



Understanding Extruded Aluminum Alloys

Alloy 6061 is one of the most widely used alloys in the 6000 Series. This standard structural alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high strength requirements and has good toughness characteristics. Applications range from transportation components to machinery and equipment applications to recreation products and consumer durables. Alcoa produces 6061 for use in standard and custom shapes, rod and bar products, and seamless and structural pipe and tube.

Alloy 6061 has excellent corrosion resistance to atmospheric conditions and good corrosion resistance to sea water. This alloy also offers good finishing characteristics and responds well to anodizing; however, where cosmetic appearance is critical, consider the use of alloy 6063. The most common anodizing methods include clear, clear and color dye, and hardcoat.

Alloy 6061 is easily welded and joined by various commercial methods. (Caution: direct contact by dissimilar metals can cause galvanic corrosion.) Since 6061 is a heat-treatable alloy, strength in its -T6 condition can be reduced in the weld region. Selection of an appropriate filler alloy will depend on the desired weld characteristics. Consult the Material Safety Data Sheet (MSDS) for proper safety and

handling precautions when using alloy 6061.

For screw machine applications, alloy 6061 has adequate machinability characteristics in the heat-treated -T6/-T6511 condition. With -T6/-T6511 mechanical properties, chips from machining (particularly turning and drilling) are difficult to break. Chip breakers are recommended, and special machining techniques (i.e. peck drilling) can improve chip formation. To enhance the machinability of its ECON-O-ROD®, ACC-U-ROD®, ECON-O-PLATE® and ACC-U-PLATE® products, Alcoa has developed a unique chemistry for alloy 6061, which conforms to industry specifications.

For minor bending applications, special forming tempers -T6S2, -T6S15, -T6S9 or -T6S10 may be sufficient to facilitate bending (dependent upon bend radius and degree of bend). When more severe bends are required, a softer temper condition such as -T1, -T4 or even -O may be necessary to prevent cracking.

Alcoa offers alloy 6061 in a variety of standard tempers, as well as special tempers developed for unique applications. These are summarized below:

6061 Temper Designations and Definitions	
Alcoa produces 6061 alloy with a wide selection of standard and special tempers. In the annealed condition (-O temper), 6061 is extremely ductile and well suited for severe forming applications. When solution heat-treated and naturally aged (-T4 condition), 6061 has good formability for bending. After artificial aging (precipitation heat-treating), 6061-T4 is capable of developing -T6 properties.	
Standard Tempers	Standard Temper Definitions*
F	As fabricated. There is no special control over thermal conditions and there are no mechanical property limits.
O	Annealed. Applies to products that are annealed to obtain the lowest strength temper.
T1	Cooled from an elevated temperature shaping process and naturally aged. (See Note B.)
T4, T4511	Solution heat-treated and naturally aged. (See Notes C & D.)
T51	Cooled from an elevated temperature shaping process and artificially aged. (See Note B.)
T6, T6511	Solution heat-treated and artificially aged. (See Notes C & D.)
Alcoa Special Tempers**	Alcoa Special Temper Definitions
T4S6	For 6061 extrusions requiring maximum formability in the unaged condition and subsequently aged to -T6. May not meet -T4 minimum mechanical properties, but will meet -T6 minimum when properly aged. Test reports state -T6 properties to demonstrate heat treat capabilities, but extrusions are supplied unaged. (See Note A.)
T6S2, T6S15	For 6061 extrusions requiring good formability; meets standard 6061-T6 minimum properties.
T6S9, T6S10	For 6061 extrusions requiring improved forming characteristics not obtainable with -T6S2 and -T6S15 tempers. Lower minimum properties of 35.0 ksi tensile & 30.0 ksi yield guaranteed to enhance formability. (See Note A.)
T6S4	Applies to 6061 extrusions requiring maximum hardness for strength and good machinability. Same minimum tensile and yield strengths as standard -T6, but with lower minimum elongation of 6%. (See Note A.)
T6H, T6511H	Alcoa's "H" temper is offered for special applications requiring improved machinability and higher minimum mechanical properties than standard -T6 or -T6511. Minimum properties of 42 ksi tensile, 38 ksi yield, and 10.0% elongation are guaranteed. "H" temper is available for rod, bar, and certain solid profiles with a principle thickness of .500" or greater. (See Notes C & D.)
T6G, T6511G	Alcoa's "G" temper is available for applications requiring a uniform grain structure to enhance anodized appearance for rod and bar sizes with a thickness of 2.00" or greater. A minimal peripheral grain band may still be present, but it is greatly reduced compared to standard -T6/-T6511. Minimum mechanical properties are same as "H" tempers. (See Notes C & D.)
T6X, T6511X	Alcoa's "X" temper is available for special applications requiring a uniform recrystallized grain structure in extrusions less than 2" thickness to enhance anodizing appearance. Other benefits include improved machinability, same mechanical properties as 6061-T6/T6511. (See Notes C & D.)
T5S26	For 6061 press-quenched and over-aged extrusions requiring improved stamping characteristics. Minimum mechanical properties are 26.0 ksi tensile, 16 ksi yield, 16% elongation. (See Note A.)

