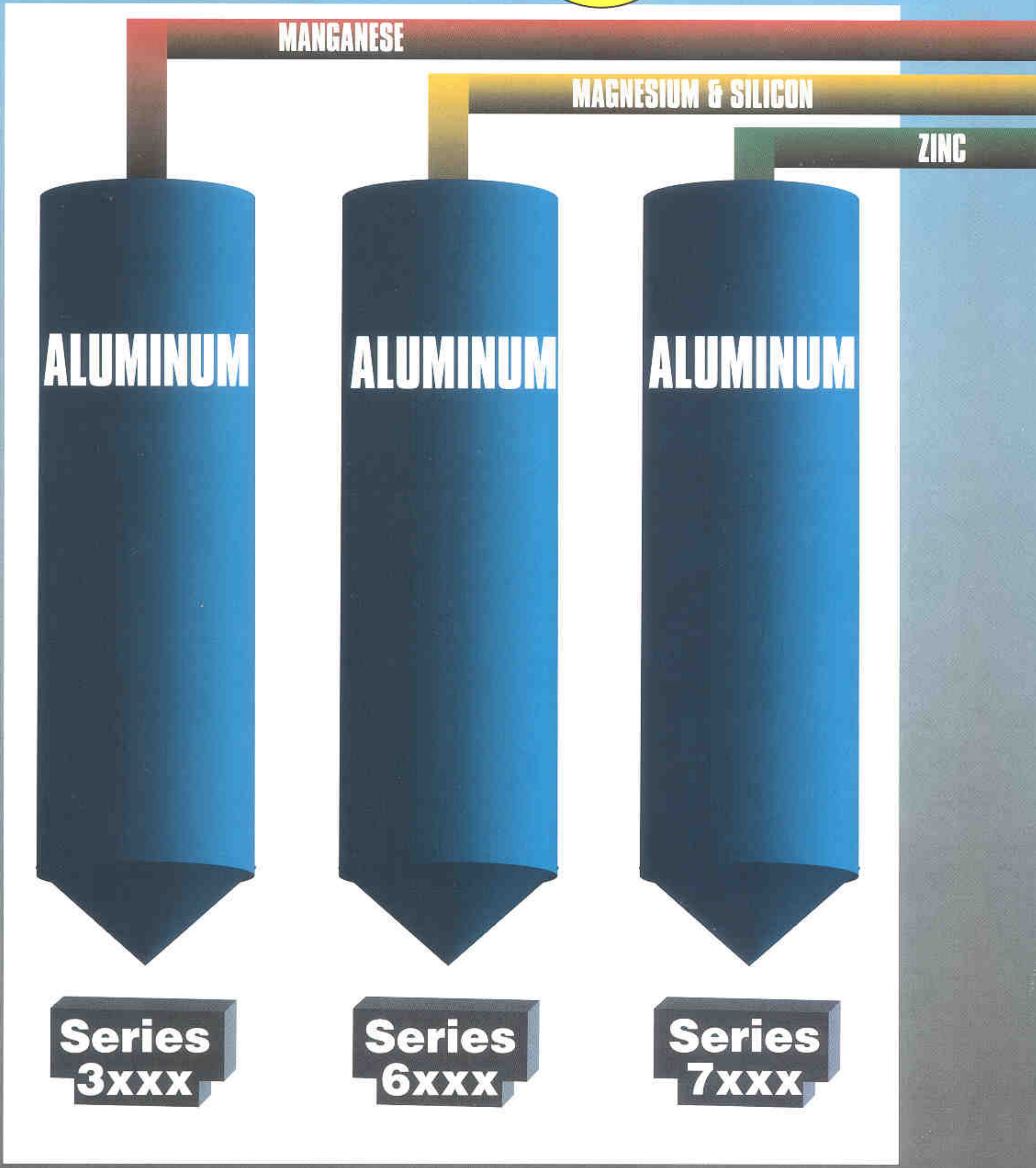
THE SHAPE MAKERS®

A Publication of the Aluminum Extruders Council

EXTRUSION SP Alloys TLIGHT



THE SHAPE MAKERS

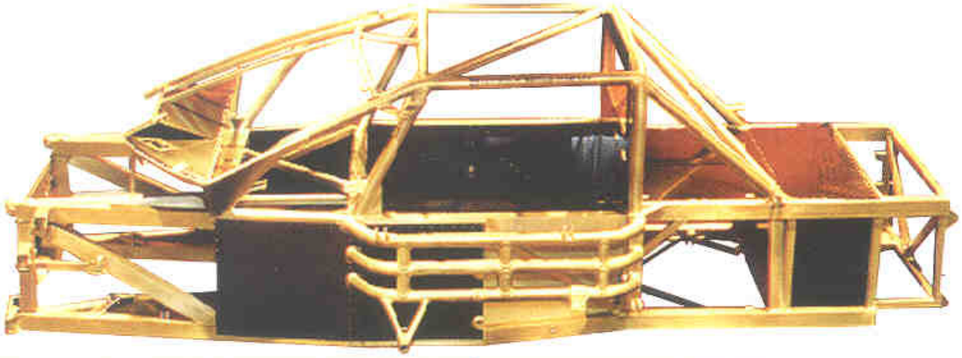
Perhaps when most people think of aluminum they think of an empty soda can, easily crushed under the foot of a child. Aluminum, however, when alloyed with other metals, can be exceptionally strong -- strong enough to build bridges that support the weight of multi-ton vehicles, yet light enough to be used in building jet aircraft and automobiles.

5XXX Series.
Due to its excellent corrosion resistance in marine applications, magnesium is a good alloying material for extruded masts, hull components, and crossbars.

What is an extrusion alloy?
Simply put, an aluminum extrusion alloy is a predetermined mixture of one or more elements together with aluminum, to be heated and hydraulically pressed through an extrusion die. Some of the common elements alloyed with aluminum include copper, magnesium, manganese, chromium, silicon, iron, nickel, and zinc. These alloying elements are usually added to aluminum in amounts ranging from .01 to 7.0 percent. Product performance is determined in part by the alloy composition and in part by production method; and the production method, in turn, is strongly influenced by the temper given the alloy through various types of mechanical and thermal treatments. Structural and certain physical properties can also be influenced significantly by the choice of alloy and temper.

