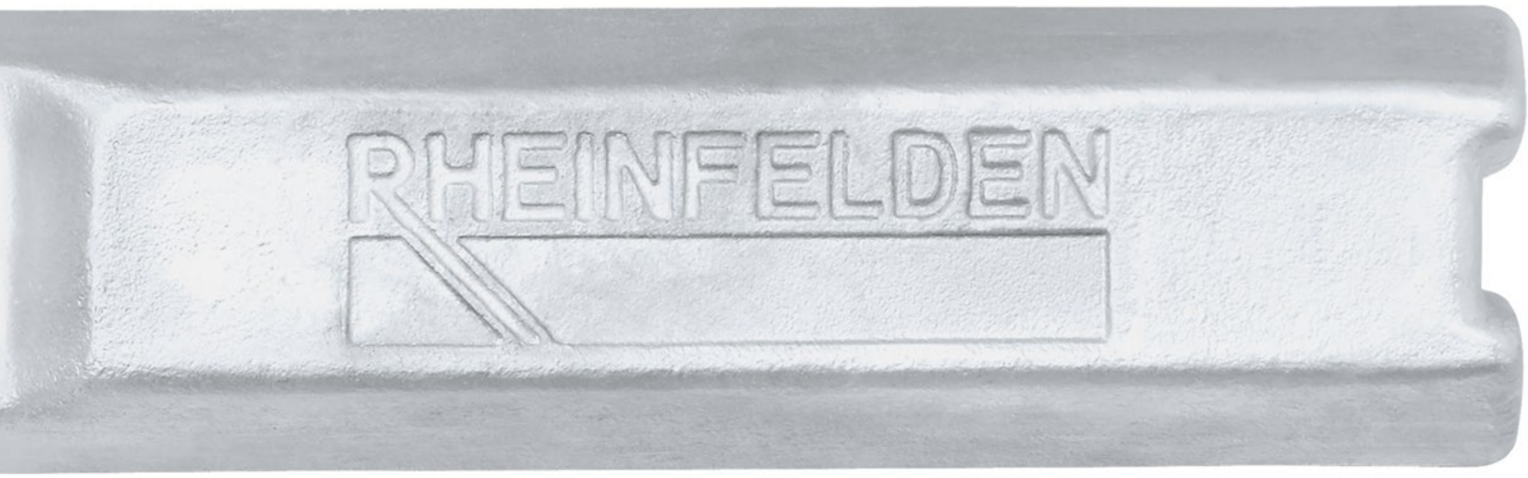
Primary aluminium
Casting alloys

RHEINFELDEN ALLOYS



RHEINFELDEN
Solutions thru Innovation

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ALUMINIUM RHEINFELDEN Group

“Fortschritt aus Tradition”

ALUMINIUM RHEINFELDEN Group: This history of aluminium in Germany started at Rheinfelden. In 1898 Europe’s first river power station brought about the establishment of the first aluminium smelter in Germany, at Rheinfelden, Baden.
The company has always operated in three business segments and in October 2008 restructuring turned ALUMINIUM RHEINFELDEN GmbH into a holding company and the former ALLOYS, SEMIS and CARBON divisions became independent GmbH & Co. KGs (the German equivalent to a limited partnership with a limited liability company as general partner).
www.rheinfelden-group.eu

Our policy

RHEINFELDEN ALLOYS GmbH & Co. KG is an innovative manufacturer of aluminium cast alloys, able to rapidly adapt to changing market requirements. The company is sited at the heart of Europe’s heterogeneous casting market, a market which places very varied requirements on aluminium. This location offers benefits, as does the agility of this owner-managed company and the wealth of experience which staff have gained over the years.

When we develop new materials we always aim to achieve efficient and careful use of aluminium casting. Through the use of materials tailored and refined to increase performance, RHEINFELDEN ALLOYS is constantly striving to help reduce vehicle weight and therefore cut fuel consumption and emissions.

RHEINFELDEN ALLOYS GmbH & Co. KG: RHEINFELDEN ALLOYS can be found wherever steel designs or iron castings can be replaced by light aluminium castings. RHEINFELDEN ALLOYS is a powerful partner, especially to the automotive and mechanical engineering sectors, providing alloys tailored to the process and cast part in line with the customer's particular needs.
www.rheinfelden-alloys.eu · Tel. +49 7623 93 490

RHEINFELDEN SEMIS GmbH & Co. KG: Primary aluminium slugs, blanks and pre-cut parts in a great variety of dimensions form the primary material for tubes, cans and containers and for technical applications.
www.rheinfelden-semis.eu · Tel. +49 7623 93 464

RHEINFELDEN CARBON GmbH & Co. KG: Ramming pastes for the aluminium and ferro-alloy industry, gas calcined anthracite and Soederberg pastes for the manufacture of high-purity ferro-alloys and silicon.
www.rheinfelden-carbon.eu · Tel. +49 7623 93 211

Panoramic view of the entire complex

RHEINFELDEN FAST ALLOYS®

Ordered today
Produced tomorrow
Ready for shipment one day later

Seven good reasons for Rheinfelden Fast Alloys

- No storage costs
- No finance costs
- No LME speculation
- No supply bottleneck
- Flexibility for your production
- Contemporary reaction to market change
- Higher flexibility close to your costumer's request

Forms of delivery

RHEINFELDEN Ingot: Since the new RHEINFELDEN Production System came on line, all our materials have been supplied in the form of RHEINFELDEN ingots. This ingot form is replacing the HSG ingot yet retains all the advantages of the old form of delivery.

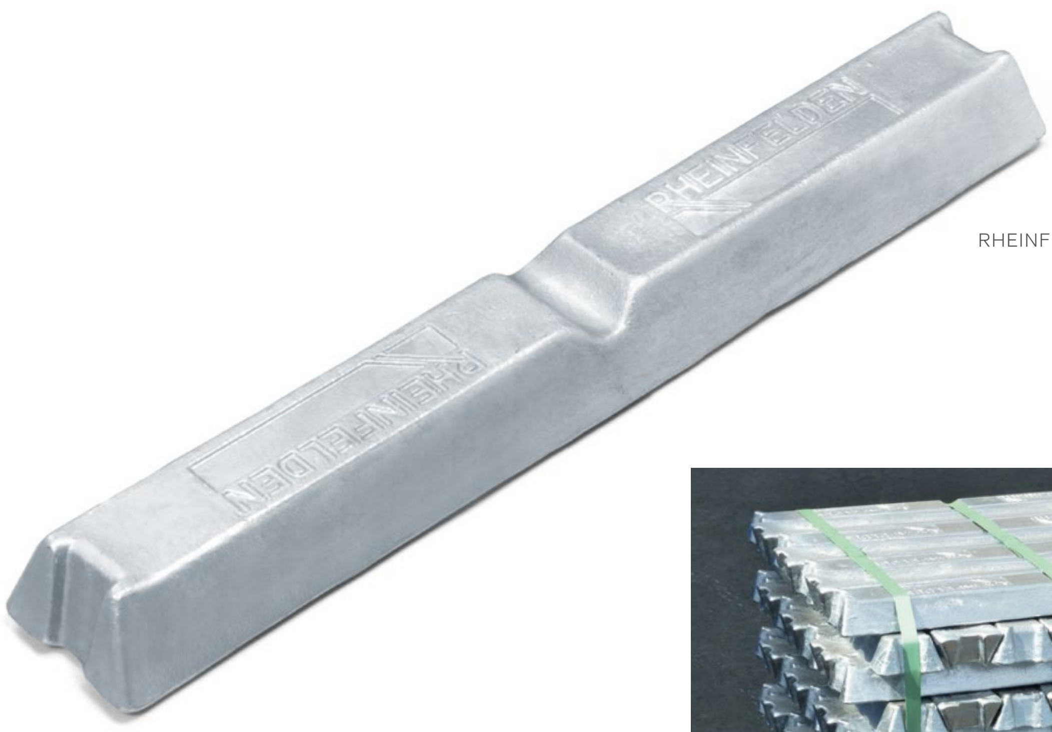
Liquid metal: If you want us to deliver metal to go straight into production, we can also supply liquid metal.

Analysis: The delivery slip contains the average actual batch analysis.

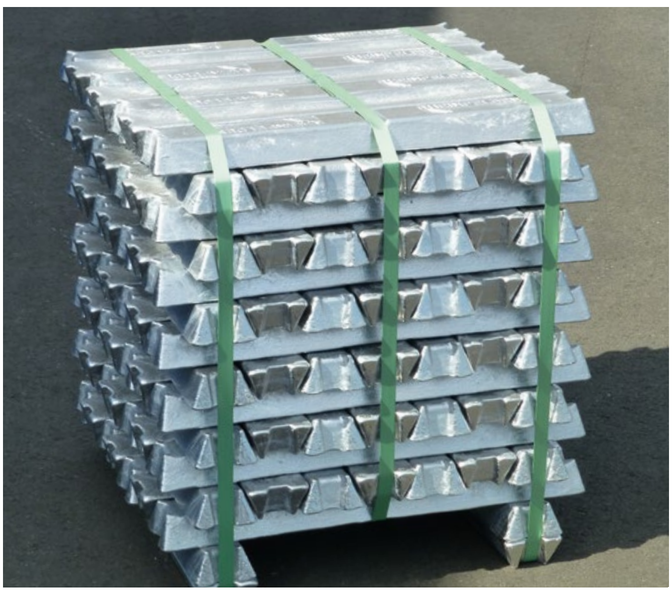
Stack labelling: Each stack features an information label containing the brand name and/or alloy group name, internal material number, stack weight and on request a colour marking. The batch number consists of the year in the sequential production number and the number in the sequenze. Machine-readable bar codes can be printed in this label.

Ingot	
Weight	6 – 8 kg
Base area	716 × 108 mm
Height	up to 52 mm

Stack of 13 layers	
Stack weight	up to 760 kg
Base area	716 × 716 mm
Stack height	up to 780 mm



RHEINFELDEN-Ingot



The stack of RHEINFELDEN ALLOYS is built with 95 single ingots including the 4 base ingots; here the stack with 13 layers of ingots.

Customer support and research and development

Every product and every customer has individual requirements of the material. The customer Support team at RHEINFELDEN ALLOYS has the job of anticipating these needs and producing tailored materials, fitting the castings and your requirements.

RHEINFELDEN customer support

Please contact our customer support team and use our TechCenter installations at RHEINFELDEN ALLOYS also for your foundry concerns.

We can advise on the use of aluminium casting, the design of castings and the choice of alloy. We can help you overcome casting problems and shed light on why you are producing rejects. We also share our knowledge of the processing, welding and surface treatment of aluminium casting. We can conduct metal analyses, microstructural analyses and mechanical strength measurements on your behalf.

A wide range of publications and processing data sheets are also available.
www.rheinfelden-alloys.eu

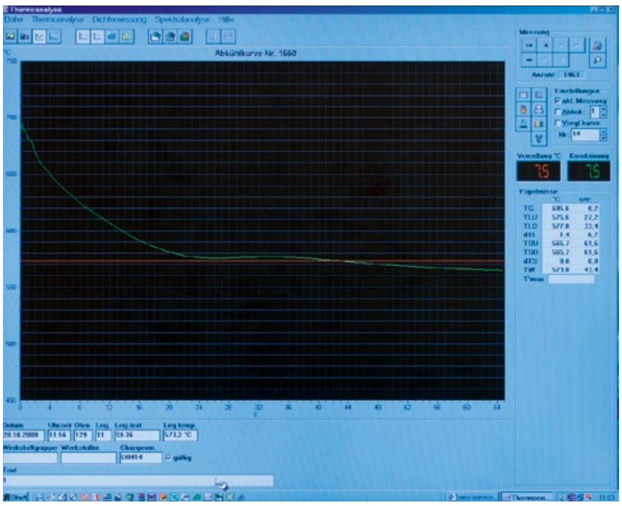
The customer support team at RHEINFELDEN ALLOYS is your partner in the concern of using aluminium casting alloys. We stand at your side if there comes up the question to design or cast an aluminium casting product.

Use our experience for your success.

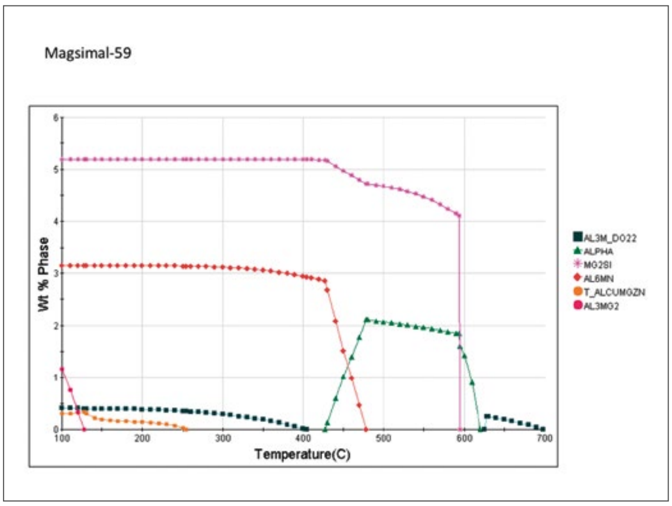
RHEINFELDEN technical centre

We operate a casting materials technical centre in Rheinfelden to enable us to provide a high-class customer service and to develop our cast alloys in line with the market's needs.

Time is increasingly of the essence when our customers experience casting technology problems. It is therefore crucial that we have the facilities to allow us to quickly solve problems through experimentation and immediately incorporate new findings into production. This technical support, renowned throughout the industry, is available exclusively to RHEINFELDEN ALLOYS customers.



Material testing evaluation diagram



Phase growing simulation of Magsimal-59

The goals of research and development

The technical centre assists the customer support team and runs development projects with the following goals:

- To optimise the mechanical and casting properties of our aluminium casting alloys
- To develop alloys under consideration of the appropriate casting method
- To collaborate with designers on use of our casting alloy most suited to the materials, including testing mechanical properties
- To simplify metallurgical work in our customers' foundries

Our technical centre is equipped with labs for metallography, spectral analysis and casting material testing, enabling structural analyses, tensile testing, component testing and other analyses to be performed.

We at RHEINFELDEN ALLOYS development use also phase simulation software for calculations and optimization of our wide range of casting alloys. Highlighted is here the solidification and phase growing simulation of Magsimal-59.

First of all there is still a lot of practice needed before simulate a new alloy composition.

International links, for example with WPI, Worcester USA, Vincenza university, RWTH Aachen, TU Clausthal, Fraunhofer Institut, STZ Esslingen and Friedrichshafen, allow further analyses to be undertaken. These include dynamic material and component testing, mechanical properties at elevated temperatures, corrosion behaviour, quantitative structural analysis and electron-optical analysis (scanning electronmicroscope, qualitative microanalyse etc.).

We want to offer the heterogeneous market a wide range of customised aluminium casting alloys for investment casting, sand and chill casting, as well as for HPDC which satisfy customers' specific application and processing requirements. RHEINFELDEN ALLOYS has set itself the goal of supplementing aluminium's natural lightness with the strength and forming properties required to enable it to help cut emissions in automotive engineering.

RHEINFELDEN sales service

The portfolio of RHEINFELDEN ALLOYS sales department is always adjusted to the request of our costumer. RHEINFELDEN ALLOYS has the possibility to offer different commercial strategies.

RHEINFELDEN Internet portal

www.rheinfelden-alloys.eu

Get the spirit of Rheinfelden

Anticorodal® – infinitely adaptable

As Anticorodal alloys can be adapted to virtually all different fields of work and production methods, countless possible uses are emerging for this material. Outstanding mechanical properties, electrical conductivity, corrosion resisting thanks to low silicon content, but slightly harder to cast. As with Silafont alloys, to ensure cost-effective use, it is well worth providing a complete definition of the material being used and tailoring it to both the parts to be produced and your production process.

The creatures of the sea provide the natural metaphor for this alloy. Such creatures adapt to different conditions and have developed a whole series of special attributes in order to do this.

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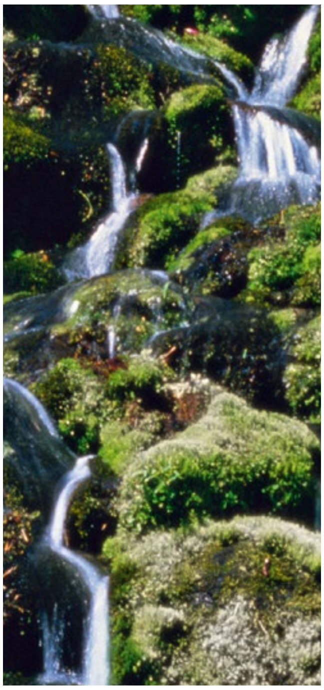

Silafont® – an infinite wealth of properties

A family of materials which can be adapted to the parts to be produced and the customer's individual production process with ultimate precision. Can be processed using any casting procedure, outstanding flow properties, can be modified with sodium or strontium to further enhance its properties. For complex, delicate components which have to satisfy precisely defined requirements and, if they feature the right components, make maximum production efficiency possible.

Silafont emulates flowing water, that flows continually to the sea, advances at any angle, washing around every stone and every shape in its way. Homogeneous and easily in the very same way that Silafont fills the cavities in the mould.

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Castaman®

An alloy family, that use the possibilities of recycling, to a desired high sustainability – to come represented in carbon footprint counter.

Nature's role model: the lupine, growing from the humus of last year's crop.

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Castasil® – large areas, high dimensional stability, fantastic to cast

An alloy, produced for large, high pressure die cast structural parts in the automotive construction industry. Lamborghini produced the first series in the Gallardo Spyder.
Numerous manufacturers now recognise the benefits of this alloy: high dimensional stability, can be used without heat treatment, shapes well and easy to weld.

Nature's equivalent: the vine branch which turns towards the sun, flexible, elastic and yet incredibly tough and strong.

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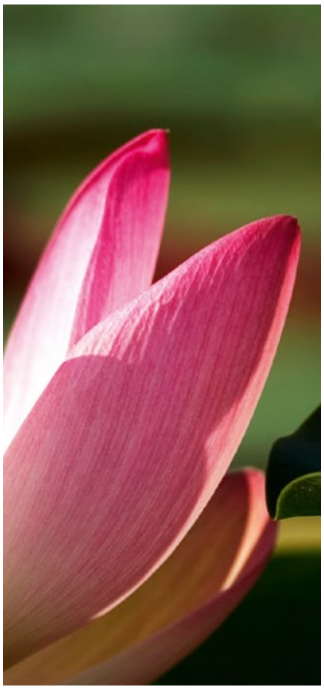

Unifont® – high strenght and regenerative powers

Unifont alloys offer high strength without heat treatment and outstanding casting properties, but limited shaping properties. They are used for components which are often large and difficult, especially in circumstances which require high strength levels: in mechanical engineering, domestic appliances and medical technology. Thanks to their self-hardening character, they regenerate themselves after thermal overload.

Nature's role model: the water lily which closes its petals for protection at night and only opens them again when the sun rises.

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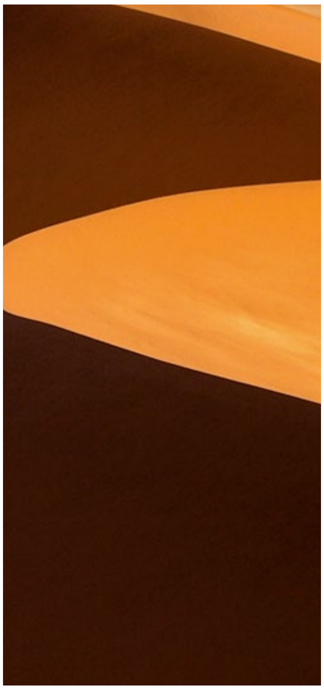

Castadur® – the power of regeneration

A self-hardening material of high formability which gains strength without losing its ability to stretch. And even if it loses its properties, from overheating for example, they return. Castadur's softly radiant surface is easy to polish, making it popular for everyday objects such as furniture.

The material's homogeneity and silent power are reminiscent of desert sand dunes, which, shaped by the wind, are always taking on new shapes while remaining the same.

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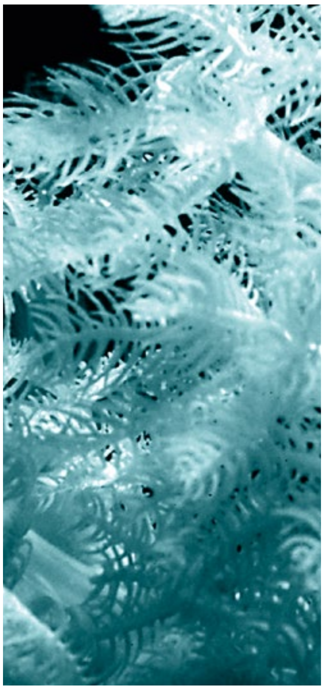

Peraluman® – beautiful, soft sheen, impact resistant and tensile

Thanks to their absolute corrosion resistance and associated resistance to acids and salts, these alloys are used to manufacture machines for the production of foodstuffs. The parts are impact resistant and display good elongation. Their particularly soft sheen and their ability to anodise in colour enable them to be used in places where looks are important.

The metaphor from nature for this alloy is soft coral. It is gracefully structured and appears bright in dark water – it has the same matt sheen as parts produced from Peraluman.

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Magsimal® – of filigree lightness, but extremely resilient

An alloy for delicate parts which need to retain their strength and precise form over a long period. Good weldability, high resilience, can be used in virtually any application. Supreme corrosion resistance, even to salt water.

Parts which simulate the structure of the wings of a dragonfly: wafer thin, elastic and yet offering incredible strength and resilience, they enable this dainty insect to fly distances that never cease to amaze.

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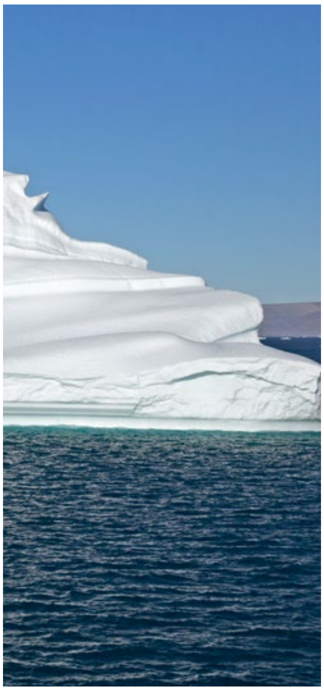

Aluman® – resistant even at very high temperatures

The alloy with the highest melting point of all aluminium alloys. Its good thermal conductivity makes this alloy perfectly suited to the manufacture of cast parts such as heat exchangers. Aluman parts display a high solidification temperature which means that they remain solid when surrounding aluminium alloys have already become liquid. A workpiece cast from Aluman can therefore be soldered with an eutectic AlSi alloy.

Its counterpart in nature is fresh water icebergs which float in the salt water of polar seas as they don't share the same melting point.

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Alufont® – the ultimate strength for lightweight construction

This alloy's outstanding mechanical properties make it a serious alternative to steel. It is easy to weld and excellent to machine, and it can be used wherever parts are subject to high force and load levels. Its low weight also makes it ideal for elements that have to be moved: in motorsport, in machines or for example as a hinged element for telescopic lifting platforms.

As with crystals, these alloys have their strength from the inner structure.

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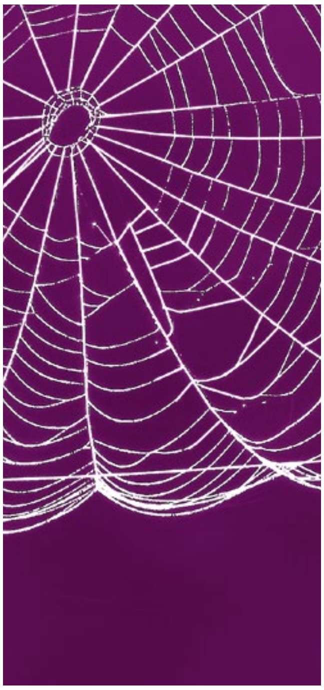

Thermodur® – a glimpse into the future

A new material that withstands high temperatures like never before, allowing it to play a key role in increased efficiency in combustion engines: increased output, lower fuel consumption, greater durability and lower emissions.

This alloy simulates the spider's silk: outstanding mechanical properties, maximum strength, stable, resilient and incredibly light.

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Quick finder for selecting the right alloy

The first step in producing a casting is to select the alloy most suited to the production process and requirements. The table covering these two pages provides an overview of our most common materials, their areas of use and properties. It will help you chose the right casting material. This table is no substitute for the service provided by our technical advisors, but does provide an overview and allows users to access the information as and when they need it.

		Areas of use																				
Alloy	**Chemical denomination**	Architecture	Fittings	Cars	Builder's hardware	Lighting	Aircraft	Heavy casting	Domestic appliances	Electrical conductors	Air conditioning	Automotive engineering	Manufacture of engines	Art casting	Foodstuffs industry	Mechanical engineering	Model/mould construction	Optics/furniture	Shipbuilding	Chemical industry	Textile industry	Defence engineering
Anticorodal-04	AlSi0.5Mg									x					x	x		x		x		
Anticorodal-50	AlSi5Mg	x	x			x			x		x			x	x	x	x	x	x	x		
Anticorodal-70	AlSi7Mg0.3	x	x	x		x	x		x		x	x	x	x	x	x	x		x	x		x
Anticorodal-78dv	AlSi7Mg0.3	x		x			x					x	x		x	x			x	x	x	x
Anticorodal-71	AlSi7Mg0.3-E									x												
Anticorodal-72	AlSi7Mg0.6	x					x		x			x			x	x	x		x	x		x
Silafont-30	AlSi9Mg		x	x		x		x	x		x	x	x	x	x	x			x		x	x
Silafont-36	AlSi10MnMg	x	x	x		x	x		x		x	x			x	x			x			x
Silafont-38	AlSi9MnMgZn	x		x		x		x	x		x	x				x					x	x
Silafont-09	AlSi9		x	x		x			x		x	x			x	x			x			x
Silafont-13	AlSi11	x							x		x			x	x	x						
Silafont-20	AlSi11Mg	x		x				x				x			x	x						
Silafont-70	AlSi12CuNiMg			x								x										
Silafont-90	AlSi17Cu4Mg			x								x										
Castaman-35	AlSi10MnMg		x	x		x			x		x	x		x	x	x			x			
Castasil-37	AlSi9MnMoZr	x		x		x	x		x		x	x			x	x			x			x
Castasil-21	AlSi9Sr			x		x				x	x					x			x			x
Unifont-90	AlZn10Si8Mg							x	x							x	x	x			x	x
Unifont-94	AlZn10Si8Mg			x								x				x		x				
Castadur-30	AlZn3Mg3Cr	x		x		x			x			x		x			x	x				
Castadur-50	AlZn5Mg	x				x			x					x		x	x	x				
Peraluman-30	AlMg3	x	x		x	x			x		x			x	x	x	x	x	x	x		
Peraluman-36	AlMg3Si	x	x		x	x		x	x					x	x	x	x	x		x		
Peraluman-50	AlMg5	x	x		x	x			x		x			x	x			x	x	x		
Peraluman-56	AlMg5Si	x	x			x			x		x			x	x	x		x	x	x		
Magsimal-59	AlMg5Si2Mn	x		x			x		x		x	x			x	x		x	x	x		x
Alufont-47	AlCu4TiMg			x								x				x					x	x
Alufont-48	AlCu4TiMgAg			x								x	x			x						x
Alufont-52	AlCu4Ti			x								x	x			x					x	x
Alufont-60	AlCu5NiCoSbZr			x									x									x
Thermodur-72	AlMg7Si3Mn			x			x				x	x	x			x			x	x		
Thermodur-73	AlSi11Cu2Ni2Mg2Mn			x							x	x	x			x						x
Rotoren-Al 99.7	Al99.7-E			x		x				x					x		x	x		x		
Aluman-16	AlMn1.6			x							x	x				x						

● excellent
◕ very good
◐ good
◔ all right
○ poor
– not applicable

Appropriate casting method			Distinguishing properties																						
Sand casting	Gravity die casting	High pressure die casting	Flangeability	Electrical conductivity	Suitable for decorative anodising	Suitable for technical anodising	Suitable for punch riveting	Strength in as-cast state	Casting properties	Elongation	Hardness	Corrosion resistance	For constructions with thin walls	For constructions with thick walls	Hard solderability	Maximum strength at 20 °C	Resistance to salt water	Polishability	Impact toughness/ductility	Weldability	Machinability at F	Machinability following T6	Wear resistance	Mechanical properties at elevated temperatures (200 °C)
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Tables for selecting alloys

The tables will aid designers in selecting the suitable casting alloy for the casting they are producing. They contain details of the 0.2 % yield tensile strength, elongation and corrosion resistance. The values indicate the performance of the alloys which can be achieved through appropriate casting technology work in the casting or its sub-sections.

Sand casting, as-cast state

0,2 % yield tensile strength $R_{p0,2}$ [MPa]

Elongation A [%]	60–120	90–160	200–230
0,5–3		Silafont-70 Silafont-20	Unifont-90 T1 Thermodur-73
3–6	Anticorodal-70/-78 dv Silafont-30 Peraluman-30/-36 Peraluman-50	Anticorodal-50 Peraluman-56 Castadur-50	
6–13	Silafont-13	Castadur-30	

Sand casting, heat-treated

0,2 % yield tensile strength $R_{p0,2}$ [MPa]

Elongation A [%]	90–160	160–300	300–450
0,3–3	Peraluman-56 T6	Anticorodal-50 T6 Anticorodal-72 T6 Silafont-20 T6 Silafont-70 T6	
2–5		Anticorodal-70/-78 dv T6 Silafont-30 T6 Peraluman-36	Alufont-47 T6 Alufont-48 T6 Alufont-52 T6
4–8	Anticorodal-70/-78 dv T64 Silafont-13 O Peraluman-30 T6	Anticorodal-50 T4 Alufont-47 T4 Alufont-48 T64 Alufont-52 T64	

Gravity die casting, as-cast state

0,2 % yield tensile strength $R_{p0,2}$ [MPa]

Elongation A [%]	70–100	90–180	180–260
0,5–2			Silafont-70 Silafont-90 Thermodur-73
2–6	Peraluman-36	Anticorodal-50 Anticorodal-70 Silafont-30 Peraluman-56	Unifont-90 T1
6–20	Peraluman-30	Silafont-13 Silafont-20 Peraluman-50	Thermodur-72

Treatment state

F	As-cast state		**T4**	Naturally aged		**T6**	Artifically aged
O	Annealed		**T5**	Stabilised		**T64**	Partially aged
T1	Self-aged		**T5**	Quenched and aged		**T7**	Overaged

Gravity die casting, heat-treated

0,2 % yield tensile strength $R_{p0,2}$ [MPa]

Elongation A [%]	120–200	200–300	300–450
0,5–4		Anticorodal-50 T6	Silafont-70 T6 Silafont-90 T6 Alufont-36 T6
4–8	Anticorodal-50 T4 Peraluman-56 T6	Anticorodal-70/-78 dv T6 Anticorodal-72 T64 Silafont-30 T6 Silafont-20 T6	Alufont-47 T6 Alufont-48 T6 Alufont-52 T6
8–12	Anticorodal-70/-78 dv T64 Silafont-13 O Peraluman-30 T6	Alufont-47 T4 Alufont-52 T64	

High pressure die casting

0,2 % yield tensile strength $R_{p0,2}$ [MPa]

Elongation A [%]	80–120	120–220	220–280
–1			Silafont-90 Thermodur-73
1–5		Silafont-38	Unifont-94 T1
5–20	Anticorodal-04 Silafont-36 T4 Aluman-16 Castasil-21	Silafont-09 Silafont-36 Magsimal-59 Castasil-37 Silafont-36 T5/T7 Thermodur-72 Castaman-35	Silafont-36 T6 Silafont-38 T6

Corrosion resistance

Castability

Corrosion resistance	average	good	very good	excellent
with surface protection	Alufont-47/-48 Alufont-52/-60 Silafont-90	Silafont-70 Thermodur-73		
from weathering	Castadur-30/-50		Silafont-30 Unifont-90 Unifont-94 Castasil-37 Castasil-21	Silafont-13 Silafont-20 Silafont-09 Silafont-36/-38 Castaman-35
from salt water	Anticorodal-04 Peraluman-30/-36 Peraluman-50/-56	Anticorodal-50 Anticorodal-70/-78dv Anticorodal-71 Anticorodal-72	Magsimal-59 Thermodur-72	

Publications

www.rheinfelden-alloys.eu

Catalogues		**Code**
Primary aluminium casting alloys	Manual	
Primary aluminium casting alloys	Leporello	
Primary Aluminium Alloys for Pressure Die Casting	Manual	

Manuals and processing data sheets		
Anticorodal-04	Ac-04	507
Anticorodal-50	Ac-50	504
Anticorodal-70/72	Ac-70, Ac-72	501
Anticorodal-71	Ac-71	508
Silafont-30	Sf-30	511
Silafont-36	Sf-36	518
Silafont-38	Sf-38	519
Silafont-09	Sf-09	516
Silafont-13	Sf-13	513
Silafont-20	Sf-20	512
Silafont-70	Sf-70	515
Castaman-35	Cm-35	571
Castasil-21	Ci-21	562
Castasil-37	Ci-37	561
Unifont-90	Uf-90	531
Unifont-94	Uf-94	532
Peraluman-30/36	Pe-30, Pe-36	541
Peraluman-50/56	Pe-50, Pe-56	542
Magsimal-59	Ma-59	545
Alufont-52	Af-52	521
Alufont-47	Af-47	522
Alufont-48	Af-48	523
Thermodur-72	Td-72	563
Thermodur-73	Td-73	562
Aluminium for rotors	RB	551

Anticorodal® – infinitely adaptable

As Anticorodal alloys can be adapted to virtually all different fields of work and production methods, countless possible uses are emerging for this material. Outstanding mechanical properties, electrical conductivity, corrosion resisting thanks to low silicon content, but slightly harder to cast. As with Silafont alloys, to enjoy cost-effective use, it is well worth providing a complete definition of the material being used and tailoring it to both the parts to be produced and your production process.

The creatures of the sea provide the natural metaphor for this alloy. Such creatures adapt to different conditions and have developed a whole series of special attributes in order to do this.

Anticorodal®-04 [AlSi0.5Mg]

Areas of use

For castings with high electrical conductivity. Electrical conductors, foodstuffs industry, mechanical engineering, optics/furniture, chemical industry

Distinguishing characteristics

Alloy for medium strength and medium hardness electrical conductors. Best corrosion resistance, very good weldability and suitable for decorative anodising (with the exception of high pressure die casting). Very well suited to hard soldering.

Alloy denomination

Chemical denomination: AlSi0.5Mg

Chemical composition [% of mass]

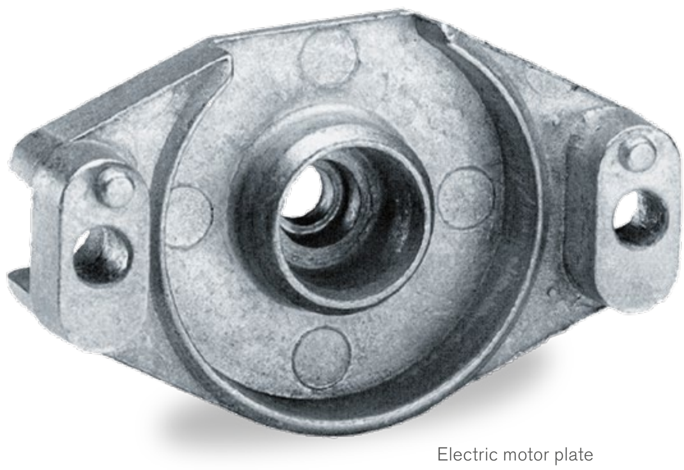
Si	Fe	Cu	Mn	**Mg**	Zn	**Ti**
0.3–0.6	0.8	0.01	0.01	**0.3–0.6**	0.07	**0.01**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	60–100 (50)	90–130 (80)	15–20 (10)	35–40 (35)
Sand casting	T7	160–180 (150)	190–210 (180)	3–5 (3)	70–75 (70)
Gravity die casting	F	80–120 (70)	100–140 (90)	18–22 (12)	40–45 (40)
Gravity die casting	T7	170–190 (150)	200–220 (190)	3–6 (3)	70–80 (70)
HPDC	F	80–120	100–140	7–12	40–45

Note chapter "Technical Information"!

Conductors for high-voltage systems
Anticorodal-04, overaged
Sand casting, ground
120 × 350 × 120 mm, weight: 12.5 kg



Electric motor plate
Anticorodal-04
High pressure die casting
55 × 32 × 18 mm, weight: 20 g

Anticorodal®-50 [AlSi5Mg]

Areas of use

Architecture, fittings, lighting, domestic appliances, air conditioning, art casting, foodstuffs industry, mechanical engineering, model/mould construction, optics/furniture, shipbuilding, chemical industry

Distinguishing characteristics

Outstanding resistance to weathering and very good resistance to salt water; good mechanical properties in as-cast state and very good after artificial ageing; very good polishability and machinability, particularly when artificially aged.
Good weldability, excellently suited to technical anodising.

Alloy denomination

Chemical denomination: AlSi5Mg

Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	Zn	**Ti**
5.0 – 6.0	0.15	0.02	0.10	**0.4 – 0.8**	0.10	**0.20**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	100 – 130 (90)	140 – 180 (130)	2 – 4 (1)	60 – 70 (55)
Sand casting	T4	150 – 180 (120)	200 – 270 (150)	4 – 10 (2)	75 – 90 (70)
Sand casting	T6	220 – 290 (160)	260 – 320 (180)	2 – 4 (1)	95 – 115 (85)
Gravity die casting	F	120 – 160 (100)	160 – 200 (140)	2 – 5 (1)	60 – 75 (60)
Gravity die casting	T4	160 – 190 (130)	210 – 270 (170)	5 – 10 (3)	75 – 90 (70)
Gravity die casting	T6	240 – 290 (180)	260 – 320 (190)	2 – 7 (1)	100 – 115 (90)

Note chapter “Technical Information”!

Cover for woodworking machine
Anticorodal-50, as-cast state
Gravity die casting, hard anodised
450 × 310 × 330 mm, weight: 5.0 kg

Anticorodal®-70 [AlSi7Mg0.3]

Areas of use

Architecture, fittings, cars, lighting, aircraft, domestic appliances, air conditioning, automotive engineering, manufacture of engines, art casting, foodstuffs industry, mechanical engineering, model/mould construction, shipbuilding, chemical industry, defence engineering

Distinguishing characteristics

Universal alloy with very good mechanical properties, outstanding corrosion resistance, very good weldability and very good machining characteristics.

Alloy denomination

Chemical denomination: AlSi7Mg0.3   Numerical denomination: 42 100

Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	Zn	**Ti**	**other**
6.5 – 7.5	0.15	0.02	0.05	**0.30 – 0.45**	0.07	**0.18**	**(Na/Sr)**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	80 – 140 (80)	140 – 220 (140)	2 – 6 (2)	45 – 60 (45)
Sand casting	T64	120 – 170 (120)	200 – 270 (200)	4 – 10 (4)	60 – 80 (55)
Sand casting	T6	200 – 280 (200)	240 – 320 (240)	3 – 6 (2.5)	80 – 110 (80)
Gravity die casting	F	90 – 150 (90)	180 – 240 (180)	4 – 9 (2)	55 – 70 (50)
Gravity die casting	T64	180 – 200 (140)	250 – 270 (220)	8 – 12 (5)	80 – 95 (80)
Gravity die casting	T6	220 – 280 (200)	290 – 340 (250)	5 – 9 (3.5)	90 – 125 (90)

Note chapter "Technical Information"!

Industrial fuelling fittings
Anticorodal-70, artificially aged
Sand casting, pressure-sealed
Ø 140 × 190 mm, weight: 4.0 kg

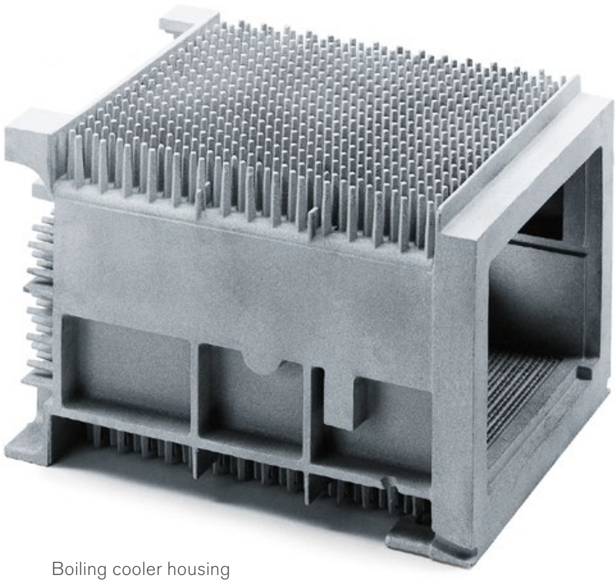
Pressure equalisation housing in Airbus 310
Anticorodal-70 permanently modified, artificially aged
Gravity die casting, anodised
Ø 295 × 190 mm, weight: 2.1 kg

Anticorodal®-70 [AlSi7Mg0.3]

Contact carrier for high-voltage switch
Anticorodal-70, artificially aged
Gravity die casting, surface ground
520 × 290 × 130 mm, weight: 21.7 kg

Electric suspension track housing
Anticorodal-70, artificially aged
Sand casting
760 × 280 × 250 mm, weight: 18.5 kg

Longitudinal carrier for wheel suspension
Anticorodal-70, artificially aged
Sand casting with single-part core
450 × 200 × 135 mm, weight: 2.5 kg



Boiling cooler housing
Anticorodal-70, artificially aged
Sand casting, surface blasted
530 × 380 × 310 mm, weight: 26 kg

Anticorodal®-78 dv [AlSi7Mg0.3]

Areas of use

Architecture, cars, aircraft, automotive engineering, manufacture of engines, foodstuffs industry, mechanical engineering, shipbuilding, chemical industry, textile industry, defence engineering, highly dynamically loaded components

Distinguishing characteristics

Permanently modified alloy especially for sand casting with very good mechanical properties, outstanding corrosion resistance, very good weldability and very good machining characteristics.

