RioTinto

Primary aluminum foundry alloys

Fourth edition
April 2019

Contents

Front cover image: Cast ingot from PLS.
Left image: Rio Tinto hydro-power station of Shipshaw.

The most responsible aluminium for the cleanest applications

As pioneers, we co-founded the Aluminium Stewardship Initiative (ASI); we were the first fostering low CO_2 aluminium use with RenewAl™ and we are partnering to develop Elysis breakthrough smelting technology.

We invite you to take part in the new sustainability benchmark
ASI is a third party certification assessing transparency in the aluminium value chain based on these criteria:

Rio Tinto is the first company to earn both the ASI performance standard and Chain of Custody certification.

asi Aluminium Stewardship Initiative

Social
- Human rights
- Labour rights
- Occupational health and safety

Governance
- Business integrity
- Policy and management
- Transparency
- Material stewardship

Environment
- Greenhouse gas emissions
- Emissions, effluents and wastes
- Water Stewardship
- Biodiversity

Recycling is not enough…
That's why we created RenewAl™
RenewAl™ is a comprehensive package of aluminium with a certified CO_2 content of 4tCO_2/tAL or below and customised services. RenewAl™ offers a cleaner start to your product lifecycle.

Customised services

- **Certification**: Third-party certified CO_2 emissions (Scope 1&2)
- **Technical expertise**: Assistance in leveraging ow CO_2 aluminium
- **Traceability**: Product tracked from mine to metal
- **CO_2 reduction strategies**: Support to optimise your low CO_2 sources
- **Life cycle analysis**: Contribution to specific calculation on lifecycle
- **Co-branding**: Unique partnerships with RenewAl™

RenewAl™
Low CO_2 Aluminium

We produce a 3x lower CO_2 footprint with RenewAl™

Certified CO_2 content 4tCO_2/tAL or below
Tonnes of CO_2 emitted per tonne of aluminium produced (Scope 1&2)

4.0
RenewAl™

11.5
Industry Average

Our partnership created a revolution
Joining know how and expertise to create a revolutionary way to make aluminium. As the world's first carbon-free aluminium smelting process, it eliminates all direct greenhouse gases and produces pure oxygen.

Committed to innovation that sharpens your competitiveness

We're known for outstanding products and technical support, plus excellent customer service. With so much at stake in your business, consider all the benefits of making us your primary aluminium supplier of choice.

Alloy and product development
If you don't find the perfect alloy or solutions for your needs among our offering, talk to us. We'll work with you to develop precisely what you need.

It is through global partnerships and alliances with universities, colleges, institutions and private R&D centres, that we give you access to cutting-edge alloys and products.

Leading technical support
It's not just about alloys, of course. We're the preferred partner because of our outstanding services. This includes training your teams, assessing your process and offering solutions that enhance your productivity.

Security of supply
As a global company, we're always close by. This means we can offer a range of cost-cutting benefits, including faster response times and more robust supply chains.

A responsible partnership
We're committed to reduce your supply chain's CO_2 footprint and underscore your own commitment to sustainability. How will we do that? With one of the lowest CO_2 aluminium and most sustainable value chain in the industry. RenewAl™, ASI and Elysis are all initiatives allowing us to give you more in a responsive manner.

Americas
Europe, Middle East & Africa
Asia Pacific

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Primary foundry ingot

Rio Tinto is a leading global supplier of primary aluminum.

Rio Tinto has become a global supplier of primary foundry ingot to casting foundries as a result of our:

- consistent high level product quality;
- world class technical support, customer service and R&D;
- broad range of foundry alloys;
- low carbon emissions; and
- available production capacity to meet supply requirements.

Product quality

High purity

Our primary foundry ingot is produced from high purity (low iron) primary metal. Carefully selected alloying elements are added and mixed in specific holding furnaces to reduce contamination and then cast into ingot form under stringent handling and casting practices. Our low level of trace impurities and iron allows individual foundries to achieve the optimal properties from castings.

Metal cleanliness and consistency

Technologies developed at our world class laboratories enable the production centers to blend our customers' alloys to the tightest casting tolerances. The result is clean metal with strict control on trace elements. Rio Tinto's metal consistency enables foundry casters to optimize their operations.

Technical support, customer service and research and development

Focus on customers and providing innovative solutions

We are committed to keeping up with our customers' needs. Our exclusive role as a supplier of primary aluminum foundry ingot demonstrates our desire to be the supplier of choice to global and regional customers. We also understand an important requirement of successful customers anywhere in the world: a strategic partner who is able to provide innovative solutions for increased productivity and competitiveness.

Technical assistance

We are available to address our customers' concerns, including issues and/or questions regarding the casting process, fabrication, corrosion, and mechanical properties. Assisted by a multi-skilled team of experts, we offer technical solutions; we metallographically examine customer samples; we develop fact-based approaches; and we provide a written report of our findings. We follow up with the customer and, if necessary, visit their facility to assist in the application of our recommendations. We work to ensure a satisfactory end result and substantial value for our customers.

For solutions to your technical challenges, please contact your local representative who will put you in touch with the appropriate technical expert.

Research and development

Rio Tinto's Research and Development group is comprised of a global system of three research laboratories, applied engineering centers and plant technical departments in Canada, France and Australia.

The Arvida Research and Development Center (ARDC), located in Quebec, Canada specializes in foundry ingot and focuses on:

- developing new alloys as required by our customer base;
- providing technical and product development support;
- expanding fundamental understanding of alloy/process interactions;
- the selection, application and handling of foundry alloys; and
- improving predictable capability for alloy behavior

In order to develop better and more efficient processes, ARDC implements a range of technical support resources, including design, fabrication and casting. These resources allow our research team to develop, test and evaluate their ideas and transform them into useful and practical solutions.

Associations
We are members of several industry associations, including:

- The Aluminum Association (AA)
- American Foundry Society (AFS)
- Advanced Casting Research Center (ACRC)
- American Society for Testing and Materials (ASTM)
- Aluminium Stewardship Initiative (ASI)

Selection of foundry alloys

Alloy offerings and specification
Within our broad alloy offerings, we have the flexibility to produce alloys according to specific customer requirements. Strontium-modified alloys can be produced to order based on chemistries specified by our customers. This capability, combined with technical support provided by our team of experienced researchers, foundry technologists and knowledgeable sales and administrative staff, comprises the full service package we offer to our foundry customers.

Ingot sizes
Our smelter facilities and casthouses offer a range of foundry ingot sizes:

- small form ranging from 18 to 50 lbs. (8 to 23kg); and
- T-ingot form with the most popular weight being between 1,200 to 2,000 pounds (544 to 907kg). Other T-ingot sizes are subject to inquiry.

Low CO_2 aluminum

Reducing our carbon footprint
As governments continue to set stricter limits for fuel economy and CO_2 emissions, consumers are turning to aluminium for weight saving solutions. 78% of our globally produced, primary aluminum comes from carbon-free energy. A metric tonne of aluminum produced at one of our smelters has a 65% smaller CO_2 footprint than the industry average. Together, we can help create a more sustainable world.

Foundry casting operations[1]

Beauharnois Works (Quebec, Canada)
Beauharnois Works is located in southwestern Quebec, approximately 27 miles (45km) southwest of Montreal. The annual capacity of 48,000 metric tonnes consists of specialty small form foundry ingot cast into 32 lb. (14.7kg) ingots. The plant's flexibility allows for the handling of small orders and the availability of a wide selection of alloys.

PLS Works (Quebec, Canada)
PLS Works is located in the "aluminum valley," approximately 135 miles (220km) north of Quebec City in the Jonquiere area. The annual production capacity of 50,000 metric tonnes, the PLS operation specializes in small form foundry ingot, making it the most modern production facility for primary small form foundry ingot in North America. The entire production is cast into small form foundry ingots 32 lb. (14.7kg).

[1] All facilities are ISO 9001 certified.

Alma Works (Quebec, Canada)
Alma Works is located in the “aluminum valley” approximately 156 miles (250km) north of Quebec City in the Saguenay-Lake St-Jean area. The annual capacity of 465,000 metric tonnes consists of foundry T-ingots, aluminum rod and hot metal production. Two horizontal casting machines produce a mix of foundry type (Al-Si alloys) T-ingots. The most popular T-ingot weight ranges between 1,200 to 2,000 lbs. (544 to 907kg). Other T-ingot sizes are subject to inquiry.

Bell Bay Aluminium Smelter (Tasmania, Australia)
Our Bell Bay smelter is located on the Tamar River in Northern Tasmania, Australia about 31 miles (50km) north of the City of Launceston. The annual capacity of 189,000 metric tonnes consists of slab, T-bar, and ingot products. Bell Bay can produce foundry alloys in T-bar shapes and 18 lbs. (8kg) and 26 lbs. (12kg) small form ingots.

New Zealand Aluminium Smelter (Tiwai Peninsula, New Zealand)
NZAS is located on Tiwai Point at the southern tip of South Island of New Zealand and is about 16 miles (25km) from the City of Invercargill. The annual capacity of 270,000 metric tonnes consists of the highest purity aluminum in the world. Apart from various high purity product lines, NZAS also produces foundry alloys in 50 lbs. (23kg) small form ingot.

Aluminerie Bécancour (Quebec, Canada)
The Bécancour smelter (ABI) is located on the shores of the St. Lawrence River. Rio Tinto owns 25.05 per cent of the smelter along with Alcoa (74.95 per cent ownership). The Bécancour Smelter has a production capacity of 446,000 metric tonnes of aluminum annually in the for of rolling ingots, T-ingots (pure and unalloyed) and billets.

Ingot product availability*

Remelt casting centers		Alloy types					
		Standard purity 99.7% Al	Medium & high purity 99.8% Al	Electrical conductor alloy	Standard alloys Al-Si-Mg	Specialty alloys	Coating Al-Si
Beauharnois Works (Quebec, Canada)	Small form 32 lbs. (14.7kg)	X		X	X	X	X
PLS Works (Quebec, Canada)	Small form 32 lbs. (14.7kg)	X		X	X	X	X
Alma Works (Quebec, Canada)	T-ingot 1,200-2,000 lbs. (544-907kg)	X		X	X		X
Alma Works (Quebec, Canada)	Cast-cut 22 lbs. (10kg)	X		X	X	X	X
ABI Works (Quebec, Canada)	T-ingot up to 1,636 lbs. (742kg)	X		X	X	X	X
Kitimat Works (British Columbia)	Small form 32 lbs. (14.7kg)	X	X	X	X	X	
Bell Bay Aluminium Smelter BBY (Tasmania, AUS)	T-ingot 720-1,400 lbs. (327-635kg)				X		X
Bell Bay Aluminium Smelter BBY (Tasmania, AUS)	Small form 18 lbs. (8kg) 26 lbs. (12kg)	X	X	X	X	X	X
New Zealand Aluminium Smelter NZAS (Tiwai Peninsula, NZ)	Small form 50 lbs. (23kg)	X	X	X	X	X	X
Boyne Smelters Ltd. BSL (Queensland, AUS)	Small form 50 lbs. (23kg)	X	X	X			
Sohar Aluminium (Oman)	Small form 35 lbs. (23kg)	X	X				
Tomago Aluminium (AUS)	T-ingot 720-1,400 lbs. (327-635kg)						X
Tomago Aluminium (AUS)	Small form 50 lbs. (23kg)	X					

*This is a general overview - for more information, please contact Rio Tinto regional office.

Foundry alloys, composition and general applications

Heat treatment of aluminum alloy castings
The following pages contain times and temperatures for heat treatment which are typical for various thicknesses and geometries commonly encountered in cast parts, but may not provide the optimum heat treatment for a specific casting.

No matter what apparatus is used for heat treating aluminum castings, careful evaluation is required to ensure that the casting responds properly to heat treatment and is not overheated or damaged by the heat treatment environment.

Heat-treatment process
Any specified solution, heat treatment temperature contained in this booklet refers to the temperature of the metal being treated. In absence of a suitable metal temperature device, the soaking times that appear or the various alloys may be used. Note that the ranges quoted are, in most cases, quite wide.

In general, chemically modified castings that are solidified rapidly require solutionizing times close to the low end of each range. Examples, including thin permanent mold castings and those with thick sections, will require soak times closer to the high end of the appropriate range. Regardless, the times chosen must result in castings which meet the required physical and mechanical properties.

