



## Copper and Copper Alloys - Introduction to Copper and its Alloys

Copper is the oldest metal used by man. Its use dates back to prehistoric times. Copper has been mined for more than 10,000 years with a Copper pendant found in current day Iraq being dated to 8700BC. By 5000BC Copper was being smelted from simple Copper Oxides.

Copper is found as native metal and in minerals cuprite, malachite, azurite, chalcopyrite and bornite. It is also often a by-product of silver production. Sulphides, oxides and carbonates are the most important ores.

Copper and Copper alloys are some of the most versatile engineering materials available. The combination of physical properties such as strength, conductivity, corrosion resistance, machinability and ductility make Copper suitable for a wide range of applications. These properties can be further enhanced with variations in composition and manufacturing methods.

The largest end use for Copper is in the building industry. Within the building industry the use of copper based materials is broad. Construction industry related applications for Copper include:

- ~ Roofing
- ~ Cladding
- ~ Rainwater systems
- ~ Heating systems
- ~ Water pipes and fittings
- ~ Oil and gas lines
- ~ Electrical wiring

### JOINING

Commonly employed processes such as brazing, welding and soldering can be used to join most Copper alloys. Soldering is often used for electrical connections. High Lead content alloys are unsuitable for welding.

Copper and Copper alloys can also be joined using mechanical means such as rivets and screws.

### ELECTRICAL CONDUCTIVITY

The electrical conductivity of copper is second only to silver. The conductivity of Copper is 97% of the conductivity of Silver. Due to its much lower cost and greater abundance, Copper has traditionally been the standard material used for electricity transmission applications.

However, weight considerations mean that a large proportion of overhead high voltage power lines now use Aluminium rather than Copper. By weight, the conductivity of Aluminium is around twice that of Copper. The Aluminium alloys used do have a low strength and need to be reinforced with a galvanised or Aluminium coated high tensile steel wire in each strand.

Although additions of other elements will improve properties like strength, there will be some loss in electrical conductivity. As an example a 1% addition of Cadmium can increase strength by 50%. However, this will result in a corresponding decrease in electrical conductivity of 15%.

### CASTING

The nature of the casting process means that most cast Copper alloys have a greater range of alloying elements than wrought alloys.

### APPLICATIONS

Copper and Copper alloys can be used in an extraordinary range of applications. Some of the applications for Copper include:

- ~ Power transmission lines
- ~ Architectural applications
- ~ Cooking utensils
- ~ Spark plugs
- ~ Electrical wiring, cables and busbars
- ~ High conductivity wires
- ~ Electrodes
- ~ Heat exchangers
- ~ Refrigeration tubing
- ~ Plumbing
- ~ Water-cooled Copper crucibles

In addition, there are many more applications for the Copper Alloys - Brass and Bronze



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### SURFACE OXIDATION / PATINATION

Most Copper alloys will develop a blue-green patina when exposed to the elements outdoors. Typical of this is the colour of the Copper Statue of Liberty in New York. Some Copper alloys will darken after prolonged exposure to the elements and take on a brown to black colour.

Lacquer coatings can be used to protect the surface and retain the original alloy colour. An acrylic coating with benzotriazole as an additive will last several years under most outdoor, abrasion-free conditions.

### STRUCTURE

Copper has a face centred cubic (FCC) crystal structure. Copper and its alloys have a range of yellow/gold/red colours and when polished develop a bright metallic lustre.

### HOT & COLD WORKING

Although able to be work hardened, Copper and Copper alloys can be both hot and cold worked. Ductility can be restored by annealing. This can be done either by a specific annealing process or by incidental annealing through welding or brazing procedures.

### PROPERTIES OF COPPER ALLOYS

#### Key Properties of Copper Alloys

Copper is a tough, ductile and malleable material. These properties make copper extremely suitable for tube forming, wire drawing, spinning and deep drawing. The other key properties exhibited by Copper and its alloys include:

- ~ Excellent heat conductivity
- ~ Excellent electrical conductivity
- ~ Good corrosion resistance
- ~ Good biofouling resistance
- ~ Good machinability
- ~ Retention of mechanical and electrical properties at cryogenic temperatures
- ~ Non-magnetic

#### Other Properties

~ Copper and Copper alloys have a peculiar smell and disagreeable taste. These may be transferred by contact and therefore should be kept clear of foodstuffs, although some cooking pans do use these metals.

~ Most commercially used metals have a metallic white or silver colour. Copper and Copper alloys have a range of yellow/gold/red colours.

#### Melting Point

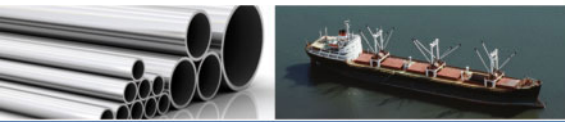
The melting point for pure Copper is 1083°C.