Alloy denomination

Chemical denomination: AlSi7Mg0.3 Numerical denomination: 42 100

Chemical composition [% of mass]

Si	**Fe**	Cu	Mn	**Mg**	Zn	**Ti**	**other**
6.5 – 7.5	**0.12**	0.02	0.05	**0.30 – 0.45**	0.07	**0.18**	**Sr**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	80 – 140 (80)	140 – 220 (140)	2 – 6 (2)	45 – 60 (45)
Sand casting	T64	120 – 170 (120)	200 – 270 (200)	4 – 10 (4)	60 – 80 (55)
Sand casting	T6	200 – 280 (200)	240 – 320 (240)	3 – 6 (2.5)	80 – 110 (80)

Note chapter “Technical Information”!

Compressor wheel
Anticorodal-78 permanently modified, artificially aged
Sand casting
Ø 215 × 60 mm, weight: 2.1 kg

Anticorodal®-71 [AlSi7Mg0.3 - E]

Areas of use

For castings with high electrical conductivity.

Distinguishing characteristics

High strength and hardness after heat treatment. Very good casting properties, very good corrosion resistance, very good weldability and machinability.

Alloy denomination

Chemical denomination: AlSi7Mg0.3 - E   Numerical denomination: 42 100

Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	Zn	**Ti**	**other**
6.5 – 7.5	0.15	0.01	0.01	**0.30 – 0.45**	0.07	**0.01**	**(Na/Sr)**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	T7	160 – 200 (150)	220 – 250 (210)	2 – 4 (2)	70 – 80 (70)
Gravity die casting	T7	160 – 200 (150)	220 – 250 (210)	4 – 6 (3)	70 – 80 (70)

Note chapter "Technical Information"!

Flat connecting terminal
Anticorodal-71, overaged
Gravity die casting
180 × 240 × 240 mm, weight: 5.6 kg

Electrical conductors in gearshift housings
Anticorodal-71, overaged
Sand casting, surface ground
350 × 210 × 180 mm, weight: 4.1 kg

Anticorodal®-72 [AlSi7Mg0.6]

Areas of use

Architecture, aircraft, domestic appliances, automotive engineering, foodstuffs industry, mechanical engineering, model/mould construction, shipbuilding, chemical industry, defence engineering

Distinguishing characteristics

Alloy with very good mechanical properties, outstanding corrosion resistance, very good weldability and very good machining characteristics. Higher Mg content than Anticorodal-70, giving it higher strength and hardness with less elongation.

Alloy denomination

Chemical denomination: AlSi7Mg0.6   Numerical denomination: 42 200

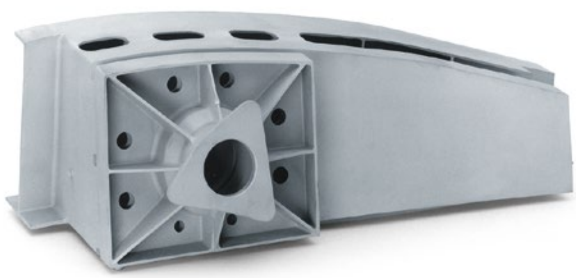
Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	Zn	**Ti**	**other**
6.5 – 7.5	0.15	0.02	0.05	**0.50 – 0.70**	0.07	**0.18**	**(Na/Sr)**

Mechanical properties

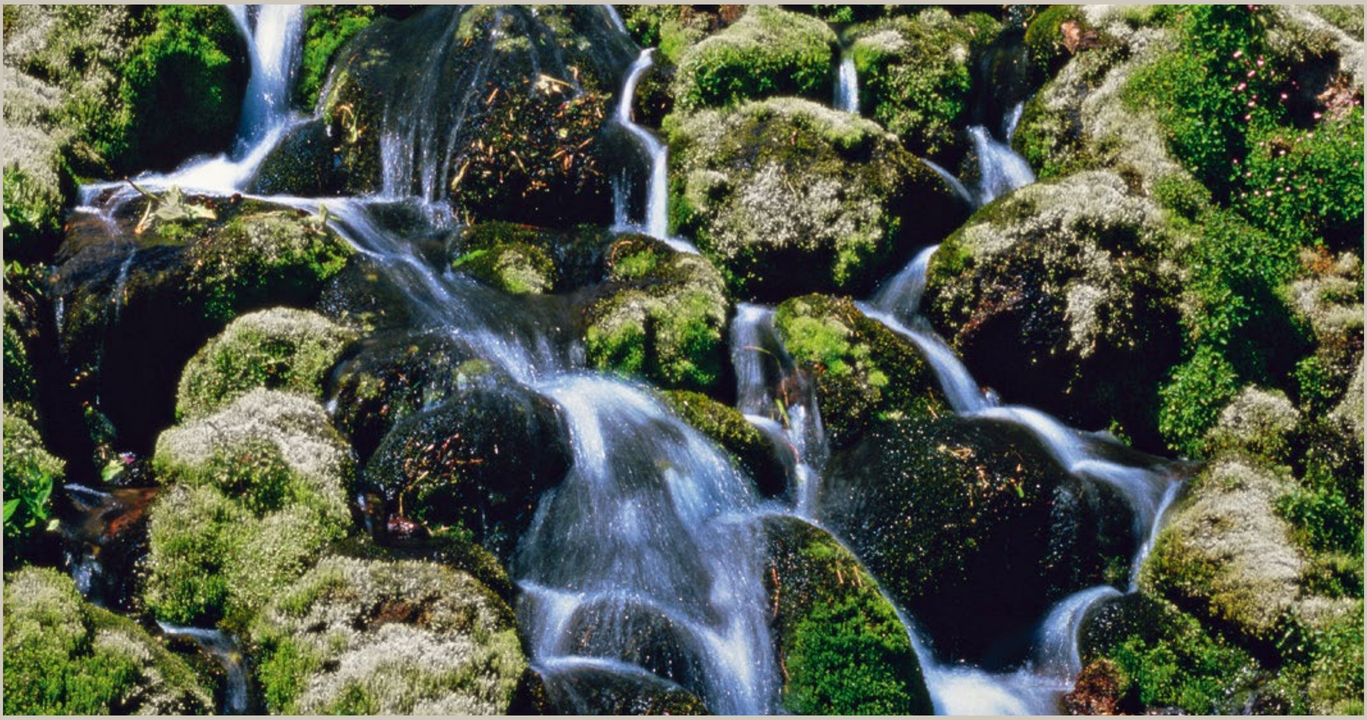
Casting method	Treatment state	YTS $R_{p0.2}$ [MPa]	UTS R_m [MPa]	Elongation A [%]	Brinell hardness HBW
Sand casting	T6	220 – 280 (220)	250 – 320 (250)	1 – 2 (1)	90 – 110 (90)
Gravity die casting	T64	210 – 240 (150)	290 – 320 (230)	6 – 8 (3)	90 – 100 (90)
Gravity die casting	T6	240 – 280 (220)	320 – 350 (270)	4 – 6 (2.5)	100 – 115 (100)

Note chapter "Technical Information"!



Landing flap suspension on Airbus 320
Anticorodal-72, artificially aged
Low pressure fine casting
575 × 250 × 210 mm, weight: 4.7 kg

Fisherman's anchor for offshore sailors
Anticorodal-72, artificially aged, partially aged
Gravity die casting, sand casting
660 × 460 × 180 mm, weight: 5.4 kg



Silafont® – an infinite wealth of properties

A family of materials which can be adapted to the parts to be produced and the customer's individual production process with ultimate precision. Can be processed using any casting procedure, outstanding flow properties, can be modified with sodium or strontium to further enhance properties. For complex, delicate components which have to satisfy precisely defined requirements and, if they feature the right components, make maximum production efficiency possible.

Silafont emulates flowing water, that flows continually to the sea, advances at any angle, washing around every stone and every shape in its way. Homogeneous and easily in the very same way that Silafont fills the cavities in the mould.

Silafont®-30 [AlSi9Mg]

Areas of use

Fittings, cars, lighting, heavy casting, domestic appliances, air conditioning, automotive engineering, manufacture of engines, art casting, foodstuffs industry, mechanical engineering, shipbuilding, textile industry, defence engineering
Well suited to large and complicated castings.

Distinguishing characteristics

One of the most important AlSi casting alloys which can be aged, with very good casting properties and outstanding corrosion resistance. High strength values after artificial ageing. Excellent weldability, very good machinability.

Alloy denomination

Chemical denomination: AlSi9Mg   Numerical denomination: 43 300

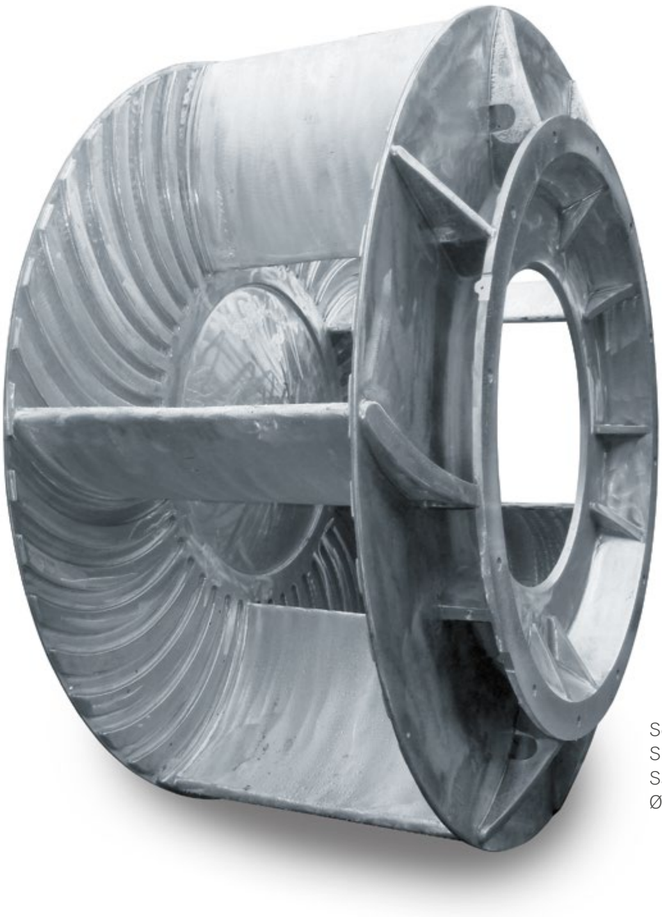
Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	Zn	Ti	**other**
9.0–10.0	0.15	0.02	0.05	**0.30–0.45**	0.07	0.15	**(Na/Sr)**

Mechanical properties

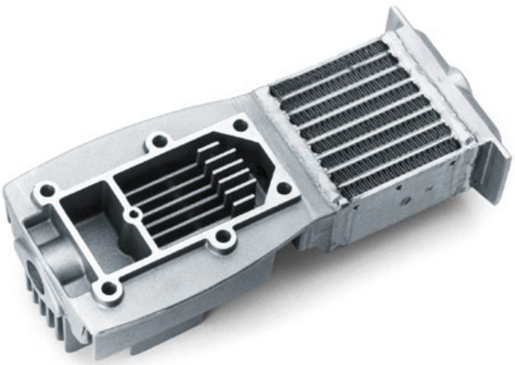
Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	80–140 (80)	160–220 (150)	2–6 (2)	50–70 (50)
Sand casting	T6	200–310 (180)	250–330 (220)	2–5 (2)	80–115 (75)
Gravity die casting	F	90–150 (90)	180–240 (180)	2–9 (2)	60–80 (60)
Gravity die casting	T64	180–210 (140)	250–290 (220)	6–10 (3)	80–90 (80)
Gravity die casting	T6	210–310 (190)	290–360 (240)	4–7 (2)	90–120 (90)

Note chapter "Technical Information"!



Sound-damper body for large diesel engines
Silafont-30, as-cast state
Sand casting, cast in two parts, welded
Ø 2300 × 1000 mm, weight: 900 kg

Distributor for laser generator
Silafont-30, artificially aged
Sand casting, helium-tight
950 × 730 × 220 mm, weight: 42 kg



Cylinder head for compressor
Silafont-30, as-cast state
Gravity die casting, welded, pressure-sealed
390 × 160 × 110 mm, weight: 4.2 kg

Intermediate flange for SF_6 switch system
Silafont-30, artificially aged
Sand casting, pressure-sealed
Ø 560 × 270 mm, weight: 64 kg

Compressor housing
Silafont-30, artificially aged
Sand casting, pressure-sealed
290 × 270 × 120 mm, weight: 2.0 kg

Silafont®-36 [AlSi10MnMg]

Areas of use

Architecture, fittings, cars, lighting, aircraft, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, shipbuilding, defence engineering, welded designs

Distinguishing characteristics

High pressure die casting alloy with excellent castability, very good elongation in as-cast state, maximum elongation after heat treatment. Very good corrosion resistance, good polishability, very good machinability, very good weldability.

Alloy denomination

Chemical denomination: AlSi10MnMg Numerical denomination: 43 500

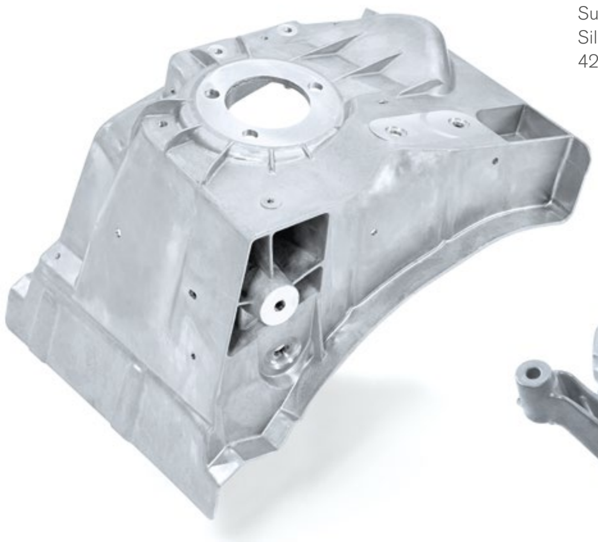
Chemical composition [% of mass]

Si	Fe	Cu	**Mn**	**Mg**	Zn	Ti	**other**
9.5–11.5	0.15	0.03	**0.5–0.8**	**0.1–0.5**	0.07	0.15	**Sr**

Mechanical properties

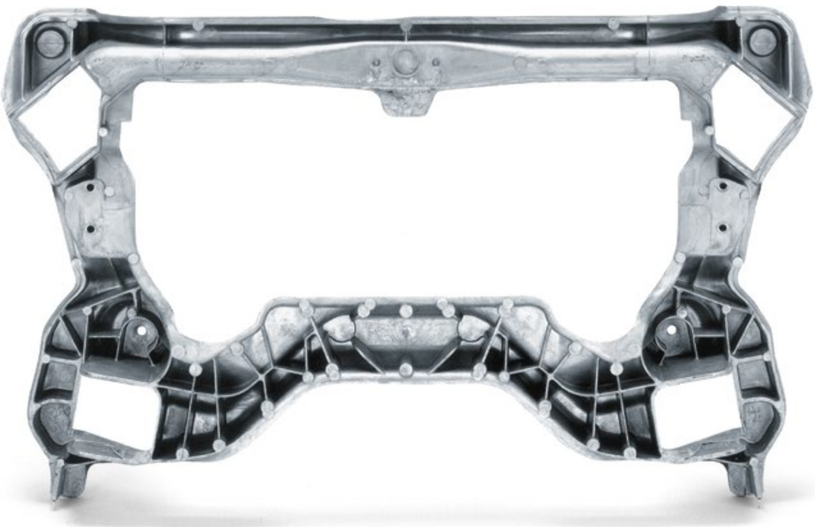
Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
HPDC	F	120–150	250–290	5–11	75–95
HPDC	T5	155–245	275–340	4–9	80–110
HPDC	T4	95–140	210–260	15–22	60–75
HPDC	T6	210–280	290–340	7–12	90–110
HPDC	T7	120–170	200–240	15–20	60–75

Note chapter "Technical Information"!



Suspension-strut dome
Silafont-36
420 × 350 × 330 mm, weight: 4.3 kg

Cross member off-road vehicle
Silafont-36
High pressure die casting
1020 × 690 × 280 mm, weight: 10.3 kg

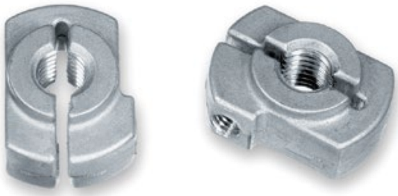


Integral carrier
Silafont-36, aged
High pressure die casting, with forced bleeding
920 × 580 × 170 mm, weight: 10.0 kg

Steering column with a high force
at break in the area of steering lock
Silafont-36
High pressure die casting
450 × 70 × 90 mm, weight: 0.96 kg

Engine bracket for BMW magnesium engine,
due high resistance against contact corrosion
Silafont-36
High pressure die casting
270 × 170 × 210 mm, weight: 1.5 kg

Wheel hub for off-road motorbike
Silafont-36, pre-cast core hole
High pressure die casting, shot-blasted
Ø 170 × 145 mm weight: 1.0 kg



Lock nut for steering column
Silafont-36
High pressure die casting
20 × 12 × 7 mm, weight: 9 g

Silafont®-38 [AlSi9MnMgZn]

Areas of use

Weight reduced car body structures for vehicles, mechanical engineering

Distinguishing charcteristics

Casting alloy with very high mechanical properties after T6 treatment including a air queching for reduced distorsion. Very high yield strenght combined with high values of elongation for crash relevant structural die castings. Silafont-38 substitutes sheet designs in vehicle design and offers high cost and weight reduction.

Alloy denomination

Chemical denomination: AlSi9MnMgZn

Chemical composition [% of mass]

[%]	Si	Fe	Cu	Mn	Mg	Zn	Ti	Sr	others
min.	**8.0**		**0.1**	**0.5**	**0.1**	**0.1**		**0.010**	
max.	**10.0**	0.15	**0.4**	**0.8**	**0.5**	**0.4**	**0.15**	**0.02**	0.10

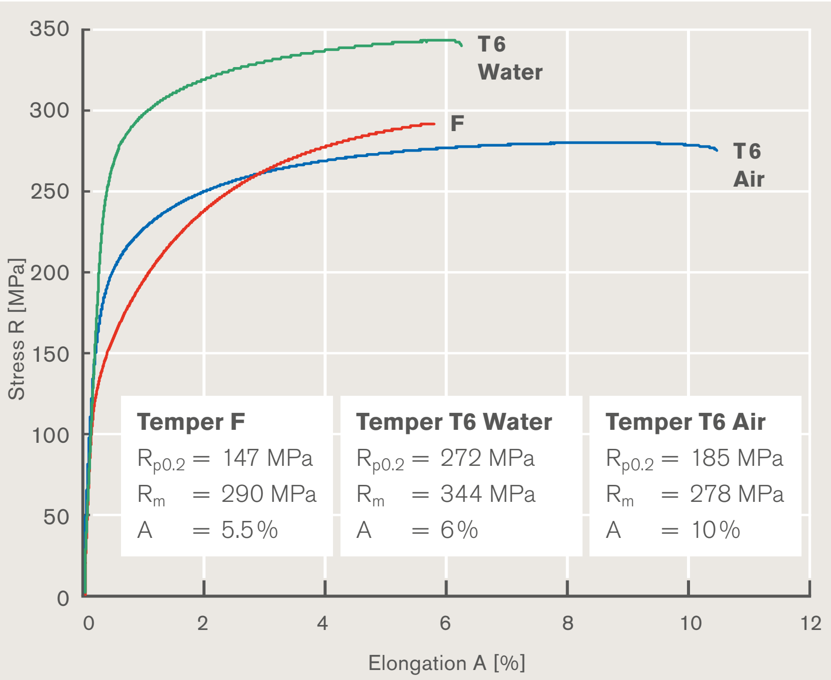
Mechanical properties

Casting method	Treatment state	Quenching cooling	YTS $R_{p0.2}$ [MPa]	UTS R_m [MPa]	Elongation A [%]
HPDC	F		140–160	270–300	3–7
HPDC	T6	Water	230–270	300–345	6–9
HPDC	T6	Air	180–200	250–275	8–10

Note chapter "Technical Information"!

Processing properties compared to standard pressure die casting alloys

Alloy type	Silafont-38	Silafont-36	Silafont-09
Sticking tendency	low	low	low
Die life	100%	100%	100%
Linear shrinkage	0.4–0.6%	0.4–0.6%	0.4–0.6%



Silafont®-09 [AlSi9]

Areas of use

Large apparatus parts, fittings, cars, lighting, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, shipbuilding, defence engineering

Distinguishing characteristics

Flangeable high pressure die casting alloy with very good casting properties, even with thick-walled designs. Very good corrosion resistance to weathering and water.

Alloy denomination

Chemical denomination: AlSi9 Numerical denomination: 44 400

Chemical composition [% of mass]

Si	**Fe**	Cu	**Mn**	Mg	Zn	Ti
9.5 – 10.6	**0.4**	0.02	**0.4**	0.05	0.10	0.10

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
HPDC	F	120 – 180	240 – 280	4 – 8	55 – 80

Note chapter "Technical Information"!

Heating plate for espresso machine
Silafont-09
High pressure die casting, flanged
138 × 91 × 42 mm, weight: 0.71 kg

Fan blade
Silafont-09
High pressure die casting
410 × 20 × 55 mm, weight: 0.6 kg

Silafont®-13 [AlSi11]

Areas of use

Architecture, domestic appliances, air conditioning, foodstuffs industry, mechanical engineering

Distinguishing characteristics

Near eutectic AlSi universal alloy with average mechanical properties, high elongation and impact toughness.
Higher elongation due temper O anneling. Outstanding castability, very good corrosion resistance, outstanding weldability.
Good sheen after mechanical polishing.

Alloy denomination

Chemical denomination: AlSi11 numerical if Si content < 11.8 %: 44 000

Chemical composition [% of mass]

Si	Fe	Cu	Mn	Mg	Zn	Ti	**other**
10.0 – 13.5	0.15	0.02	0.05	0.05	0.07	0.15	**(Na/Sr)**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	70 – 120 (70)	150 – 210 (150)	7 – 13 (6)	45 – 60 (45)
Sand casting	O	60 – 120 (70)	150 – 210 (150)	9 – 15 (8)	45 – 60 (45)
Gravity die casting	F	80 – 150 (80)	170 – 240 (160)	7 – 16 (6)	45 – 60 (45)
Gravity die casting	O	60 – 120 (60)	180 – 240 (160)	10 – 18 (10)	45 – 65 (45)

Note chapter “Technical Information”!

Conductor anchoring
Silafont-13
Low-pressure die casting, welded design
820 × 250 × 370 mm, weight: 5.6 kg

Truck cooler collector
Silafont-13
Gravity die casting
800 × 140 × 120 mm, weight: 3.8 kg

Cross-flow radiator
Silafont-13
Gravity die casting, welded design with wrought alloy
450 × 410 × 110 mm, weight: 4.5 kg

Silafont®-20 [AlSi11Mg]

Areas of use

Architecture, cars, heavy casting, automotive engineering, foodstuffs industry, mechanical engineering

Distinguishing characteristics

Near eutectic, heat-treatable AlSi alloy with high mechanical properties. Outstanding corrosion resistance to weathering and water. Outstanding weldability. Good machinability after ageing. Silafont-20 dv offers particularly good ductility properties.

Alloy denomination

Chemical denomination: AlSi11Mg   Numerical denomination: 44 000

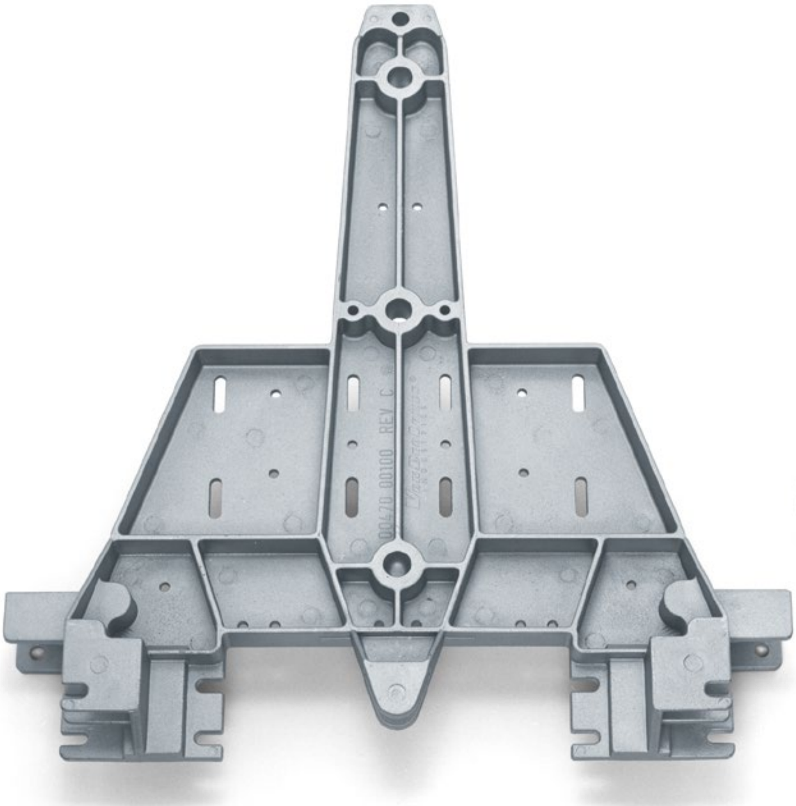
Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	Zn	Ti	**other**
10.0 – 11.8	0.15	0.02	0.05	**0.10 – 0.45**	0.07	0.15	**Na/Sr**

Mechanical properties

Casting method	Treatment state	YTS $R_{p0.2}$ [MPa]	UTS R_m [MPa]	Elongation A [%]	Brinell hardness HBW
Sand casting	F	80 – 140 (70)	170 – 220 (170)	2 – 4 (1.5)	50 – 60 (50)
Sand casting	T6	120 – 300 (110)	200 – 320 (200)	1 – 3 (0.5)	65 – 120 (55)
Gravity die casting	F	80 – 130 (80)	180 – 230 (180)	3 – 16 (3)	55 – 75 (55)
Gravity die casting	T6	125 – 320 (120)	210 – 350 (210)	4 – 15 (3)	70 – 125 (70)

Note chapter "Technical Information"!



Base element for plate-type conveyor
Silafont-20,
Low-pressure die casting, permanently modified
980 × 780 × 200 mm, weight: 18.5 kg

Motorbike rear swinging fork
Silafont-20 permanently modified
Low-pressure die casting
570 × 240 mm, weight: 4.5 kg

Silafont®-70 [AlSi12CuNiMg]

Areas of use

Cars, automotive engineering

Parts which are subjected to high strength loads at high temperatures.

Distinguishing characteristics

Very high ultimate tensile strength, yield tensile strength and hardness values are achieved through full artificial ageing.

Good mechanical properties at higher temperatures. Good machining characteristics. Reduced corrosion resistance.

Good running and sliding properties, wear resistant.

Alloy denomination

Chemical denomination: AlSi12CuNiMg   Numerical denomination: 48 000

Chemical composition [% of mass]

Si	Fe	**Cu**	Mn	**Mg**	Zn	Ti	**other**
11.0 – 13.5	0.15	**0.8 – 1.3**	0.05	**0.9 – 1.3**	0.10	0.10	**0.8 – 1.3 Ni**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	120 – 170 (110)	130 – 180 (120)	0.5 – 1.5 (0.5)	80 – 90 (80)
Sand casting	T6	200 – 300 (190)	220 – 300 (200)	0.3 – 1.0 (0.3)	130 – 160 (130)
Sand casting	T5	140 – 190 (140)	160 – 190 (160)	0.2 – 1.0 (0.2)	80 – 90 (80)
Gravity die casting	F	190 – 260 (180)	200 – 270 (190)	1.0 – 2.5 (0.5)	90 – 105 (90)
Gravity die casting	T6	320 – 390 (280)	350 – 400 (300)	0.5 – 2.0 (0.5)	135 – 160 (135)
Gravity die casting	T5	185 – 210 (150)	200 – 230 (180)	0.5 – 2.0 (0.5)	90 – 110 (90)

Note chapter "Technical Information"!

Housing for screw pumps
Silafont-70, artificially aged
Sand casting
Ø 200 × 700 mm, weight: 12.0 kg

Cylinder housing with cylinder head
Silafont-70, artificially aged
Gravity die casting
290 × 175 × 170 mm, weight: 5.4 kg

Castaman®

An alloy family, that use the possibilities of recycling, to a desired high sustainability – to come represented in carbon footprint counter.

Nature's role model: the lupine, growing from the humus of last year's crop.

Castaman®-35 [AlSi10MnMg]

Areas of use

Large and huge structural car body casts, lighting, automotive engineering, mechanical engineering

Distinguishing characteristics

High pressure die casting alloy with very good casting properties, even with thick-walled designs.
Very good corrosion resistance to weathering and water.

Alloy denomination

Chemical denomination: AlSi10MnMg Numerical denomination: 43 500

Chemical composition [% of mass]

Si	Fe	Cu	Mn	Mg	Zn	Ti	other
9.5–11.0	**0.2**	0.03	**0.5–0.8**	**0.2–0.5**	0.10	0.15	**Sr**

Mechanical properties

Casting method	Treatment state	YTS $R_{p0.2}$ [MPa]	UTS R_m [MPa]	Elongation A [%]	Brinell hardness [HBW]
HPDC	**F**	**120–150**	**200–2720**	**4–9**	**75–90**
HPDC	**T6**	**180–260**	**250–320**	**6–12**	**80–110**

Processing properties compared to other high pressure die casting alloys

Alloy type	Castaman-35	Silafont-36	Silafont-09
Sticking tendency	low	low	low
Die life	100%	100%	100%
Linear shrinkage	0.4–0.6%	0.4–0.6%	0.4–0.6%

Note chapter “Technical Information”!

Castasil® – large areas, high dimensional stability, fantastic to cast

An alloy, produced for large, high pressure die cast structural parts in the automotive construction industry. Lamborghini produced the first series in the Gallardo Spyder. Numerous manufacturers now recognise the benefits of this alloy: high dimensional stability, can be used without heat treatment, shapes well and easy to weld.

Nature's equivalent: the vine branch which turns towards the sun, flexible, elastic and yet incredibly tough and strong.

Castasil®-37 [AlSi9MnMoZr]

Areas of use

Connection nodes for space frame designs; thin-walled body parts; architecture, cars, lighting, aircraft, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, shipbuilding, defence engineering; replaces high pressure die castings with T7 or T6 with air quenching

Distinguishing characteristics

High pressure die casting alloy with excellent castability. Very high elongation in as-cast state as a result of which it can be used in more ways when in as-cast state. Further increase in ductility thanks to single-stage heat treatment. No distortion or blisters from solution heat treatment, very good corrosion resistance, no long-term ageing due to heat, good machinability, ideal for riveting and adhesive bonding in automotive engineering.

Alloy denomination

Chemical denomination: AlSi9MnMoZr

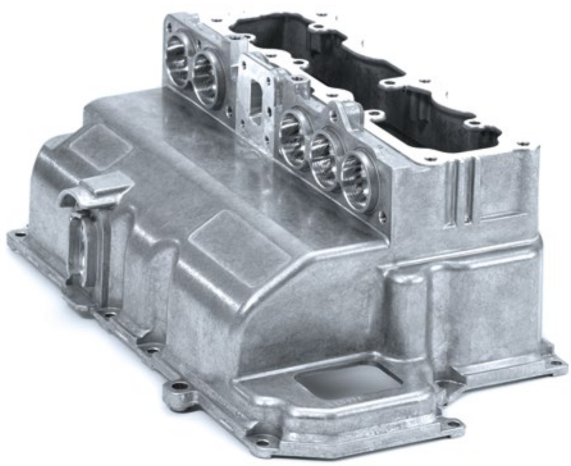
Chemical composition [% of mass]

Si	Fe	Cu	**Mn**	Mg	Zn	**Mo**	**Zr**	**other**
8.5 – 10.5	0.15	0.05	**0.35 – 0.60**	0.06	0.07	**0.1 – 0.3**	**0.1 – 0.3**	**Sr**

Mechanical properties

Casting method	Treatment state	Wall thickness	YTS $R_{p0.2}$ [MPa]	UTS R_m [MPa]	Elongation A [%]
HPDC	F	2 – 3	120 – 150	260 – 300	10 – 14
HPDC	F	3 – 5	100 – 130	230 – 280	10 – 14
HPDC	F	5 – 7	80 – 110	200 – 250	10 – 14

Note chapter “Technical Information”!

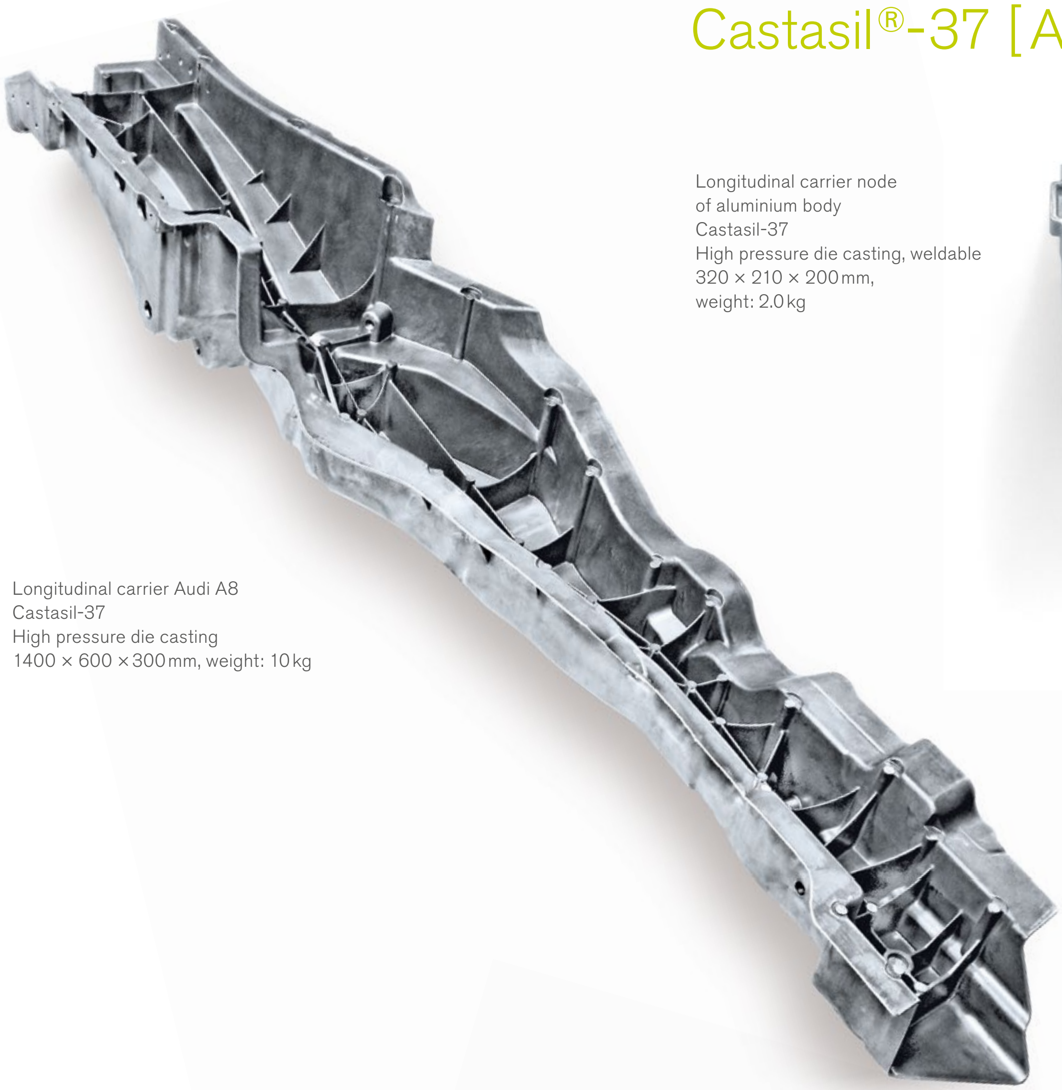


Upper safety housing for high voltage plug connectors
Castasil-37
High pressure die casting
210 × 330 × 140 mm, Gewicht: 1.5 kg

Suspension-strut dome
Castasil-37
High pressure die casting, wall thickness: 5 mm,
430 × 330 × 340 mm, weight: 4.4 kg

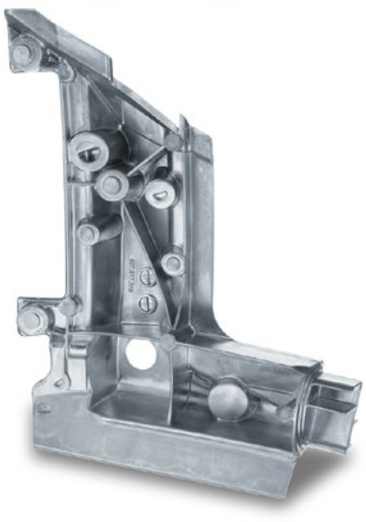
Castasil®-37 [AlSi9MnMoZr]

Longitudinal carrier node
of aluminium body
Castasil-37
High pressure die casting, weldable
320 × 210 × 200 mm,
weight: 2.0 kg



Longitudinal carrier Audi A8
Castasil-37
High pressure die casting
1400 × 600 × 300 mm, weight: 10 kg

Convertible soft-top lever
Castasil-37
High pressure die casting
510 × 100 × 80 mm, weight: 0.56 kg



Reinforcement for convertible soft-top
Castasil-37
High pressure die casting, weldable
260 × 220 × 60 mm, weight: 0.6 kg

Internal door parts for a sports car
Castasil-37
High pressure die casting
620 × 340 × 170 mm, weight: 1.2 kg
700 × 340 × 170 mm, weight: 2.1 kg

Castasil®-21 [AlSi9Sr]

Areas of use

Also for huge castings with requirements in terms of high thermal or electrical conductivity.
Conductor plate for electronics, automotive and mechanical engineering, LED-lighting, air cooling

Distinguishing characteristics

High pressure die casting alloy with high casting ability, optimized for high thermal or electrical conductivity. A casting treatment O gives highest conductivity compared with other AlSi-die casting alloys. Flangeable, very good corrosion resistance to weather.

Alloy denomination

Chemical denomination: AlSi9Sr

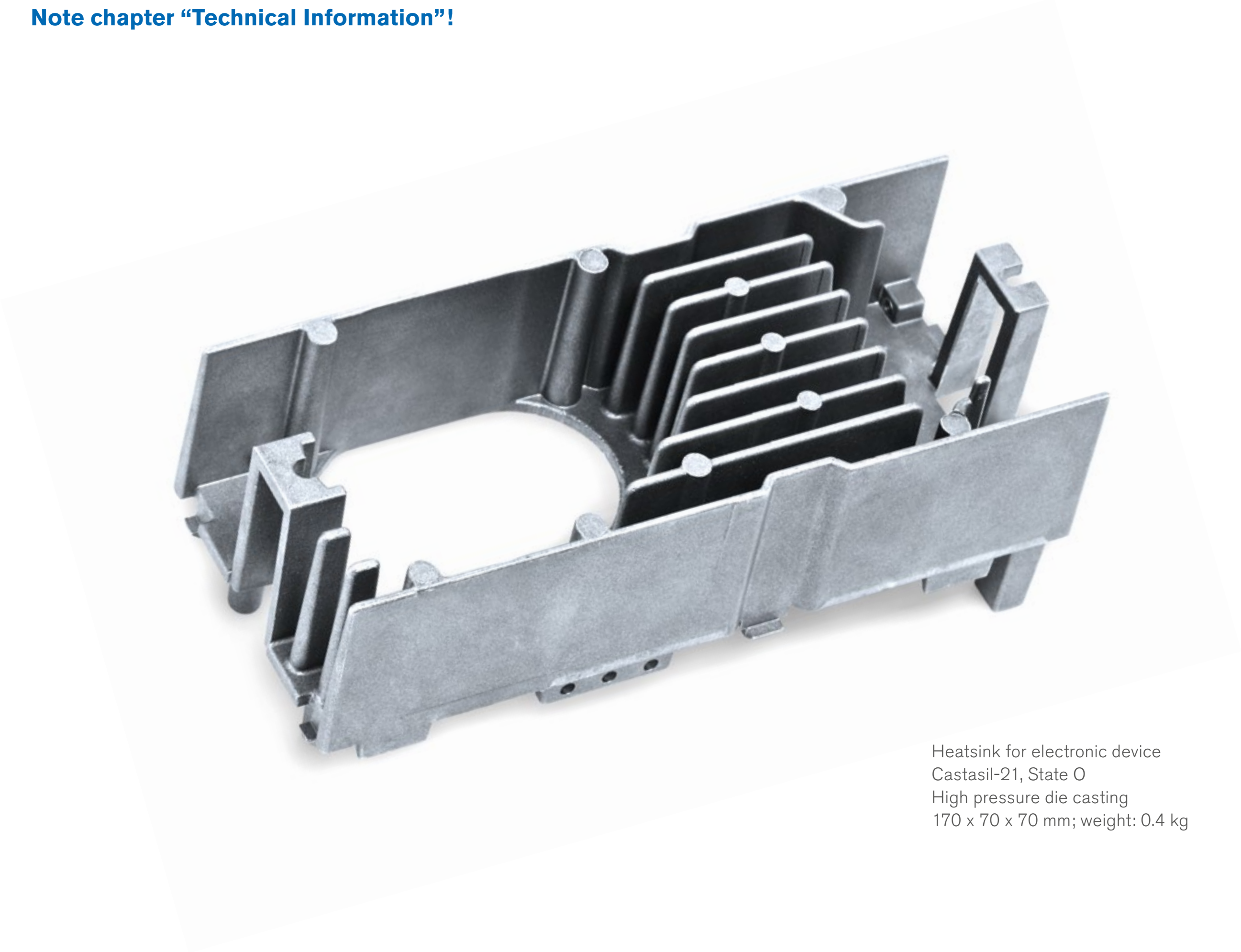
Chemical composition [% of mass]

Si	**Fe**	Cu	**Mn**	Mg	Zn	**Ti**	**other**
8.0–9.0	**0.5–0.7**	0.02	**0.01**	0.03	0.07	**0.01**	**Sr**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
HPDC	F	90–100	200–230	6–9	60–70
HPDC	O	80–90	170–190	9–14	55–65

Note chapter "Technical Information"!



