92	28	15	10.0	(d)
5050	A95050	O	21	8	24	...	36	15	12	10.0	...
		H32	25	21	9	...	46	17	13	10.0	...
		H34	28	24	8	...	53	18	13	10.0	...
		H36	30	26	7	...	58	19	14	10.0	...
		H38	32	29	6	...	63	20	14	10.0	...
5051	A95051	O	24	10	17	...	45	14	13	10.0	(d)
		H34	32	24	6	...	63	19	13	10.0	(d)
		H38	40	32	5	...	73	23	14	10.0	(d)
		H39	42	40	4	...	77	24	14	10.0	(d)
5052	A95052	O	28	13	25	30	47	18	16	10.2	...
		H32	33	28	12	18	60	20	17	10.2	...
		H34	38	31	10	14	68	21	18	10.2	...
		H36	40	35	8	10	73	23	19	10.2	...
		H38	42	37	7	8	77	24	20	10.2	...
5056	A95056	O	42	22	...	35	65	26	20	10.3	...
		H18	63	59	...	10	105	34	22	10.3	...

(continued)

(a) Offset = 0.2%. (b) At 500,000,000 cycles in R.R. Moore rotating-bending machines. (c) Under tensile loading. (d) No typical properties are published for this alloy and temper; values shown have been derived by relational analysis.

Table 8A (Continued)

Alloy	UNS No.	Temper	Ultimate tensile strength, ksi	Tensile yield strength(a), ksi	Elongation in 4*D*, %	Elongation in 2 in., %	Brinell hardness number (BHN)	Ultimate shear strength, ksi	Fatigue endurance limit(b), ksi	Modulus of elasticity (*E*)(c), $\times 10^3$ ksi	Notes
		H38	60	50	...	15	100	32	22	10.3	...
5059	A95059	O	52	25	26	...	92	30	24	10.3	(d)
		H111	52	25	26	...	92	30	24	10.3	(d)
		H116	58	42	12	...	122	34	25	10.3	(d)
		H321	58	42	12	...	122	34	25	10.3	(d)
5083	A95083	O	42	21	...	22	75	25	18	10.3	...
		H114	49	38	11	...	83	28	23	10.3	(d)
		H116	46	33	...	16	80	27	23	10.3	...
		H131	48	34	10	12	82	28	23	10.3	(d)
		H321	46	33	...	16	80	27	23	10.3	...
5086	A95086	O	38	17	22	...	70	23	17	10.3	...
		H32	42	30	12	...	75	25	18	10.3	...
		H34	47	37	10	...	85	27	20	10.3	...
		H39	52	47	5	...	90	30	22	10.3	(d)
		H116	42	30	12	...	75	25	18	10.3	...
		H321	44	31	12	...	78	26	23	10.3	(d)
5154	A95154	O	35	17	27	...	58	22	17	10.2	...
		H32	39	30	15	...	67	22	18	10.2	...
		H34	42	33	13	...	73	24	19	10.2	...
		H36	45	36	12	...	78	26	20	10.2	...
		H38	48	39	10	...	80	28	21	10.2	...
5182	A95182	O	32	14	26	...	58	19	15	10.3	...
		H111	42	19	19	...	80	24	18	10.3	(d)
		H39	60	54	5	...	105	35	20	10.3	(d)