Quenching
During quenching, it is important that cooling proceeds rapidly through the 750-500°F (400-260°C) range in order to avoid the type of premature precipitation detrimental to tensile properties and corrosion resistance. For casting alloys, the quench delay should not exceed 45 seconds. Reduced quench delay may be necessary to attain the tensile requirements shown in the product specifications for C355.0 and A356.0 sand castings or investment castings and 354.0, A356.0, A357.0 and A444.0 permanent mold castings.

Aluminum foundry alloy selection table

Typical casting, fabrication and application characteristics

Foundry alloys	Casting method	General castability	Fluidity	Hot shortness	Shrinkage tendency	Elevated temperature strength	Corrosion resistance	Pressure tightness	Machin-ability	Weldability	Anodizing appearance	Resistance to die soldering
206.2	Sand & PM	4	4	4	2	1	4	4	2	4	3	
A206.2	Sand & PM	4	4	4	2	1	4	4	2	4	3	
B206.2	Sand & PM	4	4	4	2	1	4	4	2	4	3	
242.2	Sand & PM	4	3	4	2	1	4	4	2	4	3	
A242.2	Sand & PM	3	4	4	2	1	4	4	2	4	3	
304.1	Die	1	1	1	2	1	1	1	2	1	1	1
319.2	Sand & PM	2	2	2	2	3	3	2	2	2	4	
354.2	Sand & PM	1	1	1	1	2	3	1	4	3	4	
355.2	Sand & PM	1	1	1	2	2	3	1	3	1	4	
C355.2	Sand & PM	1	1	1	1	2	3	1	3	1	4	
356.2	Sand & PM	1	1	1	1	3	2	1	3	1	4	
A356.2	Sand & PM	1	1	1	1	3	2	1	3	1	4	
Revolution-Al™	Sand & PM	1	1	1	1	3	2	1	3	1	4	
357.1	Sand & PM	1	1	1	1	3	2	1	3	2	4	
F357.1	Sand & PM	1	1	1	1	3	2	1	3	2	4	
A359.2	Sand & PM	1	1	1	3	2	2	2	4	1	4	
F357.2	Sand & PM	1	1	1	1	3	2	1	3	2	4	
A360.2	Die	2	2	1	2	1	3	1	4	X	3	2
A365.1 Aural™ -2, -3	Die	1	1	1	2	1	2	1	3	1	3	2
374.1 Aural™-5	Die	1	1	1	2	1	2	1	3	1	3	2
375.1 Aural™-6	Die	1	1	1	2	1	2	1	3	1	3	2

Ratings: 1 = excellent 2 = very good 3 = good 4 = fair 5 = poor X = not recommended
Sand = sand casting PM = permanent mold Die = die casting

Aluminum foundry alloy selection table (continued)

Typical casting, fabrication and application characteristics

Foundry alloys	Casting method	General castability	Fluidity	Hot shortness	Shrinkage tendency	Elevated temperature strength	Corrosion resistance	Pressure tightness	Machin-ability	Weldability	Anodizing appearance	Resistance to die soldering
A380.2	Die	2	2	2	3	3	4	2	3	X	4	1
390.2	Die	3	1	2	3	1	3	2	4	X	5	1
A390.1	Sand & PM	2	1	3	3	1	3	3	4	3	5	
413.2	Die	1	1	1	3	3	2	1	4	X	5	1-3
A413.2	Die	1	1	1	3	3	2	1	4	X	5	1-3
	Sand & PM	1	1	1	2	3	1	1	5	1	4	
B413.1	Sand & PM	1	1	1	2	3	1	1	5	1	4	
443.2	Sand	1	2	1	2	4	2	2	4	1	5	
	PM	1	2	1	2	4	2	2	4	1	4	
	Die	3	2	2	3	5	2	2	4	X	2	4
444.2	Sand & PM	1	1	1	2	2	2	2	4	1	4	
A444.2	Sand & PM	2	2	1	2	2	2	2	4	1	4	
A514.2	Sand	4	4	4	5	3	1	5	1	3	1	
515.2	Sand, PM & Die	4	4	4	4	3	2	5	2	4	1	
518.2	Die	5	5	4	4	3	2	5	1	X	1	5
520.2	Sand	4	4	4	5	5	1	5	1	4	1	
A535.1	Sand & PM	4	4-5	3-4	3	3	1	5	1	4	1	
B535.2	Sand & PM	4	4	4	3	3	1	5	1	4	1	
712.2	Sand	4	3	5	3	2	3	4	1	4	2	
713.1	Sand & PM	4	3	5	4	4	2	3	1	4	2	
771.2	Sand & PM	4	3	5	4	4	3	4	1	4	1	

Ratings: 1 = excellent 2 = very good 3 = good 4 = fair 5 = poor X = not recommended
Sand = sand casting PM = permanent mold Die = die casting

Alloys 206.2, A206.2 and B206.2 for permanent mold and sand casting

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sn	Other Each	Other Total
206.2	0.10	.10	4.2-5.0	0.20-.50	.20-0.35	-	0.03	0.05	0.15-0.25	-	0.05	0.15
A206.2	0.05	0.07	4.2-5.0	0.20-.50	.20-0.35	-	0.03	0.05	0.15-0.25	0.05	0.05	0.15
B206.2	0.05	0.07	4.2-5.0	0.20-.50	.20-0.35	-	0.03	0.05	0.05	0.05	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension: Ultimate strength MPa (ksi)	Tension: Yield strength 0.20% offset MPa (ksi)	Tension: Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)	Fatigue strength[3] MPa (ksi)[4]	Fracture toughness MPa-m 1/2 (ksi-in. 1/2)	Charpy impact J (ft-lb)
T4	PM	431 (62)	264 (38)	17.0	285 (41)	292 (42)	100	-	-	-	-
	Sand	354 (51)	250 (36)	7.0	264 (38)	278 (40)	100	-	-	-	-
T7	Sand	436 (63)	347 (50)	11.7	372 (54)	257 (37)	120	90 (13)	205 (30)	43 (39.1)	9.5 (7.01)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.
[4]Values determined 30 days after casting.

Thermal treatments

T4 temper

Solutionize at 950°F (510°C) for two hours then raise to 985°F (530°C) for an additional 14 to 20 hours; aged minimum of five days at room temperature.

These alloys are stress corrosion, crack prone when in T6 temper and should not be used in the T6 temper for applications that are exposed to even mildly corrosive environments.

T6 temper

Solutionize at 950°F (510°C) for two hours then raise to 985°F (530°C) for an additional 14 to 24 hours at room temperature, followed by 20 hours at 310°F (155°C).

T7 temper

Solutionize at 985°F (510°C) for two hours then raise to 950°F (530°C) for an additional at room temperature, followed by four to five hours at 370°F (190°C).

Application characteristics

Alloy 206.2 is a high strength alloy with excellent fracture toughness and elevated temperature strength. This alloy is used for high performance applications such as automotive suspension knuckles, aerospace thrust reversers and turbine impellors. Other applications include downsizing castings that are made with A356.2. This alloy can also be used to cast shapes in the same configuration as cast iron and obtain equal physical and mechanical properties.

Castability

This alloy is generally hot, short and difficult to cast and requires close attention to proper gating and rising techniques which assure strong temperature gradients and good directional solidification.

Solidification range

1058-1202°F (570-650°C).

Weldability

Fair repair welding characteristics.

Finishing

Very good machinability.

Corrosion resistance

This alloy's resistance to corrosion is fair due to the copper content of this alloy.

Alloy 242.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.6	0.6	3.5-4.5	0.10	1.3-1.8	-	1.7-2.3	0.10	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2 in. (50mm)				
T21	Sand	185 (27)	125 (18)	2.0	125 (18)	145 (21)	70	55 (8)
T571	Sand	220 (32)	205 (30)	0.5	235 (34)	180 (26)	70-100	75 (11)
T77	Sand	165 (24)	90 (13)	1.0	165 (24)	165 (24)	60-90	70 (10)
T571	PM	275 (40)	235 (34)	1.0	235 (34)	205 (30)	90-120	70 (10)
T61	PM	325 (47)	290 (42)	0.5	305 (44)	240 (35)	95-125	65 (9.5)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

Annealing
Sand: Two to four hours at 645-655°F (340-345°C).

T21 Temper
Sand: Two to four hours at 645-655°F (340-345°C).

T571 Temper
Sand: Eight hours at 400°F (205°C); still-air cooling.
PM: 22 to 26 hours at 340°F (170°C) or seven to nine hours at 400°F (205°F).

T61 Temper
Sand: Solutionize at 960°F (515°C) for two to six hours[1]; then at 446-455°F (230-235°C) for one to eight hours.
PM: Four to 12 hours at 960°F (515°C) ; then three to five hours at 400°F (205°F).

T77 Temper
Sand only: One to three hours at 645-655°F (340-345°C) (US Patent No. 1822877).[1]

Application characteristics
An excellent high temperature strength alloy. Typical applications include motorcycles, diesel and aircraft pistons, air-cooled cylinder heads and aircraft generator housings.

Castability
The rating of alloy 242.2 is only fair for all the common criteria of castability. Shrinkage tendency is very good. Generally hot, short and difficult to cast, this alloy requires close attention to proper gating and rising techniques which assure strong temperature gradients and good directional solidification.

Solidification range
1175-990°F (635-530°C).

Weldability
Fair repair welding characteristics.

Finishing
Very good machinability.

Corrosion resistance
This alloy's resistance to corrosion is fair due to the copper content of this alloy.

[1]Quenching is achieved by air blast.

Alloy 304.1 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
9.0-11.5	0.8-1.2	0.05-0.08	0.3-0.5	0.3-0.5	0.05-0.03	0.03	0.2	0.03-0.18	0.03	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2 in. (50mm)	Compressive yield strength[1] MPa (ksi)	Thermal Conductivity (W/ m.k)	Electrical Conductivity % AICS	Die life
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Die	297 (43)	172 (25)	5.0	-	120	32%	100% of A380

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics

Alloy 304.1 is a patented alloy of Delphi Technologies, Inc. (K-ALLOY). 304.1 is a general purpose alloy exhibiting superior corrosion resistance and excellent castability, with higher strength, moderate elongation and excellent thermal conductivity. Recommended for automotive use as a superior replacement to A380 for its corrosion resistance and comparable die life. Part applications include powertrain and electronics housings, body structures, lighting housings, battery enclosures, chassis components and crossmembers. Outdoor lighting, furniture, marine and other demanding corrosion applications use 304.1.

Castability

304.1 (K-Alloy) has excellent fluidity and long die life.

Casting Temperature

1080-1285°F (638-696°C).

Machinability

This alloy has superior machinability from its low alloy content.

Finishing

Anodizing and plating is not generally necessary. As -cast surface polishes well and is resistant to staining.

Corrosion resistance

Superior corrosion resistance.

Alloy 319.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
5.5-6.5	0.6	3.0-4.0	0.10	0.10	-	0.10	0.10	0.20	-	0.20

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2 in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Sand	185 (27)	125 (18)	2.0	130 (19)	150 (22)	70	70 (10)
	PM	235 (34)	130 (19)	2.5	130 (19)	165 (24)	85	-
T5	Sand	172 (25)	-	<1.0	-	-	65-95	-
T6	Sand	214 (31)	138 (20)	2.0	170 (25)	200 (29)	65-95	75 (11)
	PM	234 (34)	185 (27)	2.0	-	185 (27)	75-105	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

Annealing to relieve stress and reduce growth
PM and Sand: Two hours at 650°F (345°C); air cool to room temperature.

F temper
As-cast.

T5 Temper
Sand Only: Seven to nine hours at 400°F ± 5° (205°C ± 3°).

T6 Temper
Sand: 12 hours at 940°F ± 5° (505°C ± 3°); quench in water at 150-212°F (65-100°C);then age for two to five hours at 940°F ± 5° (155°C ± 3°).
PM: Four to 12 hours at 935-945°F (500-510°C); then quench and age as above for Sand.

Application characteristics
319.2 is a medium strength alloy with very good casting and welding characteristics. Typical uses for sand castings include gasoline and crankcases and oil pans. Applications of PM castings range from computer frames to cylinder heads of water-cooled engines.

Castability
Fluidity, resistance to hot cracking, shrinkage and pressure tightness are all rated very good.

Solidification range
1120-960°F (605-515°C).

Weldability
Response is rated very good to arc welding methods and good to resistance and gas methods.