Heatsink for electronic device
Castasil-21, State O
High pressure die casting
170 x 70 x 70 mm; weight: 0.4 kg

Unifont® – high strength and regenerative power

Unifont alloys offer high strength without heat treatment and outstanding casting properties, but limited shaping properties. They are used for components which are often large and difficult, especially in circumstances which require high strength levels: in mechanical engineering, domestic appliances and medical technology. Thanks to their self-hardening character, they regenerate themselves after overloads.

Nature's role model: the water lily which closes its petals for protection at night and only opens them again when the sun rises.

Unifont®-90 [AlZn10Si8Mg]

Areas of use

Heavy casting, mechanical engineering, pattern and mould construction, optics, furniture, textile industry, hydraulic cast, domestic appliances, defence engineering

Distinguishing characteristics

Self-ageing alloy with very good strength and elongation properties, especially in low-pressure gravity die casting. Very good mechanical polishability and machinability. Good weldability. Aged again following e.g. thermal loading from welding. Casting properties similar to Silafont-30.

Alloy denomination

Chemical denomination: AlZn10Si8Mg   Numerical denomination: 71 100

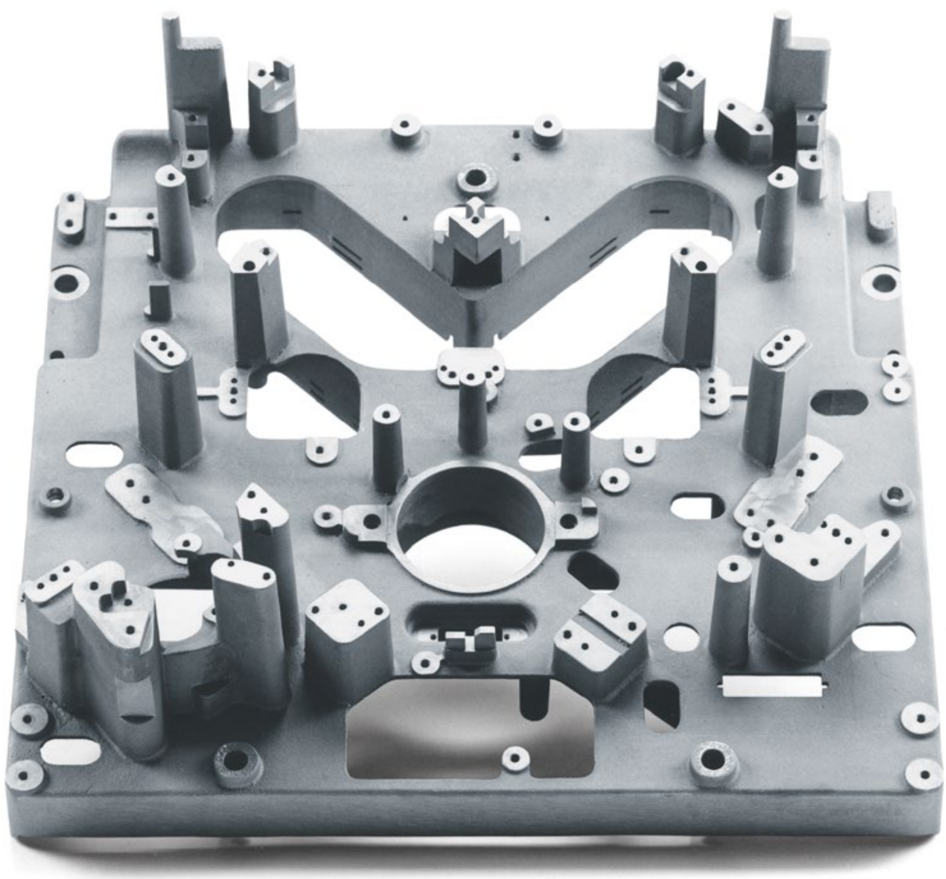
Chemical composition [% of mass]

Si	Fe	Cu	Mn	**Mg**	**Zn**	Ti	**other**
8.5–9.5	0.15	0.03	0.10	**0.3–0.5**	**9.0–10.0**	0.15	**(Na/Sr)**

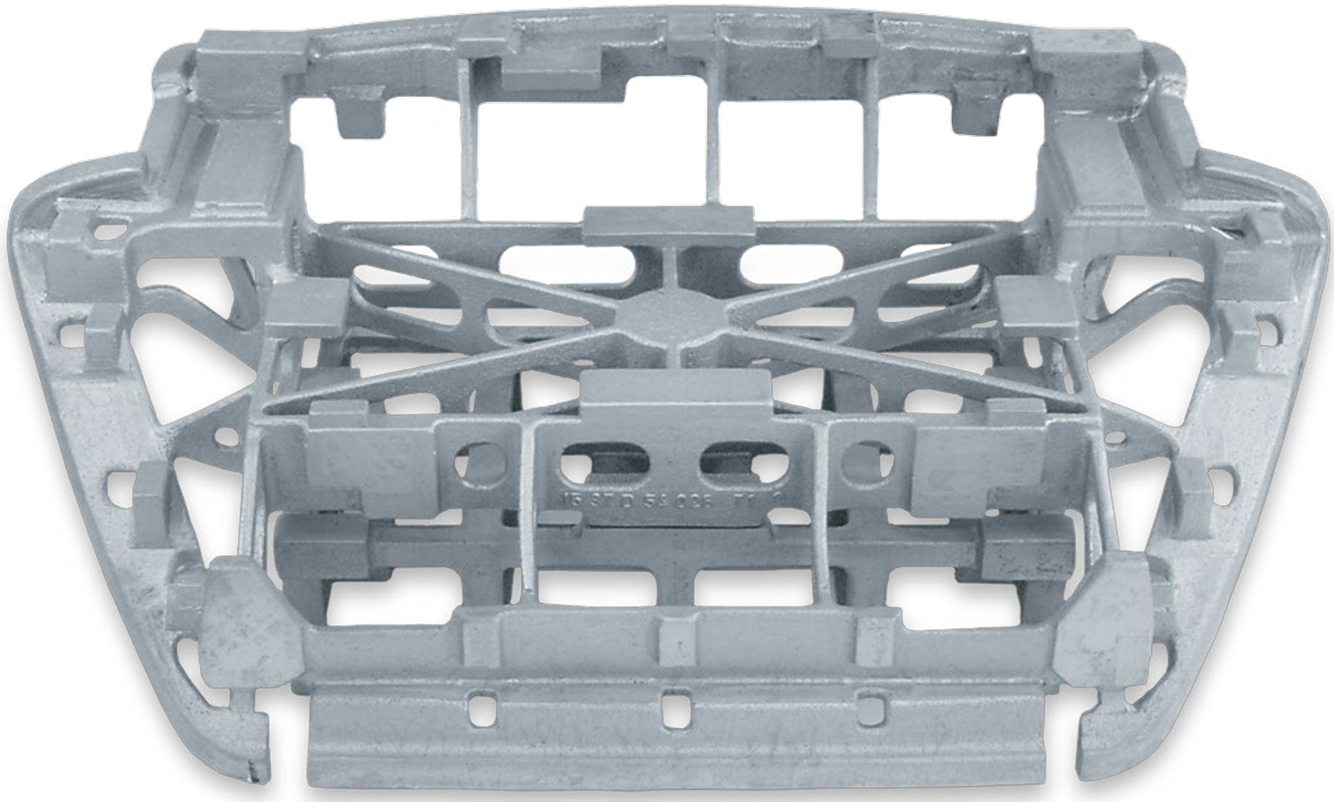
Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HB
Sand casting	T1	190–230 (170)	220–250 (180)	1–2 (1)	90–100 (90)
Gravity die casting	T1	220–250 (220)	280–320 (230)	1–4 (1)	100–120 (95)

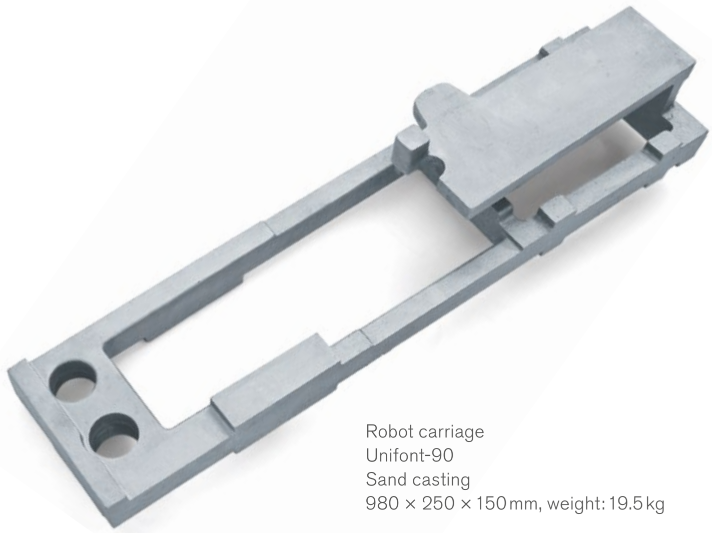
Note chapter "Technical Information"!



Base plate for film cutting equipment
Unifont-90
Sand casting, electrically conductive, hard anodised
500 × 500 × 170 mm, weight: 4.8 kg



Door sheet metal template
Unifont-90a
Sand casting as finished casting
1400 × 900 × 900 mm, weight: 70 kg



Robot carriage
Unifont-90
Sand casting
980 × 250 × 150 mm, weight: 19.5 kg

Weft holder
Unifont-90
Gravity die casting
320 × 70 × 55 mm, weight: 0.5 kg

Unifont®-94 [AlZn10Si8Mg]

Areas of use

Cars, automotive engineering, mechanical engineering, optics, furniture

Distinguishing characteristics

Self-ageing high pressure die casting alloy for high pressure die casting with high compression strength, but not with static tensile strength.

Alloy denomination

Chemical denomination: AlZn10Si8Mg

Chemical composition [% of mass]

Si	Fe	Cu	Mn	Mg	Zn	Ti
8.5 – 9.5	**0.4**	0.03	**0.4**	**0.3 – 0.5**	**9.0 – 10.0**	0.10

Mechanical properties

Casting method	Treatment state	YTS $R_{p0.2}$ [MPa]	UTS R_m [MPa]	Elongation A [%]	Brinell hardness HBW
HPDC	T1	230 – 280	300 – 350	1 – 4	105 – 120

Note chapter "Technical Information"!

Bearing cores for vibration damper
Unifont-94
High pressure die casting, rubber-metal compound
Ø 45 – 80 mm, height: 40 – 123 mm, weight: 78 – 450 g

Table bracket for seats in aircraft
Unifont-94
High pressure die casting, painted
310 × 65 × 18 mm, weight: 0.16 kg

Castadur® – the power of regeneration

A self-hardening material of high formability which gains strength without losing its ability to stretch. And even if it loses its properties, from overheating for example, they return. Castadur's softly radiant surface is easy to polish, making it popular for everyday objects such as furniture.

The material's homogeneity and silent power are reminiscent of desert sand dunes, which shaped by the wind are always taking on new shapes while remaining the same.

Castadur®-30 [AlZn3Mg3Cr]

Areas of use

Architecture, cars, lighting, domestic appliances, automotive engineering, art casts, pattern and mould construction, optics and furniture

Distinguishing characteristics

Self-ageing alloy for sand and gravity die casting. High strength and elongation, good castability.
Perfectly suited to decorative and technical anodising.

Alloy denomination

Chemical denomination: AlZn3Mg3Cr

Chemical composition [% of mass]

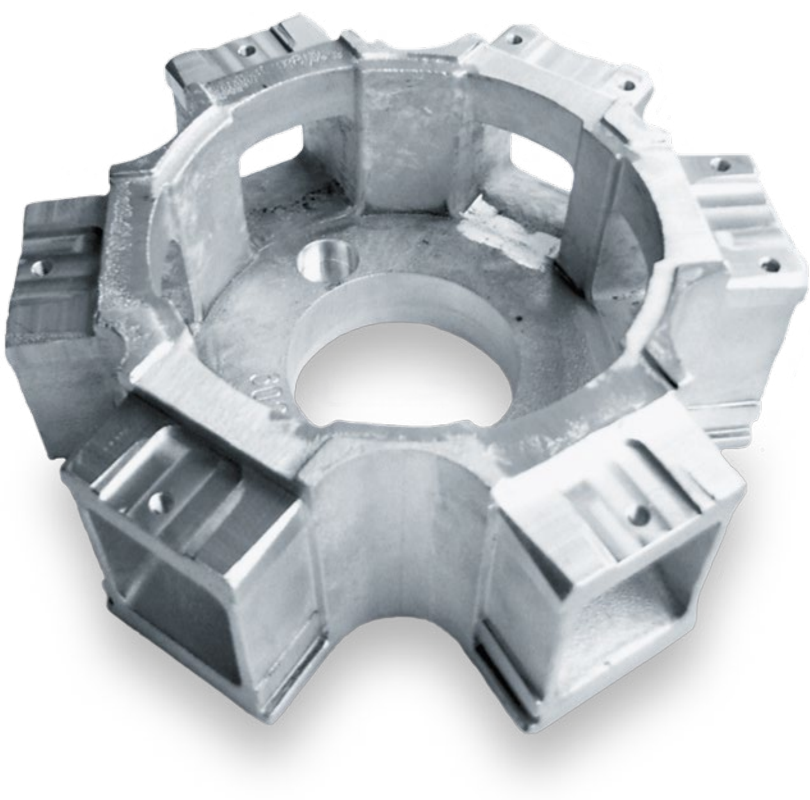
Si	Fe	Cu	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Be**
0.15	0.15	0.05	**0.10 – 0.2**	**2.5 – 3.0**	**0.25 – 0.35**	**2.2 – 2.8**	**0.03 – 0.15**	**0.004**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Gravity die casting	T1	140 – 160	260 – 290	10 – 20	75 – 85

Note chapter "Technical Information"!

Please refer to the ageing diagram on page 102.



Cast node for glass dome design
Castadur-30
Gravity die casting
Ø 260 × 110 mm, weight: 2.3 kg

Peraluman® – beautiful, soft sheen, impact resistant and tensile

Thanks to their absolute corrosion resistance and associated resistance to acids and salts, these alloys are used to manufacture machines for the production of foodstuffs. The parts are impact resistant and display good elongation after fractures. Their particularly soft sheen and their ability to anodise in colour enable them to be used in areas where looks count.

The metaphor from nature for this alloy is soft coral. It is gracefully structured and appears bright in dark water – it has the same matt sheen as parts produced from Peraluman.

Peraluman®-30 [AlMg3]

Areas of use

Architecture, fittings, builder's hardware, lighting, domestic appliances, air conditioning, art casting, foodstuffs industry, mechanical engineering, pattern and mould construction, optics and furniture, shipbuilding, chemical industry

Distinguishing characteristics

Excellent chemical resistance, particularly to salt water. Perfectly suited to decorative anodic oxidation, outstanding sheen after mechanical polishing. Very good elongation and impact toughness values. This alloy requires high-quality casting technique.

Alloy denomination

Chemical denomination: AlMg3 Numerical denomination: 51 100

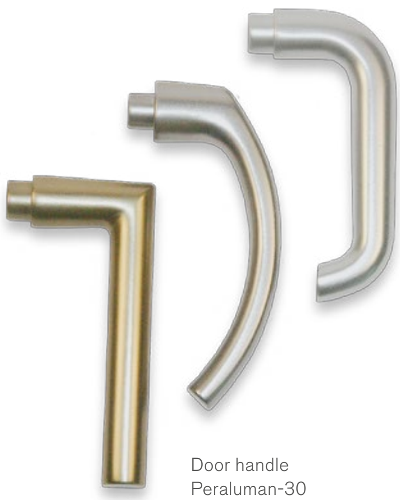
Chemical composition [% of mass]

Si	Fe	Cu	**Mn**	**Mg**	Zn	**Ti**	**other**
0.45	0.15	0.02	**0.01 – 0.4**	**2.7 – 3.5**	0.10	**0.01 – 0.15**	**Be**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	70 – 100 (60)	170 – 190 (140)	4 – 8 (4)	50 – 60 (45)
Sand casting	T6	140 – 160 (110)	200 – 240 (160)	6 – 8 (5)	65 – 75 (60)
Gravity die casting	F	70 – 100 (70)	170 – 210 (150)	9 – 16 (6)	50 – 60 (50)
Gravity die casting	T6	140 – 160 (110)	240 – 260 (180)	15 – 20 (12)	70 – 80 (70)

Note chapter "Technical Information"!



Door handle
Peraluman-30
Gravity die casting, decoratively anodised
135 × 65 × 15 mm, weight: 140 g

Support cylinder for food processing
Peraluman-30
Gravity die casting, decoratively anodised
Ø 220 × 330 mm, weight: 3.5 kg

Peraluman®-50 [AlMg5]

Areas of use

Architecture, fittings, builder's hardware, lighting, domestic appliances, air conditioning, art casting, foodstuffs industry, optics and furniture, shipbuilding, chemical industry

Distinguishing characteristics

Excellent chemical resistance, particularly to salt water. Perfectly suited to decorative anodic oxidation, outstanding sheen after mechanical polishing. Very good elongation and impact toughness values. This alloy requires high-quality casting technique.

Alloy denomination

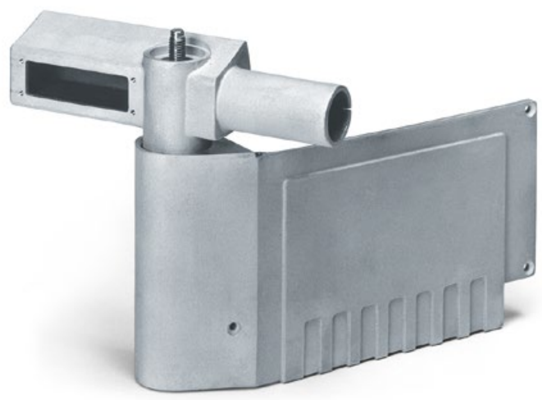
Chemical denomination: AlMg5 Numerical denomination: 51 300

Si	Fe	Cu	**Mn**	**Mg**	Zn	**Ti**	**other**
0.30	0.15	0.02	**0.01 – 0.4**	**4.8 – 5.5**	0.10	**0.01 – 0.15**	**Be**

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	100 – 120 (90)	190 – 250 (170)	10 – 15 (8)	55 – 70 (50)
Gravity die casting	F	100 – 140 (100)	200 – 260 (180)	10 – 25 (8)	60 – 75 (55)

Note chapter "Technical Information"!

Cooling half-shell for X-ray devices
Peraluman-50
Sand casting
640 × 440 × 170 mm, weight: 19 kg



Input housing for autopilot
on offshore yachts
Peraluman-50
Sand casting, anodically oxidised
290 × 210 × 40 mm, weight: 0.4 kg

Peraluman®-56 [AlMg5Si]

Areas of use

Architecture, fittings, lighting, domestic appliances, air conditioning, art casting, foodstuffs industry, mechanical engineering, optics/furniture, shipbuilding, chemical industry

Distinguishing characteristics

Heat-treatable alloy with average mechanical properties and high elongation.
Outstanding corrosion resistance, very good sheen after mechanical polishing.
Excellent machinability. This alloy requires high-quality casting technique.

Alloy denomination

Chemical denomination: AlMg5Si Numerical denomination: 51 400

Chemical composition [% of mass]

Si	Fe	Cu	**Mn**	**Mg**	Zn	**Ti**	**other**
0.9–1.3	0.15	0.02	**0.01–0.4**	**4.8–5.5**	0.10	**0.01–0.15**	**Be**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	F	110–130 (100)	160–200 (140)	3–4 (2)	60–80 (55)
Sand casting	T6	110–160 (110)	180–220 (160)	3–4 (2)	70–80 (65)
Gravity die casting	F	110–150 (100)	180–240 (150)	3–5 (3)	65–85 (60)
Gravity die casting	T6	110–160 (110)	210–260 (200)	3–18 (5)	75–85 (70)

Note chapter “Technical Information”!

Pump housing
Peraluman-56
Sand casting
Ø 390 × 115 mm, weight: 9.2 kg

Stator for centrifugal pump
Peraluman-56
Sand casting
Ø 245 × 50 mm, weight: 0.95 kg

Magsimal® – of filigree lightness, but extremely resilient

An alloy for delicate parts which need to retain their strength and precise form over a long period. Good weldability, high resilience, can be used in virtually any application. Maximum corrosion resistance, even to salt water.

Parts which simulate the structure of the wings of a dragonfly: wafer thin, elastic and yet offering maximum strength and resilience, they enable this dainty insect to fly distances that never cease to amaze.

Magsimal®-59 [AlMg5Si2Mn]

Areas of use

Architecture, cars, aircraft, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, optics and furniture, shipbuilding, chemical industry

Distinguishing characteristics

High pressure die casting alloy with excellent mechanical and dynamic properties with thin walls.
Very good weldability, suited to stamp riveting. Very good corrosion resistance, excellent mechanical polishability and good machinability, ideal adhesive bonding in car body design.

Alloy denomination

Chemical denomination: AlMg5Si2Mn   Numerical denomination: 51 500

Chemical composition [% of mass]

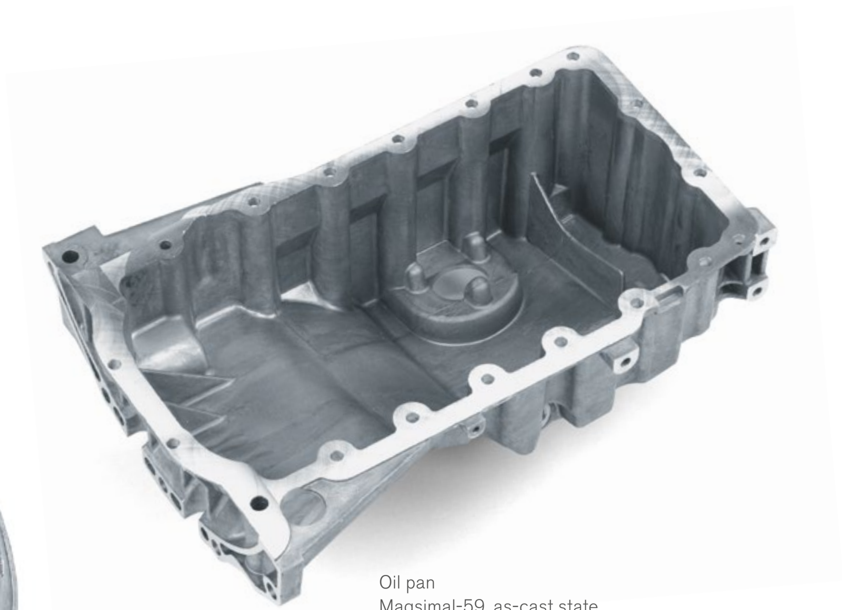
Si	Fe	Cu	**Mn**	**Mg**	Zn	Ti	**Be**
1.8–2.6	0.20	0.03	**0.5–0.8**	**5.0–6.0**	0.07	0.20	**0.004**

Mechanical properties

Casting method	**Treatment state**	**Wall thickness**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]
HPDC	F	< 2	> 220	> 300	10–15
HPDC	F	2–4	160–220	310–340	12–18
HPDC	F	4–6	140–170	250–320	9–14
HPDC	F	6–12	120–145	220–260	8–12

Note chapter "Technical Information"!

Strut mounting for sports car
Magsimal-59, as-cast state
High pressure die casting, wall thickness 3 mm
590 × 450 × 340 mm, weight: 3.0 kg



Oil pan
Magsimal-59, as-cast state
High pressure die casting, wall thickness 2.2 mm
440 × 310 × 180 mm, weight: 3.0 kg

Magsimal®-59 [AlMg5Si2Mn]

Door design for four-door sports car
Magsimal-59, as-cast state
High pressure die casting, wall thickness 2 mm
1140 × 690 × 155 mm, weight: 4.1 kg

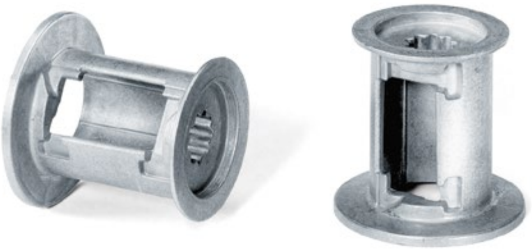
Node for window frame
Magsimal-59, as-cast state
High pressure die casting, weldable
Up to 510 mm long, weight: 0.20 – 0.35 kg

Internal door part for vehicle
Magsimal-59, as-cast state
High pressure die casting, suited to welding
610 x 250 x 100 mm, Gewicht: 1.0 kg

Internal door parts for off-road vehicle
Magsimal-59, as-cast state
High pressure die casting, suited to welding,
wall thickness 1.8 – 2.0 mm up to 1400 mm,
weight: 2.2 kg

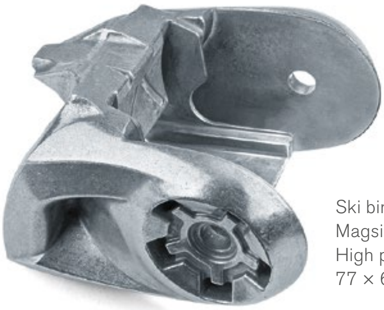
Rear cross member
Magsimal-59, as-cast state
High pressure die casting, wall thickness 4 mm
1080 × 370 × 150 mm, weight: 6.5 kg

Magsimal®-59 [AlMg5Si2Mn]



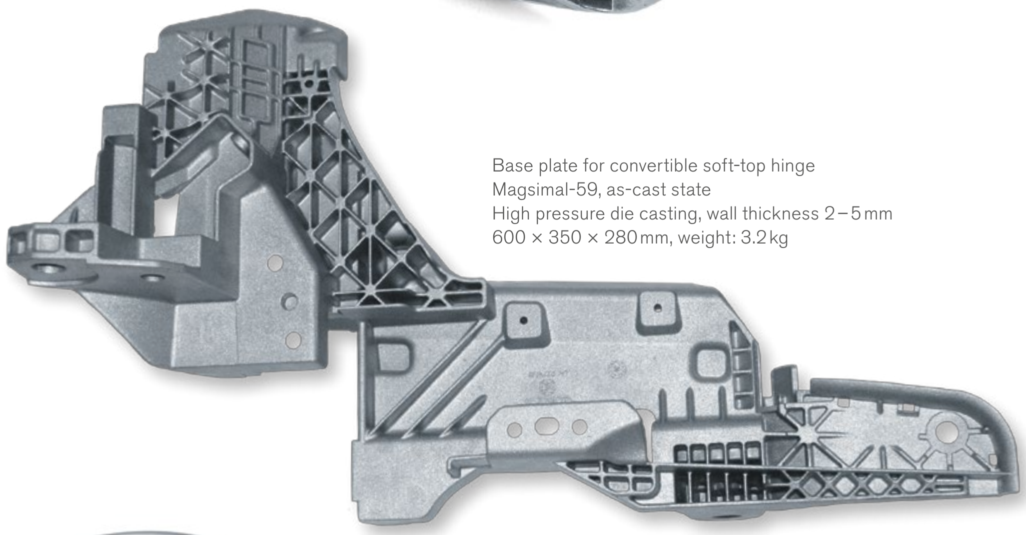
Belt retractor spindle
Magsimal-59, as-cast state
High pressure die casting,
wall thickness 1.0 – 5.0 mm
Ø 56 × 55 mm, weight: 66 g

Endcover
Magsimal-59, as-cast state
High pressure die casting,
polished surface
34 × 15 × 13 mm, weight: 6.0 g



Ski binding
Magsimal-59, as-cast state
High pressure die casting, polished
77 × 69 × 53 mm, weight: 150 g

Ski boot clasp
Magsimal-59, as-cast state
High pressure die casting
76 × 23 × 18 mm, weight: 20 g



Base plate for convertible soft-top hinge
Magsimal-59, as-cast state
High pressure die casting, wall thickness 2 – 5 mm
600 × 350 × 280 mm, weight: 3.2 kg

Rim, MZ motorbike
Magsimal-59, as-cast state
High pressure die casting,
cast in two parts, electron beam welded
Ø 460 × 180 mm, weight: 6.4 kg

Stabiliser rod bracket
Magsimal-59, as-cast state
High pressure die casting, wall thickness 3 mm
130 × 85 × 45 mm, weight: 0.2 kg

With thanks to our customers:
ae-group, Gerstungen
Druckguss Hof, Hof
Formal, Italy
Georg Fischer Automotive, Herzogenburg, Austria
JVM Light Metal Castings, Worcester, GB
KSM Castings GmbH, Hildesheim
Microtech, Italy
Sander, Ennepetal
Cervati, Italy

Aluman® – resistant even at very high temperatures

The alloy with the highest melting point of all aluminium alloys. Its good thermal conductivity makes the alloy perfectly suited to the manufacture of cast parts such as heat exchangers.

Aluman parts display a high solidification temperature which means that they remain solid when surrounding aluminium alloys are liquid. A workpiece cast from Aluman can therefore be soldered with an eutectic AlSi alloy.

Its counterpart in nature is fresh water icebergs which float in the salt water of polar seas as they don't share the same melting point.

Aluman®-16 [AlMn1.6]

Areas of use

Cars, air conditioning, automotive engineering, mechanical engineering

Distinguishing characteristics

Casting alloy which can be hard soldered. Designed for High pressure die casting, but also usable as sand and gravity die casting alloy.

Alloy denomination

Chemical denomination: AlMn1.6

Chemical composition [% of mass]

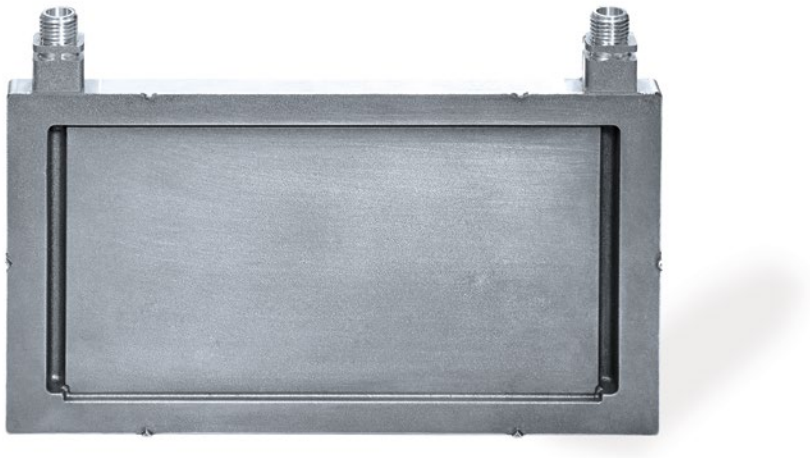
Si	**Fe**	Cu	**Mn**	Mg	Zn	Ti
0.15	**0.20–0.90**	0.03	**1.4–1.6**	0.05	0.10	0.15

Mechanical properties

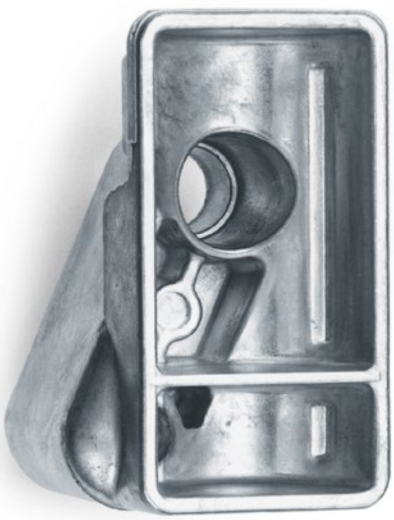
Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
HPDC	F	90–120	160–180	8–15	40–60
Sand casting	F	80–100	130–160	4–8	40–50

Note chapter "Technical Information"!

Radiator pipe connection
Aluman-16
Sand casting
Max. 70 × 60 × 45 mm, weight: 0.3 kg



Base plate for electronic device, assembled due hard soldering
Aluman-16
Sand casting
230 × 160 × 15 mm, weight: 0.9 kg



Collector box for oil radiator
Aluman-16
High pressure die casting
77 × 40 × 55 mm, weight: max. 0.13 kg

Alufont® – the ultimate strength for lightweight construction

This alloy's outstanding mechanical properties make it a serious alternative to steel. It is easy to weld and excellent to machine, and it can be used wherever parts are subject to high force and load levels. Its low weight also makes it ideal for elements that have to be moved: in motorsport, in machines or for example as a hinged element for telescopic lifting platforms.

As with crystals, these alloys have the structure of their joints to thank for their strength.

Alufont®-52 [AlCu4Ti]

Areas of use

All kinds of highly loaded parts where corrosion properties are no obstacle.

Cars, automotive engineering, manufacture of engines, mechanical engineering, textile industry, defence engineering

Distinguishing characteristics

High-strength alloy for partial and artificial ageing. Outstanding machinability, very good polishing properties, good weldability, limited corrosion resistance. Mechanical values may be greatly varied by modifying artificial ageing.

Alloy denomination

Chemical denomination: AlCu4Ti   Numerical denomination: 21 100

Chemical composition [% of mass]

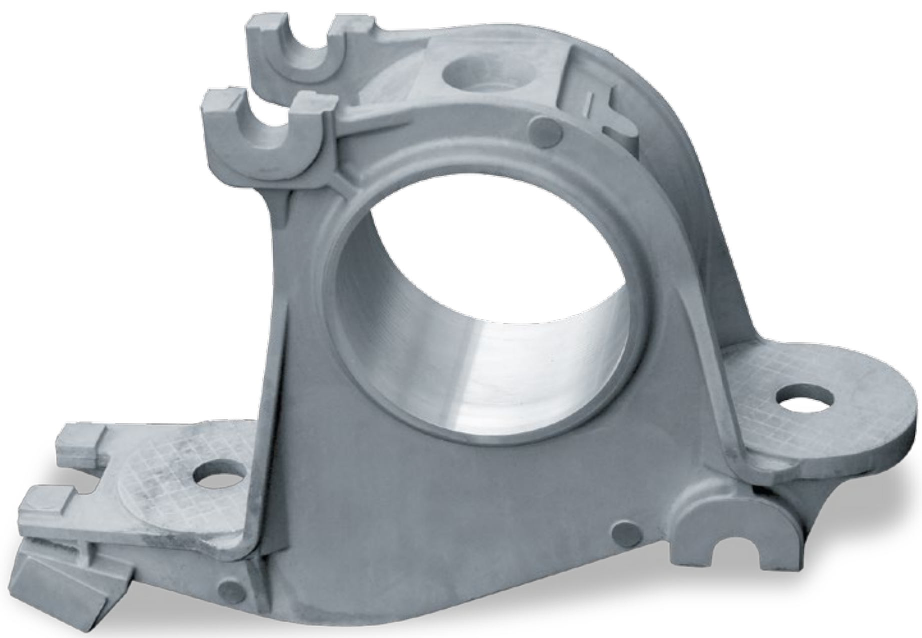
Si	Fe	**Cu**	**Mn**	Mg	Zn	**Ti**
0.15	0.15	**4.2–5.2**	**0.01–0.5**	0.03	0.07	**0.15–0.25**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	T64	210–240 (180)	300–360 (260)	8–15 (4)	90–100 (90)
Sand casting	T6	300–420 (280)	400–475 (350)	3–4 (2)	125–145 (120)
Gravity die casting	T64	210–250 (190)	360–400 (300)	12–20 (10)	90–120 (90)
Gravity die casting	T6	310–400 (300)	420–475 (400)	7–16 (4)	130–145 (130)

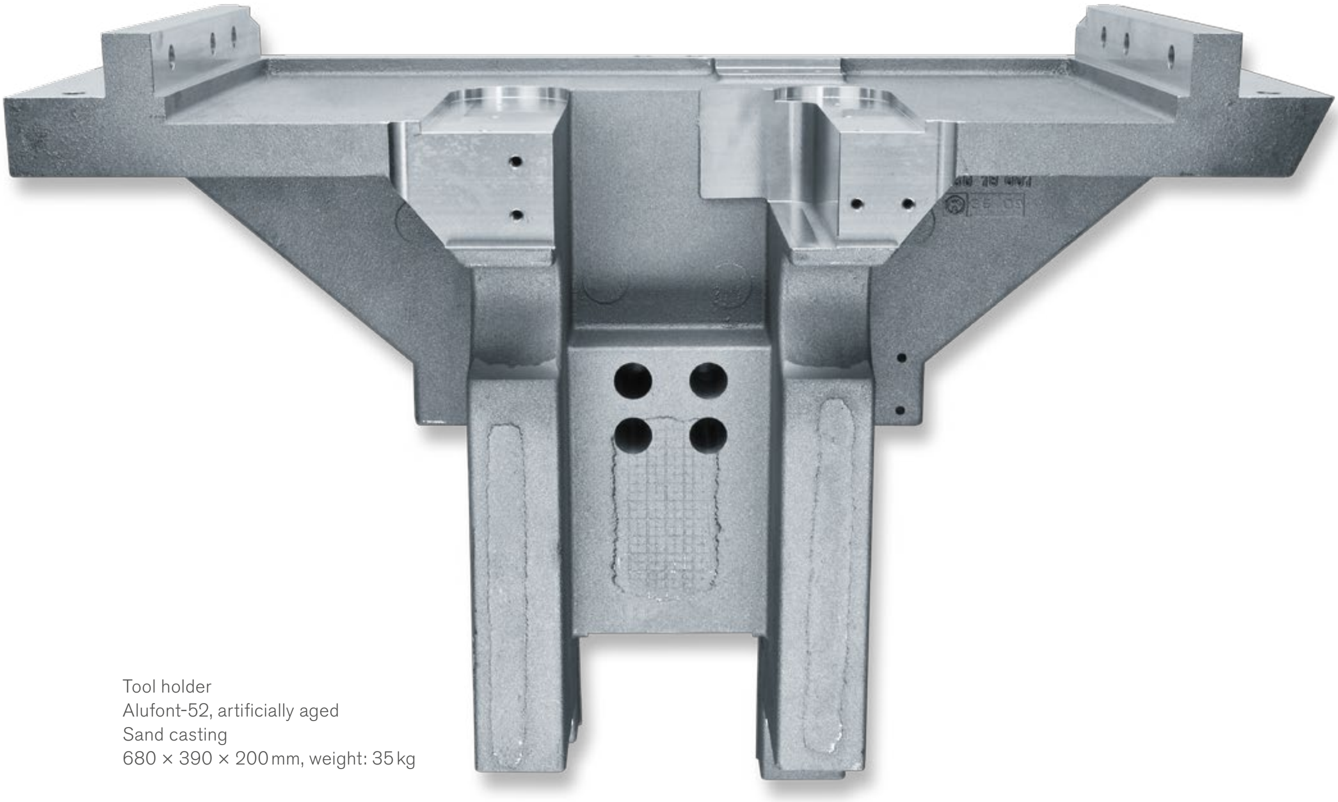
Note chapter “Technical Information”!

Clamp element
Alufont-52, artificially aged
Gravity die casting
70 × 70 × 30 mm, weight: 0.1 kg



Wheelset bearing housing for rail vehicle
Alufont-52, artificially aged
Sand casting
920 × 840 × 330 mm, weight: 62 kg

Alufont®-52 [AlCu4Ti]



Tool holder
Alufont-52, artificially aged
Sand casting
680 × 390 × 200 mm, weight: 35 kg

Mechanism for robot arm
Alufont-52, artificially aged
Sand casting
190 × 60 × 20 mm, weight: 0.14 kg

ICE II gearbox housing
Alufont-52, artificially aged
Sand casting
1800 × 850 × 250 mm, weight: 175 kg

Alufont®-48 [AlCu4TiMgAg]

Areas of use

Cars, automotive engineering, manufacture of engines, mechanical engineering, defence engineering

Distinguishing characteristics

Aluminium casting alloy with maximum ultimate tensile strength, yield tensile strength and hardness values, combined with outstanding elongation. Values may be varied greatly by modifying artificial ageing.
Outstanding machinability, very good polishing properties, good weldability.

