ROLLED PRODUCTS MANUAL

Introduction

In February 2023 the Australian Aluminium Council (AAC) published on-line the *'Aluminium Extrusion Manual'.* To compliment the above publication the Council has now produced a manual to cover rolled products (sheet, coil, and plate). Foil products are not included at this stage.

It is intended that the publication will replace, or bring up to date, the information on rolled products that was included in the AAC publication *'Aluminium Standards and Data – Wrought Products'* dated 1993.

Since 1993 significant changes have taken place in the Australian aluminium industry and all aluminium rolled products are now produced overseas. This manual will endeavour to cover all the standard stock alloys and tempers as well as a limited range of other alloys and tempers.

The guaranteed minimum mechanical properties align with both the AS/NZS 1734:1997 and the Aluminum Association 'Aluminum Standards and Data 2017' however although the dimensional tolerance data aligns directly with AS/NZS 1734:1997 there are some differences with Aluminum Standards and Data 2017'. It is strongly recommended that when material is purchased from overseas there is an understanding as to the tolerancing standards being used.

The Australian Aluminium Council welcomes any suggested corrections or comments.

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The Characteristics of Aluminium Alloys

Aluminium is:

Lightweight
Volume for volume, aluminium is approximately one-third of the weight of iron, steel, copper or brass. (One cubic metre of aluminium weighs approximately 2,700 kg; a cubic metre of steel 7,800 kg.) The light weight of aluminium is an advantage in many product applications and is crucial in some. It may also reduce shipping and handling costs, thus providing a "hidden" benefit for both manufacturer and customer. Because of its light weight, aluminium is easy and cheap to transport.

Strong
By appropriate alloying and treatment, aluminium alloys can be produced with a guaranteed minimum yield strength as high as 300 MPa and are stronger than some steels. However, aluminium alloys are made in a wide variety of strengths and may be selected to match product needs.

High in Strength-to-Weight Ratio
Aluminium offers a combination of strength and lightness exhibited by few other materials. This combination may be measured in terms of a "strength-to-weight" ratio: a material's ultimate tensile strength divided by its density. Aluminium's advantage in this respect founded the modern aerospace industry and serves widely in various forms of transportation and other applications.

Resilient
Aluminium products behave elastically under static and dynamic loading conditions. This resilience, or ability to resume both shape and size, not only protects the form of an aluminium product, but may be "designed in" as a deliberate product function when flexible strength is important.

Ductile at Low Temperatures
As the temperature is reduced, aluminium alloys increase in strength without loss in ductility, making them particularly suitable for low-temperature applications, including cryogenics.

Corrosion-Resistant
Aluminium is highly resistant to corrosion. On surfaces exposed to the atmosphere a thin (5 to 10 nm), transparent, inert oxide film forms and protects the metal from further oxidation. If this protective layer is scratched through, it rapidly reforms and the metal remains protected against corrosion. Properly alloyed and treated, aluminium can resist corrosion by water, salt and other environmental factors. It can also resist attack by some acids and a wide range of other chemical and physical agents.

Non-Toxic
Aluminium is non-toxic and is widely used in food preparation and packaging, and in chemical processing and handling. It has a smooth, non-porous, easily cleaned surface which does not absorb bacteria-sustaining materials.

Thermal Conductivity
On the basis of either cost or weight, aluminium conducts heat better than any other common metal. Its superior performance in this respect is important in heat exchange applications — either

heating or cooling — and aluminium heat exchangers are common in the food, chemical, petroleum, aircraft, automotive and other industries.

Reflective
Aluminium is an excellent reflector of radiant energy. It reflects more than 80% of both visible light and the invisible radiation beyond both ends of the visible spectrum. It is very effective as a shield against, and a reflector of, light and infra-red (heat) radiation, as well as the electromagnetic waves of radio and radar.

Electrical Conductivity
Volume for volume, aluminium's ability to conduct electricity is approximately 62% of copper. However, since aluminium has less than one-third the density of copper, an aluminium conductor of equivalent current carrying capacity is only half the weight of a copper conductor. Aluminium is often the most economical choice for electrical system components, and it is used almost universally for bulk power transmission. The electrical conductivity of aluminium is reduced when it is highly alloyed.

Non-Magnetic
The non-magnetic property of aluminium makes it particularly useful for a variety of electrical and electronic applications, for high-voltage hardware and electrical shielding in busbar housings, for equipment used in strong magnetic fields and for enclosures for magnetic compasses and other sensitive electrical/magnetic devices.

Non-Sparking
Although not as well-known as some of the other properties of aluminium, its non-sparking characteristic (against itself and other non-ferrous metals) makes aluminium an essential material for products used with highly flammable or explosive substances and atmospheres.

Non-Combustible
Aluminium in normal wrought product form such as extrusions, sheet, and plate, does not burn and is therefore a widely used material in buildings, vehicles and other applications where fire is a potential hazard to life or property.
This is really self-evident when we consider what we do with aluminium products such as welding, melting for castings, cookware. Most aluminium alloys melt somewhere in the range of 600-660C. Hazardous emissions are not generated when aluminium is exposed to heat.
Aluminium and other metals when in powder form needs to be treated carefully because of the possibility of rapid oxidisation and explosion.

The Rolling Process

The three forms of aluminium produced by rolling are foil, sheet and plate. The principal distinction between these forms is product thickness. **Plate** is over 6.0 mm thickness; **Sheet** is over 0.15 mm up to 6.0 mm and **Foil** is material 0.15 mm thickness and below.

All three forms begin with the rolling of heated rolling ingot. Depending upon the alloy, the ingots are heated to temperatures 400^0C – 496^0C range so that the material can be reduced to the required thickness , usually 5 mm – 12 mm thick, with the minimum number of passes through the hot mill. Further reductions to final thickness are usually achieved by cold rolling, although plate may be brought to thickness completely by hot rolling.

Generally, with non-heat treatable alloys, the required temper of the final product is achieved by annealing at an appropriate stage so that when cold-rolled to final thickness, the correct temper is obtained. Heat-treatable alloys are brought to temper by heat-treatment after rolling.

Rolled Product Alloys

The alloys most commonly used in Australia for rolled products are of the non-heat treatable 3000 and 5000 series. Countries with aircraft and aerospace industries are large users of the heat-treatable alloys from the 2000 and 7000 series.

Table 1: Rolled Product Alloys — Characteristics and Typical Applications

Alloy	Characteristics	Typical Applications
1100, 1200	99.9% Al Excellent corrosion resistance and formability	Spun components, general sheet metal work.
1350	99.5% Al Excellent electrical conductivity	Electrical conductors including bus bars.
2024	Cu based alloy with very high strength, poor corrosion resistance.	Aircraft sheeting
3003, 3203, 3005, 3105	Mn based alloy excellent corrosion resistance.	Chemical equipment, closures, high strength foil, sheet metal work
3004, 3004A	Mn and Mg based alloy	Roofing sheet, can bodies, sheet metal work
5005, 5251, 5052	Mg based alloys	Sheet metal work, small boats
5083 5383	4.5% Mg	Marine, road transport, general plate applications. Should not be used at temperatures above 65^{0}C
6061	Heat-treatable	
7075	Heat-treatable	Aircraft applications

Rolled Product Alloys – Effect of Alloying Elements

1000 Series
Aluminium of 99% or higher purity has many applications, especially in the electrical and chemical fields. These alloys are characterised by excellent corrosion resistance, high thermal and electrical conductivity, low mechanical properties and excellent workability. Moderate increases in strength may be obtained by strain-hardening. Iron and silicon are the major impurities.

2000 Series
Copper is the principal alloying element in this group. These alloys require solution heat-treatment to obtain optimum properties; in the heat-treated condition mechanical properties are similar to and sometimes exceed those of mild steel. In some instances, artificial ageing is employed to further increase the mechanical properties. This treatment materially increases yield strength, with attendant loss in elongation; its effect on ultimate tensile strength is not as great. The alloys in the 2000 series do not have as good corrosion resistance as most other aluminium alloys and under certain conditions they may be subject to intergranular corrosion.

3000 Series
Manganese is the major alloying element of alloys in this group, which are generally non-heat-treatable. Because only a limited percentage of manganese, up to about 1.5%, can be effectively added to aluminium, it is used as a major element in only a few instances. These, however, are popular and are widely used as general-purpose alloys for moderate-strength applications requiring good workability.

4000 Series
The major alloying element of this group is silicon, which can be added in sufficient quantities to cause substantial lowering of the melting point without producing brittleness in the resulting alloys. For these reasons aluminium-silicon alloys are used in welding wire and as brazing alloys where a lower melting point than that of the parent metal is required. Most alloys in this series are non-heat-treatable, but when used in welding heat-treatable alloys they will pick up some of the alloying constituents of the latter and so respond to heat treatment to a limited extent. The alloys containing appreciable amounts of silicon become dark grey when anodic oxide finishes are applied.

5000 Series
Magnesium is one of the most effective and widely used alloying elements for aluminium. When it is used as the major alloying element, or with manganese, the result is a moderate to high-strength non-heat-treatable alloy. Magnesium is considerably more effective than manganese as a hardener, about 0.8% magnesium being equal to 1.25% manganese and it can be added in considerably higher quantities. Alloys in this series possess good welding characteristics and good resistance to corrosion in marine atmospheres. However, certain limitations should be placed on the amount of cold work and the safe operating temperatures permissible for the higher magnesium content alloys (e.g., 083) to avoid susceptibility to stress corrosion and exfoliation attack.

6000 Series
Alloys in this group contain silicon and magnesium in appropriate proportions to form magnesium silicide, thus making them capable of being heat-treated. Though less strong than most of the 2000 or 7000 alloys, the magnesium-silicon (or magnesium-silicide) alloys possess good formability and

corrosion resistance, with medium strength. Alloys in this heat-treatable group may be formed in the T4 temper (solution heat-treated but not artificially aged) and then reach full T6 properties by artificial ageing.

7000 Series

Zinc is the major alloying element in this group and when coupled with a smaller percentage of magnesium results in heat-treatable alloys of very high strength. Usually, other elements such as copper and chromium are also added in small quantities. Corrosion resistance is as for the 2000 series.

8000 Series

Used for alloys not covered by the above series.

Rolled Product Alloys – Temper Designation System

The temper designation system is used for all forms of wrought aluminium and aluminium alloys. It is based on the sequences of basic treatments usually used to produce the various tempers. The temper designation follows the alloy designation, the two being separated by a dash.

Basic temper designations consist of letters. Subdivisions of the basic tempers, where required, are indicated by one or more digits following the letter. These designate specific sequences of basic treatments, but only operations recognised as significantly influencing the characteristics of the product are indicated. Should some other variation of the same sequence of basic operations be applied to the same alloy, resulting in different characteristics, then additional digits are added to the designation.

The basic temper designations and subdivisions are as follows:

F: As fabricated Applies to products which acquire some temper from shaping processes not having special control over the amount of strain-hardening or thermal treatment. For wrought products, there are no mechanical property limits.

0: Annealed, recrystallised Applies to the softest temper of wrought products.

H: Strain-Hardened Applies to products which have their strength increased by strain-hardening with or without supplementary thermal treatments to produce partial softening. The H is always followed by two or more digits. The first digit indicates the specific combination of basic operations as follows:

H1: Strain-hardened only Applies to products which are strain-hardened to obtain the desired mechanical properties without supplementary thermal treatment. The number following this designation indicates the degree of strain-hardening.

H2: Strain-hardened and then partially annealed Applies to products which are strain-hardened more than the desired final amount and then reduced in strength to the desired level by partial annealing. For alloys that age-soften at room temperature, the H2 tempers have approximately the same ultimate strength as the corresponding H3 tempers. For other alloys, the H2 tempers have approximately the same ultimate strength as the corresponding H1 tempers and slightly higher elongations. The number following this designation indicates the degree of strain-hardening remaining after the product has been partially annealed.

H3: Strain-hardened and then stabilized Applies to products which are strain-hardened and then stabilized by a low-temperature heating to slightly lower their strength and increase ductility. This designation applies only to the magnesium-containing alloys which, unless stabilized, slightly age-soften at room temperature. The number following this designation indicates the degree of strain-hardening remaining after the product has been strain-hardened a specific amount and then stabilized.

The final degree of strain-hardening is designated as follows. Numeral 8 has been assigned to indicate tempers having a final degree of strain-hardening equivalent to that resulting from approximately 75% reduction of area. Tempers between 0 (annealed) and 8 (fully-hard) are designated by the numerals 1 through 7. Material having an ultimate strength about midway between that of the 0 temper and that of the 8 temper is designated by the number 4 (half- hard), between 0 and 4 by the numeral 2 (quarter-hard), between 4 and 8 by the numeral 6 (three-quarter-hard) and so on for the numerals 1, 3, 5 and 7. Numeral 9 designates extra hard tempers.

The third digit, when used, indicates a variation of a two-digit H temper. It is used when the degree of control of temper or the mechanical properties are different from, but close to, those for the two-digit H temper designation to which it is added. For this purpose, numerals 1 to 9 may be arbitrarily assigned and registered with the Australian Aluminium Council for an alloy and product to indicate a specific degree of control of temper or specific mechanical property limits.

The following three-digit H temper designations have been assigned for wrought products in all alloys:

H111: Applies to products which are strain-hardened less than the amount required for a controlled H11 temper.

H112: Applies to products not having special control over the amount of strain-hardening or thermal treatment but which acquire some temper incidental to the shaping processes and for which there are mechanical property limits or mechanical property testing is required.

H121: Applies to products which are strain-hardened less than the amount required for a controlled H12 temper.

H311: Applies to products which are strain-hardened less than the amount required for a controlled H31 temper.

H321: Applies to products which are strain-hardened less than the amount required for a controlled H32 temper. It is specially fabricated to have acceptable resistance to stress-corrosion cracking and exfoliation attack. The H116 temper is also used for this application.

T: Thermally treated to produce stable tempers other than F, 0, or H. Applies to products which are thermally treated, with or without supplementary strain-hardening, to produce stable tempers. The T is always followed by one or more digits. Numbers 1 through 9 have been assigned to indicate specific sequences of basic treatments. A period of natural ageing at room temperature may occur between or after the operations listed for tempers T3 to T9. Control of this period is exercised when it is metallurgically important. Solution heat-treated as applied to tempers T3, T4, T6, T7, T8 or T9, can also be applied to rapid cooling from an elevated temperature working process.

The significance of the digits following the T is as follows:

T1: Cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition. Applies to products for which the rate of cooling from an elevated temperature shaping process, such as extrusion, is such that their strength is increased by room temperature ageing.

T3: Solution heat-treated or cooled from an elevated temperature shaping process and then cold-worked and naturally aged to a substantially stable condition. Applies to products which are cold worked to improve strength, or in which the effect of cold work in flattening or straightening is recognised in applicable specifications.

T4: Solution heat-treated or cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition. Applies to products which are not cold worked after solution heat-treatment, or in which the effect of cold work in flattening or straightening may not be recognised in applicable specifications.

T5: Cooled from an elevated temperature shaping process and then artificially aged. Applies to products which are cooled from an elevated temperature shaping process, such as casting or extrusion and then artificially aged to improve mechanical properties or dimensional stability or both.

T6: Solution heat-treated or cooled from an elevated temperature shaping process and then artificially aged. Applies to products which are not cold worked after solution heat treatment, or in which the effect of cold work in flattening or straightening may not be recognised in applicable specifications.