Alloying aluminum with other elements like (to name just a few) manganese, magnesium, copper or zinc, produces a variety of desirable characteristics such as corrosion-resistance, increased strength, or improved formability. The proper balance of alloying material depends on the intended

3XXX Series.
The good workability of manganese makes this element a prime alloy for use in furniture tubing, toys and other consumer durables.

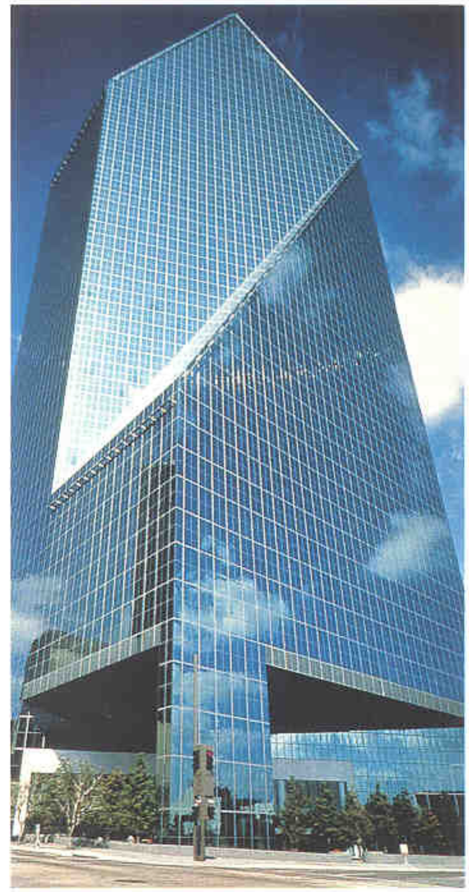


6XXX Series
Lightweight aluminum space frames require high strength and consistent repeatability for mass production. The 6000-series alloys (such as 6061), which feature a high strength-to-weight ratio, ease of extrusion and fabrication, and are readily machinable, are often used for such applications.

application of the finished piece. For example, aluminum alloyed in the 5XXX and 6XXX series (see Major Alloying Elements Table) is particularly suitable for application in bridge design. Properties making these alloys particularly desirable include:

- Very lightweight, one-third that of steel and concrete.
- High strength, comparable to steel and steel/concrete composites.
- Strength and ductility as high or higher at sub-zero temperatures as at room temperature.
- Exceptional corrosion resistance.
- Ease of fabrication by many techniques, including extrusion, to unique advantageous structural configurations.

