Austral Wright Metals

at the cutting edge

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PRODUCT DATA SHEET

Introduction to Aluminium and Aluminium Alloys

Aluminium Alloys

A unique combination of properties puts aluminium and its alloys among our most versatile engineering and construction materials. All alloys are light in weight, yet some have strengths greater than that of structural steel. The majority of alloys are highly durable under the majority of service conditions and no coloured salts are formed to stain adjacent surfaces or discolour products with which they come in contact, such as fabrics in the textile industry and solutions in chemical equipment. They have no toxic reaction. Aluminium and most of its alloys have good electrical and thermal conductivities and high reflectivity to both heat and light.

Aluminium and most of its alloys can easily be worked into any form and readily accept a wide variety of surface finishes.

Light weight is perhaps aluminium's best known characteristic having a density of approximately 2.7×10^3 kilograms per cubic metre at 20^0C as compared with 7.9×10^3 for copper.

Commercially pure aluminium has a tensile strength of about 90 MPa. Its usefulness as a structural material in this form is thus somewhat limited. However, by working the metal, as by cold rolling, its strength can be approximately doubled. Much larger increases in strength can be obtained by alloying aluminium with small percentages of one or more other metals such as manganese, silicon, copper, magnesium or zinc. Like pure aluminium, the alloys are also made stronger by cold working. Some of the alloys are further strengthened and hardened by heat treatment so that today aluminium alloys having tensile strengths approaching 700 MPa have been developed.

A wide variety of mechanical characteristics, or tempers, is available in aluminium alloys through various combinations of cold working and heat treatment. In specifying the temper for any given product, the fabricating process and the amount of cold work to which it will subject the metal should be kept in mind. In other words, the temper specified should be such that the amount of cold work the metal will receive during fabrication will develop the desired characteristics in the finished product. At sub-zero temperatures aluminium alloys increase in strength without loss of ductility or brittle fracture problems, so that aluminium is a particularly useful metal for low-temperature applications including cryogenics.

Aluminium has a high resistance to corrosion because on surfaces exposed to the atmosphere, a thin transparent oxide skin forms immediately and protects the metal from further oxidation. Unless exposed to some substance or condition, which destroys this protective oxide coating, the metal remains protected against corrosion. Aluminium is highly resistant to weathering, even in industrial atmospheres, which often corrode other metals. It is also corrosion-resistant to attack by some acids. The metal can safely be used in the presence of certain mild alkalis with the aid of inhibitors, but general direct contact with alkaline substances should be avoided as these attack the oxide skin and are therefore corrosive to aluminium.

Some alloys are less resistant to corrosion than others, particularly certain high-strength alloys. Such alloys in some forms can be protected effectively from the majority of corrosive influences by cladding the exposed surface or surfaces with a thin layer of an appropriate aluminium alloy.

In accordance with sound design principles, direct contact with certain other metals should be avoided in the presence of an electrolyte as galvanic corrosion of the aluminium may take place in the vicinity of the contact area. Several well-established preventative measures can be applied.

The fact that aluminium is non toxic was discovered in the early days of the industry. It is this characteristic which enables the metal to be used in cooking utensils without any harmful effects of the body, and today a great deal of aluminium equipment is used by food processing industries. The same characteristic permits aluminium foil wrapping to be used safely in direct contact with food products.

Aluminium is one of the two common metals having an electrical conductivity high enough for use as an electrical conductor. The conductivity of electrical-conductor grade (alloy 1350) is approximately 36 MS/m (62% of IACS).

Because aluminium has less than one-third the density of copper, an aluminium conductor of equivalent current carrying capacity is only half the mass of a copper conductor.

The high thermal conductivity of aluminium came prominently into play in the first large-scale commercial application of the metal – in cooking utensils. This characteristic is important in heat exchange applications where the transfer of thermal energy from one medium to another is involved, either heating or cooling. Thus aluminium heat exchangers are common in the food, chemical, petroleum, aircraft and other industries.

Aluminium is also an excellent reflector of radiant energy through the entire range of wavelengths from ultra-violet through the visible spectrum to infrared and heat waves as well as electromagnetic waves of radio and radar.

Aluminium has a light reflectivity of over 80%, which has led to its wide use in lighting fixtures. These reflectivity characteristics lead to its use as an insulating material. For example, aluminium roofing reflects a high percentage of the sun's heat so that buildings roofed with this material are cooler in summer. In the same way the excellent reflecting properties of aluminium ensure that buildings roofed with this material are warmer in winter.

Not so well known as some of the other properties of aluminium are its non-sparking (against itself and other non-ferrous metals) and non-magnetic characteristics. Nevertheless, these are of great importance for some uses. Its non-magnetic properties make the metal useful for electrical shielding purposes such as in busbar housings or enclosures for other electrical or magnetic equipment.

Aluminium may be fabricated readily into any form. Often it can compete successfully with cheaper materials having a lower degree of workability. The metal can be cast by any method known to foundrymen; it can be rolled to any desired thickness down to foil approximately 6 µm: aluminium sheet can be stamped, drawn, spun or roll formed. The metal also may be hammered or forged. Aluminium wire, drawn from rod, may be stranded into cable of any desired size and type. There is almost no limit to the different shapes in which the metal may be extruded.

All aluminium alloys may be machined relatively speedily and easily, important factors contributing to the low cost of finished aluminium parts. The metal may be turned, milled, bored, or machined in other manners at the maximum speeds of which the majority of machines are capable. Another advantage of their flexible machining characteristics is that aluminium rod and bar, particularly the free machining alloys such as 2011 and 6262, may readily be employed in the high-speed manufacture of automatic screw-machine parts.