T7: Solution heat-treated or cooled from an elevated temperature shaping process and then stabilized. Applies to products which are stabilized to carry them beyond the point of maximum strength to provide control of some special characteristics.

T8: Solution heat-treated or cooled from an elevated temperature shaping process , cold worked and then artificially aged. Applies to products which are cold worked to improve strength, or in which the effect of cold work in flattening or straightening is recognised in applicable specifications.

T9: Solution heat-treated or cooled from an elevated temperature shaping process, artificially aged and then cold worked. Applies to products which are cold worked to improve strength.

Additional digits may be added to designations T1 through T9 to indicate a variation in treatment which significantly alters the characteristics of the product.

The following two-digit temper designations have been assigned for wrought products heat-treated from the 0 or F temper to demonstrate response to heat-treatment:

T42: Solution heat-treated or cooled from an elevated temperature shaping process from the 0 or F temper to demonstrate response to heat-treatment and naturally aged to a substantially stable condition.

T62: Solution heat-treated or cooled from an elevated temperature shaping process from the 0 or F temper to demonstrate response to heat-treatment and artificially aged.

Temper designations T42 and T62 may also be applied to wrought products heat-treated from any temper by the user when such heat-treatment results in the mechanical properties applicable to these tempers.

Stress relieved by stretching.

T51: Applies to plate and rolled or cold-finished rod and bar when stretched the indicated amounts after solution heat-treatment or after cooling from an elevated temperature shaping process. The products receive no further straightening after stretching.

Plate	1.5 to 3% permanent set
Rolled or Cold-Finished Rod and Bar	1 to 3% permanent set

Wrought Alloys – Chemical Compositions

Table 2: Chemical Composition Limits of Registered Alloys [1 2] – covers alloys used for extrusions and rolled products.

International Registered Designation	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc			Titanium	Others [3]		Aluminium
											Each	Total	
1199	0.006	0.006	0.006	0.002	0.006		0.006	0.005 Ga	0.005 V	0.002	0.002		99.99[5]
1050	0.25	0.40	0.05	0.05	0.05		0.05		0.05 V	0.03	0.03		99.50[4]
1070	0.20	0.25	0.04	0.03	0.03		0.04	0.03 Ga	0.05 V	0.03	0.03		99.70[4]
1350	0.10	0.40	0.05	0.01		0.01	0.05		0.05 B	0.02 V + Ti	0.03	0.10	99.50[4]
1145	0.55 Si + Fe		0.05	0.05	0.05		0.05		0.05 V	0.03	0.03		99.45[4]
1150	0.45 Si + Fe		0.05-0.20	0.05	0.05		0.05			0.03	0.03		99.50[4]
1100	0.95 Si + Fe		0.05-0.20	0.05			0.10		[6]		0.05	0.15	99.00[4]
1120	0.10	0.40	0.05-0.35	0.04	0.20	0.01	0.05	0.03 Ga	0.05 B	0.02 V + Ti	0.03	0.10	99.20[4]
1200	1.00 Si + Fe		0.05	0.05			0.10		[6]	0.05	0.05	0.15	99.00[4]
1230	0.70 Si + Fe		0.10	0.05	0.05		0.10		0.05 V	0.03	0.03		99.30[4]
2011	0.40	0.7	5.0-6.0				0.30		[7]		0.05	0.15	Rem
2014	0.50-1.2	0.7	3.9-5.0	0.40-1.2	0.20-0.8	0.10	0.25			0.15	0.05	0.15	Rem
2014A	0.50-0.9	0.50	3.9-5.0	0.40-1.2	0.20-0.8	0.10	0.25		0.10 Ni	0.20 Zn + Ti	0.05	0.15	Rem
2024	0.50	0.50	3.8-4.9	0.30-0.9	1.2-1.8	0.10	0.25			0.15	0.05	0.15	Rem
3003	0.60	0.7	0.05-0.20	1.0-1.5			0.10				0.05	0.15	Rem
3203	0.60	0.7	0.05	1.0-1.5			0.10		[6]		0.05	0.15	Rem
3004	0.30	0.7	0.25	1.0-1.5	0.8-1.3		0.25				0.05	0.15	Rem
3004A	0.40	0.7	0.25	0.8-1.5	0.8-1.5	0.10	0.25		0.03 Pb	0.05	0.05	0.15	Rem
3005	0.60	0.7	0.30	1.0-1.5	0.20-0.6	0.10	0.25			0.10	0.05	0.15	Rem
3105	0.60	0.7	0.30	0.30-0.08	0.20-0.8	0.20	0.40			0.10	0.05	0.15	Rem
4043	4.5-6.0	0.8	0.30	0.05	0.05		0.10		[6]	0.20	0.05	0.15	Rem

International Registered Designation	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc		Titanium	Others [3]		Aluminium
										Each	Total	
4047	11.0-13.0	0.8	0.30	0.15	0.10		0.20	[6]		0.05	0.15	Rem
5005	0.30	0.7	0.20	0.20	0.50-1.1	0.10	0.25			0.05	0.15	Rem
5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10			0.05	0.15	Rem
5251	0.40	0.50	0.15	0.10-0.50	1.7-2.4	0.15	0.15		0.15	0.05	0.15	Rem
5252	0.08	0.10	0.10	0.10	2.2-2.8		0.05	0.05 V		0.03	0.10	Rem
5454	0.25	0.40	0.10	0.50-1.0	2.4-3.0	0.05-0.20	0.25		0.20	0.05	0.15	Rem
5056	0.30	0.40	0.10	0.05-0.20	4.5-5.6	0.05-0.20	0.10			0.05	0.15	Rem
5356	0.25	0.40	0.10	0.05-0.20	4.5-5.5	0.05-0.20	0.10	[6]	0.06-0.20	0.05	0.15	Rem
5383	0.25	0.25	0.20	0.7-1.0	4.0-5.2	0.25	0.40	[10]	0.15	0.05	0.15	Rem
5457	0.08	0.10	0.20	0.15-0.45	0.8-1.2		0.05	0.05 V		0.03	0.10	Rem
5557	0.10	0.12	0.15	0.10-0.40	0.40-0.8			0.05 V		0.03	0.10	Rem
5082	0.20	0.35	0.15	0.15	4.0-5.0	0.15	0.25		0.10	0.05	0.15	Rem
5083	0.40	0.40	0.10	0.40-1.0	4.0-4.9	0.05-0.25	0.25		0.15	0.05	0.15	Rem
5086	0.40	0.50	0.10	0.20-0.7	3.5-4.5	0.05-0.25	0.25		0.15	0.05	0.15	Rem
5182	0.20	0.35	0.15	0.20-0.50	4.0-5.0	0.10	0.25		0.10	0.05	0.15	Rem
6060	0.30-0.6	0.10-0.30	0.10	0.10	0.35-0.6	0.05	0.15		0.10	0.05	0.15	Rem
6103	0.35-1.1	0.60	0.2-0.3	0.8	0.8-1.5	0.35	0.20		0.10	0.05	0.15	Rem
6261	0.4-0.7	0.40	0.15-0.40	0.20-0.35	0.7-1.0	0.10	0.20		0.10	0.05	0.15	Rem
6106	0.30-0.6	0.35	0.25	0.05-0.20	0.40-0.8	0.20	0.10			0.05	0.10	Rem
6005A	0.50-0.9	0.35	0.3	0.50	0.40-0.7	0.30	0.20		0.10	0.05	0.15	Rem
6082	0.70-1.3	0.50	0.10	0.40-1.0	0.6-1.2	0.25	0.20		0.10	0.05	0.15	Rem
6061A	0.40-0.8	0.70	0.15-0.70	0.15	0.8-1.2	0.04-0.35	0.25	0.003 Pb	0.15	0.05	0.15	Rem
6003	0.35-1.0	0.60	0.10	0.8	0.8-1.5	0.35	0.20		0.10	0.05	0.15	Rem
6101	0.30-0.7	0.50	0.10	0.03	0.35--0.8	0.03	0.10	0.06 B		0.03	0.10	Rem
6201A	0.50-0.7	0.50	0.04		0.6-0.9			0.06 B		0.03	0.10	Rem
6351	0.7-1.3	0.50	0.10	0.40-0.8	0.40-0.8		0.20		0.20	0.05	0.15	Rem

International Registered Designation	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc		Titanium	Others [3]		Aluminium
										Each	Total	
6253	[8]	0.50	0.10		1.0-1.5	0.04-0.35	1.6-2.4			0.05	0.15	Rem
6061	0.40-0.8	0.70	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25		0.15	0.05	0.15	Rem
6262	0.40-0.8	0.70	0.15-0.40	0.15	0.8-1.2	0.04-0.14	0.25	[9]	0.15	0.05	0.15	Rem
6063	0.20-0.6	0.35	0.10	0.10	0.45-0.9	0.10	0.10		0.10	0.05	0.15	Rem
6463A	0.20-0.6	0.15	.025	0.05	0.30-0.9		0.05			0.05	0.15	Rem
7005	0.35	0.40	0.10	0.20-0.7	1.0-1.8	0.06-0.20	4.0-5.0	0.08-0.20 Zr	0.01-0.06	0.05	0.15	Rem
7072	0.7 Si + Fe		0.10	0.10	0.10		0.8-1.3			0.05	0.15	Rem
7075	0.40	0.50	1.2-2.0	0.30	2.1-2.9	0.18-0.28	5.1-6.1		0.20	0.05	0.15	Rem
8006	0.40	1.2-2.0	0.30	0.30-1.0	0.10		0.10			0.05	0.15	Rem
8008	0.60	0.9-1.6	0.20	0.50-1.0			0.10		0.10	0.05	0.15	Rem
8011	0.50-0.9	0.6-1.0	0.10	0.10	0.05	0.05	0.10		0.08	0.05	0.15	Rem

Footnotes:

1. Composition in % maximum unless shown as a range or a minimum.
2. For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis is rounded off to the nearest unit in the last right hand place of figures used in expressing the specified limit, in accordance with the following:

   When the figure next beyond the last figure or place to be retained is less than 5, the figure in the place retained should be kept unchanged.
   When the figure next beyond the last figure or place to be retained is greater than 5, the figure in the last place retained should be increased by 1.
   When the figure next beyond the last figure or place to be retained is 5 and
   (i) there are no figures, or only zeros, beyond this 5, if the figure in the last place to be retained is odd, it should be increased by 1; if even, it should be kept unchanged.
   (ii) if the 5 is followed by any figures other than zeros, the figure in the last place retained should be increased by 1, whether odd or even.
3. Analysis is regularly made only for the elements for which specific limits are shown, except for unalloyed aluminium. If, however, the presence of other elements is suspected to be, or in the course of routine analysis is indicated to be in excess of the specified limits, further analysis is made to determine that these other elements are not in excess of the amount specified.
4. The aluminium content for unalloyed aluminium not made by a refining process is the difference between 100.00% and the sum of all other metallic elements present in amounts of 0.010% or more each, expressed to the second decimal.

5. The aluminium content for unalloyed aluminium made by a refining process is the difference between 100.00% and the sum of all other metallic elements present in amounts of 0.0010% or more each, expressed to the third decimal.
6. 0.0008% max Be for welding electrodes and filler wire only.
7. 0.20-0.6% Bi, 0.20-0.6% Pb.
8. 45-65% of the Magnesium content.
9. 0.40-0.7% Bi, 0.40-0.7% Pb.

Rolled Products – Mechanical Property Limits.

Table 3: Mechanical Property Limits[1] – Sheet and Plate

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
1050 – 0	0.15	0.5		95			15
	0.5	0.8		95			20
	0.8	1.3		95			25
	1.3	6		95			30
1050 – H12[4]	0.25	0.5	80	110			4
	0.5	0.8	80	110			5
	0.8	1.3	80	110			6
	1.3	2.6	80	110			8
	2.6	6	80	110			12
1050 – H14[4]	0.25	0.3	100	125			2
	0.3	0.5	100	125			3
	0.5	0.8	100	125			4
	0.8	1.3	100	125			5
	1.3	2.6	100	125			6
	2.6	12	100	125			8
1050 – H16[4]	0.15	0.5	115	140			2
	0.5	0.8	115	140			3
	0.8	1.3	115	140			4
	1.3	4	115	140			5
1050 – H18	0.15	0.5	130				1
	0.5	0.8	130				2
	0.8	1.3	130				3
	1.3	2.6	130				4
	1.6	6	130				5
1050 – H112	6	25	60				30
1100 – O	0.15	0.5	75	105	255		15
	0.5	0.8	75	105	255		20
	0.8	1.3	75	105	255		25
	1.3	6	75	105	255		30
	6	75	75	105	255		26
1100 – H12[4]	0.4	0.5	95	130	755		3

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	0.5	0.8	95	130	755		4
	0.8	1.3	95	130	755		6
	1.3	3	95	130	755		8
	3	6	95	130	755		9
	12	50	95	130	755		10
1100 - H14[4]	0.25	0.3	110	145			1
	0.3	0.5	110	145	955		2
	0.5	0.8	110	145	955		3
	0.8	1.3	110	145	955		4
	1.3	3	110	145	955		5
	3	12	110	145	955		6
	12	25	110	145	955		8
1100 - H16[4]	0.15	0.5	130	165	1155		1
	0.5	0.8	130	165	1155		2
	0.8	1.3	130	165	1155		3
	1.3	4	130	165	1155		4
1100 - H18	0.15	0.5	150				1
	0.5	0.8	150				2
	0.8	1.3	150				3
	1.3	3.25	150				4
1100 - H112	6	12	90		505		9
	12	50	85		355		13
	50	75	80		305		18
1150 – H14[4]	0.25	0.3	95	130			1
	0.3	0.5	95	130			2
	0.5	0.8	95	130			3
	0.8	1.3	95	130			4
	1.3	2.6	95	130			5
	2.6	6	95	130			6
1150 – H16[4]	0.15	0.5	115	150			1
	0.5	0.8	115	150			2
	0.8	1.3	115	150			3
	1.3	2.6	115	150			4

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	2.6	4	115	150			5
1150 – H18	0.15	0.5	135				1
	0.5	0.8	135				2
	0.8	1.3	135				3
	1.3	3.25	135				4
1200 - O	0.15	0.5		105	255		15
	0.5	0.8		105	255		20
	0.8	1.3		105	255		25
	1.3	6		105	255		30
	6	75	75	105	255		26
1150 – H16[4]	0.15	0.5	115	150			1
	0.5	0.8	115	150			2
	0.8	1.3	115	150			3
	1.3	2.6	115	150			4
	2.6	4	115	150			5
1150 – H18	0.15	0.5	135				1
	0.5	0.8	135				2
	0.8	1.3	135				3
	1.3	3.25	135				4
1200 - O	0.15	0.5		105	255		15
	0.5	0.8		105	255		20
	0.8	1.3		105	255		25
	1.3	6		105	255		30
	6	75	75	105	255		26
1200 – H12[4]	0.4	0.5	95	130	755		3
	0.5	0.8	95	130	755		4
	0.8	1.3	95	130	755		6
	1.3	3	95	130	755		8
	3	12	95	130	755		9
	12	50	95	130	755		10
1200 - H14[4]	0.25	0.3	110	145	955		1
	0.3	0.5	110	145	955		2
	0.5	0.8	110	145	955		3
	0.8	1.3	110	145	955		4
	1.3	3	110	145	955		5