Wrought Alloy Designation	Major Alloying Elements and Alloy Characteristics
1000 Series	***Minimum 99% aluminum*** High corrosion resistance. Excellent finishability. Easily joined by all methods. Low strength, poor machinability. Excellent workability. High electrical conductivity.
2000 Series	***Copper*** High strength. Relatively low corrosion resistance. Excellent machinability. Heat treatable.
3000 Series	***Manganese*** Low to medium strength. Good corrosion resistance. Poor machinability. Good workability.
4000 Series	***Silicon*** Not available as extruded products.
5000 Series	***Magnesium*** Low to moderate strength. Excellent marine corrosion resistance. Very good weldability.
6000 Series	***Magnesium & Silicon*** Most popular extrusion alloy class. Good strength. Good corrosion resistance. Good machinability. Good weldability. Good formability Heat treatable.
7000 Series	***Zinc*** Very high strength. Poor corrosion resistance. Good machinability. Heat treatable.



6XXX Series.
Silicon and magnesium, the major alloying elements in this series, contribute to good strength, corrosion resistance, weldability, and machinability, making this the most popular series for an extrusion. These alloys are used in a wide variety of architectural applications, as well as in transportation.

MAJOR ALLOYING ELEMENTS TABLE

The table on the left represents the series of elements commonly alloyed with aluminum to achieve desired characteristics. Aluminum alloys are grouped by major alloying elements.

EFFECTS OF ALLOYING ELEMENTS

The addition of alloying elements modifies the properties and characteristics of aluminum. Such aspects as density, electrical and thermal conductivity, thermal expansion, mechanical properties, ability to finish and harden, and corrosion resistance are all affected by combining the alloying elements with aluminum.

Manganese, for example increases the mechanical strength of certain aluminum alloys. Zinc, in combination with magnesium, produces a material that can be age-hardened, as in alloys 7075 and 7178. Alloys vary in degree of extrudability. Many extrude easily, others are considered relatively easy, while a few are quite difficult to extrude and require procedures that slow the process. For example, alloys 6063, 6101 and 6463 are rated as having excellent extrudability, while 7075, 7079 and 7178 are categorized as difficult to extrude. Because of its adaptability to a number of large-volume uses and ease of extrudability, 6063 is used to produce a large percentage of aluminum profiles. New, cutting-edge aluminum alloys are being developed to produce even stronger, lighter extrusions for use in aviation and deep-space vehicles. Aluminum-lithium is one of the new alloy classes. Lithium, one of the lightest metals known, is about one-fifth as dense as aluminum. When combined with aluminum into a new alloy, it's 7 to 10 percent lighter and up to 30 percent stiffer than conventional aircraft alloys.

Extrusion Alloys		Designation
> 99% pure Aluminum	Al	1xxx
Copper	Cu	2xxx
Manganese	Mn	3xxx
Silicon	Si	4xxx
Magnesium	Mg	5xxx
Magnesium and Silicon	MgSi	6xxx
Zinc	Zn	7xxx
Other		8xxx

TEMPERS

All aluminum alloys, regardless of product form, are classified as either heat-treatable or non-heat-treatable. Those alloys classified as non-heat-treatable develop maximum strength characteristics through cold work after extruding, if section shape permits. Non-heat-treatable alloys are found in the 1XXX, 3XXX and 5XXX series.

Heat-treatable alloys attain their maximum strength through controlled heat treatment. This group has the highest strength of all aluminum alloys and falls in the 2XXX, 6XXX, and 7XXX series.

The Temper Designation System lists the modification methods applied to heat-treatable and non-heat-treatable alloys:

F As Extruded: No special control over thermal conditions or strain-hardening; no mechanical property limits.
O Annealed: Thermally treated to obtain the lowest strength temper.
H Strain-hardened: Cold working used to increase strength and hardness.
T Thermally Treated: Thermally treated to produce stable tempers other than F, O, or H.

A complete alloy-temper designation reads like this: "6063-T5." This designation indicates a particular alloy of the 6000 series (Mg and Si) which is thermally treated by being cooled from an elevated temperature and artificially aged.