### CORROSION RESISTANCE

All Copper alloys resist corrosion by fresh water and steam. In most rural, marine and industrial atmospheres Copper alloys are also resistant to corrosion. Copper is resistant to saline solutions, soils, non-oxidising minerals, organic acids and caustic solutions. Moist ammonia, halogens, sulphides, solutions containing ammonia ions and oxidising acids, like nitric acid, will attack Copper. Copper alloys also have poor resistance to inorganic acids.

The corrosion resistance of Copper alloys comes from the formation of adherent films on the material surface. These films are relatively impervious to corrosion therefore protecting the base metal from further attack.

Copper Nickel alloys, Aluminium Brass, and Aluminium Bronzes demonstrate superior resistance to saltwater corrosion.



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### WROUGHT COPPER ALLOYS

Wrought copper alloys are produced using a variety of different production methods. These methods including processes such as rolling, extrusion, drawing and stamping. Such processes may be followed by annealing (softening), cold working, hardening by heat treatments or stress relieving to achieve the desired properties.

### COPPER USAGE

The building industry is the largest single consumer of Copper alloys. The following list is a breakdown of Copper consumption by industry on an annual basis:

- ~ Building industry - 47%
- ~ Electronic products - 23%
- ~ Transportation - 10%
- ~ Consumer products - 11%
- ~ Industrial machinery - 9%

There are around 370 commercial compositions for Copper alloys. The most common alloy tends to be C106/ CW024A - the standard water tube grade of Copper.

World consumption of Copper and Copper alloys now exceeds 18 million tonnes per annum.

### TEMPER

Copper alloys can be specified according to temper levels. The temper is imparted by cold working and subsequent degrees of annealing.

Typical tempers for Copper alloys are

- ~ Soft
- ~ Half-hard
- ~ Hard
- ~ Spring
- ~ Extra-spring.

Yield strength of a hard-temper Copper alloy is approximately two-thirds of the materials' tensile strength.

### YIELD STRENGTH

The yield point for Copper alloys is not sharply defined. As a result it tends to be reported as either a 0.5% extension under load or as 0.2% offset.

Most commonly the 0.5% extension yield strength of annealed material registers as approximately one-third the tensile strength. Hardening by cold working means the material becomes less ductile, and yield strength approaches the tensile strength.

### RECYCLING

Copper alloys are highly suited to recycling. Around 40% of the annual consumption of Copper alloys is derived from recycled Copper materials.

The recycling rate for Free Machining Brass (CZ121/CW614N) is particularly high with clean/dry swarf having a high value, which contributes to the cost-benefit calculations in material selection.



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### REVISION HISTORY

Datasheet Updated	13 November 2018
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specifications, but methods for identifying chemical compositions. Property requirements are covered in EN, ASTM, government and military standards for each composition.

The alloy designation system used in the UK and across Europe uses a 6 character alpha-numeric series.

The 1<sup>st</sup> letter is C for Copper-based material

The second letter indicates the product form:

- ◆ B = Ingot for re-melting to produce cast products
- ◆ C = Cast products
- ◆ F = Filler materials for brazing and welding
- ◆ M = Master Alloys
- ◆ R = Refined unwrought Copper
- ◆ S = Scrap
- ◆ W = Wrought products
- ◆ X = Non-standard materials

There is then a 3 digit number between 001 and 999 with the numbers being in groups as shown in the table below

There is then a letter indicating the Copper or alloy grouping, also shown in the table

Number Series	Letters	Materials
001 - 099	A or B	Copper
100 - 199	C or D	Copper Alloys, Min. 95% Cu
200 - 299	E or F	Copper Alloys, <95% Cu
300 - 349	G	Copper-Aluminium Alloys
350 - 399	H	Copper-Nickel Alloys
400 - 449	J	Copper-Nickel-Zinc Alloys
450 - 499	K	Copper-Tin Alloys
500 - 599	L or M	Copper-Zinc Alloys - Binary
600 - 699	N or P	Copper-Zinc-Lead Alloys
700 - 799	R or S	Copper-Zinc Alloys - Complex

The method for designating Copper alloys is an expansion upon the system developed by the US Copper and Brass industry using five digits preceded by the letter C.

UNS Numbers	Types	Alloy Names
C10000-C19999	Wrought	Coppers, High-Copper Alloys
C20000-C49999	Wrought	Brasses
C50000-C59999	Wrought	Phosphor Bronzes
C60600-C64200	Wrought	Aluminium Bronzes
C64700-C66100	Wrought	Silicon Bronzes
C66400-C69800	Wrought	Brasses
C70000-C79999	Wrought	Copper nickels, nickel silvers
C80000-C82800	Cast	Coppers, High-Copper Alloys
C83300-C85800	Cast	Brasses
C86100-C86800	Cast	Manganese Bronzes
C87200-C87900	Cast	Silicon Bronzes and Brasses
C90200-C94800	Cast	Tin Bronzes
C95200-C95800	Cast	Aluminium Bronzes
C96200-C97800	Cast	Copper Nickels, Nickel Silvers
C98200-C98800	Cast	Leaded Copper
C99300-C99750	Cast	Special Alloys