COPPER

Copper & Copper Alloys

Copper is a metal with some very important properties, the main ones being its high electrical conductivity, its high thermal conductivity, its excellent resistance to corrosion, and its ease of fabrication, either hot or cold.

Copper is also ductile and malleable and has a relatively low melting point at just over 1 080°C.

The three basic commercial grades of copper that are available are:

- Tough pitch copper, containing up to 0,1% oxygen
- Phosphorous deoxidised (PDO) copper, containing up to 0,04% phosphorous
- Oxygen-free copper, containing no deoxidants.

The phosphorous deoxidised grade was originally developed to overcome problems encountered when flame welding tough pitch copper. It is now the standard commercial weldable grade used for pressure vessels and radiators. Oxygen-free grades have significantly higher electrical conductivity than oxygen-containing grades and are therefore used widely as electrical conductors.

Types

Copper and copper alloys are generally grouped by compositional type and identified in standards by number or letter/number designations. However, it has been, and still is, common practice to refer to copper and copper alloys by their traditional names, such as brass and bronze, rather than by letters and number designations.

Copper and copper alloys may be divided into groups by general composition, and each group contains a range of specific alloys. The main groups considered here are:

- Unalloyed copper
- Beryllium copper
- Brasses
- Bronzes
- Silicon bronzes
- Aluminium bronzes
- Cupro-nickels.

Welding

As has been stated earlier, copper has a very high thermal conductivity and a high coefficient of expansion. These provide the main problems encountered during welding of unalloyed copper. High levels of preheat and heat inputs are required for fusion welding. These in turn can cause distortion problems. Copper is also susceptible to hot cracking so heavy restraint needs to be avoided.

The thermal conductivity of many copper alloys is relatively low and welding without preheat may be possible. However, several alloys will crack readily when welded if too much heat is put into the weld area or if welding is carried out under restraint. Any copper alloys containing lead should not be welded.

Welding Processes

Copper and its alloys can be welded, most frequently using inert gas shielded processes, such as MIG and TIG. MMA is used occasionally for welding some copper alloys and gas welding and brazing are also used for some applications.

TIG welding bronze statue

Shielding gases for TIG or MIG welding may be pure argon or helium-argon mixtures, such as the Afrox Copashield®. Pure argon tends to produce a narrow penetration profile that is not very deep. This means that high levels of preheat are required to avoid fusion defects. Helium-argon mixtures with between 50% and 75% helium increase the energy available to the weld so that good weld fusion and penetration can be achieved at minimum preheat temperatures.

High power density processes, like laser and electron beams, are also suitable for welding copper and copper alloys.

The submerged arc and flux cored wire processes are not used for welding copper or copper alloy systems.

Welding Copper

Unalloyed Copper

Tough pitch copper contains oxygen and welding this type of copper can result in weld metal porosity and embrittlement if hydrogen is present. The oxygen and hydrogen combine to form steam and 'steam porosity' is likely to occur if these types of copper are welded with the oxy-acetylene process. Oxygen-free and PDO grades of copper have better weldability than tough pitch copper.

The usual welding processes for copper are MIG and TIG. Filler metals, such as AWS A5.7 type ERCu or BS 2901-3 type C1A, with the addition of de-oxidants, should be used to control porosity.

With all coppers, the main problem is that heat is rapidly dissipated from the weld and this can lead to fusion defects if enough heat is not put into the joint area. Preheat is, therefore, recommended for thicknesses above 5 mm. Preheat levels range from about 200°C at 5 mm to 600°C and above at 20 mm. Highest preheats are required when welding with argon shielding gas but may be lowered or avoided if helium or helium gas mixtures are used, due to the increase in the heat input these gases provide.

Beryllium Copper

Welding of beryllium copper is not carried out extensively, but when it is, the preferred processes are MIG and TIG. Filler metals used to weld unalloyed coppers are used for copper beryllium alloys, since filler metals containing beryllium are not available.

However, welding can present a few problems. Cracking in the HAZ, due to the presence of age-hardening precipitates, may occur if insufficient preheat is applied. Also, beryllium will oxidise rapidly and be given off as fume if the arc region is not properly protected with inert shielding gas. The main problem here is that fume containing beryllium oxide is highly toxic and can cause death.

