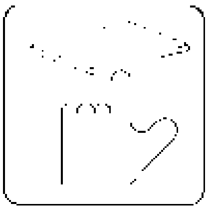
Advantages of Aluminium

A unique combination of properties makes aluminium and its alloys one of the most versatile engineering and construction materials available today.

Lightweight

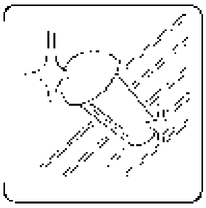


Aluminium is one of the lightest available commercial metals with a density approximately one third that of steel or copper.

Its high strength to weight ratio makes it particularly important to transportation industries allowing increased payloads and fuel savings. Catamaran ferries, petroleum tankers and aircraft are good examples of aluminium's use in transport.

In other fabrications, aluminium's lightweight can reduce the need for special handling or lifting equipment.

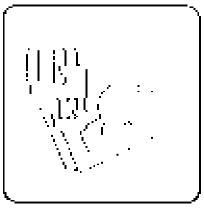
Excellent Corrosion Resistance



Aluminium has excellent resistance to corrosion due to the thin layer of aluminium oxide that forms on the surface of aluminium when it is exposed to air.

In many applications, aluminium can be left in the mill finished condition. Should additional protection or decorative finishes be required, then aluminium can be either anodised or painted.

Strong



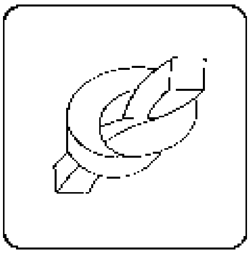
Although tensile strength of pure aluminium is not high, mechanical properties can be markedly increased by the addition of alloying elements and tempering. You can choose the alloy with the most suitable characteristics for your application.

Typical alloying elements are manganese, silicon, copper and magnesium.

Strong at Low Temperatures

Where as steel becomes brittle at low temperatures, aluminium increases in tensile strength and retains excellent toughness.

Easy to Work



Aluminium can be easily fabricated into various forms such as foil, sheets, geometric shapes, rod, tube and wire.

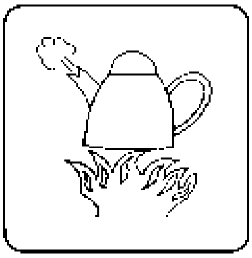
It also displays excellent machinability and plasticity ideal for bending, cutting, spinning, roll forming, hammering, forging and drawing. Aluminium can be turned, milled or bored readily, using the correct toolage.

In fact, most aluminium alloys can be machined speedily and easily. An important factor contributing to the low cost of finished aluminium parts.

Aluminium is a popular choice of material for complex-sectioned hollow extrusions.

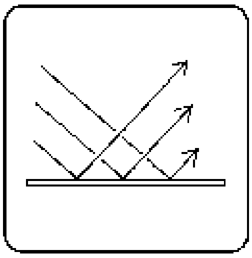
Almost any method of joining is applicable - riveting, welding, brazing or soldering. A wide variety of mechanical aluminum fasteners simplifies the assembly of many products. Adhesive bonding of aluminium parts is successfully employed in many applications including aircraft components, car bodies and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

Good Heat Conductor



Aluminium is about three times as thermally-conductive as steel. This characteristic is important in heat-exchange applications (whether heating or cooling). Aluminium is used extensively in cooking utensils, air conditioning, industrial heat exchangers and automotive parts.

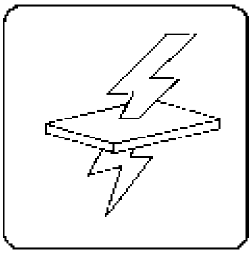
High Reflectivity



Aluminium is an excellent reflector of radiant energy through the entire range of wave lengths. From ultra-violet through the visible spectrum to infra-red and heat waves, as well as electromagnetic waves such as radio and radar.

Aluminium has a light reflectivity of over 80% which has led to its wide use in lighting fixtures. These reflectivity characteristics also lead to its use as an insulating material. For example, aluminium roofing reflects a high percentage of the sun’s heat, promoting a cool interior atmosphere in summer, yet insulating against heat loss in winter.

Good Electrical Conductor

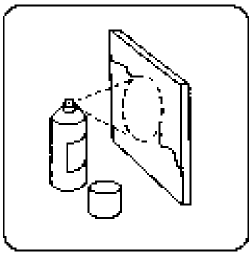


Aluminium is one of the two common metals having electrical conductivity high enough for use as an electrical conductor. The conductivity of electrical-conductor grade (alloy 1350) is about 62% that of the International Annealed Copper Standard.

However, aluminium is only a third the weight of copper, which means it conducts about twice as much electricity as copper of the same weight.

Aluminium is widely utilised in power-transmission cables, transformers, busbars and bases of electrical bulbs.

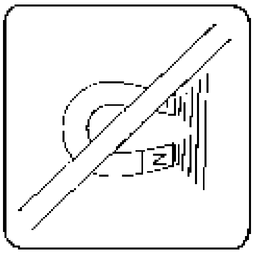
Easy Surface Treatment



For many applications, aluminium requires 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, a wide variety of surface finishes are available to suit. Chemical, electrochemical and paint finishes are all used.

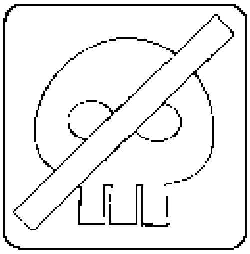
Above all, anodising treatment can provide excellent corrosion resistance and a wide range of colour variations. Such finishes are widely used for both interior and exterior applications.

Non-magnetic



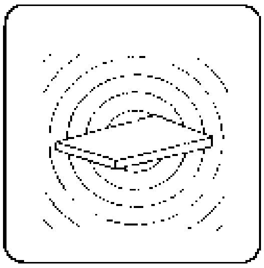
Aluminium has non-magnetic properties which make it useful for electrical shielding such as busbar or magnetic compass housings. Other applications include computer disks and parabolic antennas.

Non-toxic



The fact that aluminium is essentially 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 effect on the body. Aluminium with its smooth surface is easily cleaned, promoting a hygienic environment for food processing. Aluminium foil wrapping and containers are used extensively and safely in direct contact with food products.

Others



Easy to recycle

Due to a low melting temperature, it is economically recyclable, requiring only about 5% the energy required for smelting. It is an ideal material in this age of energy and resource saving.

Sound absorbing

Used for ceilings.

Shock absorbing

Due to its low modulus of elasticity, aluminium is used for automobile bumpers and the like.

