Aluminium Data – Ingots and Castings

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The Australian Aluminium Council Limited

The Australian Aluminium Council (AAC)is the peak industry association representing the Australian aluminium industry. The AAC's members are the companies operating in each of the following sectors:

- Bauxite exploration
- Bauxite mining
- Alumina refining
- Aluminium metal production
- High Purity Alumina (HPA) production
- Semi-fabricated aluminium production and distribution

The AAC aims to:

- Increase understanding of the aluminium industry in Australia and internationally
- Encourage the growth of the aluminium industry in Australia and the use of aluminium in Australia and overseas
- Act as a focal point for the industry on key national issues such as climate change, trade, health and the environment
- Inform and assist all those with an interest or involvement within the industry

The AAC develops and maintains material specifications, standards, and other technical data for users both within and outside the industry.

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Introduction

This edition of the Ingots and Casting manual presents data on the mechanical, chemical, physical, and other properties of aluminium casting alloys in ingot form and castings in general use in Australia.

The manual also contains information on the general characteristics of aluminium and its alloys, alloy and temper designation systems, and metallurgical aspects of casting alloys, together with general data on handling, storing, sampling, and testing.

Related Australian Standards

AS 1874 – Aluminium and Aluminium Alloys – Ingots and Castings

Abbreviations and Symbols

AAC	Australian Aluminium Council	Kg	kilogram
AS	Australian Standard	m	metre
ASTM	American Society for Testing and Materials	mm	millimetre
BS	British Standards Institution or British Standard	max	maximum
°C	Degrees Celsius	min	minimum
HB	Hardness, Brinell Scale	MPa	megapascal
HRB	Hardness, Brinell Scale	Rem	remainder
HV	Hardness Vickers Scale	Typ.	typical
Hr	Hour	ult	ultimate
IACS	International Annealed Copper Standard	W	watts
J.I.S.	Japanese Industrial Standards or Japanese Standards Association	SI	International System of Units
K	Kelvin		

Definition of Terms

The following basic terms are used in the text and the tables presented in this publication. Since a complete understanding of these terms will enhance the usefulness of the information presented, accepted definitions of these terms are included.

Castability
An arbitrary measure of the ease of casting a material. Similar terms are fluidity and mould filling capacity.

Compressive Yield
Compressive Yield is the compressive stress that produces a specified permanent deformation in a material. In aluminium alloys, the value of permanent deformation is taken as 0.2 percent of the initial gauge length, the same as the tensile yield.

Corrosion Resistance
The resistance to loss of volume, strength and sensitivity to exposure to specific reagents. The net effect can be both functional and/or aesthetic.

Density
Mass of material per unit volume. SI units kg/m^3.

Electrical Conductivity
Electrical Conductivity is the capacity of a material to conduct a flow of an electric current. Conductivity values for aluminium are expressed as percentages of the conductivity of the International Annealed Copper Standard (IACS), which has a resistivity of 1.7241* microhm-cm at 20°C
(*ref. P10 Copper wire tables: United States. National Bureau of Standards: Free Download, Borrow, and Streaming: Internet Archive)

Electrical Resistivity
Electrical resistivity is the electrical resistance of a body of unit length and unit cross-sectional area. The value of 0.017241 microhm-metre at 20°C is the resistivity equivalent to the IACS for 100 percent conductivity.

Elongation
Elongation is the increase in distance between two gauge marks. The original gauge length is usually 50 mm for flat specimens or 5.65 times the square root of the cross-sectional area for round specimens. Elongation values depend to some extent upon the size and form of the test specimens. For example, the values obtained from flat specimens will be lower for thin than for thick material.

Endurance Limit
Endurance Limit (Fatigue Strength) is the limiting stress below which a material will withstand a large number of alternating stress cycles. In the case of aluminium alloys, endurance limits are based on 5,000,000,000 cycles of complete stress reversals, using the rotating-beam type of machine and specimen.

Eutectic
A mixture of two or more substances has a minimum melting point, e.g., the Al-Si eutectic point is approximately 12.6% Si.

Fluidity
The ease with which a material in liquid form will flow into and fill a mould.

Freezing Range
The temperature range over which an alloy solidifies is defined by the difference between the liquidus and solidus temperatures in the alloy system phase diagram.

Grain Refinement
Techniques involving minor alloy additions and melting practice facilitate the inoculation of uniform fine grains throughout the cast structure. They are typically used in slower cooling rate casting processes.

Hardness
Hardness measures resistance to plastic deformation by indentation or penetration. Standard scales used for aluminium alloys are the Brinall (HB), Vickers (HV), and Rockwell B (HRB) scales.

Hot Shortness
A term for metals that tend to be brittle when hot worked or that separate by cracking during solidification, sometimes called contraction cracking.

Hypereutectic
Alloys have a composition higher than the eutectic composition - e.g. Al-Si alloys with >12.6% Si.

Hypoeutectic
Alloys with a lower composition than the eutectic composition - e.g., Al-Si alloys with <12.6% Si.

Metal Matrix Composite
The addition of non-metallic particles, fibres, or reinforcement to a metal with the aim of improving stiffness, strength, or wear resistance.

Modification
Change of eutectic silicon morphology from acicular to fibrous.

Modulus of Elasticity
The modulus of Elasticity is the ratio of stress to corresponding strain throughout the range, which is proportional in an elastic material. As there are three kinds of stresses, there are three kinds of moduli of elasticity for any material – modulus in tension, in compression and there are three kinds of elasticity for any material: modulus in tension, compression, and shear.

Modulus of Rigidity
Modulus of Rigidity is the same as modulus of elasticity in shear.

Morphology
Relating to the shape of particles in a microstructure.

Pressure Tightness
A casting section can maintain pressure without leaking. A measure of the degree of soundness.

Shear Strength
Shear strength is the maximum shearing stress that a material is capable of developing under shear load. In practice, it is considered the maximum average stress calculated by dividing the ultimate

load in the plane of shear by the original area subject to shear. Shear strength is usually determined by inserting a cylindrical specimen through round holes in three hardened steel blocks, the centre of which is pulled (or pushed) between the other two to shear the specimen on two planes. The maximum load divided by the combined cross-sectional area of the two planes is the shear strength.

Strain
Strain measures the change in size or shape of a body due to force, referenced to its original size or shape. Tensile or compressive strain is the change, due to force, per unit length in an original linear dimension in the direction of the force. It is usually measured as the change (in mm) per mm length.

Stress
Stress is the intensity of the force within a loaded body that resists a change in shape. It is measured in megapascals (MPa). Stress is normally calculated on the basis of the original cross-section dimensions. The three kinds of stresses are tensile, compressive, and shearing. Flexure or bending involves a combination of tensile and compressive stress.

Stress Corrosion
Cracking in a sensitive material caused by the simultaneous presence of tensile stresses and a specific corrosive medium.

Temper
Post casting treatment used to modify the mechanical properties of a material.

Thermal conductivity
A measure of the rate of heat flow through a material (typical units W/mk)

Ultimate Tensile Strength
Ultimate Tensile Strength is the maximum tensile stress that a material can develop under a gradual and uniformly applied strain. Tensile strength is calculated from the maximum applied load during a tensile test and the original cross-sectional area of the specimen.

Yield Strength
Yield Strength is the stress at which a material exhibits a specified permanent deformation after being strained beyond the elastic limit. The permanent deformation value used for aluminium and its alloys is 0.002 mm per mm, 0.2 percent. The term yield strength used in this publication is synonymous with the 0.2 percent proof stress used in AS and BS specifications. For aluminium alloys, the yield strength in tension and compression are approximately equal.

General Characteristics of Aluminium and its Alloys

A unique combination of properties makes aluminium one of our most versatile engineering and construction materials, And a recital of its characteristics is impressive. It is light in weight, yet some of its alloys, particularly when heat treated, have high strengths. It has high resistance to corrosion under the majority of service conditions and no coloured salts are formed to stain adjacent surfaces or discolour products with which it comes into contact, such as fabrics in the textile industry and solutions in chemical equipment. It has good electrical and thermal conductivities and high reflectivity to both heat and light. The metal can be easily cast into any form and readily accepts a wide variety of surface finishes.

Light weight is perhaps aluminium's best known characteristic. It has an average density of 2.70 x 10^3 kilogram per cubic metre, as compared with 7.9 x 10^3 for iron, 8.8 x 10^3 for copper and 7.1 X 10^3 for zinc. Thus, in applications where the physical volume of metal is the controlling factor, aluminium goes about three times as far as any of the preceding metals.

Commercially pure aluminium has a tensile strength of about 90 megapascal (MPa). Increases in strength can be obtained by alloying aluminium with one or more other metals such as silicon, copper, magnesium or zinc. Some of the alloys are further strengthened and hardened by heat treatments, so that aluminium alloy castings are capable of tensile strengths in excess of 300 MPa. Even higher strengths have recently become available through the use of metal - matrix composites though at the expense of ductility.

Aluminium and its alloys lose part of their strength at elevated temperatures, although some alloys retain useful strength at temperatures from 200° C to 260° C. At sub-zero temperatures, however, their strength increases, without the corresponding loss of ductility which steel suffers from, so that aluminium is a particularly useful metal for low-temperature applications.