		H391	63	57	7	...	110	37	21	10.3	(d)
		H48	56	50	7	...	100	32	19	10.3	(d)
		H481	59	54	7	...	105	34	20	10.3	(d)
		H49	60	53	7	...	105	35	20	10.3	(d)
5252	A95252	H24	33	24	10	...	60	19	18	10.2	(d)
		H25	34	24	10	...	62	20	19	10.2	(d)
		H28	42	35	5	...	75	24	20	10.2	(d)
5254	A95254	O	33	13	22	...	60	19	17	10.2	(d)
		H32	40	29	13	...	73	23	18	10.2	(d)
		H34	43	32	12	...	78	25	19	10.2	(d)
		H36	46	35	11	...	82	27	20	10.2	(d)
		H38	50	39	10	...	88	29	21	10.2	(d)
		H112	34	13	...	17	62	20	17	10.2	(d)
5383	A95383	O	46	23	...	19	87	28	18	10.3	...
		H116	53	36	...	12	100	32	23	10.3	...
		H321	50	31	...	14	95	30	23	10.3	...
5454	A95454	O	36	17	22	...	62	23	16	10.2	...
		H32	40	30	10	...	73	24	18	10.2	...
		H34	44	35	10	...	81	26	20	10.2	...
		H111	38	26	14	...	70	23	17	10.2	...
5456	A95456	O	45	23	...	24	60	27	21	10.3	...
		H116	51	37	...	16	90	30	23	10.3	...
		H321	51	37	...	16	90	30	23	10.3	...
5657	A95657	H25	23	20	12	...	40	12	13	10.0	...
		H28, H38	28	24	7	...	50	15	15	10.0	...
5754	A95754	O	32	14	26	...	55	19	16	10.3	...
6005	A96005	T5	44	39	12	...	90	26	11	10.0	(d)
		T51	39	33	...	10	85	23	10	10.0	(d)
6005A	A96005A	T1	28	17	...	17	50	16	10	10.0	(d)
		T5	42	38	10	13	80	25	11	10.0	(d)
		T61	45	40	12	17	95	27	11	10.0	(d)
6009	A96009	T4	32	18	25	...	60	19	12	10.0	...
		T62	43	38	11	...	75	26	14	10.0	...
6010	A96010	T4	39	22	22	...	85	23	13	10.0	(d)
		T6, T62	54	50	10	...	95	31	15	10.0	(d)
6013	A96013	T4	44	23	...	22	90	26	14	10.0	(d)
		T6, T651	59	53	...	8	105	34	16	10.0	(d)
		T8	62	60	...	10	110	36	16	10.0	(d)
6020	A96020	T651*x*	42	39	...	12	80	24	13	10.0	(d)
		T8	45	43		14	90	26	14	10.0	(d)
6022	A96022	T4	37	22	26	...	65	22	12	10.0	...
		T62	47	42	12	...	90	28	14	10.0	...
6041	A96041	T6-type	50	44	...	12	...	29	14	10.0	(d)
6042	A96042	T5, T551*x*	45	38	...	12	90	26	12	10.0	(d)
6053	A96053	T6	40	33	...	13	85	23	12	10.0	(d)
6056	A96056	T4, T451*x*	56	40	...	17	100	32	15	10.0	(d)
		T6	63	59	...	12	110	37	16	10.0	(d)
		T72	58	53	...	12	105	34	15	10.0	(d)
6060	A96060	T51	24	18	10	...	45	14	9	10.0	...
		T61	33	28	11	...	60	20	9	10.0	...
6061	A96061	O	18	8	25	30	30	12	6	10.0	...