Typical Tempers for Extrusions

O	Fully annealed.
H112	Strain-hardened; used for nonheat-treatable alloys.
T1	Cooled from an elevated temperature and naturally aged.
T4	Solution heat-treated and naturally aged.
T5	Cooled from an elevated temperature and artificially aged.
T6	Solution heat-treated and artificially aged.

7XXX series.
Zinc is alloyed with aluminum to produce lightweight, very strong extrusions, used in automotive applications and jet aircraft structures.

Aluminum Extrusion Alloys: Number and Characteristics	Major Alloying Elements (Percent)	Temper and Thickness[1]-in.		Tensile Strength-ksi				Elongation[2] percent min in 2 in. or 4D[3]
				Ultimate		Yield		
				min	max	min	max	
1060								
Softest alloy available.Primarily used for sheathing tube for the wire and cable industry.	99.6% min. Aluminum	-0	All	8.5	14.0	2.5	..	25
		-H112	All	8.5	..	2.5	..	25
1100								
Commercially pure aluminum. Used in a variety of applications where strength is not a priority. Corrosion resistant and formable. Can be anodized and polished.	99% min. Aluminum Cu .05-0.20	-0	All	11.0	15.5	3.0	..	25
		-H112	All	11.0	..	3.0	..	..
1350								
Developed especially for electrical conductor use with a minimum conductivity of 61-62% IACS. Used in both solid and tubular forms.	99.5% min. Aluminum	-0	.375-1.000	8.5	14.0	..	..	..
		-H111	All	8.5	..	3.5	..	
2014								
Used in structural members in aircraft and transportation equipment. Excellent for resistance and spot welding.	Cu 3.9-5.0 Si .50-1.2 Mn .40-1.2 Mg .20-.8	-0	All	..	30.0	..	18.0	12
		-T4,T4510 & T4511[5,7]	All	50.0	..	35.0	..	12
		-T42[4,8]	All	50.0	..	29.0	..	12
		-T6, T6510[5] & T6511[5]	Up thru 0.499	60.0	..	53.0	..	7
			0.500-0.749	64.0	..	58.0	..	7
			0.750 & over[11]	68.0	..	60.0	..	7
			0.750 & over[12]	68.0	..	58.0	..	6
		-T62[4,8]	Up thru 0.749	60.0	..	53.0	..	7
			0.750 & over[11]	60.0	..	53.0	..	7
			0.750 & over[12]	60.0	..	53.0	..	6
2024								
Principally used for structural members in aircraft construct-tion. Similar to 2014 in strength and behavior. Can be spot welded.	Cu 3.8-4.9 Mg 1.2-1.8 Mn .30- .9	-0	All	..	35.0	..	19.0	12
		-T3, T3510[5,7] & T3511[5,7]	Up thru 0.249	57.0	..	42.0	..	12[16]
			0.250-0.749	60.0	..	44.0	..	12[16]
			0.750-1.499	65.0	..	46.0	..	10
			1.500 & over[11]	70.0	..	52.0[14]	..	10
			1.500 & over[12]	68.0	..	48.0[15]	..	8
		-T42[4,8]	Up thru 0.749	57.0	..	38.0	..	12
			0.750-1.499	57.0	..	38.0	..	10
			1.500 & over[11]	57.0	..	38.0	..	10
			1.500 & over[12]	57.0	..	38.0	..	8
		-T81,T8510[5] & T8511[5]	0.050-0.249	64.0	..	56.0	..	4
			0.250-1.499	66.0	..	58.0		5
			1.500 & over[13]	66.0	..	58.0	..	5
3003								
Good corrosion resistance, formability, and weldability. Used in chemical equipment, furniture, condensers, heat exchangers, and pressure vessels.	Mn 1.0-1.5	-0	All	14.0	19.0	5.0	..	25
		H112	All	14.0	..	5.0	..	25
5083								
Designed for welded structures requiring maximum joint strength or subject to vibration and fatigue. Good corrosion resistance.	Mg 4.0-4.9 Mn .4-1.0	-0	Up thru 5.000[13]	39.0	51.0	16.0	..	14
		-H111	Up thru 5.000[13]	40.0	..	24.0	..	12
		-H112	Up thru 5.000[13]	39.0	..	16.0	..	12
		Up thru 32 sq. in. (All)						

