AMETAL® - TA'S DEZINCIFICATION RESISTANT COPPER ALLOY

AMETAL® is a patented special copper alloy, combining excellent corrosion resistance with high mechanical strength.

AMETAL®

TA's dezincification-resistant copper alloy, AMETAL®, was developed by the Company at the beginning of the 1960s for use in the then recently introduced die-casting production method, and was patented in 1963. It has been progressively improved over the years, so that there are now three variants, each optimised for specific applications:

1. Die-casting
2. Hot stamping
3. Bar machining

AMETAL® APPLICATIONS

AMETAL® is a special copper alloy, combining excellent corrosion resistance with high mechanical strength. The most important applications for the various TA products made from it are as follows:

Shut-off valves for heating and cooling systems and for tap water systems.

Balancing valves for heating and cooling systems.

Components for connection of hard and soft copper pipes, steel pipes and cross-linked polyethene pipes (PEX), for heating and cooling systems, tap water systems and process plant installations.

We constantly improve our alloys: 1999 saw the introduction of a new fine-grained die-casting alloy with aid of a very low boron addition (about 5 ppm). In conjunction with the very fast cooling process that is inherent in die-casting, this creates a very finely grained and homogenous structure in the metal. With our own x-ray spectrometer, we can control the chemical analysis to a high degree of precision.

The end result is a product that meets the most stringent requirements in respect of dezincification resistance.

1. AMETAL® - DIE-CAST

Ingots of AMETAL® are melted at 970°C in an induction furnace. An automatic charger carries the molten metal to the die-casting machine and empties it into the recipient chamber, from where a piston presses it at high pressure and speed into the steel die.
The die incorporates cooling coils, through which water circulates to speed up solidification of the metal and to protect the die from overheating. When the metal has solidified, the die opens and the moulded item is ejected by stripper pins and the cycle is repeated. (See figures 1-3).

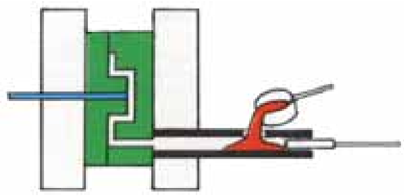


Figure 1. Starting point of the cold chamber die-casting machine cycle. Molten metal is being poured into the cold chamber.

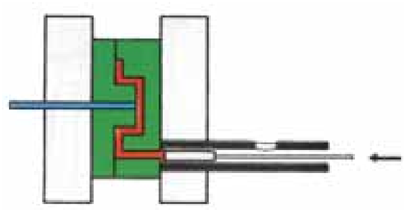


Figure 2. The piston is pressed into the cold chamber and forces the metal into the die.

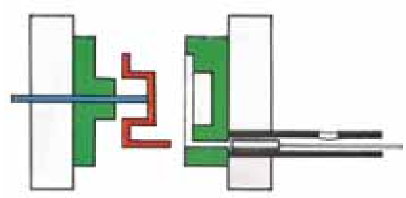


Figure 3. When the molten metal has solidified, the die opens and the casting is ejected.

2. AMETAL® - HOT STAMPED

The raw material for the process consists of round AMETAL® bars. They are cut into small pellets, heated to about 800°C in an induction furnace and hot stamped to shape in a screw or eccentric press. (See figures 4-6).
Optimisation of the properties and production processes of the alloy have resulted in the AMETAL® bars today being produced by horizontal continuous casting (figure 7): previously, they were produced by the classical methods of vertical or horizontal casting, followed by extrusion (figure 8).

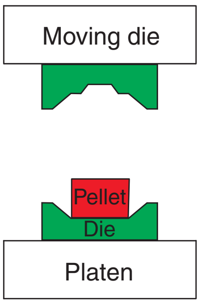


Figure 4. Starting point of the hot stamping cycle. The heated pellet is in the lower part of the die.

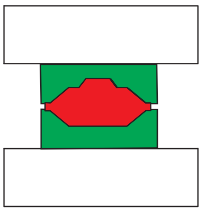


Figure 5. The press closes, and squeezes the pellet to the required shape.

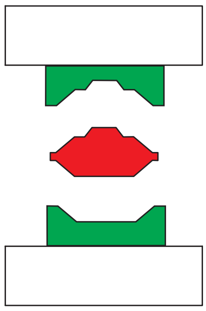


Figure 6. The press opens and the part is removed.

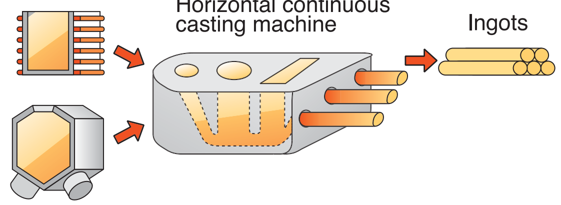


Figure 7. Manufacturing bars by horizontal continuous casting.