*For further details of definitions, see Aluminum Association's [Aluminum Standards and Data](#) manual and [Tempers for Aluminum and Aluminum Alloy Products](#). **Note A:** The specified special temper will not conform to Military, Federal, ASTM, ASME and AMS specifications. **Note B:** Applies to products that are not cold worked after cooling from an elevated temperature shaping process, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical properties. **Note C:** Applies to products that are not cold worked after solution heat-treatment, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical properties. **Note D:** Temper -T4511 and -T6511 apply to products that are stress-relieved by stretching.

**Alcoa Special Temper designations are unregistered tempers for reference only and provided for customer use to identify unique processing, material, or end use application characteristics.

Alloy 6061 Chemical Analysis

Liquidus Temperature: 1206°F

Solidus Temperature: 1080°F

Density: 0.098 lb./in.³

Percent Weight	Elements										
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others Each	Others Total	Aluminum
Minimum	.40	—	.15	—	.8	.04	—	—	—	—	—
Maximum	.8	.7	.40	.15	1.2	.35	.25	.15	.05	.15	Remainder

Average Coefficient of Thermal Expansion (68° to 212°F) = 13.1 x 10⁻⁶ (inch per inch per °F)

Alloy 6061 Mechanical Property Limits for Rod, Bar, Tube, Pipe and Standard Shapes

Temper	Specified Section or Wall Thickness ² (inches)	Tensile Strength (ksi)				Elongation ³ Percent Min. in 2 inch or 4D ⁵	Typical Brinell Hardness (500 kg load/ 10 mm ball)	Typical Ultimate Shearing Strength (ksi)
		Ultimate		Yield (0.2% offset)				
		Min.	Max.	Min.	Max.			
Standard Tempers¹								
O	All	—	22.0	—	16.0	16	30	12
T1	Up thru 0.625	26.0	—	14.0	—	16	—	—
T4, T4511 ⁴	All	26.0	—	16.0	—	16	65	24
T51	Up thru 0.625	35.0	—	30.0	—	8	—	—
T6, T6511 ⁴	Up thru 0.249	38.0	—	35.0	—	8	95	30
	0.250 and over	38.0	—	35.0	—	10	95	30
Alcoa Special Tempers[*]								
T6S2, T6S15	Up thru 0.249	38.0	—	35.0	—	8	95	30
	0.250 and over	38.0	—	35.0	—	10	95	30
T6S9, T6S10	Up thru 0.249	35.0	—	30.0	—	8	—	—
	0.250 and over	35.0	—	30.0	—	10	—	—
T6S4	All	38.0	—	35.0	—	6	95	—
T6H, T6511H	1.000 and over	42.0	—	38.0	—	10	95	30
T6G, T6511G	3.000 and over	42.0	—	38.0	—	10	95	30
T6X, T6511X	.250 thru 1.999	38.0	—	35.0	—	10	95	30
T5S26	All	26.0	—	16.0	—	16	65	24

① The mechanical property limits for standard tempers are listed in the "standards section" of the Aluminum Association's Aluminum Standards and Data manual. ② The thickness of the cross section from which the tension test specimen is taken determines the applicable mechanical properties. ③ For material of such dimensions that a standard test specimen cannot be taken, or for shapes thinner than 0.062", the test for elongation is not required. ④ 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. ⑤ D = Specimen diameter.

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Comparative Characteristics of Related Alloys/Tempers¹

Alloy	Temper	Formability		Machinability				General Corrosion Resistance				Weldability (Arc with Inert Gas)				Brazeability				Anodizing Response				
		Low	High	D	C	B	A	D	C	B	A	D	C	B	A	D	C	B	A	D	C	B	A	
6061	-O	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	N/A
6061	-T1, -T4, -T4S6, -T4511	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████
6061	-T6, -T6511, -T6S4	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████
6061	-T6H, -T6G, -T6511H, -T6511G	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████
6061	-T6S2, -T6S15	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	N/A
6061	-T6S9, -T6S10	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	N/A
6061	-T51	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	N/A
6061	-T5S26	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	N/A
6262	-T6, -T6511	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████
6063	-T6	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████
6063	-T5, -T52	██████████	██████████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████	████

① Rating: A=Excellent B=Good C=Fair D=Poor For further details of explanation of ratings, see Aluminum Association's Aluminum Standards and Data manual.

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