Aluminum Extrusion Alloys: Number and Characteristics	Major Alloying Elements (Percent)	Temper and Thickness[1]-in.		Tensile Strength-ksi Ultimate min	Ultimate max	Yield min	Yield max	Elongation[2] percent min in 2 in. or 4D[3]
5086								
Similar to 5083; has slightly lower mechanical properties.	Mg 3.5-4.5 Mn .20-.7	-0	Up thru 5.000[13]	35.0	46.0	14.0	..	14
		-H111	Up thru 5.000[13]	36.0	..	21.0	..	12
		-H112 Up thru 32 sq. in. (All)	Up thru 5.000[13]	35.0	..	14.0	..	12
5154								
Excellent corrosion resistance and weldability. Used for welded structures, storage tanks, pressure vessels, salt water service.	Si 0.25 Fe 0.40 Mg 3.1-3.9 Cr .15-.35	-0	All	30.0	41.0	11.0	..	..
		-H112	All	30.0	..	11.0	..	..
5454								
Used in marine, transportation, ordnance and cryogenic industries. Medium strength weldable alloy with excellent corrosion resistance.	Mg 2.4-3.0 Mn .50-1.0	-0	Up thru 5.000[13]	31.0	41.0	12.0	..	14
		-H111	Up thru 5.000[13]	33.0	..	19.0	..	12
		-H112 Up thru 32 sq. in. (All)	Up thru 5.000[13]	31.0	..	12.0	..	12
6005								
Similar to 6061 alloy. Used in structural applications.	Si .6-.9 Mg .40-.6	-T1	Up thru 0.500	25.0	..	15.0	..	16
		-T5	Up thru 0.124	38.0	..	35.0	..	8
			0.125-1.000	38.0	..	35.0	..	10
6060								
Has better extrudability than 6063. The minimum mechanical properties (with the exception of minimum welded properties), response to finishing process and corrosion resistance are similar to 6063.	Si .30-.6 Mg .35-.6	-T51[19]	Up thru .125	22.0	..	16.0	..	8
			Up thru 1.000	22.0	30.0	16.0	25.0	8
		-T61[19]	Up thru .124	30.0	..	25.0	..	8
			.125-1.000	30.0	..	25.0	..	10
6061								
Most versatile of heat-treatable group. Will take considerable forming in T4. Good corrosion resistance. Used in transportation and structural applications.	Mg .8-1.2 Si .40-.8	-0	All	..	22.0	..	16.0	16
		-T1	Up thru 0.625	26.0	..	14.0	..	16
		-T4,T4510[5,7] and T4511[5,7]	All	26.0	..	16.0	..	16
		-T42[4,8]	All	26.0	..	12.0	..	16
		-T51	Up thru 0.625	35.0	..	30.0	..	8
		-T6,T62,[4,8] T6510[5] and T6511[5]	Up thru 0.249	38.0	..	35.0	..	8
			0.250 and over	38.0	..	35.0	..	10
6063								
The most popular extrusion alloy. Takes a good surface finish, is corrosion-resistant, and can be heat-treated for strength.	Mg .45-.9 Si .20-.6	-0	All	..	19.0	..	..	18
		-T1	Up thru 0.500	17.0	..	9.0	..	12
			0.501-1.000	16.0	..	8.0	..	12
		-T4 and T42[4,8]	Up thru 0.500	19.0	..	10.0	..	14
			0.501-1.000	18.0	..	9.0	..	14
		-T5	Up thru 0.500	22.0	..	16.0	..	8
			0.501-1.000	21.0	..	15.0	..	8
		-T52	Up thru 1.000	22.0	30.0	16.0	25.0	8
		-T6 and T62[4,8]	Up thru 0.124	30.0	..	25.0	..	8
			0.125-1.000	30.0	..	25.0	..	10
6101								
High strength bus conductors, good extrudability, weldability, brazeability, good resistance to stress corrosion cracking with average machinability.	Si 0.30-0.7 Mg 0.35-0.8	-T6	.125-.500	29.0	..	25.0	..	15
		-T61	.125- .749	20.0	..	15.0	..	19
			.750-1.499	18.0	..	11.0	..	
			1.500-2.000	15.0	..	8.0	..	
		-T63	.125-1.000	27.0	..	22.0	..	17
		-T64	.125-1.000	15.0	..	8.0	..	20
		-T65	.125- .749	25.0	32.0	20.0	27.0	..

