Copper

Copper and 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 1080°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% phosphorus
- Oxygen-free copper, containing no deoxidants

The phosphorus 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, many 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

WARNING Welding can give rise to electric shock, excessive noise, eye and skin burns due to the arc rays, and a potential health hazard if you breathe in the emitted fumes and gases. Read all the manufacturer's instructions to achieve the correct welding conditions and ask your employer for the Materials Safety Data Sheets. Refer to www.boc.com.au or www.boc.co.nz

Shielding gases for TIG or MIG welding may be pure argon or helium-argon mixtures, such as the BOC range of Alushield® gases. Pure argon tends to produce a narrow penetration profile that is not very deep. This means than high levels of preheat are required to avoid fusion defects. Helium-argon mixtures with between 50% and 75% helium increases 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 beam, 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 5mm. Preheat levels range from about 200°C at 5 mm to 600°C and above at 20mm. 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 quantity.

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 they 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 used 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.

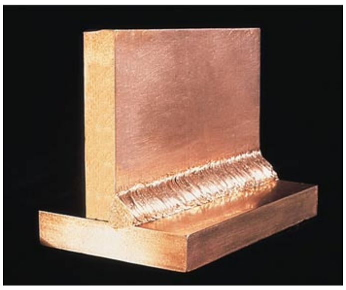
Cupro-nickels

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 Alushield® shielding gases are generally preferred for MIG and TIG welding, the latter often being carried out using DC electrode negative. Specialist shielding gases such as Specshield® 11 He / 2 H_2 are used to reduce the incidence of surface oxides which can form on these materials, especially with multi-pass TIG welding.

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



MMA Electrodes

Bronzecraft AC-DC

- Phosphor bronze electrode containing 7% tin
- For welding copper and copper alloys
- Also for joining copper and copper alloys to steel
- Easy to use, high quality weld deposit appearance

Classifications
AS/NZS 2576: E 6200 – A2 AWS/ASME-SFA A5.6: E CuSn – C

Typical all weld metal mechanical properties	
0.2% Proof stress	315 MPa
Tensile strength	460 MPa
Elongation (%)	22
Hardness	120 HV30

Typical all weld metal analysis (%)					
Mn	Sn	Al	P	Fe	Cu
0.02	7.50	0.008	0.26	0.20	Bal

Packaging and operating data — AC (min. 45 OCV) DC- polarity						
Electrode		Approx no. rods/kg	Current range (A)	Packet (kg)	Carton (kg)	Part No.
Size (mm)	Length (mm)					
3.2	350	30	70–110	2.5	15 (6 x 2.5)	611783

Autocraft Deoxised Copper

- A high copper alloy for GMA joining and overlay applications
- Fabricating deoxidised copper and electrolytic pitch copper components
- Repair of copper castings
- Lower strength welding of galvanised steels and deoxidised copper to mild steel joints
- Typical applications include the GMA welding of copper transformer connectors, copper bus bars, billet moulds and heater elements etc.

Classifications
AWS/ASME-SFA A5.7: ERCu

Typical all weld metal mechanical properties	
	Welding grade Argon
0.2% Proof stress	55 MPa
Tensile strength	200 MPa
Elongation (in 2 inches)	30%
Electrical conductivity	40% IACS
Hardness	55 HB
Weld metal density	7.47 x 103 /m³

Typical wire analysis (%) limits

Mn	Si	P	Sn	Cu	Others
0.5	0.5	0.15	1.0	>98.0	0.50

Single values are maximum allowable, unless otherwise stated.

Recommended shielding gas

Alushield® Light
Alushield® Heavy
Welding Grade Argon

Packaging and operating data

Dia. (mm)	Voltage (V)	Wire feed speed (m/min)	Current range (A)	Pack type	Pack weight (kg)	Part No.
1.6	28–32	5.5–11.5	160–380	Spool	13	720260

Autocraft Silicon Bronze

- A copper based wire for the GMA welding of copper-silicon alloys, including cusilman and everdur
- Used for the lower strength welding of steels
- Extensively used for the GMA welding of copper-silicon alloys used in hot water systems, heat exchangers, calorifiers and marine components for their corrosion resistance

Classifications
AWS/ASME-SFA A5.7: ERCuSi–A

Typical all weld metal mechanical properties	
	Welding grade Argon
0.2% Proof stress	170 MPa
Tensile strength	380 MPa
Elongation (in 2 inches)	50%

Typical wire analysis (%)

Fe	Mn	Si	Sn	Zn	Cu
0.25	1.0	3.40	0.90	0.90	Bal

Recommended shielding gas

Welding Grade Argon
Argoshield® 100
Argoshield® Universal
Argoshield® 52
Stainshield®

Packaging and operating data

Dia. (mm)	Voltage (V)	Wire feed speed (m/min)	Current range (A)	Pack type	Pack weight (kg)	Part No.
0.8	15–20	4.5–10.5	65–150	Handi Spool	4.5	720159
0.9	21–26	7.5–14.5	100–250	Spool	13	720015
1.2	22–28	5.5–11.5	160–380	Spool	13	720255

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