Aluminium has a high resistance to corrosion because a thin transparent oxide film that forms immediately and protects the metal from further oxidation. Unless exposed to some substance or condition which destroys this protective oxide coating, the metal remains generally protected against corrosion. Aluminium is highly resistant to weathering, even in industrial atmospheres which often corrode other metals. It is also resistant to corrosive attack by many acids. The metal can safely be used in the presence of certain mild alkalis with the aid of inhibitors, but general contact with alkaline substances should be avoided as these attack the oxide skin and are therefore corrosive to aluminium. These desirable characteristics of aluminium are transmitted to the casting alloys in varying degrees - see Table 7: Relative Ratings.

In accordance with sound design principles, direct contact with certain other metals should be avoided in the presence of an electrolyte as galvanic corrosion of the aluminium may take place in the vicinity of the contact area. Several well-established preventative measures, such as the use of bituminous paint coatings or insulating tape at the contact points, can be applied. Aluminium can also be used to sacrificially protect structures such as oil rigs where use is made of its tendency to corrode in preference to the materials to which it is connected.

The fact that under normal conditions aluminium poses no known health risks was discovered in the early days of the industry. It is this characteristic which enables the metal to be used in cooking utensils without any harmful effect on the body and today a great deal of aluminium equipment is used by the food processing industries. The same characteristic permits aluminium foil wrapping to be used safely in direct contact with food products.

Aluminium is one of the two most common metals having an electrical conductivity high enough for use as an electrical conductor. The conductivity of electrical-conductor grade is about 62 percent that of the International Annealed Copper Standard. Because aluminium has less than one-third the density of copper, an aluminium conductor has twice the current carrying capacity of an equivalent weight of copper.

The high thermal conductivity of aluminium, again about twice that of copper on an equivalent weight basis, came prominently into play in the first large scale commercial application of the metal in cooking utensils. This characteristic is important in heat exchange applications where the transfer of thermal energy from one medium to another is involved, either heating or cooling. Uses include:

- aluminium heat exchangers, which are common in the food, chemical, petroleum, aircraft, automobile and other industries
- electrically heated appliances and utensils; and
- automobile cylinder heads and blocks for internal combustion engines.

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

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

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

The metal can be cast by all current foundry techniques. The low density and low melting temperature of aluminium combine to practically eliminate the problem of sand washes which are common in the founding of ferrous metals. Similarly lower mould pressures, more lightly rammed moulds and generally lighter moulding equipment can be used when casting aluminium alloys. Castings are used for products with intricate contours and hollowed or cored areas.

Choice of castings over other product forms is usually based on lower final part cost rather than on mechanical properties. Few castings have mechanical properties equal to those of a wrought alloy of similar composition. Thicker sections and more intricate designs are used to compensate for the lower mechanical properties. Reinforcing ribs, internal passageways, bosses and other complex design features which would be costly to machine in a part made from a wrought alloy can be cast in place by appropriate machining of the pattern or die.

The high strength to weight ratio and ease of casting have led to the increasing use of cast aluminium products such as aluminium wheels, cylinder heads and blocks and suspension components in the automotive industry.

The ease and speed with which aluminium may be machined is one of the important factors contributing to the low cost of finished aluminium parts. The metal may be turned, milled, bored or machined in other manners at high surface speeds generating a fine surface finish with excellent machining economics.

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

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

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

Many applications require the extreme versatility of aluminium. Almost every day its unique combination of properties is being put to work in new ways.

Safe Handling and Storage of Aluminium Ingots (and scrap)

Safe handling and storage of aluminium (including ingots and scrap) should be identified as a risk in any casthouse or foundry and proper routines and control measures covering incoming control, storage, handling, furnace charging and the use of any equipment in contact with liquid aluminium must be in place and regularly monitored.

If water comes into contact with molten aluminium, it can trigger a hazardous explosion due to either a physical or chemical reaction. In a physical reaction, water rapidly turns into steam, expanding violently, potentially ejecting molten aluminium many meters in every direction. A chemical reaction can occur at high temperature when aluminium reacts with water for form aluminium oxide releasing hydrogen. This reaction is exothermic releasing both heat and energy.

In addition to water and moisture hazard, aluminium must be free from contaminants such as alkalis, nitrates, phosphates and acids as these also pose an explosion hazard.

Controls should be in place to eliminate potential sources of moisture including the presence of closed containers, crimped pipes or tubes (particular care should be taken with baled scrap), condensation on cold metal, the presence of shrinkage voids in ingots or sows, rain or water ingress in buildings/store locations, the risk of using wet or moist tools/equipment (including launders, sampling equipment, casting moulds etc) that may come in contact with molten aluminium. Aluminium should be charged in a completely dry condition.

Storing aluminium

Aluminium should be stored in a clean and dry location. Away from all other materials. Care should be taken to avoid contamination from other items that might enter a casthouse/foundry or otherwise come into the raw materials (including other metals or items such as beverage cans or bottles).

Care should be taken in consideration of condensation, for example where ingots are packaged with plastic wrap, this should be removed, and consideration of temperature differences between storage and furnace charging areas where condensation can occur.

Although aluminium is to be remelted, excessive corrosion or contamination from dust and other items should be avoided, such contamination may give rise to non-metallic inclusions.

Following is a Material Safety Data Sheet which is available from the remelt ingot producers: -

MATERIAL SAFETY DATA SHEET: Ingot producer company details.

SECTION 1 – MATERIAL IDENTIFICATION

Material Name: Aluminium Metal Formula: Al
Description: Remelt Ingot

SECTION 2 – INGREDIENTS AND HAZARDS

Material or components	*CAS No.*	*% by weight Aluminium*	*Hazard Data*
Aluminium Al	7429-90-5	80% Nominal -99.999%	Non-toxic under normal conditions of use.

Alloying and trace elements, such as:

Silicon (Si)	7440-21-3
Iron (Fe)	7439-89-6
Copper (Cu)	7440-50-8
Manganese (Mn)	7439-96-5
Chromium (Cr)	7440-47-3
Zinc (Zn)	7440-66-6
Tin (Sn)	7440-31-5
Nickel (Ni)	7440-02-0
Titanium (Ti)	7440-32-6
Strontium (Sr)	7440-24-6
Boron (B)	7440-42-8
Beryllium (Be)	7440-04-17

For further information see References.

SECTION 3 – PHYSICAL DATA

Appearance and Odour:	Silver coloured, ductile metal with no odour.
Solubility in water:	Insoluble.
Vapour Density (air=1)	Not applicable.
Vapour Pressure: (mm/Hg at 1248 °C)	1
Boiling Point: (°C)	2467
Specific Gravity: (water=1)	2.7
Melting Point Range: (°C) (depending on alloy composition)	480-660

SECTION 4 – FIRE AND EXPLOSION DATA

Flashpoint and Method:	None in normal use.
Autoignition Temperature:	Not applicable.
Decomposition Temperature:	Not applicable.
Flammability Limits (in air):	Not applicable.
Extinguishing Media:	Dry Sand Dry Chemical Powder.

Under normal conditions no particular hazard exists and the appropriate firefighting measures for the surrounding area should be adhered to.

Molten aluminium may explode on contact with water or moisture and may react violently with rust, certain metal oxides and nitrates. Concrete can rupture on contact with molten aluminium.

If a metal fire exists, use an appropriate **class D** fire extinguisher (**dry chemical powder**) or smother with dry sand or scrap metal.

Fire and Explosion Hazard: Finely divided aluminium is easily ignited when it forms an air suspension and may present an explosion hazard if exposed to temperatures above 650 °C. Aluminium metal may lose structural strength when subjected to fire and will melt to a hazardous liquid at temperatures in the range of 480 to 660 oC. The exact melting point is dependent on the alloy involved.

Remelt aluminium ingot and scrap will sometimes contain shrinkage cracks and sub-surface cavities, which may accumulate water during transit or storage. Under certain weather conditions, condensation can form on metal surfaces and/or plastic wraps. As a safety precaution, remove any surface contaminants and preheat the remelt material thoroughly. Failure to completely remove all contained moisture may result in a violent explosion when the material is immersed in molten metal.

SECTION 5 – REACTIVITY DATA.

The material is stable under normal conditions of use, storage and transportation.
For finely divided aluminium, e.g. as a powder:

With water:	Generates hydrogen and heats slowly. Water/Aluminium mixtures may be hazardous when confined.
With Heat:	Can burn or explode in air if exposed to temperatures above 650 °C. If metal is subject to temperatures above 850 °C a violent explosive reaction is possible.
With strong oxidisers:	Violent reaction with much heat generation.
With acid and alkalis:	Reacts to generate hydrogen.
With halogenated compounds:	Halogenated compounds can react violently with finely divided aluminium.

Some aluminium alloys react readily with air to form hydrated surface oxidation compounds which can explosively dehydrate at temperatures above 650 °C.

SECTION 6 – HEALTH HAZARD INFORMATION

Aluminium metal in most forms is non-toxic. It is not readily absorbed through the skin or gastrointestinal tract and only poorly through the lungs.

Repeated inhalation of massive levels of fine aluminium powder may cause pulmonary fibrosis and emphysema. Aluminium powders can be irritating to the eyes and respiratory system. Aluminium is defined as a nuisance dust by the American Conference of Government Industrial Hygienists (ACGIH).