Welding of copper alloys containing beryllium must be carried out with care and the use of fume extraction equipment and personal respiratory protection is essential.

Brasses

Brasses are not readily weldable, since the application of a welding arc causes the zinc to boil off as zinc oxide fume. Zinc oxide may be identified during welding as dense white fumes rising from the brass, impairing the welder's visibility and leaving white 'cobwebs' on equipment and surrounding attachments as further evidence. Zinc oxide will cause zinc fume fever if inhaled in sufficient quantities.

Loss of zinc from the vicinity of the weld can affect the properties of the material and also causes porosity in the weld metal.

If it is essential to weld brass, use of TIG welding, with a silicon bronze filler rod such as AWS A5.7 type ERCuSi-A or BS 2901-3 type C9 would be the preferred option. Zinc will inevitably be lost from the brass and some weld metal porosity will occur, but may be kept to a minimum with care.

Welding of free-machining brass, containing significant amounts of lead, should not be attempted since it will almost certainly crack.

Silver brazing or soldering of brass is a better idea than welding and can be carried out using suitable braze metals and fluxes.

Bronzes

Bronzes, such as phosphor bronze and gunmetal, are not normally welded during manufacture, but may require repairs to be carried out from time to time. They are not the easiest materials to weld and are frequently brazed or soldered rather than welded.

Phosphor bronzes are likely to suffer hot cracking when welded, but reasonable results can be achieved using MIG or TIG welding with copper-tin filler metals such as AWS A5.7 type ERCuSn-A or BS 2901-3 type C10. Moderate preheat is normally required and high restraint should be avoided.

Gunmetal too may be welded similarly with care (provided it does not contain lead), but hot cracking is a distinct possibility.

'Leaded' phosphor bronzes and gunmetals are generally considered to be unweldable and hot cracking is virtually certain to result if attempts are made to weld these materials.

Bell metal is very difficult to weld because it is hard and brittle and prone to hot cracking. However, cracked church bells have been successfully repair-welded using gas welding and TIG welding with strips of matching bell metal composition as filler metal. High preheat, continuous heating throughout the welding process, and very slow cooling after welding are essential measures to be adopted to prevent cracking.

Aluminium Bronzes

Aluminium bronzes are generally weldable, usually without preheat since the thermal conductivity of aluminium bronze is relatively low. Welding with MMA electrodes is possible, but MIG and TIG are the preferred welding processes. When TIG welding with argon shielding gas, the use of AC current is necessary to break down the tenacious aluminium oxide film, but DC electrode negative may be used with helium-rich shielding gas.

Matching aluminium bronze filler metals are generally used when welding these alloys, and include fillers such as AWS A5.7 types ERCuAl-A2 and ERCuAl-A3, or BS 2901-3 types C12Fe and C13.

Porosity is likely to be a problem in multi-pass welds if correct cleaning procedures are not adopted, and high restraint may induce cracking.

Silicon Bronzes

Silicon bronzes are reasonably weldable and, again, preheat is generally not required. MMA electrodes are available, but the preferred welding processes are MIG and TIG. Silicon bronze filler metals with about 3% silicon are used and fillers of this type conform to specifications such as AWS A5.7 types ERCuSi-A or BS 2901-3 types C9.

Although an oxide film is likely to form on the weld, it is still standard practice to use DC electrode negative when TIG welding with either argon shielding gas or with a helium-argon mixture.

Hot cracking is a potential problem with silicon bronzes and so excessive heating and high restraint should be avoided.

Cupro-Nickels

Cupro-nickel alloys are readily weldable and may be welded using MMA, MIG, or TIG welding processes, generally without preheat. High quality welds can be obtained with all these welding processes.

Electrodes and filler metals conforming to 70/30 copper-nickel are readily available. These conform to specifications such as AWS A5.7 types ECuNi (MMA) and ERCuNi (MIG and TIG) or BS 2901-3 type C18. Filler metal conforming to 90/10 copper-nickel is listed in BS 2901-3 as type C16. Fillers for cupro-nickels usually include titanium as deoxidant, to prevent the formation of porosity.