Finishing
Electroplated finishes are very good; mechanical and anodized finishes are fair.

Corrosion resistance
Resistance of alloy 319.2 castings to most common forms of corrosion is good, but in industrial and saltwater environments, the laying surfaces should be protected. Chemical conversion coatings can be applied for additional protection.

Alloy 354.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
8.6-9.4	0.2	1.6-2.0	0.10	0.45-0.6	-	-	0.10	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2 in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
T61 (at room temperature)	PM	380 (55)	285 (41)	6.0	227 (33)	-	-	145 (21)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

Solution treatment
980°F (525°C); hold at this temperature for ten to 12 hours; quench in hot water at 140-176°F (60-80°C).

T61 temper
PM: 980°F (525°C) for ten to 12 hours; room temperature for eight hours; then 310°F (155°C) for ten to 12 hours.

T62 temper
PM: 980°F (525°C) for ten to 12 hours; room temperature for eight hours; then 340°F (170°C) for six to ten hours.

Application characteristics

354.2 is a high strength alloy with excellent castability characteristics. Permanent mold castings are used in applications requiring high strengths and heat treatability, particularly elevated temperature strengths used for automotive turbo charger impellors and scrolls for automotive air conditioners.

Castability
Fluidity, resistance to hot cracking, shrinkage and pressure tightness are all rated excellent.

Solidification range
1100-1000°F (996-538°C).

Machinability
Rated fair.

Weldability
Response is rated good.

Finishing
Anodized finishes are fair.

Corrosion resistance
Alloy 354.2 castings corrosion resistance most common forms of corrosion is good.

Alloy 355.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
4.5-5.5	0.14-0.25	1.0-1.5	0.05	0.50-0.6	-	-	0.05	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2 in. (50mm)				
T51	Sand	195 (28)	160 (23)	1.5	165 (24)	150 (22)	65	55 (8)
	PM	205 (30)	165 (24)	2.0	165 (24)	165 (24)	75	-
T6	Sand	240 (35)	170 (25)	3.0	180 (26)	195 (28)	80	60 (9)
	PM	290 (42)	185 (27)	4.0	185 (27)	235 (34)	90	70 (10)
T61	Sand	270 (39)	240 (35)	1.0	255 (37)	215 (31)	90	65 (9.5)
T62	PM	310 (45)	275 (40)	1.5	275 (40)	250 (36)	105	70 (10)
T7	Sand	260 (38)	250 (36)	0.5	260 (38)	195 (28)	85	70 (10)
	PM	275 (40)	205 (30)	2.0	205 (30)	205 (30)	85	70 (10)
T71	Sand	240 (35)	200 (29)	1.5	205 (30)	180 (26)	75	70 (10)
	PM	250 (36)	215 (31)	3.0	215 (31)	185 (27)	85	70 (10)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

Annealing to relieve stresses and reduce growth
PM and Sand: Soak for two hours at 650°F (345°C); air cool to room temperature.

T5 temper
Sand and PM: Soak seven to nine hours at 440°F ±5° (225°C±3°).

T6 temper
Sand: Soak 12 hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age for three to five hours at 310°F (155°C).
PM.: Soak four to 12 hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age two to five hours at 310°F (155°C).

T61 temper
Sand only: Soak 12 hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age for eight to ten hours at 310°F (155°C).

T62 temper
PM only: Soak four to twelve hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age for fourteen to eighteen hours at 340°F (170°C).

T7 temper
Sand: Soak 12 hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age for three to five hours at 440°F (225°C).
PM.: Soak twelve hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age seven to nine hours at 440°F (225°C).

T71 temper
Sand: Soak 12 hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age for four to six hours at 475°F (245°C).
PM.: Soak four to four to twelve hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age three to six hours at 475°F (245°C).

Application characteristics
Alloy 355.2 is a heat-treatable, medium strength alloy suitable for a large variety of products, including castings with high temperature applications. Typical sand castings include compressor pistons, crankcases and gear housing. Typical PM castings include aircraft fittings, compressors and transmission cases.

Castability
Fluidity, resistance to hot cracking, shrinkage tendency and pressure tightness are all rated excellent. Feeding characteristics are particularly good for thick sections.

Solidification range
1150-1015°F (620-545°C).

Machinability
Machinability of heat-treated casting is good. Use well sharpened, high speed tools.

Weldability
Excellent for all standard welding procedures.

Finishing
Alloy 355.2 is a preferred electroplating alloy due tnd castings for functional purposes. Response to conversion coatings and mechanical finishing is good. Anodized finishes are gray and rated fair.

Corrosion resistance
Rated good. Conversion coatings cam be used for added protection.

Alloy C355.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
4.5-5.5	0.13	1.0-1.5	0.05	0.50-0.6	-	-	0.05	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2 in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
T6	Sand	270 (39)	200 (29)	5.0	-	-	85	-
	PM	330 (48)	195 (28)	8.0	-	-	90	-
T61	PM	315 (46)	235 (34)	6.0	250 (36)	220 (32)	100	95 (14)
T62	PM	330 (48)	255 (37)	5.0	-	-	100	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

T6 temper
Sand and PM: Soak twelve hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age eight plus hours at 310°F (155°C).

T61 temper
PM only: Soak six to twelve hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age at room temperature for eight hours plus; then age ten to twelve hours at 310°F (155°C).

T62 temper
PM only: Soak eight to ten hours at 980°F (525°C); quench in water at 150-212°F (65-100°C); then age fourteen to eighteen hours at 340°F (170°C).

Application characteristics
Alloy C355.2 is a modification of 355.2 that develops higher elongations and tensile strengths than are possible with 355.0 castings. Both PM and sand castings are used for aircraft and aerospace structural components and other highly stressed castings.

Castability
The rating of alloy C355.2 is excellent for all the common criteria of castability.

Solidification range
1150-1015°F (620-545°C).

Machinability
Rated good. Light removal of metal with carbide tipped tools operated at high speed is recommended.

Weldability
Excellent for all standard welding applications.

Finishing
With this alloy, best results are obtained with chemical conversion and electroplating. Sand castings are plated for functional purposes and PM castings for decorative purposes. The use of electroplated PM castings should be confined to noncorrosive environments. Mechanical and anodized finishes are fair.

Corrosion resistance
Rated good for most atmospheric conditions. Additional protection can be provided by chemical conversion coatings.

Alloy 356.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
6.5-7.5	0.13-0.25	0.10	0.05	0.30-0.6	-	-	0.05	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2 in. (50mm)				
F	Sand	165 (24)	90 (13)	5.0	-	-	-	-
	PM	180 (26)	90 (13)	5.0	-	-	-	-
T51	Sand	170 (25)	140 (20)	2.0	145 (21)	140 (20)	60	55 (8)
	PM	185 (27)	140 (20)	-	-	-	-	-
T6	Sand	230 (33)	165 (24)	3.5	170 (25)	180 (26)	70	60 (8.7)
	PM	260 (38)	185 (27)	5.0	185 (27)	205 (30)	80	90 (13)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Annealing to relieve stress and reduce growth
PM and Sand: Soak for two hours at 650°F (345°C); air cool to room temperature.

T51 temper
Sand and PM: Soak seven to nine hours at 440°F (225°C).

T6 temper
Sand: Soak 12 hours at 980°F (525°C); quench in water at 150-212°F (65-100°C);then age for three to five hours at 310°F (155°C).
PM: Soak four to twelve hours at 1000°F (540°C); then quench in water at 150-212°F (65-100°C); then age two to five hours at 310°F (155°C).

Application characteristics

Alloy 356.2 is a medium strength, heat-treatable alloy used for general purpose castings requiring good corrosion resistance. Typical uses are outboard motor parts, marine fittings, storage tank fittings and gray, anodized architectural components.
In the T6 temper, it is often used in marine applications requiring pressure tightness and corrosion resistance.

Castability

This alloy is resistant to hot cracking and solidification shrinkage. Pressure tightness and fluidity are rated excellent.
Solidification range
1135-1035°F (610-555°C).

Machinability

Machinability of good in the heat-treated tempers. To minimize tool wear, use flood lubrication and carbide tipped tools with high positive rakes run at maximum speeds.

Weldability

Generally ranked as having excellent weldability with all common welding procedures.

Finishing

Anodizes to an attractive gray color suitable for architectural and decorative applications. Often used for high strength porcelain enameled castings as it can be aged after enameled. Responds very well to electroplating and chemical conversion coating. PM castings can be plated for decorative purposes, but should be confined to noncorrosive environments.

Corrosion resistance

Alloy 356.2 castings have excellent corrosion resistance. They are suitable for marine and industrial environments and, if required, chemical conversion coatings can be applied for additional protection.

Alloy A356.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
6.5-7.5	0.12	0.10	0.05	0.30-0.45	-	-	0.05	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2 in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Sand	160 (23)	85 (12)	6.0	-	-	-	-
	PM	185 (27)	90 (13)	8.0	-	-	-	-
T6	Sand	275 (40)	205 (30)	6.0	145 (21)	140 (20)	70-150	55 (8)
	PM	285 (41)	205 (30)	12.0	-	-	80	-
T61	PM	285 (41)	205 (30)	7.0-12.0	220 (32)	195 (28)	70-100	90 (13)
T71	Sand	205 (30)	140 (20)	3.0	-	-	-	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

Annealing to relieve stress and reduce growth
PM and Sand: Soak for two hours at 650°F (345°C); air cool to room temperature.

F temper
As-cast.

T6 temper
Sand: Soak twelve hours at 1000°F (540°C); quench in water at 150-212°F (65-100°C); age eight plus hours at room temperature; then two to five hours at 310°F (155°C).
PM: Soak six to twelve hours at 1000°F (540°C); quench in water at 150-212°F (65-100°C); age eight plus hours at room temperature; then three to five hours at 310°F (155°C).

T61 temper
PM only: Soak six to twelve hours at 1000°F (540°C); quench in water at 150-212°F (65-100°C); then age for six to twelve hours at room temperature; then ten to twelve hours at 310°F (155°C).

T71 temper
Sand only: Soak twelve hours at 1000°F (540°C); then quench in water at 150-212°F (65-100°C); then age eight plus hours at room temperature; then three hours at 475°F (245°C).

Application characteristics
Alloy A356.2 is a medium strength, heat-treatable alloy with good pressure tightness and excellent corrosion resistance. It is a very fluid alloy, well suited to the casting of thin sections and structural parts. Typical applications are airframe castings, truck chassis parts, missile components and wheels.

Compared with alloy 356.2, A356.2 has the same level of alloying elements, but because of its lower level of impurities, it is stronger and more ductile.

Castability
This alloy is a very fluid alloy with excellent casting characteristics. Heavy chilling is recommended to ensure the development of optimum properties when sand casting.

Solidification range
1135-1035°F (610-555°C).

Machinability
Rated very good in the T61 temper. The use of carbide-tipped tools at moderate to fast speeds will minimize the effect of the abrasiveness that is typical of high silicon alloys.

Weldability
Responds exceptionally well to welding by all common methods.

Finishing
Electroplated finishes are very good if castings are sound and smooth with rounded corners. Both PM and sand castings can be plated for decorative applications in noncorrosive environments. Mechanical finishes are good, but anodized finishes are generally only used for protection.

Corrosion resistance
Alloy A356.2 castings have excellent resistance to most forms of corrosion.

Alloys 357.1, F357.1 and F357.2 for permanent mold and sand castings

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Be	Other	
											Each	Total
357.1	6.5-7.5	0.12	0.05	0.03	0.45-0.6	-	-	0.05	0.20	-	0.05	0.10
F357.1	6.5-7.5	0.07	0.20	0.10	0.45-0.7	-	-	0.10	0.04-0.20	0.002 max	0.05	0.15
F357.2	6.5-7.5	0.07	0.20	0.10	0.45-0.7	-	-	0.10	0.04-0.20	0.0003 max	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
T62	Sand & PM	360 (520)	290 (42)	8.0	-	-	-	115 (17)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.
[4]Values determined 30 days after casting.

Thermal treatments

T51 temper
Sand only: Soak seven to nine hours at 445°F (230°C).

T6 temper
Sand: Soak 12 hours at 1000°F (540°C); cool in water at 150-212°F (65-100°C);then age for two to five hours at 310°F (155°C).
PM: Soak twelve hours at 1000°F (540°C); cool in water at 150-212°F (65-100°C); then age three to five hours at 310°F (155°C).