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	3	12	110	145	955		6
	12	25	110	145	955		8
1200 - H16[4]	0.15	0.3	130	165	1155		1
	0.5	0.5	130	165	1155		2
	0.8	0.8	130	165	1155		3
	1.3	4	130	165	1155		4
1200 – H18	0.15	0.5	150				1
	0.5	0.8	150				2
	0.8	1.3	150				3
	1.3	3.25	150				4
1200 - H112	6	12	90		505		9
	12	50	85		355		12
	50	75	80		305		18
1350 – O	0.15	75		95	15		
1350 – H12	0.4	50	80		60		
1350 – H14	0.22	50	95		70		
1350 – H16	0.15	4	110		75		
1350 – H18	0.15	3.25	125		80		
2024 – O[11]	0.25	6		220		95	12
2024 – T42[12]	0.25	0.5	425		260		12
	0.5	6	425		260		15
2024 – T62[12]	0.25	6	440		345		5
2024 – T72[8]	0.25	6	415		315		5
3003 - O	0.15	0.2	95	130	355		14
	0.2	0.3	95	130	355		18
	0.3	0.8	95	130	355		20
	0.8	1.3	95	130	355		23
	1.3	6	95	130	355		25
	6	75	95	130	355		21

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
3003 - H14[4]	0.25	0.3	135	180	1155		1
	0.3	0.5	135	180	1155		2
	0.5	0.8	135	180	1155		3
	0.8	1.3	135	180	1155		4
	1.3	3	135	180	1155		5
	3	4	135	180	1155		6
	4	6	135	180	1155		7
	6	12	135	180	1155		8
	12	25	135	180	1155		8
3003 - H16[4]	0.15	0.5	165	205	1455		1
	0.5	0.8	165	205	1455		2
	0.8	1.3	165	205	1455		3
	1.3	4	165	205	1455		4
3003 - H18	0.15	0.5	185		1655		1
	0.5	0.8	185		1655		2
	0.8	1.3	185		1655		3
	1.3	3.25	185		1655		4
3003 – H112	6	12	115		705		8
	12	50	105		405		10
	50	75	100		405		16
3004 - O	0.15	0.2	150	200	605		-
	0.2	0.5	150	200	605		10
	0.5	0.8	150	200	605		14
	0.8	1.3	150	200	605		16
	1.3	6	150	200	605		18
3004 – H32[4]	0.4	0.5	195	240	1455		1
	0.5	0.8	195	240	1455		3
	0.8	1.3	195	240	1455		4
	1.3	3	195	240	1455		5
	3	6	195	240	1455		6
3004 – H34[4]	0.25	0.5	220	265	1705		1
	0.5	1.3	220	265	1705		3
	1.3	3	220	265	1705		4
	3	6	220	265	1705		5

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
3004 – H36[4]	0.15	0.2	240	285	1955		-
	0.2	0.5	240	285	1955		1
	0.5	0.8	240	285	1955		2
	0.8	1.3	240	285	1955		3
	1.3	4	240	285	1955		4
3004 – H38[4]	0.15	0.2	260		2155		-
	0.2	0.5	260		2155		1
	0.5	0.8	260		2155		2
	0.8	1.3	260		2155		3
	1.3	3.25	260		2155		4
Alclad 3004 – O[9]	0.15	0.2	145	195	555		-
	0.2	0.5	145	195	555		10
	0.5	0.8	145	195	555		14
	0.8	1.3	145	195	555		16
	1.3	6	145	195	555		18
Alclad 3004 – H32[4,9]	0.4	0.5	185	235	1355		1
	0.5	0.8	185	235	1355		3
	0.8	1.3	185	235	1355		4
	1.3	3	185	235	1355		5
	3	6	185	235	1355		6
Alclad 3004 – H36[4,9]	0.15	0.2	235	275	1855		-
	0.2	0.5	235	275	1855		1
	0.5	0.8	235	275	1855		2
	0.8	1.3	235	275	1855		3
	1.3	4	235	275	1855		4
Alclad 3004 – H38[9]	0.15	0.2	255				-
	0.2	0.5	255				1
	0.5	0.8	255				2
	0.8	1.3	255				3
	1.3	3.25	255				4
3005 – O	0.15	0.2	105	145			14

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	0.2	0.25	105	145			18
	0.25	0.4	105	145			22
	0.4	6	105	145			24
3005 – H12[4]	0.15	0.25	125	165			3
	0.25	0.3	125	165			4
	0.3	80	125	165			5
	0.8	1.3	125	165			6
	1.3	6	125	165			7
3005 – H14[4]	0.15	0.25	150	195			1
	0.25	0.3	150	195			2
	0.3	0.8	150	195			3
	0.8	1.3	150	195			4
	1.3	6	150	195			5
3005 – H16[4]	0.15	0.25	180	230			-
	0.25	0.3	180	230			1
	0.3	0.8	180	230			2
	0.8	1.3	180	230			3
	1.3	4	180	230			4
3005 – H18	0.15	0.3	205				-
	0.3	0.8	205				1
	0.8	1.3	205				2
	1.3	3.25	205				3
3005 – H25	0.15	0.32	180	235	150		1
	0.32	0.63	180	235	150		2
	0.63	1.2	180	235	150		3
	1.2	2	180	235	150		4
3005 – H26	0.15	0.32	190	250	165		1
	0.32	0.63	190	250	165		2
	0.63	1.2	190	250	165		3
	1.2	2	190	250	165		4
3005 – H27	0.15	0.32	205	260	180		1
	0.32	0.63	205	260	180		2
	0.63	1.2	205	260	180		3
	1.2	2	205	260	180		4
3005 – H28	0.15	0.32	215		185		1

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	0.32	0.63	215		185		2
	0.63	1.2	215		185		3
	1.2	2	215		185		4
3105 – O	0.3	0.65	95	145	355		16
	0.65	1.2	95	145	355		19
	1.2	2	95	145	355		20
3105 – H12	0.4	0.65	130	180	1055		1
	0.65	1.2	130	180	1055		2
	1.2	2	130	180	1055		3
3105 – H14	0.3	0.6	150	200	1255		1
	0.65	1.2	150	200	1255		2
	1.2	2	150	200	1255		3
3105 – H16	0.3	0.65	170	220	1455		1
	0.65	1.2	170	220	1455		1
	1.2	2	170	220	1455		2
3105 – H18	0.3	0.65	190		1655		1
	0.65	1.2	190		1655		1
	1.2	2	190		1655		2
3105 – H25	0.3	0.65	160		1305		2
	0.65	1.2	160		1305		4
	1.2	2	160		1305		6
5005 – O	0.15	0.2	105	145			12
	0.2	0.3	105	145			14
	0.3	0.5	105	145	355		16
	0.5	0.8	105	145	355		18
	0.8	1.3	105	145	355		2
	1.3	3	105	145	355		21
	3	6	105	145	355		22
5005 – H12	0.4	0.5	125	165	955		2
	0.5	0.8	125	165	955		3
	0.8	1.3	125	165	955		4
	1.3	3	125	165	955		6
	3	4	125	165	955		7
	4	6	125	165	955		8
5005 – H14	0.25	0.8	145	185	1155		1
	0.8	1.3	145	185	1155		2
	1.3	3	145	185	1155		3
	3	4	145	185	1155		5
	4	6	145	185	1155		6
5005 – H16	0.15	0.8	165	205	1355		1

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	0.8	1.3	165	205	1355		2
	1.3	4	165	205	1355		3
5005 – H18	0.15	0.8	185				1
	0.8	1.3	185				2
	1.3	3.25	185				3
5005 – H19	0.15	1	195				1
5005 – H22/H32	0.4	0.5	115	160	855		3
	0.5	0.8	115	160	855		4
	0.8	1.3	115	160	855		5
	1.3	3	115	160	855		7
	3	4	115	160	855		8
	4	6	115	160	855		9
5005 – H24/H34	0.25	0.3	135	180	1055		2
	0.3	0.8	135	180	1055		3
	0.8	1.3	135	180	1055		4
	1.3	3	135	180	1055		5
	3	4	135	180	1055		6
	4	6	135	180	1055		7
5005 – H26/H36	0.15	0.2	160	200	1255		1
	0.2	0.5	160	200	1255		2
	0.5	0.8	160	200	1255		3
	0.8	4	160	200	1255		4
5005 – H38	0.15	0.3	180				1
	0.3	0.5	180				2
	0.5	0.8	180				3
	0.8	3.25	180				4
5052 – O	0.15	0.2	170	215			-
	0.2	0.3	170	215			14
	0.3	0.5	170	215	655		15
	0.5	0.8	170	215	655		16
	0.8	1.3	170	215	655		18
	1.3	3	170	215	655		19
	3	6	170	215	655		20
	6	75	170	215	655		16

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
5052 – H22/H32	0.4	0.5	215	265	1605		4
	0.5	1.3	215	265	1605		5
	1.3	3	215	265	1605		7
	3	6	215	265	1605		9
	6	12	215	265	1605		11
	12	50	215	265	1605		10
5052 – H24/H34	0.25	0.5	235	285	1805		3
	0.5	1.3	235	285	1805		4
	1.3	3	235	285	1805		6
	3	6	235	285	1805		7
	6	25	235	285	1805		8
5052 – H26/H36	0.15	0.2	255	305			2
	0.2	0.8	255	305	2005		3
	0.8	4	255	305	2005		4
5052 – H38[4]	0.15	0.2	270				2
	0.2	0.8	270		2205		3
	0.8	3.25	270		2205		4
5052 – H112	6	12	190		1105		7
	12	50	170		655		10
	50	75	170		655		14
5052 – H391	0.15	2	290		2405		3
5083 - O	1.2	6	275	350	125	200	16
	6	80	270	345	115	200	16
	80	120	260		110		12
	120	160	255		105		12
	160	200	250		100		10
5083 – H112	6	12.5	275		125		12
	12.5	40	275		125		10
	40	80	270		115		10
5083 – H116[10]	1.6	12.5	305		215		10
	12.5	30	305		215		10

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	30	40	305		215		10
	40	80	285		200		10
5083 – H321	3	12.5	305	385	215	295	12
	12.5	40	305	385	215	295	10
	40	80	285	385	200	295	10
5086 – O	0.5	0.63	240	305	95		15
	0.63	1.2	240	305	95		16
	1.2	6.3	240	305	95		18
	6.3	50	240	305	95		16
5182 – H14	0.15	0.5	325	385			5
5182 – H19	0.15	0.5	385				2
5251 – O	0.2	0.5	170	215	655		15
	0.5	0.8	170	215	655		18
	0.8	6	170	215	655		20
	6	75	170	215	655		16
5251 – H22/H32	0.25	0.5	200	255	1305		4
	0.5	1.3	200	255	1305		5
	1.3	2.6	200	255	1305		7
	2.6	6	200	255	1305		9
	6	12	200	255	1305		11
	12	50	200	255	1305		10
5251 – H24/H34	0.25	0.5	230	275	1805		3
	0.5	1.3	230	275	1805		4
	1.3	3	230	275	1805		6
	3	6	230	275	1805		7
	6	25	230	275	1805		8
5251 – H26/H36	0.2	0.8	250	295	2105		3
	0.8	4	250	295	2105		4
5251 – H38[4]	0.2	0.8	260		2255		3
	0.8	3.25	260		2255		4
5254A – H32[4]	0.5	1.3	250	295	180		5

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	1.3	6	250	295	180		8
5254A – H34[4]	0.25	1.3	280	320	225		4
	1.3	4	280	320	225		6
	4	6	280	320	225		7
5383– O	2	40	290		145		17
5383– H32	2	40	305		220		10
5383– H34	2	40	340		270		5
5383– H111	2	40	290		145		17
5383– H116	2	40	305		220		10
5383 - H321	2	40	305		220		10
5454 – H34[4]	0.5	1.3	270	325	200		4
	1.3	4	270	325	200		6
	4	6	270	325	200		7
	6	25	270	325	200		8
5454 – H112	6	12	220		125		8
	12	50	215		80		9
	50	75	215		80		13
6061 – O[11]	0.25	0.5		150			14
	0.5	3.25		150			16
	3.25	12		150			18
	12	25		150			16
6061 – T4	0.25	0.5	205		115		14
	0.5	6	205		115		16
	6	25	205		115		16
6061 – T42[12]	0.25	0.5	205		95		14
	0.5	6	205		95		16
	6	25	205		95		18
6061 – T6 &T62[12]	0.25	0.5	290		240		8

Alloy and Temper	Thickness[1] (mm)		Tensile Strength (Mpa)				Elongation3 (% min in 50mm or 5.65 √A)
			Ultimate		Yield		
	Over	Up to	min	max	min	max	
	0.5	12	290		240		10
	12	25	290		240		7
8011 - O	0.15	0.3	75	105			16
	0.3	0.8	75	105			20
	0.8	1.3	75	105			25
	1.3	5	75	105			30
8011 – H12	0.2	0.5	100	135			3
	0.5	0.8	100	135			4
	0.8	1.3	100	135			6
	1.3	3	100	135			8
	3	6	100	135			9
8011 – H14	0.2	0.5	115	150			2
	0.5	0.8	115	150			3
	0.8	1.3	115	150			4
	1.3	3	115	150			5
	3	6	115	150			7
8011 – H16	0.2	0.5	140	170			1
	0.5	0.8	140	170			2
	0.8	1.3	140	170			3
	1.3	3	140	170			4
	3	6	140	170			5
8011 – H18	0.2	0.5	160				1
	0.5	0.8	160				2
	0.8	1.3	160				3
	1.3	3	160				4

Footnotes:

1. Mechanical test specimens are taken as agreed with the manufacturer or as required by the appropriate standard.
2. The type of test specimen used depends on the thickness of material.
3. A = cross-sectional area of specimen.
4. For the corresponding H2 temper, the limits for maximum ultimate tensile strength and minimum yield strength do not apply.
5. These yield strengths are not determined or guaranteed unless specifically requested.
6. Cladding alloy is 1230; 5% of composite thickness per side.
7. Cladding alloy is 1230; 2.5% of composite thickness per side.
8. T72 is a special temper for improved stress corrosion resistance.
9. Cladding alloy is 7072; 5% of composite thickness per side.
10. A special temper for armour plate.

11. Annealed (O temper) material shall, upon heat treatment or heat treatment and ageing, be capable of developing the mechanical properties applicable to T42 or T62 temper material respectively.
12. Material heat-treated (T42) or heat-treated and aged (T62) from any temper by the user, should attain the mechanical properties applicable to these tempers.
13. Material in this temper has characteristics that substantially eliminate the susceptibility of alloy 5083 to exfoliate under certain corrosion conditions. Representative samples from individual production batches are subject to an agreed exfoliation corrosion resistance test.