Argon or Copashield® shielding gases are generally preferred for MIG and TIG welding, the latter often being carried out using DC electrode negative.

Contaminants such as sulphur, phosphorous and lead are detrimental to cupro-nickels and are likely to cause cracking. Thorough cleaning of these alloys before welding is required.

Copper-Based Filler Selection Guide

Base Metal	Copper	Tin Bronze	Red Brass	Yellow Brass	Nickel Silver	Aluminium Bronze	Silicon Bronze	Copper Nickel
Carbon & Low Alloy Steel	Aluminium Bronze	Tin Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze
Cast Iron	Aluminium Bronze	Tin Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze
Copper Nickel	Aluminium Bronze	Tin Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Copper Nickel
Silicon Bronze	Tin Bronze	Tin Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Silicon Bronze	
Aluminium Bronze	Aluminium Bronze	Tin Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze	Aluminium Bronze		
Nickel Silver	Silicon Bronze	Tin Bronze	Tin Bronze	Aluminium Bronze	Aluminium Bronze			
Yellow Brass	Silicon Bronze	Tin Bronze	Tin Bronze	Aluminium Bronze				
Red Brass	Tin Bronze	Tin Bronze	Tin Bronze					
Phosphor Bronze	Tin Bronze	Tin Bronze						
Copper	Cuprofil CuSn							

Copper MIG & TIG Wires

Afrox Cuprofil

Afrox Cuprofil is a deoxidised copper filler wire for the welding of pure copper where maximum thermal and electrical conductivity are required. Afrox Cuprofil should be shielded with pure argon, pure helium or an argon/helium mixture (Copashield®) for thicker sections. Flow rates of 10-18 ℓ/min should be used.

Applications

Applications include plate for chemical plant and moulds, stills and calorifiers, rods and wires for electrical components and tubes for heat exchangers.

Materials to be Welded		
Oxygen-free copper		
BS grade	C103, UNS C10200, ISO Cu-OF/Cu-OFS	

Classifications		
AWS	A5.7	ERCu
DIN	1733	SG-CuSn (2.1006)
BS	2901Pt3	C7
EN	24373	Cu1898 (CuSn1)

Chemical Analysis (All weld metal)			
% Copper	98,0	**% Lead**	0,01 max
% Aluminium	0,01 max	**% Iron**	0,03 max
% Silicon	0,1 - 0,5	**% Phosphorous**	0,015 max
% Manganese	0,1 - 0,5	**% Arsenic**	0,03 max
% Nickel	0,05 max	**% Others Total**	0,10 max
% Tin	0,5 - 1,0		

Typical Mechanical Properties (All weld metal in the as welded condition)	
Tensile Strength	210 - 245 MPa
Hardness	60 - 80 HB

Typical Physical Properties	
Melting Range	1 020 - 1 050
Density kg/dm³	8,9
Electrical Conductivity at 20°C sm/mm²	15 - 20
Thermal Conductivity at 20°C W/(m/K)	120 - 145

Packing Data		
Diameter (mm)	**Pack Mass (kg)**	**Item Number**
1,2	15,0	W033130
1,6	15,0	W033131

Afrox Filmax Silicon Bronze R
Afrox TIG Silicon Bronze

Afrox Filmax Silicon Bronze R and Afrox TIG Silicon Bronze are pure copper filler wires deoxidised with 3% silicon for welding a wider range of copper alloys than Afrox Cuprofil and Afrox TIG Cu including overlaying of steels and cast irons. The Afrox Filmax Silicon Bronze R wire is optimised for laser brazing. Afrox Filmax Silicon Bronze R should be shielded with pure argon, pure helium or an argon/helium mixture (Copashield®) for thicker sections. Flow rates of 10 - 18 ℓ/min should be used. Afrox TIG Silicon Bronze should be shielded with pure argon but pure helium provides deeper penetration, higher travel speeds and allows preheat to be reduced.

Applications

Applications include plate for chemical plant and moulds, stills and calorifiers, rods and wires for electrical components and tubes for heat exchangers. Also excellent for MIG brazing and laser brazing onto galvanised steel for automotive body panels.