T7 temper
Sand only: Soak twelve hours at 1000°F (540°C); cool in water at 150-212°F (65-100°C);then age for seven to nine hours at 445°F (230°C).

T71 temper
Sand only: Soak twelve hours at 1000°F (540°C); cool in water at 150-212°F (65-100°C);then age for two to four hours at 480°F (250°C).

Application characteristics
Alloys 357 and F357 are the most commonly used alloys in the aerospace industry. Castable high strength alloy, these parts combine good fabrication characteristics with a wide range of obtainable properties.

Castability
The rating of alloy 357.1 is excellent for all common criteria of castability.

Solidification range
1135-1035°F (610-555°C).

Machinability
Machinability is rated good.

Weldability
Weldability is rated very good.

Finishing
The anodizes appearance is rated fair.

Corrosion resistance
Alloy 357.1, F357.1 and F357.2 castings have very good corrosion resistance.

Alloy Revolution-Al™ AlSi7MgMn for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
6.5-7.5	0.12	0.10	0.30-0.40	0.45-0.55	-	-	0.05	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2 in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Sand	160 (23)	85 (12)	6.0	-	-	-	-
	PM	185 (27)	90 (13)	8.0	-	-	-	-
T6	Sand	275 (40)	205 (30)	6.0	-	-	-	-
	PM	320-340 (46-49)	240-280 (35-41)	5.0-8.0	-	-	-	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

Annealing to relieve stress and reduce growth
PM and Sand: Soak for two hours at 650°F (345°C); air cool to room temperature.

F temper
As-cast.

T6 temper
Sand: Soak twelve hours at 1000°F (540°C); quench in water at 150-212°F (65-100°C); age eight plus hours at room temperature; then two to five hours at 320°F (160°C). At comparable aging practices, Revolution-Al™ heat treatment can be reduced by 2hrs.

PM: Soak six to twelve hours at 1000°F (540°C); quench in water at 150-212°F (65-100°C); age eight plus hours at room temperature; then three to five hours at 310°F (155°C).

Application characteristics
Revolution-Al™ is a medium strength, heat-treatable alloy with good pressure tightness and excellent corrosion resistance. It is a very fluid alloy, well suited to the casting of thin sections and structural parts. Typical applications are airframe castings, chassis parts, suspension components and wheels.

Compared with alloy 356.2, Revolution-Al™ has the same level of alloying elements, but because of its lower level of impurities and enhanced composition it is 10-15% stronger and more ductile.

Castability
This alloy is a very fluid alloy with excellent casting characteristics. Heavy chilling is recommended to ensure the development of optimum properties when sand casting.

Solidification range
1135-1035°F (610-555°C).

Machinability
Rated very good in the T6 temper. The use of carbide-tipped tools at moderate to fast speeds will minimize the effect of the abrasiveness that is typical of high silicon alloys.

Weldability
Responds exceptionally well to welding by all common methods.

Finishing
Electroplated finishes are very good if castings are sound and smooth with rounded corners. Both PM and sand castings can be plated for decorative applications in noncorrosive environments. Mechanical finishes are good, but anodized finishes are generally only used for protection.

Corrosion resistance
Alloy Revolution-Al™ castings have excellent resistance to most forms of corrosion.

Patent WO 2017/165962 Al

Alloy A359.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
8.5-9.5	0.12	0.10	0.10	0.55-0.7	-	-	0.10	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
T62	Sand & PM	360 (520)	290 (42)	8.0	-	-	-	115 (17)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.
[4]Values determined 30 days after casting.

Thermal treatments

T61 temper
PM: Solutionize ten to 14 hours at 1000°F (540°C); hot water quench 140-175°F (60-80°C); hold at room temperature for eight hours; then soak at 310°F (155°C) for 10 to twelve hours.

T62 temper
PM: Solutionize ten to 14 hours at 1000°F (540°C); hot water quench 140-175°F (60-80°C); hold at room temperature for eight hours; then soak at 340°F (170°C) for six to ten hours.

Application characteristics
Alloy A359.2 is a moderately high strength permanent mold casting alloy frequently used when higher fluidity than 356/357 is required for use in a structural part.

Castability
The rating of alloy A359.2 is excellent for all common criteria of castability.

Solidification range
1135-1035°F (610-555°C).

Machinability
Machinability is rated fair.

Weldability
Weldability is rated good.

Finishing
The anodizes appearance is rated fair.

Corrosion resistance
Alloy A359.2 castings have very good corrosion resistance.

Alloy A365.1 (Aural™-2) for high integrity die casting

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sr	Other Each	Other Total
Aural™-2	9.5-11.5	0.15-0.20	0.02	0.30-0.6	0.15-0.6	-	-	0.03	0.10	0.03	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension: Ultimate strength MPa (ksi)	Tension: Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.
F	Die	280-320 (41-46)	130-160 (19-23)	5-11	-	-	70-105
T4	Die	200-270 (29-39)	100-150 (15-22)	15-22	-	-	95-115
T5	Die	270-320 (39-46)	165-220 (24-32)	4-8	-	-	60-75
T6	Die	210-250 (30-36)	100-160 (14-23)	8-14	-	-	100-110
T7	Die	190-220 (28-32)	120-150 (17-22)	12-18	-	-	60-75
O	Die	180-200 (26-29)	90-110 (13-16)	14-20	-	-	-

[1]Tensile properties and hardness values determined by tests on standard ASTM B557 flat specimens without surface finishing; each cast in permanent molds.

Thermal treatments

F temper
As-cast.

T4 temper
Soak at 896-932°F (480-500°C) during two to five hours at metal temperature.

T5 temper
Air quenching after casting.
Aging: 320-446°F (160-230°C).
Stabilization or artificial ageing treatment. Cast quenched in water immediately after being removed from the mold, soak at 338-446°F (170-230°C) for up to three hours.

T6 temper
Soak at 896-932°F (480-500°C) during two to five hours at metal temperature. Water quenching at 68°F (20°C).
Aging: 311-338°F (155-170°C) during two to three hours.

T7 temper
Soak at 824-968°F (440-520°C) during one to five hours at metal temperature. Fast quenching at 68°F (20°C).
Aging: 320-446°F (160-230°C) during one to five hours.
[Special heat treatment for low distortion of thin large parts are available on request.]

0 temper
Soft annealing at less than 752°F (400°C) during ten to 40 minutes. Air cooling.

Application characteristics
Aural™-2 is a medium strength, heat-treatable alloy with high ductility which shows excellent corrosion resistance. This alloy is specially designed for highly demanding pressure die casting applications. Due to its very good fluidity, it is well-suited to the casting of thin and large structural parts. Typical applications are energy absorbing, safety critical castings for automotive such as shock towers, space frame or suspension structural parts. The low level of impurities of Aural™-2 leads to an interesting balance of strength and ductility.

Castability
Aural™-2 is a very fluid alloy with excellent casting characteristics. The tendencies to hot tearing, as well as shrink porosity, are very low. Liquid metal feeding during casting is good.

Solidification range
1036-1094°F (558-590°C).

Machinability
Machinability is rated medium in the T5 temper and good in the T6 temper.

Joining
Aural™-2 responds exceptionally well to welding, adhesive and riveting technology by all common methods.

Finishing
Generally speaking, this alloy is not used for decorative applications, Anodized and e-coating finishes are generally only used for protection.

Corrosion resistance
Aural™-2 castings show a good resistance to most forms of corrosion. Resistance can be further enhanced by chemical conversion coating.

Alloy A365.1 (Aural™-3) for high integrity die casting

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sr	Other Each	Other Total
Aural™-3	9.5-11.5	0.15-0.20	0.02	0.30-0.60	0.3-0.6	-	-	0.03	0.10	0.03	0.03	0.1

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension: Ultimate strength MPa (ksi)	Tension: Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.
F	Die	300-340 (44-49)	160-180 (23-26)	6-10	-	-	-
T4	Die	200-240 (29-35)	100-140 (14-20)	12-17	-	-	-
T5	Die	300-340 (44-49)	190-240 (28-35)	4-6.5	-	-	-
T6	Die	235-275 (34-40)	130-215 (19-31)	9.5-13.5	-	-	-
T7	Die	225-245 (33-36)	170-190 (25-28)	8-11	-	-	-
O	Die	180-200 (26-29)	90-110 (13-16)	14-20	-	-	-

[1]Tensile properties and hardness values determined by tests on standard ASTM B557 flat specimens without surface finishing; each cast in permanent molds.
*Properties in development.

Thermal treatments

F temper
As-cast.

T4 temper
Soak at 896-932°F (480-500°C) during two to five hours at metal temperature.

T5 temper
Air quenching after casting.
Aging: 320-446°F (160-230°C).
Stabilization or artificial ageing treatment. Cast quenched in water immediately after being removed from the mold, soak at 338-446°F (170-230°C) for up to three hours.

T6 temper
Soak at 896-932°F (480-500°C) during two to five hours at metal temperature. Water quenching at 68°F (20°C).
Aging: 311-338°F (155-170°C) during two to three hours.

T7 temper
Soak at 824-968°F (440-520°C) during one to five hours at metal temperature. Fast quenching at 68°F (20°C).
Aging: 320-446°F (160-230°C) during one to five hours.
[Special heat treatment for low distortion of thin large parts are available on request.]

Application characteristics
Aural™-3 is a medium strength, heat-treatable alloy with high yield strength while maintaining good ductility which shows excellent corrosion resistance. This alloy is specially designed for highly demanding pressure die casting applications. Due to its very good fluidity, it is well-suited to the casting of thin and large components, as well as structural parts. Typical applications are energy absorbing, safety critical castings for automotive, like shock towers, space frame or suspension structural parts. The low level of impurities of Aural™-3 leads to an interesting balance of strength and ductility.

Castability
Aural™-3 is a very fluid alloy with excellent casting characteristics. The tendencies to hot tearing, as well as shrink porosity, are very low. Liquid metal feeding during casting is good.

Solidification range
1036-1097°F (558-592°C).

Machinability
Machinability is rated medium in the T5 temper and good in the T6 temper.

Joining
Aural™-3 responds exceptionally well to welding, adhesive and riveting technology by all common methods.

Finishing
Generally speaking, this alloy is not used for decorative applications, Anodized and e-coating finishes are generally only used for protection.

Corrosion resistance
Aural™-3 castings show a good resistance to most forms of corrosion. Resistance can be further enhanced by chemical conversion coating.

Alloy 374.1 (Aural™-5) for high integrity die casting

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sr	Other Each	Other Total
Aural™-5	6.5-8.5	0.10-0.20	0.02	0.35-0.7	0.15-0.4	-	-	0.03	0.04-0.15	0.03	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension: Ultimate strength MPa (ksi)	Tension: Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.
F	Die	240-270 (35-39)	110-130 (16-19)	8-12	-	-	-
T4	Die	160-200 (23-29)	60-100 (9-14)	17-22	-	-	-
T5	Die	200-260 (29-38)	120-160 (17-23)	7-11	-	-	-

[1]Tensile properties and hardness values determined by tests on standard ASTM B557 flat specimens without surface finishing; each cast in permanent molds.

Thermal treatments

F temper
As-cast.

T4 temper
Soak at 896-932°F (480-500°C) during two to five hours at metal temperature.

T5 temper
Air quenching after casting.
Aging: 320-446°F (160-230°C).
Stabilization or artificial ageing treatment. Cast quenched in water immediately after being removed from the mold, soak at 338-446°F (170-230°C) for up to three hours.

Application characteristics

Aural™-5 is a medium strength, heat-treatable alloy combining good ductility and yield strength properties without solution heat treatment avoiding the shape distortion. A simple T5 artificial ageing can be applied to the casting which shows excellent corrosion resistance. This alloy is specially designed for highly demanding pressure die casting applications. Due to its very good fluidity, it is well-suited to the casting of thin and large structural parts. Typical applications are energy absorbing, safety critical castings for automotive such as shock towers, space frame or suspension structural parts. The low level of impurities of Aural™-5 leads to an interesting balance of strength and ductility.

Castability

Aural™-5 is a very fluid alloy with excellent casting characteristics. The tendencies to hot tearing, as well as shrink porosity, are very low. Liquid metal feeding during casting is good.

Solidification range

1036-1142°F (558-617°C).

Machinability

Machinability is rated medium in the T5 temper and good in the T6 temper.

Joining

Aural™-5 responds exceptionally well to welding, adhesive and riveting technology by all common methods.