Rolled Products – Standard Tolerances

The tolerances below are in line with those nominated in AS/NZS 1734:1997

Table 4: Thickness Tolerances [1 2] – Sheet and Plate

Specified Thickness (mm)		**TOLERANCE** (± mm) Specified Width (mm)								
		Over	-	900	1200	1500	1800	2100	2250	2400
Over	Up to	Up to	900	1200	1500	1800	2100	2250	2400	3000
0.15	**0.25**		0.04	0.06	0.07					
0.25	**0.45**		0.04	0.06	0.08					
0.45	**0.70**		0.05	0.06	0.10	0.10				
0.70	**0.90**		0.05	0.06	0.13	0.13				
0.90	**1.10**		0.06	0.08	0.13	0.13				
1.10	**1.80**		0.08	0.10	0.15	0.15				
1.80	**2.00**		0.08	0.10	0.15	0.15				
2.00	**2.50**		0.09	0.10	0.15	0.15				
2.50	**2.80**		0.10	0.13	0.18	0.18				
2.80	**3.00**		0.11	0.13	0.18	0.18	0.20	0.41	0.46	0.51
3.00	**3.50**		0.11	0.13	0.18	0.30	0.36	0.41	0.46	0.51
3.50	**4.50**		0.15	0.20	0.23	0.36	0.41	0.43	0.48	0.58
4.50	**5.00**		0.18	0.25	0.28	0.41	0.43	0.43	0.56	0.66
5.00	**6.00**		0.23	0.28	0.33	0.46	0.46	0.46	0.61	0.71
6.00	**8.00**		0.33	0.33	0.38	0.51	0.51	0.51	0.64	0.76
8.00	**11.00**		0.48	0.48	0.51	0.58	0.64	0.64	0.66	0.84
11.00	**16.00**		0.64	0.64	0.64	0.64	0.76	0.76	0.89	0.89
16.00	**22.00**		0.76	0.76	0.76	0.73	0.94	0.94	1.14	1.14
22.00	**28.00**		0.89	0.89	0.89	0.89	1.14	1.14	1.40	1.40
28.00	**35.00**		1.02	1.02	1.02	1.02	1.32	1.32	1.65	1.65
35.00	**40.00**		1.14	1.14	1.14	1.14	1.52	1.52	1.91	1.91
40.00	**50.00**		1.32	1.32	1.32	1.32	1.78	1.78	2.24	2.24
50.00	**60.00**		1.52	1.52	1.52	1.52	2.03	2.03	2.54	2.54
60.00	**70.00**		1.91	1.91	1.91	1.91	2.54	2.54	3.18	3.18
70.00	**80.00**		2.29	2.29	2.29	2.29	3.05	3.05	3.81	3.81

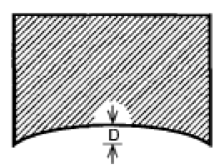
Table 5: Width Tolerances – Flat Sheet and Plate

Specified Thickness (mm)		TOLERANCE (+ mm) Specified Width (mm)										
		Over	-	100	600	900	1200	1800	-	300	1200	2100
Over	Up to	Up to	100	600	900	1200	1800	3000	300	1200	2100	3000
0.15	**2.50**		± 1.0	± 2.0	± 2.0	± 3.0	± 4.0	± 5.0				
2.50	**6.00**		± 3.0	± 3.0	± 3.0	± 5.0	± 5.0	± 6.0				
6.00	**12.00**		± 10.0 - 0.0	± 10.0 - 0.0	± 10.0 - 0.0	± 10.0 - 0.0	± 10.0 - 0.0	± 10.0 - 0.0				
12.00	**80.00**								+ 5.0 - 0.0	+ 10.0 - 0.0	+ 13.0 - 0.0	+16.0 - 0.0

Table 6: Width Tolerances – Slit Coiled Sheet

Specified Thickness (mm)		TOLERANCE (+ mm) Specified Width (mm)					
		Over	-	150	300	600	1200
Over	Up to	Up to	100	300	600	1200	1500
-	**2.0**		0.25	0.40	1.0	1.5	2.0
2.0	**3.0**		0.30	0.50	1.0	1.5	2.0

Table 7: Lateral Bow Tolerances – Coiled Sheet



Specified Thickness (mm)		TOLERANCE (mm) Allowable deviation, D, in 1,800 mm of a side edge from a straight line Specified Width (mm)											
		Over	-		12		25		50		100		300
Over	Up to	Up to	12[3]		25		50		100		300		-
0.15	**1.60**				20.0		15.0		10.0		6.0		5.0
1.60	**3.00[4]**								10.0		6.0		5.0

Table 8: Lateral Bow Tolerances[1] – Flat Sheet and Plate

Specified Width (mm)		**Specified Thickness** (mm)		**TOLERANCE (mm)** Allowable Deviation, D, from straight Specified Length (mm)												
				Over	-	900	1500	2400	3000	3900	4500	5400	6000	7200	8100	9000
Over	Up to	Over	Up to	Up to	900	1500	2400	3000	3900	5400	5400	6000	7200	8100	9000	9900
-	**100**	**0.15**	**3.00**		2.0	6.0	13.0	25.0	38.0	51.0	76.0	102.0	112.0	133.0	153.0	173.0
100	**900**	**0.15**	**6.00**		1.0	2.0	3.0	3.0	5.0	25.0	38.0	51.0	70.0	83.0	98.0	113.0
900	**-**	**0.15**	**6.00**		1.0	2.0	3.0	3.0	5.0	8.0	11.0	15.0	18.0	21.0	24.0	27.0
-	**300**	**6.00**	**80.00**		2.0	6.0	13.0	25.0	38.0	51.0	76.0	102.0	112.0	133.0	153.0	173.0[5]
300	**450**	**6.00**	**80.00**		1.0	2.0	3.0	6.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0[5]
450	**-**	**6.00**	**80.00**		1.0	2.0	3.0	3.0	5.0	8.0	11.0	15.0	18.0	21.0	24.0	27.0[5]

Table 9: Length Tolerances – Flat Sheet and Plate

Specified Thickness (mm)		**TOLERANCE (mm)** Specified Length (mm)									
		Over	-	1200	3000	3600	4500	6000	-	300	1200	2100
Over	Up to	Up to	1200	3000	3600	4500	6000	-	300	1200	2100	-
0.15	**6.00**		± 2.0	± 3.0	± 4.0	± 4.0	± 6.0	± 6.0				
6.00	**12.00**		+ 10.0 - 0.0	+ 10.0 - 0.0	+ 10.0 - 0.0	+ 10.0 - 0.0	+ 10.0 - 0.0	+ 10.0 - 0.0				
12.00	**80.00**								+ 5.0 - 0.0	+ 10.0 - 0.0	+ 13.0 - 0.0	+ 16.0 - 0.0

Table 10: Squareness Tolerances[1] – Flat Sheet and Plate

Specified Thickness (mm)		TOLERANCE (mm) Allowable Difference, BB - AA, between diagonals	
		Specified Length (mm)	
Over	Up to	Up to 3600	Over 3600
-	**300**	3.0	5.0
300	**600**	5.0	8.0
600	**1200**	8.0	11.0
1200	**1500**	11.0	14.0
1500	**1800**	13.0	18.0
1800	**2100**	14.0	21.0
2100	**2400**	16.0	23.0
2400	**2700**	19.0	25.0
2700	**3600**	22.0	29.0

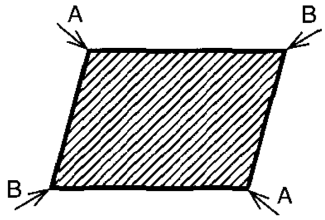


Table 11: Flatness Tolerances – Flat Sheet[6]

Alloy	Specified Thickness (mm)		TOLERANCE[8 9 10] (mm) Longitudinal or Transverse Distance Centre to Centre of Buckles or Edge Waves7 (mm)					
			Over	-	600	900	1200	1800
	Over	Up to	Up to	600	900	1200	1800	-
Group I	**0.5**	**1.6**		3.0	5.0	6.0	10.0	13.0
	1.6	**6.0**		3.0	6.0	10.0	13.0	16.0
Group II	**0.5**	**1.6**		5.0	6.0	10.0	13.0	16.0
	1.6	**6.0**		5.0	10.0	13.0	16.0	19.0
Group I Alloys:	**1080A 1050 1150 1350 1100 1200 3102 3003 3203 3005**							
	3105 4343 5005 5050A 5457 5557 8006 8008 8011							
Group II Alloys:	**2014 2024 Aclad 2024 3004 Alclad 3004 5251 5052**							
	5252 5154A 5454 5182 5083 5086 6061 7072							

Table 12: Longitudinal Flatness Tolerance – Sawn or Sheared Plate

Alloy	Specified Thickness (mm)		TOLERANCE[12]
	Over	Up to	Allowable Deviation from Flat[11]
All except 6061	6.0	80.0	7.0 mm in any 1800 mm or less
6061	6.0	16.0	8.0 mm in any 1800 mm or less
	16.0	80.0	25.0 mm in any 1800 mm or less

Table 13: Transverse Flatness Tolerances – Sawn or Sheared Plate

Alloy	Specified Thickness (mm)		TOLERANCE[12] (mm) Allowable Deviation from Flat[11] Specified Width (mm)			
			Over	-	600	1200
	Over	Up to	Up to	600	1200	1800
All except 6061	6.0	16.0		Only short-cycle	10.0	13.0
	16.0	40.0		flatness applies	7.0	10.0
	40.0	80.0			5.0	7.0
6061	6.0	40.0		Only short-cycle	10.0	13.0
	40.0	80.0		flatness applies	7.0	

Table 14: Short-Cycle Flatness Tolerances[14] – Sawn or Sheared Plate

Alloy	Specified Thickness (mm)		TOLERANCE[12] (mm)
	Over	Up to	Allowable Deviation from Flat[15]
All except 6061	6.0	80.0	3.5
	6.0	16.0	2.5
6061	16.0	80.0	6.5

Footnotes

1. When a dimension tolerance is specified other than as an equal bilateral tolerance, the value of the standard tolerance is that which would apply to the mean of the maximum and minimum dimensions permitted under the tolerance.
2. For products rolled for brightness on a flat sheet mill, these tolerances may not apply. The supplier should be consulted.
3. Tolerances for widths up to and including 12 mm shall be as agreed upon between purchaser and vendor at the time the contract or order is entered.
4. Tolerances for thicknesses greater than 1.6mm, in widths up to and including 50mm, shall be as agreed upon between purchaser and vendor at the time the contract or order is entered.
5. Also applicable to any 9,900 mm segment of longer plate.

6. Not applicable to cut-to-length sheet, panel flat sheet, coiled sheet, or sheet over 1,500 mm wide.
7. Also applicable to overall length or width of sheet if only one longitudinal and/or transverse buckle or edge wave is present.
8. Allowable deviation from flat with sheet positioned on a flat horizontal surface to minimise deviation.
9. Not applicable to annealed (0 temper) or HX8 tempers.
10. Not applicable to end or corner turn-up.
11. As measured with the plate resting on a flat surface concave side upwards, using a straight edge and a feeler gauge, dial gauge, or scale.
12. Not applicable to annealed (0 temper) plate in any alloy, or F temper plate in heat-treatable alloys.
13. For widths over 1,800 mm these tolerances apply for any 1,800 mm of total width.
14. Short-cycle flatness is the flatness over any 600 mm span in any direction.
15. As measured with the plate resting on a flat surface, using a frame with rollers mounted on 600 mm centres, with a depth gauge in the centre.

Rolled Products – Application Data

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. The manner in which aluminium responds to various environments and design situations is reviewed in this section and advice is given on the use of aluminium in specific applications.

ATMOSPHERIC EXPOSURE

Aluminium's natural affinity with oxygen results in the formation of a transparent oxide film when aluminium is exposed to air. The oxide film is generally 5 to 10 nm thick, extremely hard, chemically stable, corrosion resistant and adheres strongly to the parent metal surface, producing an integrated material. Once formed it prevents further oxidation and, if damaged in any way, will reform if sufficient oxygen is available. The only practical reason for removing the film is to facilitate anodising or welding. Anodising enables a thicker, more controlled deposition of oxide film — in welding, the oxide film inhibits metal fusion.

The behaviour of the oxide film under atmospheric exposure can therefore be described as self-healing. If the surface is pitted by any of the air-borne pollutants usually found in industrial or marine atmospheres (sulphuric acid, sodium chloride, etc.) the resulting chemical reaction produces a larger volume of powdered corrosion product than the volume of the original pit. This seals the surface of the aluminium and inhibits further corrosive reaction. In general, the ratio of corrosion product to pit volume is approximately 240:1.

With time, existing pits (which are usually of a shallow hemispherical shape) become sealed and the rate of formation of new pits declines to the extent that eventually all reaction may be considered to have ceased. The depth of pitting is extremely small and the process is known as "weathering". The type and level of pollution will determine general appearance and this may vary from a soft bluish-grey colour in rural areas to a dark grey or black in industrial areas. 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.

Exposure trials conducted on samples of alloys of the 3000 series, the 5000 series and the 6000 series subjected to different types of environmental conditions (marine, industrial and rural) have shown that in each case pit depth becomes essentially constant with respect to time, indicating that a stable condition of weathering is reached. Not surprisingly, this occurs somewhat sooner in the less severe conditions of a rural environment. The curves of UTS v exposure time show that weathering produces very little reduction in ultimate tensile strength, even after a prolonged exposure of 12 years. The curves become asymptotic to lines parallel to the time axis, indicating that a substantially stable strength is reached.

Figure 1: Pit Depth vs. Exposure Time - Typical of 3000 series and 5000 series alloys

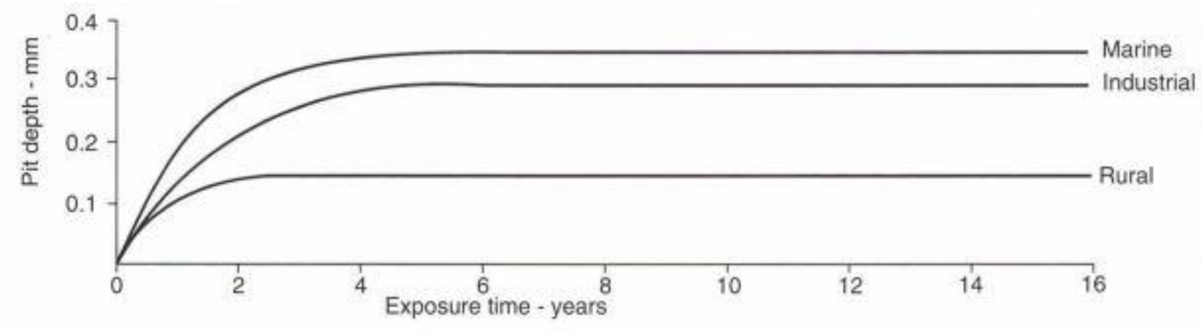
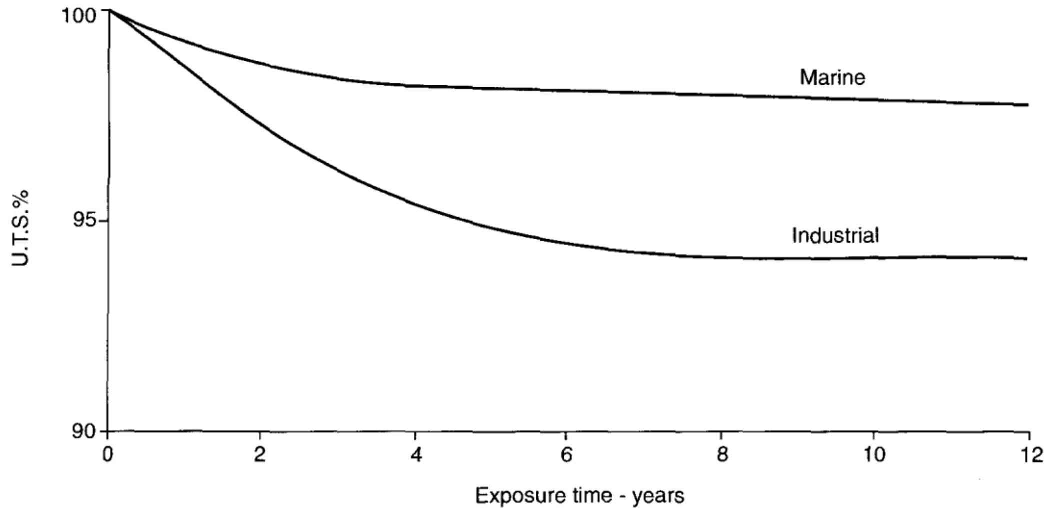


Figure 2: Ultimate Tensile Strength v Exposure Time — Typical of 3000 series and 5000 series alloys



CONTACT WITH CHEMICALS

The behaviour of aluminium alloys in contact with a wide range of chemicals is well documented. In general, direct chemical attack of aluminium only occurs to any great extent in situations where the pH is below 5 or above 8 (i.e., in strong acid or alkaline conditions). It is therefore necessary to know the degree of acidity/alkalinity of the chemical under consideration and the temperature at which it will operate — in some cases the temperature may significantly alter the rate of chemical reaction or be a major factor in initiating chemical attack.