Materials to be Welded

General purpose including phosphorus deoxidised copper, silicon bronze, nickel silver and some brasses.

Classifications		
AWS	A5.7	ERCuSi-A
DIN	1733	SG-CuSi3 (2,1461)
BS	2901Pt3	C9
EN	24373	CU6560 CuSi3Mn1

Chemical Analysis (All weld metal)			
% Copper	Bal.	**% Tin**	0,2 max
% Aluminium	0,01 max	**% Iron**	0,3 max
% Zinc	0,02 max	**% Silicon**	2,8 - 4,0*
% Manganese	0,75 - 1,5	**% Lead**	0,02 max
% Phosphorous	0,02 max	**% Others Total**	0,4 max

* For Afrox Filmax Silicon Bronze R the % silicon is 2,8% - 3,1%

Typical Mechanical Properties (All weld metal in the as welded condition)	
Tensile Strength	330 - 370 MPa
% Elongation on 5d	40 max
Hardness	80 - 90 HB

Packing Data

MIG			TIG			
Diameter (mm)	**Pack Mass (kg)**	**Item Number**	**Diameter (mm)**	**Pack Mass (kg)**	**Consumable Length (mm)**	**Item Number**
1,0	15,0	W033122	1,6	5,0	1 000	W077610
1,2	15,0	W077616	2,4	5,0	1 000	W077611
1,6	15,0	W033126	3,2	5,0	1 000	W077612

Afrox Filmax CuAl-8
Afrox TIG CuAl-8

Afrox Filmax CuAl-8 and Afrox TIG CuAl-8 is an iron-free aluminium bronze. It is recommended for use as a surfacing metal for wear resistant surfaces having relatively light loads, for resistance to corrosive media such as salt or brackish water, and for resistance to many commonly used acids in varying concentrations and temperatures. This alloy is not recommended for joining, but is excellent for metal spraying and overlaying. Afrox Filmax CuAl-8 should be shielded with pure argon, pure helium or an argon/helium mixture (Copashield®) for thicker sections. Flow rates of 10 - 18 ℓ/min should be used.

Applications

Used to overlay on surfaces needing a bronze wearing surface.

Shipbuilding:	Propellers, pumps, shafts and valves, bearings, main shafts
Chemical industry:	Gate valves, sleeves, pipes, heat exchangers and gear housings
Automotive industry:	Maintenance of car parts and tools, bearings in general and galvanised steel sheets
Construction industry:	Overlaying of aluminium bronze with steel base materials

Classifications		
AWS	A5.7	ERCuAl-Al
DIN	1733	SG-CuAl8 (2.0921)
BS	2901Pt3	C28
EN	24373	Cu6100 CuA17 (nearest)

Chemical Analysis (All weld metal)			
% Copper	Bal.	**% Zinc**	0,02 max
% Aluminium	7,5 - 9,5	**% Lead**	0,02 max
% Silicon	0,2 max	**% Iron**	0,5 max
% Manganese	1,0 max	**% Others Total**	0,4 max
% Nickel	0,8 max		

Typical Mechanical Properties (All weld metal in the as welded condition)	
Tensile Strength	390 - 450 MPa
% Elongation on 5d	45 max
Hardness	80 - 110 HB
Hardness (Work Hardened)	140 HB

Packing Data

MIG			TIG			
Diameter (mm)	**Pack Mass (kg)**	**Item Number**	**Diameter (mm)**	**Pack Mass (kg)**	**Consumable Length (mm)**	**Item Number**
1,2	15,0	W077595	2,4	5,0	1 000	W077726
1,6	15,0	W077596	-	-	-	-

Afrox Filmax Aluminium Bronze
Afrox TIG Aluminium Bronze

Afrox Filmax Aluminium Bronze and Afrox TIG Aluminium Bronze are solid copper filler wires containing approximately 10% aluminium and 1% iron. These alloys are suitable for welding 5 - 11% aluminium bronzes plus other copper alloys as listed below. For brasses, the weld colour is similar and the presence of aluminium in the filler helps to suppress zinc volatilisation during welding. It can also be used for joining dissimilar alloys, e.g. copper to steel, copper to cast iron, brass to steel, aluminium bronze to steel, etc. These alloys are also suitable for welding components which are subject to sea water corrosion. Afrox Filmax Aluminium Bronze should be shielded with pure argon, pure helium or an argon/helium mixture (Copashield®) for thicker sections. Flow rates of 10 - 18 ℓ/min should be used. Afrox TIG Aluminium Bronze should be shielded with pure argon but pure helium provides deeper penetration, higher travel speeds and allows preheat to be reduced.