Finishing

Generally speaking, this alloy is not used for decorative applications, Anodized and e-coating finishes are generally only used for protection.

Corrosion resistance

Aural™-5 castings show a good resistance to most forms of corrosion. Resistance can be further enhanced by chemical conversion coating.

Alloy 375.1 (Aural™-6) for high integrity die casting

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sr	Other Each	Other Total
Aural™-6	9.5-11.5	0.10-0.20	0.02	0.30-0.70	0.15	-	-	0.03	0.04-0.15	0.03	0.03	0.1

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension: Ultimate strength MPa (ksi)	Tension: Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.
F	Die	250-280 (36-41)	100-120 (14-17)	10-14	-	-	-

[1]Tensile properties and hardness values determined by tests on standard ASTM B557 flat specimens without surface finishing; each cast in permanent molds.
*Properties in development.

Thermal treatments

F temper
As-cast.

Application characteristics
Aural™-6 is a medium strength, non-heat-treatable alloy with medium yield strength while maintaining good ductility which shows excellent corrosion resistance. This alloy is specially designed for highly demanding pressure die casting applications. Due to its very good fluidity, it is well-suited to the casting of thin and large components, as well as structural parts. Typical applications are energy absorbing, safety critical castings for automotive, like shock towers, space frame or suspension structural parts. The low level of impurities of Aural™-6 leads to an interesting balance of strength and ductility.

Castability
Aural™-6 is a very fluid alloy with excellent casting characteristics. The tendencies to hot tearing, as well as shrink porosity, are very low. Liquid metal feeding during casting is good.

Solidification range
1067-1099°F (575-593°C).

Machinability
Machinability is rated medium in the T5 temper and good in the T6 temper.

Joining
Aural™-6 responds exceptionally well to welding, adhesive and riveting technology by all common methods.

Finishing
Generally speaking, this alloy is not used for decorative applications, Anodized and e-coating finishes are generally only used for protection.

Corrosion resistance
Aural™-6 castings show a good resistance to most forms of corrosion. Resistance can be further enhanced by chemical conversion coating.

Alloy A360.2 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
9.0-10.0	0.6	0.10	0.05	0.45-0.6	-	-	0.5	-	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
F	Die	315 (46)	165 (24)	5.0	276 (40)	180 (26)	-	120 (17)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
General purpose casting alloy used for cover plates, instrument cases and other general purpose die castings where excellent pressure tightness, resistance to hot cracking, strength at elevated temperatures and/or the ability to be electroplated are required.

Castability
The rating of alloy A360.2 is very good with excellent pressure tightness and resistance to hot cracking.

Solidification range
1105-1035°F (595-555°C).

Machinability
Machinability is rated good.

Weldability
Weldability is rated very good.

Finishing
The anodizes appearance is rated good.

Corrosion resistance
Corrosion resistance is rated good.

Alloy A380.2 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
7.5-9.5	0.6	3.0-4.0	0.10	0.10	-	0.10	0.10	-	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
F	Die	325 (47)	160 (23)	3.5	117 (17)	185 (27)	80	138 (20)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Widely used general purpose casting alloy for pulleys, tool housing and fuel pumps. A380.2 is a modification of 380.2 and is used where more elongation than 380.2 is required. It has very good casting characteristics, good mechanical properties and very good elevated temperature strength.

Castability
The rating of alloy A380.2 is very good for fluidity, resistance to hot shortness and pressure tightness.

Solidification range
1105-1000°F (595-540°C).

Machinability
Machinability is rated good.

Weldability
Weldability is rated fair.

Finishing
The anodizes appearance is rated good. Electroplating produces an excellent finish.

Corrosion resistance
Corrosion resistance is rated fair for most common corrosive environments.

Alloy 390.2 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
16.0-18.0	0.6-1.1	4.0-5.0	0.1	0.50-0.65	-	-	0.1	0.2	0.1	0.2

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Die	280 (41)	240 (35)	up to 1.0	-	-	120	140 (20)
T5	Die	295 (43)	260 (38)	up to 1.0	-	-	125	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

T5 temper
Age at 450°F (230°C) for eight hours.

Application characteristics
Alloy 390.2 castings show high wear resistance, low coefficient of thermal expansion, excellent elevated temperature strength and good fluidity. Typical application is engine blocks.

Castability
The rating of alloy 390.2 is very good with excellent fluidity.

Solidification range
1200-945°F (650-505°C).

Machinability
Machinability is rated fair to poor. Carbide cutting tools should be used.

Finishing
The anodized appearance is rated poor. Chemical conversion coatings.

Corrosion resistance
Alloy 390.2 castings have good corrosion resistance which can be increased with chemical conversion coatings.

Alloy A390.1 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
16.0-18.0	0.40	4.0-5.0	0.10	0.50-0.65	-	-	0.10	0.20	0.10	0.20

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F, T5	Sand	180 (26)	180 (26)	<1.0	-	-	100	-
	PM	200 (29)	200 (29)	1.0	-	-	110	-
T6	Sand	275 (40)	275 (40)	<1.0	-	-	140	105 (15)
	PM	310 (45)	310 (45)	<1.0	-	-	145	115 (17)
T7	Sand	250 (36)	250 (36)	<1.0	-	-	115	-
	PM	260 (38)	260 (38)	<1.0	-	-	120	100 (15)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

T6 temper
PM and Sand: Solutionize at 925°F (495°C) for six to 12 hours; quench in boiling water; then age at 175°F (350°C) for eight hours.

T7 temper
PM and Sand: Solutionizing at 925°F (495°C) for six to twelve hours; quench in boiling water; then age at 450°F (230°C) for eight hours.

Alloy 413.2 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
11.0-13.0	0.7-1.1	0.10	0.10	0.07	-	0.10	0.10	0.10	-	0.20

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Die	296 (43)	140 (21)	2.5	-	170 (25)	-	130 (19)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Alloy 413.2 is a general purpose with good casting characteristics for casting thin and intricate parts for applications that require excellent castability, resistance to corrosion and pressure tightness. Recommended for architectural, ornamental and food and dairy equipment; also large instrument cases, street lamp housings and outboard marine pistons.

Castability
Alloy 413.2 has excellent fluidity, resistance to hot cracking and pressure tightness. Hot shortness and die soldering tendency are good.

Solidification range
1080-1065°F (582-574°C).

Machinability
This alloy has fair machinability; however, problems can result in rapid tool wear due to abrasiveness caused by the high silicon content. Tungsten tooling is recommended.

Weldability
Exhibits fair welding characteristics in arc, resistance or gas methods. Brazing is not recommended.

Finishing
The anodized appearance is poor; however, protective chemical coatings are good. Mechanical finishes, including polishes are poor.

Corrosion resistance
Very good corrosion resistance. Chemical conversion coatings are often used for additional protection.

Alloy A413.2 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
11.0-13.0	0.6	0.10	0.05	0.05	-	0.05	0.05	0.05	-	0.10

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Die	290 (42)	131 (19)	3.5	-	170 (25)	-	130 (19)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Alloy A413.2 is a general purpose alloy with good characteristics for casting thin and intricate parts for applications that require excellent castability, resistance to corrosion and pressure tightness. Recommended for architectural, ornamental and food and dairy equipment; also large instrument cases, street lamp housings and outboard marine pistons.

Castability
Alloy A413.2 has excellent fluidity, resistance to hot cracking and pressure tightness. Hot shortness and die soldering tendency are good.

Solidification range
1080-1065°F (582-574°C).

Machinability
This alloy has fair machinability; however, problems can result in rapid tool wear due to abrasiveness caused by the high silicon content. Tungsten tooling, when practical, is recommended.

Weldability
Exhibits fair welding characteristics in arc, resistance or gas methods. Brazing is not recommended.

Finishing
The anodized appearance is poor; however, protective chemical coatings are good. Mechanical finishes, including polishes are poor.

Corrosion resistance
Very good corrosion resistance. Chemical conversion coatings are often used for additional protection.

Alloy B413.1 (G6290) for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
11.0-13.0	0.2	0.10	0.05	0.05	-	0.05	0.05	0.05	-	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
F	Die	210 (30.5)	75 (11)	11	-	120 (17.5)	-	65 (9.5)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics

B413.1 (G6290) is a designation for a primary alloy. As such, Fe levels are frequently maintained well below the maxima in the AA specifications when the alloy is used for load bearing castings such as automotive wheels or fatigue critical applications such as charge air coolers.

Alloy B413.1 (G6290) is a general purpose alloy with high elongation and good characteristics for casting thin and intricate parts for applications that require excellent castability, resistance to corrosion and pressure tightness. Recommended for architectural, ornamental and food and dairy equipment; also large instrument cases, street lamp housings and outboard marine pistons.

Castability

This alloy has excellent fluidity, resistance to hot cracking and pressure tightness. Hot shortness and die soldering tendency are good.

Solidification range

1080-1065°F (582-574°C).

Machinability

This alloy has fair machinability; however, problems can result in rapid tool wear due to abrasiveness caused by the high silicon content. Tungsten tooling, when practical, is recommended.

Weldability

Exhibits fair welding characteristics in arc, resistance or gas methods. Brazing is not recommended.

Finishing

The anodized appearance is poor; however, protective chemical coatings are good. Mechanical finishes, including polishes are poor.

Corrosion resistance

Very good corrosion resistance. Chemical conversion coatings are often used for additional protection.

Alloy 443.2 for die, permanent and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
4.5-6.0	0.6	0.10	0.10	0.10	-	-	0.10	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Sand	130 (19)[2]	55 (8)[2]	8.0[2]	60 (9)	95 (14)	40[3]	55 (8)
F	PM	160 (23)[2]	60 (9)[2]	10[2]	60 (9)	110 (16)	45[3]	55 (8)
F	Die	230 (33)[4]	110 (16)[4]	9.0[4]	90 (13)	145 (21)	50	115 (17)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.
4Tensile properties determined from ASTM standard round, 0.25 in. (6mm) test specimens cast on a cold chamber (high pressure) die casting machine.

Thermal treatments

F temper
As-cast.

Annealing to relieve stresses and reduce growth
PM and Sand: Soak for two hours at 650°F (345°C); air cool to room temperature.

Annealing to increase ductility
Die only: Soak four to six hours at 500-700°F (260-370°C); cool in furnace or still air.

Stress, relieving to reduce internal stresses
Die only: Soak for four to six hours at 350-500°F (175-260°C); cool in still air.

Application characteristics
Alloy 443.2 is a non-heat-treatable, moderate strength alloy with very good corrosion resistance. It is used for die castings where above average ductility is required and for sand and PM castings where ductility is required other than strength is required. Typical applications are cookware, marine fittings, tire molds and architectural castings to be anodized gray.

Castability
This alloy has very good to excellent PM and sand casting characteristics. Die casting characteristics are good.
Solidification range
1170-1065°F (630-575°C).

Machinability
This alloy has fair machinability for all types of castings. Tool wear and dragging will be minimized by the use of carbide-tipped tools with large rake angles and liberal applications of cutting liquid.

Weldability
Welding characteristics of PM and sand castings are excellent for all standard welding methods, but the welding of die castings is not recommended.

Finishing
All types of 443.0 castings (die, PM, sand) respond very well to electroplating. Responses to mechanical finishing range from fair for die and PM castings to poor for sand castings. Results from anodizing are fair for PM castings, but poor for die and sand castings.

Corrosion resistance
The corrosion resistance of alloy 443.2 in ordinary marine and domestic environments is rated very good for die, sand and PM castings. Chemical conversion coatings and anodic coatings improve the corrosion resistance of all types of alloy 443.0 castings.

Alloy 444.2 for permanent mold casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
6.5-7.5	0.12	0.05	0.05	0.05	-	-	0.05	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
T4	PM	165 (24)	70 (10)	24.0	75 (11)	110 (16)	45	55 (8)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

T4 temper
Solutionize eight to 12 hours at 1000°F (540°C); quench in water at 150-212°F (65-100°C).

Alloy 444.2 castings have especially high ductility and very good impact resistance. In addition, this alloy has the inherent advantages of the binary aluminum-silicon system, i.e., superior castability, very good corrosion resistance and excellent weldability.

Application characteristics
Typical applications of alloy 444.0 castings are highway railing posts and other products where impact resistance is a primary consideration.

Castability
Binary aluminum-silicon alloys like alloy 444.2 have very good castability, pressure tightness, resistance to hot cracking, low solidification shrinkage and fluidity.