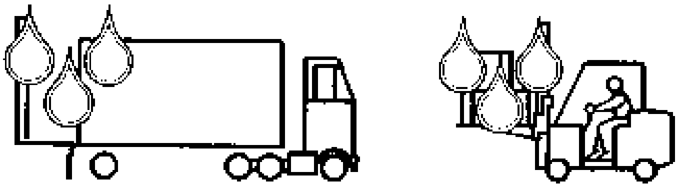
Non-sparking

Aluminium is void of sparking properties against itself and other non-ferrous metals.

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, lightweight combined with strength in aircraft, railway rolling stock, trucks and other transportation equipment. High resistance to corrosion and high thermal conductivity are important 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 cost whatever the application.

Many applications require the extreme versatility which only aluminium possesses. Almost daily, unique combinations of these properties are being put to work in new ways.

Handling and Storing Aluminium



Aluminum Water Stain Prevention

When You Receive Metal

1. Check for wetness.
   (a) Is the metal wet? Is the wrapping paper puckered up or wet?
   (b) If it is wet, note it on all copies of the receiving papers.
   (c) Inform the Purchasing Department or Quality Control immediately.
2. Check to see if the metal feels cold.
   If it does:
   (a) Tell your supervisor immediately.
   (b) Leave the metal in a cool indoor area away from drafts to allow it to warm up slowly. (If this is not done, and metal is put in a heated warehouse immediately, it may sweat and become water stained.)
   (c) After the metal is reasonably warm (about a day later), move it to the warehouse.

When You Move Metal Between Areas

Check to see if the temperature in the area the metal will be taken to is higher than the temperature in the area the metal is coming from.

If the difference is more than 11^{o}C (20^{o}F):

(a) Only move as much metal as will be used immediately.
(b) Tell your supervisor.
(c) Leave the remainder of the metal where it is until ready for use.

Note:

If you experience any signs of moisture, dampness or water staining on your delivery, please call your local Capral Aluminium Centre immediately.

Corrosion

Exposure

Aluminium and its alloys have excellent durability and corrosion resistance, but, like most materials, their behaviour can be influenced by the way in which they are used.

Aluminium's natural affinity with oxygen results in the formation of a transparent oxide film when aluminium is exposed to air. This oxide film is generally 5 to 10µm thick, extremely hard, chemically stable, corrosion resistant and adheres strongly to the parent metal surface. If damaged in any way, it will reform if enough oxygen is available. The film is removed to facilitate anodising or welding.

In anodising, a thicker, more controlled deposit of oxide film is added.

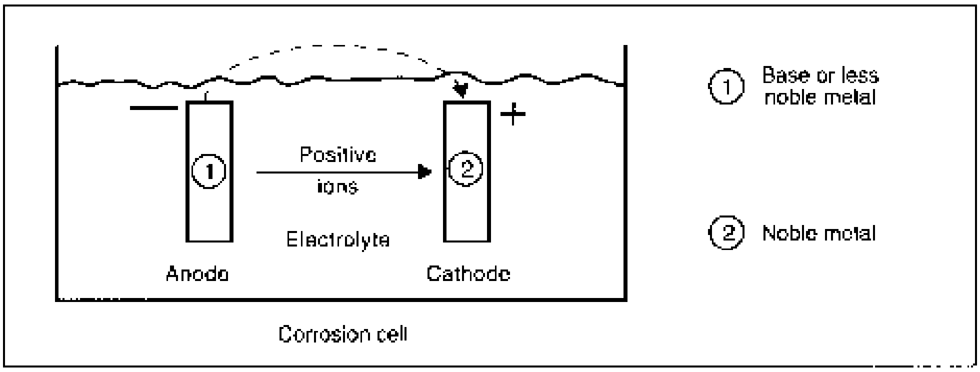
In welding, the oxide film inhibits metal fusion.

Galvanic Corrosion

Takes place when dissimilar metals are coupled together in the presence of moisture. The severity of the corrosion depends largely on the circumstances in which the electrolytic couple formed producing a current flow from the less noble metal (*anode*) to the more noble metal (*cathode*) and resulting in corrosion of the less noble metal.

Galvanic corrosion may be prevented by insulating dissimilar metals from each other with an electrically inert, non-absorbent barrier.

This type of connection is used between the aluminium superstructure and steel decking on ships.



The Principle of Galvanic Reaction

A Guide to Galvanic Corrosion Effects Between Aluminium and Other Metals

Metal	Galvanic Corrosion Effect When Coupled With Aluminium or an Aluminium Alloy	
Gold, Platinum, Silver	Attack accelerated in most environments	These metals, and especially those at the top of the list, are generally cathodic to aluminium and its alloys, which are therefore preferentially attacked when corrosion occurs.
Copper, Copper Alloys, Silver Solder	Attack accelerated in most atmospheres and under conditions of total immersion.	
Solder Coatings on steel or copper	Attack accelerated at interface in severe or moderate atmospheres and under conditions of total immersion.	
Nickel and Nickel Alloys	Attack accelerated in marine or industrial atmospheres and under conditions of total immersion, but not in mild environments.	
Steel, Cast Iron	Attack accelerated in marine or industrial atmospheres and under conditions of total immersion, but not in mild environments.	
Lead, Tin	Attack accelerated only in severe environments such as marine and some industrial.	
Tin-Zinc Plating (80-20) on steel	Attack accelerated only in severe atmospheres and under conditions of total immersion.	
Pure Aluminium and Aluminium Alloys not containing substantial amounts of copper or zinc	When aluminium is alloyed with appreciable amounts of copper it becomes more noble and when it is alloyed with appreciable amounts of zinc it becomes less noble. In marine or industrial atmospheres, or when totally immersed, an aluminium alloy suffers acclerated attack when in good electrical contact with another aluminium alloy that contains substantial amounts of copper, such as the alloys in the 2000 series.	
Cadmium	No acceleration of attack on cadmium except in fairly severe atmospheres in contact with an aluminium alloy containing copper and under conditions of total immersion	These metals are generally anodic to aluminium and are attacked when corrosion occurs, thereby protecting the aluminium
Zinc and Zinc Alloys	Attack on zinc is accelerated in severe environments such as marine or industrial and under conditions of total immersion	
Magnesium and Magnesium Alloys	Attack on magnesium is accelerated in severe environment such as marine or industrial and under conditions of total immersion.	Attack on aluminium may also be accelerated
Titanium	Little data available, but attack on aluminium is known to be accelerated in severe marine or industrial conditions and when immersed in seawater.	These metals form inert protective film that tend to reduce galvanic reaction. Where attack occurs, the aluminium base material suffers.
Stainless Steel (18-8, 18-8-2 and 13% Cr)	No acceleration of attack on aluminium in moderate atmospheres, but attack may be accelerated in severe marine or industrial atmosphers and under conditions of total immersion.	
Chromium Plate	No acceleration of attack on aluminium when plating is not less than 0.0025mm thick, except in severe atmospheres.	