FUMES: Fumes of certain alloying elements contained in molten aluminium may result in upper respiratory irritation.

DUST & FINES:

Eye Contact:	Flush well under running water. If irritation develops consult a physician.
Inhalation:	If irritation or pulmonary symptoms develop, consult a physician.
Skin Contact:	Flush with water, wash with soap and water. If irritation persists, consult a physician.

BURNS: In the case of burns caused by molten aluminium flush thoroughly with cold water and seek medical attention.
Note: Excessive exposure to cold water following a burn can lead to hypothermia.

SECTION 7 –SPILL, LEAK AND DISPOSAL PROCEDURES

SPILL:	Avoid contact with skin and eyes. Wear protective clothing and heat resistant gloves. Contain spill with sand, earth or vermiculite. DO NOT attempt to arrest the flow of molten aluminium with shovels or hand tools. Handle molten aluminium metal to minimise exposure risk to personnel in accordance with the Aluminum Association's "Guidelines for Handling Molten Aluminium".
NEUTRALISING CHEMICALS:	N/A
DISPOSAL:	Recovered material may be recycled and remelted as scrap.

SECTION 8 – SPECIAL PROTECTION INFORMATION

Ventilation requirements: As necessary to meet all T.L.V requirements.

These are:	Aluminium metal and oxide	- Total dust	- 10mg/m3 (TWA)
		- Respirable dust	- 5mg/m3 (TWA)
	Pyro powders and welding fume		- 5mg/m3 (TWA)
	Copper fume		- 0.2mg/m3 (TWA)

Where the exposure limit may be exceeded, use the appropriate respirator.

When handling molten aluminium, it is essential to protect eyes and skin from direct contact. Exposed skin may be at risk from burns due to radiant heat.

Eyes:	Safety Glasses or preferably a full-face mask.
Hands:	Heat resistant gloves.
Feet:	Safety boots or shoes.
Other clothing & equipment:	Follow the Aluminum Association's "Guidelines for Handling Molten Aluminum".

SECTION 9 – STORAGE, HANDLING, MELTING AND SPECIAL PRECAUTIONS.

Store away from strong alkalis, halogens, oxidising agents and chlorinated hydrocarbons.
Prevent contact with dilute hydrochloric acid, sulphuric acid, potassium and sodium hydroxides. It is good practice to assume all remelt ingot or melting scrap is wet and must be dried prior to use.
The following minimum guidelines for melting are recommended:

1. Inspect all remelt ingots prior to furnace charging and remove surface contamination, such as water, ice, snow, paint, dirt, rust, deposits of grease and oil, or other surface contaminants resulting from shipment or storage.

2. Store ingots in dry, heated areas to prevent moisture or contaminants from ingressing into cracks or cavities if stored outside.
3. Preheat and dry the ingot adequately before charging it into a furnace. This is typically done using ovens, homogenising furnaces, gas flames, or placing the ingot on furnace sills, if they are suitable for that purpose. Ensure there is no evidence of moisture on the preheated ingot before charging it fully into melt.
4. Perform the furnace charging sequence in such a way that full submersion of remelt ingots in molten aluminium is avoided to prevent entrapment of moisture beneath molten metal. Handle molten aluminium according to the Aluminum Association's *"Guidelines for Handling Molten Aluminum"*.

SECTION 10 – REFERENCES

Guidelines for Handling Molten Aluminum | The Aluminum Association

CAS Registry Services℠ | CAS

Sampling and Testing

Ingots

Aluminium ingots for remelting are sampled and tested by the manufacturer to determine conformance to the limits for chemical composition. Testing for mechanical and physical properties is not normally carried out by the ingot manufacturer unless specified by the customer.

Sampling for Chemical Analysis: Ingots

The accepted practice is to take duplicate samples in the form of chill cast discs, from the beginning, middle and end of pour for each group of ingots poured from the same source of molten metal. Ingots conforming to the chemical composition are identified by cast number and alloy. Non-conforming product is brought into specification prior to pouring.

Castings

For certain specification purposes the mechanical properties of aluminium casting alloys are based on tests of individually cast specimens, having a test section as set out below.
The test bar casting is designed to provide optimum reproducibility of results and to reflect such changes in chemical composition, metal treatment practices, or heat treatment processes as may have occurred in the production process.
However, the properties of separately cast test bars do not necessarily represent the properties that are provided by castings.

The mechanical properties listed may be determined using test bars produced as follows:

1. **Permanent Mould Casting Alloys:**
   Standard 12.5mm diameter test specimens, with or without machining, each cast in a gravity mould. (see Footnote 1)
   Figs. 1 and 3 (a) and (b) illustrate details of castings for fully machined tensile test pieces. A cast-to-shape tensile test piece shall be produced in a mould whose design is the responsibility of the supplier, provided that the dimensional requirements of Footnote 1 are satisfied.
2. **Pressure Die Casting Alloys:**
   Standard 6.4mm diameter test specimens, cast in a cold chamber (high pressure) die casting machine. (See Footnote 2) (Note: Minimum properties are not listed for die casting alloys. Typical properties only are listed.)
3. **Sand Casting Alloys:**
   Standard 12.5mm diameter test specimens with or without machining, each cast in a sand mould. (See Footnote 1)
   Figs. 1 and 2 illustrate details of castings for fully machined tensile pieces. A cast-to-shape tensile test piece shall be produced in a mould whose design is the responsibility of the supplier, provided that the dimensional requirements of Footnote 1 are satisfied.
4. **Investment Castings:**
   Standard samples prepared in accordance with AS1391, ASTM E8M or ASTM B557 may be prepared either machined or as-cast. Alloys are typically the same as permanent mold cast and sand cast compositions. Required properties typically align with sand castings, although different specification may have different requirements.

Test Methods

The latest issues of the following recognised specifications are used where applicable.

Sampling and Sample Preparation

ASTM E716

Sampling and Sample Preparation of Aluminum and Aluminum Alloys for Determination of Chemical Composition by Spectrochemical Analysis

AS 2612:1997

Aluminium and aluminium alloys — Sampling for chemical and spectrochemical analysis

Chemical Analysis

ASTM E1251

Methods for Emission
Spectrochemical Analysis of Aluminium and Aluminium Alloys, or

ASTM E34

Methods for Chemical Analysis of Aluminium and Aluminium Base Alloys.

AS 2883

Procedures for the Setting Up, Calibration and Standardisation of Atomic Emission Spectrometers

Tension

ASTM E8/E8M

Methods of Tension Testing of metallic Materials.

ISO 6892-1 Tensile Testing of Materials
AS 1391: Tensile Testing of Metals.
ASTM B557: Standard Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

See Footnotes.

Electrical Conductivity of Resistivity

ASTM E1004:

Method of Test for Electrical Conductivity by use of Eddy Currents.

ASTM B193

Method of Test for Resistivity of Electrical Conductor Materials

Common casting processes

Sand Casting

Sand casting is the simplest method of casting aluminium. Molten metal is poured into a sand mould under gravity or low pressure. This process has low equipment costs. It is used to cast complex shape castings requiring intricate cores or for large castings. Typically, this process is used in small production numbers; however, it can also be used for high volumes. Several sand casting processes have recently been developed referred to as "precision sand casting" processes. These have been designed for high volume production of engine blocks and cylinder heads.

Gravity Permanent Mould Casting

Castings are produced by pouring molten metal into permanent metal moulds under gravity. Moulds are coated with a ceramic mould wash. Equipment costs are low in simple shaped gravity moulds. Castings can be cored. Used in the production of medium volume castings, frequently using a tilting action (90°) cavity filled method.

Low Pressure Die Casting (LPDC)

A gas pressurised furnace forces metal into a mould, typically counter gravity to reduce metal turbulence. Pressure is maintained until the casting is solid. Yields are high as runners and risers are excluded. Castings can be cored. Tooling costs are high. Used in the production of high volumes of high quality castings.

High Pressure Die Casting

Die castings are produced by injecting molten metal under pressure e.g., 700kPa, in to a metal die. The process is used when high production rates are required. Castings produced are near net shape and require little finishing. Surface quality is high. Castings generally have high internal porosity. Equipment costs are high requiring complex machinery and tooling.

High Pressure Vacuum Die Casting (HPVDC)

Similar to Low Pressure Die casting, with the main difference a vacuum is applied to remove air and gases from the die cavity and metal delivery system prior to injecting the molten metal. The advantage over HPDC is reduced porosity allowing for HPVDC parts to be heat treated and thus achieve better mechanical properties (in particular elongation).

Squeeze Casting – Indirect

Metal is forced into a die cavity using a plunger and the casting is solidified under pressure. Production and solidification rates are high with the castings frequently used for defect free, high quality structural applications. Typical alloy grades are 601, 603 commonly with T6 or T5 heat treatment. Castings are produced at near net shape and require little finishing. Equipment costs are high requiring complex machinery and tooling. Process yield is low due to the large gate dimensions and remnant biscuit. Hard salt cores can be used.

Lost Foam Casting

An expandable styrene foam pattern, replicating the component to be produced, is attached to a running and gating system in the same foam dipped into a hard setting refractory coating. The coated pattern is then surrounded by loose sand for support using vibration compaction techniques. Molten metal is then poured directly into the foam gating system through a typical down sprue. The foam pattern volatilises into the permeable sand and is replaced by metal. Intricate and complex shapes can be produced, without cores as the consumable pattern contains all the finished part features.