Solidification range
1145-1065°F (620-570°C).

Machinability
Machinability is only fair because if the alloy's high ductility and the abrasiveness of its silicon content. Sharp carbide-tipped tools and liberal amounts of cutting fluid are recommended.

Weldability
Excellent response to all common welding procedures.

Finishing
Very good response to conversion coatings. Anodized finishes are gray and rated fair. Response to mechanical finishing is poor. Results from anodizing are fair for PM castings, but poor for die and sand castings.

Corrosion resistance
Rated very good in most urban and industrial atmospheres.

Alloy A514.2 for sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.30	0.30	0.10	0.10	3.6-4.5	-	-	0.10	0.20	-	0.25

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F	Sand	170 (25)	85 (12)	9.0	85 (12)	140 (20)	35-65	50 (7)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Alloy A514.2 is used where excellent resistance to corrosion and tarnish are required. Examples are dairy and food handling applications, cooking utensils, fittings for chemical and sewage use and hardware and ornamental applications.

Castability
The casting characteristics of alloy A514.2 are not good due to its poor ratings for feeding ability, shrinkage and pressure tightness. Resistance to hot cracking, hot shortness and fluidity are rated fair.

Solidification range
Liquidus: 1170°F (630°C)
Solidus: 1090°F (585°C)

Machinability
Machinability is rated good.

Weldability
Good for welding with arc, gas and resistance spot and seam methods.

Finishing
Excellent anodized appearance and protection. This alloy takes an excellent polished finish; electroplating is rated poor.

Corrosion resistance
Excellent resistance to corrosion and tarnish from all common and many chemical atmospheres. Chemical conversion coating offers maximum protection.

Alloy 515.2 for permanent mold, sand and die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.50-1.0	0.6-1.0	0.10	0.40-0.6	2.7-4.0	-	-	0.05	-	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
F	Die	283 (41)	-	10.0	-	-	-	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Alloy 515.2 a high or moderate strength alloy with excellent elongation. Uses include energy absorbing automotive parts.

Castability
Does not exhibit good casting characteristics. Fluidity, shrinkage and resistance to hot cracking are rated fair. Pressure tightness is poor.

Machinability
Machinability is rated very good.

Weldability
Weldability is rated fair.

Finishing
Anodized finishes are rated excellent.

Corrosion resistance
Excellent resistance to corrosion.

Alloy 518.2 for die casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.25	0.70	0.10	0.10	7.6-8.5	-	0.05	-	0.05	-	0.10

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
F	Die	310 (45)	193 (28)	5-8	207 (30)	80	159 (23)	6.6 (9)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Non-heat-treatable alloy 518.2 has excellent resistance to tarnish and corrosion as well as excellent machinability. It also has high strength and ductility, but poor castability. It has excellent response to anodizing and mechanical finishes. Typical uses are for architectural, ornamental, marine hardware and fittings.

Castability
This alloy has poor fluidity, hot shortness, resistance to hot cracking and pressure tightness. Problems can result from poor feeding characteristics and die soldering.

Solidification range
1150-995° (620-535°C).

Machinability
Alloy 518.2 is possibly the best of the die casting alloys for machinability.

Finishing
Exhibits excellent polishing finishes. It anodizes very well with a natural aluminum finish. However, it is difficult to obtain a uniform appearance after anodizing. Chemical conversion coatings add excellent protection. Electroplating characteristics are poor.

Corrosion resistance
Among the die casting alloys, alloy 518.2 has the highest corrosion resistance characteristics. Its excellent receptiveness to chemical conversion coatings make it suitable for applications exposed to severe environments.

Alloy 520.2 for sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.15	0.20	0.20	0.10	9.6-10.6	-	-	-	0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
F	Sand	315 (46)	170 (25)	14.0	180 (26)	235 (34)	60-90	55 (8)
T4	Sand	330 (48)	180 (26)	16.0	185 (27)	235 (34)	60-90	55 (8)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

F temper
As-cast.

Application characteristics
Among sand casting alloys, alloy 520.2 has one of the highest ratings for strength, elongation and corrosion resistance. It also exhibits excellent machinability. These characteristics find use in parts that require shock resistance as well as strength, such as aircraft fittings, railcar passenger frames, truck and bus frames and bridge castings. Rapid decrease in properties with increasing temperatures.

Castability
This alloy is only fair for hot shortness and resistance to hot cracking. Its pressure tightness, feeding ability and solidification shrinkage are poor. This alloy requires careful foundry practices as it has a high tendency to react with the sand and also for microporosity.

Solidification range
1120-840° (605-450°C).

Machinability
Excellent machinability in T4 temper.

Weldability
Rated fair. Resistance methods give best results, followed by arc and then gas methods. Brazing is not usually employed.

Finishing
Excellent finishes can be obtained by mechanical polishing or anodizing.

Corrosion resistance
Excellent corrosion resistance qualities. Chemical conversion coatings give greater protection.

Alloys A535.1 and B535.2 for permanent mold and sand casting

Ingot composition limits*

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other Each	Other Total
A535.1	0.20	0.15	0.1	0.10-0.25	6.6-7.5	-	-	-	0.25	0.05	0.15
B535.2	0.10	0.12	0.05	0.05	6.6-7.5	-	-	-	0.10-0.25	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension: Ultimate strength MPa (ksi)	Tension: Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
F	PM	290 (42)	140 (20)	13.0	162 (23.5)	190 (27.6)	60-90	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments
Stress relieving for dimensional stability: 700-800°F (370-425°C) for five hours; cool in still air.

F temper
As-cast.

Application characteristics
Alloys A535.1 and B535.2 provide the design engineer one aluminum alloy in which combinations of high strength, high ductility, high shock resistance, high corrosion resistance, superior machinability, dimensional stability and stability of mechanical properties are instantly available.

An aluminum-magnesium alloy that retains a high level of strength, shock resistance and ductility after a thermal treatment to ensure dimensional stability. It is well suited to the production of parts that require strength and a high degree of dimensional stability, such as impellors, optical equipment and parts for instruments and computing devices. Aircraft components and missile guidance systems. Neither alloy A535.1 nor B535.2 contain beryllium (Be) as part of their specifications and are safer to melt and handle than alloy 535.2

Castability
Somewhat better suited to sand casting than permanent mold casting. Fluidity is fair for sand casting, but poor for PM. Resistance to hot cracking is good in sand casting, but only fair in PM casting. Shrinkage tendency is good with sand and PM castings, but pressure tightness is poor.

Solidification range
Alloy A535.1: 1150-1020°F (620-550°C).
Alloy B535.2: 1165-1020°F (630-550°C).

Machinability
Machinability characteristics are excellent despite the alloy's high ductility. Best surface finishes are obtained when machining at maximum speeds with carbide tools.

Weldability
Rated only fair.

Finishing
Anodized results are very good. Clear anodic coatings are produced and can be dyed a wide variety of colors. Electroplating chrome coatings can also be applied.

Corrosion resistance
Both PM and sand castings in these alloys have excellent corrosion resistance. Their relatively high magnesium content gives them protection against mild alkalis or salt spray. Anodic coatings give additional corrosion protection.

Alloy 712.2 for sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.15	0.40	0.25	0.10	0.50-0.65	0.40-0.6	-	5.0-6.5	0.15-0.25	0.05	0.20

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
F or T5[4]	Sand	240 (35)	170 (25)	5.0	-	180 (26)	60-90	62 (9)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.
[4]Better properties are generally obtained from natural aging as opposed to T5 tempered castings.

Thermal treatments

F temper
As-cast.

T5 temper
Room temperature for 21 days or at 315°F (157°C) for six to eight hours.

Note: The natural aging capability of 712.2 manifests itself in a number of useful ways. Operations such as stress relieving, brazing or welding which would destroy the temper in normal heat-treated casting have only a temporary impact of 712.2. The castings will recover their temper by a natural aging over the next ten to 21 days.

Application characteristics
Alloy 712.2 is used when a good combination of mechanical properties is required without heat treatment. Other characteristics are high dimensional stability, shock and corrosion resistance and machinability. Used for parts that require good strength or impact resistance such as marine castings, farm machinery, machine tool parts and aircraft components, molds for plastic polymers.

Castability
Overall fair castability is shown by alloy 712.2. The alloy's fluidity and shrinkage are rated good; however, resistance to hot cracking and pressure tightness are only fair. Hot shortness is poor.

Solidification range
1140-1060°F (615-570°C).

Machinability
Machinability characteristics are excellent.

Weldability
Welding characteristics are fair for most common methods. The alloy is recommended for brazing.

Finishing
Alloy takes a good polished finish and its anodized finish is very good.

Corrosion resistance
This alloy has good resistance to corrosion. Additional protection obtained from chemical conversion coatings.

Alloy 713.1 for permanent mold sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.25	0.8	0.40-1.0	0.6	0.25-0.50	0.35	0.15	7.0-8.0	0.25	0.10	0.25

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension			Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)	Elongation at break % in 2in. (50mm)				
T5	Sand	205 (30)	150 (22)	4.0	170 (25)	180 (26)	60-90	60 (9)
T5	PM	220 (32)	150 (22)	3.0	170 (25)	180 (26)	60-90	60 (9)

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments

T5 temper
Stress relief treatment and naturally aging: If alloy 713.1 is given a stress relief treatment at 850°F (450°C) for six hours and air cooled, it ages naturally at room temperature. Casting are hard enough for machining after ten to 14 days and reach full strength after 21 days.

T5 temper
Artificially aged: Soak at 259°F (120°C) for 13 hours.

Note: The natural aging capability of 713.1 manifests itself in a number of useful ways. Operations, such as stress relieving, brazing or welding which would destroy the temper in normal heat-treated casting have only a temporary impact of 713.1. The castings will recover their temper by a natural aging over the next ten to 21 days.

Application characteristics
High strength 713.1 is an alloy which naturally ages at room temperature making it ideal for castings that are too thick or too large to heat treat economically. This alloy's mechanical properties produced through natural aging are equivalent to those of common heat treated aluminum cast alloys. Aluminum furniture and applications where an excellent surface finish is required such as molds for blow molding of plastic. Among its uses are housings, machinery parts and lever arms.

Castability
Castability of alloy 713.1 is fair. When heavier gates and risers are adequate to compensate for its shrinkage rate, pressure type parts can be successfully cast. It has excellent ductility.

Solidification range
1185-1100°F (640-595°C).

Machinability
Good machinability and polishing characteristics. Very good dimensional stability.

Weldability
Common welding methods are fair for joining. Readily brazed using any of the common brazing methods.

Finishing
Alloy 713.1 produces excellent finishes as well as a very good anodized finish.

Corrosion resistance
Corrosion resistance of this alloy is rated good.

Alloy 771.2 for permanent mold and sand casting

Ingot composition limits*

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Other	
									Each	Total
0.10	0.10	0.10	0.10	0.85-1.0	0.06-0.20	-	6.5-7.5	0.10-0.20	0.05	0.15

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Typical mechanical properties

Temper	Casting method	Tension		Elongation at break % in 2in. (50mm)	Compressive yield strength[1] MPa (ksi)	Shear strength MPa (ksi)	Hardness[2] Brinell No.	Fatigue strength[3] MPa (ksi)
		Ultimate strength MPa (ksi)	Yield strength 0.20% offset MPa (ksi)					
T5	Sand	290 (42)	260 (38)	1.5	-	-	85-115	-
T51	Sand	220 (32)	185 (27)	3.0	-	-	70-100	-
T52	Sand	250 (36)	205 (30)	1.5	-	-	70-100	-
T53	Sand	248 (36)	186 (27)	1.5	-	-	-	-
T6	Sand	290 (42)	240 (35)	5.0	-	-	75-105	-
T71	Sand	330 (48)	310 (45)	2.0	370 (54)	-	105-135	-

[1]Test results from specimens with an L/r ratio of 12.
[2]Tensile properties and hardness values determined by tests on standard 0.50 in. (12.5mm) diameter test specimens without surface finishing; each cast in permanent or green sand molds.
[3]Endurance limit is based on 500 million cycles of completely reversed stresses using a rotating beam-type machine and specimen, unless otherwise specified.

Thermal treatments
Artificially aged

T5 temper
Hold at 350-360°F (177-183°C) for three to five hours; cool outside furnace in still air to room temperature.