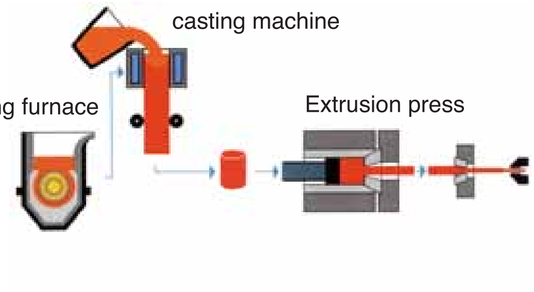


Figure 8. Manufacturing bars by vertical continuous casting and extrusion.

3. AMETAL® - BAR, TUBE AND PROFILE

Machined AMETAL® items from bars, tubes and profiles. AMETAL® bars, and machined in automatic machines. This means that the parts of the production process that have the greatest effect on the mechanical properties of the material are carried out by Tour & Anderssons' subcontractors, and are:
- Smelting and alloying of the raw materials in induction furnaces to produce AMETAL®.
- Casting the molten metal into ingots in vertical or horizontal continuous casting machines.
- Extrusion to a suitable stock shape: bar, tube, profile.
- Heat treatment to convert the β-phase to α-phase.
- Acid etching to remove the oxide skin formed during heat treatment.
- Cold drawing to produce the correct size and hardness.

Figures 8 and 9 show the entire process in simplified form.

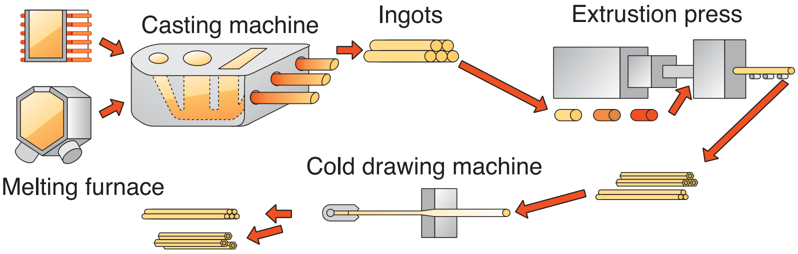


Figure 9. Manufacturing bars by horizontal continuous casting and extrusion.

THE EFFECT OF MANUFACTURING METHOD ON ALLOYING CONSTITUENTS AND RESULTING METALLURGICAL STRUCTURE

AMETAL® stands out among copper alloys for its combination of suitability for manufacture of complicated shapes and excellent corrosion resistance and mechanical properties. Naturally, to obtain this performance means that the composition of the metal must be held within certain limits. The table below shows the nominal chemical analyses of the three AMETAL® alloys.

	Cu+Ni	Zn (approx.)	Pb	Si	Fe	As	Al	Sn (max)	Ni (max)	Mn (max)	Other (max)
1 AMETAL® GJPR	63,7	**32,5**	1,9	0,73	0,25	0,06	0,05	**0,40**	**0,40**	**0,15**	**0,2**
2 AMETAL® PRV	65,0	**31,8**	1,8	0,65	0,15	0,05	0,28	**0,30**	**0,30**	**-**	**0,2**
3 AMETAL® bar, tube, profile	65,5	**31,3**	1,8	0,65	0,15	0,05	max 0,03	**0,30**	**0,30**	**-**	**0,2**

Key: GJPR = die-cast, PRV = hot stamped

1. Die-casting, which starts from molten metal and is a fast process, requires melt of high fluidity, which is why this alloy has higher zinc and silicon contents.
The rapid cooling process also means that the crystalline structure is more dispersed and disordered, and that any porosities are small (= microporous). The crystalline structure and its size are affected by the solidification time: thick sections cool more slowly than thin sections. However, heat treatment for phase conversion is unnecessary as the structure is dispersed, which is a considerable benefit for castings.

2. Hot stamping, which starts from a heated bar blank, requires a higher proportion of β-phase material at the shaping temperature, as the β-phase is easier to hot stamp. See Figure 10.

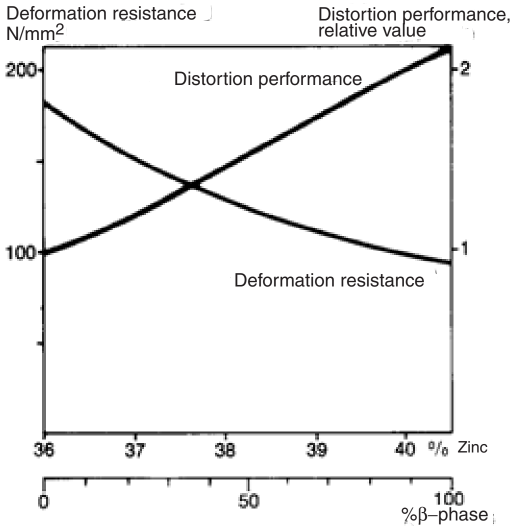


Figure 10 The effect of β-phase percentage on the deformation resistance and relative distortion performance of hot stamping. A higher β-phase proportion is achieved by increasing the amount of aluminium. Much of the β-phase is converted to α-phase by subsequent heat treatment, thus ensuring good dezincification resistance.