(continued)

(a) Offset = 0.2%. (b) At 500,000,000 cycles in R.R. Moore rotating-bending machines. (c) Under tensile loading. (d) No typical properties are published for this alloy and temper; values shown have been derived by relational analysis.

Table 8A (Continued)

Alloy	UNS No.	Temper	Ultimate tensile strength, ksi	Tensile yield strength(a), ksi	Elongation in 4*D*, %	Elongation in 2 in., %	Brinell hardness number (BHN)	Ultimate shear strength, ksi	Fatigue endurance limit(b), ksi	Modulus of elasticity (*E*)(c), $\times 10^3$ ksi	Notes
		T1	22	13	20	···	40	14	7	10.0	···
		T4, T451	35	21	22	25	65	24	14	10.0	···
		T51	42	35	11	···	80	25	14	10.0	···
		T6, T651	45	40	12	17	95	30	14	10.0	···
Alclad	Alc A96061	O	17	7	25	···	···	11	···	10.0	···
6061		T4, T451	33	19	22	···	···	22	···	10.0	···
		T6, T651	42	37	12	···	···	27	···	10.0	···
6062	A96062	T5	42	35	11	···	80	25	14	10.0	···
		T6	45	40	12	17	95	30	14	10.0	···
6063	A96063	O	13	7	···	···	25	10	6	10.0	···
		T4	25	13	22	···	45	15	8	10.0	···
		T5	27	21	12	···	60	17	10	10.0	···
		T6	35	31	12	···	73	22	10	10.0	···
		T65	39	36	11	···	82	25	11	10.0	···
		T83	37	35	9	···	82	22	10	10.0	···
		T837			···	···	···	···	···	···	···
6066	A96066	O	22	12	···	18	43	14	6	10.0	···
		T4, T451	52	30	···	18	90	29	8	10.0	···
		T6, T651	57	52	···	12	120	34	16	10.0	···
6070	A96070	T6	55	51	10	···	110	34	14	10.0	···
6082	A96082	T5	43	39	11	···	80	29	12	10.0	···
		T6, T651*x*	49	46	12	14	95	31	14	10.0	···
6101	A96101	H111	14	11	···	···	25	8	6	10.0	···
		T6	32	28	15	···	70	20	7	10.0	···
6105	A96105	T5	41	38	11	···	75	25	8	10.0	···
6111	A96111	T4	42	22	26	···	75	25	8	10.0	···
		T41	39	22	26	···	75	23	8	10.0	···
		T62	52	46	11	···	95	31	12	10.0	···
6151	A96151	T6	48	41	···	12	100	28	14	10.0	(d)
Alclad	Alc A96156	T4	44	26	17	···	···	26	···	10.0	(d)
6156		T62	57	52	10	···	···	33	···	10.0	(d)
6162	A96162	T5, T551*x*	42	35	11	···	80	25	14	10.0	(d)
		T6, T651*x*	45	40	12	17	95	30	14	10.0	(d)
6201	A96201	T81	50	45	···	5	90	29	15	10.0	(d)
6205	A96205	T1	28	17	18	···	48	16	8	10.0	(d)
		T5	42	38	10	···	75	24	10	10.0	(d)
		T54	50	46	10	···	90	29	15	10.0	(d)
6262	A96262	T9	58	55	···	10	120	35	13	10.0	···
6351	A96351	T4	36	22	20	···	65	22	9	10.0	···
		T5	42	38	11	···	89	25	11	10	···
		T6	45	41	14	···	95	29	13	10.0	···
6360	A96360	T5	27	21	12	···	60	17	10	10.0	···
		T6	35	31	12	···	73	22	10	10.0	···
6463	A96463	T1	19	11	14	···	35	11	6	10.0	
		T5	24	18	10	···	44	14	9	10.0	
		T6, T62	33	28	10	···	65	19	10	10.0	
6560	A96560	T5	27	21	12	···	60	17	10	10.0	
		T6	35	31	12	···	73	22	10	10.0	
7004	A97004	T5	58	49	15	···	110	32	20	10.4	
7005	A97005	T53	57	50	15	···	105	32	20	10.4	
7010	A97010	T7451	77	67	11	11	140	44	23	10.4	
		T7651	82	72	10	10	150	47	23	10.4	
7019	A97019	T651	64	54	···	14	125	37	20	10.4	
7021	A97021	O	31	20	20	···	60	18	9	10.3	
		T6-type	60	55	10	···	112	35	20	10.3	
7029	A97029	T5	62	55	15	···	110	39	20	10.2	
7033	A97033	T6	74	64	···	12	140	43	22	10.4	
7037	A97037	T7452	···	···	···	···	···	···	···	···	
7039	A97039	T64	65	56	10	···	124	38	21	10.4	
7040	A97040	T74511	78	68	8	8	145	44	22	10.5	···
7049	A97049	T73	75	65	···	12	135	44	22	10.4	···
		T7352	75	63	···	11	135	43	22	10.4	···
7050	A97050	T7351*x*	72	63	···	12	132	42	22	10.4	···
		T7451	76	68	···	11	138	44	22	10.4	···
		T7651	80	71	···	11	145	47	22	10.4	···
7055	A97055	O	30	20	···	16	58	18	7	10.6	(d)
		T7451	90	85	10	10	165	51	23	10.6	···
		T7651	95	80	10	10	170	54	23	10.6	···
		T7751, T7751*x*	98	94	10	10	185	59	24	10.6	(d)
		T7951, T7951*x*	101	98	8	8	190	61	24	10.6	(d)
7068	A97068	T651*x*	106	101	···	6	200	63	25	10.5	(d)
7075	A97075	O	33	15	17	16	60	22	7	10.4	···
		T6, T651	83	73	11	11	150	48	23	10.4	···
		T73, T735*x*	73	63	12	12	135	43	22	10.4	···
Alclad	Alc A97075	O	32	14	17	···	···	22	···	10.4	···
7075		T6, T651	76	67	11	···	···	46	···	10.4	···

(continued)

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