Alloy denomination

Chemical denomination: AlCu4TiMgAg

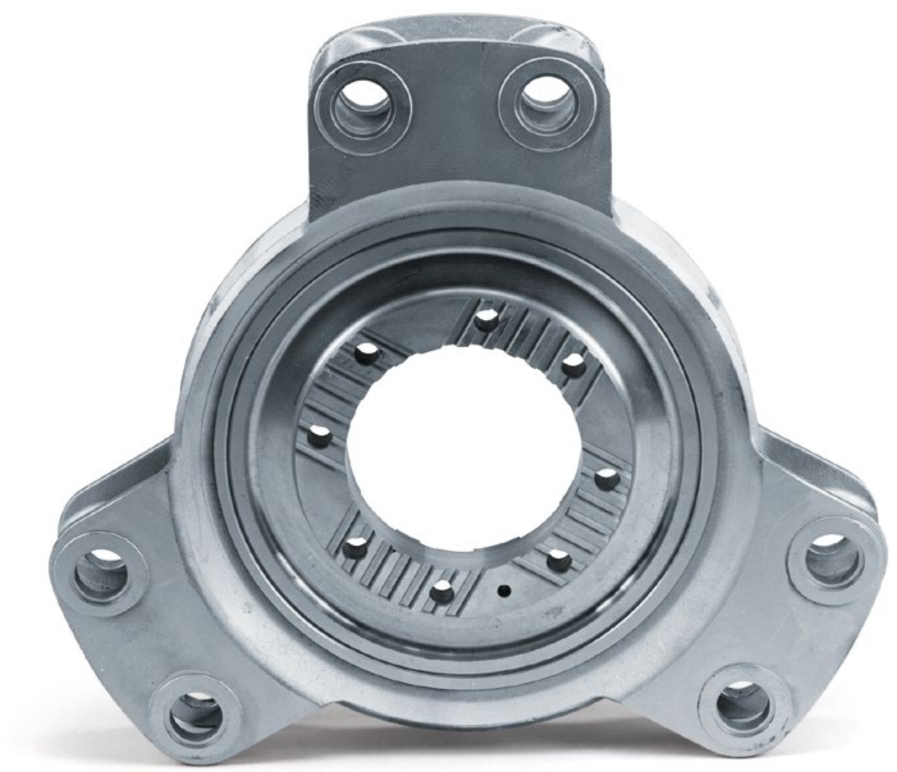
Chemical composition [% of mass]

Si	Fe	**Cu**	**Mn**	**Mg**	Zn	**Ti**	**other**
0.05	0.10	**4.0 – 5.0**	**0.01 – 0.5**	**0.15 – 0.35**	0.05	**0.15 – 0.35**	**0.4 – 1.0 Ag**

Mechanical properties

Casting method	**Treatment state**	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
Sand casting	T64	200 – 270 (180)	370 – 430 (320)	14 – 18 (7)	105 – 120 (100)
Sand casting	T6	410 – 450 (320)	460 – 510 (380)	3 – 7 (2)	130 – 150 (125)
Gravity die casting	T6	410 – 460 (340)	460 – 510 (440)	5 – 8 (3)	130 – 150 (130)

Note chapter "Technical Information"!



Star-shaped flange for rail vehicles
Alufont-48, artificially aged
Sand casting
Ø 700 × 100 mm, weight: 38 kg

Thermodur® – a glimpse into the future

A new material that withstands high temperatures like never before, allowing it play a key role in increased efficiency in combustion engines: increased output, lower fuel consumption, greater durability and lower emissions.

This alloy simulates the spider's silk: outstanding mechanical properties, maximum strength, stable, resilient and incredibly light.

Thermodur®-72 [AlMg7Si3Mn]

Areas of use

Manufacture of engines, crankcases, engine components

Distinguishing characteristics

High pressure die casting alloy for the manufacture of engines for parts that require very good mechanical properties at elevated temperatures and high corrosion resistance.

Alloy denomination

Chemical denomination: AlMg7Si3Mn

Chemical composition [% of mass]

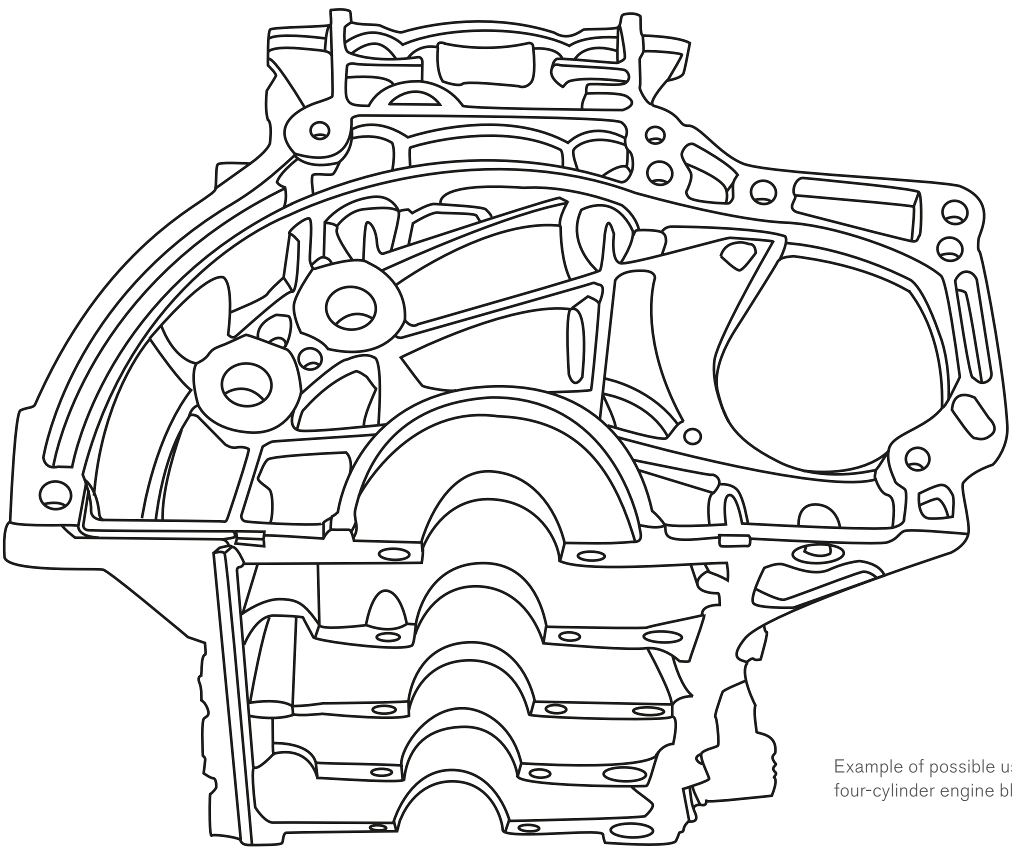
Si	Fe	Cu	**Mn**	**Mg**	Zn	Ti	**other**
2.8 – 3.2	0.15	0.03	**0.5 – 0.8**	**7.0 – 8.8**	0.07	0.15	**0.004 Be**

Mechanical properties

Ageing temperature	**Ageing** time	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
20 °C		190 – 220	350 – 380	7 – 10	80 – 100
150 °C	500 h	220 – 245	260 – 290	> 15	
225 °C	500 h	150 – 175	180 – 205	>20	

Note chapter “Technical Information”!

Tested at temperature indicated



Example of possible use:
four-cylinder engine block, looking at bearing blocks

Thermodur®-73 [AlSi11Cu2Ni2Mg2Mn]

Areas of use

Cars, manufacture of engines

Distinguishing characteristics

Very good hardness and high strength in as-cast state, very good mechanical properties at elevated temperatures. Good castability for sand, chill and high pressure die casting. Very good wear resistance. Excellent weldability and machinability.

Alloy denomination

Chemical denomination: AlSi11Cu2Ni2Mg2Mn

Chemical composition [% of mass]

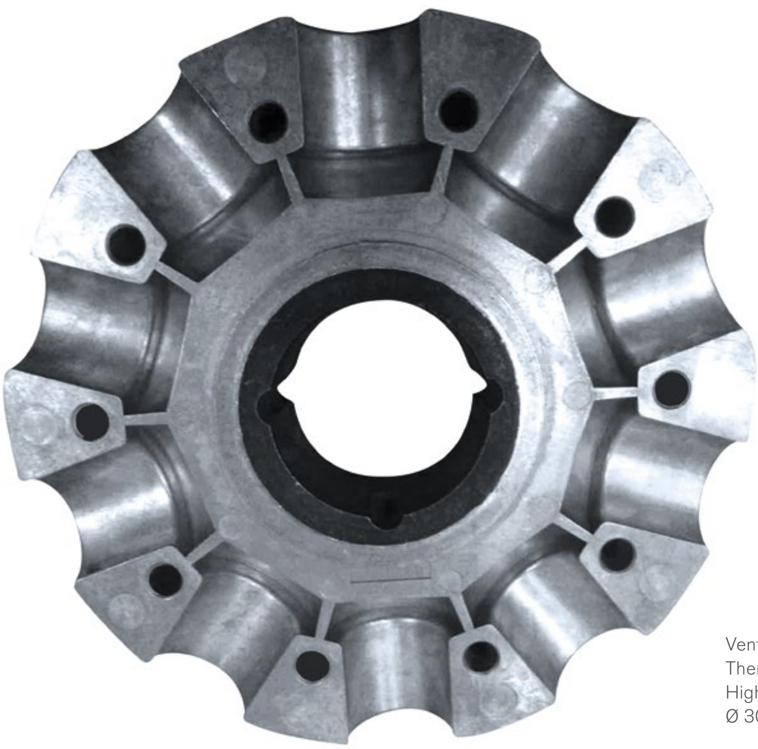
Si	Fe	**Cu**	Mn	**Mg**	Zn	Ti	**other**
10.0–11.8	0.15	**1.8–2.3**	0.4	**1.8–2.3**	0.10	0.10	**1.8–2.3 Ni; Sr**

Mechanical properties

Ageing temperature	**Ageing** time	**YTS** $R_{p0.2}$ [MPa]	**UTS** R_m [MPa]	**Elongation** A [%]	**Brinell hardness** HBW
20 °C		270–300	300–320	<1	130–150
150 °C	500 h	280–310	330–355	<1	
225 °C	500 h	130–155	250–280	1–2	

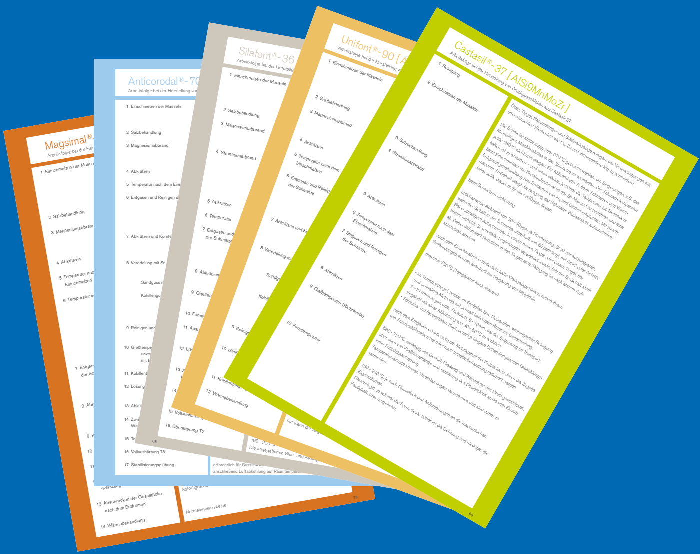
Note chapter "Technical Information"!

Tested at temperature indicated



Ventilator hub
Thermodur-73, as-cast state
High pressure die casting with steel insert
Ø 305 x 43 mm; weight: 5.9 kg

Processing data sheets



RHEINFELDEN ALLOYS provides the following processing data sheets in order to detail how to work with the various alloys. If you use our casting alloys, please feel free to copy the following pages and use them in your company. They contain practical instructions and demonstrate the processes step by step.

Not all alloys are listed here, but the processing data sheet from within the corresponding alloy family can be used, Peraluman-56 can for example also be used for Peraluman-30.

The recommendations correspond to typical foundry circumstances. For example a crucible or tower melting furnace is considered for melting down; the circumstances in a huge melting furnace may differ from the recommendations. Fine returns should also not be used for primary aluminium high pressure die casting alloys.

The volumes listed here are all percentages by weight, calculated for the charge weight.
The temperatures quoted all relate to the temperature of melt, even for casting. The heat treatment recommendations apply for the standard process and may be varied, to minimise distortion for example.

If you have any questions relating to your specific alloy application and processing, please contact our foundry experts.

Anticorodal®-70 [AlSi7Mg0.3]

Sequence of work when producing castings from Anticorodal-70

RHEINFELDEN
Solutions thru Innovation

1 Melting down the ingots	As quickly as possible in powerful furnaces to keep Mg melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes to avoid segregation and entrapped oxides
2 Salt treatment	Not needed when melting
3 Magnesium burnout	Normally a melting loss of 0.05 mass % per fusion; compensation is required if the Mg content of an Anticorodal-70 / -70 dv melt is less than 0.25 %; AlMg master or casting alloy or pure magnesium can be added
4 Skimming	Needed after melting down
5 Temperature after melting down	Maximum of 780 °C (check temperature!)
6 Degassing and refining the melts	• Effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min • Gas flushing lance with fine porous head needs longer treatment times (cooling!) • Gas flushing tablet emitting nitrogen at a rate of 150 – 350 l nitrogen/kg (bell plunger procedure)
7 Skimming and grain refining	Grain refining for Anticorodal-70 with granular microstructure: after careful skimming grain refining with TiB master alloy or tabletted fluxes on nucleation states of ≥ 9, i.e. grain size of less than 2.5 mm^2
8 Modification with Sr	When using permanently modified ingots only if the strontium content has fallen below 0.015 %; use AlSr master alloy, preferably one containing just 5 % strontium, for modification
Sand casting with Na	• With 0.03 – 0.04 vacuum-packed sodium or 0.2 – 0.3 exothermic modification tablets or 0.05 – 0.2 salt granulate (details provided as % of charge weight)
Gravity die casting with Na	• Thick-walled gravity die casting and gravity die casting with sand cores: with 0.015 – 0.025 vacuum-packed sodium or 0.1 – 0.2 exothermic modification tablets or 0.05 – 0.2 salt granulate (details provided as % of charge weight) Thin-walled gravity die casting is only modified with sodium in seldom cases
9 Refining and skimming	Gas treatment with rotor is the preferred option, e.g. using integrated melt processing while adding sodium-salt granulate and gas refining at the same time
10 Pouring temperature (approx. values)	Depends on design, size and wall thickness of casting
unmodified	720 – 760 °C
permanently modified	740 – 780 °C
11 Gravity die temperature	300 – 400 °C depending on casting
12 Solution heat treatment	520 – 535 °C for 6 – 10 hours; for special components: 535 – 545 °C / 24 hours (The annealing and ageing times stated apply without a heating-up time.)
13 Cooling solution heat treatment temperature	In water (10 – 40 °C) without a delay wherever possible
14 Delay time before artificial ageing	Only if trimming is needed, maximum of 12 hours
15 Partial ageing T64	150 – 160 °C / 2 – 3 hours for high elongation
16 Full artificial ageing T6	155 – 165 °C / 6 – 8 hours for high strength
17 Stabilisation annealing	Required for castings with thermal loading: 210 – 230 °C / 6 – 8 hours, followed by cooling to room temperature in the air

Silafont®-36 [AlSi10MnMg]

Sequence of work when producing high pressure die castings from Silafont-36

RHEINFELDEN
Solutions thru Innovation

1 Melting down the ingots	As quickly as possible in efficient furnaces to keep magnesium melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes to avoid segregation and entrapped oxides; proportion of returns may extend to 50 %
2 Salt treatment	Not needed when melting
3 Magnesium burnout	Normally a melting loss of 0.03 % per fusion; compensation is only required if the magnesium content of the melts is outside tolerance, add magnesium master alloy or pure magnesium
4 Strontium burnout	Usually melting loss of 30 – 50 ppm per fusion; Sr should only be added if the Sr content of the melts is less than 80 ppm, add AlSr5 or AlSr10. When fusing for the first time in a new crucible or in a crucible which has not yet been used for Sr-modified alloys, the Sr content falls sharply. Strontium will diffuse into the crucible, saturation is reached after the first fusion
5 Skimming	Needed after melting down
6 Temperature	After melting down maximum of 780 °C for holding temperature
7 Degassing and refining the melts	• In the transport crucible, better in a holding crucible or receptacle or in a dosing furnace with bottom blocks; effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Gas flushing tablets emitting nitrogen in the bell plunger procedure are not very suitable
8 Skimming	Required after melting down; the metal content of the skimmings may be reduced by adding melt fluxes within or after the impeller treatment
9 Pouring temperature (approx. values)	680 – 710 °C – depends on design, flow path and wall thickness of high pressure die casting, but also on the length of the flow channel in the dosing furnace and possibly on chamber heating
10 Mould temperature	Die surface temperature 250 – 350 °C
11 Ageing by T5	Water quenching immediately after the casting is taken out as high a temperature as possible > 300 °C, 10 h delaytime, aging 1 h with 200 °C
12 Solution heat treatment	480 – 490 °C / 2 – 3 hours; for special components: 400 °C / 0.5 hours
13 Cooling after solution heat treatment	In water (10 – 60 °C) without a delay wherever possible to < 200 °C; if cooling in the air, only a significantly lower yield tensile strength can be obtained
14 Delay time before artificial ageing	Only if trimming is needed, usually maximum of 12 hours
15 Full artificial ageing T6	155 – 170 °C / 2 – 3 hours
16 Overageing T7	190 – 230 °C / 2 – 3 hours
	The annealing and ageing times stated apply without a heating-up time

Castasil®-37 [AlSi9MnMoZr]

Sequence of work when producing high pressure die castings from Castasil-37

1 Refining	Clean furnace, crucible, treatment and casting tools to avoid impurities from unwanted elements such as Cu, Zn and especially Mg!
2 Melting down the ingots	The melt should be quickly heated to above 670 °C to avoid segregations, e.g. of the solid solution containing Mn in the melt. The temperature of melt should not exceed 780 °C. An Sr melting loss should be expected when melting and keeping warm – the higher the temperature, the greater the loss. Sr melting loss should be expected in particular when melting down returns and degassing treatment is recommended to remove the H_2 and oxides. As the Sr content increases, so does the tendency for the melt to absorb hydrogen; this should not therefore exceed 350 ppm.
3 Salt treatment	Not needed when melting
4 Strontium burnout	Usually melting loss of 30 – 50 ppm per fusion; Sr should only be added if the Sr content of the melts is less than 60 ppm, add AlSr5 or AlSr10. When fusing for the first time in a new crucible or in a crucible which has not yet been used for Sr-modified alloys, the Sr content falls sharply. Strontium will diffuse into the crucible; saturation is reached after the first fusion
5 Skimming	Needed after melting down; as well as their potential for danger, cold tools may result in molybdenum segregation
6 Temperature after melting down and in the dosing furnace	After melting down maximum of 780 °C for holding temperature. Don't keep the melt at temperature below 680 °C and steer melt if possible. Recomended temperature in the dosing furnace: 710 – 720 °C
7 Degassing and refining the melts	• In the transport crucible, better in casting or dosing furnace; effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min; during degassing in the transport crucible, cooling of 30 – 50 °C should be expected • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Tablets for melt cleaning are inefficient
8 Skimming	Required after degassing; the metal content of the skimmings may be reduced by adding melt fluxes during or after impeller treatment
9 Pouring temperature (approx. values)	680 – 720 °C depends on design, flow path and wall thickness of high pressure die casting, but also on the length and insulation of the flow channel from the dosing furnace and on use of shot sleeve heating. Temperature losses may cause initial solidification and should therefore be avoided
10 Mould temperature	250 – 350 °C, depending on cast and requirements of mechanical properties As a rule: the warmer the mould, the higher the elongation and the lower the strength.
11 Die chamber temperature	Preheat the chamber electrical or with oil > 200 °C

Castadur®- 30 [AlZn3Mg3Cr]

Sequence of work when producing castings from Castadur-30

1 Melting down the ingots	The crucibles used must not release any silicon to the alloy (maximum silicon content 0.14 %). Hot cracking sensitivity increases at higher silicon contents. The crucible usually has to be rinsed with Al99.5 or AlMg alloy for this purpose. Melting down should take place as quickly as possible in an efficient furnace so that zinc and magnesium melting loss, gas absorption and oxidation of melts remain low. Preheated ingots and returns should be replenished in small quantities. The high chrome content may result in segregation at low holding temperatures below 670 °C combined with long standing times. Salt treatment is not needed when melting
2 Magnesium burnout	Melting loss of 0.1 % per fusion usually occurs and can be ignored
3 Skimming	Needed after melting down
4 Temperature after melting down	Maximum of 820 °C (check temperature!)
5 Degassing and refining the melts	When using an impeller or gas flushing lance, the high temperature loss during treatment should be taken into account. Recommended starting temperature: > 780 °C • Effective refining and fastest method using quick-running gas rotor, 7 – 10 l/min argon or nitrogen, 3 – 6 min • Gas flushing lance with fine porous head, needs longer treatment times A Quality of DI < 1 can be easily achieved and maintained with effective refining
6 Skimming and grain refining	Is not needed with Castadur-30 after melting down ingot material After a longer holding phase and with a high use of returns, a small addition of grain refiners is recommended, e.g. grain refiner tablets or AlTi5B1 wire (0.5 kg/t) can be added just before pouring
7 Modification	Not needed as contains no silicon
8 Pouring temperature (approx. values)	Varies depending on casting method, design, size and wall thickness of castings:
Sand casting	720 – 760 °C (recommendation 730 °C)
Gravity die casting	730 – 760 °C (recommendation 750 °C)
9 Model design	Shrinkage of 1.0 – 1.3 % The high centre line formation of blowholes must be remedied by specific solidification. The ingate and feeder head design should be selected accordingly
10 Gravity die temperature	250 – 400 °C depending on casting; at high gravity die temperatures, fewer cracks form; we therefore recommend: 350 °C
11 Removal of casting	When removed from the moulding box or gravity die, castings are still very soft. Castings with dimensional accuracy measurements must be removed with care

Unifont®-90 [AlZn10Si8Mg]

Sequence of work when producing castings from Unifont-90

RHEINFELDEN
Solutions thru Innovation

1 Melting down the ingots	As quickly as possible in efficient furnaces to keep Mg melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes; even a low level of Cu impurity of 0,05 % in the melt composition should also be avoided!
2 Salt treatment	Not needed when melting
3 Magnesium burnout	Normally melting loss of 0.05 % per fusion; compensation is needed if the total magnesium content falls below 0.25 % and is achieved by adding Mg master alloy or pure magnesium
4 Skimming	Needed after melting down
5 Temperature after melting down	Maximum of 780 °C (check temperature!)
6 Degassing and refining the melts	• Effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Gas flushing tablet emitting nitrogen at a rate of 150 – 350 l nitrogen/kg (bell plunger procedure)
7 Skimming and grain refining	Best for Unifont-90 with granular microstructure, with a high proportion of returns: after skimming, grain refining with TiB master alloy or tabletted fluxes on nucleation states in excess of = 9, i.e. grain size of less than 2.5 mm^2
8 Modification with Sr	When using permanently modified ingots only if the strontium content has fallen below 0.015 %; modify with AlSr master alloy, preferably one containing only 5 % strontium
Sand casting with Na	• With 0.03 – 0.04 vacuum-packed sodium or 0.2 – 0.3 exothermic modification tablets or 0.05 – 0.2 salt granulate (details provided as % of charge weight)
Gravity die casting with Na	• Thick-walled gravity die casting and gravity die casting with sand cores: with 0.015 – 0.025 vacuum-packed sodium or 0.1 – 0.2 exothermic modification tablets or 0.05 – 0.2 salt granulate (details provided as % of charge weight) Thin-walled gravity die casting is only modified with sodium in rare cases
9 Refining and skimming	Gas treatment with rotor is the preferred option, e.g. using integrated melt processing while adding sodium-salt granulate and gas refining at the same time
10 Pouring temperature (approx. values)	Varies depending on casting method, design, size and wall thickness of castings:
Sand casting	710 – 740 °C
Gravity die casting	720 – 750 °C
11 Gravity die temperature	300 – 400 °C depending on casting
12 Heat treatment	Only if the cast is being used straight away: age at 100 – 120 °C / 10 – 16 hours

Peraluman®-56 [AlMg5Si]

Sequence of work when producing castings from Peraluman-56

RHEINFELDEN
Solutions thru Innovation

1 Melting down the ingots	As quickly as possible in efficient furnaces to keep Mg melting loss, oxidation and gas absorption of melts low; even a low level of Cu impurity in the melt composition should also be avoided
2 Salt treatment when melting down	Not needed when melting ingots; useful for avoiding oxidation when using small returns
3 Magnesium burnout	Not important
4 Skimming	Needed after melting down!
5 Temperature after melting down	Normally maximum of 780 °C (check temperature!)
6 Degassing and refining the melts	Needed! • Effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Gas flushing tablets do not achieve the necessary effect! Also vacuum treatment with nitrogen recirculation is possible
7 Skimming after refining treatment	Careful skimming absolutely essential, if using salt, ensure a Na-free salt mixture
8 Grain refinement	Needed with grain refiner based on TiB_2: 0.15 – 0.30 % tabletted fluxes, 0.1 – 0.2 % master alloy wire (volume in relation to weight of melt)
9 Standing and skimming	Leave to stand for several minutes, then carefully skim
10 Pouring temperature (approx. values)	
Sand casting	700 – 740 °C
Gravity die casting	710 – 770 °C
11 Gravity die temperature	350 – 420 °C, depending on casting
12 Solution heat treatment	Slowly heat up to 540 – 550 °C, annealing time of 4 – 8 hours The annealing times stated apply without a heating-up time
13 Cooling solution heat treatment temperature	In water of around 20 °C to 60 °C without a delay wherever possible
14 Delay time before artificial ageing	Maximum of 24 hours
15 Artificial ageing for artificial hardening	160 – 170 °C / 8 – 10 hours

Magsimal®-59 [AlMg5Si2Mn]

Sequence of work when producing high pressure die castings from Magsimal-59

RHEINFELDEN
Solutions thru Innovation

1 Melting down the ingots	As quickly as possible in efficient furnaces to keep Mg melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes to avoid segregation; use refractory materials with a high clay content; avoid phosphorous and sodium absorption
2 Salt treatment	Prohibited! There is a risk of Na pick up
3 Magnesium burnout	Normally melting loss of 0.1 % per fusion, correction not normally needed; if the Mg content is significantly below 5.0 %, add pure magnesium of maximum 0.5 %
4 Skimming	Needed after melting down
5 Temperature after melting down	Maximum of 780 °C (check temperature!)
6 Temperature in holding furnace	Do not allow to fall below 650 °C and keep melt moving by means of: • convection • rotor (impeller) Do not use deep furnace with cover heating if melt is inactive! Use refractory materials with a high clay content!
7 Degassing and refining the melts	• Effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Gas flushing tablets do not achieve the necessary effect!
8 Skimming	Careful skimming needed Only totally Na-free salts may be used to reduce the metal content of skimmings!
9 Grain refining	Prohibited!
10 Modification	Prohibited! The elongation achievable would be reduced considerably
11 Pouring temperature (approx. values)	690 – 730 °C, varies depending on design, size and wall thickness of high pressure die castings
12 Die temperature	200 – 300 °C, depending on casting and requirements of mechanical properties As a rule: the warmer the mould, the higher the elongation and the lower the strength.
13 Quenching castings after removal from mould	Immediate quenching in water reduces the yield tensile strength and increases elongation
14 Heat treatment	Normally none
15 stress-relief annealing	Only in special cases for T5 and O; if necessary, age T5 at up to 250 °C and for up to 90 min, the yield tensile strength will increase and elongation decrease; if necessary, age O at between 320 °C and 380 °C and for up to 90 min, the yield tensile strength will decrease and elongation increase

Alufont®-52 [AlCu4Ti]

Sequence of work when producing castings from Alufont-52

1 Melting down the ingots	As quickly as possible in efficient furnaces to keep oxidation and gas absorption of melts low; ensure as little Si as possible is absorbed in the melt composition!
2 Salt treatment when melting down	Not needed
3 Skimming	Needed after melting down
4 Temperature after melting down	Maximum of 800 °C (check temperature!)
5 Degassing and refining the melts	• Effective refining and fastest method using quick-running rotor for gas feeding, 7 – 10 l/min argon or nitrogen, 6 – 10 min • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Gas flushing tablet emitting nitrogen at a rate of 150 – 350 l nitrogen/kg (bell plunger procedure)
6 Standing and skimming	Leave to stand for around 10 minutes, then carefully skim
7 Grain refinement	Grain refiner based on TiB_2: 0.15 – 0.30 % tableted fluxes, 0.1 – 0.2 % master alloy wire (percentages by weight in relation to charge weight)
8 Standing and skimming	Leave to stand for at least 10 minutes, then carefully skim
9 Pouring temperature (approx. values) Sand casting Gravity die casting	Varies depending on casting method, design, size and wall thickness of castings: 720 – 760 °C 730 – 780 °C
10 Gravity die temperature	300 – 450 °C
11 Solution heat treatment	The annealing time does not include the heating-up time to reach annealing temperature. • Thin-walled castings (< 8 mm wall thickness): any but do not heat to 525 – 535 °C too quickly; hold for 8 – 10 hours; quench in water (20 – 50 °C) • Thick-walled castings (> 8 mm wall thickness): slowly heat up to 520 – 530 °C; hold for 12 – 18 hours; quench in water (20 – 50 °C) • Very thick-walled castings (> 20 mm wall thickness) are solution heat treated with stepped annealing
12 Stepped annealing	Slowly heat up to 490 °C; hold for 4 – 6 hours; then heat up to 520 °C; hold for 8 – 12 hours; quench in water (20 – 50 °C)
13 Artificial and/or full artificial ageing	170 ± 5 °C / 6 – 7 hours; artificial and/or full artificial ageing produces high values for ultimate tensile strength, yield tensile strength and hardness with average elongation; partial ageing on the other hand produces very high elongation with lower levels of ultimate tensile strength, yield tensile strength and hardness
14 Partial ageing	140 ± 5 °C / 6 – 7 hours
15 Cooling after ageing	Any, typically in air

Technical information

This chapter details the chemical, mechanical and physical properties of the aluminium casting alloys from RHEINFELDEN ALLOYS. They can be compared using tables.

Advice is also provided on how to work with our casting alloys in the melt process and how to gain optimum pouring results.
Various stages of processing are given in detail:

- Grain refinement
- Modification
- Quality of melt
- Refining the melts
- Melt testing
- Artificial ageing, heat treatment and self-ageing
- Heat treatment for high pressure die castings
- Fatigue strength
- Corrosion and corrosion protection
- Producing welded designs
- Joining techniques for high pressure die castings
- Machining

This part of the manual has been updated by our customer support staff.

We consider this a very important part of the manual as it isn't just the quality of casting alloy used which is key to successful applications, the right way of working before, during and after pouring is also of great importance. More questions will certainly arise during your work and as new developments enter the market. The RHEINFELDEN ALLOYS foundry specialists will happily answer these.

The mechanical properties are based on in-house measurements of our alloys and most exceed the values stipulated in the EN 1706 European standard.

The mechanical values were measured for sand and gravity die castings on separately cast test pieces and on test pieces taken from the castings; for high pressure die casting, values were only measured on test pieces. The ranges of mechanical properties stated indicate the performance of the alloys and the amount of scatter depending on material and pouring. The respective maximum value is for the designer's information. These values can also be reached in the casting or sub-areas with favourable casting conditions and corresponding casting technology work. The figures provided in brackets are minimum values in the casting with wall thicknesses of up to 20 mm. The properties of the aluminium casting alloys are affected by metal impurity, especially by increased levels of iron.

The primary aluminium casting alloys supplied by RHEINFELDEN ALLOYS have an iron content of less than 0.15 % unless higher Fe contents are needed. The analysis limits in the alloys we supply are precisely defined in order to ensure good uniformity in the casting process and other properties.

Chemical compositions

Alloys of a consistently high purity are key to producing high-quality castings. The RHEINFELDEN ALLOYS quality system allows this level of purity to be met.

The main alloy components are printed in bold. Individual values in the table are the maximum contents of alloy and accompanying elements. The alloys which RHEINFELDEN ALLOYS supplies sometimes have narrower alloy component ranges and a lower content of impurity than stipulated in the standard. This ensures good uniformity in the casting process and other properties.

European standard EN 1676 for alloyed aluminium in ingots applies.

The numerical alloy denomination is based on the European standard (EN). Alloys without these denominations are not included in the EN or have wider limits in composition.
Alloys with special compositions can be produced by agreement.

In the case of aluminium-silicon alloys, on request a modified microstructure with sodium (modified subsequently or in advance) or strontium (permanently modified) can be set rather than the granular microstructure. This choice is indicated by the denomination (Na/Sr) in the last column.

Brand name	Chemical denomination	Numerical denomination
Anticorodal-04	AlSi0.5Mg	
Anticorodal-50	AlSi5Mg	
Anticorodal-70	AlSi7Mg0.3	42 100
Anticorodal-78dv	AlSi7Mg0.3	42 100
Anticorodal-71	AlSi7Mg0.3-E	
Anticorodal-72	AlSi7Mg0.6	42 200
Silafont-30	AlSi9Mg	43 300
Silafont-36	AlSi10MnMg	43 500
Silafont-38	AlSi9MnMgZn	
Silafont-09	AlSi9	44 400
Silafont-13	AlSi11	
Silafont-20	AlSi11Mg	44 000
Silafont-70	AlSi12CuNiMg	48 000
Silafont-90	AlSi17Cu4Mg	
Castaman-35	AlSi10MnMg	
Castasil-37	AlSi9MnMoZr	
Castasil-21	AlSi9Sr	
Unifont-90	AlZn10Si8Mg	71 100
Unifont-94	AlZn10Si8Mg	
Castadur-30	AlZn3Mg3Cr	
Castadur-50	AlZn5Mg	
Peraluman-30	AlMg3	51 100
Peraluman-36	AlMg3Si	
Peraluman-50	AlMg5	51 300
Peraluman-56	AlMg5Si	51 400
Magsimal-59	AlMg5Si2Mn	51 500
Alufont-47	AlCu4TiMg	21 000
Alufont-48	AlCu4TiMgAg	
Alufont-52	AlCu4Ti	21 100
Alufont-60	AlCu5NiCoSbZr	
Thermodur-72	AlMg7Si3Mn	
Thermodur-73	AlSi11Cu2Ni2Mg2Mn	
Rotoren-Al 99.7	Al99.7-E	
Aluman-16	AlMn1.6	

Composition							
Si	Fe	Cu	Mn	Mg	Zn	Ti	other
0.3–0.6	**0.8**	0.01	0.01	**0.3–0.6**	0.07	**0.01**	
5.0–6.0	0.15	0.02	0.10	**0.4–0.8**	0.10	**0.20**	
6.5–7.5	0.15	0.02	0.10	**0.30–0.45**	0.07	**0.18**	**(Na/Sr)**
6.5–7.5	0.12	0.02	0.05	**0.30–0.45**	0.07	**0.18**	**Sr**
6.5–7.5	0.15	0.01	0.01	**0.30–0.45**	0.07	**0.01**	**(Na/Sr)**
6.5–7.5	0.15	0.02	0.05	**0.50–0.70**	0.07	**0.18**	**(Na/Sr)**
9.0–10.0	0.15	0.02	0.05	**0.30–0.45**	0.07	0.15	**(Na/Sr)**
9.5–11.5	0.15	0.03	**0.5–0.8**	**0.1–0.5**	0.07	0.15	**Sr**
8.5–10.0	0.15	**0.1–0.4**	**0.5–0.8**	**0.1–0.5**	**0.1–0.4**	0.15	**Sr**
9.5–10.6	**0.4**	0.02	**0.4**	0.05	0.10	0.10	
10.0–13.5	0.15	0.02	0.05	0.05	0.07	0.15	**(Na/Sr)**
10.0–11.8	0.15	0.02	0.05	**0.10–0.45**	0.07	0.15	**(Na/Sr)**
11.0–13.5	0.15	**0.8–1.3**	0.05	**0.9–1.3**	0.10	0.10	**0.8–1.3 Ni**
16.0–18.0	0.3	**4.0–5.0**	0.15	**0.5–0.6**	0.10	0.20	
9.5–11.0	0.2	0.03	**0.5–0.8**	**0.2–0.5**	0.10	0.15	**Sr**
8.5–10.5	0.15	0.05	**0.35–0.6**	**0.06**	0.07	0.15	**0.1–0.3 Mo 0.1–0.3 Zr Sr**
8.0–9.0	**0.5–0.7**	0.02	**0.01**	0.03	0.07	**0.01**	**Sr**
8.5–9.3	0.15	0.03	0.10	**0.3–0.5**	**9.0–10.0**	0.15	**(Na/Sr)**
8.5–9.5	**0.4**	0.03	**0.4**	**0.3–0.5**	**9.0–10.0**	0.10	
0.15	0.2	0.05	**0.1–0.2**	**2.5–3.0**	**2.2–2.8**	**0.15**	**0.2–0.4 Cr; Be**
0.15	0.2	0.05	**0.1–0.2**	**0.4–0.8**	**4.9–5.8**	**0.15**	**0.2–0.4 Cr**
0.45	0.15	0.02	**0.01–0.4**	**2.7–3.5**	0.10	**0.01–0.15**	**Be**
0.9–1.3	0.15	0.02	**0.01–0.4**	**2.7–3.5**	0.10	**0.01–0.15**	**Be**
0.30	0.15	0.02	**0.01–0.4**	**4.8–5.5**	0.10	**0.01–0.15**	**Be**
0.9–1.3	0.15	0.02	**0.01–0.4**	**4.8–5.5**	0.10	**0.01–0.15**	**Be**
1.8–2.6	0.20	0.03	**0.5–0.8**	**5.0–6.0**	0.07	0.20	**Be; V**
0.15	0.15	**4.2–5.0**	0.10	**0.20–0.35**	0.07	**0.15–0.25**	
0.05	0.10	**4.0–5.0**	**0.01–0.5**	**0.15–0.35**	0.05	**0.15–0.35**	**0.4–1.0 Ag**
0.15	0.15	**4.2–5.2**	**0.01–0.5**	0.03	0.07	**0.15–0.25**	
0.20	0.30	**4.5–5.2**	**0.1–0.3**	0.10	0.10	**0.15–0.30**	**1.3–1.7 Ni 0.10–0.40 Co 0.10–0.30 Zr & Sb**
3.0 – 3.8	0.15	0.05	**0.5–0.8**	**7.0–8.0**	0.10	0.20	**Be; V**
10.0–11.8	0.15	**1.8–2.3**	**0.4**	**1.8–2.3**	0.10	0.10	**1.8–2.3 Ni; Sr**
0.20	**0.25**	0.01	0.02	0.02	0.07	0.02	**Mn+Ti+V+ Cr≤0.02%**
0.15	**0.20–0.90**	0.03	**1.4–1.6**	0.05	0.10	0.15	