Aluminum Extrusion Alloys: Number and Characteristics	Major Alloying Elements (Percent)	Temper and Thickness [1]-in.		Tensile Strength-ksi Ultimate min	Ultimate max	Yield min	Yield max	Elongation [2] percent min in 2 in. or 4D[3]
6105								
Good medium to high strength with average machinability and good corrosion resistance.	Si .60-1.0 Mg .45-.80	-T1	Up thru .500	25.0	..	15.0	..	16
		-T5	Up thru .500	38.0	..	35.0	..	8
6262								
Best machining of all extrusion alloys. Good corrosion resistance.	Mg .8-1.2 Si .40-.8 Pb .4-.7 Bi .4-.7	-T6,T62,[4,8] T6510[5] and T6511[5]	All	38.0	..	35.0	..	10
6351								
Similar to 6061 alloy. Used in structural applications. Will take considerable forming in T4. Good corrosion resistance. Used in transportation and general structures.	Si .7-1.3 Mg .40-.8 Mn .40-.8	-T1	Up thru 0.499	26.0	..	13.0	..	15
		-T4	Up thru 0.749	32.0	..	19.0	..	16
		-T5	Up thru 0.249	38.0	..	35.0	..	8
			0.250-1.000	38.0	..	35.0	..	10
		-T51	0.125-1.00	36.0	..	33.0	..	10
		-T54	Up thru 0.500	30.0	..	20.0	..	10
		-T6	Up thru 0.124	42.0	..	37.0	..	8
			0.125-0.749	42.0	..	37.0	..	10
6463								
Designed to accept a bright finish through anodizing or polishing. Decorative trim applications; machinable and heat-treatable.	Mg .45-.9 Si .20-.6 High purity version of 6063	-T1	Up thru 0.500[17]	17.0	..	9.0	..	12
		-T5	Up thru 0.500[17]	22.0	..	16.0	..	8
		-T6 and T62[4,8]	Up thru 0.124[17]	30.0	..	25.0	..	8
			0.125-0.500[17]	30.0	..	25.0	..	10
7005								
Used in automotive and other transportation applications where added strength is required.	Zn 4.0-5.0 Mg 1.0-1.8 Mn .20-.7	-T53	All	50.0	..	44.0	..	10
7050								
Used in applications requiring high strength and stress corrosion resistance.	Zn 5.7-6.7 Mg 1.9-2.6 Cu 2.0-2.6	-T73510[9] & T73511[9]	up to 5.0 [13]	70.0	..	60.0	..	8
		-T74510[20] & T74511[20]	up to 5.0 [13]	73.0	..	63.0	..	7
		-T76510[21] & T76511[21]	up to 0.499 [13]	77.0	..	68.0	..	7
		-T76510[21] & T76511[21]	0.50 to 5.0 [13]	79.0	..	69.0	..	7
7075								
Used for aircraft structural members, when extra strength is required. Can be spot welded.	Zn 5.1-6.1 Mg 2.1-2.9 Cu 1.2-2.0	-0	All	..	40.0	..	24.0	10
		-T6, T62,[4,8] T6510[5] & T6511[5]	Up thru 0.249	78.0	..	70.0	..	7
			0.250,0-0.499	81.0	..	73.0	..	7
			0.500-1.499	81.0	..	72.0	..	7
			1.500-2.999	81.0	..	72.0	..	7
			3.000-4.499[17]	81.0	..	71.0	..	7
			3.000-4.499[18]	78.0	..	70.0	..	6
			4.500-5.000[13]	78.0	..	68.0	..	6
		-T73,[9] T73510[5,9] &T73511[5,9]	0.062-0.249	68.0	..	58.0	..	7
			0.250-1.499	70.0	..	61.0	..	8
			1.500-2.999	69.0	..	59.0	..	8
			3.000-4.499[17]	68.0	..	57.0	..	7
			3.000-4.499[18]	65.0	..	55.0	..	7