CONTACT WITH OTHER MATERIALS

When aluminium is to be used in contact with other materials in wet or moist conditions, it is necessary to assess the situation and determine whether some form of protection is required. A consideration of the materials commonly used in combination with aluminium follows.

Metals

When two dissimilar metals are coupled together in the presence of moisture a galvanic reaction may occur and cause corrosion of one of the metals. See Figure 1.4 below. In such circumstances the electrolytic couple formed produces a current flow from the less noble metal (which acts as an anode) to the more noble metal (which acts as a cathode) and results in corrosion of the less noble metal. The phenomenon is usually consistent with the relative positions of the two metals in the electro-chemical series.

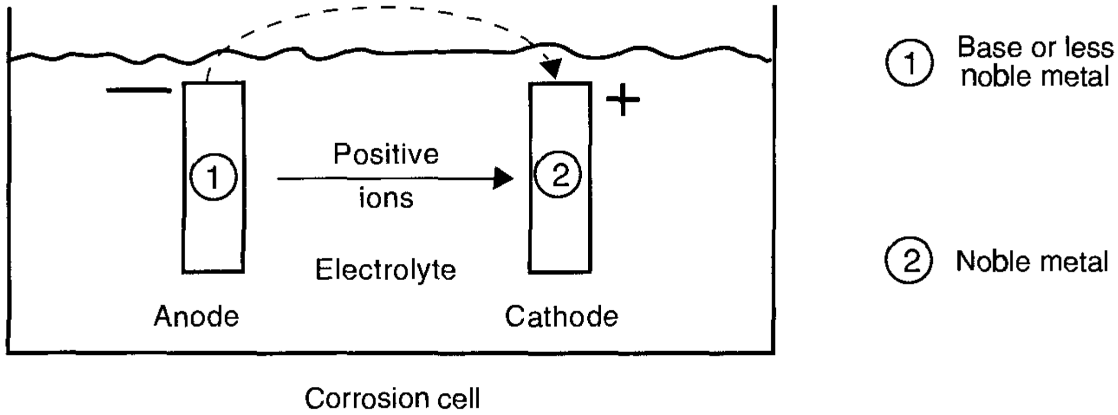


Fig. 3: The Principle of Galvanic Reaction

The severity of corrosion also depends on the degree of separation, the electrical resistance of the metal path, the conductivity of the solution and the relative areas of each metal. In practice, however, 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.

Table 15: 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

Wood
Dry wood usually has no reaction on aluminium, but wood that is unseasoned or in damp conditions should be coated with an aluminium or bituminous paint. In very aggressive environments (immersion) a non-absorbent insulating gasket should be inserted between the wood and aluminium contact surfaces. Timber treated with preservative may require special consideration and advice should be obtained from the aluminium supplier.

Insulating Materials
Insulating materials, such as foam or felt washers, fire protection, etc., may cause corrosion of aluminium if they become wet when in contact with it. Apart from the possibility of attack from leached-out chemicals, corrosion may result from the reduced availability of oxygen caused by the poultice action of the wet insulating material. The aluminium may be protected by using an inert barrier.

Concrete
Under perfectly dry conditions aluminium buried in concrete needs no protection. In practice, however, such conditions are rarely achieved. It is therefore recommended that all aluminium surfaces in direct contact with concrete be coated with bituminous paint. The steel reinforcement used in concrete should never be allowed to come in contact with aluminium since galvanic corrosion will result. The chemical reaction may also cause spalling of the concrete.

Table 16: A Guide to Galvanic Corrosion Effects Between Aluminium and Other Metals

<table>
<tr><th>Metal</th><th colspan="2">Galvanic Corrosion Effect
When Coupled with Aluminium or an Aluminium Alloy</th></tr>
<tr><td>Gold, platinum, silver</td><td>Attack accelerated in most environments
(changed font)</td><td rowspan="6">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.</td></tr>
<tr><td>Copper, copper alloys, silver solder</td><td>Attack accelerated in most atmospheres and under conditions of total immersion.</td></tr>
<tr><td>Solder coatings on steel or copper</td><td>Attack accelerated at interface in severe or moderate atmospheres and under conditions of total immersion.</td></tr>
<tr><td>Nickel and nickel alloys, steel, cast Iron</td><td>Attack accelerated in marine or industrial atmospheres and under conditions of total immersion, but not in mild environments.</td></tr>
<tr><td>Lead, tin</td><td>Attack accelerated only in severe environments such as marine and some industrial.</td></tr>
<tr><td>Tin – zinc plating
(80 – 20) on steel</td><td>Attack accelerated only in severe atmospheres and under conditions of total immersion.</td></tr>
<tr><td>Pure aluminium and aluminium alloys not containing substantial amounts of copper or zinc</td><td colspan="2">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 accelerated attack when in good electrical contact with another aluminium alloy that contains substantial amounts of copper, such as the alloys in the 2000 series.</td></tr>
<tr><td>Cadmium</td><td>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.</td><td rowspan="2">These metals are generally anodic to aluminium and are attacked when corrosion occurs, thereby protecting the aluminium.</td></tr>
<tr><td>Zinc and Zinc alloys</td><td>Attack on zinc is accelerated in severe environments such as marine or industrial and under conditions of total immersion.</td></tr>
<tr><td>Magnesium and Magnesium Alloys</td><td>Attack on magnesium is accelerated in severe environments such as marine or industrial and under conditions of total immersion.</td><td>Attack on aluminium may also be accelerated.</td></tr>
<tr><td>Titanium</td><td>Little data available, but attack on aluminium is known to be accelerated in severe marine or industrial conditions and when immersed in seawater.</td><td>These metals form inert protective films that tend to reduce galvanic reaction.</td></tr>
</table>

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 atmospheres and under conditions of total immersion.	Where attack occurs, the aluminium base material suffers.
Chromium Plate	No acceleration of attack on aluminium when plating is greater than 0.0025 mm thick, except in severe atmospheres.	

Handling, Storing and Maintenance of Aluminium

Aluminium is one of the easiest materials to keep in good condition. It has a high natural resistance to corrosive conditions normally encountered during shipment and storage and a little care will maintain its original appearance for a long time. The principal things to guard against are conditions that might cause surface abrasions or water stains.

Suppliers make every effort to pack aluminium so that "traffic marks" or "rub marks" do not occur during shipment and so that it remains dry. All incoming shipments should be inspected promptly, since suppliers generally have a time limit in which damage claims will be honoured.

Traffic marks may appear as scratches, surface abrasions, or a condition resembling cinders embedded in the metal. They result from mechanical abrasion and subsequent oxidation of the abraded areas. Their principal disadvantage lies in their unsightliness and their effect on finishing operations.

To avoid traffic marks, suppliers pack the metal so that it is not subjected to undue flexing or twisting and so that the units within a package do not rub against each other. Products subject to damage by flexing or bending usually are packed on skids or in timber boxes. Paper or cardboard is used where necessary for cushioning thin or soft metal. Steel strapping is used to reinforce skids and boxes and to bind wrapped bundles.

Water stains are non-metallic in appearance and, while usually whitish, may appear iridescent depending upon the alloy or degree of oxidation. They are caused by the entrapment of moisture between adjacent surfaces of closely packed material. The purer aluminium alloys are more resistant to water stain, while the condition seems most pronounced on those alloys having high magnesium content. Water stain is a superficial condition and the mechanical properties of the metal having such stain are not affected. If a shipment of aluminium arrives in a wet condition, it should be thoroughly dried before storing. This may be done by evaporation in air or by means of dry air currents. When the moisture is removed in this manner within a short period after the metal becomes wet, no stain will result. If stain has occurred and the moist condition causing it is removed, the stain will not develop further. Once safely dry, the metal should not be stored near such obvious water sources as steam and water pipes and it should be kept at a reasonable distance from open doors and windows.

Condensation is perhaps the most troublesome cause of water stains. Under severe conditions, condensation may also cause surface deterioration which may only become apparent if the material is subsequently etched and anodised. It may be prevented by avoiding conditions where the temperature of the metal drops below the dew point of the surrounding air, or, conversely, conditions where the moisture of the air increases enough to carry the dew point above the metal temperature. It is thus important to ensure that a sudden fall in temperature or increase in humidity does not occur in the places of storage. Aluminium packed in original boxes should never be left in the open, because the greater variation in temperature and humidity outdoors increases the possibility of condensation. Even if the package is wrapped with "waterproof" paper, the impossibility of obtaining a perfect seal makes outdoor storage highly undesirable. So-called waterproof packages are designed solely for the protection of the metal during shipment and are not meant to withstand any extended exposure to the weather.

If possible, cold metal should be located in a dry storage place until its temperature has increased substantially before it is brought into a heated room with a higher humidity. This may be accomplished by placing a new shipment in temporary storage where its temperature is raised slowly to that of the permanent storage room.

Where water stains have occurred, the degree of staining may be judged fairly accurately by the relative roughness of the stained area. If the surface is reasonably smooth, the stain is merely superficial and its appearance can be improved by mechanical or chemical treatments. Scratch-brushing or the use of steel wool and oil is effective in removing water stain. If a chemical dip without undue etching is preferred, an aqueous solution containing 10% by volume of sulphuric acid and 3% by weight of chromic acid at about 80°C may be employed.

In storing aluminium, it is desirable to avoid contact between it and other metals since this sometimes results in scratches or other marks. The use of wood-faced shelving racks and bins is recommended. It is also good practice to keep aluminium away from caustics, nitrates, phosphates and some acids.

In the continuous use of large quantities of metal, the oldest stock should be used first. Occasional checking of the stock on hand will help to prevent any serious corrosion.

MAINTENANCE

Aluminium alloys require little or no maintenance to retain their original mechanical properties. However, without regular cleaning surfaces can become stained, particularly when under prolonged exposure on industrial sites. Mill-finished aluminium may be cleaned by rubbing down with fine wire wool and methylated spirits. Anodised surfaces are more resistant to staining but, nevertheless, benefit from regular washing down with soapy water. Proprietary cleaners are available for both mill-finished and anodised surfaces.

Bending Radii

Table 17: Recommended Minimum Inside Bending Radii for 90° Cold Forming of Sheet and Plate[1,2,3]

Alloy	Temper	Radii for Various Thicknesses Expressed in Terms of Thickness t							
		t=0.4 mm	t=0.8 mm	t=1.6 mm	t=3.0 mm	t=4.0 mm	t=6.0 mm	t=10 mm	t=12 mm
1100	**- O**	0t	0 t	0 t	0 t	0 t	0.5 t	1 t	1.5 t
1200	**- H12**	0t	0 t	0 t	0.5 t	1 t	1 t	1.5 t	2 t
	- H14	0t	0 t	0 t	1 t	1 t	1.5 t	2 t	2.5 t
	- H16	0t	0.5 t	1 t	1.5 t				
	- H18	1 t	1.5 t	2 t	3 t				
2024	**- O**	0t	1 t	1 t	1 t	1 t	1 t	2.5 t	4 t
	- T42	2.5 t	3 t	4 t	5 t	5 t	6 t	7 t	8 t
3003	**- O**	0t	0 t	0 t	0 t	0.5 t	1 t	1 t	1.5 t
3005	**- H14**	0t	0 t	0 t	1 t	1 t	1.5 t	2 t	2.5 t
5005[4]	**- H16**	0.5 t	0.5 t	1 t	1.5 t				
	- H18	0t	1 t	2 t	3 t				
3004	**- O**	0t	0 t	0 t	0.5 t	1 t	1 t		
	- H32	0t	0 t	0.5 t	1 t	1 t	1.5 t		
	- H34	0t	1 t	1 t	1.5 t	1.5 t	2.5 t		
	- H36	1 t	1 t	1.5 t	2.5 t				
	- H38	1 t	1.5 t	2.5 t	3 t				
5052	**- O**	0 t	0 t	0 t	0.5 t	1 t	1 t	1.5 t	1.5 t
5251	**- H32**	0 t	0 t	1 t	1.5 t	1.5 t	1.5 t	1.5 t	2 t
	- H34	0 t	1 t	1.5 t	2 t	2 t	2.5 t	2.5 t	3 t
	- H36	1 t	1 t	1.5 t	2.5 t				
	- H38	1 t	1.5 t	2.5 t	3 t				
5454	**- H32**	0t	0.5 t	1 t	1.5 t	1.5 t	2 t	2.5 t	3.5 t
	- H34	0.5 t	1 t	1.5 t	2 t	2.5 t	3 t	3.5 t	4 t
	- H112						2 t	2.5 t	3 t
5083	**- O**			0.5 t	1 t	1 t	1 t	1.5 t	1.5 t
	- H112								
	- H116		1.5 t	1.5 t	2 t	2 t	2 t	2.5 t	3 t
	- H321								
6061[2]	**- O**	0 t	0 t	0 t	1 t	1 t	1 t	1.5 t	2 t
	-T4 & T42	0 t	0.5 t	1 t	1.5 t	2.5 t	3 t	3.5 t	4 t

	- T6 & T62	1 t	1 t	1.5 t	2.5 t	3 t	4 t	4.5 t	5 t
7075	**- O**	0 t	0 t	1 t	1 t	1.5 t	2.5 t	3.5 t	4 t
	-T6	3 t	4 t	5 t	6 t	6 t	8 t	9 t	9.5 t

Footnotes:

1. The radii listed are the minimum recommended for bending sheets and plates without fracturing in a standard press brake with air bend ties. 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.
2. Heat-treatable alloys can be formed over appreciably smaller radii immediately after solution heat treatment.
3. The H112 temper (applicable to non-hear-treatable alloys) is supplied in the as-fabricated condition without special property control, but usually may be formed over radii applicable to the H14 (or H34) temper or smaller.
4. Applicable to 5005 H1X and H3X tempers.

Welding

Welding is a widely accepted method of joining aluminium and the techniques for welding aluminium are well known in the engineering and manufacturing industries. The basic welding processes are **Gas Tungsten Arc Weld (GTAW) also known as Tungsten Inert Gas (TIG) Process and Gas Metal Arc Weld (GMAW) also known as Metal Inert Gas (MIG) Process.**

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

Surface Preparation

Cleanliness and removal of the oxide film are most important. The proposed weld area must be degreased using methylated spirits, acetone, etc. and the joint wiped dry. It is necessary to provide adequate ventilation for any solvents used, particularly industrial cleaning solvents such as carbon tetrachloride, trichloroethylene, etc. After degreasing, the joint is cleaned with stainless steel wire brushes, or a chemical etch cleaner, to remove the oxide film. Welding should then be carried out as soon as possible.