The Electro-Chemical Series

BASE METAL	Magnesium Zinc Aluminium Cadmium Mild Steel Cast Iron Lead Tin Brasses Copper Bronzes Monel Metal Silver Solders (70% Ag 30% Cu) Nickel Stainless Steel (Type 304) Silver Titanium Graphite Gold
NOBLE METAL	Platinum

Pitting

Pitting is the localised form of corrosion that usually occurs at random in the form of small pits or craters (of roughly hemispherical shape). Pits usually become covered with a mound of corrosion product. The rate of penetration of a pit usually diminishes with time, and frequently the pitting can be tolerated if the wall thickness is adequate. The frequency and depth of pitting vary somewhat from one alloy to another. The depth of pitting is extremely small and the process is known as “weathering”. The type and level of pollution will determine general appearance.

Regular maintenance and washing down of aluminium should prevent permanent discolouration from the effects of industrial pollutants.

Anodised surfaces retain their original appearance for much longer periods when regular maintenance is provided.

Poultice Action

Poultice Action is a form of corrosion that takes place under moist conditions when porous materials such as asbestos, cloth, cork, paper, etc absorb water and act as a poultice. The corrosive action is the result of differences in oxygen concentration in the water in adjacent areas of the material. It may be increased by corrosive chemicals extracted from the material.

Simple Rules to Avoid Corrosion

Since the corrosion behaviour of alloyed aluminium is influenced by the physical conditions of the environment, contact with dissimilar metals and by the presence of crevices, the design of equipment made with aluminium can have an appreciable influence on the nature and rate of corrosion.

- Never use aluminium in anaerobic (no oxygen) conditions.
- Seal all joints and bolt holes.
- Eliminate corners and crevices which are difficult to clean.
- Butt weld where possible.
- Avoid dissimilar metal contact whenever possible.

Contact With Materials

Wood

- Dry wood has no reaction to aluminium.
- Unseasoned/damp wood should be coated with an aluminium or bituminous paint.
- Treated timber may require special consideration and referral to the supplier.

Insulation

- Foam, felt, fire retardant may cause corrosion of aluminium if they become wet when in contact with it.
- Protect the aluminium by using an inert barrier.

Concrete

- No protection under perfectly dry conditions.
- As these conditions are rare, all aluminium surfaces in direct contact with concrete should be coated with bituminous paint.

Chemicals

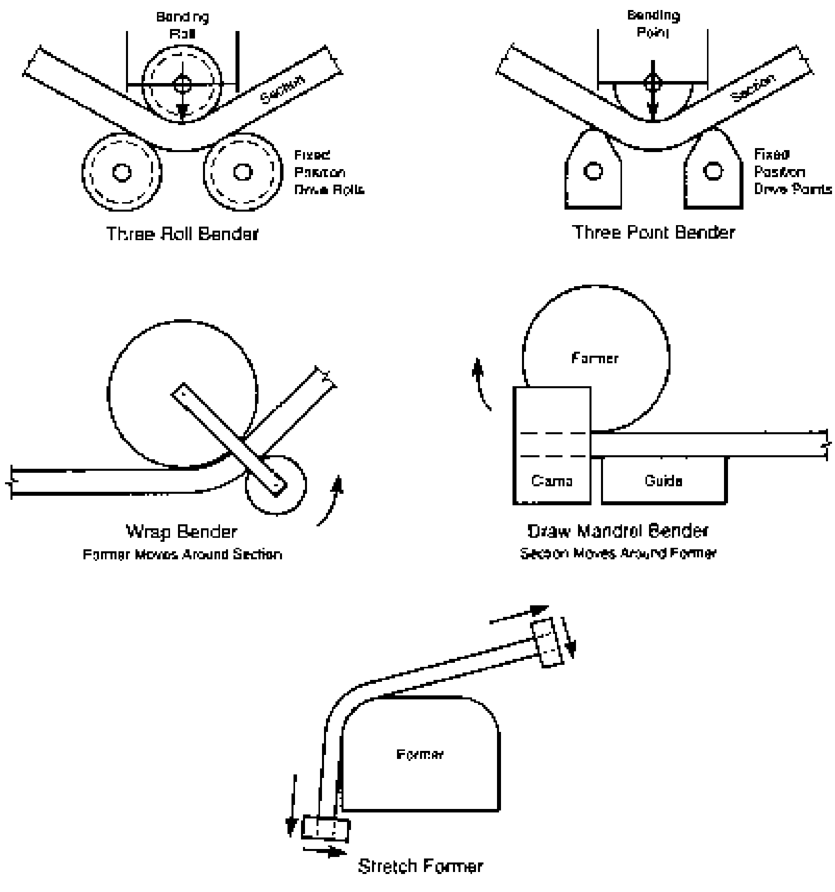
- A direct chemical attack of aluminium only occurs to any great extent in strong acid of alkaline conditions.
- In some cases the temperature may significantly alter the rate of chemical reaction or be a major factor in initiating chemical attack.

Forming Process - Bending

Bending

There are several types of forming machines suitable for bending aluminium sections. The choice depends upon the class of section, whether solid, open or hollow; the range of support tooling available; the alloy and temper. Tubing is by far the most commonly bent extruded product.

Bending may be carried out by four main methods:



Bending Methods

The three roll bender has a central moveable roller which is gradually depressed until the desired radius is obtained. The three point bender has a similar method of operation, the load being either applied gradually or impacted. The roll and point methods of bending are usually applied to robust sections.

In both wrap and mandrel benders, it is possible to provide formers and other support tools which minimise the amount of buckling and enable tighter radii to be obtained.

The stretch former puts the section into tension and then, moving laterally, wraps it around a former. This method reduces the likelihood of compression failure.

Drawn tube should be specified where tight tolerances are required and where a higher level of mechanical property is necessary than is available in an extruded product. Drawn tube bends more consistently than extruded tube, again, due to the range in the mechanical properties.

Section bending is a specialist procedure and generally the soft tempers should be used, particularly for complex shapes.

General Considerations

Forming Quality Tempers

Heat treated alloys of T5 and T6 tempers and T8 drawn tempers can be bent, but the range of mechanical properties in each temper is too wide to give a consistency of bends.

It is for this reason we have developed 6060-T595 to maximise formability, yet still maintain a reasonable level of typical mechanical properties.

It is important for us to know customer's requirements so that this alloy and temper can be recommended.