Aluminum Extrusion Alloys: Number and Characteristics	Major Alloying Elements (Percent)	Temper and Thickness [1]-in.		Tensile Strength-ksi				Elongation [2] percent min in 2 in. or 4D[3]
				Ultimate		Yield		
				min	max	min	max	
7178								
Used primarily for aircraft structural members where high strength is required but where impact loading is not experienced.	Zn 6.3-7.3 Mg 2.4-3.1 Cu 1.6-2.4 Cr 0.18-0.28	-0 [13]	All [13]	..	40.0	..	24.0	10
		-T6,T6510[5] & T6511[5]	Up thru 0.061[17]	82.0	..	76.0	..	..
			0.062-0.249 [17]	84.0	..	76.0	..	5
			0.250-1.499 [11]	87.0	..	78.0	..	5
			1.500-2.499 [11]	86.0	..	77.0	..	5
			1.500-2.499 [12]	84.0	..	75.0	..	5
			2.500-2.999 [13]	82.0	..	71.0	..	5
		-T62[4,8]	Up thru 0.061[17]	79.0	..	73.0	..	..
			0.062-0.249 [17]	82.0	..	74.0	..	5
			0.250-1.499 [11]	86.0	..	77.0	..	5
			1.500-2.499 [11]	86.0	..	77.0	..	5
			1.500-2.499 [12]	84.0	..	75.0	..	5
			2.500-2.999 [13]	82.0	..	71.0	..	5
		-T76,[10] T76510[5,10] &T76511[5,10]	0.125-0.249 [17]	76.0	..	66.0	..	7
			0.250-0.499 [17]	77.0	..	67.0	..	7
			0.500-1.000 [17]	77.0	..	67.0	..	7

Footnotes for Extrusion Alloys Table

[1]The thickness of the cross-section from which the tension test specimen is taken determines the applicable mechanical properties. The data base and criteria upon which these mechanical property limits are established are outlined in the Aluminum Association publication *Aluminum Standards and Data* (ASD) Section 6, "Mechanical Properties."

[2]For material of such dimensions that a standard test specimen cannot be taken, or for shapes thinner than 0.062 inch, the test for elongation is not required.

[3]D represents specimen diameter.

[4]These properties can usually be obtained by the user when the material is properly solution heat-treated or solution and precipitation heat-treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers which are solution heat-treated or solution- and precipitation-treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

[5]For stress-relieved tempers the characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

[6]Processes such as flattening, leveling, or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to ASD,1993, Section 4, Certification.)

[7]Upon artificial aging, T3, T31, T3510, T3511, T4, T4510, T4511 temper material shall be capable of developing the mechanical properties applicable to the T8, T81, T8510, T8511, T6, T6510 and T6511 tempers, respectively.

[8]This temper is not available from the material producer.

[9]Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined in Table 6.4 of ASD, 1993.

[10]Material in this temper when tested in accordance with ASTM G34-72 will exhibit exfoliation less than that shown in Category B, Figure 2 of ASTM G34-72. Also, material, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 25 ksi will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined in Table 6.4 of ASD, 1993.

[11]Up through 25 sq. in. area.

[12]25 sq. in. through 32 sq. in. area.

[13]Up through 32 sq. in. area.

[14]Minimum yield for tube is 48.0 ksi.

[15]Minimum yield for tube is 46.0 ksi.

[16]Minimum elongation for tube is 10%.

[17]Up through 20 sq. in. area.

[18]Over 20 thru 32 sq. in. area.

[19]Registered with The Aluminum Association, Inc. Other tempers, such as -0, -T1, -T4, -T42, -T51, -T52, and -T62 are not yet registered with The Aluminum Association, but are expected to be the same as for AA6063.

[20]Material in this temper, when tested at the t/10 plane in accordance with ASTM G34-72, will exhibit exfoliation less than that shown in Category EB, Figure 2 of ASTM G34-90. Also, material, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 35 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined in Tables 6-7 through 6-10 of *Aluminum Standards and Data (1997)*.

[21]Material in this temper, when tested at the t/10 plane in accordance with ASTM G34-90, will exhibit exfoliation less than that shown in Category EB, Figure 2 of ASTM G34-72. Also, material, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 17 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined in Tables 6-7 through 6-10 of *Aluminum Standards and Data (1997)*.

(Excluding alloys 6060, 6351, 7005 and 7050, reproduced from Aluminum Standards and Data, 1993,Tables 11.1, 12.1, and 16.3.)

THE SHAPEMAKERS®

aec ALUMINUM EXTRUDERS COUNCIL

1000 N. Rand Road, Suite 214
Wauconda, IL 60084 USA
Phone (847) 526-2010
Fax (847) 526-3993
mail@aec.org
http://www.aec.org

For More Information

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