Shell Moulding

Process is similar to sand casting with the exception that the mould consists of a thin shell (4-10mm) into which the metal is poured.

Plaster Mould Casting

Castings are produced by pouring metal into permeable plaster moulds. Castings have a smooth surface finish with good surface detail. Castings walls as thin as 0.5mm are possible. Slow solidification rates reduce internal stresses so that any casting distortion is negligible.

Investment Casting

A "wax pattern" is produced by injecting wax or plastic into a pattern die. The pattern is attached to gating and runner systems and this assembly is dipped in a hard setting refractory slurry. The wax pattern is melted out of the refractory mould to leave a replica of the wax pattern as a cavity. The mould is heated to cure the refractory and to volatilise the remaining pattern material. The moulds are heated and molten metal is poured into the mould cavity. When the casting is solid, the mould is broken away from the castings.

Semi Solid Processes

A number of processes have been developed in which metal is forced into a die in a semi- solid form and solidified under pressure e.g. thixomoulding and semi solid moulding. Casting quality is high, components produced are near net shape and require little finishing. Equipment costs and process complexity can be high. Perceived as equivalent to squeeze casting in mechanical properties and suited to high integrity applications.

Giga Casting

Also referred to as “Megacasting”, this process possesses the capability to combine many individual parts into a single, exceptionally large casting. This process is based on the HPVDC process, but has the ability to produce shot weights of 80-100kg compared to much smaller parts from other diecasting processes.

Alloy and Temper Designation System

Alloy Designation System

The alloy designation system consists of two letters plus three digits to identify aluminium casting alloys. In addition to this designation, a manufacturer's code may be added as a suffix to indicate that a special variance applies to the alloy.

Prefix Letters

The first letter prefix is used to indicate either the original alloy composition, prefix A., or subsequent composition variations by use of the letters B, C, D, etc., which are assigned consecutively.
The second letter prefix is used to indicate whether the alloy is, or is not structure pre-modified in accordance with Table 1 below:

TABLE 1: Second Letter Prefix

Structure Modification	Second Letter PREFIX*
NO MODIFICATION	A
SODIUM	B
STRONTIUM	C
ANTIMONY	D
PHOSPHORUS	E

* Other letters will be assigned as required

For example, AA601 is unmodified Al-Si-Mg alloy, whereas AC601 alloy may contain a trace addition of 0.005 to 0.03Sr, for example.

Aluminium and Aluminium Alloy Groups

In the three digit system the first digit indicates the alloy group as shown in Table 2. The 1XX series is for minimum aluminium purities of 99.0 percent and greater. The 2XX through 7XX series group aluminium alloys by major alloying elements. The 8XX series is reserved for "other" major alloying elements other than those concerned in the series 2XX to 7XX and the 9XX is used for hardeners and modifying ingot.

TABLE 2: Designations for Alloy Groups

Alloy	Major Alloying Elements	Alloy Number
Aluminium (99.0%) min & greater -		1XX
Aluminium alloys grouped by major alloying elements	Copper	2XX
	Copper/Silicon	3XX
	Silicon	4XX
	Magnesium	5XX
	Magnesium/Silicon	6XX
	Zinc	7XX
	Others	8XX
	Hardeners/Modifiers	9XX

Aluminium

In the 1XX group for minimum aluminium purities of 99.0 percent and greater, the last two of the three digits in the designation indicate the minimum percentage of aluminium. These digits are the same as the two digits to the right of the decimal point in the minimum aluminium percentage when it is expressed to the nearest 0.01 percent.

Aluminium Alloys

In the 2XX through 7XX alloy groups, the last two digits serve to identify the different alloys in the group. In the 9XX series the second digit identifies the major alloying element, as per the digit in the 1XX to 7XX series, and the third digit the different hardener or modifier in the group.

Manufacturer's Code

A suffix letter or a decimal point and numeral, is used to indicate that a special variance has been applied by the manufacturer of the ingot. The variance shall not conflict with the published AAC Chemical Composition Limits or footnotes thereto.
The variance is specific to the ingot manufacturer and not registered with the AAC.
NOTE: Use of the same letter by another ingot manufacturer does not imply equivalence.

Standard Limits for Alloying Elements and Impurities

Standard limits for alloying elements and impurities may be expressed to the following places: -

Less than 1/1000 percent	0.000X
1/1000 percent to 1/100 percent	0.00X
Over 1/100 percent to 1/10 percent	0.0X
(Alloys and unalloyed aluminium not made by a refining process)	
Over 1/10 percent to 1/2 percent	0.XX
Over 1/2 percent	0.X, X, X, etc.

The aluminium content for unalloyed aluminium not made by a refining process is the difference between 100.00 percent and the sum of all other metallic elements present in the amounts of 0.010 percent or more, each expressed to the second decimal place before determining the sum. See also Specification ASTM E29 (Standard Practice for Using Significant Digits in Test Data).

Temper Designation System

The temper designation system is used to describe the heat treatment practices for all aluminium alloy castings. It is based on the sequences of commonly used treatments to produce the various tempers as detailed below.

The basic temper designations are indicated by the letters "F" and "T" where

F = alloys not thermally treated
T = thermally treated.

The temper designation follows the alloy designation, the two being separated by a dash (e.g. AC603-T6).

For the F temper, guaranteed test bar properties are quoted for alloys in sand and permanent mould castings only. No guaranteed properties can be given for test bars in pressure die castings - typical properties only are quoted.

Temper Designation

F or F1	As cast - cooled naturally from the mould in room temperature air with no further heat treatment.
F2	As cast - stress relieved or annealed to improve ductility and dimensional stability. No mechanical properties quoted.
T1	As cast - naturally cooled from the mould and then naturally aged to a substantially stable condition.
T4	Solution heat treated and naturally aged to a substantially stable condition. Mechanical properties and stability may change over a long period of time.
T5	Naturally cooled from the mould and then artificially aged to attain improved mechanical properties and dimensional stability.
T6	Solution heat treated and artificially aged to attain optimum mechanical properties and generally good dimensional stability.
T7	Solution heat treated and over- aged for improved dimensional stability, but usually with some reduction from the optimum mechanical properties.

The T5, T6 and T7 designations are sometimes followed by one or more numbers which indicate changes from the originally developed treatment.

For a description of the heat treatment process also refer to Section 8, Metallurgical Aspects, Heat - Treatable Alloys. For information regarding common heat treatment practices refer to Table 5, Mechanical Properties of Test Bars.

Metallurgical Aspects

In high-purity form, aluminium is soft and ductile and has poor castability and mechanical properties. However, by adding small amounts of other elements called alloying elements, the metal's casting characteristics and mechanical properties can be vastly improved. The addition of certain elements to aluminium such as copper, produce alloys whose metallurgical structure can be altered by heat treatment with resultant improvement in mechanical properties. Based on their reaction to thermal treatment, the commercial aluminium casting alloys can be broadly classified into two categories, non-heat- treatable and heat-treatable.

Non-Heat-Treatable Alloys

The alloys that are generally regarded as non-heat-treatable depend upon the hardening effect of elements such as silicon or magnesium. Also included in this group are the die casting alloys, although many of these alloys are capable of responding to heat treatment.

Heat-Treatable Alloys

The initial strength of alloys in this group is enhanced by the addition of alloying elements such as copper, magnesium, combined additions of zinc and magnesium or magnesium and silicon. These elements, either between themselves or in conjunction with aluminium, form compounds which have limited solid solubility in aluminium at room temperature, but show increasing solubility with increasing temperature. This difference in solid solubility of the compounds at various temperatures is the characteristic that makes the alloys heat-treatable and permits a marked improvement in the mechanical properties.

In the T6 temper, the first step, called the solution heat treatment, involves heating the alloy to a pre-determined elevated temperature for a specific time to obtain the maximum concentration of the hardening solutes in solid solution. This is followed by rapid quenching, usually in warm water, to retain the solid solution formed at the solution heat treatment temperature.

At room or elevated temperature, the alloys are not stable after quenching and precipitation of the constituents from the super-saturated solution begins. After a period of several days at room temperature, termed natural ageing, the alloy exhibits a degree of age- hardening, the rate and extent of such hardening varying depending on composition.

Many alloys approach a stable condition at room temperature, but some, particularly those containing magnesium and silicon or magnesium and zinc, continue to age- harden for long periods of time at room temperature. By heating for a controlled time at a slightly elevated temperature, even further strengthening is possible and properties are stabilised. This process is called artificial ageing or precipitation hardening. By the proper combination of solution heat treatment, quenching, and artificial ageing, the highest strengths are obtained.

Pressure die castings are not normally solution heat treated, as the casting process may lead to the entrapment of gasses under pressure within the metal matrix and heating to the required temperature can cause blistering. Pressure diecastings may however be successfully heat treated if the times of solution treatment are particularly short, and the temperatures lower than would normally be used. Under these conditions blistering can be minimised or avoided. Some alloys are occasionally subjected to a low temperature T5 treatment to improve properties, relieve stresses, or to obtain increased ductility.