In general, the lower the mechanical properties, the more formable the product. In the case of the -0 and T4 tempers, the bend radius will be more controllable with little or no spring back occurring, the other tempers will have variable amounts of spring back. It is advisable to supply the -0 or T4 tempers when the bending machines are automatically controlled.

Alloys and tempers available specifically for bending and possible applications are;

Alloy/Temper	Commodity	Applications
1200-0	Drawn tube	Tight bends. Refrigeration appliances, very low properties. Consistent bends.
1200-H12	Drawn tube	Medium bends. Refrigeration appliances.
6060-T591	Extruded, rod, bar, tube and some shapes	Tight bends. Consistent bending. Low properties. Windows and difficult shapes.
6060-T595	Extruded, rod, bar, tube and some shapes	Medium bends. Caravan windows and trim.
6060-T81	Drawn tube	General purpose, high strength, large radii necessary. Bull bars.
6060-T891	Drawn tube	Good properties when flattening may be required. Truck mirrors.
6106-T4	Extruded, rod, bar, tube and some shapes	Tight bends. Consistent bending. Low properties. Windows and difficult shapes.

In addition, the bending characteristics of the aluminium alloys most frequently used in the extrusion industry are;

Alloy	Temper	Bending Characteristic
6060	T1	Very Good
6063	T5	Good
6106	T4	Very Good
	T6	Good
6005A	T4	Good
6061	T6	Fair
6082	T6	Fair
6101	T6	Good
6463A	T1	Very Good
7005	T593	Fair

The formability of all alloys and tempers is improved by working the metal at elevated temperatures. A general safe maximum temperature range at which mechanical properties are not seriously affected is in the range of 150-200C.

Welding does however have an adverse effect on formability in that it tends to reduce the ductility of the metal in the welded area.

Shape Factors

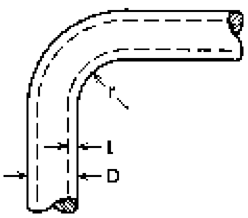
The complexity of shapes available in aluminium alloys makes it very difficult to provide information covering every situation. By considering the behaviour of the various elements of a shape in relation to the axis of bending, it is possible to predict the most likely mode of failure of a section when it is bent through too tight a radius.

Recommended Bending Radii for Round Tube

Recommended Miniumu Inside Bending Radii (r) for Selected Sizes of Round Tube - Mandrel Bending

Tube Size		Radii for Various Alloys and Tempers (mm)					
Outside Diameter (mm)	Wall Thickness (mm)	1200-O 1350-O	6106-O 6060-O 6063-O 6061-O 6351-O	6106-T4 6061-T4 6351-T4 6063-T4	6060-T5 6063-T5 & T6 6101-T5 &T6 6106-T6	6005A-T6 6061-T6 6351-T6	6060-T81 6063-T81
10	**1.0** **1.6**	12 10	15 13	16 14	18 16	20 18	18 16
12	**1.0** **1.6**	16 12	16 15	18 17	22 20	25 23	28 26
16	**1.0** **1.6**	19 17	22 20	30 23	32 26	35 32	38 32
20	**1.0** **1.6**	25 22	28 25	38 32	40 32	50 40	60 40
25	**1.2** **1.6** **3.0**	38 35 30	45 45 42	50 46 40	56 50 45	62 56 52	70 65 50
28	**1.2** **1.6** **3.0**	45 42 34	54 50 40	60 54 42	68 58 45	84 64 50	98 75 50
32	**1.2** **2.0** **3.0**	54 42 38	62 48 42	80 58 46	80 60 52	100 80 60	110 80 70
40	**1.6** **2.0** **3.0**	64 56 48	72 64 54	90 80 60	95 80 70	120 100 80	140 110 85
50	**1.6** **2.0** **3.0** **4.0**	90 84 70 68	112 98 80 70	125 110 95 80	140 126 110 90	175 150 125 120	220 190 150 140
60	**2.0** **3.0** **4.0** **6.0**	110 100 85 70	120 105 90 80	150 120 100 90	170 130 120 100	220 180 150 130	260 220 190 150
80	**2.0** **3.0** **4.0** **6.0**	165 140 135 120	190 170 150 130	220 185 160 140	240 200 180 160	340 250 220 200	400 320 280 250

Note: It is recommended that test bends are carried out before final selections is made.



Where
D = outside diameter of tube (mm)
t = wall thickness of tube (mm)
r = inside radius of bend (mm)

Recommended Bending Radii for Sheet and Plate

Recommended Minimum Inside Bending Radii for 90 degree Cold Forming of Sheet and Plate (Bending transverse to rolling direction)

Alloy	Temper	Radii for Various Thicknesses Expressed in Terms of Thickness t							
		t=0.4mm	t=0.8mm	t=1.6mm	t=3.0mm	t=4.0mm	t=6.0mm	t=10.0mm	t=12.0mm
1080A 1050 1350 1150	**- O**	0.0 t	0.0 t	0.0 t	0.0 t	0.0 t	0.5 t	0.5 t	1.0 t
	- H12	0.0 t	0.0 t	0.0 t	0.0 t	0.0 t	0.5 t	1.0 t	1.5 t
	- H14	0.0 t	0.0 t	0.0 t	0.5 t	0.5 t	1.0 t	1.5 t	2.0 t
	- H16	0.0 t	0.0 t	0.5 t	1.0 t				
	- H18	0.5 t	1.0 t	1.5 t	2.0				
1100 1200	**- O**	0.0 t	0.0 t	0.0 t	0.0 t	0.0 t	0.5 t	1.0 t	1.5 t
	- H12	0.0 t	0.0 t	0.0 t	0.5 t	1.0 t	1.0 t	1.5 t	2.0 t
	- H14	0.0 t	0.0 t	0.0 t	1.0 t	1.0 t	1.5 t	2.0 t	2.5 t
	- H16	0.0 t	0.5 t	1.0 t	1.5 t				
	- H18	1.0 t	1.5 t	2.0 t	3.0 t				
5052 5251	**- O**	0.0 t	0.0 t	0.0 t	0.5 t	1.0 t	1.0 t	1.5 t	1.5 t
	- H32	0.0 t	0.0 t	1.0 t	1.5 t	1.5 t	1.5 t	1.5 t	2.0 t
	- H34	0.0 t	1.0 t	1.5 t	2.0 t	2.0 t	2.5 t	2.5 t	3.0 t
	- H36	1.0 t	1.0 t	1.5 t	2.5 t				
	- H38	1.0 t	1.5 t	2.5 t	3.0 t				
5454	**- O**	0.0 t	0.0 t	0.5 t	1.0 t	1.0 t	1.0 t	1.5 t	1.5 t
	- H32	0.0 t	0.5 t	1.0 t	1.5 t	1.5 t	2.0 t	2.5 t	3.5 t
	- H34	0.5 t	1.0 t	1.5 t	2.0 t	2.5 t	3.0 t	3.5 t	4.0 t
	- H112						2.0 t	2.5 t	3.0 t
5083	**- O**				1.0 t	1.0 t	1.0 t	1.5 t	1.5 t
	- H116				2.3 t	3.0 t	3.0 t	3.8 t	4.5 t
	- H311				1.5 t	1.5 t	1.5 t	2.0 t	2.5 t
	- H321				2.0 t	2.0 t	2.0 t	2.5 t	3.0 t
	- H323				2.0 t	2.5 t	3.0 t		
	- H343				3.0 t	3.5 t	4.0 t		
5086	**- O**	0.0 t	0.0 t	0.5 t	1.0 t	1.0 t	1.0 t	1.5 t	1.5 t
	- H32	0.0 t	1.5 t	1.5 t	2.0 t	2.0 t	2.0 t	2.5 t	3.0 t
	- H34	0.5 t	1.0 t	1.5 t	2.0 t	2.5 t	3.0 t	3.5 t	4.0 t
	- H36				3.0 t	3.5 t			
	- H112					1.5 t	2.0 t	2.0 t	2.5 t
6061	**- O**	0.0 t	0.0 t	0.0 t	1.0 t	1.0 t	1.0 t	1.5 t	2.0 t
	- T4	0.0 t	0.5 t	1.0 t	1.5 t	2.5 t	3.0 t	3.5 t	4.0 t
	- T6	1.0 t	1.0 t	1.5 t	2.5 t	3.0 t	4.0 t	4.5 t	5.0 t