Almost any method of joining is applicable to aluminium – riveting, welding, brazing, or soldering. A wide variety of mechanical aluminium fasteners simplifies the assembly of many products. Adhesive bonding of aluminium parts has been successfully employed in many applications including aircraft components and some building applications.

For many applications, aluminium needs no protective or decorative coating: the surface supplied is entirely adequate without further finishing. Mechanical finishes such as polishing, embossing, sand blasting, or wire brushing meet a variety of needs. Where the plain aluminium surface does not suffice, any of a wide variety of surface finishes may be applied. Chemical, electrochemical and paint finishes are all used. Many colors are available in both chemical and anodized finishes. If paint, lacquer, or enamel is used, any colour possible with these finishes may be applied. Porcelain enamels have been developed for aluminium and the metal may also be electroplated.

These are the characteristics that give aluminium its extreme versatility. In the majority of applications, two or more of these characteristics come prominently into play; for example, light weight combined with strength in aircraft, railway rolling stock, trucks and other transportation. High resistance to corrosion and high thermal conductivity are important in equipment for the chemical and petroleum industries; these properties combine with non-toxicity for food processing equipment. Attractive appearance together with high resistance to weathering and low maintenance requirements have led to extensive use in buildings of all types. High reflectivity, excellent weathering characteristics and light weight are all important in roofing materials. Light-weight contributes to low handling and shipping costs whatever the application.

Many applications require the extreme versatility which can only be provided by aluminium. For example, cars, high speed catamarans and other marine craft.

Aluminium does not burn and will not ignite. It does not add to the fire load or spread surface flame.

Aluminium has a thermal conductivity four times that of steel and a specific heat twice that of steel. Heat is therefore conducted away from aluminium faster than from steel and a greater heat input is required to bring the aluminium up to a given temperature.

A test certificate is usually necessary for any structural application that requires a timed fire resistance rating. Although aluminium components have obtained fire resistance ratings in excess of 30 minutes, it is not possible to make accurate predictions. It is therefore necessary to conduct appropriate testing and obtained certified approval for each type of application. Where higher time ratings are required, conventional fire-resisting materials must be used in conjunction with the aluminium.

Advantages of Aluminium **The metal**	**Advantages of Aluminium** **Products**
Light	Attractive appearance
Strong	Suitable for a wide range of finishes
High strength to weight ratio	Virtually seamless
Resilient / tough	Easy to fabricate
Ductile at low temperatures	Joinable by various methods
Corrosion resistant	Suitable for complex, integral shapes
Non Toxic	Suitable for easy assembly designs
Heat conducting	Produced to precise, close tolerances
Reflective	Produced with uniform quality
Electrically conducting	Recyclable
Non magnetic	Cost effective
Non sparking	Provide freedom of design

Types of Aluminium Alloys

Some aluminium alloys are heat treatable, some are not.

The non heat treatable alloys contain small amounts of elements such as manganese, silicon, iron and magnesium in solid solution. The alloys can be strengthened by cold work or strain hardening, that is by rolling or drawing.

The heat treatable alloys contain elements such as copper, magnesium, zinc and silicon. The first step in heat treatment is to heat the alloy to a high temperature (~300 – 500^{o}C, depending on the alloy) to take the alloying elements into solution. After cooling to room temperature, the metal is reheated to 100 – 200^{o}C to allow second phase particles to form in the microstructure, which increases the strength (and reduces the ductility).

Aluminium Alloy Numbering and the Effect of Alloying Elements

The aluminium alloys were originally given 4 digit numbers assigned by the Aluminum Association USA, in a sequential order. Cast alloys were numbered in a similar way, with a 4 digit number including a decimal point. These numbers does not convey the content of the alloy, beyond the first digit, which sorts the alloys into groups, depending on the principal alloying elements.

Alloys are now often referred to by their UNS numbers. For wrought alloys, these add 'A9' before the Aluminum Association number, and for cast alloys 'A0' or 'A1'.

Aluminum Association Numbering System

Wrought Alloys		Cast Alloys	
Aluminium (Commercially pure, Al > 99.00%)	1xxx	Aluminium (Commercially pure, Al > 99.00%)	1xx.x
Copper	2xxx	Copper	2xx.x
Manganese	3xxx	Silicon, + copper &/or magnesium	3xx.x
Silicon	4xxx	Silicon	4xx.x
Magnesium	5xxx	Magnesium	5xx.x
Magnesium & silicon	6xxx	Unused series	6xx.x
Zinc	7xxx	Zinc	7xx.x
Other elements	8xxx	Tin	8xx.x
Unused series	9xxx	Other elements	9xx.x

Temper Designation System

F: As fabricated. For wrought products, there are no mechanical property limits.

O: Annealed, recrystallised. Softest temper of the wrought products.

H: Strain hardened. Strength increased by cold work, which may be followed by a heat treatment for partial softening. The H is always followed by two or three digits indicating the treatment and result:

H1: Strain hardened only, no subsequent heat treatment.
H2: Strain hardened, then partially annealed to reduce their strength.
H3: Strain hardened, then heat treated to stabilize the strength – used for alloys containing magnesium only.
The second digit indicates the strength level achieved for the alloy:

0: Annealed	**1**: 1/8th Hard	**2**: ¼ Hard	**3**: 3/8th Hard
4: ½ Hard	**5**: 5/8th Hard	**6**: ¾ Hard	**7**: 7/8th Hard

8: Full Hard (~75% reduction of area in cold work)
9: Extra Hard

e.g. **A95052 H34** = alloy 5052, strain hardened and stabilized to half hard, which for this alloy is 0.2% Proof Stress 180 MPa minimum, Tensile Strength 235 – 285 MPa, Elongation 3 – 8%.