Carborundum wheels are not recommended for cleaning, since they produce grit particles which become embedded in the aluminium surface and contaminate the weld. Filler wire is cleaned by wiping with wire wool. Pre-packed spool wire is supplied in a clean condition.

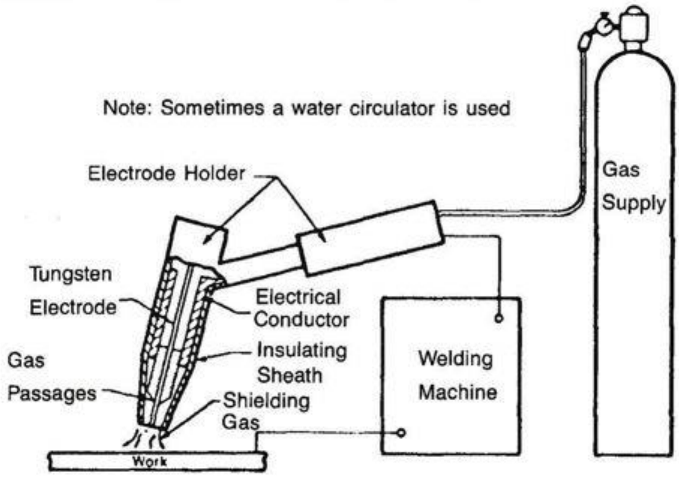
Gas Tungsten Arc Weld (GTAW) also known as Tungsten Inert Gas (TIG) Process

In the tungsten inert gas process, an alternating current arc is struck between the workpiece and a non-consumable tungsten electrode (although an alternating current (AC) process is the most common there are times when direct current electrode positive (DCEP) or direct current electrode negative (DCEN) may be used. Filler metal may or may not be added. Although a mechanized ~~TIG~~ GTAW system is available, the process is more widely used as a manual system where close control of the welding conditions can be readily maintained.

The resulting welds are usually of good appearance and penetration, particularly in situations where a backing plate cannot be used. Figure 3.3 shows a schematic layout of a typical GTAW welding system.

Gas Metal Arc Weld (GMAW) also known as Metal Inert Gas (MIG) Process

In the GMAW process, a direct current arc is struck between the workpiece and a consumable wire electrode which is constantly fed from a spool. The arc is self-adjusting and takes into account small movements of the torch. Penetration and appearance are not as easy to control as in the GTAW system, although the addition of pulsed arc equipment can improve penetration and reduce the need for backing plates. Figure 3.4 shows a schematic layout of a typical GMAW welding system. Small spool hand guns, sometimes called "fine wire guns", are also available with GMAW and, since they do not require long electrode wire feed leads, they may be used to increase the area of work accessible from the base unit.



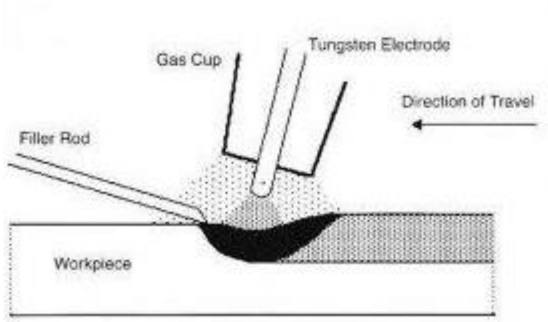


Fig. 4: A Typical GTAW Welding System

GTAW Process with added filler

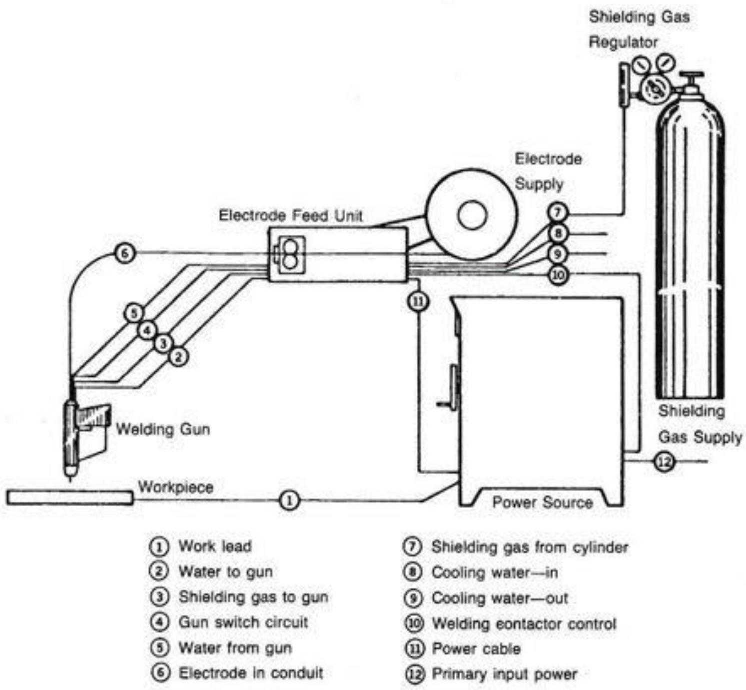
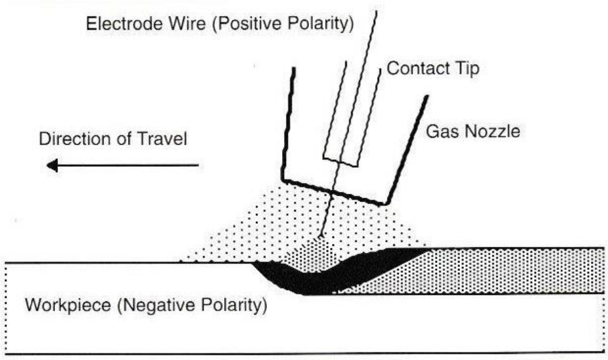


Fig. 4: A Typical GMAW Welding System



The Semiautomatic GMAW Process

Filler Alloy Selection

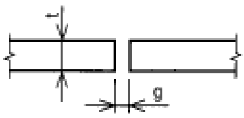
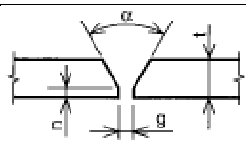
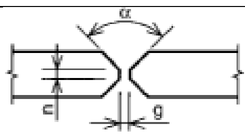
The selection of the most suitable filler alloy for each welding circumstance is both simple and complex. It is simple when structures are to be built of the common alloys using fabrication practices and when they are exposed to common service conditions. However special base alloys, special fabricating procedures or special service conditions may call for special filler alloys in which case the selection is more complex.

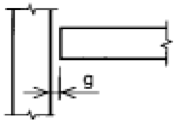
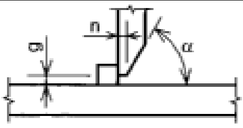
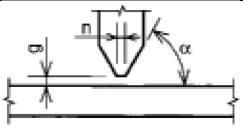
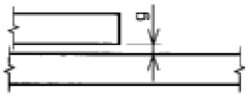
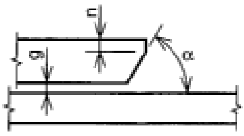
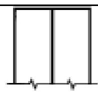
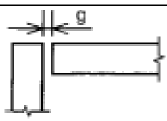
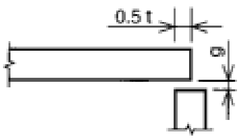
The most common filler alloys are 5356 and 4043.

Alloy 5356 (or 5183, 5556, 5554) is used when welding 5000 series sheet and plate products. It is also used when welded components are anodised so as to achieve a better colour match. It can also be used weld extrusions of the 6000 series to themselves or to alloys of the 1000, 3000 or 5000 series. When service operating conditions exceed 65^{0}C filler alloy 5554 should be used.

Alloy 4043 can be used to weld the 1000, 3000 and 6000 alloy series either to themselves or in combination. It can used to weld 5005 sheet products but not the alloys containing increased Mg.

Table 18: Edge Preparation and Fit-Up for GTAW and GMAW Welding

Minimum Thickness t		Gap g		Root Face	Angle	
of Parent Metal (mm)		(mm)		n	a	Joint Detail
GTAW	GMAW	nominal	maximum	(mm)	(degrees)	
0.8 c	-	Nil	Nil	-	-	
1.2 c	-	Nil	Nil	-	-	
1.6 c	-	Nil	0.8	-	-	
4.8 c	-	Nil	1.6	-	-	
-	3.2 c	1.6	2.4	-	-	
-	4.8 c	2.4	3.2	-	-	
-	3.2 p	4.8	6.4	-	-	
-	8.0	Nil	0.8	1.6	60.0	
-	6.4 c	1.6	2.4	1.6	60.0	
-	4.8 p	3.2	4.8	Nil	60.0	
6.4	-	Nil	1.6	1.6	7.5	
-	12.7	Nil	0.8	1.6	90.0	
-	15.9	Nil	0.8	1.6	90.0	

Minimum Thickness t of Parent Metal (mm)		Gap g (mm)		Root Face n (mm)	Angle a (degrees)	Joint Detail
GTAW	GMAW	nominal	maximum			
1.6	-	Nil	Nil	-	-	
2.4	3.2	Nil	0.8	-	-	
6.4	4.8	Nil	1.6	-	-	
-	6.4 p	1.6	3.2	0.8	60.0	
-	9.5	Nil	0.8	0.8	60.0	
1.6	-	Nil	Nil	-	-	
-	3.2	Nil	0.8	-	-	
8.9	4.8	Nil	1.6	-	-	
-	12.7	Nil	1.6	3.2	60.0	
-	19.0	Nil	1.6	4.8	60.0	
-	25.4	Nil	1.6	6.4	60.0	
0.8	-	Nil	Nil	-	-	
1.2 c	-	Nil	0.8	-	-	
2.4	-	Nil	Nil	-	-	
1.6	-	Nil	Nil	-	-	
3.2 c	-	Nil	Nil	-	-	

Where c = Temporary Backing Plate, p = Permanent Backing Plate

Welded Joint Design

The design of a satisfactory welded joint must consider both the practicalities of the welding process and the structural requirements of the joint itself. The edge preparation for welding will depend on the type of weld proposed (butt, bevel or fillet), the thickness of material to be joined and the welding process to be employed.

The strength of welds is covered by the Aluminium Structures Code AS/NZS 1664.

Brazing

Brazing is a fusion joining method in which an aluminium filler metal having a melting point below the solidus of the base metal is heated , together with the base metal, until the filler metal melts and flows through the joint by capillary action. There is no melting of the base or core metal. All brazing, with the single exception of vacuum brazing, require flux to remove the aluminium oxide and make coalescence possible.

Alloys that are suitable for brazing include the non-heat-treatable alloys 1100.3003.3004 whilst the heat-treatable alloys 6061, 6060 and 6063 respond well. Some alloys with lower melting points are not suitable for brazing and these include 2024 and 7075.

The 5000 series alloys having more than 2% magnesium are difficult to flux braze because existing fluxes are not effective in removing their tenacious oxides.

Soldering

Aluminium soldering is a fusion joining method that employs a metal different from the base metal as filler, and the liquidus of the filler is below 449^{0}C. No melting of the base metal takes place. Like brazing, it relies on the filler metal flowing through tightly fitted joints by capillary action. Most aluminium soldering is done with a flux, although there are techniques such as abrasion soldering and ultra sonic soldering that remove, or at least disperse, the aluminium oxide sufficiently to allow sound joints to be made.

Aluminium alloys containing no more than 1% Mg or 4% Si are the most readily soldered. Alloys containing greater amounts of these elements have poor wetting characteristics but can be soldered by special techniques such as pre-plating before flux soldering or by abrasion soldering.

Adhesive Bonding

Because the aluminium oxide tightly adheres to the metal and because it also forms strong bonds with metal bonding adhesives, aluminium can be bonded to itself and to a wide range of other metals and materials.

The advantages of adhesive bonding include:

- No heat induced distortion.
- All alloys as well as other materials can be bonded.
- Joints are sealed.
- Bonded joints have excellent shear strength.
- Stress concentrations are eliminated thus improving fatigue performance.

The disadvantages of adhesive bonding include:

- Adhesive joints generally have poor peel strength.
- Surface preparation of the aluminium is essential for the durability of bonded joints.
- Durability of bonded joints can be affected by environmental factors such as humidity and temperature.
- Care and skill are necessary to produce consistently sound joints.

Wrought Products – Typical Mechanical Properties

Table 19: Typical Mechanical Properties' Including Extrusions and Rolled Products

Alloy and Temper		Tensile Strength (MPa)		Elongation (% mm in 50 mm, 1.5 mm thick specimen)	Hardness[2]		Shear Strength, Ultimate (MPa)	Fatigue Strength Endurance Limit[3] (MPa)	Modulus of Elasticity[4] (MPa $x10^3$)
		Ultimate	Yield		Vickers	Brinell (500 kg load 10 mm ball)			
1080A	**— 0**	60	30	45	19	18	62		69
	— H14	105	95	12	31	30	69		69
	— H18	140	130	6	40	38	76		69
	— H112	60	50	50[5]	19	18	62	21	69
1050	**— 0**	70	30	43	21	20	55	21	69
	— H12	100	85	15					69
	— H14	110	95	10	32	31			69
	— H16	125	115	6					69
	— H18	145	140	6	41	39	90		69
	— H112	75	50	45[5]	22		55	21	69
1100	**— 0**	90	35	35		23	62	34	69
	— H12	110	105	12		28	69	41	69
	— H14	125	115	9		32	76	48	69
	— H16	145	140	6		38	83	62	69
	— H18	165	150	5		44	90	62	69
	— H112	100	60	20[5]					69
1145	**— 0**	70	30	43	21	20	55	21	69
	— H12	100	85	15					69
	— H14	110	95	10	32	31			69
	— H16	125	115	6					69
	— H18	145	140	6	41	39	90		69
1150	**— 0**	70	30	35	24				69
	— H12	100	85	12	34				69
	— H14	110	95	9	39				69
	— H16	125	115	6	43				69
	— H18	145	140	5	50				69
1200	**— 0**	90	35	35		23	62	34	69
	— H12	110	105	12		28	69	41	69
	— H14	125	115	9		32	76	48	69
	— H16	145	140	6		38	83	62	69
	— H18	165	150	5		44	90	62	69
	— H112	100	60	20[5]	25				69
1350	**— 0**	70	30	40	21		55		69
	— H12	100	85				62		69
	— H14	110	95				69		69
	— H16	125	110				76		69
	— H18	145	130				90		69
	— H19	185	165				103	48	69
	— H111	90	40	40					69
	— H112	90	55	40	22		55	21	69
2011	**— T3**	380	295	15[5]	110	95	221	124	70
	— T4	310	145	20					70
	— T6	395	270	17	110		234	124	70
	— T8	405	310	12[5]	105	100	241	124	70
2014	**— T4**	425	290	20[5]	130	105	262	138	73
	— T451	425	290	20[5]	130	105	262	138	73
	— T6	495	450	13[5]	145	135	290	124	73
	— T651	495	450	13[5]	145	135	290	124	73