T6 temper
Hold at 1080-1100°F (580-595°C) for six hours; cool outside furnace in still air; age by holding for three hours at 265°F (130°C) followed by cooling in still air.

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T51 temper
Age by holding at 405°F (205°C) for six hours; cool in still air.

T52 temper
Hold at 775°F (415°C) for five hours; cool from 775-650°F (415-345°C) in two hours or more; cool from 650-450°F (345-230°C) in approximately two hours; cool from 250°F (120°C) to room temperature in still air of furnace; harden by reheating to 330°F (165°F) for six to 16 hours and cooling outside of furnace in still air.

T71 temper
Hold at 1080-1100°F (580-595°C) for six hours; cool outside furnace in still air; age by holding at 285°F (140°C) for 15 hours followed by cooling in still air. Similar properties can be obtained by aging at 310°F (155°C) for three hours.

Note: The natural aging capability of 771.2 manifests itself in a number of useful ways. Operations such as stress relieving, brazing or welding, which would destroy the temper in normal heat-treated casting have only a temporary impact of 771.2. The castings will recover their temper by a natural aging over the next ten to 21 days.

Application characteristics
Applications where high strength and dimensional stability are important. Wide range of aerospace applications.

Castability
Castability of alloy 771.2 is fair. Careful control of solidification conditions are required to produce sound, defect-free castings.

Solidification range
1189-1119°F (643-604°C).

Machinability
Alloy 771.2 has excellent stability and machinability.

Weldability
Rated fair. If parts are to be welded, the operation should be made part of the heat treating cycle. The eutectic melting point of alloy 771.2 is high, an advantage that in castings that are to be assembled by brazing.

Finishing
Polishes to a high luster; anodizes with a clear appearance.

Corrosion resistance
Good corrosion resistance.

Typical tensile properties at elevated temperatures

Alloy 242.0-T571
Typical tensile properties at elevated temperatures[1]

Casting method	Test temperature F° (C°)	Ultimate strength MPa (ksi)	Yield strength[2] MPA (ksi)	Elongation % in 2 in. (50mm)
Sand	75 (24)	220 (32)	205 (30)	0.2
	300 (150)	205 (30)	195 (28)	0.5
	400 (204)	180 (26)	145 (21)	1.0
	500 (260)	90 (13)	55 (8)	8.0
	600 (315)	55 (8)	30 (4)	20.0
PM	75 (24)	275 (40)	235 (34)	1.0
	300 (150)	255 (37)	230 (33)	1.0
	400 (205)	195 (28)	150 (22)	2.0
	500 (260)	90 (13)	55 (8)	15.0
	600 (315)	55 (8)	30 (4)	35.0

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Alloy 354.0-T61
Typical tensile properties at elevated temperatures[1]

Test temperature F° (C°)	Time at temperature hours	Ultimate strength MPa (ksi)	Yield strength[2] MPa (ksi)	Elongation % in 2 in. (50mm)
75 (24)	-	380 (55)	285 (41)	6
212 (100)	0.5	345 (50)	285 (41)	6
	10	350 (51)	285 (41)	6
	100	360 (52)	290 (42)	6
	1,000	370 (54)	310 (45)	6
	10,000	415 (60)	340 (49)	6
300 (150)	0.5	325 (47)	275 (40)	6
	10	345 (50)	295 (43)	6
	100	350 (51)	315 (46)	6
	1,000	340 (49)	305 (44)	6
	10,000	290 (42)	240 (53)	6
400 (205)	0.5	290 (42)	270 (39)	6
	10	270 (39)	250 (36)	9
	100	205 (30)	180 (26)	17
	1,000	130 (19)	105 (15)	30
	10,000	105 (15)	75 (11)	45
500 (260)	0.5	195 (28)	170 (25)	16.0
	10	115 (17)	105 (15)	22.0
	100	80 (12)	65 (9.5)	35.0
	1,000	65 (9.5)	50 (7.5)	50.0
	10,000	60 (8.5)	40 (6)	65.0
600 (315)	0.5	90 (13)	80 (12)	29.0
	10	60 (8.5)	50 (7)	60
	100	40 (6)	35 (5)	85
	1,000	-	-	-
	10,000	-	-	-

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Alloys 355.0-T6 and C355.0-T6
Typical tensile properties at elevated temperatures[1]

Casting method	Test temperature F° (C°)	Ultimate strength MPa (ksi)	Yield strength[2] MPA (ksi)	Elongation % in 2 in. (50mm)
Alloy 355.0-T6 Sand	75 (24)	240 (35)	170 (25)	3
	212 (100)	240 (35)	170 (25)	2
	300 (149)	230 (33)	170 (25)	1.5
	400 (204)	115 (17)	90 (13)	8
	500 (260)	65 (9.5)	35 (5)	16
	600 (315)	40 (6)	20 (3)	36
	700 (371)	25 (3.5)	15 (2)	50
Alloy 355.0-T6 PM	75 (24)	290 (42)	185 (27)	4
	212 (100)	275 (40)	185 (27)	5
	300 (149)	220 (32)	170 (25)	10
	400 (204)	130 (19)	90 (13)	20
	500 (260)	65 (9.5)	25 (2.5)	40
	600 (315)	40 (6)	20 (3)	50
	700 (371)	25 (3.5)	15 (2)	60
Alloy C355.0-T6 PM	75 (24)	315 (46)	235 (34)	6
	212 (100)	295 (43)	235 (34)	6
	300 (149)	260 (38)	235 (34)	10
	400 (204)	95 (14)	70 (10)	40
	500 (260)	45 (6.5)	40 (5.5)	60
	600 (315)	30 (4)	20 (3)	70
	700 (371)	25 (3.5)	15 (2.5)	90

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Alloys 356.0-T6 and A356.0-T61
Typical tensile properties at elevated temperatures[1]

Casting method	Test temperature F° (C°)	Ultimate strength MPa (ksi)	Yield strength[2] MPA (ksi)	Elongation % in 2 in. (50mm)
Alloy 356.0-T6 Sand	75 (24)	230 (33)	165 (24)	3.5
	212 (100)	220 (32)	165 (24)	4
	300 (149)	160 (23)	140 (20)	6
	400 (204)	85 (12)	55 (8)	18
	500 (260)	50 (7.5)	33 (5)	35
	600 (315)	30 (4)	20 (3)	60
	700 (371)	15 (2.5)	15 (2)	80
Alloy 356.0-T6 PM	75 (24)	260 (38)	185 (27)	5
	212 (100)	205 (30)	170 (25)	6
	300 (149)	145 (21)	115 (17)	10
	400 (204)	85 (12)	60 (8.5)	30
	500 (260)	50 (7.5)	35 (5)	55
	600 (315)	30 (4)	20 (3)	70
	700 (371)	25 (3.5)	15 (2)	80
Alloy A356.0-T61 PM	75 (24)	285 (41)	205 (30)	10
	212 (100)	255 (37)	195 (28)	16
	300 (149)	145 (21)	115 (17)	20
	400 (204)	85 (12)	55 (8.5)	40
	500 (260)	50 (7.5)	35 (5)	55
	600 (315)	30 (4)	20 (3)	70
	700 (371)	15 (2.5)	15 (2)	80

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Alloy 357.0-T62
Typical tensile properties at elevated temperatures[1]

Test temperature F° (C°)	Time at temperature hours	Ultimate strength MPa (ksi)	Yield strength[2] MPa (ksi)	Elongation % in 2 in. (50mm)
75 (24)	-	360 (52)	290 (42)	8
212 (100)	0.5	315 (46)	270 (39)	10
	10	315 (46)	270 (39)	10
	100	315 (46)	270 (39)	10
	1,000	315 (46)	275 (40)	8
	10,000	330 (48)	310 (45)	6
300 (150)	0.5	270 (39)	240 (35)	10
	10	285 (41)	255 (37)	9
	100	290 (42)	275 (40)	7
	1,000	260 (38)	250 (36)	7
	10,000	160 (23)	145 (21)	20
400 (205)	0.5	250 (36)	240 (35)	6
	10	205 (30)	195 (28)	7
	100	160 (23)	145 (21)	23
	1,000	85 (12)	70 (10)	40
	10,000	70 (10)	50 (7.5)	50
500 (260)	0.5	160 (23)	150 (22)	16.0
	10	85 (12)	75 (11)	23.0
	100	55 (8)	50 (7)	55.0
315 (600)	0.5	70 (10)	65 (9.5)	35.0

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Alloy 359.0-T61
Typical tensile properties at elevated temperatures[1]

Test temperature F° (C°)	Time at temperature hours	Ultimate strength MPa (ksi)	Yield strength[2] MPa (ksi)	Elongation % in 2 in. (50mm)
75 (24)	-	380 (55)	285 (41)	6
212 (100)	0.5	345 (50)	285 (41)	6
	10	350 (51)	285 (41)	6
	100	360 (52)	290 (42)	6
	1,000	370 (54)	310 (45)	6
	10,000	415 (60)	340 (49)	6
300 (150)	0.5	325 (47)	275 (40)	6
	10	345 (50)	295 (43)	6
	100	350 (51)	315 (46)	6
	1,000	340 (49)	305 (44)	6
	10,000	290 (42)	240 (35)	6
400 (205)	0.5	290 (42)	270 (39)	6
	10	270 (39)	250 (36)	9
	100	205 (30)	180 (26)	17
	1,000	130 (19)	105 (15)	30
	10,000	105 (15)	75 (11)	45
500 (260)	0.5	195 (28)	170 (25)	16.0
	10	115 (17)	105 (15)	22.0
	100	80 (12)	65 (9.5)	35.0
	1,000	65 (9.5)	50 (7.5)	50.0
	10,000	60 (8.5)	40 (6)	65.0
600 (315)	0.5	90 (13)	80 (12)	29.0
	10	60 (8.5)	50 (7)	60
	100	40 (6)	35 (5)	85
	1,000	-	-	-
	10,000	-	-	-

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Additional Alloys
Typical tensile properties at elevated temperatures[1]

Alloy / Temper	Test temperature F° (C°)	Ultimate strength MPa (ksi)	Yield strength[2] MPA (ksi)	Elongation % in 2 in. (50mm)
Alloy 360.0-F	75 (24)	325 (47)	170 (25)	3
	212 (100)	305 (44)	170 (25)	2
	300 (150)	240 (35)	165 (24)	4
	400 (205)	150 (22)	95 (14)	8
	500 (260)	85 (12)	50 (7.5)	20
	600 (315)	50 (7)	30 (4.5)	35
Alloy A360.0-F	75 (24)	260 (38)	185 (27)	5
	212 (100)	205 (30)	170 (25)	6
	300 (150)	145 (21)	115 (17)	10
	400 (205)	85 (12)	60 (8.5)	30
	500 (260)	50 (7.5)	35 (55)	55
	600 (315)	30 (4)	20 (3)	70
Alloy 380.0-F, Die	75 (24)	330 (48)	165 (24)	3
	212 (100)	310 (45)	165 (24)	4
	300 (149)	235 (34)	150 (22)	5
	400 (204)	165 (24)	110 (16)	8
	500 (260)	90 (13)	55 (8)	20
	600 (315)	50 (7)	30 (4)	30
	700 (371)	30 (4)	15 (2.5)	35
Alloy 413.0-F	75 (24)	295 (43)	145 (21)	3
	212 (100)	255 (37)	140 (20)	5
	300 (150)	220 (32)	130 (19)	8
	400 (205)	165 (24)	105 (15)	15
	500 (260)	90 (13)	60 (9)	30
	600 (315)	50 (7)	30 (4)	35
Alloy 443.0-F, Die	75 (24)	230 (33)	110 (16)	9
	212 (100)	195 (28)	110 (16)	9
	300 (149)	150 (22)	105 (15)	10
	400 (204)	110 (16)	85 (12)	25
	500 (260)	60 (9)	40 (6)	30
	600 (315)	35 (5)	25 (3.5)	35
	700 (371)	25 (3.5)	15 (2.5)	35
Alloy 514.0-F	75 (24)	170 (25)	85 (12)	9
	300 (150)	150 (22)	85 (12)	7
	400 (205)	125 (18)	85 (12)	9
	500 (260)	90 (13)	55 (8)	12
	600 (315)	60 (9)	30 (4)	17
Alloy 520.0-F	75 (24)	315 (46)	170 (25)	14
	300 (150)	240 (35)	130 (19)	16
	400 (205)	150 (22)	80 (11.5)	40
	500 (260)	105 (15)	50 (7.5)	55
	600 (315)	70 (10.5)	25 (3.5)	70
Alloy 535.0-F	300 (150)	260 (37.8)	-	11
	400 (205)	220 (32.3)	-	14
	500 (260)	180 (26.7)	-	13
	600 (315)	140 (20.8)	-	1
Alloy 535.0-T6, PM	75 (24)	275 (40)	-	13
	212 (100)	260 (38)	-	11
	300 (149)	235 (34)	-	14
	400 (204)	221 (32)	-	14
	500 (260)	185 (27)	-	13
	600 (315)	145 (21)	-	13
	700 (371)	105 (15)	-	12
Alloy 712.0-F	175 (80)	235 (33.8)	210 (30.7)	3
	250 (120)	205 (29.5)	175 (25.2)	2
	350 (175)	350 (135)	115 (17)	6

[1]Lowest strengths during 10,000 hours of exposure at testing temperature.
[2]Offset equals 0.2 percent.