Note: The radii listed are the minimum recommended for bending sheets and plates without fracturing in a standard press brake with air bend dies. Other types of bending operations may require larger radii or permit smaller radii. The minimum permissible radii will also vary with the design and condition of tooling

Heat-treatable alloys can be formed over appreciably smaller radii immediately after solution heat treatment.

The H112 temper (applicable to non-heat-treatable alloys) is supplied in the as-fabricated condition without special property control, but usually can be formed over radii applicable to the H14 (or H34) temper or smaller.

Applicable to 5005 H1X and H3X tempers.

To bend structural shapes, three roll, three point, or wrap benders may be used with or without restraint to the walls of the section. As minimum bend radii are functions of the alloy, the temper, the proportions of the cross section, and the standard of appearance demanded, it is not possible to give hard and fast rules, and practical trials should be made. As a preliminary guide the bend radius may be obtained from:

$$R = \frac{100y}{\delta}\left(1 - \frac{\delta}{\theta}\right)$$

If the extreme fibre is in compression and *y*, or *b*, exceeds *3t* the value of *R* obtained from the equation above will be multiplied by:

Outstanding legs in the plane of bending *y/3t*

Flanges at right angles to the plane of bending *b/3t*

Where R = radius of curvature of neutral axis

y = distance from neutral axis to extreme fibre,

δ = percentage elongation of the alloy

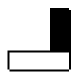
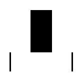
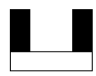
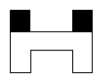
b = flange width,

t = thickness,

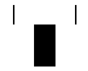
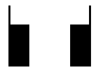
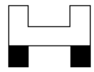
θ = angle of bend, degrees (>δ)

Recommended Bending Radii for Web and Flange Elements

Web - Tensile Failure

Alloy	Temper	Minimum Bending Radii					Typical Sections
		y/t 1	2	4	8	12	
6060 6063 6106	T1	0.7y	0.7y	0.8y	2.0y	3.5y	
	T5, T6	0.8y	0.8y	1.4y	3.5y	7.0y	
6005A 6061 6082	T4	2.5y	2.5y	2.5y	3.0y	5.0y	
	T6	2.5y	2.5y	2.5y	3.5y	7.0y	

Web - Compressive Buckling Failure

Alloy	Temper	Minimum Bending Radii y/t 2	3	4	6	Typical Sections
6060 6063 6106	T1	1.0y	3.5y	8.0y	20.0y	
	T5, T6	1.0y	4.0y	10.0y	20.0y	
6005A 6061 6082	T4	1.8y	4.0y	10.0y	20.0y	
	T6	1.8y	5.0y	10.0y	25.0y	

Radii are measured to the neutral axis of the section and are expressed in terms of y.

y = the maximum distance from the outer fibres of the element to the neutral axis of the whole section.

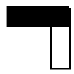
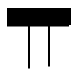
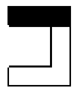
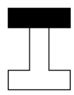
t = the thickness of the element.

w = the width of a flange

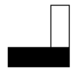
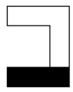
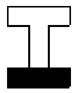
Flange= an element perpendicular to the plane in which bending occurs. Denoted by [flange symbol]

Web = an element parallel to the plane in which bending occurs. Denoted by [web symbol]

Flange - Tensile Failure

Alloy	Temper	Minimum Bending Radii w/t 4	8	Typical Sections
6060 6063 6106	T1	7.0y	8.0y	
	T5, T6	10.0y	10.0y	
6005A 6061 6082	T4	8.0y	8.0y	
	T6	10.0y	10.0y	

Flange - Compressive BucklingFailure

Alloy	Temper	Minimum Bending Radii		Typical Sections
		w/t 4	8	
6060 6063 6106	T1	5.0y	8.0y	
	T5, T6	8.0y	20.0y	
6005A 6061 6082	T4	7.0y	12.0y	
	T6	8.0y	20.0y	

Note:

1. For bulb flanges with bulb diameters greater than 3 times the flange thickness, multiply the minimum bending radii by 0.6.
2. In the compressive buckling mode, the use of support tooling can reduce the minimum bending radii below the values shown. The extent of the reduction depends on the type of tooling used.

Lubrication

Because aluminium tends to “stick” to steel forming tools, lubrication is necessary to prevent this and possible damage both to the formed part and to the toolage.

Light lubricants such as kerosene are useful for general light forming operations such as press brake and roll forming, stretch wrap forming and certain cutting operations.

Heavier lubricants are used for spinning and deep drawing.

These are generally specially formulated oils which allow the metal under pressure to move over the tool surface without sticking to it.

Mineral oils are used as lubricants for bending and swaging.

Joining Process - Welding

Welding uses an intense heat source to cause localised melting and fusion of the parent metal of the joint. Filler metal may or may not be used.

A wide variety of processes are used to weld aluminium, some common, others highly specialised.