Alloy and Temper	Tensile Strength (MPa)		Elongation (% mm in 50 mm, 1.5 mm thick specimen)	Hardness[2]		Shear Strength, Ultimate (MPa)	Fatigue Strength Endurance Limit[3] (MPa)	Modulus of Elasticity[4] (MPa x10^3)
	Ultimate	Yield		Vickers	Brinell (500 kg load 10 mm ball)			
2024 — 0	185	75	20		47	124	90	73
— T42	470	325	20		120	283	138	73
3003 — 0	110	40	30		28	76	48	69
— H14	150	145	8		40	97	62	69
— H16	180	170	5		47	103	69	69
— H18	200	185	4		55	110	69	69
— H112	125	85						69
3004 — 0	180	70	20		45	110	97	69
— H32	215	170	10		52	117	103	69
— H34	240	200	9		63	124	103	69
— H36	260	230	5		70	138	110	69
— H38	285	250	5		77	145	110	69
Alclad 3004 — 0	180	70	20			110		69
— H32	215	170	10			117		69
— H34	240	200	9			124		69
— H36	260	230	5			138		69
— H38	285	250	5			145		69
3005 — 0	130	60	25	36		83		69
— H12	145	140	10					69
— H14	180	165	8	60				69
— H16	205	200	4	66				69
— H18	240	230	4			124		69
5005 — 0	125	40	25	30	28	76		69
— H12	140	130	10	40		97		69
— H14	160	150	6	45		97		69
— H16	180	170	5	50		103		69
— H18	200	195	4	56		110		69
— H32	140	115	11		36	97		69
— H34	160	140	8		41	97		69
— H36	180	165	6		46	103		69
— H38	200	185	5		51	110		69
5052 — 0	195	90	25		47	124	110	70
— H32	230	195	12		60	138	117	70
— H34	260	215	10		68	145	124	70
— H36	275	240	8		73	159	131	70
— H38	290	255	7		77	165	138	70
— H112	205	125						70
5083 — O	290	145	22	70	67	172	152	71
— H111	310	215	20	80	80	179	152	71
— H112	295	160	20	70		172	152	71
— H121	350	235	16					71
— H311	315	195	19					71
— H321	315	230	16		82	179	159	71
— H323	325	250	10		84	193		71
— H343	360	285	8		92	207		71
5086 — O	260	115	22		60	159	145	71
— H32	290	205	12		72	172	152	71
— H34	325	255	10		83	186	159	71
— H36	345	285	8		87	193		71
— H38	360	305	7					71

Alloy and Temper		Tensile Strength (MPa)		Elongation (% mm in 50 mm, 1.5 mm thick specimen)	Hardness[2]		Shear Strength, Ultimate (MPa)	Fatigue Strength Endurance Limit[3] (MPa)	Modulus of Elasticity[4] (MPa $x10^3$)
		Ultimate	Yield		Vickers	Brinell (500 kg load 10 mm ball)			
	— H112	270	130	14		64	159	145	71
5251	**— 0**	185	75	24	48		124	90	
	— H32	220	185	10	74				
	— H34	250	205	7	80		138	124	
	— H36	270	230	6	90				
	— H38	285	240	5	92				
5454	**— O**	250	115	22		62	159		70
	— H32	275	205	10		73	165		70
	— H34	305	240	10		81	179		70
	— H112	250	125	18		62	159		70
5557	**— O**	110	40	25		28	76		69
	— H25	160	140	12		40	97		69
6005A	**— T5**	285	265	12					
6060	**— O**	90	50	30					
	— T1	150	70	20					
	— T5	220	180	12	70	68			
	— T52	190	130	15					
	— T81	250	230	11					
6061	**— O**	125	55	25		30	83	62	69
	— T4	240	145	22		65	165	97	69
	— T451	240	145	22		65	165	97	69
	— T6	310	275	12		95	207	97	69
	— T651	310	275	12		95	207	97	69
	— T8	385	370	12			234		69
	— T9	345	305	12					69
	— T91	365	325	8					69
	— T92	385	360	5					69
	— T93	415	385	4					69
	— H13	180	105	10					69
6063	**— O**	90	50	30	30	25	69	55	69
	— T1	150	90	20	45	42	97	62	69
	— T31	180		12					69
	— T32	205		8					69
	— T33	260	240	20					69
	— T34	340	325	15					69
	— T4	170	90	22		48	110	69	69
	— T5	220	180	12			117	69	69
	— T6	240	215	12		73	152	69	69
	— T81	250	230	11	85				69
	— T82	260	255	9					69
	— T83	280	270	8	90	82	152		69
	— T84	315	305						69
	—H112	150	90	20	45		97	62	69
	— H14	160	95	18					69
	— H18	200	150	8					69
6082	**— T1**	270	150	20					69
	— T5	315	285	12					69
6101	**— H111**		75						69
	— T5	205	180	12	75		138	69	69
	— T6	220	195	12	75	71	138	69	69
	— T61	170	140	22[5]					69
	— T64	115	60	24[5]					69

Alloy and Temper	Tensile Strength (MPa)		Elongation (% mm in 50 mm, 1.5 mm thick specimen)	Hardness[2]		Shear Strength, Ultimate (MPa)	Fatigue Strength Endurance Limit[3] (MPa)	Modulus of Elasticity[4] (MPa x10^3)
	Ultimate	Yield		Vickers	Brinell (500 kg load 10 mm ball)			
6106 — T4	180	90	22					
— T6	250	230	13					
— T83	300	270	12					
6201A— T8	310	290	4					69
— T81	330	310	4					69
6262 — T6	310	275	12	100		207	97	69
— T91	350	320	10	110		241	90	69
6351 — 14	240	165	20	70	65	165	97	69
— T5	310	275	12		95	207	97	69
— T6	330	310	11	103				69
6463A—T1	150	90	20		42	97	69	69
— T5	220	180	12		60	117	69	69
— T6	240	215	12		74	152	69	69
7075 — O	230	105	17	14	60	150		72
— T6	570	505	11	9	150	330	160	72
— T651	570	505	11	9	150	330	160	72
8011 — O	90	35	30					69
— H12	115	105	10					69
— H14	130	120	8					69
— H16	150	140	5					69
— H18	175	160	4					69

Footnotes

1. These typical properties are averages (at 25ºC) for various forms, sizes and methods of manufacture and may not exactly describe any one particular product. Typical tensile strength and elongation properties **should not be used for design purposes**.
2. Hardness is commonly reported neither of the two units quoted. A complete listing in both units is not given because of difficulties of exact correlation between the two systems.
3. Based on 500,000,000 cycles of completely reversed stress using the R. R. Moore type of machine and specimen.
4. Average of tension and compression moduli. Compression modulus is about 2% greater than tension modulus.
5. Round test specimens used.
6. Unless otherwise stated all data is based on an ambient temperature of 25ºC.

Wrought Products – Typical Physical Properties

Table 19: Typical Physical Properties – Includes Extrusions and Rolled Products - Not for Design

Alloy and Temper		Thermal Conductivity at 25°C (W/(m.K))	Electrical Conductivity[1] at 20°C (MS/m)	Electrical Resistivity at 20°C (μΩ.m)	Density (kg/m³ x10³)	Coefficient of Thermal Expansion[2] per °C	Melting Range, approximate (°C)
1050	**—O**	234	35	0.028	2.70	24.0	650—660
	— H18	230	35	0.029			
1080A	**— O**	234	36	0.028	2.70	24.0	645
	— H18	230	35	0.028			
1100	**— O**	222	34	0.029	2.71	23.6	645—655
	— H18	218	33	0.030			
1145	**— O**	234	35	0.028	2.70	24.0	650—660
	— H18	230	35	0.029			
1150	**— O**	222	34	0.029	2.70	24.0	645—655
	— H18	218	33	0.030			
1199	**— All tempers**	239	37	0.026	2.70	23.6	660
1200	**— O**	222	34	0.029	2.71	24.0	645—655
	— H18	218	33	0.030			
1350	**— All tempers**	234	36	0.028	2.70	23.8	645—655
2011	**— T3**	151	23	0.044	2.82	22.8	535—645
	— T8	172	26	0.038			
2014	**— T4**	134	20	0.051	2.80	23.0	510—640
	— T6	155	23	0.043			
2014A	**— T4**	134	20	0.051	2.80	23.0	510—640
	— T6	155	23	0.043			
2024	**— 0**	193	29	0.034	2.77	23.2	500—640
	— T42	121	17	0.057	2.77	23.2	500—640
	—T62	151	22	0.045	2.77	23.2	500—640
3003	**— 0**	193	29	0.034	2.73	23.2	645—655
	— H18	155	23	0.043	2.73	23.2	645—655
3004	**— 0**	188	28	0.035	2.72	24.0	630—650
	— H18	151	23	0.044	2.72	24.0	630—650
3005	**— 0**	193	29	0.034	2.73	23.6	635—650
	— H18	155	23	0.043	2.73	23.6	635—650
3203	**— 0**	193	29	0.034	2.73	24.0	645—655
	— H18	155	24	0.041	2.73	24.0	645—655
4043	**— F**	163	24	0.041	2.69	22.0	575—630
4047	**— F**	155	21	0.047	2.66	22.0	575
4343A	**— F**	159	23	0.044	2.68	22.0	575—610
4543	**— All tempers**	163	24	0.041	2.69	22.0	575—630
5005	**— All tempers**	201	30	0.033	2.70	23.8	630—650
5052	**— 0**	138	21	0.047	2.69	24.0	595—650
	— H38	138	20	0.049	2.69	24.0	595—650
5056	**— 0**	117	17	0.059	2.64	24.1	570—640
	— H38	109	16	0.064	2.64	24.1	570—640
5083	**— All tempers**	117	17	0.059	2.66	23.8	570—640
5086	**— All tempers**	126	18	0.055	2.66	23.8	685—640
5154A	**— All tempers**	126	19	0.053	2.66	24.0	595—645
5251	**— All tempers**	138	20	0.049	2.68	23.8	595—650
5356	**— F**	109	16	0.064	2.66	24.0	570—640
5454	**— All tempers**	134	20	0.051	2.68	23.6	600—645
5457	**— All tempers**	176	27	0.037	2.70	24.0	630—655

Alloy and Temper		Thermal Conductivity at 25°C (W/(m.K))	Electrical Conductivity[1] at 20°C (MS/m)	Electrical Resistivity at 20°C (μΩ.m)	Density (kg/m³ x10³)	Coefficient of Thermal Expansion[2] per °C	Melting Range, approximate (°C)
5556	**— F**				2.66	24.0	570—640
5557	**— All tempers**	188	28	0.035	2.70	23.6	640—655
6060	**— O**	218	34	0.030	2.70	23.4	615—650
	— T1	193	29	0.034			
	— T5	209	32	0.031			
6061	**— O**	180	27	0.037	2.70	23.6	580—650
	— T4	155	23	0.043			
	— T6	167	25	0.040			
6063	**— O**	218	34	0.030	2.70	23.4	615—650
	— T1	193	29	0.034			
	— T5	209	32	0.031			
	— T6	201	31	0.033			
6082	**— T1**	165		0.043	2.70	24.0	
	— T6	174	23.8	0.042	2.71	23.5	
6101	**— H111**	226	35	0.029	2.70	23.4	615—650
	— T5	218	33	0.030			
	— T6	218	33	0.030			
	— T61	222	34	0.029			
	— T64	226	35	0.029			
6163A	**— T1**	193	29	0.034	2.70	23.4	615—650
	— T5	209	32	0.031			
	— T6	201	31	0.033			
6201A	**— T8**		32	0.031	2.70	23.6	615—650
	— T81		31	0.032			
6262	**— T6**	167	25	0.040	2.72	23.4	580—650
	— T91	172	26	0.039			
6351	**— T4**	163	26	0.034	2.70	23.0	555—650
	— T6	172	28	0.036			
7072	**— O**	222	34	0.029	2.72	23.6	645—655
	— T5						
	— T6						
7075	**— T6**	130	19.2	0.052	2.8	23.5	475-630

Footnotes

[1] For comparative purposes, the electrical conductivity of the value of 100% of the International Annealed Copper Standard is 58 MS/m.

[2] Figures are average in the temperature range 20°C-100°C. The coefficient tabulated must be multiplied by 10-6; e.g. 23.6 x 10-6 = 0.0000236.

Wrought Products – Typical Tensile Properties at Various Temperatures

Table 20: Typical Tensile Properties at Various Temperatures[1] (includes extrusions and rolled products)

Alloy and Temper	Temperature	Tensile Strength (MPa)		Elongation in 50mm
	(°C)	Ultimate	Yield[2]	(%)
1100 - O	-195	170	40	50
1200 – O	-80	105	40	43
	-30	95	35	40
	25	90	35	40
	100	70	30	45
	150	55	30	55
	205	40	25	65
	260	30	20	75
	315	20	15	80
	370	15	10	85
1100 – H14	-195	205	140	45
1200 – H14	-80	140	125	24
	-30	130	115	20
	25	125	115	20
	100	110	105	20
	150	95	85	23
	205	70	50	26
	260	30	20	75
	315	20	15	80
	370	15	10	85
1100 – H18	-195	235	180	30
1200 – H18	-80	180	160	16
	-30	170	160	15
	25	165	150	15
	100	145	130	15
	150	125	100	20
	205	40	25	65
	260	30	20	75
	315	20	15	80
	370	15	10	85
2011 – T3	25	380	295	15
	100	325	235	16
	150	195	130	25
	205	110	75	35
	260	45	25	45
	315	20	10	90
	370	15	10	125
2014 – T6	-195	580	495	14
-T651	-80	510	450	13
	-30	495	425	13
	25	485	415	13
	100	435	395	15
	150	275	240	20

Alloy and Temper	Temperature	Tensile Strength (MPa)		Elongation in 50mm
	(°C)	Ultimate	Yield[2]	(%)
	205	110	90	38
	260	65	50	52
	315	45	35	65
	370	30	25	72
2024 T4	-195	580	420	19
	-80	490	340	19
	-30	475	325	19
	25	470	325	19
	100	435	310	19
	150	310	250	17
	205	180	130	27
	260	75	60	55
	315	50	40	75
	370	35	30	100
3003 – O	-195	230	60	46
3203 – O	-80	140	50	42
	-30	115	45	41
	25	110	40	40
	100	90	40	43
	150	75	35	47
	205	60	30	60
	260	40	25	65
	315	30	15	70
	370	20	10	70
3003 – H14	-195	240	170	30
3203 – H14	-80	165	150	18
	-30	150	145	16
	25	150	145	16
	100	145	130	16
	150	125	110	16
	205	95	60	20
	260	50	30	60
	315	30	15	70
	370	20	10	70
3003 – H18	-195	285	230	23
3203 – H18	-80	220	200	11
	-30	205	195	10
	25	200	185	10
	100	180	145	10
	150	160	110	11
	205	95	60	18
	260	50	30	60
	315	30	15	70
	370	20	10	70
3004 – O	-195	290	90	38
	-80	195	75	30
	-30	180	70	26
	25	180	70	25