Rio Tinto ingot for remelting

Rio Tinto produces standard and high purity grades of unalloyed aluminum, as well as alloys for electrical conductor alloys, rotor alloys and alloys for metal coating. Rio Tinto remelt ingot is produced from primary aluminum utilizing carefully controlled techniques to achieve optimum quality on all shipments.

Unalloyed ingot

Ingot composition limits*

AA Designation	Si	Fe	Zn	Ga	V	Others	
						Each	Total
P1020A	0.10	0.20	0.02	0.04	0.03	0.03	0.10
P1015A	0.10	0.15	0.03	0.04	0.03	0.03	0.10
P0610A	0.06	0.10	0.03	0.04	0.02	0.02	0.05
P0506A	0.05	0.06	0.03	0.03	0.02	0.02	0.05
P0404A	0.04	0.04	0.03	0.03	0.01	0.01	0.03

Rio Tinto can produce a specification tailored to customer requirements; particularly with regard to control of trace elements.
*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Electrical conductor ingot

Ingot composition limits*

AA Designation	Al minimum	Si	Fe	Mn	Cr	Ti	V	Others	
								Each	Total
1350	99.60	0.10	0.30	0.005	0.002	0.003	0.003	0.02	0.10
1370	99.70	0.07	0.19	0.005	0.002	0.002	0.002	0.02	0.10

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder.

Rotor Alloy

Ingot composition limits*

AA Designation		Al	Si	Fe	Cu	Zn	Sum of Mn + Cr + Ti + V	Each	Total	Fe / Si ratio	Electrical Conductivity (Min. % IACS)
100.1	Max		0.15	0.8	0.10	0.05	0.025	0.03	0.10		54
	Min	99.00		0.6							
130.1	Max				0.10	0.05	0.025				56
	Min	99.30								2.5	
150.1	Max				0.05	0.05	0.025	0.03	0.10		57
	Min	99.5								2.0	
160.1	Max		0.10	0.25		0.05	0.025	0.03	0.10		58
	Min	99.6								2.0	
170.1	Max							0.03	0.10		59
	Min										

*Given as a maximum percentage by mass weight, unless shown as a range. Aluminum is the remainder

Alloy selection for rotor applications

The compositions of Rio Tinto rotor alloys are the end result of studies aimed at achieving the best castability possible for the indicated conductivity level. For most applications, rotor manufacturers strive for maximum conductivity, but as the size and complexity of the rotor increases, some sacrifice is unavoidable if the castability level needed to allow the part to be mad at an acceptable scrap rate is to be achieved.

AA100.1 is produced with a very high Fe level. This reduces its electrical conductivity while at the same time reducing the tendency towards hot cracking and shrinkage during casting. This is the alloy generally recommended for larger rotors in which one or more dimensions exceed 125mm or five inches.

AA130.1 is a good choice when the design introduces serious castability requirements but the minimal conductivity of 100.1 is insufficient.

AA150.1 and AA160.1 are both good choices when high conductivity is needed together with some castability.

AA170.1 is at the opposite end of the spectrum where purity is important. It is the clear choice when considerations of castability are outweighed by the need to achieve as high an electrical conductivity in the rotor as technically feasible.

Increase conductivity →

Increase rotor size ←

Increase castability ←

The Effect of chemical composition

The relationship between electrical conductivity and the composition of aluminum has long been recognized. In the basis of occurrence and effect on conductivity, elements found in rotor metal fall into three groups.

- Copper, magnesium, zinc, nickel and gallium are neglible factors either because they only have a very slight effect on conductivity or because they are only present in insignificant quantities.
- Iron and silicon are important because they are present in significant quantities and have a moderate effect on conductivity. Their presence is, however, required for castability and, thus, they are controlled with regard to both total content and ratio.
- Titantium, vanadium, manganese and chromium have a marked effect on conductivity when present, even in trace quantities. The total of these elements is carefully controlled.

Glossary of terms

Anodizing is rated on the uniformity and brightness of the coating formed in conventional sulphuric acid electrolyte (0.7-mil sulphuric acid with a water seal). Other anodizing procedures will give different appearances than those listed.

Brinell hardness refers to a measure of resistance to indentation. It is obtained by applying a load through a ball indenter and measuring the diameter of the indentation in the metal. The hardness value is obtained by dividing the applied load in kilograms by the spherical area of the impression in square millimeters.

Castability ratings are relative, rather than a quantitative term used to indicate the suitability of the aluminum alloy for casting a sound, finished part requiring little machining. It is affected by fluidity, resistance to hot cracking, pressure tightness and shrinkage during solidification. However, castability is not solely dependent on the metal. Improper mold design and foundry techniques can adversely affect the production of a sound part from a readily castable metal.

Compression yield strength is the maximum stress that the metal, under compression, can withstand without a predefined amount of deformation.

Corrosion resistance ratings indicate the alloy's resistance in standard salt spray tests. Corrosion is an electrochemical process that can eventually affect the surface finish and reduce the strength of the metal.

Elongation is the increase in distance between two gauge marks that results from stressing the specimen in tension to fracture.

Fluidity is the molten alloy's capability to flow readily into the cavity and fill thin sections when at a low pouring temperature.

Machinability rating is the metal's characteristics related to cutting ease, chip characteristics, surface smoothness, and tool life. For the heat treatable alloy, the ratings are based on T6 temper. Non-heat treatable alloys are rated in the as-cast condition. Self aging alloys are rated after they have been aged at room temperature to their stable condition.

Pressure tightness is the resistance to leakage through the casting under pressure. A pressure test, is a measurement the relative soundness of the casting. The test is performed by sealing all openings of a casting, pressuring the interior and immersing it in water. Leakage in the casting will be evident by escaping air bubbles.

Resistance to hot cracking is the alloy's capacity to withstand cracking caused by contraction stresses while cooling.

Shear strength is the maximum shear stress which a material is capable of developing. It is considered to be the maximum average stress computed by dividing the ultimate load in a plane of shear by the original area subject to shear.

Solidification shrinkage tendency during solidification the volume of the metal decreases and this contraction causes shrinkage voids which must be refilled with metal, while it is still molten from risers; otherwise unsound casting will result. The rating indicates the amount of feed metal required from the risers in order to compensate for the shrinkage tendency.

Ultimate or tensile strength is the maximum shear stress which a material is capable of developing under a gradual and uniformly applied load. Tensile strength is calculated from the maximum load carried during a tension test and the original cross-sectional area of the specimen.

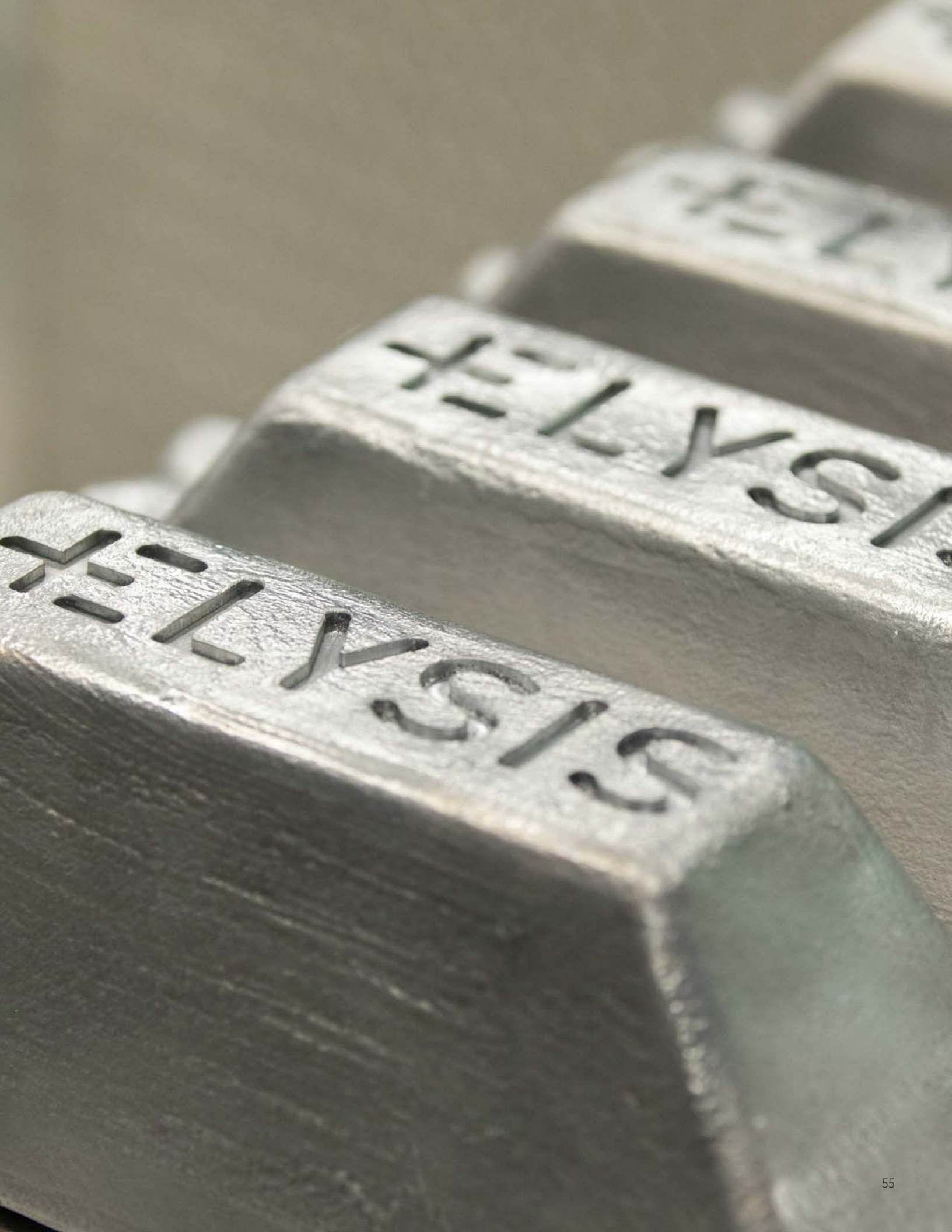
Weldability is the ease by which parts can be joined and the quality of the weld.

Yield strength is the stress at which a material exhibits a specified permanent set. The value of set used for aluminum and its alloys is 0.002 inch per inch 0.02 percent. This represents that level, beyond elastic deformation at which a 0.2% maximum permanent plastic deformation occurs.

Thermal treatment designations
Permanent mild and sand castings can be heat treated to improve mechanical and physical properties.

Die castings can only be stressed relieved and not solution heat treated because they generally have a porous internal structure containing some gas and they may blister at high temperature.

- T2, T21 - stress relief and anneal.
- T4 - solution heat treat and quench. It is usual practice to artificially age certain aluminum casting alloys to attain maximum mechanical properties,
- T5, T51, T551 - artificially aged. The relatively low temperature heat treatment serves to stabilize castings dimensionally and improve machinability while improving mechanical properties somewhat.
- T6, T61, T62, T65 - solution heat treat, quench and artificially age. The heat treatment results in maximum tensile and yield strengths with adequate elongation. The aging process stabilizes the properties.
- T7, T71, T75, T77 - solution heat treat, quench and artificially over-aged. This heat treatment stabilizes the castings and improves mechanical properties. Compared to T6 series of thermal treatments, these treatments usually result in a slowly lower tensile and yield strength, but increases elongation.



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