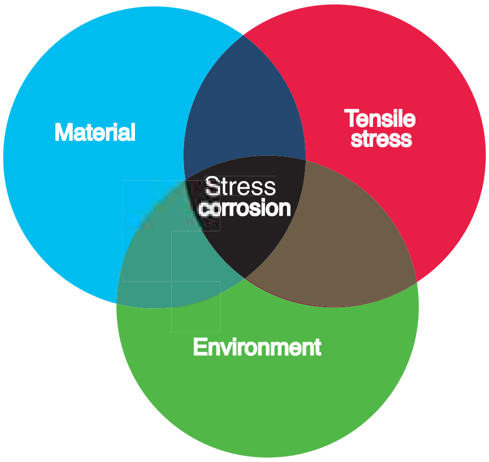
3. Machining parts requires good machinability of the metal, which includes good chip-breaking properties. This is why a certain minimum quantity of lead is required, for good chip-breaking and lubrication performance, while quantities of manganese and iron, which produce particles that accelerate tool wear, may not exceed certain values.
α/β-brass has better chip-breaking performance as a result of the grain boundaries and interaction between the α and β crystals. Nevertheless, AMETAL® is heat-treated prior to machining in order to remove the β-phase. This is done because the phases in the extruded bars tend to lie in long strips as a result of the method of manufacture. Long β-phases would provide a point of attack for deep dezincification. The copper concentration in this version of the alloy is higher than that in the other two versions in order to be certain of total conversion of β-phase to α-phase.
Heat treatment softens the material, producing a single crystalline phase and fewer grain boundaries, and so it is necessary to cold-draw the material to harden it before machining. Cold drawing also improves the dimensional accuracy of the bars. The amount of reduction affects the hardness of the material and so also its machinability.

It can be mentioned, as a comment on the table above, that all three alloys have been type-approved by SITAC for use in tap water systems as follows:
AMETAL® GJPR: TG no. 4482/86 and 1105/99
AMETAL® PRV and bar: TG no. 4378/86
In addition, AMETAL® easily meets the most stringent anti-dezincification requirements in Australian and British standards. The AMETAL® GJPR and AMETAL® PRV alloys are the subjects of patent applications.

A COMPARISON OF THE PROPERTIES OF VARIOUS COPPER/ZINC ALLOYS AS USED IN THE PLUMBING SECTOR

Material property	Free machining brass	Gunmetal, cast	AMETAL®, die cast	AMETAL®, bar
UTS, R_m, N/mm²	500	200	470	470
Yield strength, $R_{p0,2}$, N/mm²	400	90	280	340
Rupture extension, A_5, %	20	13	16	20
Hardness, HV	150	70	120	145
Dezincification resistance	Poor	Excellent	Excellent	Excellent
Sensitivity to stress corrosion	High	Very low	Low	Low

Stress corrosion is the most treacherous type of corrosion, as it can result in sudden and complete failure. It occurs when three adverse factors act together, as shown in the diagram below.



The risk of stress corrosion can be minimised by keeping away from the critical sector by:

- Appropriate choice of material.

- Avoiding the use of parts made of ordinary brass in difficult environments.

- Avoiding excessive tensile stresses in couplings.

It is therefore important to ensure that couplings are made of alloys with low stress corrosion sensitivity, such as AMETAL®, with high mechanical strength and good corrosion resistance.

Erosion corrosion (turbulence corrosion) occurs when the water in the pipe is flowing at excessive velocity, or when the water is corrosive. The effect is simply to wear the part away. With its high hardness and mechanical strength, AMETAL® is highly resistant to this form of corrosion, but even then it can be attacked by excessive water velocities. It is therefore important to keep the water velocity down to a reasonable level. (See the manufacturer's specifications).

Dezincification is a stealthy form of corrosion. The zinc in the brass is preferentially dissolved, leaving a brittle, porous copper body. It is the most difficult form of corrosion of plumbing fittings to deal with. Factors that affect the occurrence of dezincification are, particularly:
- The chemical composition of the alloy.
- The manufacturing process and crystal structure of the alloy.
- The ability of the alloy to form a protective layer.
- The corrosivity of the water.

Ordinary free machining brass (CuZn39Pb3) has good mechanical properties, but is not dezincification-resistant, and so is unsuitable for use in tap water systems.

Gunmetal, which is a relatively common material for use in valve bodies, is highly resistant to dezincification and to other forms of attack, such as stress corrosion. However, its mechanical properties are poorer, due to a high amount of casting porosity.

AMETAL® also has good mechanical properties, and has a lower content of casting porosities, due to being die-cast.

There are two main reasons for AMETAL®'s excellent resistance to dezincification:

1. A carefully developed combination of alloying constituents, with a high copper content and the addition of silicon.

2. An optimum crystalline structure: 100% α-phase in bar (machined) and die-cast AMETAL®, and a fine-grained β-phase structure, surrounded by α-phase material, in pressure die-cast products.

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