Mechanical properties

Alloy denomination	Numerical denomination	Chemical denominationg	Casting process	Treatment state	0.2 %-yield tensile strength $R_{p0.2}$ MPa	Ultimate tensile strength R_m MPa	Elongation A %	Brinell hardness HBW 5/250–30	Fatigue resistance σ_{bw} MPa
Anticorodal-04		AlSi0.5Mg	S	F	60–100 (50)	90–130 (80)	15–20 (10)	35–40 (35)	
			S	T7	160–180 (150)	190–210 (180)	3–5 (3)	70–75 (70)	
			K	F	80–120 (70)	100–140 (90)	18–22 (12)	40–45 (40)	
			K	T7	170–190 (150)	200–220 (190)	3–6 (3)	70–80 (70)	
			D	F	80–120	100–140	7–12	40–45	
Anticorodal-50		AlSi5Mg	S	F	100–130 (90)	140–180 (130)	2–4 (1)	60–70 (55)	60–65
			S	T4	150–180 (120)	200–270 (150)	4–10 (2)	75–90 (70)	70–75
			S	T6	220–290 (160)	260–320 (180)	2–4 (1)	95–115 (85)	70–75
			K	F	120–160 (100)	160–200 (140)	2–5 (1)	60–75 (60)	70–75
			K	T4	160–190 (130)	210–270 (170)	5–10 (3)	75–90 (70)	80–85
			K	T6	240–290 (180)	260–320 (190)	2–7 (1)	100–115 (90)	80–85
Anticorodal-70	42 100	AlSi7Mg0.3	S	F	80–140 (80)	140–220 (140)	2–6 (2)	45–60 (45)	
			S	T64	120–170 (120)	200–270 (200)	4–10 (4)	60–80 (55)	
			S	T6	220–280 (200)	240–320 (240)	3–6 (2.5)	80–110 (80)	90–100
			K	F	90–150 (90)	180–240 (180)	4–9 (2)	55–70 (50)	
			K	T64	180–200 (140)	250–270 (220)	8–12 (5)	80–95 (80)	
			K	T6	220–280 (200)	290–340 (250)	5–9 (3.5)	90–125 (90)	
Anticorodal-71		AlSi7Mg0.3-E	S	T7	160–200 (150)	220–250 (210)	2–4 (2)	70–80 (70)	
			K	T7	160–200 (150)	220–250 (210)	4–6 (3)	70–80 (70)	
Anticorodal-72	42 200	AlSi7Mg0.6	S	T6	220–280 (220)	250–320 (250)	1–2 (1)	90–110 (90)	90–110
			K	T64	210–240 (150)	290–320 (230)	6–8 (3)	90–100 (90)	
			K	T6	240–280 (220)	320–350 (270)	4–6 (2.5)	100–115 (100)	110–115
Silafont-30	43 300	AlSi9Mg	S	F	80–140 (80)	160–220 (150)	2–6 (2)	50–70 (50)	65–75
			S	T6	200–310 (180)	250–330 (220)	2–5 (2)	80–115 (75)	80–100
			K	F	90–150 (90)	180–240 (180)	2–9 (2)	60–80 (60)	80–100
			K	T64	180–210 (140)	250–290 (220)	6–10 (3)	80–90 (80)	
			K	T6	210–310 (190)	290–360 (240)	4–7 (2)	90–120 (90)	90–110
Silafont-36	43 500	AlSi10MnMg	D	F	120–150	250–290	5–11	75–95	80–90
			D	T5	155–245	275–340	4–9	80–110	
			D	T4	95–140	210–260	15–22	60–75	
			D	T6	210–280	290–340	7–12	90–110	
			D	T7	120–170	200–240	15–20	60–75	
Silafont-38		AlSi9MnMgZn	D	F	140–160	270–300	3–7	80–105	
			D	Water-T6	230–260	300–345	6–9	90–115	
			D	Air-T6	180–200	250–275	8–10	80–110	
Silafont-09	44 400	AlSi9	D	F	120–180	220–280	4–8	55–80	60–70
Silafont-13		AlSi11	S	F	70–120 (70)	150–210 (150)	7–13 (6)	45–60 (45)	55–70
			S	O	60–120 (60)	150–210 (150)	9–15 (8)	45–60 (45)	85–100
			K	F	80–150 (80)	170–240 (160)	7–16 (6)	45–60 (45)	70–90
			K	O	60–120 (60)	180–240 (160)	10–18 (10)	45–65 (45)	90–110
Silafont-20	44 000	AlSi11Mg	S	F	80–140 (70)	170–220 (170)	2–4 (1.5)	50–60 (50)	65–75
			S	T6	120–300 (110)	200–320 (200)	1–3 (0.5)	65–120 (55)	90–120
			K	F	80–130 (80)	180–230 (180)	3–16 (3)	55–75 (55)	80–100
			K	T6	125–320 (120)	210–350 (210)	4–15 (3)	70–125 (70)	100–120
Silafont-70	48 000	AlSi12CuNiMg	S	F	120–170 (110)	130–180 (120)	0.5–1.5 (0.5)	80–90 (80)	75–85
			K	F	190–260 (180)	200–270 (190)	1.0–2.5 (0.5)	90–105 (90)	80–90
			K	T6	320–390 (280)	350–400 (300)	0.5–2.0 (0.5)	135–160 (130)	100–110
			K	T5	185–210 (150)	200–230 (180)	0.5–2.0 (0.5)	90–110 (90)	
Silafont-90		AlSi17Cu4Mg	K	F	170–225 (160)	180–235 (170)	0.4–0.9 (0.3)	110–120 (110)	
			K	T5	160–225 (160)	165–230 (165)	0.4–0.8 (0.3)	105–115 (110)	
			D	T5	220–265	230–295	0.5–1.0	110–120	
Castaman-35		AlSi10MnMg	D	T6	180–260	250–320	6–12	80–110	

Alloy denomination	Numerical denomination	Chemical denominating	Casting process	Treatment state	0.2%-yield tensile strength $R_{p0.2}$ MPa	Ultimate tensile strength R_m MPa	Elongation A %	Brinell hardness HBW 5/250–30	Fatigue resistance σ_{bw} MPa
Castasil-37		AlSi9MnMoZr	D 2–3 mm	F	120–150	260–300	10–14	60–75	
			D 3–5 mm	F	100–130	230–280	10–14	60–75	80–95
			D 5–7 mm	F	80–110	200–250	10–14	60–75	
Castasil-21		AlSi9Sr	D	F	90–100	200–230	6–9	60–70	
			D	O	80–90	170–190	9–15	55–65	
Unifont-90	71 100	AlZn10Si8Mg	S	T1	190–230 (170)	220–250 (180)	1–2 (1)	90–100 (90)	80–100
			K	T1	220–250 (220)	280–320 (230)	1–4 (1)	100–120 (95)	90–110
Unifont-94		AlZn10Si8Mg	D	T1	230–280	300–350	1–4	105–120	70–90
Castadur-30		AlZn3Mg3Cr	K	T1	140–160	260–290	10–20	75–85	
Castadur-50		AlZn5Mg	S	T1	160–200	220–280	5–10	75–85	
Peraluman-30	51 100	AlMg3	S	F	70–100 (60)	170–190 (140)	4–8 (4)	50–60 (45)	70–80
			S	T6	140–160 (110)	200–240 (160)	6–8 (5)	65–75 (60)	75–85
			K	F	70–100 (70)	170–210 (150)	9–16 (6)	50–60 (50)	90–100
			K	T6	140–160 (110)	240–260 (180)	15–20 (12)	70–80 (70)	100–110
Peraluman-36		AlMg3Si	S	F	80–100 (70)	140–190 (130)	3–8 (3)	50–60 (45)	60–65
			S	T6	160–220 (140)	220–280 (180)	2–8 (2)	70–90 (65)	75–80
			K	F	70–100 (70)	160–210 (160)	6–14 (5)	50–65 (50)	70–80
			K	T6	160–220 (150)	250–300 (220)	5–15 (5)	75–90 (75)	80–90
Peraluman-50	51 300	AlMg5	S	F	100–120 (90)	190–250 (170)	10–15 (8)	55–70 (50)	60–80
			K	F	100–140 (100)	200–260 (180)	10–25 (8)	60–75 (55)	70–80
Peraluman-56	51 400	AlMg5Si	S	F	110–130 (100)	160–200 (140)	3–4 (2)	60–80 (55)	60–80
			S	T6	110–160 (110)	180–220 (160)	3–4 (2)	70–80 (65)	70–90
			K	F	110–150 (100)	180–240 (150)	3–5 (3)	65–85 (60)	70–80
			K	T6	110–160 (110)	210–260 (200)	3–18 (5)	75–85 (70)	70–90
Magsimal-59	51 500	AlMg5Si2Mn	D 2–4 mm	F	160–220	310–340	12–18	85–105	90–100
			D 4–6 mm	F	140–170	250–320	9–14	80–90	
			D 6–12 mm	F	120–145	220–260	8–12	75–85	
Alufont-47	21 000	AlCu4MgTi	S	T4	220–280 (180)	300–400 (240)	5–15 (3)	90–115 (85)	80–100
			S	T6	240–350 (220)	350–420 (280)	3–10 (1)	95–125 (90)	80–100
			K	T4	220–300 (200)	320–420 (280)	8–18 (5)	95–115 (90)	100–110
Alufont-48		AlCu4MgAgTi	S	T64	200–270 (180)	370–430 (320)	14–18 (7)	105–120 (100)	
			S	T6	410–450 (320)	460–510 (380)	3–7 (2)	130–150 (125)	80–100
			K	T6	410–460 (340)	460–510 (440)	5–8 (3)	130–150 (130)	100–110
Alufont-52	21 100	AlCu4Ti	S	T64	210–240 (180)	300–360 (260)	8–15 (4)	90–100 (90)	80–100
			S	T6	300–420 (280)	400–475 (350)	3–4 (2)	125–145 (120)	80–100
			K	T64	210–250 (190)	360–400 (300)	12–20 (10)	90–120 (90)	100–110
			K	T6	310–400 (300)	420–475 (400)	7–16 (4)	130–145 (130)	100–110
Alufont-60		AlCu5NiCoSbZr	S	T7	145–165 (140)	180–220 (180)	1–1.5 (1)	85–95 (85)	90–100
			S	O	160–180 (160)	180–200 (180)	1–1.5 (1)	80–90 (80)	90–100
Thermodur-72		AlMg7Si3Mn	D	20 °C	190–220	350–380	7–10	80–100	
			D	150 °C/500 h 1)	220–245	260–290	<15		
			D	225 °C/500 h 1)	150–175	180–205	<20		
Thermodur-73		AlSi11Mg2Cu2Ni2	D	20 °C	270–300	300–320	<1	130–150	
			D	150 °C/500 h 1)	280–310	330–355	<1		
			D	225 °C/500 h 1)	130–155	250–280	1–2		
Rotoren-Al 99.7		Al99.7-E	D	F	20–40	80–120	10–25	15–25	
Aluman-16		AlMn1.6	D	F	90–120	160–180	8–15	40–60	
			S	F	80–100	130–160	4–8	40–50	

The details relating to the casting method use the following abbreviations:

S Sand casting
K Gravity die casting
D High pressure die casting

1) Long-term aged; tested at temperature

Physical properties

The details of physical properties relate to heat-treatable alloys in a heat-treated state. They are heavily influenced by fluctuations in the alloy composition and the microstructure state. This explains why some of the measurement ranges are so large. The details for the melt and solidification ranges take into account the initial signs of partial melting resulting from segregation in the cast structure, which may occur in particular when heating up quickly at far below the theoretical equilibrium temperature.

Brandname	**Chemical denomination**	**Density (approximate value)** kg/dm³	**Young's modulus** GPa	**Linear thermal expansion coeffizient 20–200 °C** $\frac{1}{K} \times 10^{-6}$	**Thermal conductivity 20–200 °C** $\frac{W}{K \times cm}$
Anticorodal-04	AlSi0.5Mg	2.67	66–73	23	2.0
Anticorodal-50	AlSi5Mg	2.67	65–75	23	1.5
Anticorodal-70	AlSi7Mg0.3	2.66	69–75	22	1.6
Anticorodal-78dv	AlSi7Mg0.3	2.66	69–75	22	1.6
Anticorodal-71	AlSi7Mg0.3-E	2.66	69–75	22	1.8
Anticorodal-72	AlSi7Mg0.6	2.66	71–75	22	1.5
Silafont-30	AlSi9Mg	2.65	74–83	21	1.5
Silafont-36	AlSi10MnMg	2.64	74–83	21	1.5
Silafont-38	AlSi9MnMgZn	2.67	74–83	21	1.4
Silafont-09	AlSi9	2.65	62–78	21	1.4
Silafont-13	AlSi11	2.64	65–81	21	1.4
Silafont-20	AlSi11Mg	2.64	76–83	21	1.4
Silafont-70	AlSi12CuNiMg	2.68	77–83	21	1.2
Silafont-90	AlSi17Cu4Mg	2.73	77–83	18	1.1
Castaman-35	AlSi10MnMg	2.64	74–83	21	1.4
Castasil-37	AlSi9MnMoZr	2.69	68–75	21	1.3
Castasil-21	AlSi9Sr	2.65	62–78	21	1.7
Unifont-90	AlZn10Si8Mg	2.85	74–80	21	1.2
Unifont-94	AlZn10Si8Mg	2.85	74–80	21	1.2
Castadur-30	AlZn3Mg3Cr	2.74	70–72	24	1.2
Castadur-50	AlZn5Mg	2.78	71–74	24	1.3
Peraluman-30	AlMg3	2.66	63–73	24	1.3
Peraluman-36	AlMg3Si	2.66	66–74	24	1.2
Peraluman-50	AlMg5	2.63	63–73	24	1.2
Peraluman-56	AlMg5Si	2.63	68–75	24	1.1
Magsimal-59	AlMg5Si2Mn	2.63	70–80	24	1.1
Alufont-47	AlCu4TiMg	2.75	65–72	23	1.3
Alufont-48	AlCu4TiMgAg	2.79	65–72	23	1.3
Alufont-52	AlCu4Ti	2.75	65–73	23	1.3
Alufont-60	AlCu5NiCoSbZr	2.84	72–76	22.5	1.2
Thermodur-72	AlMg7Si3Mn	2.61	75–85		
Thermodur-73	AlSi11Cu2Ni2Mg2Mn	2.74	85–90		
Rotoren-Al 99.7	Al99.7-E	2.67	65–70	24	2.3
Aluman-16	AlMn1.6	2.73	65–72	24	1.5

Treatment state

F	As-cast state	**T4**	Naturally aged	**T6**	Artificially aged
O	Annealed	**T5**	Stabilised	**T64**	Partially aged
T1	Self-aged	**T5**	Quenched and aged	**T7**	Overaged

Electrical conductivity		Linear shrinkage			Melt and solidification range
MS/m or m/(Ω × mm²)	% IACS	**Sand casting** %	**Gravity die casting** %	**High pressure die casting** %	°C
29–31.5	50.0–54.0	1.1–1.2	0.8–1.1	0.5–1.0	600–650
21–26	36.0–45.0	1.1–1.2	0.8–1.1		550–625
21–27	36.0–46.5	1.1–1.2	0.8–1.1		550–625
21–27	36.0–46.5	1.1–1.2	0.8–1.1		550–625
27–29	46.5–50.0	1.1–1.2	0.8–1.1		550–625
20–26	34.5–45.0	1.1–1.2	0.8–1.1		550–625
21–26	36.0–45.0	1.0–1.1	0.7–1.0		550–600
21–26	36.0–45.0			0.4–0.6	550–590
21–22	36.0–38.0			0.4–0.6	550–585
18–24	31.0–41.5			0.4–0.6	550–595
17–27	29.5–46.5	1.0–1.1	0.7–1.0		565–585
18–26	31.0–45.0	1.0–1.1	0.7–1.0		565–585
16–22	27.5–38.0	1.0–1.1	0.7–1.0	0.4–0.6	545–600
14–17	24.0–29.5	0.6–0.8	0.4–0.6	0.3–0.5	510–650
21–26	36.0–45.0			0.4–0.6	550–590
18–22	31.0–38.0			0.4–0.6	550–600
25–28	43.0–48.5			0.4–0.6	550–595
16–20	27.5–34.5	1.1–1.2	0.8–1.1		550–650
16–20	27.5–34.5			0.5–0.8	550–650
17–20	29.5–34.5	1.0–1.4	0.7–1.1		555–650
18–21	31.0–36.0	1.0–1.4			555–655
16–23	27.5–39.5	1.1–1.5	0.8–1.2		560–650
15–23	26.0–39.5	1.1–1.5	0.8–1.2		560–650
15–21	26.0–36.0	1.0–1.4	0.7–1.1		545–645
14–21	24.0–36.0	1.0–1.4	0.7–1.1		545–645
14–16	24.0–27.5			0.6–1.1	580–620
17–23	29.5–39.5	1.3–1.5	0.8–1.2		540–650
17–23	29.5–39.5	1.3–1.5	0.8–1.2		525–645
17–23	29.5–39.5	1.3–1.5	0.8–1.2		540–650
17–21	29.5–36.0	1.3–1.5			545–650
			0.7–1.2	0.6–1.1	
		1.0–1.1	0.7–1.0	0.4–0.6	
34.5–36.5	59.5–63.0	1.5–1.8		1.0–1.4	655–660
20–26	34.5–45.0	1.2–1.5		0.8–1.2	645–660

Properties at low and high temperatures

Use at low temperatures

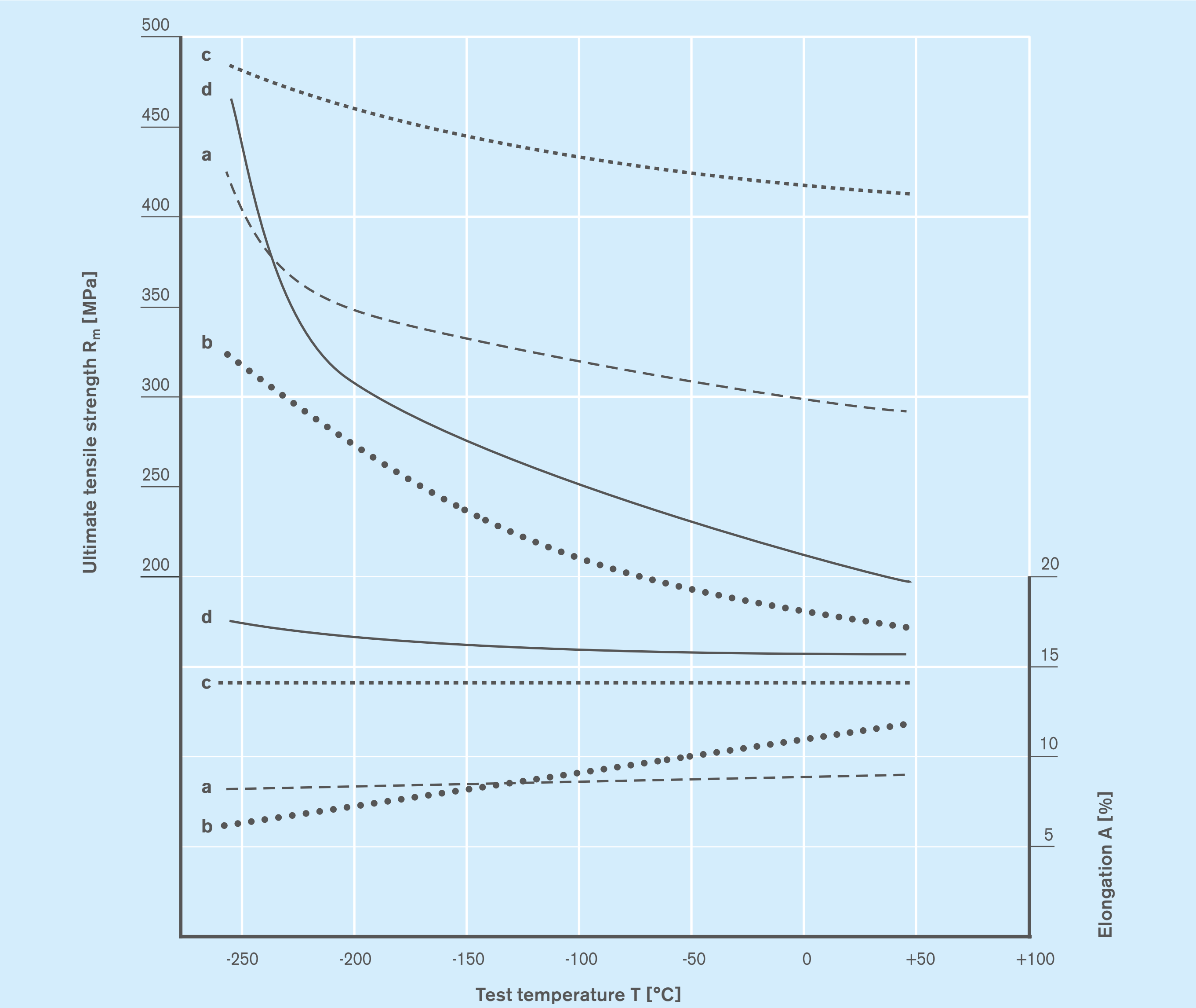
Unlike most iron-carbon alloys, aluminium alloys do not go brittle even at low temperatures. Ultimate tensile strength, fatigue resistance and impact toughness increase steadily as the temperature falls while elongation generally decreases somewhat.

Use at high temperatures

Temperature- and time-dependent processes determine how aluminium alloy castings behave at high temperatures. Depending on their initial state, dissolution and precipitation processes, ageing or overageing and very slow slip phenomena in the microstructure (creep) all have a role to play.

One single form of measurement cannot record the various influences with any accuracy. Brief measurements of mechanical properties at elevated temperatures do not include time-dependent processes and therefore only have limited use as a design basis. Even the more meaningful long-term measurements of the time yield limit and creep rupture strength do not allow an exact prediction of casting behaviour during operation. They may however be of some use to the designer.

Reliable design bases are usually only obtained from a technological test procedure. The properties of aluminium which also make it suitable for use at high temperatures are only shown to

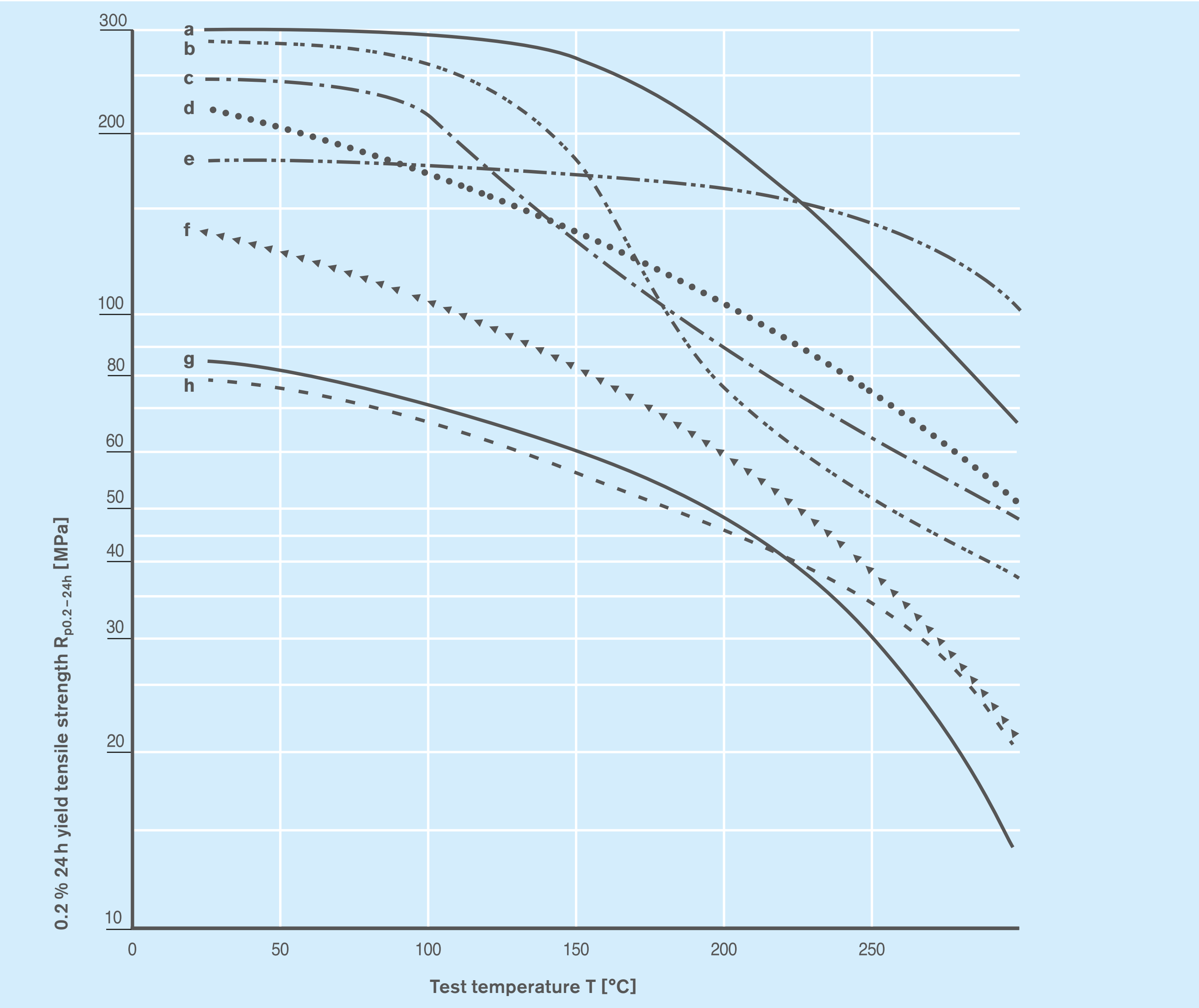


Properties of various casting alloys at low temperatures				
a Anticorodal-70	Gravity die casting	Artificially aged	AlSi7Mg0.3	T6
b Silafont-13	Sand casting	As-cast state	AlSi11	F
c Alufont-52	Gravity die casting	Partially aged at 150 °C	AlCu4Ti	T64
d Peraluman-30	Gravity die casting	As-cast state	AlMg3	F

advantage under operating conditions: resistance to scaling, high thermal conductivity and high heat storage capacity.

The thermal conductivity of aluminium alloys is three to four times that of carbon steels and six to eight times that of heat-resistant steels. This allows the alloys to absorb and discharge heat so fast that the aluminium part's own temperature can be kept below critical values, even at a high surface temperature. Rapid temperature equalisation within an aluminium part prevents thermal stresses and the formation of cracks. Only a few of the many aluminium casting alloys can be described as displaying thermal resistance. They are mainly the higher alloy materials such as Silafont-70, Silafont-90, Alufont-57, Alufont-60 and Thermodur-72/-73.

Numerous examples of the successful use of aluminium alloys in combustion engines (pistons, cylinder heads, engine blocks) prove that despite its low heat resistance measurements aluminium is also a useful design material for high-temperature technology.



0.2 %–24 h Yield strenght of different casting alloys as function of temperature (chill casting)							
a Thermodur-73	As-cast state/500 h	AlSi11Mg2Cu2Ni2	F	e Alufont-57	Naturally aged	AlCu4NiMg	T4
b Silafont-30	Artificially aged	AlSi9Mg	T6	f Silafont-09	HPDC as-cast	AlSi9	F
c Unifont-90	Self-aged	AlZn10Si8Mg	T1	g Silafont-13	As-cast state	AlSi11	F
d Silafont-70	Stabilised	AlSi12CuNiMg	T5	h Peraluman-30	As-cast state	AlMg3	F

Mechanical properties under various influences

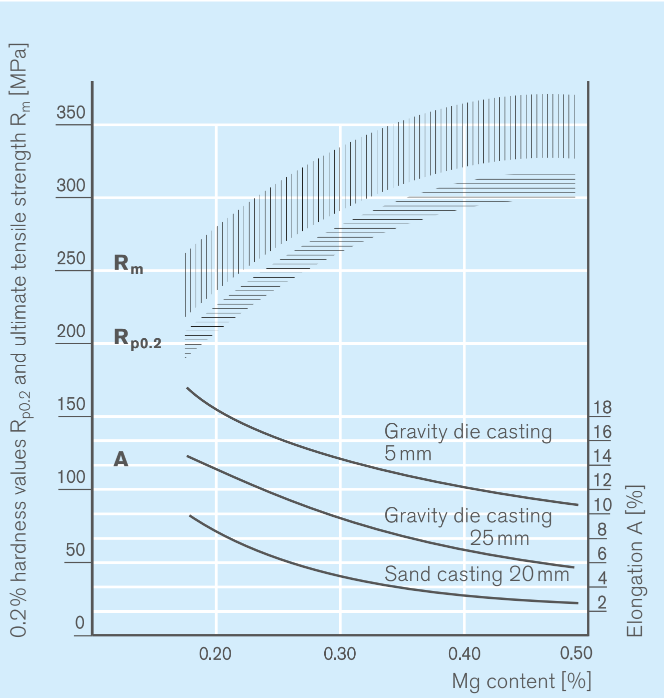


Fig. 1: Influence on mechanical properties of magnesium content in various gravity die castings made from Anticorodal-70, AlSi7Mg0.3 T6 with different wall thicknesses. The castings were quenched in water immediately after solution heat treatment

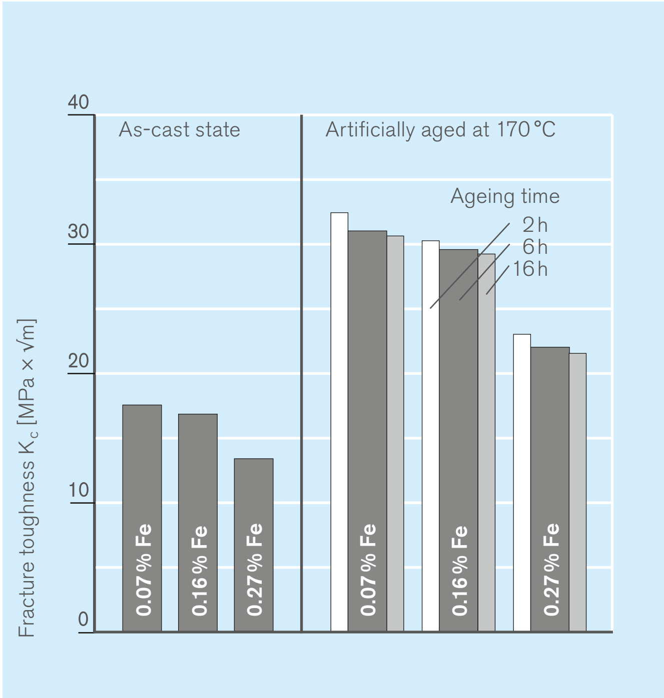


Fig. 2: Influence of iron content on fracture toughness for Silafont-30, AlSi9Mg as strontium modified gravity die casting sample

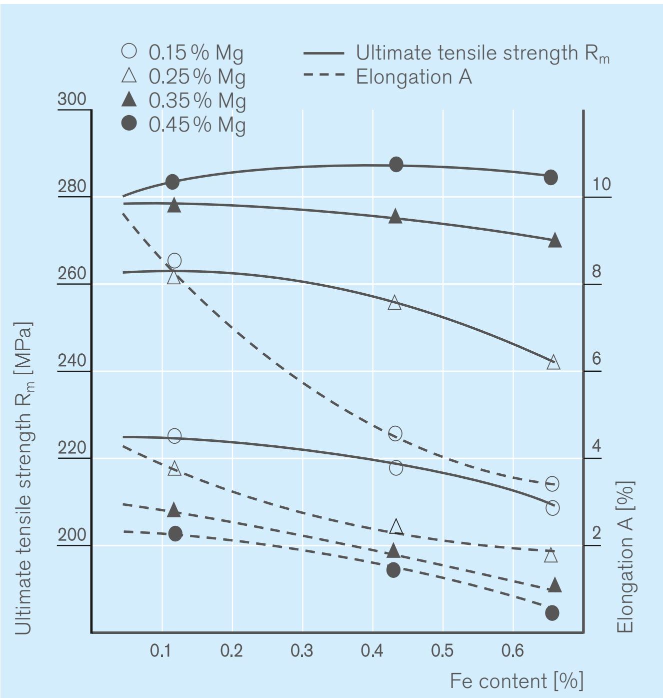


Fig. 3: Influence of Mg and Fe content on ultimate tensile strength and elongation in artificially aged sand casting test pieces, 16 mm diameter made from Silafont-30, AlSi9Mg T6

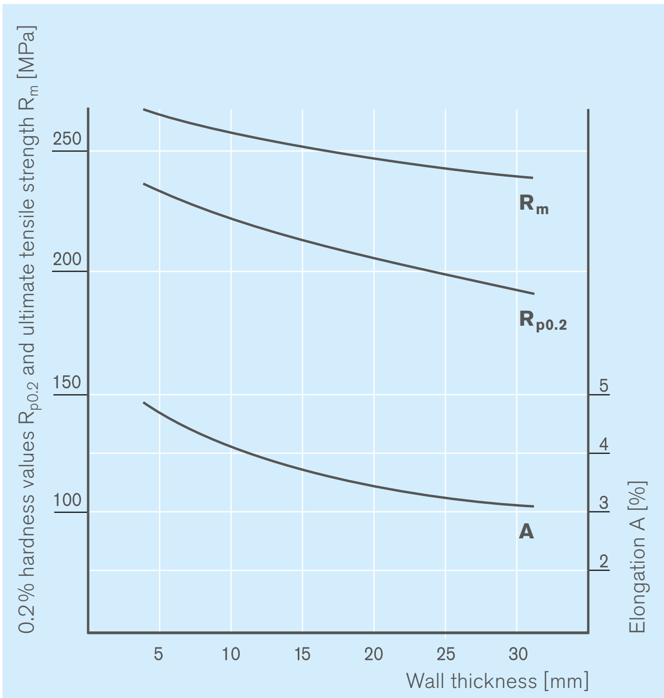


Fig. 4: Dependency of mechanical properties on wall thickness of artificially aged sand castings made from Anticorodal-70, AlSi7Mg0.3 T6

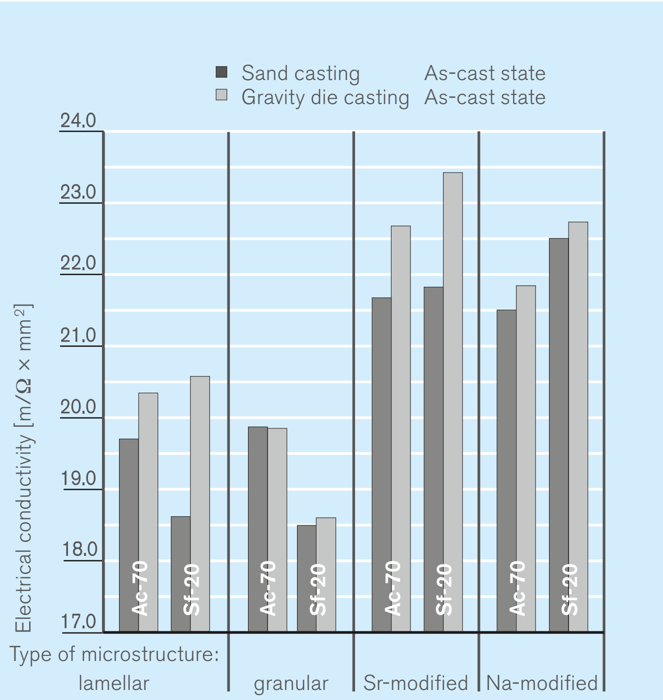


Fig. 5: Dependency of electrical conductivity on the microstructure modification of Anticorodal-70, AlSi7Mg0.3 and Silafont-20, AlSi11Mg in as-cast state

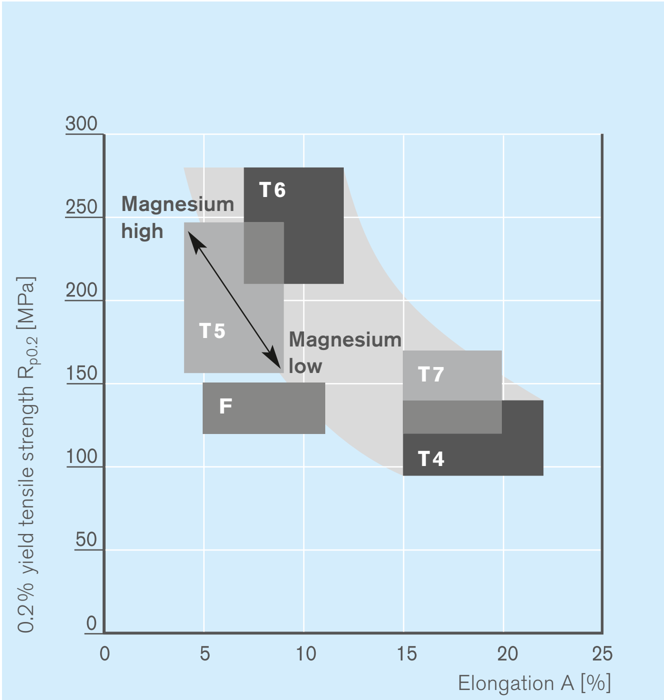


Fig. 6: Range of variation in mechanical values of high pressure die casting alloy Silafont-36, AlSi10MgMn due to various heat treatment states and magnesium content

Additional mechanical properties	
Compressive strength	$\sigma_{dB} \approx 1.5 \times R_m$ [MPa]
Offset yield strength	$\sigma_{d0.2} \approx 0.8 - 1.0 \times R_{p0.2}$ [MPa]
Rigidity strength	$\tau_B \approx 0.60 - 0.65 \times R_m$ [MPa]
Shear strength	$\tau_{sB} \approx 0.6 - 0.8 \times R_m$ [MPa]
Surface pressure	$p \approx 0.8 \times R_{p0.2}$ [MPa] applies to static strain; during dynamic loading should be assumed from the fatigue strength
Rigidity or shear modulus	$1/ß = G \approx 0.385 \times$ Young's modulus [MPa]
Torsional strength	$\approx R_m$ [MPa]
Twist limit	$\approx 0.2 - 0.5 \times R_{p0.2}$ [MPa]

Grain refinement

Effect of grain refinement

The purpose of grain refinement is to increase the number of nuclei in the melt and produce a finer formation of:

• aluminium solid solution, growth in dendrite form
• aluminium grain, comprising dendrites and remaining melt
• eutectic aluminium-silicon grain
• primary silicon in hypereutectic aluminium-silicon alloys.

Impact of grain refinement

If growth of the named structural constituents is kept low, the aluminium casting benefits from the following:

• better internal feed in casting
• enhanced flow and die filling properties for melts
• reduction in porosity in cast structure
• reduced hot cracking tendency
• higher mechanical values
• more economic machining
• less grain-boundary precipitate and therefore greater ductility
• attractive decorative appearance
• improved surface corrosion resistance.

This positive influence of grain refinement results from the fact that the aluminium solid solution, the dendrite, grows as the casting solidifies from the cast surface into the heart of the casting and in cases of large-scale and fast growth prevents the replenishing metal from filling the volume deficit resulting from solidification (Fig. 1 – 4). However the greater number of nuclei results in more smaller dendrites (Fig. 5). The remaining melt, which itself also still contains dendrites, produces a good internal feed in the casting thanks to the improved flow and die filling properties and reduces the shrinkage porosity and hot cracking tendency in the cast structure.

The greater number of nuclei in the melt produces many small aluminium grains formed from dendrites. For heterogeneous AlSi casting alloys, the smallest grain size is 200 – 500 µm. For the homogeneous alloys, AlCu, AlZn and AlMg, it is 100 µm.

The same applies to the eutectic grains of the AlSi alloys (Fig. 6). Small grains produce the benefits stated above and also impact positively on the mechanical values, surface roughness when machining and lower grain-boundary precipitate which is required for ductile casting. After polishing, a fine grain lends the casting an attractive decorative appearance, especially after anodic oxidation. Fine grains are essential for a casting's high surface corrosion resistance as corrosive damage is in fact notches in the casting surface.

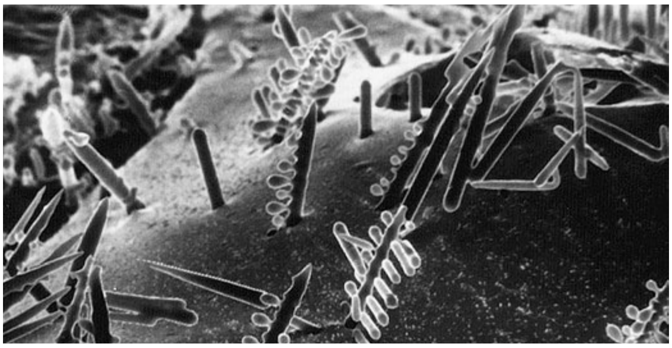


Fig. 1: Dendrites growing vertically to the casting surface

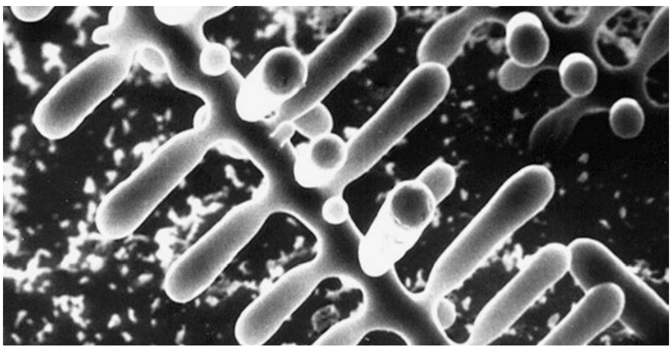


Fig. 2: Dendrites growing together

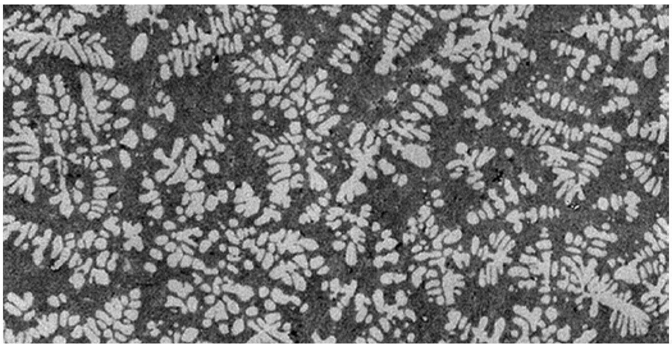
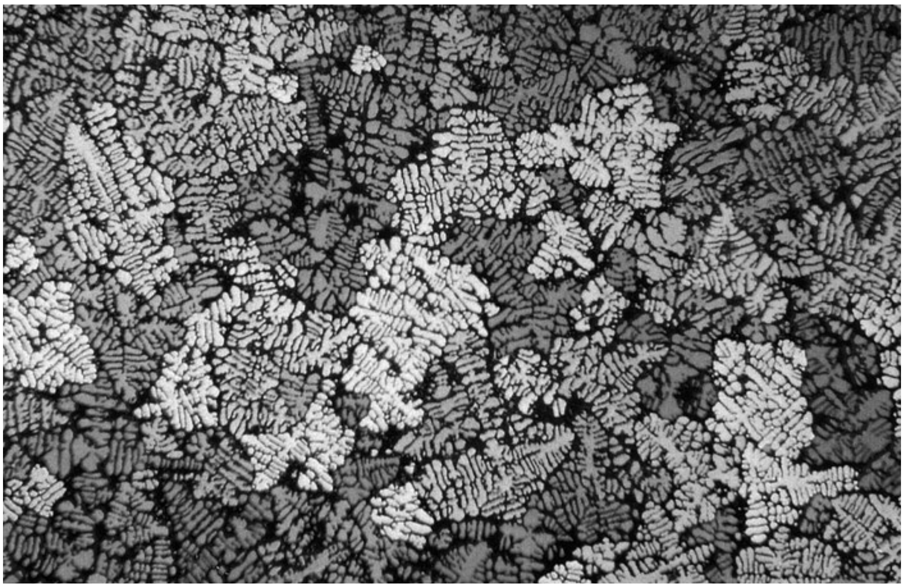


Fig. 3: Refined dendrites

Fig. 4: Aluminium grains, made up of dendrites



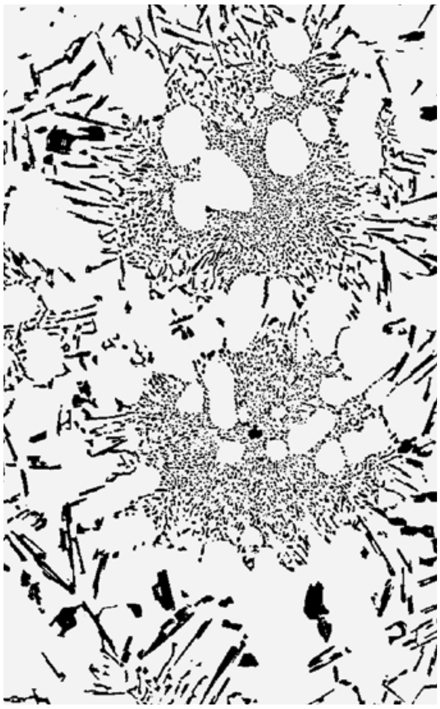
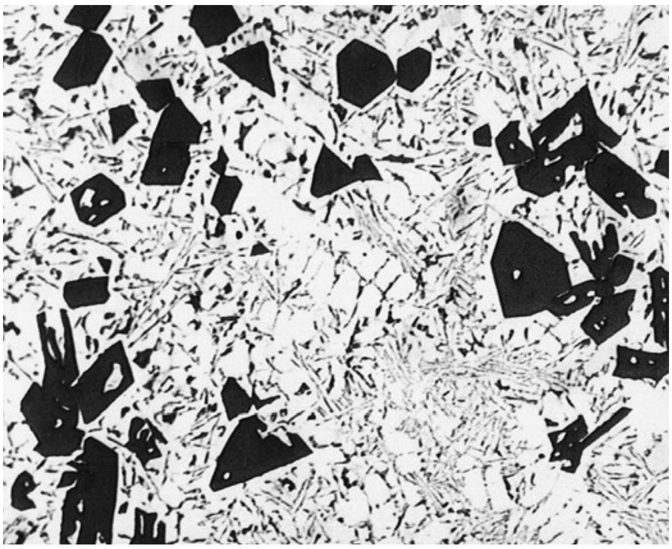


Fig. 6: Silafont-30, eutectic AlSi grains

The reason for refining the primary silicon in the hypereutectic AlSi alloys is not just to ensure a small pseudo-hexagonal silicon grain, but also a uniform distribution in the matrix (Fig. 7). Primary silicon grains with an edge length of 20 – 50 µm are stipulated for the cylinder surfaces of aluminium crankcases.