Applications

Applications include corrosion resistant and spark resistant pumps, castings, machinery parts, heat exchangers for offshore, marine and mining equipment.

Materials to be Welded	
Aluminium bronze	UNS C61400, BS CA101 - 103, BS 1400 AB1 (cast), Alloy D
Beryllium copper	Cu + 0,5 - 2% Be, closest strength
Brass	Cu + Zn
Aluminium brass	e.g. Yorkalbro Cu - 22% Zn - 2% Al
Manganese bronze	Cu + 20 - 45% Zn + 1 - 3% Mn
Silicon bronze	Cu + 1 - 3,5% Si

Classifications		
AWS	A5.7	ERCuAl-A2
DIN	1733	SG-CuAl10Fe (2.0937)
BS	2901Pt3	C13
EN	24373	Cu6180 CuAi

Chemical Analysis (All weld metal)			
% Copper	Bal.	**% Zinc**	0,02 max
% Aluminium	9,0 - 11,0	**% Lead**	0,02 max
% Silicon	0,1 max	**% Iron**	0,75 - 1,5
% Manganese	1,0 max	**% Others Total**	0,40 max
% Nickel	1,0 max		

Typical Mechanical Properties (All weld metal in the as welded condition)	
Tensile Strength	390 - 500 MPa
% Elongation on 5d	45 max
Hardness	90 - 120 HB
Hardness (Work Hardened)	140 - 160 HB

Packing Data

MIG			TIG			
Diameter (mm)	**Pack Mass (kg)**	**Item Number**	**Diameter (mm)**	**Pack Mass (kg)**	**Consumable Length (mm)**	**Item Number**
1,2	15,0	W033142	1,6	5,0	1 000	W077585

Oxy-Fuel Welding & Brazing Rods

Afrox M15 Bronze

A widely used brazing and bronze welding rod depositing metal which has good tensile strength. This versatile brazing rod is ideally suited for sheet metal work such as motor bodies, tubular and galvanised iron fabrication as well as for copper and for brazing cast iron, and heavy steel sections. The product may be used for fusion-weld brass.

Classifications		
AWS	A5.27 R	CuZn-C
EN	24373	Cu4700 CuZn40Sn
Rod Identification		
M15	Stamped	

Typical Chemical Analysis (Wire analysis)			
% Copper	56,0 - 60,0	**% Iron**	0,25 - 1,2
% Manganese	0,01 - 0,5	**% Tin**	0,8 - 1,1
% Silicon	0,04 - 0,15	**% Zinc**	Bal.

Physical and Mechanical Properties	
Melting Range	860°C - 890°C
Tensile Strength	460 MPa
Approximate Brinell Hardness	125 HB

Brazing/Welding Parameters	
Process	Oxy-acetylene
Flame Setting	Neutral (depending on base metal)
Flux	Use with Afrox M15 Brazing Flux (Item Number W001553)

Packing Data			
Diameter (mm)	**Consumable Length (mm)**	**Pack Mass (kg)**	**Item Number**
2,0	750	5,0	W000504
3,2	750	5,0	W000500
5,0	750	5,0	W000501
6,3	750	5,0	W000502

Afrox Fluxobronze M15

A general purpose flux coated bronze alloy used for bronze welding and brazing copper, cast iron, steel sheet and for light assembly work. This low fuming brass rod is fast flowing and leaves minimal flux residue. The fast flowing nature of the alloy reduces heat input which causes distortion.