Effect of Alloying Elements

The elements most commonly used in casting alloys include silicon, copper, magnesium and titanium. Other elements less commonly added include manganese, zinc, nickel, chromium, tin, iron and beryllium. The individual alloying elements must be controlled to produce the desired casting characteristics and mechanical properties.

100 Series

Unalloyed aluminium of 99.0 percent or higher purity commercially available from aluminium smelters is characterised by high electrical and thermal conductivity and low mechanical properties. Iron and silicon are the main impurities. The principle applications in this form are for remelt and alloying into wrought and casting alloys, overhead electrical power cables, rotors for electrical motors, sacrificial anodes and computer discs.

200 Series

Copper is the principal alloying element. It increases the strength of alloys in both the heat treated and non-heat treated conditions. It reduces internal shrinks and improves machinability in the castings. However, copper additions make the alloy more difficult to cast due to hot shortness and decreased fluidity. Aluminium's corrosion resistance is reduced by the addition of copper. This series has been replaced by the 300 series in Australia.

300 Series

The alloys in this group contain copper and silicon and they have almost completely replaced the original binary aluminium copper alloys (200 series). The silicon provides good casting characteristics and the addition of copper imparts moderately high strength and improved machinability with reduced ductility and lower resistance to corrosion.
The alloys respond to heat treatment although some are not normally considered heat-treatable alloys and are used in the as- cast condition.

400 Series

Silicon is the major alloying element and is one of the most widely used alloying elements. Silicon improves the fluidity of the molten aluminium, adds strength to the alloy, improves weldability, but does not contribute to machinability. The aluminium silicon casting alloys are one of the most widely used general purpose alloys because of their superior casting characteristics.

These alloys are usually modified by the addition of small amounts of sodium or strontium to prevent the formation of primary silicon crystals which are detrimental to obtaining maximum mechanical properties in the casting. The aluminium silicon alloys do not require heat treatment.

500 Series

Magnesium is the major alloying element, which has excellent mechanical properties, high resistance to corrosion, good machinability, and an attractive appearance. Magnesium alloys have solid solubility characteristics which makes them heat-treatable. However, only alloys with a magnesium content above 9 percent show any appreciable response to heat treatment. In general, magnesium additions provide both increased strength and ductility in the alloy.

These alloys have poor feeding characteristics and require more care in the running and gating to produce sound castings. The high level of magnesium in these alloys make them difficult to cast because they generate a thick oxide film which results in higher surface tension.

600 Series
These alloys are similar to 400 series with an addition of magnesium which enables the formation of magnesium silicide. Controlled precipitation of magnesium silicide during heat treatment results in significant improvements to mechanical properties. These alloys are commonly modified by the addition of small amounts of strontium and possess the highly desirable features of castability, pressure-tightness, high strength, good corrosion resistance and high ductility levels making these alloys suitable for safely critical applications.

700 Series
Zinc is the major alloying element and when used in combination with magnesium the alloy exhibits good impact resistance, high strength, and excellent ductility without heat treatment. These alloys naturally age at room temperature over a short period of time, and have mechanical properties comparable to some heat-treated alloys without having to solution heat-treat or artificially age them. Zinc additions to aluminium make the alloy susceptible to hot shortness and shrinkage when used in large amounts. Care must be taken with these alloys as castings are subject to stress corrosion cracking and their use for stressed or safety critical parts is not recommended.

800 Series
The major alloying element is tin. The outstanding contribution that tin makes to aluminium is to improve its anti- friction characteristics in bearing alloys. Tin improves the machinability of aluminium and its alloys and is added to some alloys, particularly the copper alloys, for this purpose. The tin bearing alloys have high resistance to corrosion by engine oil. It should be noted that tin does not readily dissolve in aluminium which results in a non-homogenous distribution of the tin.

900 Series
This is used for alloys not covered by the above series, such as aluminium hardener alloys (e.g. AA941).

Factors which guide the selection of aluminium casting alloys

Two of the main parameters regarding the selection of aluminium alloys for casting are castability and mechanical properties. The two parameters are interrelated and dependant on the casting process. Other contributions to grade selection; **Pressure tightness, corrosion resistance, machinability, wear resistance, surface finish and physical properties such as thermal expansion and conductivity.**

The mechanical properties quoted in these tables are those pertaining to test bars which have been cast to size under controlled conditions. The mechanical properties of castings can vary 60%-110% from these quoted values depending on the section thickness and other process dependent variables, principally solidification rate.
Castability may be defined as that property of an alloy system which, due to its particular mode of solidification, will impart a high degree of soundness to the cast part, other things being equal especially the ability to fill the mould/cavity.

Alloys with high strength do not always possess good castability. For example 2XX and 7XX series alloys (see Table 2 on page 23 for alloy code definitions) are both susceptible to cracking during solidification (hot-shortness) and shrinkage porosity in heavy sections.

To obtain a consistently sound product it is advisable to choose an alloy with good castabilty and slightly lower strength properties, or to use an alternate process with an inherent solidification rate consistent with part requirements and castability. The alloy series may be classified in order of castability as follows: 6XX, 3XX, 4XX, 5XX, 2XX, 7XX.

Pressure tightness is a function of castability and dependant on the absence of through section thickness interlinked porosity. Some castings are impregnated and sealed to confirm pressure tightness.

Corrosion resistance is a function of chemical composition. Generally the copper- free alloys have greater corrosion resistance than those containing copper. The 7XX series alloys are susceptible to stress corrosion, and appropriate control measures need to be considered.

Machinability and wear resistance are in general terms a function of hardness and chemical composition - especially Silicon and its morphology. This in turn depends on the response to heat treatment and the level of modification.

Thermal expansion and **conductivity** depend on chemical composition, while surface finish can be a function of several of the factors, mentioned and the casting/moulding practices employed.

Table 3: Chemical Composition Limits of Aluminium Ingots and Castings [1,2]

Refer to AS 1874-2000 Aluminium and Aluminium Alloys - Ingots and Castings

AAC Alloy Designation	Use[3]	Silicon (Si)	Iron[4] (Fe)	Copper (Cu)	Manganese (Mn)	Magnesium[5] (Mg)	Chromium (Cr)	Nickel (Ni)	Zinc (Zn)	Tin (Sn)	Lead (Pb)	Titanium (Ti)	Other Each	Elements Total	Aluminium (Minimum)
AA150		0.30	0.40										0.03	0.15	99.50
AA160	Elec.	0.10	0.30	(Fe Min 2.0 x Si) (Mn + Ti + Cr + V = 0.01 Max)									0.02	0.10	99.60
AA170		0.10	0.20	(also, Ga = 0.04% Max., V = 0.03% max.)									0.03	0.10	99.70
BA170	Elec.	(Fe Min >=1.5 x Si, Fe & Si not included in "Other Elements") (Mn + Ti + Cr + V = 0.025 Max)											0.03	0.10	99.70
AA175		0.20	0.20	0.02									0.03	0.10	99.75
AA180		0.10	0.10	0.02									0.03	0.10	99.80
AA185		0.10	0.10	0.02									0.03	0.10	99.85
AA190		0.05	0.07		(also, Ga = 0.03 % max., V = 0.02 % max.)				0.03				0.02	0.05	99.90
AA303	SP	4.0-5.0	0.8[6]	2.0-4.0	0.7[6]	0.15	0.10	0.30	0.50	0.15	0.15	0.20	0.05	0.20	Rem.
AA305	P	8.5-10.5	0.90	2.0-4.0	0.50	0.6-1.5	0.10	0.50	1.0	0.15	0.25	0.25	0.05	0.20	Rem.
AA307	D	9.0-11.5	1.00	0.7-2.5	0.50	0.30	0.10	0.50	2.0	0.25	0.35	0.20	0.05	0.20	Rem.
AA309	SP	4.5-5.5	0.25	1.0-1.5	0.05	0.5-0.6			0.05			0.20	0.05	0.15	Rem.
AA311	SP	4.0-6.0	0.15	1.0-1.5	0.05	0.05			0.10			0.20	0.05	0.20	Rem.
CA313	D	7.5-9.5	1.30	3.0-4.0	0.50	0.30	0.10	0.50	3.0	0.25	0.35	0.20	0.05	0.20	Rem.
AA315	D	10.5-12.0	1.30	3.0-4.5	0.50	0.10	0.10	0.50	1.0	0.35	0.25	0.20	0.05	0.20	Rem.
AA317	SP	6.0-8.0	0.80	1.5-2.5	0.20-0.60	0.35	0.10	0.35	1.0	0.15	0.25	0.20	0.05	0.20	Rem.
AA319	P	11.0-13.0	0.70	0.8-1.3	0.35	0.8-1.3	0.10	1.0-2.5	0.25	0.20	0.15	0.20	0.05	0.20	Rem.
BA323	SP	7.5-8.5	0.30	3.5-4.0	0.30-0.50	0.30-0.40		0.05	0.10			0.15	0.05	0.15	Rem.
BB325	SP	7.5-8.5	0.80	2.0-3.5	0.10-0.30	0.20-0.50		0.30	0.20-0.50	0.10	0.20	0.15	0.05	0.15	Rem.
CA327	SP	5.5-6.8	0.25	3.0-4.0	0.50	0.10-0.18		0.10	0.10			0.15	0.05	0.15	Rem.
AC331[8]	D	13.8-14.5	0.6-1.0	1.9-2.2	0.35-0.50	0.50-0.7		1.0-1.4				0.10	0.05	0.15	Rem.
AA335	D	9.6-12.0	0.9[4]	1.5-3.5	0.50	0.30	0.10	0.50	1.0	0.30	0.25	0.20	0.05	0.20	Rem.
AA337	P	8.5-10.5	0.8[4]	2.0-4.0	0.50	0.6-1.5[7]	0.10	0.50-1.5	0.50	0.20	0.15	0.20	0.05	0.20	Rem.
AA339	SP	5.0-7.0	0.8[4]	2.0-4.0	0.50	0.50	0.10	0.30	1.0	0.20	0.15	0.20	0.05	0.20	Rem.
CA401	SP	12.0-13.0	0.40	0.10	0.10	0.05		0.05	0.10			0.20	0.05	0.15	Rem.
CB401	SP	12.0-13.0	0.40	0.10	0.05	0.05		0.05	0.10			0.20	0.05	0.20	Rem.