Fig. 5 top: Anticorodal-70, aluminium grains before grain refinement
Fig. 5 bottom: Anticorodal-70, aluminium grains after grain refinement



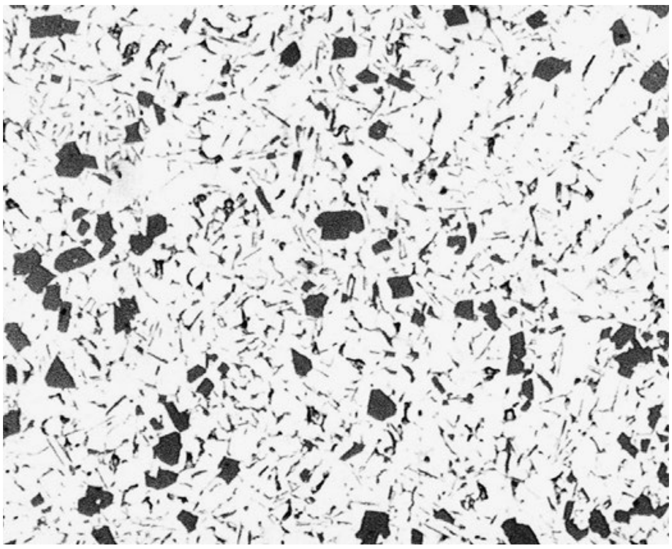


Fig. 7 left: Silafont-90, grain refinement of primary silicon using phosphorous, before grain refinement
Fig. 7 right: Silafont-90, grain refinement of primary silicon using phosphorous, after grain refinement

Grain refiner

The best grain refinement is achieved with the two double fluorides: potassium-titanium fluoride and potassium-boron fluoride. Both salts are available pressed in tablets; one variant has an exothermic reaction. Both salts react in the melt and produce extremely small titanium-diboride nuclei (TiB_2). After around 20 minutes, this excellent nucleation abates and after 40 minutes grain refinement has to be repeated. This is of no significance to sand casting because the melt doesn't stand for long periods.

A considerably longer grain refinement effect is achieved with titanium diboride nuclei from master alloys. The most common AlTiB master alloy contains 5 % titanium and 1 % boron; the master alloy containing 1.7 % titanium and 1.7 % boron is particularly effective for casting alloys. The titanium diboride nuclei from the master alloy are significantly coarser, agglomerate in the melt over time and segregate. The master alloys are added to the melt in the form of ingot plates, wire, blanks or granulates.

Titanium, used simply as an alloy element, has a grain refining effect in the casting alloy through the peritectic precipitation of titanium aluminide ($TiAl_3$). Grain refinement starts at the peritectic point of 0.15 % titanium. Titanium carbide, another grain refiner, is hardly ever used for casting alloys.

If AlSi casting alloys contain phosphorous, during the modification with sodium or strontium this forms phosphides, which refine the eutectic grain in particular.

The best grain refiner for primary silicon is phosphorous. This is added in the form of phosphorous copper, aluminium ferrous phosphorous, and melt compounds which release phosphorous.

Grain refinement process

Casting alloys from RHEINFELDEN ALLOYS are subject to long-term grain refinement during production to simplify the job of the caster.

As described in the melt testing chapter, the nucleation state should be at least 9. By using returns or after gas rotor refinement, nucleation in the melt abates and grain refining has to be repeated to return the nucleation state back to at least 9.

Attention! The best grain refinement for aluminium-silicon alloys is achieved by additions before modification.

Salt grain refining tablets should remain on the melt surface until the tablet edges have just started to melt or, for exothermic tablets, until the igniting flame appears. The tablets are then plunged into the melt with a dry, dressed perforated bell. If the tablets react in too lively a manner, they should be added in portions.

If the melt is processed using a rotor, tablets are added to the melt using either a retainer or salt granulates though the vortex which forms. In both cases, work can only be undertaken in crucibles with a capacity of more than 350 kg, 0.1 % or more should be added in each case.

Grain refinement master alloys in the form of wire or granulates can be easily stirred into the melt. Ingot plates and/or sections and blanks must be dissolved in the melt in a circular motion using a skimming ladle. If the melt is treated with the rotor, the best approach is to add the master alloy just before the end of treatment. The amounts to be added are 0.02 – 0.05 %.

To refine the grain of primary silicon, melt compounds which release phosphorous are added to the melt at temperatures in excess of 780 °C using the bell plunger. Phosphorous copper and aluminium ferrous phosphorous master alloys which dissolve immediately when stirred in can be used at lower temperatures. Depending on the primary silicon content in the hypereutectic AlSi alloy, the additions to the melt make up 0.2 – 0.6 %.

Gravity die castings which are very complicated and difficult to pour are often cast using ladle grain refinement.
A wire section of AlTiB master alloy is placed in the empty ladle and the melt ladled. The gravity die can be cast after a very short waiting period.

Grain refinement checks and monitoring

The processes used to check and monitor grain refinement are discussed in the melt testing chapter.

Modification

Cast structure

With AlSi casting alloys, in modifications the eutectic silicon in an alloy may appear granular, lamellar and modified (Fig. 1).

• Granular, eutectic silicon forms a distinct break in the soft matrix given its coarse, edged structure. The material is less ductile. The granular modification is stabilised using phosphorous.

• Lamellar, eutectic silicon may produce a more ductile material but is hard to cast because of its sponge-like solidification and therefore has a great tendency to form blowholes. The connected centre line blowholes are particularly striking (Fig. 2). The lamellar microstructure is stabilised using antimony.

• The modification produces a ductile material which is perfect for casting. The modification is stabilised using sodium and strontium.

A granular microstructure can be changed by adding sodium or strontium to the modification. A lamellar microstructure on the other hand is not totally modified by the modifying element. The resultant structure is a mixture of both modifications. This is why AlSi alloys should contain less than 30 ppm of antimony. The mixed microstructure is highly problematic for casters because of microporosity and blowholes in the cast.

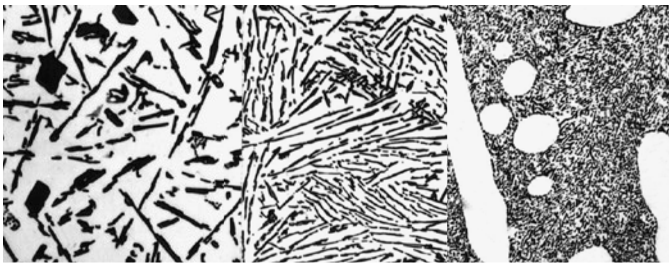


Fig. 1: Structural modification of AlSi eutectic: granular, lamellar, modified

Fig. 2: Centre line blowhole in lamellar cast structure

Influence of modification

Modification influences the following properties of AlSi alloys:

• Quality of melt
• Internal feed
• Porosity
• Hot cracking tendency
• Flow and die filling properties
• Length of eutectic Si particles
• Mechanical properties
• Machinability with regard to die wear and shape

Modification treatment involving sodium or strontium reduces the quality of melt, i.e. the negative pressure density falls at 80 mbar. If the melt is left to stand, the negative pressure density rises again but the density level required for a good casting is only achieved several hours later. The melt must therefore be refined after modification and this is best done with the rotor. The melting loss of the modification additions is low with treatment times of up to 10 minutes (Fig. 3). As the casting is solidifying, modified melts produce shells which improve the internal feed and reduce porosity and the hot cracking tendency even though the flow and die filling properties are worse.

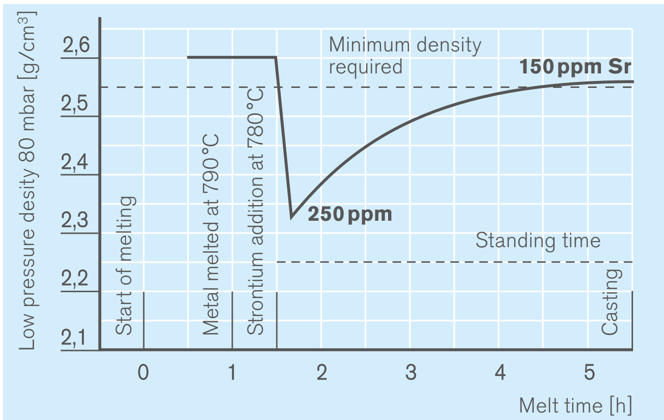


Fig. 3: Quality of melt after modification

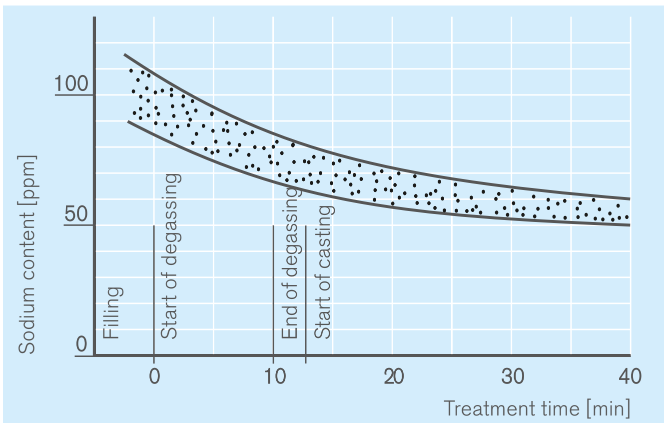


Fig. 3: Sodium content before and after melt degassing using rotor for Silafont-30, AlSi9Mg

The average length of the eutectic silicon particles is reduced by modification, but so is that of the intermetallic particles, most of which are iron compounds.
This is clearly shown in Fig. 4 using unmodified and strontium modified gravity die casting and sand casting test pieces of the Anticorodal-70 alloy.

	Ultimate tensile strength R_m [MPa]		**Elongation** A [%]	
	Sand	Gravity die	Sand	Gravity die
granular	150	180	5	6
modified	210	240	12	13

The ultimate tensile strength and in particular the elongation in the casting is increased by modification (Tab. above).
The elongation and 0.2 % yield tensile strength are affected in different ways. Modification only raises the yield tensile strength slightly. Modification has the greatest impact on elongation if the iron content is low (Fig. 5). Here a granular unmodified alloy is compared with a strontium modified one using T6 heat-treated Anticorodal-70 with 0.03 % Fe.
Up to 100 % greater elongation can be achieved through modification! The influence of iron content on elongation is shown in Fig. 6.

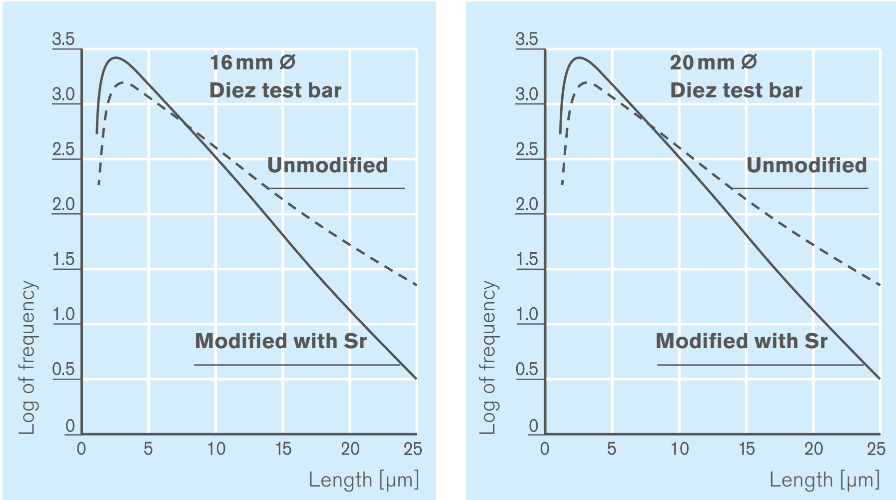


Fig. 4: Length of silicon and inter-metallic particles in unmodified and strontium-modified Anticorodal-70, AlSi7Mg0.3

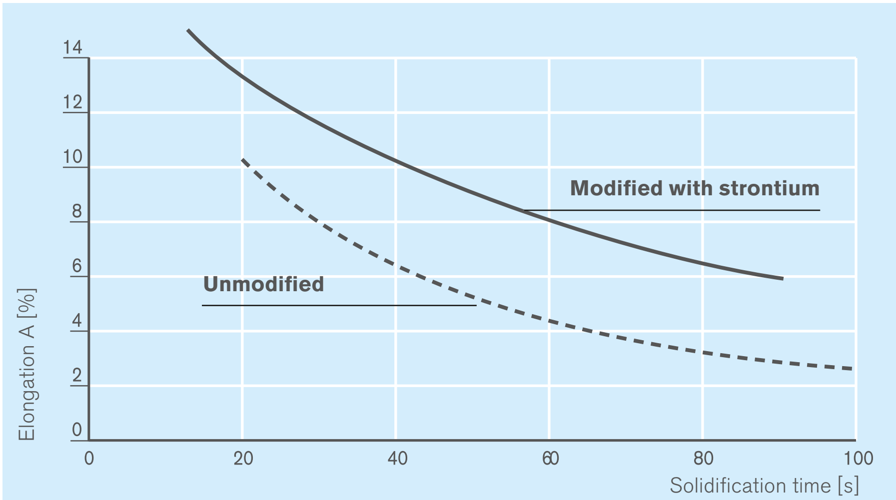


Fig. 5: Dependency of elongation on solidification time for Anticorodal-70 T6, unmodified and strontium-modified

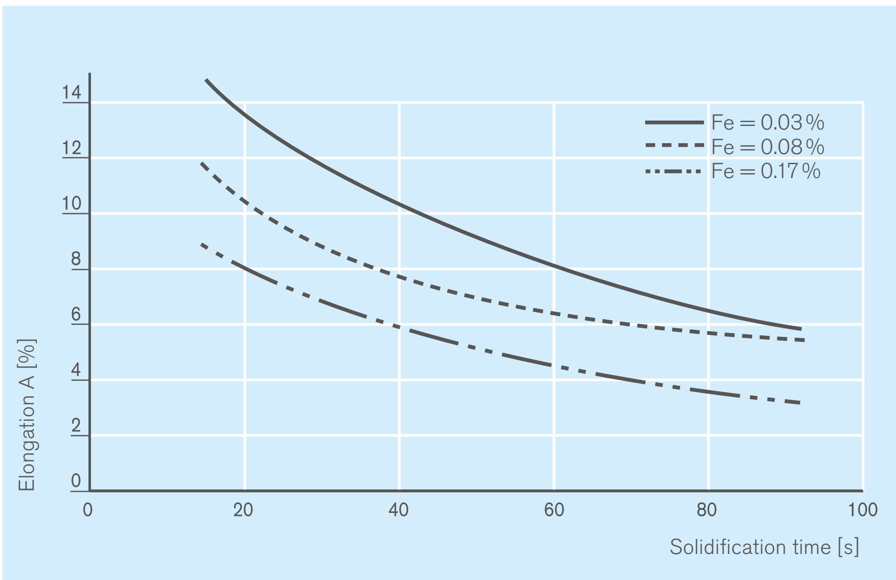


Fig. 6: Dependency of elongation on iron content for Anticorodal-70 dv T6

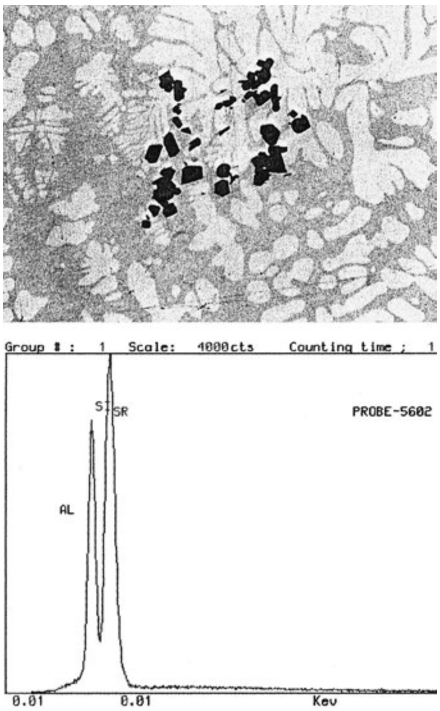


Fig.7: Intermetallic SrSi phases in AlSi cast structure

Modifying element

The classic modifying element is sodium. It is added to the melt either in a metallic form or as a granulate or tablet in a salt which then releases the sodium. Vacuum-packed sodium is available in airtight aluminium cans containing portions of 12.5 – 100 g. Sodium metal is also commercially available in various sized portions, in airtight packs.

Loose salt, usually a mix of sodium chloride, potassium chloride and sodium fluoride, is hardly ever used these days in aluminium foundries because the crucible walls are attacked by the salt melt. Instead salt mixtures, in pressed tablet or broken granulate form, are commonly used for modification. Modification tablets with aluminium casting and/or magnesium chips with an exothermal reaction have become very popular. The sodium is released very quickly from the tablet, a major improvement on tablets without an exothermal reaction where there is a greater risk of local overmodification in the melt.

New on the market are salt mixture granulates which are added to the melt surface without releasing dust to the surroundings. These are popular for adding to the vortex during rotor treatment.

Modification with strontium, also known as permanent modification, offers the benefits of a higher melt and vaporisation point over sodium (Tab. 1). The melting loss from strontium is therefore lower and the melts have a lower oxide content. The pouring stream has a thinner skin of oxide around it and the melt absorbs less gas and oxides when filling the die. Strontium metal is more rarely used for modification in foundries using moulds which prefer AlSr master alloys with 3, 5 and 10 % strontium. Master alloys with a higher strontium content contain intermetallic aluminium and strontium compounds which have no modifying effect. These are high-melting and are used as a separate brittle phase in the soft cast structure matrix (Fig. 7). The 3 % master alloy is the best way of adding strontium for modification. SrAl master alloy with 90 % Sr and 10 % Al packed in aluminium cans has a low melt point of 580 °C and reacts exothermally in the melt at temperatures of 650 – 700 °C.

Strontium modification has not only penetrated the world of gravity die casting but also sand and high pressure die casting. When sand casting, the water content of the bentonite-bound foundry sand should not exceed 3 % because otherwise the strontium-modified alloys will absorb more hydrogen. The various bentonites also display different water vapour characteristics when flowing into the melt. In addition, the Sr content must not exceed 250 ppm.

Antimony is not a modifying element.

If used in AlSi alloys at levels of 30 ppm or more, it will have a negative effect as the lamellar cast structure which hampers casting is stabilised. The sodium and strontium modification is disrupted as antimony, sodium and strontium precipitate in the melt. Even magnesium is precipitated in an intermetallic phase if antimony is used and is then no longer available for artificial ageing.

While strontium is a form of long-term modification, sodium modification only lasts for a short period. It is quite significant after around 30 minutes but has totally abated after 2 hours when additional modification is needed (Fig. 8). To maintain sodium modification, the caster often uses permablocks, which are melted blocks of salt or salt blanks. These are placed on the bath surface of the melt (Fig. 9). One 500 g block should be added per m^2 bath area.

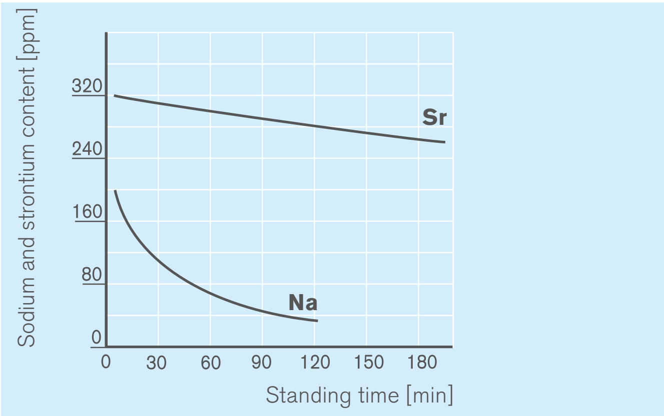


Fig. 8: Sodium and strontium melting loss in Silafont-13

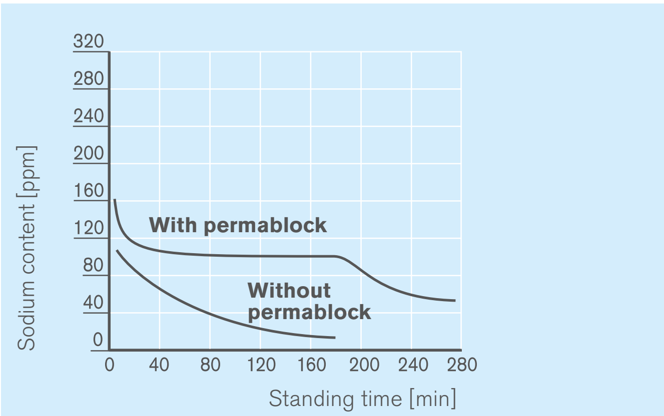


Fig.9: Compensation of sodium melting loss using a permablock

Modification process

RHEINFELDEN ALLOYS supplies AlSi alloys with granular eutectic or AlSi eutectic pre-modified or partly modified with sodium and permanently modified with strontium.

Although a lot of sodium is lost when melting down the ingots containing sodium, with a little subsequent modification the caster obtains a well modified cast structure without the risk of overmodification. A Na content of more than 20 – 60 ppm is sufficient for modification with gravity die casting if the melt has been pre-modified.

As described in the chapter on melt testing a good modification can be obtained with depressions and/or modification levels of 4 – 6 K. Due to the slower solidification, sand castings need higher depressions than gravity die castings. Tab. 2 shows eutectic temperatures.

Metallic, vacuum-packed sodium cannot be plunged straight into the bath because of the poor distribution of sodium. A small amount of modification salt is sprinkled onto the melt surface and the caster waits for the salt to start to melt. Only then is the sodium added to the salt and both are plunged into the melt using the dry, dressed perforated bell. Good stirring is important for preventing local overmodification.
Depending on the silicon content of the alloys, for sand casting 0.01 – 0.04 % should be added; half this amount is sufficient for gravity die casting.

The modification salt is spread over the melt surface and quickly stirred into the melt once it starts to sinter. This is best done by stirring in figures of eight. Since the modification salt will attack the crucible, it should be checked for cracks. Depending on the silicon content of the alloy, for sand casting 0.4 – 1.5 % should be added; half this amount is sufficient for gravity die casting.

Salts pressed into tablets do not attack the crucible. The tablets should remain on the melt surface until the tablet edges have just started to melt or, for exothermic tablets, until the igniting flame appears. The tablets are then plunged into the melt with a dry, dressed perforated bell. The bell must be moved to prevent local overmodification in the melt. If the tablets react in too lively a manner, they should be added in portions. This is a proven way of preventing local overmodification.

If the melt is processed using a rotor, tablets are added to the melt using a retainer or granulate though the vortex which forms. The rotor quickly and uniformly distributes the sodium released into the melt. As working with a retainer results in the melt temperature dropping, the retainer should only be used for melt volumes of 350 kg or more; the impeller which also produces a vortex requires a slightly emptier crucible. The modification tablets available on the market feature very different volumes of sodium which means that depending on the type of tablet and silicon content of the alloy, additional volumes of 0.1 – 0.4 % are used for sand casting; half this volume is added for gravity die casting, 0.1 – 0.3 % should be added in granulate form.

Metallic strontium, packed in aluminium foil, should be added to the melt using a bell plunger and stirred continuously. If local overmodification occurs in the melt despite you doing this, it will not have as negative an impact as sodium overmodification. Modification with AlSr master alloys does not reduce the melt quality as much as shown in Fig. 3. It is important to know that the yield of the modifying strontium in the melt is considerably less marked with a master alloy strontium content of more than 10 %. One exception to this is the SrAl alloy with 90 % Sr and 10 % Al because this has a low melt point of 580 °C and reacts exothermally in the melt. It does not have to be added to the melt with a bell plunger. Placing the master alloy on the melt is very often sufficient.

Depending on the silicon content of the AlSi alloys, the contents of the modifying strontium in the melt are:

High pressure die casting	60 – 120 ppm
Gravity die casting	80 – 200 ppm
Sand casting	70 – 150 ppm

This is clearly shown in Fig. 10, Anticorodal-70

Sodium		Strontium	
Melt point	98 °C	Melt point	769 °C
Vaporisation point	883 °C	Vaporisation point	1384 °C

Tab. 1: Melt and vaporisation points of sodium and strontium metal

Eutectic temperatures of AlSi casting alloys			
Anticorodal-70	573.0 °C	Silafont-30	574.0 °C
Anticorodal-72	572.0 °C	Silafont-13	577.5 °C
Unifont-90	562.0 °C	Silafont-20	576.0 °C

Tab. 2: Eutectic temperatures

Overmodification

Overmodification of AlSi alloys using sodium and strontium results from adding too large an amount or too concentrated an amount and distributing the modifying element too slowly in the melt which produces local overmodification. Overmodification as a result of dosing errors can be avoided by following the dosing requirements. Local overmodification in the melt can be avoided by quickly distributing the modifying agent throughout the melt volume.

Overmodification from sodium produces a very poor melt quality and defective casting. Overmodification from sodium has little impact on the melt and casting quality. Overmodification starts from around 120 ppm sodium in the melt and involves high gas absorption and a high tendency for blowholes to form in the melt. Overmodified melts have to be rejected. Replenishing with unmodified metal will not resolve the defect. Overmodification produces strips of remaining melt in the cast structure along the eutectic grains, containing iron and titanium needles as well as the recently formed intermetallic phase which contains sodium (Fig. 11).

Even local sodium overmodification in the melt starts to affect the melt quality and impairs the internal feed in the casting. Once overmodification has occurred it cannot be reversed. The intermetallic phases of sodium, iron and titanium are retained. They result in local accumulations of intermetallic plates containing iron (Fig. 12). The poor melt quality produced locally may remain in what is otherwise a healthy melt and result in the formation of pores just below the casting surface in casting areas which form in horizontal layers at the top of the die. After casting the pores cannot be seen but they emerge once the casting is blasted or machined (Fig. 13).

Checking and monitoring modification

The processes involved in checking and monitoring modification are detailed in the melt testing chapter.

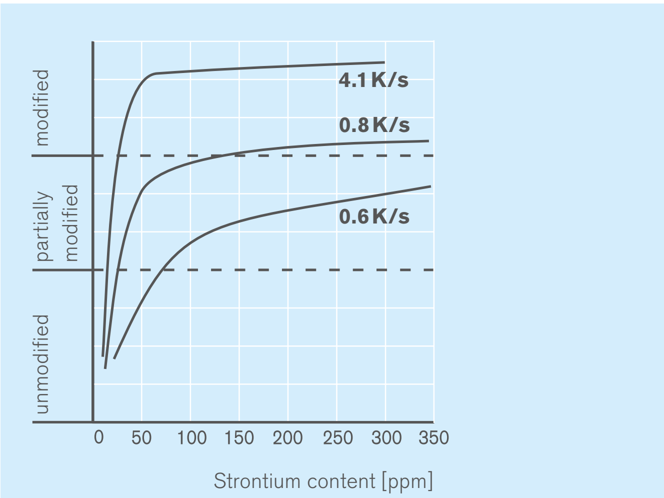


Fig. 10: Strontium content required to reach the degrees of modification for Anticorodal-70 castings solidified at different speeds

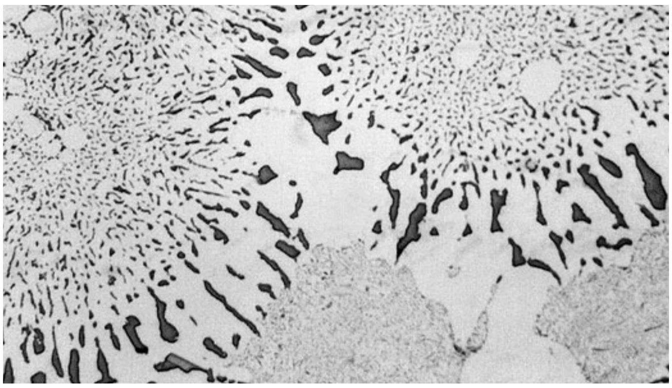


Fig. 11: Boundaries of overmodification in AlSi12

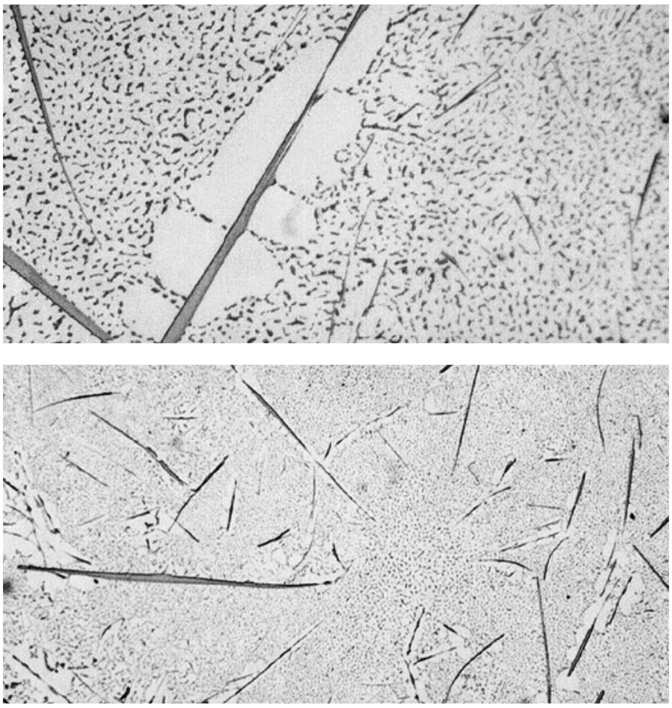


Fig. 12: Accumulation of intermetallic, plate-like phases containing iron in overmodified AlSi12

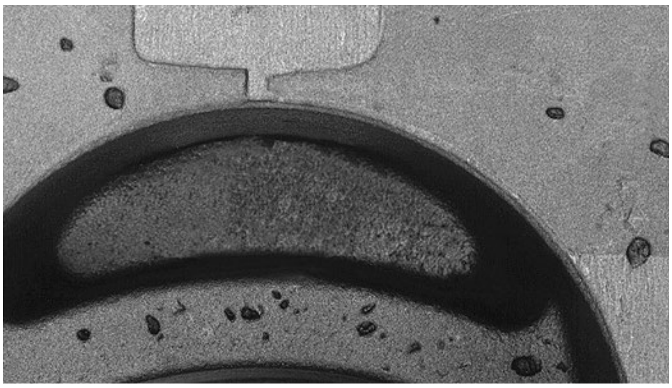


Fig. 13: Casting pores, exposed by surface blasting the casting

Causes of poor melt quality which result in casting defects

Improper actions during the production and transport of melts reduce the melt quality. Casting defects such as entrapped oxides, gas porosity, shrinkage porosity and macro blowholes can often be explained by such actions.

Sources of defects include:

1. Melting down too slowly
2. Replenishing with cold metal
3. Touching the flame with thin-walled returns
4. High temperature of melt
5. Inappropriate furnace maintenance
6. Poor furnace maintenance
7. Reacting with the crucible
8. Incorrect melt processing
9. Turbulent transport of melt

1. If ingots and returns are melted down too slowly, the plastic phase lasts too long. The oxides of aluminium and the alloy elements produced in such conditions cannot be cleanly separated from what has already melted, most remains in the melt and forms oxide skin cocoons in the melt (Fig. 1). The melting loss increases significantly. The plastic state should therefore be avoided. The pasty phase lasts for relatively long periods in overfilled furnaces where use is not adapted to the melt capacity. This also applies to electrically resistance-heated casting furnaces which are only designed as holding furnaces.

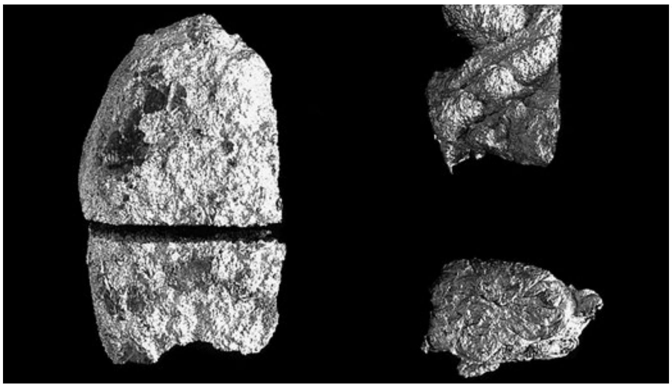


Fig. 1: Oxide skin cocoons

Depending on the alloy's "segregation factor", plate-shaped crystals containing iron may also form and interrupt the homogeneous cast structure (Fig. 2). They upset the magnetic flux in the cast structure. The lines of force are deflected at the plate edges and form peaks in tension, which greatly reduce the elongation and result in early micro-cracks if the casting is subject to dynamic loading. The solid solution plates containing iron also prevent internal feeding in the casting.

2. Replenishing with cold ingots and returns results in local supercooling in the melt as a result of which oxide pipes in the ingots and returns do not separate perfectly from the melt. Segregations occur and manganese aids the precipitation of hard crystals. Fissured to compact, hexagonal AlFeMnSi crystals 10 – 100 µm in size form in alloys with a higher Fe content. The micro hardness of these crystals is 200 – 750 HV (Fig. 3), or more for compact crystals.

3. Small scaly returns oxidise in a lively manner if they come into contact with the melt flame. The oxide skins formed in the process accumulate like balls (Fig. 4). Oxides in this closed form remain stubbornly bound internally to the melt. The oxides can only be removed from the melt once the oxide skin can be torn off through the addition of melt fluxes. The salts are added as required by the circumstances in the form of fine, or preferably coarse, granulate. If the machining chips or sparkling high pressure die casting content cannot be melted down in appropriate furnaces, this task should be assigned to a refinery.

4. Temperatures in excess of 800 °C greatly damage the aluminium melt. The absorption of hydrogen and formation of oxide increase quickly at high temperatures, especially if the air humidity in the vicinity of the melt furnace or transport crucible is high. Because of the change in solubility of hydrogen when moving from a liquid to a solid state, undesirable gas bubbles form in the casting, mainly on the oxides acting as nuclei (Fig. 2 in refinement chapter). Containers and dies in direct contact

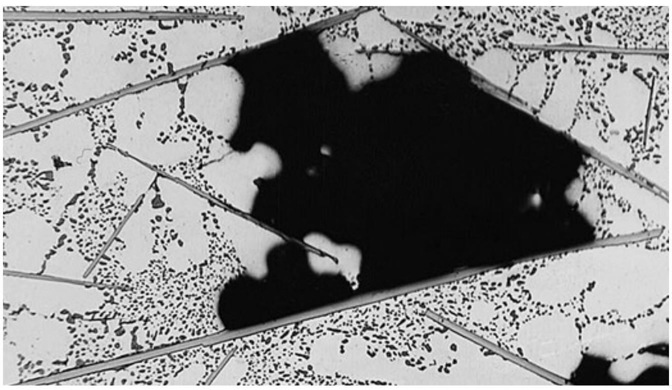


Fig. 2: Precipitated AlFeSi plates

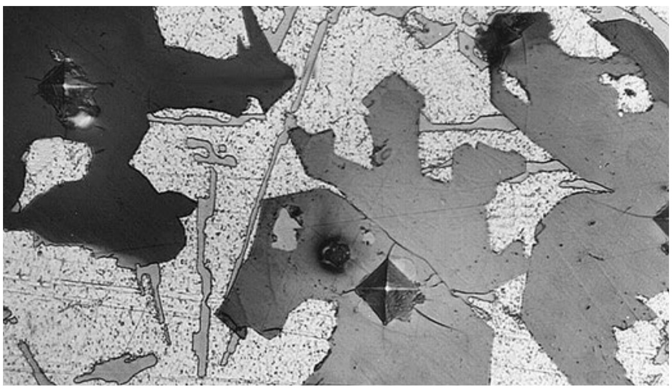


Fig. 3: Compact AlMnFeSi precipitation

with the melt must be heated up separately, to melt temperature wherever possible. Delays should be avoided in transporting and processing the melt. If using dressed tools and insulation, even when decanting, the melt does not have to be heated so much. Reactions with refractory materials are also less likely.

5. Refractory furnace cladding not suitable for aluminium melts will react with the melt. The reaction products contaminate the melt (Fig. 5); the furnace liner is mineralised. The amphoteric behaviour of aluminium should be taken into account when selecting refractory materials. Materials with an Al_2O_3 content of more than 85 % have proven their value in such circumstances. Preference should also be given to particularly dense refractory materials, especially if they come into contact with AlMgSi melts, as virtually no infiltration will then occur.

6. Furnaces which are not kept clean allow oxides to crystallise (Fig. 6) and deposits to form e.g, from corundum (Al_2O_3), periclase (MgO), spinel ($MgAl_2O_4$), oxide hydrate (OAlOH), zirconium oxide (ZrO_2) or quartz (SiO_2). Melt temperatures of 700 °C in the furnace with a normal supply of air will after 25 hours result in the formation of corundum nuclei, at 800 °C this will happen after just 7 hours. These hard inclusions are only avoided through a shorter refinement interval.

7. In order to rule out the possibility of reactions between the melt/holding crucible and aluminium melt, we would recommend annealing it for several hours at 800 °C before use. This applies equally to clay-graphite crucibles and silicon-carbide crucibles. The reaction products formed in the melt during improper handling result in what are known as “black inclusions” in the cast structure.

8. Over-lively bath movement when degassing the melt must be avoided. The bubbles of refinement gas rising to the surface must not draw the oxide-rich surface of the bath into the melt. Melts may however also be ruined by improper grain refinement and modification, as is reported in the chapters on grain refinement and modification.

9. When transferring aluminium melts, turbulence must not develop in the pouring stream. It must be a laminar and closed stream. Free falling should be avoided through the use of suitable channel or pipe systems. Turbulent metal flows don’t just entrain air with them but also the constantly reforming oxide pipe of the melt. The 80 mbar density sample demonstrates how improper transfer impairs the quality of the melt. A melt with a density of 2.65 g/cm^3 was poured from the furnace straight into a crucible; the height of the drop was 2.10 m. After this turbulent transfer, the melt in the crucible had a density of just 2.43 g/cm^3. After using a calculated pipe system to decant, the melt quality in the crucible rose again to a density of 2.55 g/cm^3.