Classifications		
AWS	A5.27 R	CuZn-C
EN	24373	Cu4700 CuZn405n

Typical Chemical Analysis (Wire analysis)			
% Copper	56,0 - 60,0	**% Iron**	0,25 - 1,2
% Manganese	0,01 - 0,5	**% Tin**	0,8 - 1,1
% Silicon	0,04 - 0,15	**% Zinc**	Bal.

Physical Mechanical Properties	
Melting Range	860°C
Approximate Tensile Strength of Deposited Metal	440 MPa
Approximate Brinell Hardness	120 HB

Brazing/Welding Parameters	
Process	Oxy-acetylene
Flame Setting	Neutral

Packing Data			
Diameter (mm)	**Consumable Length (mm)**	**Pack Mass (kg)**	**Item Number**
2,5	450	5,0	W000375
3,2	450	5,0	W000376

Afrox Nickel Bronze DB

A versatile 10% nickel bronze alloy rod suitable for bronze welding and brazing of steel, cast iron and copper alloys. Since the weld deposit work hardens in service, the rod is ideal for building up worn or broken parts such as gear teeth, bearings, valve seats and faces. It is widely used for maintenance work.

Classifications			
EN	24373	Cu7730 CuZn40Ni10	

Chemical Analysis (Wire analysis)			
% Copper	46,0 - 50,0	**% Lead**	0,05 max
% Nickel	9,0 - 11,0	**% Aluminium**	0,01 max
% Silicon	0,04 - 0,25	**% Zinc**	Bal.
% Phosphorous	0,25 max		

Physical Mechanical Properties	
Melting Range	800°C - 910°C
Approximate Tensile Strength of Deposited Metal	530 MPa
Approximate Brinell Hardness	
As Deposited	150 HB
Work Hardened	320 HB

Brazing/Welding Parameters	
Process	Oxy-acetylene
Flame Setting	Slightly oxidising
Flux	Use with Afrox M15 Brazing Flux (Item Number W001553)

Packing Data			
Diameter (mm)	**Consumable Length (mm)**	**Pack Mass (kg)**	**Item Number**
1,5	700	5,0	W000520
3,2	700	5,0	W000521

Copper/Phosphorous & Copper/Silver Brazing Alloys

Product	Item Number	Diameter (mm)	Pack Mass (kg)	Description	Specification & Classification	Colour Code	Nominal Composition (%)					Melting Range (°C)	Tensile Strength (MPa)
							Ag	Cu	Zn	P	Other		
Silfos 15	W001221 W001321 W001222 W001322	1,5 1,5 3,0 3,0	1,0 5,0 1,0 5,0	These 'self-fluxing' alloys are recommended for fluxless brazing of copper to copper. They should not be used where the nickel content of the alloy exceeds 10% or on ferrous or nickel alloys due to brittleness. The silver bearing alloys possess greater ductility than the copper phosphorous types and are recommended where the joints are subject to significant levels of stress or vibration.	BS 1845 CP 1 DIN 8513 L-ag15P*	Blue	15	Rem	-	4,5	-	645 - 700	637
Eezibraze 2	W001233 W001333 W001232 W001332 W001235	1,5 1,5 3,0 3,0 4,5	1,0 5,0 1,0 5,0 1,0		BS 1845 CP 2 DIN 8513 L-Ag 2*	Yellow	2	Rem	-	6,5	-	645 - 740	490
Copperflo 1	W001244	2,0	-		BS 1845 CP 3 DIN 8513 L-Cu7P*	Grey	-	Rem	-	7,5	-	714 - 800	-
Copperflo 2	W001249	3,0	-		-	Pink	-	-	-	6,0	-	690 - 800	-
Copperflo 3	W001251	3,0	-		BS 1845 CP 6	Orange	-	Rem	-	6,2	-	714 - 850	-

Copper Brazing Fluxes

Afrox M15 Brazing Flux

Afrox M15 Brazing Flux is a white powdered flux with a melting point of 800°C. It is recommended for use when brazing or bronze welding mild steel, copper, brass, cast iron, and galvanised iron. For galvanised work, mix powder with water to form a paste and paint onto both sides of joint to protect heated zinc from flame and atmosphere.

Packing Data	
Container Mass (g)	**Item Number**
500 (jar)	W001553