AAC Alloy Designation	Use[3]	Silicon (Si)	Iron[4] (Fe)	Copper (Cu)	Manganese (Mn)	Magnesium[5] (Mg)	Chromium (Cr)	Nickel (Ni)	Zinc (Zn)	Tin (Sn)	Lead (Pb)	Titanium (Ti)	Other Each	Elements Total	Aluminium (Minimum)
CC401	SP	12.0-13.0	0.40	0.10	0.05	0.05		0.05	0.10			0.20	0.05	0.20	Rem.
DA401	SP	10.0-13.0	1.0	0.60	0.5	0.25	0.10	0.50	0.40	0.15	0.15	0.20	0.05	0.25	Rem.
EA401	SP	11.0-13.0	0.60	0.15	0.5	0.1	0.10	0.10	0.15	0.05	0.15	0.20	0.05	0.20	Rem.
AB405	SP	6.5-7.5	0.15	0.10	0.1	0.05			0.10			0.20	0.05	0.15	Rem.
AA505	S	0.3	0.60	0.10	0.3-0.7	3.0-6.0		0.10	0.10	0.05	0.05	0.20	0.05	0.15	Rem.
AA601	SP	6.5-7.5	0.20	0.05	0.05	0.30-0.40			0.05			0.20	0.05	0.15	Rem.
AC601	SP	6.5-7.5	0.20	0.05	0.05	0.30-0.40			0.05			0.20	0.05	0.15	Rem.
CC601	SP	6.5-7.5	0.20	0.05	0.05	0.25-0.35			0.05			0.20	0.05	0.15	Rem.
DA601	SP	6.5-7.5	0.50	0.25	0.35	0.30-0.50			0.35			0.25	0.05	0.15	Rem.
AA5603	SP	6.5-7.5	0.15	0.05	0.03	0.45-0.7			0.05			0.20	0.05	0.15	Rem.
AC603	SP	6.5-7.5	0.15	0.05	0.03	0.45-0.7			0.05			0.20	0.05	0.15	Rem.
CA605	D	9.0-10.0	0.7-1.1	0.60	0.35	0.45-0.6		0.5	0.50	0.15			0.05	0.25	Rem.
BA701	S	0.25	0.50	0.15	0.15	0.50-0.7	0.40-0.6	0.1	4.8-5.7	0.05	0.05	0.15-0.25	0.05	0.15	Rem.
AA941		2.6-3.3	0.40	0.03	0.03						0.01		0.03	0.15	Rem.

Footnotes TABLE 3

1. Composition in percent maximum unless shown as a range or a minimum. Standard limits for elements and impurities are expressed to the following places:

For the purpose of assessing compliance to these limits, the specified limiting values herein shall be interpreted in accordance with the 'rounding method' described in AS 2706, i.e., the observed or calculated value shall be rounded to the same number of figures as in the specified limiting value and then compared with the specified limiting value. For example, for specified limiting values of 2.5, 2.50 and 2.500, the observed or calculated value would be rounded respectively to the nearest 0.1, 0.01 or 0.001.

2. Use:
   ELEC = ELECTRICAL
   S = SAND CASTING
   P = PERMANENT MOULD CASTING
   D = PRESSURE DIE CASTING

3. For these alloys only, iron maximum relates to ingot. The maximum iron for castings may vary as follows:

   If Fe maximum in ingot is 0.9% then castings 0.40% greater.
   If Fe maximum in ingot is 0.8% then castings 0.20% greater.
   If Fe maximum in ingot is 0.7% then castings 0.10% greater.
   If Fe maximum in ingot is 0.20% (or less) then castings 0.05% greater.

4. For these alloys only, magnesium maximum relates to ingot. The maximum magnesium for castings may vary as follows:
   If Mg maximum in ingot is 0.15% (or less) then castings 0.05% less.

5. Iron + manganese not to exceed 1.3 percent.

6. For castings in this alloy the magnesium range is 0.50-1.5.

7. This is where alloy designation specifies sodium or strontium addition, sufficient amounts are added to provide eutectic modification, so the alloy can be AC331.

Table 4 Nearest Related Composition Specifications.

AAC Alloy	British Standard Alloy	Aluminum Association (US) Alloy Type	ISO Alloy	Japanese (JIS) Alloy
BA303	LM4	319	AlSi5Cu3	AC2A
AA305	LM26	332	AlSi10Cu	AC8B
AA307	LM26	-	AlSi10Cu	ADC12
AA309	LM16	355	AlSi5Cu1Mg	AC4D
AA311	-	A305	AlSi5Cu1Mg	-

CA313	LM24	A380/C380	AlSi9Cu3Fe	
AA615	-	A384	-	-
AA317	LM27	328	AlSi7Cu2Mn	-
AA319	LM13	A336	AlSi12Mg1Cu1	AC8A
BA323		-	-	-
BB325	LM24	-	AlSi8Cu3Fe	-
CA327	LM21	319	AlSi6Cu4	AC2B
AC331			-	-
AA335	-	383	-	ADC12
AA337	LM13	332	AlSi10Cu	AC8B
AA339	LM4	319	AlSi5Cu3	AC2B
CA401	LM6	A413	AlSi12	AC3A
CB401	LM6	A413	AlSi12	AC3A
CC401	LM6	A413	AlSi12	AC3A
DA401	LM20	A413	AlSi12Fe	ADC12
EA401	LM6	413	-	ADC12
AB405	-	A444	-	-
AA505				
AA601	LM25	A356	AlSi7Mg	AC4C
AC601	LM25	A356	AlSi7Mg	AC4C
CC601	LM25	A356	AlSi7Mg	AC4C
DA601	LM25	356	AlSi7Mg	AC4C
AA603	LM25	357	AlSiMg0.5	-
AC603	LM25	357	AlSiMg0.5	-
CA605	-	360	AlSi10MgFe	-
BA701	DTD5008	712	AlZn5Mg	-

Footnotes

1. This table is to be referred to as a guide only

Table 5 Mechanical Properties of Test Bars[1]

Alloy and Temper		Casting Method	Tensile Strength			Elongation (% on 50mm min)		Brinell Hardness	Compressive Yield	Fatigue Strength	Shear Strength	Recommended Heat Treatment Method [2,3]
			Ult (min)	(MPa) Ult (typ.)	Yield (typ.)	(min)	(typ.)	(typ.)	(MPa) (typ.)	(MPa) (500 x 10^6 cycles)	(MPa) (typ.)	
AA303	-T1	S	135	150	85	1.5	2	70	-	-	140	-
	-T6	S	225	250	140	-	1	100	-	-	-	515°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 165° for 6-18 hours.
	-T1	P	150	195	95	2	3	80	-	-	150	-
	-T6	P	275	310	165	-	2	110	-	-	-	515°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 165° for 6-18 hours.
AA305	-T5	P	215	250	195	-	1	105	-	95	195	Age at 200°C for 4-8 hours.
AA307	-F1	D	-	250	-	-	3	80	-	-	-	-
AA309	-T4	S	-	165	105	-	3	65	-	50	150	-
	-T51	S	170	195	160	-	1	65	165	55	150	Age at 225°C for 4-8 hours.
	-T6	S	220	240	170	2	3	80	180	60	195	525°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 155° for 4 hours.
	-T62	S	-	295	275	-	2	90	255	60	220	525°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 170° for 8-10 hours.
	-T51	P	185	205	165	-	2	75	165	-	165	Age at 225°C for 8 hours.
	-T6	P	255	290	185	1.5	4	90	185	70	235	525°C for 2-16 hours, quench in hot water (not less than 60°C). Age at 155° for 4 hours.