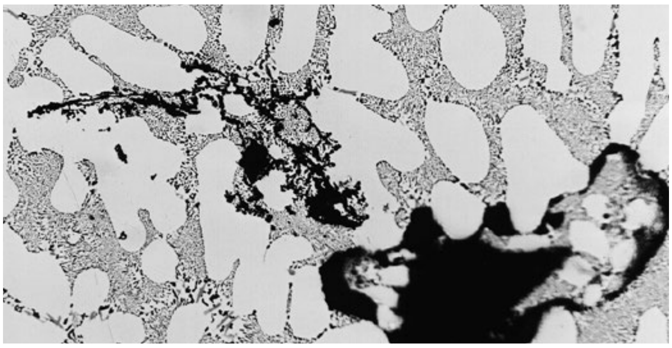


Fig. 5: Reaction bubble with oxide skin cluster

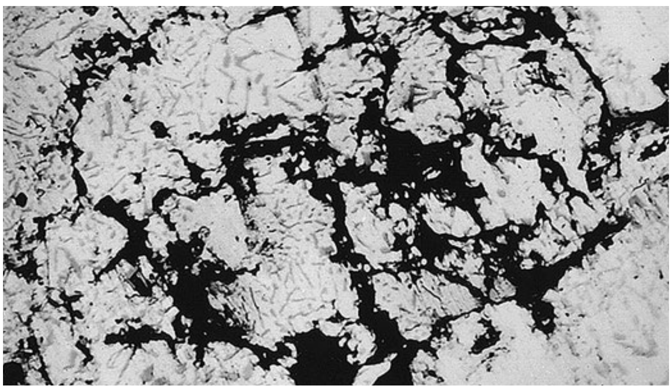


Fig. 4: Accumulated oxide skins, ball of oxide

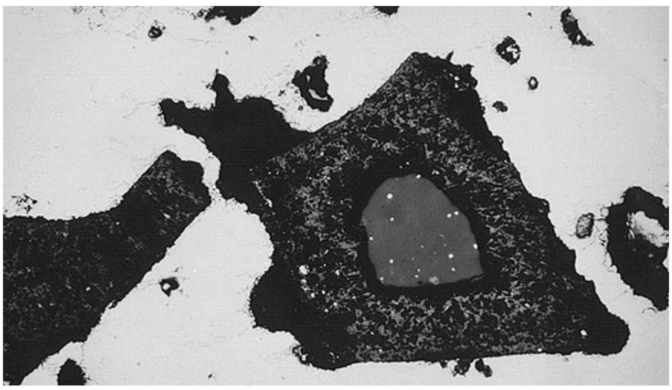


Fig. 6: Crystallised oxides

Refining aluminium casting alloy melts

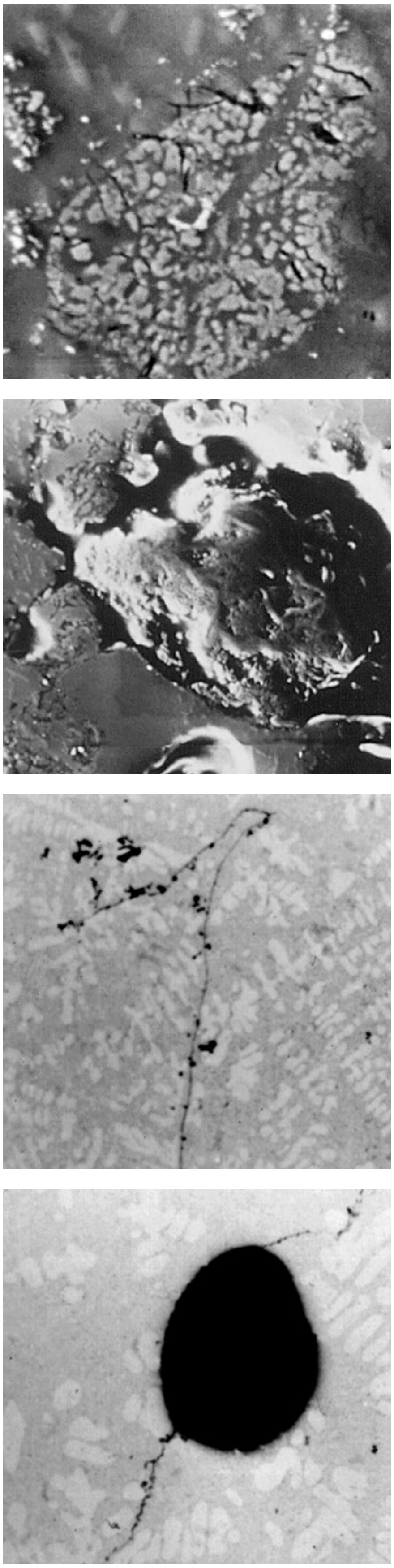


Fig. 1: Different types of oxide (from top):
compact oxide;
flaky oxide;
oxide skin;
oxide skin with gas bubble

Melt impurities

All the mistakes which can be made when melting down ingots and returns, transporting and decanting melts and processing melts lead to a poor melt quality as a result of oxides and a high hydrogen content. Refer to section: Causes of poor melt quality which result in casting defects.

A distinction should be made between three kinds of oxides (Fig. 1): compact oxide, flaked oxide, oxide skins. Compact and flaked oxides can be removed from the aluminium melt with relative ease; this is not the case with oxide skins. These are microoxides which only become apparent on the microsection and float in the melt in their various sizes.

Hydrogen occurs in aluminium casting alloy melts in two forms: as hydrogen atomically dissolved in the melt and as a molecularly precipitated gas, usually in close association with microoxides (Fig. 2).

Process for refining melt

Coarse oxides are generally easier to remove from the melt and this can be done using filters or by flushing. A salt mixture of pressed gas flushing tablets is used to refine melts in individual applications. The tablets are placed on the base of the crucible using a dry, dressed perforated bell. They release nitrogen when in a nuclear state and release no smoke or odours. 1 kg tablets used at melt temperatures of around 720 °C will produce between 150 and 350 l of nitrogen.

Ceramic foam filters have proved to be a good solution especially in high pressure die casting foundries which remelt in a closed loop. The filter captures all kinds of oxides (Fig. 3) and therefore also the majority of the hydrogen. After use the filter has to be heated continually to prevent the melt solidifying in the filter's pore cells. A quadratic ceramic foam filter with an edge length of 450 mm can refine around 20 t of melt. The same ceramic foam filters but of a smaller size are used by casters in the tip system with sand and gravity die casting.

The molecularly precipitated hydrogen remains stubbornly in the melt if it has attached itself to microoxides. Removing this hydrogen means removing all the microoxides. Melt processing tablets containing oxide-binding salts are used for this purpose.

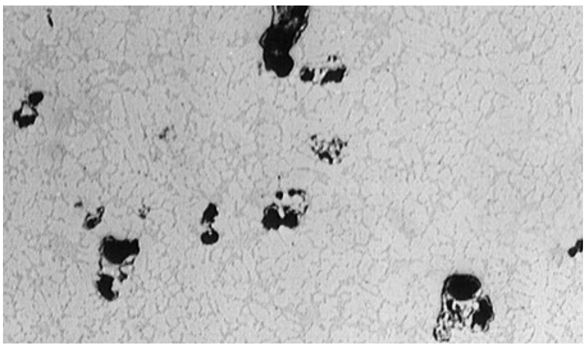


Fig. 2: Accumulation of oxide skins with gas bubble inclusions

Melt refining with a gas flushing lance can be used with inert gases such as argon and nitrogen, or in combination with suitable degas treatment with reactive gases such as chlorine. Gas mixtures of inert and reactive gases are also used here. It is important that the gases are added to the melt in a finely distributed form. The end of the lance must therefore feature a fine porosity head. The gas treatment process takes a very long time and cools the melt a lot.

Refining melts using negative pressure and/or vacuum degassing involves no magnesium or strontium burnout and keeps the loss of sodium within limits for modified melts. Reducing pressure to 1–3 mbar has the effect of greatly reducing the partial hydrogen pressure on the surface of the bath such that the dissolved hydrogen escapes from the melt very quickly. The low pressure on the surface of the bath is not present in the melt because of metallostatic pressure. The pressure at 10 cm below the surface of the bath is 25 mbar. The melt must therefore be circulated with a gas flushing lance to ensure that all the metal comes into contact with the surface of the bath. Some of the microoxides are also removed. The negative pressure equipment is frequently heated because melt processing may take 5–30 minutes.

The inert gases argon or nitrogen also cause dissolved hydrogen to be physically removed from the melt through the reduction in partial pressure.
The combined removal of oxide and hydrogen from melts using gas rotors is now the most effective, environmentally sound and fastest method. This process involves a graphite rotor adapted to the crucible size drawing the inert gases as low as possible in the full melt crucible. The high level of rotation causes the rotor to pulverise the gas flow and at the same time distribute the rising bubbles of gas over the crucible width.

The rule of thumb for effective refinement is:
speed of rotor rotation = 500–600 rpm
treatment time = 6–10 minutes
with 7–10 l/hour of argon or nitrogen for 600 kg of melt.

If argon or nitrogen is being used, the waterfree variant (Quality 5.3) must be ensured. The level of melt refinement achievable is greatly affected by the rotor and gas quality. Reduced treatment times can be used such that the crucible does not have to be heated. The melt can also be refined in a continuous process with the rotor (Fig. 4).

Gravity die casters also use forming gas, comprising 70% argon and 30% hydrogen, as the flushing gas if the casting needs a finely distributed hydrogen porosity in order to avoid coarse blowholes and shrinkage pores. Specifically added nano-structured oxides also act in the same way. As there are so many nuclei, they bring about the precipitation of fine hydrogen gas pores.

Refining modified melts

Only short-term gas flushing treatment is permitted to prevent sodium and strontium burnout in modified melts. Tabletted fluxes emitting only nitrogen have proven a good solution; modified melts refined using ceramic foam filters are only sufficiently refined of oxides. The best way of refining modified melts currently in use is a process involving an effective gas rotor, see the chapter on modification. The negative pressure degassing does however produce very low gas contents for modified melts.

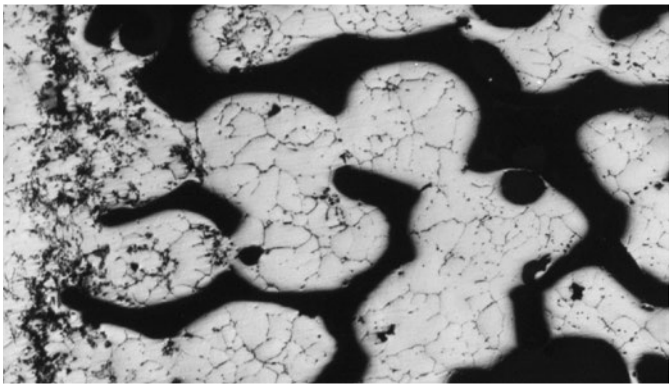


Fig. 3: Foam ceramic filter; black = ceramic flowing from left to right

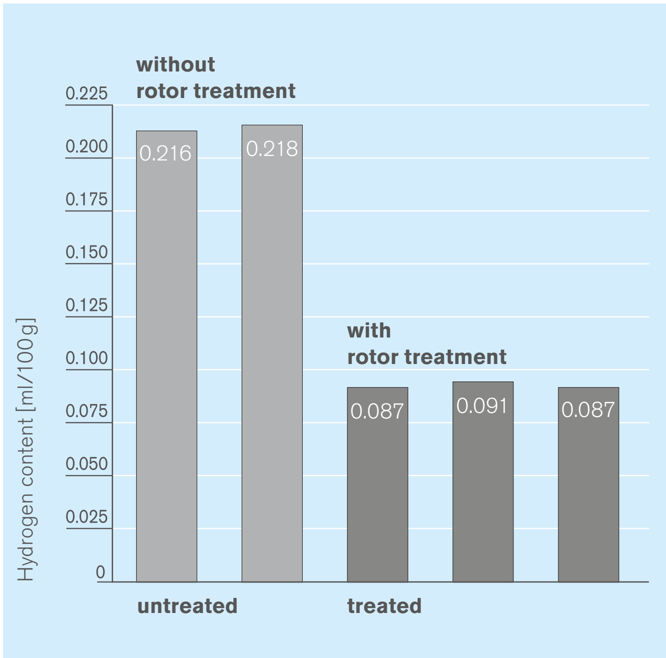


Fig. 4: Effect of a rotor in the continuous refinement process

Melt testing

The melt quality must be perfect for an immaculate casting. The density index, nucleation state, degree of modification of AlSi alloys and gas content provide evidence of the melt quality. The density index can be calculated using the negative pressure density measurement and the nucleation state and degree of modification from the thermal analysis. The gas content is measured using the aluminium melt tester. These tests can be used for every casting to quickly ascertain the melt quality needed for a healthy casting.

Calculating negative pressure density

This test method involves a melt of around 80 g being solidified in a dressed iron crucible in a vacuum chamber with negative pressure of 80 mbar. The time it takes the sample to solidify depends on the alloy but will be around 4 minutes. A sample from the same melt is solidified in parallel at atmospheric pressure. The density of both samples is calculated using Archimedes‘ principle. The impact of pressure on the microstructure of the density sample can be clearly seen in Fig. 1 using a melt of Anticorodal-70 dv with strontium modification.

The sample which solidified under atmospheric pressure has a considerably more dense cast structure and therefore a greater density of 2.62 g/cm³. On the other hand the sample which solidified at less than 80 mbar displays a relaxed, porous microstructure and a lower density of 2.35 g/cm³. The density index is 10.3 % and is calculated using this formula:

$$DI\,[\%] = \frac{\rho 1000\text{ mbar} - \rho 80\text{ mbar}}{\rho 1000\text{ mbar}} \times 100$$

Experience has shown that the following minimum values are needed for the 80-mbar pressure density for the alloy groups if you are to obtain a good casting:	
AlSi alloys	2.55 g/cm³
AlCu alloys	2.65 g/cm³
AlMg alloys	2.55 g/cm³
AlZnSi alloys	2.75 g/cm³
AlSiCu alloys	2.65 g/cm³

The density index of 10.3 % is too high to pour a casting with a healthy microstructure. Every casting has its own optimum density index. Experience shows that the average density index should not exceed 4 %. Some challenging castings require higher 80-mbar negative pressure density values for a healthy casting.

Fig. 2 shows the dependency of the pore volume in the casting on the negative pressure density. This also takes account of the solidification time.

The influence of solidification time on pore volume in the cast structure for different negative pressure densities can be seen in Fig. 3. This shows that at a very low negative pressure density, a high speed of solidification has virtually no impact on producing a lower pore volume in the cast structure.

Thermal analysis

Testing the melt‘s negative pressure density alone is not enough to ensure that a healthy, dense casting is being poured.

A good low density index provides no clues as to the growth of aluminium solid solutions, i.e. dendrites. Despite having a good density index, it is possible for dendrites to be growing too fast and for this to result in leaks in the thin wall thicknesses of the casting. The thermal analysis provides information on the nuclear state of the melt, especially growth of the primary crystals, the dendrites.

Monitoring grain refinement

The progression of primary crystals provides evidence of the grain size which the computer in the thermal analysis device calls the nucleation state (KF), Fig. 4 shows flat progression of primary crystals with a high nucleation state of KF = 13.5.

The primary crystals in the second diagram in the same figure have a much more distinct progression and a lower nucleation state of KF = 9.4.

In order to avoid volume deficits in the casting, the nucleation state KF should be above 9.

The maximum grain refinement values are recorded in the table below:

Sf-13, Sf-20	= 14.1
Sf-30	= 14.9
Uf-90	= 13.4
Ac-70, Ac-72, Ac-78 dv	= 15.7

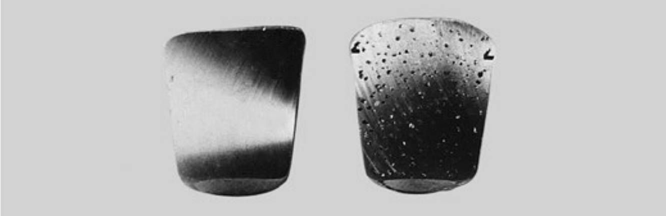


Fig. 1: Cut-open samples from a negative pressure density test using Anticorodal-70 dv

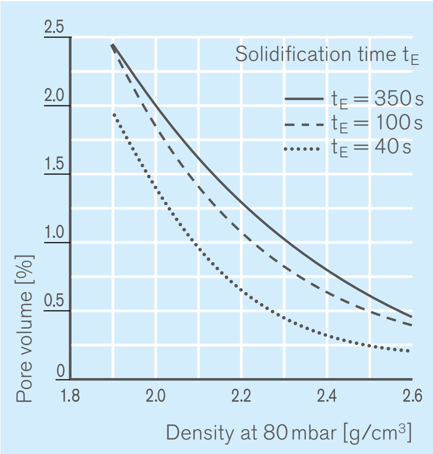


Fig. 2: Dependency of pore volume in casting structure on negative pressure density at 80 mbar

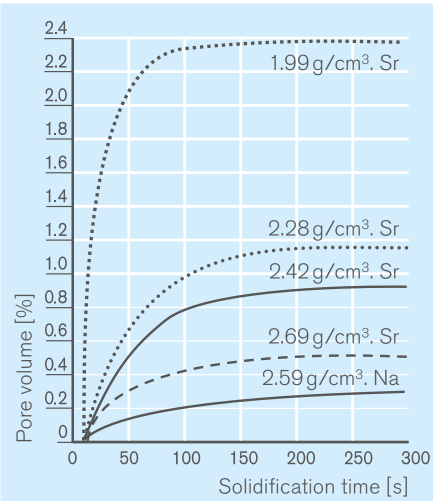


Fig. 3: Dependency of pore volume in cast structure on solidification time for melts with different negative pressure densities

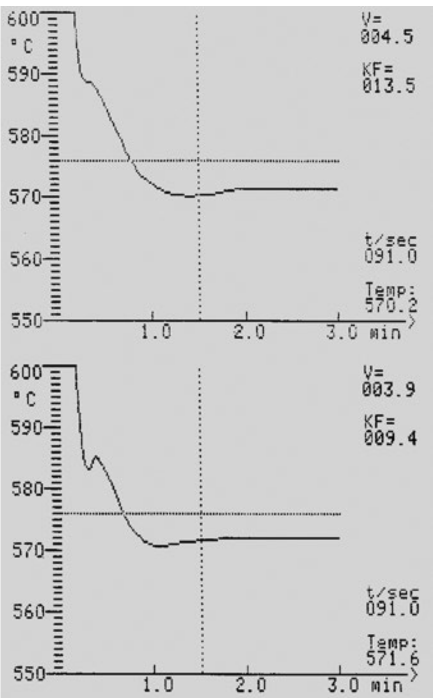


Fig. 4: Print-outs from thermal analysis

Since the nucleation state and degree of modification are contradictory, you should not aim for the highest possible nucleation state to ensure good modification of the casting. There is no point in adding more grain refiner to the melt if the maximum grain refinement values stated have already been reached. Not only is this a waste of money, but it will impair the modification, the microstructure and therefore the mechanical properties. The nucleation states listed are values from the computer in the EMTEC thermal analysis equipment, most commonly found in aluminium foundries. A guideline is entered in the computer for classification of grain size and this may differ when using other types of equipment; e.g. a nucleation state of KF 9 has a grain surface of 2.5 mm^2.

Monitoring modification

A thermal analysis is a good way of monitoring Na modification in AlSi melts. The analysis measures supercooling, i.e. the difference in temperature between the eutectic temperature of the unmodified melt and the eutectic temperature of the modified melt. This difference in temperature is known as depression. We have found that a depression of between 4 and 6 K ensures good modification. Due to the slower solidification, sand castings need higher depressions than gravity die castings. However the depression for sand castings with wall thicknesses of more than 40 mm should not exceed 5 K as a porous cast structure may otherwise result. As mentioned in the section on grain refinement, depression, also known as the degree of modification, is the opposite of nucleation state. A very high level of modification reduces the nucleation state which must not fall below 9 or the initial signs of micro and macro blowholes may result.

Aluminium melt tester

Using an aluminium melt tester involves solidifying around 80 g of melt at an increasingly negative pressure in a vacuum flask with sight glass. The emergence of the first bubbles on the surface of the sample is recorded in modern equipment with a camera. Pressure and temperature are recorded and the gas and/or hydrogen content of the melt calculated from these figures. Sand casters and gravity die casters in particular use the aluminium melt tester to set the hydrogen level which the casting needs for a healthy cast structure.

Melt testing using flow through filter

The flow volume or the time it takes for a particular volume to pass through a filter can be used to test casting alloys. A coarse filter, such as “Qualiflash”, will only provide insufficiently accurate quality levels. A fine filter with pressure support on the melt surface, as is offered by e.g. “PoDFA”, records a grain refinement nucleus as an impurity impacting on throughflow and is not therefore commonly used.

Artificial ageing
Heat treatment for special purposes
Self-ageing

Preface

The mechanical properties of most aluminium casting alloys can be greatly enhanced as required by the caster using heat treatment. The type of process used is determined by the intended effect and depends on casting alloy, casting method and solidification time.

The following casting states can be achieved from the most important type of heat treatment, artificial ageing:
artificially aged (T6)
partially aged (T64)
naturally aged (T4)

This treatment always consists of solution heat treatment and quenching; the subsequent ageing process then either takes place in heat or at room temperature depending on the desired state. A distinction is made between full and partial ageing depending on the ageing temperature and time chosen. No further heat treatment is required after solution heat treatment and quenching when using natural ageing. The castings age at room temperature.

Other heat treatment methods for castings include:
annealing
stress-relief annealing
stabilising
artificial ageing
overageing

Self-ageing alloys are alloys where the composition is consciously chosen so that simply storing the castings without any kind of heat treatment will result in a considerable increase in hardness and strength.

Artificial ageing

Artificial ageing normally comprises three stages of treatment:
• solution heat treatment
• quenching
• artificial, partial ageing or natural ageing

Precipitation occurs in the aluminium solid solution when ageing. This may take place when the aluminium solid solution displays decreasing solubility for one particular alloy component as the temperature falls. If the melt is rapidly cooled from a high solution heat treatment temperature by quenching, the structural constituent dissolved in the solid solution cannot be precipitated. The solid solution supersaturated in this way tries to precipitate this constituent again during ageing and to approach an equilibrium.

Artificial ageing can be repeated, starting with solution heat treatment for a shorter period of 4 hours. If repeated several times, there is a risk of the grains coarsening. If this happens, the mechanical properties of the casting become sub-optimum.

Solution heat treatment

Solution heat treatment causes a greater number of ageing constituents of the alloy to dissolve than is the case with an equilibrium at room temperature. The eutectic silicon is also cast in AlSi alloys. Temperature and time must be coordinated and the size of structural constituents determined by the casting's solidification time must be taken into account.

The annealing temperature should be as high as possible because solubility and speed of diffusion increase sharply with temperature. In practice it is around 10 – 15 °C below the melt temperature for low-melting structural constituents. The temperature must be kept at a level of at least ± 5 °C precisely.

The table contains approximate values for the heat treatment of our casting alloys.

The temperature should be slowly raised during solution heat treatment to remove the grain precipitation by means of diffusion. Otherwise there is a risk of the grains starting to melt. We would therefore recommend stepped annealing for thick-walled sand castings made from Alufont: 4 – 6 h at 490 °C, followed by 8 – 12 h at 520 °C. The annealing period is determined by the wall thicknesses of the casting, casting method and solution heat treatment temperature. The annealing time is calculated from the point when the ultimate temperature is reached.
The heating-up time is not taken into account.

Alloy	Chemical denomination	State	Solution heat treatment temperature °C	Solution heat treatment duration h	Quenching water temperature °C	Ageing temperature °C	Ageing duration h
Anticorodal-04	AlSi0.5Mg	T6	520–530	6–8	20	180–190	6–8
		T7	520–530	6–8	20	220–240	4–6
Anticorodal-50	AlSi5Mg	T6	520–535	4–8	20	155–160	7–9
		T4	520–535	4–8	20	15–30	120
Anticorodal-70	AlSi7Mg0.3	T6	520–545	4–10	20	155–165	6–8
		T64	520–545	4–10	20	150–160	2–3
Anticorodal-78dv	AlSi7Mg0.3	T6	520–545	4–20	20	145–160	2–15
Anticorodal-71	AlSi7Mg0.3-E	T6	520–545	4–8	20	155–165	6–8
		T7	520–545	4–8	20	200–230	6–8
Anticorodal-72	AlSi7Mg0.6	T6	520–545	4–10	20	155–165	6–8
		T64	520–545	4–10	20	150–160	2–3
Silafont-30	AlSi9Mg	T6	520–535	6–10	20	160–170	6–8
		T5	–	–	Air	210–230	6–8
Silafont-36	AlSi10MnMg	T6	480–490	2–5	20/Air	155–170	2–6
		T7	480–490	1–5	20/Air	190–230	1–3
		T4	480–490	2–5	20/Air	15–30	120
		T5	–	–	20	155–190	2–5
Silafont-38	AlSi9MnMgZn	T6	470–490	1–3	20/Air	155–190	1–3
		T6	470–490	1–3	20/Air	155–210	1–3
Silafont-13	AlSi11	O	520–530	6–8	20	–	–
Silafont-20	AlSi11Mg	T6	520–535	6–10	20	130–170	6–8
		T5	–	–	Air	210–230	5–8
Silafont-70	AlSi12CuNiMg	T6	520–530	5–10	20–80	165–185	5–8
		T5	–	–	Air	210–220	10–12
Castaman-35	AlSi10MnMg	T6	480–490	2–5	20/Air	155–170	2–6
Castasil-21	AlSi9Sr	O	345–355	1–2	Air	–	–
Alufont-47	AlCu4TiMg	T4	520–530	8–16	20–80	15–30	120
Alufont-48	AlCu4TiMgAg	T6	525–530	8–16	20–80	160–180	6–7
Alufont-52	AlCu4Ti	T6	525–535	8–16	20–50	160–175	6–7
		T64	525–535	8–10	20–50	135–145	6–7
Alufont-60	AlCu5NiCoSbZr	T7	535–545	10–15	80	210–220	12–16
		O	345–355	5–10	Air		
Thermodur-73	AlSi11Cu2Ni2Mg2Mn	T5	–	–	Air	210–270	10–12

EN	Denomination		Previous denomination
F	as-cast state	as-cast state, production state	
O	annealed	soft annealed	g
T1	self-aged	naturally aged	rl
T1		controlled cooling after casting	
T4	naturally aged	solution heat treated, quenched, naturally aged	ka
T5	stabilised	overaged without solution heat treatment	st
T5	quenched artificially aged	artificial aged without solution heat treatment	aw
T6	Artificially aged	solution heat treated, quenched and fully artificial aged	wa
T64	partially aged	solution heat treated, quenched and not fully artificial aged, underaged	ta
T7	overaged	solution heat treated, quenched and overaged, stabilised state	ü

The finer the cast structure, the faster the ageing constituents dissolve. The following applies to AlSi alloys:

- shorter time for gravity die casting, thin-walled sand casting and higher solution heat treatment temperature
- longer time for sand casting, thick-walled gravity die casting and lower solution heat treatment temperature.

Since the castings still only display low strength levels at a high annealing temperature, complicated castings must be stacked such that distortion from their own weight is kept low. Special annealing tools are needed in a few cases.

Depending on casting technique, high pressure die castings are harder to put through solution heat treatment than sand castings or gravity die castings due to the differing levels of gas bubbles included in the cast structure. Thanks to very fine grained solidification resulting from the high speed of cooling, solution heat treatment can deliver good results with a shorter time and lower temperature (480 – 490 °C).

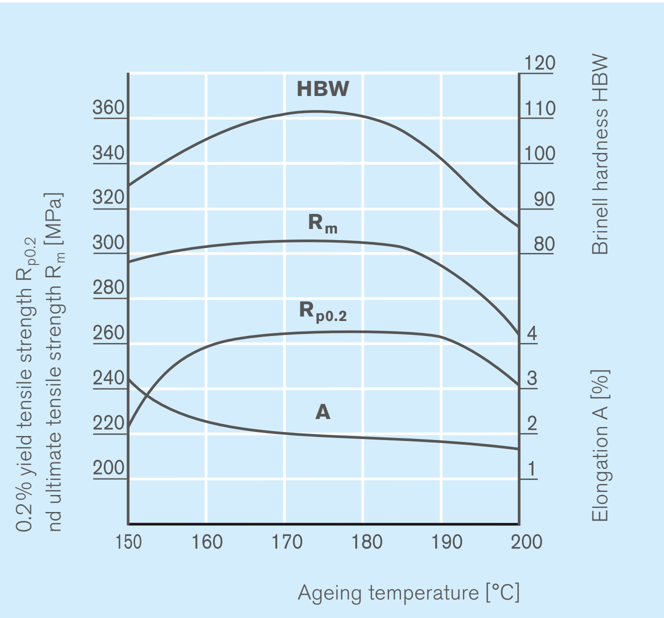


Fig. 1: Influence of artificial ageing temperature on properties of Silafont-30, AlSi9Mg, sand casting. Ageing time of 7 hours each, magnesium content of 0.28 %

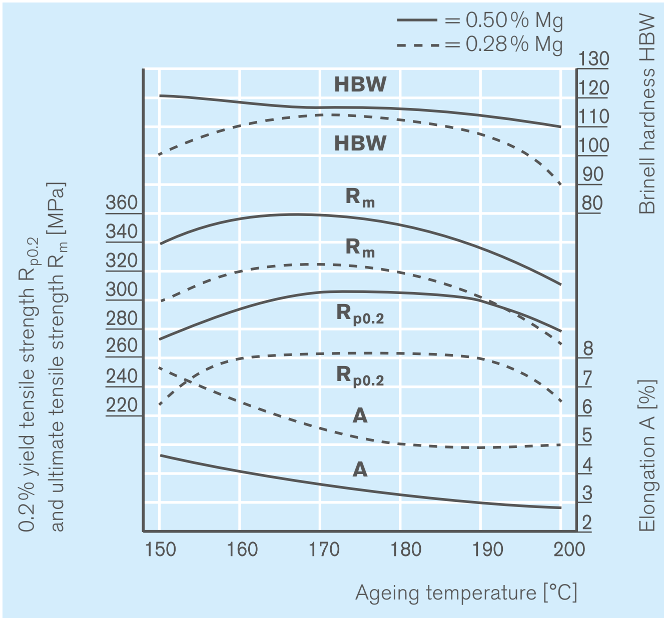


Fig. 2: Influence of ageing temperature on properties of Silafont-30 dv, AlSi9Mg, gravity die casting containing 0.28 % and 0.50 % magnesium. Ageing time of 7 hours each

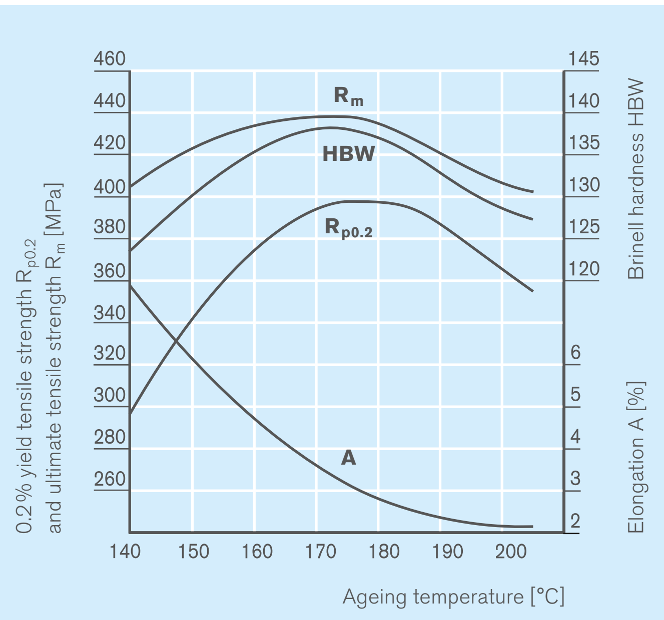


Fig. 3: Influence of ageing temperature on properties of Alufont-52, AlCu4Ti, sand casting. Ageing time of 7 hours each

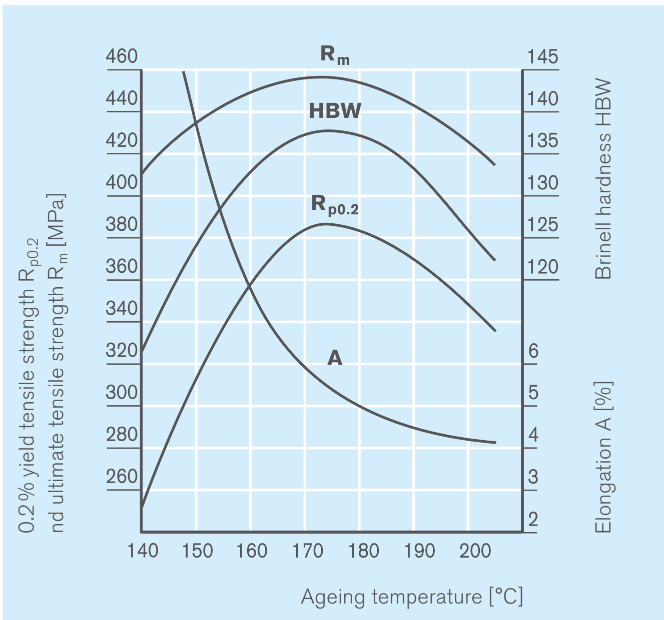


Fig. 4: Influence of ageing temperature on properties of Alufont-52, AlCu4Ti, gravity die casting. Ageing time of 7 hours each

Quenching
Quickly quenching the hot castings prevents the dissolved alloying elements in the aluminium solid solution from precipitating again. Water at room temperature is normally used for quenching. The water bath may be heated to no more than 60 °C as a result of quenching. Should the water temperature be higher locally, there is a risk of steam bubbles forming in the casting pockets and centre of the cage.

Shorter annealing times are generally used for gravity die castings and longer ones for sand castings. If working with AlCu alloys, use the figures for solution heat treatment for castings with wall thicknesses of up to 8 mm. Castings with thicker walls should be annealed at temperatures 10 °C lower for 12 – 18 h. A table comparing the names of the states can be found on page 99.

The time between the castings being removed from the annealing furnace and quenching should be as short as possible: 10 seconds for thin-walled castings and 30 seconds for thick-walled ones. Depending on design, e.g. abruptly changing wall thicknesses, high mechanical stresses may arise when quenching. The water temperature can be increased to 60 °C for castings and alloys with a tendency to high casting or quenching stresses.

In special cases, e.g. large high pressure die castings, quenching must be performed in an air flow, with or without water spray, or a polymer bath. The cooling rate should exceed 3.5 – 4 °C. The yield tensile strength in particular will however fall sharply in such cases.
If the castings require dressing, this must be undertaken immediately after quenching when still soft.

Artificial ageing (T6)
Artificial ageing of castings after solution heat treatment and quenching, usually at 155 – 180 °C, rectifies the enforced state of the alloy elements in the oversaturated solution. Hardness and strength are increased by sub-microscopic precipitation processes. Elongation steadily decreases at the same time. Maximum levels of hardness and strength are exceeded if ageing lasts any longer. Such processes can be controlled by the ageing temperature and duration selected. The higher the ageing temperature, the faster the processes. If the ageing temperature is too high, maximum strength is not reached (Fig. 1 and 6). Artificial ageing ends with cooling to below 100 °C.

If solution heat treated and quenched castings are delayed at room temperature for several hours before artificial ageing, maximum ultimate tensile strength, yield tensile strength and hardness values are not reached.

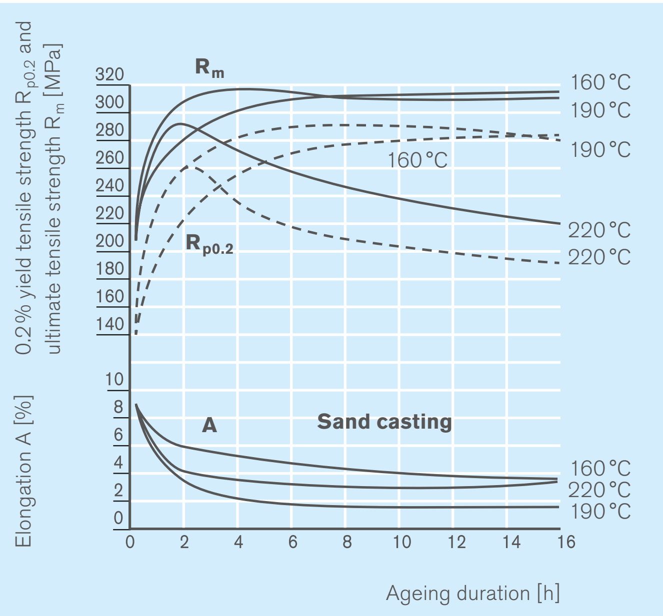


Fig. 5: Strength and elongation properties of an Anticorodal-70, AlSi7Mg0.3 quenched after solution heat treatment. Artificially aged at various temperatures over various periods

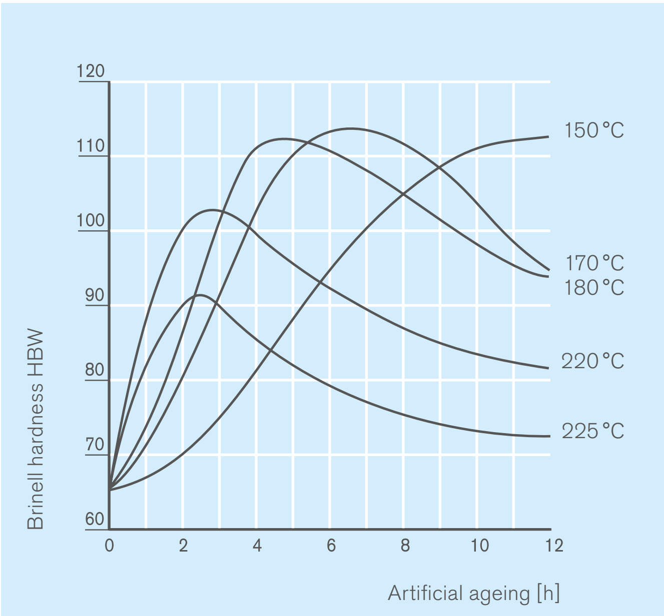


Fig. 6: Hardness spread of a Silafont-30, AlSi9Mg, gravity die casting. Artificial ageing at various temperatures over various periods after solution heat treatment and quenching

Partial ageing (T64)

Partial ageing is artificial ageing carried out in a shorter time or at a lower temperature after solution heat treatment. It aims to deliver higher elongation without maximum strength and hardness values.

Natural ageing (T4)

Castings from heat-treatable alloys, e.g. Anticorodal-50 and Alufont-47, but also high pressure die casting alloy Silafont-36, are stored at room temperature for around 6 days after solution heat treatment and quenching. This increases strength levels and delivers very good elongation values.

Heat treatment for special purposes

Special properties in the castings for special applications can be achieved through other specific forms of heat treatment.

Annealing (O)

If castings are annealed for several hours at 350 – 450 °C and cooled in the furnace, formability is improved through the casting of silicon crystals. Such castings can be cold formed using riveting and flanging. Elongation and fatigue strength are also improved.

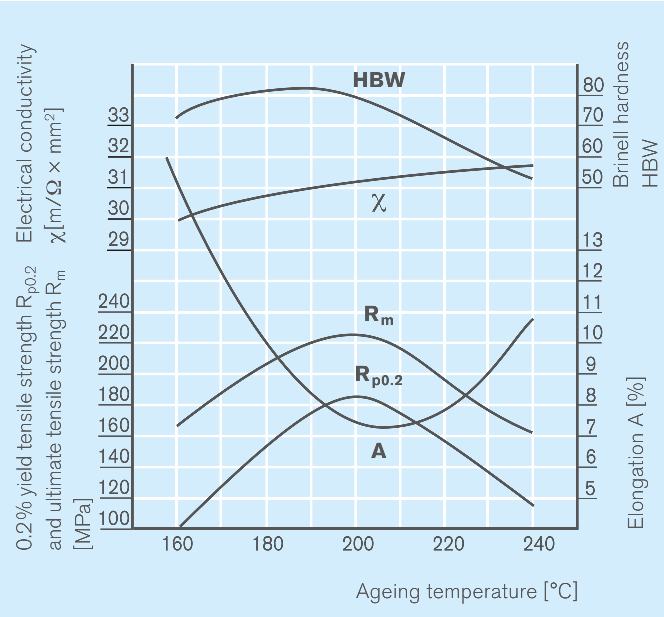


Fig. 7: Influence of ageing temperature on the properties of Anticorodal-04, AlSi0.5Mg. Ageing time of 7 hours each

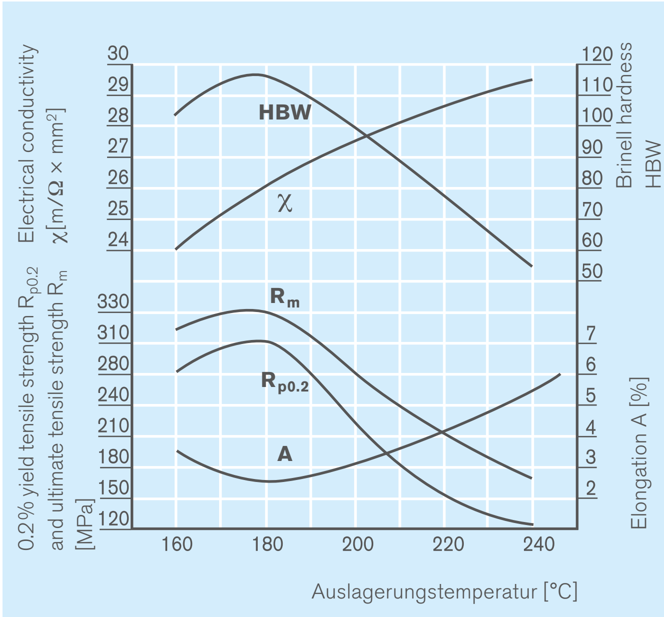


Fig. 8: Influence of ageing temperature on the properties of Anticorodal-71, AlSiMg0.3. Ageing time of 7 hours each

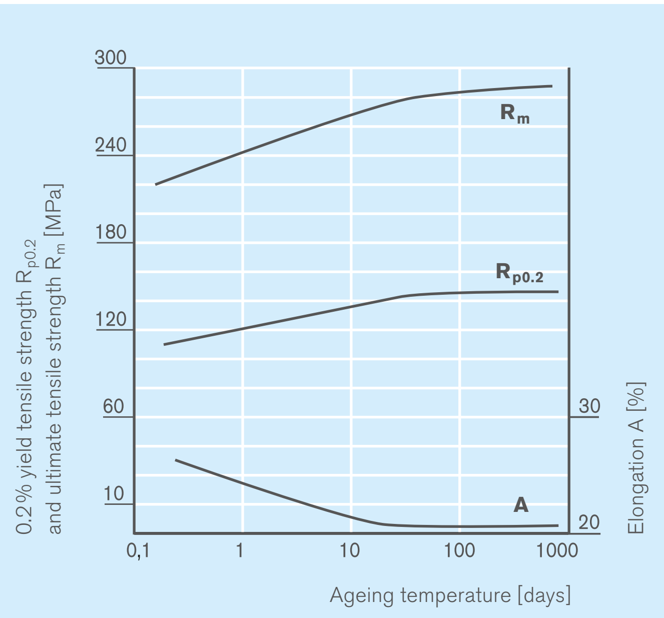


Fig.9: Mechanical properties on French gravity die casting test pieces made from self-ageing alloy Castadur-30, AlZn3Mg3Cr in days after casting

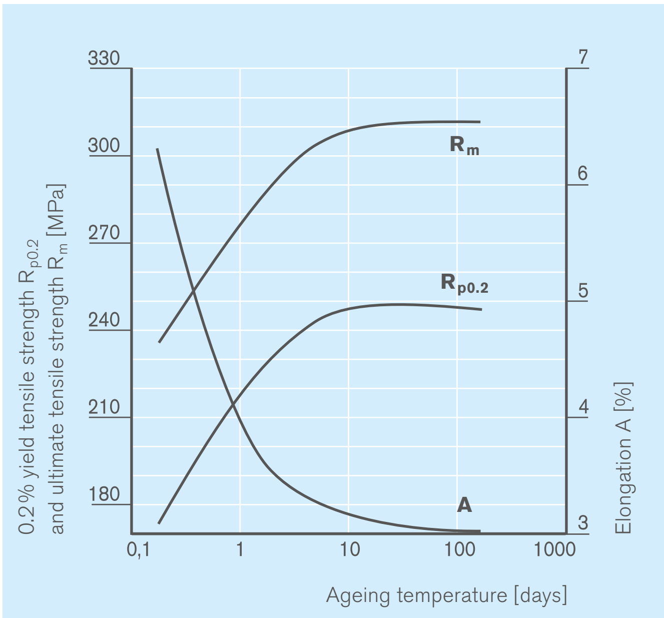


Fig.10: Mechanical properties on gravity die casting test pieces with 16 mm Ø made from self-ageing alloy Castadur-90, AlZn10Si8Mg in days after casting

The near eutectic alloy Silafont-13 is annealed at 520 – 530 °C for around 6 – 8 hours, high pressure die casting alloys for shorter periods at a lower temperature.