Arc Welding

- T.I.G. (Tungsten Inert Gas)
- M.I.G. (Metal Inert Gas)
- Pulse Arc (lower than normal currents)
- Stud (attaching studs and fasteners to metal)
- Atomic Hydrogen (intense heat - rare)
- Carbon Arc (rarely used)
- Metal Arc (not good quality - repairs)

Oxy-Gas Welding

- Standard oxy-fuel techniques (oxy acetylene/oxy hydrogen)

Resistance Welding

- Spot
- Seam
- Flash Butt
- Resistance Butt
- Projection
- Percussion

Applicable to all aluminium alloys but more particularly to the heat-treatable alloys which are difficult to weld by the fusion process.

Specialised Welding

- Pressure
- Ultrasonic
- Friction
- Thermit
- Induction and resistance seam

- Electron Beam
- Laser Beam
- Plasma Arc

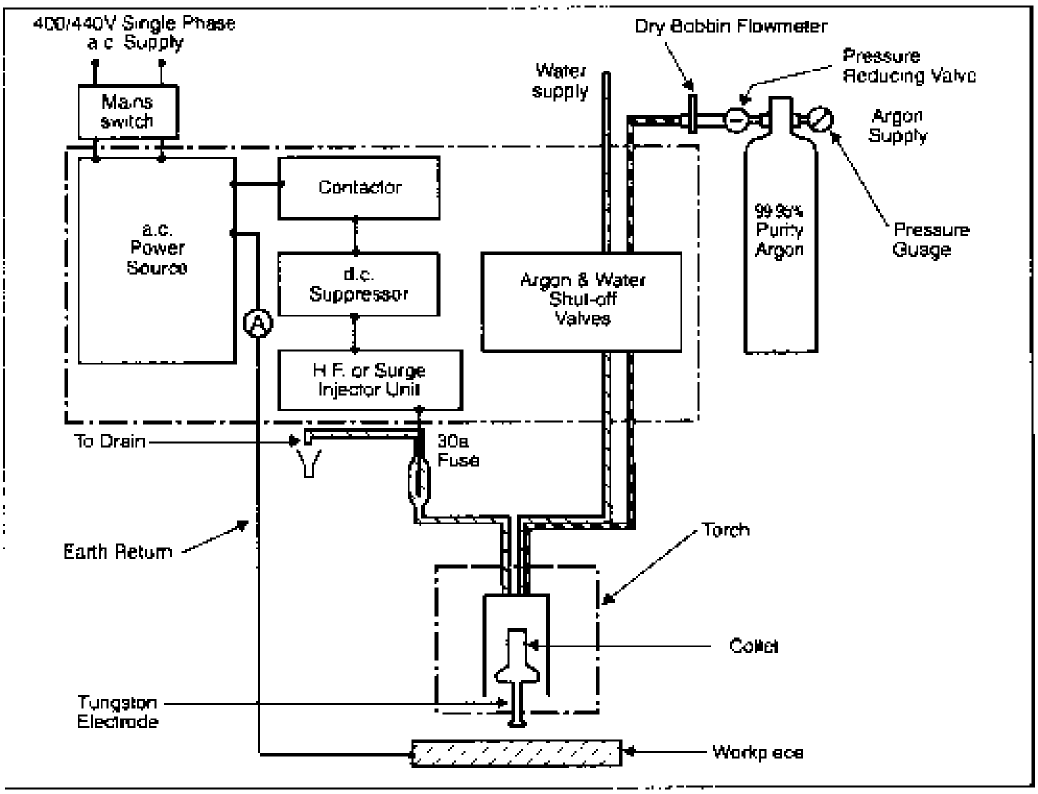
All applicable to the joining of aluminium but very limited application.

Welding is a widely accepted method of joining aluminium and the techniques are well known in the engineering and manufacturing industries.

The most commonly used basic welding processes are tungsten inert gas (T.I.G.) and metal inert gas (M.I.G.).

As the names suggest, both process are inert-gas-shielded systems which shroud the weld area from the air to prevent to reformation of oxide film.

A Typical TIG (GTAW) Welding System



A Typical TIG Welding System

Note:

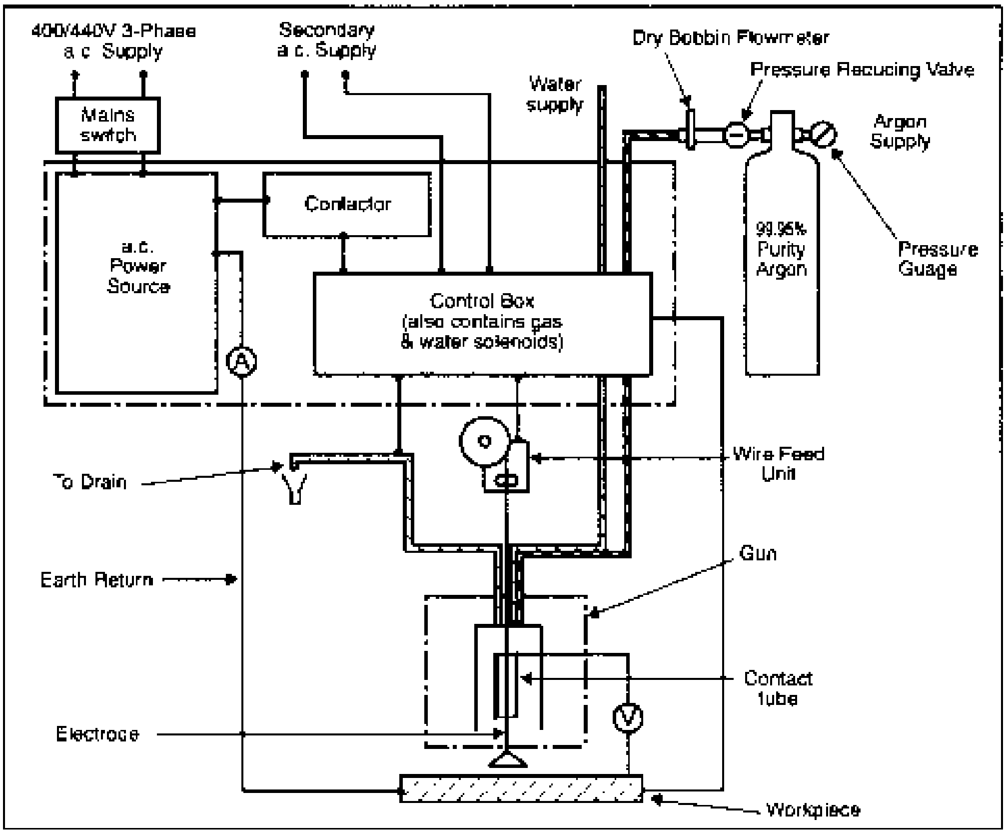
1. Composite TIG welding units include all the necessary auxiliaries. The argon and water shut off valves are usually controlled by solenoids, but may also be manually operated.
2. The main power cable, fuse and torch can be air or water cooled.