Alloy and Temper	Casting Method	Tensile Strength			Elongation (% on 50mm min)		Brinell Hardness	Compressive Yield	Fatigue Strength	Shear Strength	Recommended Heat Treatment Method [2,3]
		Ult (min)	(MPa) Ult (typ.)	Yield (typ.)	(min)	(typ.)	(typ.)	(MPa) (typ.)	(MPa) (500 x 10^6 cycles)	(MPa) (typ.)	
-T62	P	275	310	275	-	2	105	275	75	-	500-525°C for 2hours minimum, quench in hot water (not less than 60°C). Age at 170° for 8-12 hours.
AA311 -T6	S	-	220	155	-	3.5	80	-	-	-	490-505°C for 2-hours minimum, quench in hot water (not less than 60°C). Age at 165° for 4-8 hours.
-F1	P	-	125	50	7	-	40	-	-	-	-
AA311 -T6	P	-	255	165	-	5	-	-	-	-	490-505°C for 2-hours minimum, quench in hot water (not less than 60°C). Age at 165° for 8 hours.
CA313 -F1	D	-	270	160	-	5	85	115	140	195	-
AA315 -F1	D	-	330	165	-	2.5	-	-	140	200	-
AA317 -F1	S	140	-	-	1	-	75	90	-	-	-
-F1	P	160	-	-	2	-	80	100	-	-	-
AA319 -T5	P	215	250	195	-	1	105	-	-	-	Age at 250°C for 4-8 hours.
BA323 -T6	S	-	295	-	-	0.5	-	-	-	-	490-505°C for 2-hours minimum, quench in hot water (not less than 60°C). Age at 165° for 4-8 hours.
	P	-	380	330	-	1.5	-	-	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 165° for 8 hours.
BB325 -T6	S	-	290	-	-	0.5	-	-	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 165° for 8 hours.
	P	-	380	330	-	1.5	-	-	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C).. Age at 165° for 8 hours.

Alloy and Temper	Casting Method	Tensile Strength			Elongation (% on 50mm min)		Brinell Hardness	Compressive Yield	Fatigue Strength	Shear Strength	Recommended Heat Treatment Method [2,3]
		Ult (min)	(MPa) Ult (typ.)	Yield (typ.)	(min)	(typ.)	(typ.)	(MPa) (typ.)	(MPa) (500 x 10^6 cycles)	(MPa) (typ.)	
CA327 -T1	S	155	185	125	-	2	-	130	70	150	-
-T5	S	170	205	180	1	1.5	-	185	75	165	Age at 205°C for 8 hours.
-T6	S	210	245	165	1.5	2	-	170	75	200	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 165° for 8 hours.
-T1	P	185	235	130	-	2.5	-	135	85	180	-
-T6	P	230	275	185	-	3	-	185	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 155° for 2-5 hours.
AC331	D	Mechanical Properties not available									
AA335 -F1	D	-	250	-	-	3	80	-	-	-	-
A337 -F1	P	-	175	-	-	-	-	-	-	-	-
-T5	P	-	215	-	-	-	90	-	-	-	Age at 180°C for 8 hours.
-T6	P	-	275	-	-	-	110	-	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 170° for 6-12 hours.
AA339 -F1	S	-	135	-	-	-	-	-	-	-	-
-T6	S	-	195	-	-	-	80	-	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 160° for 4-8 hours.
-F1	P	-	155	-	1	-	-	-	-	-	-
-T6	P	-	245	-	1	-	90	-	-	-	490-505°C for 2 hours minimum, quench in hot water (not less than 60°C). Age at 160° for 4-8 hours.
CA401/											
CB401/											

Alloy and Temper	Casting Method	Tensile Strength			Elongation (% on 50mm min)		Brinell Hardness	Compressive Yield	Fatigue Strength	Shear Strength	Recommended Heat Treatment Method [2,3]
		Ult (min)	(MPa) Ult (typ.)	Yield (typ.)	(min)	(typ.)	(typ.)	(MPa) (typ.)	(MPa) (500 x 10^6 cycles)	(MPa) (typ.)	
CC401 -F1	S	160	180	70	5	7	50	-	50	125	-
-F1	P	190	205	90	7	9	60	-	75	-	-
DA401 -F1	D	-	260	130	-	2	65	-	130	170	-
EA401 -F1	S	160	170	55	5	7	55	-	-	-	-
AB405	S	Mechanical Properties not available									
-T4	P	140	-	-	20	-	-	-	-	-	535^{o}C for 2 hours minimum, quench in cold water
AA505	S	Mechanical Properties not available									
AA601/											
AC601/											
CC601 -T1	S	130	160	90	2	5	55	-	-	-	-
-T5	S	155	180	130	-	3	60	150	55	125	Age at 225^{o}C for 8 hours
-T6	S	205	255	185	3	5	70	170	60	180	530-540°C for 2 hours minimum, quench in hot water (not less than 60°C). Either age immediately, or optionally hold at room temperature for 8-16 hours. Age at 155° for 4 hours or 2h at 180°C.
AA601/											
AC601/											
CC601 -T1	P	140	195	95	3	6	-	-	-	-	-
-T5	P	170	180	140	-	6	60	-	-	-	Age at 225^{o}C for 8 hours

Alloy and Temper	Casting Method	Tensile Strength			Elongation (% on 50mm min)		Brinell Hardness	Compressive Yield	Fatigue Strength	Shear Strength	Recommended Heat Treatment Method [2,3]
		Ult (min)	(MPa) Ult (typ.)	Yield (typ.)	(min)	(typ.)	(typ.)	(MPa) (typ.)	(MPa) (500 x 10^6 cycles)	(MPa) (typ.)	
-T6	P	220	275	185	5	10	100	185	90	195	530-540°C for 2 hours minimum, quench in hot water (not less than 60°C). Either age immediately, or optionally hold at room temperature for 8-16 hours. Age at 155° for 4 hours or 2h at 180°C.
-T61	P	260	295	205	3	8	105	220	90	195	530-540°C for 2 hours minimum, quench in hot water (not less than 60°C). Either age immediately, or optionally hold at room temperature for 8-16 hours. Age at 155° for 4 hours or 2h at 180°C.
DA601 -T1	S	130	145	85	2	3	55	-	-	-	-
-T6	S	205	230	150	3	4	75	140	60	170	530-540°C for 2 hours minimum, quench in hot water (not less than 60°C). Either age immediately, or optionally hold at room temperature for 8-16 hours. Age at 155° for 4 hours or 2h at 180°C.
-T1	P	145	170	85	3	4	65	-	-	-	-
-T6	P	225	240	165	3	4	90	170	90	185	530-540°C for 2 hours minimum, quench in hot water (not less than 60°C). Either age immediately, or optionally hold at room temperature for 8-16 hours. Age at 155° for 4 hours or 2h at 180°C.

Alloy and Temper	Casting Method	Tensile Strength			Elongation (% on 50mm min)		Brinell Hardness	Compressive Yield	Fatigue Strength	Shear Strength	Recommended Heat Treatment Method [2,3]
		Ult (min)	(MPa) Ult (typ.)	Yield (typ.)	(min)	(typ.)	(typ.)	(MPa) (typ.)	(MPa) (500 x 10^6 cycles)	(MPa) (typ.)	
AA603 /											
AC603 -T6	S	270	315	250	1	5	90	-	-	-	530-40°C for a minimum of 2 hours, quench in hot water (not less than 60°C). Age at 160° for 4 hours or 2h at 180°C.
-T6	P	290	345	275	3	7	100	-	-	-	530-40°C for a minimum of 2 hours, quench in hot water (not less than 60°C). Age at 160° for 4 hours or 2h at 180°C.
CA605 -F1	D	-	325	170	-	3	75	-	130	205	-
BA701 -T1	S	215	235	150	4	5	75	115	60	180	Naturally age to stabilized over 14-30 days
-T5	S	215	255	180	4	5	80	-	-	-	Naturally age over 14-30 days or naturally age 24 hours and 180ºC for 10 hours.

Footnotes:

1. The values listed represent properties obtained from separately cast test bars controlled within the ingot composition limits and with an optimum degree of internal soundness.
2. Nominal metal temperature should be obtained as rapidly as possible and be maintained within ± 5ºC during the time at temperature.
3. For maximum effectiveness of solution heat treatment quench water temperature should be kept within a range to minimise distortion while still producing a sufficiently high quenching rate.

Table 6. Typical Physical Properties

Alloy and Temper		Casting Method	Thermal Conductivity at 25° C W/m.K	Electrical Conductivity at 20° C, % IACS Equal Volume	Density kg/m³ x 10 ³	Average Coefficient of Thermal Expansion per C[1]	Freezing Range Approx. °C
AA303	-T1	S	121	32	2.77	21.0	625-525
	-T6	S	121	32	2.77	21.0	625-525
	-T1	P	121	32	2.77	21.0	625-525
	-T6	P	121	32	2.77	21.0	625-525
AA305	-T5	P	105	26	2.77	20.0	640-520
AA307	-F1	D	100	26	2.70	20.0	570-525
AA309	-T1	S	167	42	2.71	22.3	620-545
	-T51	S	167	43	2.71	22.3	620-545
	-T6	S	142	36	2.71	22.3	620-545
	-T62	S	142	-	2.71	22.3	620-545
	-T51	P	167	43	2.71	22.3	620-545
	-T6	P	151	39	2.71	22.3	620-545
	-T62	P	151	39	2.71	22.3	620-545
AA311	-F1	S/P	151	39	2.71	22.0	620-545
CA313	-F1	D	96	24	2.77	21.0	580-520
AA315	-F1	D	96	23	2.70	-	580-520
AA317	-F1	S	154	27	2.75	21.5	605-525
	-F1	P	154	27	2.75	21.5	605-525
AA319	-T5	P	105	26	2.77	20.0	640-520
BA323		S	Properties Not Available				
		P	Properties Not Available				
BB325		S	Properties Not Available				
		P	Properties Not Available				
CA327	-T1	S	109	27	2.77	21.8	605-515
	-T5	S	109	27	2.77	21.4	605-515
	-T6	S	109	27	2.77	21.4	605-515
	-T1	P	109	27	2.77	22.2	605-515
AC331	-F1	D	Properties Not Available				
AA335	-F1	D	100	26	2.70	20.0	570-525
AA337	-T5	P	105	26	2.77	20.0	640-520
AA339		S/P	Properties Not Available				
CA401/							
CB401/							
CC401	-F1	S	142	37	2.65	20.8	580-570
	-F1	P	142	37	2.65	20.8	580-570
DA401	-F1	S	121	37	2.65	20.0	575-565
	-F1	P	121	37	2.65	20.0	575-565
	-F1	D	121	37	2.65	20.0	575-565