Stress-relief annealing (T5)

When solidifying castings, internal stresses occur as a result of different wall thicknesses, different speeds of cooling and the fact that various areas of the casting prevent shrinkage. In order to prevent the castings from distorting during operation, they can be annealed to be free of stresses before final machining. This annealing treatment is undertaken at 200 – 300 °C for several hours. The higher the temperature and the longer the treatment, the more effective it is. This treatment is undertaken on castings which require very accurate dimensions.

Designs with welded castings, including high pressure die castings, are annealed to remove the shrinkage stresses produced during welding at considerably greater speed.

Stabilising (T5)

Precipitation processes occur in all castings at higher operating temperatures and result in tiny changes in volume. This can be prevented in precision parts (pistons, optical modules and precision engineering) by undertaking stabilising annealing. The annealing temperature depends on the subsequent operating temperature. The annealing temperature is approx. 200 – 300 °C, rarely any lower.

Artificial ageing (T5)

This form of treatment is ageing without solution heat treatment. Artificial ageing can be used to improve the strength and hardness of simple gravity die castings or high pressure die castings made from heat-treatable alloys. A better result can be achieved if the castings are quenched in cold water immediately after being removed from the casting die. The temperature of the casting must be in excess of 350 °C when plunging. Huge scatter should be expected in the various wall thicknesses of the casting.

Overageing (T7)

After solution heat treatment and quenching, artificial ageing is undertaken at 200 – 240 °C. The aim of this process is higher electrical conductivity and elongation with lower strength in the alloys Anticorodal-04 and Anticorodal-71 (Fig. 7 and 8).

Self-ageing (T1)

Very good mechanical properties can be achieved in special alloys with a high zinc content, such as Unifont-90 and Unifont-94, Castadur-50, AlZn5Mg or Castadur-30, AlZn3Mg3 without heat treatment. This process is known as self-ageing and must not be confused with cold ageing which comes before solution heat treatment with quenching. Self-ageing starts when the castings are removed from the mould. The increase in strength is normally complete 8 days later (Fig. 9 and 10). Self-ageing alloys are used to cut heat treatment costs or for technical reasons, e.g. lower distortion level needed or due to the huge size of a casting.

Heat treatment for high pressure die castings

The mechanical properties of even high pressure die casting alloy Silafont-36 can be significantly improved through heat treatment. Unlike the case with sand and gravity die castings, here the high pressure die method determines the possible kind of heat treatment process. The crucial factor is whether solution heat treatment is even possible. If solution heat treatment is required, high pressure die castings have to be produced under special production conditions, such as enforced ventilation of the mould, controlled application of mould release agent and controlled metal flow. Gas or air inclusions in the surface areas of castings cast in the conventional way lead to the formation of blisters on the casting surface.

When working with large high pressure die castings in particular, it should be noted that the castings will distort if not correctly stored in the furnace and if suitable techniques are not used when plunging in the water bath.

Heat treatment without solution heat treatment

Annealing (O)

This form of heat treatment undertaken at 380 °C for 30 – 60 minutes reduces stresses in the rapidly solidified high pressure die casting microstructure and therefore increases elongation. This increased formability allows the cast design elements to be riveted and flanged, even when working with Silafont-36 with a higher magnesium content.

Artificial ageing (T5)

The yield tensile strength can be raised slightly using this simplified heat treatment process without any risk of the casting distorting. The risk of this happening during quenching and the amount of subsequent dressing work are also considerably lower than for heat treatment with solution heat treatment.

Once removed from the moulds, the castings are immediately quenched in the water bath and artificially aged. The effectiveness of artificial ageing is greatly determined by the temperature in the casting when removing from the mould and more precisely when plunging in the water. The higher this temperature (around 400 °C), the greater the potential for ageing during artificial ageing. Raising the yield tensile strength any further requires a delay of more than 10 hours before ageing at 190 °C for 120 minutes.

Heat treatments with solution heat treatment

Due to the fine-grained solidification of high pressure die castings, solution heat treatment can produce good results in a shorter time and at a lower temperature (480 – 490 °C) than in gravity die castings. Due to the Silafont-36 material, use temperatures of 520 – 535 °C.

Natural ageing (T4)

Amongst the various forms of heat treatment, natural ageing produces castings with the greatest elongation. The castings are solution heat treated, quenched and naturally aged for more than 6 days at room temperature. The casting is first held at the solution heat treatment temperature of 460 – 500 °C for 3 hours such that the elements soluble in the solid solution can diffuse in it. At the same time, the eutectic silicon is cast, making maximum elongation possible. Subsequent quenching in water prevents the dissolved elements from precipitating. Most of them remain in the solid solution matrix and only result in a small increase in strength during natural ageing.

Artifically aged (T6)

Heat treatment following T6 involves complete heat treatment with solution heat treatment (depending on the requirements between 460 – 500 °C), quenching in water and then artificial ageing. Because of the high temperature used for solution heat treatment, there is a risk of surface defects forming as the gas pores previously embedded start to expand. Measures must also be taken to prevent unwanted distortion when quenching the castings in water. Only full artificial ageing at 160 – 250 °C results in maximum alloy strength. Elongation produces values lower than when in the as-cast state. A Silafont-36 with a magnesium content of no less than 0.25 % should be used.

Overageing (T7)

If you start with fully aged state T6 and apply longer ageing times or higher temperatures (235 °C / 90 minutes), overaged state T7 will result. The aim of this treatment is a thermally stable cast structure with very good elongation and higher strength values than in state T4, Silafont-36 with a Mg content of less than 0.20 % produces the maximum elongation.

Quenching in air following solution heat treatment

In order to minimise high pressure die casting distortion, the casting is quenched in air rather than water after the solution heat treatment. From metallurgical side it is necessary to obtain more than 3 K/s in the temperature range between 500 and 350 °C. A yield tensile strength of more than 120 MPa can only be achieved with a magnesium content in excess of 0.30 %, if then aged for 2 hours at a temperature of 170 °C. This is more than 30 % below the maximum attainable yield tensile strength.

Fatigue strength

Dependence on quality of the structure

The quality of the structure is affected by the choice of alloy, its heat treatment, and in the case of AlSi alloys, the way the structure is formed. Fine distribution or avoidance of heterogeneous phases, such as silicon and iron, is desirable (Fig. 1). The silicon content lowers the fatigue strength of AlCu alloys, as does an iron content exceeding 0.16 % in AlSi alloys. A coarse structure and high grain boundary coating reduce the notch toughness (K_c) and fatigue strength (σ_w).

The casting process dictates the solidification and filling conditions, which also have an impact on the occurrence of pores, blowholes and oxides. A short solidification time results in a finer structure and therefore a significant improvement in the resistance to vibration. For example, a separately cast ingot of tempered AlSiMG alloy that solidifies in 5 seconds can withstand reversed bending stresses of $\sigma_{bw} = \pm$ 100 MPa with a fatigue life of $n = 50 \times 10^6$ whilst with a sand casting with an approximately 5-minute solidification period (30 mm wall thickness), this value falls to $\sigma_{bw} = \pm$ 30 MPa in order to achieve the same lifetime without fracture.

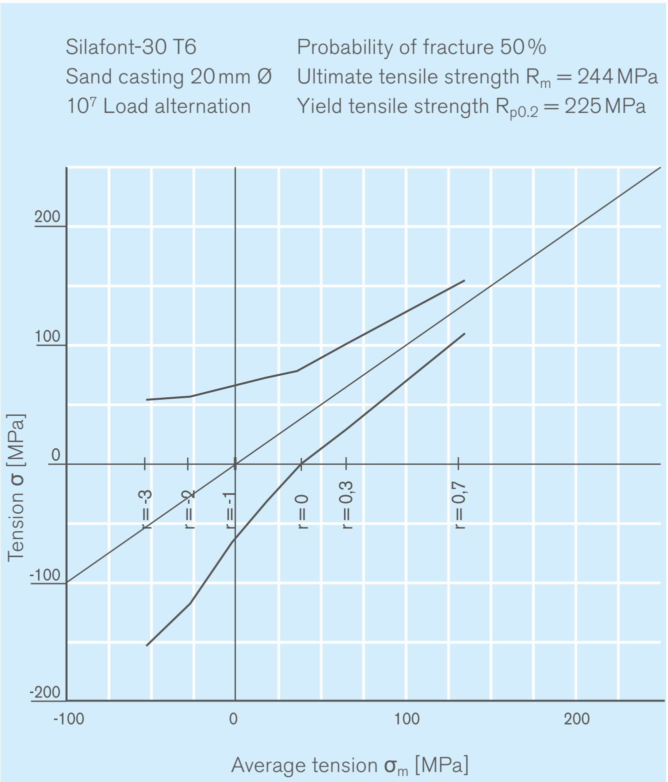


Fig. 2: Fatigue strength graph according to Smith for sand casting samples made from Silafont-30 T6, AlSi9Mg

Dependence on the surface quality

The term surface quality is defined as follows:

- the roughness of the surface as a result of the casting process
- casting defects such as heat cracks, stretcher strain marks and imperfections introduced by the mould material
- notching through corrosion or extreme mechanical stresses
- surface coatings

Synthetic resin coatings and ground surfaces increase the fatigue strength; hard surface layers, such as those that are created with anodising and chroming processes, reduce it.

Dependence on the stress range

The vibration fatigue strength is critically dependent on the level of stress (compression, alternate loads and tensile loads). The maximum strength in the pulsating range (r = 0.7) is always higher than in the alternating range (r = -1). The adjacent Smith diagram is based on DIN 50 100 (Fig. 2).

Note on the values for resistance to alternating stresses

The values for resistance to alternating stress in the chapter on mechanical properties are values from tests in accordance with DIN 50 113 or 50 142.

Note that in a casting in accordance with the criteria above, the resistance to alternating stress values can be reduced to as little as 25 % of the values given in the table if conditions are unfavourable. The functional safety of castings should therefore be subjected to dynamic component testing.

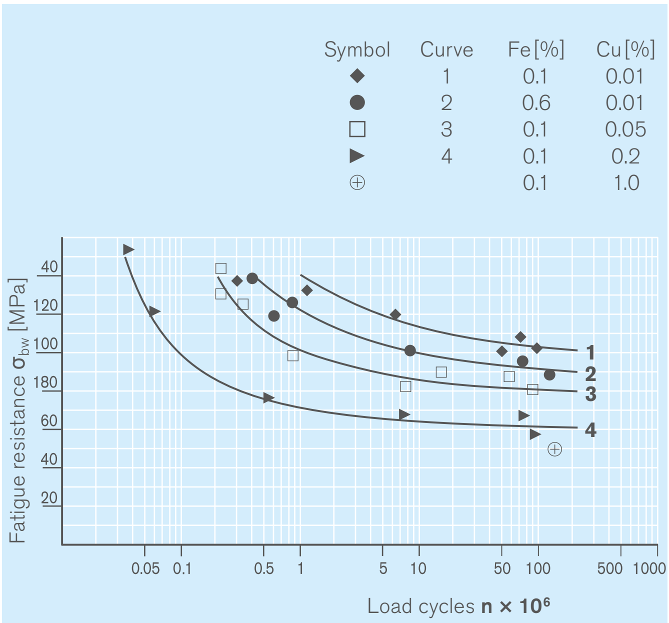


Fig. 1: Results from alternating bending tests on gravity die castings made from Unifont-90, AlZn10Si8Mg with different levels of iron and copper content

Corrosion

Thanks to its ability to form protective oxide coatings, aluminium offers excellent corrosion resistance for many purposes (Tab. 1). The corrosion resistance of an aluminium casting is greatly determined by the resistance of its oxide layer under the prevailing conditions. In the case of sand cast or heat-treated castings, the oxide layer is however 0.1 µm thick after a longer storage period in the elements. Destruction of the oxide layer may trigger a corrosive attack from aggressive media.

Silicon generally has less influence on the response to corrosion. The AlSi5, AlSi12, AlSi20 increments do however offer impressive corrosion properties. A higher Si content than that needed to attain good casting properties and sufficient mechanical strength should not therefore be selected.
The addition of magnesium or manganese ensures specific corrosion protection from salt water containing chloride and to a limited extent also to media containing weak alkalis.

Impurities in heavy metals such as copper, lead, nickel and iron may be harmful. Even small volumes will cause considerable corrosion damage. The link between the level of corrosion and copper content is shown in Fig. 1. This is the result of a real-life 33-month long test conducted on high pressure die cast alloy AlSi12 with varying levels of copper content. The corrosive attack on a gravity die casting with a higher copper content can be seen in Fig. 2 and 3. The remaining eutectic is attacked and dissolved selectively while silicon needles and the solid solution (dendrites) remain unaffected.

The formation of a local element often explains why corrosion concentrates in particular areas. Local elements occur in the presence of dampness and are the result of:

- external contact between aluminium and nobler metals, such as heavy metal components or non-alloyed steel
- solutions containing heavy metals
- penetrated sparkling foreign metals
- solid solution precipitations, especially compounds containing heavy metals in the aluminium alloy microstructure.

The purer the aluminium, the more resistant it is to corrosion. Both alloying elements and impurities affect the general resistance to corrosion to a certain extent.

Corrosion resistance

Corrosion resistance / Castability	average	good	very good	excellent
with surface protection	Af-47/-48 Af-52/-60	Sf-70 Td-73		
from weathering	Ca-30/-50		Sf-30 Uf-90 Uf-94 Ci-37 Ci-21	Sf-13 Sf-20 Sf-09 Sf-36/-38 Cm-35
from salt water	Ac-04 Pe-30/-36 Pe-50/-56	Ac-50 Ac-70/78dv Ac-71 Ac-72	Ma-59 Td-72	

Tab. 1: Castability and corrosion resistance of various aluminium casting alloys

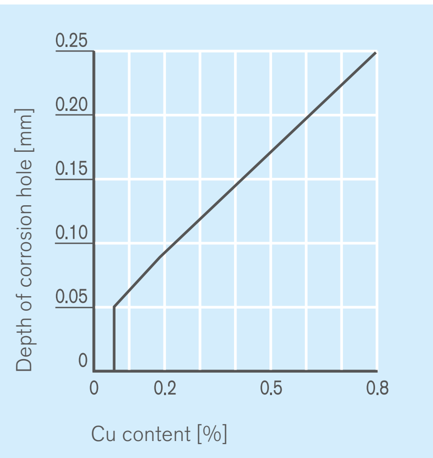


Fig. 1: Link between depth of corrosion hold in high pressure die cast AlSi12 and copper content

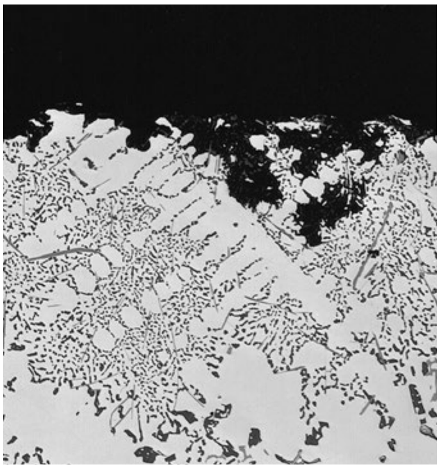


Fig. 2: Microsection of a gravity die casting made from AlSi12 with selective corrosive attack by residual eutectic

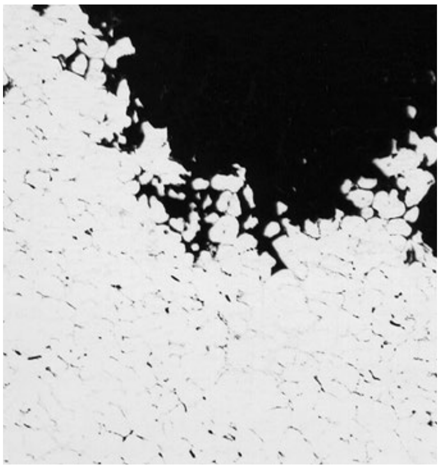


Fig. 3: Microsection of a sand casting after a prolonged corrosive attack

Corrosion protection

Polished surfaces are more corrosion resisting than the cast skin or roughly machined areas. Both gravity die castings and high pressure die castings are barrel finished by shot polishing with stainless steel balls. The compressed surface ensures a high level of corrosion protection.

The protective effect of the natural oxide skin can be boosted by layers of oxide up to 80 µm thick produced by electrolysis. This technical protective form of oxidation is possible with any aluminium alloy. Decorative oxide layers are best on silicon-free casting alloys and are 10 – 25 µm thick. TiZr-based layers of phosphate and chromate produced chemically can also be used as oxidation protection and the chromate layers in particular as a good adhesive layer for organic coatings (Fig. 3).

The lacquer coating on the castings requires pretreatment to suit the coating in the form of grinding or blasting with corundum. Steel grain must not be used because scoring will result in contact corrosion. The de-greasing and refinement of high pressure die castings before coating should be closely coordinated with the high pressure caster in terms of the mould release agent he uses and / or remaining material, e. g. from the penetration crack test. Castings subject to severe surface loads are then primed.

All castings should pass through additional heat treatment at 140 – 200 °C for more than 1 hour between the final rinse and the coating being applied for all gases to be emitted on the die surface. If castings are heat-treatable or have already been heattreated, this hardening process is continued.

The powder lacquers to be applied next have thicknesses of 25 – 100 µm and are enamelled at baking temperatures of 120 – 220 °C for 20 minutes. If lacquering in several colours, the casting passes through the enamelling furnace the corresponding number of times (Fig. 5). Ageing effects start at 140 °C. The following changes result in the Silafont-20 dv car wheel shown when lacquering. This started as a gravity die casting in as-cast state.

Lacquer	$R_{p0.2}$ MPa	R_m MPa	A %	HBW
none	85	195	12.5	62
with	104	201	10.3	63

There is an impact to mechanical properties due KTL-coating, especially with thin-walled die castings; but not with Castasil-37.

As well as offering general corrosion protection, coatings often also provide sufficient protection from contact corrosion. Plastic insulating parts or paste-like seals are better suited to this. The risk of contact corrosion in the event of contact between construction steel and aluminium can be reduced by zinc-coating the steel parts. Stainless steels do not generally produce contact corrosion when making contact with aluminium.

Galvanic layers can offer protection to aluminium castings with a dense outer structure as is the case with gravity die castings for electrical engineering which are given a layer of silver to protect from spark corrosion.

If they contain sulphur and phosphorous, cooling and lubrication media used when machining aluminium castings may result in corrosion damage. Silica-based coolants should be used and the machined castings degreased straight away.

Fig. 4: Flow meter cell for jet fuel; chromated before coating

Fig. 5: Car wheel with multi-coloured lacquer

Welded designs with aluminium castings

Welded designs made from casting materials or mixed designs made from cast and wrought materials are state of the art, used e.g. for lightweight constructions in vehicle bodies or for large constructions in energy plants. These applications make specific use of the benefits of the casting technique, in particular the design scope and reliable welding technique (Tab. 1).

The physical, chemical and mechanical properties of aluminium produce particular welding characteristics which are very different to those of ferrous materials. In particular the stable oxide layer on the surface has to be removed or torn off to ensure perfect welded joints. When arc welding with protective atmosphere, this oxide layer is removed by the cleaning effect of the ionised protective atmosphere along with the interaction of the electrons flowing between the workpiece and electrode.

Despite the low melt range, when compared with ferrous materials, welding aluminium requires roughly the same amount of heat because of the high thermal conductivity and melt heat. Aluminium shrinkage during solidification and cooling often produces welding cracks, distortion and internal stresses.

The liquid aluminium may absorb hydrogen from its surroundings. This is precipitated during solidification, resulting in pores of different sizes in the weld seams depending on the speed of solidification.

Welding with protective atmosphere
Welding with protective atmosphere is the one welding method which allows the peculiarities of aluminium welding to be mastered to perfection. Inert gases such as argon (quality 4.8) are usually used as the protective atmosphere.

Casting materials	Anticorodal-50 Anticorodal-70 Castasil-21	Silafont-30 Silafont-13 Silafont-20 Castasil-37 Silafont-36	Unifont-90	Peraluman-30 Peraluman-50/-56 Castadur-30/-50 Magsimal-59	Alufont-52 Alufont-47
Anticorodal-50 Anticorodal-70	AlSi5				
Silafont-30 Silafont-13 Silafont-20 Castasil-37 Castasil-21 Silafont-36	AlSi5	AlSi5 AlSi10			
Unifont-90	AlSi5	AlMg4,5Mn AlSi10	AlMg4,5Mn AlSi10		
Peraluman-30 Peraluman-50/-56 Castadur-30/-50 Magsimal-59 Thermodur-72	AlMg3 AlMg5	AlSi5 AlMg3 AlMg5	AlMg4,5Mn	AlMg3 AlMg5 AlMg4,5Mn	
Alufont-52 Alufont-47		AlSi5 AlMg5		AlMg5 (AlSi5)	AlMg5 (AlSi5)
Wrought materials					
AlMgSi1	AlSi5	AlSi5	AlSi5	AlSi5 AlMg5	AlSi5 AlMg5
AlZn4,5Mg1	AlSi5 AlMg5	AlSi5 AlMg5	AlMg4,5Mn	AlMg5 AlMg4,5Mn	AlSi5 AlMg4,5Mn
AlMg2,7Mn	AlSi5 AlMg5 AlMg4,5Mn	AlSi5 AlMg5 AlMg4,5Mn	AlMg4,5Mn	AlMg5 AlMg4,5Mn	AlSi5 AlMg5 AlMg4,5Mn

Table 1: Choice of addition materials for welding aluminium cast materials and for combining with wrought and casting materials

There are numerous modified methods which are used for particular welding work. Arc welding with protective atmosphere gas works with electrodes which cannot be melted (WIG) or melting electrodes (MIG).

When manually WIG welding with the same kind of addition material, the casting defects which arose during casting (blow-holes, mechanical damage, differing dimensions) are rectified.

Given its high speed, the MIG method is the most popular for series welding with castings. The method uses direct current and electrodes with positive polarity.

These days MIG pulsed welding is performed by robots and using welding parameter programs to monitor the very different wall thicknesses on the material transition between wire and casting.

The plasma MIG method with its ideal formation of arcs and screening of the protective atmosphere is suited to applications with tough seal integrity, surface quality and mechanical loading requirements, e.g. high-stress gearshift housings.

Casting materials which can be welded

The differing structural formation, gas porosity, micro blowholes and cast skin near the weld seam greatly influence the quality of the weld joint. If specific casting guidelines are observed, perfect joints can be produced and are suited to use in high-stress designs.
The AlSi alloys are particularly good for welding.

The following display particularly good weldability:	
Silafont-13, AlSi11	Silafont-36, AlSi10MnMg
Silafont-30, AlSi9Mg	Castasil-37, AlSi9MnMoZr
	Castasil-21, AlSi9Sr

Good weldability:	
Anticorodal-70, AlSi7Mg0.3	Magsimal-59, AlMg5Si2Mn
Alufont-52, AlCu4Ti	Unifont-90, AlZn10Si8Mg
Peraluman-30, AlMg3	Thermodur-72

A distinct heat influence zone forms around the weld seam in aluminium alloys. Changes to the structure which impact on strength occur in this zone, depending on the base material, heat treatment state, addition metal, welding method and geometry.

Alloys which have already been aged suffer strength problems as a result of welding. In the worst case scenario, strengths may fall to that of the as-cast state of gravity die castings. A self-ageing alloy ages again after welding. Non-rusting tools should be used to brush or grind off the cast skin on solution heat treated castings in order to prepare welding edges.

The design of the weld joint and accurate welding (bath protection, edge shape, edge preparation, cleaning) are crucial to producing a welded design suitable for aluminium.

Addition metal

The choice of addition metal depends on the composition of the base materials and the properties required of the weld joint. The addition metals used for protective atmosphere welding of casting materials are listed in Table 1. In principle select addition metals of a similar alloy; exceptions are possible if required due to welding considerations.

As a result of the weld seams shrinking, most of the internal welding stresses occurring nearby are tensile stresses. The stresses can be reduced slightly by avoiding clusters of seams, workpiece preheating or subsequent shot peening. Significant reductions can however only be obtained from stress-free annealing. In artificially aged alloys, this results in a reduction in strength; if followed by artificial ageing, strength values can only be returned to those of state T5. Appropriate welding and design measures should be taken to avoid dressing welded designs wherever possible.

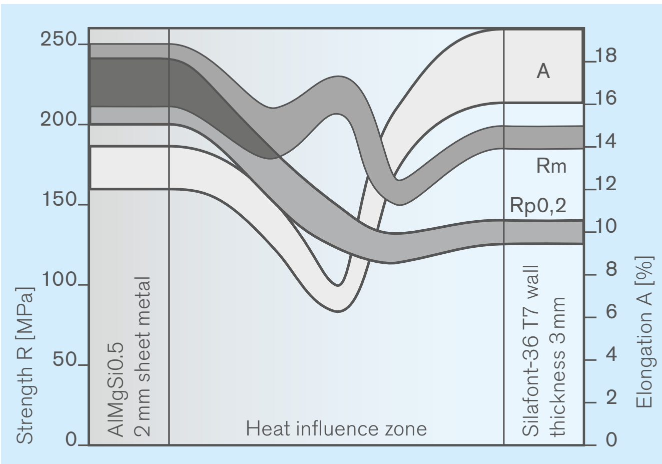


Fig. 1: Strength values of the heat influence zone of MIG welding with AlSi12 addition material

Joining techniques for die castings

Flanging

Silafont-36 with a magnesium content of approx. 0,16 % can be used particularly for flanging technology. The designer can thus join the aluminium pressure die castings to other materials such as steel and plastic. This can be applied as fixing but also as structural jointing technology with appropriate construction design. The configuration of the flanging edge mostly requires an elongation of at least 8 % on the pressure die cast material. Therefore high internal quality requirements are set on this area of the casting. As consequence, in this kind of applications the design of the die must guarantee good metal flow in the flanging edge. What has to be kept in mind especially with Magsimal-59.

Glueing

Magsimal-59 and Castasil-37 are die casting alloys with the requested properties for structural application in the as cast state. There is no dimensional correction needed due there is no heat-treatment. That gives high benefit to the assembling with glueing.

Self-piercing riveting

Joints, in which the casting is the lower layer in the riveting joint, have particularly high requirements concerning the absence of defects in the cast material. Figures 2a and 2b show the result of a self-piercing riveting trial in our laboratory.

It should be noted that Castasil-37 can be self-piercing riveted in the as-cast state also under these severe design conditions, i.e. using a rivet die with flat geometry. The Castasil-37 batch used for this trial had a yield strenght of 114 MPa, an ultimate tensile strength of 255 MPa and 14 % elongation. A further improvement in deformability is achieved in temper O.

Welding

The suitability of high pressure die castings for welding is highly dependent on the melt and high pressure die casting process. Casting materials and melt and high pressure die casting methods which ensure low gas absorption and oxide impurity during high pressure die casting are needed.

The designer may place weld seams in zones with less loading, but, for a high pressure die casting, they should also be close to the ingate.

Fig. 3 shows 8 target levels of the high pressure die casting, the final one being a casting suitable for welding and heat treatment. The high pressure die casting methods and stages required for these are illustrated in terms of removing air, transport of melt and application of mould release agent.

High pressure die castings made from Silafont-36 and Castasil-37 are particularly well suited to welding, with both MIG and WIG standard methods. The AlSi5 or AlSi10 welding addition material is preferred for welded designs with AlMgSi0.5 wrought alloys. The weld seams and/or heat influence zones between components made from aluminium wrought alloys and high pressure die castings made from Silafont-36 and Castasil-37 withstand repeated loads perfectly if the cast edges feature a low number of pores and are virtually free of the oxide skin after any T7 heat treatment undertaken.

Fig. 1 on page befor states the mechanical values in the heat influence zone. Unlike elongation, the strength values in this zone are hardly influenced.

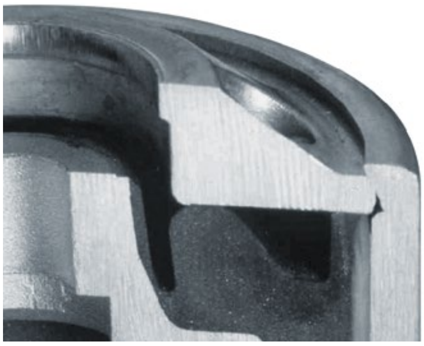


Fig. 1: Vibration damper housing made of Silafont-36, AlSi10MnMg, with structural flanging

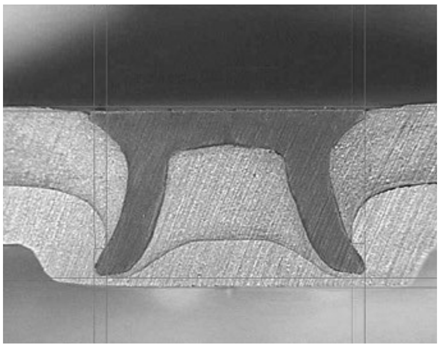


Fig. 2a: Cross section of a self-piercing riveting trial, 5 mm rivet, 1.5 mm AlMg3 sheet metal, under Castasil-37, AlSi9MnMoZr die cast plate in the as-cast state (F)

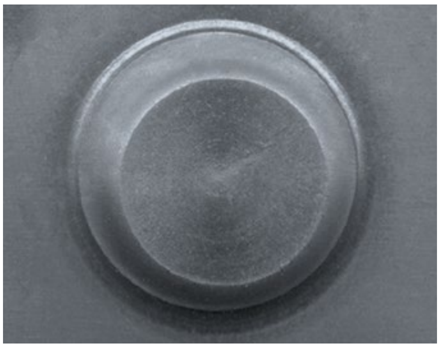


Fig. 2b: View from below

Magsimal-59 and Thermodur-72 have a higher shrinkage rate and contraction force than AlSi high pressure die casting alloys. Mould release agents recently developed for work with this alloy improve both: the ease of flow and the ability to slide during ejection; and due this the suitability of the high pressure die castings for welding.

Design welding with castings made from Magsimal-59 and Thermodur-72 is undertaken with the AlMg4.5MnZr addition material using the WIG method or laser/electron beam welding method.

Wall thickness 4 mm	R_{p02} [MPa]	R_m [MPa]	A [%]
Not welded	165	287	17
Welded	148	246	6

The mechanical properties applicable to manual MIG welding with the AlMg4.5Mn addition material illustrate how the mechanical properties of Magsimal-59 in the heat influence zone are hardly affected compared with elongation.

8 Target levels for HPDC

There are higher requirements for the production of crash relevant structural castings than for general purposes. Depending on your requested targets shows the 8-level-staircase the right alloy and for the main areas of HPDC some suggestions.

We devide between dosing technique, air reduction in the cavity, melt handling and application of die release agent.

Fig. 3 shows 8 target levels of the high pressure die casts, the final one being a casting suitable for welding and heat treatment.

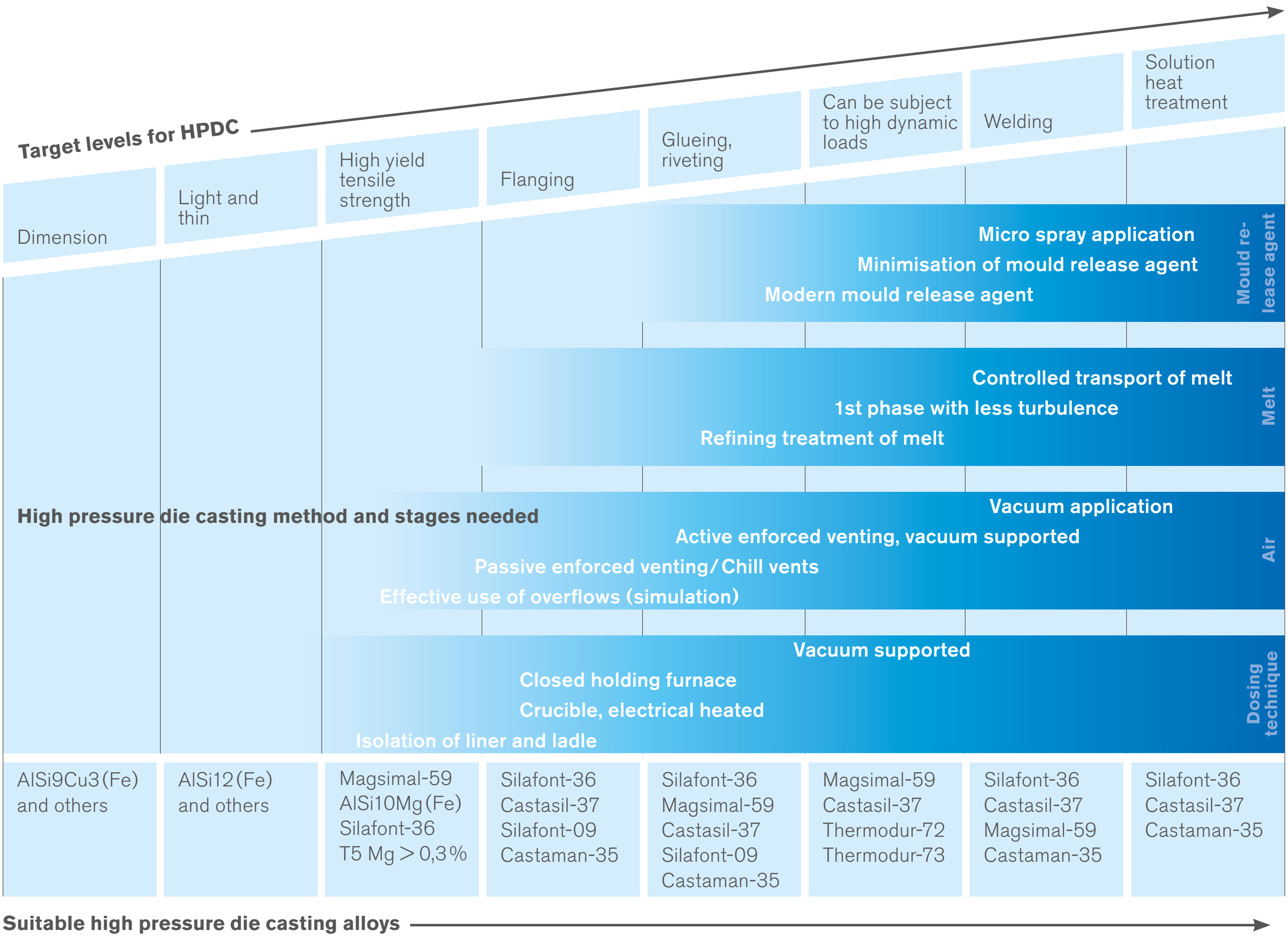


Fig. 3: Eight target levels of high pressure die casting with details of the alloys to use and the high pressure die casting method and stages required

Machining aluminium castings

Wear criteria for machining tools

Tool service lives or cutting distances affect economic viability in production. Short service lives or cutting distances are only recommended for small volume production runs as replacing the tool may have a huge negative impact on time in large-scale volume production.

Tool wear is often only seen as a major factor when considering the silicon content of an aluminium casting. But simply knowing the silicon content does not help you know the loads to which the tools can be subjected. The microstructure and strength are key to determining wear levels; less so for carbide tools than HSS tools, e.g. hammer drills. Tools equipped with diamonds are of course the best cutters.

Primary aluminium casting alloy Silafont-13, AlSi11 has two structure states: granular (Fig. 1) and a modified structure (Fig. 2). We have found with carbide tools that castings with a granular structure have service lives up to 10 % shorter than those of modified ones. Even greater differences have been found during cutting distance and service life tests with HSS drills (Fig. 3).

Ageing has yet a greater impact on service life or cutting distance than the structural modification of silicon content in alloys. Artificial ageing of a Anticorodal-70, AlSi7Mg0.3 reduces the tool cutting distance by 75 % compared with the as-cast state.

These comparisons should illustrate how the machine parameters must be adapted to the microstructure when machining is in order to deliver cost effectiveness.

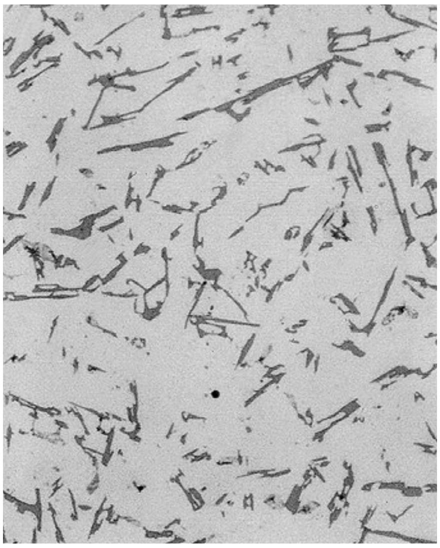


Fig. 1: Granular structural modification of a Silafont-13, AlSi11 casting alloy

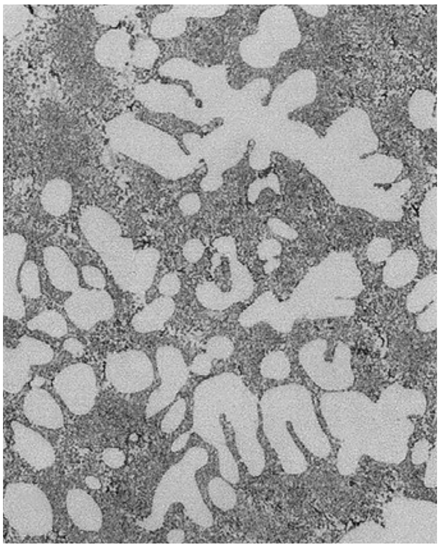


Fig. 2: Modified structure of a Silafont-13, AlSi11 casting alloy

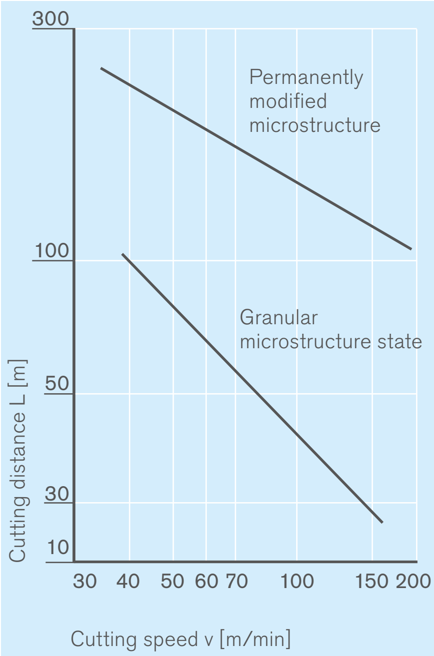


Fig. 3: Influence of microstructure state on cutting distance for Silafont-70, AlSi12CuNiMg

We would like to thank all our business partners who have provided castings or photographs for this publication.

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