Metal Thickness Capacity of TIG and MIG Welding Systems

Welding System	Thickness of Parent Metal (mm)		Welding Equipment
	min	max	
TIG	1.2	9.5 (Note 1)	Composite unit (350A) with Transformer (350A), High Frequency or Surge Injector unit, Suppressor and Welding Torches
MIG 0.5kg	1.6	8.0 (Note 2)	Composite unit (250A) with Wire Feed unit and Welding Gun for 0.5kg Spool
MIG 5kg	4.8	None	Composite unit (250A) with Wire Feed unit and Welding Gun for 5kg Spool

Note:
1. Although the TIG process can weld thicker material, it is not normally used for aluminium greater than 9.5mm in thickness for economic reasons.
2. In theory there is no upper limit to metal thickness for 0.5kg MIG, but it is more economical to use 5kg MIG for aluminium greater than 8.0mm in thickness.

A Typical MIG (GMAW) Welding System



A Typical MIG Welding System

Note:

1. The a.c. supply is 110v for 0.5kg MIG and 220v for 5kg MIG welding.
2. Composite MIG welding units have the contactor and control box built in.
3. The filler wire feed unit is integral with the gun in 0.5kg MIG and independent of it in 5kg MIG systems.
4. A voltage pick-up lead is required for 0.5kg MIG.
5. The main power cable and gun of 5kg MIG can be water cooled.
6. Arc voltage in MIG welding processes is measured with a voltmeter connected between the contact tube and the workpiece.

Preparation

Cleanliness and removal of the oxide film are most important. The proposed weld area must be degreased using methylated spirits, acetone, etc. Oxides, grease or oil films left on the edges to be joined will cause unsound welds and the mechanical efficiency of the weld will be adversely affected. The joint must be wiped dry.

After degreasing, the joint is cleaned with stainless steel wire brushes, or a chemical etch cleaner to remove the oxide film. Welding should be carried out as soon as possible.

The majority of T.I.G. and M.I.G. welding is done manually, however, they are ideal processes for mechanising. This leads to improvements in terms of increased welding speed, more consistent penetration, bead shape and general appearance and a greater degree of repeatability which is essential for volume production welding work.

The chief differences between the T.I.G. and M.I.G. processes are in the ***electrodes*** and the characteristics of the power used. In T.I.G. welding, the electrode is tungsten (non-consumable), which is used to maintain the arc; an appropriate aluminium filler material is added separately as required. Argon is fed to the torch through a flexible tube so that the whole of the arc and the weld pool are shrouded with argon, effectively preventing oxidation.

Conventional T.I.G. welding of aluminium is performed with AC current.

In M.I.G. welding, the electrode is aluminium filler wire fed continuously through the gun or torch from a reel into the weld pool as fast as it is consumed; the arc is struck between the tip of this wire and the metal being welded. For welding aluminium, the gas may be argon, helium, or a mixture of both, which is fed through the torch to provide a protective shroud. The current supply is DC (reverse polarity) with the electrode positive.

The choice of correct fill composition is of fundamental importance when fusion welding the various aluminium alloys. As well as the important consideration of corrosion resistance and the strength required of the weld, the filler metal must be compatible with the alloy to be welded. Weld cracking may result from using incorrect filler alloys.

The correct joint design is important to ensure adequate penetration. Backing strips should be used where feasible; the backing bar may be of steel, stainless steel, copper or aluminium.

For the T.I.G. process, the joint design and root openings required are determined by the thickness of the aluminium to be jointed and the structural requirements of the weldment.

For the M.I.G. process, the square butt joint is satisfactory up to 6mm. For thicker material either a single-vee or double-vee bevel may be necessary.

The four primary conditions which must be correct for a good weld are:

- Volts
- Amps
- Gas Flow
- Arc Travel Speed

Each job requires a particular set of welding conditions depending on the type and position of weld and the thickness of the metal.

Filler Wire

Alloys in the 5000 and 6000 series can be welded readily to a wide range of other aluminium alloys. The table below shows the preferred weld filler wire for such combinations of parent metals and, where appropriate, gives an alternative filler wire which can be used when the finished component is to be anodised and a close colour match is required between the weld area and the parent metal. Alloys in the 2000 series are not shown in the table since they are not recommended for fusion welding using the TIG and MIG processes.

Filler Metal Selection Chart for the Welding of Wrought Alloys[1,2]

The following table is extracted from "Successful Welding of Aluminium" published by WTIA (Welding Technology Institute of Australia) and should be used as a guide only.

First Alloy Subgroup	Second Alloy Subgroup						
	Itself (or same subgroup)	7005	6006[3] 6061 6082	5154A 5454	5083 5086	5052 5251	5005 5050A
1050[4]	1100[7]	5356[7]	4043	4043[9]	5356[7]	4043[9]	4043[9]
5005 5050A	4043 [8,9]	5356[9]	4043[6]	5356[6]	5356[9]	4043[9]	4043[9]
5052 5251	5356 [5,6,7]	5356[9]	5356 [6,7]	5356[6]	5356[9]		
5083	5183[9]	5183[9]	5356[9]	5356[9]			
5086	5356[9]	5356[9]	5356[9]	5356[6]			
5154A 5383	5356[5,6,8] 5183[9]	5356[6] 5183[9]	5356[6,7] 5356[9]	5356[6] 5356[9]	5356[9]		
5454	5554[7,9,11]	5356[6]	5356[6,7]				
6060[3] 6061 6082	4043[6]	5356[6,7]					
7005	5356[9,10]						

Note:

1. Service conditions such as immersion in fresh or salt water, exposure to specific chemicals, or a sustained high temperature (over 65°C) may limit the choice of filler metals. Filler metals 5356, 5183, 5556 and 5654 are not recommended for sustained temperature service over 65°C.

2. Recommendations in the main body of this table are the preferred choice and apply for most applications. Further information refer to WTIA Technical Note 2.

3. Other alloys in this group include: 6005A, 6101, 6106 and 6261.

4. Other alloys in this group include: 1080A, 1150, 1350 and 3203.

5. 5654 filler is used for welding base metal alloys for low-temperature hydrogen peroxide service (less 65°C).

6. 5183, 5356, 5554, 5556 and 5654 may be used. 5554 is only 5xxx series filler alloy listed suitable for service temperature over 65°C.