Alloy and Temper		Casting Method	Thermal Conductivity at 25° C W/m.K	Electrical Conductivity at 20° C, % IACS Equal Volume	Density kg/m³ x 10 ³	Average Coefficient of Thermal Expansion per C[1]	Freezing Range Approx. °C
EA401	-F1	S	142	37	2.65	20.0	575-565
	-F1	P	142	37	2.65	20.0	575-565
AB405	-T4	P/S	151	39	2.68	21.5	610-555
AA505	-F1	S	Properties Not Available				
AA601/ AC601/ CC601	-T1	S	-	-		21.4	610-560
	-T5	S	151	39	2.68	21.4	610-560
	-T6	S	151	39	2.68	21.4	610-560
	-T1	P	-	-	2.68	21.4	610-560
	-T5	P	151	40	2.68	21.4	610-560
	-T6	P	151	40	2.68	21.4	610-560
	-T61	P	151	39	2.68	21.4	610-560
DA601	-T1	S	151	39	2.68	21.4	610-560
	-T6	S	151	39	2.68	21.4	610-560
	-T1	P	151	39	2.68	21.4	610-560
	-T6	P	151	40	2.68	21.4	610-560
AA603	-T6	S	151	39	2.68	21.0	610-555
	-T6	P	151	39	2.68	21.4	610-555
AC603	-T6	S	151	39	2.68	21.0	610-555
	-T6	P	151	39	2.68	21.4	610-555
CA605	-F1	D	151	37	2.68	20.0	595-555
BA701	-T1	S	-	25	2.77	23.0	650-600
	-T5	S	-	25	2.77	23.0	650-600

Footnotes:

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

Table 7. Relative Ratings.

Intending Buyers / Designers of castings should consult suppliers of ingots or castings regarding alloy suitability and availability.
Ratings: E = Excellent G = Good F = Fair U = Unsuitable

Alloy	Castability			Corrosion Resistance	Machinability	Pressure Tightness	Weldability	Typical Uses / General Comments
	S	P	D					
AA303	G	G	-	F	G	G	G	General purpose alloy with a moderate degree of strength used for general engineering purposes in such applications as pump bodies, crankcases, auto cylinder heads and blocks.
AA305		G		F	G	G	F	Used for auto diesel and marine engine pistons, pulleys and bearings
AA307			E	F	F	G	U	Pressure diecasting alloy suitable for thin wall castings
AA309	G	G		F	G	G	G	Auto crankcases, blocks and heads
AA311	G	G		F	G	G	G	Alloy used principally for tyre moulds
CA313			E	F	G	G	U	The most widely used general purpose alloy. Used principally for pressure diecastings having thin walls such as domestic appliance housings, lawn mower and machinery components, automotive components such as transmission parts, crankcases, heatsinks, timing cases, rocker covers, oil pumps and water pumps.
AA315			E	F	F	G	U	General purpose alloy with high fluidity, used for thin wall castings, such as automotive parts and housings.
AA317	G	G		F	G	G	G	General purpose and engineering components
AA319		G		F	G	G	F	Used for special automotive pistons. Low thermal expansion rate with high strength at elevated temperatures and good wear resistance.
BA323	G	G		F	G	G	G	Used for auto products such as cylinder heads and inlet manifolds.
BB325	G	G		F	G	G	G	Used for auto products such as cylinder heads and inlet manifolds.

Alloy	Castability			Corrosion Resistance	Machinability	Pressure Tightness	Weldability	Typical Uses / General Comments
	S	P	D					
CA327	G	G	F	G	G	G	G	Suitable for most general engineering purposes and where moderate strength is desirable. Its characteristics are suitable for thin sections and also for castings required to be pressure tight.
AC331			E	F	E	E	U	Used for impact and sliding wear resistance in high temperature applications such as automotive engines and low temperature applications such as refrigerators.
AA335			E	F	F	G	U	Widely used pressure diecasting alloy with high fluidity used for automotive components.
AA337		G		F	G	G	F	Auto piston alloy combining good wear resistance and low thermal expansion.
AA339	G	G		F	G	G	G	For general purpose castings requiring a moderate degree of strength. Used for automotive components such as valve bodies and clutch housings.
CA401	E			E	F	F	E	Widely used in automotive, marine, chemical, furniture, food processing, domestic appliances and general engineering components.
CB401								
CC401								
CB401		E		E	F	F	E	As above
DA401	E	E		G	F	F	U	General purpose alloy having excellent mould-filling characteristics, used for castings having intricate shape and thin sections. Used for architectural and outdoor furniture parts, meter housings, lawnmower base plates and automotive and domestic appliance components requiring good corrosion resistance.
EA401	E	E	E	E	F	F	E	General purpose alloy having excellent casting characteristics suitable for thin walled castings. Used for motor housings, meter cases, marine and road transport fittings.

Alloy	Castability S	Castability P	Castability D	Corrosion Resistance	Machinability	Pressure Tightness	Weldability	Typical Uses / General Comments
AB405	E	E		E	F	F	E	General purpose alloy used in structural applications such as bridge barrier rail posts.
AA505	F			E	E	E	F	Alloy used for tyre moulds
AA601								
CC601	E	E	E	E	G	G	E	Transmission cases, truck axle housings, wheel cylinder blocks, railway tank car fittings, marine hardware, valve bodies and bridge rail parts.
AC601	E			E	G	G	E	Used in applications where corrosion resistance combined with high strength is required. Used in food, chemical, marine applications and, in particular, automotive wheels. Its potential is increased by heat treatment.
CC601								
DA601	E	E		E	G	G	E	Heat-treatable alloy having excellent casting characteristics. Used for pump parts, marine hardware, automotive housings and cases, water cooled cylinder blocks.
AA603 AC603	E	E		E	F	E	E	Easily Cast and exhibits good electrical conductivity and high strength.
CA605			E	G	F	E	U	General Purpose alloy having excellent casting ability and good corrosion resistance suitable for motor housings, cover plates, instrument cases, marine and road transport fittings, aircraft and general purpose castings.
BA701	F			E[2]	E	F	F	Castings where high mechanical properties can be obtained without heat treatment. High resistance to atmospheric corrosion but highly susceptible to stress corrosion cracking and should not be used without a full stress relieving heat treatment. (See also Footnote 2)

Footnotes:

1. Unsoundness in castings may adversely affect the weldability rating
2. This rating relates to atmospheric corrosion. These alloys are susceptible to stress corrosion cracking and their use for stressed parts is not recommended without reference to an aluminium supplier.

Casting Quality Standards

Casting quality is dependent on a number of variables, with similar emphasis on material grade, component design, method of manufacture and manufacturing foundry with all having a potential contribution.
For assistance in the method of specification of quality and techniques/standards used in assessment, the casting user is recommended to the Aluminum Association (USA) Metallurgical Series (M) standards.

VIZ. AA-CS-M5-92 Aluminium Casting Quality Standard
AA-CS-M6-85 Radiography
AA-CS-M7-85 Penetrant and other
NDI Techniques

Impregnation of castings

This technique consists of "filling" or impregnating castings that exhibit through section, interconnected porosity using various penetrating and hardenable mixtures. The technique is usually done under a vacuum-pressure cycle in an autoclave tank followed by a curing cycle.
Typical reagents are water glass, filled sodium silicate, polyestestyrene, methacrylics and epoxy. Sealing should only be considered after completion of machining operations.

Where the process is considered acceptable it can avoid the loss of serviceable castings, achieve pressure tightness and/or contribute to the application of high quality surface coatings. The acceptability of the practice should always be discussed with the purchaser/manufacturer on initial enquiry. Guidelines for the process are contained in the AA Metallurgical Series (M) standard. AA-CS-M8-85.

Welding of aluminium castings

Welding, both as a subsequent manufacturing process and for casting reclamation involves a number of issues which require discussion between purchaser and manufacturer at the time of initial enquiry. Some casting processes with a high level of gas entrapment give rise to considerable difficulties in welding and higher level heat treatment cycles. This can have an effect on surface quality if welding is permitted or performed as a means of recovery of surface defective castings.

Similarly, properly prepared and performed welding of castings has produced a large number of successful applications of castings as part of a welded fabrication. Good quality welds within a casting will normally provide mechanical properties - including fatigue, indistinguishable to those of the parent metal.

Reference is recommended to the Aluminum Association (USA) Metallurgical Series (M) standard, AA-CS-M9--74, Welding of Aluminium Castings, and the radiographic assessment standard AA-CS-M6-85 for weldment evaluation.