Alloy and Temper	Temperature	Tensile Strength (MPa)		Elongation in 50mm
	(°C)	Ultimate	Yield[2]	(%)
	100	180	70	25
	150	150	70	35
	205	95	65	55
	260	70	50	70
	315	50	35	80
	370	35	20	90
3004 – H34	-195	360	235	26
	-80	260	205	16
	-30	250	200	13
	25	240	200	12
	100	235	200	13
	150	195	170	22
	205	145	105	35
	260	85	50	55
	315	50	35	80
	370	35	20	90
3004 – H38	-195	400	295	20
	-80	305	260	10
	-30	290	250	7
	25	285	250	6
	1000	275	250	7
	150	215	185	15
	205	150	105	30
	260	95	50	50
	315	50	35	80
	370	35	20	90
5050A – O	-195	255	70	
	-80	150	60	
	-30	145	55	
	25	145	55	
	100	145	55	
	150	130	55	
	205	95	50	
	260	60	40	
	315	40	30	
	370	25	20	
5050A – H34	-195	305	205	
	-80	205	170	
	-30	195	165	
	25	195	165	
	100	195	165	
	150	170	150	
	205	95	50	
	260	60	40	
	315	40	30	
	370	25	20	
5050A – H38	-195	315	250	
	-80	235	205	

Alloy and Temper	Temperature	Tensile Strength (MPa)		Elongation in 50mm
	(°C)	Ultimate	Yield[2]	(%)
	-30	220	200	
	25	220	200	
	100	215	200	
	150	185	170	
	205	95	50	
	260	60	40	
	315	40	30	
	370	25	20	
5052 – O	-195	305	110	46
5251 – O	-80	200	90	35
	-30	195	90	32
	25	195	90	30
	100	195	90	36
	150	160	90	50
	205	115	75	60
	260	85	50	80
	315	50	40	110
	370	35	20	130
5052 – H34	-195	380	250	28
5251 – H34	-80	275	220	21
	-30	260	215	18
	25	260	215	16
	100	260	215	18
	150	205	185	27
	205	165	105	45
	260	85	50	80
	315	50	40	110
	370	35	20	130
5052 – H38	-195	415	305	25
5251 – H38	-80	305	260	18
	-30	290	255	15
	25	290	255	14
	100	275	250	16
	150	235	195	24
	205	175	105	45
	260	85	50	80
	315	50	40	110
	370	35	20	130
5154A – O	-195	360	130	46
	-80	250	115	35
	-30	240	115	32
	25	240	115	30
	100	240	115	36
	150	200	110	50
	205	150	105	60
	260	115	75	80
	315	75	50	110
	370	40	30	130

Alloy and Temper	Temperature (°C)	Tensile Strength (MPa) Ultimate	Yield[2]	Elongation in 50mm (%)
5454 – O	-195	370	130	39
	-80	255	115	30
	-30	250	115	27
	25	250	115	25
	100	250	115	31
	150	200	110	50
	205	150	105	60
	260	115	75	80
	315	75	50	110
	370	40	30	130
5454 – H32	-195	405	250	32
	-80	290	215	23
	-30	285	205	20
	25	275	205	18
	100	270	200	20
	150	220	180	37
	205	170	130	458
	260	115	75	80
	315	75	50	110
	370	40	30	130
5454 – H34	-195	435	285	30
	-80	315	250	21
	-30	305	240	18
	25	305	240	16
	100	295	235	18
	150	235	195	32
	205	180	130	45
	260	115	75	80
	315	75	50	110
	370	40	30	130
5083 – O	-195	405	165	36
	-80	295	145	30
	-30	290	145	27
	25	290	145	25
	100	275	145	36
	150	215	130	50
	205	150	115	60
	260	115	75	80
	315	75	50	110
	370	40	30	130
5086 – O	-195	380	130	46
	-80	270	115	35
	-30	260	115	32
	25	260	115	30
	100	260	115	36
	150	200	110	50
	205	150	105	60
	260	115	75	80

Alloy and Temper	Temperature	Tensile Strength (MPa)		Elongation in 50mm
	(°C)	Ultimate	Yield[2]	(%)
	315	75	50	110
	370	40	30	130
6351 – T5	-195	405	325	17
	-80	350	305	10
	-30	330	295	11
	25	310	285	11
	100	285	270	12
	150	170	150	18
	205	65	50	35
6351 – T6	-195	435	365	14
	-80	370	330	10
	-30	350	325	10
	25	330	310	11
	100	295	290	12
	150	185	165	18
6061 – T6	-195	415	325	22
-T651	-80	340	290	18
	-30	325	285	17
	25	310	275	17
	100	290	260	18
	150	235	215	20
	205	130	105	28
	260	50	35	60
	315	30	20	85
	370	20	10	95
6262 – T91	-195	445	390	14
	-80	375	340	10
	-30	360	325	10
	25	350	320	10
	100	320	305	10
	150	230	215	14
	205	90	75	34
6063 – T1	-195	235	110	44
	-80	180	105	36
	-30	165	95	34
	25	150	90	33
	100	150	95	18
	150	145	105	20
	205	60	45	40
	260	30	25	75
	315	20	15	80
	370	15	15	105
6063 – T5	-195	290	200	28
	-80	235	185	24
	-30	230	185	23
	25	220	180	22
	100	195	170	18
	150	160	150	20

Alloy and Temper	Temperature	Tensile Strength (MPa)		Elongation in 50mm
	(°C)	Ultimate	Yield[2]	(%)
	205	60	45	40
	260	30	25	75
	315	20	15	80
	370	15	15	105
6063 – T6	-195	325	250	24
	-80	260	230	20
	-30	250	220	19
	25	240	215	18
	100	215	195	15
	150	145	140	20
	205	60	45	40
	260	30	25	75
	315	25	15	80
	370	15	15	105

Footnotes

[1] These data are based on a limited amount of testing and represent the lowest strength during 10,000 hours of exposure at testing temperature under no load; stress applied at 34.5 MPa/minute to yield strength and then at strain rate of 0.05 mm/minute to failure. Under some conditions of temperature and time, the application of heat will adversely affect certain other properties of some alloys.

[2] Offset = 0.2%.

Wrought Products – Typical Heat Treatments

Table 21: Typical Annealing Conditions for Aluminium Alloy Mill Products

(Annealing to 0 Temper from Any Other Temper)

Alloy	Metal Temperature (°C)	Time at Temperature[1] (Hours)
1050,1080A,**1100, 1145,1150,1200, 1350**	350	0.5-2
1119	300	0.5-2
2011,2014,2024	410	2—3
3003	410	0.5-2
3004,3005	350	0.5-2
3203	410	0.5-2
4043,4047,4343 4543	350	0.5-2
5005	350	0.5-2
5005A,5052,5056 5083,5086,5154A 5251, 5356, 5454 5457, 5556, 5557	350	0.5-2
6005A, 6060, 6061 6063, 6082	410	2—3
6101	410	2—3
6106, 6201A, 6261 6262, 6351, 6463A	410	2—3

Footnotes

[1] For those alloys where time at temperature is shown as 0.5-2 hours, the time need not be longer than that required to bring all parts of the load to the annealing temperature.

[2] Rate of cooling is unimportant.

[3] Controlled cooling is required to remove the effect of solution treatment. A maximum cooling rate of 20°C per hour must be maintained until a temperature of about 290°C is reached. Below this temperature the rate for cooling is unimportant. To remove the effects of cold work, or to partially remove the effects of heat treatment, heating at 345°C for 2-3 hours followed by uncontrolled cooling, is sufficient.

Table 22: Typical Solution Heat Treatments and Age Hardening Treatments for Aluminium Alloy Mill Products

Alloy And Temper	Solution Treatment Temperature[123] (°C)	Aging Temperature (°C)	Time
2011,2014 2024 – T42	525	Ambient	5 Days
2011 - T62	505	160	14 Hours
2014 – T62	505	160	18 Hours
2024 - T62	495	190	9 Hours
6005A,6060, 6061,6063, 6082,6106, 6262,6253, 6261,6262, 6351 – T42	520	Ambient	5 Days
6005A,6060, 6061,6063, 6082,6101 6106,6261 6262,6351 - T62	520	175	8 Hours

Footnotes

[1] The required time at temperature depends on the thickness of the product.

[2] Material should be quenched from the solution treatment temperature as rapidly as possible and with minimum delay after removal from the furnace. Unless otherwise indicated, when material is quenched by total immersion in water, the water should be at ambient temperature and be suitably cooled, or of such volume so as to remain below 37°C during the whole quench cycle.

[3] The nominal metal temperatures should be attained as rapidly as possible and be maintained within ±5°C during the time at nominal temperature.

Relevant Standards and References

AS/NZS 1734 Aluminium and aluminium alloys – Flat sheet, coiled sheet and plate

AS 2848.1 Aluminium and aluminium alloys – Compositions and designations

AS/NZS 1665 Welding of aluminium structures

AS/NZS 1664 Aluminium structures

Aluminum Standards and Data (2017 Metric SI) – (published by the Aluminum Association (USA))

Welding Aluminum: Theory and Practice – (published by the Aluminum Association (USA))

Aluminium Standards, Data and Design – Wrought Products – (Published by the Australian Aluminium Council but now out of print)

Appendix I

Recycling Aluminium

Aluminium can be recycled again and again, almost infinitely, making it an incredibly sustainable material. Around 75% of the almost 1.5 billion tonnes of aluminium ever produced is still in productive use today as it can be recycled endlessly. Aluminium's life cycle provides significant benefits through recycling, saving 95% of the energy it would take to make primary aluminium metal. Every year, more than 30 million tonnes of aluminium scrap is recycled globally, ensuring its status as one of the most recycled materials on the planet[1].

The global Recycling Efficiency Rate (RER) of aluminium is currently 76%[2]. The RER defines how efficiently aluminium is recycled throughout the value chain. It is an indicator used to estimate the amount of recycled aluminium produced annually from scrap, as a percentage of the total amount of available scrap sources. This rate includes collection, processing and melting losses, but internal scrap is not included.

Global Demand

Aluminium is one of the commodities most widely used in the global transition to a clean energy future[3]. It is also recognised for its importance to both economic development and low emissions transition. Aluminium use is highly correlated with GDP, so as countries urbanise, per capita use of aluminium increases. It is expected that by 2050, global demand for aluminium is expected to nearly double. While an increasing proportion will be met through recycled aluminium, there will still be increased production of primary aluminium requiring a comparable increase in global bauxite mining and alumina refining rates.

Aluminium scrap is sourced from a wide array of consumer, commercial and industrial sources that include electronic items and wiring, beverage drink containers, motor vehicles, aviation and marine industry, as well as numerous other manufactured man-made goods. In fact, anywhere these metals are being or have been used they provide a point source of supply for recycling and reuse.

Types of Scrap

There are generally considered to be three categories of aluminium scrap:

1. Pre-consumer[4] scrap is surplus material that arises during the manufacture and fabrication of aluminium products, up to the point where they are post-consumer to the final consumer. For example, offcuts of aluminium sheet or extrusions are considered pre-consumer scrap. Sometimes, this pre-consumer scrap can be safely recycled by aluminium smelters as its composition is known.
2. Post-Consumer scrap is material that has been used by the consumer and subsequently discarded. For example, used beverage cans, window frames, electrical cabling and car cylinder heads are all considered post-consumer scrap. Aluminium smelters are generally unable to safely accept this post-consumer scrap as its composition is usually unknown and it can be contaminated.

[1] https://international-aluminium.org/work_areas/recycling/
[2] https://international-aluminium.org/resource/aluminium-recycling-fact-sheet/
[3] https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action
[4] Sometimes pre consumer scrap is known as new scrap.

3. Internal Scrap is scrap which internal scrap, that is scrap which is pre consumer and is remelted in the same company where it was generated.

Global Collaboration

The Council, as part of the International Aluminium Institute (IAI), contributes to the global effort to increase aluminium recycling rates and improve sustainability as well as enhancing transparency for products using aluminium scrap.

The IAI has published a range of papers on recycling including:

- Reference Document on Carbon Footprint Calculations of Aluminium Scrap; and
- Guidelines on Transparency – Aluminium Scrap.

For more information visit the International Aluminium Institute[5].

Australia's Current Aluminium Recycling Capability

However, despite having an integrated primary aluminium sector, the closure of Australia's car industry a decade ago was accompanied by a closure in the two aluminium rolling mills[6] which also provided aluminium remelt capabilities. Australia has lost this manufacturing capability.

As aluminium smelters cannot safely accept general contaminated scrap, specialist metal recyclers currently collect and export both pre and post-consumer scrap for recycling. There are currently some small scale recycling initiatives within the domestic industry:

- Boyne Smelters Limited (BSL) recycles around 156 million aluminium cans[7] every year and is Australia's largest aluminium can recycling facility. BSL took part in Australia's first Circular Economy Lab in 2019 – a Queensland Government initiative designed to launch innovative projects. One of the outcomes is a collaboration between BSL and Container Exchange which runs Queensland's Containers for Change scheme. Through this partnership, BSL is exploring ways to recycle even more of Queensland's aluminium cans. This would reduce aluminium cans sent offshore for recycling and, in doing so, retain value in Queensland.
- In 2022, Capral Aluminium and Tomago Aluminium[8], announced a partnership to remelt 550 tonnes of pre consumer scrap annually. This industry leading arrangement is the first of its kind within Australia. Pre consumer scrap offers an entry point into increased recycled content for Australian manufacturers.
- It is challenging for primary producers to ensure scrap re-processing is commercially viable due to supply chain/logistics costs as well as scrap recovery rates when remelting. However, within the existing industry, pre consumer scrap offers a simpler, more cost-efficient feedstock for recycled billet product and may offer an initial entry point into increased recycled content for Australian supply chains and the industry is exploring this further in 2023.

[5] https://www.international-aluminium.org/
[6] https://news.alcoa.com/press-releases/press-release-details/2014/Alcoa-to-Close-Point-Henry-Aluminum-Smelter-and-Rolling-Mills-in-Australia/default.aspx
[7] https://www.riotinto.com/en/operations/australia/boyne-smelters-ltd
[8] https://www.capral.com.au/blog/news/capral-and-tomago-aluminium-agreement-to-local-aluminium-remelting/

Currently all of Australia's recyclers of aluminium export their scrap. None of the largest companies including Sims Metal Management and Infrabuild Recycling have any local remelting capability, rather they send their scrap offshore to end users. More than 95% of Australia's scrap aluminium is exported for recycling. The major buyers are in South Korea and Indonesia. Other main markets include European countries and India.

Australia's Potential Recycling Capability

Recent work[9] undertaken by the Council in conjunction with Deloitte and Coreo found that significant opportunities in manufacturing and recycling can be unlocked by cross-value chain coordination, including with Government and its agencies. There are clear opportunities for value-added manufacturing enabled by the existing integrated aluminium industry. This includes an opportunity for Australia to redevelop its recycling capability as part of an integrated circular industry policy**Error! Bookmark not defined.**. This new manufacturing capability would fit with Australia's need to transition some regional economies, providing the potential for a new manufacturing base not linked to the location of a mineral deposit. This would cut across multiple commodities as well as a circular industry approach to the development of Australia's emerging clean energy industries, where these could be established with circularity in their design. The work identified two flagship projects which the Council believes would present a different approach to industry policy, two of which are relevant to Australia's future capability in a circular economy.

1. Increase recycling capacity - Global demand for recycled aluminium is growing rapidly, driven by emerging minimum content requirements from governments and corporate demand for low carbon products. A circular industry policy could lower cost and risk for domestic pre- and post-consumer scrap reprocessing.
2. A closed-loop mine-to-panel solar value chain - Aluminium is the second largest input by weight, and domestic extruders already have the capability to produce frame and rail for the sector. Solar panels, and other new renewable manufacturing should be designed with recyclability in their design.

[9] https://aluminium.org.au/news/aac-deloitte-and-coreo-cast-anew-project/