7. 4043 may be used.

8. Filler metal with the same analysis as the base metal may be used.

9. 5183, 5356 or 5556 may be used.

10. 5039 is preferred but not readily available.

11. 5554 is only 5xxx series filler alloy listed suitable for service temperatures over 65°C.

A Guide to Successful Welding of Aluminium

The following tables are extracted from “Successful Welding of Aluminium” published by WTIA (Welding Technology Institute of Australia) and should be used as a guide only.

Commonly Available[1] Wrought Alloy Products Suitable for Welding

Alloy	Material					
	Sheet, Coil & Plate	Extruded Rod, Bar	Extruded Tube	Extruded Shapes	Drawn Rod, Bar	Drawn Tube
1050	*					
1200	*	*				
1350[2]	*	*	*	*		
5005	*					
5083	*	*	*			
5383[3]	*	*	*			
5251	*					
5052	*					
5454	*					
6005A		*	*	*		
6060		*	*	*	*	*
6061[3]	*	*	*	*	*	*
6082[2]		*	*	*		
6101[2]		*	*	*	*	*
6106		*	*	*		
7005[4]		*				

Note:
1. Indicates the form in which the alloy is typically available “off the shelf”. Other alloys and different alloy/product combinations are possible.
2. Mainly used for electrical conductors.
3. Mainly used for structural purposes.
4. Limited availability and weldability - seek specialist advice for welding

Minimum Mechanical Properties for Welded Aluminium Alloys (refer also to AS1664)

Alloy and Temper	Product	Thickness Range mm	Tensile Strength (MPa)		Compressive Strength (MPa)	Shear Strength (MPa)		Bearing Strength (MPa)	
			Tensile	Yield[1]	Yield[1]	Tensile	Yield	Tensile	Yield
1200-H12-H14	All	All	75	32	32	55	17	158	55
5005-H12-H14-H16-H32-H34-H36	All	All	103	48	48	62	27	193	68
5052-H32-H34-H36-H38-H391	All	All	172	89	89	110	51	344	131
5083-H111	Extrusion	All	268	144	137	158	82	537	220
5083-H321	Plate	<=40	275	165	165	165	96	551	248
5083-H321	Plate	>40 <=75	268	159	159	165	90	538	234
5083-H323-H343	Sheet	<=6	275	165	165	165	96	551	248
5086-H112	Sheet	>4.8 <=6	241	117	117	144	65	482	193
5086-H112	Plate	>6 <=25	241	110	110	144	62	482	193
5086-H112	Plate	>25 <=50	241	96	96	144	55	482	193
5086-H32-H34	Sheet/Plate	All	214	131	131	144	75	482	193
5251-H32-H34-H36	Sheet/Plate	All	170	89	89	110	51	344	131
5383	Sheet/Plate	All	290	165	165	165	NA	NA	NA
5454-H34	Sheet/Plate	All	213	110	110	131	65	427	165
6006A-T5	Extrusions	NA	NA	NA	NA	NA	NA	NA	NA
6060[2]-T5	Extrusions/ Drawn Tube	All	117	75	75	75	NA	NA	NA
6061-T6	Extrusions/ Drawn Tube	All	165	137	137	103	82	344	206
6082-T5-T6	Extrusions	NA	NA	NA	NA	NA	NA	NA	NA
6106[3]-T6	Extrusions/ Drawn Tube	NA	NA	NA	NA	NA	NA	NA	NA

Note:
1. 0.2 percent offset in 250mm guage length across a butt weld.
2. Mechnical properties of alloy 6060 similar to those of 6063
3. Mechanical properties of alloy 6106 are smimlar to those of 6063

Understanding Tolerances

What Tolerances Are

Every manufacturing process has limits of accuracy, imposed by technology or economics, which are routinely taken into acount in design and production.

Most manufacturers and customers expect to provide, or receive, products whose dimensions are reliable within mutually acceptable deviation limits. Those limits are called tolerances, and a clear agreement on them at the time of ordering benefits both the extrusion supplier and the user. It protects the user by ensuring that the extruded product will be suitable for use and it protects the extruder from having products rejected by a customer with unreasonable expectations.

Where Tolerances are Applied

The shape of an aluminium extruded product is described by specifying the dimensions of its cross-sectional profile on an engineering drawing, and by specifying the delivered length.

The allowed tolerances are usually expressed in plus-or-minus fractions or percentages of a dimension, applied to zones where the dimensions are to be held within these specified limits.

Unless otherwise specified, standard industry tolerances are applied. Special tolerances may be specified in consultation with the extruder.

Extrusion tolerances are applied to a variety of physical dimensions.

Standard tolerances for extruded rod, bar and shapes are applied to cross section/ wall thickness, length, straigthness, twist, flatness, surface roughness, end cut squareness (vertical and transverse), contour (curved surfaces), corner and fillet radii and angularity.

Extruded tube has standard tolerances for diameter, wall thickness and width and depth for square or rectangular tubes.

Standard Tolerances

The industry's standard tolerances were developed by technical committees of the Australian Aluminium Council, taking into account both the capabilities of extruders and the needs of users.

These Industry Standards are published in Australian Standards AS/NZS1866 and AS/NZS1734. Both publications are updated periodically to reflect improvements in extruder capabilities and changes in user needs.

Standard tolerances are not simple, uniform fractional formulas. There are many different specific numbers of formulas published in tables. The various tolerances are established to match the various degrees of difficulty an extruder faces in controlling different toleranced dimensions. As a result, tolerances vary with cross-sectional size (as measured by the profile's fit within a circumscribing circle), and even with the location of each dimension on a complex shape. Alloy composition and temper also influence certain tolerances, and are reflected in the standard tolerance tables.

Because of all these important considerations, tolerancing tables are complex. But their significance is simple and important: under standard tolerances, aluminium extrusions are routinely produced with dimensions accurate within tenths or hundredth of a millimetre. For most purposes, that is a more than ample degree of precision.

Special Tolerances

Even tighter tolerances than the Industry Standard can be specified when necessary. To achieve them, however, requires more involved die corrections, slower extrusion rates, increased inspections, and sometimes a higher rejection rate. All that special care adds up, of course, to higher costs to the extruder and higher prices to the customer.

In rare instances, a desired tolerance may not be possible; but an experienced extrusion supplier such as Capral may be able to suggest a design change that solves the problem and still meets the purchaser's economic and functional requirements.

The purchaser and the vendor should agree on any special tolerances at the time an order is entered, and should specify them on the order and engineering drawing.

If no special tolerances are ordered, standard tolerances will be applied.